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MORPHOMETRIC PARAMETERS OF THE WATER BODIES OF BAGRY WIELKIE AND BAGRY MAŁE IN THE BIODIVERSITY CONTEXT

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Abstract

The article presents the results of nature-based and geodetic query of two neighbouring endorheic borrow pits, i.e., Bagry Wielkie and Staw Płaszowski (Bagry Małe), situated almost in the centre of the Krakow city. The movements of water tables in 2016–2023 were observed (from the moment of ecological disaster in the Staw Płaszowski, in February 2016) and bathymetric maps were presented.

Based on geodetic measurements carried out in 2016–2022 and direct observations of nature, documenting biodiversity of both reservoirs in 2019–2022, the authors reviewed the state of biosphere in this location. Surveying, observations and interviews allowed parameterization of both water bodies (morphometric data and bathymetric maps) and creating up-to-date database (location on maps, qualitative and quantitative elements of flora and fauna). The material makes base for further studies with the application of more advanced photogrammetric technologies and UAV technologies, which can make data contained in this publication more accurate.

Keywords: environmental monitoring, Bagry Wielkie and Bagry Małe biodiversity, Bagry Wielkie and Bagry Małe morphometric parameters

PARAMETRYZACJA MORFOMETRYCZNA ZBIORNIKÓW BAGRY WIELKIE I BAGRY MAŁE NA TLE BIORÓŻNORODNOŚCI

Abstrakt

W artykule przedstawiono wyniki przyrodniczej i geodezyjnej kwerendy dwóch sąsiadujących w przestrzeni miejskiej Krakowa bezodpływowych zbiorników pogórniczych, tj. Bagrów Wielkich i Stawu Płaszowskiego (Bagrów Małych), usytuowanych niemal w centrum Krakowa. Przeanalizowano ruch zwierciadeł wody w okresie 2016–2023 (od chwili katastrofy ekologicznej w obrębie Stawu zarejestrowanej w lutym 2016 roku) oraz przedstawiono mapy batymetryczne.

Na podstawie pomiarów geodezyjnych prowadzonych w latach 2016–2022 i bezpośrednich obserwacji przyrodniczych dokumentujących bioróżnorodność obu zbiorników w latach 2019–2022, autorzy dokonali przeglądu stanu biosfery w obrębie tych lokalizacji. Pomiary geodezyjne i wywiady przyrodnicze dały podstawę sparametryzowania obu akwenów (dane morfometryczne i mapy batymetryczne) oraz stworzenia aktualnej bazy przyrodniczej (mapy lokalizacji, dane jakościowe oraz ilościowe elementów flory i fauny). Zgromadzony materiał stanowi wartościowe podstawy do dalszych prac badawczych

z wykorzystaniem bardziej zaawansowanych i przydatnych w tych szczególnych warunkach technik fotogrametrycznych i technologii UAV, które w przyszłości mogą usprawnić pozyskiwanie i zwiększyć dokładność danych rozpoznania przyrodniczego zawartych w niniejszej publikacji.

Słowa kluczowe: monitoring środowiska, bioróżnorodność Bagrów Wielkich i Bagrów Małych, parametryzacja morfometryczna Bagrów Wielkich i Bagrów Małych

1. INTRODUCTION

The quality and comfort of life in cities is a result of historic conditions, accommodation facilities, availability of basic services and contact with nature, i.e., areas of greenery and recreational areas (parks, water bodies, rivers and streams) [1]. The world's urban population is growing constantly and the proportion of people living in cities has been growing over the history. Although, in recent years, in developed countries (including Poland) this trend seems to slow down or even revert, the proportion of people living in cities remains high and social urbanization (urban lifestyle among the residents of villages) as well as spatial urbanization (growing urban areas) and the construction of new roads (including connection between urban and rural areas) generate growing demand for construction materials (sand, gravel, clay). The result of these changes is the formation of post-mining cavities and significant degradation of habitats [2, 3]. Moreover, these post-mining areas in urban agglomerations are characterized by low biodiversity index [4, 5], which is also characteristic for the areas situated in the vicinity of post-mining borrow pits filled with water, nowadays treated as very attractive residential areas. As stated by M.K. Steel and J.B. Hoffernan [6], urbanised areas are characterised by the deficiency of water areas, compared to built-up and industrial areas. Thus, the action to protect water areas and nature in urban environment is very important in maintaining biodiversity, i.e., preserving the natural capital [7], significantly improving aesthetic and landscape values of post-mining (post-industrial) areas and improving water balance in the area of the water bodies. Many anthropogenic water reservoirs are formed by spontaneous filling post-exploitation pits with ground waters and precipitation waters. Polish Waters (in Polish: *Wody Polskie*) estimated that there are 100 Polish artificial water bodies in Poland of total retention exceeding 1mln m^3. Many of them were formed before the Second World War or during Nazi German occupation. One of such water bodies is Bagry Wielkie (retention above 1.4 mln m^3 of water). Bagry Wielkie was formed on industrial scale in two stages (in 1940s during German occupation and in early 1970s). Bagry Małe is a post-mining pit filled with water formed during Nazi German occupation, nowadays filled with water.

The purpose of the paper was to study two anthropogenic water bodies: Bagry Wielkie (also called Bagry) and Bagry Małe (also called Staw Płaszowski) in terms of their morphometric parameters as well as flora and fauna. Interdisciplinary studies of both water bodies were carried out in 2016–2022. These studies should contribute to better protection of both water bodies and the assessment of urban environment around two objects, which is very important in achieving sustainable development of urban blue green infrastructure [8]. For many years residential and industrial buildings have been constructed around the water bodies. They pose threat to the natural environment of both water bodies. Building office centres, shopping centres, stores, blocks of flats) involved drainage. In February 2016 drainage led to lowering the water table in the Staw Płaszowski. Experts classified this situation as ecological catastrophe. Covering the adjacent areas by concrete also contributes to instability of the water tables in both water bodies, significantly diminishing the amount of ground waters permeating to the bowls of the water bodies. It is especially important in dry seasons, during hydrological droughts and can significantly damage the natural environment.

2. STUDY AREA

Until the Second World War the development of the city of Krakow was based on materials obtained in the outskirts (Płaszów, Prokocim, Zakrzówek, Przylasek Rusiecki, Dąbie). Mining industry based on common resources (clay, sand, gravel, loam) provided brick industry materials necessary for the functioning of the former royal capital. WW2 and Nazi German occupation made Kraków the capital of the General Government and important centre of transportation and supply for

the Eastern Front. Before the war the region of Bagry was a small mining area providing clay and other construction materials predominantly to the neighbouring brickyards. During Nazi occupation the area became an important local mining centre working for the development of road and railway infrastructure, industry and residential infrastructure in the region of Płaszów and Prokocim [9]. During Nazi occupation the demand for clay, sand and gravel caused the formation of another mining centre in the vicinity of the thriving and modernized railway in Płaszów [8]. The water bodies were formed naturally, after ceasing the exploitation, when the pumps stopped working and the cavities were filled with water. The shape and area of both reservoirs resulted from the way of management of the adjacent areas, i.e., the presence of communication systems – railway and roads.

The distance between the shorelines of both analysed water bodies in 2018 was 738 m.

