

Article

Assessment of the Local Impact of Retention Reservoirs—A Case Study of Jagodno (Existing) and Sarny (Planned) Reservoirs Located in Poland

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Abstract: The construction of retention reservoirs that cause permanent water damming is a complex subject and requires an interdisciplinary approach to environmental issues. The scope of the conducted study includes (1) a natural inventory of the area of Jagodno Reservoir in central Poland, which has been in operation for almost a decade, (2) a natural inventory of the area where a reservoir of similar size could potentially be built (Sarny, in southwestern Poland), (3) an assessment of the local community's attitudes toward the operation or construction of individual facilities, (4) analysis and use of the obtained results to predict the local impact of Sarny Reservoir. The results of this study indicate areas where the impact of Jagodno Reservoir should be considered negative, neutral, or positive and what effect can be expected during the construction of Sarny Reservoir. One of the more significant results for Jagodno Reservoir, we should point out, is the appearance of a few waterfowl breeding at the site (4 species), a substantial expansion of the ichthyofauna population (from 9 to 24 species, which does not apply only to native species), a local loss of 91E0 habitat (willow riparian forests) and the appearance of one species of an invasive plant (Canadian goldenrod), a favorable impact on the water quality of the River Wiązownica (reduction in total and nitrate nitrogen loads by an average of 43.4% and 58.2%, respectively), and a positive assessment of the reservoir's impact on the development of the region by the local community (19 out of 26 village leaders expressed positive opinions with no unambiguously negative votes).

Keywords: retention reservoir; environmental impact; ecosystem; environmental assessment



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1. Introduction

In the era of undeniable and progressive climate change, many areas require taking action to limit the negative effects of the more frequent occurrence of extreme hydrometeorological phenomena. Retention reservoirs are an engineering solution that can protect local infrastructure against floods or droughts. Such facilities allow water to be collected for any further use, supporting the development of water-scarce regions and stabilizing the flow in the stream below the dam [1–3]. However, it should be remembered that retention reservoirs have a significant impact on the environment, which is a very complex issue that combines various scientific disciplines and requires interdisciplinary research. Undoubtedly, the construction of a dam on the river and the artificial creation of a permanent flood zone will significantly affect the local ecosystem. Its main elements, exposed to direct impacts, include the local community, avifauna, ichthyofauna, local flora (including the possibility of invasive species), surface and groundwater quality, soils in the vicinity of the flood zone, and the morphology of the watercourse below the dam's cross-section [4–6]. There are facilities around the world that have significantly affected local communities and upset the ecological balance of the region. An extreme example is the Three Gorges

Reservoir, the construction of which resulted in the flooding of an area of about 1000 square kilometers and the need to resettle 1.3 million people. It is impossible to briefly summarize the total environmental impact of this construction; however, attempts have been made to assess the impact on specific aspects. Among other things, it has been pointed out that the most negative phenomena include the reduction in sediment movement downstream, its accumulation in the reservoir, and thus problems with deteriorating water quality upstream of the dam [7,8]. Observations of changes in the species composition of ichthyofauna are also undeniable [8,9]. By creating a retention reservoir at a given location and thereby changing the living conditions of the various species, we also change their quantitative and qualitative composition. There is a development of organisms that are favored by the body of water to carry out their life processes (for example, plankton-eating fish). A whole new sequence of interrelationships between organisms is being created, whereas an example we may mention is a change in the composition of aquatic vegetation (current-loving vegetation gives way to rooted/watercourse vegetation), which creates favorable conditions for the development of phytophilous fish (e.g., pike) [10,11]. Smaller reservoirs can also negatively impact the local ecosystem, such as the Chotiari Reservoir in Pakistan, the creation of which has resulted in the transformation of regionally fertile agricultural land into unproductive and saline soil [6]. Another issue that is gradually being raised more and more in connection with the operation of reservoirs is the emission of greenhouse gases from the floodplain [12]. Such a circumstance should be considered especially in the case of the construction of large facilities equipped with hydropower units [13]. The number of previously mentioned elements exposed to potential impacts (which is not a complete list) indicates the need for an extensive inventory of the existing state to give a picture of potential environmental interference. Conclusions from such an inventorization will allow the selection of appropriate technological solutions for the planned facility. They may point to disproportionate ecological damage and the need to suspend the investment in the selected variant. Social issues and the possibility of conflicts caused by people's approaches to sustainability, which differ on many levels, should also not be overlooked. Two extreme views can be distinguished here, i.e., natural-centric and anthropocentric, which regularly clash, especially when planning significant strategic investments [14]. In the case of reservoirs, the crucial economic importance of these facilities, which can serve flood control, energy, navigation, tourism, and drought leveling functions, is often emphasized [15]. Thus, following the rule of the golden mean, it is necessary to maintain the right balance between the economic, environmental, and social aspects.

To reduce environmental pollution and overexploitation of natural resources, various legal regulations are introduced as a result of the country's environmental policy. Among the primary tools for nature conservation in, for example, European Union countries and the United States is the Environmental Impact Assessment ("EIA") procedure. In the case of the EU and the issued Council of Europe Directives [16], the procedure is very standardized and based on a similar scheme, the basic elements of which are listed below:

1. Determine whether the proposed project qualifies as a project that may always have a significant impact on the environment and whether it requires an EIA;
2. If an EIA is required—it must include a description and assessment of the impact on all natural elements within the project's range of influence, along with consideration of mitigation measures, a comparison of different options for implementing the project, and the creation of a monitoring plan;
3. Preparation of a report that is made available to the public, on the basis of which an appropriate administrative decision will be issued by a state body, allowing the investment to begin.

The administrative decision mentioned in the last subsection may be subject to appeal, which can be used by nature-centric associations that challenge the quality of the EIA performed. As an example, Poland can be mentioned here, where a positive decision was issued by the Regional Director of Environmental Protection, specifying the environmental conditions for the construction of "Wierna Rzeka" Reservoir, which was, however,

rescinded by a higher-level authority due to an appeal by two pro-environmental organizations. The main objections of these organizations were the lack of consideration of the dry reservoir option in the EIA, the disproportionality of the assumed compensation measures, the lack of an accurate inventory in terms of the presence of breeding pairs of birds, as well as the planned stocking with alien species [17]. This circumstance, among others, was the basis for selecting avifauna and ichthyofauna as one of the main areas of research, the results of which are presented in this article.

Bearing in mind the legal regulations imposing a comprehensive conduct of an EIA, the reports created on its basis are an incomparably valuable source of comprehensive information on the state of the ecosystem of a given region. However, in terms of the impact itself, proposals are adopted *ex ante*. Although these assumptions are often built on the best available knowledge, the complexity of the environment frequently proves to be beyond the ability to effectively predict all aspects of the impact of a given investment [15]. To continuously improve this effectiveness, *ex post* studies are needed after the construction and years of operation of a given facility, comparing the actual state with previously made assumptions. Due to the widespread presence of already functioning retention reservoirs of various sizes in different countries, regions, and environments, there is great potential and space for scientific research in this area.

A fully comprehensive determination of the environmental impact of a reservoir is not possible within a single scientific publication, and most often, they focus on one selected issue [5,18–21]. Their emergence, however, should be considered a precious phenomenon since, with them, people who are interested can be brought closer to drawing universal conclusions in selected areas. Also, for this article, the decision was made to select five primary areas of research in an effort to expand scientific knowledge in this particular area, while consciously excluding, for example, the equally important (and requiring more extensive analysis) impacts of reservoirs on mammals or invertebrates, groundwater, as well as on debris transport, water balance, and potential reservoir siltation. However, any sound scientific investigation is essential from the perspective of moving away from chaotic exchanges on emotional grounds to reasoned discussion with a solid factual basis derived from the knowledge acquired by humanity. The goals behind the creation of this manuscript are (1) to locate the functioning reservoir for which an EIA was conducted at the stage of planning the investment—Jagodno Reservoir, (2) to locate the area where a reservoir of similar size could potentially be built—Sarny Reservoir, (3) to conduct *ex ante* studies of Sarny Reservoir and *ex post* studies of Jagodno Reservoir for selected elements of the local environment, (4) to compare the results of the studies with the results of the inventory of the Jagodno Reservoir area at the stage of creating the EIA, and (5) conclusions and discussion, including on the potential impact of Sarny Reservoir.

2. Materials and Methods

Two locations were chosen as the study area—Jagodno Reservoir, which has been in operation since 2015, and an area where a reservoir (Sarny) of similar size could potentially be built. At these locations, inventories were made of selected environmental elements, i.e., the species composition of avifauna, ichthyofauna, and flora, as well as river water quality surveys and an attempt to identify public sentiment in connection with the operation or planned construction of the facility. A graphical abstract of the article is shown in Figure 1.

2.1. Jagodno Reservoir

The reservoir is located in central Poland, in the estuary section of the valley of the Wiązownica River—a watercourse with a total length of 117.6 km and a catchment area of 265.62 km². This partially regulated river has low average flows (about 1.2 m³/s), and for the reservoir project, the Q1% flow was set at 51 m³/s [22]. The reservoir spans over an area of 45 hectares, having a flood capacity of about 0.5 million m³. In the canopy of the reservoir was located the so-called bird island with an area of 1300 m². The fundamental element of the reservoir is a soil dam with an integrated bleed/overflow structure, additionally

equipped with a fish ladder to allow fish migration. The flood zone included areas that were previously occupied mainly by meadows with locally more intensive vegetation along the banks of the Wiązownica River. The reservoir area after and before construction is shown in Figure 2.

