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APPLICATION OF IPS INDEX BASED IN EPILITHIC DIATOMS and PHYSICO CHEMICAL DATA FOR EVALUATION OF WATER QUALITY

Lirika Kupe[1*], Marsela Alikaj[1], Elona Bahiti[1], Alma Imeri[1], Irena Duka[2]

[1]Department of Agronomic Sciences, Faculty of Agriculture and Environment, Agriculture University of Tirana, Tirana, Albania;*
[2]Department of Environment and Natural Resources, Faculty of Agriculture and Environment, Agriculture University of Tirana, Tirana, Albania;

[*]Corresponding Author Lirika Kupe, e-mail address: lkupe@ubt.edu.al;

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ABSTRACT

The studies conducted in this research work emphasizes on the use of Sensitive Pollution Index (IPS) based on epilithic diatom community towards evaluation of water quality in Shkodra Lake. Benthic diatoms are the groups of diatoms, which are less vulnerable to disturbances be they of a physical, chemical or other nature thus making the convenient indices for the ecosystem under consideration. Benthic diatoms were gathered from five sampling sites situated in proximity to the shores of Shkodra Lake, including: Shterbeq (Sh1), which is close to the Montenegro border Kompleksi Hysaj (Sh2), Vraka (Sh3), Shiroka (Sh4) and Zogaj (Sh5). The findings reveal that the water quality is not uniform over the space meaning that there are some human socio-economic activities and some natural factors that are affecting the ecological state of the lake. In total, two field trips were conducted in Decembre 2023 and May 2024. It is often found that, as compared to diatoms, chemical indicators of water quality are of less reproductive value. Nevertheless, because their communities can assimilate rising concentrations of both organic as well as inorganic chemical constituents, they are often preferred for in situ biomonitoring. This study shows that some significant shifts in species composition can be detected in relation to changes in dominance patterns of specific species from Shkodra Lake's aquatic communities. The identified dominant species include a total of 92 diatom species, including most dominant species like as: *Cocconeis placentula* var. *lineata* (Ehrenberg) *Van Heurck*, *Cymbella affinis* Kützing *agg*., *Eunotia glacialis* F. Meister 1912, *Gomphonema olivaceum* (Hornemann) Brébisson var. *olivaceum*, *Cyclotella ocellata* Pantocsek, *Aulacoseira granulata* (Ehrenberg) Simonsen, *Fragilaria incognita* E. Reichardt, *Gomphonema truncatum* Ehr., *Nitzschia dissipata* (Kützing), etc. About 88 species belong pennate diatoms and four belong centric diatoms. The proceedings of this research include the application of the IPS index and water quality assessment for different locations in Shkodra Lake, proving the detail of the water quality assessment conducting by mean of the IPS index and the crucial role diatoms play in monitoring freshwaters (Prygiel J. and Coste M, 1993; Miho et. al., 2010)). In our study, the IPS (sensitive pollution index) has been calculated also to show the connections between BOD, COD, total and P determination., Nitrates, Nitrites, pH, etc. The Sensitive Pollution Index fluctuated between moderate and very good quality but only Shiroka station was classify as Poor quality.

Keywords*:* Shkodra lake, karstic lake, epilithic diatoms, Sensitive Pollution Index, water quality.

INTRODUCTION

Shkodra Lake is located in the western region of the Balkan Peninsula, situated along the border between Albania and Montenegro, specifically positioned between the coordinates: 42°21'54'' N & 19°09'52'' E in the north (Malo Blato, Sinjac), 42°03'15'' N & 19°30'00'' E in the south (Buna River spring), 42°03'15'' N & 19°30'00'' E in the east (close to Shkodra city), and 42°21'19'' N & 19°01'28'' E (close to Rijeka Crnojevica). The surface area of the Shkodra Lake watershed is 5179 km², with 1027 km² located in the Albanian territory (Kabo et. al. 1990-1991). Furthermore, Shkodra Lake is of significant regional importance. The area also represents particular values in hydrological and ecological aspects, given the connection of the lake with a larger hydrographic network in the Balkans through the Drini River (Ohrid and Prespa lakes) and with the Adriatic Sea through the Buna River. The Water Framework Directive (WFD, 2000) requires that standards methods are used for the monitoring of water quality based on the biological elements. The Water Framework Directive employs a variety of metrics for the evaluation of the extent of impact resulting from a given pressure. This led to a strong recommendation from these networks of experts for the harmonisation of these methodologies and the potential identification of common metrics. The biological material collected is typically characterised by a high level of taxonomic resolution, with a substantial number of organisms identified to the species level.

