RESTORATION OF LAKE PRESPA

LAKE PRESPA WATER QUALITY MONITORING REPORT

2013-2016

PSI HYDROBIOLOGICAL INSTITUTE – OHRID

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(Macedonian Part)

DRAFT MONITORING REPORT

PSI HYDROBIOLOGICAL INSTITUTE – OHRID
REPUBLIC OF MACEDONIA

Background

The transboundary Prespa Lake basin, situated in the Balkan Peninsula, is an ecosystem of global significance. The basin hosts unique habitats and species that are important from both European and global conservation perspectives. Prespa Lake, one of the world's ancient lakes is a very unique ecological and hydrological system that over the past years, has faced serious environmental challenges such as pollution and eutrophication caused primarily by the ineffective planning for land and water use and unsound resource management practices.

Because of its local and global significance, and the ongoing degradation processes, the Prespa Lake ecosystem has been in the focus of interest of the three states sharing its basin, but also of the international community. As a result, various initiatives were supported over the past years with the aim to build sustainable capacities for overcoming the region's environmental challenges. Thanks to the technical and financial support from UNDP, the Swiss Agency for Development and Cooperation (SDC) and the Global Environment Facility (GEF), a variety of projects in the areas of agriculture, forestry, fisheries, water and land-use management, nature conservation, solid waste and wastewater management, river restoration, pollution prevention and control, and others, have been successfully implemented. Major community action was mobilized, productive partnerships and networks have been established and tangible results have already been achieved in reducing the pressures to the lake ecosystem. However, additional efforts need to be taken to reverse the trends of the decades' long degradation processes for good, and to ultimately improve the ecological status and functions of the ecosystem.

The recent comprehensive investigations of the Lake's ecological status, carried out within the UNDP/GEF Prespa project, greatly helped in understanding and 'quantifying' the environmental challenges and their root causes. Perhaps one of the most acute problems that the entire ecosystem is currently facing is the eutrophication, caused by the nutrient and organic inputs originating from agricultural runoff, watershed's erosion processes, wastewaters and solid waste. In order to address the ongoing lake's degradation processes, UNDP, financially supported by SDC, has launched a new project that will introduce a set of comprehensive measures to significantly improve the Lake's overall health, strengthen its resilience, and ensure, in the long-run, control of the eutrophication processes.

Scope of Work

The objective of this assignment is to implement a 30-monthwater quality monitoring programme for the Prespa Lake ecosystem that can be used to (1) evaluate the ecological health of the lake, (2) support modeling to evaluate restoration options and their potential for improving water quality, and (3) track changes in water quality over time.

Although Prespa Lake and its watershed are a transboundary resource, including land and water areas in the three neighboring countries, at this time, the project can only support new data collection and implementation activities in the Macedonian part. Thus, the scope of work for this project is restricted only to this part of the watershed.

Duties and Responsibilities

Under the supervision of the Project Manager and overall guidance by the International Technical Adviser, as well as in close cooperation with the representatives of the relevant national institutions (e.g. Municipality of Resen, Ministry of Environment and Physical Planning) the Hydrobiological Institute – Ohrid (HIO) was responsible for carrying out all aspects of this assignment including:

1. **Develop aninitial core monitoring plan** based upon prior sampling efforts and data that already exist in the various previous studies, and the recently completed Prespa Lake Watershed Management Plan (link here: http://prespa.iwlearn.org/prespa-lake-watershed-managament-plan). While recognizing that new parameters and monitoring sites may need to be added to the programme to support a parallel lake and watershed modeling project, the core monitoring programme should focus on sites that provide continuity with previous sampling efforts and that conform to the following guidelines:

    a) Monitoring in the watershed – focused on the mouths of major tributaries (8 – 12 stations/sampling points) – monthly frequency
        - Basic physico-chemical parameters (Temperature, Suspended solids, Dissolved oxygen, Conductivity, pH/Alkalinity)
        - Nutrient loading at the mouths (total and dissolved phosphorus, total and dissolved nitrogen, total organic carbon)
        - Other parameters only as necessary to calculate annual water and phosphorus balances.

    b) Monitoring in the Lake (6 – 8 stations/sampling points)
        - Basic physico-chemical parameters (Temperature, Suspended solids, Dissolved oxygen, Conductivity, pH/Alkalinity) – monthly frequency
        - Nutrient concentrations (profiles of total and dissolved phosphorus, total and dissolved nitrogen, total organic carbon) - monthly frequency
        - Algae (phytoplankton), from all stations (algal groups and chlorophyll a) - monthly frequency
        - Occasional macrophyte sampling from shoreline stations (summer and fall)
        - Occasional macrozoobenthos sampling (spring and fall)
        - Fish monitoring - according EU WFD CEN Standard 14757 (abundance and diversity on four lake sub-water bodies)
        - Sediment analyses (redox profiles, total phosphorus and nitrogen, TOC) – (spring, summer and fall)
        - Other parameters only as necessary to calculate annual water and phosphorus balances.

    c) As soon as the core monitoring plan is approved by the UNDP, HIO will **implement the sampling and analysis programme for the next 30 months**, taking full advantage of staff and equipment associated with the new Lake Monitoring Station (LMS) that the UNDP is establishing in the lakeshore village of Stenje. The equipment includes both a new monitoring boat and a full suite of laboratory equipment (technical specifications appear in Annexes 2 and 3). Although it will be the responsibility of the Contractor to ensure that the necessary monitoring data are collected during the term of this assignment, the sampling and analysis should be approached as an interactive training exercise with the aim of building long-term local capacities in the LMS. By the end of the project, the staff of the LMS should be fully trained in most aspects of routine sample collection and analysis.

    d) The Contractor shall also **conduct additional lake and watershed sampling and analysis as requested** by the parallel watershed and lake modeling initiative. This additional data collection might include:
        - Up to six additional sampling sites for nutrient and physico-chemical analysis and chlorophyll *a* for 1 year – monthly frequency

MONITORING REPORT 2013 -2016 year

LIST OF PARTICIPANTS

Field of monitoring	Expert Name
Project manager	MSci Zoran Spirkovski
Physical – chemical	Dr. Elizabeta Veljanoska – Sarafiloska Silvana Vasileska
Phytoplancton, chl *a*	Dr. Suzana Patceva Msci Jovica Leshoski
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Fish	Dr. Trajce Talevski Msci Zoran Spirkovski Dusica Ilik-Boeva Blagoja Trajcevski
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Zaim Ramadan	
Biljana Naneva	

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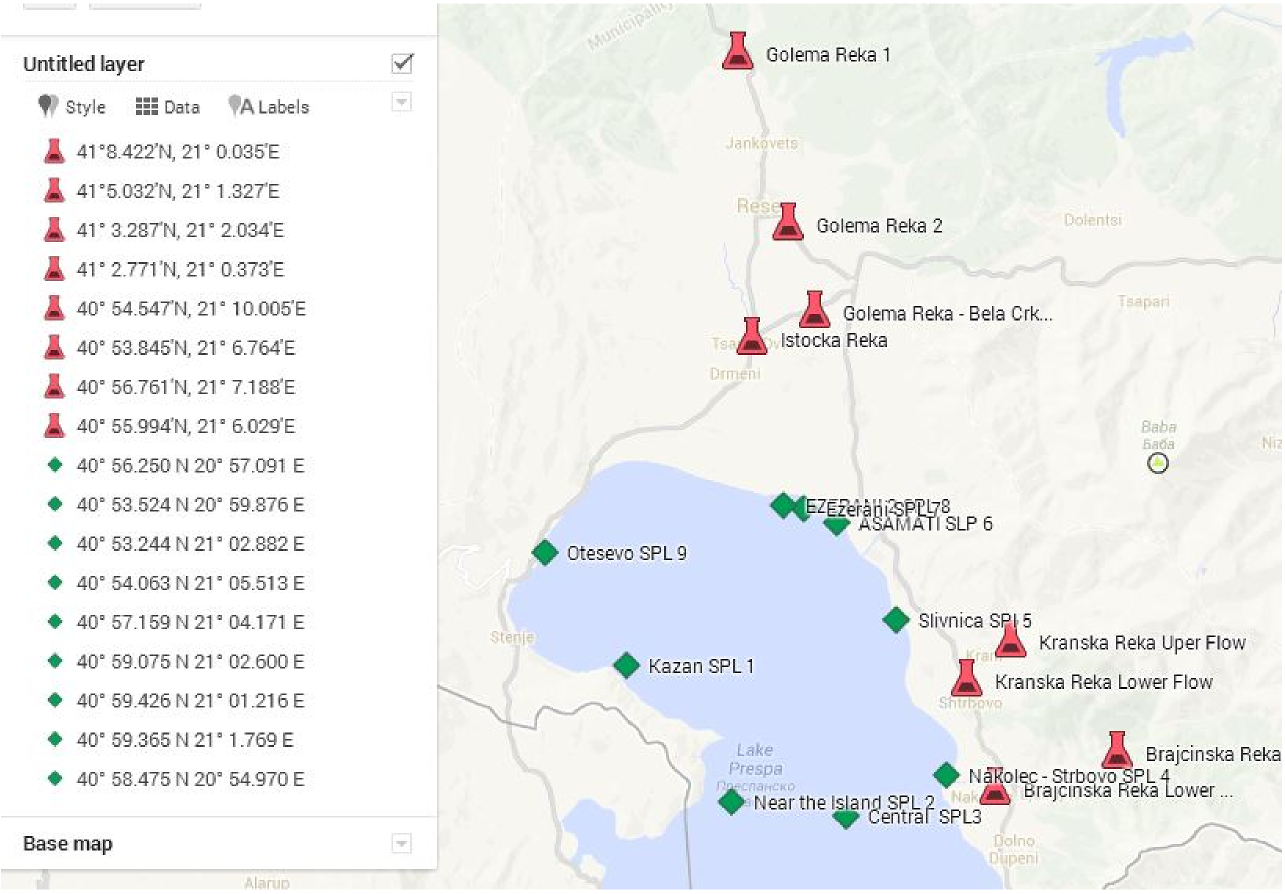
I. Sampling stations for the Monitoring program of Lake Prespa

Lake Stations (total depth)	**Latitute and Longitude**	**Sampling Depths**
SP 1 Pelagic (Kazan) (34m d)	40° 56.250 N, 20° 57.091 E	0m. 10m. 20m. 34m
SP 2 Near the Island (19m d)	40° 53.524 N, 20° 59.876 E	0m 5m 10m 19 m
SP 3 Central 1 (16m d)	40° 53.244 N, 21° 02.882 E	0m. 5m. 10m 16 m
SP 4 Nakolec-Strbovo (3m d)	40° 54.063 N, 21° 05.513 E	Surface
SP 5 Slivnica (3m d)	40° 57.159 N, 21° 04.171 E	Surface
SP 6 Asamati (3m d)	40° 59.075 N, 21° 02.600 E	Surface
SP 7 Ezerani 1 (3m d)	40° 59.365 N, 21° 1.769 E	Surface
SP 8 Ezerani 2 (3m d)	40° 59.426 N, 21° 01.216 E	Surface
SP 9 Otesevo (3m d)	40° 58.475 N, 20° 54.970 E	Surface
River Stations	**Latitude and Longitude**	**Sample types**
SPR 1 Gleme Reka Uper Flow	41° 8.422'N, 21° 0.035'E	Flow and water samples
SPR 2 Golema Reka 2 at Resen (Bridge)	41° 5.032'N, 21° 1.327'E	Flow and water samples
SPR 3 Golema Reka – Bela Crkva2	41° 3.287'N, 21° 2.034'E	Flow and water samples
SPR 4 Istocka Reka	41° 2.771'N, 21° 0.373'E	Flow and water samples
SPR 5 Brajcinska Reka Upper Flow	40° 54.547'N, 21° 10.005'E	Flow and water samples
SPR 6 Brajcinska Reka Lower Flow	40° 56.761'N, 21° 7.188'E	Flow and water samples
SPR 7 Kranska Reka Upper Flow	40° 56.761'N, 21° 7.188'E	Flow and water samples
SPR 8 Kranska Reka Lower Flow	40° 55.994'N, 21° 6.029'E	Flow and water samples

Sampling locations in Prespa Lake and Watershed

Physico-chemical, nutrient, and phytoplankton measurements/samples will be collected from the lake (stations SP1-9) in triplicate on (or about) the following dates: January 15, March 1, April 15, May 15, June 1, June 15, July 1, July 15, August 1, August 15, September 1, September 15, October 1, November 15.

Samples will be collected from tributary stations using a rainfall event-based sampling strategy. 8-12 significant rainfall events will be targeted for sampling, with a remaining 3 collections during drier periods.



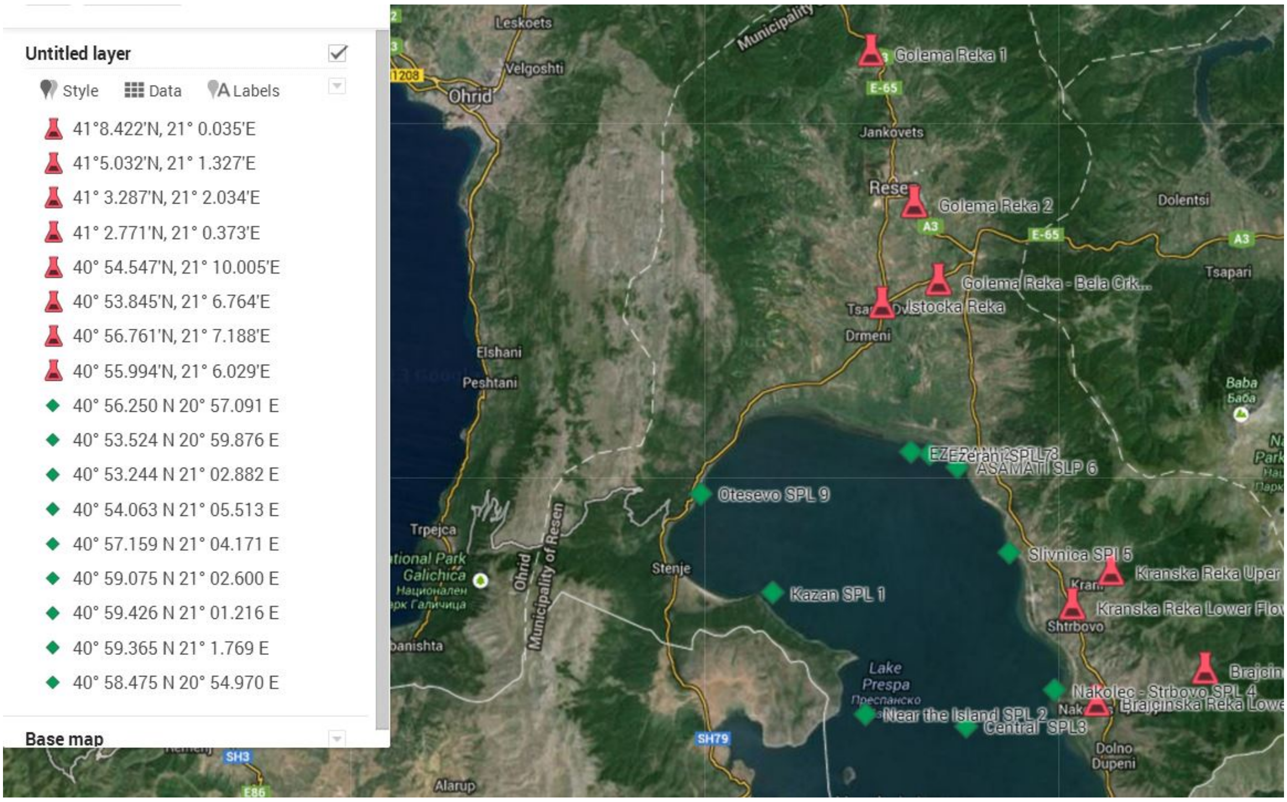


Figure 1.1. Sampling Stations in Prespa Lake and Watershed.

In red colour River SP – In green Lake SP

2. Water quality monitoring

2.1. Monitoring Of The Watershed waters Focused Of The Major Tributaries

The ecological system of lakes is highly depend on the environment, i.e. on the physical, chemical and biological conditions in the watershed area. Human impact and the changes caused by human activities as well as natural changes could cause an increasing flow of nutrients. Nutrients aspecially phosphorus as limiting element of eutrophication can affect of trophic state of the water bodies.

The industrial growth, the agriculture that is forced by the application of agrotechnical means, and modern lifestyle are significantly contributing to the change of the quality of the aquatic ecosystems. This impact, primarily induced by man, i.e. his impact on the environment has influenced Lake Prespa as well, a lake whose qualities are well known (VeljanoskaSarafiloska, 2011; VeljanoskaSarafioska et al., 2011). The antrophogenic impact, especially seen in certain areas on the shoreline, near the mouth of the rivers, contributes to the presence of the so called hot spots, with an alarming condition of the water quality.

The physico-chemical parameters which are the subject of analyses are: transparency, temperature, pH, conductivity, dissolved oxygen, organic matter (through permanganate consumption), total and dissolved phosphorus, total and dissolved nitrogen, total suspended solids, water flow (rivers).

The classification of the water is done according to the Carlson index for the trophic state, 1977, Aizaki et al., 1981; OECD clasification (1982) and the Directive for Classification of waters (1999).

The application of Carlson's method for the determination of the trophic state of the water refers to the following parameters: concentration of total phosphorus, and Secchi transparency, that provid the numeric value of the trophic state index.

1.1. Results

1.1.1. Temperature

The figure 1.1-1 shows the values of the annual average temperatures of thewater in the investigated sites for the period 2014-2016. From the figure can be noted that the values registered for Golema River were higher than in Kranska and Brajcinska, whichare mountain rivers.

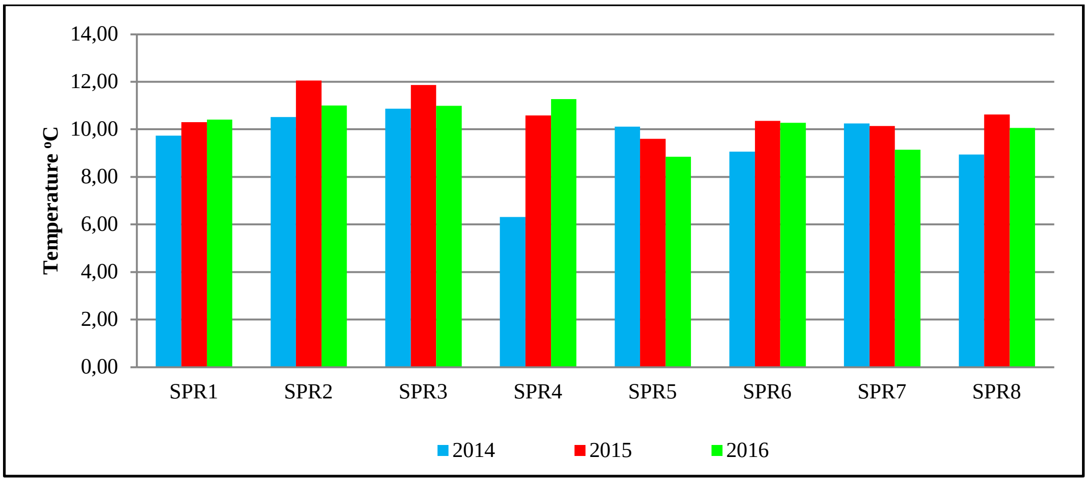


Figure 1.1. Average annual values for temperature in the water from sampling points

1.1.2. pH

The values for pH in the water samples collected from all sampling sites, during the analysed period (2014-2016) were very variable (Fig. 1.2.).

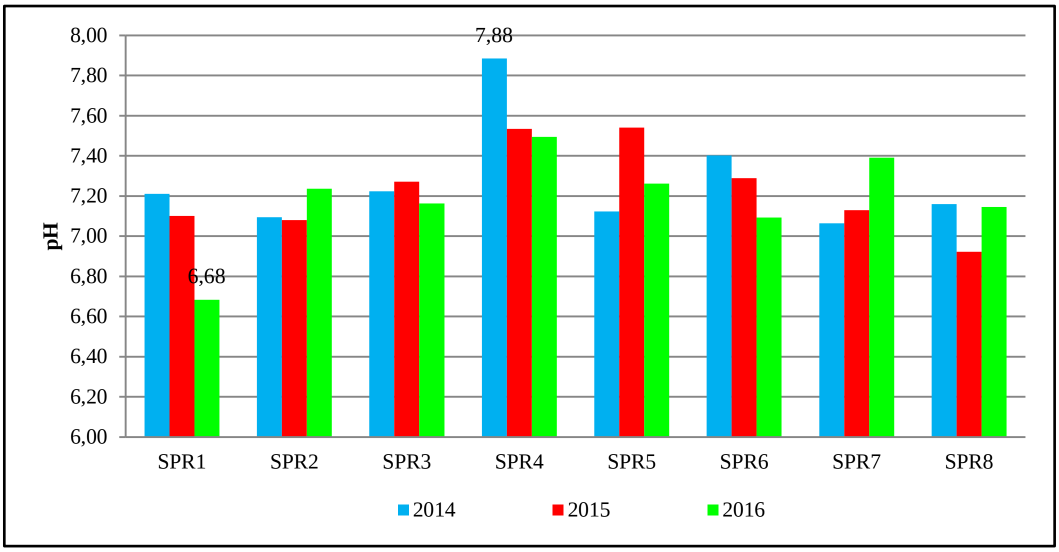


Figure 1.2. Average annual values for pH in the water from sampling points

The average annual values of this parameter are in the range from 6.68 at SPR1 Junction Golema River with Leva River to 7.88 at Istocka River. Golema River is in fact very loaded with industrial, communal and waste water from households that greatly affect the water quality.

1.1.3 Conductivity

The average annual values for conductivity are presented in figure 1.1-3. The conductivity of the water from the sampling points varied between 29.3 μScm^{-1} at SPR7-River Kranska upper flow and 213.7 μScm^{-1} at SPR2-River Golema petrol station Resen.

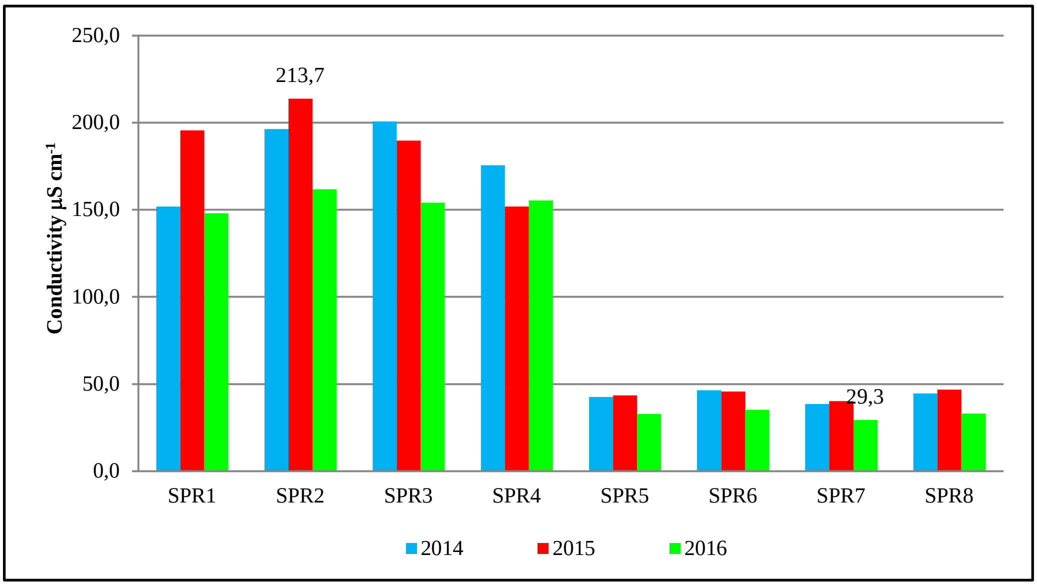


Figure 1.3. Average annual values for conductivity in the water from sampling points

The lowest values for conductivity during the investigated period were registered for SPR5 and SPR6 (River Brajcinska upper and lower flow), SPR7 and SPR8 (River Kranska upper and lower flow).

1.1.4.Total alkalinity

The total alkalinity average annuel values have varied from 20.3 mg l^{-1} $CaCO_3$ at SPR8 (River Kranska lower flow) to 116.6 mg l^{-1} $CaCO_3$ at SPR1Junction River Golema with Leva Reka(Fig. 1.4.). The lowest values for this parameter for all investigated period were measured for River Kranska (upper and lower flow) and River Brajcinska (upper and lower flow).

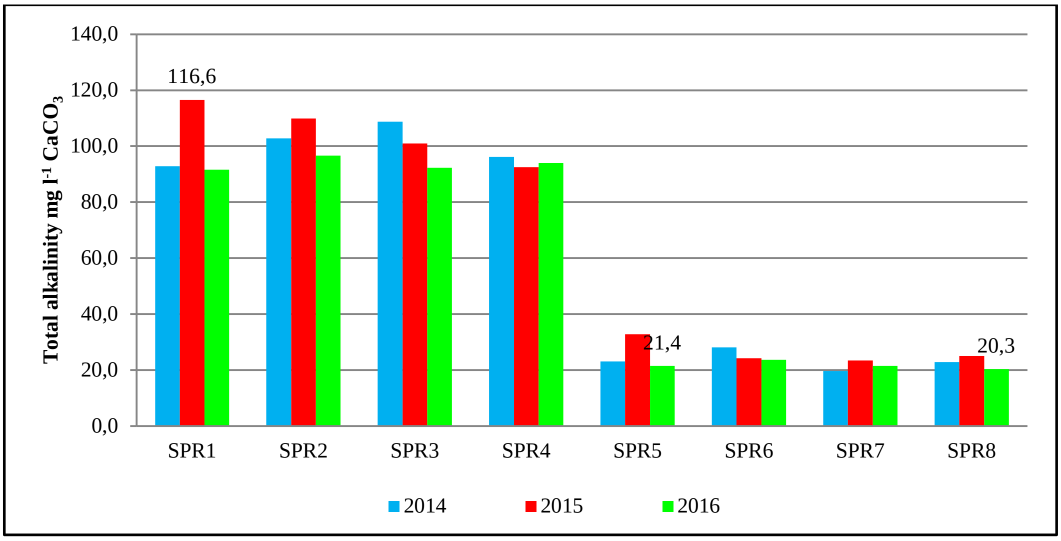


Figure 1.4. Average annual values for conductivity in the water from sampling points

1.1.5. Total suspended solids

Results for total suspended solids are presented in Figure 1.5.

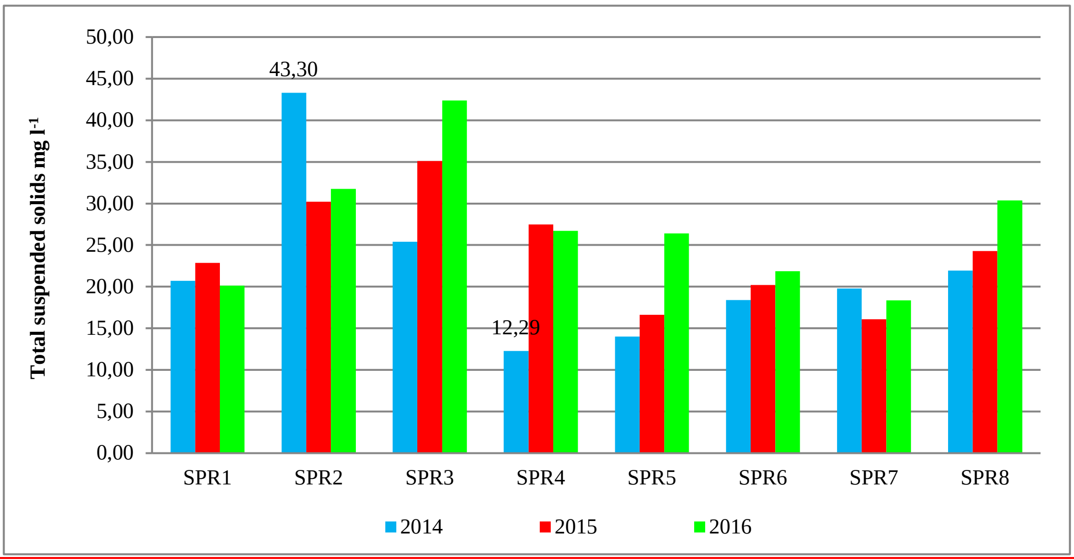


Figure 1.5. Average annual values for suspended solids in the water from sampling points

The highest values in terms of total suspended solids (organic and inorganic) are recorded in water samples collected from Golema River Bela Crkva and Golema River Petrol station Resen. Maximum average of 43,3 mg l^{-1} was registered in 2014 for SPR2. In other localities, Brajcinska, Kranska and Istocka River, the value for this parameter is the highest during 2015, but with significantly lower values compared to River Golema. It is characteristic to note that in the basins of the three rivers are mostly covered with a stones, unlike the River Golema, where there is muddy ground.

1.1.6. Dissolved oxygen

The values for the concentration of dissolved oxygen (whichis essential for the production and the support of all life in the lakes i.e in all water ecosystems) are presented in figure 1.6.

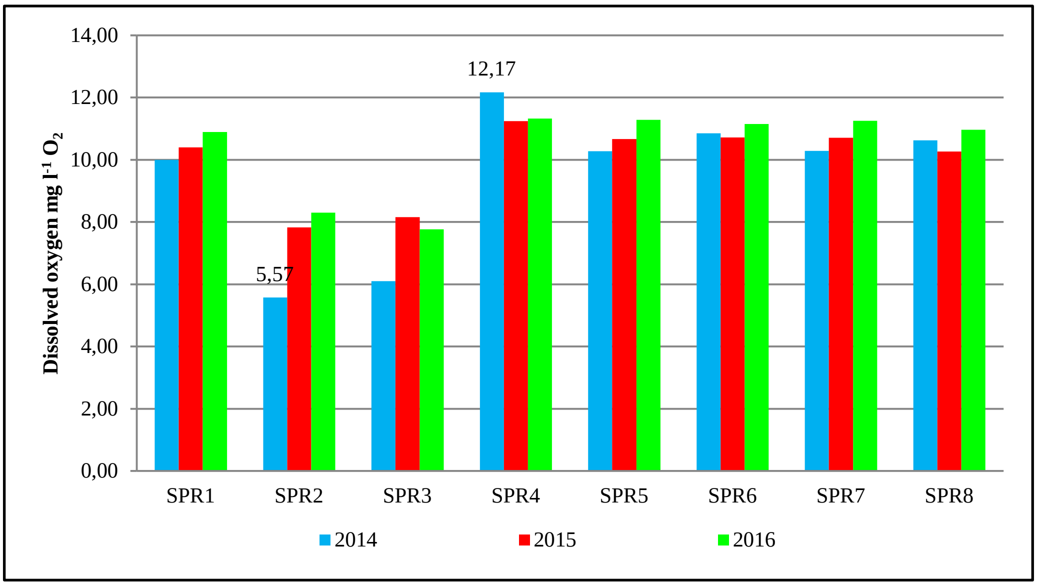


Figure 1.6. Average annual values for dissolved oxygen in the water from sampling points

Values for concentrations of dissolved oxygen vary in the different research years and between investigated sampling points - Rivers. During the whole researched period 2014-2016, the lowest values were recorded in the water samples collected of Golema River (in the three points that are the subject of this research), especially in its lower reaches at locations of Bela Crkva and Resen petrol station. Golema River is primarily a major recipient of industrial waste water and drainage water from agricultural areas, leading to intensification of oxidation processes in this system and use of the oxygen primarily for the mineralization of organic biodegradable substances. Fluctuations in water level in Golema River, especially in the summer also affect the concentrations of this parameter. Unlike the river, other rivers are mountainous and have a higher flow which in turn leads to greater aeration of the water.

1.1.7. Organic matter

The overview of organic loading in places subject to analyses is presented in Figure 1.7. The consumption of $KMnO_4$ is an indirect measure for the quantity of organic biodegradable matter in the water (the quantity of consumed permanganate depends on the quantity of organic substance in the water and their chemical structure).

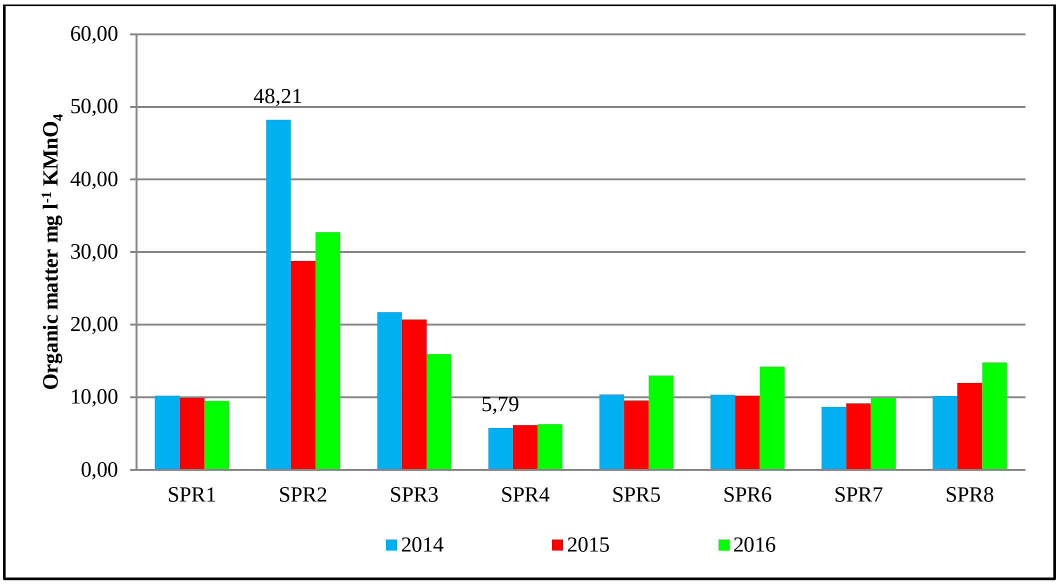


Figure 1.7. Average annual values for organic matter in the water from sampling points

The obtained results for this parameter indicate that usually the highest values during all analysed periods (2014-2016) was measured in the water sample collected from SPR2 River Golema petrol station Resen (maximal value was registered in SPR2 48.21 mg l^{-1} during 2014). This is due to the fact that River Golema pass through agricultural areas and settlements and this river is "the end-recipient" of the industrial waste water, drainage water and sewage from households which are discharge directly into the river. During the investigated period of three years, the other rivers registered relatively lower organic load, and lower average annual values of this parameter generally under 12 mgl^{-1} $KMnO_4$. Organic load is primarily due to drainage water that flow into the river beds after intense rains and municipal utility unresolved issues (municipal and water from households in certain parts are discharged directly into the river beds). The lowest values for organic biodegradable substances are recorded in water samples collected from Istocka River.

1.1.8. Nitrate-nitrogen

Results for nitrate-nitrogen are presented in Figure1.8.The concentrations of nitrate-nitrogen in the sampling points varied from 47.43 □g^{-1} NO_3-N at SPR5R.Brajcinska upper flow and 211.68 at SPR2 River Golema Resen Petrol station.

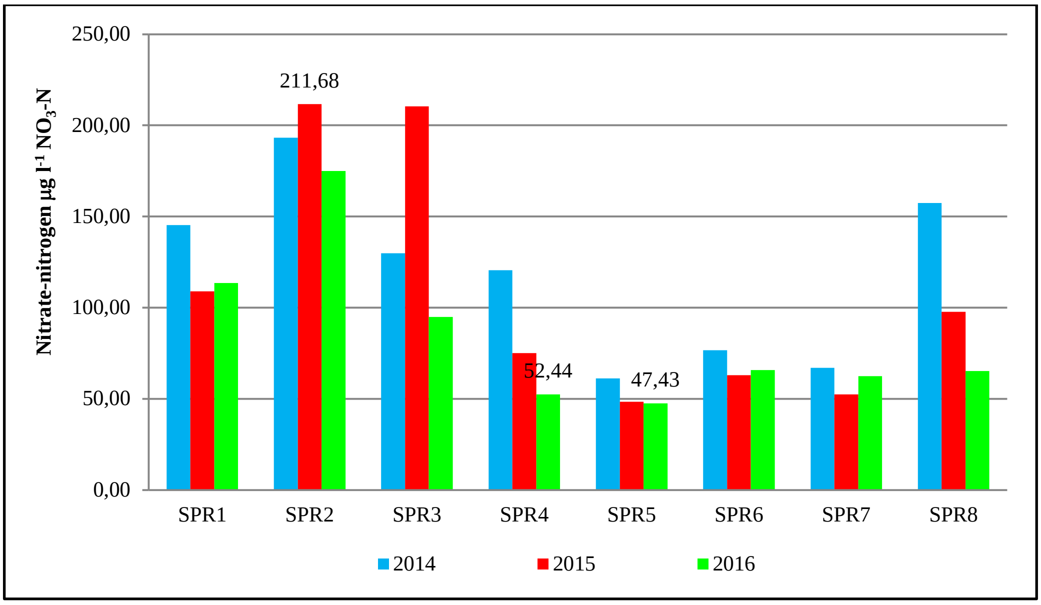


Figure 1.8. Average annual values for nitrate-nitrogen in the water from sampling points

The maximum values for this nitric form, again are registered in Golema River, which is correlated with the presence of biodegradable organic substances with the highest values which were also observed in this River. Visible organic and nutrient pollution of the river is primarily due to the communal waste and water from households, drainage water after rains that flow into the riverbed and further increases the concentration of the nitric form.

1.1.9. Total nitrogen

The average annual results for total nitrogen (2014-2016) are presented in figure 1.9.

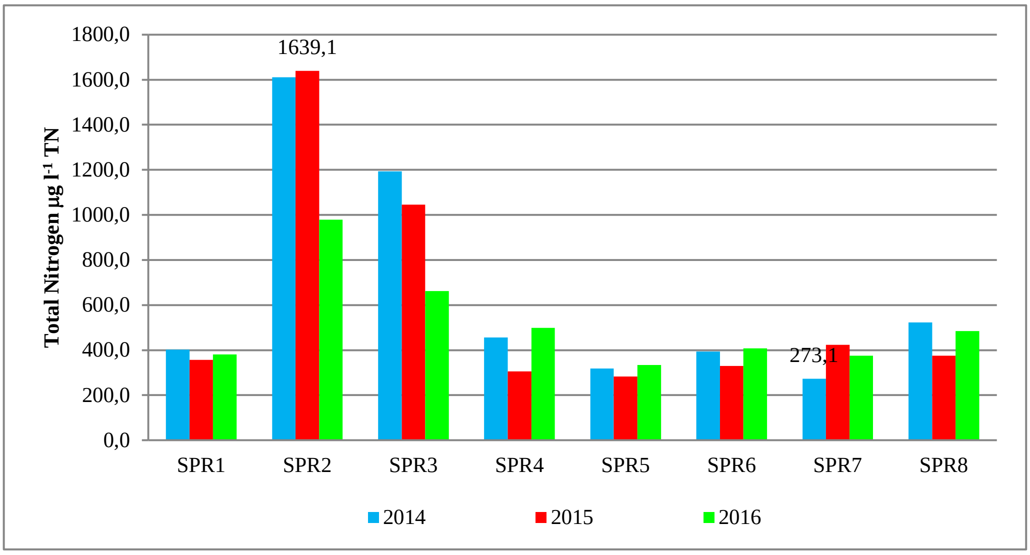


Figure 1.9 Average annual values for total nitrogen in the water from sampling points

The nutrient loads are very high in SPR2 (R. Golema petrol station Resen) and SPR3 (River Golema at Bela Crkva). The maximum value for the concentration of total nitrogen as a sum of organic and inorganic forms of nitrogen in the water sample from SPR2 is 1639.1μg l^{-1} TN (2015). The minimum value is 273.1μg l^{-1} TN, for SPR7 (2014). During the analysed period the values for total nitrogen concentration in the water samples from the most of sampling siteswere below500 μg l^{-1} TN.

1.1.10. Total phosphorus

Total phosphorous, as an essential nutrient, is one of the most limiting factors in the productivity and the eutrophication processes of aquatic ecosystems. The average annual results for the concentration of total phosphorus in the water samples from the analysed sampling points are presented in Figure 1.10.

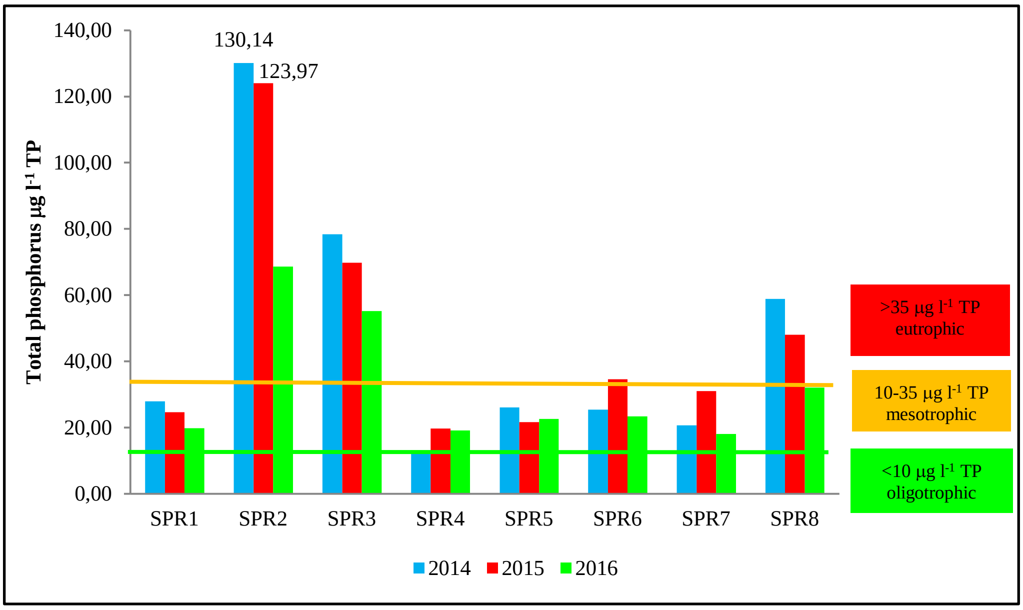


Figure 1.10. Average annual values for total phosphorus in the water from sampling points

The maximum values for the concentration of total phosphorus for all investigated periodare registered at SPR2-River Golema petrol station Resen, SPR3-River Golema at Bela Crkva, and SPR8-River Kranska lower flow.High concentrations of total phosphorus are primarily due to the drainage water from agricultural areas where this river is flowing for most of its course. Additional factor for these values is the low level of water in the river, especially during the summer period when the concentration of attendees nutrients and organic matter in this aquatic ecosystems happens. It is characteristic to note that during the summer, in the bed of Golema River, industrial and municipal waste waters are dominant. River water of this quality flows directly into Lake Prespa, which leads to further pollution in the littoral zone of the lake, especially near the river inflow of Golema River (Ezerani and Asamati).

Generally, more values for the concentration of the total phosphorus during the analysed period were in a mesotrophic state(i.e. IV-V class according to the Directive for Classification of waters - Official Gazette No 18/99), with the exception of the values for SPR2 (River Golema petrol station), SPR3 (River Golema at Bela Crkva) during the all investigated period, they belong to the eutrophic state.

1.1.11. Dissolved phosphorus -Phosphate

The average annual results for the concentration of dissolved phosphorus (phosphates) in the water samples from the analysed sampling points are presented in Figure 1.11.

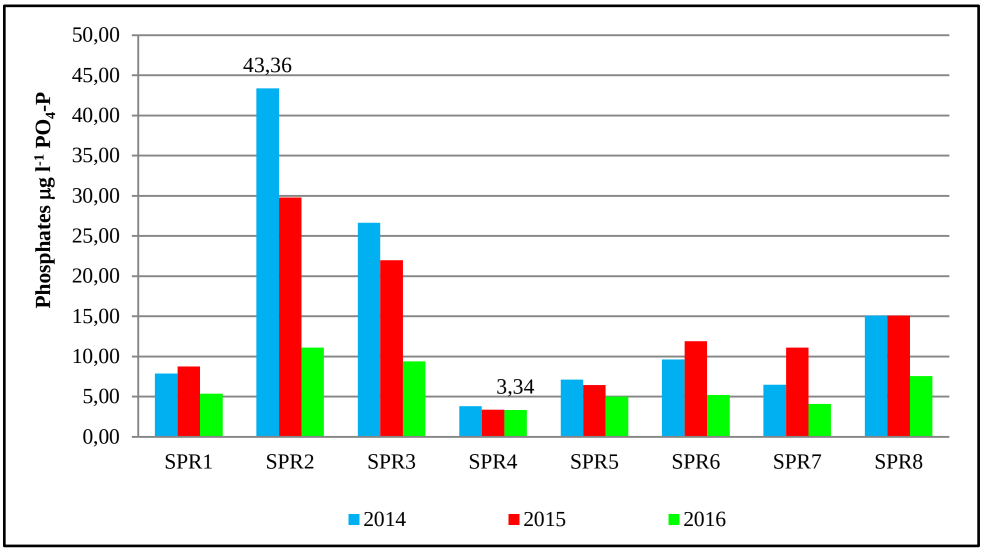


Figure 1.11. Average annual values for phosphates in the water from sampling points

The values for this parameter varied from 3.34 $\mu g\ l^{-1}$ at SPR4-River Istocka,to43.36 $\mu g\ l^{-1}$ at SPR2 -River Golema petrol station Resen.

Values for concentrations of phosphate follow the dynamics of quantity and changes in the concentrations obtained for total phosphorus. During the entire period studied (2014-2016) the highest values for this parameter are recorded in the water of SP2 Golema River at the petrol station in Resen and SP3 at Bela Crkva. In the water of river Istocka are registered the lowest concentrations of phosphate. Generally, the lowest values for this parameter are recorded in the current 2016.

1.1.12. Water flow

The average annual values for water flow are presented in figure 1.12.

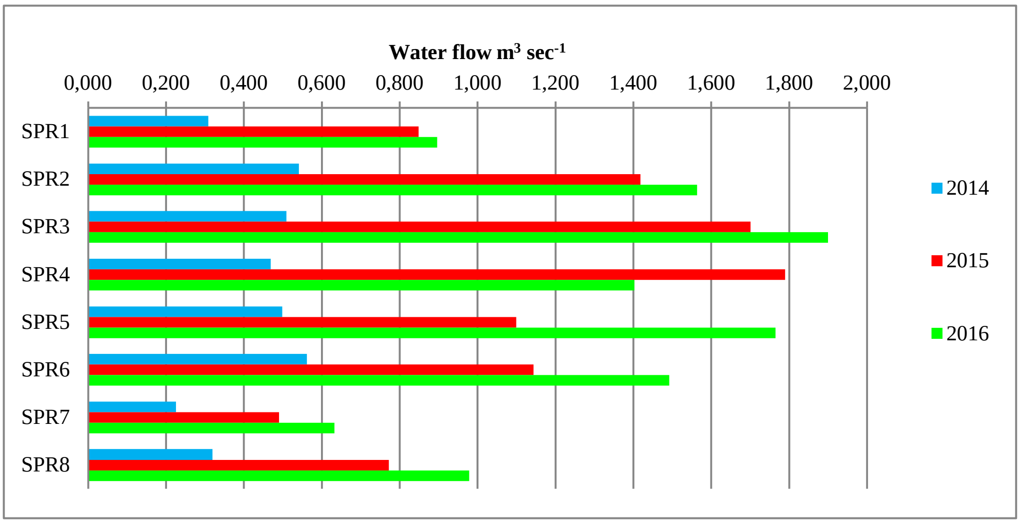


Figure 1.12. Average annual values for water flow in the water from sampling points

From the figure we can conclude that the lowest values for water flow are recorded in 2014, while the highest values are observed in 2016. The amounts of rainfall during the year greatly contributed to the variation in the amount of water in the riverbed. Moreover,the use of river water from the local population for irrigation of agricultural areas influences on the amount of water.

1.2. Conclusions

During the three-year research period (2014-2016), it can be concluded that the highest values in terms of concentrations of nutrients (total and dissolved nitrogen and total and dissolved phosphorus) was recorded in water samples collectable from Golema River, especially in SPR2 Golema River Petrol station Resen and SPR3 River Golema at Bela Crkva. This state of the water quality of the Golema River is primarily due to the impact of industrial waste water and municipal waste water from households which migrates directly in the river, and in the Lake as a final recipient.

An additional factor affecting the state of water quality in the River Golema and of course other rivers is the fact that during the summer in the riverbeds of these surface inflows amount of the water is very low, contributing to much higher concentrations of nutrients and organic matter in the water (especially alarming is the situation with Golema River). Drainage waters that flow from agricultural areas through which the rivers pass in the Prespa region, are another reason for the increase of nutrients in river systems, particularly for the increased concentration of total phosphorus (due primarily to the agricultural fertilizers used in the region where the main occupation is agriculture).

The state of the rivers Kranska and Brajcinska in their upper flows is far better compared to Golema River, and the human influence is considerably lower. This is obvious from the results of nutrient and organic load. In the lower flows of these rivers that pass through settlements and arable agricultural areas, based on the analyzed water samples, anthropogenic influence can be detected, and increasing nutrient concentrations relative to the upper reaches of rivers. Especially this is the case in Kranska River. Based on the results, we generally conclude that the water quality in the rivers is reflected on the water quality of Lake Prespa, primarily in the littoral zone near their inflows.

Generally, more values for the concentration of the total phosphorus during the analysed period were in a mesotrophic state(i.e. IV-V class according to the Directive for Classification of waters - Official Gazette No 18/99), with the exception of the values for SPR2 (River Golema petrol station), SPR3 (River Golema at Bela Crkva) during the all investigated period, they belong to the eutrophic state.

1.3. Lake Prespa Littoral And Pelagial Zone

1.3.1. Transparency

The average annual values for transparency during the investigated period were presented at figure 1.13. Transparency of Lake Prespa water varied between 2.6 m at SP8Ezerani 2and 4.2 mat SP2 Near the Island. Higher annuel values for this parameter are measured during 2015 and 2016.