Nowadays, drainless water bodies Bagry Wielkie and Bagry Małe belong to the biggest and most valuable water bodies in the terms of nature, landscape, economy, and recreation, situated within the borders of the city of Krakow (Fig. 1). They are situated near the city centre in the valley on the right bank of the Vistula River, in the city district XIII, Kraków-Podgórze. The beginning of Bagry Wielkie goes back to the first years of 20th century, when clay was exploited for brickyards (liquidated by now). In 1940s the mining of sand, gravel and clay intensified (especially in the eastern part of the borrow pit), due to the upgrading of the railway junction Płaszów for the needs of Nazi Germany. Due to the drainage of the pit (using pumps) it was possible to mine directly from the bottom and transport the product by the narrow-gauge train out of the pit. After the war, until late 1960s, mainly sand and gravel in the western part of the pit was exploited for the needs of constructing blocks of flats (production of prefab elements). Barges equipped with excavators were used. Thus, the morphology of the bottom in this part of the water body is more divert than in the eastern part (bathymetrical map – Fig. 5). North-west from Bagry Wielkie a pit was formed during Nazi German occupation, which later became Bagry Małe (Staw Płaszowski). After the

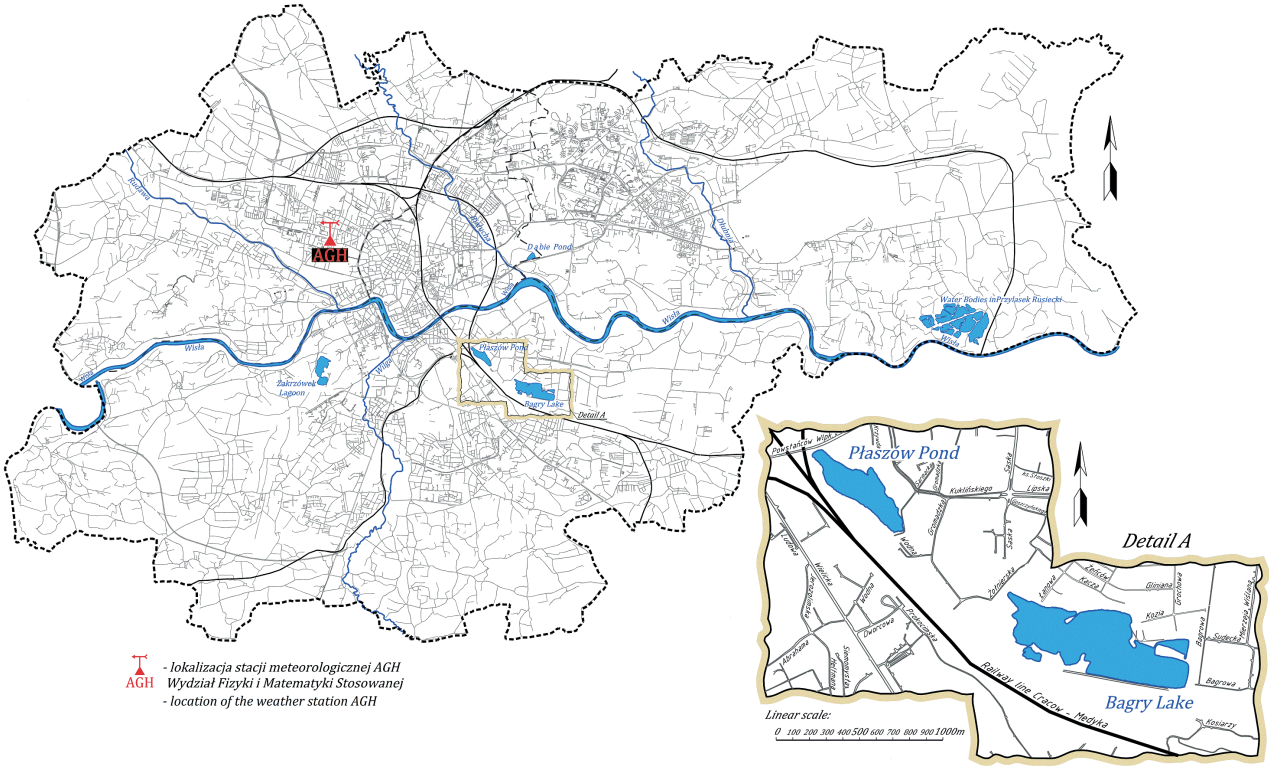

Fig. 1. Location of the Bagry Reservoir and Staw Płaszowski with the city borders and transportation networks
Ryc. 1. Lokalizacja Zalewu Bagry i Stawu Płaszowskiego na tle granic miasta i układów komunikacyjnych

end of mining, both pits were spontaneously filled with ground waters. Nowadays Bagry Wielkie (total area 30.63 ha) is used for sport and recreation. The large area and big depth (–4.66 m) make very good conditions for this. There are two bathing areas and a marina in the Bagry. Morphometric parameters of Bagry Wielkie are also favourable for angling, which is also common there. Staw Płaszowski, due to smaller area (8.96 ha) and small mean depth –1.06 m, cannot fulfil these functions (bathymetric map – Fig. 6). The only possible activity is angling, and even this is limited, due to frequent incidents of hypoxia. The character of the shoreline and ecosystem formed over the decades suggest that this area should be made ecological utility. Both water bodies and their shores are visited by birds for foraging and nesting.

3. TOOLS FOR THE PROTECTION OF NATURAL RESOURCES OF THE KRAKOW WATER BODIES

Bagry Wielkie and Staw Płaszowski are drainless water bodies. The state of water resources and the quality of the waters in the reservoir depend on the intensity of weather phenomena (precipitation and thaw) and ground waters. Retention and keeping relatively constant level of the water table and preserving a high quality waters can be disturbed by intensification of construction works in the area adjacent to the buffer zone of both water bodies. Introducing artificial forms, such as large-format buildings, car parks, roads, etc., to the environment caused drainage and directed streams of rain and thaw waters to the drainage system. Concrete surface does not allow waters to permeate the ground and, consequently, halts water retention (in micro-scale). Additionally, climatic changes cause irregularity of precipitation, high variability of their intensity and high thermal amplitudes significantly impact the state of natural environment and its components (quantity and quality of waters, flora and fauna).

Staw Płaszowski is small and shallow. It is situated between the railway Kraków-Medyka, Commercial Centre (Polish: Centrum Handlowe) called King Square (formerly CH Tandeta) and a residential area. The only functions it can fulfil are ecological (small retention and ecological utility), and educational (bird watching). Its shallow and muddy bottom and intense overgrowing with the common reed (*Phragmites australis* (Cav.) Trin. ex Steud) and broadleaf cattail (*Typha latifolia* L.) do not make favourable conditions for fish. Despite the efforts of the Krakow Angling Association (Krakowski Związek Wędkarski – KZW). Regular stocking was not successful, because the fry could not survive. The idea to protect natural and landscape values of the Staw Płaszowski has been present for many years, among the residents of Krakow, especially the ones living in the Płaszów area. Due to their efforts the Council of the City District XIII Podgórze in Resolution no. XII/127/2007 of 22nd May 2007 included the following information that: *Staw Płaszowski makes refuge for many species of water fowl, protected by law and is located in the zone of the formation of the ecosystem*. This was the beginning of the efforts to put this area under some protection, although, as proved later, this action was not sufficient (ecological catastrophe of 2016 caused by human activities [10]). Carried out so far environmental expertise referring to this water body and its vicinity indicate deterioration of the habitats and the state of flora and fauna [10]. This is aggravated by the fact that the adjacent areas are designed for investment and communication lines (traffic) generate noise and air pollution. Nevertheless, for many years emergency actions have been carried out to bring this green enclave to good shape. The area is prepared for the function of a city park (Polish: Park Miejski Staw Płaszowski). According to the expert team of the Bureau of Scientific Research and Expertises „Green Vetiver" this area, because of the low state of waters, noise and pollution, is not very attractive for the breeding of the protected animal species [9]. Moreover, sudden changes of the water table can disturb the biological equilibrium (chart – Fig. 2), which especially threatens small populations of amphibians and reptiles. Thus, for many years the proposals have been made to clean the bottom of reservoir from silt residues and deepening the water body, which would increase the attractiveness of the object for wildlife (restoring the resources of the fish populations) and limit process of spontaneous and intensive overgrowing it with reed and broadleaf cattail, as well as minimize the danger of ecological catastrophes, like in 2016.