It is evident that epilithic diatoms exhibit more specific environmental preferences and tolerances compared to the majority of aquatic biota. These organisms are essential due to their role as primary producers, contributing significantly to oxygen generation, akin to other algal groups, and serving as a foundational component of aquatic food chains. Although some diatoms may form filamentous colonies, the predominant form is unicellular. Characterized by their siliceous cell walls, diatoms are abundantly found in various aquatic environments, including rivers, lakes, and oceans. Additionally, they are capable of functioning as epiphytes on macrophytes. (Round, et. al., 1990). Benthic diatoms have been demonstrated to be a valuable tool for water bioassessment and monitoring in numerous European studies (Eloranta & Soininen, 2002; Feio *et al*., 2007; Kelly, 1998; Prygiel & Coste, 1993). In comparison to benthic macroinvertebrates, diatoms offer a more sensitive indicator of water quality due to their shorter life cycle and role as primary producers (Kupe *et al*. 2023; Hering *et al*. 2006; Steinberg & Schiefele 1988; Triest *et al*. 2001). Diatoms are a common tool in the study of water quality. Biomonitoring techniques have been employed for over a century to assess the impacts of diverse forms of pollution in freshwater ecosystems (Kolkwitz and Marsson 1902; Kupe *et. al*. 2013). Diatoms predominantly bloom in freshwater environments and are present in all aquatic basins. They are fundamental organisms in the assessment of aqueous ecosystems and have been employed for over a decade in several European countries.

Diatoms are widely regarded as the earliest biological community to respond to eutrophication pressures and are the most direct indicator of the Water Framework Directive. However, the diatom community is notably diverse and dynamic. The development of an ecological classification system that is specifically tailored to the analysis of nutrient pressures necessitates the minimization of the effects of seasonal variability, which are associated with the changing physical and biological structure of the water, and the magnification of the signal that is related to nutrient pressures (WFD, 2000).

The impact of individual species or taxes on nutrient pressures can be either positive or negative. Positive indicators include species of diatoms, such as *Cyclotella ocellata*. In contrast, species of green algae (like *Scenedesmus*) are considered negative indicators. Nevertheless, the assignment of taxa to functional groups still typically necessitates taxonomic resolution at the genus level, with species-level identification being required for certain taxa.

The diatoms growth of Shkodra Lake was relatively high during the May 2024 and Decembre 2023, were identify about 92 diatom taxa. The diatom community dominated by *Cyclotella ocellata* Pantocsek, *Gomphonema truncatum* Ehr., *Navicula radiosa* Kützing, *Aulacoseira granulata* (Ehrenberg) Simonsen, *Diatoma mesodon* Ehrenberg Kützing, *Eunotia bilunaris* (Ehr.) Mills var.mucophila Lange-Bertalot Norpel & All, *Fragilaria incognita* E.Reichardt , *Nitzschia dissipata* (Kützing), *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck , *Achnanthes minutissima* Kuetz.var *minutissima, Cymbella affinis* Kützing agg., *Meridion circulare* var. *constrictum* (Ralfs) Van Heurck, *Eunotia glacialis* Meister, *Fragilaria (Ulnaria) ulna Sippen angustissima* (Grun.) Lange-Bertalot, etc.

The aim of our study is to evaluate the potential of diatoms as biological indicators for assessing water quality in accordance with the Water Framework Directive (WFD). The research employs a range of biological indicators, including the Sensitive Pollution Index (IPS), to investigate the interrelationships between chemical oxygen demand (COD), biological oxygen demand (BOD), nitrate and nitrite concentrations, pH levels, total phosphorus (P) determination, and other relevant parameters. The occurrence of water eutrophication, stemming from changes in nutrient levels, can significantly impact ecosystem dynamics. To evaluate diatom population variability across different seasons and locations, various indices are employed to ascertain their effectiveness in monitoring the relatively unpolluted waters of Shkodra Lake.

