HYDROBIOLOGY

1. Introduction

Lakes and rivers are a very important part of our natural heritage (Adakole et al., 2008), over the years they have been widely utilized to the extent that few if any still remain in their natural condition. Surface waters quality depends not only on natural processes such as precipitation inputs, erosion and weathering of crustal material and biota interrelationships but also on anthropogenic influences such as urbanization, industrial and agricultural activities (Papatheodorou et al., 2006).

Few years ago Lake Durowskie was strongly eutrophic with cyanobacterial water blooms. To improve the lake water quality and restore ecosystem services, the local Authority decided to start restoration measures in 2009, using three methods: oxygenation of hypolimnetic waters using wind aerators, phosphorus immobilization using iron treatment, and biomanipulation measures – stocking the lake with pike fingerlings (Goldyn et al., 2013).

The main aims of physico-chemical study were;

I. Determination of nutrients coming in and out of the lake

II. Assesment of current ecological state of the lake

III. Evaluation of long-term changes after restoration

The investigation of physico-chemical parameters are important in assessing the ecological condition of freshwater ecosystem, the parameters include Oxygen concentration (O_2), Electrical conductivity (EC), Temperature, pH, Turbidity, ChlorophyII-a, Total Phosphorus (TP), Nitrate concentrations, flow velocity, turbidity among others.

The amount of biological nutrients available will determine the trophic state of the water. This is due to the fact that different aquatic organisms exhibit varying response to changes in the available measures of these parameters. Furthermore, the nutrient load from the inflow and outflow discharge can be used to estimate the amount of nutrient retained in the water body taking other factors into consideration.

Essentially, chlorophyII-a, total phosphorus and transparency (Secchi Depth) can be used as indicators to estimate the trophic state of a lake which is assessed by Carlson's Trophic State Index (TSI) equations (Carlson and Simpson 1996).

2. Materials and methods

2.1. Investigated Area

Durowskie Lake (Fig.1.) is a postglacial-exorheic lake which is elongated in shape. Its coordinate lies on N 52°49'6'' and E 17°12'1'' situated in the direction northward southward in the Wielkopolska Region (central Poland). The lake is thermally stratified, with an area of 143.7 ha and a maximum depth of 14.6 (Goldyn et al., 2014).

River Struga Golaniecka flows through the lake supplying it with nutrients from the catchment area. The river catchment area is typically agricultural. Forests cover only 19% of its surface. Nevertheless, the Lake Durowskie is surrounded by forest from the north, but the town Wągrowiec is adjacent to the southern part of the lake.

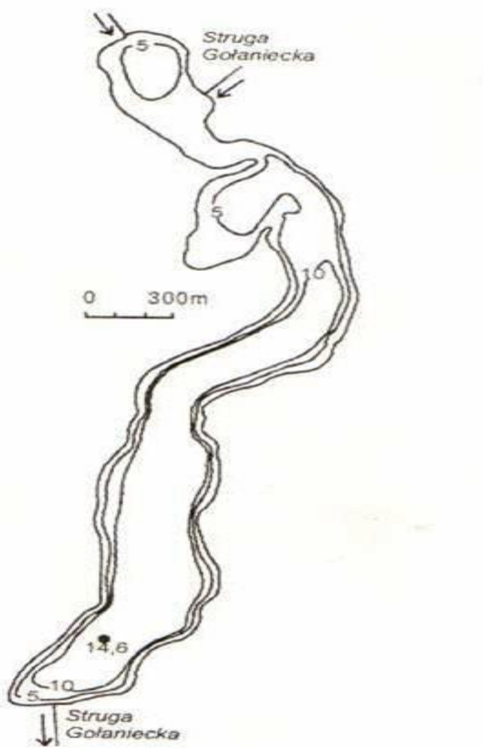

Fig.1. Bathymetric map of Durowskie Lake

Five other lakes situated on the river course above the Durowskie Lake are strongly eutrophicated (Goldyn et al., 2013). Lake Durowskie has ecological, cultural as well as economical values in the region, as it is one of the main destinations for tourism and recreational activities.

Tab.1. Morfological parameters of Durowskie Lake

surface	143,7 ha
volume	11322900 m^3
max depth	14,6 m
mean depth	7,9 m
main tributary	Struga Gołaniecka
surface of the whole catchment area	236,1 km^2
surface of the direct catchment area	1581,3 ha
share of agricultural area	58,26 %
share of forest	33,52 %
urban area	8,25%

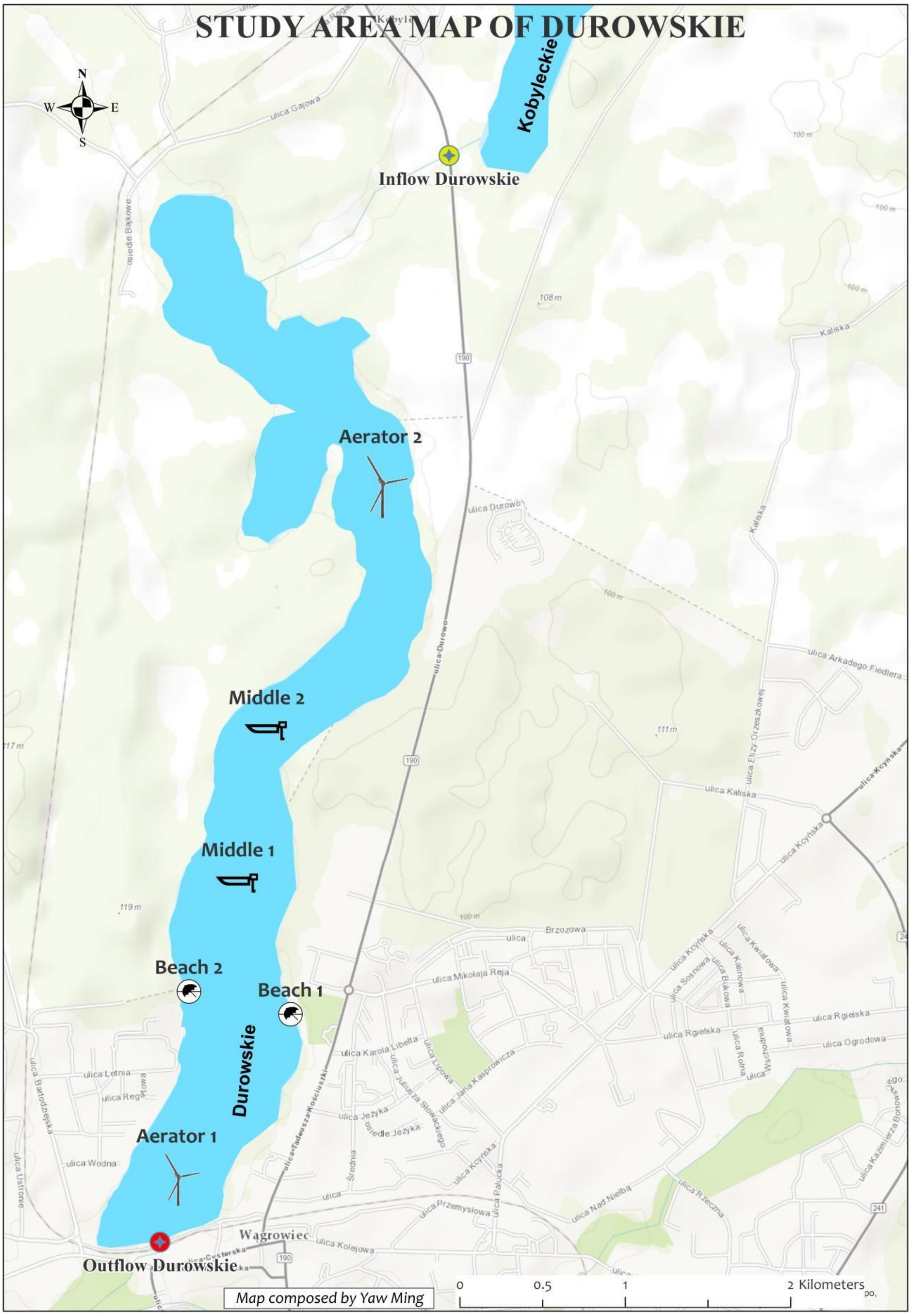

Fig.2. Stations distribution on Durowskie Lake

2.2. Field Work

In order to access the ecological status of Lake Durowskie, certain physico-chemical properties of the lake were measured. These included discharge of the lake, PH, Electrical conductance (EC) Total dissolved salts (TDS), Dissolved oxygen, Temperature, Transperancy as well as the concentration of certain nutrients in the lake. in order to measure the discharge at the inflow and the outflow of lake Durowskie, the velocity and width of the stream channel were measured. The velocity of the stream was measured by a electromagnetic velocity meter (FlowSens)(SEBA Hydrometrie, Germany). The cross sections were the measurements were taken were divided into different transects, which were defined by its width and depth. In addition, the distance from the river bank and the water level at each vertical section were measured. Within each subsection, the velocity was measured at different water depths along the vertical cross section and at right angel to the flow direction. However, for very shallow parts of the stream, only one velocity measurement was made. To make accurate measurements, relatively flat portions of the lake were selected during the measurements. The total discharge Q (m3/s) was calculated by multiplication of the area of each subsection (m2) with the average velocity (m/s) of each section For the study of nitrate, phosphorus, chloride, , and magnesium water samples were collected form the sampling stations for further analysis in the laboratory at UAM.

For analysing the chlorophyll a content of the lake, water samples were collected at the inflow and outflow of Lake Durowskie as well as the inflow of lake Kobyleckie. Samples were also take from certain point on the lake include aerator 1 and 2; Middle 1 and 2; Beach 1 and 2. Samples were taken from the surface as well different depth in order to analyze the vertical variation in chloroplly-a in the lake.

