University of Piraeus

Department of European & International Studies

M.Sc. Programme in "Energy: Strategy, Law and Economics"

Thesis submitted to the University of Piraeus:

Water Quality Analysis in the Lake of Kastoria and Depiction of their Intertemporal Changes

Professor: Dr. Athanasios Dagoumas

Student: Stefania Kraim

Athens, September 2021

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Stefania Kraim

Abstract:

Freshwater on earth's surface constitutes only the 2.5% of the whole; of which 2,5% only 1% is accessible for use. Understandably, lakes are amongst the most important freshwater resources that are on our planet. Considering that most of them have been working their formation for thousands even tens of thousands of years we understand the paramount importance behind their protection and sustainability. As per available literature lakes globally seem to be on a quality-deteriorating on-going state with almost half of the lakes in Europe, America and Asia being in Eutrophic state. In this paper the focal point will be the Lake of Kastoria that besides being a fresh water source is a driving factor of this small city's economy but also is a determining factor in regards with the quality of life of the people that live in its close quarters. Using available literature and measurements provided by the Management Body of Protected Areas of Western Macedonia, an analysis and comparison and contrast of the data took place and valuable conclusions were drawn that aided in the proposition of suitable recommendations in the scope of securing sustainability of the lake and the ensuring the passing on to the next generations.

Acknowledgements:

I would like to dedicate this undertaking to my closest people; family and loved ones who with their continuous support have been immensely helpful through tough times and have always believed in my ability to push forward despite adversity or challenges that life puts in the way.

Also, would like to thank my colleagues in the Management Body of Protected Areas of Western Macedonia that have assisted me with the provision of the measurement data for this undertaking.

Finally, I wish to thank my supervising professor for this undertaking, Dr. Athanasios Dagoumas that provided me with valuable guidance and assistance for the completion of the said.

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Introduction:

Water (chemical formula H_2O) is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent). It is vital for all known forms of life, even though it provides no calories or organic nutrients. The word water comes from Old English wæter, from Proto-Germanic *water. Humans consist of over 50% water in our bodies and the Earth's surface is covered by 71% in water. It is only reasonable to understand that water is of paramount importance for all living things on this planet as the consumption of water is what keeps us alive. As in all things that is put into our systems any water won't do, pure, clear, disease free and free of noxious elements is the water that we aim to consume. This doesn't only apply in our microcosm, but also applies in the macrocosm of the totality of our planet. Ecosystems need pure and clear water to thrive, the trees the birds the fish in the sea, rivers and lakes, every living thing needs access to this treasure of nature. Unfortunately, humans with our intense industrial activity plus the irresponsible release of toxic materials and sewage waters to bodies of waters rivers, seas, lakes adding to the washing-off of fertilizers and pesticides from the fields, have created a dire situation for many ecosystems around the world especially close to cities.

During this undertaking the field of research will be narrowed down to lakes and specifically the lake of Kastoria. Going through the undertaking an analysis of general notions about lakes, how they are described, characterized, and classified will be conducted. In addition, the phenomenon of Eutrophication will be put under the microscope and explanations as to the way it works will be ventured as well as how human activity has intensified this phenomenon. Moreover, adding to the above vital parameters that are directly connected with water quality will be presented.

In continuance the focus will be moved to the area of Kastoria where information about the municipality and city will be shared as well as insights in regards with the economy. Moving on, the focal point will be transferred to the Lake Orestiada or Lake of Kastoria itself where the natural ecosystem(s) will be explored the importance of the lake will be stated and sources of pollution of the lake will be listed.

In the next part of the undertaking the lake measurements will be analyzed and valuable conclusions will be drawn that will allow comments on the current state of the lake as well as recommendations for solutions to potential issues to safeguard Kastoria's most valuable treasure to be made.

Chapter 1: Characteristics of a Lake

General Description

According to Otterbine Barebo (2003) a lake is a body of water surrounded by land and is geologically defined being temporary. This can translate that the aforementioned body of water can dry at certain periods and be filled again under specific circumstances for example due to seasonal conditions or heavy rainfall periods. The temporal character of the lake is also such due to the fact that these bodies of water undergo an aging process and will dissipate through time. Most of the lakes are a result of a catastrophic phenomenon such as volcanic eruptions, tectonic plate movements, intense river or glacial activity. Although nature has the leading role in the lake creation, lakes can also be man-made that by definition are noted as reservoirs. (Jørgensen, 1980).

All lakes are special and can be considered totally unique ecosystems. Besides the causal factor behind their creation the lakes have their own characteristics that constitute an identity as unique as people's fingerprints. The different sizes, ratios of elements inside, surrounding shoreline, soil elements, elevation among others can create extraordinary environments. Usual characteristics of lakes are inflow and outflow, nutrients, pH, temperature, oxygen content, size, drainage basin and productivity (Rzętała et. al 2011)).

Shifts in the level of a lake are determined by the difference between the input and the output compared with the total volume. Most important input factors are water masses carried by streams, rivers and channels, precipitation, groundwater channels and aquifers as well as artificial sources from outside the catchment area. As output one can consider evaporation from surface, groundwater flows and any water off-pumping for any use by humans. Another important factor that can determine this fraction of input/output is the general climate conditions and human water requirements.

An additional category that can be used to characterize lakes is the basis of their profile of nutrients. This is quite important as it affects plant and micro-plant organism growth. Lakes that are short in nutrients tend to be on the oligotrophic scale and they are usually clear, having a low presence of plantation. Lakes containing medium level of nutrients are defined as Mesotrophic; these ones are clear with medium levels of plantation. Moving on, we have the ones rich in nutrients that are named Eutrophic. These lakes have a booming plant life and there are also algal blooms present on some occasions. Finally, there are the lakes that are extremely rich in nutrition factors. These lakes have reached that state usually due to human activity such as the intense use of fertilizers in the surrounding areas of the lake, drainage from plants or villages/towns/cities in the catchment area. This surge of nutrient elements creates an imbalance in the ecosystem of the lake as they create the phenomenon known as Eutrophication in its heavy forms, that can disrupt the oxygen circle within the body of water, and in extreme cases even lead to the death of populations of fish or other aquatic organisms that have this ecosystem as their habitat (Chapin, F. Stuart, III 2011).

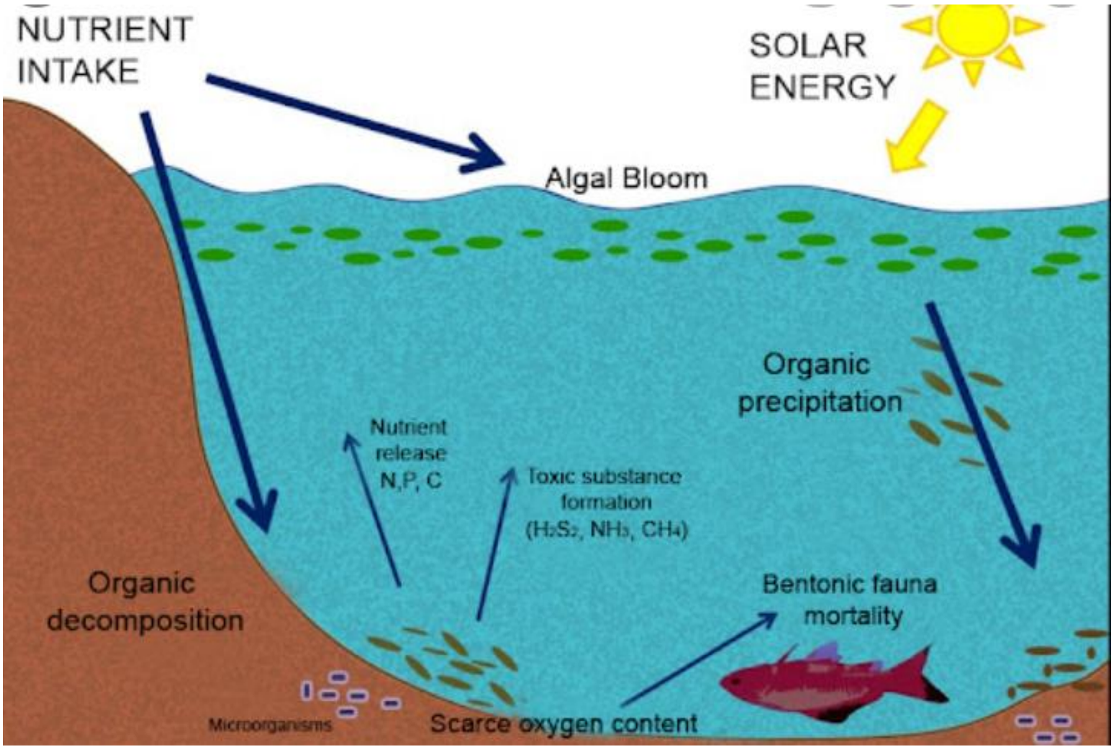


Figure 1. Eutrophication (sourc. ENI official site)

Size is also a factor that affects the dynamics within the lake ecosystem. Such relationships can be the ratio of lake surface and length of the shoreline, the volume of water that is being affected by sunlight among others. These intertwined factors determine how the lake will behave in certain environmental conditions, biological productivity and the ability to handle pollution. For example, a smaller lake can have a lower ability of handling pollution in comparison to a greater one. In addition, a smaller lake might be more susceptible to damage from human activities at the shoreline.

Lake morphology / shore configuration varies from lake to lake, there are lakes with steep shorelines, others with long shallow shorelines in a beach-like fashion, and others even have bays. These shoreline characteristics play a key part in the water body mixing and subsequently the plant populations. Bowl shaped lakes could be more efficient in battling potential pollution whereas lakes that have many bays, could tend to accumulate pollution in these “closed spaces”.

Lake morphometry is another lake characteristic that is connected with the shape regarding the depth of the lake. This factor also plays an important role especially on vertical mixing. In deep masses of water, there is a possibility that there is a layer-like phenomenon where the surface characteristics can vastly differ from the ones of the waters of the deep. Although in shallower waters, as the vertical mixing capability is higher the waters can likely be homogenous. In these kinds of lakes characteristics like oxygen levels, temperature, level of photosynthesis and plantation are more or less the same regardless of the depth. (Joy P. Michaud, 1991).

Moving forward, the lakes have specific zones according to their light penetration, nutrients addition, level of photosynthesis among others. These are as follows:

1) The littoral zone: These zones are the ones that can be found at shallow waters that are penetrated well with sunlight and the nutrients are being received by surface runoff.
2) The Limnetic zone: This zone is characterized by open water with sufficient light penetration especially in the upper water body of the lake where most of the photosynthesis occurs.
3) The Profundal zone: The deep-water area that is not reached by effective light. This region is rare in small or shallow lakes.
4) The Benthic zone: This zone includes all bottom areas. Various types of sediments and soil are the main elements here. The Benthic zone is more susceptible to pollution as most of the times pollutants will drop at the bedrock of the lake.
(Jørgensen, 1980)

Classification of Lakes

According to Jørgensen, lakes can be classified based on the depth of the lake that is the main factor of "layering" and the water mixing/circulation within the lake, and the trophic level that is the one that labels the level of productivity.

1. Based on **Depth or Stratification** (layering) we have the following types of lakes:
    a. Shallow lakes/ponds where there is no layering
    b. Dimictic lakes – where there are seasonal changes in the body of waters
    c. Cold monomictic lakes – temp never above 4dgr Celsius usually Polar Areas
    d. Warm monomictic lakes – always over 4 degrees Celsius usually subtropic areas
    e. Polymictic lakes – nonstop circulation of waters usually mountain lakes or near equator
    f. Oligomictic lakes – very slowly mixed, mostly tropical zones
    g. Meromictic lakes – permanently layered due to the chemistry of the water

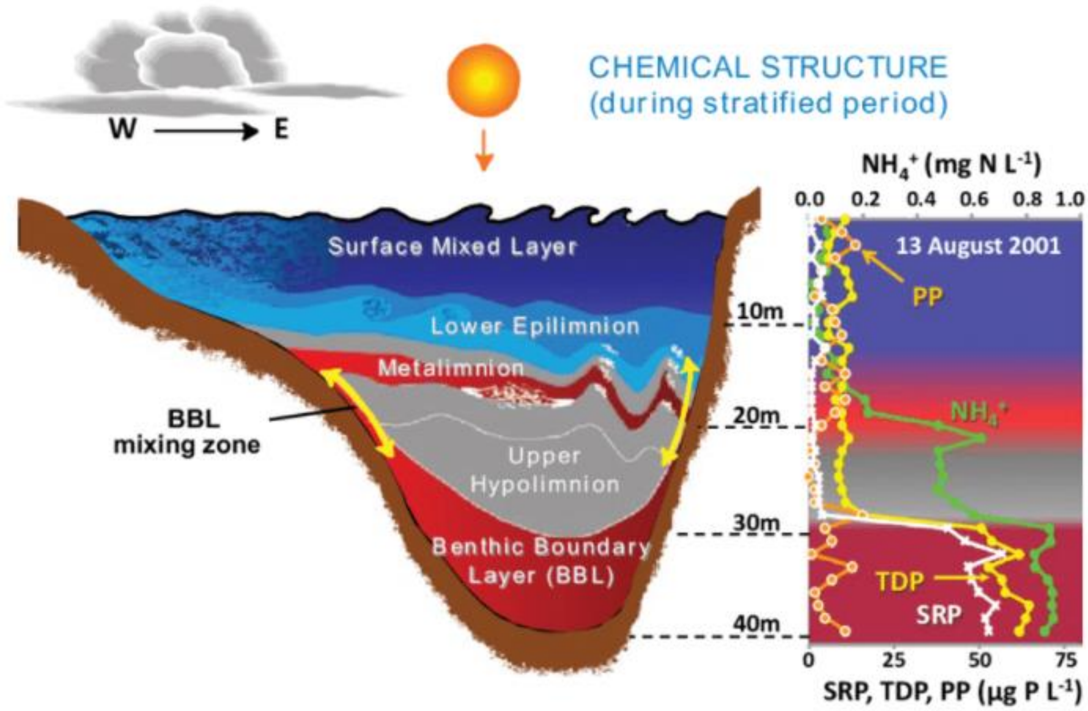


Figure 2. Stratification Example of a Lake (sourc. Researchgate.net)

2. Based on the **trophic level** lakes can be separated to:
    a. Oligotrophic: These lakes are usually clear and cold. The level of nutrient factors is low and only a small amount of plantation can be observed.
    b. Mesotrophic: These lakes usually have a medium level of nutrients within their waters. Algae and weed plantation can be found here due to the higher phosphoric levels in these bodies of water.
    c. Eutrophic: these lakes have very high nutrient levels and intense plantation of weed, algae, and other plants. The pH of the water here is Alkaline, and the phosphoric content is quite high.

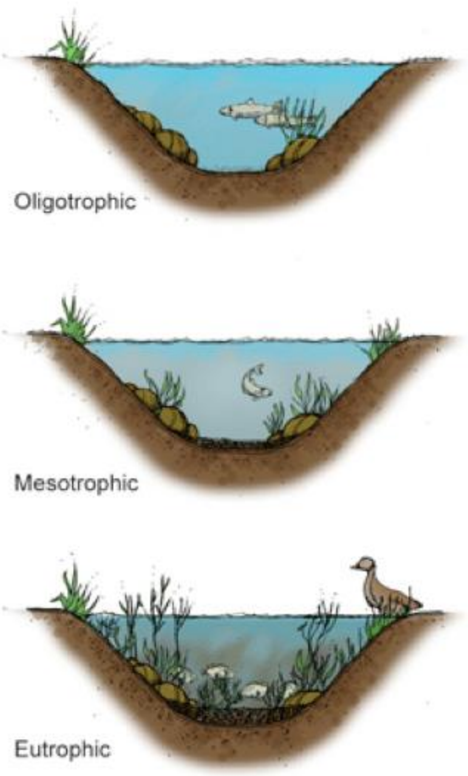


Figure 3. Trophic Catetgorization of Lakes (sourc. Lakeandwetlands)

Chapter 2: Eutrophication

The aging process in lake - eutrophication process

As everything living on our planet, so lakes do age too as they undergo a process dubbed as Eutrophication. Aging is a key factor when we are talking about the longevity and sustainability of a lake. It is of paramount importance to keep the balance within the lake ecosystem and the whole bodies of water in order for a lake to age at a slower ratio. The aging process is the change of a lake from an oligotrophic state to an eutrophic state which also is accompanied by changes in its chemical, physical and biological characteristics (Gilbert M. Masters, 1991).

This process is being fueled by the rise in the level of nutrients, especially ones like nitrogen and phosphorus. This leads to a rapid rise in the level of photosynthesis and the start of a build-up of organic matter in the lake. In addition to this buildup of organic matter sediment accumulates in the bed of the lake over time. Both the above, make the lake increasingly shallower and due to that, warmer. If only nature takes its course, this whole process can take even thousands of years but when human activity is put into the equation then the aging speed of the lake drastically increases (Gilbert M. Masters, 1991). Eutrophication that is intensified due to human activity is called "Cultural Eutrophication" and has been viewed as a form pollution and nowadays most of the lakes in America, Europe and Asia can be characterized as eutrophic.

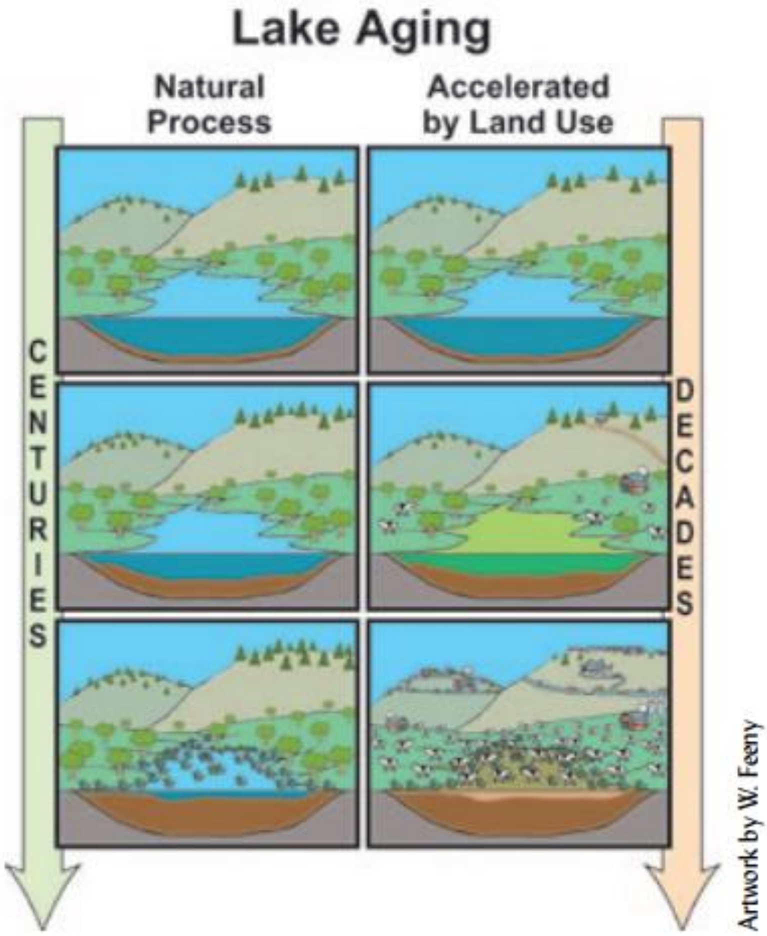


Figure 4. Lake Aging (sourc. Issues In Echology Summer 1998)

Eutrophication Indicators

Sven Erik Jørgensen in his work Lake Management (1980) uses

1. Total Organic Carbon Concentration (TOC) which is a measure of the total amount of carbon in organic compounds in pure water and aqueous systems. (Elga Veolia Lab Site)
2. Total phosphorus (TP) is a measure of all of forms of phosphorus combined (State of The Bay Site)
3. Total Nitrogen (TN) is the sum of nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO2-N), ammonia-nitrogen (NH3-N) and organically bonded nitrogen. (Chemscan Site)
4. Biomass Productivity

In order to assign the classification of a lake to a eutrophic state.

Below tables created by the author based on Jørgensen's work.