On the other hand, the morphometric parameters of the bigger water body – Zalew Bagry, predesignate this to fulfil many functions. The functions are the following: sport and recreation in the north-eastern and eastern part (two beaches and bathing zones, rentals of

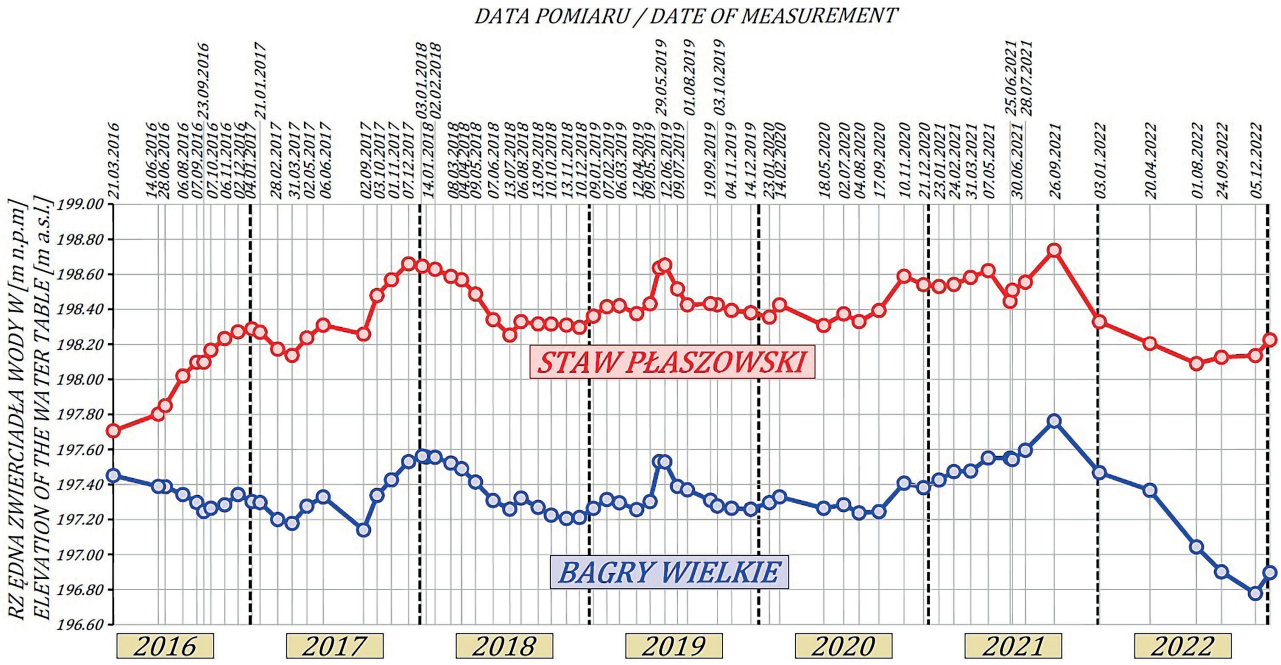

Fig. 2. Water table – chart of changes in the Bagry and Staw Płaszowski – March 2016 – January 2023
Ryc. 2. Wykresy zmian zwierciadeł wód Zalewu Bagry i Stawu Płaszowskiego w okresie 03.2016 – 01.2023

pedalos, canoes, motorboats, sailing boats, etc.), economic (fishing supervised by the Angling Association KZW Kraków) and in the southern and south-western part – ecological function. Unfortunately, multifunctional character of the water body often causes the conflict of interests. This results from overcrowding the reservoir with visitors, especially the ones using motor boats, causing excessive noise. This is nuisance for the residents of the neighbouring buildings (family houses and blocks of flats) and wild birds, having their habitats in the reed rush.

The loophole in the land use regulations with the division into zones and the lack of the proper care limited the possibilities of keeping the areas of Bagry and Staw Płaszowski in a proper condition. Thus, unauthorized garbage deposits appear on the surrounding meadows (including the vicinity of the shorelines). Traffic in the vicinity of the wildlife habitats also contributes to the damage to local ecosystems and their fauna. For many years the residents of Płaszów have been informing the Board of Urban Greenery (Polish: Zarząd Zieleni Miejskiej) on the need to issue regulations [11] limiting the sport and recreational activities in some areas of the water body and its vicinity. Up till now the only protective measure was establishing the City Park of the Bagry Reservoir (*Park Miejski Zalew Bagry*) by the Resolution no. XLII/1142/20 by the City Council of Krakow of 8th July 2020 [12]. The total area of the park is 49.18 ha. The set of legal regulations was established, and the rules are displayed on the information boards around the reservoir, as well as contained in the Enclosure 1 [13] of the Resolution [12]. Local conservationists and the analysis of environmental conditions allowed the City Council of Krakow to mark the zones of active recreation and quiet zones, which was written in [13]. Following these regulations, alongside the southern and south-west shore, the protective zone for nesting birds was marked with buoys. This means the ban for all the activities within the zone all year round.

4. METHODS OF ASSESSING WATER RESOURCES IN RESERVOIRS

According to A. Choiński and M. Ptak [14] only about 1/3 of all the water bodies in Poland have detail bathymetric maps. A large part of these maps goes back to the turn of 1950s and 1960s, when following the instructions of the Institute of Inland Fishery (Polish: Instytut Rybactwa Śródlądowego – IRŚ) with the seat in Olsztyn, a lot of morphometric information was

collected and illustrated in the form of detail cartographic materials. In the following years supplementary bathymetric measurements were carried out on a smaller scale for the needs of the Atlas of the Polish Lakes (Atlas Jezior Polski) with the application of simplified inventory methods. Thus, a relatively small set of data on resources of stagnant waters in Poland results from the fact that inventory processes are work and time consuming in case of such objects and getting topographic information is expensive. Nevertheless, the obtained information is very valuable. It allows a careful query of water resources and makes base for the assessment of the scale and speed of changes in subaquatic parameters of water bodies [3].