The basic physico-chemical water parameters such as PH, Temperature, Electrical conductivity (EC), Oxygen content were measured using the YSI water quality sampling meter. Measurements were taken at the inflow and outflow of lake Durowskie and the inflow of lake Kobyleckie. Similarly to the chlorophyll a sampling, these aforementioned parameters were also measured at different points on the lake including aerator 1 and 2; Middle 1 and 2; Beach 1 and 2. Measurements were also made at different depths of the lake.

The transparency or turbidity of the lake was measured using the Secchi disk. Measurements made in the field were recorded in a field notebook for further analysis.

Water samples were also collected at the six stations on lake Durowskie for chlorophyll a analysis. The water samples were filtered and preserved for chlorophyll a analysis in Pozan. In addition to this, samples were also taken from upstream lakes including Kobyleckie, Bukawieckie, Grylewskie Laskowickie. Other physico chemical parameters such as pH, temperature, electrical conductivity oxygen content as well as nutrient concentration were also measured.

In order to calculate the nutrient flowing into and out of the lake, the nutrient load was calculated for different time scales. Calculating the nutrient load will give an estimate of how much nutrient is retained in the lake which is very important for further lake restoration measures.

2.3. Trophic State Index (Carlson and Simpson, 1996)

The Trophic State Index (TSI) was used to define the trophic status of the Durowskie lake (including the up-stream lakes). This classification system is designed to assess individual lakes based on the amount of biological productivity occurring in the water and measured as Chlorophyll *a*, total Phosphorus and transparency (Secchi Depth). With this index the trophic state of the ecological condition of th lake can be determined.

The calculation of the Trophic State Index (TSI) was produced with the following formulas, which were established by Carlson's and Simpsons' as Trophic State Index (TSI) equations.

$$\mathbf{TSI\ (Chl\ \mathit{a}) = 9.81\ ln(Chl\ \mathit{a}) + 30.6}$$

$$\mathbf{TSI\ (TP) = 14.42\ ln(TP) + 4.15}$$

$$\mathbf{TSI\ (Sd) = 60 - 14.41\ ln(Sd)}$$

$$\mathbf{TSI = 0.54\ TSI\ (Chl\ a) + 0.297\ TSI\ (Sd) + 0.163\ TSI\ (TP)}$$

The quantities of nitrogen, phosphorus and other biologically useful nutrients are the primary determinants of a lake's trophic state index (TSI). Nutrient such as phosphorus turns to be limiting resources in standing water bodies, therefore, a little increase in the concentration tends to result in an increased aquatic plant growth which includes red-blue algae and consequently, a corollary increases in subsequent trophic level of such water. Essentially, a lake's trophic index may be used to make a rough estimate of its biological condition.

2.4. Laboratory analysis

The method for determining the concentration of chlorophyll a is based on the condensation on a filter (made of fiberglass) together with a known volume of water.

The filter with the chlorophyll sample is masked into a pulp in a mortal, and filled with acetone in a test tube (app. 10ml). The sample is then extracted from the pulp using a centrifuge and placed in a fridge (4°C) for approximately 24 hours. The chlorophyll measurement is then made on the next day. Each sample is filled into a cuvette and measured in a photometer with wavelength of 663nm and 750nm. After this measurement, 0,1ml of HCL are added to the samples and measured again after 10 minutes at the same wavelengths as the first one. (665nm and 750 nm).

The content of chlorophyll-*a* is calculated with the formula below:

Chl *a* (µg/l) = 26, 73 * [(A663b – A750b) – (A665HCla – A750HCla)] * Vacet.E/VH2OW * 1000

Aa = marked absorption of the extract after adding acid

Ab = marked absorption of the extract before adding acid

VE = volume of the prepared extract

VW = volume of the filtered water sample

26,73 = conversion factor

2.4.1. Nutrient concentration

To determine the nutrient concentration of the stations sampled, all the water samples were analysed in the lab at Pozan(University of Adams M). The main equipment used was the photometer. The respective concentration of each nutrient was then calculated with a Microsoft excel using special formula for conversion.

2.4.2. Ammonium Nitrogen (NH4-N)

Using the Neßler reagent, the ammonium content of the sample could be measured with a photometer by electromagnetic absorption at the wavelength of 410 nm. For this purpose 50 ml of the sampled water was poured into a Neßler glass. 1 ml of sodium-potassium tartrate as well as 1 ml of Neßler reagent were added to the sampled water and and mixed. The colour of the resulting compound could directly indicate the presecence or absenc of Ammonium with a yellow colour indicating the presence of Ammonium.

2.4.3. Nitrite Nitrogen (NO_2-N)

To analyze the Nitrate concentration, 100 ml of the sampled water was poured into a Neßler glass. 1 ml of sulfanilic and was added and mixed. After 5 minutes, 1 ml of naphthylamine and 1 ml of acetate buffer were also added and stirred. A stong presence nitrite is indicated with a pink colour of the solution. After 10 minutes, the solution was measured with a photometer at a wavelength of 520 nm.

2.4.4. Nitrate Nitrogen (NO_3-N)

In order to calculate the nitrate nitrogen concentration, 5 ml of the sampled water was poured into evaporating dishes. 2-3 drops of 0.5 % NaOH and 1 ml of 0.5% sodium salicylate were added to the sampled water in the evaporating dishes. The evaporating dishes were then placed in water baths and then evaporated. Afterwards, the dried dishes were removed and cooled down to add 1 ml of concentrated sulphuric acid. The acid was stirred in the dish sides and left for 10 minutes. Afterwards, the solution was removed and placed into Neßler glass. 7 ml of alcalic sodium-potassium tartrate was added and mixed. The resulting solution was measured with a photometer at a wavelength of 410 nm.

2.4.5. Total Phosphorus (TP)

To measure the total phopspherus concentration of the water samples, 50 ml each of the water sample was poured into a mineralization tube. A few few drops of phenolphthalein, 1 ml of sulfuric acid and 10 ml of potassium peroxidsulfate was then added to the water. Dry test-tubes were inserted into a steel stand and placed on a hot pot. Afterwards, suction pipes were placed on the tubes and the suction pump was started, boiling at a temperature of 220 °C for 40 minutes. The solution from the tube together with distilled water was then transferred into a Neßler glass. a few drops of phenolphthalein and concentrated (6N) NaOH were added to neutralize the solution. Finally, 1 ml of ascorbic acid and 2 ml of molybdenum acid was added and stirred up. The observance of a pink colour indicates the presence of phospherous in the solution. After 10 minutes the solution was measured by a photometer at a wavelength of 850 nm.

2.4.6. Phosphate (PO_4)

The measurement of phosphate was made by pouring 50 ml of water sample into a Neßler glass and adding 1 ml ascorbic acid and 2 ml molybdenum acid. After 10 minutes the solution is measured by a photometer at a wavelength of 850 nm.

2.5. Data analysis

In order to calculate the amount of nutrient flowing into and out of lake Durowskie, the discharge as well as the nutrient concentration at these points were used. The formula below was used to calculate the nutrient present at different part of the lake per day.

Nutrient per day = [Nutrient concentration (mg/l)] x discharge [m^3/s] x 86,400

3. Results and Discussions

To assess the ecological state of the lake Durowskie, the basic physico chemical parameters were analysed to compare the spatial variations in these parameters along the lake.

3.1. Dissolved oxygen

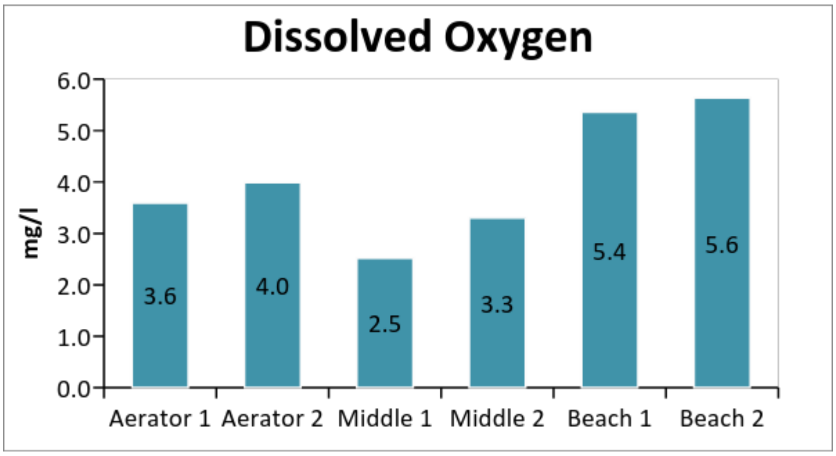

Fig. 3. Dissolved oxygen concentrations on selected stations in Durowskie Lake

From the analysis, the highest dissolved oxygen on the lake was recorded at Beach 1 and 2. Aerator 1 and 2 also had much higher dissolved oxygen than Middle 1 and 2 however lower than the two beaches. Logically, one would expect the sites closer to the aerators to have higher dissolved oxygen than other parts of the lake but this was not the case. One reason for the higher dissolved oxygen recorded at the beach could be due to the constant mixing of the water by kayak, speed boat and other water vehicles as well as swimming in this areas.

