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FROM RESTORATION TO REVITALIZATION: HOW TO RECOVER RECREATIONAL VALUES OF URBAN LAKES. A CASE STUDY OF LAKE DOMOWE DUŻE IN SZCZYTNO

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A b s t r a c t

Lake Domowe Duże (surface area 54 ha, maximum depth 7.2 m) is one of the two lakes lying in the town limits of Szczytno. For years, despite its large recreational potential, the lake had been rarely exploited by town residents or visitors due to its classless water quality. The restoration project initiated in 2010 has raised interest in spending leisure time on this lake. The natural conditions affecting the lake's waterfront have been analyzed, as well as the impact of the lake's morphometric properties and the land management along the shoreline on a possible use of the lake for recreation, including angling.

The results suggest that owing to its large size and morphometric diversity, as well as the recently developed infrastructure for the tourism industry, Lake Domowe Duże can serve various forms of recreation. The improvement of the lake's water quality achieved in recent years has created opportunities for water recreational activities and enhanced the angling quality of this water body.

OD REKULTYWACJI DO REWITALIZACJI – PRZYWRACANIE WALORÓW REKREACYJNYCH AKWENOM MIEJSKIM NA PRZYKŁADZIE JEZIORA DOMOWEGO DUŻEGO W SZCZYTNIE

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S ł o w a k l u c z o w e: jezioro, rekultywacja, rekreacja, zagospodarowanie turystyczne, jakość wody.

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Abstrakt

Jezioro Domowe Duże (powierzchnia 54 ha, głębokość maksymalna 7,2 m) jest jednym z dwóch akwenów miejskich Szczytna. Mimo znacznego potencjału do rekreacyjnego wykorzystania, zbiornik ten, z uwagi na pozaklasową jakość wód, w niewielkim stopniu służył mieszkańcom i turystom. Zainicjowana w 2010 r. rekultywacja jeziora spowodowała wzrost zainteresowania aktywnym wypoczynkiem nad badanym akwenem.

W pracy przeanalizowano istniejące uwarunkowania przyrodnicze kształtowania przestrzeni przywodnej jeziora oraz wpływ cech morfometrycznych zbiornika i sposobu zagospodarowania linii brzegowej na możliwość wykorzystania rekreacyjnego, w tym do uprawiania wędkarstwa.

Uzyskane wyniki wskazują, że dzięki swej wielkości i zróżnicowaniu morfometrycznemu, a także powstaniu nowych elementów infrastrukturalnych, bazy turystycznej, Jezioro Domowe Duże może być wykorzystywane do różnorodnych form rekreacji. Uzyskana w ostatnich latach poprawa jakości wody stwarza dogodne warunki do rekreacji nawodnej, jak również pozytywnie wpływa na atrakcyjność wędkarską akwenu.

Introduction

Among all landscape features, lakes are undeniably among the greatest nature treasure. Lakes also enhance the recreational value of lake districts. However, they are extremely vulnerable landscape elements, sensitive to anthropopressure and ecological degradation (KAJAK 2001, DUNALSKA et al. 2015). Clean lakes are an excellent base for development of tourism. Conversely, eutrophic and hypertrophic lakes can repel recreation seekers, and water pollution can pose a threat to the health and even life of swimmers. This hazard can be viewed as caused by chemical pollutants, resulting from water contamination, or by substances released into the water environment due to hypertrophy, i.e. overfertilization of a given ecosystem. The latter include organic and inorganic decomposition products, such as methane, hydrogen sulfide and other volatile compounds, e.g. responsible for noxious smell, and toxins released by decomposing cells of algae and blue-green algae (KAJAK 2001).

Eutrophication of lakes is a natural development. It occurs in every landlocked water body, surrounded by a catchment basin which feeds it with water and organic matter. If the natural conditions are undisturbed, eutrophication is very slow, imperceptible in an average person's lifespan. However, anthropogenic transformations of the environs of lakes which have been taking place over the past few decades have enlarged the influx of contaminants to lake waters, which rapidly accelerates their ageing (KAJAK 2001). Urban lakes are in a specific situation (BIRCH and MCCASKIE 1999, TANDYRAK et al. 2015). Against the backdrop of omnipresent industrialization and urbanization, lakes are perceived as a refuge and are willingly chosen as sites for regaining physical and mental well-being (HALL and HARKONEN 2006).

