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UNIVERSITATEA „ALEXANDRU IOAN CUZA“ din IAŞI

-Hydrology and Management Report-

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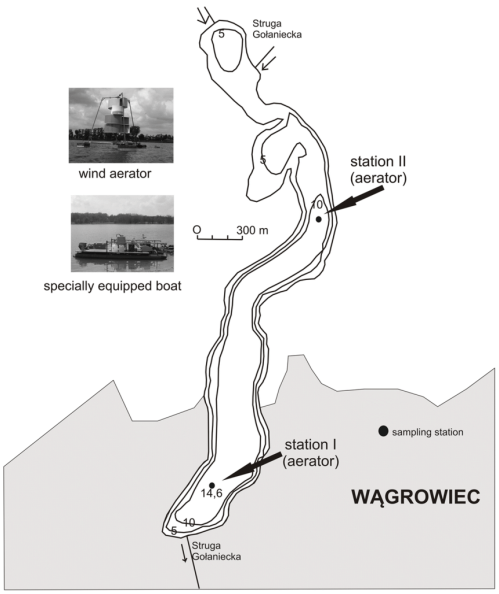
Introduction

After strong cyanobacterial water blooms, restoration measures in Lake Durowskie started in 2009. Three main restoration measures were implemented, these were oxygenation of hypolimnetic waters through the use of wind aerators (figure x.), phosphorus immobilization using iron treatment, and biomanipulation measures – stocking the lake with pike fingerlings.



1.1 Study Area

The study took place in Lake Durowskie, in Wągrowiec, Poland. The postglacial, ribbon lake of 6 km length covers the area of 143.7 ha and is connected to the lakes: Zamkowe, Laskowickie, Grylewskie, Bukowieckie, Kobyleckie by its main tributary river, Struga Gołaniecka. The catchment surface of the lake is 1581.3 ha , where 58.26% is

covered by agricultural area, 33.52% forest area and 8.25 % is the urban area (Figure 3) (Messyasz, Pikosz et al.,2022)

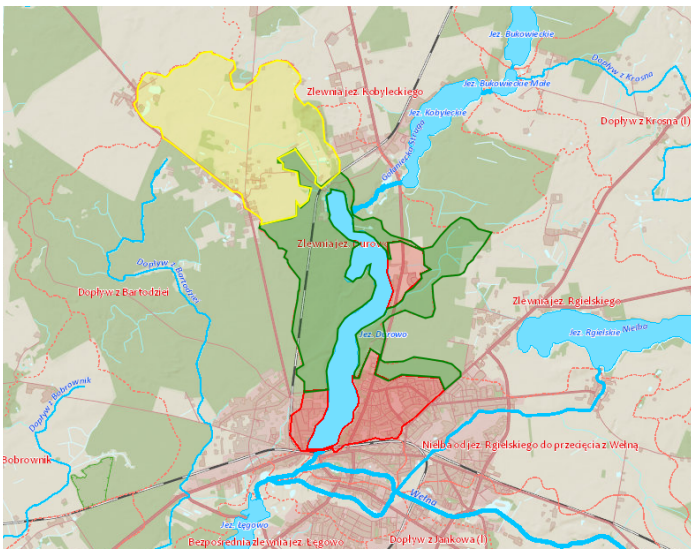


Figure3. Catchment of the Lake Durowskie, with distinction of the land use source: Hydroportal

2. Hydrology analysis

2.1 Introduction

Lake Durowksie was characterized by severe eutrophy. It is under strong anthropogenic pressure and is located in a heavily urbanized area. Since 2009, reclamation has been carried out by means of biomanipulation, aeration of hypolimnion water using aerators and phosphorus inactivation. Measurements have been made of water parameters at the sites, inflow and outflow of the watercourse (Struga Gołaniecka) flowing through the lake. The results obtained including pH, electrolytic conductivity and oxygen concentration will help determine changes in the ecological status of Lake Durowskie and will be helpful in minimizing their further development.

2.2 Methods

Field Work

The sampling took place at two locations (figure 1), inflow (A) and outflow (B) of Lake Durowskie, during 3 days, 27- 29 of June. The main purpose of the Summer School is education, therefore samples were taken by different groups, hence some variability is expected.