3.2. pH

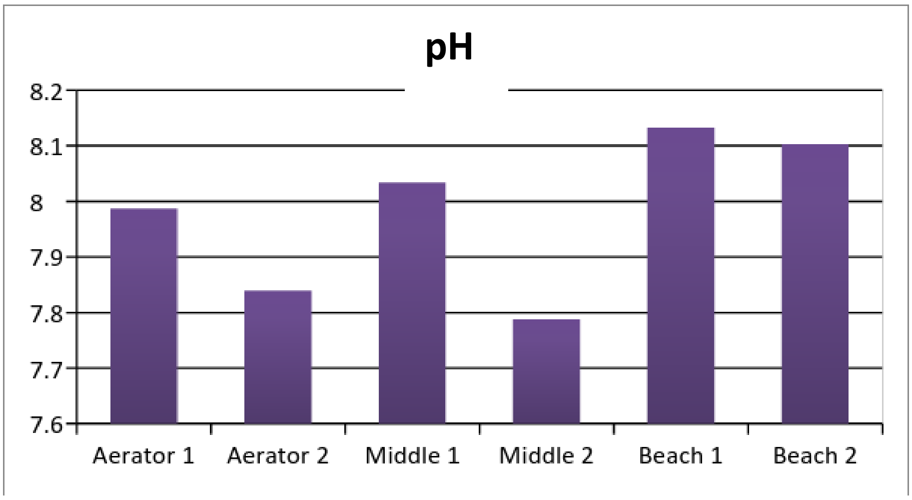

Fig.4. pH trends on selected stations in Durowskie Lake

The average pH recorded along the lake ranged between 7.8 and 8.1. This shows very little variation in the pH at different part of the lake. With these figures, the pH of the lake could be described as having a neutral to a bit alkaline pH. The relatively higher pH recorded at the two beaches could be as a result of pollution from bathing creams and detergents.

3.3. Turbidity

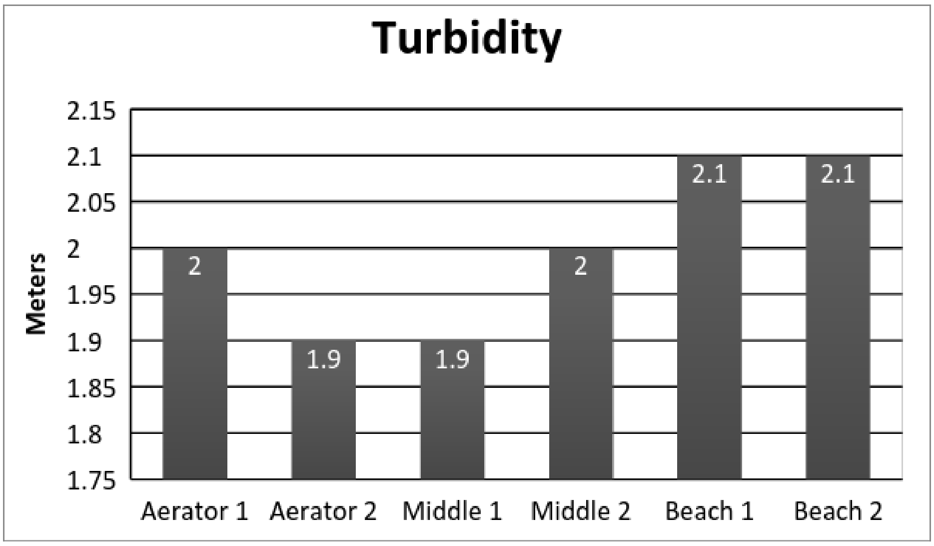

Fig. 5. Turbidity trends on selected stations in Durowskie Lake

Transparency measurements of the lake made with Secchi disk revealed a similar trend in transparency along the lake. Although the values recorded were very close ranging from 1.9 meters to 2.1 meters, the southern part of the lake (consisting of measuring stations such as Beach 1 and 2, and Aerator 1) had a much higher transparency measurement than stations in the northern part of the lake.

Other physic-chemical parameters which were measured on the lake such as temperature and Electrical conductivity have significantly similar measure along different parts of the lake. The average temperature of the surface of the lake was about 23^{O}C as expected the main changes in temperature was within the vertical cross section of the lake reaching 6.1 ^{O}C and 6.0 ^{O}C at 14 meters below the surface at Middle 2 and Aerator 1 respectively. Electrical conductivity also showed similar trend. The first 4 meters below the surface had similar reading but however starts to decrease with decreasing depth from 5 meters downwards.

3.4. Annual nutrient flow

The nutrients load of lake Durowskie was calculated for each station from the estimate of the discharge and nutrient concentration at that station. From this, the nutrient load coming in per day at the inflow and outflow of lake Durowskie was calculated. The nutrient load for other upstream rivers was also calculated. The annual nutrient flow into and out of lake Durowskie was also calculated in order to estimate the amount of nutrient that is left in the lake annually.

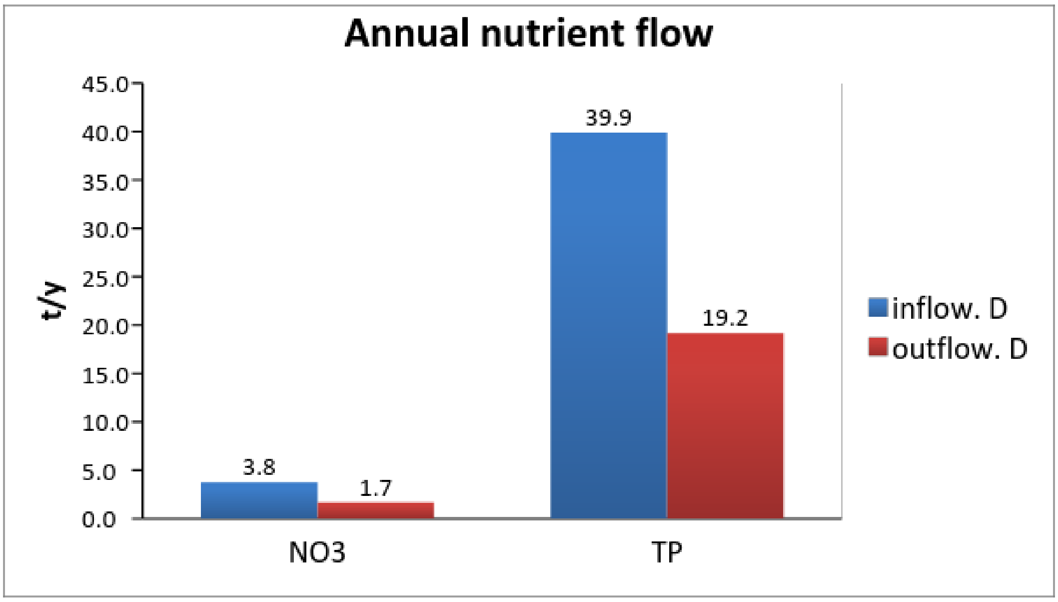

Fig. 6. Annual nutrient flow of NO_3 and TP in Durowskie Lake for 2016

From the result presented above, it can seen that the amount of nutrient entering the water from the upstream is quite high, from the amount of nutrient flowing out of the lake. Total phosphorus will have the highest nutrient flow reaching 40 tons per year. It was estimated that 2.1 tonne and 20.7 tonne Nitrate (NO_3) and TP respectively will be left in the lake annually. The remainly amount will partially sink to the bottom of the lake will some amount will also be used by algae and macrophyte for growth. It must however be noted that when these plants die, they decompose and the nutrients are released and recirculated into the lake.

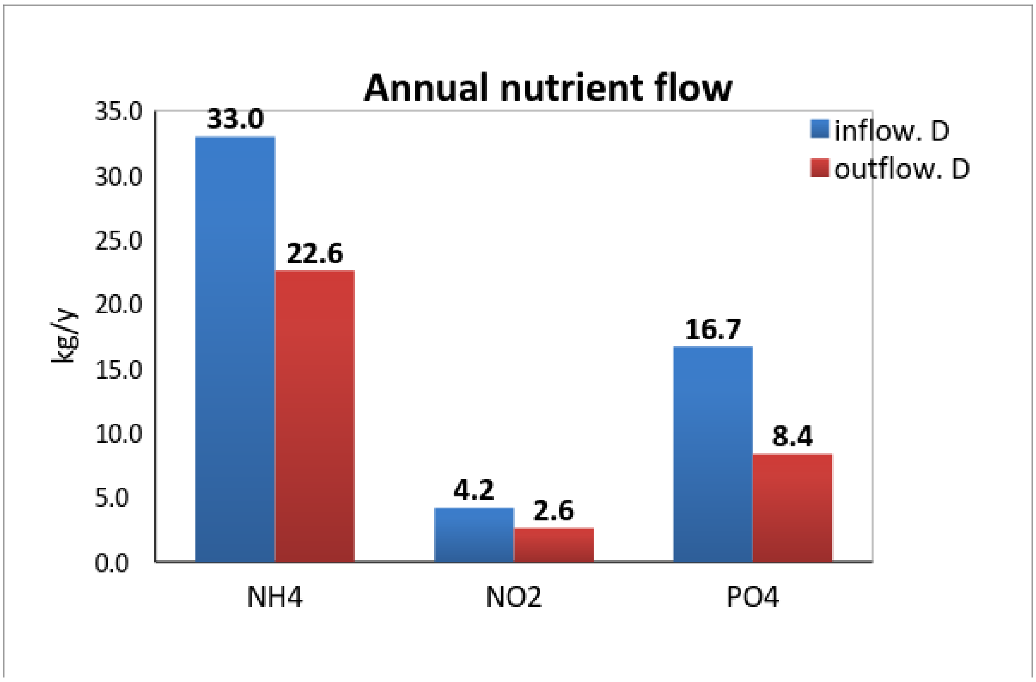

Fig.7. Annual nutrient flow of NH_4, NO_2 and PO_4 in Durowskie Lake for 2016

There was also a similar trend for other minerals such as Ammonia (NH_4), Nitrate (NO_2) and Phosphate (PO_4). The amount of nutrient that is coming in per year is always higher the amount leaving the lake. However, compared to Total phosphate and Nitrate (NO_3), these nutrients have a much lower amount flowing into and out of the lake.