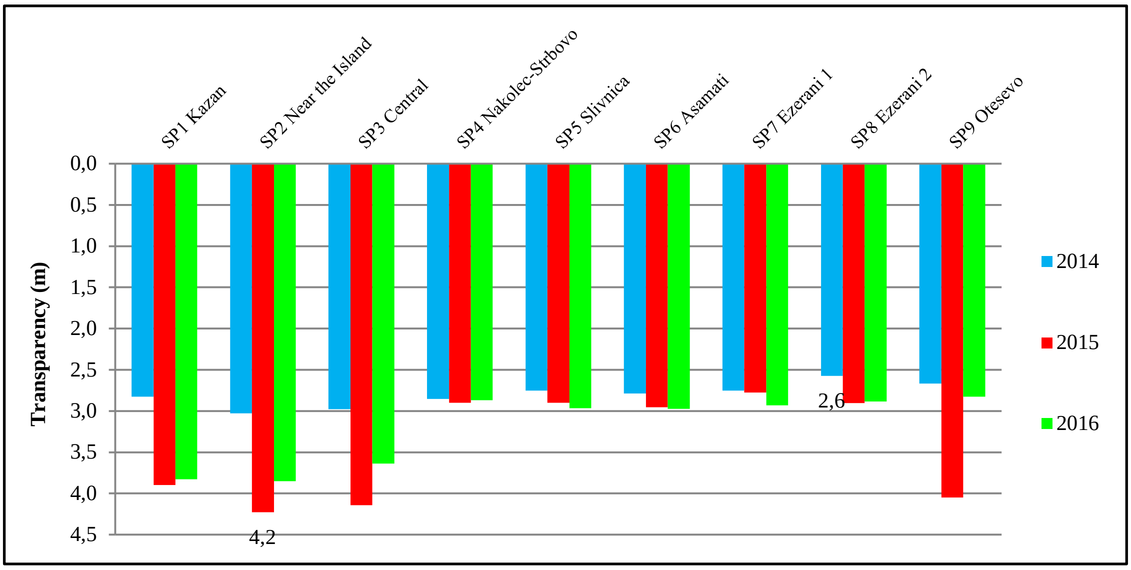


Figure 1.13. Average annual values for transparency (2014-2016)

1.3.2. Temperature

Average annual values for temperature at sampling point from Lake Prespa are presented on Fig. 1.14

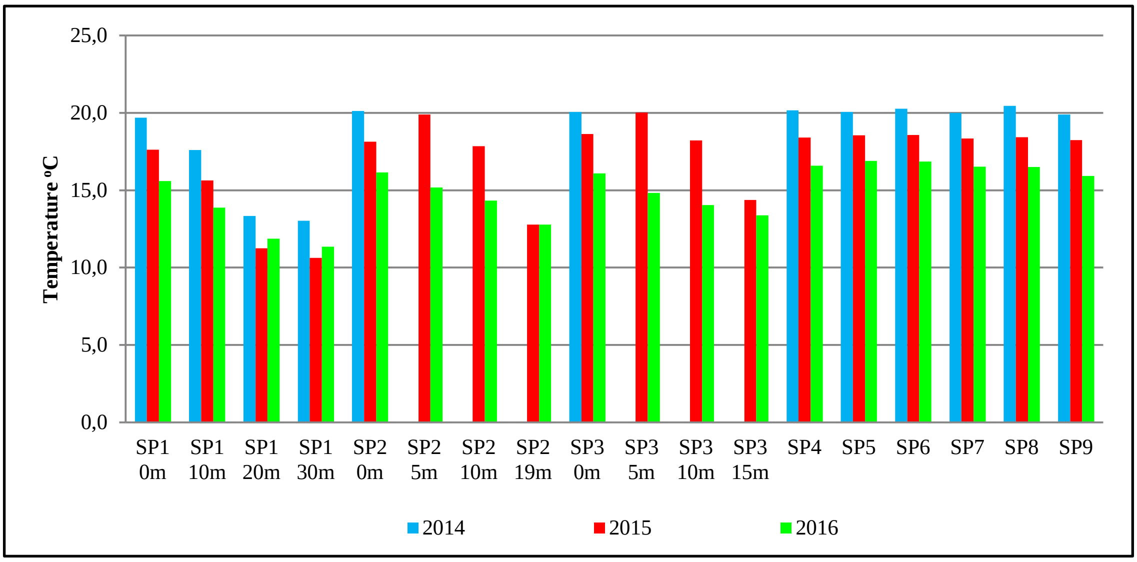


Figure 1.14. Average annual values for temperature in the water from sampling points

Through out the researched period, the lowest mean temperatures are registered in the current 2016 year, probably due to atmospheric precipitation (rainfall) that was frequent in 2016. Isothermy during the winter is characteristic of Prespa Lake, which points to mixing of the lake ecosystem.

On Figure 1.15.a are presented seasonal values for temperature during 2014, on 1.15.b for 2015 and on 1.15c for 2016, for all sampling sites.

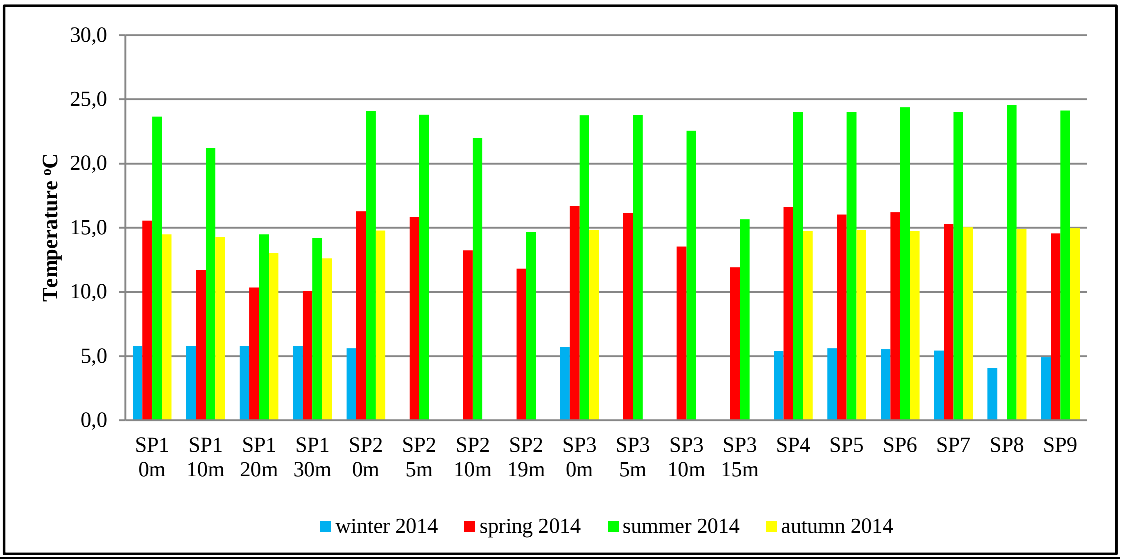


Figure 1.15.a. Seasonal temperature changes in the water from sampling points during 2014

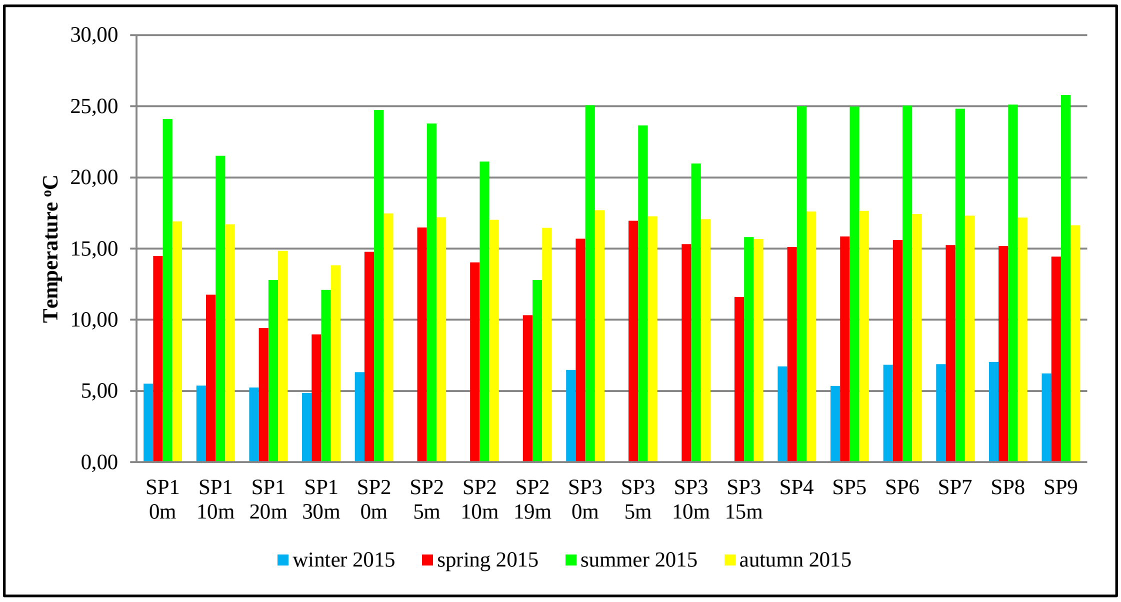


Figure1.15.b. Seasonal temperature changes in the water from sampling points during 2015

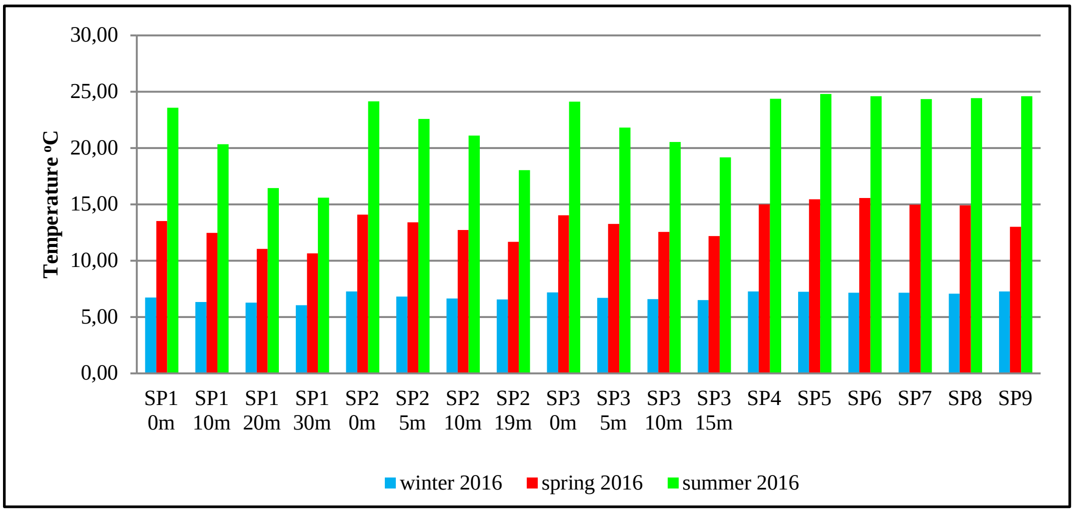


Figure1.15.c. Seasonal temperature changes in the water from sampling points during 2016

In general, maximal temperature values were measured during the heating period (summer months). Highest values were measured at the surface water for all investigated points, during the summer period. The lowest values for this parameter were measured during the winter period. During the winter period the values for this parameter are very similar. This condition is result of mixing of the lake water.Water temperature in Lake Prespa,during spring and summer period, typically varies from the surface to the deeper layers.

1.3.3. pH

The values for pH in the water samples collected from all sampling sites, during the analysed period 2014-2016 were very similar (Fig. 1.16.).

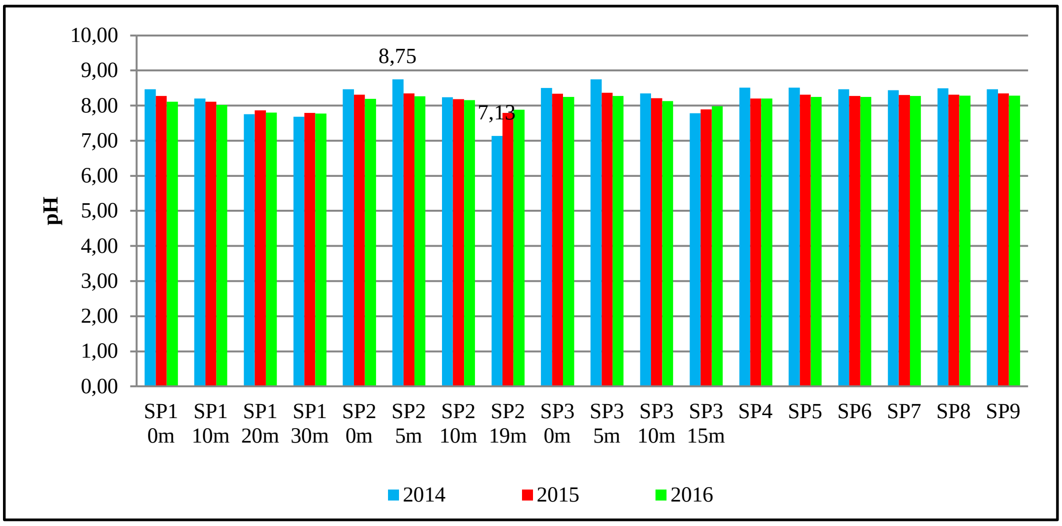


Figure 1.16. Average annual values for pH in the water from sampling points (2014-2016)

The values for pH in the water samples collected from all sampling sites, during the analysed period 2014-2016 varied between 7.13 (SP2 Near the Island 19m) to 8.75 (SP2 Near the Island 5m). Generally, the pH values in the surface layers of the lake is higher than in the deeper layers, due to the more intensive processes of mineralization of organic matter in the deeper layers and production of CO_2. In the surface layers has a more intense process of photosynthesis and use of dissolved CO_2, which increases the pH, decreases the acidity of the water.

1.3.4. Total alkalinity

The total alkalinity values have varied from 97.5 mg l^{-1} $CaCO_3$ to 125.9 mg l^{-1} $CaCO_3$ during the investigated period 2014-2016. At the samples collected from all sampling points, values for total alkalinity are very similar during the investigated period (Fig. 1.17.). Generally, the values for this parametar are over 100 mg l^{-1} $CaCO_3$.

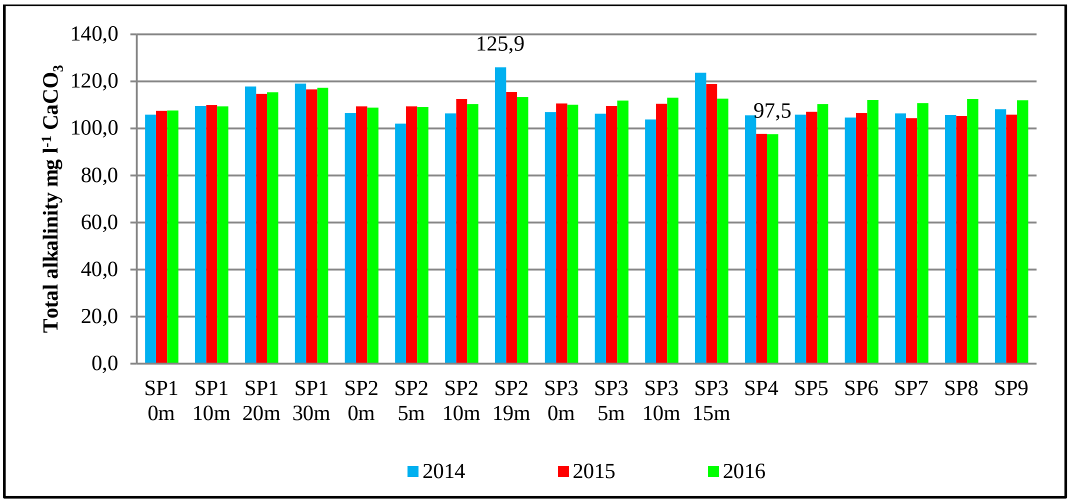


Figure 1.17. Average annual values for total alkalinity in the water from sampling points (2014-2016)

1.3.5. Conductivity

The average annual values for conductivity for investigated period 2014-2016 are presented in figure 1.18. The conductivity of the water from the sampling points varied between 202.25μScm^{-1} and 259.33μScm^{-1}.The values for this parametar are very similar for all sampling points during the investigated period and caracteristic for natural lakes.

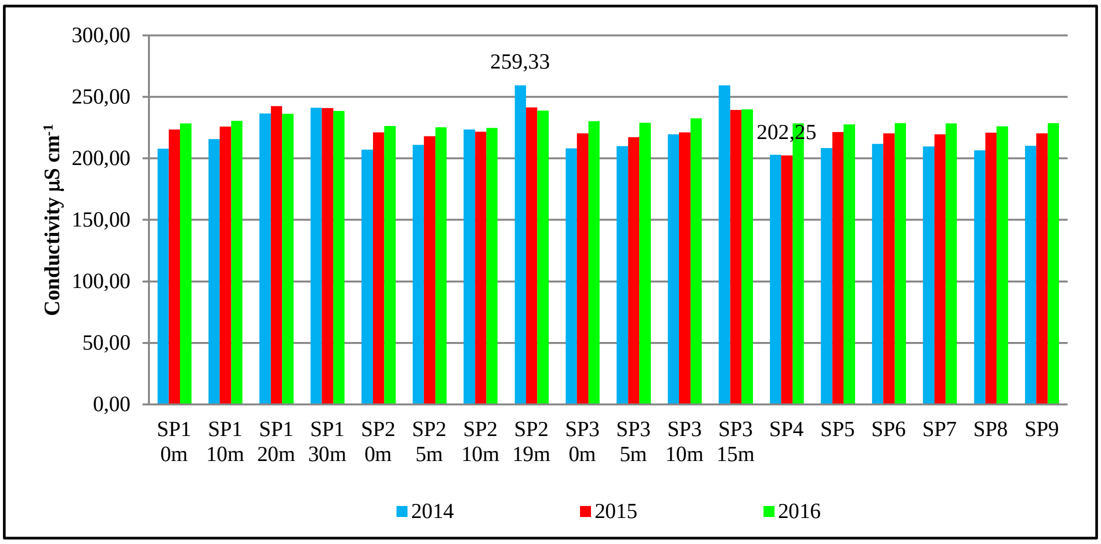


Figure1.18. Conductivity changes in the water from sampling points(2014-2016)

1.3.6. Total suspended solids

Results for total suspended solids are presented in Figure 1.19.

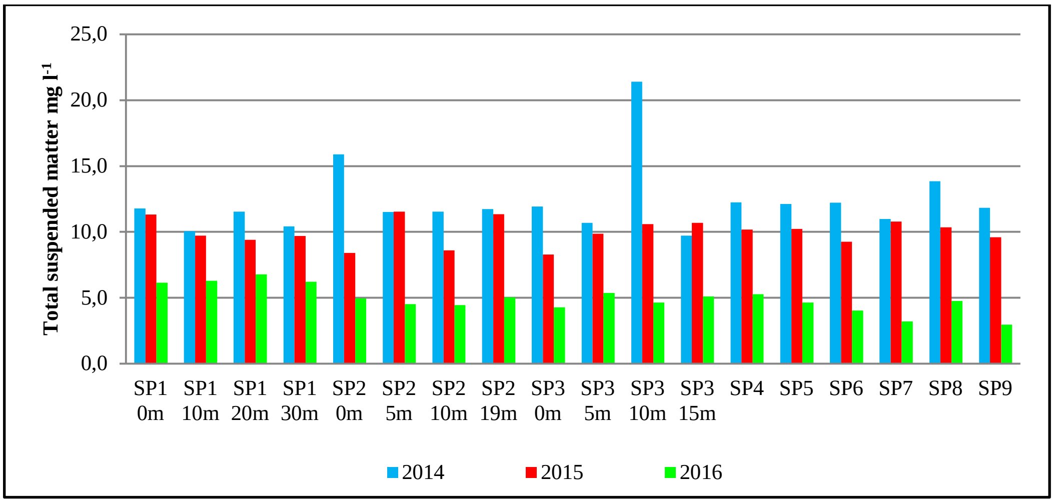


Figure 1.19. Average annual values for total suspended solids in the water (2014-2016)

The minimum value for total suspended solids was registered during 2016 for all investigated points.

1.3.7. Dissolved oxygen

Oxygen is essential to the production and the support of all life in the lakes i.e in all water ecosystems. The average annual values for the concentration of dissolved oxygen are presented in figure1.20.

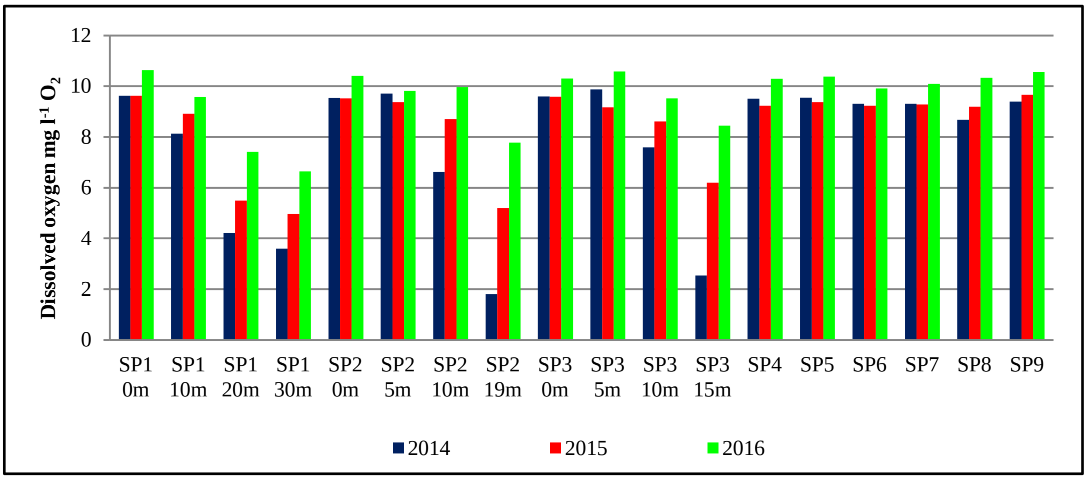


Figure 1.20. Average annual values for dissolved oxygen in the water (2014-2016)

During all sampling campaigns it was observed that surface water in all sampling points have been well supplied with oxygen (Figure 1.21.a. - 1.21.c.). All values for this parameter are above 8 mg l^{-1} O_2. Maximal values for this parameter were measured during the winter period for all investigated period 2014-2016. Exception of this situation is observed in deeper layers from the Lake during summer period when were measured the lowest values for this parameter.

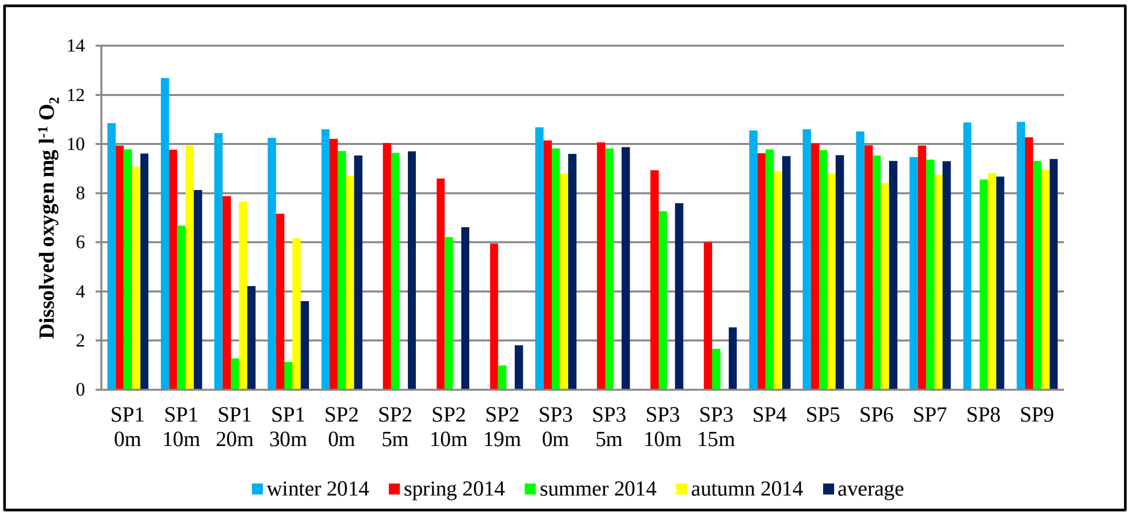


Figure 1.21.a. Seasonal changes of concentration of dissolved oxygen in the water for 2014

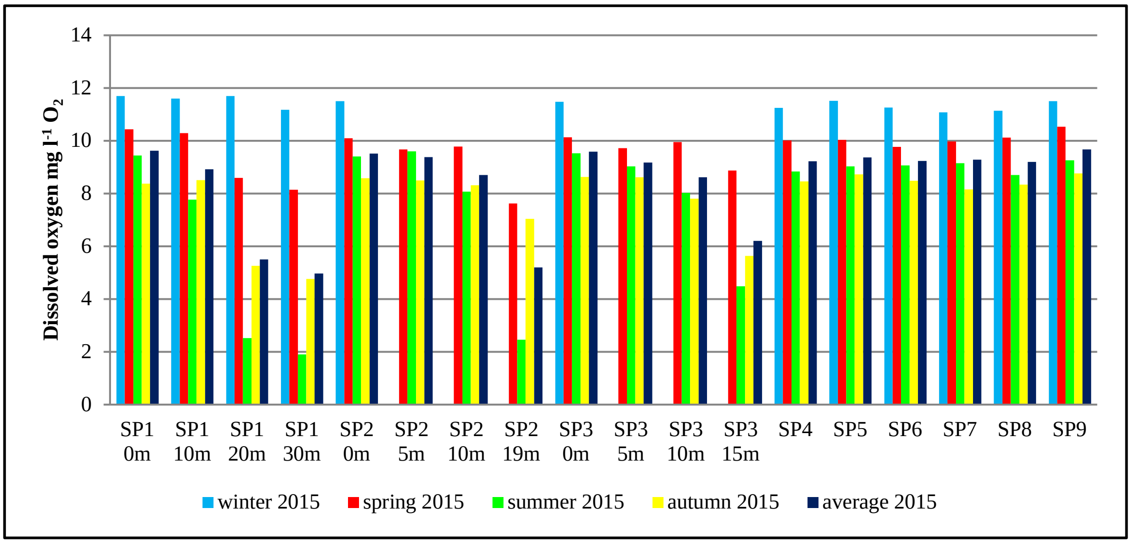


Figure 1.21.b. Seasonal changes of concentration of dissolved oxygen in the water for 2015

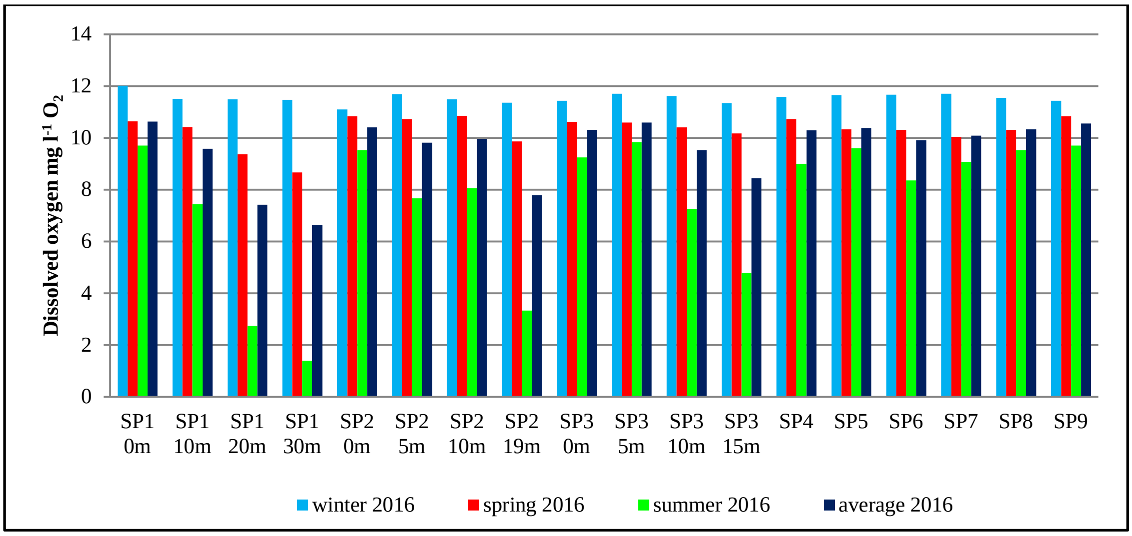


Figure 1.21.c. Seasonal changes of concentration of dissolved oxygen in the water for 2016

1.3.8. Organic matter

The consumption of $KMnO_4$ is an indirect measure for the quantity of organic biodegradable matter in the water (the quantity of consumed permanganate depends on the quantity of organic substance in the water and their chemical structure). The average annual values for the concentration of biodegradable organic matter are presented on figure 1.22., and the seasonal values for this parameter are on figures1.22.a. to 1.22.c).

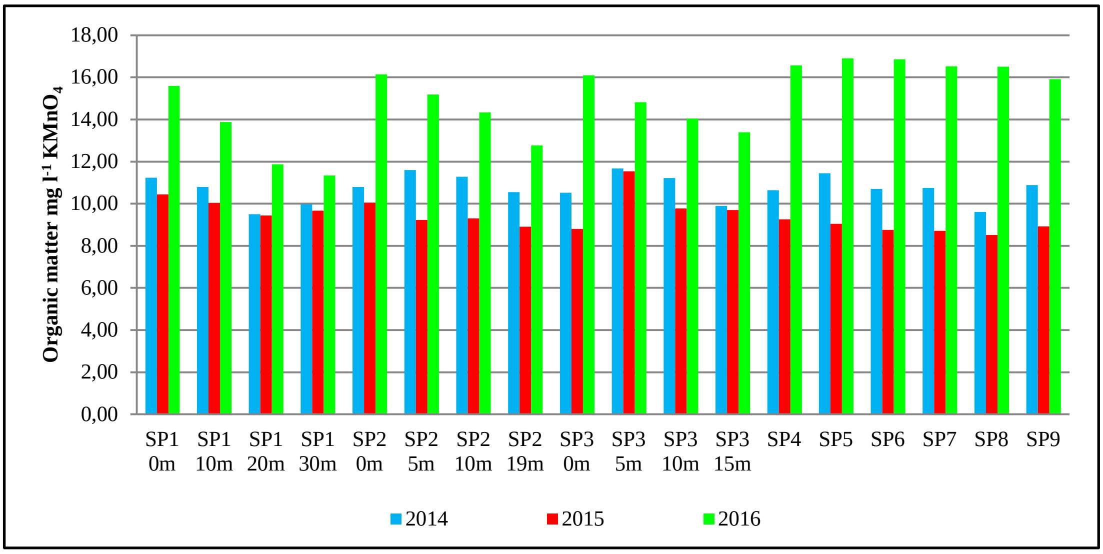


Figure 1.22 Average annual values for organic biodegradable matter in water (2014-2016)

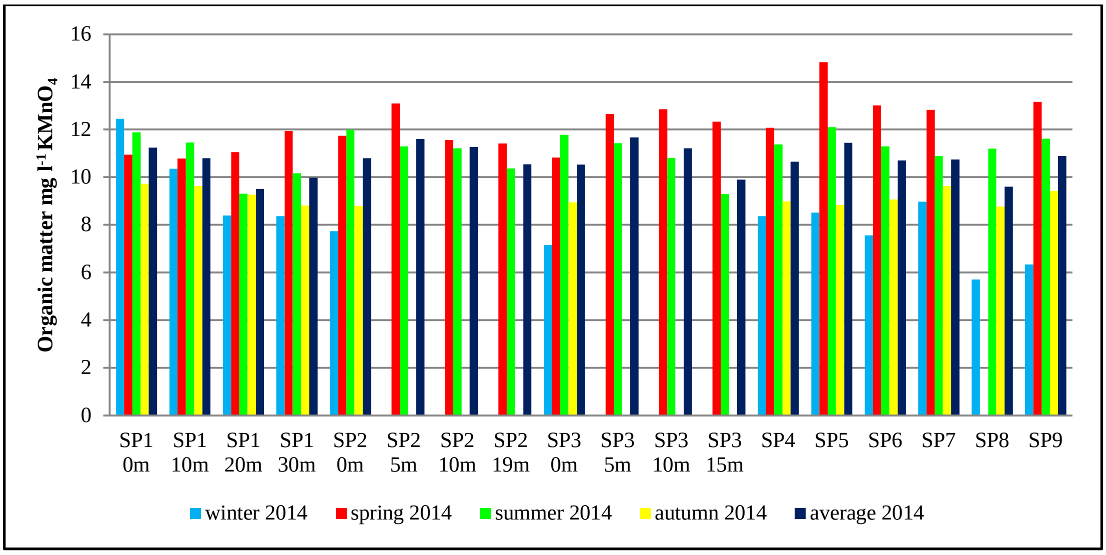


Figure 1.22.a. Seasonal values for organic biodegradable matter in water for 2014

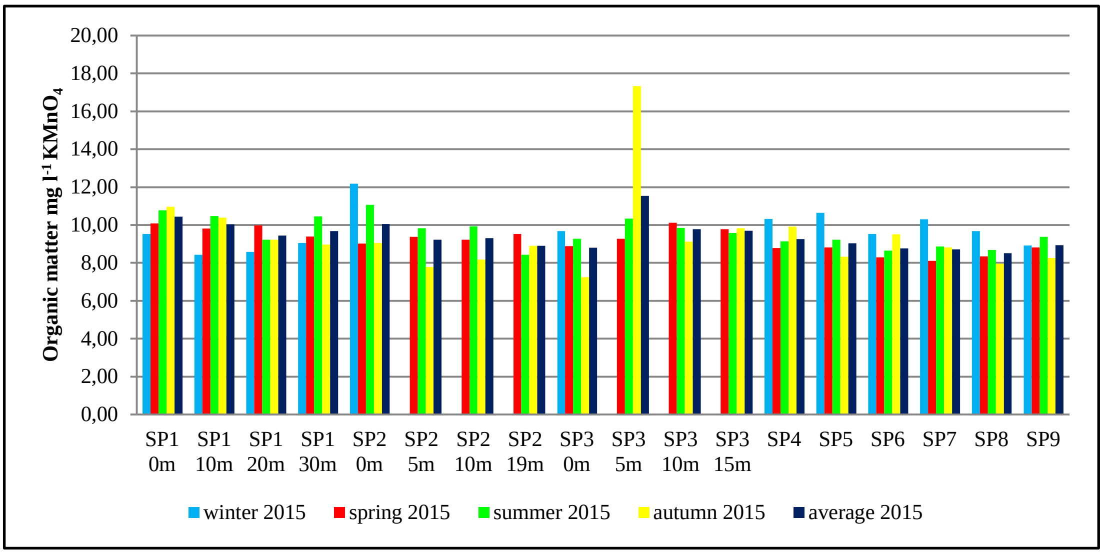


Figure 1.22.b. Seasonal values for organic biodegradable matter in water for 2015

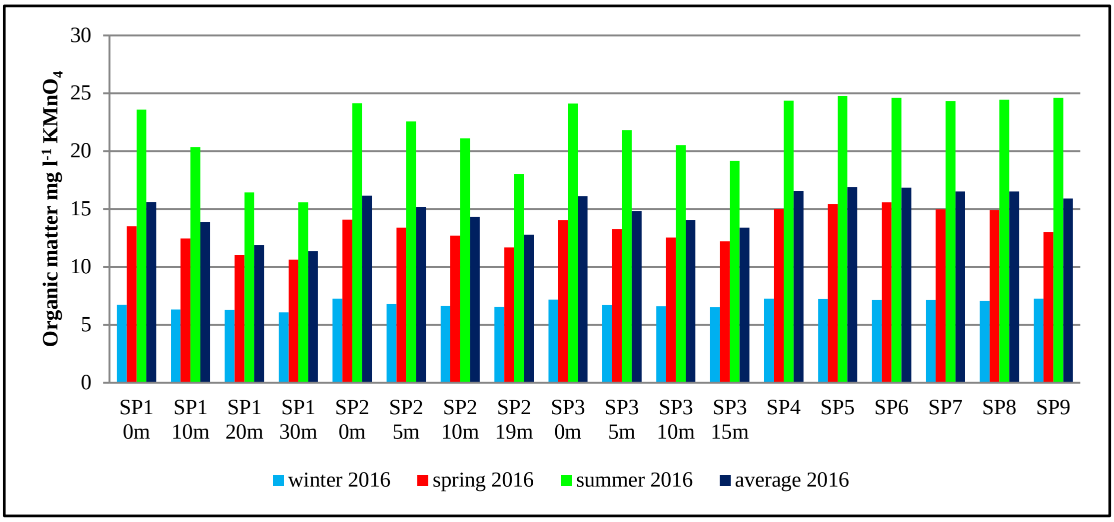


Figure 1.22.c. Seasonal values for organic biodegradable matter in water for 2016

From the charts that depict the seasonal distribution of the concentrations of dissolved organic biodegradable substances may be noted that during the summer and spring period theregistered values are the highest. Moreover,compared by years,the highest values for this parameter were observed in the study in 2016.During 2014 and2015 the values for this parameter in the water samples generallywere below the 11 mg $l^{-1}KMnO_4$.

1.3.9. Nitrate - Ntrogen

Average annual values for concentration of nitrate-nitrogen are presented in Figure 1.23.

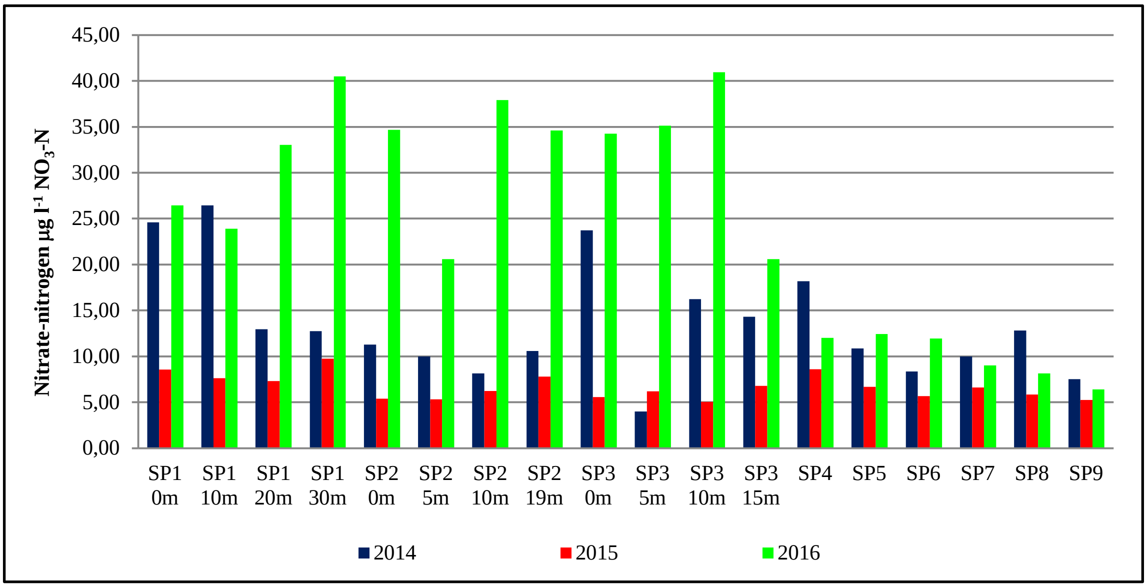


Figure 1.23 Average annual values for nitrate - nitrogen concentration in water (2014-2016)

The values for nitrate-nitrogen concentration during the investigated period (2014-2016) were very variable. Maximal values for this nitrogen form were detected during 2016.

The average annual values obtained for nitrate nitrogen in water samples indicate that this form of nitrogen is most prevalent during 2016. Significantly higher values are registered in the sample collectors in the vertical profiles of the Lake and in the deeper layers of the Lake. More intensive processes of mineralization of biodegradable organic matter lead to increased concentrations of nitrates in the ecosystem. This condition is correlated with the values obtained for the organic biodegradable substances which were the highest during 2016. Significantly lower concentrations of nitrate are registered in the littoral zone, probably because of the presence of a wide strip of cane, which acts as a natural biofilter for the lake and incorporateд this nitrogen form that is most accessible wildlife in its biomass.This results with natural reduction in nitrate concentrations and their consumption by the vegetation present in the littoral zone.

1.3.10. Total nitrogen

The average annual values for total nitrogen are presented on figure 1.24. The seasonal values for the concentration of total nitrogen are presented on figures 1.24.a-1.24.c.

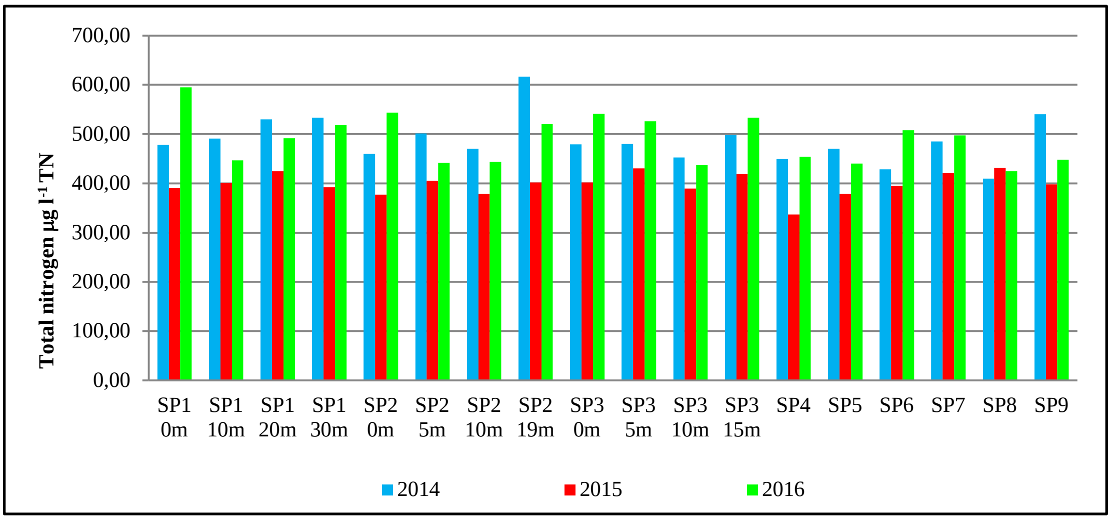


Figure 1.24. Average annual values for total nitrogen concentration in water (2014-2016)

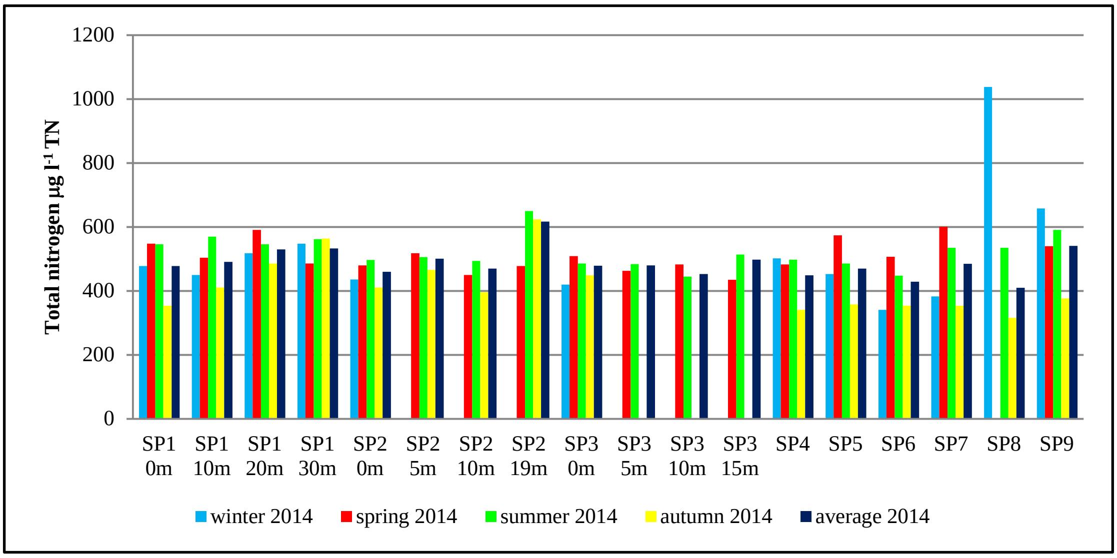


Figure 1.24a. Seasonal values for concentartion of total nitrogen in water for 2014

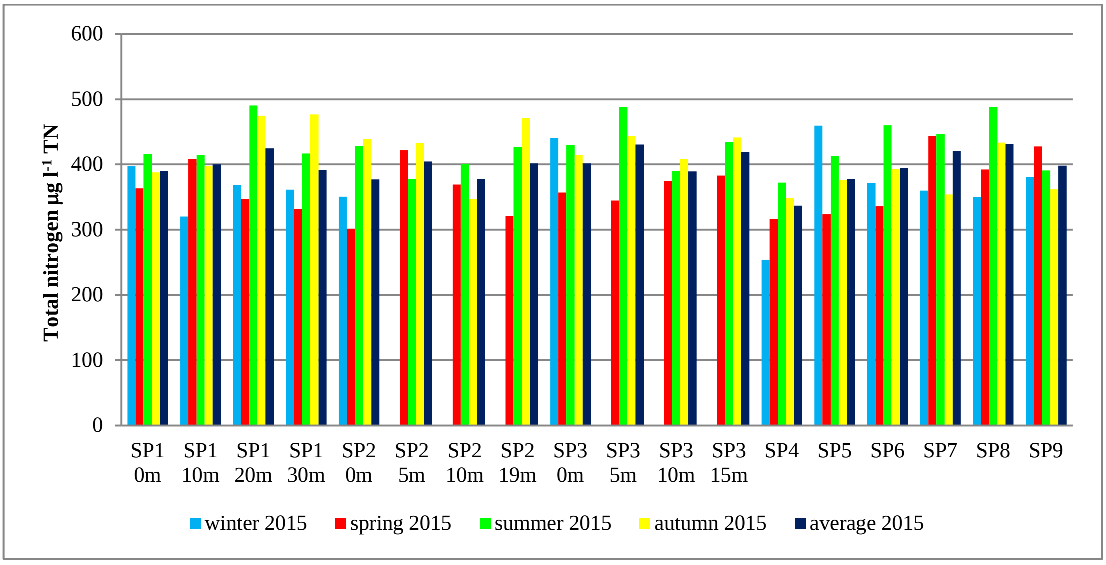


Figure 1.24.b. Seasonal values for concentartion of total nitrogen in water for 2015

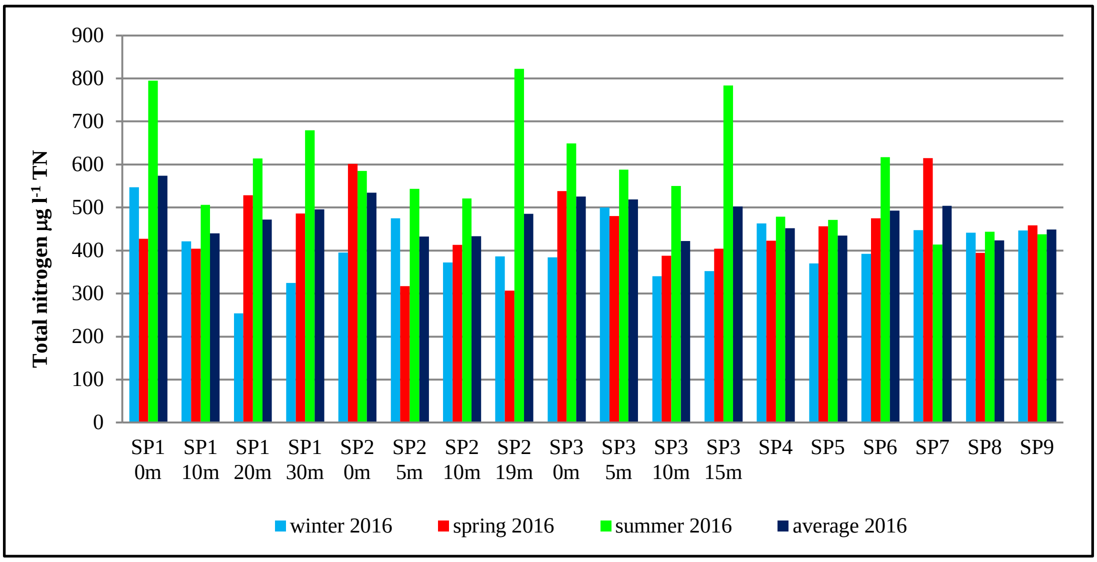


Figure 1.24.c. Seasonal values for concentartion of total nitrogen in water for 2016

During the analysed three years period the average values for total nitrogen concentration in the water samples from the most of sampling sites were below 500µg l^{-1} TN.

According OECD classification (OECD, 1982) and Directive for Classification of waters (Official Gazette No 18/99), based on concentration of total nitrogen, the water quality from the littoral and pelagial zone of Lake Prespa belong to II-IV class i.e. mesotrophic state.

1.3.11. Dissolved phosphorus -Phosphate

The results for the average annual concentration of dissolved phosphorus (phosphates) in the water samples from the analysed sampling points are presented in Figure 1.25.

