



# Management of Lake Durowskie

**Summer School 2017**

**'Ecological state of lake during restoration measures'**

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## Introduction

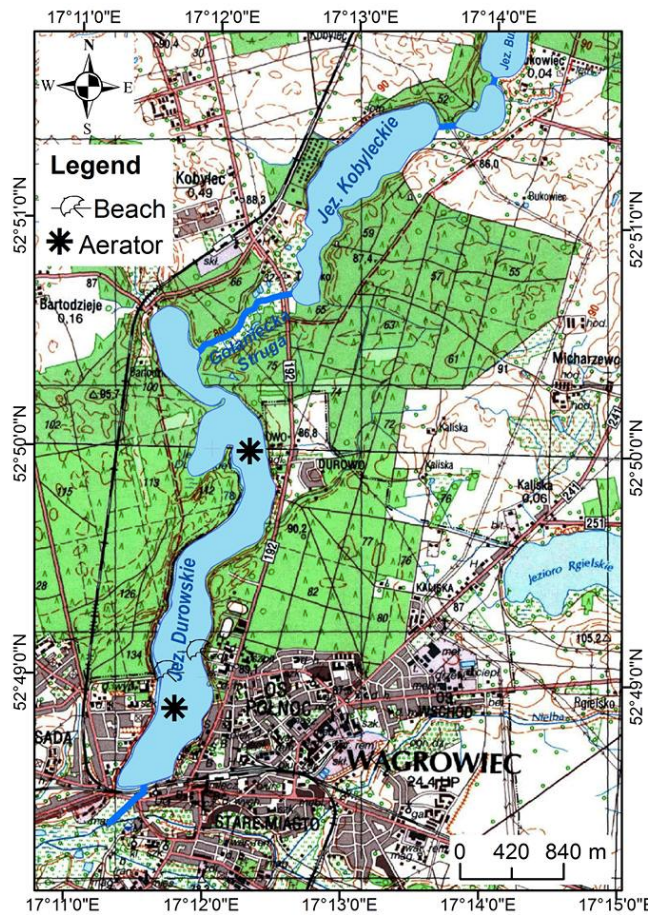


Figure 1. Map depicting Lake Durowskie with location of beaches and aerators

Wągrowiec is a town in northwestern Poland, with an economy largely centered around tourism. The hub of tourism is Lake Durowskie, which is a site for several recreational activities such as swimming, fishing, kayaking, boating, etc. There are also tracks for walking and biking along the lakeside. The bathing beach at the lake was closed for swimming in 1999 due to eutrophication of the lake which caused a toxic cyanobacteria bloom. In response to this, the management of the city implemented restoration measures in 2009, which improved the condition of the lake and facilitated the reopening of the beach.

The summer school has been conducted each year since the implementation of these measures with the

aim of determining the ecological state of the lake in response to restoration, considering not only the physico-chemical variables of water quality and the chlorophyll-a, but also the qualitative composition and abundance of phytoplankton, macrophytes and benthic macroinvertebrates. The lake and its surrounding are studied by walks and kayaking, to identify sources of nutrient input which could be contributing to eutrophication. The lakes upstream to Durowskie were also visited this year to detect their contribution to the inflow of nutrients. Using the monitoring data obtained and the trends seen from previous years, and taking into account risks, this report suggests management options for Lake Durowskie with the goal of establishing top-down trophic control and minimizing the risk of the return of cyanoblooms.



### **Management response**

Restoration measures started in 2009 using three methods: oxygenation of hypolimnetic waters using wind aerators, phosphorus immobilization using iron treatment and bio-manipulation measures – stocking the lake with pike fingerlings. Figure 1 shows the position of the aerators in the lake. These measures have been carried out since 2009, with slight variations in implementation depending on the situation. For example, to prevent the predation of juvenile pike fingerlings by bigger fish, an experimental measure was taken this year to have a delayed introduction when the fish were already grown. The positive or negative impact of this measure is yet unknown. There have also been measures to control erosion around the lake, however it is unknown whether these measures were part of the restoration portfolio.

### **Environmental response**

Up until now there have been records of moderate successes in improving the ecological state of Lake Durowskie, with better conditions at the northern section of the lake. The southern section remains poor and there have been records of increasing numbers of cyanobacteria mostly at the inflow. Reports from algae monitoring in 2016 suggests that Lake Durowskie is eutrophic and even hypertrophic at areas such as the inflow. The current state of Lake Durowskie with respect to phytoplankton (refer to phytoplankton report) shows that there is a high biomass of phytoplankton especially at the inflow. This increase in biomass is often linked to the high influx of nutrients from other lakes where there are moderate or no restoration measures, increasing the chance of cyanobacteria blooms as more nutrient rich water flows into the lake. With this current situation there is an increased chance of cyanobacteria blooms as more nutrient rich water from the other lakes flow into Lake Durowskie. The results from monitoring of macroinvertebrates indicate that the lake conditions are better close to the shoreline, that is in the shallow region, and still eutrophic in the deeper regions. In relation to the physicochemical aspects (refer to physicochemical report) the status of the lake is mesotrophic. Still, the south part of the lake presents a greater concentration of phosphorus than the northern part. The monitoring done this year shows greater concentrations of phosphorus in the inflow of the upstream lakes, that eventually ends up in Lake Durowskie. In relation to macrophytes the number of associations has increased, however the percentage of species that indicate good water quality is not significant. An overview of the monitoring parameters indicates that, even though the situation has improved in



some aspects due to the measures implemented, other issues in the lake still need to be further addressed with additional measures to make the remediation more efficient, as the input from the upper lakes greatly affects the lakes water quality.

**Pressures on restoration**

The monitoring data suggests that the condition of the lake is improving, however it isn't stable and a significant disturbance could shift it back towards a eutrophic state. Hence, it is necessary to understand the threats to the restoration of the lake. The conceptual model shown in Figure 1 summarizes the situation and tries to identify the pressures.