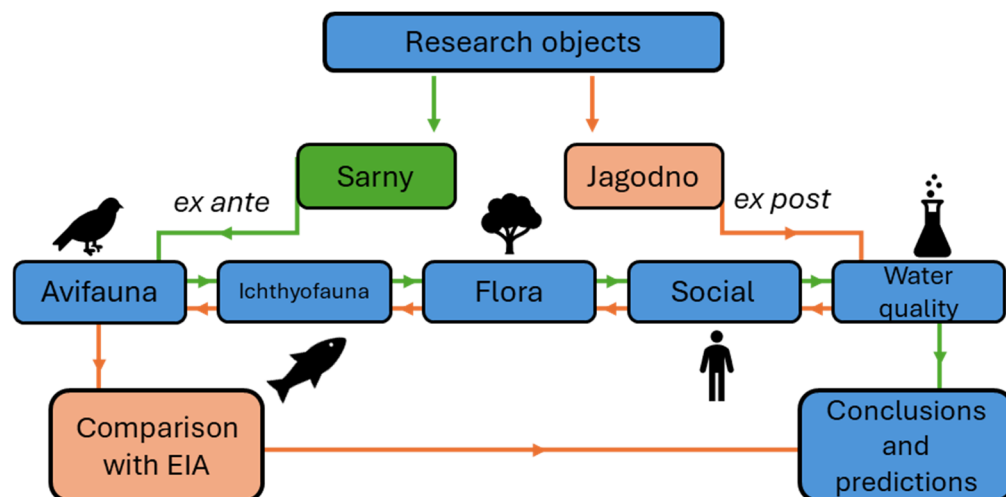


Figure 1. Graphic abstract of the article.

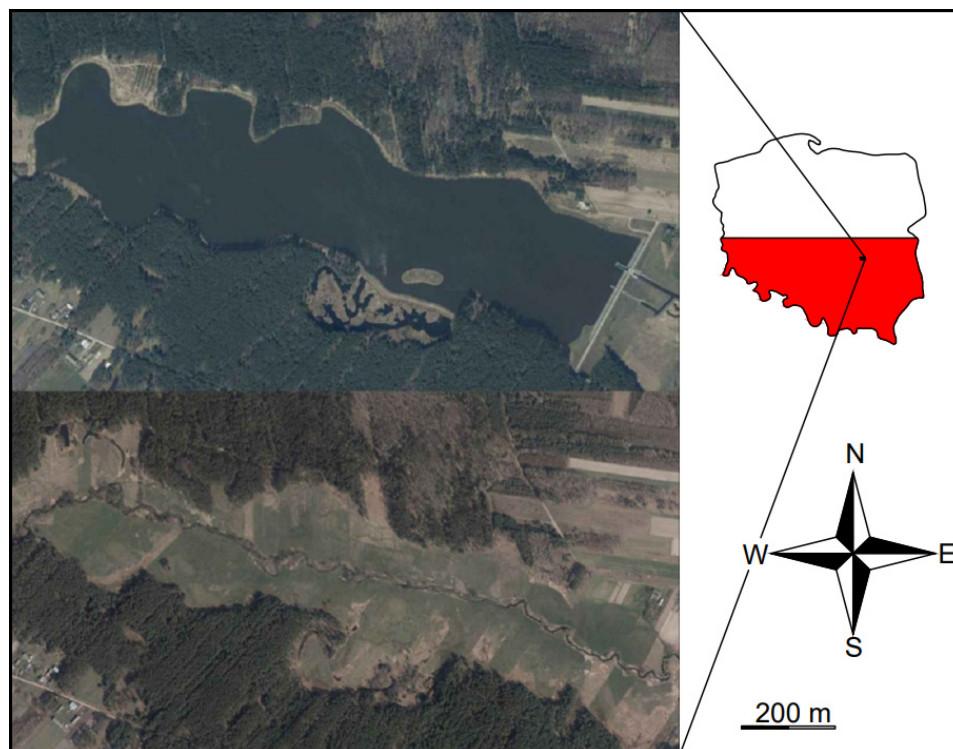


Figure 2. Site of Jagodno Reservoir after and before construction [23].

2.2. Sarny Reservoir

In an effort to increase flood safety in the Nysa Klodzka River valley in southwestern Poland, the State Water Company “Wody Polskie” has taken steps to build dam reservoirs directly on the river or on its tributaries. In connection with these activities, the creation of Sarny Reservoir near the mouth of the Włodzica River was also considered, but it ultimately did not happen despite a location potentially well suited for such a facility. The Włodzica River is 54.51 km long and has a catchment area of 105.41 km². It has a foothill characteristic,

which is associated with higher gradients and water velocity. For the preliminary concept of the reservoir, a $Q_{1\%}$ of $78 \text{ m}^3/\text{s}$ has been calculated. The reservoir would occupy an area of 44 hectares capable of storing 2.3 million m^3 of water. Currently, this area mainly consists of unused agricultural meadows locally covered with trees, especially in the immediate vicinity of the river. In addition, there are few residential buildings on the site. The area is shown in Figure 3.

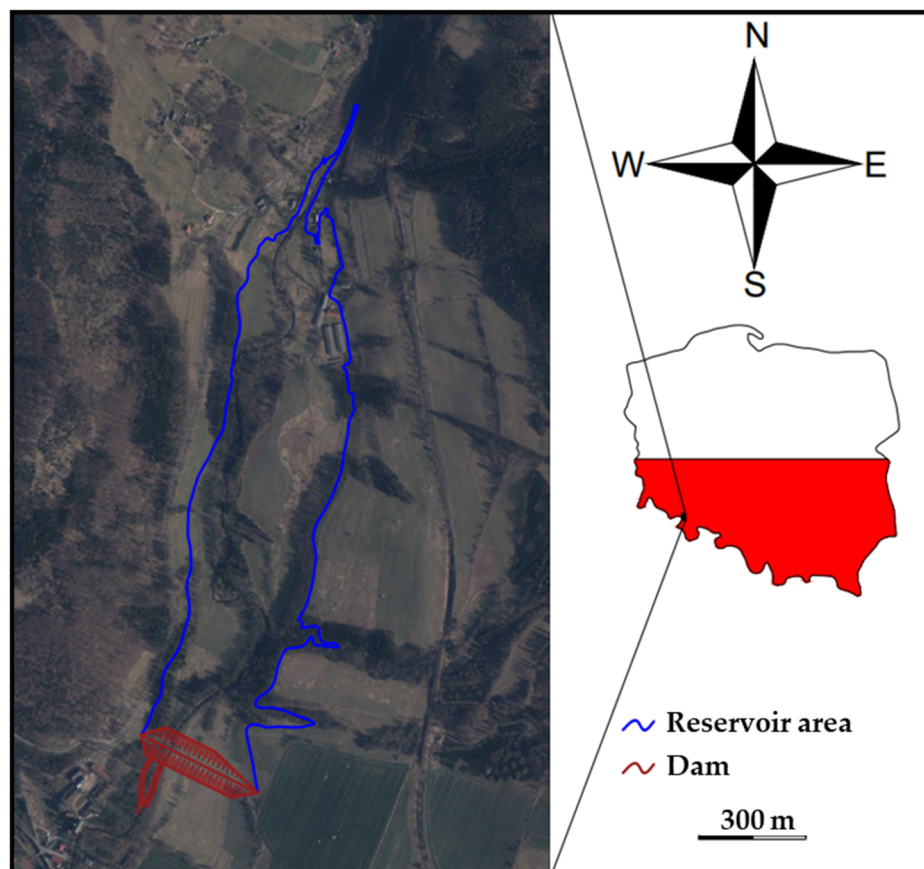


Figure 3. Area of potential Sany Reservoir.

To illustrate the similarities and differences between the analyzed reservoirs, Table 1 summarizes the various parameters that define the characteristics of the object.

Table 1. Comparison of parameters of Jagodno and Sarny Reservoirs.

Parameter	Jagodno	Sarny
Length of the supply watercourse	117.6 km	54.51 km
Catchment area	265.62 km^2	105.41 km^2
Most frequent flow	0.292 m^3/s	n.a.
Flow rate $Q_{1\%}$	51 m^3/s	78 m^3/s
Reservoir area	45 ha	44 ha
Reservoir capacity	0.5 million m^3	2.3 million m^3

2.3. Avifauna, Ichthyofauna, Flora

An assessment of the species composition of avifauna, ichthyofauna, and flora was carried out based on a review of available sources, publicized literature on the subject, dialogue with local stakeholders and environmental activists, and our own field research. In the case of avifauna, one of the relevant sources was the online database Ornitho.pl,

which has been operating to collect and share verified bird observations in Poland since 2015 [24]. Additional information on ichthyofauna was obtained from the Polish Angling Associations working in the region, as well as from data obtained during regulatory work on the Nysa Klodzka River and made available by the Provincial Inspectorate for Environmental Protection (“WIOŚ”), the latter of which are the results of field studies based on electrofishing carried out by wading upstream across the entire width of the river [25]. For Jagodno Reservoir, the results obtained were compared with the inventory results from the stage of creating the EIA.

Field surveys of avifauna and flora for Jagodno Reservoir were conducted over six days, on the dates 28–30 July 2023, 26 November 2023, 3 March 2024, and 1 April 2024. The same surveys were conducted for the Sarny potential reservoir site over six days, on the dates 22–23 July 2023, 27 August 2023, 25 November 2023, 2 March 2024, and 24 March 2024.

Observations of avifauna were made using binoculars and a camera. A similar pattern was adopted for most of the days on which the surveys were conducted, i.e., starting observations from the early morning hours just after sunrise and continuing them over the entire area (around the reservoir or in its potential canopy) for 4 to 6 h. The focus was primarily on assessing whether the observed species exhibit behaviors that may indicate that they are breeding in the area. To identify these behaviors, they relied on the literature’s distinguishing criteria to determine the likelihood of nesting, such as singing, mating flights, or tooting [26].