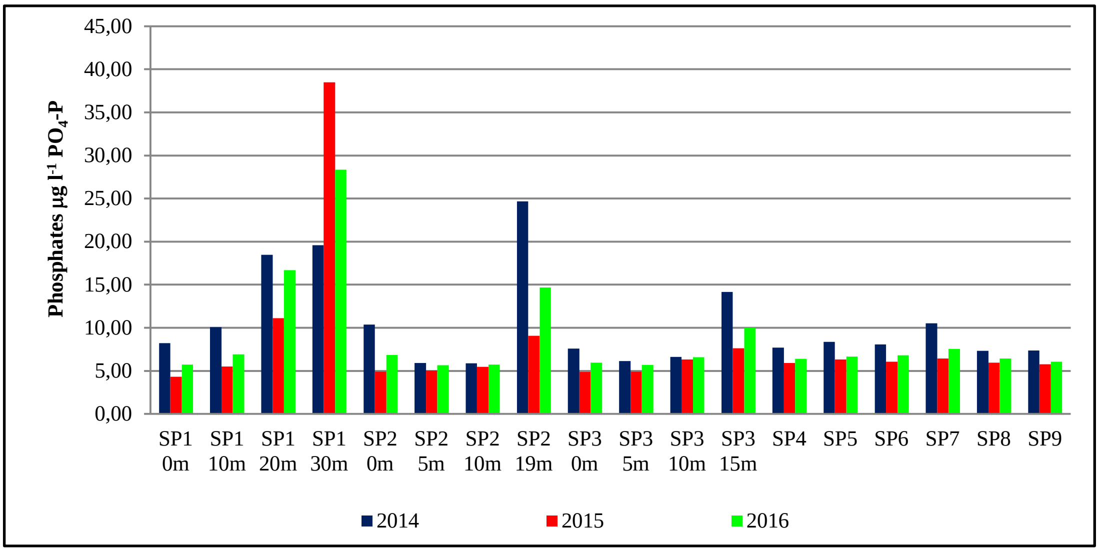


Figure 1.25. Average annual values for phosphates concentration in water (2014-2016)

The values for phosphate indicate of their continuous presence in the aquatic ecosystem. Their stratification, or increased concentrations of these substances in the deeper lake layers, which is directly dependent on the process of their assimilation by the plankton (in the surface layers and 5-10 meters depth) and degradation of organic matter in the deeper layers (15, 19, 20 and 30 meters).

1.3.12. Total phosphorus

Total phosphorous, as an essential nutrient, is one of the most limiting factors in the productivity and the eutrophication processes of aquatic ecosystems. The results for average annual values for total phosphorus are presented on figure 1.26.

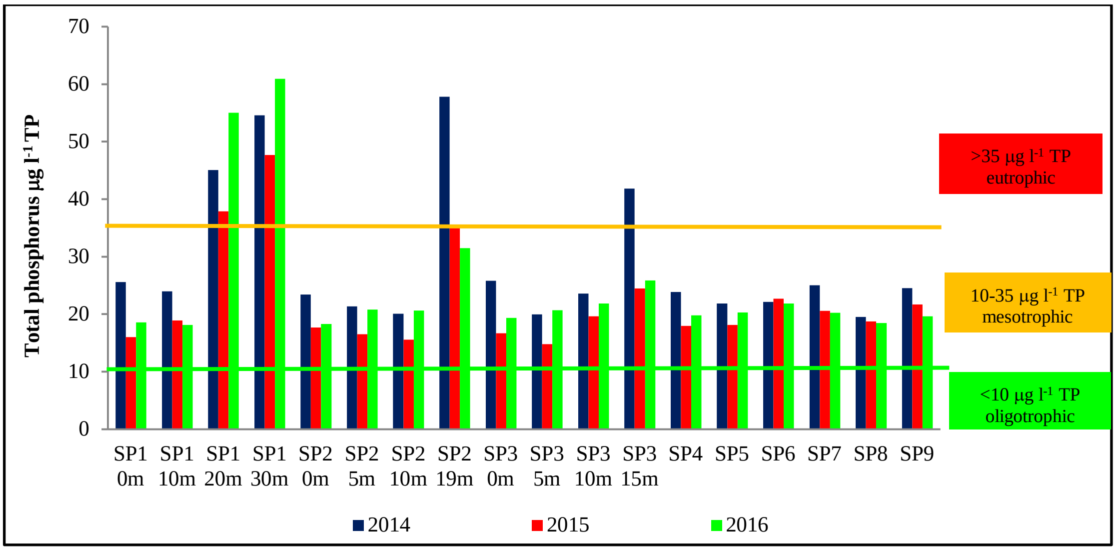


Figure 1.26. Average annual values for concentartion of total phosphorus in water (2014-2016)

During the three-year investigated period, it can be noted that in 2014 and 2015 in several investigated sites by the littoral zone of Lake Prespa are registered higher values for concentrations of total phosphorus that indicate eutrophic character. Such is the situation in the localities SP4 Nakolec-Strbovo, SP7 Ezerani 1, SP9 Otesevo. This situation is due to the impact of the rivers Golema and Brajcinska flowing in the littoral zone of the Lake near the sites SP4 and SP7, which are recipients of industrial and municipal waste water. Drainage water from nearby agricultural areas which cover a large area in the Prespa region is an additional source of nutrients, especially phosphorus to the aquatic ecosystems. The highest values during the investigated period were registered in Kazan SP1 20 and 30 m. This is especially evident during the summer and spring period of the research during the all three years.

The seasonal values for the concentration of total phosphorus in the water samples from the analysed sampling points are presented in Figure 1.27.a. - 1.27.c.

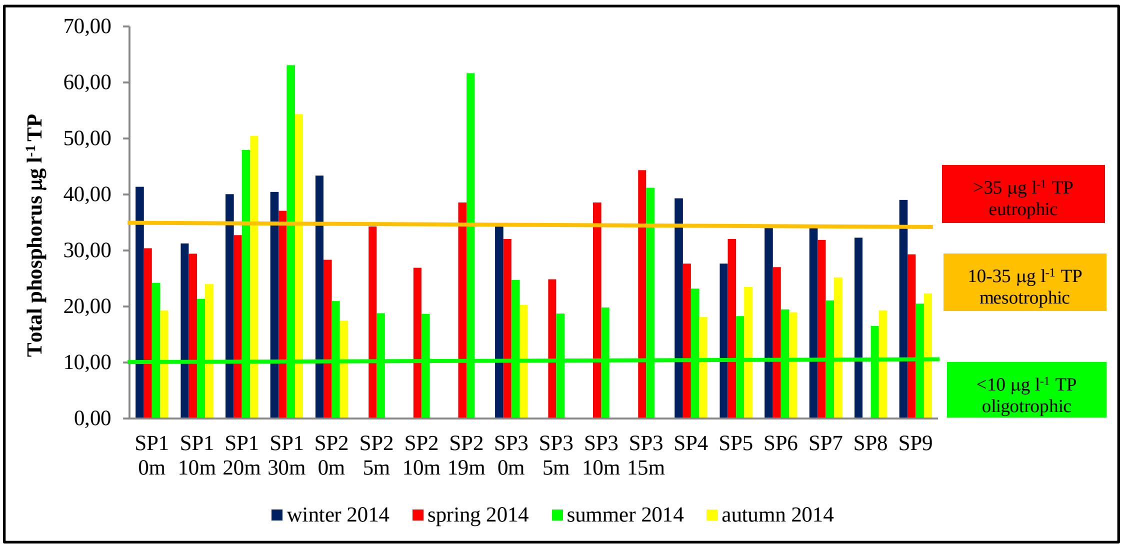


Figure 1.27.a. Seasonal values for concentartion of total phosphorus in water for 2014

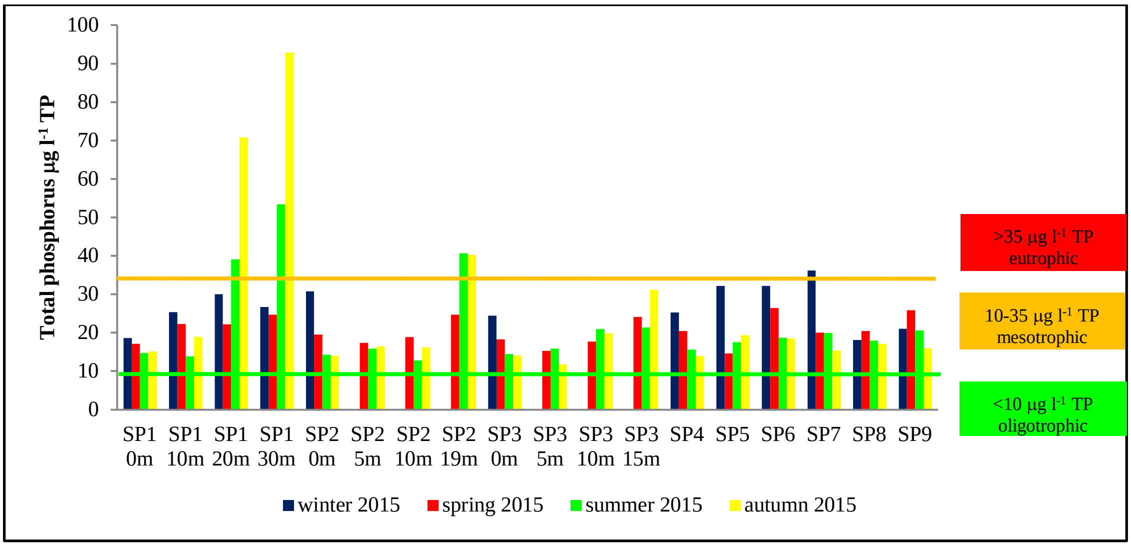


Figure 1.27.b. Seasonal values for concentartion of total phosphorus in water for 2015

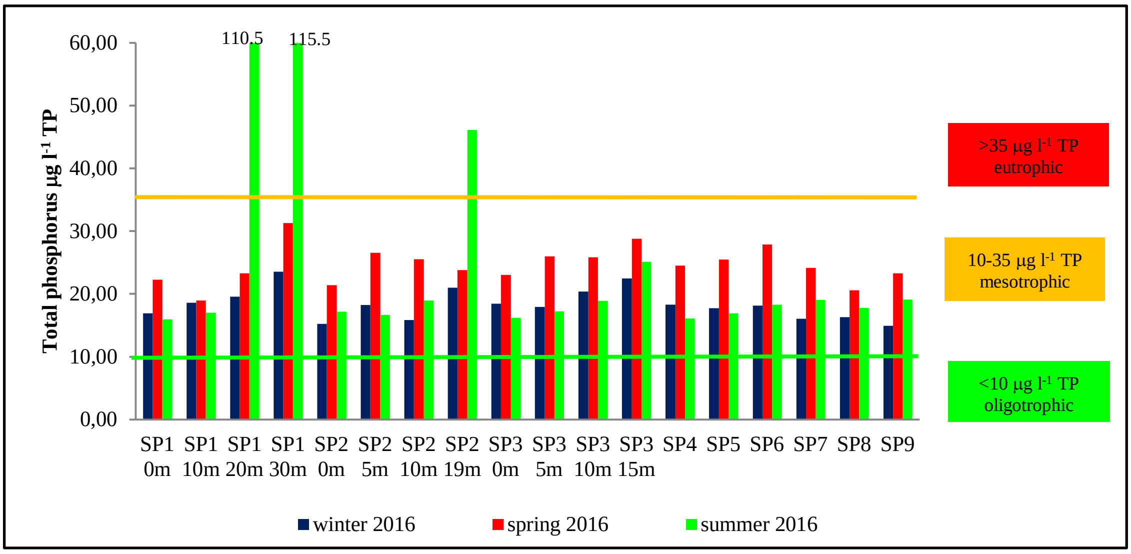


Figure 1.27.c. Seasonal values for concentartion of total phosphorus in water for 2016

Generally more average annual values for concentration of total phosphorus during the investigated period belong to mesotrophic state -according OECD classification of water (moderate according WFD). Exception of this situation is observed in SP1 Kazan20 m and 30m (during 2014-2016), SP2 Near the Island 19m (2014) and SP3 Central 15m (2014), which localites belong to eutrophic state-according OECD classification of water (poor according WFD). According to the Water Framework Directive we can define the status of Lake Prespa as moderate.

For phosphorus, it is well known that anaerobic conditions above the sediment surface can strongly stimulate the release of phosphorus from the sediment. Due the fact that during the summer period at the 15, 19, 20 and 30 m depth of Lake (the bottom of the Lake) concentration of dissolved oxygen is very low (there is a anoxic condition), the values for concentration of total phosphorus during this period are very high. The changes in the volume of the Lake have a direct effect on the concentrations of dissolved nutrients.

1.3.13 Trophic state index (TSI)

Carlson's trophic state index is a summary of quick and indicative parameters for the presentation of the trophic condition of certain water ecosystems. The calculation of this index is done by taking all characteristics into consideration (physical, chemical and biological) of the water represented via suitable researched parameters: Secchi depth (SD), total phosphorus concentration (TP) and chlorophyll *a* concentration (Chl*a*).

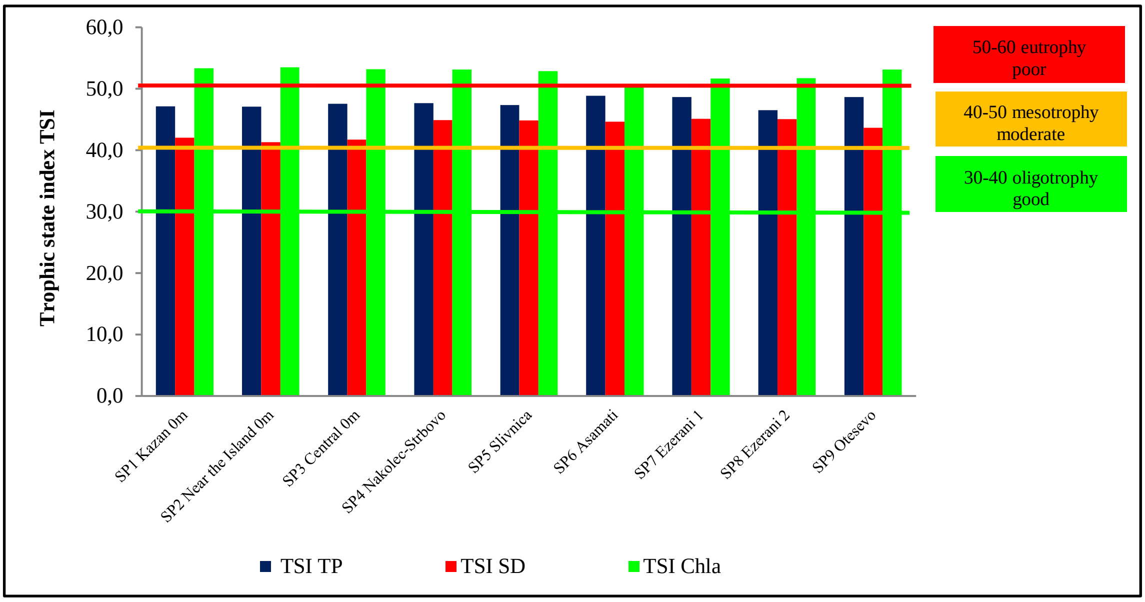


Figure 1.28. Average valuesfortrophic state index based on total phosphorus - TSI(TP), secchi depth TSI(SD) and chlorophyll a TSI (Chl a)

Based on numerical values obtained for the index of trophic state as an average value for the three-year period studied, calculated according to the concentrations of total phosphorus and chlorophyll *a* and transparency, Prespa Lake belong to mesotrophic-eutrophic aquatic ecosystems.

The figures 1.28. and 1.29. are presenting average annual values of trophic state index based on the concentrations of total phosphorus and chlorophyll *a*.

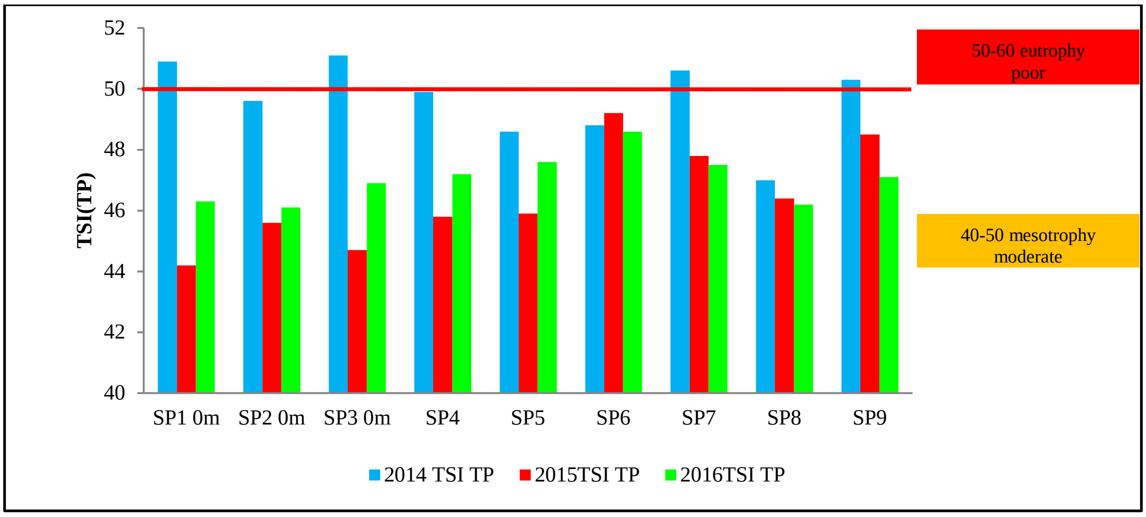


Figure 1.29 Trophic state indexbased on total phosphorus - TSI(TP) for2014

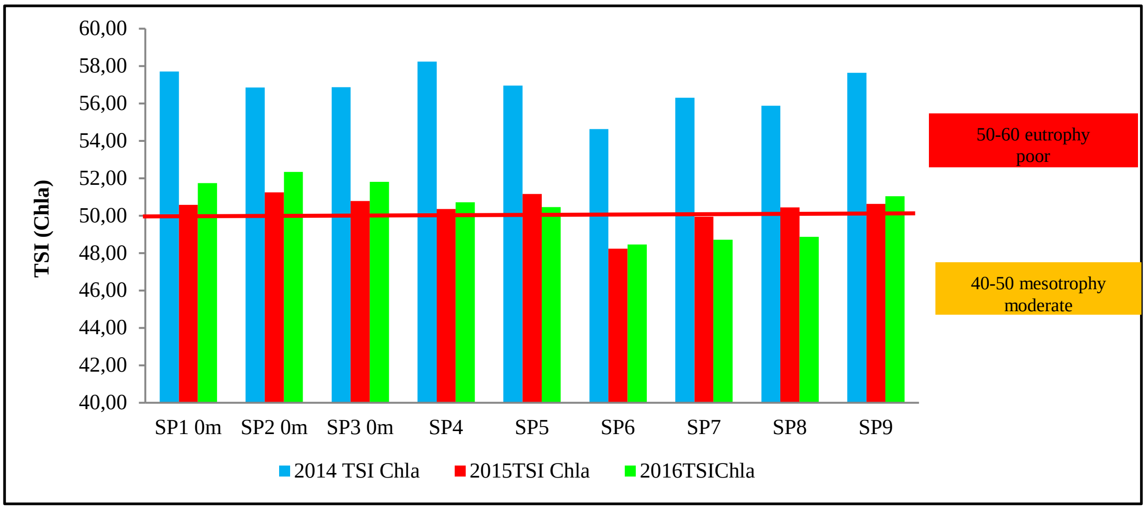


Figure 1.30. Trophic state indexbased on chlorophyll a-TSI(Chla) for2014

According to the average annual values of trophic state index based on the total phosphorus concentrations during the three-year period of research, it can be generally concluded that the highest numerical values are obtained for the research in 2014. In that period in most measuring points were recorded crossing to eutrophic trophic state (SP1;SP3, SP7 and SP9). In 2015 and 2016 there is a decrease of numerical values for the trophic state index based on the total phosphorus concentrations, which is certainly as a result of lower values for concentrations of this nutrient in the sampling sites. During this period, the trophic state of Lake Prespa is mesotrophic.

The average annual values of trophic state index based on the concentrations of chlorophyll *a*, follow the dynamics of the distribution-change values TSI index based on the total phosphorus. In this case also, in 2014 are obtained the highest values of trophic state index which reflects the highest measured concentrations of chlorophyll *a* in investigated localities. In 2014 the results indicate eutrophic trophic state, while the 2015 and 2016 values TSI based on chlorophyll *a* are lower and belong to mesotrophic-eutrophic range.

1.3.14. Correlation between concentrations of dissolved oxygen and chlorophyll *a*.

The Figure 1.31. shows the ratio between the concentrations of dissolved oxygen and the content of chlorophyll *a* and it indicates a positive correlation between these two parameters. Overall, the top layers and layers at depth of 5 and 10 meters have higher values for both parameters indicating a more intensive process of photosynthesis given the greater availability of light in those depths. By reducing the availability of light in the deep layers 15-30 meters the values for both parameters are reduced.

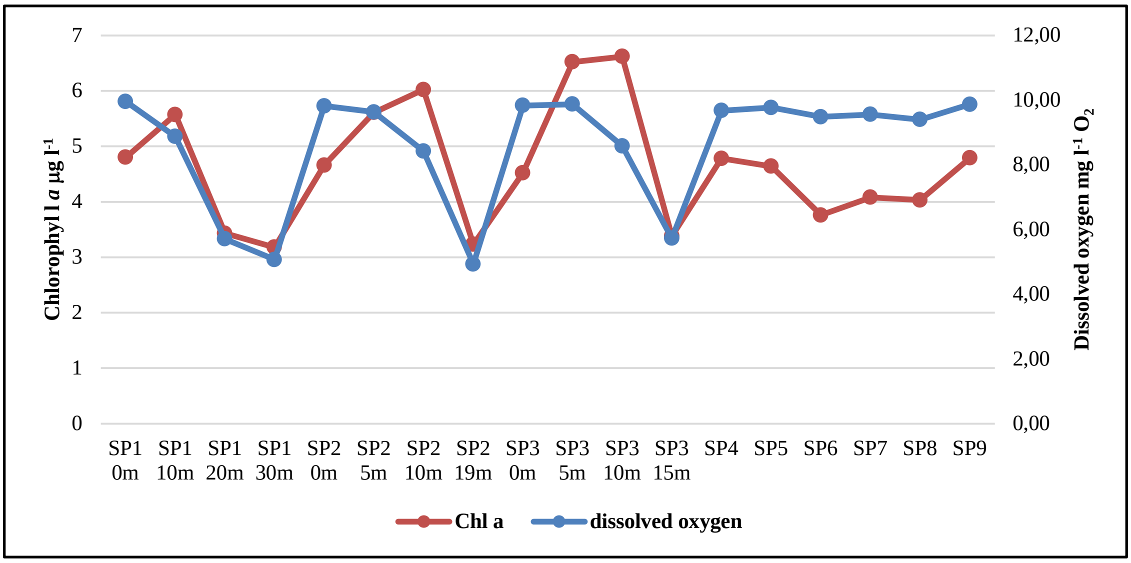


Figure 1.31. Correlation between concentration of dissolved oxygen and chlorophyll a

Nutrient limitation in Lake Prespa

The ratio TN/TP for Lake Prespa was presented on figure 1.32.

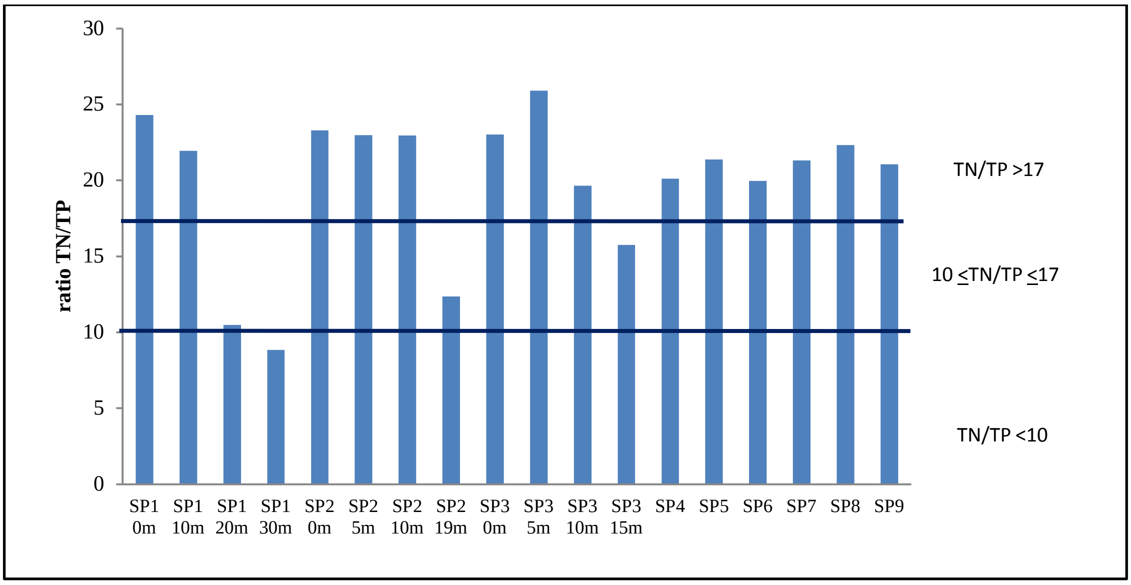


Figure 1.32. TN/TP ratio for Lake Prespa

Generally, Lake Prespa is phosphorus limited ecosystem, i.e. phosphorus was limiting nutrient for phytoplankton growth (figure 1.2-17)

From this figure, during our investigations, were found several cases in which nitrogen was limiting nutrient for phytoplankton growth (at deeper layer from the Lake, 20 and 30 m).

1.3.14.b Conclusions

The impact of Golema River is reflected in the littoral zone of Lake Prespa near its inflow (Ezerani). The influence is manifested in the littoral zone of the Lake, is a potential danger to water in the pelagial zone, because significant phosphorus concentrations may be transported in the deep layers of the lake as a result of lake currents. In their research Jawes&Barko (at Andersen, 1997), concluded that phosphorus released in the littoral zone can be transported in the pelagic zone as a result of the currents and the convective movements.

According OECD classification (OECD, 1982) and Directive for Classification of waters (Official Gazette No 18/99), based on concentration of total nitrogen, the water quality from the littoral and pelagial zone of Lake Prespa belong to II-IV class i.e. mesotrophic state.

For phosphorus, it is well known that anaerobic conditions above the sediment surface can strongly stimulate the release of phosphorus from the sediment. Due the fact that during the summer period at the 15, 19, 20 and30 m depth of Lake (the bottom of the lake) concentration of dissolved oxygen is very low (there is an anoxic condition), the values for concentration of total phosphorus during this period are very high.Changes in the volume of the lake also appear to be having a direct effect on the concentrations of dissolved nutrients within it, since there is less water to dilute the loads from both external sources and releases from the sediment.

Generally, more average annual values for concentration of total phosphorus during the investigated period belong to mesotrophic state -according OECD classification of water (moderate according WFD). Exception of this situation is observed in SP1 Kazan20 m and 30m (during 2014-2016), SP2 Near the Island 19m (2014) and SP3 Central 15m (2014), which localities belong to eutrophic state-according OECD classification of water (poor according WFD). According to the Water Framework Directive the status of Lake Prespa is moderate.

Lake Prespa is phosphorus limited ecosystem, i.e. phosphorus was limiting nutrient for phytoplankton growth.

Based on numerical values obtained for the index of trophic state (TSI) as an average value for the three-year period studied, calculated according to the concentrations of total phosphorus and chlorophyll *a* and transparency, Prespa Lake belong to mesotrophic-eutrophic aquatic ecosystems.

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1.3. Phytoplankton of Lake Prespa

Phytoplankton form the base of many food webs in lakes. It consists of unicellular and a colonial algae (from < 1μm to >500μm) floating in the water within euphotic zone where light is available for photosynthesis.

This method uses the principle that an increase in nutrients (particularly phosphorus) leads to an increases in phytoplankton biomass and a change in the taxonomic composition, often leading to an increased occurrence of cyanobacteria (blue-green algae). Due to their short life cycle, planktonic algae respond quickly to environmental changes and are thus a valuable indicator of water quality.

According to Water framework Directive (WFD) phytoplankton has been identified as a key biological quality element (BQE) to be used in lake ecological quality assessment.

Lake phytoplankton is composed of many different taxa which respond to many physical and chemical influences and certain bloom forming species of cyanobacteria are associated with nutrient enrichment.

Chlorophyll *a* is the green pigment in phytoplankton which allows photosynthesis to take place. Chlorophyll *a* concentration is an indicator of phytoplankton biomass and its concentration is proportional to the total amount of the phytoplankton. Besides, chlorophyll *a* concentration is one of the most indicative parameters of the water trophic state.

Phytoplankton samples were taken during triennial investigated period (2014-2016) in different seasons with special emphasis on summer.

The total abundance of phytoplankton was considerably higher in summer than in other seasons (Tab.1.3. 1-11) which is characteristic for meso-eutrophic lakes.

During the triennial investigations the total abundance of phytoplankton was significantly higher in 2014 compared to 2015 and 2016 (Fig. 1.3.1). The highest average annual phytoplankton abudance was identified in 2014 at SP 3 Central 5m depth (1 610 800 Cell/L) followed by SP 2 Near the Island 5m (1 237 250 Cell/L) and SP 3 Central 10 m depth (1 176 500 Cell/L) (Fig. 1.3.2). The lowest average annual phytoplankton abudance was observed in 2016 at deeper layer of SP 1 Pelagic (Kazan) 30 m (69 100 Cell/L) and 20 m (83 412 Cell/L) (Fig. 1.3.1). In the surface layer of pelagic points (SP1, SP2 and SP3) and In the littoral sampling points were not observed significant difference between phytoplankton abudance in each season respectively (Fig. 1.3.1).

Average phytoplankton abudance in the investigated littoal points of Lake Prespa during the triennial investigated period was fairly close and varied between 384 021 Cell/L at SP 8 Ezerani 2, 429 793 Cell/L at SP 6 Asamati, 4.78 $\mu g\ l^{-1}$ and maximum of 483 150 Cell/L at SP 9 Otesevo (Fig. 1.3.2).

The highest average phytoplankton abudance in the water column of Lake Prespa was observed at 5 m depth and it was slightly lower at 10 m depth and in the surface layer (Fig. 1.3.2.).

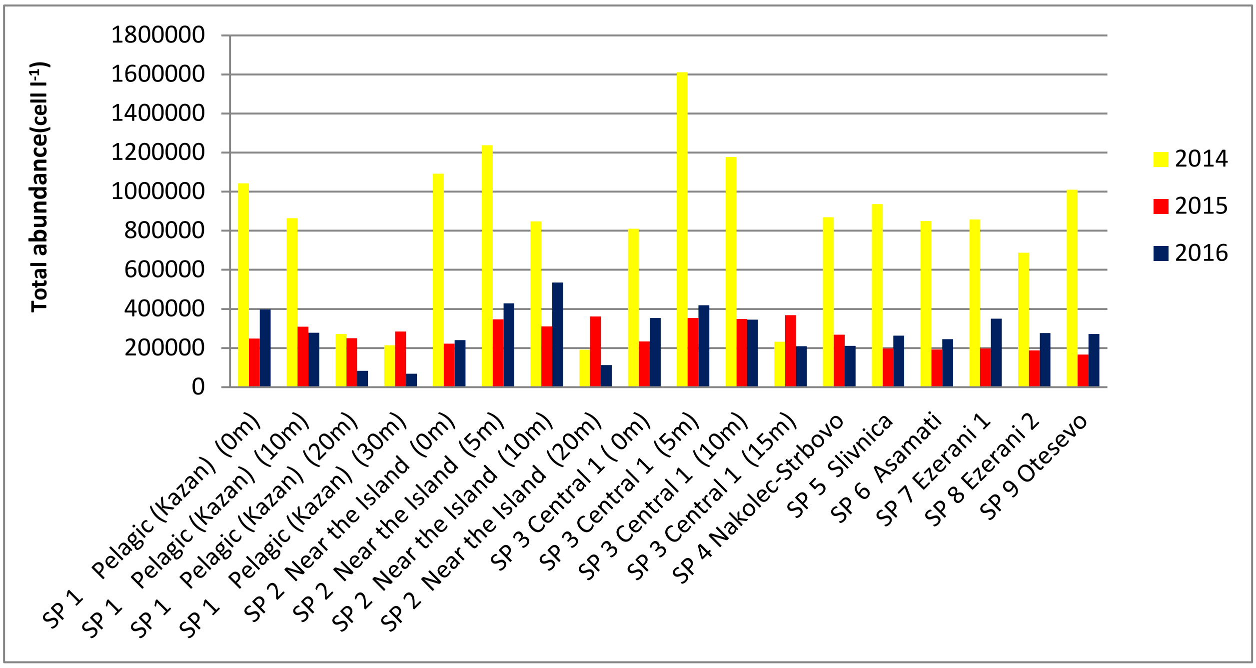

Figure 2.1. Average annual phytoplankton abudance (Cell/L) in the investigated points of Lake Prespa

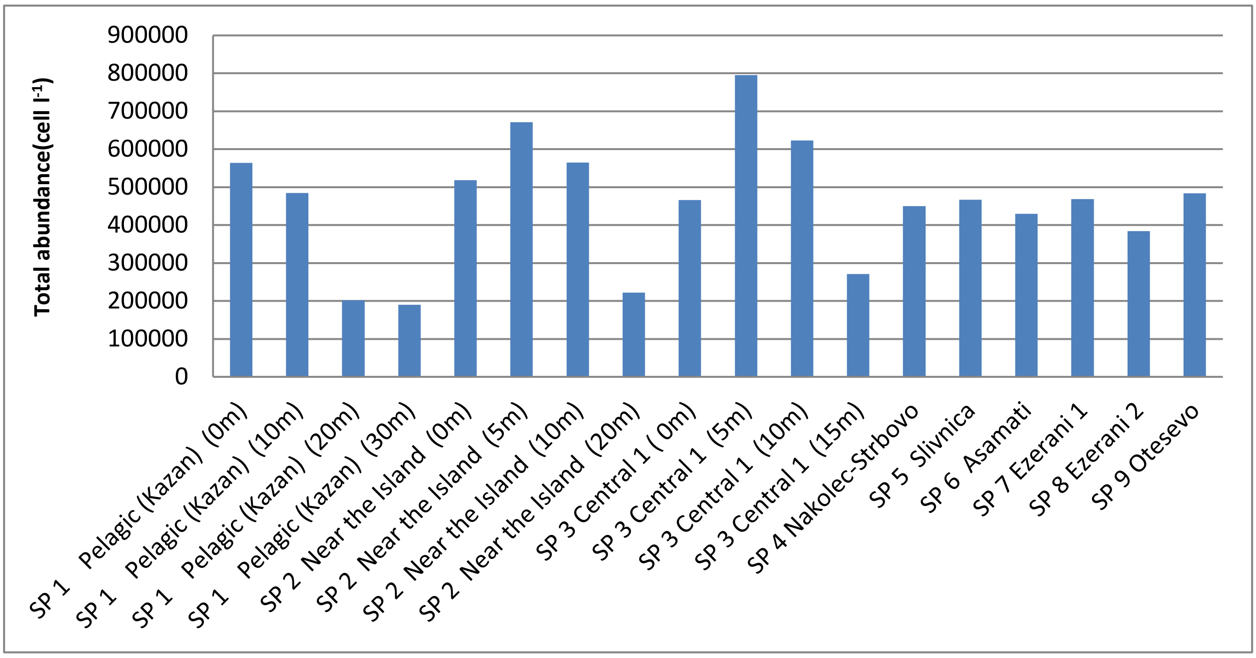

Figure.2.2. Average phytoplankton abudance (Cell/L) in the investigated points of Lake Prespa during the triennial investigated period

The phytoplankton species collected during these campaigns belong to 6 divisions:

- Cyanophyta
- Bacillariophyta

- Chlorophyta
- Chrysophyta
- Pyrrophyta
- Euglenophyta

Most phytoplankton species identified belong to the Bacillariophyta and Cyanophyta and these two divisions had the main role in the phytoplankton. Investigations showed distinct seasonal differences in phytoplankton composition. Bacillariophyta were the dominant group in winter, spring and autumn period contributing in average between 32.72% (SP 8 Ezerani 2) and 70.95% (SP 1 Pelagic Kazan - 20m) in 2014, between 48.75% (SP 2 Near the Island 5m) and 80.84% (SP 2 Near the Island - 20m) in 2015, between 51.26% (SP 3 Central 1 - 5m) and 71.74% (SP 2 Near the Island 20m) of the total number of identified species in 2016 (Tab. 1.3.1, 1.3.3, 1.3.5).

The highest abudance of blue – green algae (Cyanophyta) in Lake Prespa was observed in summer period. So, very significant parameter is average summer percentage of this algal group.

The average summer percentage of Cyanophyta during the three investigated years indicated trend of a decrease of the participation of *Cyanophyta. In 2014 percentage varied* between 83.88% (SP 8 Ezerani 2) and 34.81% (SP 1 Pelagic Kazan - 30m) , in 2015 between 55.12% (SP 3 Central 1 - 10m) and 12.62% (SP 2 Near the Island 20m) and in 2016 between 51.56% (SP 3 Central 1 - 0m) and 14.44% (SP 1 Pelagic Kazan - 30m) (Tab. 1.3.2, 1.3.4, 1.3.6).

Also, it was observed decrease of the average annual percentage of Cyanophyta. In 2014 maximum value was 51.82% at SP 3 Central 1 - 0m, followed by 49.87% at SP 8 Ezerani 2 (Tab. 1.3.1); in 2015 maximum 36.62% was observed at SP 3 Central 1 - 10m, followed by 32.52% at SP 3 Central 1 - 5m (Tab. 3) and in 2016 it was recorded maximum 23.16% at SP 1 Pelagic Kazan - 0m, followed by 21.79% at SP 3 Central 1 - 0m (Tab. 1.3.5).

The recorded decrease in the percentage of Cyanophyta suggests improving of the trophic state of Lake Prespa, because in process of eutrophication in the lakes participation Cyanophyta generally increase.

For comparison, during the investigated period 2001-2003, in Lake Prespa a tendency of increased percentage presence of blue-green algae had been observed from 30,89% in 2001 and 31,71% and 55,6% in 2002 and 2003, in that order (Patceva, 2005).

In the summer of 2016 for the first time was identified species Raphidiopsis mediterranea that had never before been present in the phytoplankton of Lake Prespa.

The other groups of algae contributed significantly lower part of the total abudance. Average annual percentage of green algae (Chlorophyta) varied between 3.78% (SP 1 Pelagic Kazan - 30m) and 11.51% (SP 1 Pelagic Kazan - 20m) in 2014; between 0.16% (SP 2 Near the Island 0m) and 7.49% (SP 3 Central 1 - 15m); between 6.92% (SP 6 Asamati) and 25.63% (SP 1 Pelagic Kazan - 30m) (Tab. 1.3.1, 1.3.3, 1.3.5).

Presents of Crysophyta is a very sensitive indicator of changes in the water trophic state. In the investigated 2014 maximum average annual percentage of 0.29% was observed at SP 7 Ezerani 1 and maximum average summer percentage of 0.98% at SP 2 Near the Island 0m. In 2015 was founded significantly increase the presence of Crysophyta, with maximum average annual percentage of 9.85% at SP 1 Pelagic Kazan - 0m and maximum average summer percentage of 16.32% at SP 2 Near the Island 5m and in 2016 maximum average annual percentage of 4.59% was observed at SP 2 Near the Island 5m and maximum average summer percentage of 8.02% at SP 2 Near the Island 5m, too. Percentage of Crysophyta corresponds to improving of the water trophic state in 2015 and 2016 (Tab. 1.3. 1-6).

During the investigated period 2001-2003 these two groups of algae contributed unsubstantial part of the total density: *Chlorophyta* with average annual percentage of 1.7% in 2001, 1.81% in 2002 and 0.73% in 2003 and *Chrysophyta* with average annual percentage of 2.16% in 2001, 0.93% in 2002 and only 0.3% in 2003. This was rather supportive argument of the notion that during the last decades in Lake Prespa there were occurring certain negative processes which result in aggravation of its trophic state (Patceva, 2005).

Pyrrophyta is group of algae which generally has the highest growth in the summer period in surface layers where at high temperatures and light intensity. In 2014 maximum average annual percentage of 7.10% was founded at SP 8 Ezerani 2 and maximum average summer percentage of 9.82% at the same sampling point. In 2015 maximum average annual percentage of 7.28% and average summer percentage of 15.85% was founded at SP 8 Ezerani 2, too and in 2016 maximum average annual percentage of 10.60% was founded at SP 5 Slivnica and maximum average summer percentage of 13.20% at SP 4 Nakolec-Strbovo (Tab. 1.3. 1-6).

In the previous investigations (2001-2003) average percentage of Pyrropyta was 1.8% in 2001, 0.14% in 2002 and 3.3% in 2003 (Patceva, 2005).

Euglenophyta contributed unsubstantial part of the total abudance, usually less than 1%. Species of this group were determined incidentally at certain sampling points (Tab. 1.3. 1-6).

Table 1.3 1. Average annual percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2014

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 3 Central 1 (0m)
Cyanophyta	45.86	34.97	17.54	32.45	45.26	51.82
Bacillariophyta	42.70	57.29	70.95	63.09	41.90	40.03
Chlorophyta	9.37	6.87	11.51	3.78	9.19	6.15
Chrysophyta	0.19	0.09		0.05	0.60	0.72
Pyrrophyta	1.84	0.77		0.00	3.06	1.28
Euglenophyta	0.04			0.63		

	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesevo
Cyanophyta	43.04	39.37	43.86	41.39	49.87	41.99
Bacillariophyta	41.80	50.21	45.68	49.62	32.72	48.84
Chlorophyta	11.37	7.72	8.01	5.12	10.27	5.78
Chrysophyta	0.27	0.15	0.18	0.29	0.03	0.16
Pyrrophyta	3.52	2.55	2.27	3.58	7.10	3.23
Euglenophyta						

Table 1.3.2. Average summer percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2014

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 2 Near the Island 5m	SP 2 Near the Island 10m	SP 2 Near the Island 20m
Cyanophyta	71.59	51.93	51.75	34.81	69.04	73.77	64.38	45.02
Bacillariophyta	25.12	45.53	45.37	60.01	26.14	20.79	34.87	54.28
Chlorophyta	0.20	1.75	2.10	2.46	0.16	4.48	0.17	0.31
Chrysophyta	0.26	0.13	0.13	0.08	0.98	0.24	0.24	0.23
Pyrrophyta	2.79	0.66	0.66	0.00	3.68	0.71	0.33	0.16
Euglenophyta	0.05			2.64				

	SP 3 Central 1 (0m)	SP 3 Central 1 (5m)	SP 3 Central 1 (10m)	SP 3 Central 1 (15m)	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesevo
Cyanophyta	71.57	78.67	73.44	67.66	68.44	69.47	66.32	64.11	83.88	64.28
Bacillariophyta	26.08	20.11	26.26	23.61	26.38	29.18	31.21	31.96	5.97	30.68
Chlorophyta	0.19	0.20	0.20	7.49	0.25	0.19	0.21	1.04	0.24	0.44
Chrysophyta	0.31	0.60	0.00	0.33	0.45	0.27	0.28	0.30	0.08	0.26
Pyrrophyta	1.85	0.42	0.10	0.00	4.48	0.89	1.99	2.58	9.82	4.34
Euglenophyta				0.91						

Table 1.3.3. Average annual percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2015

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 2 Near the Island 5m	SP 2 Near the Island 10m	SP 2 Near the Island 20m
Cyanophyta	21.35	17.89	7.83	6.65	23.49	28.85	31.16	8.05
Bacillariophyta	52.69	61.24	83.53	86.13	56.52	48.75	53.81	80.84
Chlorophyta	12.58	11.59	8.02	6.54	10.76	11.59	11.04	10.33
Chrysophyta	9.85	7.99	0.00	0.00	6.40	9.43	2.01	0.15
Pyrrophyta	3.14	1.30	0.62	0.60	2.84	1.15	1.68	0.59
Euglenophyta	0.39			0.07		0.22	0.31	0.04

	SP 3 Central 1 (0m)	SP 3 Central 1 (5m)	SP 3 Central 1 (10m)	SP 3 Central 1 (15m)	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesev o
Cyanophyta	31.16	32.52	36.62	21.06	25.31	25.59	24.80	18.86	18.64	22.73
Bacillariophyta	53.00	47.63	53.98	69.35	56.23	54.13	58.66	60.30	56.11	59.41
Chlorophyta	7.19	8.68	6.55	7.30	8.86	13.46	10.36	13.29	14.26	8.95
Chrysophyta	5.78	9.31	1.51	0.17	2.69	3.23	1.58	2.68	3.57	2.88
Pyrrophyta	2.88	1.67	1.15	2.07	6.91	3.59	4.55	4.87	7.28	5.83
Euglenophyta		0.19	0.19	0.05			0.04		0.14	0.19

Table 1.3.4. Average summer percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2015

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 2 Near the Island 5m	SP 2 Near the Island 10m	SP 2 Near the Island 20m
Cyanophyta	40.49	32.02	15.80	13.10	41.90	49.54	53.44	12.62
Bacillariophyta	28.62	41.14	77.75	83.67	23.92	23.42	32.03	76.74
Chlorophyta	13.42	13.84	5.88	2.25	10.81	9.30	10.06	9.94
Chrysophyta	12.70	11.88	0.00	0.00	16.17	16.32	3.42	0.27
Pyrrophyta	4.77	1.12	0.57	0.88	7.19	1.42	0.90	0.35
Euglenophyta				0.10			0.15	0.08

	SP 3 Central 1 (0m)	SP 3 Central 1 (5m)	SP 3 Central 1 (10m)	SP 3 Central 1 (15m)	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesev o
Cyanophyta	41.90	46.68	55.12	27.93	49.35	51.73	49.24	37.72	37.91	48.22
Bacillariophyta	23.92	25.37	34.91	59.14	23.11	22.37	29.43	38.94	25.77	23.55
Chlorophyta	10.81	10.37	7.20	10.18	10.27	14.78	9.61	8.84	13.52	10.34
Chrysophyta	16.17	16.22	2.30	0.30	4.83	5.86	2.60	4.36	6.95	5.27
Pyrrophyta	7.19	1.29	0.47	2.44	12.44	5.27	9.13	10.14	15.85	12.62
Euglenophyta		0.07								

Table 1.3.5. Average annual percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2016

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 2 Near the Island 5m	SP 2 Near the Island 10m	SP 2 Near the Island 20m
Cyanophyta	23.16	10.19	11.33	5.42	21.66	20.56	17.66	8.34
Bacillariophyta	57.25	69.73	70.43	65.26	60.47	52.39	62.54	71.74
Chlorophyta	13.59	13.25	11.34	25.63	15.03	17.58	9.69	14.04
Chrysophyta	0.83	0.21	0.42	0.27	1.55	3.26	0.70	0.38
Pyrrophyta	3.92	6.63	6.00	3.43	1.29	6.21	9.41	5.45
Euglenophyta	1.26		0.49					0.05

	SP 3 Central 1 (0m)	SP 3 Central 1 (5m)	SP 3 Central 1 (10m)	SP 3 Central 1 (15m)	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesev o
Cyanophyta	21.79	19.80	11.56	19.59	13.50	18.39	16.94	19.57	15.81	9.11
Bacillariophyta	52.19	51.26	69.29	60.61	63.10	61.41	68.37	58.43	66.58	63.19
Chlorophyta	18.37	15.49	11.80	17.31	13.61	8.98	6.92	13.44	11.32	18.47
Chrysophyta	2.35	4.59	0.73	0.37	1.61	0.42	0.54	0.14	0.48	0.84
Pyrrophyta	5.31	8.87	6.63	2.00	8.19	10.60	7.23	8.17	5.80	8.40
Euglenophyta				0.12		0.19		0.26		

Table 1.3.6. Average summer percentage of algal divisions in the total number of identified species in the investigated points of Lake Prespa in 2016

	SP 1 Pelagic (Kazan) 0m	SP 1 Pelagic (Kazan)10m	SP 1 Pelagic (Kazan) 20m	SP 1 Pelagic (Kazan) 30m	SP 2 Near the Island 0m	SP 2 Near the Island 5m	SP 2 Near the Island 10m	SP 2 Near the Island 20m
Cyanophyta	36.24	22.87	28.48	14.44	49.76	47.79	40.12	22.24
Bacillariophyta	54.18	64.92	52.44	56.19	40.83	41.93	54.78	69.25
Chlorophyta	2.44	12.20	16.47	29.37	2.81	7.48	4.48	8.37
Chrysophyta	1.40				3.89	2.40	0.14	
Pyrrophyta	5.74		1.31		2.72	0.40	0.48	
Euglenophyta			1.31					0.14

	SP 3 Central 1 (0m)	SP 3 Central 1 (5m)	SP 3 Central 1 (10m)	SP 3 Central 1 (15m)	SP 4 Nakolec-Strbovo	SP 5 Slivnica	SP 6 Asamati	SP 7 Ezerani 1	SP 8 Ezerani 2	SP 9 Otesevo
Cyanophyta	51.56	50.00	29.18	45.24	31.39	40.05	36.92	40.10	37.54	20.79
Bacillariophyta	39.76	31.30	65.31	49.44	53.38	47.79	55.30	52.90	45.27	55.28
Chlorophyta	1.02	5.95	4.04	5.00	1.62	1.35	2.07	2.13	7.96	17.41
Chrysophyta	1.35	8.02	0.88	0.12	0.41	1.13	1.43	0.00	1.10	1.02
Pyrrophyta	6.32	4.73	0.60	0.20	13.20	9.68	4.27	4.87	8.14	5.50
Euglenophyta										

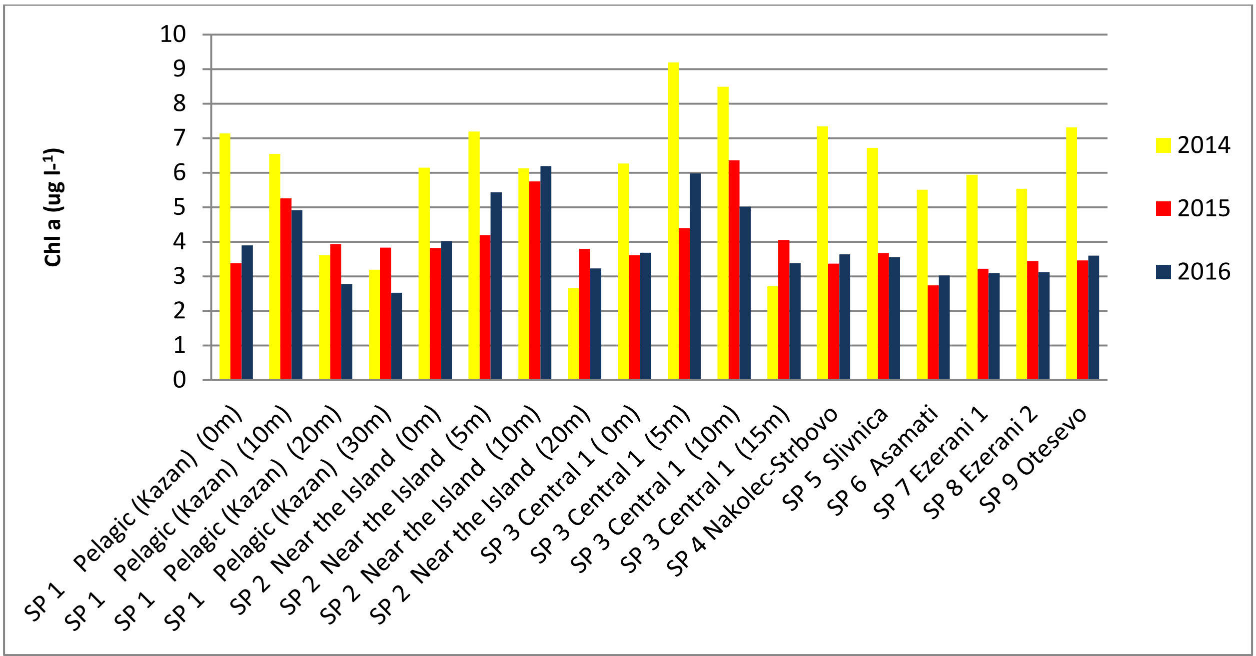

Figure 1.3.**3. Average annual chlorophyll *a* concentration (µg l-[1]) in the investigated points of Lake Prespa**

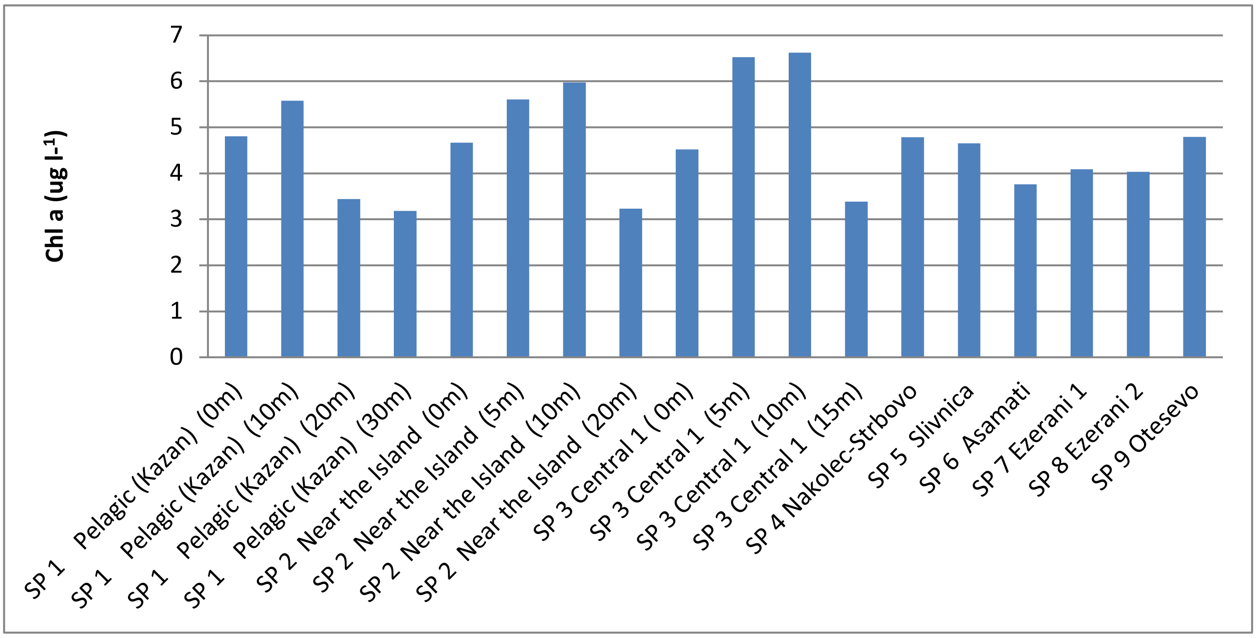

Figure 1.3.4. Average chlorophyll *a* concentration (µg l-[1]) in the investigated points of Lake Prespa during the triennial investigated period

Similar to the total phytoplankton abundance chlorophyll *a* concentrations at surface level were generally higher in summer than in other seasons. The reverse was true for the deeper layers from 15 to 30m depth. This kind of seasonal chlorophyll *a* distribution in the pelagic zone of Lake Prespa corresponds with the typical distribution of chlorophyll *a* in mesotrophic lakes from temperate zones (Marshall and Peters, 1989).