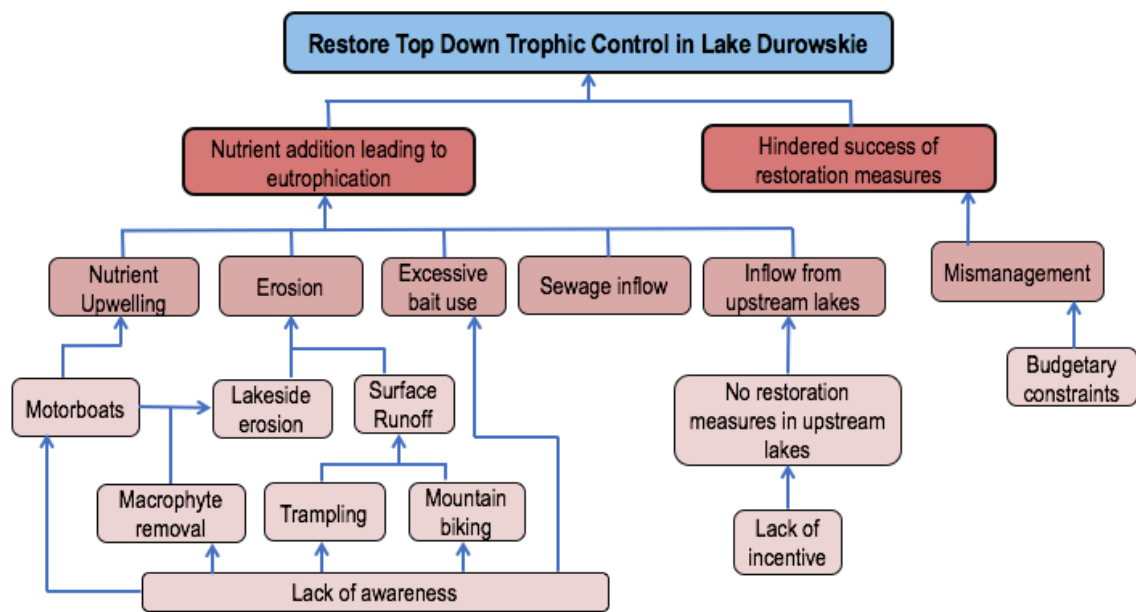


Figure 2. Conceptual model for restoration of Lake Durowskie

The two major pressures faced by the restoration process are the continued addition of nutrients to the lake, and obstacles in the successful implementation of the measures. The major sources of nutrient input are similar to the previous years, and can be read in detail in the previous lake management reports. Management alternatives mentioned later in the report delve deeper into solutions for combatting these threats.



## Management Scenarios

As detailed in the Lake Management Report from the year 2016, there are three possible management scenarios or action scenarios. Building on the information presented in the 2016 report, this section presents the strengths, weaknesses, opportunities and threats (SWOT) of these scenarios.

### Scenario A

Scenario A describes a situation where all restoration measures are discontinued. Given that the state of the lake has improved over the years and recreational activities are not impaired, it could be a financially attractive option. However, analysis of monitoring data indicates that the lake is still in an unstable state, and discontinuation of restoration could lead to a new bloom of cyanobacteria.

Strengths	Weaknesses
No immediate costs	Worsen lake health Will push back progress from previous restoration measures
Opportunities	Threats
Saved funds can be used for other development projects	Beach closure due to cyanoblooms Loss of tourism based revenue Reduced fishing catch

*Figure 3. SWOT analysis for management scenario A*

A discontinuation of restoration measures for Lake Durowskie would most likely reverse all restoration effects achieved so far and finally result in new and probably even stronger algae bloom. This would prevent touristic activities such as bathing as well as fishing because of decreasing of fish population. The SWOT analysis for Scenario A is presented in figure 3.

### Scenario B

Scenario B describes a situation in which the restoration efforts do not increase considerably and even continue at a slightly decreased intensity. This management practice has prevented cyanobacteria blooms thus far. However, this presents an unpredictable situation since the measures to restore the lake are being threatened by the pressures described in the conceptual model.



There is an increasing demand for services provided by the lake created by increasing recreational use, e.g. upgrading the camping grounds and increased use of motor boats. The planned damming of Lake Laskowieckie poses an immense threat to the restoration as it would set the surroundings of the landfill upstream under water, which would lead to dissolution of heavy metals and

Strengths	Weaknesses
No additional investments required No need for new organizational systems Cyanoblooms have been prevented so far	Slow progress Continual long-term investment Doesn't address watershed management No community involvement
Opportunities	Threats
Can provide long-term data about effectiveness of current restoration measures	Risk of return of cyanoblooms due to any significant environmental change Dam on Lake Laskowieckie could destabilize the situation

Figure 4. SWOT analysis for management scenario B

nutrients currently bound in the soil close to the lake. This could lead to an increase in inflow of nutrients to Lake Durowskie and push back the lake to a eutrophic state. It is therefore very unlikely that the lake ecosystem can withstand the increase of human induced pressures without introducing further management activities to complement the restoration measures. The core principle of long term lake management is watershed management, and a restoration plan with only in-lake management is bound to face obstacles. Figure 4 presents a SWOT analysis for this scenario.

**Scenario C**

Scenario C is to intensify restoration measures to improve the quality of the lake and save future expenses. Since it is necessary to address not just the symptoms of a problem, but also the causes, suggested measures focus on management of services provided by the lake, watershed management, and public awareness. These measures would require and promote inter-organizational and cross-boundary cooperation. They would also reduce the risk from the building of the dam

Strengths	Weaknesses
Will speed restoration process Promotes cooperation between communities Involves community participation Addresses watershed management Reduces risk of destabilization due building of dam	Increased restoration costs in the short term New organizational systems required
Opportunities	Threats
Increased tourism due to improved condition of lake and from cross boundary economic activities New investments due to improved lake health Increased awareness could increase residents' sense of pride in the lake	Conflict of interest between stakeholders Breakdown of inter-organizational cooperation Dam on Lake Laskowieckie could destabilize the situation

Figure 5. SWOT analysis for management scenario C



on Lake Laskowieckie, as well as from other possible threats. Even if no further pressures were to occur, a broadening and improvement of the restoration portfolio would enable the lake to faster return to a top-down controlled system, which is no longer dependent on restoration measures. This would also help to save expenses in the future. Figure 5 presents the SWOT analysis for this scenario.

The following section ‘Management alternatives’ describes the suggested measures and evaluates their suitability for the situation.

## Management alternatives

To intensify the restoration process and to mitigate risks, it is necessary to address the issues of watershed management, public awareness, and management of upstream lakes. Further technical measures can also be implemented to directly address the problem (Figure 6). This section presents management practices which were deemed suitable for the situation based on an evaluation criteria described in Box 1. Tables 1, 2 and 3 present the results of the evaluation of all the measures.