Here the river width and depth was measured **cross section** and the water flow velocity was afterwards measured using a Flowsens (SEBA), at different horizontal and vertical measuring points of the cross sectionallowing the $drawing of the $water flow profile.

At these locations also physical-chemical parameters were measured using a WTW Multimeter 3630i (WTW). The parameters measured were the pH, oxygen content, water temperature and conductivity. Water samples were also taken for chlorophyll- a and nutrient analysis. These will be analyzed by a different group.

Data Analysis

$$Q = v \times A \quad (1)$$

Q- Discharge

A- area of the cross section

$$L = Q \times C \quad (2)$$

L - Load

Q- discharge

C- concentration

2.3 Results

Table1. Discharge of inflow and outflow of each group.

			Q (m^3/s)		Standard Deviation (m^3/s)	
	Date	Period	Inflow	Outflow	Inflow	Outflow
G5	27/06/22	Morning	0,012	0,036	0,003	0,010
G1	28/06/22	Afternoon	0,019	0,026		
G2	28/06/22	Morning	0,014	0,01		
G3	29/06/22	Afternoon	0,015	0,023		
G4	29/06/22	Morning	0,012	0,034		

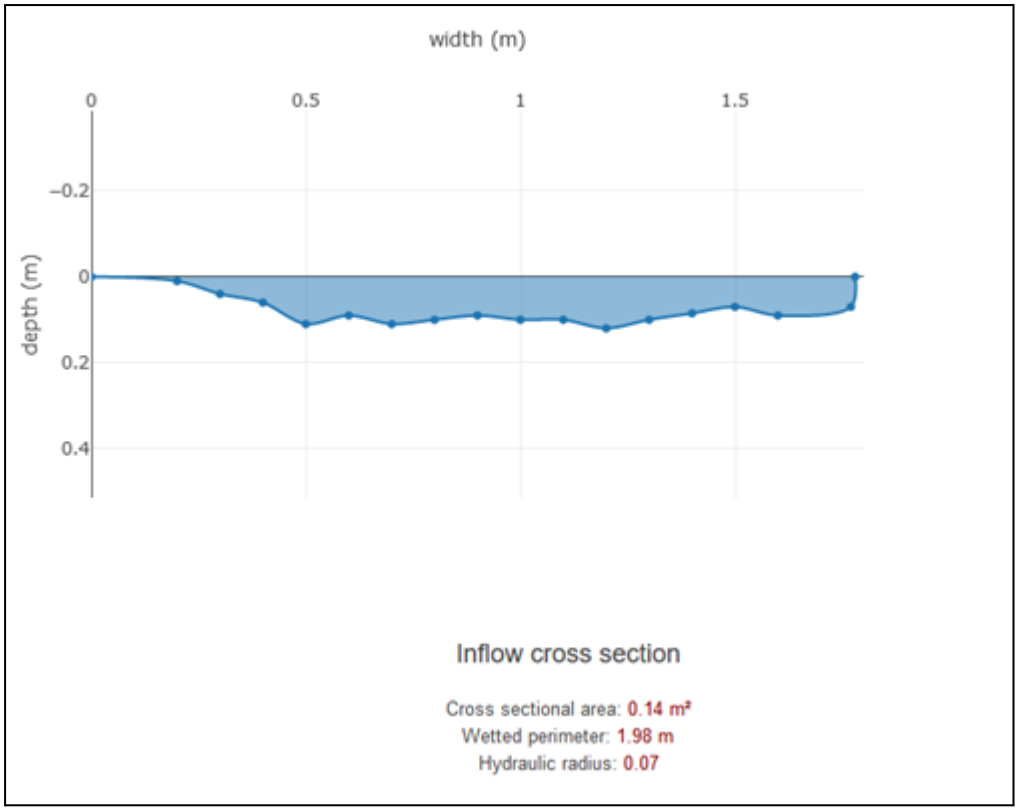


Figure X. Inflow cross section made with:https://geographyfieldwork.com/RiverCrossSection.htm