During the triennial investigations chlorophyll *a* concentrations in 2014 were significantly higher compared to 2015 and 2016 (Fig. 1.3.3). The highest average annual chlorophyll *a* concentration was observed in 2014 at SP 3 Central 5m depth (9.19 µg l^{-1}) followed by SP 3 Central 10 m depth (8.49 µg

$l^{-}1$). The lowest average annual chlorophyll *a* concentration was observed in 2016 at deeper layer of SP 1 Pelagic (Kazan) 30 m (2.53 µg l^{-1}) and 20 m (2.77 µg l^{-1}) (Fig. 1.3.3). In the surface layer of pelagic points (SP1, SP2 and SP3) chlorophyll *a* concentration was almost identical in each year and average annual values ranged between 4.52 µg l^{-1} at SP 3 Central and 4.80 µg l^{-1} at SP 1 Kazan (Fig. 1.3.4).

In the littoral sampling points were not observed significant difference between chlorophyll *a* concentrations. The values of average chlorophyll *a* concentrations varied between 3.76 µg l^{-1} at SP 6 Asamati, 4.78 µg l^{-1} at SP 4 Nakolec-Strbovo and 4,79 at SP 9 Otesevo (Fig. 1.3.4).

The highest average values of chlorophyll *a* concentration in the water column of Lake Prespa were observed at 5 and 10 m depth where phytoplankton density was the highest (Fig. 1.3.2.). In the previous investigations the highest average values of chlorophyll *a* concentration in the water column of Lake Prespa were observed between the surface layer and 5 m depth (Patceva, 2005).

Conclusions

The total abundance of phytoplankton was considerably higher in summer than in other seasons which is characteristic for meso-eutrophic lakes.

During the triennial investigations the total abundance of phytoplankton was significantly higher in 2014 compared to 2015 and 2016.

The highest average phytoplankton abudance in the water column of Lake Prespa was observed at 5 m depth and it was slightly lower at 10 m depth and in the surface layer.

Most phytoplankton species identified belong to the Bacillariophyta and Cyanophyta and these two divisions had the main role in the phytoplankton. The other groups of algae contributed significantly lower part of the total abudance.

Investigations showed distinct seasonal differences in phytoplankton composition.

Similar to the total phytoplankton abundance chlorophyll *a* concentrations at surface level were generally higher in summer than in other seasons. The reverse was true for the deeper layers from 15 to 30m depth. This kind of seasonal chlorophyll *a* distribution in the pelagic zone of Lake Prespa corresponds with the typical distribution of chlorophyll *a* in mesotrophic lakes from temperate zones.

During the triennial investigations chlorophyll *a* concentrations in 2014 were significantly higher compared to 2015 and 2016.

1.4. Relationship Between Physico-Chemical Parameters And Chlorophyll *A* Concentration

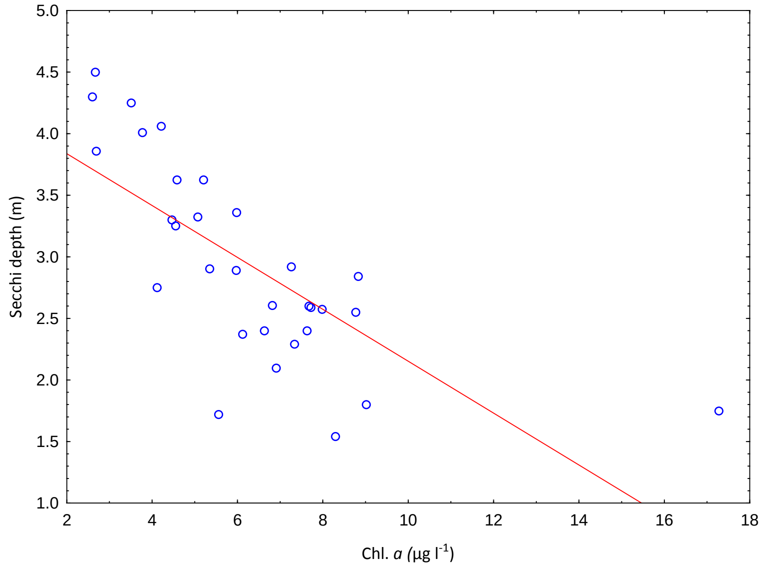

Fig.1.4.1 Correlation between Secchi depth and chlorophyll a in Lake Prespa, for year 2014 (r=-0.73, p < 0.05).

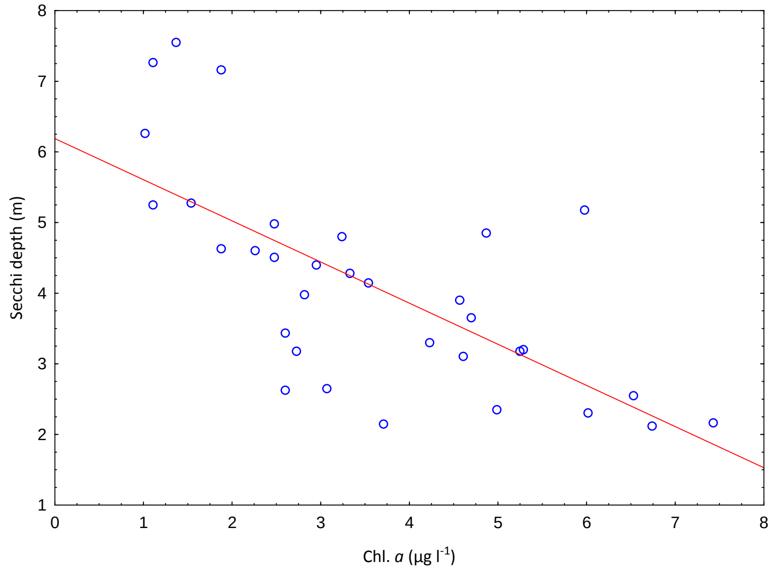

Fig. 1.4.2 Correlation between Secchi depth and chlorophyll a in Lake Prespa, for year 2015 (r=-0.69, p < 0.05).

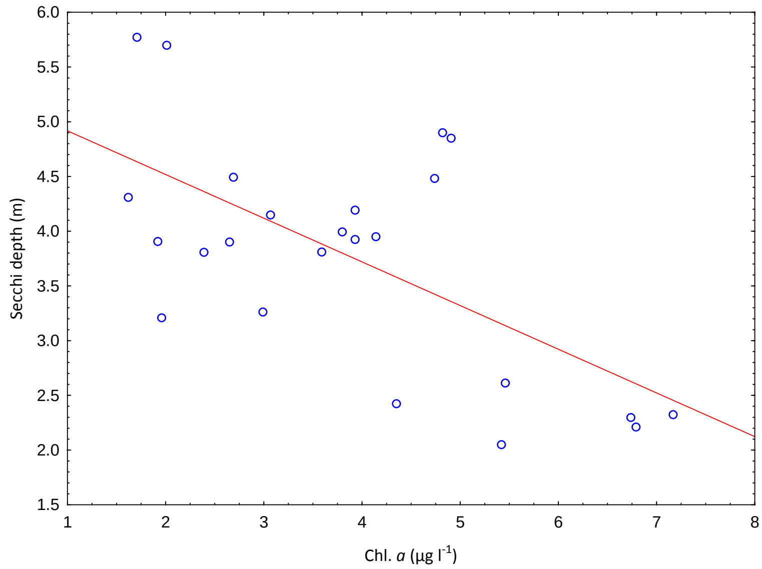

Fig. 1.4.3 Correlation between Secchi depth and chlorophyll a in Lake Prespa, for year 2016 (r=-0.63, p < 0.05).

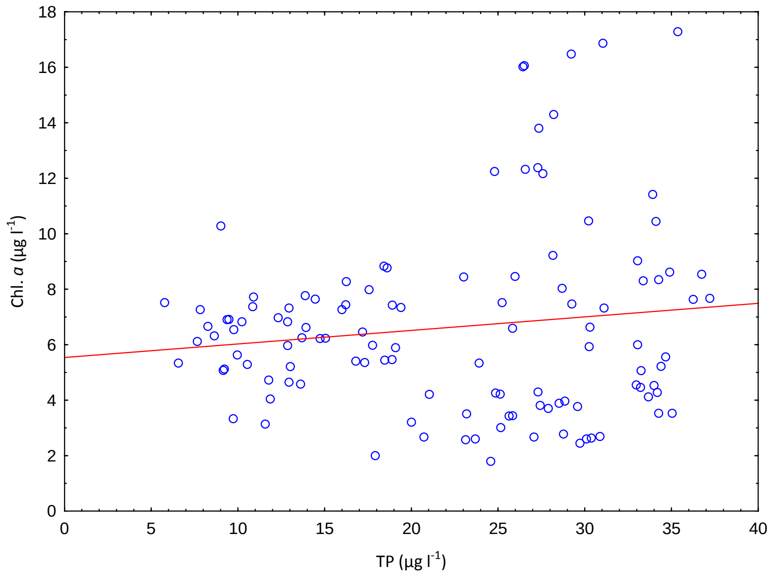

Fig. 1.4.4 Correlation between TP and chlorophyll a in Lake Prespa, for year 2014 (r=0.13, p < 0.05).

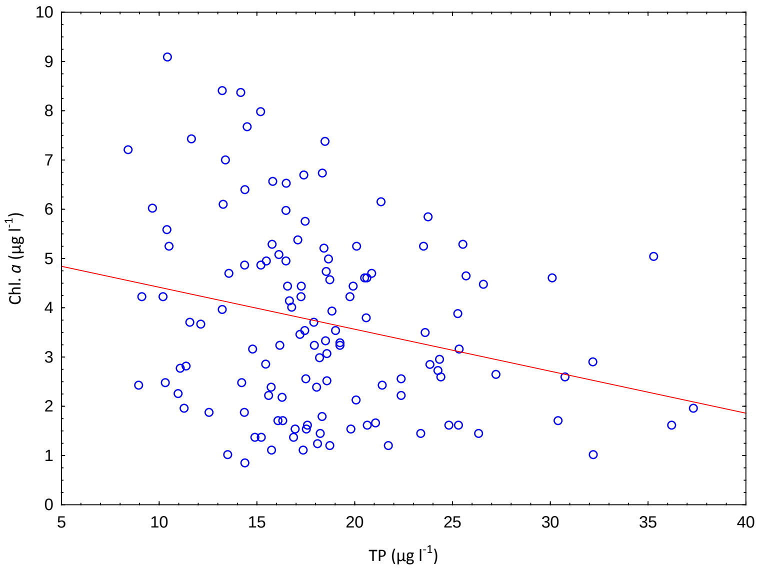

Fig. 1.4.5 Correlation between TP and chlorophyll a in Lake Prespa, for year 2015 (r=-0.25, p < 0.05).

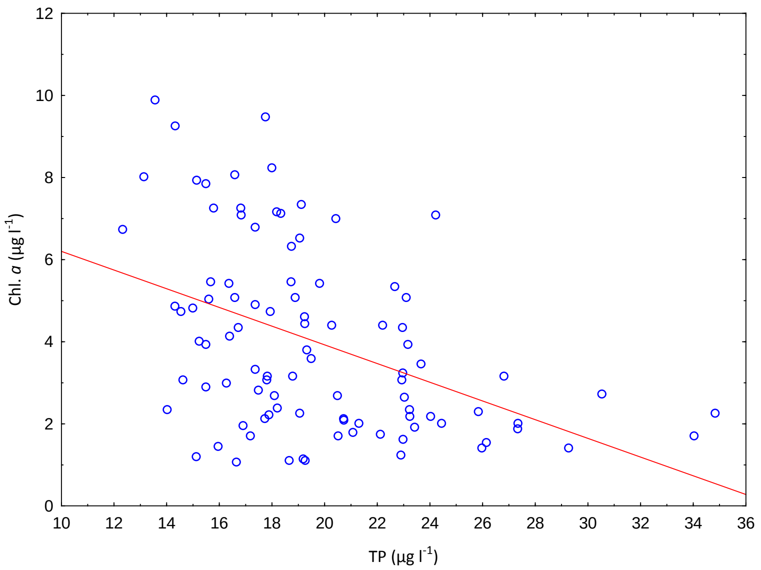

Fig. 1.4.6 Correlation between TP and chlorophyll a in Lake Prespa, for year 2016 (r=-0.44, p < 0.05).

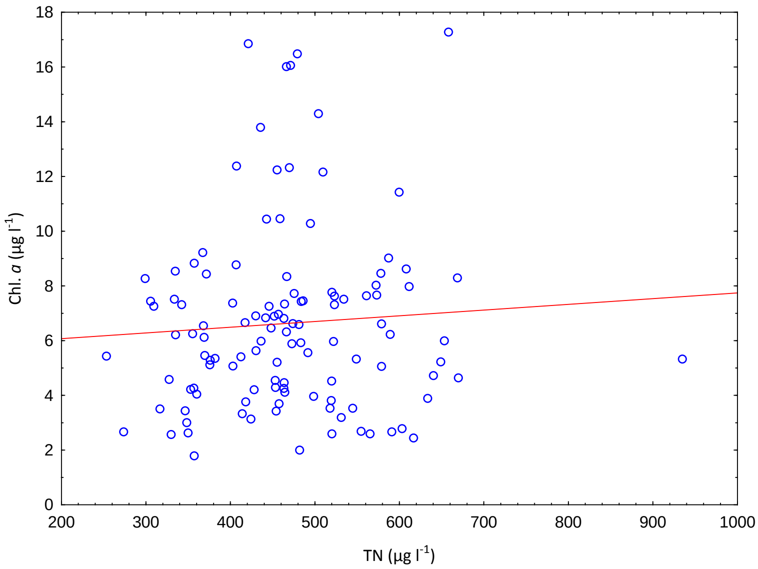

Fig. 1.4.7Correlation between TN and chlorophyll a in Lake Prespa, for year 2014 (r=0.65, p < 0.05).

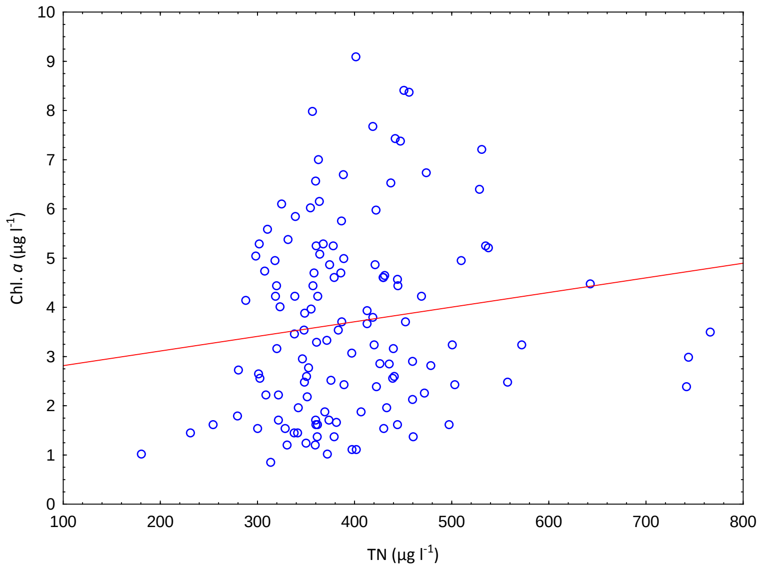

Fig. 1.4.8 Correlation between TN and chlorophyll a in Lake Prespa, for year 2015 (r=0.14, p < 0.05).

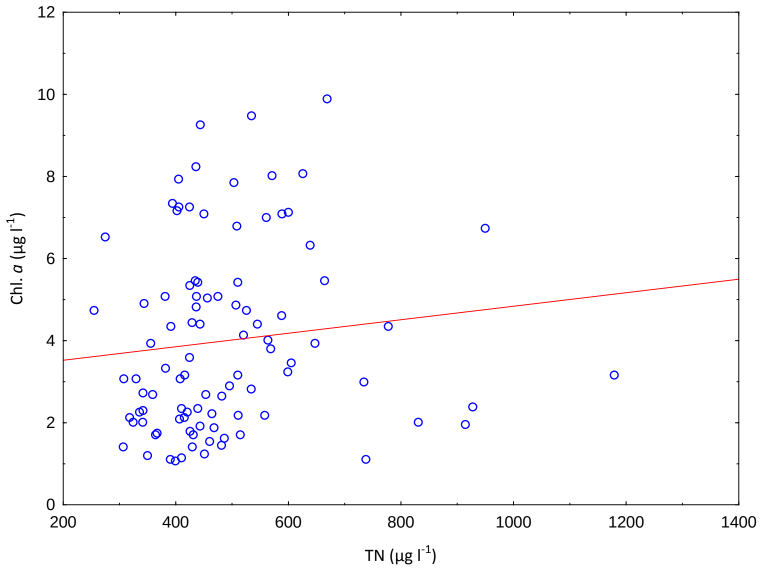

Fig. 1.4.9 Correlation between TN and chlorophyll a in Lake Prespa, for year 2016 (r=0.11, p < 0.05).

During the investigated period (2014-2016) in Lake Prespa was determined strong inverse correlation (from r=-0.63 to r=-0.73, p<0.05) between Secchi depth and Chlorophyll *a* concentration. This indicate that Secchi depth depend from chlorophyll *a* concentration, i.e. from phytoplankton biomass (Fig. 1.4. 1-3).

Based on obtained result for total phosphorus concentration and chlorophyll a concentration, was determined weak positive correlation . Significant amount of phosphorus returns from the deeper layers , especially contact layer with the bottom and sediment. This phosphorus cannot be used from the phytoplankton for its growth.

According to the previous investigations, was observed stronger correlation between Chl. *a* - TP concentrations. Seip et al. (2000) Chl. *a* is limited from one nutrient if regression is significant (p< 0.005) with great correlation coefficient (r). During our investigations, were found several cases in which nitrogen was limiting nutrient for phytoplankton growth (Fig. 1.4. 4 -1.4. 6).

Correlation between total nitrogen and concentration of chlorophyll *a* was weak because Lake Prespa is phosphorus limited ecosystem and nitrogen concentrations have no significant impact on phytoplankton growth (Fig. 1.4. 7 -1.4. 9).

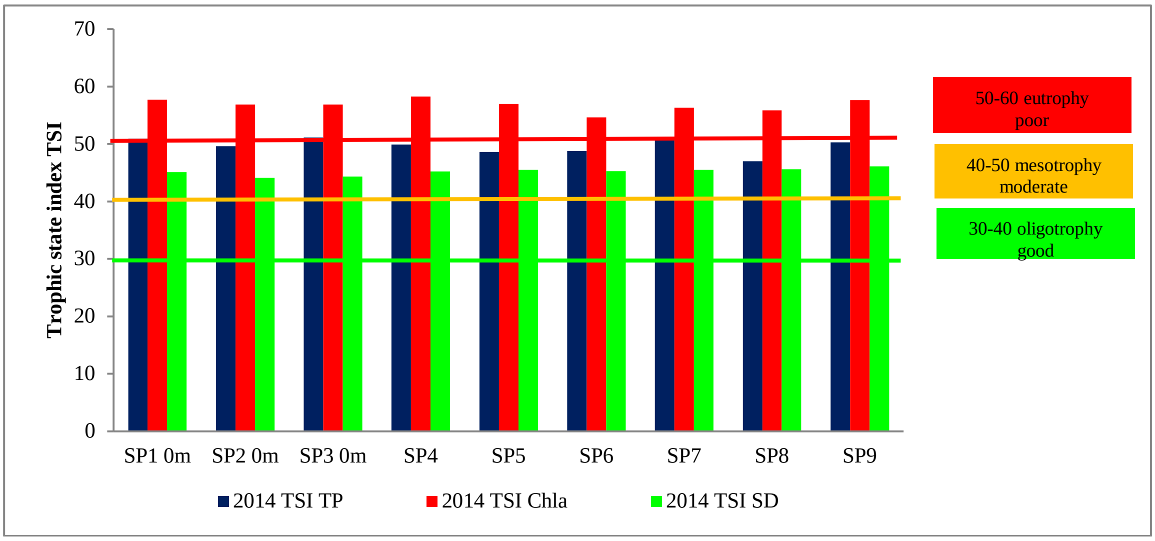

Figure 1.4.10 Trophic state index based on total phosphorus – TSI (TP), Secchi depth TSI (SD) and chlorophyll *a* concentration –TSI (Chl *a*) for 2014

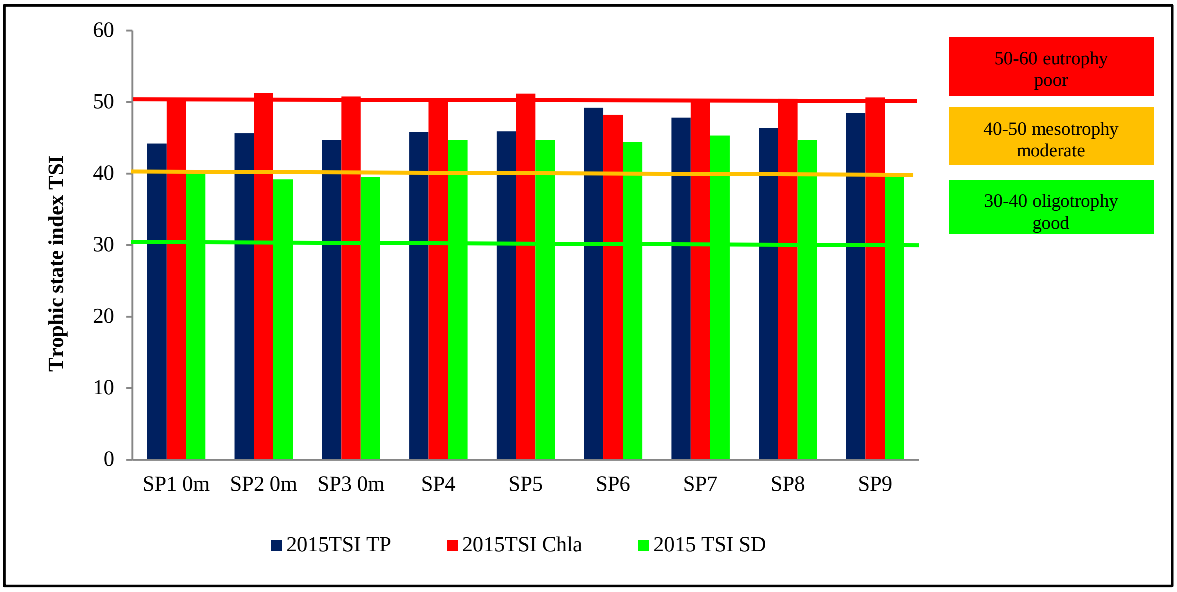

Figure 1.4.11 Trophic state index based on total phosphorus – TSI (TP), Secchi depth TSI (SD) and chlorophyll *a* concentration –TSI (Chl a) for 2015

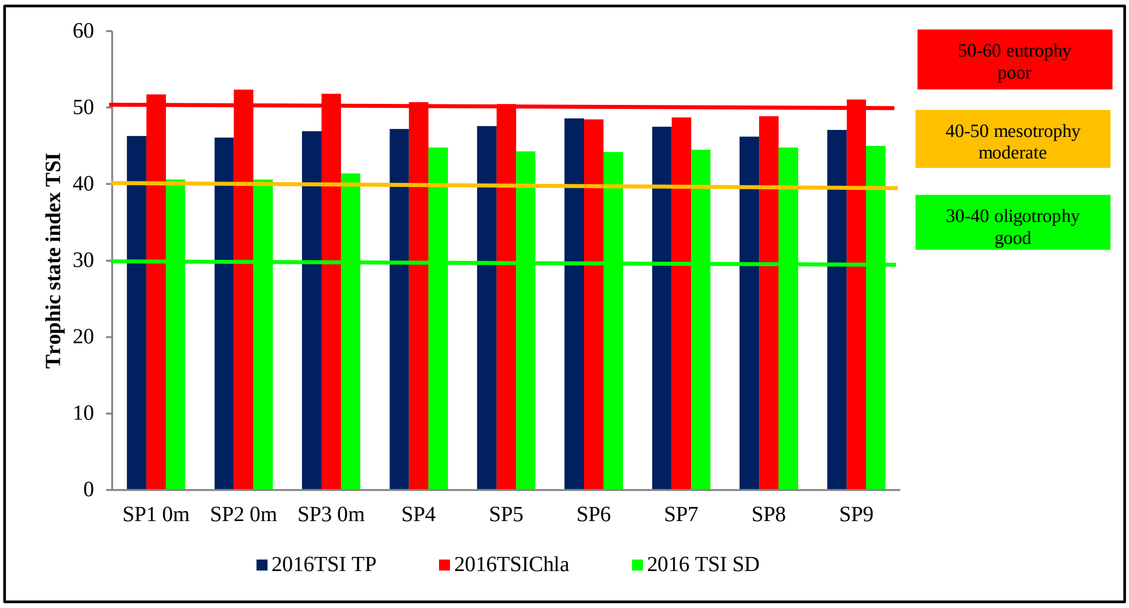

Figure 1.4.12 Trophic state index based on total phosphorus – TSI (TP), Secchi depth TSI (SD) and chlorophyll *a* concentration –TSI (Chl *a*) for 2016

The numeric values for the index of trophic state is calculated based on the concentrations of total phosphorus and chlorophyll *a* can be noted that in 2014 are registered the highest values of this index, pointing to the fact that concentrations on these two parameters are the highest. In the next two investigated years, there is a notable reduction of the numerical value of the index of trophic state based on these two parameters indicating a relative reduction in the concentrations of total phosphorus and chlorophyll *a* in this lake ecosystem. This trend is followed by Secchi detpth i.e. transparency.

1.4.1. Recommendation

From the obtained results and analysis, we suggest continuing with monitoring of the Lake on the same sampling points (Tab. 1.5.1), except sampling points Ezerani 1 and Ezerani 2, which are spatially very close and we suggest to be determined new sampling point, between these two. Also, is good to be covered Stenje area with one sampling point. The aim of this point is to be monitored western part of the Lake in the littoral zone.

For this continuous monitoring we suggest monthly frequency of sampling. Based on obtained results there is no need for two sampling campaigns per month during summer period.

Rivers should be monitored with the same dynamic and same sampling points.

In order to be determined influence of the sediment and biogeochemical cycles of nutrients, in this new monitoring will be useful, sediment sample to be analysed for presence of phosphorus and nitrogen, their forms and other physico-chemical parameters.

For determination of atmospheric influence on lake water we suggest, setting container (near the Monitoring station in Stenje) for collection of atmospheric deposits. Measurements of the atmospheric deposit is directly correlated with biogeochemical cycles of nutrients (TP and TN).

Harmful blue-green algae blooms (cHABs) have significant impacts that jeopardize the ecosystem goods and services provided by freshwaters. There is growing evidence that the spatial and temporal occurrence of cHABs is increasing due to anthropogenic pressures on freshwater ecosystems. Blue-green algae produce a wide range of bioactive compounds (cyanotoxins) that have a deleterious impact on human health and ecosystem sustainability. In our investigations was found that Cyanophyta was the dominant phytoplankton group in summer period. Hence, further investigations of phytoplankton should be directed in determination of algal toxins in water, other living organisms, algae and sediment.

References:

1. Carlson, R. E. (1977): A trophic state index for lakes. Limnol. Oceanogr. 22: 361-369.
2. Marshall, C. T. and Peters, R. H. (1989): General patterns in the seasonal development of chlorophyll *a* for temperate lakes. Limnol. Oceanogr. 34: 856-867.
3. Patceva, S (2005): Comparative analysis of the phytoplankton community and the trophic state of Lakes Ohrid and Prespa. Ph. D. thesis, University “St. Kiril and Methodius” Skopje, Macedonia.
4. Seip, K. L., E. Jeppensen, J.P. Jensen and B. Faafeng (2000): Is trophic state or regional location the strongest determinant for Chl a/TP relationships in lakes? – Aquat. Sci. 62:195-204.

2. Macrophytic vegetation

2.1. Methodology

Monitoring of macrophytes in the summer 2014, 2015 and 2016 (and autumn 2014 and 2015) in the Lake Prespa (Fig. 1.) were made in the researched sites: MV1- Oteshevo (3 transects), MV2-Ezerani (3 transects), MV3- Krani (3 transects) and MV4- Nakolec (3 transects), concerning the following:

Figure 2.1. Sampling sites/transects in Lake Prespa

- A description of characteristic vegetation zones of Lake Prespa (emerged, submerged and floating-leaved plants) in researched sites of Lake Prespa;
- Identify the collected material using appropriate floras and identifications keys;
- Prepare the table with list of all identified plants at each sampling site,
- Estimate plant abundance of presented species and total macrophyte density (ind/m^2) at each sampling site for all sampling dates.
- Calculate the Macrophyte index as bioindicator of trophic state in researched sites from Lake Prespa (Melzer 1999).
- Calculate the Evenness index and Diversity index for each sampling site, for all sampling dates.
- A discussion of the relationships between the vegetation zones and the physico-chemical characteriztics of the sites.
- Appendix of all data in an Excel spreadsheet.

The sampling of the macrophytes was conducted in summer (2014, 2015 and 2016), and autumn (2014 and 2015). At each site macrophytes were surveyed in belt transects from the upper littoral to the lower vegetation limit (Wiser method).

Plants have been collected by a Van-veen grab (Fig.3.), and the species occurrence was registered in each transect and each depth zone. The abundance of each species was estimated according to a five degree scale (Tüxen & Preising 1942 in Melzer 1999). The number of individuals /m^2 were counted by using metal frame with the surface of 1 m^2 for the emergent macrophytes, or by using the grab with the surface of 400 cm^2 for the submerged macrophytes.

The species determination was made by using floristic books (floras). The macrophyte index was calculated according to the formula described in Melzer (1999), but with updated indicator values and class boundaries as described in Melzer & Schneider (2001). There were calculated also the Shannon wiener index (H) and the Pielou's-evenness index (e).

2.2. Results and discussion

During the summer and autumn sampling campaign in each sampling site (MV1- Oteshevo, MV2- Ezerani, MV3- Krani and MV4- Nakolec) 3 transects were established perpendicular to lake shoreline (central transect, left and right from central transect), with a length covering the complete depth range of the macrophyte occurrence.
In all sampling sites during the summer (2014, 2015 and 2016), and the autumn (2014 and 2015), there were determined total of 19 representatives of macrophyte vegetation (3 emergent species and 16 submerged species). In all researched sites there were not evidenced floating species (Tab. 2.1. - Tab.2.5).

Table 3.1. List of all identified macrophytes at Oteshevo (MV1) - summer

	SPECIES	MV1 central	MV1 left	MV1 right	MV1 central	MV1 left	MV21 right	MV1 central	MV1 left	MV1 right	Total
		2014			2015			2016			
1.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	**9**
2.	*Typha angustifolia* L.		+			+	+		+	+	**5**
3.	*Potamogeton perfoliatus* L.		+	+	+	+	+	+	+	+	**8**
4.	*Potamogeton pectinatus* L.	+		+	+		+	+	+	+	**7**
5.	*Potamogeton lucens* L.	+		+	+		+	+		+	**6**
6.	*Potamogeton pusillus* L.		+	+			+				**3**
7.	*Potamogeton crispus* L.	+	+		+	+		+	+	+	**7**
8.	*Potamogeton trichoides* L.				+						**1**
9.	*Myriophyllum spicatum* L.	+			+		+	+	+	+	**7**
10.	*Ceratophyllum demersum* L.	+	+		+	+		+	+		**6**
11.	*Ceratophyllum submersum* L.		+			+		+			**3**
12.	*Vallisneria spiralis* L.	+			+		+	+	+	+	**6**
13.	*Najas marina* L.								+		**1**
14.	*Zannichellia palustris* L.	+			+			+			**3**
15.	*Chara globularis* Thuillier								+		**1**
16.	*Nitellopsis obtusa* Groves.								+		**1**
	Total	**8**	**7**	**5**	**10**	**6**	**8**	**10**	**11**	**8**	

Table 2.2. List of all identified macrophytes at Ezerani (MV2) – summer

	SPECIES	**MV2central**	**MV2 left**	**MV2 right**	**MV2 central**	**MV2 left**	**MV2 right**	**MV2 central**	**MV2 left**	**MV2 right**	**Total**
		2014			**2015**			**2016**			
1.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	**9**
2.	*Typha angustifolia* L.	+	+	+	+	+	+	+	+	+	**9**
3.	*Typa latifolia* L.				+	+	+	+	+	+	**6**
4.	*Potamogeton perfoliatus* L.	+		+	+	+	+	+	+	+	**8**
5.	*Potamogeton pectinatus* L.	+			+		+	+		+	**5**
6.	*Potamogeton lucens* L.				+	+	+		+		**4**
7.	*Potamogeton pusillus* L.	+		+	+					+	**4**
8.	*Potamogeton crispus* L.				+		+	+			**3**
9.	*Myriophyllum spicatum* L.	+	+	+	+				+		**5**
10.	*Ceratophyllum demersum* L.			+	+		+	+			**4**
11.	*Ceratophyllum submersum* L.							+			**1**
12.	*Najas marina* L.	+				+	+		+		**4**
13.	*Zannichellia palustris* L.				+						**1**
	Total	**7**	**3**	**6**	**11**	**6**	**9**	**8**	**7**	**6**	

Table 2.3. List of all identified macrophytes at Krani (MV3) - summer

	SPECIES	MV3central	MV3 left	MV3 right	MV3central	MV3left	MV3 right	MV3 central	MV3 left	MV3 right	Total
		2014			**2015**			**2016**			
1.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	**9**
2.	*Typa latifolia* L.					+	+				**2**
3.	*Potamogeton perfoliatus* L.	+			+	+			+		**4**
4.	*Potamogeton pectinatus* L.					+			+	+	**3**
5.	*Potamogeton crispus* L.								+		**1**
6.	*Potamogeton nitens* Weber.							+	+		**2**
7.	*Potamogeton salicifolius* Wolfg.								+		**1**
8.	*Myriophyllum spicatum* L.				+						**1**
9.	*Zannichellia palustris* L.					+					**1**
10.	*Chara globularis* Thuillier							+	+		**2**
	Total	**2**	**1**	**1**	**3**	**5**	**2**	**3**	**7**	**2**	

Table 2.4. List of all identified macrophytes at Nakolec (MV4) - summer

	SPECIES	MV4central	MV4left	MV4 right	MV4 central	MV4left	MV4 right	MV4 central	MV4 left	MV4 right	Total
		2014			**2015**			**2016**			
1.	Phragmites australis (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	**9**
2.	Typha angustifolia L.	+			+	+		+	+		**5**
3.	Typa latifolia L.				+	+		+	+		**4**
4.	Potamogeton perfoliatus L.	+	+		+	+		+	+		**6**
5.	Potamogeton pectinatus L.	+			+	+	+	+		+	**6**
6.	Potamogeton pusillus L.	+			+			+			**3**
7.	Myriophyllum spicatum L.	+			+			+			**3**
8.	Vallisneria spiralis L.				+						**1**
9.	Najas marina L.			+			+			+	**3**
10.	Zannichellia palustris L.	+			+		+	+		+	**5**
	Total	**7**	**2**	**2**	**9**	**5**	**4**	**8**	**4**	**4**	

Table 2.5. List of all identified macrophytes at each sampling site (autumn campaign 2014 – 2015)

	SPECIES	Mv1 central	MV1 left	MV1 right	MV2 central	MV2 left	MV2 right	MV3 central	MV3 left	MV3 right	MV4 central	MV4 left	MV4 right	total
1.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	+	+	+	+	+	+	+	+	+	+	+	12
2.	*Typha angustifolia* L.		+	+	+	+	+				+			6
3.	*Potamogeton perfoliatus* L.	+			+		+	+	+		+			6
4.	*Potamogeton lucens* L.	+	+	+										3
5.	*Myriophyllum spicatum* L.	+	+			+	+		+		+			6
6.	*Ceratophyllum demersum* L.						+							1
7.	*Vallisneria spiralis* L.	+				+								2
8.	*Najas marina* L**.**	+	+	+	+	+	+		+				+	8
9.	*Zannichellia palustris* L.					+								1
10.	*Nitellopsis obtusa* (Desv.in Loisel.) J. Groves 1919	+												1
	Total	7	5	4	4	6	6	2	4	1	4	1	2	

2.3. Description of the vegetation zones in Lake Prespa

In the littoral region of Lake Prespa there are distributed different populations of macrophyte vegetation in zones (belts). Macrophyte vegetation in Lake is characterized by presence emergent and submerged macrophytes.

Dominant emerged plant species in sampling sites from Lake Prespa was reed *Phragmites australis* (Cav.) Trin. ex Steud., which form a natural discontinuous belt. The other presented emerged plants were *Typha angustifolia* and *Typha latifolia* which were presented in the belt of reed like pure associations, but these species was presented rarely, while submerged macrophytes are the most frequent.

From the submerged macrophytes presented in sampling sites there were dominant the representatives from the genus Potamogeton: *Potamogeton perfoliatus* L., *Potamogeton pectinatus* L., *Potamogeton lucens* L., *Potamogeton pussilus* L. Lesser, *Potamogeton crispus* L., *Potamogeton trichoides* L., *Potamogeton nitens* Weber. and *Potamogeton salicifolius* Wolfg. There are also presented: *Zannichellia palustris* L., *Myriophillum spicatum* L., *Ceratophyllum demersum* L., *Ceratophyllum submersum* L., *Vallisneria spiralis* L., *Najas marina* L, *Chara globularis* Thuillier and *Nitellopsis obtusa* (Desv.in Loisel.) J. Groves 1919.

In Lake Prespa, the macrophyte vegetation shows the species diversity in sampling sites MV1- Oteshevo, MV2- Ezerani, MV3- Krani and MV4- Nakolec.

Namely, in sampling site MV1- Oteshevo, there were evidenced total of 11 species (summer 2014), 13 species (summer 2015), 14 species (summer 2016) - Tab.2.1.

In sampling site MV2- Ezerani there were evidenced total of 8 species (summer 2014), 12 species (summer 2015) and 12 species (summer 2016) - Tab.2.2.

In sampling site MV3- Krani there were evidenced 2 species (summer 2014), 6 species (summer 2015) and 7 species (summer 2016) - Tab.2.3.

In sampling site MV4-Nakolec there were evidenced 8 species (summer 2014), 10 species (summer 2015) and 9 species (summer 2016) - Tab.2.4.

In the autumn period in sampling sites MV1- Oteshevo, MV2- Ezerani, MV3- Krani and MV4- Nakolec, there were determined total of 10 representatives of macrophyte vegetation (2 emergent species and 8 submerged species). In all researched sites there were not evidenced floating species, but it was registered one species from Charophyta (*Nitellopsis obtusa*)- Tab.2.5.

Great number of macrophyte species was evidenced in sampling sites MV1- Oteshevo and MV2- Ezerani. This is probably due to the great amount of different organic and inorganic substances presented in the lake water (as untreated water from the hotel and touristic camp from MV1- Oteshevo, and inflow of the Golema River into Lake in MV2- Ezerani). There are favorable conditions that provide growth and development of more submerged species that are dense and high with flowers on the water surface and formed meadows in the bottom of the Lake. At these sampling sites the reed, *Phragmites australis* is dense, high and the reed belt is wide and continuous, and also *Typha angustifolia* is very well developed.

In other two sampling sites MV3- Krani and MV4- Nakolec the number of macrophyte species was lower. This is probably due to the minor amount of substances in the lake water, and especially from the sedimentation of the sand from rivers flowing into the lake near the researched sites (Kranska River and Brajcinska River). Therefore in these sampling sites conditions are unfavorable and the number of submerged species is very small, they were less developed. This is especially evident in sampling site MV3- Krani where it was recorded the lowest number of submerged species (2, or 1), and also the reed is less frequent and lower than in other surveyed sampling sites.

Almost in all researched sites there were evidenced alga *Cladophora* sp.

Table 2.6. MI in sampling site MV1 (summer 2014, 2015 and 2016)

Sampling sites	MI(macrophyte index, summer 2014)	MI(macrophyte index, summer 2015)	MI(macrophyte index, summer 2016)
MV1 central	**3.86**	**3.94**	**3.43**
MV1 left	**3.9**	**3.88**	**3.13**
MV1 right	**3.38**	**3.37**	**3.35**

Table 2.7. MI in sampling site MV2 (summer 2014, 2015 and 2016)

Sampling sites	MI(macrophyte index, summer 2014)	MI(macrophyte index, summer 2015)	MI(macrophyte index, summer 2016)
MV2 central	**4.37**	**2.01**	**3.7**
MV2 left	**3**	**3.22**	**3.24**
MV2 right	**3.06**	**3.49**	**3.14**

Table 2.8. MI in sampling site MV3 (summer 2014, 2015 and 2016)

Sampling sites	MI(macrophyte index, summer 2014)	MI(macrophyte index, summer 2015)	MI(macrophyte index, summer 2016)
MV3 central	**3**	**3.00**	**2.5**
MV3 left	**0**	**4.00**	**3.21**
MV3 right	**0**	**0**	**4**

Table 2.9. MI in sampling site MV4 (summer 2014, 2015 and 2016)

Sampling sites	MI(macrophyte index, summer 2014)	MI(macrophyte index, summer 2015)	MI(macrophyte index, summer 2016)
MV4 central	**3.34**	**3.39**	**3.37**
MV4 left	**3**	**3.00**	**3.00**
MV4 right	**0**	**4.5**	**4.1**

Table 2.10. MI in sampling sites in autumn 2014, 2015

Sampling sites	MI(macrophyte index) autumn 2014, 2015
MV1 central	3.05
MV1 left	3
MV1 right	3.5
MV2 central	3
MV2 left	3.03
MV2 right	3
MV3 central	3
MV3 left	3.1
MV3 right	0
MV4 central	3
MV4 left	0
MV4 right	0

2.4. Conclusions

A trial to use the traditional metrics (Shannon & Wiener Diversity index, Pielou-evenness index etc.) in assessing the ecological status of the water bodies was done by extrapolating of obtained values in the system of values between referent and bad ecological conditions, developed in Bulgaria (Project 563, 2004). Comparing the results from MI with the results obtained by traditional metrics, it is evident that this system is not always “following” the values of MI, or the real in situ status of the water bodies. Pielou index can't be used at all in the researches, because the obtained values of this index do not belong in any of the category for assessing the trophic state of the water. All this gives an advantage to MI over traditional metrics in assessing the ecological status. This is also successfully proven by the researches correlated with Lake Ohrid and using the macrophytes and the MI as a tool for assessing the ecological state in the water (Trajanovska et al. 2014).

For all calculated indexes, for more comprehensive interpretation of the ecological status, there have been used the appropriate colors in accordance to the colorful scale of European WFD: red= bad status; orange=poor status, yellow=moderate status, green=good and blue=high ecological status.

The macrophyte index (MI) in MV1 varied from moderate to massive pollution (Tab. 2.6.). In MV2, the value of the MI indicated very low to massive pollution (Tab.2.7.). In MV3, MI varied from low to massive pollution (Tab. 2.8.), and in MV4, MI indicated moderate to massive pollution (Tab.2.9).

There are not have so many differences in the values of the MI during the autumn period. The MI varied from moderate immense (in 8 out of total of 12 researched sites) to immense pollution (in only one site). In 3 of the researched sites there are no values for the MI, because there were not evidenced macrophyte species as indicator for the trophic state of the water.

As it can been seen from the Tab. 2.10., during the autumn period there are no great variations of the MI values, if compared to the values of this index in summer (Tab. 2.6. - 2.9.). Presumably, the species with low indicator index, which prevailed in the summer (ended their vegetation cycle with depleting of the nutrients), and this is especially evident in the beginning of the autumn period when the samples of macrophytes were collected.

2.5. Recommendations

- To undertake measures for prevention and mitigation of the lake pollution where the values of the Macrophytic Index indicated increased nutrient pollution.
- Predicting investigations of macrophytes from the lake to obtained data on natural places for spawning of different fish species in their communities According to the planned dynamic special emphasis will be place on collecting samples throughout the growing season of macrophyte vegetation, especially during spawning period of fish.
- Also, we recommended to removes dead parts of macrophytes after the vegetation period (reed, and some submerged macrophytes). By that way from the Lake will be removed certain quantities of different accumulated material (especially N, and P, and other substances which polluted lake water).
- It should be mentioned that anthropogenic pressure in certain localities causes changes of water quality and the composition of the substrate. As a result of these undesired effects new submerged macrophyte species with high density appear. It may result with changes in composition of native fish species which are spawning in these localities.

3. Benthic fauna

3.1. Results

3.1.1. Oteshevo: MZ1

In Oteshevo, throughout the whole research period, 108 samples from the benthic fauna have been collected from 3 transects. Three sampling (depths) have been considered per each transect: 0.5-1.5, 3-3.5 and 5m. Several bottom habitats (facies) have been identified: the higher heterogeneity was observed on 0.5-1.5 (mostly sandy-muddy, stony, or muddy); the heterogeneity decreases with the depth, so on 3-3.5 it was mostly sandy to muddy sandy, while on 5 m the bottom was pretty homogenous represented by muddy facies.