During the flora inventory, species found in the study areas were identified, particularly in the presence of protected or invasive plants. The occurrence of natural habitats listed in Council Directive 92/43/EEC of 21 May 1992, on the conservation of natural habitats and wild fauna and flora, the so-called Habitats Directive, was also recognized [27].

2.4. Water Quality

In order to identify the water quality status of the studied watercourses, water samples were collected and tested at the Environmental Research Laboratory of the Wrocław University of Life Sciences by determining nine hydrochemical indicators: total nitrogen (N), Kjeldahl nitrogen (N-Kje.), ammonium nitrogen (NH_4), nitrite nitrogen (NO_2), nitrate nitrogen (NO_3), phosphates (PO_4), total phosphorus (P), dissolved oxygen (DO), and biochemical oxygen demand (BOD_5).

In the case of the Włodzica River, water samples were taken on three dates, i.e., 22 July 2023, 25 November 2023, and 2 March 2024. One location was selected—in the cross-section of the potential dam of Sarny Reservoir. Water samples were taken on three dates for the Wiązownica River, similar to those on the Włodzica River, i.e., on 30 July 2023, 26 November 2023, and 3 March 2024. Two locations were chosen—immediately below and above Jagodno Reservoir. In addition, an approximate trophic state was determined for this reservoir based on the method of Vollenweider and Kajak, which determines the risk of eutrophication based on the average loads of total nitrogen and total phosphorus and the size of the reservoir [28,29]. This method allows you to determine the parameter that defines the water quality in the reservoir in the range from oligotrophic to eutrophic.

2.5. Social Impact

To illustrate the local community’s attitude towards the planned construction of Sarny Reservoir, the events that took place during the information and public consultation activities at the conceptual and design stages were analyzed. Also taken into account were the survey results described in the publication [30], where the respondents were residents of villages immediately adjacent to the area where the reservoir construction was considered. Consideration was given to the possible negative impact on cultural heritage resulting from the assumption that the reservoir is adjacent to the site of the historic castle and park complex.

In the case of Jagodno Reservoir, a short survey including one question was conducted to find out the position of the local community on its operation: “How do you assess

the impact of Jagodno Reservoir on the development of the region?”. The question was addressed to 26 incumbent Village Chiefs in the region, i.e., representatives of twenty-five villages in the immediate vicinity of the reservoir. In addition, information and articles published on the Internet (including on social media) about Jagodno Reservoir were reviewed to identify particular sentiments about the facility.

3. Results and Discussion

3.1. Avifauna

3.1.1. Results

Table 2 summarizes the bird species observed in the Jagodno Reservoir area during the field survey, distinguishing their occurrence status and comparing them with the Ornitho.pl database for 1 km² (where the analyzed site is located).

Table 2. Avifauna of Jagodno Reservoir.

Field Observations		Ornitho.pl Database [24]	
Species	Occurrence Status	Has It Been Observed (Since 2015)	Nesting Status
White stork (<i>Ciconia ciconia</i>)	WL	Yes	C
Sand martin (<i>Riparia riparia</i>)	WL	Yes	B
Eurasian teal (<i>Anas crecca</i>)	WP	Yes	B
Great egret (<i>Ardea alba</i>)	WL	Yes	B
Grey Heron (<i>Ardea cinerea</i>)	WL	Yes	B
Common redpoll (<i>Acanthis flammea</i>)	P	No	-
Barn swallow (<i>Hirundo rustica</i>)	WL	Yes	B
Common moorhen (<i>Gallinula chloropus</i>)	L	Yes	C
Mallard (<i>Anas platyrhynchos</i>)	L	Yes	C
Mute swan (<i>Cygnus olor</i>)	L	Yes	C
Caspian gull (<i>Larus cachinnans</i>)	WP	Yes	A
Common merganser (<i>Mergus merganser</i>)	WL	Yes	B
Western house martin (<i>Delichon urbicum</i>)	WL	Yes	C
Little grebe (<i>Tachybaptus ruficollis</i>)	L	Yes	B
White wagtail (<i>Motacilla alba</i>)	WL	Yes	C
Corn bunting (<i>Emberiza calandra</i>)	WP	Yes	A
Eurasian jay (<i>Garrulus glandarius</i>)	WL	Yes	A
Reed warbler (<i>Acrocephalus scirpaceus</i>)	WL	Yes	B
Carrion crow (<i>Corvus corone</i>)	WL	Yes	C
Crane (<i>Grus grus</i>)	WL	Yes	B

Note(s): L—breeding, WL—occurring during the breeding season, P—during the non-breeding season, not using the land, WP—in the non-breeding season, using the area (feeding ground, concentration site), A—nesting possible, B—nesting likely, C—nesting certain.

It should be noted that the 20 species identified during the field survey do not exhaust the list of all birds visiting the Jagodno Reservoir site. Several individuals were observed, the species of which could not be accurately determined and were therefore not included in Table 2. It should also be pointed out that the Ornitho.pl database distinguishes for the study area 52 species with Nesting Status A, 54 with Status B, and 16 with Status C, making a total of 122 species. In the Environmental Impact Assessment, a wildlife inventory was carried out in 2012 and 2013, indicating the identification of 60 bird species in Jagodno Reservoir planned for construction. In the vast majority, single individuals representing small avifauna were observed. Among these species, some identified during

current field surveys are absent, i.e., sand martin, teal, great egret, moorhen, mallard, mute swan, Caspian gull, merganser, grebe, and reed warbler. Eight of the listed species are waterbirds, and some nesting was found for four of them. Thus, we can assume that the creation of Jagodno Reservoir is favorable for breeding these species. Of other observations, it should be pointed out that during the inventory for the EIA, dozens of representatives of the lapwing species were identified, which were not found during the current field surveys.

Table 3 summarizes the bird species observed during the field survey in the area considered Sarny Reservoir, distinguishing their occurrence status, as well as comparing them with the Ornitho.pl database for 1 km² (where the analyzed site is located).

Table 3. Avifauna of the area of the considered Sarny Reservoir.

Field Observations		Ornitho.pl Database	
Species	Occurrence Status	Has It Been Observed (Since 2015)	Nesting Status
Great tit (<i>Parus major</i>)	WL, WP	Yes	C
Great spotted woodpecker (<i>Dendrocopos major</i>)	WL	Yes	C
Eurasian bullfinch (<i>Pyrrhula pyrrhula</i>)	WL	Yes	B
Common wood pigeon (<i>Columba palumbus</i>)	WL	Yes	C
Mallard (<i>Anas platyrhynchos</i>)	WL	No	-
Black redstart (<i>Phoenicurus ochruros</i>)	WL	Yes	C
Common blackbird (<i>Turdus merula</i>)	WL	Yes	C
Eurasian tree sparrow (<i>Passer montanus</i>)	WL, WP	Yes	A
Spotted flycatcher (<i>Muscicapa striata</i>)	WL	Yes	C
Western house martin (<i>Delichon urbicum</i>)	WL	Yes	C
Grey wagtail (<i>Motacilla cinerea</i>)	WL	Yes	B
Common chiffchaff (<i>Phylloscopus collybita</i>)	WL	Yes	B
Common redstart (<i>Phoenicurus phoenicurus</i>)	WL	Yes	C
Eurasian wren (<i>Troglodytes troglodytes</i>)	WL	Yes	B
Sparrow (<i>Passer domesticus</i>)	WL, WP	Yes	B
Eurasian chaffinch (<i>Fringilla coelebs</i>)	WL	Yes	C

Note(s): L—breeding, WL—occurring during the breeding season, P—during the non-breeding season, not using the land, WP—in the non-breeding season, using the area (feeding ground, concentration site), A—nesting possible, B—nesting likely, C—nesting certain.

Again, the 16 identified species do not exhaust the list of all birds visiting the area of Sarny Reservoir under consideration, and several individuals were observed whose species could not be precisely determined and, therefore, were not included in Table 3. The Ornitho.pl database distinguishes for the study area 30 species with Nesting Status A, 29 with Status B, and 26 with Status C, making a total of 85 species. While it has not been possible to state conclusively that the identified species are breeding directly in the studied location—the information posted in the Ornitho.pl database suggests a significant probability of this happening. Despite the presence of the river, apart from the mallard duck, no representatives of other aquatic or wetland species were observed. However, this does not entirely rule out their presence or breeding in the area. It may also be indicated by dialogue with residents and people familiar with the area, suggesting that the corncrake and black stork, among others, are present. This circumstance, however, would need to be confirmed or ruled out with more thorough research.

3.1.2. Discussion

Previous studies of the avifauna of reservoirs indicate that they can provide important breeding and wintering sites and feeding and resting places during migration. They

can also significantly increase species diversity, especially in areas where other bodies of water are lacking [19,31,32]. Since Jagodno Reservoir was built in proximity to Domaniów Reservoir, which has been in operation since 2001 (with an area of about 500 ha), it was to be expected that the species composition of the two facilities would become similar over time, especially in terms of the presence of wetland birds. Observations of the occurrence of the latter on Domaniów Reservoir are described in the publication [33], where it is indicated that 87 wetland species were found on the reservoir in the first ten years after its establishment. Although Jagodno Reservoir has been in operation for similar years, the area is not home to (and does not breed) as many of these birds. This is most likely influenced by the much smaller lagoon zone and the shorter and fortified shoreline, as well as people's intensive use of the reservoir, particularly for fishing. Also debatable is the role of the "bird island," which would provide a suitable habitat for wetland birds if it were covered with sand [19]—but it is currently densely covered with vegetation, as shown in Figure 4.



Figure 4. Photograph of densely vegetation-covered bird island on Jagodno Reservoir (28 July 2023).