MATERIAL AND METHODS

Sampling sites

Shkodra Lake is located in the northwestern region of Albania, with the northwestern portion belonging to Montenegro and the southeastern portion belonging to Albania. The lake has a length of 44 km and a width of approximately 14 km, (Kabo et. al., 1990-1991). Shkodra Lake is one of 40 karstic lakes on Earth, relatively shallow, with an average depth of up to 7 m. Biological and Chemical parameters were conducted at five sampling sites Shterbeq (Sh1), which is close to the Montenegro border, Kompleksi Hysaj (Sh2), Vraka (Sh3), Shiroka (Sh4) and Zogaj (Sh5), during Decembre 2023 and May 2024 (Figure 1). Our study focuses on ten samples, where have identify diatom species and calculate Sensitive Pollution Index (IPS) based in biological indicators.

Biological indicators

Based on water quality standards, we were focused on the following two: EN 13946:2003 and EN 14407:2004. In accordance with the methodology described in previous studies, collection of diatom samples was made in small bottles and for safekeeping they were preserved in 4% formaldehyde (Prygiel & Coste, 1993; Kupe *et. al*. 2008; Kelly & Whitton 1995). Diatom frustules were subjected to purification by boiling in concentrated hydrogen peroxide (H_2O_2) in accordance with the EN 13946:2003 standard. The data regarding species composition was obtained through a systematic count of approximately 100 oil immersion views, with an additional 500 valves measured on each slide. The resulting value yielded a 95% confidence level. Previous studies by (Prygiell & Coste, 1993; Lund et. al. 1958; Cemagref, 1982) were also consulted. Microscopic examination was used to investigate biologically the diatom communities. The communities are collected in a manner akin to epiphyte growth, adhering to different macroalgae at varying depths from the shoreline and the collected suspensions were preserved in small bottles within 4% formaldehyde (Kelly et.al., 1995; Prygiel *et. al*., 2002; Kupe et. al., 2013; Kupe *et. al*., 2015).

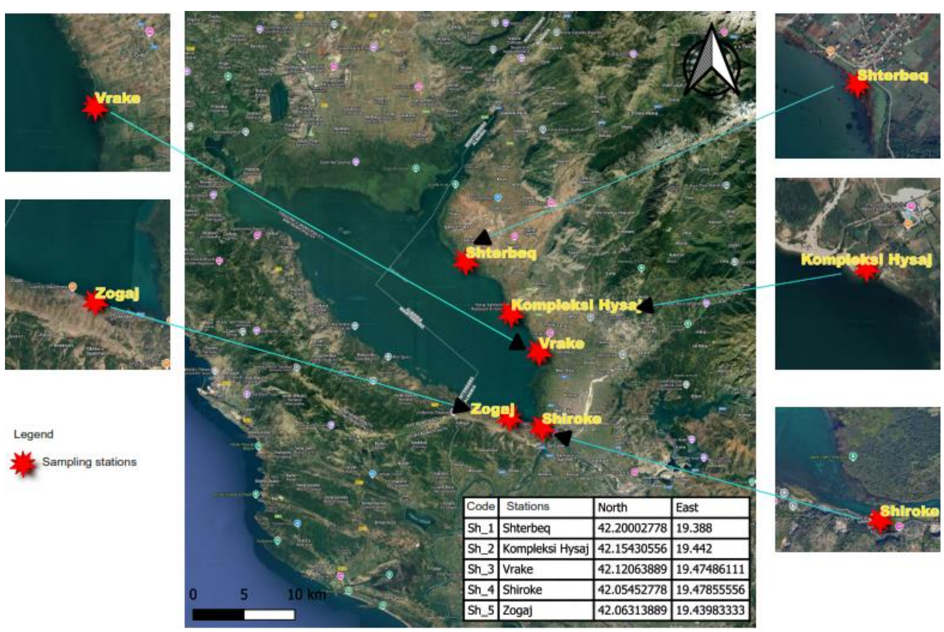

Figure 1. Sampling station's location of Shkodra Lake.

The cleaning of diatom frustules was conducted through a two-step boiling process as described by Krammer & Lange-Bertalot (2001). Initially, the material was boiled in concentrated HCl, followed by a second boiling in concentrated H_2SO_4 after washing. During the latter boiling, crystals of potassium nitrate (KNO_3) were added. A total of approximately 500 valves were counted per slide using a 100x oil immersion objective, thereby yielding a confidence level of 95% for the data on species composition (Lund *et al*., 1958; Kelly *et al*., 1995; Prygel et al., 2002). The identification of diatoms was conducted in accordance with the established literature, including the works of Cleve–Euler (1955), Pascher (1976), Krammer & Bertalot (1996–2001), and the AlgaeBase database (https://www.algaebase.org/). Moreover, a detailed account of the taxonomic nomenclature and distribution was provided for each sample. The Shannon Diversity Index (H') was calculated for each sample in accordance with the methodologies established by Eloranta and Kwandrans (1996) and Shannon and Weaver (1949). The model was initially developed at the Cemagref institute by Coste (1982) and Eloranta & Kwandrans (1996), utilising the formula proposed by Zelinka and Marvan (1961). It was subsequently refined by Eloranta & Kwandrans (1996) and Zelinka & Marvan (1961). IPS are likely in use in many countries today. We calculate the Sensitivity Pollution Index and determine quality water.