Trophic state	TOC (mg/l)	TP (µg/l)	TN (µg/l)	Total inorganic Solids (mg/l)
Oligotrophic	< 1-3	1-5	1-250	2-15
Mesotrophic	1-5	5-10	250-600	10-200
Eutrophic	5-30	10-30	500-1100	100-500
Hypereutrophic	-	30-5000	500-15000	400-60000
Dystrophic	3-30	1-10	1-500	5-200

Table 1 .1. Chemical parameters and trophic state

Trophic state	Mean primary productivity (mg/cm^2/d)	Phytoplankton biomass (mg/cm^3)	Chlorophyll (mg/m^3)	Dominant phytoplankton	Light extinction coefficient (ŋm^{-1})
Oligotrophic	50-300	20-100	0.3-3	Chrysophyceae Chryptophyceae Dinophyceae Bacillariophycea	0.05-1
Mesotrophic	250-1000	100-300	2-15		0.1-2
Eutrophic	> 1000	>300	10-500		0.5-4
Hypereutrophic	< 50-500	>50-200	10-500	Bacillariophycea Cyanophyceae Chlorophyceae Euglenophyceae	1-4
Dystrophic			0.1-10		

Table 1.2. Biological parameters used to measure the lake trophy (created by author)

Besides Jørgensen’s chosen factors for classification there are also other combinations of chemical parameters that can be used to check on the lake’s trophic state. An example could be the New York Lake Association Program in 2006 that used total phosphorus, chlorophyll and Secchi Disk* transparency. The justification of the usage of these aforementioned chemical parameters is that they are closely related to the growth of algae and weeds.

	Eutrophic	Mesotrophic	Oligotrophic
P µ g/l	>20	10-20	<10
Chl a µ g/l	>8	2-8	<2
Secchi depth (m)	<2	2-5	<5

Table 1.3. Parameters and trophic state as per NYLAP (created by author)

* The Secchi disk (or Secchi disc), as created in 1865 by Angelo Secchi, is a plain white, circular disk 30 cm (12 in) in diameter used to measure water transparency or turbidity in bodies of water. The disc is mounted on a pole or line and lowered slowly down in the water. The depth at which the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity. Since its invention, the disk has also been used in a modified, smaller 20 cm (8 in) diameter, black and white design to measure freshwater transparency. (Journal of the European Optical Society Rapid Publications, 2021)

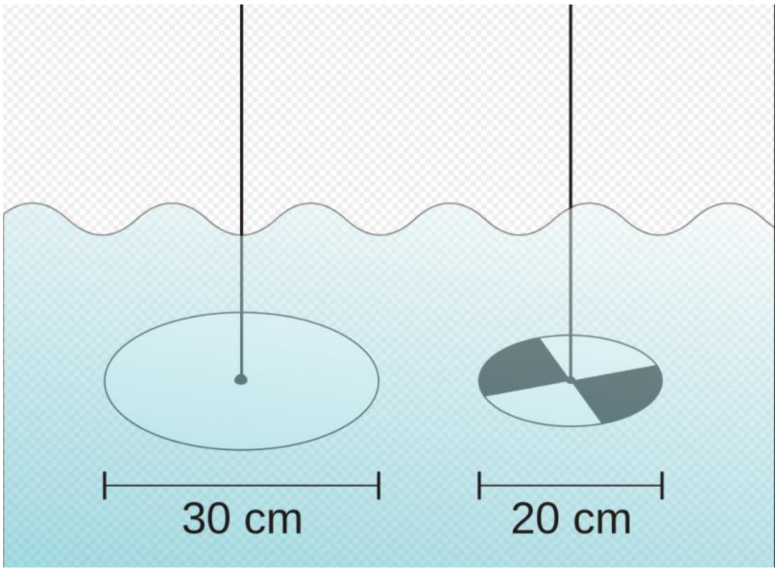


Figure 5. Secchi Disks (sourc. Limno Loan site,2022)

Influencing the Eutrophication Process

Eutrophication has its roots and causality in the increase of photosynthesis. This requires the increase of nutrients such as nitrogen and phosphorus while in the presence of light. Light penetration is a factor that is deeply interconnected with the water turbidity* which is affected by the algal production which in turn is affected by nutrient availability. Increased algal production usually increased the “smokey” effect in the water that reduces light penetration.

Clearly the leading factor that influences the Eutrophication process is the nutrient content of water. As it has been found by studies like the one of Val H. Smith in 1982 it is found that the level of chlorophyll is dependent to phosphorus and to the fractal result of total nitrogen to total phosphorus.

* Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. (US Environmental Protection Agency)

Phosphorus and Eutrophication

As David L. Corell very eloquently provides in the abstract of his paper "The Role of Phosphorus in the Eutrophication of Receiving Waters: A Review", Phosphorus (P) is an essential element for all life forms. It is a mineral nutrient. Eutrophication is the over enrichment of receiving waters with mineral nutrients. The results are excessive production of autotrophs, especially algae and cyanobacteria. This high productivity leads to high bacterial populations and high respiration rates, leading to hypoxia or anoxia in poorly mixed bottom waters and at night in surface waters during calm, warm conditions. Low dissolved oxygen causes the loss of aquatic animals and release of many materials normally bound to bottom sediments including various forms of P. This release of P reinforces the eutrophication. Excessive concentrations of P is the most common cause of eutrophication in freshwater lakes, reservoirs, streams, and headwaters of estuarine systems. In the ocean, N becomes the key mineral nutrient controlling primary production. Estuaries and continental shelf waters are a transition zone, where excessive P and N create problems. It is best to measure and regulate total P inputs to whole aquatic ecosystems, but for an easy assay it is best to measure total P concentrations, including paniculate P, in surface waters or N/P atomic ratios in phytoplankton. (D. Corell, 1998)

Phosphorus is abundant in the earth's cortex and is not found free in nature. It is found though, in 3 forms orthophosphorics, polyphosphoric ions and phosphoric elements that are combined with 36 different elements (Koumitzis, 1996). The Phosphoric compounds that are met in water can be divided in organic or inorganic, dissolved or particular. The key role in the increase of the phosphoric content in water is agriculture that stems mainly out of the use of fertilizers and from the dumping of sewage waste and liquid industrial waste in bodies of water. Among the factors that affect the phosphoric concentration in bodies of water is temperature and acidity (pH). The higher temperature is the higher the rate of decomposition of organic matter therefore the higher rate phosphates are being released in the water. Meanwhile, high temperatures increase the consumption of phosphates in photosynthetic organisms. In high pH the of ions of hydroxyl in water interact with phosphorus from compounds of iron (Fe) and Aluminium (Al) that can be found in the benthic zone. It is therefore that the increase of the pH values is increasing the concentration of phosphorus in water. Anoxic environments are benefiting the spread of phosphorus from the benthic zone into the general body of water. The increase of the concentration of Nitrous ions diminishes the rate of phosphoric release in the water due to the oxidizing action. In parallel, the presence of macrophytic plantation in a specific body of water increases the concentration of phosphorus in water. Plants are using phosphorus as an intake from the bedrock of the lake while during their development they release high amounts of phosphorus in water, a process that continues even during their death. The remaining of dead-wood in the water increases decomposition that will furtherly release phosphoric compounds (Darakas, 2011). In most waters the concentration of the total phosphorus ranges between 10-50 μg/l. Although, in oligotrophic waters the content of total phosphorus could be less than 5 μg/l. In high eutrophic environments it can surpass 100 μg/l.

Nitrogen and Eutrophication

The effect of Nitrogen is quite lower than the one of phosphorus in regards with Eutrophication. There have been studies that suggest that 7 times more nitrogen is needed to "create' the same amount of algae than phosphorus (J. Kanninen et al, 2004).

Ammonia (NH_3) and Ammonium (NH_4^+) are the most common nitrogen by-products that can be found in natural waters. The underground water sources are usually low in ammonia (about 0,2 mg/l), as the higher concentrations are being observed in underground waters that run under forests. Ammonia is not directly affecting health in low concentrations in drinking water, but it is usually a solid indicator of pollution of water from fecal matter. In concentrations over 0,2 mg/l it can affect smell and taste in water, and it diminishes the effectiveness of disinfection. Moreover, it adds to the formation of Nitrous Salts in watering systems. The highest acceptable value is considered 0,5mg/l (Darakas, 2011) Ammonia in high levels can be toxic to different marine lifeforms. As an element it is quite dissolvable in water and unstable in the most environments. Ammonia is easily transformed into nitrate (NO_3^-) in waters that contain sufficient dissolved oxygen or into nitrogen gas in waters that have no dissolved oxygen.

Nitrate (NO_3^-) Nitrite (NO_2^-) as elements are existing in the natural waters and they are a part of the Nitric Circle in nature. Although, the concentration of Nitrate/Nitrite must be low. High concentrations have their causal roots to fertilizers, fecal matters and human or animal waste. They can also be found in the air as a product of atmospheric pollution, that can be washed down on the soil by rain and penetrate the water horizon. These elements are usually stable and the changes in their concentration in waters are immediately affected by biochemical reactions. Their concentration in waters when found in nature is quite low in general whereas in some underground waters there can be a further elevation. If bodies of water are destined for drinking water and they are found with high content in Nitrate/Nitrite they are being filtered by carbon filters. They can be dangerous for the health as they can be absorbed by blood cells and oxidize the hemoglobin iron. High concentrations in waters can also bear the risk of causing the cyanosis disease to fetuses. In case of ingestion of such waters due to the acidic environment of the stomach the elements can be transmuted to nitrosamines that are potentially carcinoid matter (Loiozidou, 2006). More health issues have been identified to be caused in cases of high concentration of such (United States Government Site, 2021).

How Eutrophication Affects the Ecosystem

The factor Eutrophication affects greatly is the level of dissolved oxygen in bodies of water. Near the surface of lakes oxygen concentration is always higher as there is constant production attributed to photosynthesis; in addition, more oxygen is “pumped” into the waters by the air-water system. In contradiction, in the deeper parts of the lake the oxygen production is lower. As oxygen is produced by photosynthesis and this can be only done when sunlight is abundant, higher water turbidity in a eutrophic lake that can be caused by a high amount of algal growth can limit the ability of oxygen production in deeper parts of a lake. Adding to that, the high algal plantation due to the high nutrient content in water can be connected to the death of the plant; as the algae die, they are moved to the benthic zone, and they are decomposed. The decomposition process is one that draws oxygen from the ecosystem which in turn adds to the decrease of oxygen levels. This is a typical example of an Eutrophic Lake that oxygen levels diminish in deeper parts and can even be at value zero in specific depths and cases; whereas, for example in the case of Oligotrophic lakes similar oxygen levels can be observed near surface waters but also in the deeper or even deepest parts of the lake (Gilbert M. Masters, 1991).

Figure 6. Algae plantation limiting sunlight's access (sourc. European commission site)

Other effects that can occur from eutrophication and that could have devastating effects in the ecosystem could be:

1) Noxious Algae formations or other forms of toxic algae. Which has as a direct effect the gathering of goo masses in the water, foul odor and unappealing color in the water.
2) Loss of habitable lake parts due to the low content of oxygen
3) Increased growth of macrophytes that are limiting the access of sunlight into water.
4) Increased presence of poisonous elements like the aforementioned Ammonia, or H_2S especially in the deeper parts of the lake waters that can create a further loss of habitable space.

Due to all the aforementioned adverse effect of eutrophication and the danger it poses to the ecosystem it is of grave importance to create reference points of the water quality of lakes in order to observe over time the situation in these bodies of water and proceed in whatever necessary correction via measures taken to ensure the survivability and sustainability of a lake and its ecosystem. This can be of vital importance for local economies that depend on the quality of lake water. There are whole economies that can be devastated if local fish populations meet their demise due to loss of habitat, if the quality of water decreases dramatically that could create toxic algae formations and thus foul odor and goo mass gatherings, which could deteriorate tourists of visiting lake towns such in the case of Kastoria and it can also decrease the life quality of the permanent residents of a lake-city.

Figure 7. Toxic Algae formation in Lake Erie (sourc.Tom Philpott Mother Jones Art. 6 Aug 2014)

Figure 8. Increased Macrophyte Growth (sourc. William B.Bowden et al 2017)

Water quality standards for a lake

Water quality standards are the most important factors that we must always have on check in the whole process of a lake/water management program. These parameters translate the situation within the bodies of water, and they can provide us with valuable insights.

In the tables below that were created with the help of the data drawn from the Japanese governmental site for Environmental Quality Standards for Water Pollution, the reader will observe the connection of Nitrous and Phosphoric elements in natural or man-made lakes according to the water use purposes.

Categories	Water use	TN (mg/l)	TP (mg/l)	Summer chlorophyll a (mg/m3)	Transparency (m)
I	Conservation of natural environment, and use in II - V	<0.07	<0.005	<1	>6
II	Water supply class 1, 2, and 3, fishery class 1, bathing and use III - V	<0.15	<0.01	<3	>4
III	Water supply class 3, use IV - V	<0.40	<0.03	<20	>2
IV	Fishery class 2, and use V	0.60	<0.05	<40	>1
V	Fishery class 3, industrial water, irrigation water, conservation of environment	<1	<0.10	-	-

Table 1.4. Nitrogen and phosphorus concentrations and relevant water usage (created by author)

Water supply:

- class 1: sand filtration

- class 2: coagulation/rapid filtration

- class 3: pretreatment, advanced water treatment

Fisheries:

- class 1: salmon, trout, ayu

- class 2: pond smelt

- class 3: carp, catfish, roach

Water quality standards for lakes can also be established based on organic matter “COD” and dissolved oxygen and suspended solids “TSS” regarding water use.

Water use	COD (mg/l)	TSS (mg/l)	Dissolved oxygen (mg/l)
Conservation of natural environment	1<	1<	>2
Water supply for drinking water, fishery class 1and 2	3<	-	>7.5
Fishery class 3	5<	-	>6
Bathing	8<	-	-

Table 1.5. COD and dissolved oxygen concentration and water use (Created by author)

Chapter 3: Area of Interest - Kastoria

The Municipality of Kastoria is one of the 51 segments of Greece and one of the four that belong to the area known as Western Macedonia with population around 50,000 people. It is one of the municipalities of Macedonia which is the biggest geographical compartment of Greece. It has boarders the Municipalities of Florina, Kozani, Grevena and Ionannina and also with Albania. The capital of the municipality is Kastoria which spans over 1720 square kilometers of land. It is a semi-mountainous area with only a few areas of flat land. The flat areas are the most densely populated. Local economy is mostly characterized by its fur industry, hospitality, local food products, local commercial markets and agricultural production. The mountain areas close to the Albanian boarder are scarcely populated. The climate of the area can be characterized by cold winters and mild summers. In wintertime, the temperature frequently drops below zero and as a result the lake waters can freeze.

Economy of Kastoria

Fur Industry

Kastoria has traditionally been one of the most known places around the world for the processing and creation of fur. This long tradition is characterized by ever-increasing quality and the Fur is one of the biggest export fields of the country. The craft of fur making has its roots back in the Byzantine years where the Artificers of Kastoria did their studying in

Constantinople. The craft has been passed from generation to generation and is one of the few hand-made styles that remain to the day. After the challenges that the sector faced the last years and the increasing competition especially from the Asian manufacturers, the Fur makers are looking now to turn out more to the international markets also by moving their product abroad but also by trying to attract more international visitors to the city that could breathe new air into the industry.

Agriculture

The municipality of Kastoria has limited agricultural production. The most fertile grounds suitable for big cultivations are in the areas around the lake of Kastoria and at the Ano Haliacmon Plateau. The most common products of Kastoria are cereal, apples, legumes among other green produce. There has been an intense effort the last years to highlight the quality and market more and more the produce of the area with emphasis on the Kastoria signature and the high quality of the items. Apples, just like the "gigantes" beans of Kastoria have been acknowledged as products with protected origin.

Husbandry

The field of husbandry – besides the decrease in pure numbers of goat and sheep – has shown increased development in matters of pure number production, processing and commercial trade of husbandry products like meat, milk, wool, skins and other dairy products. The municipality in coordination with authorities are trying to boost the sector.

Forest Economy

The forest resources play a big role in the economy of the area. The sustainable exploitation of the wood areas, the protection of them and the continuous efforts towards sustainability and health of the ecosystems are of high priority of the local authorities. There has been an increasing production of lumber throughout the latest years. The boosting of commerce of lumber and the use of the forest resources are elements that could boost the local economy and generate more job positions in the immediate area, keeping and why not increasing the mountain populations that would in turn increase the influx of tourists in the mountain areas.

Fisheries

The Lake of Kastoria is one of the most traditional and important Fishery centres of inland Greece coming third following the lakes of Ioannina and Kerkini. Fishery in the area of the lake of Kastoria is one of the most important activities as besides the professional fisheries there are also amateur fishermen that enjoy it as a hobby (not commercial exploitation which is not allowed for amateurs). Generally, it can be observed that the yearly production of the lake the last 30 years could be around 78kg per hectare (ha) of lake. Alarming factor is that the fishery production has dramatically decreased the last decades from 150kg/ha back in 1960-70 and 108kg/ha in 1980-90 to todays around 78kg/ha which is almost a 45% decrease.

The yearly production per hectare of lake can be improved again not only in quantity but also in quality.

The Lake of Kastoria

Lake Orestiada or more commonly known as the Lake of Kastoria is the lake in the city of Kastoria geographically placed in the Northwest part of Greece. The lake is located 630 meters over the sea, and it covers an area of 28 km^2. Nine small rivers and streams of water flow into her and the lake drains into the Haliacmon river. Depth wise, the lake varies in different areas ranging from 9-10 meters. The Lake of Kastoria is considered to have formed about 10 million years ago. The Kastoria Peninsula, on which the town of Kastoria is located, divides the lake into two segments the larger – in the north – and the smaller – in the south. The lake itself takes its name from Oreiades which according to Greek mythology they were mountain nymphs. Orestiada lake, besides its immense natural beauty also holds sights from the time of more recent and of yore past as the Byzantine monastery of Panagia Mavriotissa and the prehistoric settlement of Dispilio, where also the Dispilio tablet was discovered in 1992. The lake is prone to freezing in winters.

Figure 9: Lake Orestiada Panoramic view (sourc. Naturagaea.com)

Figure 10: The City of Kastoria (sourc Sentra.com)

Figure 11: Lake of Kastoria Sattelite Image and map location (sourc. Biodiversity Data Journal)

The volume of water of Lake Kastoria is about 100 million cubic meters and the “opening” of its shores is 30,8 km long. The lake is being supplied also from many under-lake spring formations and also from water rain that either fall onto its surface directly or ultimately end up in it from the different rivers, streams and rivulets that are mostly located in the northern and eastern part of the city. At the South station there is a canal known as “Rema Gioli” that connects the lake with the river Haliacmon whereas mentioned above drains in with the assistance of a dam that was recently renovated by the Municipality of Kastoria. The Lake is of utmost importance for the city as it defines the scenery of the city and is also an important natural resource. (Kastoria City Site, 2021).

The Natural Ecosystem of the Lake Orestiada

The Lake is also a very important natural ecosystem with many diverse separated eco-habitats that support extremely high biodiversity in which many rare and endangered species are included. It is fascinating how such high biodiversity of plant life and animal life can be found next to a developed city. Besides the great number of bird species the Lake, the lake is the only natural lake in Greece that still is a home of shore-forest formations of hydrophilic trees which is one of the rarest ecosystems in Europe. The Lake has been characterised as a place of “extreme beauty” by the Ministry of Culture in 1974 and is a “Natura 2000” area. Throughout all the lake any hunting is forbidden and its immediate area is considered by the Hellenic Ornithological Society as an area of High Importance of the Birds of Greece.

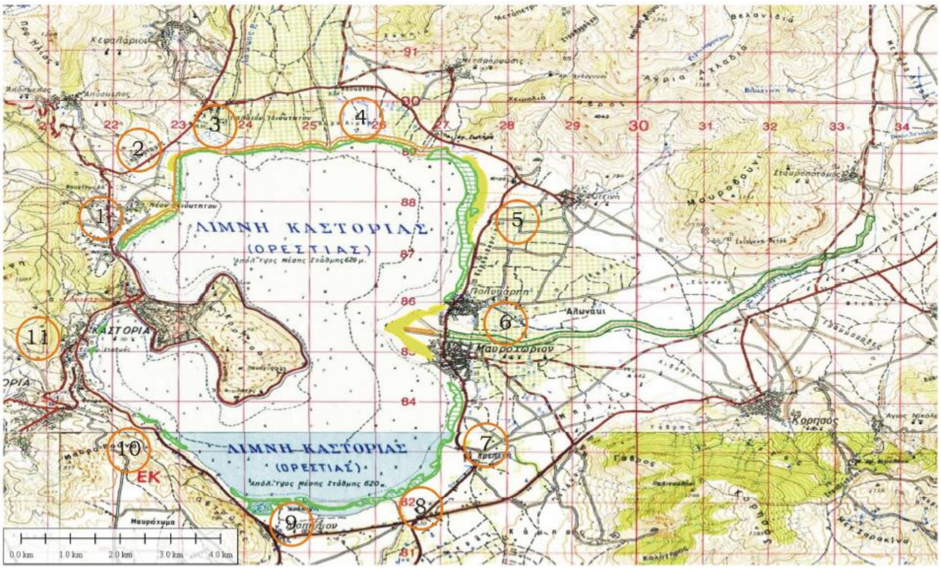


Figure 12. Map of Plantation in Lake of Kastoria showing reeds, hydrofields, lake shore forests (source Institute of Protected Areas of Western Greece)

Importance of the Lake of Kastoria

Besides its great beauty, being a home to a great number of flora and fauna species and the consideration of a gem of nature the Lake holds great importance to the local economy. Kastoria has historically been a winter destination for tourists around Greece, but also from the Balkan Peninsula. The winter scenery is unparalleled, and it attracts many tourists especially in the autumn, winter, and early spring months. Tourism has been a sizable source of income for the local economy both in regards of the industry of hospitality but also in regards with the local market. In addition, another sector of the economy that lives of the lake is the one of the fisheries. Fishing is allowed to licence holding fishermen.