3.5. Nutrient load per day

The nutrient load for each sampled station and nutrient was calculated. This was compared with data from previous year to know the temporal trend in nutrient concentration for the stations

3.5.1. Total phosphorus

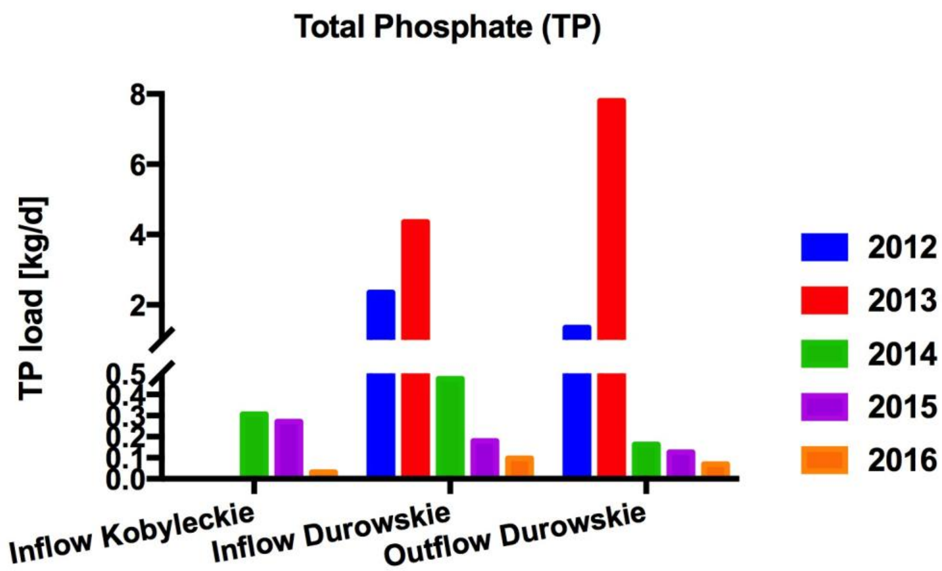

Fig.8. Total phosphorus load on selected stations

From the analysis there has been a steady reduction in the amount of Total Phosphorus from the inflow and outflow of Lake Durowskie as well as the inflow of Kobyleckie. Measurements made in 2016 were the lowest ever recorded since nutrient measurement begun. Remarkably, the lowest measurement made was at the inflow of lake Kobyleckie which was much higher than the inflow of lake Durowskie. This means there is a source of phosphate pollution at Kobyleckie which might have increased the amount of Total phosphorus flowing into Durowshie The very high Total phosphate recorded in 2013 was due to heavy rains prior to measurements

3.5.2. Ammonium

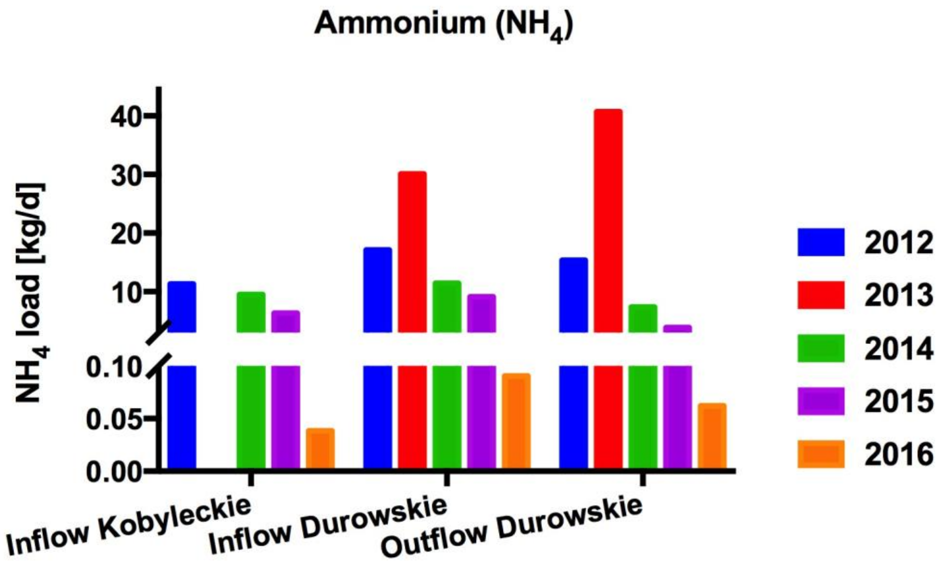

Fig.9. Ammonium load on selected stations

Ammonium (NH_4) also recorded a much lowere concentration this year as compared to the previous year. Phosphate had a similar trend over the years as Total phosphorus. Apart from 2014, the nutrient concentration in the inflow and outflow of Durowskie as well as the inflow of Kobyleckie has been reducing over the years. Similarly to total phosphorus, the lowest measurement taken this year was at the inflow of lake Kobyleckie.

3.5.3. Nitrite

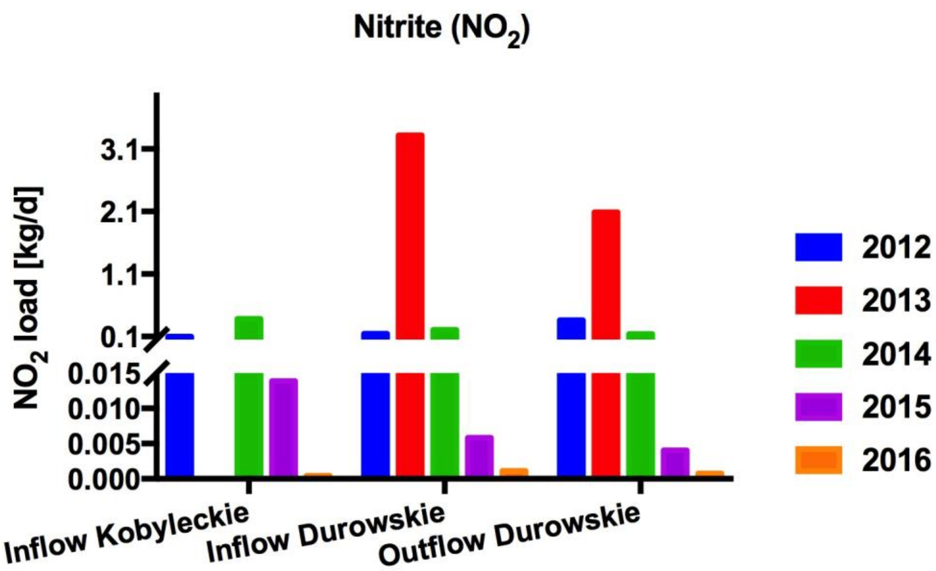

Fig.10. Nitrite load on selected stations

Nitrate (NO_2) was also very low this year as compared with previous years. Following the same trend as the two previous nutrients, the lowest measurement was made at the inflow of Kobyleckie with the highest being at the inflow of lake Durowskie.

3.5.4. Nitrate

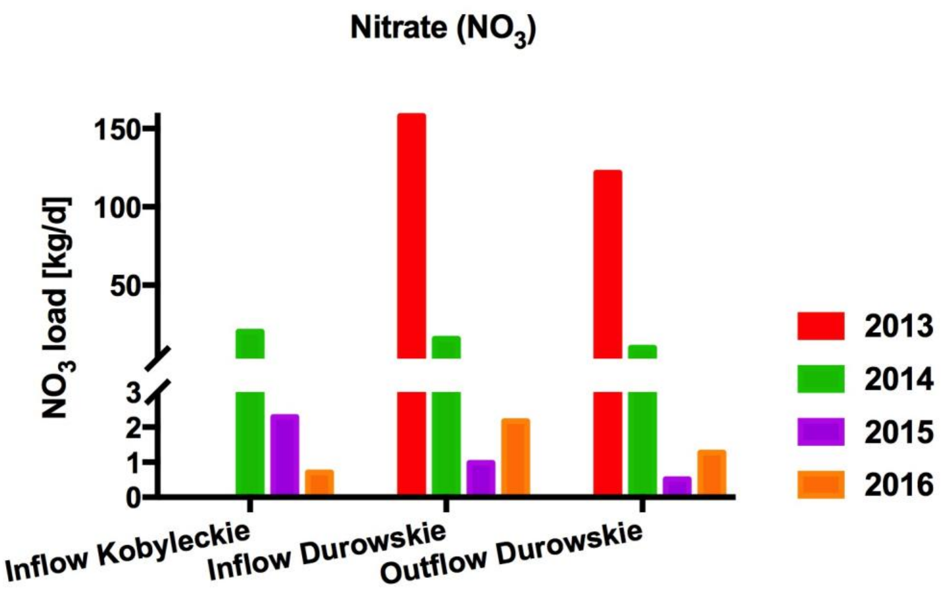

Fig. 11. Nitrate load on selected stations

Nitrate(NO_3) however did not follow the same trend of steady decrease over the year. Measurements made in 2016 were much higher than 2015 for both the inflow and outflow of Lake Durowskie.

In all, the loads of other nutrients (Phosphate, Ammonium, nitrate and nitrite) measured for this year also revealed a lower record all through. The amount of inflow into Lake Durowskie continued with its reduction trend from the previous years. Low nutrient loads in the inflows are a positive condition for the improvement of trophic state of the lake. Especially the Total phosphorus TP load is significant, as phosphate is the limiting nutrient for blue green algae growth which eventually leads to eutrophication of the lake.

Although, the amount of inflow into the lake is higher than the outflow, the estimate of nutrients retained in the lake is considerably small. A low retention of nutrients in the lake ultimately means fewer nutrients from the inflow will be capture in the lake.