Physic-Chemical parameters

In addition to the biological parameters, the chemical parameters of the samples were also subjected to analysis, including COD, BOD_5), NO_2-, NH_4+, NO_3-, and PO_4^{3-}. The analyses were performed in accordance with established ISO standard methods (ISO 6878:2004; ISO 7150:1984; ISO 7890/1:1988); (Xiao-e, et. al., 2008; ISO SSH 7890/1, 2000; ISO 6878, 2004; EN 26777, 1993) and were subjected to a comparative analysis with the objective of establishing their conformity with the standards set forth by the WFD. The determination of COD was conducted through the oxidation of organic matter in the presence of $KMnO_4$ at the boiling point and H_2SO_4. Once the oxidation phase has concluded, $KMnO_4$ continues to react with oxalic acid, resulting in the formation of residual compounds that are also identifiable using $KMnO_4$.

BOD5 was determined by the OXI-top system over a five-day incubation period. The concentration of N-NO_{2-} was determined through the reaction of nitrite present in the sample with the reagent amino-4-benzenesulfonamide in the presence of orthophosphoric acid (pH 1.9), resulting in the formation of a diazonium salt. This salt subsequently formed a complex with N-(naphthyl-1) diamino-1,2-dihydrochloride ethane, also introduced with the amino-4-benzenesulfonamide reagent, leading to the development of a pink coloration. Absorbance was quantified by measuring the optical density at a wavelength of 540 nm.

The concentration of N- NO_3- was determined through spectrometric measurement of absorbance at 324 nm, corresponding to the compound formed by the reaction between nitrites and dimethyl-2,6-phenolics in the presence of sulfuric and phosphoric acids, resulting in the production of nitro-4-dimethyl-2,6-phenol. The determination of P-PO_4^{3-} was achieved through the acid digestion of persulphate. All forms of phosphates underwent alteration to orthophosphate, which, in conjunction with antimony-molybdate and antimonial potassium tartrate, formed the complex antimony-phosphate-molybdate. This complex was then reduced by ascorbic acid, resulting in the formation of a blue molybdenum complex whose intensity was found to be directly proportional to the total phosphorus. The data can be analyzed using a Spector S-10 UV-VIS spectrophotometer with a wavelength of 885 nm. Concerning N-NH_4^+, spectrometric measurement of the blue compound formed by the reaction of ammonium with salicylate and hypochlorite ions, in the presence of sodium nitrospenta cyanoferrate (III) (sodium nitroprusside), was conducted at approximately 655 nm.

RESULTS AND DISCUSSION

Diatom species composition

Diatoms, a significant group of microscopic algae, are utilized as indicators of the underlying environmental conditions at the sampling sites. It has been demonstrated that nutrient enrichment can induce significant variations in diatom groups at the species level (Neiderhauser & Schanz, 1993). A total of 92 distinct diatom species were identified at all five sampling sites over the course of two seasons (December 2023 and May 2024). The most frequently occurring species are provided in Table 1 for reference. The diatoms belonging to the Pennates group were found to be significantly more prevalent than those of the Centrics group, because the samples were collected in benthos or in macrophytes.

Table 1. The distribution of species abundance at all sampling sites and during all sampling periods is as follows: *abundant (xxxx), common (xxx), rare (xx), very rare (x)*