Figure x. Picture of the inflow

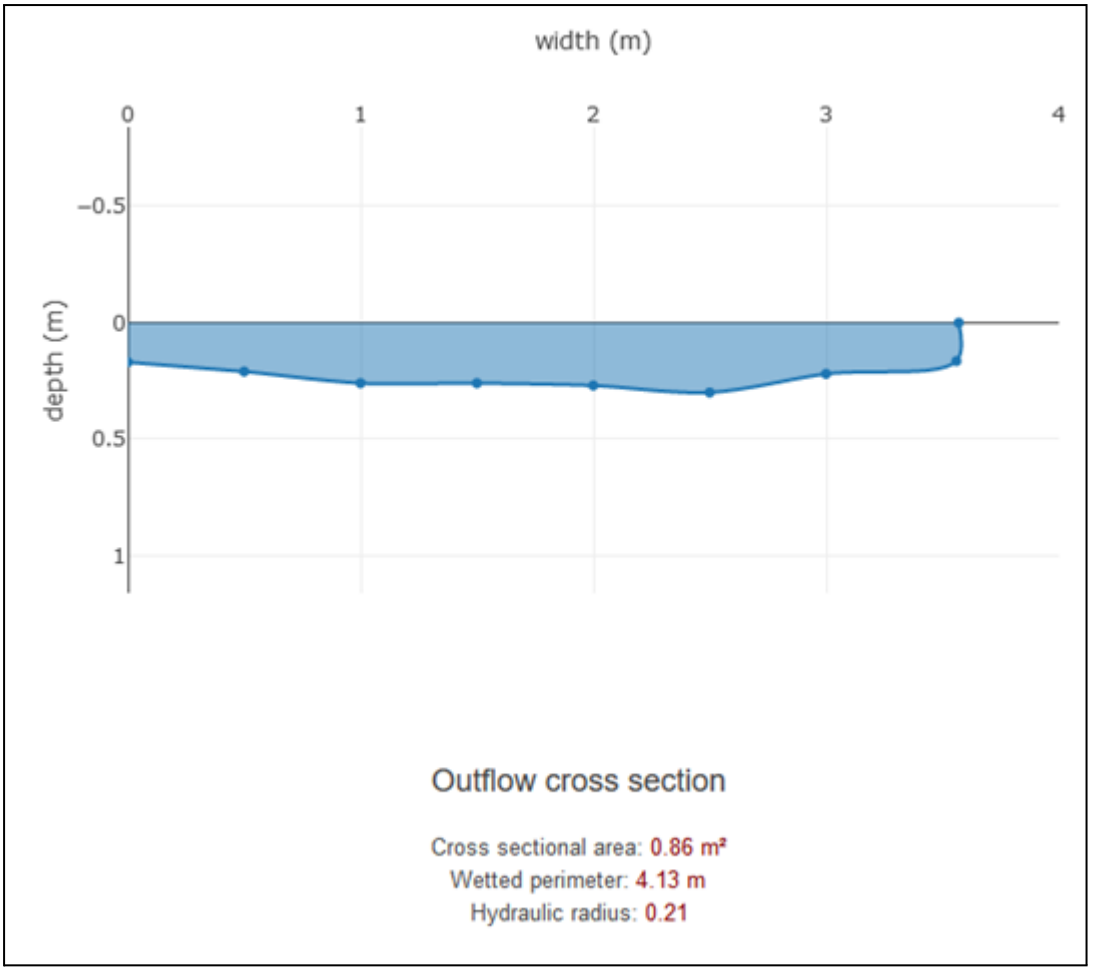


Figure Z. Outflow cross section with: :https://geographyfieldwork.com/RiverCrossSection.htm

Figure Z. Picture of the outflow

Table 2. Load of chlorophyll-a and pheophytin-a in miligrams per day.