From the aforementioned, in combination with the mere geographical placement of the Lake one can understand that it is of immense important for the city and thus of great importance also is the quality of water of the lake. In case of a severe eutrophication of the lake; or if it is suffering pollution of any other kind, it would be a devastating blow to the local economy which adding to the financial difficulties that the recession caused could cripple local businesses and income of families.

Pollution in the Lake of Kastoria

It is well known at this point that the major problems/pollution of the lake have their roots to

1) The releasing the city's and surrounding villages sewer systems in the lake, in the past.
2) The washing of the excess of fertilizers and pesticides that drained into the lake from near farming grounds, through underwater currents and rivulets.
3) The human activity of uprooting specific areas.

To tackle this the Municipality of Kastoria has put in place an especially important development program of ecological balance of the Lake. So, besides the installment of a Water Treatment unit for the City's sewerage that has been in place since the '90s, the shore villages and smaller towns have been incorporated in the plan during the recent years. Moreover, an effort has been made to control the winter rivers that gush during the winter months and to manage reeds with purpose of decreasing the levels of Nitrogen and Phosphorus that has stuck in the lower levels during older time periods.

As for the regulatory measures that were taken to protect the Ecosystem the Municipality of Kastoria

1) Has funded the undertaking of studies and research in regards with the proper boundary setting of the ecosystems in/around the lake.
2) Has implemented plans and measures for the protection of the immediate area.
3) A Fish hatchery has been created with aim to increase the fish population and diversity of the Lake.

Chapter 4: Lake Monitoring & Management

As it has already been mentioned lakes and ponds of any shape and size are very diverse ecosystems with numerous species and organisms dwelling in their vicinity. All these can affect water quality in a minor or major way. Not mattering if the lake is man-made (reservoir) or we are talking about a natural lake that was made through many thousands of years of different formations, volcanic, tectonic, or glacial activity, the parameters of the water quality give the researcher important insight about the state of the lake, information about its aging process and can be useful to create strategic plans for the sustainability and preservation of these important sources of sweet water. Freshwater on earth's surface constitutes only the 2.5% of the whole; of which 2,5% only 1% is accessible for use. Understandably, lakes are amongst the most important freshwater resources that are on our planet.

It is understandable then lake monitoring is of immense importance in order to be ever aware of changes in the water quality and address potential issues that could arise, before they develop into permanent problems. These issues can be related to turbidity, sediment build-up, thermal stratification, excess nutrient loading, algal blooms, noxious algae formations, goo presence among others.

Lake monitoring and Lake management both are equally important therefore to preserve what already seems to be in deterioration. With the term "Lake Management" we are covering many different disciplines and applications. According to Fondriest Environmental Learning Centre, management of a single lake can include strategic planning for conservation, improvement actions, restoration of parts of the ecosystem, rehabilitation programmes, as well as different forms of research on the bodies of water of within in the system. The modern practises in Lake Management have shown that the protection, conservation and rehabilitation of lakes is a marathon rather than a race; it requires many small steps and actions towards a larger goal. There are some techniques that are more efficient if they are done in a major scale. Lake Management is a complex process as complex as the ecosystems of lakes themselves and it takes a lot of effort, planning and of course funds to put a holistic Lake Management Plan into action. There is a variety of techniques available in the environmentalist's quiver that can be used to aid a lake ecosystem, from complex techniques that could restore oxygen levels and distribution of nutrient factors to more simple ones like for example dredging, cleaning of algal blooms and noxious masses or removing goo among others. All of these techniques though affect the ecosystem therefore they must be prudently used, and the project managers must monitor the state of the water quality and the stability of the ecosystem before, during and after the implementation of a Lake Management Plan.

Monitoring

In order to effectively and continuously monitor the state of the lakes and the water quality in them there are various tools that can be used in our modern world to provide us with data that can be used to observe the progress of the ecosystem.

CTD (instrument) known as Sonde:

A CTD or Sonde is an oceanography instrument used to measure the conductivity, temperature, and pressure of seawater (the D stands for "depth," which is closely related to pressure). (Baker D. J., 1981). More especially, multi-parameter sondes have usually many ports where different sensors can be attached that could measure depth, pH, temperature among other values. Most of the modern Sondes have a built-in memory as well as a solid battery that will allow them to stay a long time deployed thus gathering more data. Data loggers and external power connectivity options can allow them to be deployed for even longer periods of time, even unattended. For Lakes usually it is normal to attach sondes to a buoy.

Sondes are solid instruments for measurement but still it requires some attendance since organic build up or grime can interfere with the sensors' optimal function.

Figure 13. Multi-parameter Sonde (CTD) (sourc. Fondriest Site)

Inland Lake Monitoring System

As mentioned in the previous chapters, there are many hydrological parameters that can be monitored in a lake and as lakes are different from one another there are big differences from lake-to-lake monitoring or management project. The number of monitoring places in a lake, the locations of such monitoring places, the instruments that will be used for each monitoring will definitely be different from one lake to another. Although, besides having these differences there are some things that could be considered as shared between different monitoring projects in inland lakes.

The most effective way to collect data and measurements is if the data is provided real time. The easiest and most efficient way to do such is to create a buoy-based monitoring system. A data buoy can be the "mothership" of many sensors at multiple depth levels of the lake providing a holistic picture of the specific monitoring spots' quality of water. This buoy monitoring point can easily transmit data via the available technology to a shore server that in turn could log/store, categorize, analyse and picture data in real time. This data can also be accessed by any computer.

These systems are quite flexible and easily customizable in accordance with the need of each specific Lake Management Project. Installing batteries or even solar panels that could power the buoy-base for quite a time the point can stay unattended for long periods of time, while having the data streaming to our computers that we can effortlessly observe. In this optimal scenario when parameters move outside of the accepted or the norms in a specific area of the lake or the entirety of the lake, quick correctional actions can be taken to aid the ecosystem return to its balance.

Data Buoy

A data buoy is a floating platform that supports real-time monitoring instruments such as sensors and data loggers. In addition to housing the monitoring equipment the buoy supplies all power and can transmit sensor data in real time.

Multi-parameter Sonde

Multi-parameter sondes offer a versatile platform for deploying several sensors at a common site. These sondes can also act as an interface between sensors and a data logger or power source.

PAR Sensor

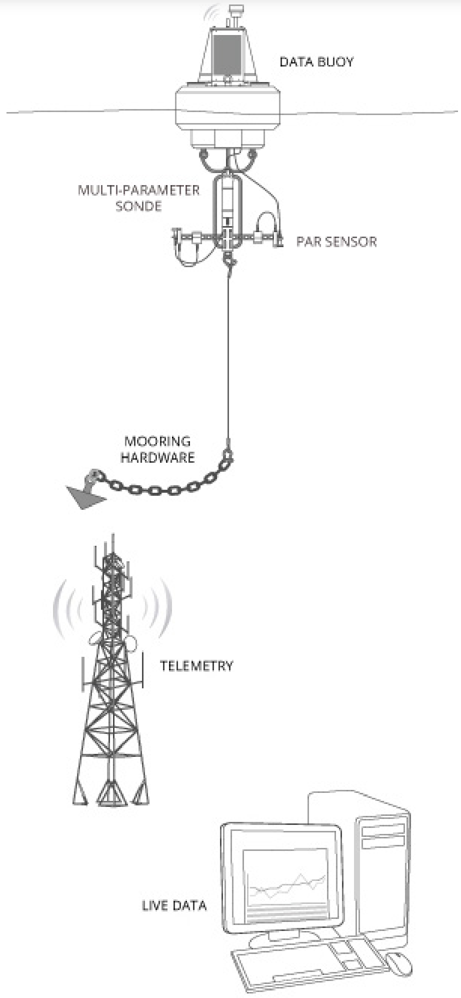
The PAR sensor uses a silicon photodiode and glass optical filters to create uniform sensitivity to light between 400 nm to 700 nm, which closely corresponds to light used by most aquatic plants and algae. Sensors can be oriented to measure both downwelling and upwelling radiation.

Mooring Hardware

Data buoys can be anchored with a single or two-point mooring based on application requirements.

Telemetry

Telemetry provides access to data in real time. The wireless communication can be radio-to-shore, cellular, or satellite based.



Live Data

Instant access to project data is available 24/7 through a cloud-based data center. Monitoring data can be viewed in real time, or as a graph to identify trends. Real-time automated alerts can be sent via text or email when specified parameters exceed pre-defined limits.

Figure 14. Data Buoy System (Fondriest)

While creating a Lake Monitoring plan, the location of the stations plays a very high importance. Careful planning and analysis must be conducted in order to decide which specific spots of the lake will be the designated monitoring points and also to determine the depth of the measurements. It has been long proven by the scientific community that collecting data from single specific points, when we talk about environmental analysis, is the most effective way to receive comprehensive measurements that will “tell a story”. It is also of equal importance to keep notes on the specific samples in regards of where they were taken. As these stations are fixed locations after the planning stage, the researcher can either take field measurements on their own during the sampling periods, or to install an aforementioned stationary station that could monitor the specific point.

Sampling

In regards with the monitoring and assessment of the water quality of a lake it is important to create sampling procedures of the surface and deeper layer waters of a lake through time. By conducting a sampling routine in specific frequent timeframes can allow the researcher to extract valuable conclusions in regards with the levels of pollution of a lake and the rate by which it is being restored in the course of time. The process of creating a sampling plan itself is determined from the goals that have been set in the start of the project. Usually, a sampling plan is being drafted where the parameters that will be tested are listed analytically, together with the exact points of sampling and the number of samples that are to be taken; moreover, the time between previous and next sampling taking must be determined as the frequency is very important as well as the way that the sampling will be conducted as far as the equipment that will be used. It is very important that through the course of the sampling and analysis no equipment will be changed which could alter extracted data and distort the whole picture.

Chapter 5: Parameters of Water Quality

Different ways of monitoring the water quality and the rate of recovery of the lake in case of pollution include quite a few parameters. According to Kryimtzis (1994) the most important are listed below:

1) Parameters of Instrumental Sampling Monitoring:
    a. Smell
    b. Taste
    c. Colour
    d. Turbidity
    e. Floating Solid Materials
2) Parameters of General of Physic Chemical Monitoring
    a. Toughness
    b. Conductivity
    c. Total Dissolved Solids (TDS)
    d. Alkalinity
    e. Chlorinity
    f. Sodium / Potassium
    g. Dissolved Oxygen
3) Parameters of Monitoring the Pollution of Waters
    a. Oxidisation (KMnO4)
    b. Biochemical Oxygen Demand (BOD)
    c. Total Organic Carbon (TOC)
    d. Nitric compounds (Ammonia, Nitrate, Nitrite)
    e. Phosphorus compounds (Phosphates, Polyphosphorics)
    f. Sulfurics and Sulphides
    g. Detergents
4) Biological Parameters
    a. Chlorophyll
    b. Phytoplankton
    c. Biodiversity
5) Microbiological Parameters
    a. Coliform bacteria
    b. Pathogens

6) Radiological Parameters
    a. A & B radiation
    b. Radioisotopes
7) Special Monitoring
    a. Biological
    b. Toxicological
    c. Monitoring of sediments

Data and Water Quality Parameters for the Lake of Kastoria

In continuation the detailed parameters that are being analysed will be described in deeper detail, which stem out of the measurements in hand for the present paper. The measurements/data have been provided by the President of the Management Body of National Protected areas of Western Macedonia. The measurements en site and the lab analysis have been conducted under the aegis of the Administrative region of Western Macedonia and their assigned teams for Lab Testing.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen Demand also known as BOD is a number that describes the amount of oxygen that is being consumed by microorganisms while organic matter decomposition is ongoing under aerobic conditions – meaning where oxygen is available – at a specific temperature. Besides the fact that we cannot see oxygen in water there is still oxygen in it and it is the driving factor of the health of the ecosystems that live upon and into these waters. Being of such a high importance dissolved oxygen in water bodies must be up to a certain concentration for all living things to thrive maintaining, preserving, and increasing aquatic life but also the whole ecosystem. One of the key factors that would enable a Lake Management system to be successful is the observation of the way that organic matter affects the concentration of dissolved oxygen. The decay of such organic matter in water is measured as biochemical or chemical oxygen demand and it is a measure of the amount of oxidizable substances in a water sample that can lower dissolved oxygen concentrations. (U.S. Geological Survey Organization, 2021).

There are specific circumstances natural and man-induced (i.e. a very hot summer or excess fertilizers being washed into the lake ecosystem) that can affect the dissolved oxygen amount in a body of water usually for the worse. The decrease of the amount of dissolved oxygen in an ecosystem can affect aquatic life and destabilize the whole ecosystem. A method that assists in understanding the effect of bacteria and/or microorganisms on the amount of oxygen that they consume to perform organic mass decomposition is the measure of Biochemical Oxygen Demand aka BOD. Observing how organic matter and specifically its decomposition affects dissolved oxygen levels in the body of water is of key importance of maintaining a balanced ecosystem. A disadvantage of the measurement of BOD is that the process takes a lot of time usually minimum 5 days.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand or COD is a measure of the amount of oxygen that can be consumed by reactions in a specific measured solution. More specifically it is the amount of oxygen that is required for the full chemical oxidation of organic matter in CO_2 and water. The oxidization is manifested with strong oxidizing mediums under low pH environments and the presence of a catalyst. Therefore, it could be said that it is an indirect measurement of the quantity of organics in waters. It is most oftenly expressed in mass of oxygen consumed over volume of a specific solution which would be in mg/L. Chemical Oxygen Demand tests can assist in determining the number of organics in water. The most common application of Chemical Oxygen Demand measure is to determine the amount of oxidizable pollutants found in surface waters – lakes and rivers – or even wastewater. It provides us with key information in regards with water quality. The measurement can be quickly done – in a small time frame, usually can be completed in 2-3 days– and with proper correlation it can even provide us BOD numbers. Waters of very good quality are characterised with values under 10mg/L. A disadvantage of COD is that both decomposable and undecomposable matter is measured. Therefore, one could say that the measurement of COD is less representative than BOD when it is purely used for the determination the organics amount. Usually it is presented in mg/lt. As a rule of thumb COD has a higher value than BOD (Vasilatos, 2010)

Acidity & Alkalinity – pH

The scale of pH is one of the most important characteristics of water. pH is a fundamental water parameter for an aquatic ecosystem as it is a measurement that affects a wide variety of factors. More specifically, pH is directly affected by the type of the chemical reactions that are taking place in a specific body of water. It can control the chemical reactions that are taking place within the said water, and it can accelerate or act as a blockage to different biochemical processes. (Charalampous, 2006). The pH scale is logarithmic and inversely indicates the concentration of hydrogen ions in the solution. This is because the formula used to calculate pH approximates the negative of the base 10 logarithm of the molar concentration[a] of hydrogen ions in the solution. More precisely, pH is the negative of the base 10 logarithm of the activity of the H^+ ion. (Bates R. 1973).

pH is measured usually at 25°C and according to values from 0-14 with natural point the value 7. Waters with pH lower than 7 are considered as acid and the ones with values over 7 as alkaline. Waters with values quite low or quite high in the pH scale are not considered a suitable environment for aquatic life and can also cause health issues to humans if ingested. Drinking water pH must be, according to law around the neutral values from 6,5-8,5 (Loizidou, 2006). Water in nature usually is measured in the range of 4-9 of the pH scale with more often occurrence of waters to be slightly alkaline due to the presence of various ions of carbon.

pH measurement is among of the most important ones in regards with water quality, as mentioned. In the past the determination of pH in waters was being done by the use of the method of chromometry, meaning that specific paper indicators were dipped in water that according to the color they obtained after seconds or minutes the pH was determined. Although, technology has done leaps the recent years and nowadays the measurement of pH of a water mass is quite easy by using specific instruments called pH-meters. A pH meter is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a "potentiometric pH meter". The difference in electrical potential relates to the acidity or pH of the solution. The pH meter is used in many applications ranging from laboratory experimentation to quality control. (Encyclopedia Britannica Online, 2016).

Water Conductivity

Conductivity in general is the measurement of the flow of electric current via a conductor. In a water solution the value of conductivity is an indicator of dissolved salts presence. (Kouimtzis et. Al 1994). As a representative measure of the concentration of total dissolved solids (aka TDS) in a solution, conductivity can also be used that is measured in mS/cm. Conductivity is used to provide water quality insights and is tightly connected with salinity. In a liquid solution the higher concentration of salts there is the higher conductivity is too. In water bodies with low salt contents, it has been found that the total dissolved solids number is the same as half the measure of conductivity. As the concentration of salts in water increases the potency of ions decreases therefore the conductivity number could be almost the same with the one of total dissolved solids in a water mass. As a water body ages like in the case of a lake, usually there is an increase in its conductivity due to the increase of the nutrient factors within the body also known as Eutrophication. Usually, in nature we find waters with conductivity from low number 50 to higher 1500 µS/cm whereas in industrial wastewater the value of conductivity can even reach over 10000 µS/cm according to Darakas (2011).

Ammonia & Ammonium

Ammonia (NH_3) and Ammonium (NH_4^+) are the most common nitrogen by-products that can be found in natural waters. The underground water sources are usually low in ammonia (about 0,2 mg/l), as the higher concentrations are being observed in underground waters that run under forests. Ammonia is not directly affecting health in low concentrations in drinking water, but it is usually a solid indicator of pollution of water from fecal matter. In concentrations over 0,2 mg/l it can affect smell and taste in water, and it diminishes the effectiveness of disinfection. Moreover, it adds to the formation of Nitrous Salts in watering systems. The highest acceptable value is considered 0,5mg/l (Darakas, 2011) Ammonia in high levels can be toxic to different marine lifeforms. As an element it is quite dissolvable in water and unstable in the most environments. Ammonia is easily transformed into nitrate (NO_3^-) in waters that contain sufficient dissolved oxygen or into nitrogen gas in waters that have no dissolved oxygen.

Nitrate & Nitrite

Nitrate (NO_3^-) Nitrite (NO_2^-) as elements are existing in the natural waters and they are a part of the Nitric Circle in nature. Although, the concentration of Nitrate/Nitrite must be low. High concentrations have their causal roots to fertilizers, fecal matters and human or animal waste. They can also be found in the air as a product of atmospheric pollution, that can be washed down on the soil by rain and penetrate the water horizon. These elements are usually stable and the changes in their concentration in waters are immediately affected by biochemical reactions. Their concentration in waters when found in nature is quite low in general whereas in some underground waters there can be a further elevation. If bodies of water are destined for drinking water and they are found with high content in Nitrate/Nitrite they are being filtered by carbon filters. They can be dangerous for the health as they can be absorbed by blood cells and oxidize the hemoglobin iron. High concentrations in waters can also bear the risk of causing the cyanosis disease to fetuses. In case of ingestion of such waters due to the acidic environment of the stomach the elements can be transmuted to nitrosamines that are potentially carcinoid matter (Loiozidou, 2006). More health issues have been identified to be caused in cases of high concentration of such (United States Government Site, 2021).

Sulfurics - Sulfate

Sulfates can be found naturally in waters or can be man induced. When found in nature they are usually the result of the decomposition of leaves that fall into a stream of water, water passing through specific rock formations or minerals, or even atmospheric decomposition. If induced by human activity, usually sulfates have their roots to plants, industrial discharges such as textile mills, pulp mills or tanneries – that sparks the interest especially in our case of Kastoria. Washed water from agricultural plantations that will move fertilizers or pesticides into a lake can also be a source of sulfites. Sulfate can be measured with a colorimetric method like the aforementioned of the pH or Ion Chromatography.

Sulfur is an essential nutrient for plants. In the case of aquatic ecosystems, the sulfur is being utilized and low concentrations of such can direly affect algal development. The most common form of sulfur found in water is sulfate. In cases where the sulfate values are lower than 0.5 mg/L, there is zero algal development. Besides its beneficial effect sulfur is not always an angel as sulfate salts can be major contaminants in natural waters.