Figure 6. Complementary Management Approaches





*Box 1. Evaluation criteria***Evaluation of management options**

The following criteria were used for the evaluation of the watershed and lake management alternatives.

1. **Effectiveness:** how well the management practice meets its goal
2. **Ease of implementation:** whether the implementation of the practice involves creation of new organizational structures, inter-organizational cooperation, or faces any other hindrance
3. **Longevity:** duration of treatment effectiveness
4. **Potential negative impacts:** how the action may lead to beneficial or adverse impacts on other elements of the lake system
5. **Potential stakeholder conflicts:** whether the management practice may lead to conflict of interest between different stakeholders
6. **Capital costs:** initial investment required to set up the measure
7. **Operating and maintenance effort:** cost and effort required for continued implementation of the measure

Each measure has been rated on a scale of 1 to 4 for the above criteria, with 1 indicated poor value for the criterion and 4 indicating excellent. For ‘effectiveness’, ‘ease of implementation’, and ‘longevity’, a value of 4 refers to a high value, such as high effectiveness. For the other four criteria, a value of 4 refers to a low value of the measure, such as low capital costs.

1	2	3	4
Poor	Fair	Good	Excellent

**Awareness and Public Education**

Lake restoration is only possible with the support of the local population and all those who visit Lake Durowskie. The behavior of these beneficiaries can also have a large effect of the ecosystem. It is important to encourage members of the community to care about the lake, especially through education and increasing a sense of ownership. People are much more likely to act as good stewards when they feel that the lake belongs to them as members of the community in Wągrowiec.

At the current time, recreational users of the lake are causing real harm in several ways. There is a significant amount of litter around the lake, especially plastic and glass containers. This is a source of pollutants for the lake and, in the case of glass, is also a significant safety hazard to



swimmers. This is in addition to harmful fishing practices and the use of eroded footpaths discussed in detailed in reports from previous years. Some of this is from visitors from other communities, but a larger number of those using the lake are from the local area.

To deal with these threats, reports from previous years proposed a lake festival and an educational path to further education and increase sense of ownership. These could be complemented with the measures below. Figure 7 shows how the measures contribute to the goal of restoration.

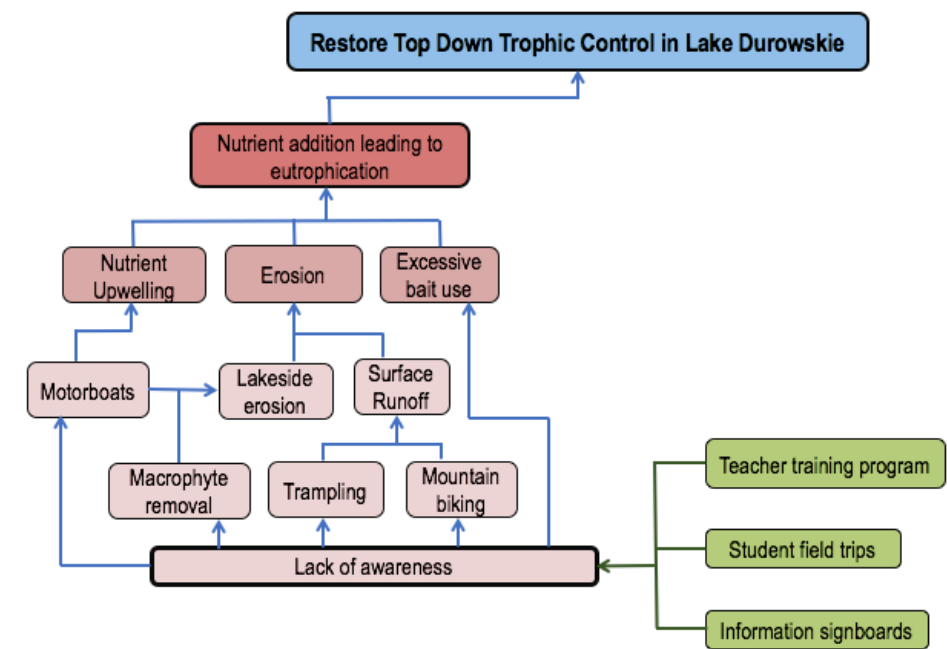


Figure 7. The impact pathway for awareness and public education measures

### ***Teacher Training Program***

The creation of a day-long training course for local teachers is proposed to be led by Dr. Wilhelm Windhorst from the University of Kiel and the students of the international summer school in 2018. Teachers would be taken around the lake, by foot and/or kayak, and would learn more about the lake, restoration measures being taken, environmental and anthropogenic threats, and ways to minimize impact. Following this, the teachers can use this information to lead the school field trips describes in the next measure.

In addition, students in this year's summer school have offered to provide some sample materials to be used by local teachers to relate the situation of the lake to other subjects being



taught at school. Integration with concepts taught in biology and chemistry classrooms would be straightforward and untranslated short texts could also be used in foreign language classes. Integrating the situation of the lake into normal lessons would be a good way to make these subjects more accessible to the students since it relates to something in their everyday lives. These in class lessons would be effective at reaching students at all levels of primary and secondary education.

### ***Student Field Trips and Lessons***

Perhaps the greatest benefit of the teacher training program would be helping teachers create similar field trips for their students. This would be an opportunity to teach the children how to be good stewards of the lake in the future in a fun and engaging learning environment. Going and doing this in the field would further engage students and help them see the real situation. This is especially true for primary students. Also, since everything is taking place within the local area in public places the organization of such trips should be quite straightforward and possible at a very low cost.

### ***Informational Signboards***

Signs with awareness and educational messages should be placed on the main entrances of the lake and the parking lot as well. The signs should contain messages about the importance of protection of the lake, its current state, the environmental measures being implemented and how the community can participate. Signs can be placed at the beginning of unauthorized paths with awareness messages about the effects of erosion in the lake to discourage hikers and mountain bikers from using them.

*Table 1. Evaluation matrix for awareness and public education measures*

<b>Practice</b>	<b>Target problem</b>	<b>Effectiveness</b>	<b>Ease of implementation</b>	<b>Longevity</b>	<b>Potential negative impacts</b>	<b>Potential Stakeholder conflicts</b>	<b>Capital costs</b>	<b>O&amp;M</b>
Teacher training program	Lack of awareness	4	3	-	4	4	4	-
Student field trips	Lack of awareness	4	3	-	4	4	4	-
Information signboards	Lack of awareness	2	4	4	4	4	4	4



**Management of recreational activities**

As describes previously and in other reports, the recreational activities supported by the lake also put pressure on the lake system, being a cause of nutrient input due to erosion, nutrient upwelling in the lake, destruction of macrophyte belt, etc. Hence it is necessary to have setups to manage these activities and limit their impact on the lake. The following section of the report describes the different activities in and around the lake and how they can be managed at a low cost and effort.