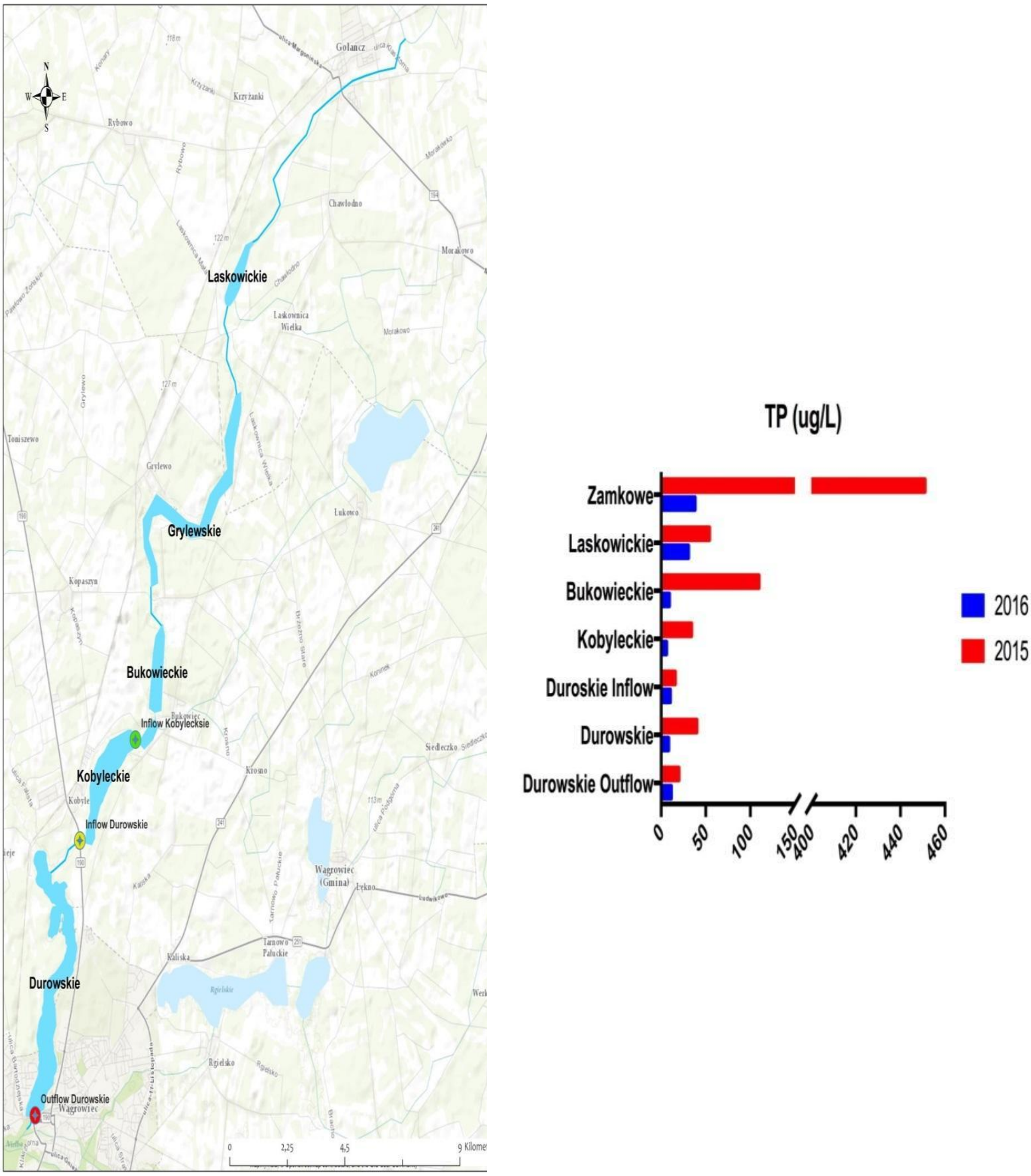

Fig. 12. Catchment area for total phosphorus

The concentration of Total Phosphorus is still high for the upper most water bodies Pond Zamkowe and lack Lackowicke. For Zamkowe this might be due to its small volume and depth and the high nutrient recharge while Lackowicke high concentration can be as a result of receiving high nutrient from its inflow from Zamkowe. Apart from the two water bodies all other upstream waters show remarkable reduction in the concentration of Total Phosphorus. All lakes in the study area recorded a much lower total phosphorus concentration load as compared to 2015. The analysis also revealed that, the amount of total phosphorus flowing from upstream lakes to downstream lakes reduces steadily for both 2015 and 2016. This supports the fact that, high concentration nutirents in downstream lakes such as Lake Durowskie is due to high pollution in the upstream lakes

The vertical black line across the graph represents the threshold of 24 µg/l between the mesotrophic and eutrophic classes after Simpson and Carlsson (1996). The higher the concentration, the worse is the trophic state. Three lakes in the study area namely Bukowieckie, Kobyleckie and Durowskie have a total phosphorus concentration which falls within the mesotrophic class using 2016 total phosphorus measurements.

Although, all the upstream water bodies showed a remarkable reduction in their Total Phosphorus (TP) concentration this year, this calls for a further investigation as what the true state of their water chemistry might be since the analysis total phosphorus in lakes such as Laskowieckie, Kobyleckie, Bukowiekie and Zamkowe was based on a single point sample collected from each of the water bodies and this might not be a good representation of the whole lake. Essentially, all the water bodies fall in the mesotrophic class index apart from Zamkowe and Lackowicke which still remains in the eutrophic state.

The ChlorophyII *a* concentration decrease for all the lakes this year apart from Laskowickie and Grylewskie which recorded a higher concentration compared to last year. Lake Laskowickie was the only lake that falls in the mesotrophic category last year but due to its increased concentration this year it has moved back to the eutrophic categorization. Overall, base ChlorophyII *a* categorization all the water bodies in the catchment area are predominantly in a eutrophic state, only Lake Kobyleckie and the outflow of Lake Durowskie falls near the classification threshold. Conclusively, a detailed investigation is required for the upstream lake of Durowskie in other to be able to give a concrete assessment of what might have caused the high chlorophyll a measurement of these lakes. This study is only limited to assessing the influence of upstream to the nutrients flowing into Durowskie. The black vertical line on the graph below shows the threshold between mesotrophic and eutrophic state of a lake.

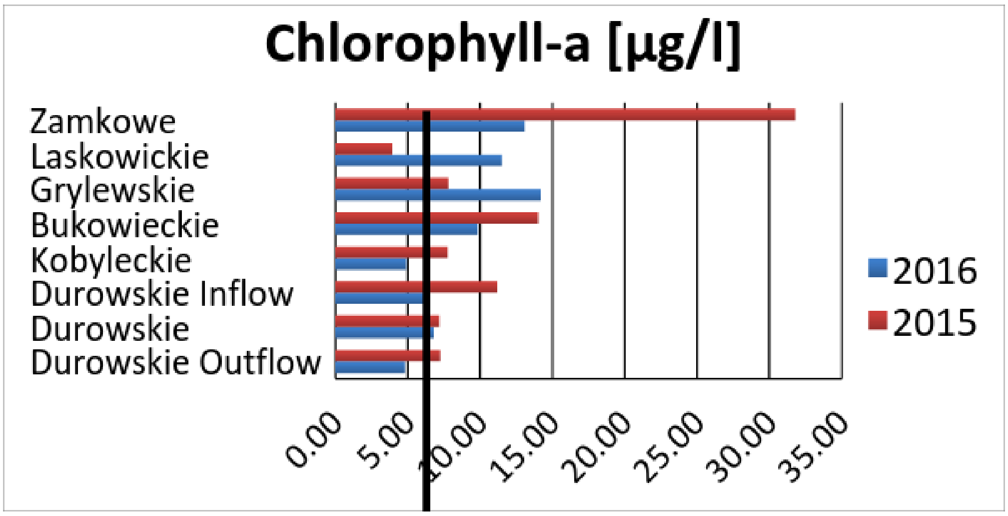

Fig. 13. Catchment area for chlorophyll-a

3.6. TSI classification of Lake Durowskie

The trophic state of the Lake Durowskie was evaluated using the Trophic State Index (TSI) developed by Carlsson and Simpson (1996). For the calculation Chlorophyll a, total phosphorous and transparency (Secchi depth) were used as indicators.

The TSI was calculated for each sampling site in the lake and the mean value for the northern part, southern part as well as the whole lake.

3.6.1. Total Phosphorus Trend

The Total Phosphorus (TP) trend for the lake was calculated for the six sample sites on the lake and the results were further categorized into north and south. With two and four sample sites falling into the north and south respectively. The southern part of the lake shows a remarkable reduction in the level of total phosphorus concentration, additionally the concentration was also reduced for the northern part of the lake. Comparing these results to the previous years a visible reduction pathway can be identify for total phosphorus since 2014 with 2016 showing the highest improvement. For the whole lake the trophic state based on total phosphorus shows that the lake moved from eutrophic class to the oligotrophic class. In as much this is a positive result, we must be mindful because it was reported that few days to the start of the summer school, phosphorus immobilization was carried out on the lake and this might be the main reason for remarkable reduction in the amount of total phosphorus for this year.