Sulfides can be a high threat towards marine and human life as they are toxic. These are formed under anaerobic conditions and a foul smell can occur. Sulfides can also have their roots to washed water from coal or other mineral extraction facilities or other industrial sources.

Sulfates in normal concentration are not posing a direct threat to humans or animals. Although, in higher concentration they can start to have mild effects on human health and body response and if waters with high concentrations are ingested over a longer period of time health can also be threatened. Moreover, at high concentrations sulfates are toxic to animals like cattle so caution must be taken also in the water that is being used to water the herds. Recommended limits for domestic supply waters is below 250 mg/L.

Turbidity

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid. (US Environmental Protection Agency). Turbidity simply put is the resistance of the body of water to the penetration of light and is a cause of floating materials.

Phosphorus & Phosphates

As David L. Corell very eloquently provides in the abstract of his paper "The Role of Phosphorus in the Eutrophication of Receiving Waters: A Review", Phosphorus (P) is an essential element for all life forms. It is a mineral nutrient. Eutrophication is the over enrichment of receiving waters with mineral nutrients. The results are excessive production of autotrophs, especially algae and cyanobacteria. This high productivity leads to high bacterial populations and high respiration rates, leading to hypoxia or anoxia in poorly mixed bottom waters and at night in surface waters during calm, warm conditions. Low dissolved oxygen causes the loss of aquatic animals and release of many materials normally bound to bottom sediments including various forms of P. This release of P reinforces the eutrophication. Excessive concentrations of P is the most common cause of eutrophication in freshwater lakes, reservoirs, streams, and headwaters of estuarine systems. In the ocean, N becomes the key mineral nutrient controlling primary production. Estuaries and continental shelf waters are a transition zone, where excessive P and N create problems. It is best to measure and regulate total P inputs to whole aquatic ecosystems, but for an easy assay it is best to measure total P concentrations, including paniculate P, in surface waters or N/P atomic ratios in phytoplankton. (D. Corell, 1998)

Phosphorus is abundant in the earth's cortex and is not found free in nature. It is found though, in 3 forms orthophosphorics, polyphosphoric ions and phosphoric elements that are combined with 36 different elements (Koumitzis, 1996). The Phosphoric compounds that are met in water can be divided in organic or inorganic, dissolved or particular. The key role in the increase of the phosphoric content in water is agriculture that stems mainly out of the use of fertilizers and from the dumping of sewage waste and liquid industrial waste in bodies of water. Among the factors that affect the phosphoric concentration in bodies of water is temperature and acidity (pH). The higher temperature is the higher the rate of decomposition of organic matter therefore the higher rate phosphates are being released in the water. Meanwhile, high temperatures increase the consumption of phosphates in photosynthetic organisms. In high pH the of ions of hydroxyl in water interact with phosphorus from compounds of iron (Fe) and Aluminium (Al) that can be found in the benthic zone. It is therefore that the increase of the pH values is increasing the concentration of phosphorus in water. Anoxic environments are benefiting the spread of phosphorus from the benthic zone into the general body of water. The increase of the concentration of Nitrous ions diminishes the rate of phosphoric release in the water due to the oxidizing action. In parallel, the presence of macrophytic plantation in a specific body of water increases the concentration of phosphorus in water. Plants are using phosphorus as an intake from the bedrock of the lake while during their development they release high amounts of phosphorus in water, a process that continues even during their death. The remaining of dead wood in the water increases decomposition that will furtherly release phosphoric compounds (Darakas, 2011). In most waters the concentration of the total phosphorus ranges between 10-50 μg/l. Although, in oligotrophic waters the content of total phosphorus could be less than 5 μg/l. In high eutrophic environments it can surpass 100 μg/l.

Water Mass Color

Last but not least, color. Color is an indicator of the origins of water. Usually, water must be transparent and uncolored. Although, the presence of coloring in bodies of water could be an indicator of the presence of specific minerals, organic compounds or other solids. Different coloring can be found in water. In cases of high iron content in waters they appear red whereas if there is a high concentration in copper the waters can appear blue. Color in water could act in the same fashion as turbidity, not allowing sunlight penetration, thus curbing the photosynthetic activity.

Chapter 5: Measurements – Graphical Presentation & Comments

In this chapter the available data of measurements in regards with the Lake Orestiada will be presented. The said data was gathered from 2012 to 2019 around the year in 3 locations labelled as North Position, Central Position and South Position to enhance the picture of the water quality throughout the body of the lake. The choice of the measurement points was a choice of the Environmental Department of the Administrative region of Western Macedonia. Generally, the choice of the sampling points in water quality research and lake management projects has to do with the accessibility of the points and the ability to collect a representative sample. The more sample points the more holistic image one can have of the water quality of a specific body of water. In regards with the time series, also the time of sample collection and the consistency was a decision by the testing party. Unfortunately, there are some blanks in the data, but the general context can provide us a clear picture about the state of the lake through the years. After the graphical presentation of the data comments will follow. Explaining what the reader can observe as well as providing clarifications for specific values. In the case of zero values that are being shown in the graphs it is important to consider that we are talking about L.o.Q. values. LoQ is the lowest concentration at which the analyte can not only be reliably detected but at which some predefined goals for bias and imprecision are met. The LoQ may be equivalent to the LoD or it could be at a much higher concentration.

The below charts have been created by the author based on the available data.

Biochemical Oxygen Demand (BOD)

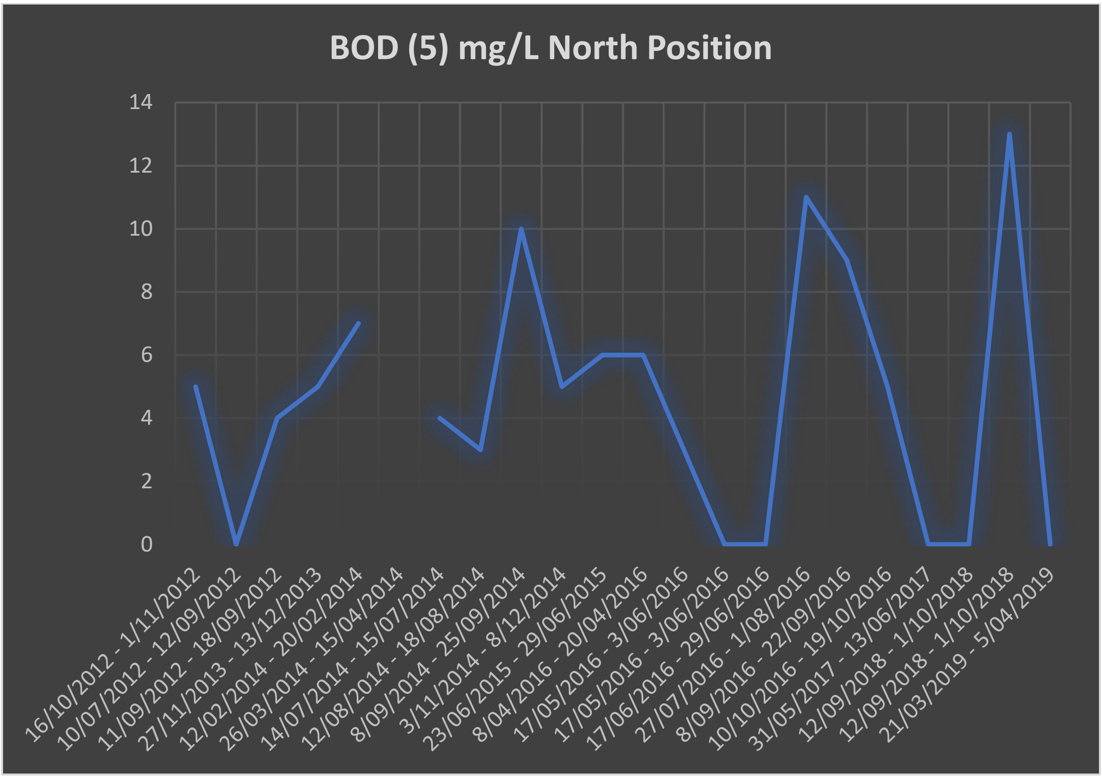


Figure 15. BOD North Position

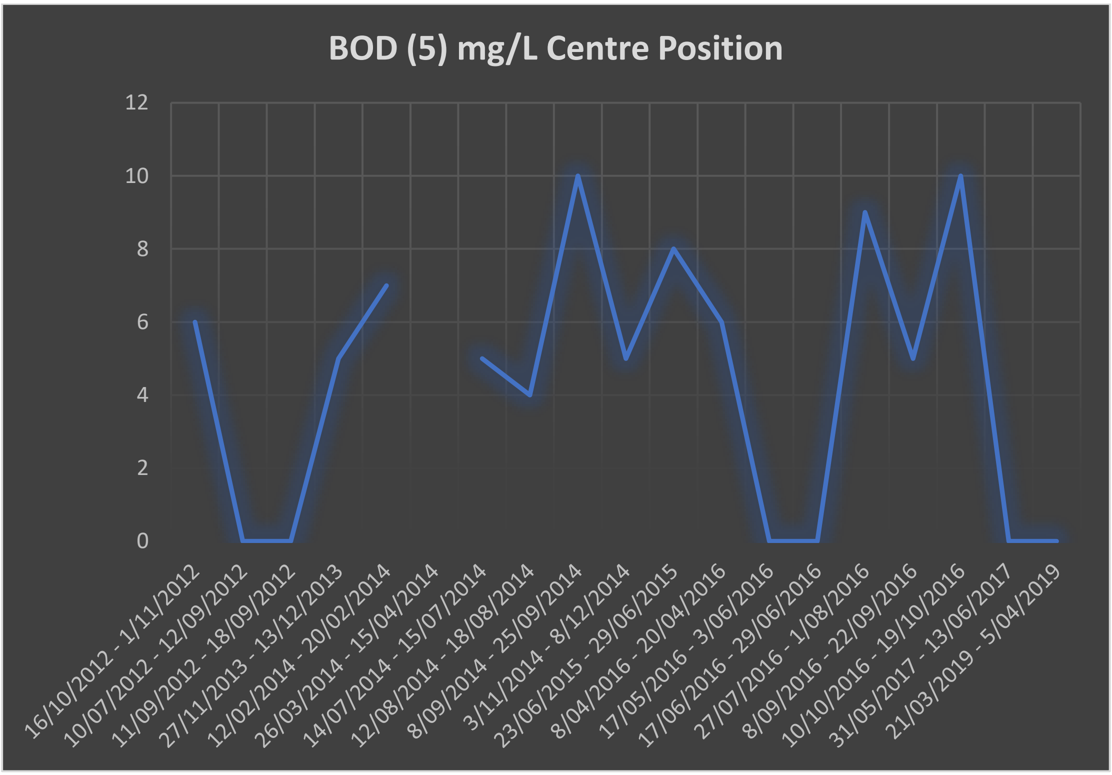


Figure 16. BOD Central Position

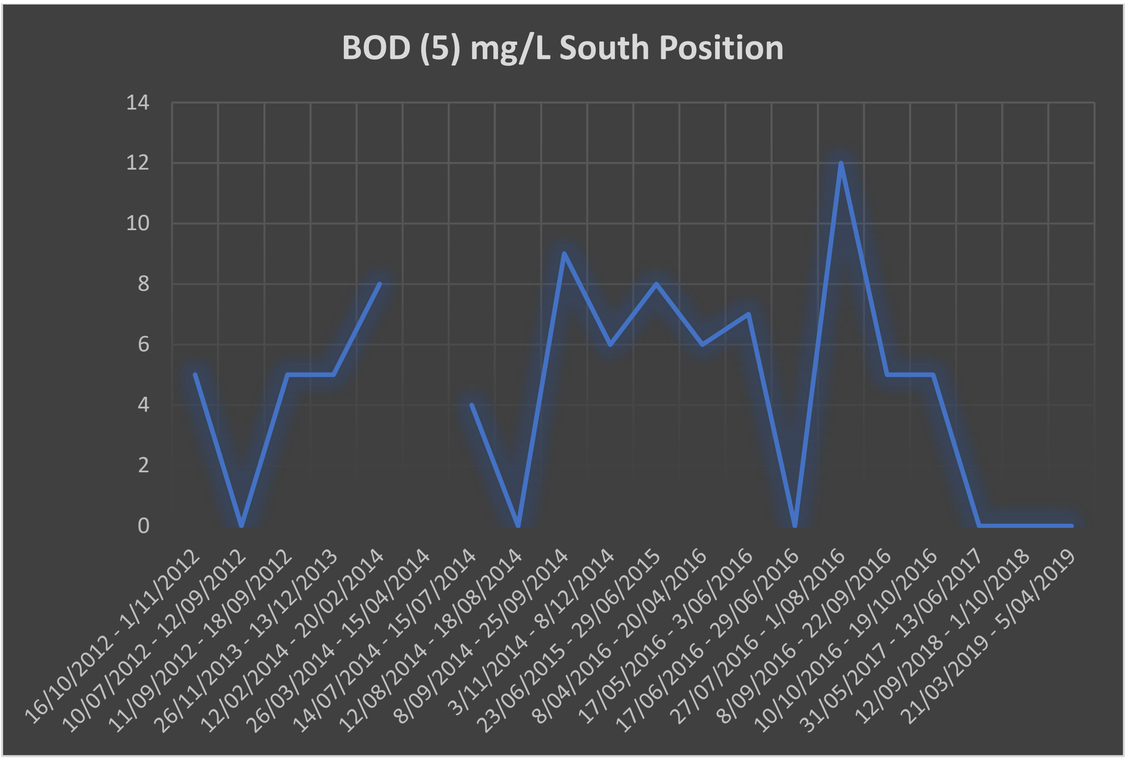


Figure 17. BOD South Position

As far as the Biochemical Oxygen Demand is concerned one can observe that the values have been more or less the same for the 3 points of sampling throughout the years with differentiations per year other times being on the rise, others on the fall. It is important to note that values that are labelled zero we have to consider an L.O.Q <3. So, values would be less than 3 for the said. As it was discussed in the previous chapters Biochemical Oxygen Demand is directly correlated to Dissolved Oxygen levels. BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. For the Lake of Kastoria the BOD levels have been from their lowest <3 to their peak, 13 in North position. Generally, the water quality based on BOD seems to be good as according to the directive 91/271 the permissible limits are below 25 mg/L. Besides that, though, the medium values of BOD show signs of potential eutrophication. At an eutrophic lake we have the effect of BOD values rising due to the high production of plant mass and the high rate of death and decomposition subsequently. Efforts must be kept on-going to avoid levels rising further. Taking in account that waters of very good quality have a BOD <10 the lake of Kastoria is in a strong path to sustainability.

Chemical Oxygen Demand (COD)

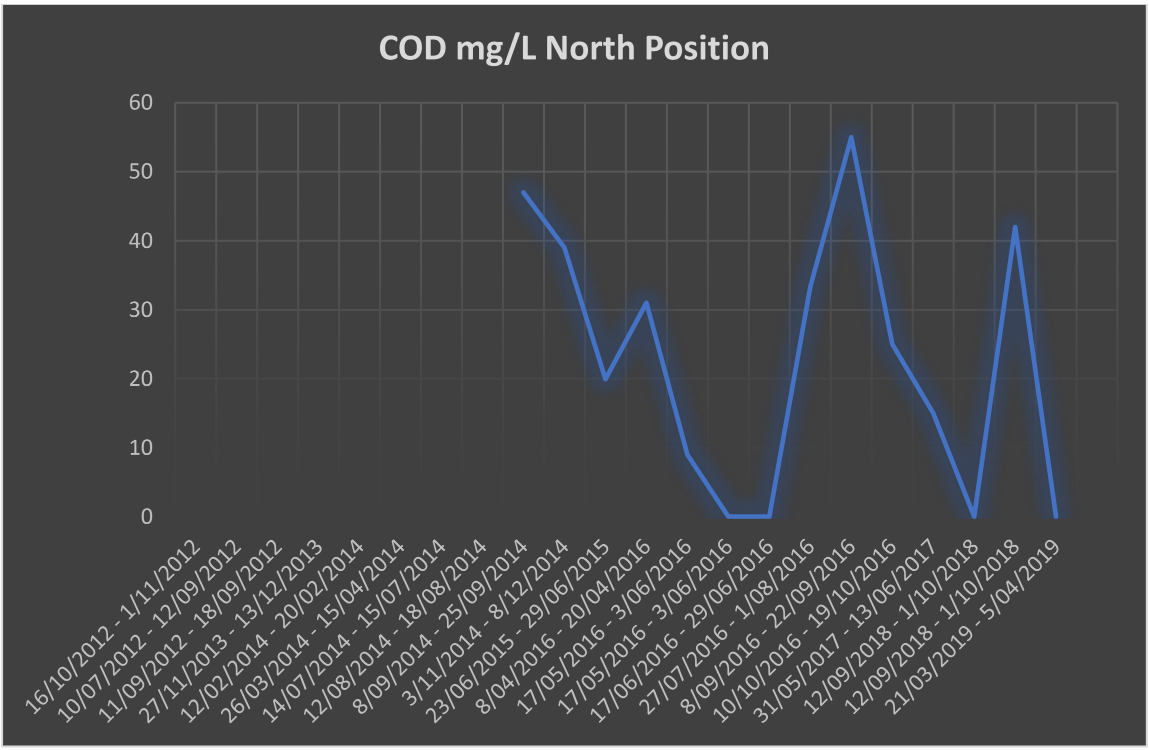


Figure 18. COD North Position

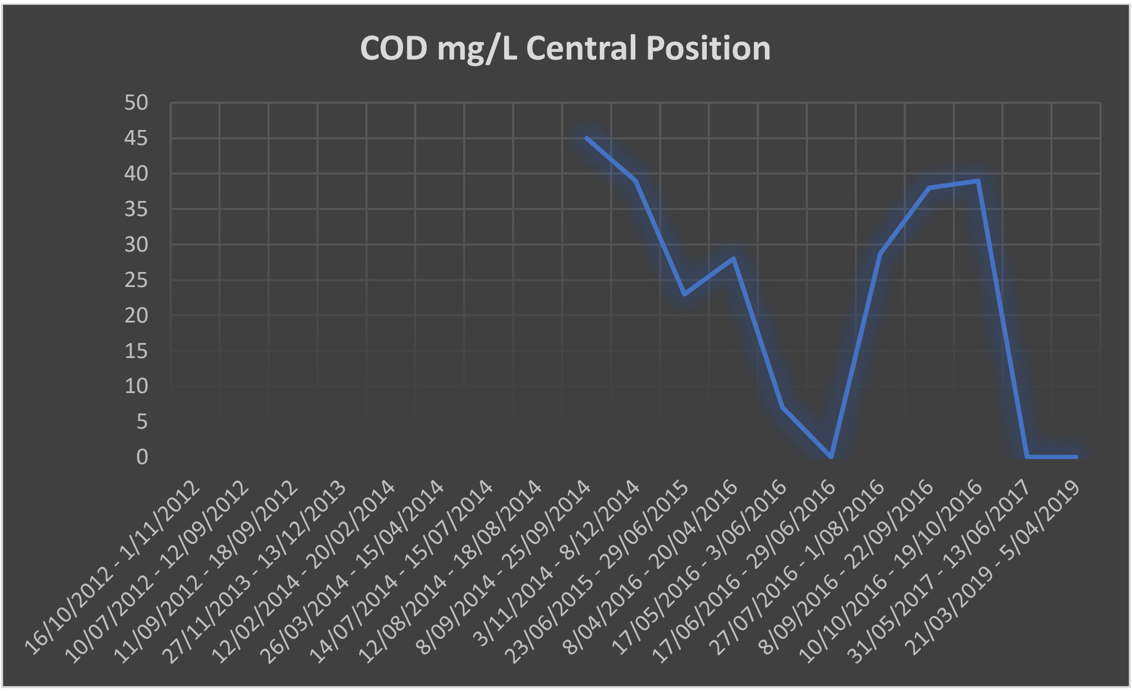


Figure 19 COD Central Position

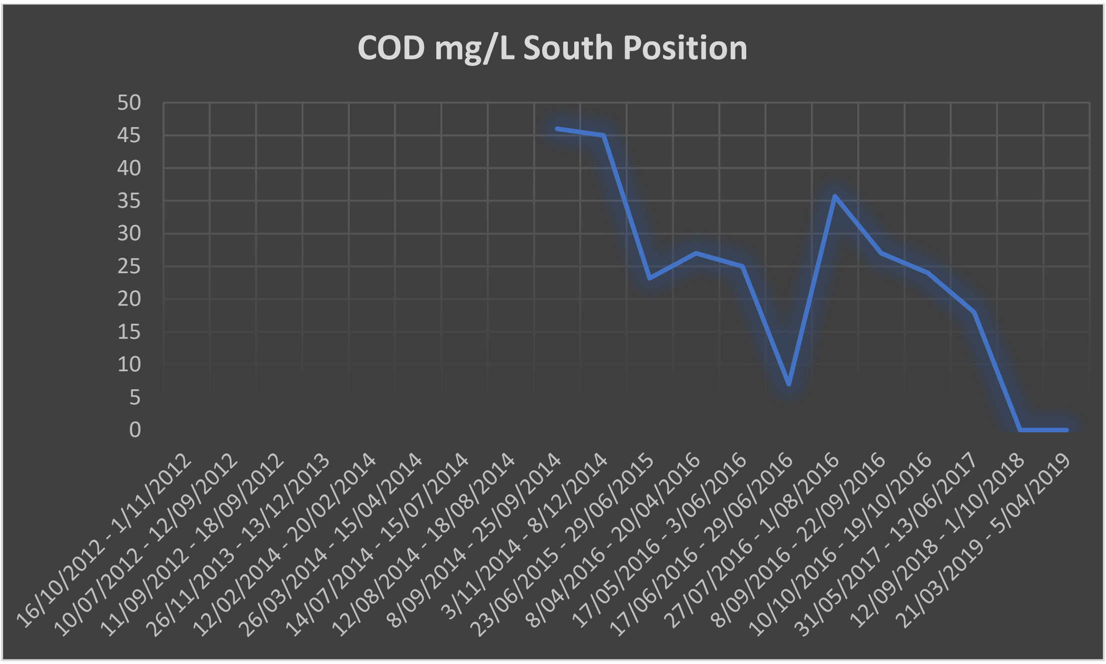


Figure 20 COD South Position

COD is used as an organic pollution index including phytoplankton growth. In regards with the Chemical Oxygen Demand or COD, we are observing that values have been in the decline for all 3 sampling points. The data show some peaks but the fortunate is that we are observing values less than 6 (< L.O.Q (6)) for the last available measurements. The values have exhibited their lowest points under 6 and their peak in North Position in 2016 with a value of 55. As COD is an indicator of organic pollution, we are observing another highlighting factor pointing out that the lake could be considered mildly Eutrophic. As the permissible limits for COD would be 125 according to the Government's Newspaper publication of permissible limits the values seem moderate for Orestiada. Still there is much work to be done to keep the lake from rapidly aging and stay in a Eutrophic state. Also, for the case of COD hope generating observation is that the values have been decreasing as years progress.