				Load (g/d)	
Group	Date	Period	Sample	Chlorophyll-a	Pheophytin-a
G5	27/6/22	Morning	Inflow	9,756	2,229
G5	27/6/22	Morning	Outflow	17,294	3,546
G1	27/6/22	Afternoon	Inflow	8,661	0,033
G1	27/6/22	Afternoon	Outflow	17,769	4,156
G2	28/6/22	Morning	Inflow	6,157	0,121
G2	28/6/22	Morning	Outflow	2,704	0,890
G3	28/6/22	Afternoon	Inflow	6,480	0,065
G3	28/6/22	Afternoon	Outflow	7,412	2,802
G4	29/6/22	Morning	Inflow	8,097	1,379
G4	29/6/22	Morning	Outflow	6,933	18,713

Table 3. Load of ammonium, nitrite, nitrate, ortho-P ans total P (phosporus) in kilograms per day.

				Load (Kg/day)				
Group	Date	Period	Sample	Ammonium N	Nitrite N	Nitrate N	Ortho-P	Total P
G5	27/6/22	Morning	Inflow	0,885	0,003	0,317	nd	0,095
G5	27/6/22	Morning	Outflow	1,876	0,009	1,026	nd	0,171
G1	27/6/22	Afternoon	Inflow	1,189	0,005	0,511	nd	0,102
G1	27/6/22	Afternoon	Outflow	1,377	0,007	0,950	nd	0,191
G2	28/6/22	Morning	Inflow	0,827	0,004	0,212	nd	0,088
G2	28/6/22	Morning	Outflow	0,443	0,003	0,281	nd	0,052
G3	28/6/22	Afternoon	Inflow	0,717	0,004	0,319	nd	0,101
G3	28/6/22	Afternoon	Outflow	1,178	0,006	0,656	nd	0,131
G4	29/6/22	Morning	Inflow	0,709	0,003	0,404	nd	0,079
G4	29/6/22	Morning	Outflow	1,848	0,009	0,755	nd	0,264

hydro part: Load=C of nutrients * discharge C (mg/L) * Q (m^3/s) -- have to convert results to kg\day (see notebook)

2.4 Discussion & conclusion

The discharge of the water streams of outflow and inflow has changed over the years. From 2012 to 2016 it was very low. In 2017 the discharge highly increased but later in 2018 it was low again. The results may vary, depending on many factors influencing their variability.

Atmospheric conditions such as rainfall could be a factor that could affect the speed of water flow in 2017. At present low flow of streams can be caused by low water level, low rainfall and drought. There are also factors that can contribute to research results such as rocks or accumulated biomass.

3. Lake Durowskie Management Practices

3.1 Introduction

Ecosystem services

The notion of ecosystem was introduced in 1935 by botanist Arthur Tansley (Trudgill, 2007; Cameron, 2022). The ecosystem comprises all the organisms that live on earth in different living environments in an impressive variety of forms, from the smallest and simplest organisms to the most complex ones. An ecosystem constitutes two factors, abiotic (without life) and biotic (with life).

Ecosystem services can be briefly defined as direct and indirect contributions of ecosystems to human wellbeing which have an impact on our survival and quality of life (Kalam, 2022).

Costanza et al were among the first authors to discuss ecosystem services in 1997, estimating that in the future these services will need more attention as they become more stressed and 'scarce' (Costanza et al., 1997; Kalam Tamanna, 2022; Mederly and Černecký, 2020).

There are four types of Ecosystem services which are detailed in figure.