Sampling period	Sampling sites	*Cyclotella ocellata Pantocsek*	*Aulacoseira granulata (Ehrenberg) Simonsen*	*Achnanthes minutissima Kuetz.var minutissima*	*Cocconeis placentula var. lineata (Ehrenberg) Van Heurck*	*Cymbella affinis Kützing agg.*	*Diatoma moniliformis Kützing*	*Diatoma vulgaris Bory gr.*	*Gomphonema olivaceum (Hornemann) BrŽbisson var. olivaceum*	*Gomphonema truncatum Ehr.*
Abundance of species										
Dec-23	Shterbeq	xxx	xxx	x	x	x	x	x	x	xx
	Kompleksi Hysaj	xxx	x	xxxx	x	xxx	xx	x	x	xxx
	Vrake	xxx	x	xxx	xxx	xx	x	xxxx	x	xx
	Shiroke	xxxx	x	x	xx	xx	xx	x	xx	xx
	Zogaj	xxxx	xxx	x	x	xx	x	xxxx	x	xx
May-24	Shterbeq	x	x	x	xxxx	xxx	x	x	xx	xx
	Kompleksi Hysaj	x	x	xxxx	xxx	x	x	x	x	x
	Vrake	x	x	xx	xxxx	xx	xx	x	xx	xxx
	Shiroke	xx	x	x	xxxx	xx	x	x	xxx	x
	Zogaj	xx	x	x	x	xx	xxxx	xxxx	xxx	xx

Some dominant species were: *Achnanthes minutissima* Küetzing var. *minutisima* which is characterized by a high degree of tolerance. (Hofman, 1994), was present in all samples, also, *Cyclotella ocellata* was observed to be more abundant in all samples. The specific preferences of each species must be taken into account when considering the characteristics of a given habitat (Lund *et al*., 1958). The most prevalent diatom species is *Cocconeis gen. sp*., particularly *Cocconeis placentula var. lineata* (Ehrenberg Van Heurck). This species was observed in all samples during May 2024, with the highest abundance recorded in Kompleski Hysaj and Vraka. Some species, such as *Cyclotella ocellata* (TW = 1.5) and *Gomphonema pumilum* (TW = 1.1; S = 1.6), are oligotrophic and only flourish in oligotrophic waters with low nutrient levels. These conditions characterize the environment of Shiroka and Zogaj during the winter months (Tab. 1).

The moderate prevalence of *Cyclotella ocellata* across the core indicates that this lake is minimally impacted by elevated nutrient loading. However, in our sampling points, we observed the dominance of tolerant species that are capable of growing in a wide range of habitats, from oligotrophic to eutrophic waters. These include*: Cocconeis placentula* (TW = 2.6; S = 1.8), *Navicula capitatoradiata* (TW = 2.3; S = 3), and other species are frequently observed in Shkodra Lake. Additionally, other species with high vitality were observed in waters with stronger mesotrophic to eutrophic characteristics, including: *Gomphonema truncatum* Ehr., *Navicula radiosa* Kützing, *Aulacoseira granulata* (Ehrenberg) Simonsen, *Diatoma mesodon* Ehrenberg Kützing, *Eunotia bilunaris* (Ehr.) Mills var.mucophila Lange-Bertalot Norpel & All, *Fragilaria incognita* E.Reichardt , *Nitzschia dissipata* (Kützing), *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, *Achnanthes minutissima* Kuetz.var *minutissima*, *Cymbella affinis* Kützing agg., *Meridion circulare* var. *constrictum* (Ralfs) Van Heurck, *Eunotia glacialis* Meister, *Fragilaria (Ulnaria) ulna Sippen angustissima* (Grun.) Lange-Bertalot, etc.

Ecological Assessment

In order to evaluate the ecological status of Shkodra Lake, a freshwater body, the pollution-sensitive index (IPS) was employed as a biological tool for biomonitoring in freshwater (Miho & Kupe, 2007; Miho *et al*., 2010; Kupe et al., 2023). This index was developed to determine the state of Shkodra Lake by assessing the impact of inorganic and organic water pollutants on the lake's trophic and saprobic indices.

Our study focuses on Pollution Sensitivity Index (IPS). In comparison to TI_{DIA} and SI, IPS provides a comprehensive insight into the pollutants present within water basins, take into account both organic and inorganic contaminants, (COD, BOD, total N and P), eutrophication (chlorophyll and nitrates) and ionic strength (chlorates, sulfates), (according to Prygiel & Coste, 1993, Bahiti, 2019; Kupe *et. al*, 2023). This kind of approach allowed us to gain a more comprehensive understanding of the ecological conditions of Shkodra Lake.

In accordance with the IPS calculation standard developed by Coste in Cemagref (1982), the French and Belgian standards indicate that water quality is of an excellent standard when IPS is between 17 and 20. Furthermore, water quality is of a good standard when IPS ranges from 13 to 17. Conversely, the presence of poor water quality is indicated by an IPS value between 9 and 13, while an IPS value of less than 5 is indicative of bad water quality.