Consequently, they are also seen as a leverage for the growth of tourism and hospitality, which determines their value for the society (FURGAŁA-SELEZNIOW et al. 2012). Meanwhile, they are exposed to a dual risk of degradation: firstly, due to a relatively stronger pressure by recreation seekers, and secondly, because of the increasing development of the lake's catchment, which generates more sewage, wastewater and rainwater, disturbs the water balance, reduces water circulation and adds more technical infrastructure along the lake's shores.

The social pressure to maintain good quality of waters in lakes that serve recreational functions gives rise to efforts to restore water bodies degraded by ill-considered human actions. Nevertheless, due to very intricate biogeochemical relations in water ecosystems, it is difficult to identify correctly the causes of degradation and therefore to work out plans for effective restoration. Hence, restoration projects frequently fail to generate expected benefits, and promotion of certain recreational functions of a given lake can even harm its water ecosystems. A need is felt to elaborate algorithms supporting lake restoration plans which would account for unique natural features and the specific character of each lake.

Our objective has been to present the assumptions and effects of a restoration plan prepared for a typical urban lake, such as Lake Domowe Duże in Szczytno, and discuss it from the perspective of their contribution to improved tourist and recreational values of this water body.

Material and Method

Research object

Lake Domowe Duże is the largest water body in the urban agglomeration of Szczytno. Together with Lake Domowe Małe (Figure 1), it composes a water complex, which adds more appeal to the town center. The catchment (the urban and rural type) covers an area of about 4.3 km^2. The northern and eastern shores, within the town limits, are flanked by the buildings in Bartna Strona Street. To the east, where the lake stretches out to some green areas, there is a municipal beach, a pier and the Interschool Sports Centre with a water equipment rental. The southern shores are occupied by some greeneries, garden allotments and farmland. The south-western end of the lake borders with the village Korpele while to the north the lake reaches a small locality called Kamionek.

For many years, Lake Domowe Duże had served as a sink for municipal sewage and wastewater, industrial wastewater and cooling waters from indus-