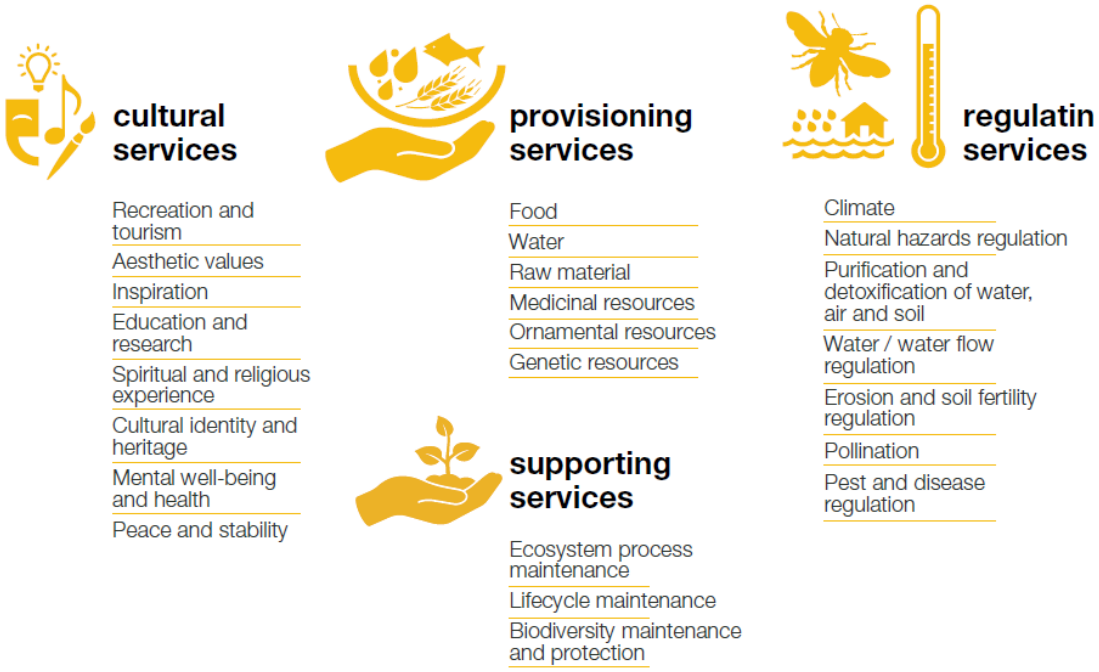


Fig. The four types of Ecosystem services, by Ivanic et al., 2020

Cultural services are the non-material benefits that humans derive from ecosystems, as they are deeply interconnected. Cultural services include aesthetic inspiration, cultural identity, spiritual experience related to the natural environment, intellectual development, recreation, aesthetic values, etc (Izakovičová et al.; 2020, FAO, 2022).

Provisioning services are products obtained directly from ecosystems for human consumption. Important goods provided by this type of service include in particular food, oils, feed, fibre, firewood, chemicals and compounds, like latex and gums (Pandey, 2020; Mederly et al., 2020). At the same time, agriculture, forestry and fishing are influenced and influence all types of ecosystem services. Many supply services are traded in the markets. In many regions, rural households also depend directly on the provision of services for their livelihoods. In this case, the services value may be much more important than is reflected in the prices they fetch on local markets (FAO,2022; Pearce, 2022).

Supporting services are those which relate to habitat functioning themselves, and therefore influence survival. For example, photosynthesis, the water cycle and nutrient cycles are the basis of ecosystems, which in turn allow us to support ourselves. This type of ecosystem service also goes down to the genetic level, such as the maintenance of viable

species gene pools. Providing living spaces for plants or animals and maintaining a diversity of plants and animals are ‘supporting services' and the basis of all ecosystems and their services (FAO, 2022; Pearce, 2022).

Regulating services are categorized as any benefit obtained from the natural processes and functioning of ecosystems. Maintaining the quality of air and soil, providing flood and disease control, or pollinating crops are some of the ‘regulating services' provided by ecosystems. They are often invisible and therefore mostly taken for granted. When they are damaged, the resulting losses can be substantial and difficult to restore (FAO, 2022; Pearce, 2022).

Ecosystem services of the Lake Durowskie

Lake Durowskie ecosystem services	
Cultural services - **Recreation and tourism;** - **Education and research;** - **Peace and stability;**	- Boats and pedal boats available, fishing, kayaking, swimming, etc. - Practice sport, like boat rowing - Research of biodiversity of the lake
Supporting services - **Biodiversity maintenance and protection**	- The lake provides living space for different species of plant and animals. There are also some human habitats on the lake shore
Provisioning services - **Food** - **Water** - **Ornamental resources**	- Fishing - Providing water for a few crops
Regulating services - **climate control**	- The increased surface of the lake allows faster water evaporation, thus cooling the air has a positive effect on the local area

Lake Durowskie encounters a lot of pressure from anthropogenic activity. Depending on the ecosystem service, it takes different forms. As a result, loads of nutrients are delivered to the water, lake banks and the bottom is degraded and fauna and flora changes are noticed. Among the factors which affect the condition of Lake Durowskie the most, following can be distinguished: the inflow of pollution from inhabited areas and the lakes in the upper stream,

the development of areas adjacent to the lake, the transformation of coastal zones and tourist pressure.