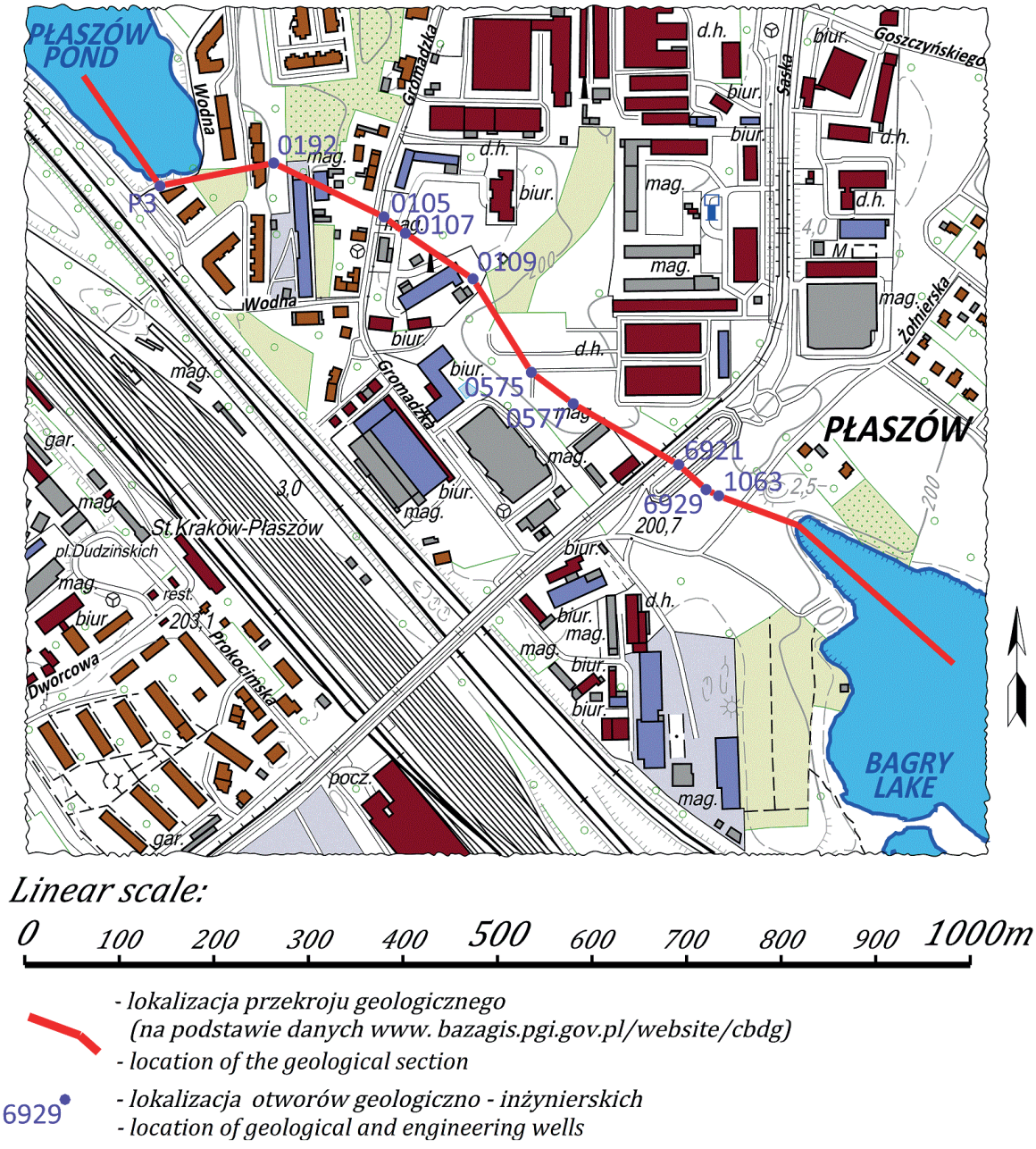

Fig. 3. Location of geological cross-section in the study area against of the fragment of the topographic map
Ryc. 3. Lokalizacja przekroju geologicznego w obszarze badań na tle fragmentu mapy topograficznej

Observations of the state of the water table in reservoirs (indirectly water resources) in the framework of environmental monitoring can be carried out in the following way:

1. periodical – based on reading the water level from the water meter staff put in the vicinity of the shoreline or using geodetic techniques (geometric or satellite levelling, GNSS);
2. on-line, automatic recording of a digital limnigraph (instruments of this type require external charging).

Choosing the way of registration depends on the frequency of the registration of changes in the water table level and the way of the management of the reservoir (access to the sources of energy empowering the meters) and possibilities of the protection of instruments (water meter staff and digital devices are likely to be damaged, destroyed or stolen).

Exact assessment of water resources requires spatial model of the bottom and the surface of the terrain directly adjacent to the shoreline, which results from periodical changes in the water table. This refers to the growth of the water level in the periods of intensive and long-lasting rains. For this purpose, supersonic sonars are applied (accuracy ±2.5 cm – ±10 cm), with the following characteristics:

1. they are equipped in GPS receivers (accuracy of positioning $m_P < \pm 2.5$ m (system EGNOS);
2. their data can be coupled with flat data of typical geodetic receivers GNSS, allowing the registration of flat coordinates in the mode of fast measurement RTN (with differential correction) with accuracy $m_P < \pm 0.05$ m (system ASG-EUPOS) in manual measurement (operator decides when the measurement should start) or automatic measurement (the moment of the measurement is defined by the time interval established from the moment of putting the system into motion).

The sonars are put on classic boats (dinghies, yachts, pedalos) or unmanned boats, so-called hydrodrones steered from the shore, or working in autonomous mode after programming the trajectory route and the area of measurement (on Google Maps).

Making full environmental inventory required full cartographic documentation in the form of situation and altitude map, as well as bathymetric map, geological cross-section (based on the data from PIG boreholes on the section Bagry Wielkie – Staw Płaszowski – Fig. 3 and 4) as well as recognizing and registration of the elements of flora and fauna. To make detail cartographic documents, which made base for the morpho-

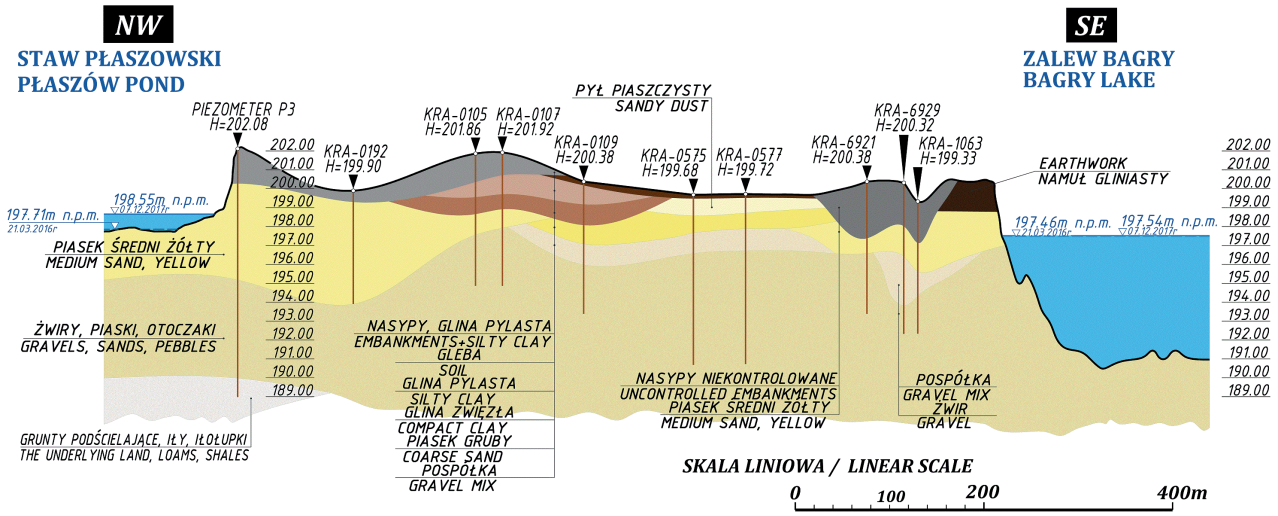

Fig. 4. Geological cross-section – development (authors' work based on PIG data – bazagis.pgi.gov.pl/website/cbdg and author's own measurements of bathymetric measurements)