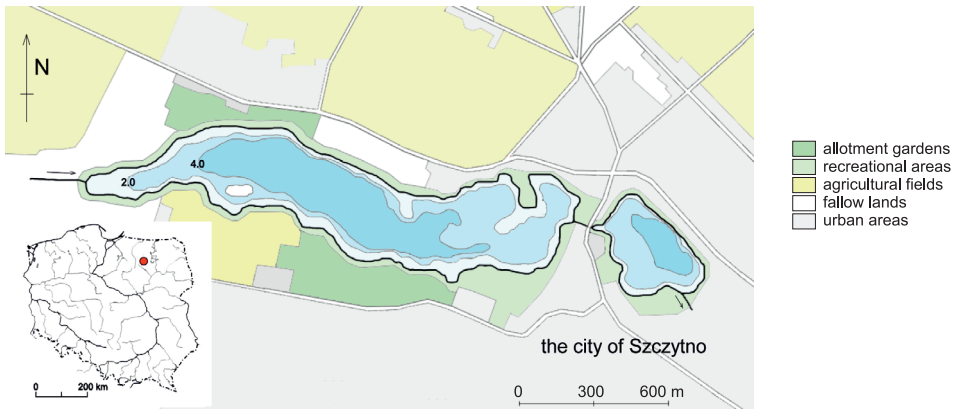

Fig. 1. Location and surroundings of Lake Domowe Duże in Szczytno

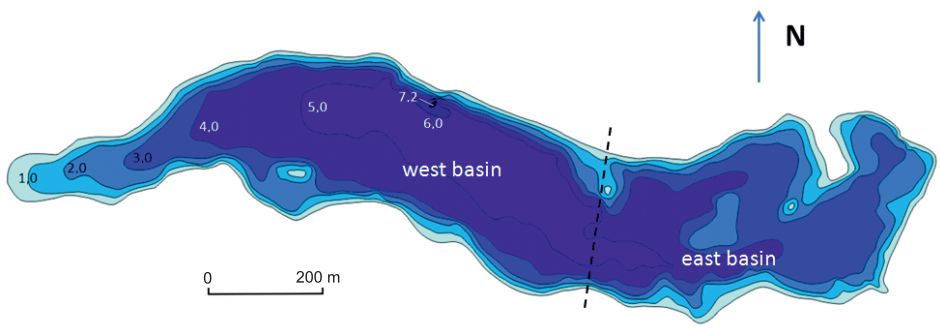

Fig. 2. Morphometric features of Lake Domowe Duże

trial plants situated in this part of Szczytno. The recent modernization of the urban sewage system has evidently limited the degree of degradation of the lake waters. Currently, there are no sources of point pollution to the lake, although the rainwater drainage system still poses a threat to the lake. The risk is compounded by the fact Lake Domowe Duże is extremely vulnerable to degradation (ŁOPATA et al. 2013) due to its low depth (Figure 2), high water mixing intensity, diverse shoreline and the type of land management in the catchment that promotes man-made pressure. With these characteristics, the lake was unable to regain a good ecological status even after the discontinuation of sewage and wastewater discharge. Another reason why the lake ecosystem could not function well was the decrease in the water table level (by over 1 m) and surface area (Table 1) due to excessive drawing of water for industrial purposes. The town council, responding to the local community's worries over the poor quality of water in Lake Domowe Duże, decided to

initiate its restoration (DUNALSKA et al. 2014), eventually carried out in 2010–2012, by the University of Warmia and Mazury in Olsztyn. Basic parameters of the shape and size of Lake Domowe Duże, according to historical sources and present, detailed measurements are presented below.

Table 1
Basic morphometric data of Lake Domowe Duże in Szczytno, according to archival and contemporary sources

Parameter	Unit	IFI 1964	UWM 2012
Area	ha	62.1	58.7
Maximum depth	m	5.4	7.2
Mean depth	m	2.8	3.45
Elongation	–	5.86	5.95
Shoreline: length	m	5300	5074
Development index	–	1.90	1.87
Fishing economic indicator	m/ha	85.3	84.6

IFI – Inland Fisheries Institute in Olsztyn
UWM – University of Warmia and Mazury in Olsztyn

Methodology

The lake's morphometric characteristics were analyzed based of archived data: the bathymetric plan and morphometric chart made by the Inland Fisheries Institute (1964, sampling density 244 points/100 ha) and more contemporary modelling produced in 2012 by the Department of Water Protection Engineering in the UWM in Olsztyn (1357 measurement points per 100 ha).

Field observations and measurements, which help to identify the accessibility of the lake's shores for tourist purposes, transformation within the waterfront zone and the lake's water quality, were done in 2004–2006 and 2010–2015 (water chemistry and hydrobiological parameters on average 4–5 times during the plant growing season), as part of the lake's monitoring conducted by the Department of Water Protection Engineering.

The assessment of the lake's recreational usefulness adhered to the guidelines of DEJA (2001). The analysis included the qualitative and quantitative valuation of the limnometric characteristics of the lake (surface area, average depth, shoreline development and elongation), the ecological condition (the shores and open waters being overgrown with emergent plants) and of the catchment (the share of forested land in the immediate surroundings of the lake).

Our analysis of the recreational suitability of the lake for angling was accomplished according to the methodology proposed by SKRZYPCZAK (2005). This evaluation included a comparative assessment of the lake's six attributes that identify if the lake's shores can reached. They fall into characteristics which make the lake more attractive for anglers (stimulants) or limiting the appeal (destimulants). The indicators were assigned weights which reflect the varied effects of given attributes on the potential use of the lake as a fishing destination. The final stage in the calculation was to derive synthetic measures of the lake's attractiveness, in a range of 0.000 to 1.000.

Research Results and Discussion

Natural conditions and the recreational usefulness of the lake

The natural attributes of Lake Domowe Duże make it a poor choice for recreational activities. In line with the broadly accepted methodology for evaluating recreational values of lakes (DEJA 2001), Lake Domowe Duże belongs to class IV, which is the category of the least attractive lakes (Table 2,

Table 2

The results of grading Lake Domowe Duże on the background of the score of features determining the suitability of water bodies for recreation

Parameter							Points
Area [ha]	mean depth [m]	shore development index	elongation index	overgrowing of the shoreline [%]	overgrowing of water surface with submerged vegetation [%]	afforestation of coastal zone [%]	
–	0.0–2.0	–	–	> **50**	> 50	no forests	0
≤ 50	**2.1–5.0**	1.00–1.50	1.0–1.4 >7	–	–	≤ **20** **80.1–100.0**	1
50.1– **–100.0**	5.1–15.0	**1.51–2.00**	**1.5–3.0** **5.1–7.0**	25.1–50.0	**10–50**	–	2
100.1–150	15.1– –30.0	2.01–2.51	3.1–5.0	–	–	20.1–40.0 60.1–80.0	3
150.1–300	–	2.51–3.00	–	≤ 25	<10	–	4
> 300	–	>3.01	–	–	–	40.1–60.0	5
Lake Domowe Duże in Szczytno (feature value/points):							
58.7/2	3.45/1	1.87/2	5.95/2	95.7/0	12.5/2	7.7/1	total points 10 (IV class)

Bold type – the range of values proper for the investigated lake.