3.2 Measures so far

The purpose of the selected reclamation measures is, first of all, to stop the progressive unfavorable processes occurring in the lake, progressive eutrophication, cyanobacterial blooms and deoxygenation of the deeper layers of the lake water. Further reclamation of Lake Durowski is expected to lead to even better improvement of water quality through:

-reduction of algal blooms, especially cyanobacteria,

-improving the oxygen conditions of the lake's waters,

-reduction in the concentration of biogenic compounds (total phosphorus < 0.1 mg/dm3),

-increasing water transparency,

-Macrophyte growth.

These methods have been selected as optimal in terms of both environmental and economic performance, and have been tested in terms of the results achieved.

1. Use of aerators - installation of two wind-powered aerators to allow oxygenation of the hypolimnion waters during the summer.

2. Stocking the lake - undertaking biomanipulation activities. The introduction of pike as an omnivorous fish to control the roach population was carried out as part of biomanipulation. The reduction of roach, a plankton-eating fish, was to contribute to the development of zooplankton, which feed on phytoplankton, in order to reduce the population of cyanobacteria in particular. Biomanipulation is also tasked with increasing the biodiversity of the water body.

3. Phosphorus inactivation through the use of iron coagulants - dosage of iron sulfate (PIX) to bind phosphorus in bottom sediments. Application of mobile and precise phosphorus inactivation with PIX in the entire water body - two treatments of mobile, precise phosphorus inactivation of the entire surface of Lake Durowski with PIX should

be carried out in one year. The treatments should be carried out between April and July. Conducting mobile and precise phosphorus inactivation is intended to reduce phytoplankton blooms, especially cyanobacteria. It also complements the oxygenation of waters with aerators. The direct ecological effect of this method is expected to be a reduction in the number of blooms, which in turn will result in increased water transparency, macrophyte development and increased potential for self-cultivation of the reservoir.

3.3 Agriculture in Lake Durowskie

Agriculture currently covers a large area of Poland. According to the research carried out in 2020 by the Polish Central Statistical Office, in 2018 there were 1.4 million farms in Poland with a total area of 16.4 million ha, accounting for 56.5% of the rural area (Główny Urząd Statystyczny, Departament Badań Przestrzennych i Środowiska, 2020). Undoubtedly, a large share of such areas contributes to pollution and degradation of the environment.

In Lake Durowskie, located in a stunning and peaceful town of Wagrowiec, the anthropogenic pressures such as agriculture, irresponsible tourism, sewage disposal and expansion of human settlements, are main factors which have been contributing towards the deterioration of its water quality.

An important source of pollution in the catchment area of Lake Durowskie, especially in the upper lakes, are agricultural areas (Messyasz, Pikosz et al.,2022). Based on land cover, agriculture is the dominating land use in the 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). There is also a problem with drainage from agricultural areas, input of nutrients from fertilizers and other chemicals such as pesticides and herbicides (mainly upstream agricultural lands, because Durowskie lake is mostly surrounded by forest). Due to the small size of agricultural land compared to the relatively high share of forests and grasslands, they play an increasingly smaller role in the influx of pollutants into the lake. The situation is much worse in the case of animal husbandry. It is known that there are many farms raising pigs in the region, and it is necessary to have information about the waste disposal methods (EEA, 2018). Currently, farmers do not pay any additional taxes to compensate for the environmental damage. In 2021 the government created a project about placing plant protection products on the market, but it did

not enter into force in the end. Using this information, for the watershed the appropriate agricultural management measures can be prescribed.

In order to improve the quality of upstream water, which will result in an improvement in water quality throughout the catchment area, cooperation and dialogue should be undertaken with upstream communities, as already proposed in previous reports. Please refer to previous reports for detailed information.

Another idea might be to impose taxes that discourage farmers from engaging in harmful practices for the environment. The government in Poland should support organic farming by for example subsidies.