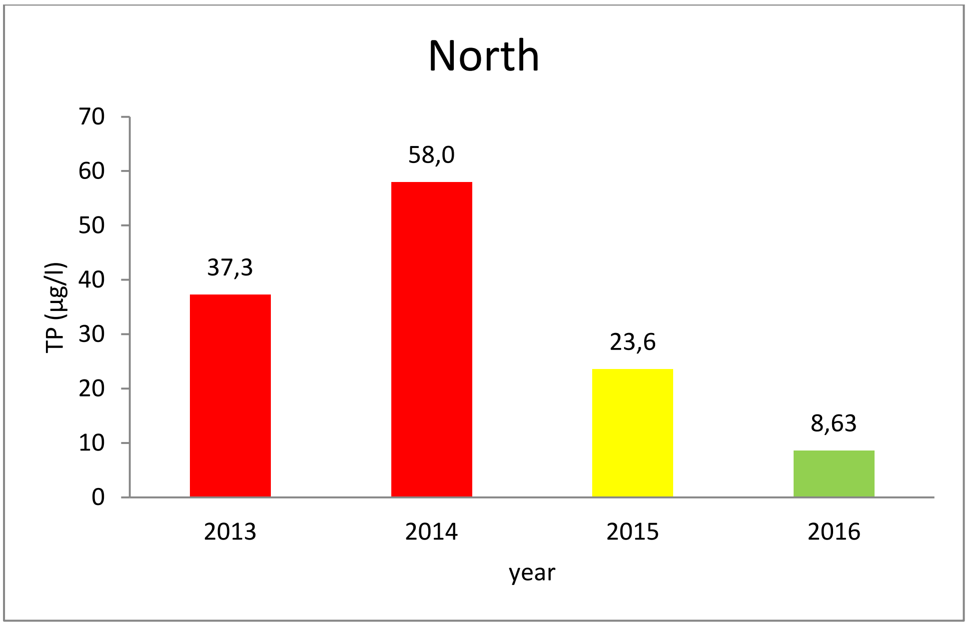

Fig. 14. Total phosphorus trend in north part of Durowskie Lake

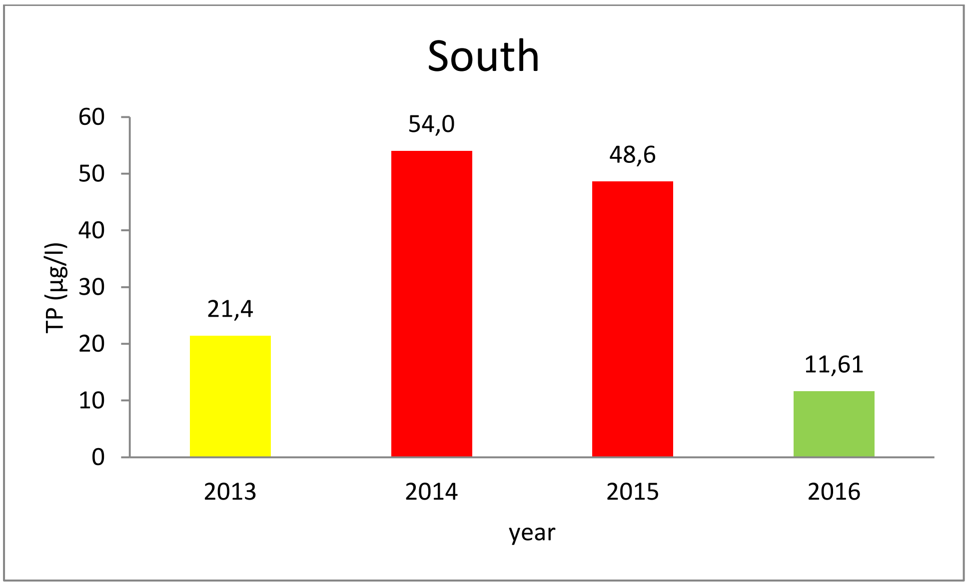

Fig. 15. Total phosphorus trend in south part of Durowskie Lake

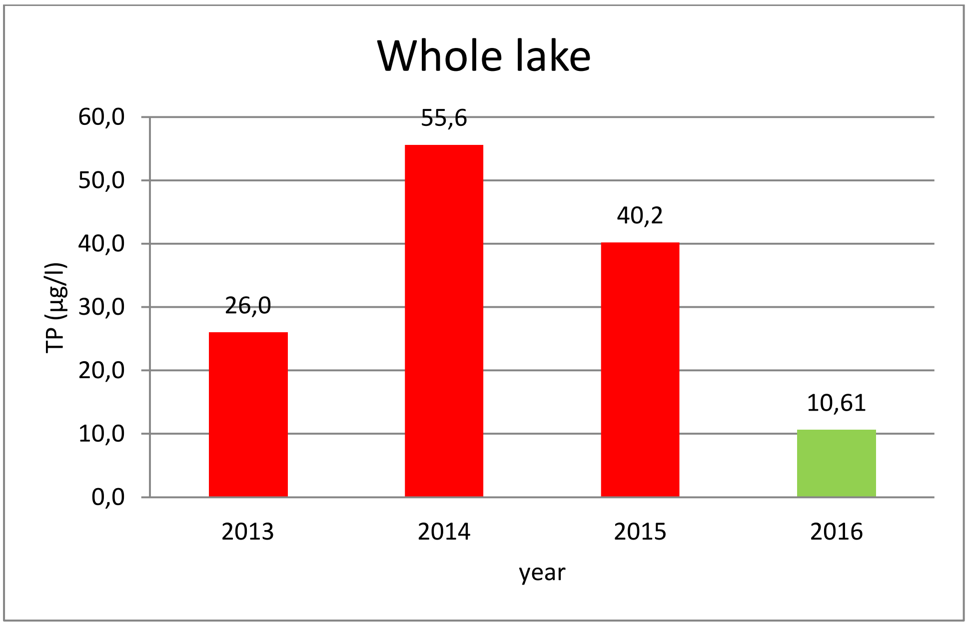

Fig. 16. Total phosphorus trend for Durowskie Lake

TP	Trophic Class
0 - 12	Oligotrophic
12 - 24	Mesotrophic
24 - 96	Eutrophic

Fig. 17. Trophic classes for total phosphorus concentrations according to Trophic State Index

3.6.2. Transparency

The transperancy of the lake was measured using the secchi disc and the average results were calculated for both the northern and southern part of the lake. The transparency which indicates the degree of turbidity of the water is one of the important parameters used in calculating the Trophic State Index (TSI) of the lake. Improvements in clarity of water were recorded in both parts of the lake. Although the southern part moved from the transition between Eutrophic to mesotrophic, the northern part still remains in the Eutrophic class. In general, based on the TSI class using the transparency, the whole lake moved from Eutrophic to mesotrophic for the year 2016. These means the amount of Total

Suspended Solid (TSS) in the water is reducing and this will allow improved penetration of light which is essential for the growth of aquatic organisms.