Acidity & Alkalinity - pH

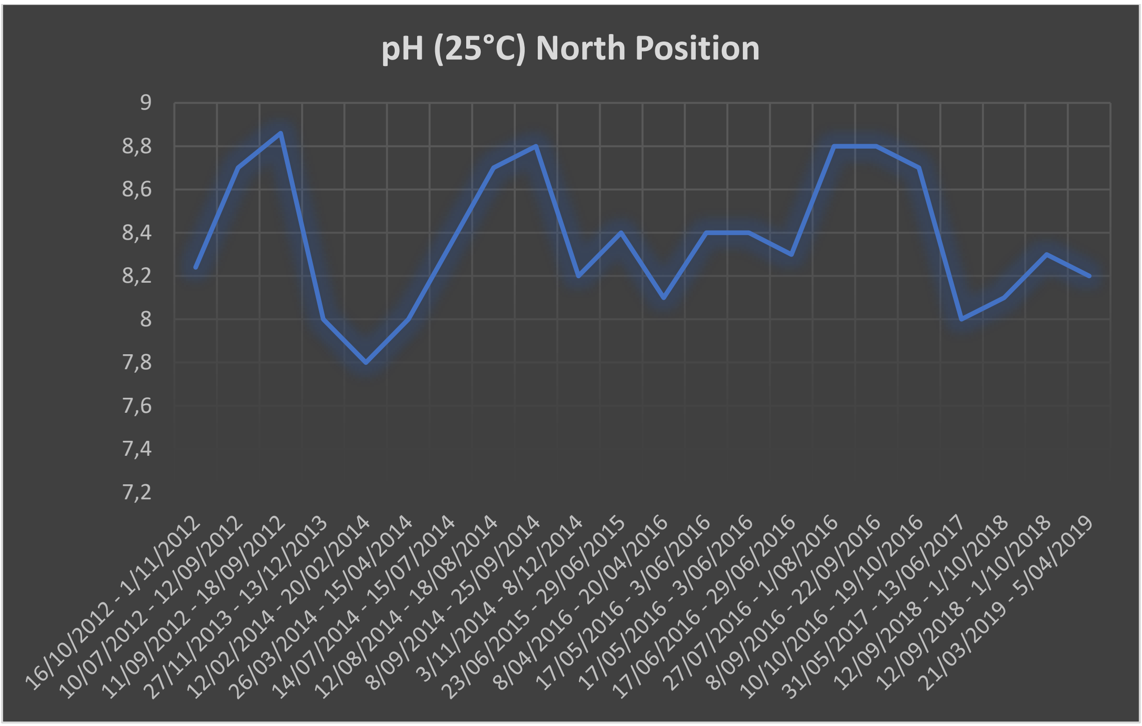


Figure 21. pH North Position

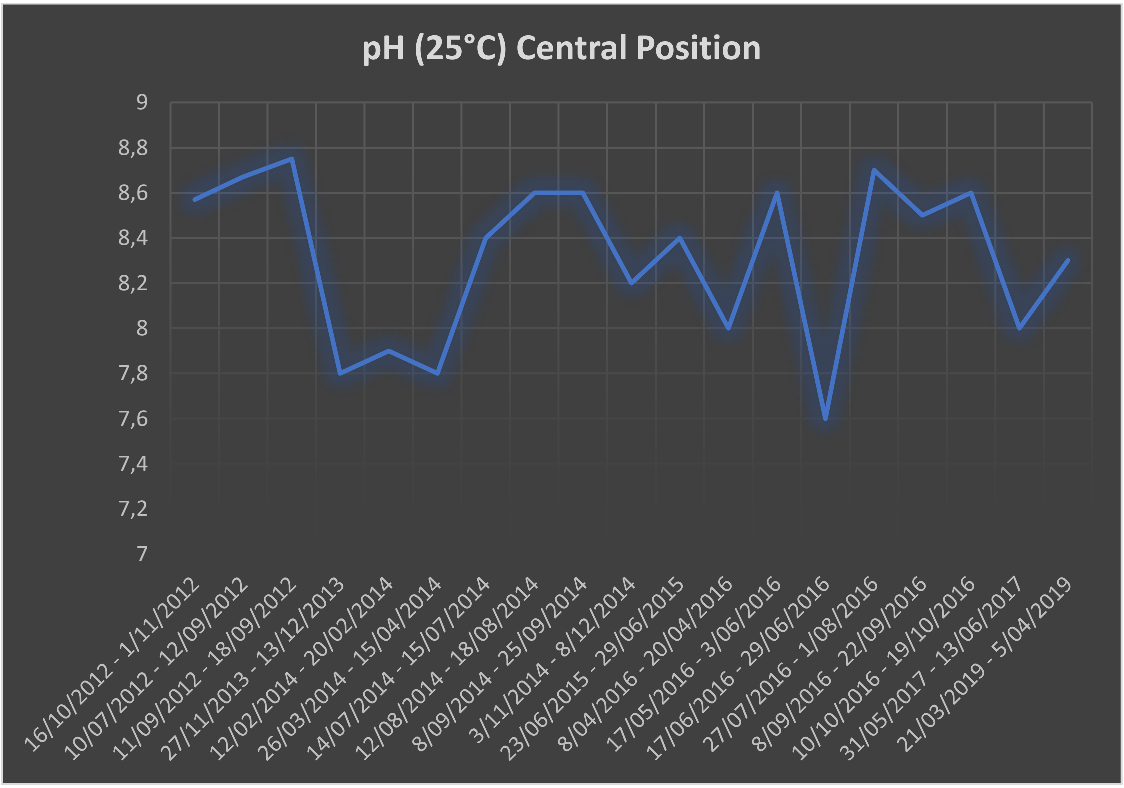


Figure 22. pH Central Position

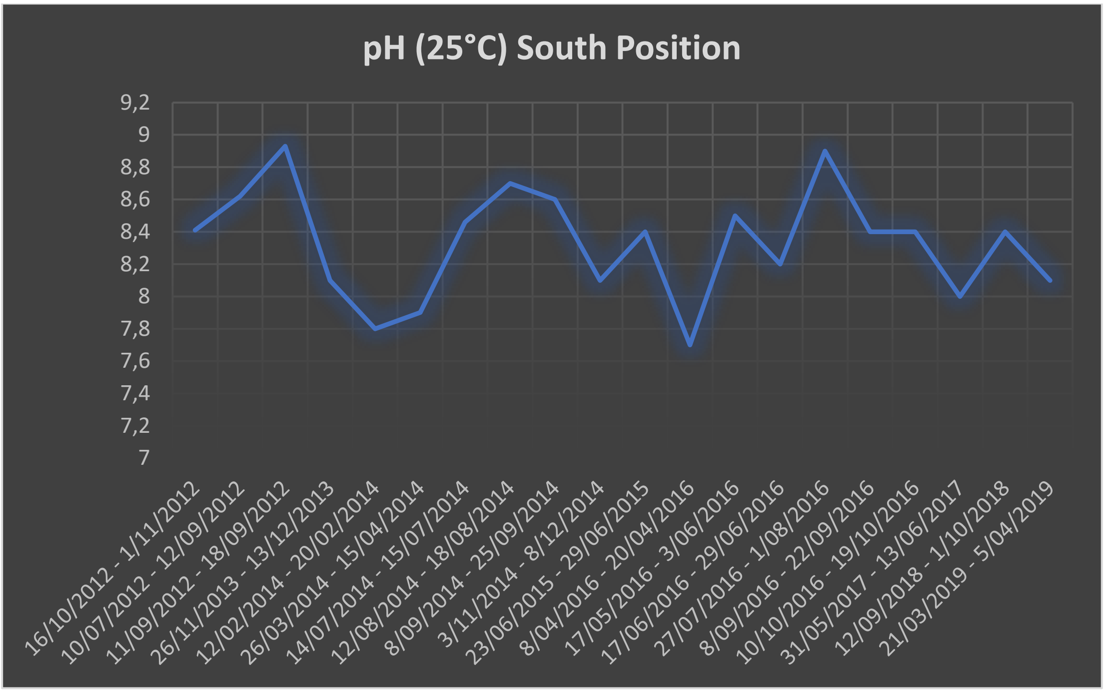


Figure 23. pH South Position

As far as the pH of the Lake is concerned generally the permissible limits are set to higher than 6.5 and lower than 9.5. One can observe that for Lake Orestiada the pH values according to the measurements has ranged from 7.5 to 8.9 that are within the limits. There have been fluctuations throughout the years in regards with the pH and the recent years the average pH of the lake seems to be around 8 which would be mildly alkaline.

Ammonium

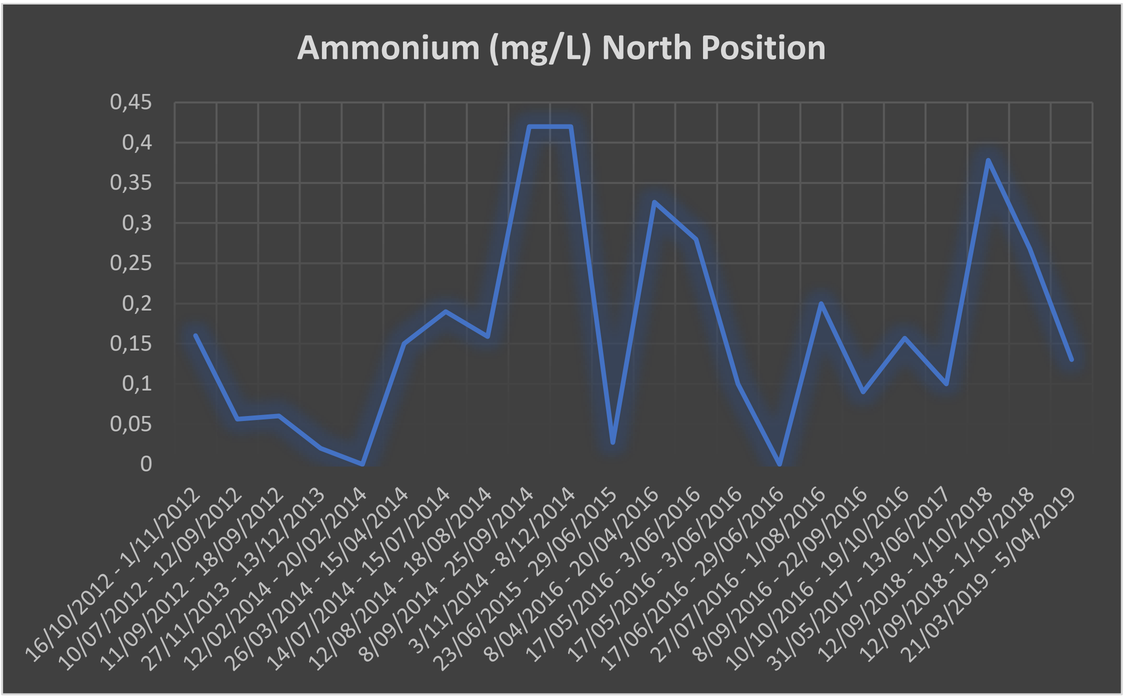


Figure 24. Ammonium North Position

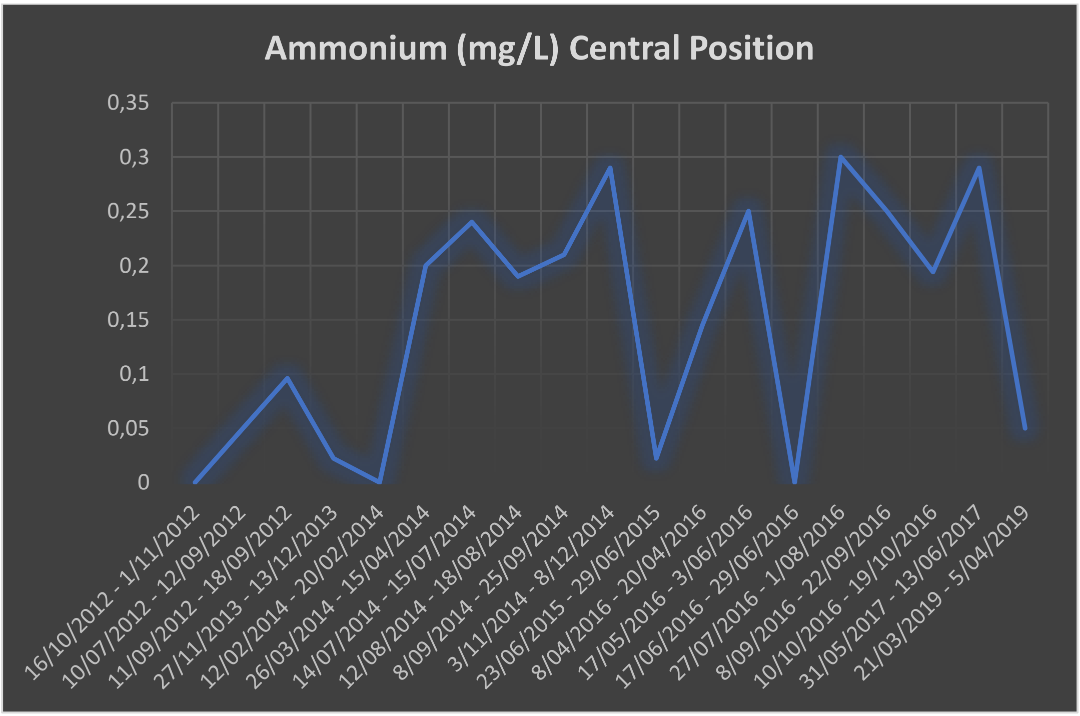


Figure 25. Ammonium Central Position

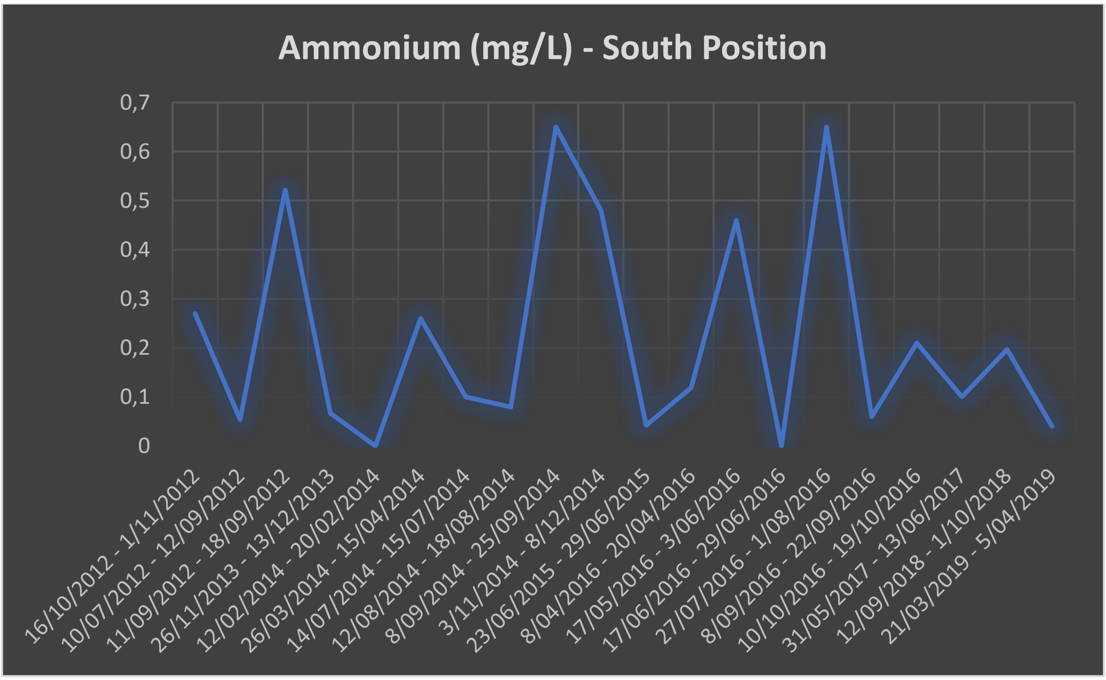


Figure 26. Ammonium South Position

In regards with the Ammonium levels in the lake the values seem to have their ups and downs throughout the years the measurements are taken. It is observed that specifically for the South Position of the measurements we have an all-time high of 0.65mg/L with most measurements ranging from <L.O.Q (0,013) to 0.42 mg/L the highest. With limit at 0.50 mg/L Kastoria Lake is within the limits but with rooms for improvement. As mentioned in previous chapters Nitric compounds can translate to eutrophication and in this case, we are observing values that have been on many occasions over 0.3 mg/L.

