water

MDPI

Article

Selected Issues of Adaptive Water Management on the Example of the Białka River Basin

Monika Bryła *, **Tomasz Walczykiewicz**, **Magdalena Skonieczna** and **Mateusz Żelazny**

Institute of Meteorology and Water Management—National Research Institute, ul. Podleśna 61, 01-673 Warsaw, Poland; tomasz.walczykiewicz@imgw.pl (T.W.); magdalena.skonieczna@imgw.pl (M.S.); mateusz.zelazny@imgw.pl (M.Ż.)
* Correspondence: monika.bryla@imgw.pl; Tel.: +48-(12)-63-98-219

Abstract: Water is a fundamental resource needed for human life and functioning and the environment. Water management requires a comprehensive, adaptive approach that also considers the dynamics of changes in the water management system. This is particularly important in areas where different groups of stakeholders intertwine, whose needs often contradict, which hampers effective water management, particularly in places of high natural value. This research aimed to analyze selected issues in water management in the Białka River Basin in Southern Poland. The analysis was based on a review of scientific publications, internet sources, and a survey on water management in the basin. Our research shows that the dominant issues in the study area are the flood risk and water pollution related to, among other factors, the intensive development of tourism. Moreover, the effective management of water resources is hampered by poor communication between the administration and stakeholders, which results in a low level of knowledge, negative attitudes towards nature protection, and the emergence of conflicts. The main conclusion of this paper indicates that, despite the existing social potential for implementing comprehensive water management methods, the lack of an appropriate legal framework prevents the implementation of concepts such as Adaptive Water Management.

Keywords: Adaptive Water Management; stakeholder engagement; legislation; survey; uncertainty in water management

Citation: Bryła, M.; Walczykiewicz, T.; Skonieczna, M.; Żelazny, M. Selected Issues of Adaptive Water Management on the Example of the Białka River Basin. *Water* **2021**, *13*, 3540. https://doi.org/10.3390/w13243540

Academic Editors: Tamara Tokarczyk and Andrzej Walega

Received: 10 November 2021
Accepted: 7 December 2021
Published: 10 December 2021

1. Introduction

Water, as a fundamental resource needed for human life and the activities of daily living and the environment, requires the particular attention of all parties involved in the process of managing its resources. Contemporary social, economic, and climatic changes are causing growing problems related to water [1]. In many regions of the world, water resources are polluted, which negatively affects the aquatic ecosystems and reduces the availability of water to humans. On the one hand, developing urbanization reduces the resources of groundwater on a local scale, enlarging the runoff of waters from the catchment area, and, on the other hand, it increases the flood risk. On a global scale, the availability of water is uneven [2]. The progressive population growth, industrialization, and the lack of appropriate conservation practices of its quality and quantity make almost 80% of the world's population vulnerable to water stress [2,3]. Exposure to water stress depends on the Earth's climatic diversity and economic conditions—highly developed countries are able to allocate much greater financial resources to water resource management than less developed countries. An additional factor that affects the quantitative and spatial availability of water resources is climate change [4–7]. Similar to other regions of the world, Europe is affected by climate change [6]. Depending on latitude or other factors (e.g., high mountain areas), these changes can be positive or negative from a water resource perspective. The negative phenomena include an increase in temperature, a decrease in snowfall in winter, and an increase in evaporation. These changes may have a negative impact on the availability of fresh water in countries such as Poland. The increased frequency of droughts [8–11] can affect both humans and the environment, causing, among others, the drying of forests [12], water shortages in agriculture [13,14], increased risk of disease, malnutrition, high infant mortality, a decrease in the efficiency of electricity production processes, and a negative impact on water quality [15]. The reason for water scarcity is not necessarily natural; for example, in certain areas of India, poor management practices and government policies exacerbate the water issues [16]. Another reason for water scarcity is also cross-border conflicts regarding access to water resources [17] or a lack of appropriate measures to protect the water quality [18–20]. Transboundary water management is one of the most difficult challenges. It requires cooperation at the level of a legal framework, communication between national authorities, a joint action plan, and compliance with agreements [21]. A further challenge in water management is the progressive urbanization and the increase in floods, including floods in cities, which are a growing threat to both people and the economy [22,23]. Extreme climatic phenomena associated with water resources can interact with many environmental and socio-economic sectors, including health, public safety, biodiversity, industry, shipping, and tourism [24].