Ryc. 4. Przekrój geologiczny – rozwinięcie (opracowany przez autorów na podstawie danych PIG – bazagis.pgi.gov.pl/website/cbdg oraz własnych pomiarów batymetrycznych)

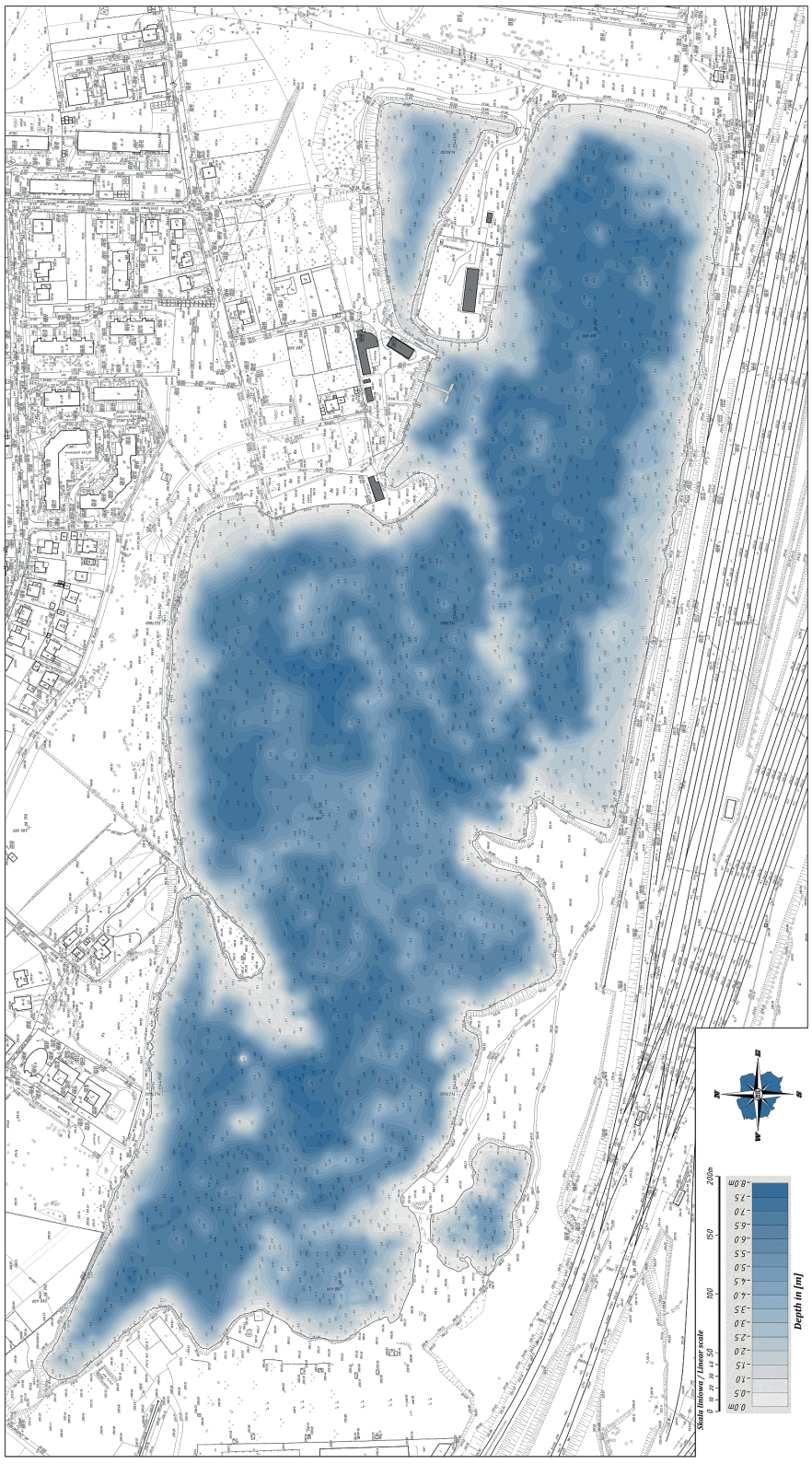

Fig. 5. Bathymetric map of Bagry Wielke
Ryc. 5. Mapa batymetryczna Bagrów Wielkich

metric parametrization of both water bodies the following geodetic methods were applied:

1. levelling measurements – water tables (Fig. 2);
2. GNSS measurements (RTK and RTN mode with the application of receiver R8s + controller TSC3 Trimble'a) shoreline, adjacent areas and positioning of a supersonic sonar during bathymetric measurements;
3. bathymetric measurements (acoustic sonars: Lowrence Elit-4 [15, 16] and Eagle Ultra II) made from a boat equipped with GNSS for precise positioning of the sonar.

The application of profiling methods (Staw Płaszowski [17]) and dispersed points (Zalew Bagry [18]), with the application of the described above measurement set, allowed the modelling of geomorphology of both of drainless water bodies in Kraków. Based on results of the geodesic and bathymetric measurements detail morphometric parameters were defined in both analysed water bodies – table 1. Such data make base for the morphometric parameters of the water body, assessment of the water balance, but first of all the direction and rate of the succession, and facilitate analyses of the course of physical and chemical processes.