Table 3). It is worth noticing, however, that the classification score (10 points) is close to the thresholds for moderately attractive lakes, and therefore it would be a far-fetched opinion that the shape of the lake's bowl or the qualities of its surroundings disqualify this lake from any recreational use. In particular, the limited plant cover of the water table (12.5%) and the diverse share of the lake's bowl together with the relatively large surface area (> 50 ha) make up the lake's potential ability to serve recreational purposes. Conversely, from the point of view of recreation seekers the lake's most undesirable feature is the very poor access to the shores (just 5% of the shoreline is free from reeds). Practically, the municipal beach located at the easternmost end of the lake is the only site suitable for sunbathing with free access to the water.

Table 3

Classes of the lakes recreational attractive (according to Deja 2001)

Lakes attractive	Class	Points
Very attractive	I	21.80–29.00
Attractive	II	16.00–21.75
Moderately attractive	III	10.20–15.95
Poorly attractive	IV	to 10.15

We also reviewed the conditions for angling in this lake. The fishery management authority responsible for the lake is the Polish Angling Association, Olsztyn Branch. Angling is allowed provided an angler has a required permit and paid a due fee to the lake's fishery management authority. There are no other fishing limits imposed or licenses required, which means there are no other formal constraints onangling. The angling value of a lake depends on the species structure in fishing grounds (CZARKOWSKI et al. 2012). In this regard, Lake Domowe Duże has much to offer – there are such fish species as carp, tench, bream, white bream, roach, rudd, grass carp, crucian and German carp, as well as predatory fish like pikeperch, perch, pike and eel. In recent years, the lake has been heavily stocked with predatory fish fry and fingerlings (data from the Polish Angling Association in Olsztyn, accessed online).

Table 4 summarizes our assessment of the lake's recreational quality for angling, completed according to SKRZYPCZAK (2005). The results suggest that the lake is moderately suitable for angling. In this regard, again, the broad belt of emergent plants growing along the shoreline proved to be a limiting factor.

Table 4

Assessment the recreational suitability of Lake Domowe Duże for fishing
(according to SKRZYPCZAK 2005)

Feature	Unit	Character of property*	Weight	Value	
				west basin (33.4 ha)	east basin (25.3 ha)
Shoreline development index	value of factor	*S*	0.10	1.54	1.45
Shoreline with a 1-5 m wide belt of emergent plants	% of shoreline length	*S*	0.25	11.7	17.0
Shoreline with a > 5 m wide belt of emergent plants	% of shoreline length	*D*	0.10	87.6	74.1
Drainage basin (up to 100 m) afforested, with thegroundwater level < 1.0 m	% of shoreline length	*S*	0.20	0,0	15.5
Drainage basin (up to 100 m) covered with boggy forests, wetlands and swamps	% of shoreline length	*D*	0.10	9.4/0.0**	0.0
Access to the water	points/100 m shoreline	*S*	0.25	2.05	3.02
The value of synthetic gauge				0.441	0.894

* *S* – stimulating nature (stymulants), *D* – limiting nature (destymulants);
** – 0.0 appointed because of the presence of a new foot/bicycle path around the lake.

At the same time, the above analysis revealed distinctly different qualities of the lake's two basins. In the light of the adopted methodology, the eastern basin appeared to be superior, with its better access to water (68 access points in total), more diverse phytolittoral (30% higher share of the shoreline only slightly overgrown with helophytes) and more attractive environs of the fishing grounds owing to the presence of tall plants. However, the fishing quality of a lake also depends on the shape of the bottom (KRUPA et al. 2007). The eastern basin has numerous shallow areas and underwater hillocks, which favour the catch of certain fish species (pike, perch, tench), while the western part of the lake, with slightly diversified relief of the bottom and a much deeper average depth (3.8 m versus 3.05 m for the eastern basin) can be preferred by pikeperch and bream. In brief, anglers' preferences will largely depend on their fishing technique and expected catch of specific fish species.

Restoration of the lake

The restoration of the lake was accomplished with a phosphorus inactivation approach. Nowadays, this is one of the most effective methods available for improvement of water quality (ŁOPATA and GAWROŃSKA 2006, ŁOPATA

2013, GROCHOWSKA et al. 2013). In essence, amounts of phosphorus in water are precipitated into insoluble compounds with special preparations. Second to nitrogen, phosphorus is the major nutrient in water that stimulates the growth of water plants, thus the proliferation of phytoplankton decreases when excess phosphorus is removed from water depths. This is a highly effective method, with results lasting for over a decade (GROCHOWSKA et al. 2013).