***Motorboats***

Waves generated by motor boats (Figure 9) erode the lake’s shoreline, especially in areas lacking in vegetation. The mooring of boats into the macrophyte belt also destroys the vegetation. In addition, they cause disturbance to aquatic ecosystems, damage docks and boats, upset kayakers, paddle boats and row boats, and may endanger swimmers. Motor boats include, but are not limited to: power boats, fishing boats, and jet skis. A few easy to implement measures can used to limit the impact of motorboats and to reduce the pressure on the lake. Figure 8 illustrates how these measures contribute towards the goal.

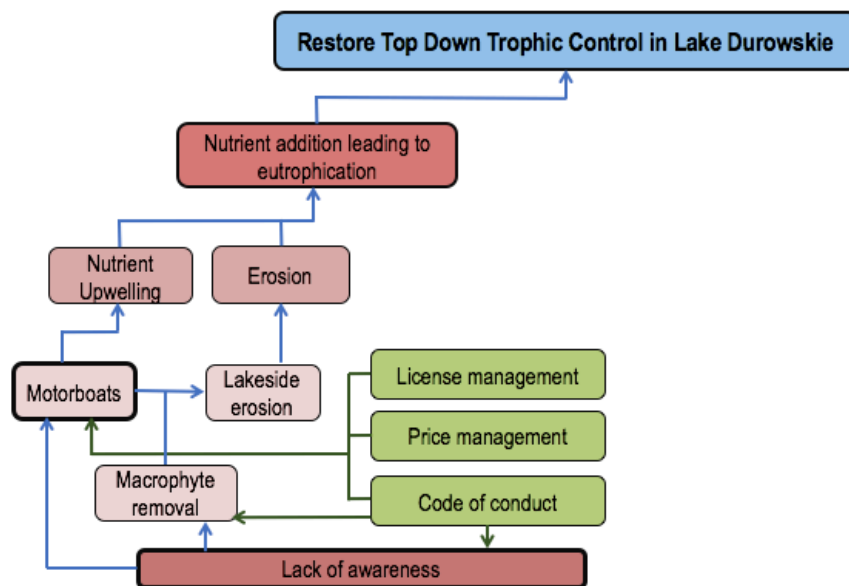


Figure 8. The impact pathway for motorboat management measures



### *Code of Conduct*



Figure 9. Waves created by motorboats

It is suggested to prescribe a code of conduct for the users of motorboat, which will establish good practices like limiting speed near kayakers, swimmers, the shore, and fishing boats, and at the same time will reduce their impact on the lake. The following conduct can be prescribed to address the negative influence of motorboats:

**Waves:** To reduce the effects of waves created by motorboats on lakeside erosion, the speed of boats should be limited to 5 kilometers per hour within 30 meters of the shore. Engine capacity should also be regulated to reduce the frequency, strength, and size of the waves.

**Water Quality:** Boats are not to throw anything into the lake or on the shoreline. All trash produced in any activity must be stored until it can be deposited in an appropriate receptacle. In addition, all boats should comply with holding tank regulations to avoid accidental spills. Boats presenting leakage of any kind should not be allowed on the lake.

**Mooring:** Boats will anchor only on designated locations to avoid damaging the macrophyte belt.

### *License Management*

In Poland, to drive a motorboat with an engine capacity of more than 10hp, a certification is required, which includes a training course about inland rules and regulations. To control the number of motor boats in the lake, every boat owner must show their motor boat license and all boats must have a license plate or its equivalent on the side. A database of the boats entering the lake should be kept as a control.

### *Price Management*

To promote the use of electric boats a fee can be charged for motorboats depending on their size and activity. Activities that involve higher speeds will require the highest fee, followed by



calm activities like fishing. Electric boats will require the lower fee to encourage their use over motorboats.

Permitted times to use motor boats should be continued and evaluated periodically. Zoning of the lake could be studied and considered to limit the area of the motor boat use as mentioned in previous reports.

***Fishing***

Currently several common fishing practices are contributing to the further eutrophication of Lake Durowskie. Among them is the common practice of fishermen using excessive amounts of bait when fishing in Lake Durowskie, in the hope of catching more fish. This input of nutrients causes further pressure of the lake and increases the likelihood of cyanobacteria blooms and other negative consequences of eutrophication. Further environmental damage related by fishing is seen with poorly constructed jetties which destroy the macrophyte belt in the region. Figure 10 shows how the suggested measures will counter the threats for restoration.