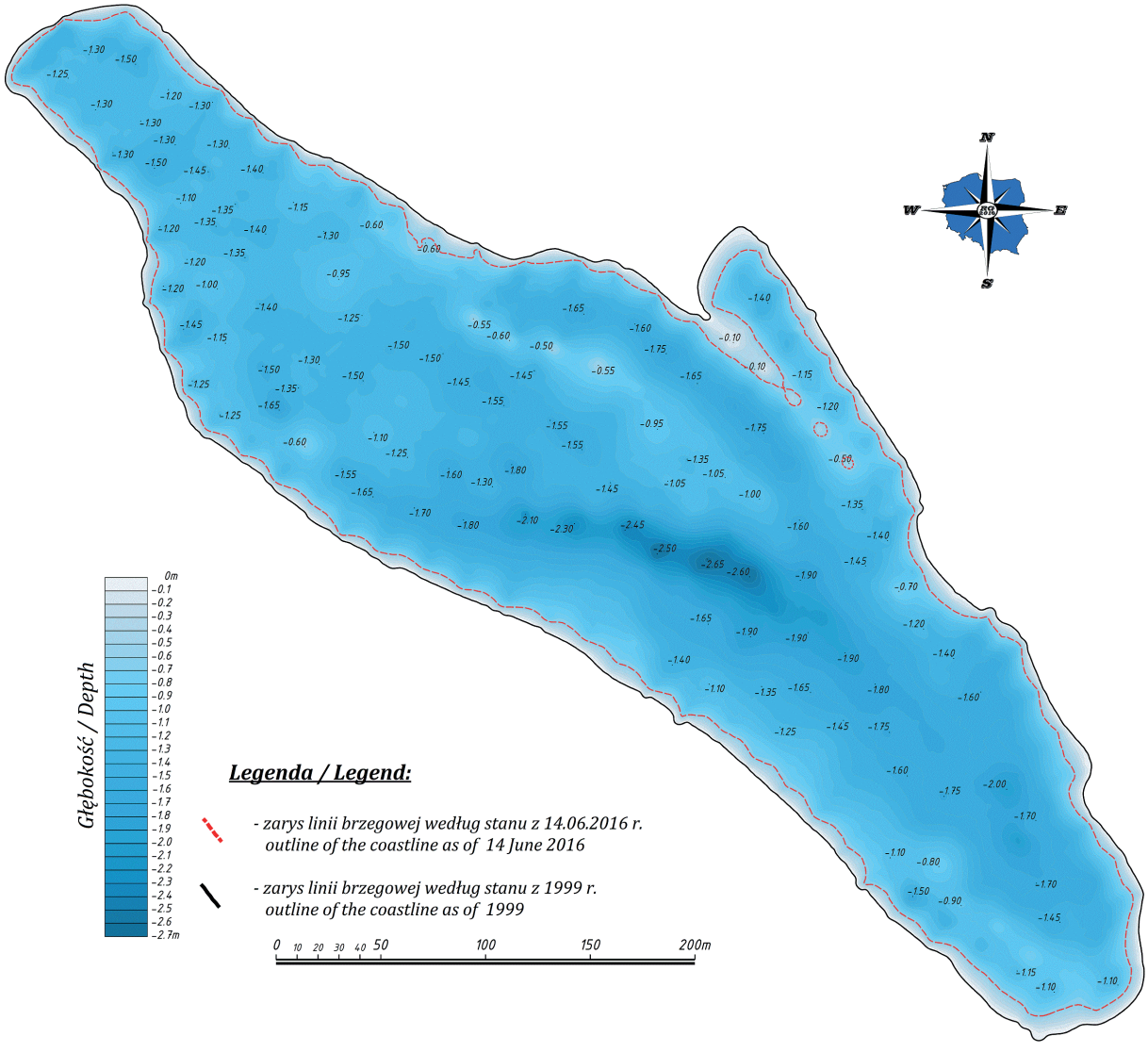

Fig. 6. Bathymetric map of Bagry Małe (Staw Płaszowski)
Ryc. 6. Mapa batymetryczna Bagrów Małych (Stawu Płaszowskiego)

Table 1. Basic morphometric parameters of the Bagry Wielkie and Staw Płaszowski – based on [17, 18]
Tabela 1. Zestawienie podstawowych parametrów morfometrycznych Bagry Wielkie i Stawu Płaszowskiego – na podstawie [17, 18]

Morphometric Parameter Parametr morfometryczny	Bagry Wielkie		Staw Płaszowski
	Large Water Akwen duży	Small Water Akwen mały	
Area of the water body [ha]	30.03	0.60	8.96
Shoreline length [m]	4066.7	364.6	1700.9
Volume of water resources [m^3]	1 405 762	11 505	94 985
Maximum depth [m]	–7.8	–5.24	–2.47
Mean depth (GRID)	–4.66	–2.04	–1.06
State of:	2016	2018	2016

Knowing the morphology of the two water bodies located in a small area, allows the assessment of the impact of human activities (impact of big engineering constructions in the adjacent areas) on the amount of water resources and ecosystem) and the speed of spontaneous regeneration of all the components of the ecosystem after identifying the source of environmental damage.

The analysed water bodies, due to their differentiated morphometric parameters (area, depth – table 1), have different functions.

In 2016, the ordinates of the water table levels were determined (based on control benchmarks) in both water bodies, which allowed the analysis of the reaction of both reservoirs to negative impact of human activities and defining the time necessary to bring water resources

Fig. 7. Bagry Wielkie in photos (authors: R. Gawałkiewicz, A. Wagner)
Ryc. 7. Bagry Wielkie w obiektywie (autorzy: R. Gawałkiewicz, A. Wagner)

Fig. 8. Bagry Małe in photos (authors: R. Gawałkiewicz, A. Wagner)
Ryc. 8. Bagry Małe w obiektywie (autorzy: R. Gawałkiewicz, A. Wagner)

back to good state (relatively constant). In October 2021 distinct reduction of the water level in both water bodies was observed (Fig. 2), which continued to be low until December 2022 (in case of Bagry Wielkie) and August 2022 (in case of Staw Płaszowski). It is suspected that the diminishing of the water table level was caused by intensive development in the neighbourhood of Bagry and the cable-stayed viaduct (streets: Żołnierska and Gromadzka) and their negative impact on the water resources of both water bodies (digging and drainage of deep excavations for the basements of the constructions). Sudden and/or distinct change of water tables, especially in case of drainless water bodies of stabilized ecosystems (different from the initial one, i.e., after the end of exploitation), can disturb the functioning of biocoenoses. This disturbance can make impossible the reproduction or even survival of the populations of species with narrow range of tolerance. Moreover, the equilibrium of the ecosystem depends on mutual links of many environmental factors in the zone above water and hydrology of the reservoir [19].

Bathymetric maps of Bagry Wielkie and Staw Płaszowski make rich cartographic material that can be extremely useful in the process of the interpretation of many phenomena taking place in the areas of both water bodies.

5. THE ANALYSIS OF THE STATE OF ENVIRONMENT (BIODIVERSITY)

Decisive factor giving water bodies unique and specific character is their morphometry. Especially in case of neighbouring water bodies of changeable morphometric parameters, their impact on flora and fauna is very distinct. Several photos exemplifying the landscape, flora and fauna of both water bodies are presented in Fig. 7 (Bagry Wielkie) and 8 (Staw Płaszowski).

The analysis of the state of environment was supplemented by the fieldwork (direct observations), the purpose of which was recognition and documentation of the places of the occurrence of certain plant and animal species. Made in such a way base of the elements of flora and fauna, in the future, will make excellent comparative material at the stage of the analysis of the state of natural environment and the assessment of the condition of both reservoirs with the adjacent areas.

Direct observations of flora and fauna allowed the definition of natural resources on the shore of the reservoirs. Our surveys of 1st August 2019 and 28th July 2022 showed 40 plant species (table 2) and 9 species of waterfowl. The surveys allowed to find only some species of those occurring in the area. Surveys carried out in 2008 and 2009 [20] showed some other plant species, not found in this study, including common centaury (*Centaurium erythraea* Rafn) at Staw Płaszowski, a species protected by the Polish law. Earlier studies showed the occurrence of other bird species, including the common pochard (*Aythya ferina* (L.)), common gull (*Larus canus* L.) on Staw Płaszowski and barn swallow flying over Bagry Wielkie [21]. The lack of observations in the present survey does not mean that the species disappeared. They simply might have been unnoticed. Table 3 presents the results of the observations in 2019 and 2022. Direct observations were carried out from the shoreline. They allowed making maps of the occurrence of plant and animal species, which was illustrated in Fig. 9 and 10. Due to the degree of the development of the reed rush (*Phragmitetum australis*) in the shore zone, which limits the observations of fauna, it would be reasonable to apply photogrammetric methods and UAV technologies, which can supplement direct observations in the future.