Table 2. Comparison between Pollution Sensitive Index (IPS) by Coste Cemagref, 1982, concentration of total Phosphorus (mg/L) and trophic classes by Rott et. al., 1999).

Index of Pollution Sensitivity (IPS) in France and Belgium (by Coste në Cemagref, 1982).		Concentration of total phosphorus (mg/l)	Trophic Classes by Rott et. al., 1999	
French, Belgium	Quality	*Year mean*	Quality	Trophic value
17 ≤ IPS ≤ 20 17.5	Very good	< 0,005	ultraoligotroph	≤ 1,0
		< 0,010	oligotroph	1,1 -1,3
13 ≤ IPS ≤ 17	Good	0,010 - 0,020	oligo-mesotroph	1,4 - 1,5
		< 0,030	mesotroph	1,6 - 1,8
9 ≤ IPS ≤ 13	Moderate	0,030 - 0,050	meso-eutroph	1,9 - 2,2
		0,030 - 0,100	eutroph	2,3 - 2,6
5 ≤ IPS ≤ 9	Poor	> 0,100	eu-polytroph	2,7 - 3,1
		0,250 - 0,650	polytroph	3,2 - 3,4
IPS < 5	Bad	> 0,650	poly-hypertrophy	> 3,4

As evidenced by the data presented in Table 3, there is a clear and consistent correlation between IPS values and water quality, with higher IPS values indicating better water quality. During the expedition carried out in December 2023, IPS oscillated from *poor* to *moderate* quality where, in Shiroka, the value of IPS was 11.4, which indicates bad water quality, while the stations of Shterbeqi, Zogaj and Vraka are classified as *moderate* water quality. The condition of the waters during the period of May 2024 is classify as good quality, where the IPS fluctuate from good quality (*Shterbeq*- 15.6; *Vraka* – 15.4; *Shiroka*- 15.9 and *Zogaj* -16.1) to very good quality in the *Kompleksi Hysaj* (17.5). The elevated IPS values, which signify moderate to good water conditions (see Table 2 & 3, Fig. 2), are associated with the presence of species such as: *Cyclotella ocellata* Pantocsek, *Achnanthes minutissima* Kützing.var *minutissima*, *Cymbella affinis* Kützing agg., *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, *Diatoma moniliformis* Kützing, *Diatoma vulgaris* Bory, *Gomphonema olovaceum var. olivaceum*. *Nitzschia dissipata* Kützing etc.

Table 3. Number of species (N); Margalef Index (d); Pollution Sensitivity Index (IPS- by Coste in Cemagref (1982); Classes of IPS and Total phosphorus (P-PO_4 mg/l) during December 2023 and May 2024 in five sampling sites of Shkodra Lake.

Sampling period	Sampling sites	Number of species, N:	Margalef Index, d (Margalef, 1958)	Specific Pollution Sensitivity Index (IPS; Coste in Cemagref, 1982)	Classes of Specific Pollution Sensitivity Index (IPS; Coste in Cemagref, 1982)	P-PO4 (mg/l)
Dec-23	Shterbeq	20	3.2	13.0	Moderate	<0.005
	Kompleksi Hysaj	32	4.4	15.4	Good	<0.005
	Vrake	30	4.1	14.4	Moderate	<0.005
	Shiroke	28	4.0	11.4	Poor	<0.005
	Zogaj	22	3.2	13.5	Moderate	<0.005
May-24	Shterbeq	19	2.8	15.6	Good	<0.005
	Kompleksi Hysaj	10	1.7	17.5	Very good	<0.005
	Vrake	16	2.3	15.4	Good	<0.005
	Shiroke	16	2.2	15.9	Good	<0.005
	Zogaj	27	3.7	16.1	Good	<0.005

The relatively low levels of phosphates and ammoniums are indicative of regions characterized by minimal human habitation and minimal impact from urban or rural pollution. Even though phosphorus pollution represents the primary environmental issue affecting water ecosystems, the situation of this nutrient in Shkodra Lake appears to be relatively favourable. The values of phosphorus in both expeditions (Tab. 3, Fig. 2) were below the limit of detection (< 0.005 mg/L), indicating that the water quality is excellent and falls within the first-class category according to the WFD (0.05 mg/L). In conclusion, it can be stated that the waters of Shkodra Lake are in a favourable condition. In terms of nutrients, the lake can be classified as being in a very good to moderate situation.