In order to inactivate phosphorus in Lake Domowe Duże, the polyaluminum chloride was used. This is a new generation coagulant with highly effective binding properties. During its application to the water, Al ions hydrolyze into hydroxides forms with high affinity to phosphorus. These particles aggregate and settle down towards the bottom sediments as amorphous flocs. As it was expected, there was a rapid reduction of the number of plankton algae and subsequent improvement in the water transparency caused directly by the limited phosphorus level in the water of Lake Domowe Duże. Average algae biomass has decreased about two times (to the value about 10 mg l^{-1}), the phosphorus content decreased below 0.1 mg l^{-1}, (about 2.5 times, comparing to concentration occurring before restoration) and the water transparency has reached a level clearly above 1 m – which is the desired value for bathing (Figure 3). As a result of this improvement of water quality, a nuisance algal blooms have been removed. This outcome, having a measurable impact on the recreational value of the lake, served as a fundamental argument for the re-establishment of a municipal bathing beach on the lake. It is worth noticing that the upper threshold of water transparency, sufficient to allow the use of waters for swimming, was achieved already in the first of the three implementation stages of the phosphorus inactivation technology.

Another manifestation of the improvement of water transparency for recreational purposes was the re-establishment of submerged plants, stimulated by a better access of light to deeper layers of water (ŁOPATA et al. 2013). The presence of submerged plants has a direct influence on the stabilization of chemical conditions within the lake waters. These plant assemblages also play numerous roles in the ecosystem: they are arefuge for valuable zooplankton as well as a breeding and foraging site for many precious fish species; moreover, they prevent the motion of bottomsediments induced by strong waves (KAJAK 2001), including the ones caused by recreational activities, for example motor water sports. A higher biodiversity of the water body is no less important as it enhances the nature-related value of the whole water ecosystem.

It should be emphasized that the restoration works had been planned so as to ensure that their impact, in respect of scheduling, execution and assurance of ecological security, would meet the expectations of the lake's fishery manager, i.e. the Polish Angling Association. Simultaneously, the project team had adopted the concept proposed by many researchers (CZARKOWSKI et al. 2012, JEPPESEN et al. 2012), suggesting that proper fishery management

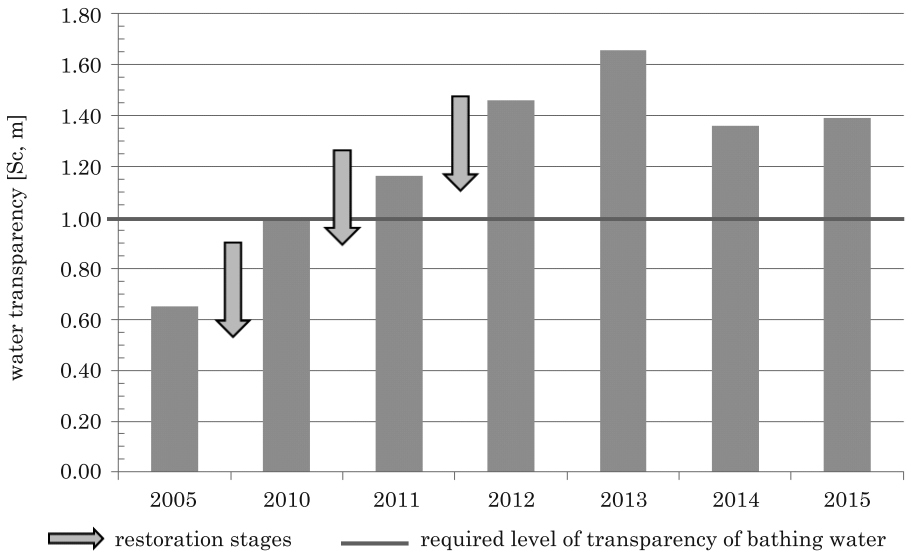

Fig. 3. Changes of water transparency in Lake Domowe Duże in recent years

could be a very efficient tool in sustaining the effects of technical lake restoration works. The stocking of fish species should be planned so as to reduce the risk of fish disturbing the bottom sediments. This is why the lake was not stocked with carp and other species which can contribute to the resuspension of bottom sediments, and therefore induce secondary water pollution. Meanwhile, the fry and fingerlings of predatory species, that is pike and pikeperch, were stocked more intensively (on average 25 thousand specimens a year). These efforts can be classified as implementation of biological restoration methods, known as fishery biomanipulation. As a consequence, the trophic cascade effect is amplified, which means that the number of zooplankton-foraging fish species decreases to the advantage of predatory species, and that creates more favourable conditions for plankton crustaceans, which control populations of plankton algae, including the most unwanted green-algae species.