Regardless of the above, a few breeding species have enriched the number of identified wetland birds in the Jagodno Reservoir area. Surveys have indicated the potential abandonment of a large group of lapwings in the area. These birds like uncovered, flat terrain, undoubtedly the grasslands currently in the flood zone [34]. After their disappearance, and due to the proximity of the reservoir's banks to the forest, it should be considered that lapwings have stopped visiting the area and most likely do not breed there, which was also the case after the Domaniów reservoir was built at that location [33].

Beginning construction of Sarny Reservoir would involve significant interference with the observed birds' existing habitat and their potential breeding habitat. The investment would be accompanied by heavy transports, intensified earthworks, and, most importantly, tree felling and eventually filling the reservoir's bowl with water. To minimize adverse impacts on avifauna, it would be necessary to start work outside the breeding season (so that birds looking for a place to nest would find construction already underway and choose another location), outside which tree cutting should also be implemented [35]. During the construction phase, adequate ornithological supervision should be ensured by agreeing with them on the details of the implementation of the various elements of the project and being in dialogue with them regarding an appropriate number of nesting platforms and nesting boxes that should be hung in the area, as well as the number and type depending on the species composition of local nesting birds. Such stalls should be cleaned and maintained regularly. In addition, appropriate technological solutions should also be adopted to make the existing reservoir an attractive and safe habitat and breeding ground for avifauna.

It should be noted here that studies and observations conducted on other reservoirs indicate that bird islands are infrastructures readily used by various bird species, especially plovers [36]. However, when constructing these facilities, it is crucial to adopt a sandy-gravel surface and engineering solutions that limit its overgrowth with vegetation [36]. If hydrometeorological conditions allow it, during the non-breeding season, it would be advisable to raise the level of damming in the reservoir so that the island is completely covered with water for a while, which would further help reduce its overgrowth. Therefore, the island should be only slightly elevated at normal damming levels, but fluctuations in water levels during the breeding season should be limited as much as possible.

No larger bodies of water operate near Sarny Reservoir under consideration. In a characterization of the breeding avifauna of the Bystrzyckie Mountains [37] (a region south of the study area), out of 116 species, only five preferred an aquatic environment. The facility closest to the site of Sarny Reservoir under consideration (at a distance of about 45 km) is the cascade of reservoirs on the Nysa Kłodzka River. These reservoirs have been in operation for a long time, and the oldest (Otmuchów) began to be used in 1933. The avifauna of these reservoirs were frequently monitored during this period, the results of which are available in numerous publications [31]. Based on them, it was noted that after the construction of the reservoirs, the population of many wetland bird species increased significantly, such as the great crested grebe, gray heron, white stork, merganser, spotted crake, crane, mute swan, black-headed gull, Caspian gull, yellow-legged gull, common tern and little tern, among others [31]. It can be expected that if Sarny Reservoir were to be built, these and related species would find a favorable habitat in the area. An interesting observation was also made in the area of the Szalejów Górny dry flood control reservoir, which was put into operation at the end of 2023 and is located only 15 km from the site of the potential Sarny Reservoir. The facility is equipped with a debris catcher, i.e., an additional pit to catch material dragged by the river during higher water levels. Through the unintentional steady flow of water into the debris catcher, it has become a place frequented by large groups of waterbirds (especially seagulls), which previously did not have such a convenient habitat in the area. It should be noted that the operation of this facility, as permanently filled with water, was not provided for in the EIA of the Szalejów Górny reservoir. If a constant inflow of water is left in its bowl, creating a potential breeding habitat for birds and other animal communities, the operating instructions for cleaning the catcher of carried debris would also need to consider environmental aspects, such as the possible timing of this action.

Field surveys carried out in the area of the Sarny Reservoir under consideration did not reveal the presence of species that (assuming the relevant guidelines are followed during the construction phase) could be directly affected by the creation of a permanent flood zone. However, precise identification of which species are breeding in the analyzed areas would require observations on a much larger scale and with greater frequency. This is also a significant conclusion from the point of view of the assumptions for the studies conducted for the EIA. It also goes without saying that when making assumptions about species composition, one should not rely only on field observations but also refer to available literature, surveys completed in nearby areas, or valuable databases created by passionate ornithologists and birdwatchers.

3.2. *Ichthyofauna*

3.2.1. Results

Table 4 lists the fish species for which information about their existence in Jagodno Reservoir was received from the Polish Anglers Association and people participating in angling competitions held at the reservoir on 29 July 2023. These data were juxtaposed with the results of surveys on 25 September 2020 provided by the Provincial Environmental Inspectorate for the location about 1 km below the dam.

Table 4. Fish of Jagodno Reservoir.

Obtained Information		WIOŚ Research	
Fish Species in Jagodno Reservoir	Was It Observed below the Reservoir (25 September 2020)	Population	
Carp (<i>Cyprinus carpio</i>)	No	-	
Tench (<i>Tinca tinca</i>)	Yes	1	
Crucian carp (<i>Carassius carassius</i>)	Yes	1	
Bream (<i>Abramis brama</i>)	No	-	
White bream (<i>Abramis bjoerkna</i>)	Yes	40	
Rudd (<i>Scardinius erythrophthalmus</i>)	No	-	
Roach (<i>Rutilus rutilus</i>)	Yes	145	
Stickleback (<i>Gasterosteus aculeatus</i>)	No	-	
Ruffe (<i>Gymnocephalus cernua</i>)	No	-	
Perch (<i>Perca fluviatilis</i>)	Yes	35	
Zander (<i>Sander lucioperca</i>)	No	-	
Pike (<i>Esox lucius</i>)	Yes	2	
Catfish (<i>Silurus glanis</i>)	No	-	
Asp (<i>Leuciscus aspius</i>)	No	-	
Chub (<i>Leuciscus cephalus</i>)	Yes	9	
Ide (<i>Leuciscus idus</i>)	Yes	2	
Dace (<i>Leuciscus leuciscus</i>)	Yes	16	
Vimba bream (<i>Vimba vimba</i>)	No	-	
Nase (<i>Chondrostoma nasus</i>)	No	-	
Eel (<i>Anguilla anguilla</i>)	No	-	
Gudgeon (<i>Gobio gobio</i>)	Yes	5	
Burbot (<i>Lota lota</i>)	No	-	
Spined loach (<i>Cobitis taenia</i>)	Yes	15	
Stone loach (<i>Barbatula barbatula</i>)	Yes	1	

It should be noted that the number of fish living in Jagodno Reservoir is relatively large. There are no precise data on the density of individual species. However, from information obtained from local anglers, it can be indicated that carp, roach, pike, tench, perch, and zander are the most abundant. The results can also be compared with the WIOŚ survey conducted in 2011 in Przytyk on the Radomka River, i.e., about 2 km from the mouth of the Wiązownica River. At the time, only five species were identified—pike, stickleback, ide, perch, and roach. In the Environmental Assessment, based on surveys from the first decade of the 19th century, the projected composition of the ichthyofauna of the Wiązownica River was represented by nine species—ide, spined loach, burbot, perch, roach, sunbleak, pike, stone loach, and bleak. On this basis, it should be concluded that in the waters of the Wiązownica River, up to the dam section of Jagodno Reservoir, 2 species of fish (sunbleak and bleak, not covered by species protection) may have disappeared, while 17 have arrived.

Table 5 lists the fish species for which information about their existence in the Włodzica River was obtained from the available literature and in dialogue with the regional Polish Angling Association. A distinction was made between locations near Sarny Reservoir under consideration and above the town of Nowa Ruda (about 5 km from the mouth of the Ścinawka River). These data were juxtaposed with the results of surveys on 22 September 2017, 3 October 2020, and 10 October 2023 provided by the Provincial Environmental

Inspectorate for the location near the mouth of the Ścinawka River, i.e., in the immediate vicinity of the site where Sarny Reservoir dam could potentially be built.

Table 5. Fish of the Włodzica River.

Obtained Information [38–40]		WIOŚ Research—Species Count [25]		
Fish Species in the Włodzica River	22 September 2017	3 October 2020	10 October 2023	
Brook trout (<i>Salvelinus fontinalis</i>) *	-	-	-	
River trout (<i>Salmo trutta m. fario</i>)	78	93	30	
Grayling (<i>Thymallus thymallus</i>)	11	16	13	
Minnow (<i>Phoxinus phoxinus</i>)	12	31	521	
Pike (<i>Esox lucius</i>) *	-	-	-	
Gudgeon (<i>Gobio gobio</i>)	-	-	3	
Stone loach (<i>Barbatula barbatula</i>)	6	18	8	
-	-	-	European bullhead (<i>Cottus gobio</i>) 5	

Note(s): * Species identified above the city of Nowa Ruda.

The results indicate that over the years, the quantitative composition of species undergoes some uncontrolled changes. In 2023, there was a significant increase in the minnow population while the number of brook trout declined. An interesting circumstance is the appearance of representatives of the whitetiphead, a protected species in Poland, as is the herring, which has been in the region for years. The species in the Włodzica River above the town of Nowa Ruda (brook trout and pike) have not been identified near the mouth of the Ścinawka River. The regulatory development of the river may influence this. Still, since the information on their occurrence is based on data from the 1970s [39], confirming or excluding their current presence in the region would be necessary.

3.2.2. Discussion

Reservoirs significantly affect the local (and sometimes supra-local) ichthyofauna population. Creating a permanent inundation zone interferes with the riverine specificity of the ecosystem, resulting in a change in the density of individual species, depending on their preferences in this area [7,8]. In the reservoirs, the structure of the ichthyofauna is being rebuilt from rheophilic to stagnophilic, i.e., the population of such fish as roach and pike is growing. In contrast, reservoirs are not places where, for example, river trout, which live in cold and fast-flowing rivers, would do well. However, the presence of Sarny Reservoir would allow for greater stocking opportunities in the region and more effective control of population size. Although the construction of Jagodno Reservoir ultimately led to a significant increase in the number of fish species in the region and made the facility the center of local fishing—stocking, however, should be a balanced and well-considered action so as not to be guided only by the desire to work for the benefit of angling tourism, but above all to strive for the restoration of native ichthyofauna while not allowing the appearance of invasive species. In the case of Sarny Reservoir, stocking with carp family species would not be permitted. The appearance of carp in Jagodno Reservoir may also seem controversial. At the same time, before the construction of this facility, they were not found in the waters of the Wiąznicza and Radomka rivers. The carp's feeding method (benthos) causes silting of the reservoir water, which accelerates the rate of eutrophication and negatively affects other fish species [41].