Water Conductivity

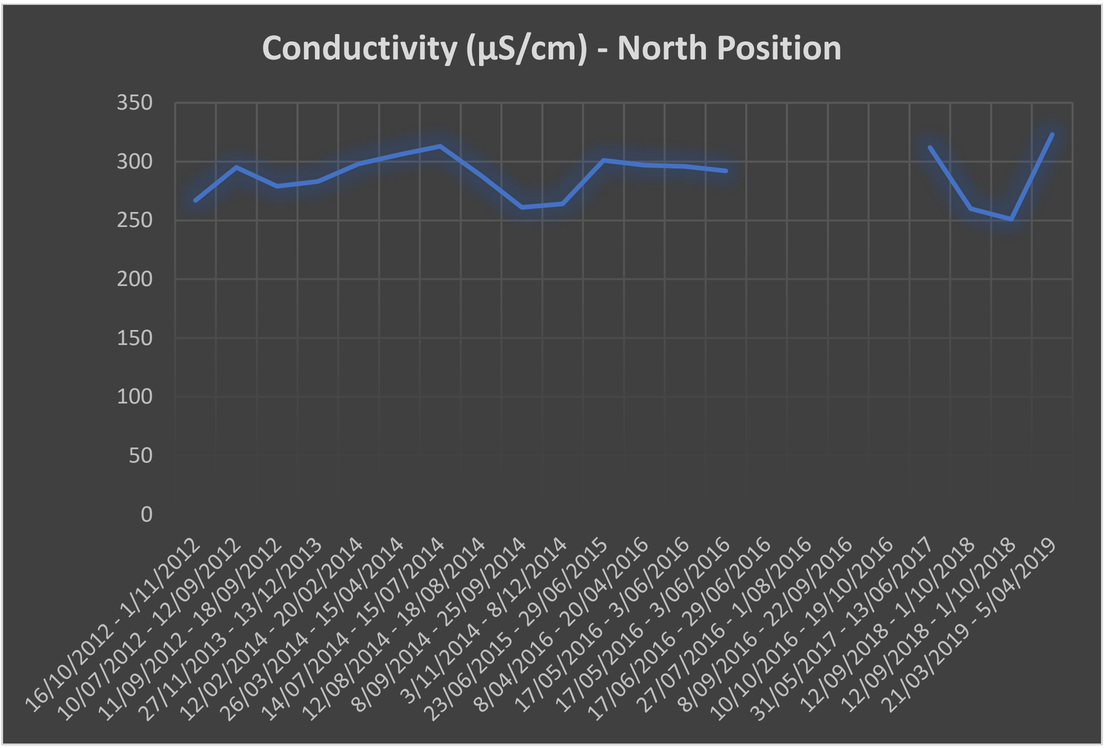


Figure 27. Conductivity North Position

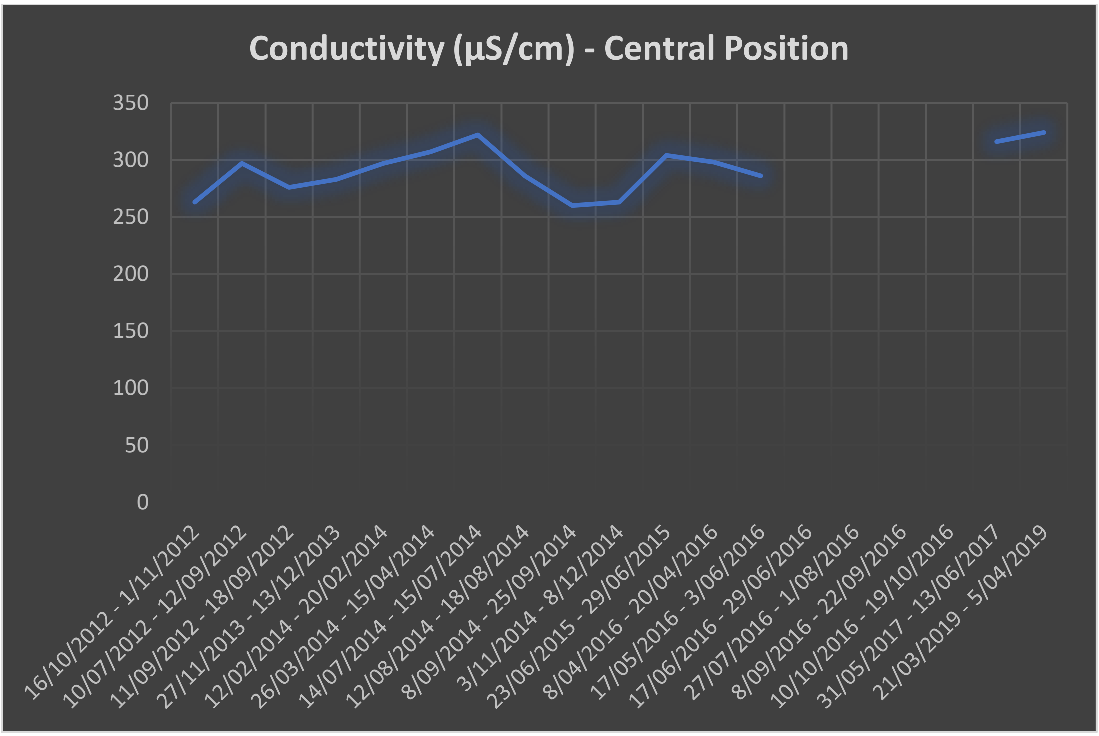


Figure 28. Conductivity Central Position

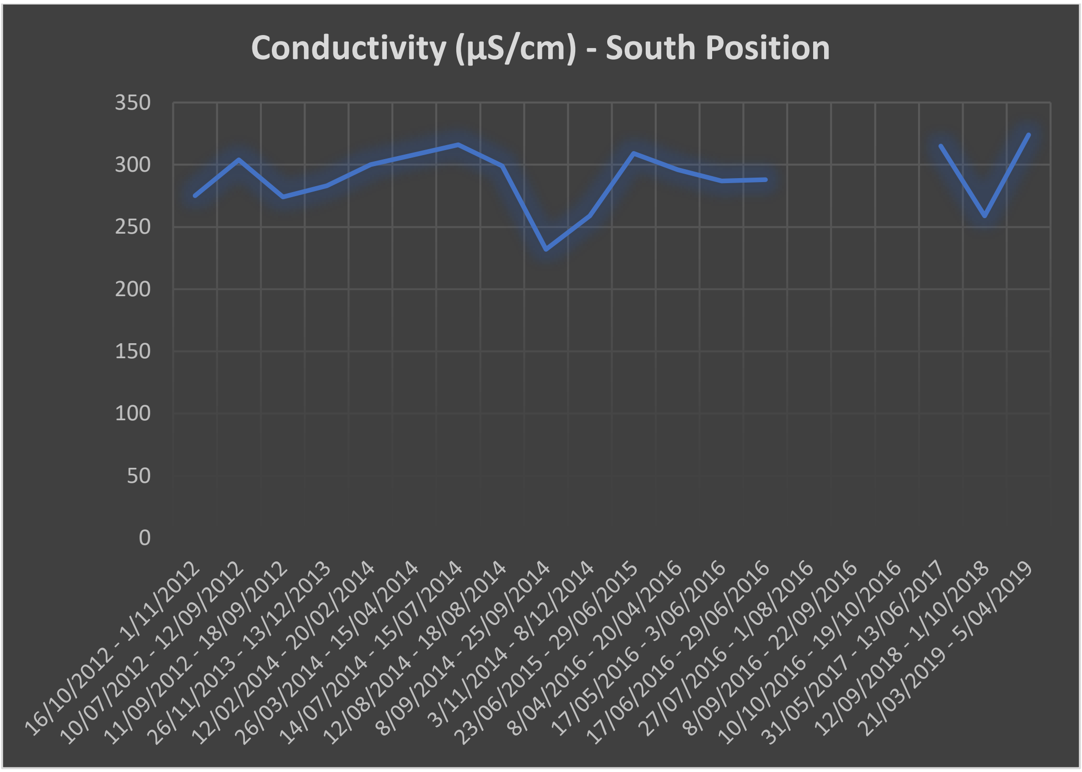


Figure 29. Conductivity South Position

Water conductivity is a good indicator of the dissolved solids and their effect in a body of water. Here we are observing that conductivity has ranged from 263 to 323 with a peak in same as detected for Ammonium in 2014 with a value of 322. Generally, the water of the lake can be characterised as Soft Water as the average values is above 250 and below 300. The conductivity levels in the lake are in good levels considering that the permissible limit is 2500 µS/cm. According to the government of Canada (Government of Canada webpage) lakes and rivers with conductivity of 200-1000 µS/cm are considered normal whereas same with levels from 0 to 200 µS/cm are considered pristine. Taking that into account the lake of Kastoria is at a very good level in regards with the total dissolved solids in its body of water for all the sampling points. This can clearly show the effort that has been made the past years of the Administrative Region and of course the Municipality of Kastoria for the improvement of the lake.

Sulfates

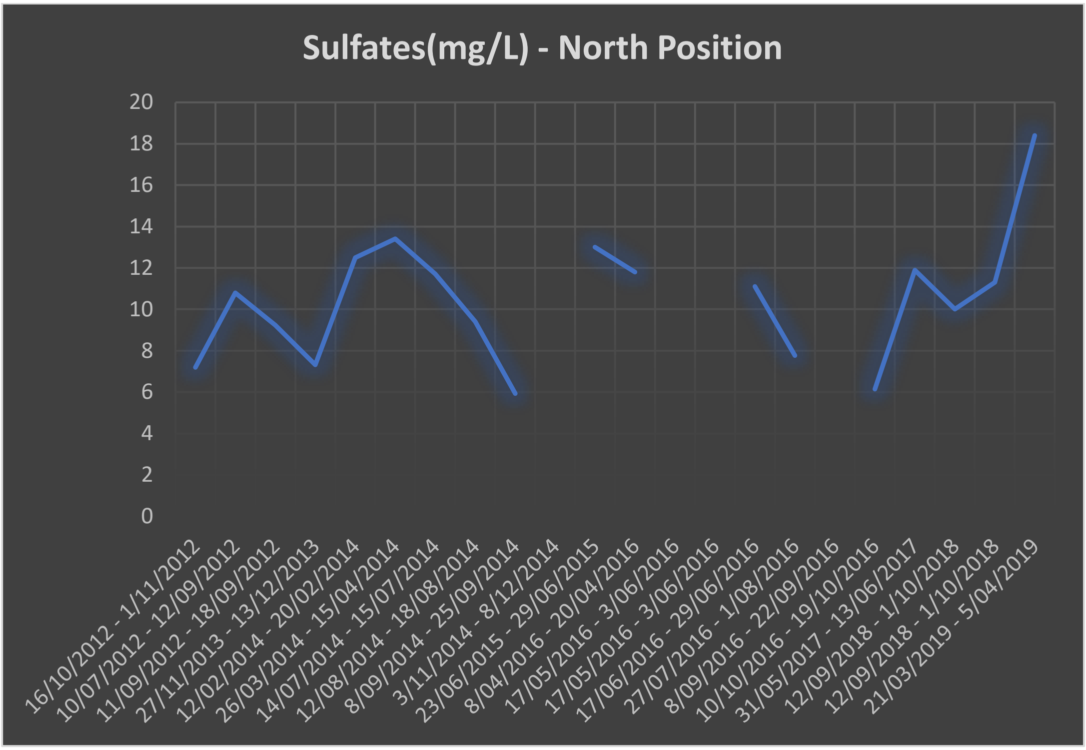


Figure 30. Sulphates North Position

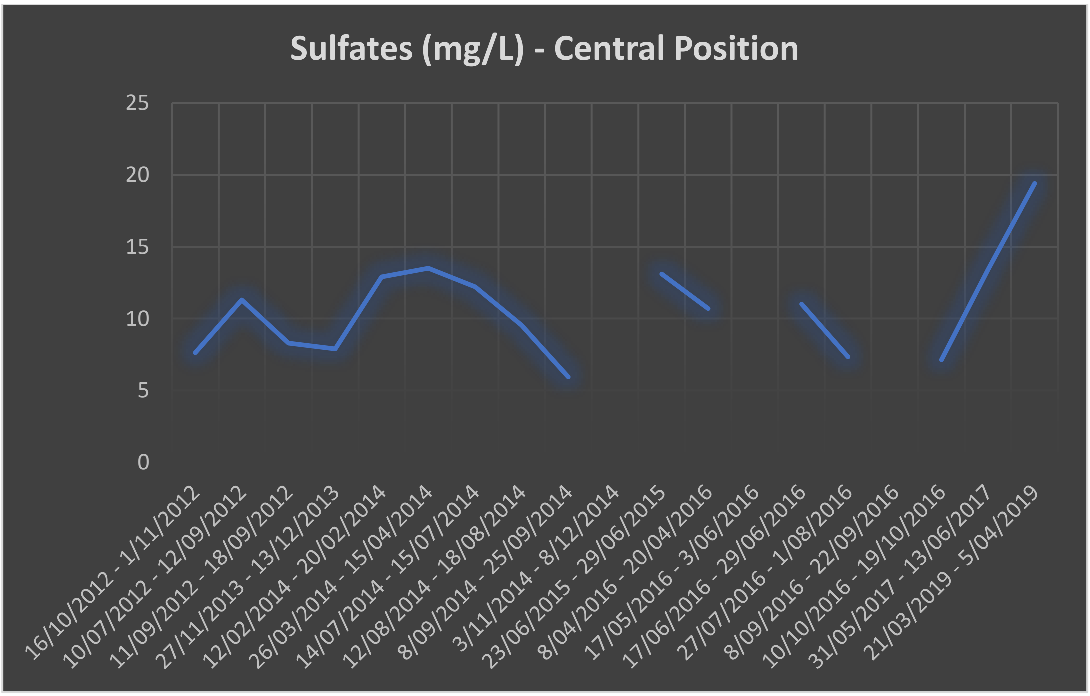


Figure 31. Sulphates Central Position

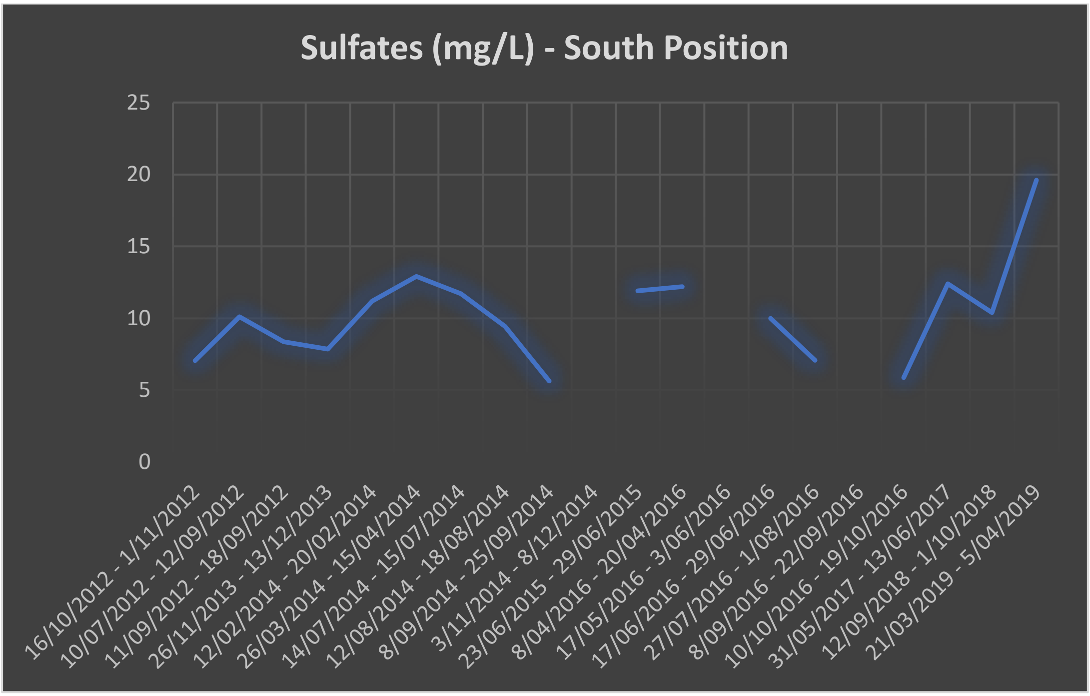


Figure 32. Sulphates South Position

Sulphates in the lake have shown an increasing trend with the highest values of the time-series being observed the latest years peaking at even 19.4 for the Central Position. As mentioned in previous chapters Sulphur is of high importance for the growth of plantation and the stability of the lake ecosystem. In this case observing the values of Lake Orestias, one can understand that the levels of the said parameter are on the good side as they are well inside the range of limit and even on the lower side with high limit being 250mg/L. The low values of Sulphurics within the body of water in the lake can aid the plant growth in a moderate way without raising any alarm for this specific parameter. This spur of growth Sulphur can bring into the lake, can further boost the ecosystem and provide new hunting grounds for herbivores and carnivores respectively. It is important to always monitor the level of sulphur and its compounds though, as to keep everything in check.