Revitalization of the near-water space

To release the recreational potential of the lake, it was essential during the restoration works to improve the water quality up to a standard when recreational use of this water body would again be possible (twenty years after bathing had been prohibited). At present, the municipal bathing beach has been thoroughly refurbished and equipped in line with the current norms as

well as the formal and legal regulations in force. The bathing season runs from 15 June to 15 September, and the beach is visited by an average of 30 to 40 people a day. To protect the lake from excessive anthropopressure, it was very important to install toilets serving the municipal beach. Now, there are two toilets available for the public in the Sports and Recreation Centre and one, opened seasonally, on the beach.

The success of the restoration works was a driving force behind the subsequent efforts undertaken to make the lake more appealing to visitors. Having recognized the need to strengthen the town's tourist potential, such actions as further development of tourist and recreational infrastructure around Lake Domowe Duże have been included in the spatial planning and economic development strategy for Szczytno. The following have been distinguished as having the highest value: the foot and bicycle path around the lake, and an active leisure park situated at the southernmost environs of the lake. Once these investments were completed, the total area under recreational use around the lake was enlarged by 10 ha. Street lights and benches were installed along the foot and bicycle path, which encourages all families, including elderly persons and children, to take advantage of this facility. Noteworthy, the construction of the path in no way collided with the goals and forms of the lake's ecosystem natural protection. The bicycle path runs on a former walking path, it has mineral surface, permeable to rainwater, is not elevated above the ground level in a way that could interfere with the surface runoff from the catchment and does not obstruct a stream that feeds to the lake (road culvert). Consequently, the cycling and walking path does not change the lake's water relations nor does it deteriorate the soil retention capacity in the lake's surroundings.

Another benefit stemming from the completed restoration project around Lake Domowe Duże is the increasing interest of town residents in the offer of the sports center and water equipment rental, which became richer to meet the growing demand. The social dimension of this development cannot be neglected because it equates promotion of physical fitness, especially among young people.

The landscape values and aesthetic quality of the lake's surroundings have also been affected by the street architecture objects, created parallel to the restoration works, for example paths, benches, terraces, flower beds with ornamental plants, which decorate the park off the eastern shores of the lake. They make a perfect contribution to the town's recreational area and, together with the mentioned infrastructure components, create a new quality of the municipal landscape, which encourages both residents and visitors to indulge in outdoor pastime activities.

Conclusion

The case of Lake Domowe Duże in Szczytno proves that urban lakes, even less attractive in regard of a possible recreational use, can play an important role in the life of local communities. They can be used by residents, but they can also serve as some leverage for the growth of tourism in a given area. Commonly, a barrier to exploiting the full recreational capacity of such water bodies is the unsatisfactory quality of water, which precludes polluted lakes from serving certain forms of tourism and recreation, mostly swimming or water sports. The studies and observations presented in this report indicate that when self-purification of a water body is impossible, even after sources of pollution have been cut off, an adequately designed restoration technological solution should be implemented to restore good water quality. For Lake Domowe Duże, it was a relatively quick and simple method, whose essence was to decrease the pool of substances nourishing the lake, such as phosphorus, by inactivation. This method is becoming an increasingly popular tool to improve degraded water bodies. However, like in any other case, a technical approach should be supported with biological methods, which would take into account unique ecological conditions of a given water body. In the case of Lake Domowe Duże, the fishery management, and especially the new fish stocking policy, implemented as a contribution of one of the lake restoration team members, turned into an additional instrument that helped to achieve the stability of water quality originally improved with the technical method.

The efforts undertaken to re-create the natural and recreational values of Lake Domowe Duże in Szczytno and its surroundings are a yet rare example of holistic projects designed to revitalize waterfronts. It should be highlighted that the satisfying outcome of this project was possible owing to the cooperation of several participants – the local government, which bears responsibility for the area occupied by the lake and its environs, the fishery management authority and the research unit. The case study discussed herein proves the importance of synergistic relationships and their activation in such projects, when the collaboration of individual subjects generates a total effect that surpasses the sum of individual effects achieved by each subject alone.

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