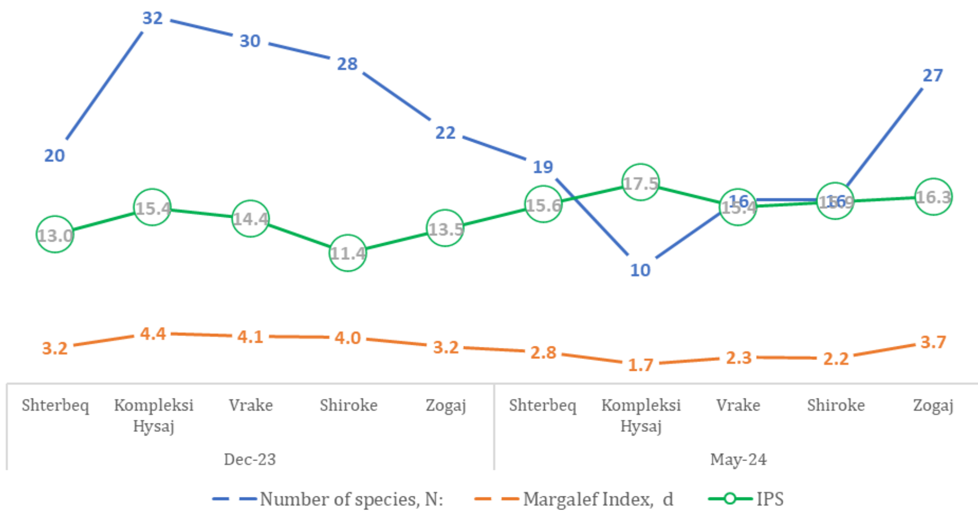

Figure 2. Number of species (N), Margalef Index (d) and Sensitivity Pollution Index (IPS) in ten sampling sites of Shkodra Lake.

Physic-chemical parameters

Based on physic-chemical parameters (table 3) the waters of Shkodra lake are slightly alkaline with the values that range from 7.66 at Sh2 to 8.02 at Zogaj station on Decembre 2023 and from 7.76 Sh2 to 8.51 in Vraka on May 2024. These values correspond to the classification of water as *Class I* according to the WFD. The values of dissolved oxygen range from 8.2 at Shiroka (Decembre 2023) to 12.6 mg/L at Shterbeq (May 2024). The waters of Shkodra lake are of first class according to WFD with values that exceed 7mg/L O2.

The term "biological oxygen demand" (BOD) is not classified as a pollutant; rather, it denotes the amount of oxygen required by microorganisms to decompose organic matter in water (WFD). As the aerobic degradation process depletes the available oxygen, it becomes unavailable for utilization by these organisms. Consequently, regulating BOD levels is essential for maintaining the health of aquatic ecosystems. Elevated BOD levels, however, signal an increased risk of oxygen depletion, which can have detrimental effects on aquatic organisms, including fish (Alikaj et al., 2023).

The concentration of BOD_5 in the waters of Shkodra Lake exhibited a range of values, from undetected to 4.8 mg/L at Shiroka, during the initial expedition, and from 1.2 mg/L during the subsequent expedition. In this context, the waters are classified as first class according to the WFD. Similarly, the values of COD represent the same situation, with values that are of the first class and range from 2.08 mg/L in the second expedition to 5.28 mg/L in the first expedition.

It is evident that the loading of nutrients into lakes has increased significantly because of human activities over recent decades. Such activities have contributed to or exacerbated the symptoms of the transformation of the aquatic ecosystem, which is known as eutrophication. The primary factors that induce water eutrophication are nitrogen and phosphorus input and enrichment of water [8].

The nutrient status of Shkodra Lake appears to be favourable, with ammonium (NH_4^+), concentrations ranging from 0.023 mg/L in the initial sampling event to 0.27 mg/L in the subsequent expedition. Based on these observations, the water quality of Shkodra Lake can be classified as belonging to the first and second categories, respectively, as stated by the Water Framework Directive (WFD) criteria (0.2-0.4 mg/L).

Table 3. Physic-chemical parameters (pH, T^0C, DO (mg/L), BOD5 (mg/L), COD (mg/L), $N\text{-}NO_3$ (mg/L), $N\text{-}NO_2$ (mg/L), $P\text{-}PO_4$ (mg/L).