Turbidity

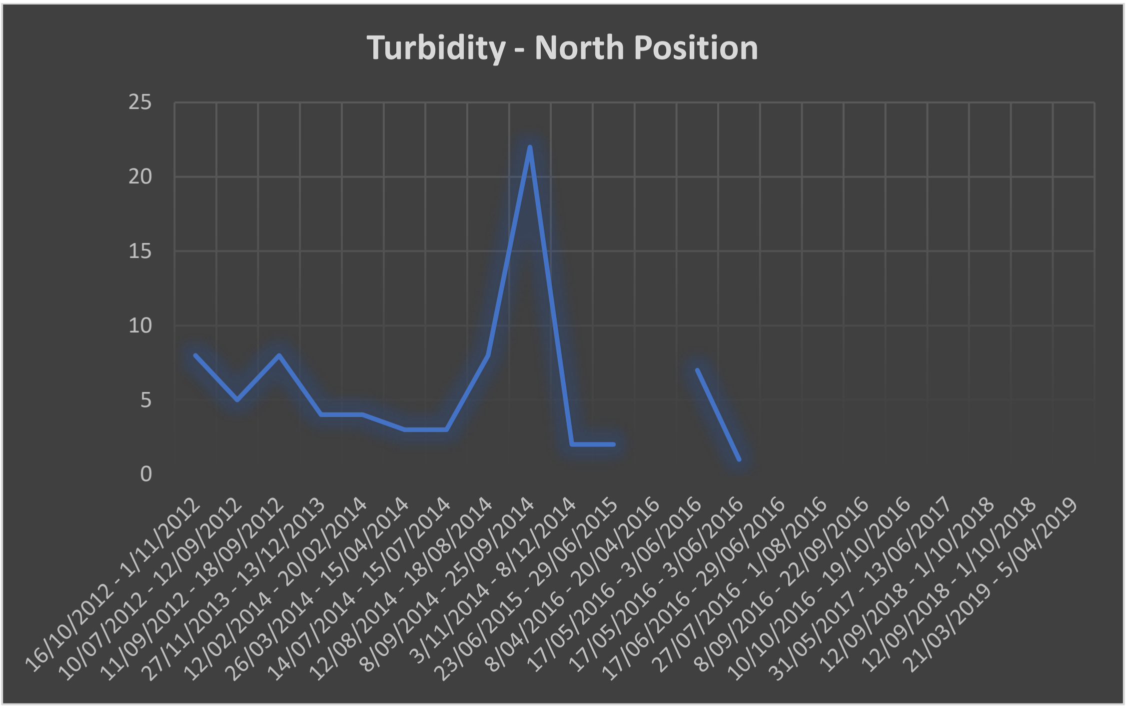


Figure 33. Turbidity North Position

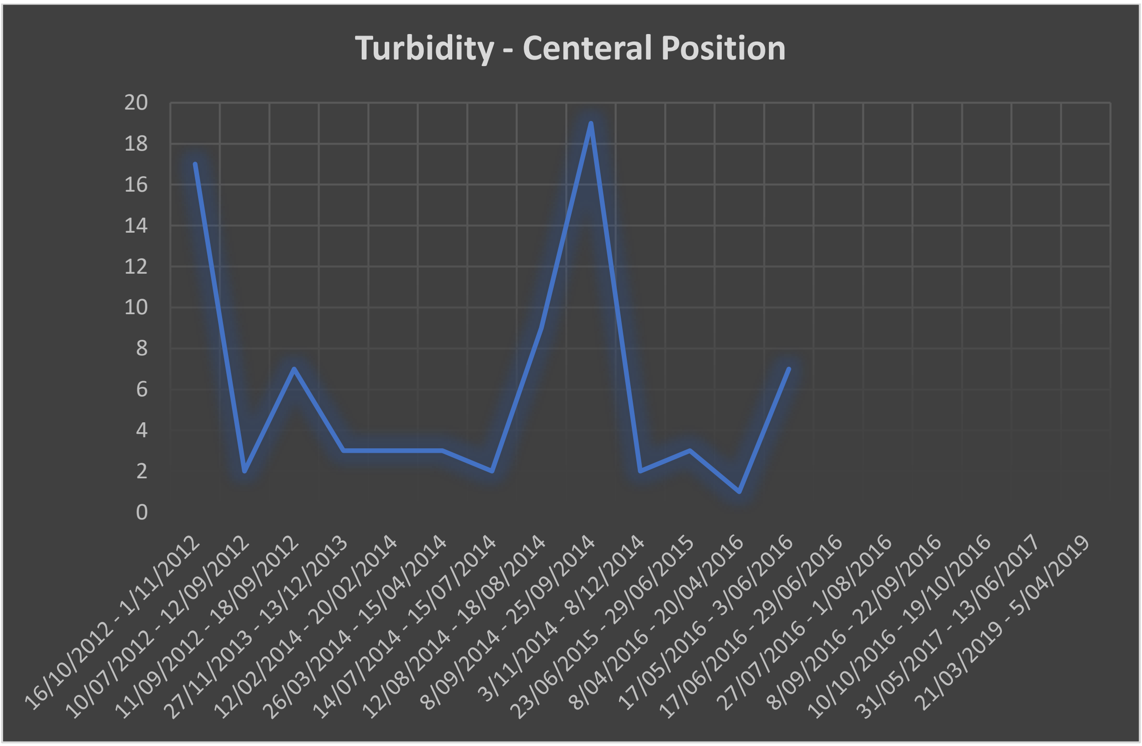


Figure 34. Turbidity Central Position

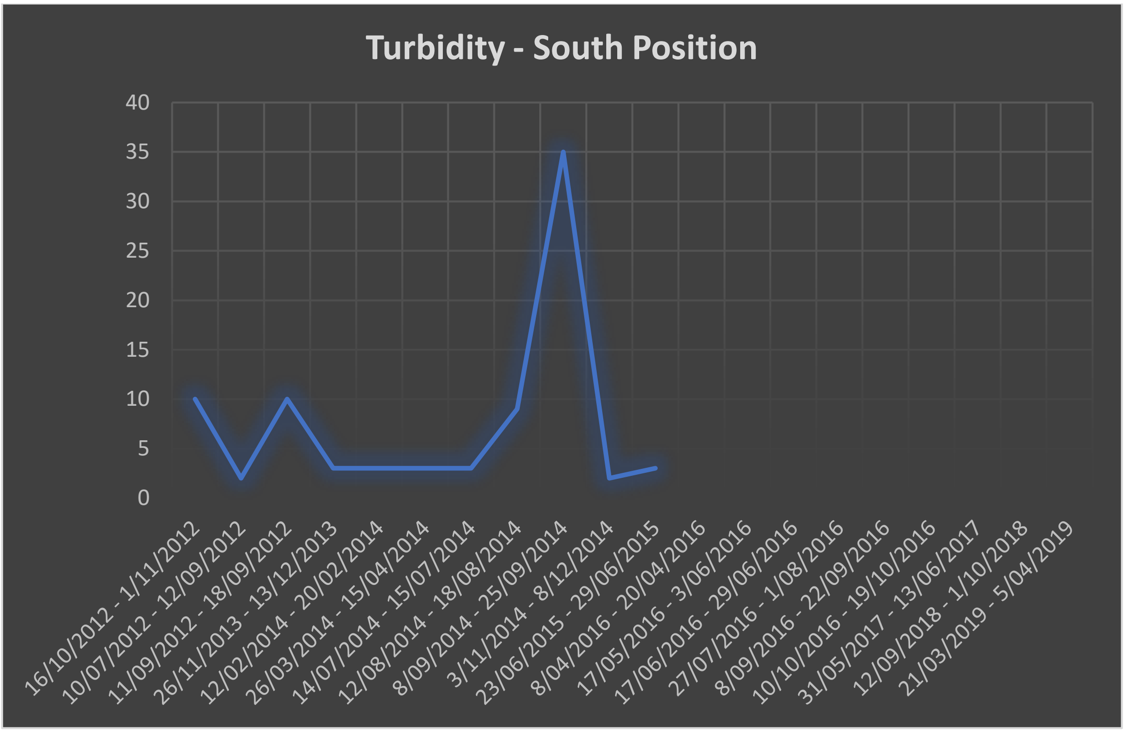


Figure 35. Turbidity South Position

Turbidity in the Lake of Kastoria has been ranging from 1 to 35 NTU during the years with values being usually around the mark of 5-10 NTU. The peak has been observed in all 3 sampling points during September of 2014 whereafter there was a drop of turbidity levels. As per the below table drawn from the state of Minnesota's site, we can understand that turbidity wise the lake of Kastoria is at a good level for recreation, fisheries, and light penetration.

Classes (and descriptions)	Turbidity (NTU)
1B (drinking water)	10
2A (cold water fishery, all recreation)	10
2B (cool/warm water fishery, all recreation)	25
2C (indigenous fish, most recreation)	25

Figure 36. Turbidity levels (sourc. Minesota USA Governmental Website)

Phosphorus & Phosphates

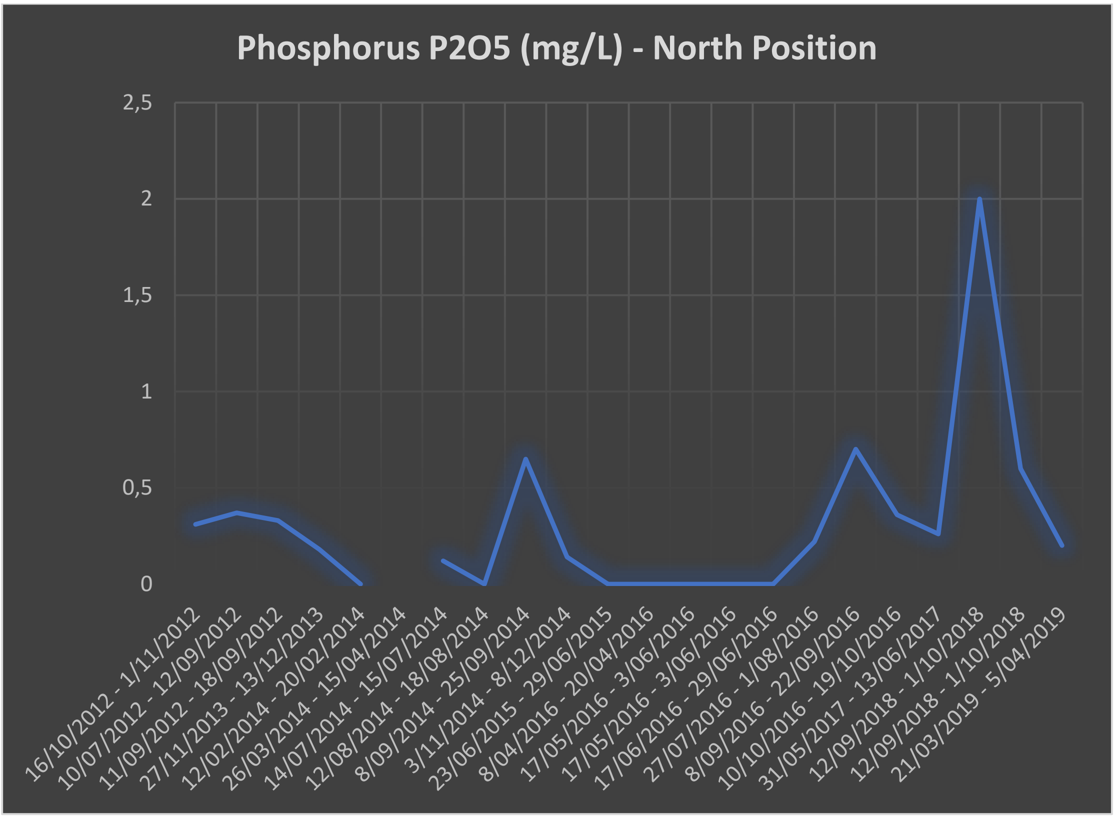


Figure 37. Phosphorus North Position

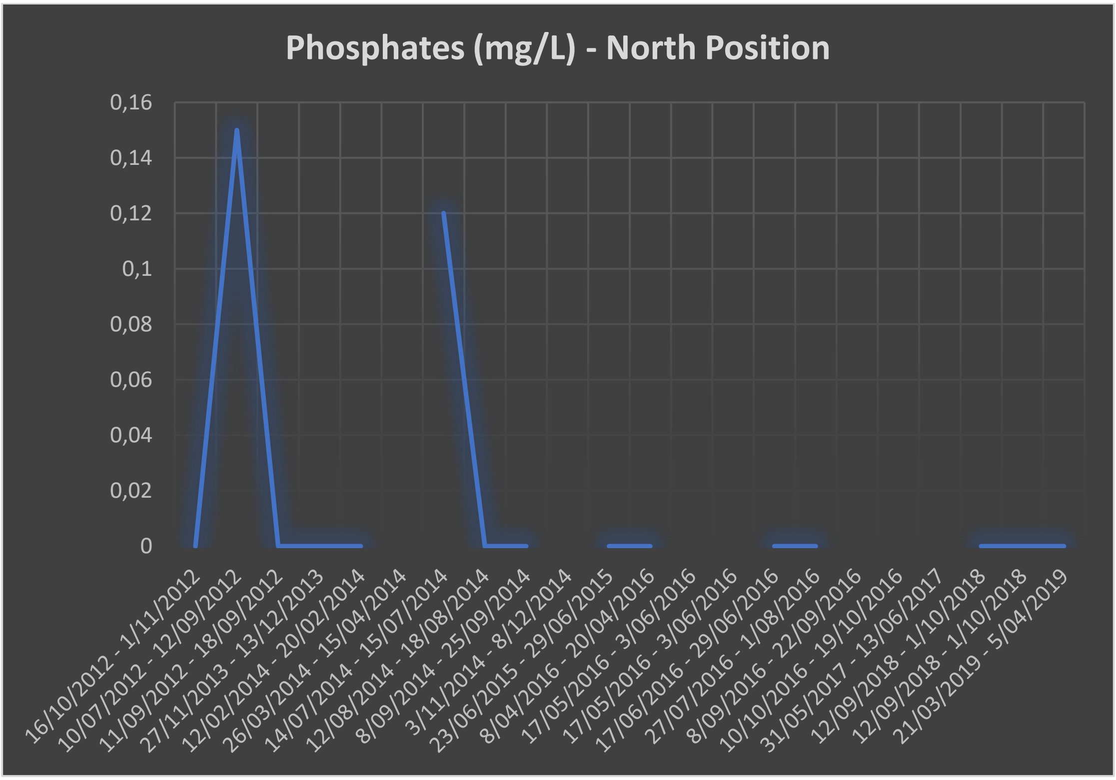


Figure 38. Phosphates North Position

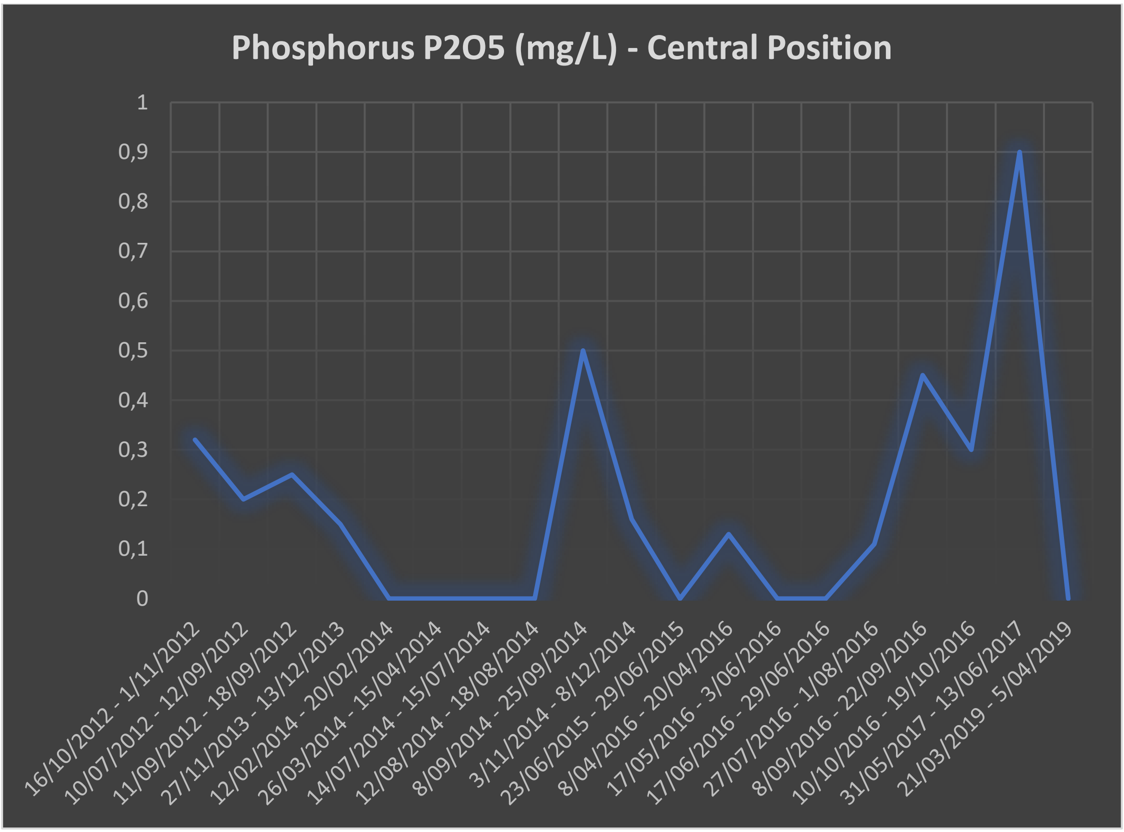


Figure 39. Phosphorus Central Position

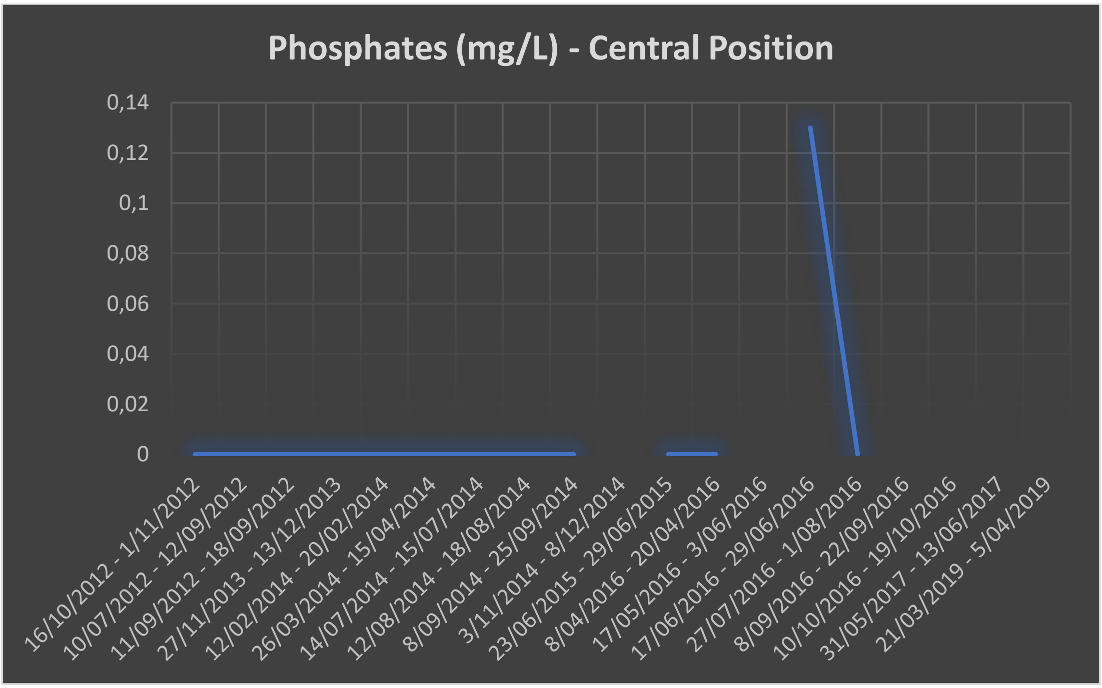


Figure 40. Phosphates Central Position

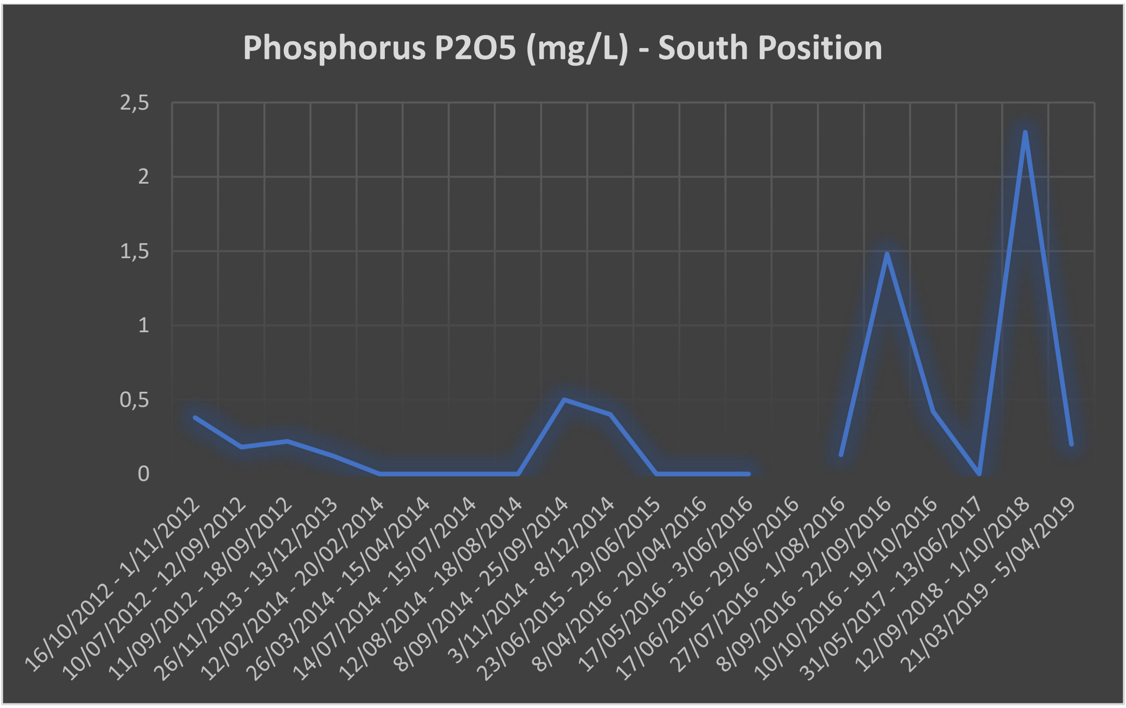


Figure 41. Phosphorus South Position

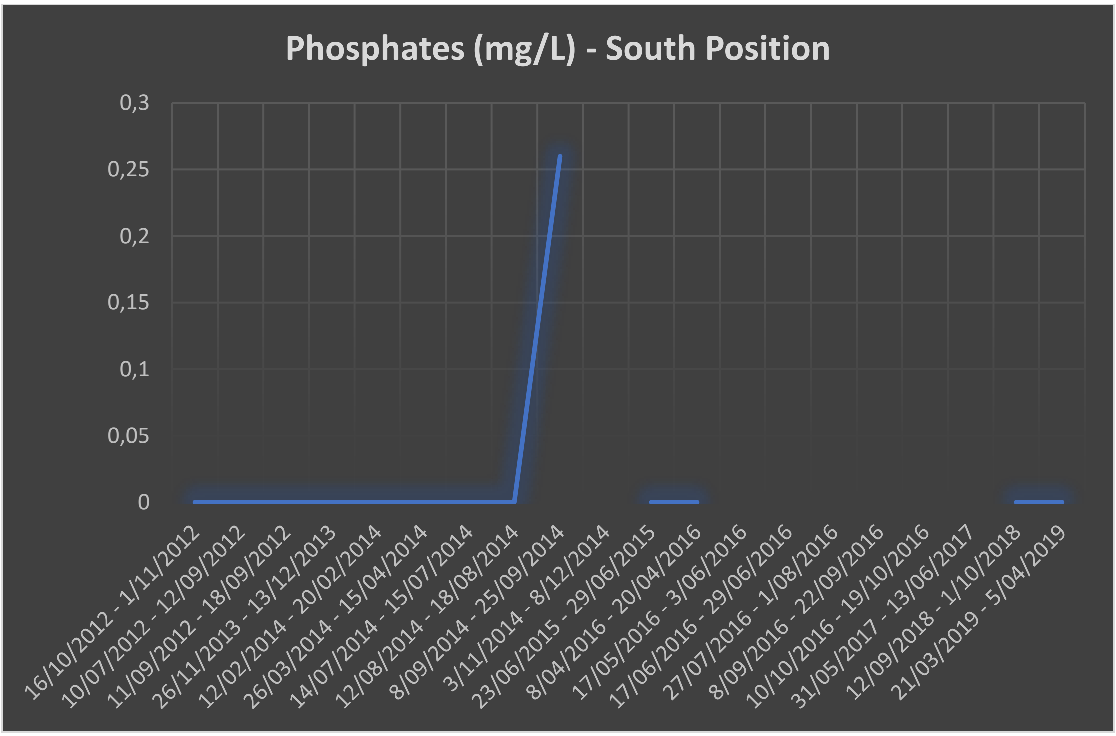


Figure 42. Phosphates South Position

Phosphorus as P_2O_5 and Phosphates are fluctuating, whereas in the case of Phosphorus values are on the rise as the time-series progresses for the North and Central Position of the samples. For the Southern the story is a bit different with peak values being detected around the late months of 2014 and diminishing values as time-series progresses with a sudden spike in 2019. Values for Phosphorus P_2O_5 have been raging from < L.O.Q (0,11) to 3.28 mg/L as max value for the South Position. Globally levels under 5 for Phosphorus are being deemed as optimal in regards with its concentration in bodies of water. We can observe that in this case of the Lake Orestiada the values of P_2O_5 were at a good level, usually floating around the 1-3 mark. It is important though to keep the situation in check as the past years a rise in the values that could indicate a bit of a disturbance in the ecosystem was detected.