When building Sarny Reservoir, to minimize negative impacts on ichthyofauna, it would be necessary to take such measures as carrying out work in the Włodzica riverbed only outside the fish spawning period, i.e., excluding the period from the beginning of March to the end of June and from the beginning of September to mid-December, with

the potential exclusion also of the period from December to March—in the case of such a decision of ichthyological supervision, which should operate throughout the construction period. With the help of this supervision, regular inspections of the state of ichthyofauna in the area of the ongoing project (especially before the start of the works) should be carried out, combined with the removal of invasive species and the trapping of rare species and their transport to a location that does not threaten their safety. In the case of the Włodzica River, the latter would apply to the slipper and whitetiphead, but also potentially to other protected species. During the river regulation carried out in 2023/2024 on the Nysa Klodzka River (the catchment area to which the Włodzica River belongs), in addition to the species listed in Table 5, chub (*Squalius cephalus*), barbel (*Barbus barbus*), perch (*Perca fluviatilis*), stickleback (*Gasterosteus aculeatus*), brook lamprey (*Lampetra planeri*), and alpine bullhead (*Cottus poecilopus*). The latter two are subject to species protection. In addition, the region is implementing a plan to restore the morphological continuity of rivers to restore the possibility of migratory species in them, including Atlantic salmon (*Salmo salar*), which was still found in the Nysa Klodzka River in the first half of the 20th century [38].

All these data (planned stocking, as well as current and projected species composition) should be considered when adopting technological assumptions for implementing Sarny Reservoir. An essential element of the dam's design would be a fish ladder, ensuring ecological continuity between the reservoir bowl and the watercourse below the dam body. However, it should be emphasized that the fish ladder does not entirely compensate for the loss of fish migration opportunities compared to an undeveloped river [42,43]. The type, size, and shape of the fish ladder and, above all, its prevailing hydraulic conditions should be strictly delineated based on assumptions about what fish will use the ladder [44–46]. In the case of Jagodno Reservoir, a divided fish ladder was used, with water depths of about 1 m and velocities between 2.0 and 4.0 m/s. The design of the fish ladder and its location in relation to the bottom outlet is shown in Figure 5.

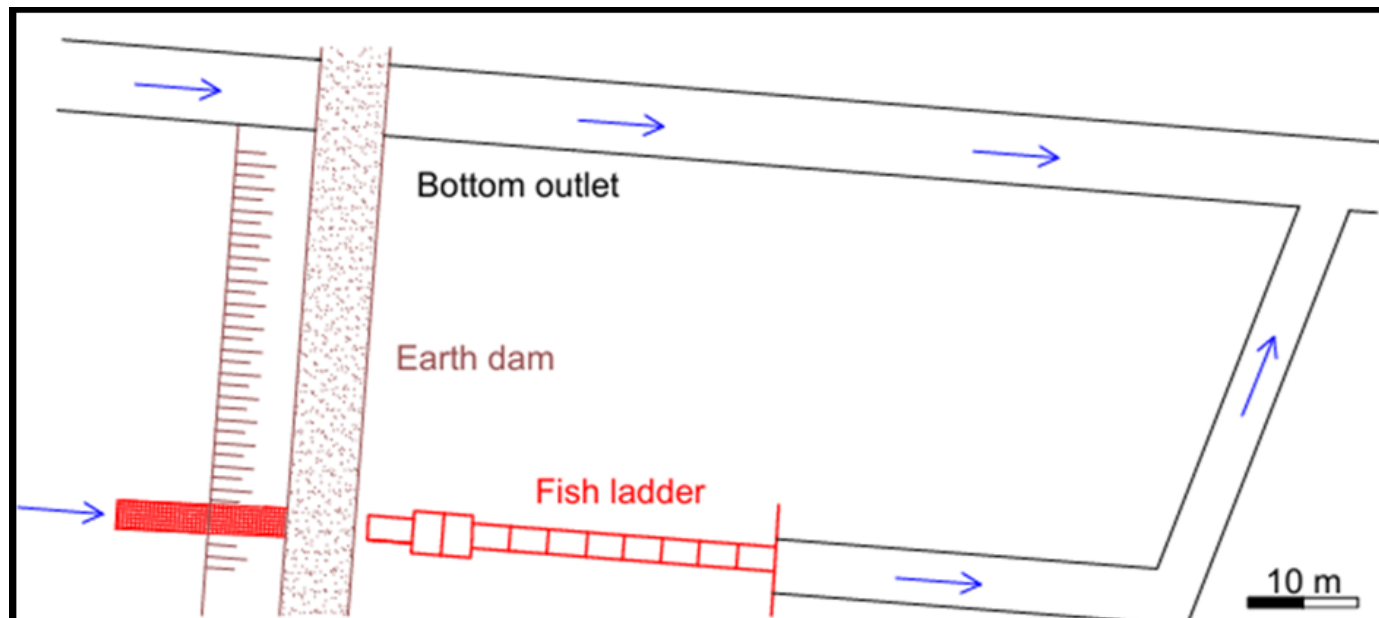


Figure 5. Top view of the fish ladder and bottom discharge of Jagodno Reservoir.

Since only 12 fish species were identified in the WIOŚ survey conducted below the dam cross-section of Jagodno Reservoir (compared to 24 residing in the reservoir), it can be assumed that some species do not use the fish ladder or do so to a limited extent. Given the high density of carp, roach, pike, tench, perch, and zander in the reservoir canopy, an interesting circumstance is the complete lack of identification of carp and zander near the mouth of the Radomka River and only single species of tench and pike. This can be influenced, among other things, by unfavorable hydraulic conditions resulting from poor

selection of the structural parameters of the fish ladder (the use of a simple linear chamber-type structure), as well as fragments of floating debris (primarily tree branches) based on the inlet to the fish ladder, which were diagnosed during the field survey and are a common problem of fish ladders, directly affecting the flow parameters of the device [47–49]. In addition, the water velocity in the fish ladder exceeds the maximum value of 2 m/s, as specified in the literature and in the guidelines in operation [50,51]. Expanded research in this area would be needed to get a complete picture of how the fish ladder is functioning concerning individual species, including greater frequency of measurements and direct monitoring of the facility’s chambers. To assess the migration potential of a fish ladder, a methodology based on comparing the maximum velocity occurring in the gap with the “burst speed” of individual fish species may be helpful [49].

3.3. Flora

3.3.1. Results

Table 6 lists the plant species that were identified during field surveys conducted at Jagodno Reservoir. These data were compared with species observed in 2012 and 2013 for the creation of the EIA [22].

Table 6. Flora of Jagodno Reservoir.

Observations during Field Research	EIA Compliance—Studies of August 2012, June 2013, July 2013
Vegetation at Jagodno Reservoir	
Ash-leaf maple (<i>Acer negundo</i>)	A
Black alder (<i>Alnus glutinosa</i>)	A
<i>Arabidopsis halleri</i>	B
Three-lobed beggarticks (<i>Bidens tripartita</i>)	B
Hedge bindweed (<i>Calystegia sepium</i>)	A
Maiden pink (<i>Dianthus deltoides</i>)	B
Hemp-agrimony (<i>Eupatorium cannabinum</i>)	A
Alder buckthorn (<i>Frangula alnus</i>)	B
Woodland geranium (<i>Geranium sylvaticum</i>)	B
Blue bonnets (<i>Jasione montana</i>)	B
Common flax (<i>Linaria vulgaris</i>)	B
Alfalfa (<i>Medicago sativa</i>)	B
Water mint (<i>Mentha aquatica</i>)	B
Bird cherry (<i>Prunus padus</i>)	B
Meadow fleabane (<i>Pentanema britannica</i>)	B
Common reed (<i>Phragmites australis</i>)	B
<i>Pimpinella</i>	A
Bird cherry (<i>Prunus padus</i>)	A
Oak (<i>Quercus</i>)	B
St. Anthony’s turnip (<i>Ranunculus bulbosus</i>)	A
Blackberry (<i>Rubus</i>)	B
Patience dock (<i>Rumex patientia</i>)	B
White willow (<i>Salix alba</i>)	A
Red elderberry (<i>Sambucus racemosa</i>)	B
White campion (<i>Silene latifolia</i>)	B
Canadian goldenrod (<i>Solidago canadensis</i>)	B
Rowan (<i>Sorbus aucuparia</i>)	B
Common hedgenettle (<i>Stachys officinalis</i>)	B
Red clover (<i>Trifolium pratense</i>)	A
Reedmace (<i>Typha</i>)	B
Common bladderwort (<i>Utricularia vulgaris</i>)	A
Great mullein (<i>Verbascum thapsus</i>)	B
Field pansy (<i>Viola arvensis</i>)	B

Note(s): A—identified in field studies and EIA, B—identified only in field studies.