Table 3.1. Oteshevo species composition list

Turbellaria
Dendrocoelum prespense (Stankovic, 1969)
Oligochaeta
Limnodrilus hoffmeisteri Claparède, 1862
Rhynchelmis komareki Hrabe 1927
Potamotrix hammoniensis (Michaelsen, 1901)
Eiseniella tetraedra (Savigny 1826)
Tubifex tubifex (Otto Friedrich Müller, 1774)
Hirudinea
Erpobdella octoculata (Linnaeus, 1758)
Glossiphonia complanata (Linnaeus, 1758)
Dina latestriata Neubert & Nesemann 1995
Dina sp.
Gastropoda
Valvata piscinalis (Muller, 1774)
Prespolitorea valvataeformis Radoman, 1973
Bithynia leachii (Sheppard, 1823)
Radix pinteri Schütt, 1974
Pyrgohydrobia prespaensis (Urbanski, 1939)
Bithynia prespensis Hadžišče, 1963
Bithynia tentaculata (Linnaeus, 1758)
Parabythinella malaprespensis Radoman 1973
Bivalvia
Dreissena presbensis Kobelt, 1915
Pisidium casertanum (Poli, 1791)
Amphipoda
Gammarus triacanthus prespensis (Karman S. & G. 1959)
Isopoda
Asellus aquaticus (Linnaeus, 1758)
Insecta
Baetis vernis Curtis, 1834
Gomphus vulgatissimus (Linnaeus, 1758)
Caenis macrura Stephens, 1836
Lepidoptera Achroia sp.
Chironomus plumosus (Linnaeus, 1758)

Table 3.1. represents the species composition list in Oteshevo locality. Thereafter in

In Oteshevo, 27 species belonging to 8 systematic groups have been registered. The portion of Gastropoda within the total number of registered species is highest-8 species out of 27 registered. The second most diverse group is Oligocheata represented by 5 species. The lowest is the portion of the Isopoda, Amphipoda and Turbellaria, whereby only one species has been registered.

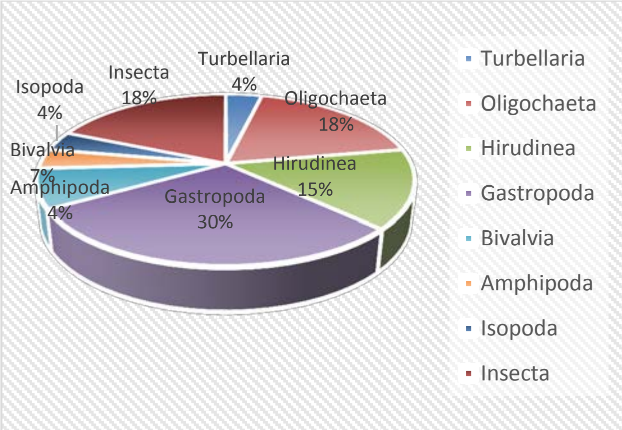

Figure 3.1. Participation of the particular groups within the total biodiversity in Oteshevo

The ratio cosmopolitan/endemic, as shown on the Figure 3.2 is shifted on the side of the cosmopolitan species. Thus, even 70 % (19 species) of the registered species are cosmopolitan while 30 % or 8 species are endemic. The highest number, or half of the endemic species come from the class of Gastropoda.

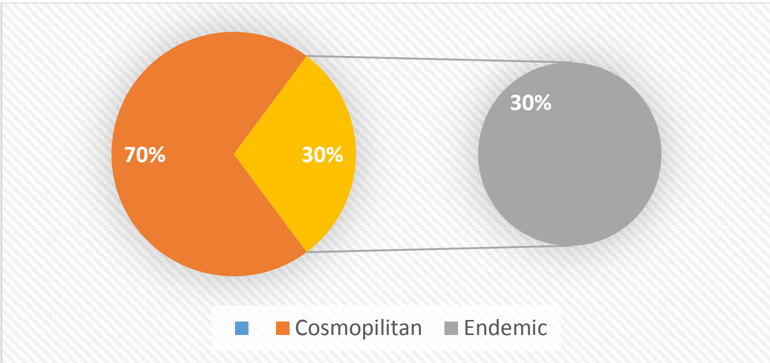

Figure 3.2. The cosmopolitans/endemics ratio in Oteshevo

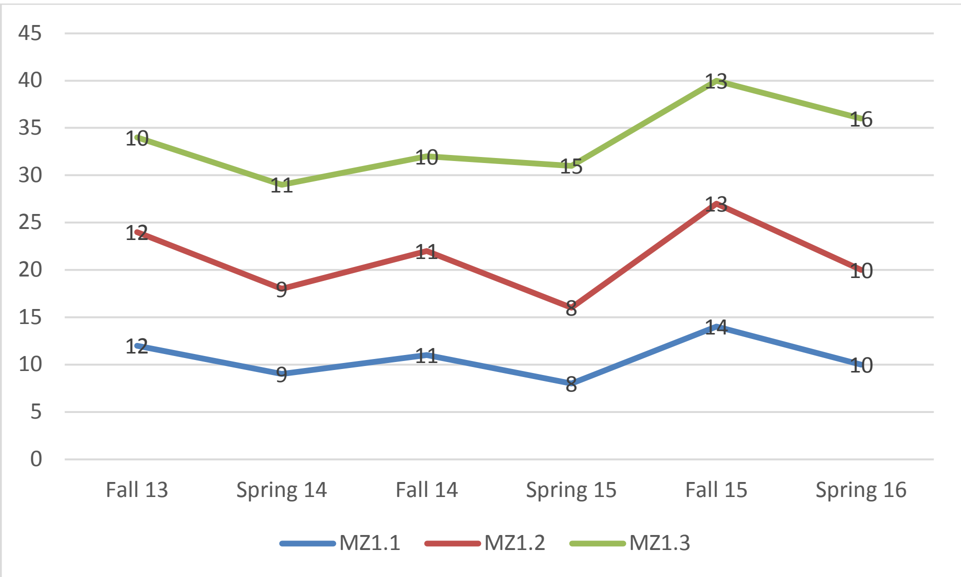

Figure 3.3. Seasonal variation of the species composition in Oteshevo

Figure 3.3 clearly states that the qualitative composition of the benthic fauna depends on the seasons and has proper seasonal variations. Thus the qualitative composition increases in fall and decreases in spring in all three transects in Oteshevo sampling locality.

Beside the seasonal correlation, the qualitative composition also depends of the depth. This correlation is shown on the Figure 3.4.

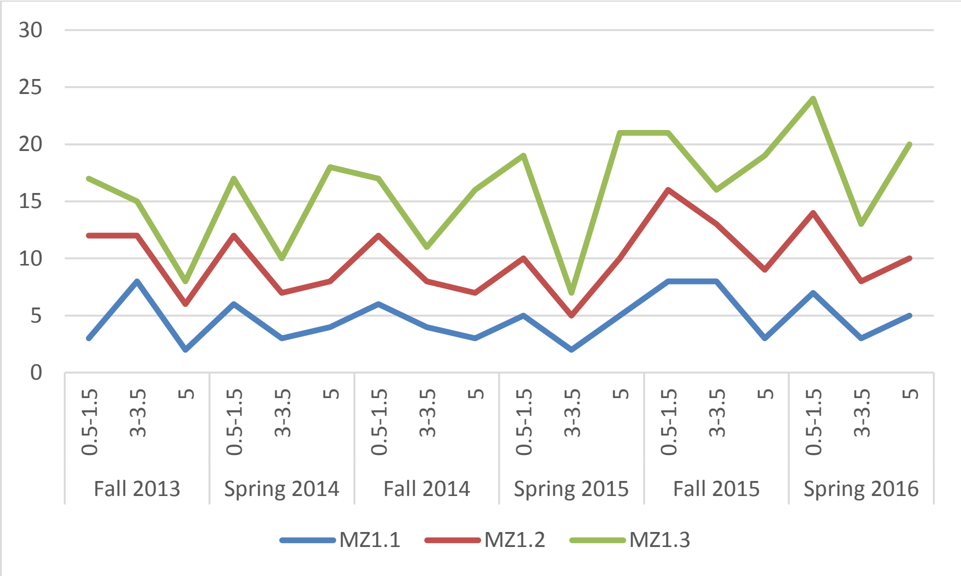

Figure 3.4. Seasonal/depth variations of the species composition in Oteshevo

As shown on Figure 3.4, the qualitative composition is always highest in the shallowest sampling points (0.5-1.5) then it sharply decreases (3-3.5m) and on the deepest sampling point (5 m), it increases again but never reaches the values of the shallowest sampling points.

The density of the benthic fauna from locality is shown in Figure 3.5.

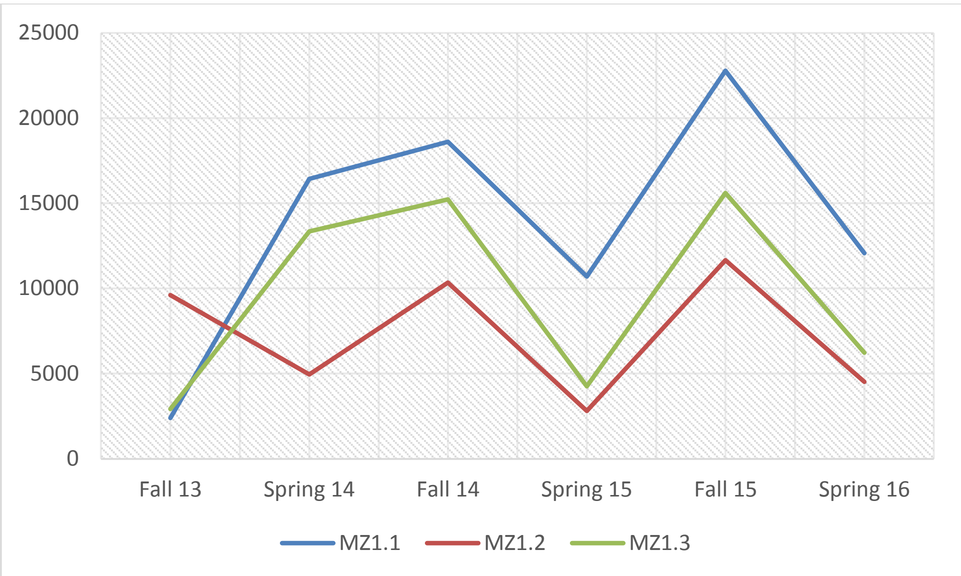

Figure 3.5. Seasonal variations in the density of benthic fauna in Oteshevo

Figure 3.5 depicts the variations in the density of the whole benthic fauna in Oteshevo throughout the whole research period. It is obvious that the spring values of the densities are lower in comparisons with the fall values. In other words, the higher densities in fall are in correlation with higher qualitative composition of the benthic fauna also registered in fall seasons (Fig. 3.3).

If the density variations of the whole benthic fauna are analyzed both in time and depth, similarly to the qualitative composition (Fig. 3.4), we see that density equally as the structure (species richness) are depth-dependent i.e. the highest density is registered on the shallowest sampling point, then the density drops on 3-3.5m, and again, as it was a case with the diversity, increases on 5 m. Based on the Figure 3.6, seems that density is more depth-dependent i.e. the seasonal influence in the density on the different depth points is not regular.

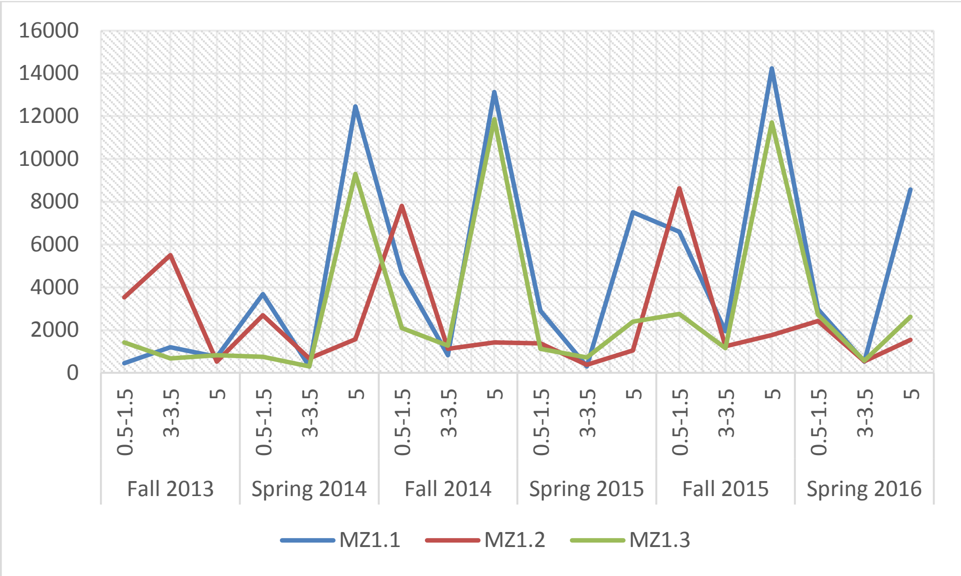

Figure 3.6. Seasonal/depth variations in the density of the benthic fauna in Oteshevo

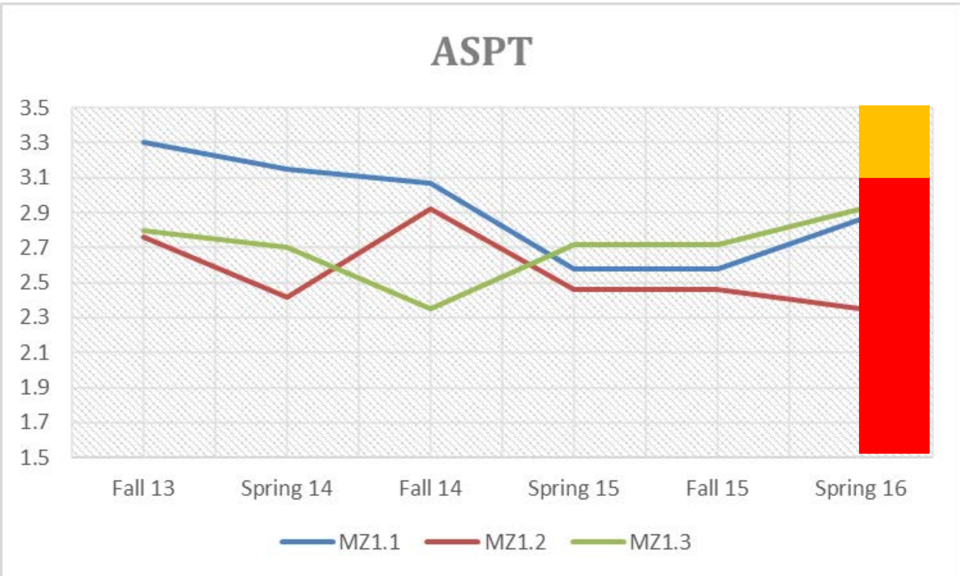

Figure 3.7. ASPT index in Oteshevo

ASPT index values are presented on the Figure 3.7. The ASPT index is used for assessing the ecological status of the sampling sites, and it reflects the community structure i.e. its health taking into consideration their sensitivity on different levels of pollution.

The results showed on Fig. 3.7 implies, in general, very poor ecological status of the sampling transects i.e. sampling sites throughout the whole research period (red color). Poor ecological status (a class better ecological status than the very bad one) based on the ASPT values have been only registered in the Fall 2013 on MZ1.1 (orange color).

BMWP score per sampling transect is shown on Figure 3.8. It reflects the sensitivity of the community based on the individual scoring within the family level. The higher the family score, the more sensitive to oxygen depletion the family is and therefore their presence indicates a cleaner or less impacted site. The effects of pollution generally are to impose a Biological Oxygen Demand upon the receiving waters and so sensitive families are progressively excluded as the BOD increases.

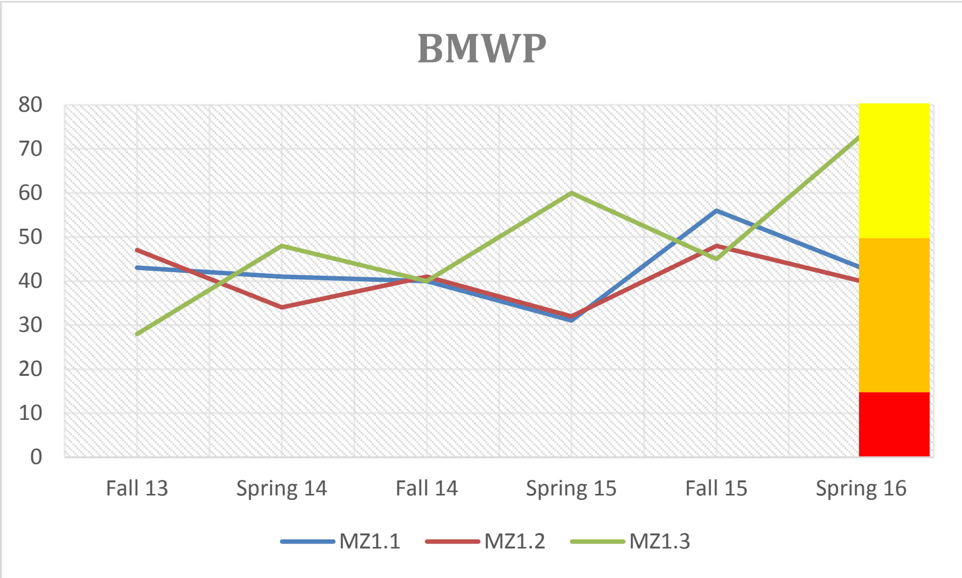

Figure 3.8. BMWP variations in Oteshevo

The BMWP scoring refers about a bit better ecological status than ASPT. Thus, based on this scoring, the ecological status is generally poor, but in MZ1.1, in spring periods during the whole research, it is moderate, i.e. level better than in the rest of the research season and transects.

However, this sampling site doesn't meet the required criteria for good ecological status as required by the EWFD. All seasons prevailing species from the less sensitive groups such as Oligochaeta, Hirudinea, Chironomidae are typical for the disturbed trophic status or general bad ecological status of the water. Thus, the most present throughout the research period, sampling transect and depths are the following species: *Gammarus triacanthus prespensis, Chironomus plumosus, Dreissena presbensis,* and *Limnodrilus hoffmeisteri*. The first one, which is the most abundant in Oteshevo characterizes BMWP score 6, the next two BMWP is 2 while the last one's BMWP is 1. Such community structure depicts deteriorated water quality, i.e. very poor to poor ecological status.

3.1.2. Ezerani: MZ2

From Ezerani sampling site, 108 samples from the benthic fauna have been collected from 3 transects. Three sampling (depths) have been considered per each transect: 0.5-1.5, 3-3.5 and 5m. Two types of bottom habitats (facies) have been identified i.e. the heterogeneity of the bottom in Ezerani was not clearly prominent as in Oteshevo. Thus, more or less, the bottom along the transects was sandy-muddy to muddy: 0.5-1.5- sandy–muddy, or muddy; on 3-3.5 sandy muddy or sandy while on 5 m the bottom was mostly muddy and some sandy-muddy fractions have been observed too.

Table 3.2. Ezerani species composition list

Oligochaeta
Limnodrilus hoffmeisteri Claparède, 1862
Rhynchelmis komareki Hrabe 1927
Potamotrix hammoniensis (Michaelsen, 1901)
Eiseniella tetraedra (Savigny 1826)
Criodrilus lacuum Hoffmeister 1845
Tubifex tubifex (Otto Friedrich Müller, 1774)
Lumbriculus variegatus (Müller, 1774)
Hirudinea
Erpobdella octoculata (Linnaeus, 1758)
Glossiphonia complanata (Linnaeus, 1758)
Dina latestriata Neubert & Nesemann 1995
Dina sp.
Gastropoda
Valvata piscinalis (Muller, 1774)
Radix pinteri Schütt, 1974
Prespolitorea valvataeformis Radoman, 1973
Pyrgohydrobia prespaensis (Urbanski, 1939)
Bithynia tentaculata (Linnaeus, 1758)
Bithynia sp.
Bivalvia
Dreissena presbensis Kobelt, 1915
Pisidium sp.
Amphipoda
Gammarus triacanthus prespensis (Karman S. & G. 1959)
Insecta
Chironomus plumosus (Linnaeus, 1758)
Diptera, Hermetia sp. Latreille 1804
Leptocerus sp.
Micronecta scholtzi (Fieber, 1860)

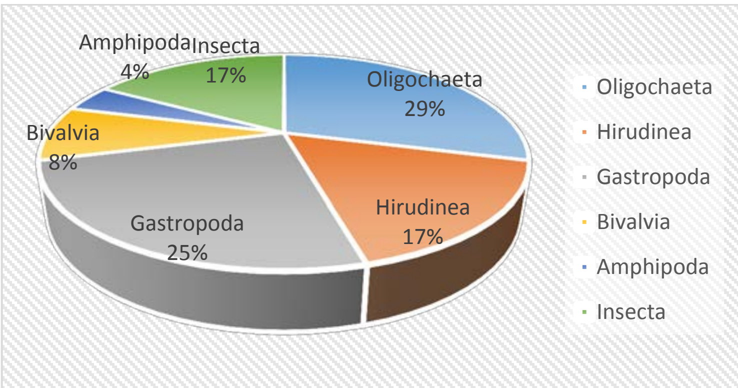

Figure 3.9. Participation of the particular groups within the total biodiversity in Ezerani

From the Table 3.2. it is obvious that the qualitative composition of the benthic fauna is slightly poorer than in Oteshevo. Here 24 species have been identified from 6 systematic groups. The qualitative composition is poorer both in the range of species (3 species less than in Oteshevo) and in the range of classes: Turbellaria and Isopoda have not been registered in this locality throughout the whole period of research. Qualitatively, among the 6 classes, the most diverse is the class of Oligochaeta with 7 species. Right after is Gastropoda with 6 species, then Hirudinea and Insecta with 4 species. Least present is the group of Amphipoda with only 1 species (Figure 3.9)

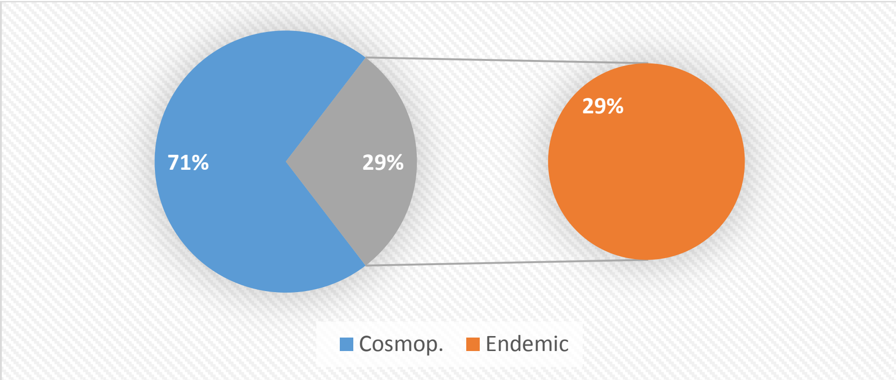

Figure 3.10. The cosmopolitans/endemics ratio in Ezerani

The ratio cosmopolitan/endemic, as shown on the Figure 3.10 is shifted on the side of the cosmopolitan species. Thus, even 71 % (17 species) of the registered species are cosmopolitan, while 29 % or 7 species are endemic, which is pretty similar with the ratio registered in Oteshevo. Again, the highest number (57%) of endemic species are from the group of Gastropoda.

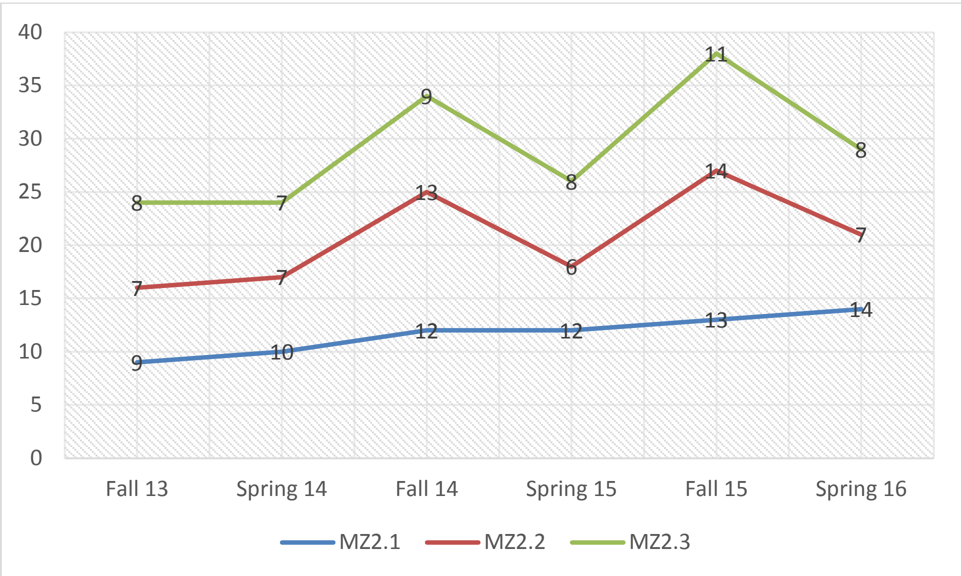

Figure 3.11. Seasonal variation of the species composition in Ezerani

Figure 3.11 clearly states that the qualitative composition of the benthic fauna depends on the seasons and has proper seasonal variations, which is well expressed in MZ2.2 and MZ2.3 and slightly irregular in MZ2.1. Thus the qualitative composition increases in fall and decreases in spring.

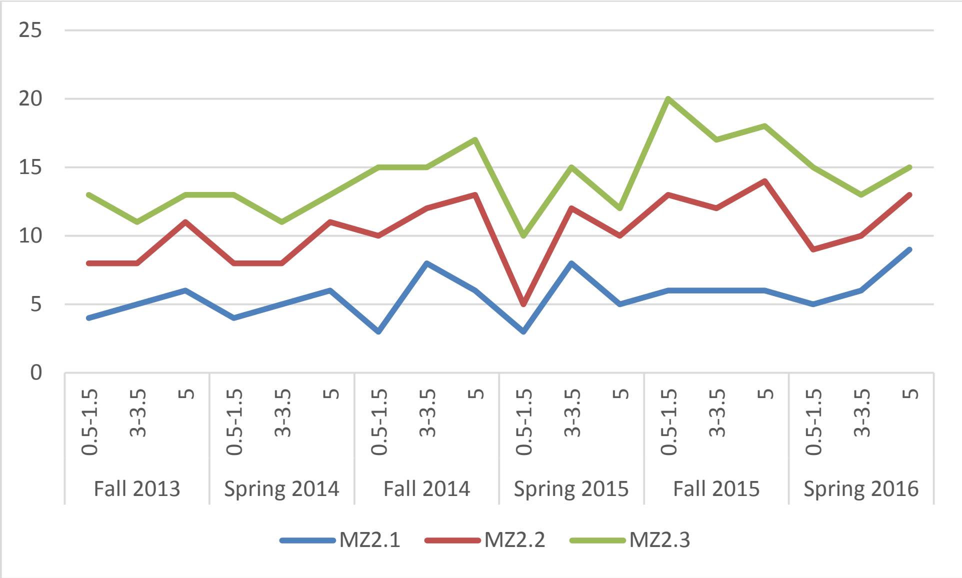

Figure 3.12. Seasonal/depth variations of the species composition in Ezerani

Beside the seasonal correlation, the qualitative composition also depends of the depth. This correlation is shown on the Figure 3.12. In most of the depth points the qualitative composition increases in the shallowest points, then decreases on 3-3.5m, while again increases on 5.

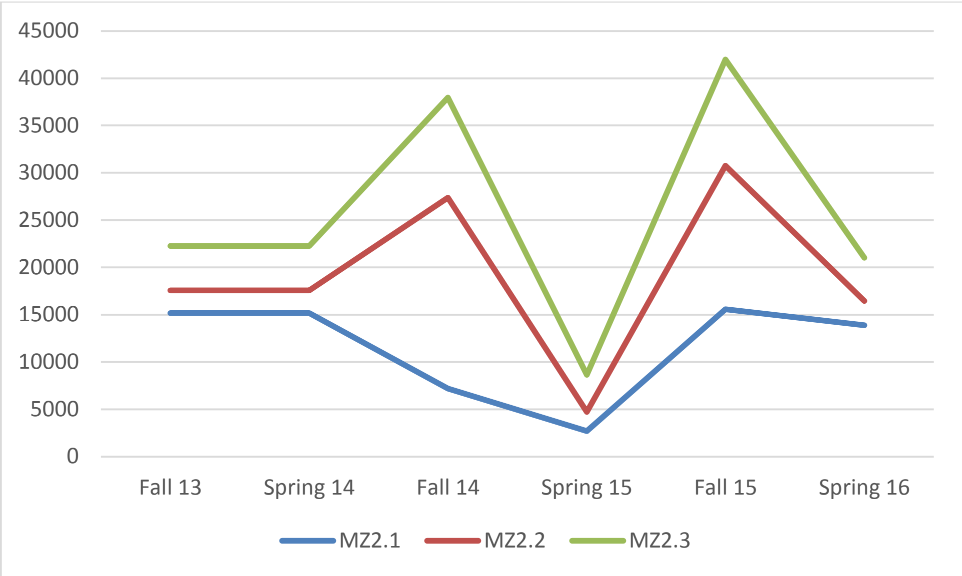

Figure 3.13. Seasonal Density variation of the benthic fauna in Ezerani

The only sharp deviation from this variation pattern is visible in Spring 2015, on all localities on 0.5-1.5m. Such deviation could be explained by the mechanical action of the waves which strength is highest on the shore and shallowest sampling points. More concrete, the mechanical action of the waves has probably replaced deeper the species populations having their life cycle either in free water or on the surface of the sediment. The only present are the species inhabiting the sediments layers.

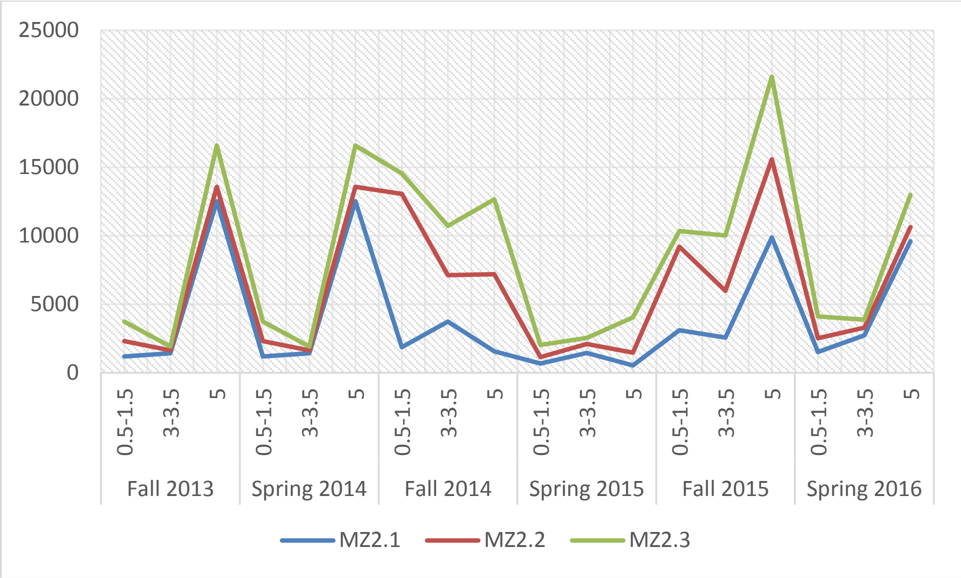

Figure 3.14. Depth and seasonal density variation of the benthic fauna in Ezerani

The poor qualitative composition of the benthic fauna registered in Spring 2015 has reflected in the general density of the benthic fauna. Thus, from the Figures 3.13-3.14 it is visible that there is an enhanced decreasing in the overall density of the benthic fauna in this season on all transects, which is also visible on the particular depth points. Beside this irregularity, the overall density regularly is higher in fall, i.e. it is higher on the shallower depth points, then decreases and increases again on 5 m.

The ASPT index values are within the boundaries indicative for very poor to poor status. Precisely, during the whole research period, with an exception in Spring 2014, the ecological status is very poor. In spring 2014 the ecological status improves in all transects reaching poor ecological status in MZ2.1 and MZ2.3, i.e. poor ecological status in MZ2.2. This short term improving in the ecological status which coincided with the spring season could be explained with the spring circulation of the water which consequently leads to better oxygenation of the water and food availability (Figure 3.15).

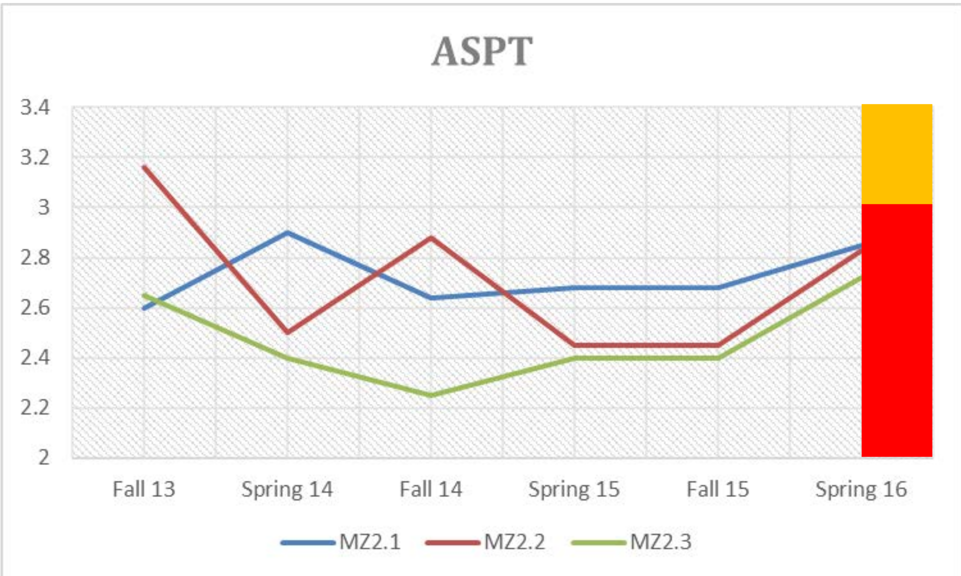

Figure 3.15. ASPT variation in Ezerani

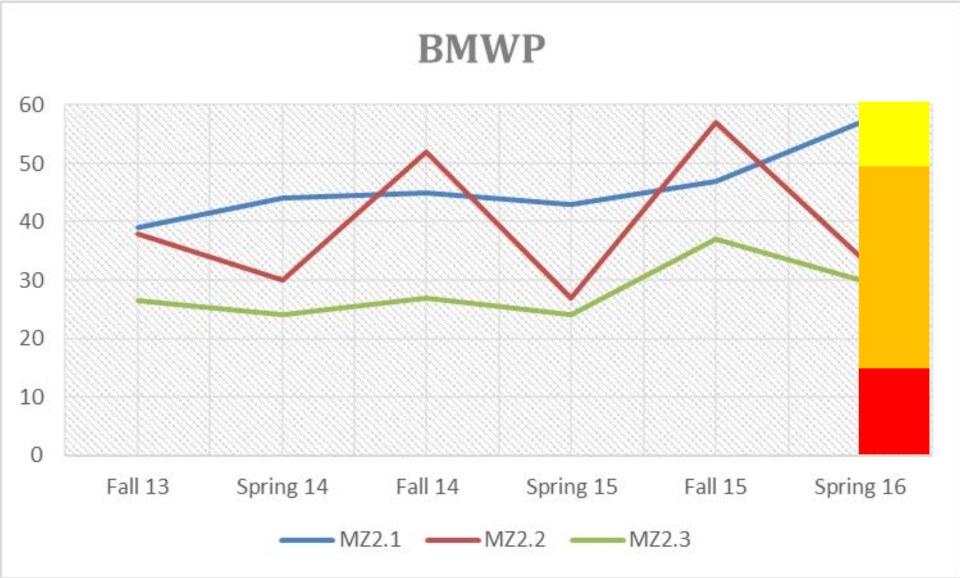

Figure 3.16. BMWP variation in Ezerani

Based on the BMWP scoring, the sampling transects are almost the whole research period within the boundaries indicative for poor ecological status. Exemptions are the transect MZ2.2 in Fall 2014 and MZ2.1 in Spring 2016 with moderate ecological status. As it was case with Oteshevo, the ecological status in Ezerani doesn't meet the requirement of EWFD for good ecological status. The values of both ASPT and BMWP indicate disturbed trophic status and certain level of pollution which has reflected on the structure and composition of the benthic fauna. From that point of view, it would be worth mentioning that the most abundant species are those belonging to the groups with low sensitive abilities on the decreased oxygen concentration and pollution such as: *Limnodrilus hoffmeisteri* or species such as *Dreissena presbensis, Gammarus triacanthus presbensis* which have been considered as indicator species with moderate sensitivity to pollution.

3.1.3.:Krani MZ3

In Krani, throughout the whole research period, 108 samples from the benthic fauna have been collected from 3 transects. Three sampling (depths) have been considered per each transect: 0.5-1.5, 3-3.5 and 5m. Several bottom habitats (facies) have been identified: on 0.5-1.5 –sandy, sandy–muddy, on 3-3.5 mostly sandy, sandy-muddy and muddy and on 5 m the bottom was muddy and muddy sandy. Sandy bottom was observed in most of the sampling depth points from this sampling locality.

Table 3.3. Krani species composition list

Turbellaria
Dendrocoelum prespense (Stankovic, 1969)
Dendrocoelum adenodactylosum (Stankovic & Komarek, 1927)
Oligochaeta
Limnodrilus hoffmeisteri Claparède, 1862
Rhynchelmis komareki Hrabe 1927
Potamotrix hammoniensis (Michaelsen, 1901)
Eiseniella tetraedra (Savigny 1826)
Criodrilus lacuum Hoffmeister 1845
Tubifex tubifex (Otto Friedrich Müller, 1774)
Limnodrilus udekamianus Claparède, 1862
Hirudinea
Erpobdella octoculata (Linnaeus, 1758)
Dina latestriata Neubert & Nesemann 1995

Dina sp.	*Gammarus triacanthus prespensis* (Karman S. & G. 1959)
Gastropoda	*Gammarus sp.*
Valvata piscinalis (Muller, 1774)	**Isopoda**
Bithynia prespensis Hadžišče, 1963	*Asellus aquaticus* (Linnaeus, 1758)
Radix pinteri Schütt, 1974	**Insecta**
Prespolitorea valvataeformis Radoman, 1973	*Chironomus plumosus* (Linnaeus, 1758)
Pyrgohydrobia prespaensis (Urbanski, 1939)	*Leptocerus sp.*
Bithynia sp.	*Limnephilus sp.*
Prespolitorea malaprespensis Radoman, 1973	*Baetis vernis* Curtis, 1834
Bivalvia	*Gomphus vulgatissimus* (Linnaeus, 1758)
Dreissena presbensis Kobelt, 1915	*Glossosoma sp.*
Pisidium sp.	*Ephemera danica* Muller 1764
Sphaerium corneum (Linnaeus, 1758)	*Baetis sp.*
Amphipoda	

Table 3.3. represents the species composition list in Krani locality. Thereafter in Krani, 33 species have been identified belonging to 8 systematic groups. This locality characterizes highest biodiversity among all other sampling localities (Figure 3.17.).

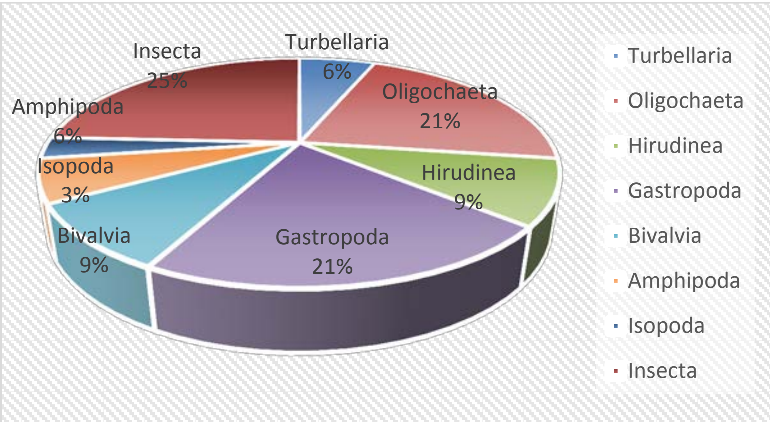

Figure 3.17. Participation of the particular groups within the total biodiversity in Krani

The portion of Insecta within the total biodiversity of Krani locality is highest-8 species out of 33 registered. The second place take the groups Oligocheata and Gastropoda, both represented with 7 species. The lowest is the portion of the Isopoda whereby only one species has been registered.

The ratio cosmopolitan/endemic, as shown on the Figure 3.18 is as usually shifted on the side of the cosmopolitan species. Thus, even 73 % (24 species) of the registered species are cosmopolitan, while 27 % or 9 species are endemic. The highest number, or half of the endemic species come from the class of Gastropoda-4 species. 2 endemic species are from the Turbellaria group while 1 endemic species belong to Bivalvia, Amphipoda and Ologochaeta.

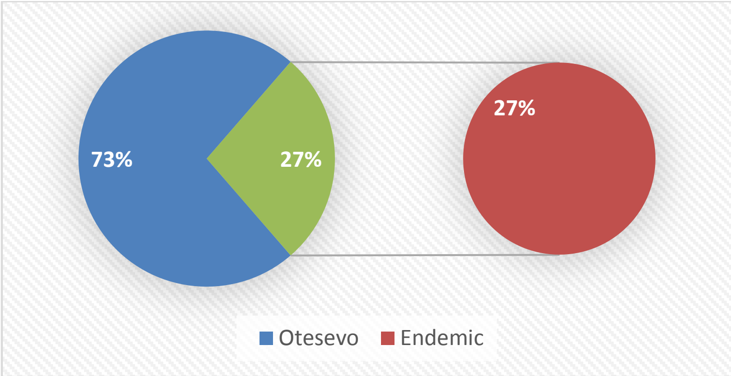

Figure 3.18. The cosmopolitans/endemics ratio in Krani

Figure 3.19 clearly states that the qualitative composition of the benthic fauna depends on the seasons and has proper seasonal variations. Thus the qualitative composition increases in fall and decreases in spring in all three transects in Krani sampling locality.

Beside the seasonal correlation, the qualitative composition also depends of the depth. This correlation is shown on the Figure 3.20. In all depth points the qualitative composition increases in the shallowest points, then decreases on 3-3.5m, while again increases on 5.

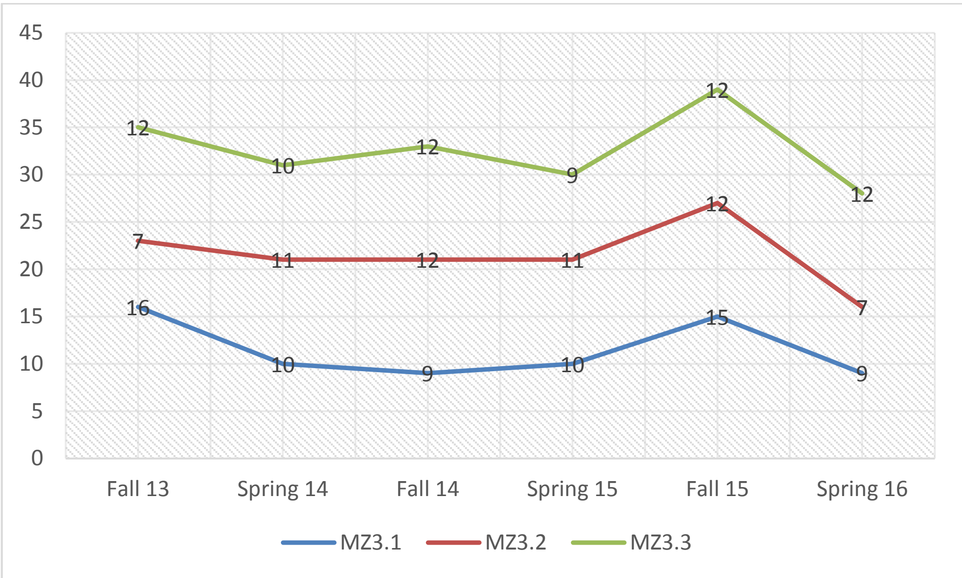

Figure 3.19. Seasonal variation of the species composition in Krani

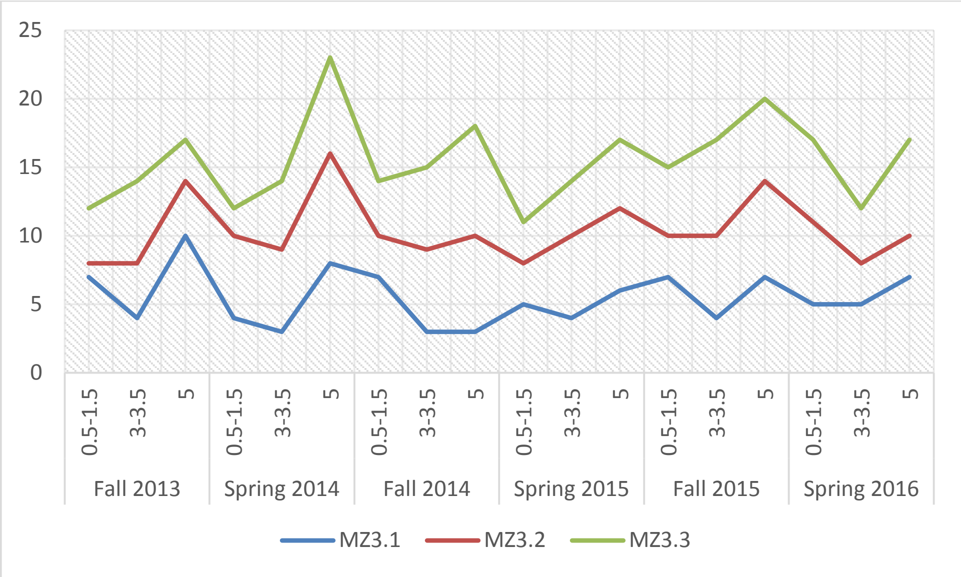

Figure 3.20: Seasonal/depth variation of the species composition in Krani

Figure 3.21 shows the overall density variation throughout the whole research period in Krani. It is well obvious that, as it was a case with the densities in Oteshevo and Ezerani, the fall densities are significantly higher in comparisons with the spring densities.

The same pattern in the variation of the densities could be observed during the seasons i.e. research period at different depth points. Thus, the spring values are always lower than the fall ones, while, in general the densities with depth has the same pattern as in Oteshevo and Ezerani (Figure 3.22): They increase on the depth points in the shallower zone, then decrease with the increasing of the depth till 3,5 m, and again, going deeper to 5 m the densities almost everywhere are getting higher values.

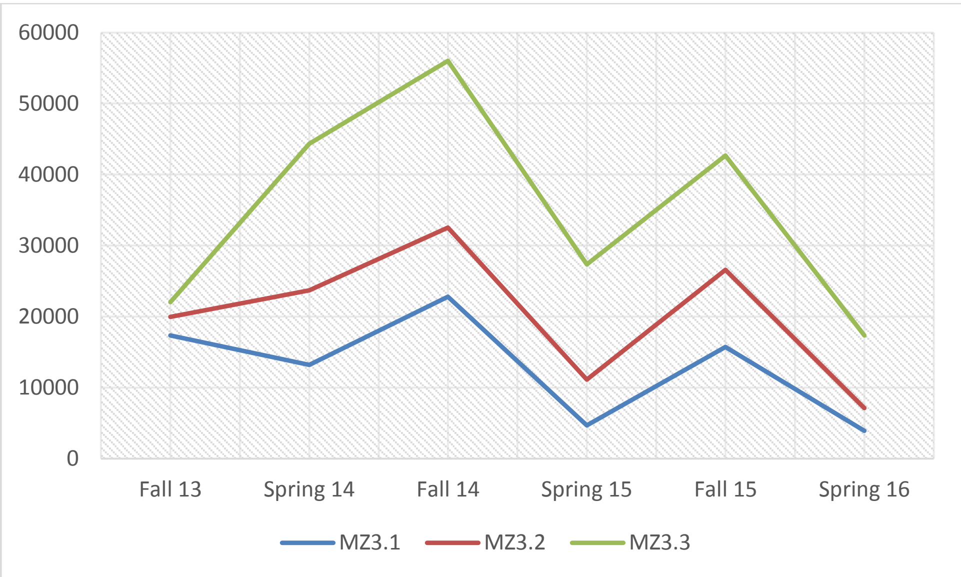

Figure 3.21. Seasonal Density variation of the benthic fauna in Krani

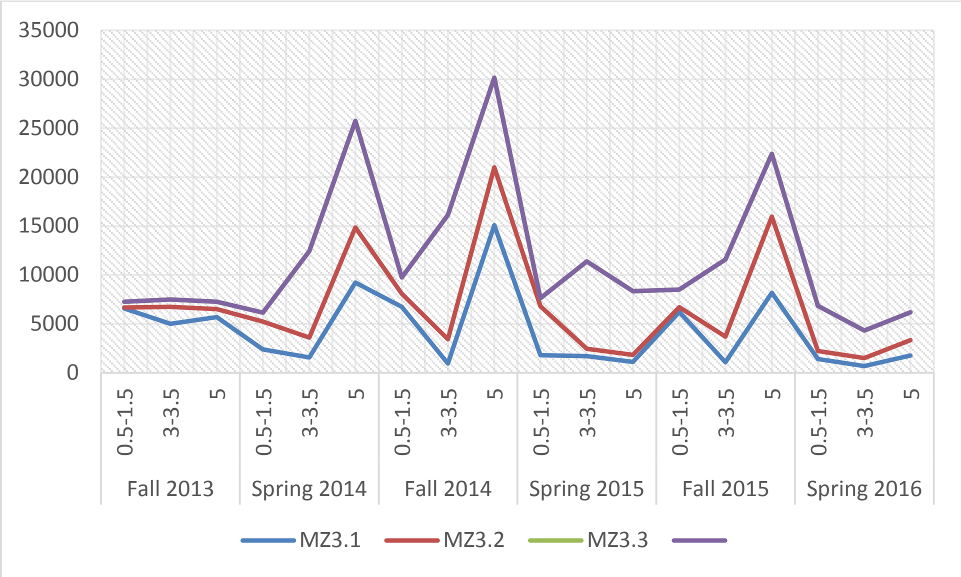

Figure 3.22. Seasonal density variation of the benthic fauna on different depth points in Krani

The ASPT values, despite still far below the good ecological status, are significantly better compared with the localities and Ezerani. Here, MZ3.3. with an exception in Spring 2016, the whole research period is in the boundaries of poor ecological status. The transect MZ3.1 during the whole research period has 4 times been assessed with poor ecological status while MZ3.2 only once.