Table 2. The taxa (species or genera) of plants forming the ecosystem around Staw Płaszowski and Bagry Wielkie
Tabela 2. Zestawienie taksonów (gatunków lub rodzajów) roślin budujących ekosystem wokół Stawu Płaszowskiego i Bagrów Wielkich

No.	Scientific name	English name	Polish name
1.	*Phragmites australis* (Cav.)	common reed	trzcina pospolita
2.	*Calamagrostis* sp. Adans	reed grass	trzcinnik
3.	*Nymphaea alba* L.	white waterlily (pink cultivar)	grzybień biały (kultywar różowy)
4.	*Pastinaca sativa* L.	parsnip	pasternak
5.	*Daucus carrota* L.	wild carrot	marchew zwyczajna (dzika)
6.	*Lobularia maritima* (L.)	sweet alyssum	smagliczka nadmorska
7.	*Tanacetum vulgare* L.	tansy	wrotycz pospolity
8.	*Artemisia vulgaris* L.	common mugwort	bylica pospolita
9.	*Achillea millefolium*	yarrow	krwawnik pospolity
10.	*Erigeron canadensis* L.	canadian horseweed	konyza kanadyjska
11.	*Hieracium umbellatum* L.	narrowleaf hawkweed	jastrzębiec baldaszkowaty
12.	*Cirsium arvense* (L.)	creeping thistle	ostrożeń polny
13.	*Epilobium hirsutum* L.	great willowherb	wierzbownica kosmata
14.	*Linaria vulgaris* Mill.	common toadflax	lnica pospolita
15.	*Geranium* sp. L.	geranium	bodziszek

16.	*Calystegia* sp. R.Br.	false bindweed	kielisznik
17.	*Verbascum* sp.	mullein	dziewanna
18.	*Saponaria officinalis* L.	common soapwort	mydlnica lekarska
19.	*Impatiens parviflora* DC.	small-flowered touch-me-not	niecierpek drobnokwiatowy
20.	*Urtica* sp. L.	nettle	pokrzywa
21.	*Sanguisorba officinalis* L.	great burnet	krwiściąg lekarski
22.	*Rosa rugosa* Thumb.	rugosa rose	róża pomarszczona
23.	*Rubus* sp. L.	blackberry	jeżyna
24.	*Prunus* (subg. Padus) sp. (Mill.) Peterm.	bird cherry	czeremcha
25.	*Prunus domestica syriaca* (Borkh.)	mirabelle plum	śliwa mirabelka
26.	*Sorbus aucuparia* L.	rowen	jarząb pospolity
27.	*Crataegus* sp. Tourn ex. L.	hawthorn	głóg
28.	*Juglans regia* L.	persian walnut	orzech włoski
29.	*Ligustrum vulgare* L.	wild privet	ligustr pospolity
30.	*Symphoricarpus albus* (L.)	common snowberry	śnieguliczka biała
31.	*Sambucus nigra* L.	black elder	dziki bez czarny
32.	*Rhus typhina* L.	staghorn sumac	sumak octowiec
33.	*Acer negundo* L.	box elder maple	klon jesionolistny
34.	*Acer platanoides* L.	norway maple	klon zwyczajny
35.	*Corylus avellana* L.	common hazel	leszczyna pospolita
36.	*Betula pendula Roth*	silver birch	brzoza brodawkowata
37.	*Alnus glutinosa* (L.)	black alder	olsza czarna
38.	*Salix* sp. L.	willow	wierzba
39.	*Populus alba* L.	silver poplar	topola biała
40/.	*Robinia pseudoacacia* L.	black locust	robinia akacjowa

6. CONCLUSIONS

Hydromorphological studies allowed the registration of the state of water bodies and the assessment of the condition of natural environment. Morphological parameters are in table 1. They make an important indicator showing the usefulness of both water bodies to fulfil certain functions. The Bagry Wielkie, due to favourable morphometric parameters, i.e., big maximal and mean depth, relatively large area and complex shoreline, can fulfil many various functions, i.e., sports and recreation, angling (economic significance), as well . Unfortunately, morphometric parameters of the Staw Płaszowski (small maximal and mean depth) do not stimulate a condition of biosphere (silting the bowl of the reservoir). Small depth of the water body stimulates its overgrowing the reservoir with the reed rush, which predestinates Bagry Małe only to the role of nice and valuable ecological utility. Moreover, the vicinity of large-size and large-area objects (including car parks) limits the possibilities of preserving the volume of the water that can be retained. Building up and covering with concrete the closest vicinity of the water body poises serious threat for good condition and functioning the flora and fauna of the Staw Płaszowski.

The location of both analysed water bodies, their geospatial characteristics, multifunctionality, significantly elevate their value as ecological utility and attractiveness of settlements Płaszów Mały and Prokocim. Permanent environmental monitoring and limiting ex-

Table 3. Species of waterfowl forming the ecosystem around Staw Płaszowski and Bagry Wielkie
Tabela 3. Zestawienie gatunków ptactwa budującego ekosystem wokół Stawu Płaszowskiego i Bagrów Wielkich

No.	Bird species or genus			Icon on the map	Number of individuals on ...			
	Scientific name	English name	Polish name		1st August 2019	28th June 2022	1st August 2019	28th June 2022
					Staw Płaszowski		Bagry Wielkie	
41.	*Cygnus olor* (Gmel.)	mute swan	łabędź niemy		3	6	2	0
42.	*Anas platyrhynchos* L.	mallard	krzyżówka		21	no data	41	24
43.	*Podiceps cristatus* (L.)	great crested grebe	perkoz dwuczuby		7	no data	33	7
44.	*Fulica atra* L.	Eurasian coot	łyska zwyczajna		67	no data	30	10
45.	*Chroicocephalus ridibundus* L.	black-headed gull	śmieszka		0	0	0	1
46.	*Sterna sp.* L.	tern	rybitwa		0	0	0	1
47.	*Panurus biarmicus* (L.)	bearded reedling	wąsatka		0	no data	3	0
48.	*Acrocephalus arundinaceus* (L.)	great reed warbler	trzciniak		0	no data	2	2
49.	*Delichon urbicum* (L.)	common house martin	oknówka		0	0	0	>6

ternal factors, negatively impacting individual components of environment make necessary condition to keep both water bodies and adjacent areas in a good shape.

All human activities in the vicinity of the water body (constructions and drainage) and natural phenomena (hydrological droughts) pose serious threat to the functioning of individual elements of natural environment, as it can be seen on the graph of water tables in both water bodies. The results presented in this paper make only a small fragment of research defining the directions of further studies. Both water bodies in the zones of shallow water and shoreline are overgrown with the reed rush (*Phragmitetum australis*), which significantly limits the access to the study area. Thus, in the future, it would be useful to investigate patches of vegetation by photogrammetric methods, which can make the results of the observations more precise.

Forming environmental utilities (officially recognised form of environmental protection) in the study area would allow keeping the water bodies and the