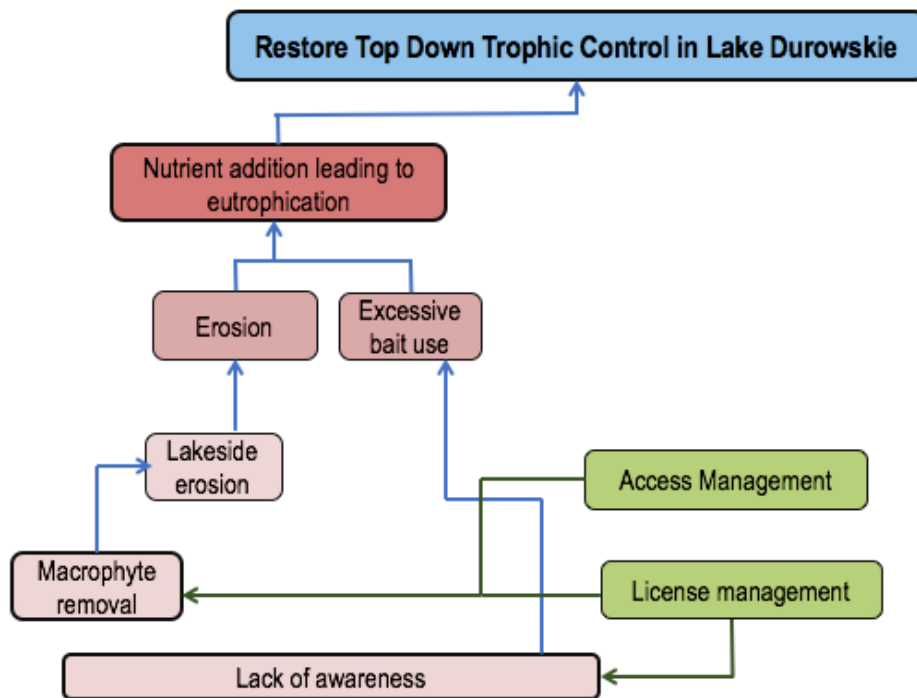


Figure 10. Impact pathway for fishing management measures



### *License Management*

Our solution to deal with pressures of fishing on the lake is to increase awareness of the effects of harmful fishing practices on the lake environment. We propose a simple new addition to the process of obtaining and renewing a license to fish on the lake based upon a similar system used to regulate mountain access in Taiwan. In order to obtain or renew a fishing permit all applicants would be required to answer several simple multiple-choice questions about how certain fishing practices harm the lake ecosystem, especially target fish species. All of the information needed to answer the questions would be provided in a single short article provided at the place of application or online. Successful completion of this small “test” would not be a significant obstacle to obtaining a permit since all answers would be simple and easily available while answering the questions. At the same time, this process ensures that all fishermen on the lake are made aware of how their actions can affect the lake ecosystem and the future success of all fishermen on the lake. By increasing this awareness, we can encourage all fishermen to avoid activities which cause undue stress upon the lake without any significant investment of funds.

### *Access Management*



*Figure 11. Patch of macrophyte belt removed for fishing*

Over the last years the number of jetties has been reduced, however many are still constructed behind the macrophyte (reed) belt or without direct access to the lake shore. Such jetties can only be used if the reeds in front of them, or between them and the lake shore, are destroyed to allow access. As mentioned in

previous reports the macrophyte belt can reduce the impact of erosion by reducing the impact of wave action on the shore and blocking sediment from flowing down the slope into the water. Macrophytes also increase water quality by absorbing nutrients flowing from the surrounding landscape and preventing them from further accumulating in the lake.



In addition to tackling this problem through education in the licensing process as described previously other actions could be taken to improve the situation. Permits to construct new fishing jetties should require that they be built in front of the macrophyte belts with easy access the shore to prevent unnecessary removal of macrophytes. Older jetties without up to date permitting should also continue to be removed as time goes on with the goal of reducing the total number of fishing jetties.

### *Hiking*

Along the walks around the lake, it was noticed that the access stairway is far from the forest parking area, which facilitates the use of trails to descend the slope to the lake. This creates paths for erosion (Figure 13). Hence it is necessary to provide suitable access paths and information to visitors.

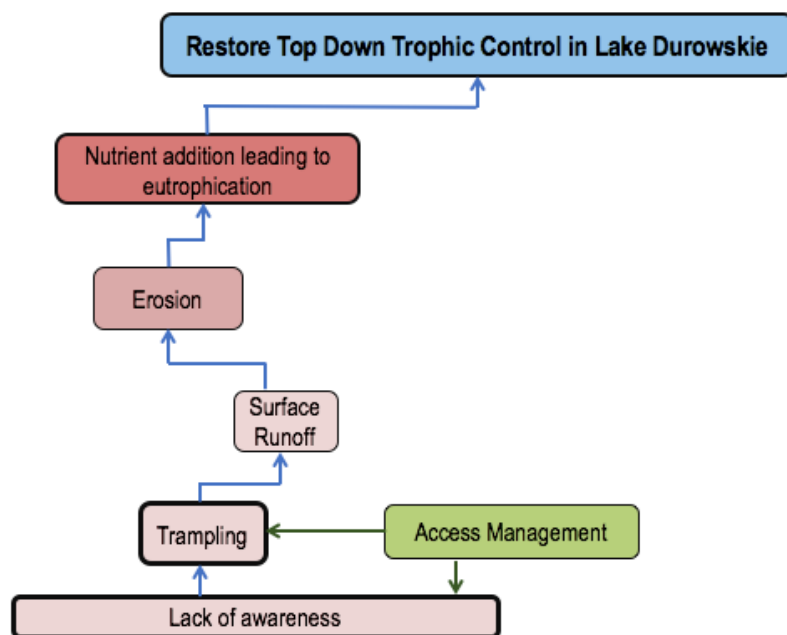


Figure 12. Conceptual model: hiking management measures





*Access Management*



Figure 13. Erosion along walking trails

The access to the lake should become more efficient to prevent people from using unauthorized paths. This can be done by implementing boardwalks, meandering paths, or stairs in strategic locations, like the entrance of the parking lot. All stairs should be posted with signs showing how far ahead the next staircase is located. Informational signs can also be posted informing people about the negative impacts of erosion.

*Mountain Biking*

Mountain biking activity in the forested area along the lake also creates pathways for erosion (figure 15). This can be reduced by the measures shown in figure 14.

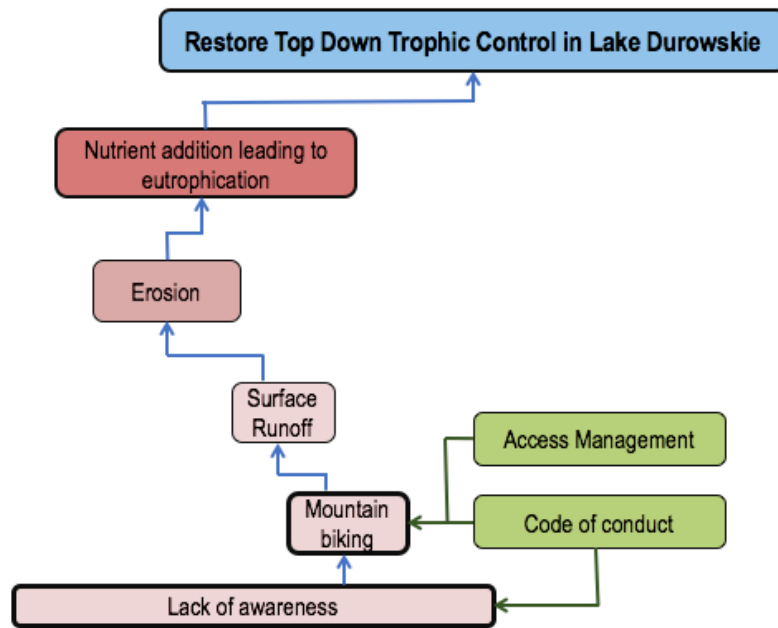


Figure 14. Impact pathway for mountain biking management measures



### *Code of Conduct*

Mitigation measures for this activity can also be addressed through prescribing a code of conduct. The code will promote responsible and courteous conduct on the trails that will at the same time aid in the reduction of erosion and it will include as aspects such as the following:

- Staying on existing trails and not creating new ones.
- Avoid riding around standing water which results in the widening of the trail.
- Do not litter and contribute to improving the trail for others by picking up and removing any litter

### *Access Management*

Since the use of off path tracks have been identified as a source of erosion, the biking track should be clearly delimited and signed with information regarding speed, direction, and distance. The entrance should contain an information board depicting the rules of the code of conduct and information regarding remediation and erosion.