Regarding the BMWP scoring, both the localities MZ3.1. and MZ3.3. have been assessed with moderate ecological status throughout the six seasons of research period, which again refers about improved ecological status in comparisons with Oteshevo and Ezerani, but still far below the good ecological status as an objective of the European Water Framework Directive.

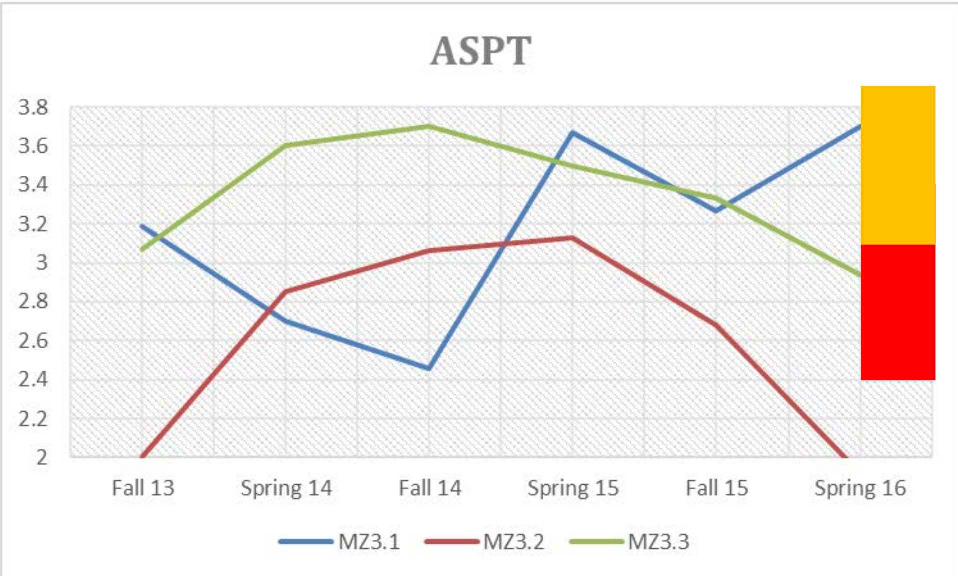

Figure 3.23. ASPT variations in Krani

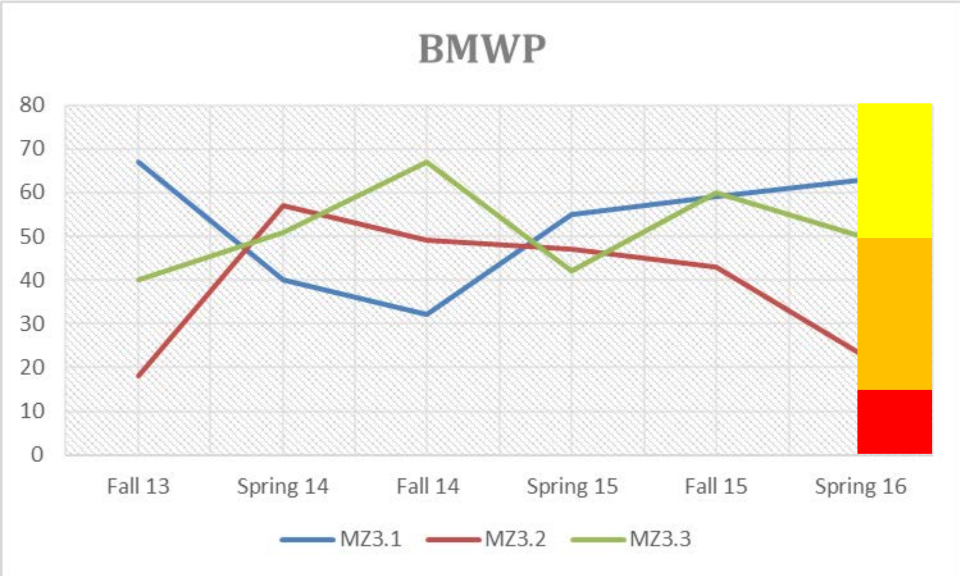

Figure 3.24. BMWP variations in Krani

The most abundant species in Krani are *Dreissena presbensis, Valvata piscinalis, Gammarus traicanthus prespensis*. What is interesting for this site is appearance of highest number of species from Insecta characterized with higher sensitivity of pollution of the water: *Ephemera danica*, *Glossosoma sp., Baetis vernis, Gomphus vulgatissimus* and few others. This imply to slight improvement in the water quality in comparison with Oteshevo and especially Ezerani.

3.1.4.: Nakolec MZ4

In Nakolec, throughout the whole research period, 108 samples from the benthic fauna have been collected from 3 transects. Three sampling (depths) have been considered per each transect covered by the following substrates (habitats): 0.5-1.5- sandy-muddy; 3-3.5 sandy-muddy, muddy, muddy-sandy and 5m- muddy and muddy-sandy.

Table 3.4. Nakolec species composition list

Turbellaria
Dendrocoelum prespense (Stankovic, 1969)
Dendrocoelum maculatum (Stankovic & Komarek, 1927)
Oligochaeta
Limnodrilus hoffmeisteri Claparède, 186
Rhynchelmis komareki Hrabe 1927
Potamotrix hammoniensis (Michaelsen, 1901)
Eiseniella tetraedra (Savigny 1826)
Tubifex tubifex (Otto Friedrich Müller, 1774)
Hirudinea
Erpobdella octoculata (Linnaeus, 1758)
Glossiphonia complanata (Linnaeus, 1758)
Dina sp.
Piscicola geometra (Linnaeus, 1758)
Gastropoda
Valvata piscinalis (Muller, 1774)
Bithynia prespensis Hadžišče, 1963
Pyrgohydrobia prespaensis (Urbanski, 1939)
Bithynia tentaculata (Linnaeus, 1758)
Parabythinella malaprespensis Radoman 1973
Bithynia sp.
Gyraulus stankovici Hadzisce, 1955
Bivalvia
Dreissena presbensis Kobelt, 1915
Pisidium sp.
Amphipoda
Gammarus triacanthus prespensis (Karman S. & G. 1959)
Isopoda
Asellus aquaticus (Linnaeus, 1758)
Insecta
Chironomus plumosus (Linnaeus, 1758)
Limnephilus sp.
Baetis vernis Curtis, 1834
Caenis macrura Stephens, 1836

The species composition in Nakolec is presented in the Table 3.4. 26 species have been identified from 8 systematic groups. Quantitatively predominates the group of Gastropoda participating with 27 % within the total biodiversity of the locality of Nakolec. The second place takess the group of Oligochaeta (19%) while Insecta and Huridinea make 15 % each in the total biodiversity (Figure 3.25.).

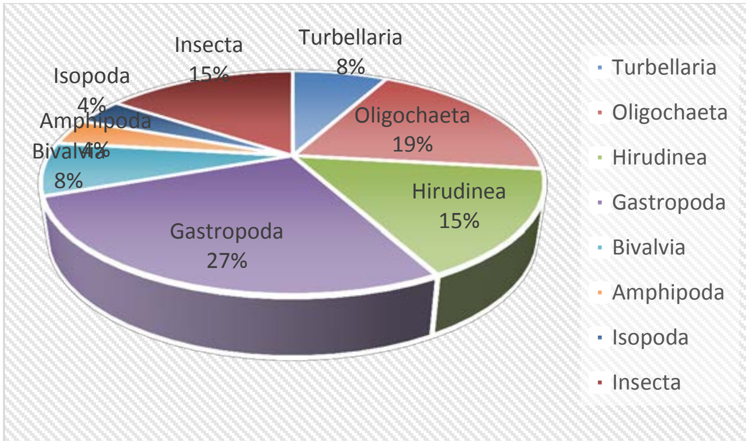

Figure 3.25. Participation of the particular groups within the total biodiversity in Nakolec

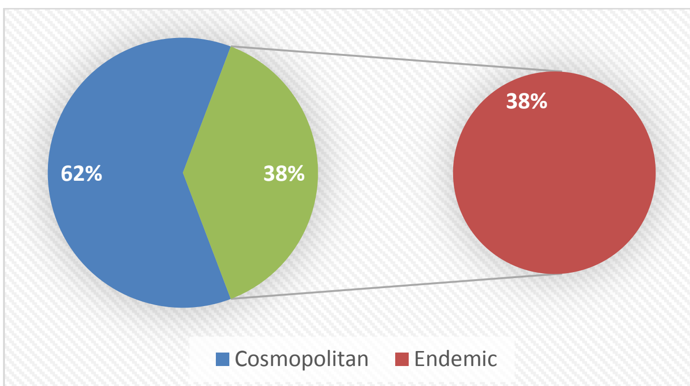

Figure 3.26. The cosmopolitans/endemics ratio in Nakolec.

The ratio between the cosmopolitan and endemic species is still shifted on the side of the cosmopolitan species, but the portion of the endemic has increased in comparison with other three localities. Here, the number of endemics has increased to 38% (Figure 3.26). The composition of the endemic species is as follow: 4 endemics are from Gastropoda, 2 from Turbellaria and one from Bivlavia, Amphipoda, Hirudinea and Oligochaeta.

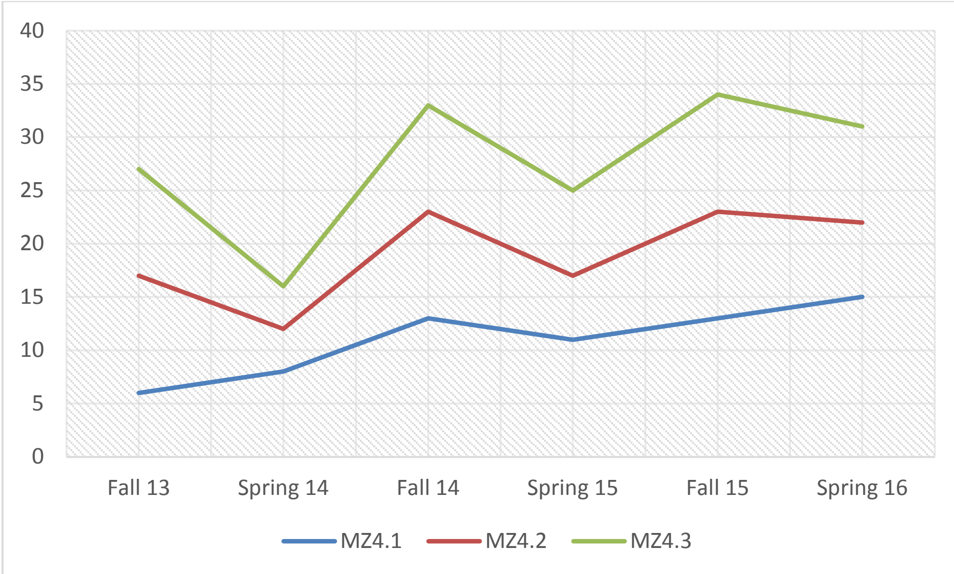

Figure 3.27. Seasonal variation of the species composition in Nakolec

The species composition as it was case with the other three localities is characterized by even seasonal distribution: it clearly increases during the fall and decreases in the spring (Figure 3.27.).

Regarding the variation of the species composition with increasing the depth, it shows the same trend as it was observed in the other three localities i.e. the species composition is higher on the shallower depths, than it drops going to 3-3.5m and increases going to the depth point of 5 m. Seasonal influence in the species composition along the different depth points is noticed too i.e. the species composition values on different depth points along the transects are higher in the fall season then in spring seasons (Figure 3.28.).

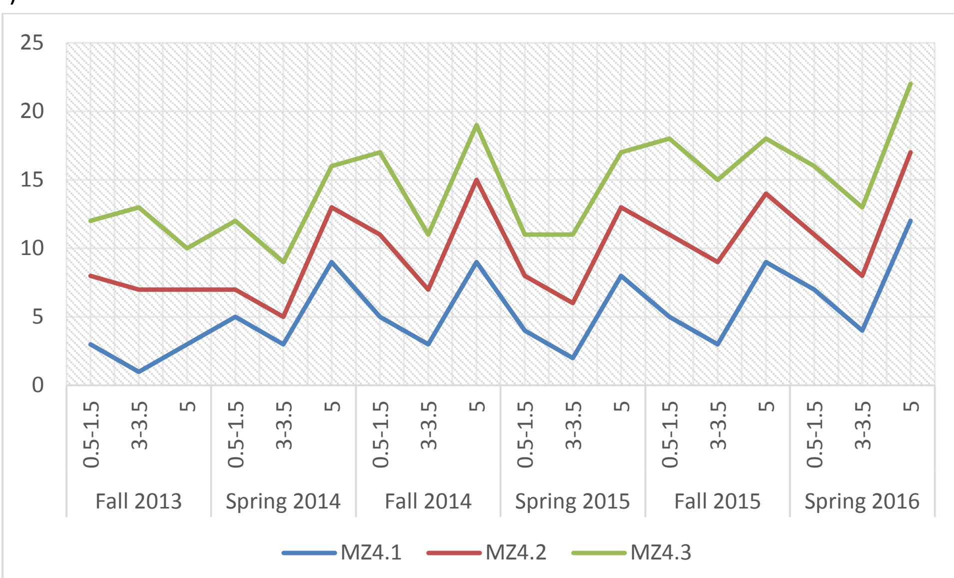

Figure 3.28. Seasonal/depth variation of the species composition in Nakolec

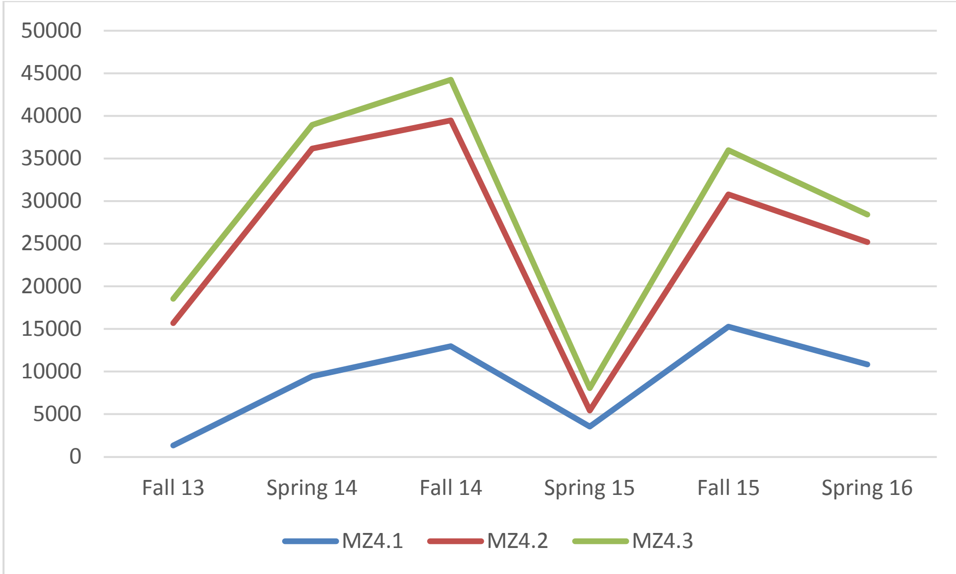

Figure 3.29. Seasonal density variation of the benthic fauna in Nakolec

The seasonal variations in the density of the benthic fauna in Nakolec are shown on the Figure 3.28. In general, the fall densities are higher than the spring ones. A very sharp decrease in the overall density in all three transects in Nakolec has been registered in Spring 2015. The raisons could be, as discusses already, mechanical displacing of the fauna by the waves into the deeper water layers.

In Nakolec, in MZ4.2 and MZ4.3, the density depth variations have irregular trend in Spring 2014 and Fall 2015. Hereafter, the highest densities have been recorded on 3-3.5 m, which is deviation from the already observed patter in the distribution of the density whereby it was lowest on 3.5. The other deviation is related with the season. The highest values are recorded in Spring 2015 (Figure 3.30). During the rest of the research period the fluctuations are even i.e. the highest values are always characteristic for fall periods and lowest densities have been recorded on 3.5 m depth point.

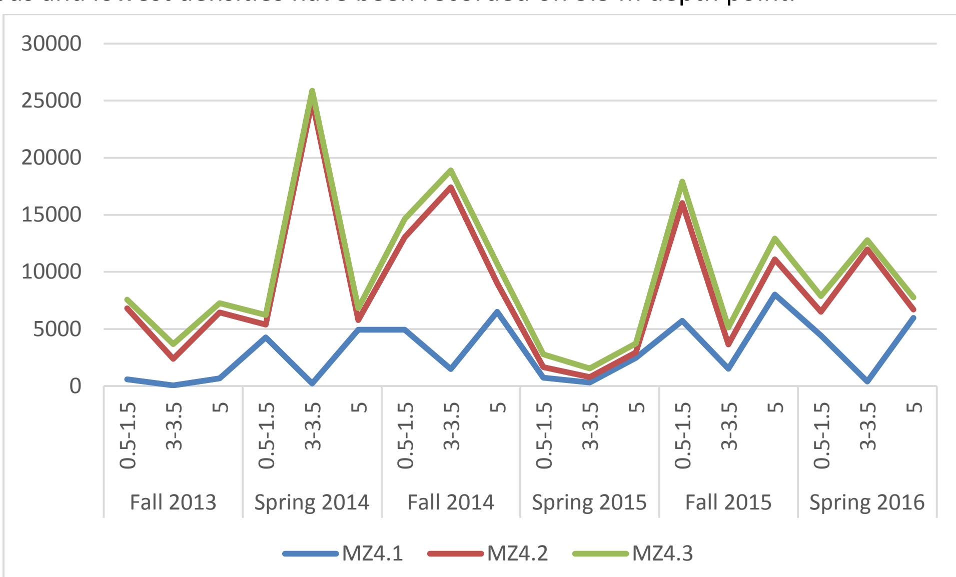

Figure 3.30. Seasonal/depth density variation of the benthic fauna in Nakolec

The ASPT values in Nakolec are in general higher than in the rest of the localities but, still, below the values indicating good ecological status. Thus, the transects MZ4.1 and MZ4.3, 4 times have been assessed with poor ecological status while three times with poor ecological status has been assessed the transect MZ4.2. This point out to the conclusion that the ecological status of the localities on the eastern, south-eastern part of Lake Prespa is a class better than on the north-western sites (Figure 3.31)

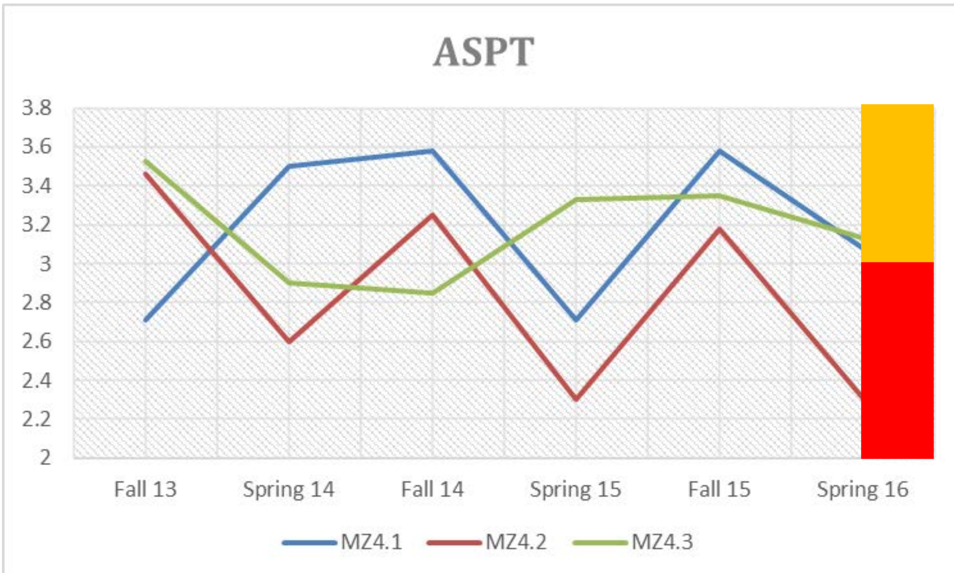

Figure 3.31. ASPT variations in the locality of Nakolec

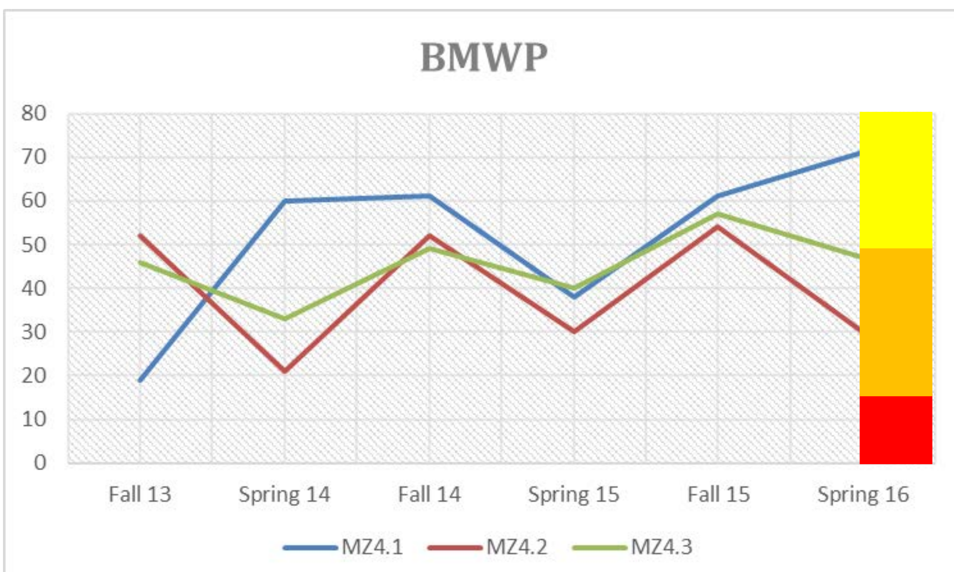

Figure 3.32. BMWP variations in the locality of Nakolec

The highest density has been recorded in the population of *Pyrgohidrobia prespaensis*, while the other most abundant species are: *Dreissena presbensis, Gammarus triacanthus prespensis, Chironomus* *plumosus* etc. Few species with higher sensitivity on pollution have been recorded in the samples (*Caenis macrura, Baetis vernis*) which is a sign of slight improvement of the water quality.

3.2. Conclusions

Based on the above presented results the following conclusions could be delivered:

- The benthic fauna of Prespa Lake, based on the obtained results from the research localities, is significantly poorer than the respective one of its sister lake-Lake Ohrid;
- 46 species from 8 systematic groups (Turbellaria, Oligochaeta, Hirudinea, Gastropoda, Bivalvia, Amphipoda, Isopoda and Insecta) have been identified throughout the full research period;
- The horizontal distribution of the biodiversity of the benthic fauna differs in different regions of the Lake: it is higher in the south eastern part than in the north-western part of the Lake;
- The highest biodiversity has been registered in the locality of Krani-33 species, which is almost 72% of the total 46 registered species;
- The biodiversity within the systematic groups is highest in the group of Insecta 12 species, then Gastropoda- 11 species, Oligochaeta-8 species, Hirudinea-5; Bivalvia-4; Turbellaria-3; Amphipoda-2; Isopoda-1 species;
- The ratio between endemic and cosmopolitan species is always shifted on the side of the cosmopolitan spices;
- The level of endemic species is significantly lower in comparisons with the respective endemic species in its sister lake –Lake Ohrid;
- The percent of endemism differs in different parts of the Lake. It increases going from the north-western to the south-eastern part of the Lake;
- The highest endemism has been recorded in the locality of Nakolec: 38 % of the total species are endemics. The second highest endemism has been registered in Oteshevo (29 %), then Ezerani (29%) and Krani (27%);
- Unlike the diversity which is highest in the class of Insecta, the highest number of endemic species are from group of Gastropoda;
- The species diversity variations have seasonal character:They are always higher in fall seasons than in the spring ones;
- A gradient in the depth distribution of the biodiversity of the benthic fauna has been registered almost in all transects and seasons. Thus, the species number it is highest on the shallowest depths, then decreases with the increasing on the depth till 3.5 m. Going deeper it increases again but never reaches the values from the shallowest depths;
- The density of the benthic fauna also depends on the season, i.e. it is always higher during the fall and lower during the spring periods.

- The density variations have, beside seasonal, depth gradient I.e. the densities are highest on 05-1.5m, then decreases and increase again on 5 m;
- None of the researched localities, neither transects have met the objective of the WFD for good ecological status;
- The ASPT indexes as reflection of the level of the pollution (through the community structure health) varied horizontally, but no proper seasonal correlation has been observed during the researched period;
- The values of ASPT index, varies within the boundaries of 2-4 which is indicative for poor and very poor ecological status;
- Based on the BMWP scoring, the ecological status of the researched localities varies between very poor to moderate ecological status;
- The ecological status of the localities of the north- western part of the Lake is lower than of the localities on the south-eastern part of the Lake;
- The lowest ecological status has been observed in Ezerani, then Oteshevo, then Krani and Nakolec.

4. Lake Prespa fish fauna

Twenty species of fish are present in Lake Prespa. Thirteen of these are indigenous, while the remaining seven are alien species that have been introduced. (Five other alien species were recorded in the second half of the twentieth century but these are no longer found amongst the fish fauna of the Lake Prespa. (Table 4.1.)

Table 4.1. Lake Prespa fish species (native and alien)

No.	Species Latin name	Species common name	native species	alien species	alien species recorded in the past
1	Alburnoides prespensis (Karaman, 1924)	Prespa spirlin	+		
2	Alburnus belvica Karaman, 1924	Prespa bleak	+		
3	Anguila anguila (Linnaeus, 1758)	European eel	+		
4	Barbatula sturanyi (Steindachner, 1892)	Stone loach	+		
5	Barbus prespensis Karaman, 1924	Prespa barbell	+		
6	Carassius gibelio (Bloch, 1782)	Prussian carp		+	
7	Chondrostoma prespensis Karaman, 1924	Prespa nase	+		
8	Cobitis meridionalis Karaman, 1924	Spined loach	+		
9	Ctenopharyngodon idella (Valanncienes, 1844)	Grass carp			+
10	Cyprinus carpio Linnaeus, 1758	Carp	+		
11	Gambusia holbrooki Girard, 1859	Mosquito fish		+	
12	Hypophtalmichthys molotrix (Valanncienes, 1844)	Silver carp			+
13	Lepomis gibbosus (Linnaeus, 1758)	Pumpkinseed		+	
14	Oncorhynchus mykiss (Walbaum, 1792)	Rainbow trout			+
15	Parabramis pekinensis (Basilewsky, 1855)	Bream			+
16	Pelasgus prespensis (Karaman, 1924)	Prespa minnow	+		
17	Phoxinus lumaireul (Schinz, 1840)	Minnow	+		
18	Pseudorasbora parva (Temminck & Schlegel, 1846)	Stone moroko		+	
19	Rhodeus amarus (Bloch, 1782)	Bitterling		+	
20	Rutilus prespensis (Karaman, 1924)	Prespa roach	+		
21	Salmo peristericus Karaman, 1938	Prespa trout	+		
22	Salmo letnica (Karaman, 1924)	Lake Ohrid trout			+
23	Silurus glanis Linnaeus, 1758	Catfish		+	
24	Squalius prespensis (Fowler, 1977)	Prespa chub	+		
25	Tinca tinca (Linnaeus, 1758)	Tench		+	

From previous investigation and literature twenty-five taxa have been identified in the Prespa Lakes. From 13 native determined, 8 fish species are endemics: *Alburnoides prespensis* (Prespa spirlin), *Alburnus belvica* (bleak), *Barbus prespensis* (Prespa barbell), *Chondrostoma prespensis* (Prespa nase), *Pelasgus prespensis* (Prespa minnow), *Rutilus prespensis* (Prespa roach), *Salmo peristericus* (Prespa trout) and *Squalius prespensis* (Prespa chub). The rest are introduced from which 7 are present and five more recorded in the past, but not present anymore.

The most widely distributed fish in the Lake Prespa at the current time belong to the carp family (*Cyprinidae*). Other native species found are as follows: *Salmonidae* – trout (1); *Cobitidae* – loaches (2); Anguillidae - eels (1).

At present alien species introduced into the lake include the following: *Siluridae* – wells (1); *Poecilidae* (1); *Centrachidae* – perches (1).

The Prespa Lake, taking in consideration the composition of its fish population is typically cyprinid lake. Besides the presence of cyprinid fishes, the Lake contains exemplars of river trout *Salmo peristericus*, coming from the rivers Brajchinska, Kranska, Leva and Agios Germanos.

From the native fishes the family Cyprinidae includes 8+1 species: *Rutilus prespensis* - roach, *Pelasgus prespensis* – Prespa minnow, *Squalius prespensis* - chub, *Phoxinus lumaireul* - Eurasian common minnow, *Chondrostoma prespense* - Prespa nase, *Barbus prespensis* – Prespa barbell, *Alburnus belvica* - belvica (nivichka), *Alburnoides prespensis* – Prespa spirlin (shlunec) and *Cyprinus carpio* – carp (which anyway is introduced – alien species, but being present more than 2000 years, in the fishery practice it is accepted as native one).

The family of loaches (Cobitidae) is presented by two species, the spine loach *Cobitis meridionalis* and the stone loach *Barbatula sturany*.

The family Anguillidae is presented by one species, the European eel *Anguilla anguilla*.

As far as allochthonous (introduced species) are concerned, for more than 12 years we can notice the presence of the catfish *Silurus glanis* and there are some caught exemplars weighting up to 36 kilograms.

The prucian carp, *Carassius gibelio* has been present for more than two decades and can also be fished.

The sunfish *Lepomis gibosus* is present more than one decade and it is very common since it can be caught in all fishing nets.

Also *Pseudorasbora parva* – stone moroko, *Gambusia holbrooki* – mosquito fish, *Rhodeus amarus* – bitterling and *Tinca tinca* – tench are present alien species in the Prespa fish fauna.

Apart from the above mentioned aliens, during the past another 5 species were recorded as present for a certain period of time. These are: *Salmo letnica* – Lake Ohrid trout, *Oncorhynchus mykiss* - rainbow trout, *Parabramis pekinensis* – white Amur bream, *Ctenopharingedon idella* – grass carp and *Hypophthalmichthys molitrix* – silver carp. None of them can be found at present.

As in the case with other natural lakes, the Prespa Lake has also suffered from great changes regarding the fish ecology and especially regarding the spawning of the bleak and the carp. In the past the bleak was spawning near the coast of the Lake, nowadays the bleak is spawning in the middle areas of the Lake. The carp is in similar situation, varying from year to year.

4.2. Lake Prespa fish monitoring methodology

Having in mind the lake's characteristics, bathymetry, habitat differentiation, and previous long term practise in experimental fishing, lake was divided in 5 sub basins, F1 – 5 (Figure 5.1.).

Fish population sampling was done according to the CEN 14757 standardized protocol, using benthic multi-mesh gillnets which are 30 m long and 1.5 m deep, composed of 12 panels with different mesh sizes ranging from 5 mm to 55 mm from knot to knot in the following order: 43mm, 19.5 mm, 6.25 mm, 10 mm, 55 mm, 8 mm, 12.5 mm, 24 mm, 15.5 mm, 5 mm, 35 mm and 29 mm.

Five sub basins different in habitat substrate, bathymetric configuration, wind exposures, and total ecological condition were sampled. Three sub basins are littoral, one is pelagic and the last one is the deepest point of Lake Prespa.

Sampling procedure of the littoral sub basins was based on stratified random sampling.

Air and water temperature, pH, O_2, transparency – Sechi disk depth and weather conditions were registered.

The Lake Prespa Station Monitoring Boat was used for setting and lifting the nets in all three consecutive years, 48 in total for 2013 for 4 sub basins and 56 for 2014 and 2015 for 5 sub basins.

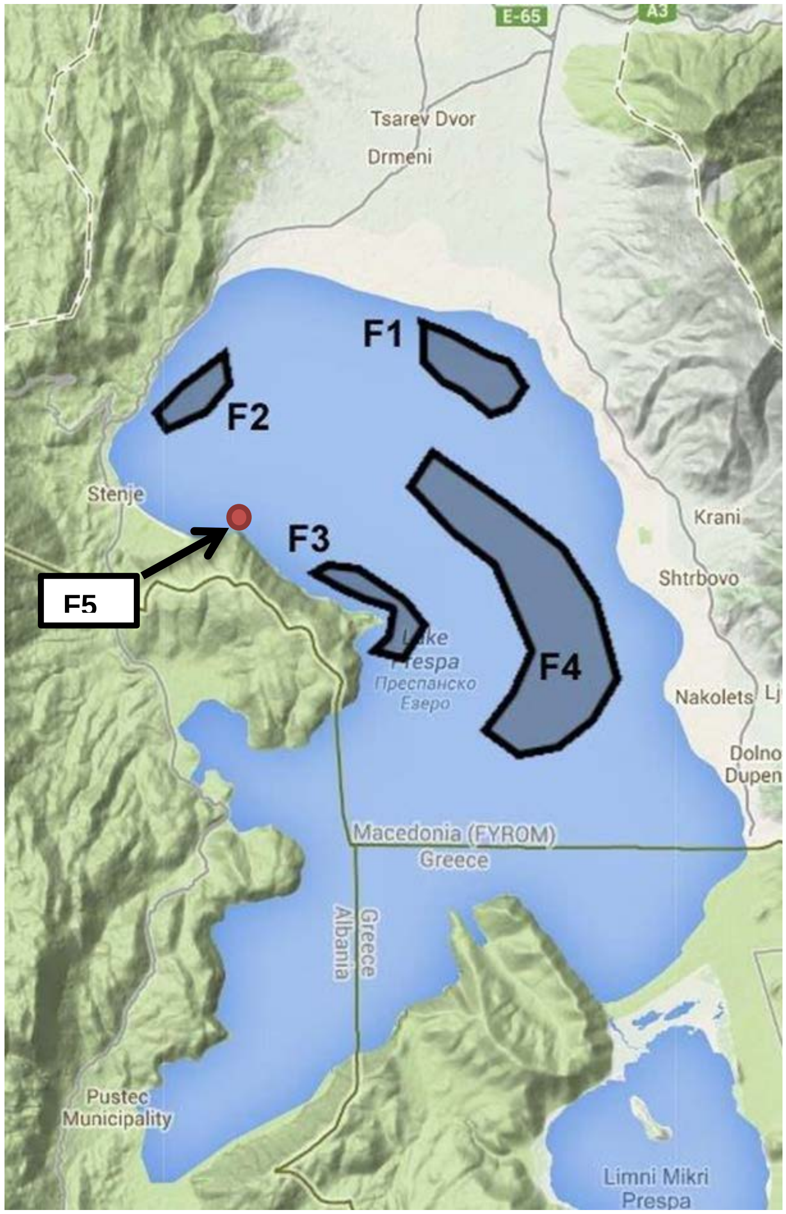

Figure 4.1. Lake Prespa sampling sub basins (F1-F5)

Considering how many individuals per species per net panel were caught, in those sub basins where there were not more than 50 individuals, all caught specimens were measured. In cases where several hundreds of one species were caught per panel, 50 individuals were measured by length and weight and the total weight and number of individuals of the rest was recorded. Weight was measured on a portable balance with accuracy of 0.1 g. Standard and total length were measured to the closest mm and for data processing just total length was used and averaged to the closest cm.

Table 4.2. Lake Prespa sampling sub basins (F1 – 5)

Sub basin (F)	Locality	Position
F1	Asamati	Littoral
F2	Otesevo	Littoral
F3	Konjsko	Littoral
F4	Central plate	Pelagic
F5	Kazan Deepest point	Pelagic

F1 (Asamati) is a locality with the following habitat distribution:

a. From the lake shore up to 1.5 meter there is a fine muddy substrate and the whole area is covered with *Phragmites* (reed belt).
b. From the reed belt on up to 3 meters depth *Potamogeton* and *Myriophyllum* are present and substrate is muddy.
c. Third part of the littoral, from 3 to 6 meters depth is a muddy area.

This locality is under direct pressure from the tributary Golema Reka which is the main source of nutrient load from the agricultural area in its watershed.

F2 (Otesevo) as the previous one has similar habitat distribution, but there is a big ecological difference since there is no tributary present, and also this part of the lake is not part of agricultural area of Prespa Lake watershed.

F3 (Konjsko) is a locality with this habitat description:

a. From the lake shore up to 2.5 meters the substrate is consisted of rocks and gravel and vegetation present in this area is *Phragmites* and *Myriophyllum*.
b. In the zone from 2.5 meters up to 4 meters depth substrate is rocky with gravel and no vegetation.
c. From 4 meter till 12 m depth substrate is sandy.

The **F4 (Central plate)** is a substitution of previously planned sub basin for multi-mesh pelagic nets sampling, and at this sub basin sampling was performed at deeper strata with benthic multi-mesh nets.

The **F5 (Kazan)** the deepest locality at Macro Prespa Lake with maximum depth of 33.2 m, in 2014 was successfully sampled with the proper pelagic nets, obtained from other project.
At this locality, the nets were set from the bottom to the surface in consequent depths rising every six meters towards the surface.

4.3. Results

4.3.1. Fish assemblages

4.3.1.1. F1 Asamati

The F1 sub-basin near the village of Asamati located at the Northeast part of Lake Prespa, regarding the fish fauna composition sampled in consecutive 2013, 2014 and 2015 year in November shows differences as in species composition (native versus alien) and as well as variation in the number of fish species presence with variation between 8 and 10 as presented in table 4.3.

Table 4.3. Fish species composition at sub basin F1 (Asamati)

No.	Species Latin name	Species common name	2013		2014		2015	
	Asamati (F1)		native	alien	native	alien	native	alien
1	Alburnoides prespensis	Prespa spirlin	+		+		+	
2	Alburnus belvica	Prespa bleak	+		+		+	
3	Barbatula sturanyi	Stone loach						
4	Barbus prespensis	Prespa barbell	+					
5	Carassius gibelio	Prussian carp						
6	Chondrostoma prespensis	Prespa nase	+		+		+	
7	Cobitis meridionalis	Spine loach	+		+		+	
8	Cyprinus carpio	Carp	+				+	
9	Gambusia holbrooki	Mosquito fish						
10	Lepomis gibbosus	Pumpkinseed		+		+		+
11	Pelasgus prespensis	Prespa minnow						
12	Phoxinus lumaireul	Minnow						
13	Pseudorasbora parva	Stone moroko		+		+		+
14	Rhodeus amarus	Bitterling		+		+		+
15	Rutilus prespensis	Prespa roach	+		+		+	
16	Salmo peristericus	Prespa trout						
17	Squalius prespensis	Prespa chub					+	
18	Tinca tinca	Tench						
Number of species			7	3	5	3	7	3

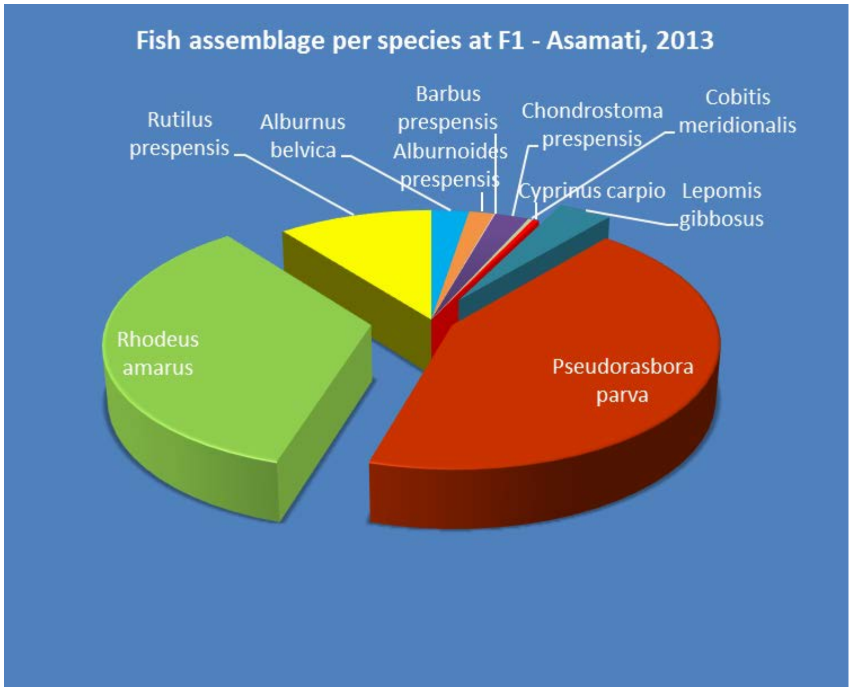

Figure 4.2. Fish assemblage per species at F1 - Asamati, 2013

From Fig. 4.2. dominance of the alien species can be seen, whilst the presence of the native and endemic species to Lake Prespa is scarce. In fact, more than 3/4 of the fish number belongs to the three aliens: *Pseudorasbora parva* (stone moroko)*, Rhodeus amarus* (bitterling) and *Lepomis gibbosus* (pumpkinseed).

In Fig. 4.3. dominance of the native species is quite evident with 3/4th of the total fish number represented by mainly the endemic Prespa bleak, roach, spirlin, nase and the non-endemic - spine loach. The alien species represented with *Pseudorasbora parva* (stone moroko)*, Rhodeus amarus* (bitterling) and *Lepomis gibbosus* (pumpkinseed) are in this case just 1/4th.

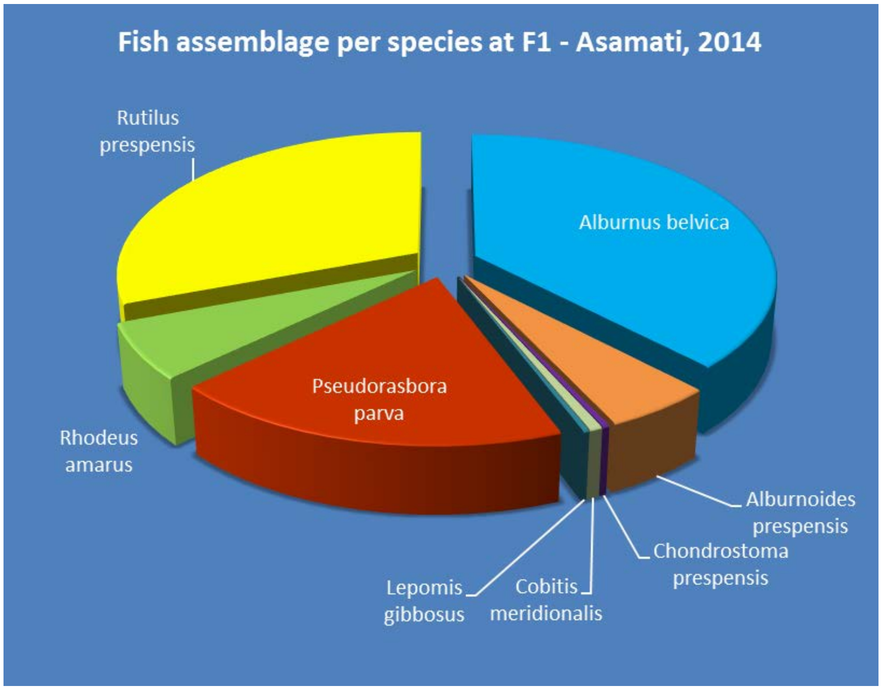

Figure 4.3. Fish assemblage per species at F1 - Asamati, 2014

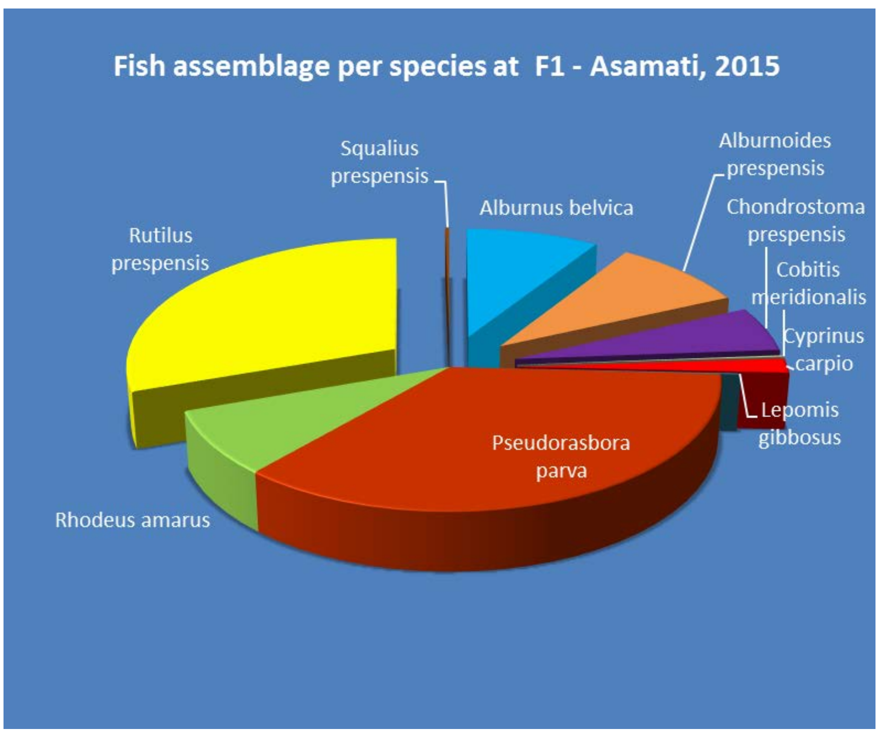

Figure 4.4. Fish assemblage per species at F1 - Asamati, 2015

Dominance of the native species is evident with around 56% of the total fish number represented by mainly the endemic Prespa roach, bleak, spirlin, nase, carp, chub and spine loach. The alien species are represented with *Pseudorasbora parva* (stone moroko), *Rhodeus amarus* (bitterling) and *Lepomis gibbosus* (pumpkinseed) can be seen from Fig. 4.4.

During the monitoring campaigns for the three consecutive years at the locality of Asamati (F1) in 2013 tremendous dominance of alien fish species was recorded whilst in the next 2014 and 2015 year the dominance of the native Prespa fish was evident. It is worth to mention that although the sampling campaigns were in November every year, the water temperature was higher in the last two years than the one in the first year.

4.3.1.2. F2 Otesevo

Table 4.4. Fish species composition at sub basin F2 (Otesevo)

No.	Species Latin name	Species common name	2013		2014		2015	
	Otesevo (F2)		native	alien	native	alien	native	alien
1	Alburnoides prespensis	Prespa spirlin	+		+		+	
2	Alburnus belvica	Prespa bleak	+		+		+	
3	Barbatula sturanyi	Stone loach						
4	Barbus prespensis	Prespa barbell	+		+			
5	Carassius gibelio	Prussian carp				+		+
6	Chondrostoma prespensis	Prespa nase	+		+		+	
7	Cobitis meridionalis	Spine loach			+		+	
8	Cyprinus carpio	Carp	+		+		+	
9	Gambusia holbrooki	Mosquito fish						
10	Lepomis gibbosus	Pumpkinseed		+		+		+
11	Pelasgus prespensis	Prespa minnow	+		+			
12	Phoxinus lumaireul	Minnow						
13	Pseudorasbora parva	Stone moroko		+		+		+
14	Rhodeus amarus	Bitterling		+				+
15	Rutilus prespensis	Prespa roach	+		+		+	
16	Salmo peristericus	Prespa trout						
17	Squalius prespensis	Prespa chub					+	
18	Tinca tinca	Tench						
Number of species			7	3	8	3	7	4

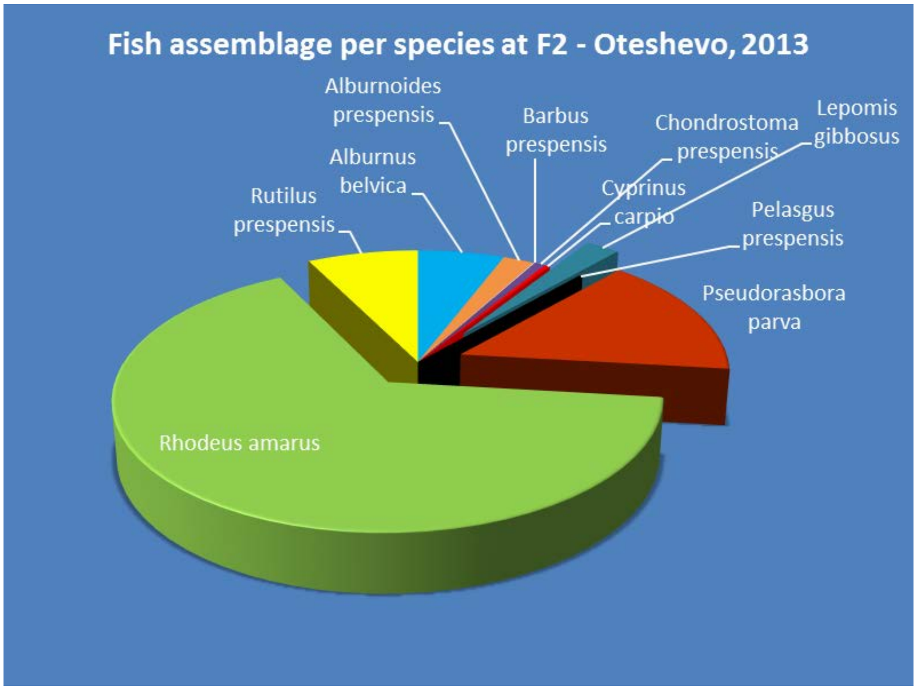

Figure 4.5. Fish assemblage per species at F2 - Otesevo, 2013

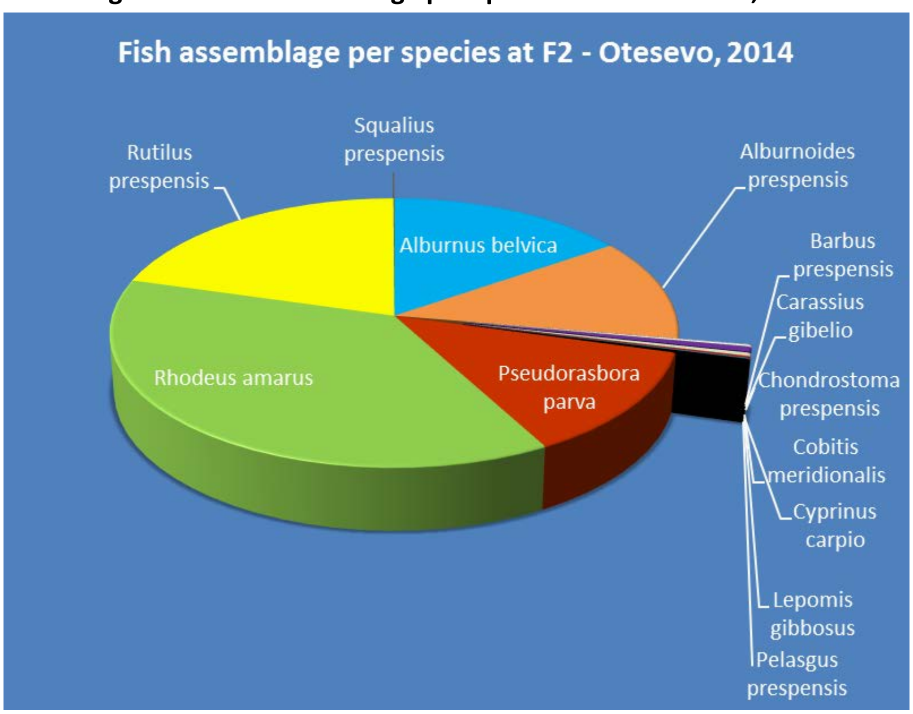

Figure 4.6. Fish assemblage per species at F2 - Otesevo, 2014

From the Fig. 4.5. dominance of the alien species can be clearly seen, mostly of one species *Rhodeus amarus* (bitterling) and the presence of the native and endemic species to Lake Prespa is drastically lower.