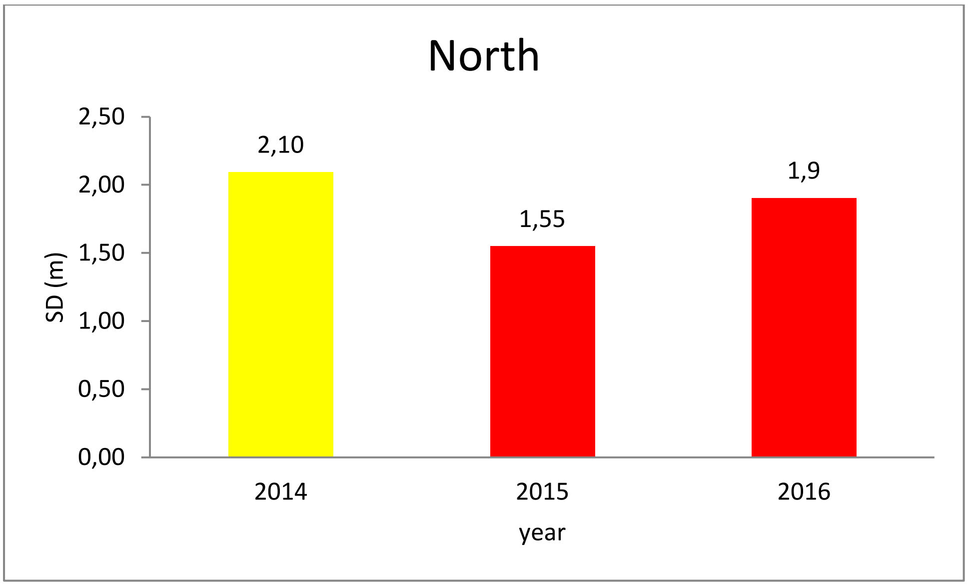

Fig. 18. Transparency trend in north part of Durowskie Lake

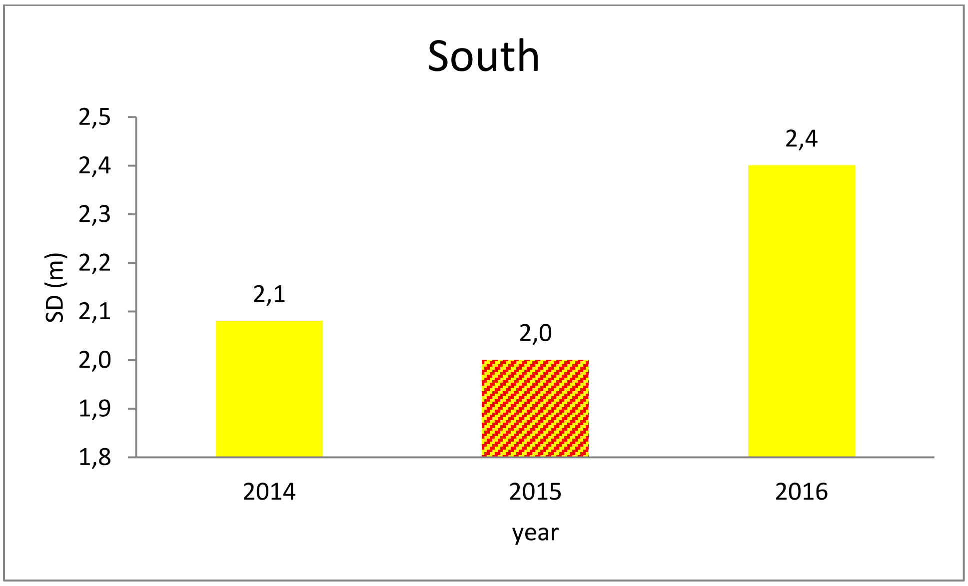

Fig. 19. Transparency trend in south part of Durowskie Lake

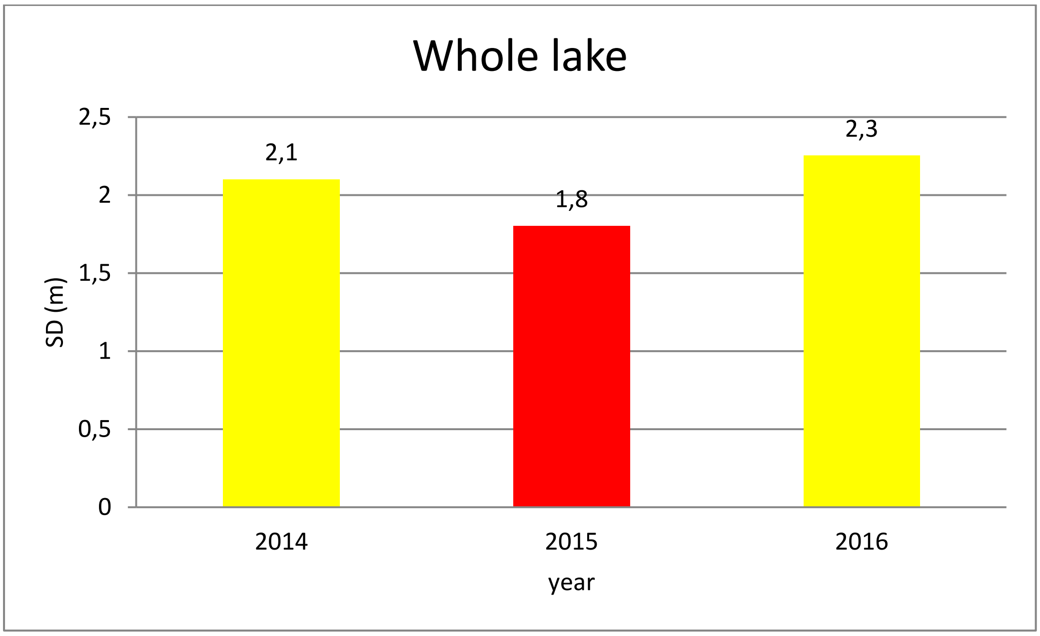

Fig. 20. Transparency trend for Durowskie Lake

SD	Trophic Class
4 - > 8	Oligotrophic
2 - 4	Mesotrophic
0.5 - 2	Eutrophic

Fig. 21. Trophic classes for transparency according to Trophic State Index

3.6.3. Chlorophyll *a* trend

The Chlorophyll a sample of the lake were analyzed using the water sample taken from each sites. This represents an estimate of the amount of photosynthesizing plants found in a sample. Chlorophyll a concentration can also be used to determine the trophic state of a lake. For the first time since 2013 the Chl *a* concentration improved from eutrophic to mesotrophic class in the northern part of the lake while the southern part of the lake still remains in the mesotrophic class same as the last two years. Though the progress is slow, the whole lake is maintaining a steady state in the mesotrophic class since 2013

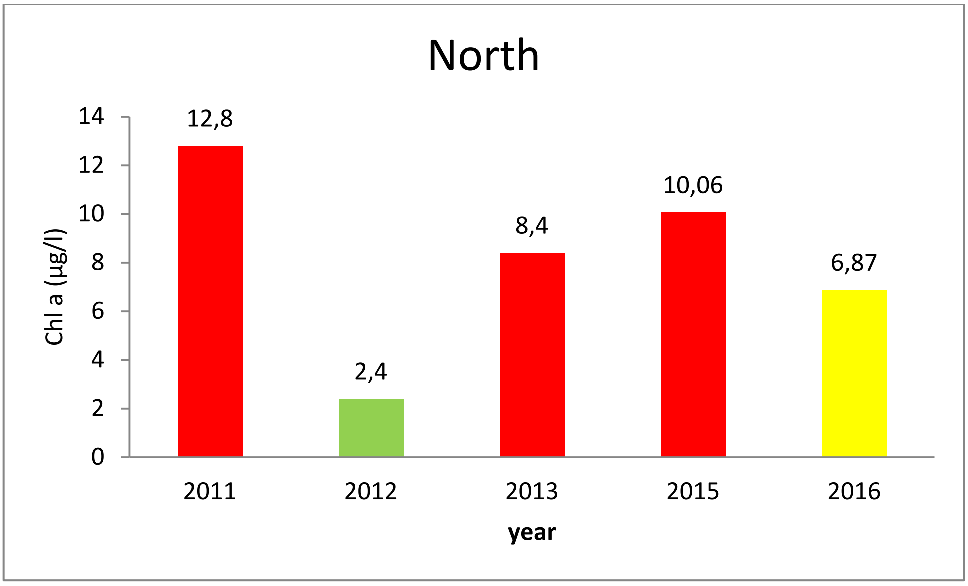

Fig. 22. Chlorophyll-a trend for north part of Durowskie Lake

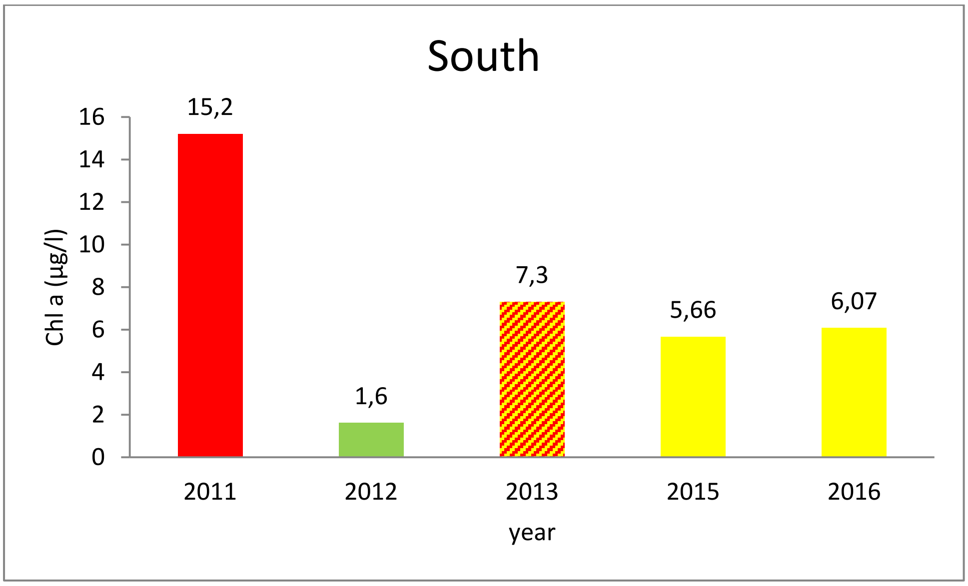

Fig. 23. Chlorophyll-a trend for south part of Durowskie Lake

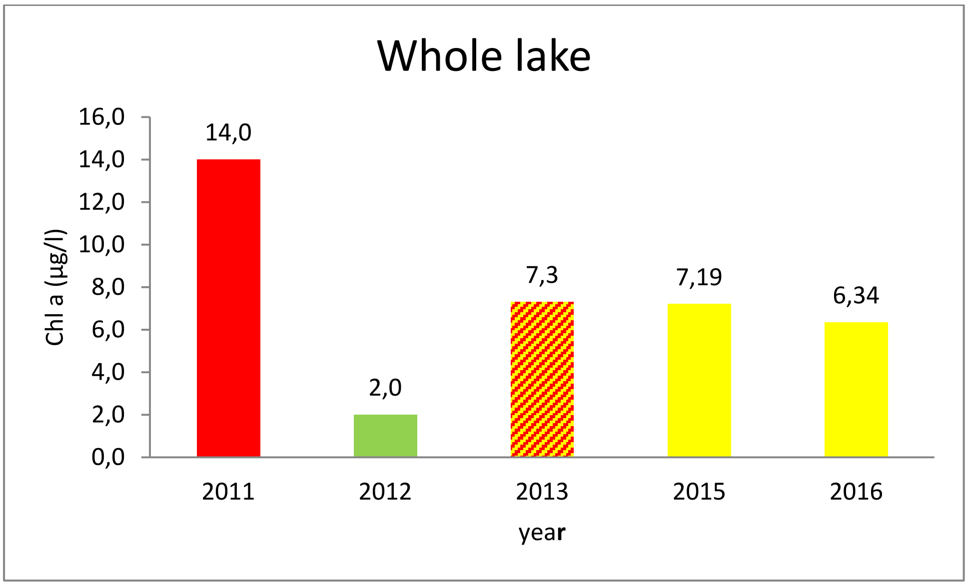

Fig. 24. Chlorophyll-a trend for Durowskie Lake

Chl a	Stan troficzny
0 - 2.6	Oligotrofia
2.6 - 7.3	Mezotrofia
7.3 - 56	Eutrofia

Fig. 25. Trophic classes for chlorophyll-a concentrations according to Trophic State Index

3.7. Ecological state of Durowskie lake in 2016 using Trophic State Index (TSI_M)

Samples were collected from six sites on the lake and analysis was made on nutrients load as well as Chlorophyll *a* concentration. The seechi disc was also used to calculate the transparency at different parts of the lake. The results are presented below;