The biking tracks should be designed with sustainable grades. An assessment of the current paths should be made to evaluate their location. It is preferred for them to be in dry, cohesive soils that can be easily compacted or have a coarse/rock bottom. Flat terrains, wet soils, and places susceptible of accumulating water should be avoided as they create mud. Alternative trails can be contemplated if the current ones are assessed to be unsuitable.



*Figure 15. Trails used for mountain biking. The erosion due to water flow is evident.*



Table 1. Evaluation matrix for recreational activity management measures

Practice	Target problem	Effectiveness	Ease of implementation	Longevity	Potential negative impacts	Potential Stakeholder conflicts	Capital costs	O&M costs
<b>Motorboats</b>								
Code of conduct	Lakeside erosion	2	4	4	4	4	4	4
License management	Lakeside erosion	2	4	4	4	2	4	4
Price management	Lakeside erosion	2	4	4	4	3	4	4
<b>Fishing</b>								
License management	Overuse of bait	3	3	4	4	4	4	4
Access management	Erosion	3	3	4	4	3	3	3
<b>Mountain biking</b>								
Code of conduct	Erosion	2	4	4	4	4	4	4
Access management	Erosion	3	2	2	3	3	3	3
<b>Hiking</b>								
Access management	Erosion	3	3	3	3	4	3	4

**Technical Measures**

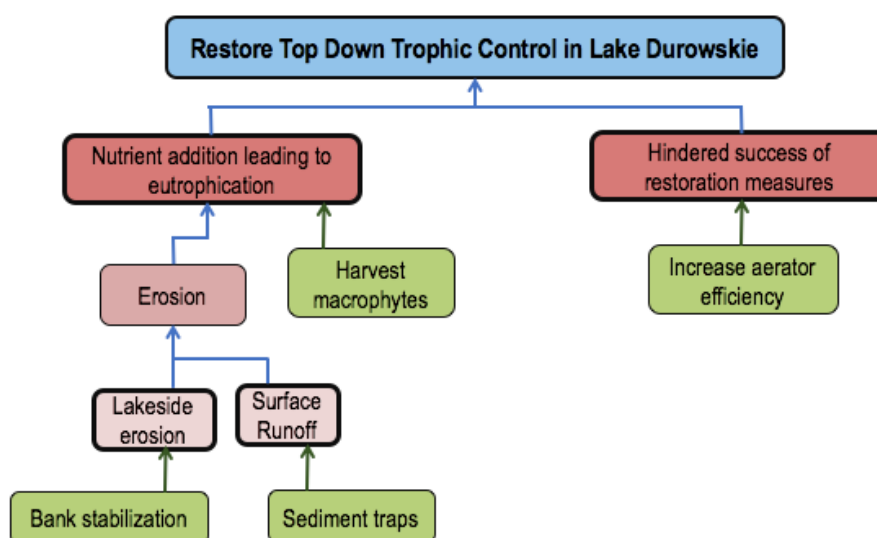


Figure 16. Impact pathway for technical measures



### ***Sediment Traps***

To capture the loosened soil caused by hiking and mountain biking that is eroded by rain, and to protect the water quality of the lake, sediment traps can be built in strategic locations where runoff and erosion have been identified. The traps can be located at the base of steep slopes, stairs, unauthorized paths, and mountain bike trails close to the lake (look at previous reports for details).

### ***Bank Stabilization***

Bank stabilization is meant to protect the shore from erosion through different methods like dikes, erosion protection and, stream channel restoration. The stabilization should be designed in a way and located in places to minimize potential impacts to the lake and its ecosystem where the shore is unstable and immediate intervention is required.

### ***Increase Efficiency of Aerators***

The two aerators present in Lake Durowskie have contributed greatly to the lake's increased health over the past years by increasing the oxygen levels in deep waters and allowing sedimentation of phosphorous (for further details see previous reports). However, while phosphorous levels have been somewhat reduced other indicators for the health of deeper waters are not as positive. The diversity and abundance of macroinvertebrates in these areas has remained very low. To further oxygenate the hypolimnetic zone it is necessary to improve or increase the number of aerators on the lake. They are currently wind powered, which means that on many days when wind is insufficient, they are inactive. This is especially common in summer when aeration of the lower layers of the lake is most important. One possible solution is the installation of electric motors powered by solar panels on one or both aerators. This supplemental power source can increase the efficiency of aeration of the hypolimnetic layer, improving the situation for macroinvertebrates and increasing the sedimentation of phosphorous out of the system. It would also be more cost effective than adding additional aerators, although ideally both solutions might be considered together.



### ***Harvest Macrophytes***

As suggested in the 2016 report, the harvesting of macrophytes could aid in the remediation of the lake, as research into the ability of reed to remove nutrients has been carried out in other locations and has proven to be effective for water quality restoration. In addition, the reed material can be used for the creation of handicrafts like hats, baskets, and paper.

Harvesting times need to be schemed to maximize its positive impacts and avoid the negative ones. The time of the year should be when the macrophytes have absorbed maximum nutrients and the evapotranspiration in the area is not high, as the water absorbed by evapotranspiration can affect water quality. The 2016 report recommends the harvesting to be held in the month of July or early August in Lake Durowskie, as they identified that period to be the one with the maximum nutrient uptake.