At Fig. 4.6 it is very evident almost equal abundance as of the native as well of the alien species. But, as it can be seen the aliens are represented with two small bodies sized species the bitterling and the stone moroko. The pumpkin seed and the silver carp, like aliens are both represented with just few specimens.

Unlike the alien's fish composition at this sub basin, the natives comprise their part of the fish community with 9 species.

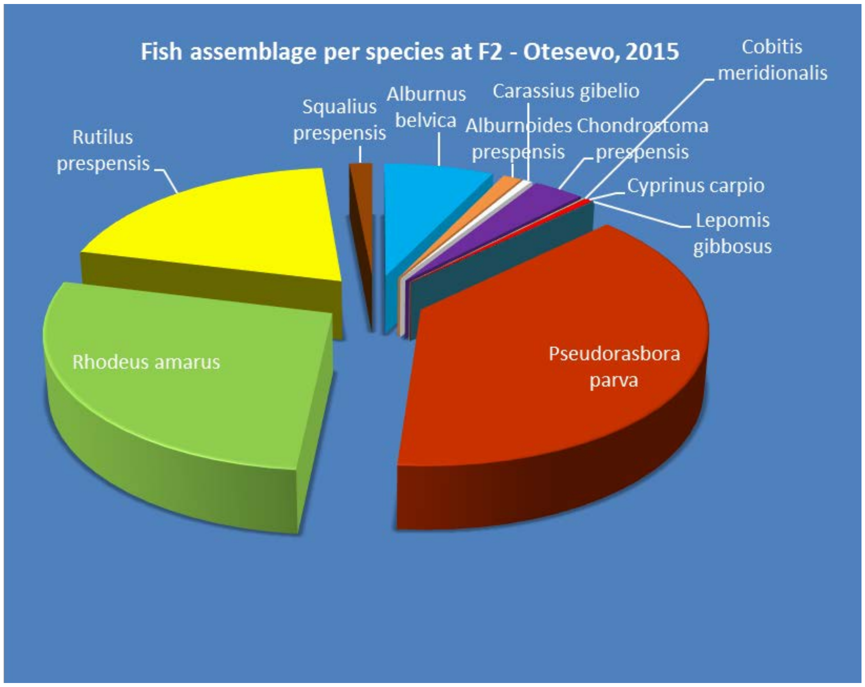

Figure 4.7. Fish assemblage per species at F2 - Otesevo, 2015

From the Fig. 4.7 it is very evident the dominance of the alien species with 2/3 consistent mainly by stone moroko and bitterling, with negligible presence of silver carp and pumpkin seed. Among the native species most abundant are the roach, bleak and Prespa nase.

This sub basin is more diverse then F1 (Asamati) and also sheltered from certain winds, which is in favor of the alien species. Thus, the high abundance of the alien fishes and the evident species composition fluctuations corresponds to the habitat's conditions.

5.3.1.3. F3 Konjsko

Table 4.5. Fish species composition at sub basin F3 (Konjsko)

No.	Species Latin name	Species common name	2013		2014		2015	
	Konjsko (F3)		native	alien	native	alien	native	alien
1	Alburnoides prespensis	Prespa spirlin	+		+		+	
2	Alburnus belvica	Prespa bleak	+		+		+	
3	Barbatula sturanyi	Stone loach						
4	Barbus prespensis	Prespa barbell	+		+		+	
5	Carassius gibelio	Prussian carp				+		
6	Chondrostoma prespensis	Prespa nase	+		+		+	

7	Cobitis meridionalis	Spined loach	+		+		+	
8	Cyprinus carpio	Carp	+		+		+	
9	Gambusia holbrooki	Mosquito fish						
10	Lepomis gibbosus	Pumpkinseed		+		+		+
11	Pelasgus prespensis	Prespa minnow	+		+		+	
12	Phoxinus lumaireul	Minnow						
13	Pseudorasbora parva	Stone moroko		+		+		+
14	Rhodeus amarus	Bitterling		+		+		+
15	Rutilus prespensis	Prespa roach	+		+		+	
16	Salmo peristericus	Prespa trout						
17	Squalius prespensis	Prespa chub			+		+	
18	Tinca tinca	Tench						
Number of species			8	3	9	4	9	3

On the following Fig. 4.8. dominance of the alien species can be clearly seen in this case also but with a bit lower participation from the previous sub-basins of 2/3 of total catch, with respectful dominance of *Rhodeus amarus* (bitterling), *Pseudorasbora parva* (stone moroko) and *Lepomis gibbosus* (pumpkin seed) in this case in 2013.

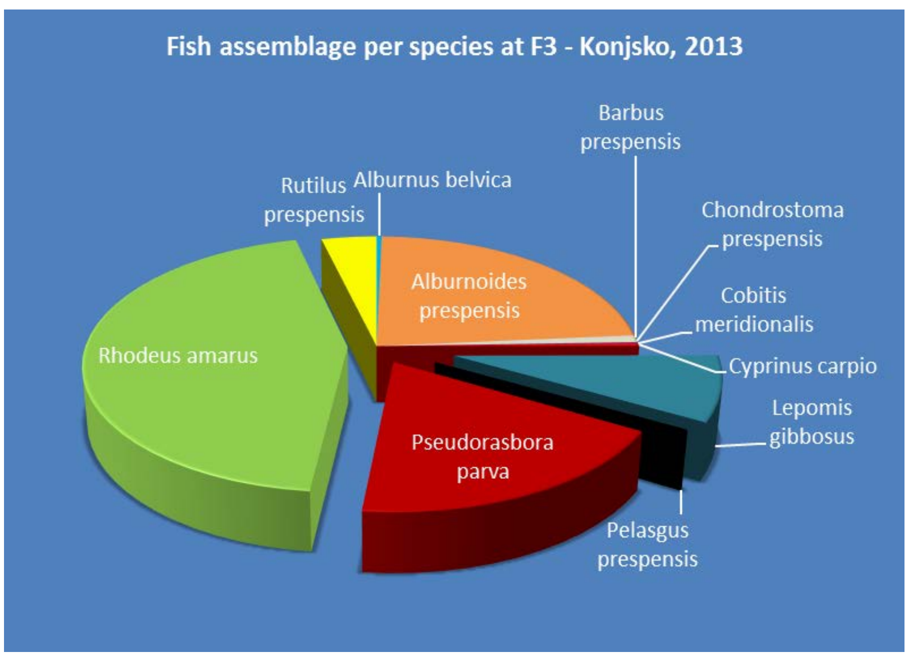

Figure 5.8. Fish assemblage per species at F3 - Konjsko, 2013

At Fig. 4.9. it is clearly expressed the dominance of the three endemic species – the Prespa spirlin, roach and bleak consequently with 63%. The presence of the remaining native species is in low amount of biomass in 2014.

The alien species are participating in the total catch in specimens at this locality with remaining 37%, comprised mainly of bitterling and stone moroko.

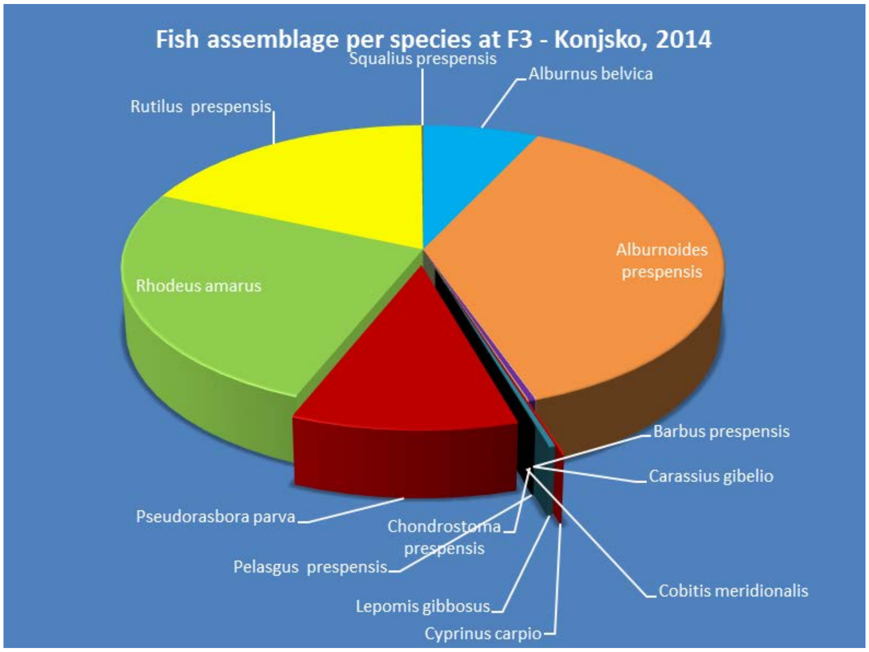

Figure 4.9. Fish assemblage per species at F3 - Konjsko, 2014

On the following Fig. 4.10. it is clearly expressed the dominance of the three endemic species – the Prespa spirlin, roach, nase and belvica consequently with 73%. The presence of the remaining native species is in low amount of biomass.

The alien species are participating in the total biomass catch at Konjsko locality with remaining 27%, comprised mainly of bitterling and stone moroko.

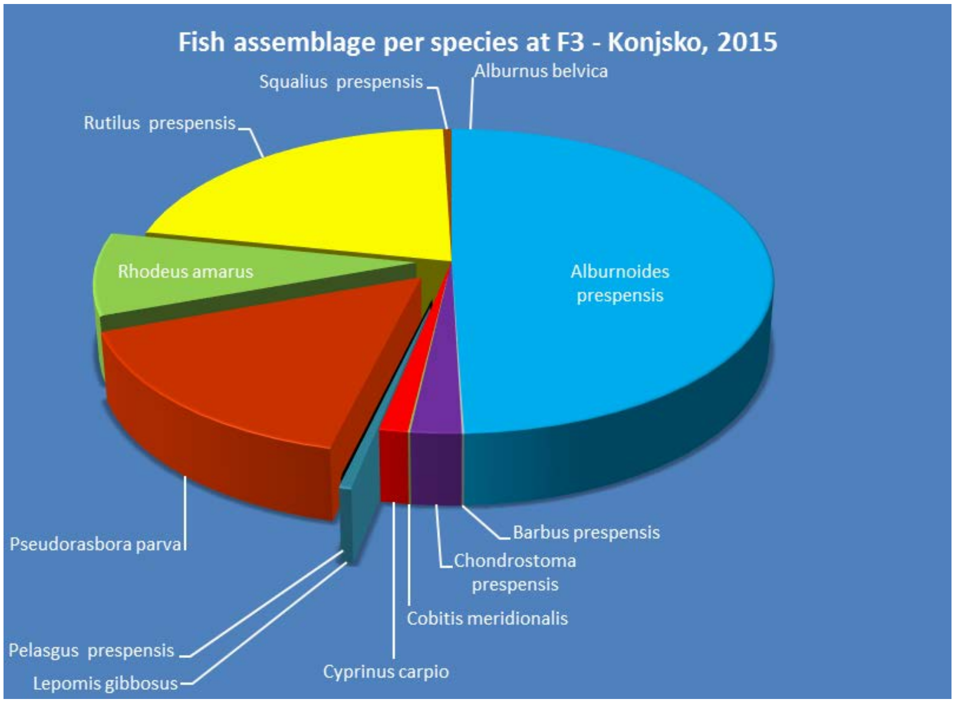

Figure 4.10. Fish assemblage per species F3 Konjsko, 2015

4.3.1.4. F4 Central plate

Table 4.5. Fish species composition at sub basin F4 (Central Plate)

No.	Species Latin name	Species common name	2013		2014		2015	
	Central Plate (F4)		native	alien	native	alien	native	alien
1	Alburnoides prespensis	Prespa spirlin	+		+		+	
2	Alburnus belvica	Prespa bleak	+		+		+	
3	Barbatula sturanyi	Stone loach						
4	Barbus prespensis	Prespa barbell						
5	Carassius gibelio	Prussian carp						
6	Chondrostoma prespensis	Prespa nase	+				+	
7	Cobitis meridionalis	Spined loach			+			
8	Cyprinus carpio	Carp	+				+	
9	Gambusia holbrooki	Mosquito fish						
10	Lepomis gibbosus	Pumpkinseed		+		+		+
11	Pelasgus prespensis	Prespa minnow						
12	Phoxinus lumaireul	Minnow						

13	Pseudorasbora parva	Stone moroko		+		+		+
14	Rhodeus amarus	Bitterling		+		+		
15	Rutilus prespensis	Prespa roach	+		+		+	
16	Salmo peristericus	Prespa trout						
17	Squalius prespensis	Prespa chub						
18	Tinca tinca	Tench						
Number of species			5	3	4	3	5	2

The most dominant species at F4 are two native species *Alburnus belvica* (Prespa bleak) and *Rutilus prespensis* (Prespa roach) and one alien *Lepomis gibbosus* (pumpkinseed).

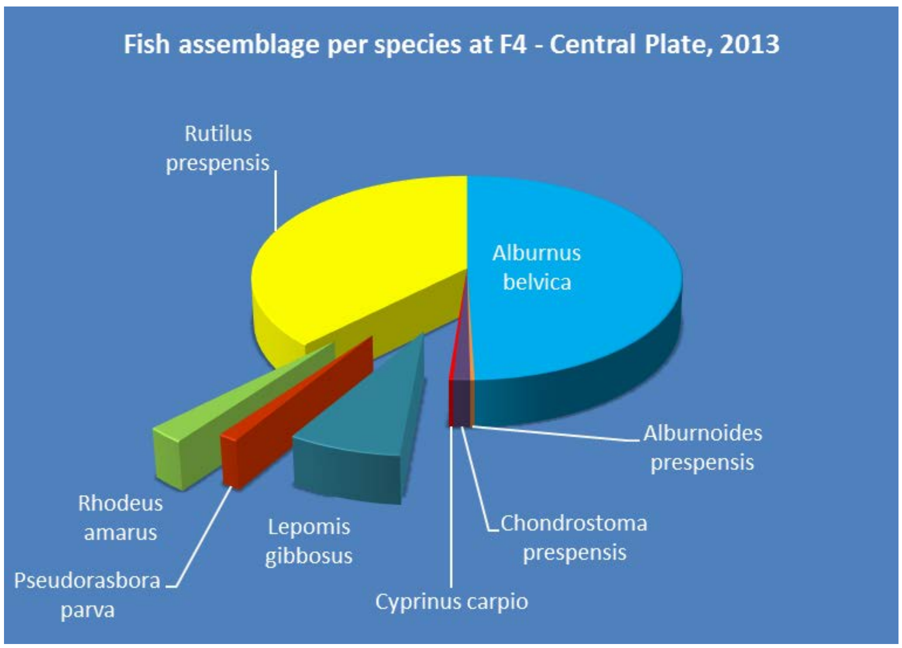

Figure 4.11. Fish assemblage per species F4 Central Plate, 2013

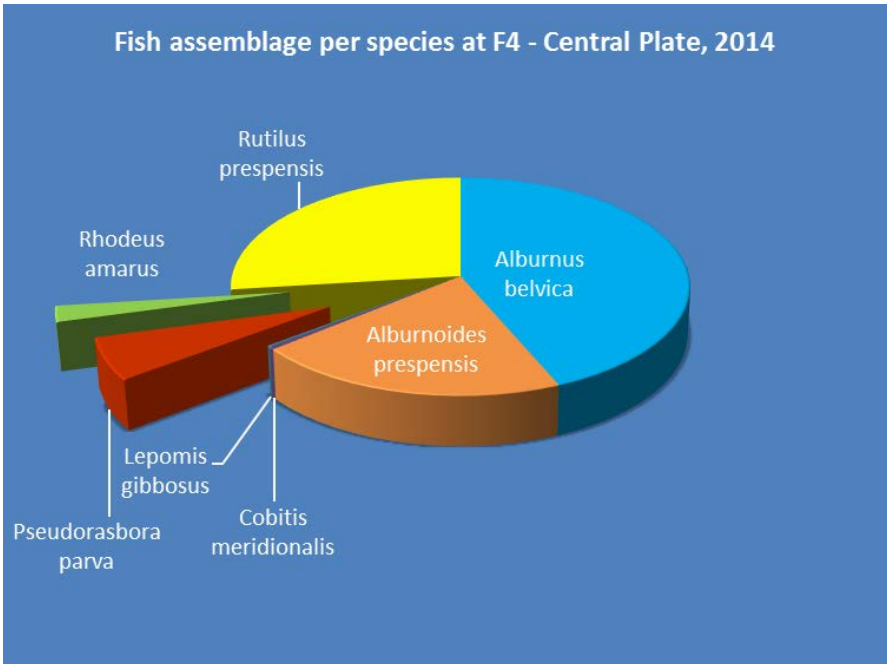

Figure 4.12. Fish assemblage per species F4 Central Plate, 2014

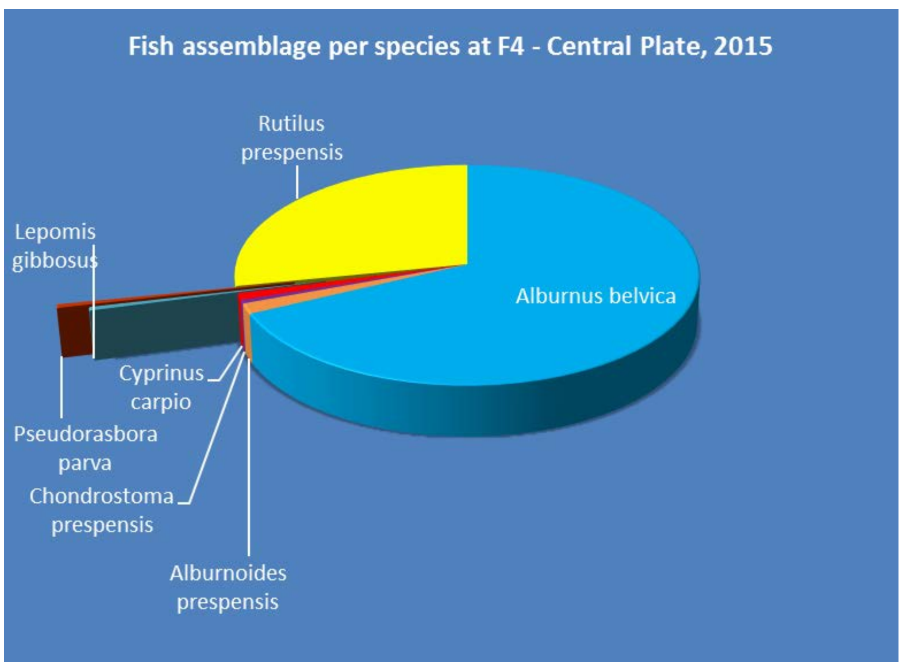

Figure 4.13. Fish assemblage per species F4 Central Plate, 2015

At this sub basin, in all of the three year period, unlike in the littoral shoreline parts of the lake, the alien species are with drastically lower abundance and mainly with three small bodies sized species the bitterling, the stone moroko and pumpkin seed. This sub basin represents also the composition of the commercial fishery catch.

4.3.1.5. F5 Kazan – Deepest point

This sub basin was monitored only in 2014 and 2015 due to lack of adequate fishing gear in 2013.

Table 4.5. Fish species composition at sub basin F5 (Kazan)

No.	Species Latin name	Species common name	2013		2014		2015	
	Central Plate (F4)		native	alien	native	alien	native	alien
1	Alburnoides prespensis	Prespa spirlin			+		+	
2	Alburnus belvica	Prespa bleak			+		+	
3	Barbatula sturanyi	Stone loach						
4	Barbus prespensis	Prespa barbell						
5	Carassius gibelio	Prussian carp						
6	Chondrostoma prespensis	Prespa nase						
7	Cobitis meridionalis	Spined loach						
8	Cyprinus carpio	Carp			+		+	
9	Gambusia holbrooki	Mosquito fish						
10	Lepomis gibbosus	Pumpkinseed						
11	Pelasgus prespensis	Prespa minnow						
12	Phoxinus lumaireul	Minnow						
13	Pseudorasbora parva	Stone moroko				+		
14	Rhodeus amarus	Bitterling						
15	Rutilus prespensis	Prespa roach			+			
16	Salmo peristericus	Prespa trout						
17	Squalius prespensis	Prespa chub						
18	Tinca tinca	Tench						
Number of species					4	1	3	

At this spot in the water column from 0 to 32 m depth with 99% was recorded the presence of Prespa bleak as this species lives in the open waters in all depths.

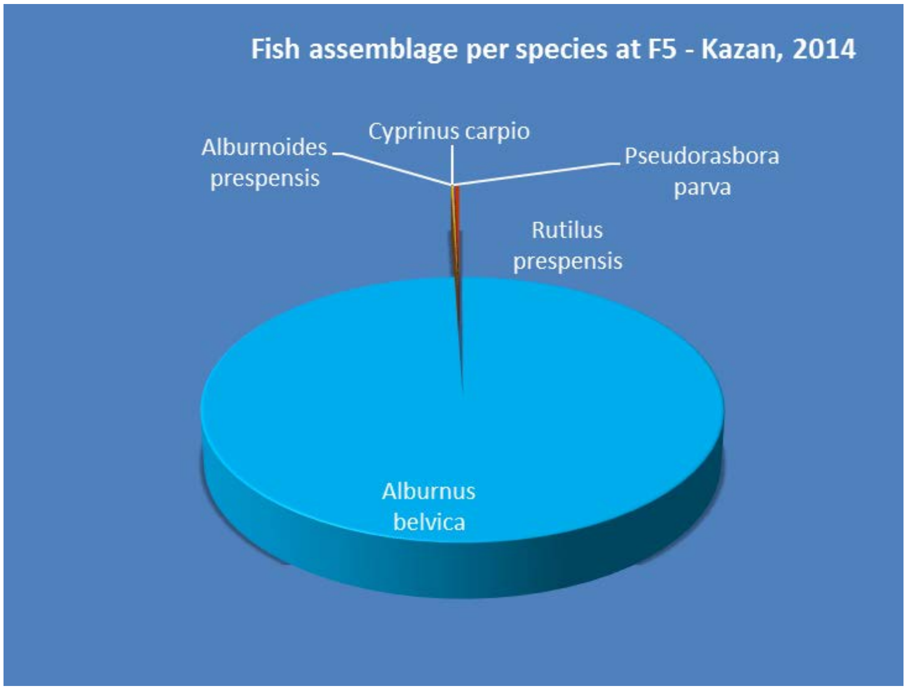

Figure 4.14. Species composition at F5 Kazan – the deepest point in 2014

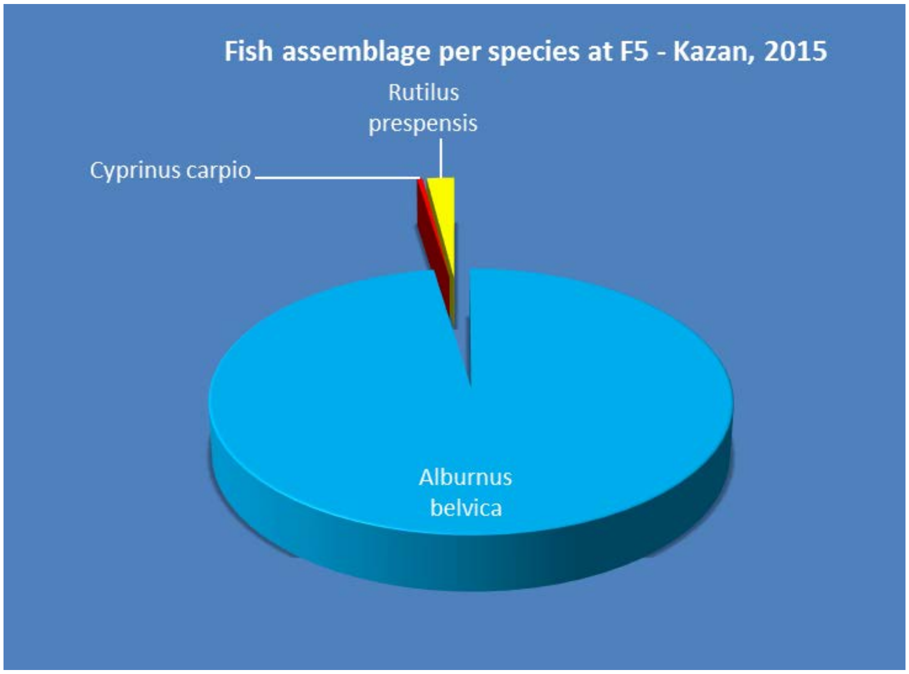

Figure 4.16. Species composition at F5 Kazan – the deepest point in 2015

At F5 in 2014 was registered presence of 4 native and 1 alien fish species. The dominance as in absolute individual number and in relative biomass belongs to the bleak in the whole water column.

At F5 in 2015 was registered presence of only three native fish species. The dominance as in absolute individual number and in relative biomass belongs to the bleak in the whole water column.

4.3.2. Fish species distribution per depth strata per sub basin

Depending of the period of the year and different activities related to fishes biology, different species are distributed in the same locality within different depth strata. This is strictly connected with the condition of the ambient – temperature, water currents, food availability. The following figures are showing the situation at the monitored sub basins F1, F2 and F3. The F4 and F5 could not be expressed in this manner as they are not littoral sites.

4.3.2.1. Sub basin F1 (Asamati)

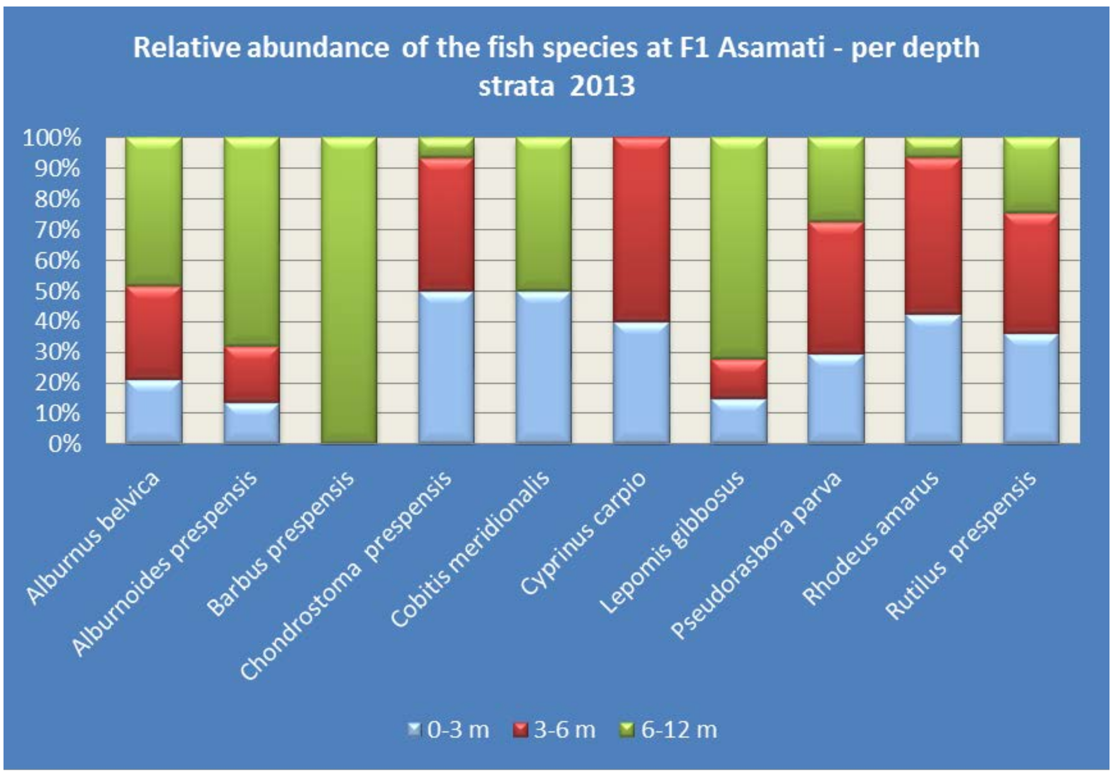

Figure 4.17. – Relative fish abundance per depth strata at F1 (Asamati) in 2013

Observing the species distribution per depth strata at the Asamati sub basin during the monitored period it is obvious relatively random distribution of the fishes over the depth from 0 to 12 m at the water column close to the bottom. This is in relation to the habitat consistence where the bottom is muddy with presence of macrophytic submersed and emergent vegetation. This area, compared with the rest of the monitored sub basins, is also with biggest reed belts, which provides adequate shelters for the fish. Also the submersed vegetation is quite dense which from other hand provides favorable nutrition grounds. Also, the influence of the inlet of River Golema affects favorable conditions for such fish’s distribution.

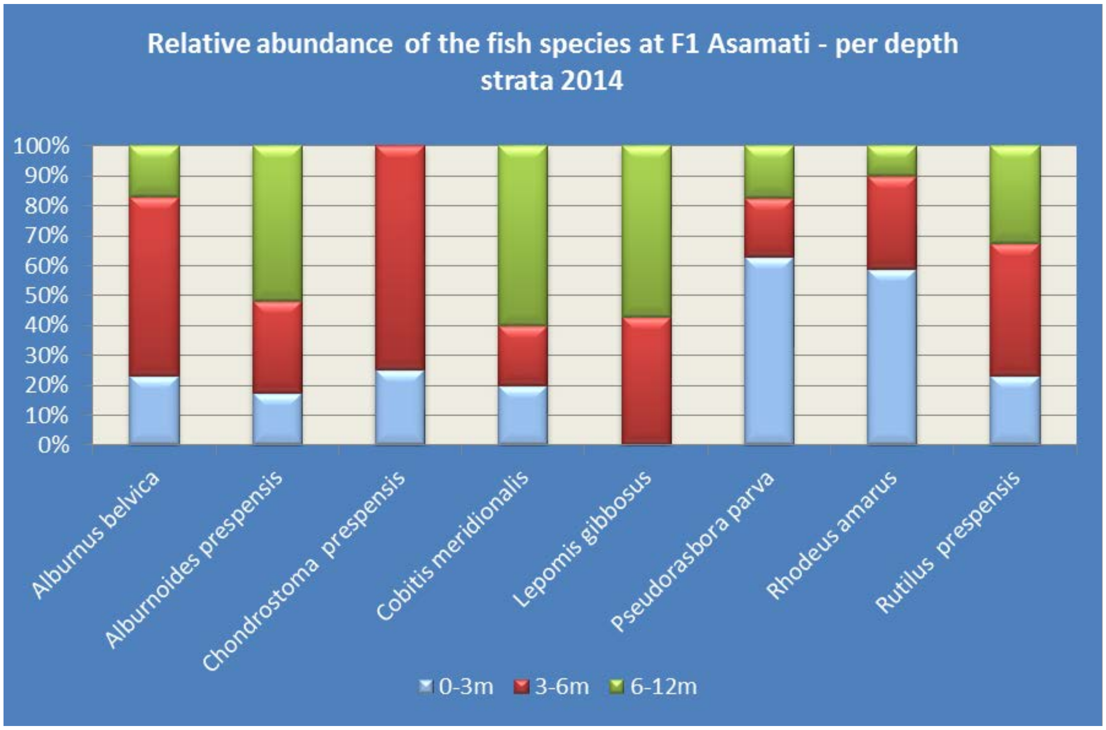

Figure 4.18. Relative abundance of fish species per depth strata at F1 Asamati in 2014

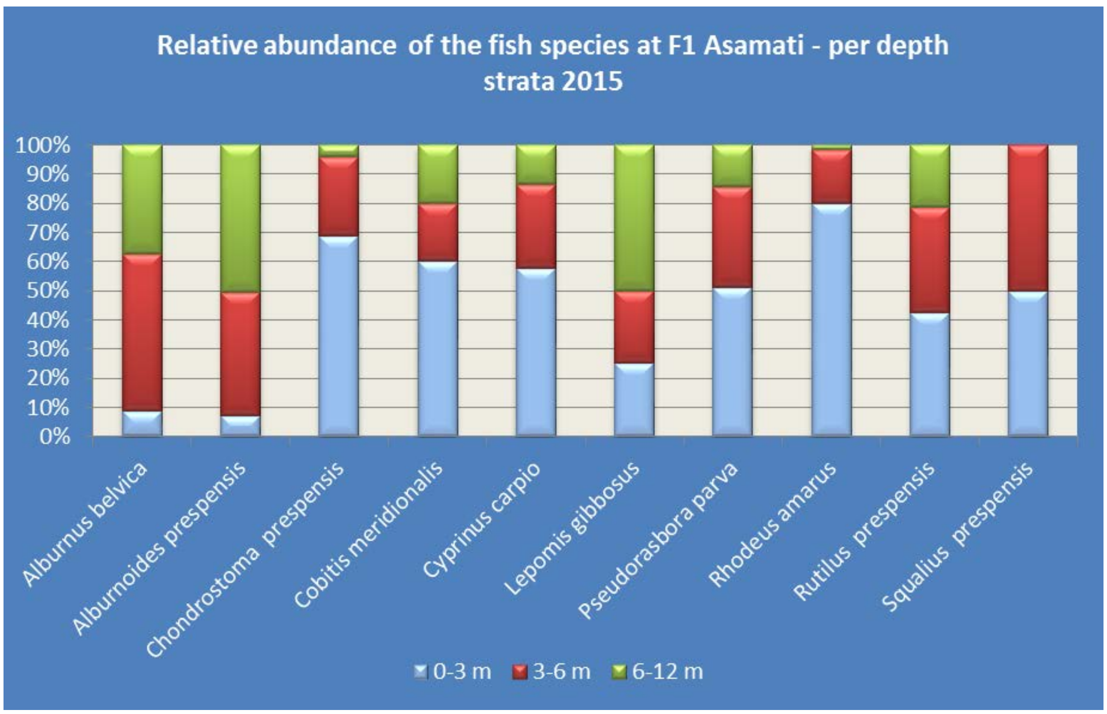

Figure 4.19. Relative abundance of fish species per depth strata at F1 Asamati 2015

4.3.2.2. Sub basin F2 (Otesevo)

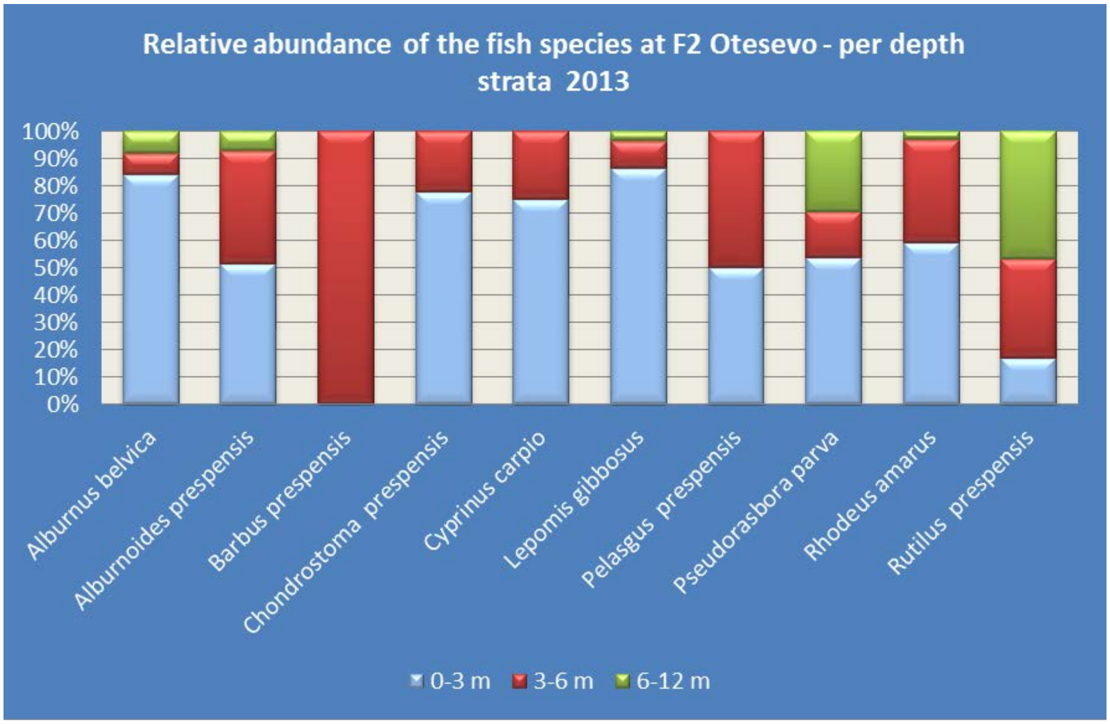

Figure 4.20. Relative abundance of fish species per depth strata at F2 Otesevo in 2013

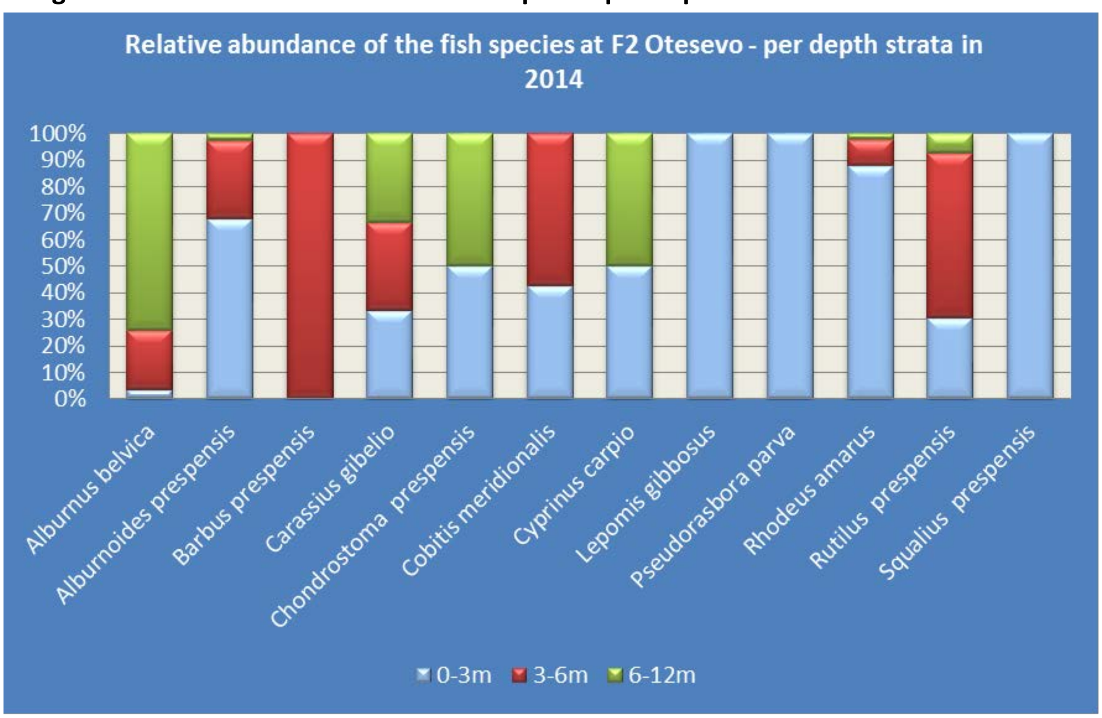

Figure 4.21. Relative abundance of fish species per depth strata at F2 Otesevo in 2014

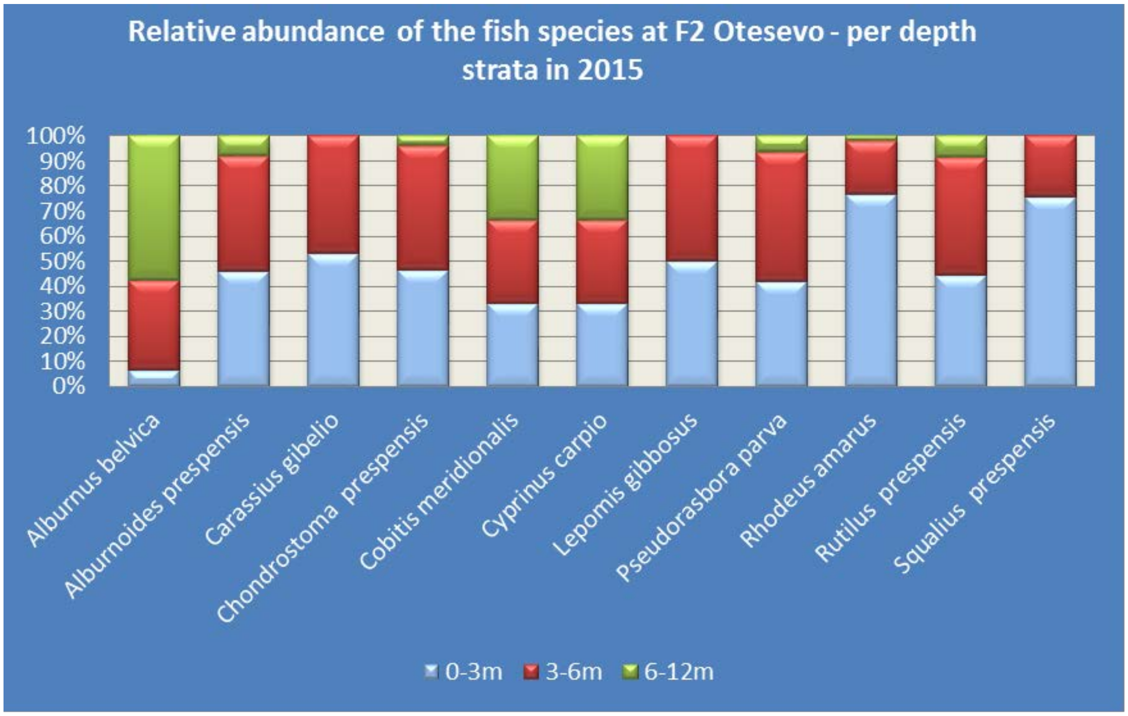

Figure 4.22. Relative abundance of fish species per depth strata at F2 Otesevo in 2015

According to ecological conditions of this sub basin like the bottom configuration and inhabitance of the macropytic vegetation which is less dense than at Asamati, it is expected that most of the fishes will be inhabiting the shallower parts of the littoral. Bearing on mind that there is influence of the communal waters from th surrounding tourist instalations and the village of Stenje, this is also contributing to such depth distribution whereas favorable food conditions are present.

In the year of 2015 the situation is slightly different where some fishes are more present in the deeper waters than the previous two years. This can be result of relatively higher water temperatures although sampled in the same period in all three years.

4.3.2.3. Sub basin F3 (Konjsko)

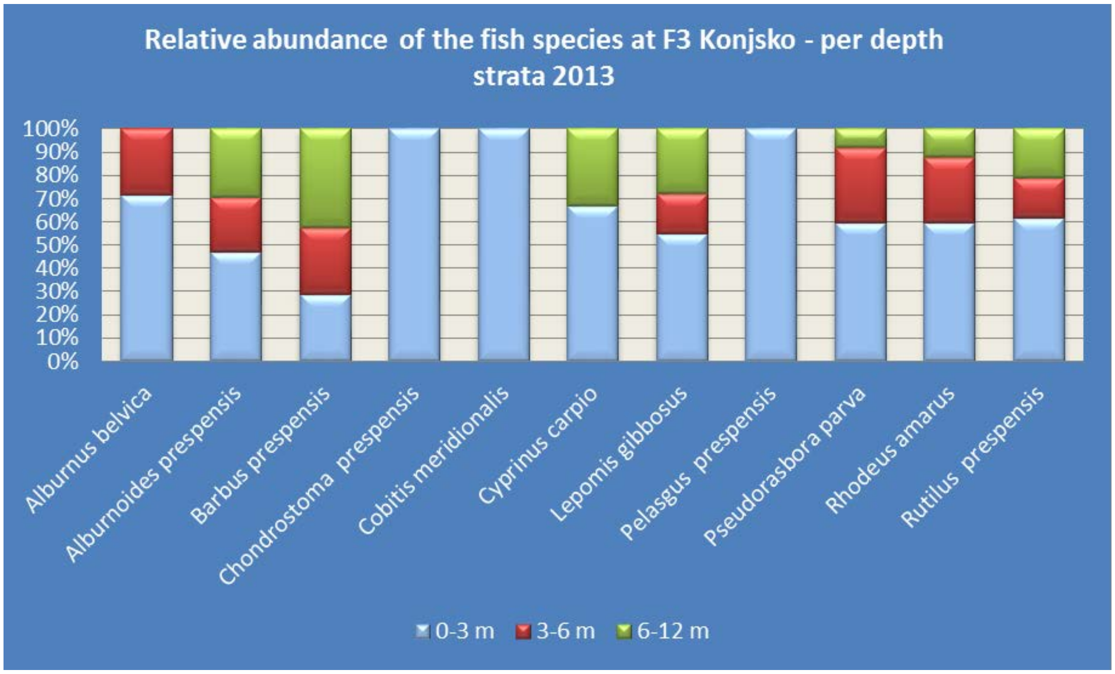

Figure 4.23. Relative abundance of fish species per depth strata at F3 Konjsko in 2013

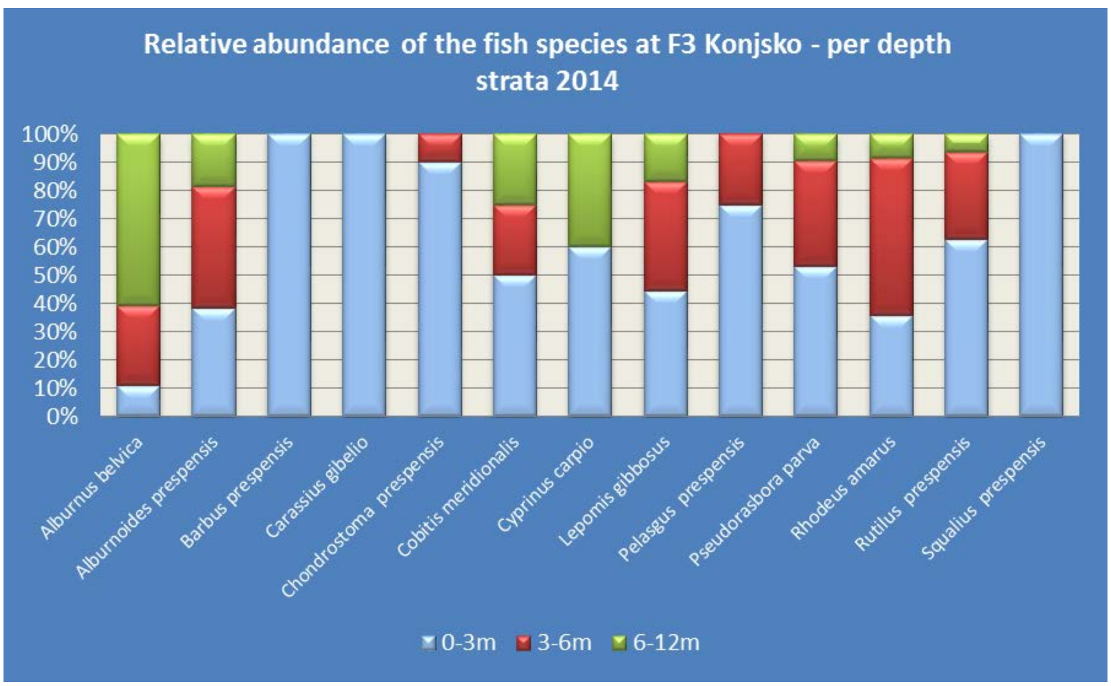

Figure 4.24. Relative abundance of fish species per depth strata at F3 Konjsko in 2014

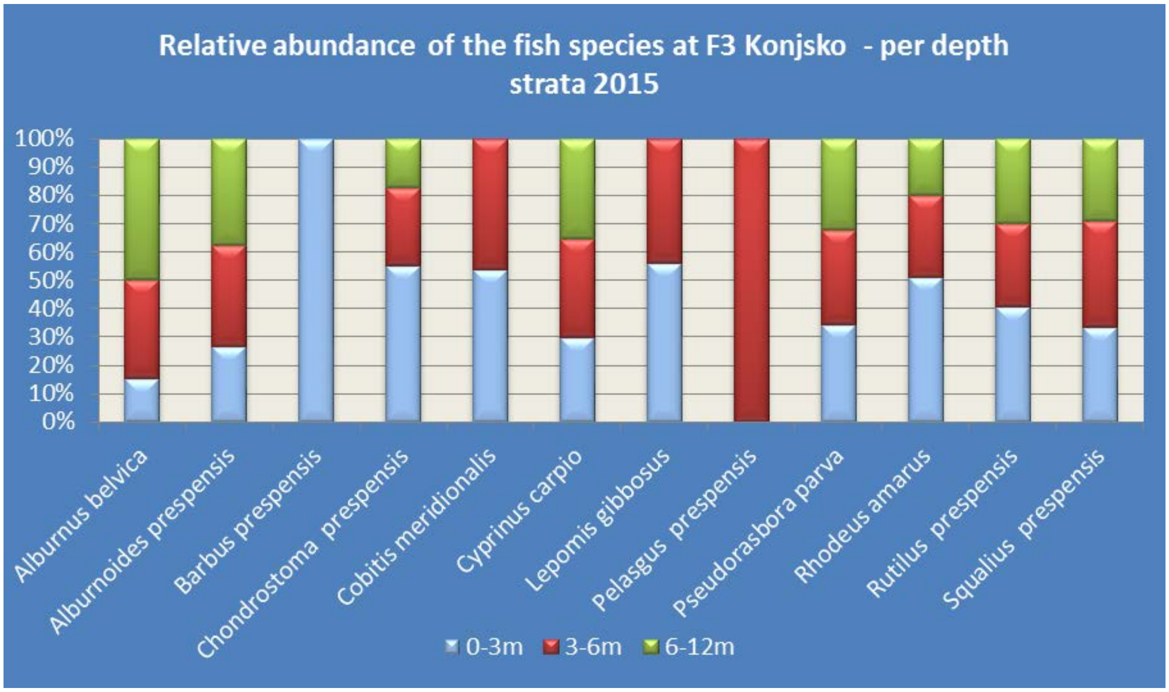

Figure 4.25. Relative abundance of fish species per depth strata at F3 Konjsko in 2015

Regarding the sub basin Konjsko where the bottom is quite rocky and with least dense macrophytic vegetation it is expected that the most of the fishes will be in the most upper close to the shore waters due to favorable sheltering and nutritional conditions from the benthic fauna.