Of the 33 plant species identified in the immediate vicinity of Jagodno Reservoir, 10 duplicated those observed in 2012–2013, i.e., before the facility’s construction. Of these ten, four are tree or shrub species. This group does not include oak trees, the young specimens of which are now growing in large numbers near the reservoir’s banks. Trees found in the study area before and after the construction of the reservoir include the ash-leaf maple, a species classified as an invasive plant in Poland [52]. Canadian goldenrod [52], which was not found in the area before the construction of the reservoir, also falls into the same category. Since it is along the bank of the Wiązownica River where willow riparian forests (Habitat Directive habitat code 91E0-1 [27]) extend locally, their degradation along the entire length of the floodplain has resulted in the loss of these habitats and a decline in white willow, which, however, still occurs near the reservoir. Most of the plant species observed that were not identified in the EIA were small angiosperms, typical throughout Poland, as were plants identified in the EIA but not identified during field surveys (17 species).

Table 7 lists the plant species identified during field surveys conducted at the potential Sarny Reservoir site.

Table 7. Flora of the Sarny potential reservoir area.

Observations during Field Research	
Vegetation in the Area of the Considered Sarny Reservoir	Comment
Ground-ivy (<i>Glechoma hederacea</i>)	Small clusters in the grasslands
Ground-ivy (<i>Betula pendula</i>)	Single specimens in the northern part of the reservoir.
Siberian squill (<i>Scilla siberica</i>)	Single specimens in the grasslands
Common yew (<i>Taxus baccata</i>)	Single specimen in the southern part of the reservoir
Black elderberry (<i>Sambucus nigra</i>)	Frequent occurrence in the southern part of the reservoir and park near the dam
Bird cherry (<i>Prunus padus</i>)	Frequent occurrence throughout the reservoir, especially along the river
Sessile oak (<i>Quercus petraea</i>)	Frequent occurrence along the river and in the northern and eastern parts of the reservoir
Pedunculate oak (<i>Quercus robur</i>)	Single specimens, including 9 classified as natural monuments (in the park near the dam)
Hawthorn (<i>Crataegus</i>)	Single specimens in the northern part of the reservoir
Common maple (<i>Acer platanoides</i>)	Single specimens throughout the reservoir, with higher density in the northern and eastern parts.
Butterbur (<i>Petasites hybridus</i>)	Single specimens in the grasslands
Hazel (<i>Corylus</i>)	Single specimens throughout the reservoir, more frequent in the southern part.
Lungwort (<i>Pulmonaria</i>)	Single specimens in the grasslands
Jonquil (<i>Narcissus jonquilla</i>)	Frequent occurrence in the park near the dam
Black alder (<i>Alnus glutinosa</i>)	Single specimens in different parts of the tank
Common nettle (<i>Urtica dioica</i>)	Frequent occurrence in the grasslands
Gooseberry (<i>Ribes uva-crispa</i>)	Small clusters in the grasslands
Black currant (<i>Ribes nigrum</i>)	Single specimens in the southern part of the reservoir
Cleavers (<i>Galium aparine</i>)	Small clusters in the grasslands
Rhododendron (<i>Rhododendron</i>)	Single specimens in the grasslands
Scots pine (<i>Pinus sylvestris</i>)	Single specimens in different parts of the tank
Broad-leaved dock (<i>Rumex obtusifolius</i>)	Frequent occurrence in the grasslands
Blackthorn plum (<i>Prunus spinosa</i>)	Single specimens in the northern part of the reservoir.
Spruce (<i>Picea</i>)	In the southern part, single specimens along the river, gradually higher density, frequent in the northern and western parts of the reservoir
Common reed (<i>Phragmites australis</i>)	A cluster of about 2.5 hectares in the northern part of the reservoir
White willow (<i>Salix alba</i>)	Frequent occurrences along the entire length of the river
Purple willow (<i>Salix purpurea</i>)	A small cluster in the northeastern part of the reservoir
Gray willow (<i>Salix cinerea</i>)	Single specimens in the northern part of the reservoir
Wood anemone (<i>Anemone nemorosa</i>)	Small clusters in the grasslands
Lesser celandine (<i>Ficaria verna</i>)	Frequent occurrence in the grasslands

The characterization of the Włodzica River as a Surface Water (under the Water Framework Directive 2000/60/EC) [53] indicates the occurrence of about 20% of the catchment area as a protected area, including the occurrence of habitats described in the Habitat Directive [27]: 6430 (montane and riparian tall grasses), 7140 (fens and moors), and 91E0 (willow, poplar, alder, and ash riparian forests). During the field survey, however, areas of only the latter habitat were identified, stretching along the Włodzica River and abounding in willow trees, cherry, spruce, and oak. Moreover, it was found that the meadows located in the canopy of the potential reservoir can be classified as poor habitat 6510 (extensively used meadows), and small areas in its northern and eastern part with a higher density of deciduous trees (especially oaks) can be habitat 9170 (Central European oak-hornbeam).

3.3.2. Discussion

Field surveys conducted in the area of Jagodno Reservoir and their comparison with the EIA showed that the species composition of the area's flora changed quite significantly after the establishment of the permanent flood zone. However, the disappearance of plants subject to strict species protection in Poland was not observed, as such plants were not present before the facility's construction. Otherwise, their preservation would be difficult or impossible to achieve and require obtaining the appropriate derogation permit for their removal. It should be pointed out that the creation of reservoirs may be associated with the loss of representatives of protected and endemic species. Still, in the case of smaller and medium-sized reservoirs, this should not involve the entire region's population, at worst, leaving relict habitats [5]. The construction of Jagodno Reservoir caused a local loss of 91E0-1 habitats (willow riparian forests). However, they still occur above the floodplain, near the banks of the River Wiązownica. Another interesting circumstance is the filling with water of the oxbow lakes area (to the south near the bird dump), which is cut off by a causeway from the main reservoir, which is well illustrated in Figure 2. The stagnant water there and the high density of terrestrial and aquatic plants (primarily native *Typhas* species) create a breeding habitat for various animal species not previously found in the region.

Another issue to be taken into account in the case of the establishment of reservoirs is the possibility of the appearance or more rapid expansion of invasive species in their area [52]. In the case of Jagodno Reservoir, two plant species considered invasive in Poland have been identified in the area, one of which (ash-leaf maple) was already present in large numbers before construction. However, during the project, no policy was made to reduce its population. Another invasive species currently found near Jagodno Reservoir is the Canadian goldenrod, a plant native to North America but quite common in Poland [52]. If large clusters of Canada goldenrod dominate other plants in the vicinity of Jagodno Reservoir—it would be advisable to consider measures to eradicate or reduce it, such as mowing and screening with other species, such as grasses [54].

The presence of invasive species has not been identified in the area of the potential Sarny Reservoir. However, the conduct of earthworks, humus heaping, excavation, and soil delivery for dam formation may promote their appearance. During the construction of the nearby (about 15 km) Szalejów Górny Dry Reservoir, there was a significant problem with the expansion of knotweed (*Reynoutria*), the uprooting, removal, and disposal of which proved to be a very costly activity for the investor. In the end, the decision was made to bury the removed knotweed at a depth of 6 m in the reservoir canopy. One would have to be prepared for such and similar actions in the case of the construction of Sarny Reservoir, in dialogue with the phytosociological supervision established for that time, until the invasive species are completely replaced by local vegetation, which of course does not apply to the reservoir canopy intended for flooding.

Aside from one representative of the common yew tree and nine pedunculate oaks with a trunk circumference at a height of 1.3 m exceeding 300 cm, which classifies them as natural monuments [55], no other species protected in Poland have been identified in the area of the potential Sarny Reservoir. The aforementioned specimens are found in the southern park, part of whose land in the original concept would have been used for the construction

of a dam with discharge facilities. Potentially, it would be possible to avoid excessive interference with the said park at the expense of reservoir capacity by moving the dam north of the assumed location. Even if such an action were possible given other assumptions about the reservoir's operation and its flood control capacity, in a significant part of the reservoir's bowl, the trees and shrubs present there, which are, among other things, part of the 91E0 and 9170 habitats, would have to be cut down and cleared. This would undeniably have a negative impact on the environment and would require measurable compensatory measures involving planting and reforestation in an area equal to or larger than that which is being degraded. It should be emphasized here that compensation in the form of planting young trees is not a comprehensive compensation for the destruction of habitats where valuable natural ecosystems have already been established or exploited by various fauna species. The most important measure to protect the environment is, therefore, to identify an area for the construction of the reservoir where the flood zone will not affect valuable habitats. Only in the absence of such a location, with a concomitant measurable socio-economic need and benefit, can sustainable interference with the habitats in question find its justification.

3.4. Water Quality

3.4.1. Results

Figures 6–8 show the results of hydrochemical tests conducted on samples taken from the inflow and outflow of Jagodno Reservoir on 30 July 2023, 26 November 2023, and 3 March 2024, respectively.

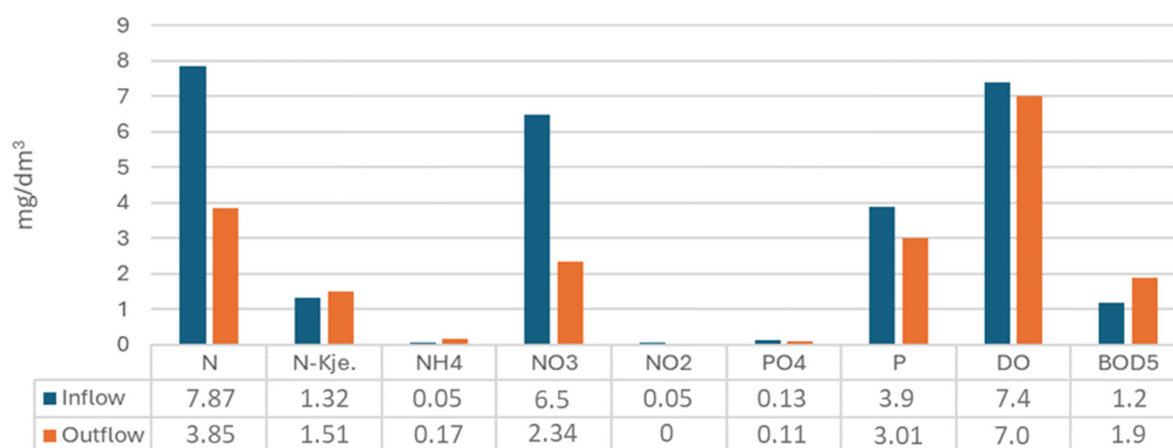


Figure 6. Results of water samples from 30 July 2023 taken at the inflow and outflow of Jagodno Reservoir.