*Table 2. Evaluation matrix for technical measures*

<b>Practice</b>	<b>Target problem</b>	<b>Effectiveness</b>	<b>Ease of implementation</b>	<b>Longevity</b>	<b>Potential negative impacts</b>	<b>Potential Stakeholder conflicts</b>	<b>Capital costs</b>	<b>O&amp;M costs</b>
Increase aerator efficiency	Eutrophication	3	2	4	4	4	2	3
Harvest macrophyte	Eutrophication	2	3	1	2	4	2	3
<b>Erosion control</b>								
Sediment traps	Erosion	4	3	3	3	4	4	3
Bank stabilization	Lakeside Erosion	4	2	4	4	4	3	3

### **Upstream Management**

Lake Durowskie is the last of the lakes in the cascade located between Gołańcz and Wągrowiec. Monitoring reports show that water quality in upper lakes is worse than in Lake Durowskie (refer to physico-chemical quality report). The high concentration of pollutants in Lake Kobyleckie is a hazard for water quality in Lake Durowskie and because of the location of Lake Durowskie, the input of pollutants from the upper lakes is unavoidable. The following measures try to mitigate the risk posed by inflow from upper lakes, with the threat addressed depicted in figure 17.



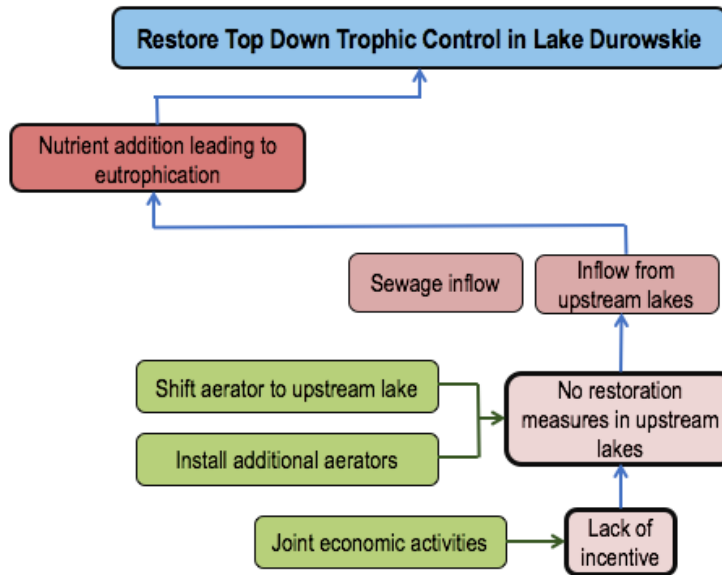


Figure 17. Impact pathway for upstream restoration management measures

### Shift Aerator from Lake Durowski to Lake Kobyleckie

Of the two aerators installed in Lake Durowskie, one is in the southern part of the lake—near to the outflow, and the second one is close to the inflow, in northern part of the lake. The southern part of the lake is deeper and mostly surrounded by urban and recreational areas such as beaches and docks. The northern part of the lake is shallow with forests in the area adjacent to the shoreline. The aerators, land cover use, bathymetry of the lake and the location of inflow and outflow causes a differentiation of water state between the northern and southern parts of the lake. Analyses based on macrophytes, macroinvertebrates, diatoms and phytoplankton show that higher water quality is observed in the northern part of the lake (refer to reports of algae, macroinvertebrates and macrophytes from 2016).

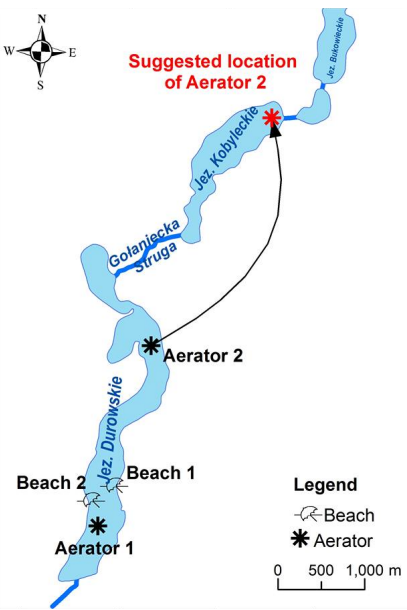


Figure 18. Suggested location of aerator in Lake Kobyleckie

Due to the permanent input of pollutants from Lake Kobyleckie and relatively stronger water quality on the northern side of the lake, we suggest transferring one aerator from the shallow, northern part of the Lake Durowskie to Lake Kobyleckie. The upper lake has a deep area near its



inflow and a shallower area to the south – close to the outflow. Introduction of an aerator to the northern (deep) part of the lake could improve water quality close to the inflow, then to the shallow part, and finally in Lake Durowskie.

### ***Install new aerator in Lake Kobyleckie***

As an alternative to the previous measure, another option is to install an additional aerator in Lake Kobyleckie. The pros and cons of the alternatives can be seen in the evaluation in table 3.

### ***Joint Economic Activities***

While watershed management, such as the addition of an aerator would be a valuable step toward restoration of top-down control in Lake Durowskie, it presents certain challenges. Since Lake Kobyleckie and all other upstream lakes are outside of the administrative area of the city of Wągrowiec any actions taking place there would require the consent, and ideally at least some funding, from the upstream communities. To encourage such cooperation, we suggest that further incentives be identified to motivate upstream communities to take an active part in managing the watershed.

Currently more or less all tourism in Wągrowiec County (Powiat Wągrowiec) is concentrated in the city of Wągrowiec. We propose the creation of recreational opportunities that could attract new visitors not only to Wągrowiec, but also to upstream communities. One possibility is the creation of a medium to long distanced kayak trail beginning in one of the upstream lakes and terminating at the end of Lake Durowskie in Wągrowiec. A rental station for kayaks could be established in one of the upstream communities with the possibility to return them in Wągrowiec. Tourists could be attracted by the prospect of the long pleasant kayak through all the lakes and bring tourist revenue to the communities they pass through rental fees, restaurant visits, and the purchase of local crafts. Introducing a flow of tourist revenue into the upstream communities would add an economic motivation for them to allow, facilitate, and participate in the further restoration of the entire watershed.