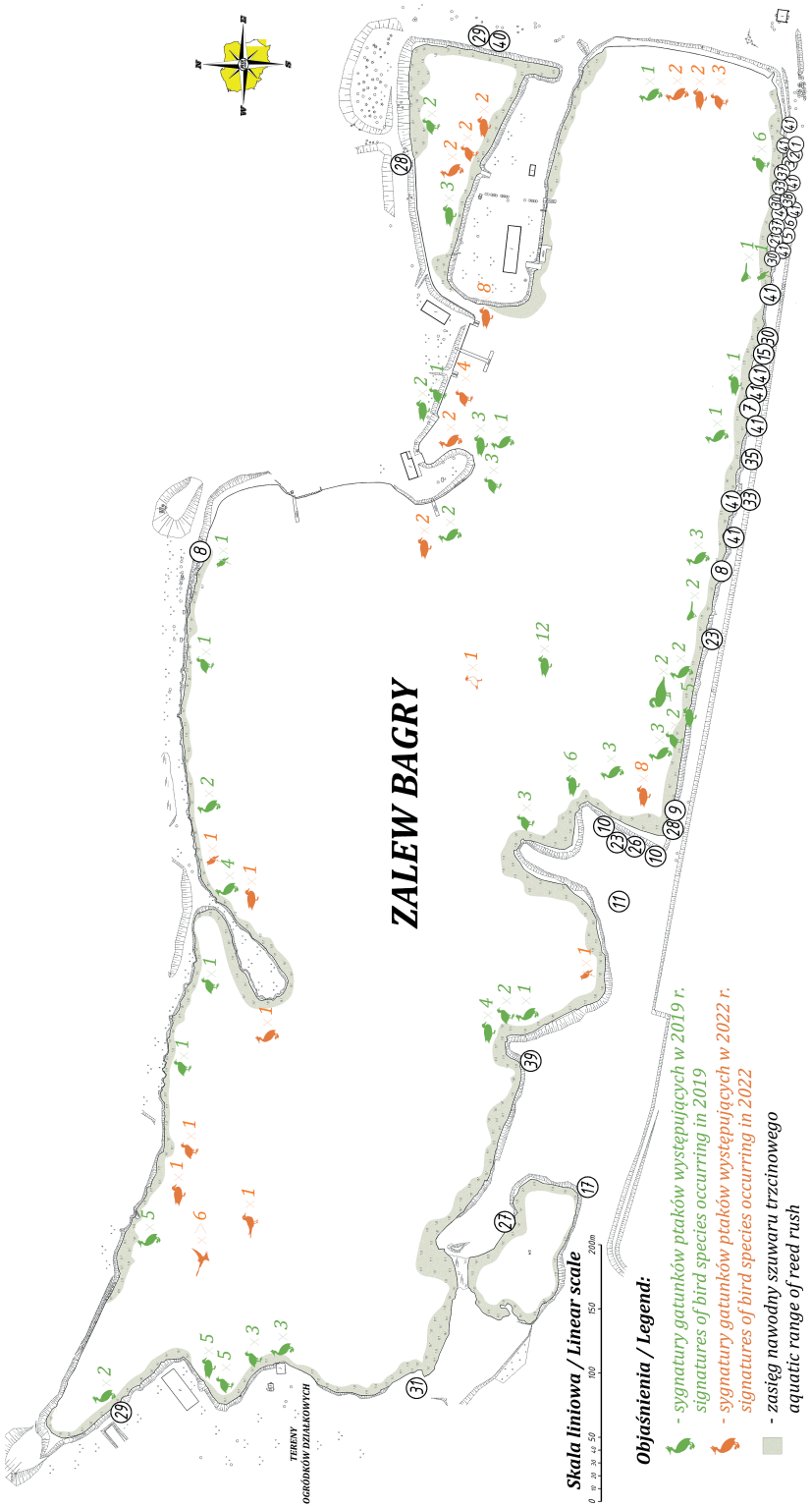

Fig. 9. Location of the inventoried elements of flora and fauna around Bagry Wielkie
①,②,③, … – marking the location of flora elements according to table 2
Ryc. 9. Lokalizacja zinwentaryzowanych elementów flory i fauny wokół Bagrów Wielkich
①,②,③, … – oznaczenie lokalizacji elementów flory według tabeli 2

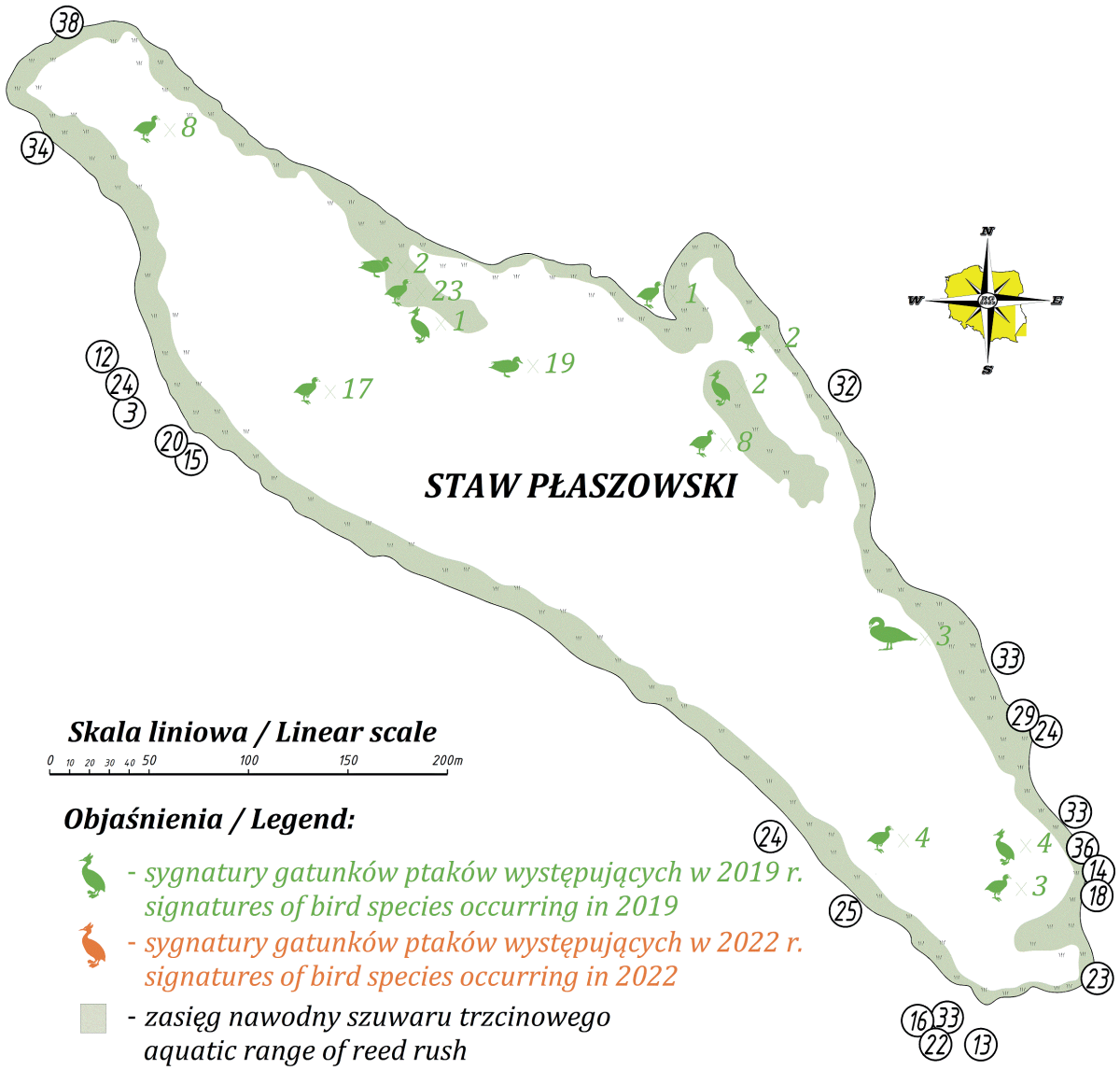

Fig. 10. Location of the inventoried elements of flora and fauna around Bagry Małe
①,②,③ – marking the location of flora elements according to table 2
Ryc. 10. Lokalizacja zinwentaryzowanych elementów flory i fauny wokół Bagrów Małych
①,②,③ – oznaczenie lokalizacji elementów flory według tabeli 2

vicinity in good ecological state. This would demand measures to protect the environment, which will generate costs. But protection will bring benefits for the residents of Krakow (recreation, sports, fishing, educational role). Despite the origin, unlike many other post-mining areas, this area has high market value. Additionally, historic and ecological values make the reservoirs of Bagry and Staw Płaszowski distinct from other post-mining areas in Poland.

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