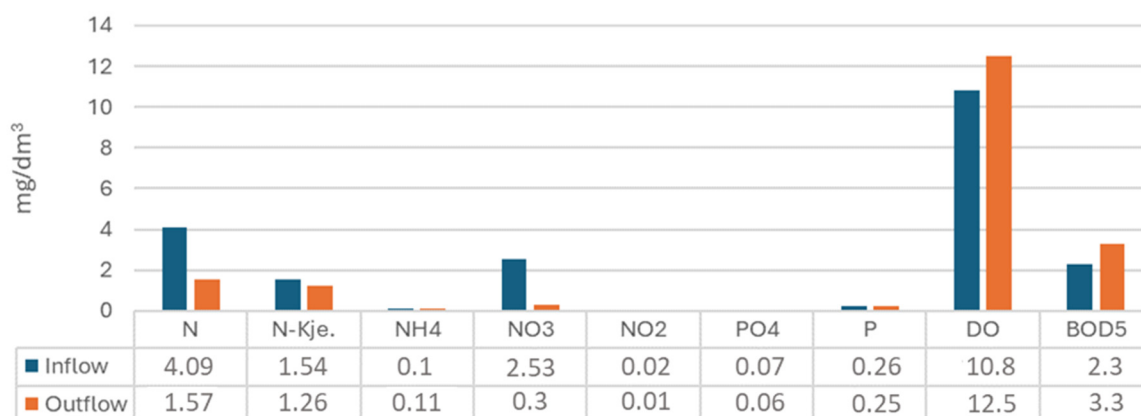


Figure 7. Results of water samples from 26 November 2023 taken at the inflow and outflow of Jagodno Reservoir.

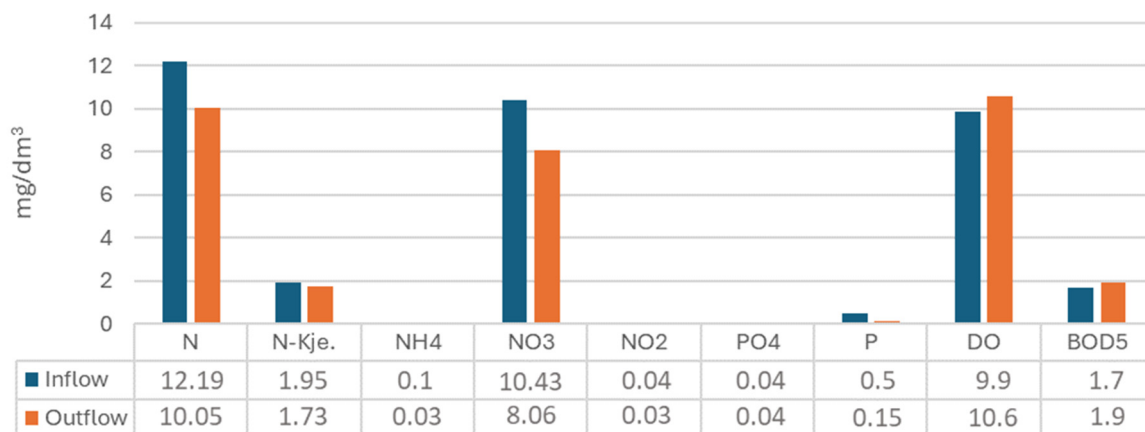


Figure 8. Results of water samples from 3 March 2024 taken at the inflow and outflow of Jagodno Reservoir.

Circumstances that can be observed for samples taken on all three dates include a significant decrease (at the outflow) in the amount of total nitrogen (by 43.4% on average) and nitrate nitrogen (by 58.2% on average) but also an increase in organic compounds, as can be inferred from the increase in BOD₅ (by 37.8% on average). In addition, on 30 July 2023 and 3 March 2024, there was a noticeable decrease in total phosphorus by 20.5% and 70%, respectively. The values of Kjeldahl nitrogen, ammonium nitrogen, nitrite nitrogen, and phosphate oscillated at similar levels or without a clear rule and clear deviations. Based on Vollenweider and Kajak's method [28,29], it was determined that the average load of total nitrogen and total phosphorus in the water flowing into the reservoir indicates the site is eutrophic.

Figure 9 shows the results of hydrochemical tests conducted on samples taken on 22 July 2023, 25 November 2023, and 2 March 2024 in the cross-section of the potential Sarny Reservoir dam.

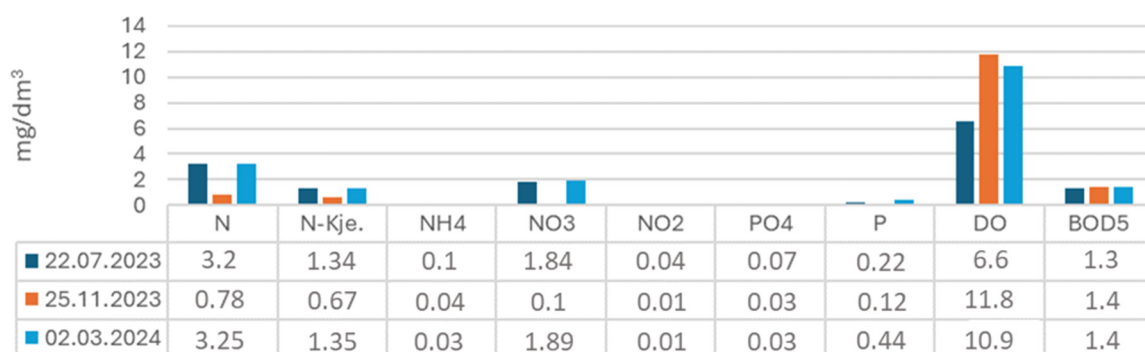


Figure 9. Results of water samples taken in the cross-section of the potential dam of Sarny Reservoir.

From the analyzed samples, significantly higher concentrations of total nitrogen, Kjeldahl nitrogen, and nitrate nitrogen can be seen for days 22 July 2023 and 2 March 2024. In addition, on 22 July 2023, relatively higher (than on the other days) values of ammonia nitrogen, nitrite nitrogen, and phosphate were also observed, while dissolved oxygen levels were underestimated. BOD₅ values were at the same level on each of the days studied.

3.4.2. Discussion

First of all, it should be emphasized that performing hydrochemical studies three times does not provide an indisputable basis for concluding the precise impact of the reservoir on the water quality of the watercourse. Such studies would have to be repeated many times, at different periods of the hydrological year, also taking into account the criterion of variability

of flow rate and catchment response to precipitation. Regardless, the obtained results of the conducted research are consistent with the results presented in available sources [56–59] and to some extent confirm the established theory about the impact of reservoirs on surface water hydrochemistry. Retention reservoirs are vulnerable to impacts resulting from the development of their catchment areas, particularly to inflows of water from watercourses contaminated as a result of their proximity to agricultural land or heavily urbanized areas, where, in addition, there may be illegal wastewater discharges [56–59]. Reservoirs accumulate nutrients in the flood zone, which may contribute to the seasonal occurrence of eutrophication in the zone. This should be considered unfavorable, especially if the reservoir is used as a tourist facility. The results of hydrochemical studies can be suggested to assess whether the reservoir waters at a given location will tend to eutrophication or what the impact of the existing facility is on the water quality of the river below the dam. In accordance with Poland's Regulation on the Classification of the Ecological Status of Surface Waters [60], concentrations of individual indicators have been determined, assigning watercourses to different water quality classes. Table 8 lists the values that correspond to assigning a river to a class of at least good.

Table 8. Values of indicators assigning the river to a class with good surface water quality [60].

N (mg/dm ³)	NH ₄ (mg/dm ³)	NO ₃ (mg/dm ³)	PO ₄ (mg/dm ³)	P (mg/dm ³)	DO (mg/dm ³)	BZT ₅ (mg/dm ³)
Lowland river (Wiązownica)						
<3.30	<0.40	<2.00	<0.09	<0.33	>7.6	<3.5
Sudeten Creek (Włodzica)						
<1.10	<0.20	<0.80	<0.04	<0.10	>9.1	<2.0

Based on the data summarized above, it should be concluded that the parameters characterizing the biogenic conditions indicate that the River Wiązownica does not classify as surface water of good quality. In July and August 2023, concentrations of total nitrogen and nitrate nitrogen reached or approached satisfactory levels at the reservoir outflow, indicating significant nutrient capture in the object's bowl. The same uptake was also observed in March 2024. However, regardless of this, total nitrogen and nitrate nitrogen concentrations at both measurement points were significantly overestimated. Thus, Jagodno Reservoir has a beneficial effect on the quality of water flowing from the River Wiązownica to its estuary located about 1 km below the dam. The site itself, due to its high nutrient influx and relatively shallow depth and capacity, is prone to the occurrence of eutrophication phenomena (as confirmed by calculations using the Vollenweider and Kajak method), but this was not observed during the field survey. This circumstance may, therefore, become apparent after the tank has been in operation for a long time.