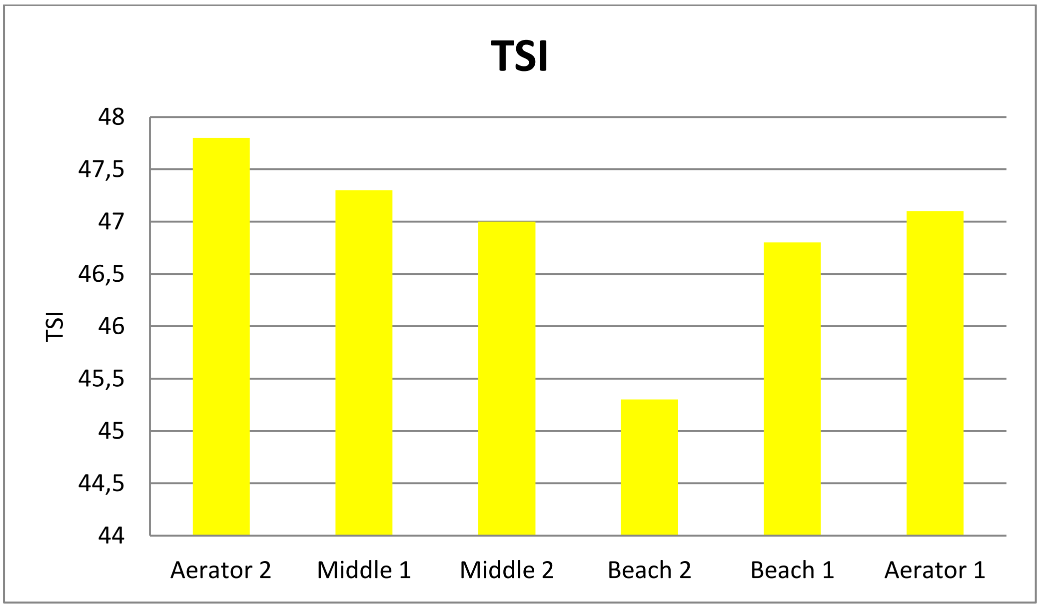

Fig. 26. Trophic State Index for selected stations on Durowskie Lake

TSI_m	Trophic Class
< 30 - 40	Oligotrophic
40 - 50	Mesotrophic
50 - 70	Eutrophic

Fig. 28. Trophic state classes

The general TSI value for all the six sites on the lake were calculated using the three parameters of TSI (TP, Chl*a* and SD). The sites were categorized into their corresponding trophic state based on their respective results using the Trophic State Index developed by Carlsson and Simpson (1996). Although, all the sites fell in the Mesotrophic class , the two beaches recorded the highest index. Also with this, the northern part of the lake has also improved by moving from the eutrophic class to the mesotrophic class

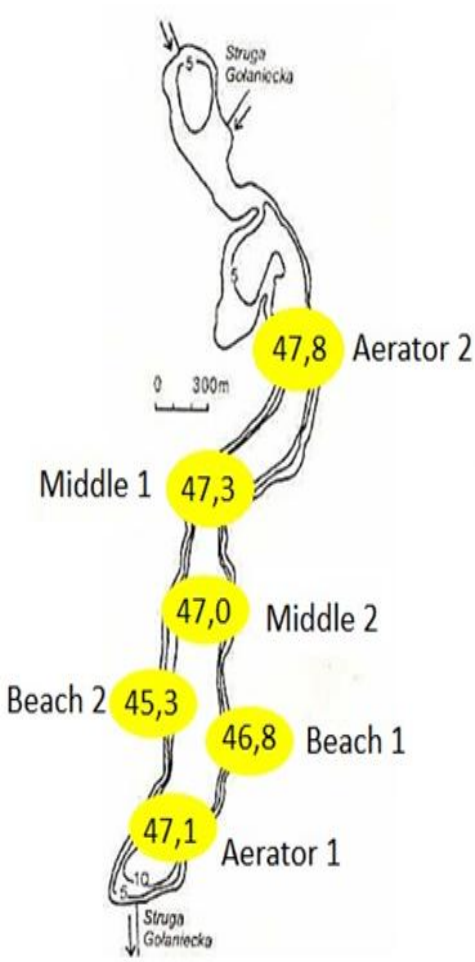

Fig. 27. Trophic State Index for selected stations on Durowskie Lake

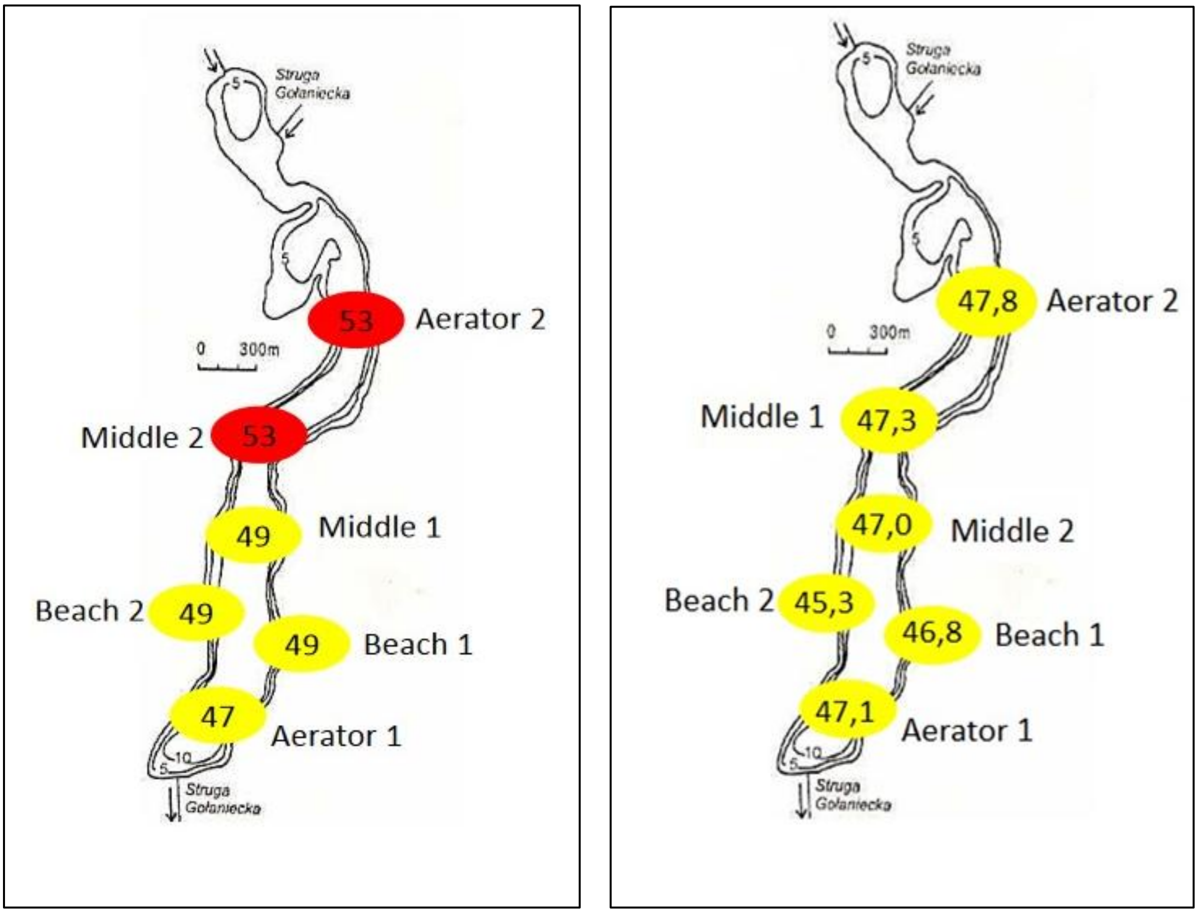

Fig. 29. Trophic state trend for Durowskie Lake

In contrast to 2015 results, all the investigated sites showed improvement in their TSI index, with Aerator 2 and Middle 1 improving from the previously held eutrophic status to mesotrophic classification. This two sites are located in the northern part of the lake and for this year they had a reduction in both the chlorophyII *a* and total phosphorus as well as an improvement in their transparency level. All this translate to an improved index in the TSI classification. This is a well-documented fact that the restoration programme started some years ago is yielding favorable results. Essentially, to ensure a better representation of the northern part of the lake a proposal of more sample sites is recommendaded for future studies.

Conclusively, although all the sites on the lake has improved to the mesotrophic class in contrast to previous years, a contionus restoration programme is highly reccommended because the whole lake TSI index of 46.9 for 2016 and 49.9 for 2015 still falls on the threshold between mesotropic and eutrophic.in other words, more efforts is still needed to achieve the oligotrophic class

4. Conclusion

In conclusion, the analysis have pointed out that, there has been a transportation of high concentration of nutrient from upstream lakes into downstream lakes. Thus, in order for restoration measures to be successful, there is the need to develop a holistic approach which will include upstream lakes as well since they are a major source of nutrient inflow into lake Durowskie. High Total phosphorus and Nitrate concentration were recorded in upstream lakes especially Zamkowe and Bukowiekie. However, these levels were much lower as compared to the previous years. There is also a reduction in the nutrient load for most of the nutrients analysed as compared to the previous years. The low total phosphorus concentration recorded this year in lake Durowskie is partly due the immobilization of phosphorus which took place sometime before the measurements were made. This shows that the restoration is going in the right direction.

The ecological state of the lake has improved according to the Trophic State Index which combines the Total phosphorus concentration, transparency and chlorophyll level of the lake. The most significant improvement was at middle 2 and aerator two which moved from the eutrophic to mesotrophic level. More significantly, all the 6 stations on the lake where measurements were made improved in the Trophic State Index rating.