Future research into the rehabilitation of Lake Durowskie should include the study of the catchment area, gathering information on agricultural waste disposal practices, and maintaining land-use maps and mapping sewage inflows. This information can be used to make informed decisions about the management of catchment areas.

Agricultural education

In order to stop the devastation of the lake, it is very important to educate farmers about the harmfulness of pesticides and other activities related to agriculture. Practices that can improve water quality and farmers knowledge are:

- workshops;

-informative campaigns with specialists about sustainability, importance of the lake and environment;

-individual consultations with experts who will help farmers on how to use less fertilizers.

3.4 Water governance

One of the pressures which result from the tourist activity is the systematic development of the shores of Lake Durowskie. Currently, a significant part of the land, directly attached to the lake, is occupied by recreational plots and housing estates of summer houses. Many properties, bordering the shoreline of the lake, are accompanied by platforms. During their construction, macrophytes are cut each time, and in many cases, the shore is hardened. As a result of these activities, the shores of the lake irretrievably lose their natural values.

In order to stop the process of the degradation of the shoreline, municipalities that care about preserving the values of their areas should adopt the Local Spatial Development Plans which exclude development areas located in the immediate vicinity of the lake (Nowak, 2019). Such measures would save the lakeside spaces from further degradation, as well as preserving the buffer zones which are so important for the lake, in which contaminated groundwater flowing from the upper parts of the catchment is cleaned. In order to eliminate the process of the embankment, illegal cut-off of macrophytes and the construction of private bathing areas, severe penalties should be introduced, referring to the provisions of the Water Law and the Environmental Protection Law (Nowak,2019). The imposition and enforcement of high fines for activities carried out without any supervision by a competent institution should effectively eliminate this practice. In the case of actions already carried out, which resulted in a change in the structure of the coastline, measures should be taken to restore its original character, including the elimination of overfilled material and platforms.

3.5 Education

With the aim of reducing the impact of anthropogenic activity on Lake Durowskie, several actions should be undertaken. In order to prevent littering of the shores of the lake by tourists, the authorities of the municipalities within which the lake is located should take care of a larger number of trash bins in the zones most visited by tourists and proper, informative banners, which encourage the community to take care of their own garbage, especially in the vicinity of the water bodies. To avoid additional problems due to overfilling, the bins must be emptied regularly (CENN,2022).

The best solution to stop the harmful behavior of tourists, such as the devastation of the bottom and shores of the lake, noise and the destruction of nesting sites and habitats, would be information campaigns to raise the environmental awareness of people resting by the lake. They should primarily take the form of information, educational and warning boards located in the zones with the highest concentration of tourists. These kinds of boards should include reflective parts, which could help people understand the value of the lake. Such a project could be developed in cooperation with AMU, where students would also learn about the described problems. This way, awareness about the already undertaken actions could be raised. Projects like “Rest Lake” should be announced and highlighted to the community, in

order to realize what kind of measures have already been undertaken and what else can be still done.

3.6 Conclusion

Lake Durowskie is an important ecosystem that significantly contributes to the local community of Wągrowiec and every summer attracts many tourists as a rest and recreation place. The scale of this contribution is poorly understood by all the users. The focus is still on consuming the services offered by this ecosystem and taking them as a guarantee, meanwhile they should be perceived as a privilege and the object of conservation for future generations.

The restoration measures undertaken aimed to fix the mistakes of the past have already demonstrated an ecological improvement of the lake. Introducing the restoration project and monitoring systematically the quality of the lake in cooperation with the Adam Mickiewicz University is commendable. However, the room for improvement is still significant. In this report, further steps have been described, as it has been done in the previous editions of the project as well. Some repetitions of the suggestions, proper action plans and cost analysis appeared, which only means that for years the problems remain unchanged and unsolved.

It turns clear that through all these years the lack of cooperation between municipalities is still the main problem. The quality of water in the Lake Durowskie depends on the other lakes in the chain, that’s why the responsibility should be shared among all stakeholders and cities that profit from the services of the lake.

As long as the communities will not understand their dependence on the surrounding ecosystem and its priority, the relationship will remain the same. To avoid that, proper education and rising awareness have to be carried out, to change the perception of the ecosystem services of the current users and ensure conscious and caring future generations.

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