The parameter values for defining a Sudeten stream (which is the Włodzica River) as surface water of good condition are much more stringent. Accordingly, concentrations of nutrients, particularly total nitrogen and nitrate nitrogen, were exceeded in July 2023 and March 2024. This phenomenon did not occur in November 2023, where only the total phosphorus load slightly exceeded the value included in the Ordinance [60]. In the case of a return to the concept of building Sarny Reservoir, hydrochemical studies would have to be carried out over a longer period of time and with greater frequency, in order to determine whether the actual interchangeability of water quality in the river does not necessitate the design of additional technical solutions such as a pre-reservoir [61]. However, based on the results of studies conducted on the inflow and outflow of Jagodno Reservoir and described in the available literature [56–59], it can be assumed that the creation of Sarny Reservoir would help reduce the movement of nutrient pollution downstream of the Włodzica River, including during the months when this inflow is increased. Comparing nutrient concentrations on similar dates at the tributary to Jagodno Reservoir and at the cross-section of the potential Jagodno Reservoir, they tend to be noticeably lower at the latter

location. This indicates that Sarny Reservoir would be less vulnerable to the phenomenon of eutrophication, which currently does not occur in Jagodno Reservoir anyway. In addition, Sarny Reservoir would have more than four times the volume and depth, which would further immunize the accumulated water against too dynamic changes in temperature that can result in, among other things, deterioration of fish habitat [11].

3.5. Social Impact

3.5.1. Results

Figure 10 illustrates the results of a survey of village heads in the municipality of Przytyk, where Jagodno Reservoir is also located.

How do you assess the impact of the Jagodno reservoir on the development of the region?

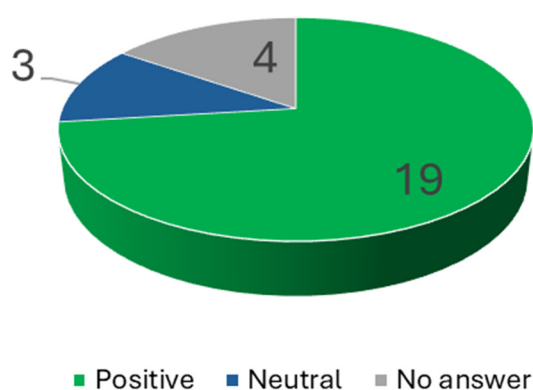


Figure 10. Responses to the question addressed to the Village Heads of Przytyk Municipality (near Jagodno Reservoir).

Among the responses, there were no negative voices, only neutral ones, where insufficient knowledge was cited to express a specific opinion. Regardless of the relatively small number of respondents—the village heads live in direct contact with the villagers—with their problems, emotions, and expectations. Therefore, their voice should be considered an important indication of the local community’s overall approach to the functioning of Jagodno Reservoir. The positive vote was mostly supported by the argument for intensified fishing and tourism in the region. In fact, analyzing the websites where Jagodno Reservoir is mentioned—is mainly concerned with information for anglers and the potential of this facility as a “no-kill” fishery, i.e., for recreational fishing only. Jagodno Reservoir also offers potential for further development in the region, and as a result, a local land use plan for the area around the reservoir in question was passed in 2019 [62]. The plan calls for single-family residential development, as well as areas designated for sports and recreation services. The available sources and social media did not encounter any negative opinions regarding the operation of Jagodno Reservoir.

Another situation concerns the contemplated Sarny Reservoir, the construction of which has not been started due to public protests organized by local residents. The campaign under the slogan “NO to reservoirs in Klodzko Land” was of great importance here. The people in charge of it deny the legitimacy of large hydro-technical investments in the region of the aforementioned Klodzko Land (southwest of Poland), address official correspondence to government bodies (including the European Union) and the World Bank, and are active on social media. Opponents of the construction of Sarny Reservoir mainly raised nature-centric arguments, as well as those regarding irreversible landscape change and the need to resettle people (in the case of Sarny Reservoir, this would be three people). The management position of Sarny Castle, which would be located in the immediate vicinity of the reservoir, was also important here. The board did not see the potential for the

development of the region's tourism in the construction of the reservoir and only raised the issue of the negative impact on cultural heritage and interference with sites under government conservation protection. Such sentiments were communicated to the entire local community, which were expressed during public consultations and resulted in the suspension of the project—including the Sarny Reservoir variant as a dry reservoir with only flood control functions. The authors of [30] present the results of a study where several years after the concept of building Sarny Reservoir was abandoned—people from nearby communities still often express a negative opinion about the construction of reservoirs, but neutral voices predominate.

3.5.2. Discussion

Analyzing the available sources and in dialogue with representatives of nearby villages, it was not found that the construction of Jagodno Reservoir aroused particular controversy or negative perception of the local community. It could also have had a beneficial impact during the implementation phase through the emergence of jobs for the region's residents. However, it should be borne in mind that environmental awareness and sensitivity have only intensified in Poland in recent years. Using the example of the circumstances observed during the planning activities for the construction of Sarny Reservoir, one can venture the assumption that, at present, the construction of a new retention reservoir in any part of the country would not meet with complete public acceptance. When evaluating the social impact of Jagodno Reservoir, it should be considered positive and offer prospects for further economic development in the region. However, it is important to maintain a balance between anthropocentric and nativocentric approaches. Already, significant human exploitation of the reservoir for recreation and fishing is resulting in a limited density of resident avifauna. Very large amounts of garbage left by people have also been observed in the forests near the shore of Jagodno Reservoir, which further negatively affects the local ecosystem by causing a threat to the soil and groundwater.

In the case of the creation of Sarny Reservoir (in an area that is richer in nature than the area where Jagodno Reservoir was created), even more emphasis should be placed on fitting the facility into the local landscape and betting on architectural and technological solutions that limit negative environmental impacts, which is the main demand of those who are skeptical about the construction of storage reservoirs. Although the initial concept actually indicated possible interference with elements of the historic castle-park complex and the 19th-century park designed by Eduard Petzold, it would have been possible to achieve compromises and maximum reduction in negative impacts on the cultural heritage through an informed dialogue. Since the region of the contemplated Sarny Reservoir is already an area frequented by tourists, there is reason to believe that the creation of a reservoir in the area would further intensify this circumstance, as evidenced by the increase in tourism at Jagodno Reservoir. It can be assumed that at the stage of public consultations, residents were not included in the planning process of the investment and were not properly presented with the benefits of Sarny Reservoir, which (in addition to those mentioned earlier) include the expansion of local infrastructure and, above all, the reduction in flood risk. It would also be particularly important to have a dialogue with those who would have to be displaced as a result of the investment and ultimately provide them with proper compensation and psychological support during the transition period [63]. Since the inhabited buildings and used farm facilities in the reservoir's bowl are in very poor condition, relocation to another nearby location that takes into account the needs of the resettlers could mean an improved quality of life for them.

4. Conclusions

The ex ante studies conducted at the site of Sarny Reservoir under consideration and ex post of the functioning Jagodno Reservoir led to the following conclusions, which are summarized by area of analysis.

4.1. Avifauna

In the area of Jagodno Reservoir, 20 species of birds have been identified. Eight of them are aquatic species that were not observed at the stage of planning the construction of the basin, of which some nesting was found. In the area of the potential Sarny Reservoir, 16 bird species have been identified, of which only 1 is classified as aquatic. The potential of Jagodno Reservoir to significantly increase waterbird populations has been limited by incorrect technical solutions and operational activities, which should have been avoided in the case of the construction of Sarny Reservoir.

4.2. Ichthyofauna

Twenty-four species of fish were found in Jagodno Reservoir, which is fifteen more than those living in the River Wiązownica before the construction of the facility. After analyzing the results of studies of the ichthyofauna of the Włodzica River, especially in the cross-section of the potential dam of Sarny Reservoir, it should be noted that over the course of 6 years, it is relatively constant in quality (up to 6 species) and variable in quantity, as illustrated by the decrease in the number of brook trout, while the number of minnows (from a dozen to more than 500) increased. Jagodno Reservoir has been dominated by angling tourism, and there are indications that the fish ladder is not working effectively enough. In the case of the construction of Sarny Reservoir, more sustainable technical and stocking solutions should be adopted.

4.3. Flora

At Jagodno Reservoir, 33 plant species were identified, 10 of which overlap with those observed before the construction of the facility (4 are trees and shrubs). The 17 species of small common angiosperms described in the EIA were not found. One species considered invasive in Poland (Canadian goldenrod) was identified. An environmentally unfavorable circumstance is also the loss of 91E0-1 (willow riparian) habitats stretching along the Wiązownica River. In the area of Sarny Reservoir under consideration, 30 plants were observed, of which there were 17 species of trees and shrubs and 13 growing in meadows. A total of 3 habitat types were identified—91E0 (white willow dominance), 9170 (oak dominance), and 6510 (meadows with poor species composition). If the reservoir is built, all these habitats would be lost.

4.4. Water Quality

A relatively large influx of nutrients was found in Jagodno Reservoir, ranging from 4.09 mg/dm³ to 12.19 mg/dm³ for total nitrogen and from 0.26 mg/dm³ to 3.90 mg/dm³ for total phosphorus, depending on the month. The reservoir captures some of these pollutants, in particular reducing concentrations of total nitrogen (by an average of 43.4%), nitrate nitrogen (by an average of 58.2%), and total phosphorus (by an average of 31.5%) in runoff waters. Water in the Włodzica River has significantly lower concentrations of tested nutrients than in the water flowing into Jagodno Reservoir. Relatively higher concentrations were recorded in July and March, with extreme values including total nitrogen of 3.25 mg/dm³, nitrate nitrogen of 1.89 mg/dm³, and total phosphorus of 0.44 mg/dm³.

4.5. Social Impact

A survey of Village Heads of all villages located in the municipality where Jagodno Reservoir is located indicated that 19 out of 26 of them positively assessed the facility's impact on the development of the region, arguing that it would intensify tourism. No negative votes were recorded in public online sources. The construction of Sarny Reservoir has not started, mainly because of the actions of activists declaring nature-centered views and opposing interference with cultural heritage and resettlement.

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