Table 3. Evaluation matrix for upstream management measures

Practice	Target problem	Effectiveness	Ease of implementation	Longevity	Potential negative impacts	Potential Stakeholder conflicts	Capital costs	O&M costs
Shift aerator to Lake Kobyleckie	Inflow from upstream	3	3	4	3	3	4	4
Additional aerator in Lake Kobyleckie	Inflow from upstream	4	2	4	4	4	2	4
Joint economic activities	Lack of incentive	3	2	4	3	3	3	3

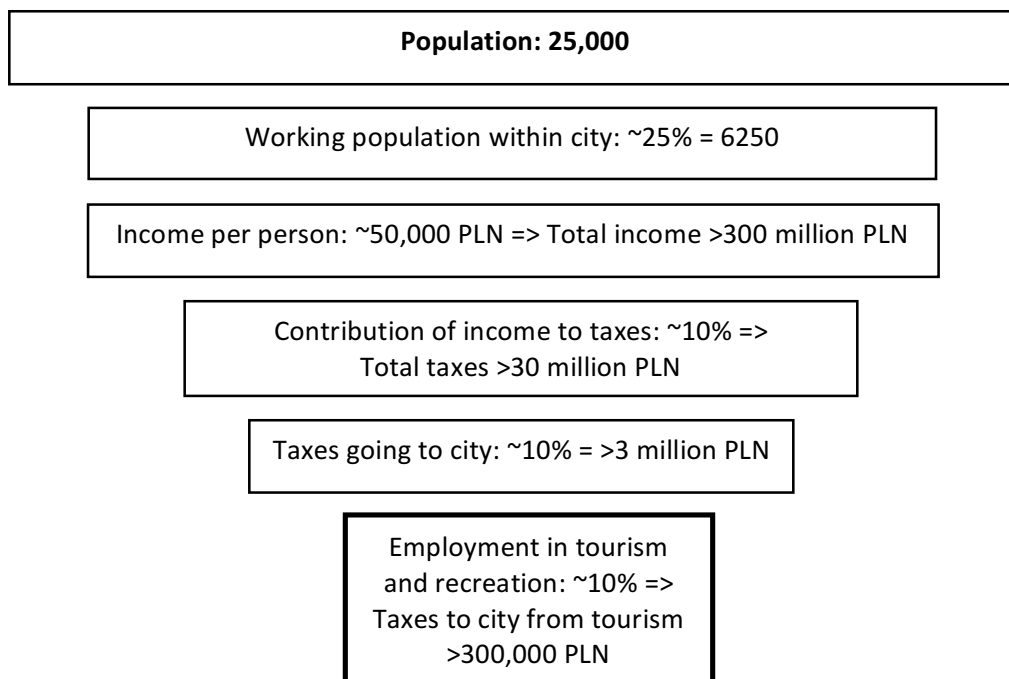
## Cost analysis

To determine the amount of money the city ought to invest in the lake it is necessary to see how much revenue the lake generates for Wągrowiec. We provide here a simple conservative estimation of the tax income generated for the city which would not be present without a healthy lake. (Figure 19)

The population of Wągrowiec is more than 25,000. If we assume that half of those inhabitants are working, and half of those are employed in Wągrowiec, then we have 6,250 people living and working in Wągrowiec. Assuming that these residents make an average of 50,000 PLN per year, they would collectively make over 300 million PLN. We further assume based on estimates previously given by the city administration that at least 10% of these people rely directly on tourism for their livelihoods. If that money were taxed at just 10%, with just 10% of that going to the city, we would estimate the total revenue generated by activities related to the lake would be over 300,000 PLN per year. Given that this far exceeds the approximately 100,000 PLN currently spent on restoration every year it is evident that additional investment in the lake restoration could be financially sound. This provides support for implementing Scenario C.







*Figure 19. Estimate for revenue generated from tourism and recreational activities for a hypothetical town. This would be the loss in case the tourism industry is adversely affected by some situation*

## Recommendations for future studies

There are several other threats which may pose obstacles in the restoration of Lake Durowski, and it is necessary to have complete information about the lake and the watershed. Based on land cover, agriculture is the dominating land use in watershed of Lake Durowskie and other lakes in the cascade. Agricultural activities can be a source of nutrient flow from fields surface (as an effect of erosion and fertilization of fields), from illegal point sources (from farms, cowsheds etc.) and subsurface runoff (e.g. leaky manure tanks). It is known that there are several farms raising pigs in the region, and it is necessary to have information about the waste disposal methods. Using this information, the appropriate agricultural management measures can be prescribed for the watershed.

Also in the analyzed region, there are urban areas. Despite the sewage system plants in Gołańcz and Wągrowiec we expect that many households release wastewaters to sewage tanks or directly to the ground. In fact, a stream of waste water was observed flowing into the lake at Gołańcz. Mapping of sewage inputs would provide information to control these inputs, and to



suggest appropriate measures for the same. Some measures would be for the authorities of region carrying out the controls on the farms and households. The owners should have documents attest to legal export of wastewaters to the sewage treatment plants. Moreover, tank tightness also could be checked. Mapping of sewage inputs could limit quantity of nutrients delivered to water system in region of Lake Durowskie which would further improve water quality.

Hence, it is our suggestion that future studies carried out regarding the restoration of Lake Durowski also study the watershed, collect information about agricultural waste disposal practices, and conduct land-use mapping, and mapping of sewage inputs. This information can be used to make informed decisions about watershed management.

## Conclusion

Restoration measures employed in Lake Durowskie have had a very positive effect over the last several years and, until now, have successfully suppressed cyanoblooms. Still, there is much progress to be made. As long as the lake continues to receive a heavy nutrient load from the inflow, it will remain in an unstable state and more vulnerable to environmental changes.

There are several possible measures which could be used to further help restore the lake to top down control, many of which require minimal funds and effort. To ensure the best possible outcomes many of these measures should be implemented. It is especially necessary to inspire a sense of ownership over the lake among the people of Wągrowiec. Further education about good practices when interacting with the lake will help minimize future impact and keep people motivated to see the water quality improve.

In the long term, it is also essential to do whatever possible to get other communities in the watershed to cooperate on some restoration efforts. While the organizational difficulties are large, the other communities must be encouraged to join the efforts. Only by addressing the entire watershed will we be able to directly address the problem in its entirety and return the system to natural control.



## Acknowledgements

We would like to thank all those who have made this study possible. We extend our heartiest gratitude to the honorable Mayor and the local Government of the Town of Wągrowiec for extending support towards organizing this summer school. We are grateful to all the members of the Adama Mickiewicza University in Poznan and the Christian Albrechts University in Kiel for organizing and managing this whole program flawlessly. We would like to express our appreciation for all our hosts from Adama Mickiewicza University for making us feel so welcome. We would also like to thank all the professors for guiding us. Special gratitude goes to Dr. Wilhelm Windhorst for guiding us, providing suggestions, and leading discussions. We would also like to thank our classmates for providing contributions to this report and making our time in Poland even more enjoyable.



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