As Phosphates are concerned, the time-series have some blanks but we have consistent levels below < L.O.Q (0,11). With limits being at 0.4 mg/L, as per the Greek regulation, it is good to observe that the levels are well below the allowed.

Nitrate & Nitrite

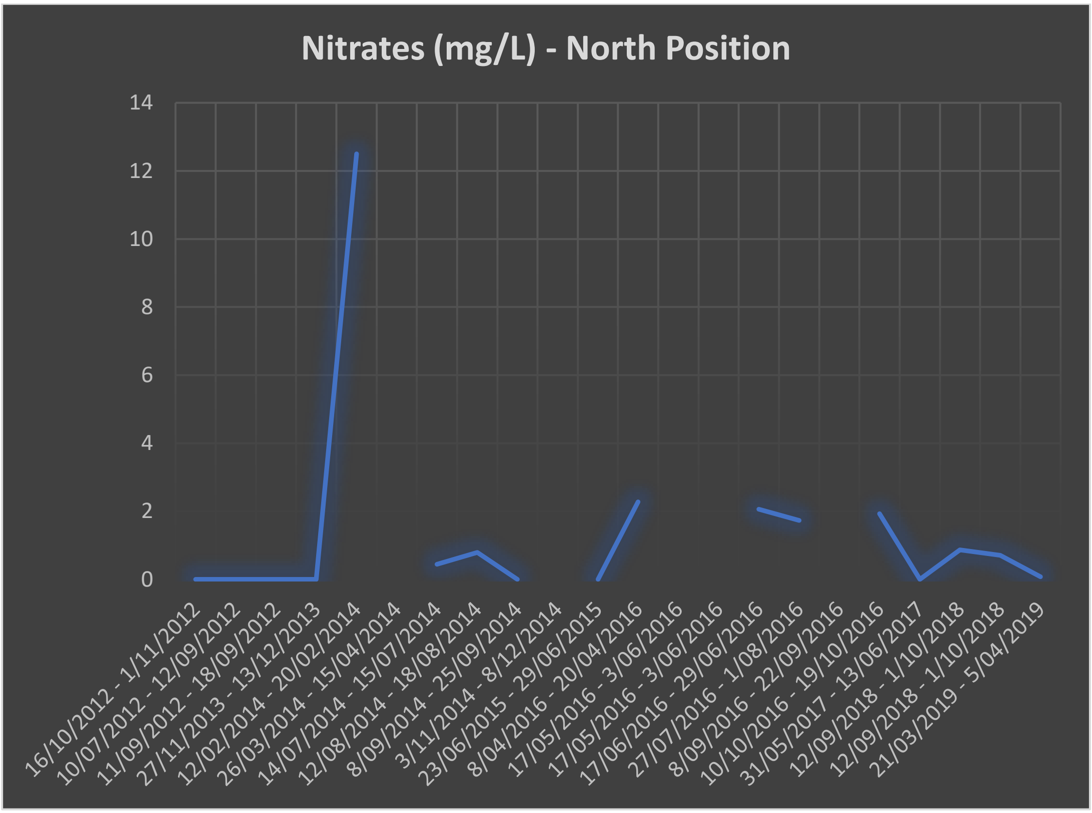


Figure 43. Nitrates North Position

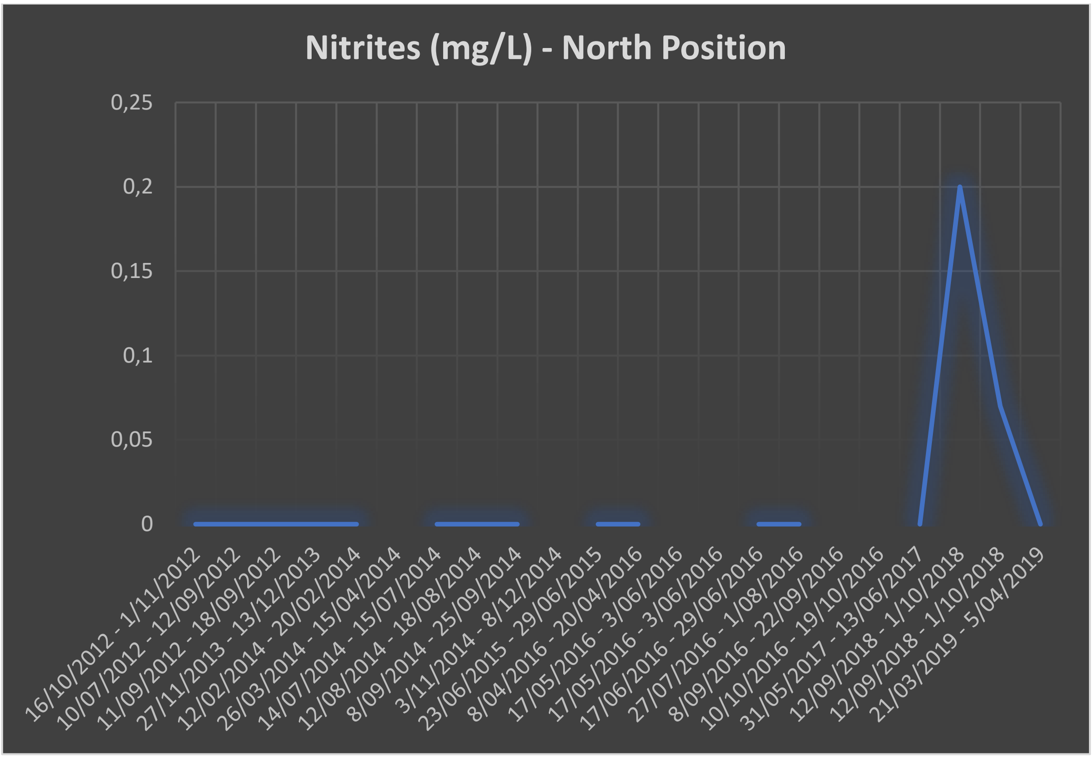


Figure 44. Nitrites North Position

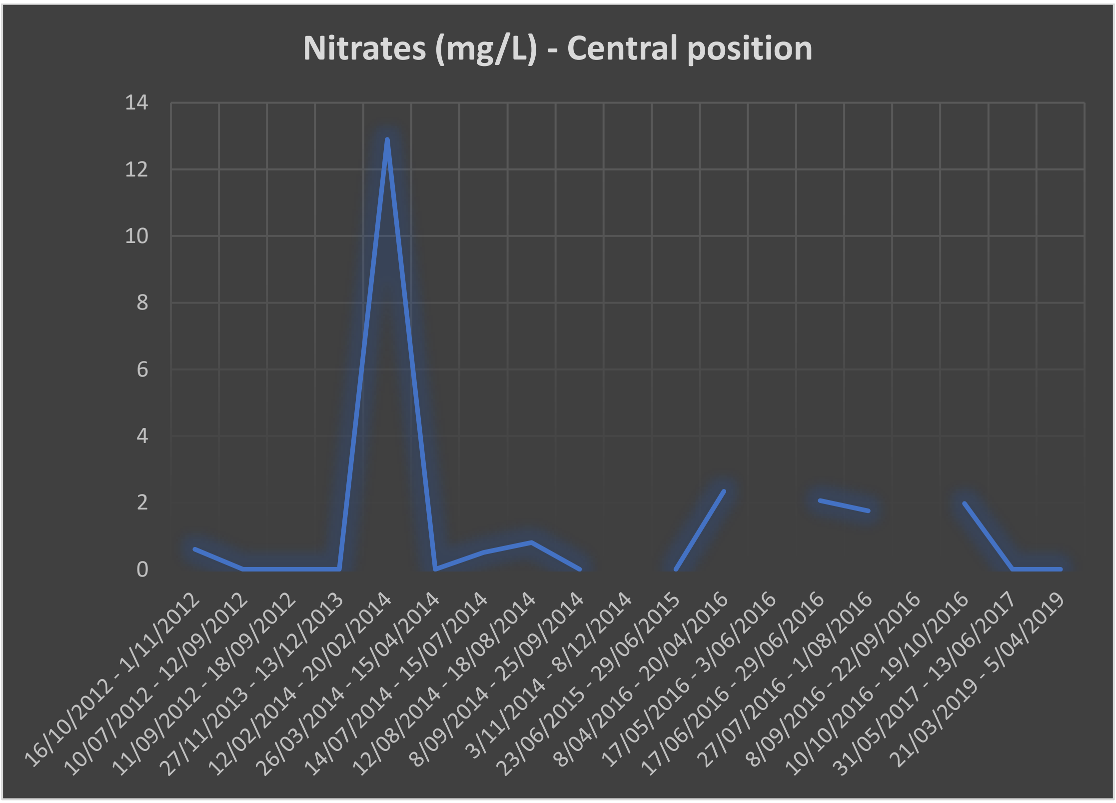


Figure 45. Nitrates Central Position

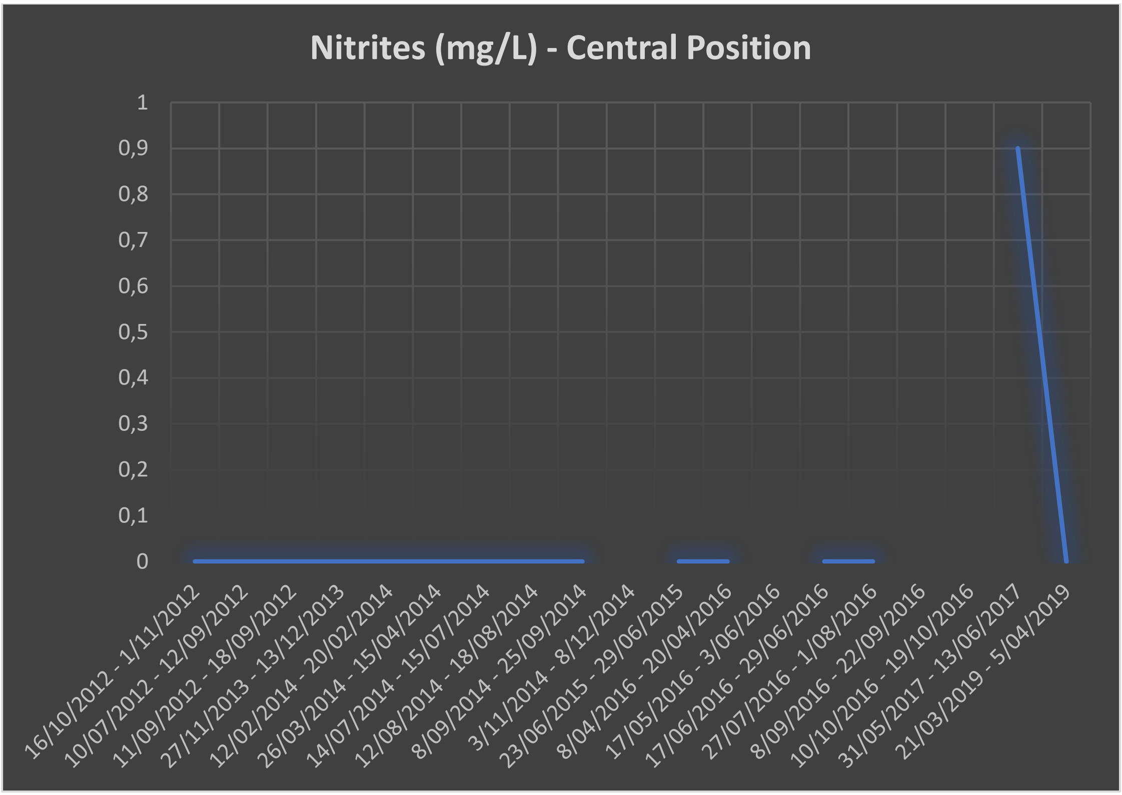


Figure 46. Nitrites Central Position

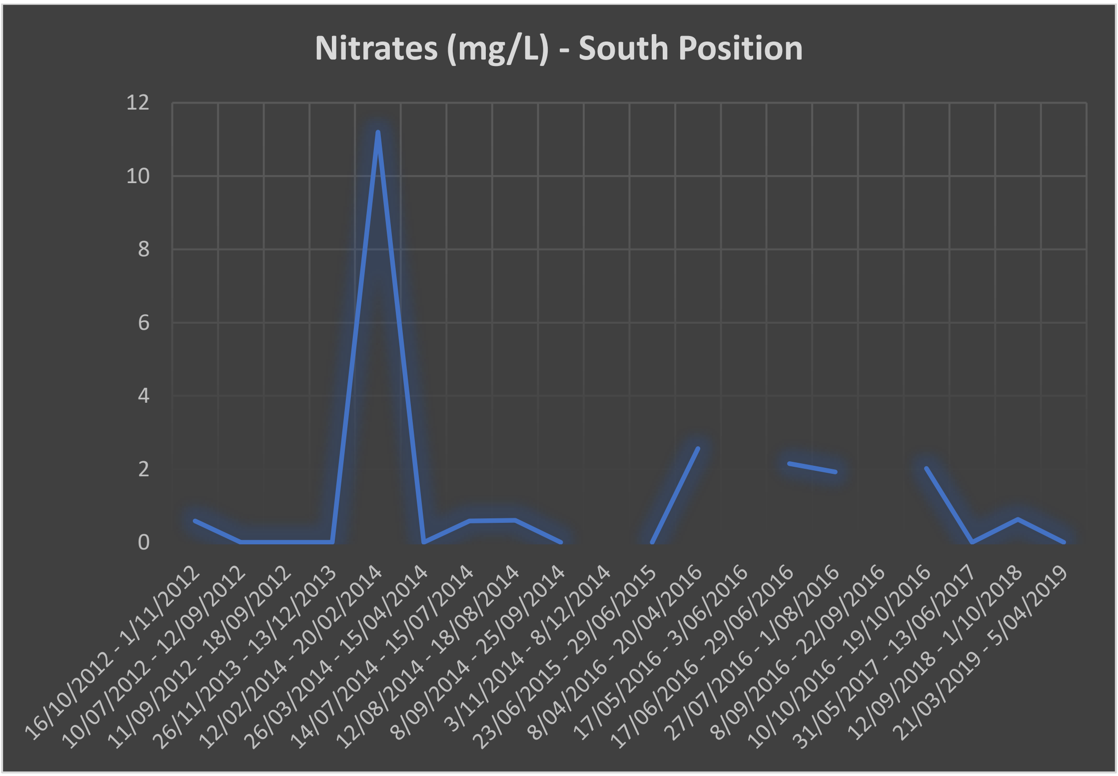


Figure 47. Nitrates South Position

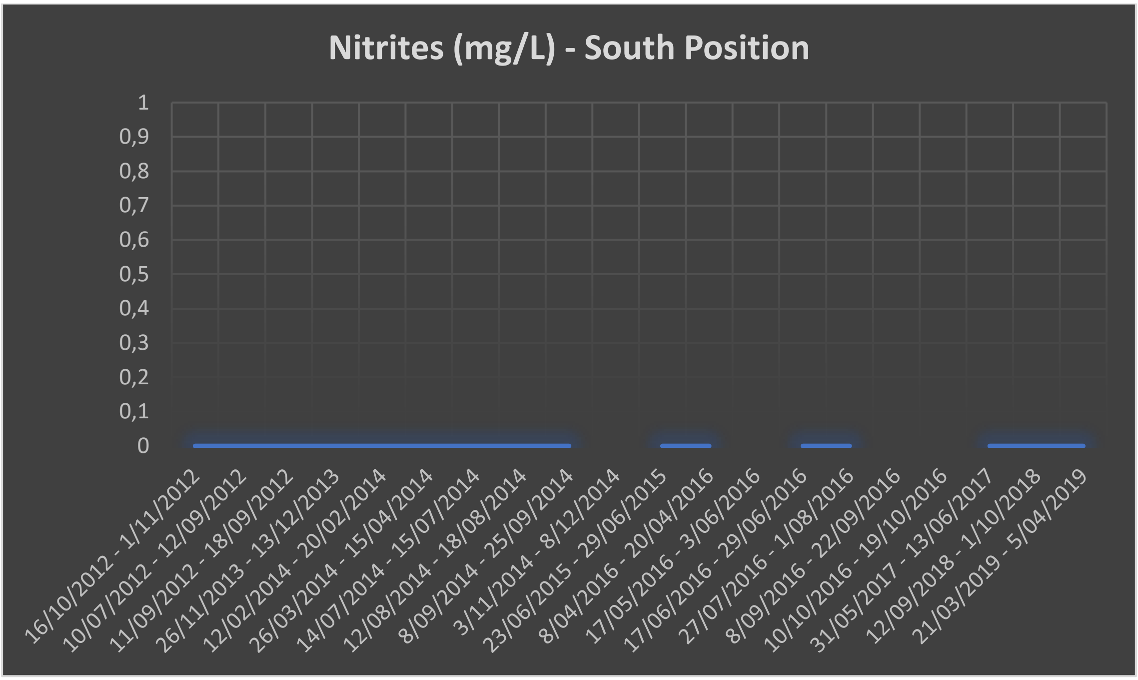


Figure 48. Nitrites South Position

Moving into the final parameter/s the data shows that Nitrates have been ranging from < L.O.Q (0,5) to 12.9 mg/L as peak value throughout the time-series. The peak has simultaneously taken place for all 3 sampling points during the late months of 2013 and the first months of 2014. Since then, the values of Nitrates have drastically fallen to the 2-4 mg/L point. With high limit being marked at 50 mg/L the lake seems to be in a quite good stage in regards with the presence of Nitrates in the water, well below the allowed level. As far as Nitrites are concerned, they are observed at values lower than 0,0006 (< L.O.Q (0,006)), with a sudden peak for the North and Central sampling position in 2018 and 2019 respectively. Generally, the values even during the peaking stage, stayed well below the allowed limits of 0.5 mg/L.

Conclusions & Epilogue

Following the data manipulation, analysis, and graphical presentations we have extracted all the above useful conclusions. Lake Orestiada has been through a lot. Due to the fact it has been the receiver of sewage, tannery and other human activity waste for many years it has reached a point in the past that the situation could be classified as dire with heavy Eutrophication and low water quality. With the collective effort of the people of the administrative region of Western Macedonia, the Municipality of Kastoria, immediate residents and residents of the outskirts of the lake, together with local authorities and environmental conservation societies it seems that the situation has been overturned.

The current situation of the lake can be characterised as a vast improvement of the state of the years past and one can even observe that the status of the lake is mildly Eutrophic or even Mesotrophic, this is a big step towards the lake's sustainability and lowering of the rate of which it ages by, so that it can gradually come to the pristine level that every stakeholder, environmental societies, government and of course the residing people want to see it at.

Besides the fact that there is this kind of improvement through the last decades it is no time to sit back and relax, now is the time to proceed furtherly, with more analytical monitoring and the implementation of a holistic and thorough Lake Management Plan the Lake can be utterly sustainable and remain for our children and our children's children. Such plan has already been formed since 2015 by the Administrative Region of Western Macedonia and other governmental organizations. As every strategy though the monitoring must always go on in order to ensure that the results that are expected of the implementation of such plan are achieved, or in the case of results not meeting expectations to re-evaluate and re-draft the plan or parts of the plan; sustainability after all is an ever-going process.

It is important to remember that the livelihood of the people in the immediate or surrounding area of the lake is deeply entwined with the well-being of the ecosystems. Having a heavily polluted lake can cause foul smell and visual pollution that could deter tourists from visiting the city. As the hospitality industry is one of the pillars of the local economy less tourism directly translates to less traffic in the local market thus less local income. Furthermore, as fisheries are also a core pillar of the local economy a highly eutrophic lake could endanger the populations of the fish curbing the production of fisheries. Taking in account that the municipality and the city more specifically have taken hits throughout the years especially following the economical crisis if the inflow of tourists and rate of fisheries production is decreased, there would be added problems for the local economy that could potentially be devastating.

The Lake of Kastoria, being the 3rd biggest lake in Greece and of utmost importance for the local economy and level of the quality of life must be sustained. The recent plan of installation of buoy systems and monitoring stations around the lake will surely make it more effective in matters of data gathering and database building, but besides the technical part the Lake needs all of us, its people, to keep a growing environmental conscience that will evolve into an idea, a way of action, a way of life to keep what once was had and is being had, to will be had.

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