The similar change in 2015 like the one in Otesevo with increased presence in the rest of the depth strata can be again the higher water temperature in this year.

4.3.4. Dominant fish species length classes per sub basin

At the following figures the length classes are expressed in cm versus species number of individuals for the three consecutive years.

Concerning the fish species length class composition in general there is difference in number of length classes present among the native and alien species. As the represented native species are fish with wider life span of several years it is expected to be represented with wider range of length (age) classes, whilst the alien species like *Pseudorasbora parva* (stone moroko) and *Rhodeus amarus* (bitterling) are fishes with mainly life range to two years is expected that their length (age) classes should be in wider narrow range of just few.

4.3.4.1. Sub basin F1 Asamati

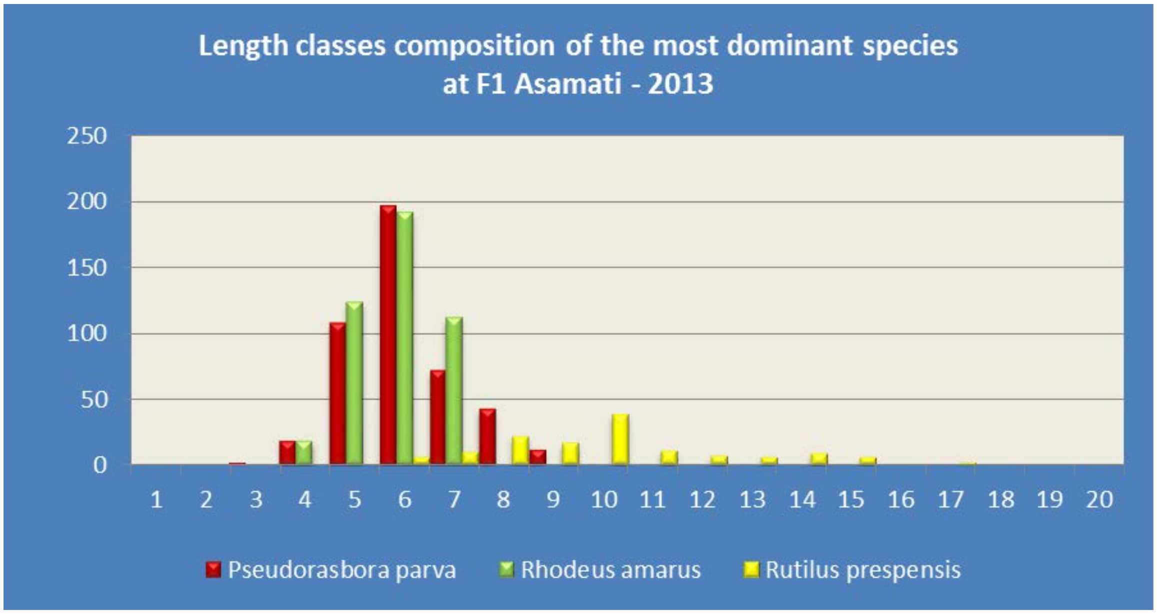

Figure 4.26. Length classes composition of most dominant species at F1 Asamati in 2013 (in number of ind.)

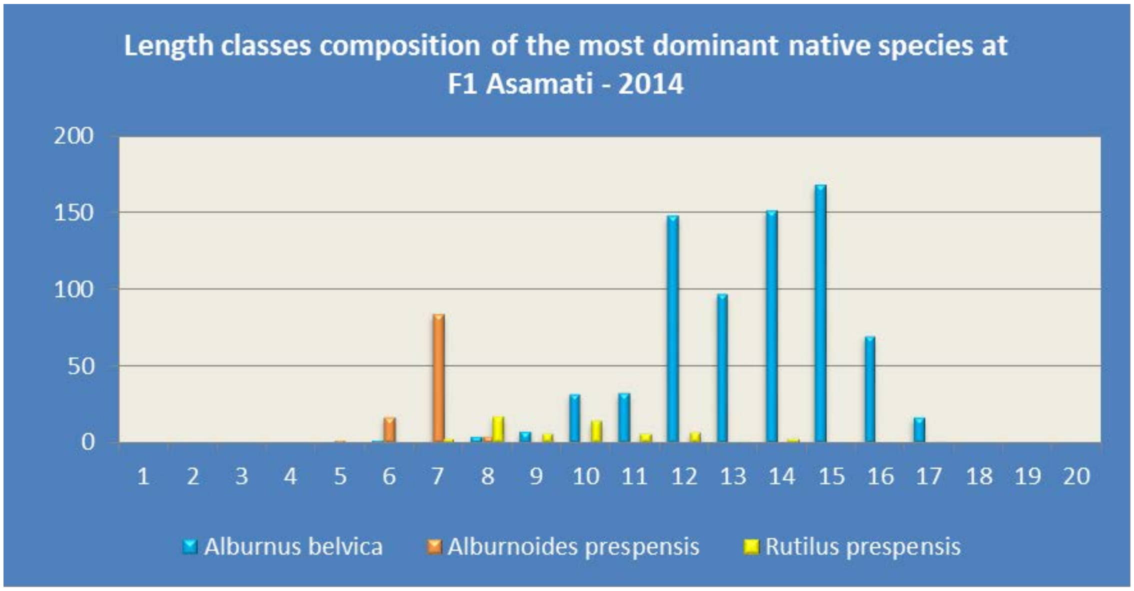

Figure 4.27 Length classes composition of dominant native species at F1 Asamati in 2014 (in number of ind.)

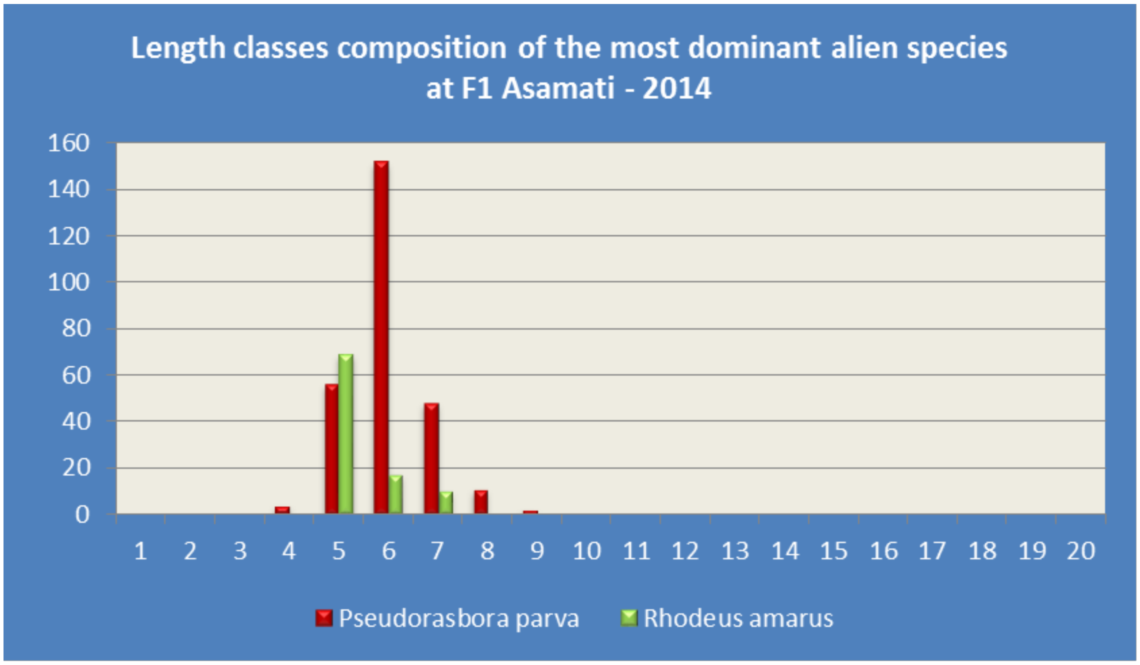

Figure 4.28. Length classes composition of dominant alien species at F1 Asamati in 2014 (in number of ind.)

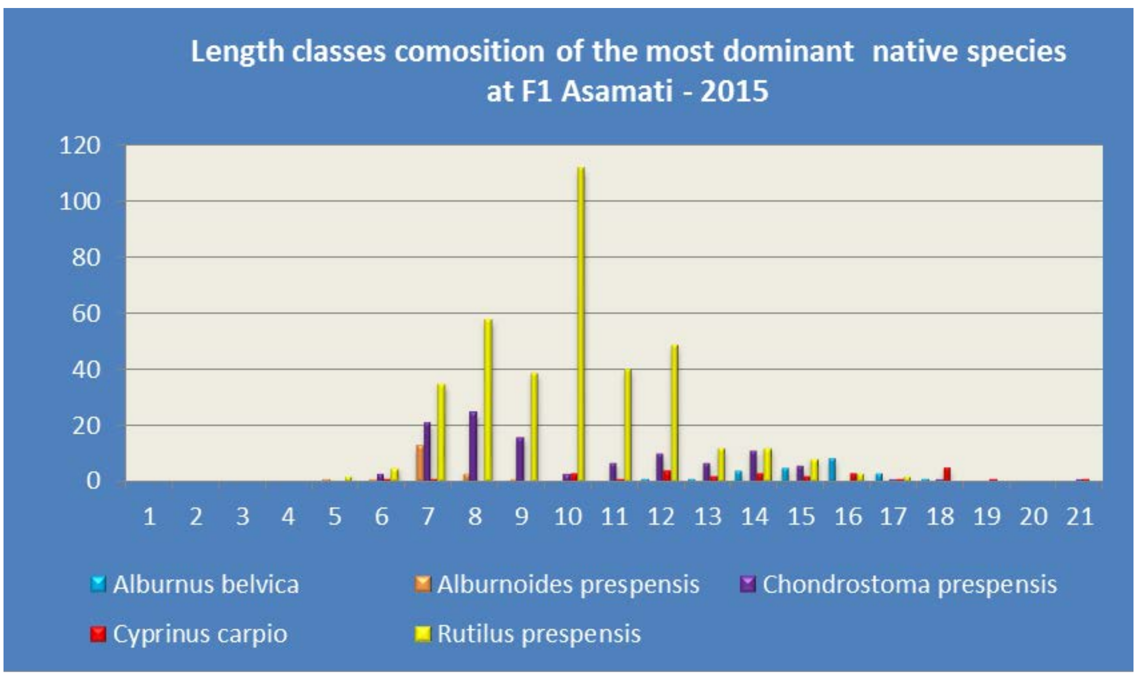

Figure 4.29. Length classes composition of dominant native species at F1 Asamati in 2015 (in number of ind.)

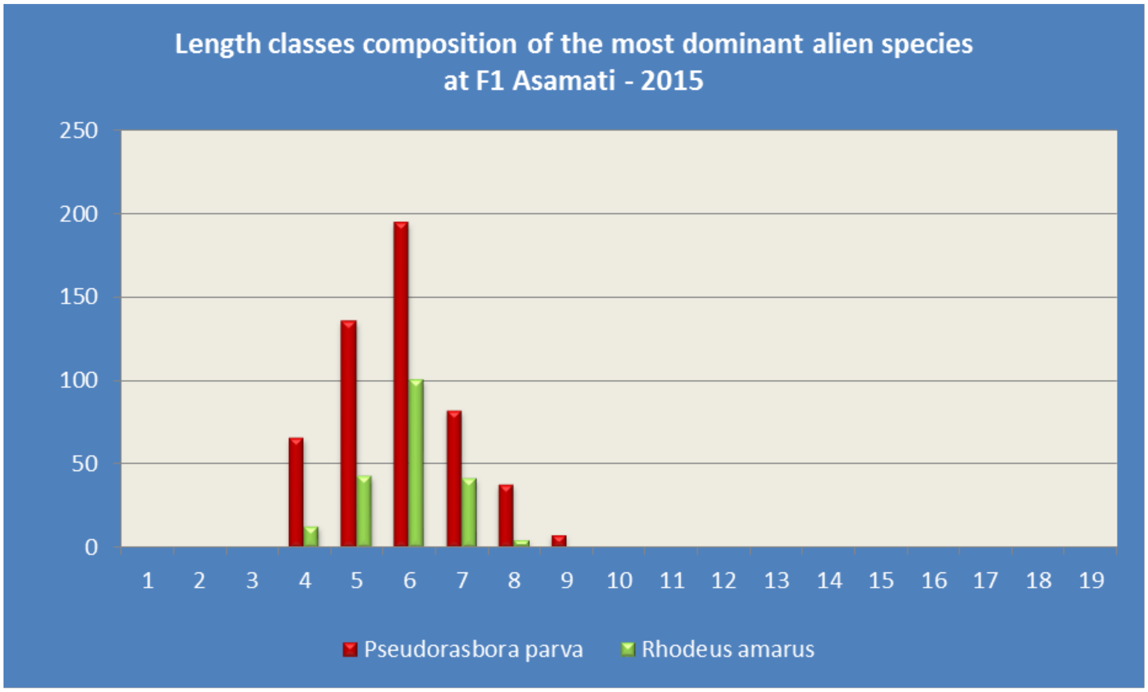

Figure 4.30. Length classes composition of dominant alien species at F1 Asamati in 2015 (in number of ind.)

In 2013 at the sub basin F1 (Asamati) juvenile and adult specimens of the alien species are present. From the native species the roach is with distribution of adult individuals. Similar length (age) structure is distributed in the rest two years, with exception in 2014 where the bleak is more dominant than the roach.

4.3.4.2. Sub basin F2 Otesevo

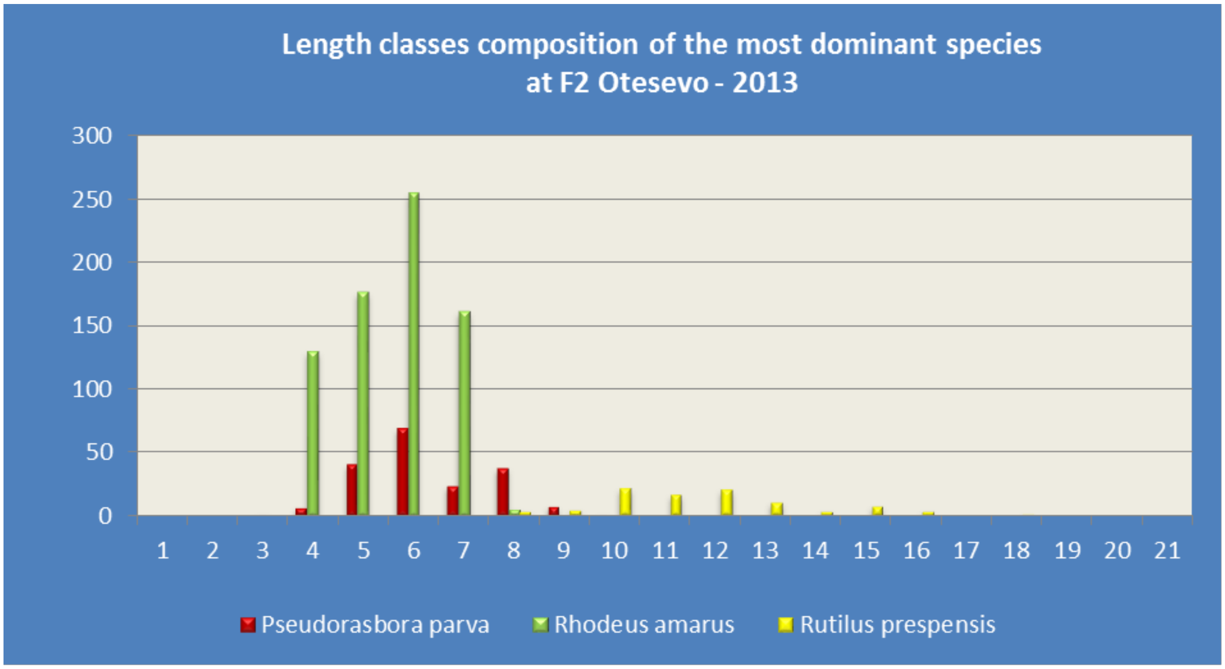

Figure 4.31. Length classes composition of dominant species at F2 Otesevo in 2013 (in number of ind.)

Concerning the sub basin F2 Otesevo in 2013 the length composition is similar like in Asamati. In 2014, the roach is the fish with most numbered length classes from juveniles to adults, mixed with adult specimens of spirlin and bleak. In 2015 again the roach is mostly represented but also some juveniles and adults of prespa nase are represented together with the specimens of bleak. The aliens are again in low number of length classes which is in correspondence with their life cycles.

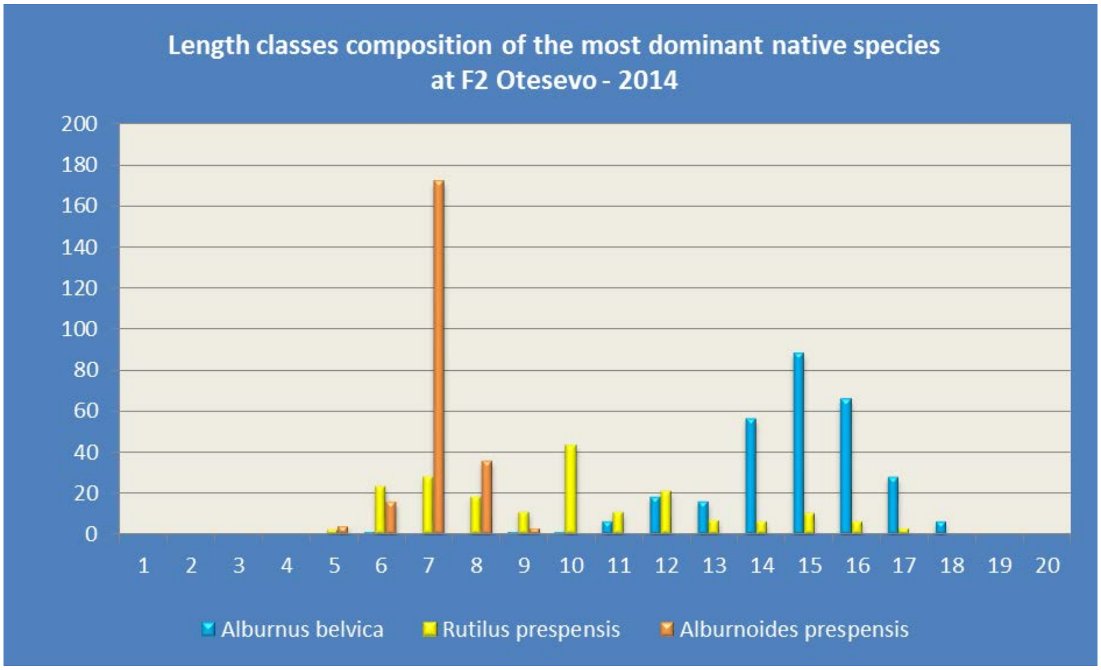

Figure 4.32. Length classes composition of dominant native species at F2 Otesevo in 2014 (in number of ind.)

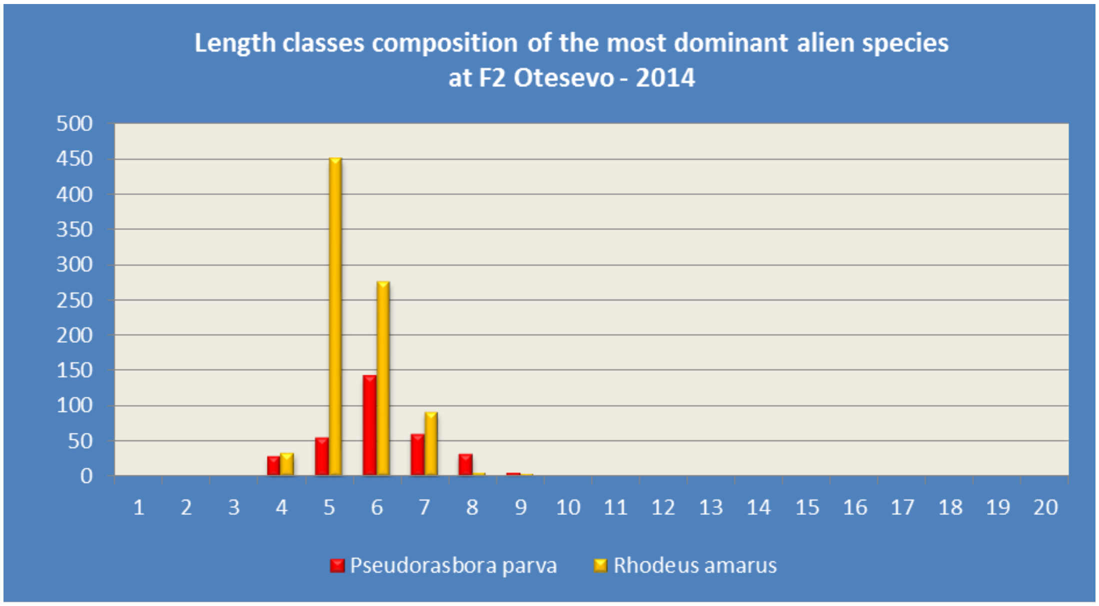

Figure 4.33. Length classes composition of dominant alien species at F2 Otesevo in 2014 (in number of ind.)

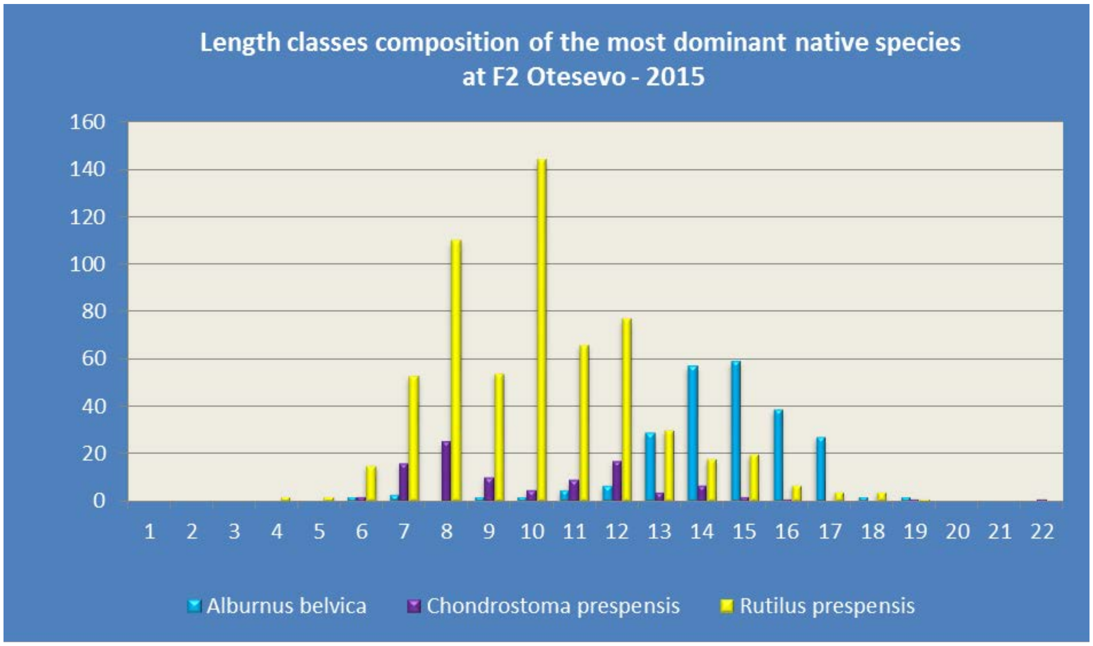

Figure 4.34. Length classes composition of dominant native species at F2 Otesevo in 2015 (in number of ind.)

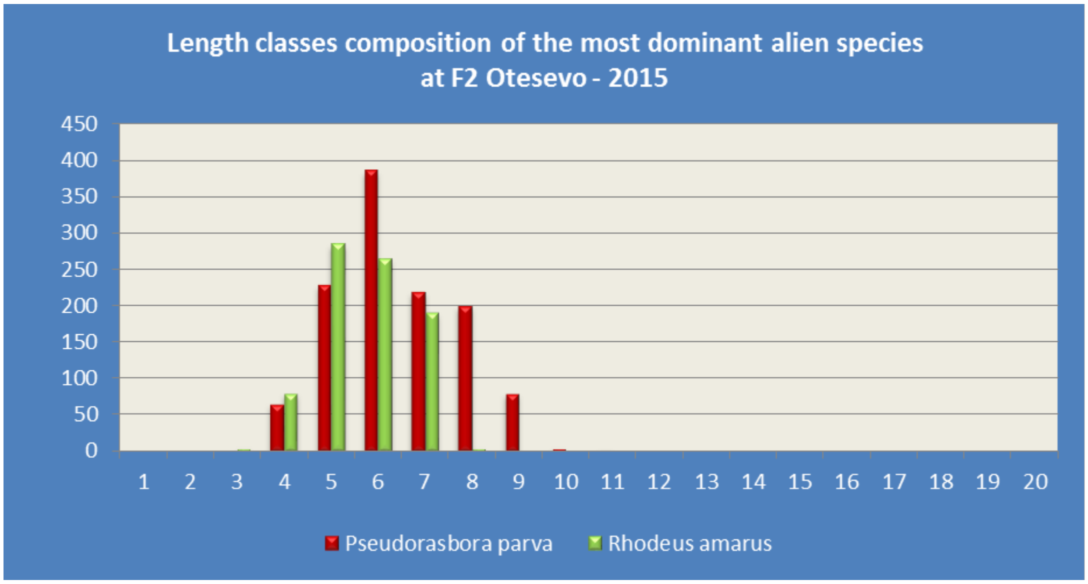

Figure 4.35. Length classes composition of dominant alien species at F2 Otesevo in 2015 (in number of ind.)

4.3.4.3. Sub basin F3 Konjsko

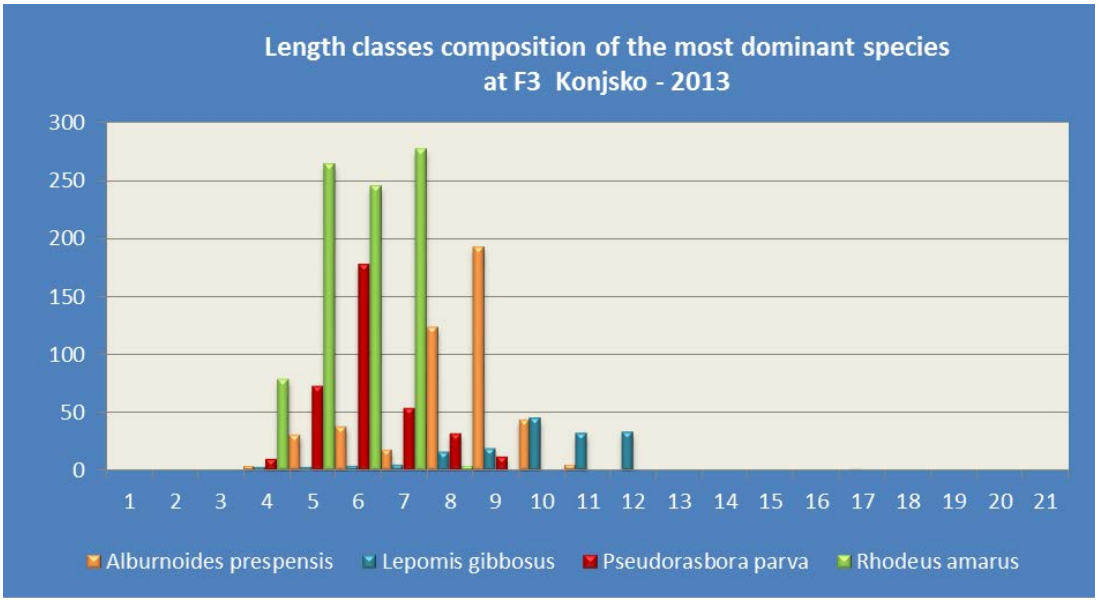

Figure 4.36. Length classes composition of dominant species at F3 Konjsko in 2013 (in number of ind.)

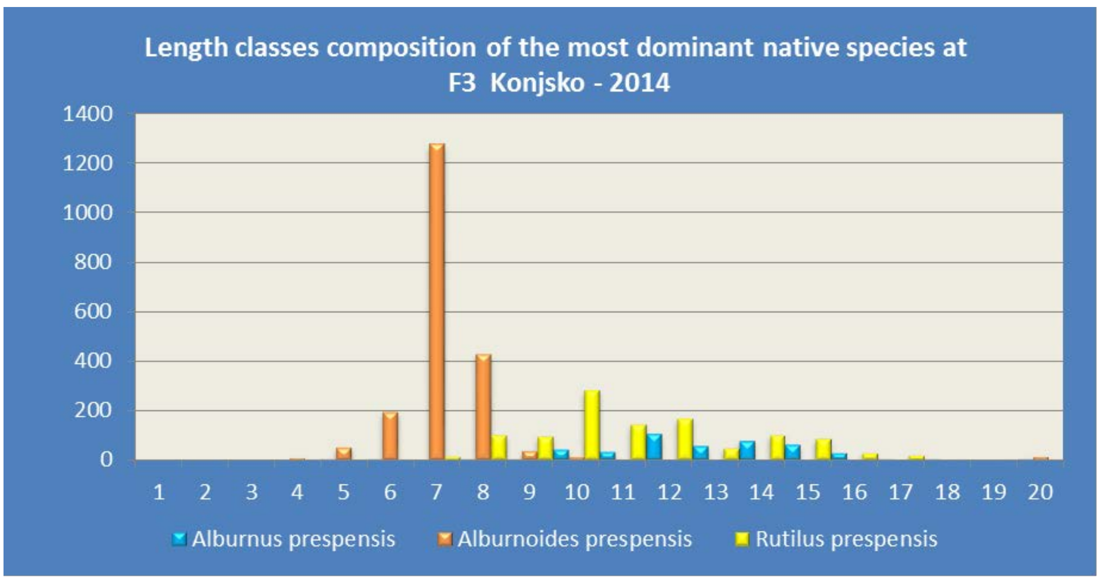

Figure 4.37. Length classes composition of dominant native species at F3 Konjsko in 2014 (in number of ind.)

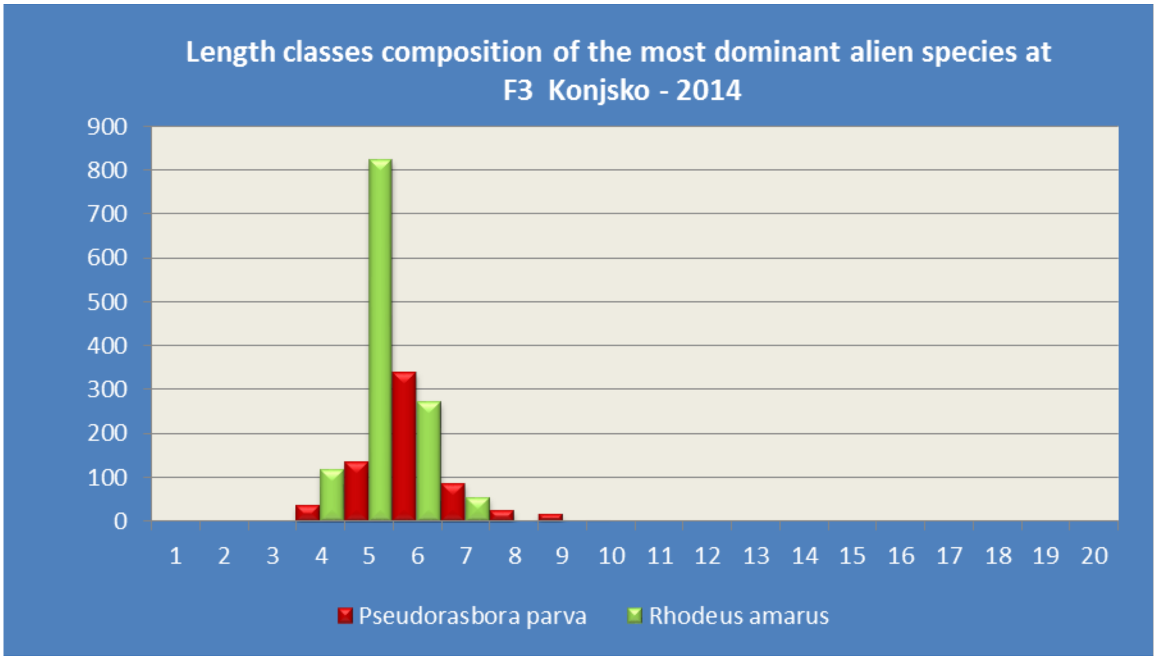

Figure 4.38. Length classes composition of dominant alien species at F3 Konjsko in 2014 (in number of ind.)

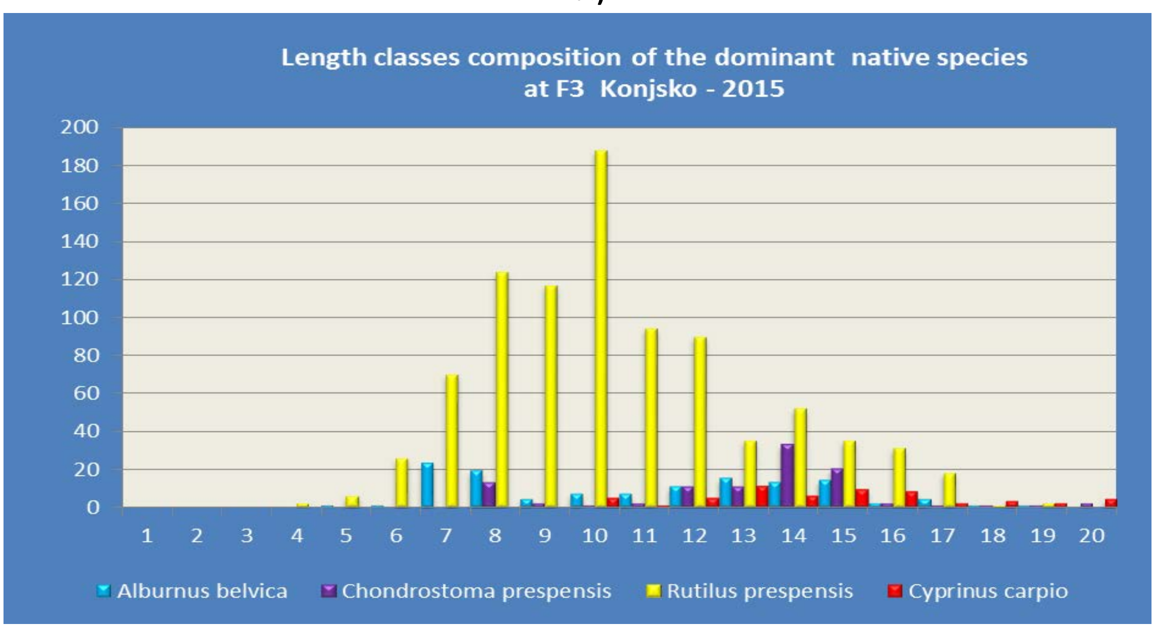

Figure 4.39. Length classes composition of dominant native species at F3 Konjsko in 2015 (in number of ind.)

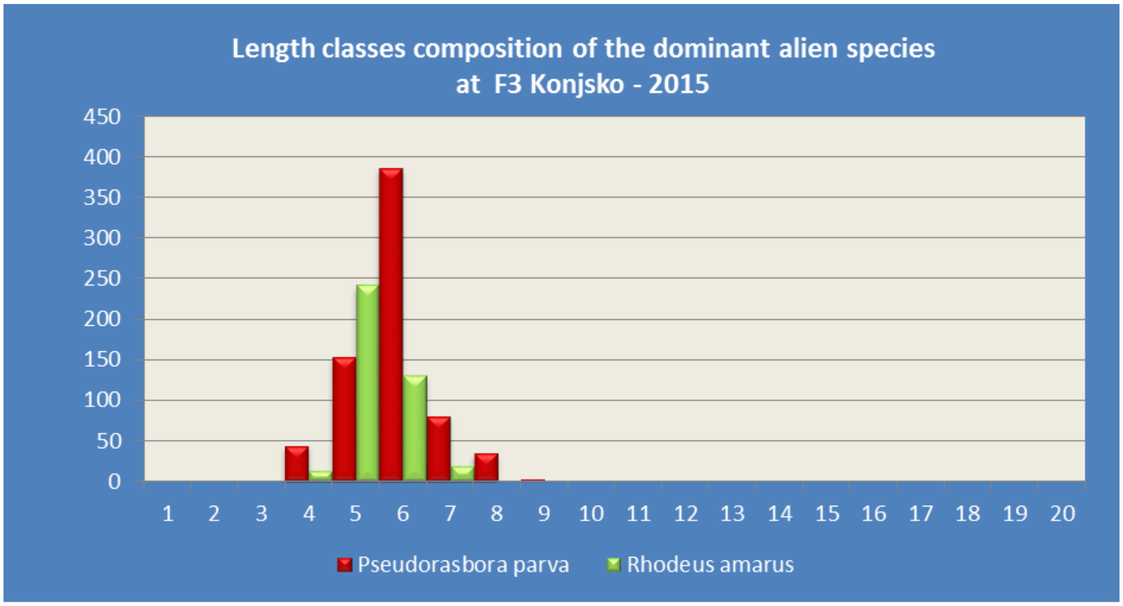

Figure 4.40. Length classes composition of dominant alien species at F3 Konjsko in 2015 (in number of ind.)

Sub basin F3 Konjsko in 2015 is characterized with dominance of the small sized stone moroko and bitterling individuals and a bit larger body sized pumpkin seed fish from the aliens, The natives are represented by juveniles and adults of Prespa spirlin. In 204 and 2015 the Prespa roach is represented with wide range of length (age) classes.

It is important that in 2015 at this sub basin the carp was represented with even 10 legth classes which can be observed only in this case compared to the rest sub basins during the whole three years.

The aliens, as usual were represented with their age specimens of first and second year of their life cycles.

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4.3.4.4. Sub basin F4 Central Plate

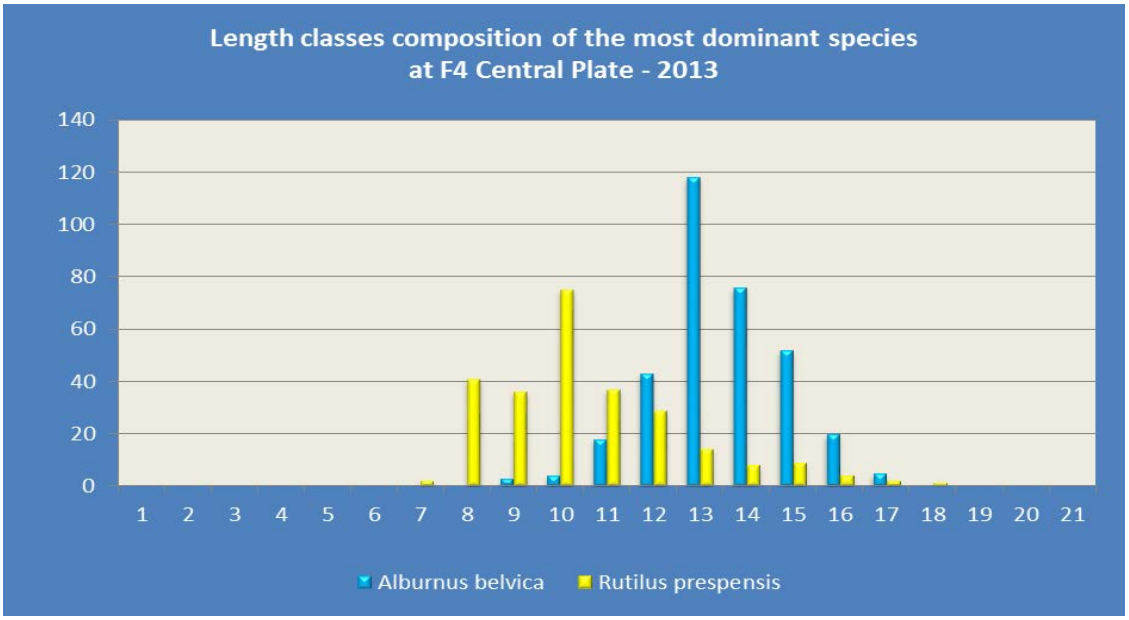

Figure 4.41. Length classes composition of dominant species at F4 Central Plate in 2013 (in number of ind.)

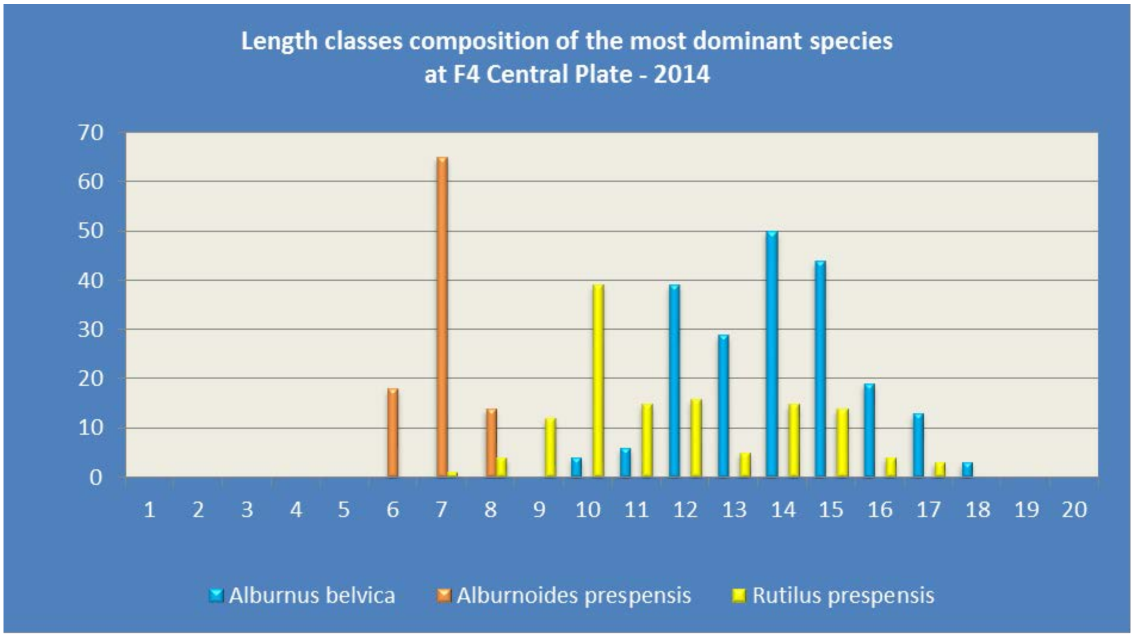

Figure 4.42. Length classes composition of dominant species at F4 Central Plate in 2014 (in number of ind.)

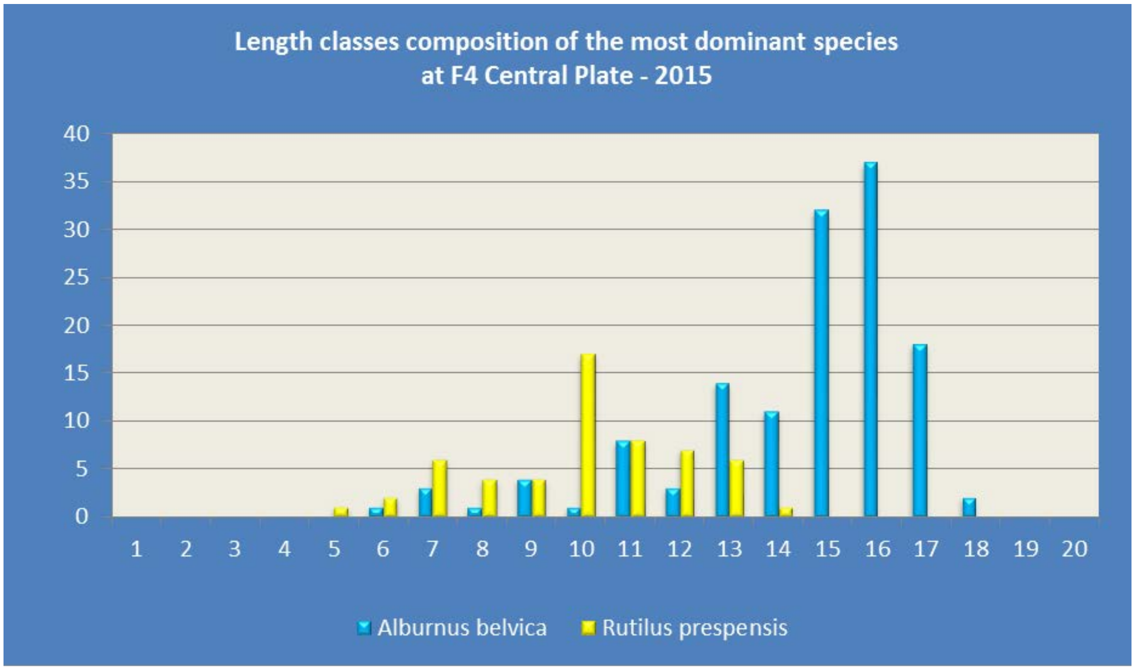

Figure 4.43. Length classes composition of dominant species at F4 Central Plate in 2015 (in number of ind.)

The sub basin F4 (Central Plate) is characterized with very scarce present of the alien fishes as this is pelagic part of the lake. Here the dominance of the roach and bleak is highly expressed.

4.4. Conclusions

Performed EN 14757 standard with MMGN on Lake Prespa and the results from the data analysis for each fish species in relation to depth strata are showing that the greatest concentrations of alien species occurred in the shallower depths, while the most economic valuable species like bleak, roach and carp at the pelagic part of the lake.

Fish biodiversity - At present Prespa Lake fish fauna is presented with 20 fish species (Table 4. 1). During the three year sampling campaigns, 13 fish species were sampled from which 9 were native and 4 alien. From the present ones in the Lake Prespa fish fauna, remained uncaught are 4 native species: eel, stone loach, one of the minnows – *Phoxinus lumaireul* and Prespa trout as well as three alien species: tench, catfish and mosquito fish. The most abundant native species in this sampling campaigns were bleak, roach and spirlin and the most abundant alien species were bitterling, stone moroko and pumpkinseed.

Fish as indicators of water quality under BQE - In the areas with higher nutrient load and macrophitic vegetation mainly alien species were present with high abundance. Bitterling and stone moroko were the most abundant followed by the pumpkinseed.

High number of alien fish species is a pressure to the native fishes due to the spawning grounds inter-competition and overlap of the ecological niche.

Spawning grounds - Prespa Lake is showing changes regarding the fish ecology and especially regarding the spawning of the bleak and the carp. In the past the bleak was spawning near the coast of the Lake, nowadays the bleak is spawning in the middle areas of the Lake. The carp is in similar situation, varying from year to year.

4.5. Recommendations

Fish species conservation

- Regulation of the endemic species by determined catch quotas by the Fishery Master Plan for Lake Prespa;
- Total ban on Prespa barbell for 6 years period;
- Total ban on Prespa trout for 3 years period;
- Stocking program only with autochthonous fish related to specific habitats;

Spawning grounds – improving habitats

- Defining strict natural fish spawning grounds (where any activities without special permission of the national management bodies are allowed);
- Improving the conditions of spawning grounds be establishing entrances in to the rivers from the lake for Prespa nase;
- Reduction of the reed belts and their eradication or spacing at certain places to allow fish entrance at different spawning substrates;
- Harvesting of the submerged macrophytic vegetation for reducing their volume all over the lake

Reduction of the alien fish species in the lake

- Harvesting of the submerged and emerged macrophytic vegetation for reducing their volume all over the lake;
- Introducing subsidies for extracting the alien species in the commercial fishery;
- Performing selective fishing related to alien fishes