Sampling period	Sampling sites	pH	TºC	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	$N\text{-}NO_3$ (mg/L)	$N\text{-}NO_2$ (mg/L)	$N\text{-}NH_4$ (mg/L)	$P\text{-}PO_4$ (mg/L)
Dec-23	Shterbeq	7,79	13	9	0	4,92	0,63	0,015	0,042	<0.005
	Kompleksi Hysaj	7,66	11	9.5	0	3,52	0,6	0,012	0,027	<0.005
	Vrake	7,86	11.5	8.5	0	3,2	0,72	0,012	0,024	<0.005
	Shiroke	7,94	12.5	8.2	4,8	5,28	0,26	0,018	0,095	<0.005
	Zogaj	8,02	12	8.5	0	3,92	0,16	0,015	0,023	<0.005
May-24	Shterbeq	*8,13*	19,5	12,6	1,2	3,76	0,028	2,5	*0,27*	<0.005
	Kompleksi Hysaj	7,76	18,7	9,1	1,2	3,68	0,012	3,2	*0,19*	<0.005
	Vrake	8,51	19,5	14	<1	2,08	0,008	2,2	*0,09*	<0.005
	Shiroke	8,31	19,6	11,1	<1	2,6	0,0085	1,36	*0,06*	<0.005
	Zogaj	8,23	19,6	10,6	<1	2,88	0,022	3,8	*0,06*	<0.005

The concentration of nitrites (NO_2^-) in the initial expedition ranged from 0.012 mg/L to 0.018 mg/L, while in the subsequent expedition, it ranged from 0.008 mg/L to 0.028 mg/L. The values correspond to the classification of the waters as first and second class (0.01 mg/L to 0.06 mg/L).
Nitrate is a nitrogenous compound that, in conjunction with phosphorus, serves as a primary nutrient essential for the growth of plants and algae. The presence of excessive nutrient levels can result in the overgrowth of vegetation and the formation of algal blooms. In freshwater ecosystems, the primary risk associated with eutrophication is phosphorus pollution. However, there is growing evidence that nitrogen compounds may also play a role in this process (Alikaj et. al., 2022).
The nitrate concentration in Shkodra Lake is of the first class in the initial expedition, with values fluctuate from 0.16 mg/L to 0.72 mg/L. In contrast, the subsequent expedition classifies the nitrate concentration as second and third class, indicating oligotrophic to mesotrophic waters. The values range from 1.36 to 3.8 mg/L. Even though phosphorus pollution represents the primary environmental issue affecting water ecosystems, the situation of this nutrient in Shkodra Lake appears to be relatively favourable. The values of phosphorus in both expeditions were below the limit of detection, indicating that the water quality is excellent and falls within the first-class category according to the WFD (0.05 mg/L). In conclusion, it can be stated that the waters of Shkodra Lake are in a favourable condition. In terms of nutrients, the lake can be classified as being in a very good to moderate situation.

CONCLUSION

In total of 92 species of diatoms were identified, comprising *Cyclotella ocellata* Pantocsek, *Achnanthes minutissima* Kützing.var. *minutissima*, *Cymbella affinis* Kützing agg., *Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck, *Diatoma moniliformis* Kützing, *Diatoma vulgaris* Bory, *Gomphonema olovaceum var. olivaceum*. *Nitzschia dissipata* Kützing etc. Sensitivity Pollution Index (IPS) vary consistently between moderate and very good water quality. During the expedition carried out in December 2023, IPS oscillated from *poor* to *moderate* quality where, in Shiroka, the value of IPS was 11.4, which indicates bad water quality, while the stations of Shterbeqi, Zogaj and Vraka are classified as *moderate* water quality. The condition of the waters during the period of May 2024 is classify as good quality, where the IPS fluctuate from good quality (*Shterbeq* was 15.6; *Vraka* was 15.4; *Shiroka* was 15.9 and *Zogaj* was 16.1) to very good quality in the *Kompleksi Hysaj* (17.5). The elevated IPS values, indicative of moderate to good water conditions (see Table 2 & 3, Fig. 2), are associated with the presence of species such as: *Cyclotella ocellata* Pantocsek, *Achnanthes minutissima* Kützing.var *minutissima*, etc. In light of Albania's commitment to aligning its environmental policies with those of the European Union, it is essential to monitor the ecological status of surface waters in accordance with the European Water Framework Directive (WFD, 2000). Accordingly, experts should consider employing these techniques to inform the development of conservation and management strategies, particularly in the context of the anticipated expansion of dams and the unsustainable development of hydropower plants.

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