Traditional management based on the provision of an adequate quantity of water of appropriate quality is insufficient in view of the increasing water-related issues. It requires a more comprehensive approach that considers the needs of the environment, society, and the economy in terms of access to water [25–29]. This approach is called Integrated Water Resource Management (IWRM) [30–32]. In this concept, stakeholder involvement is a key issue in water management. It should be based on the cooperation of various entities—representatives of the public administration, entrepreneurs, residents, nature protection associations, and other social groups that want to be involved in the water management process. This cooperation is a multi-stage process, from public consultations and meetings and the implementation of the agreed roadmaps to their evaluation [33–36]. Stakeholder involvement requires appropriate legal forms to develop tools to support the water management process [30]. IWRM points out that it is necessary to formalize this concept in water legislation as one of the stages leading to the decentralization of government management towards river basin management. Collaboration with stakeholders throughout the water management process is a key criterion for the success of IWRM. It is a comprehensive approach to the development of a water management policy in terms of both resources and services provided related to water [37]. On the other hand, decentralization can make it difficult to control the transparency and fairness of the process [38]. There are known cases around the world of newly created IWRM-related institutions becoming power-laden, gendered, and beset with conflict and factional divisions. According to critics, IWRM could be seen as a form of coercion as it imposes a set of principles and tools to be followed, or also as an idea of a hegemonic discourse that prevents any alternative [39]. The implementation of IWRM may encounter many problems, such as insufficient administrative structure, poor knowledge, and conflicts of interest in water needs [25,33,40]. As Michalak [40] indicates in his work, the lack of knowledge about the functioning of the environment and awareness of the negative effects of anthropopressure is one of the barriers to the implementation of effective water resource management. Furthermore, conflicting and often competing water needs require an appropriately integrated approach [33] that will seek to resolve water-related conflicts on a different scale—from local communities to national needs [25]. Measurement uncertainty is an additional obstacle to effective water management. According to McMillan et al. [41], this issue applies to all stages of data processing, from differences in the quality of measuring equipment and errors caused by individuals carrying out measurements to an incomplete/insufficient measurement network. This network in uncontrolled places requires empirical data interpolation with the selected method, also burdened with the uncertainty of the result. The measurement uncertainty or lack of measurement is significant in forecasting changes in the volume of water resources in view of climate change [42]. As a result, it also has a negative impact on the development of appropriate water management policies [43]. Therefore, water management requires the creation of a resilient management system capable of absorbing disruptions and adapting to changes while maintaining its functions, structure, and purpose [26,44]. Van der Keur et al. [37] indicate that Adaptive Integrated Water Resources Management (AWM) should therefore be used. Its main features are learning, reflection and adaptation capacity, co-management, the formal and informal involvement of decision makers [45], and the drive to decentralize management structures, which benefits stakeholder cooperation [28,34,46,47]. AWM provides added value to IWRM by taking into account uncertainty and adapting to changes (e.g., climate change, lack of complete hydrological data, changing water demand) in the system. It also emphasizes the education of the stakeholders involved [28,48–50]. One of the most significant elements of AWM is social learning, which aims to connect laypeople, enthusiasts, business representatives, and experts in the common goal of water resource management [27,35]. It can be defined as social interactions between stakeholders based on knowledge exchange and an understanding of the management of a water system, where knowledge is acquired from all sides—from legal persons and individuals to organizations [27]. According to Pahl-Wost [51], social learning should focus on learning the social entity as a whole to "learn management together". The framework for this process should be context-specific and involve multilateral cooperation, leading to particular outcomes. AWM also assumes the complexity of the managed systems and the limitations resulting from forecasting their behavior and the possibility of controlling them [37]. Water management will always have to proceed with an incomplete understanding of how the system operates and the effects of its management. Adaptation policy should therefore be planned, taking into account environmental and human behavior processes for measures implemented as part of water management.

Water management in Poland has been regulated by the provisions of the Water Law Act [52] since 2018. As Poland is a member state of the European Union, water management legislation is based on the assumptions of the Water Framework Directive [53]. The relatively small water resources of the country and the unfavorable climatic conditions related to, among others, the high dynamics of flow changes during the year make Poland a country that requires proper management of water resources [54]. The southern parts of Poland are mountainous areas—national and landscape park regions, which are also the main tourist and holiday regions [55]. It is an area where water management should be of particular concern to society due to its natural value and the broad group of stakeholders that benefit from the region's water resources. As a result of the research, this manuscript presents an analysis of selected issues related to water management in the Białka River Basin, located in the south of Poland—in a unique culturally and naturally significant area. The aim of the research was achieved by identifying the issues and the barriers involved in water resource management in the study area. The study was based on a query of scientific publications, press reports, and the results of a survey conducted in 2021. In essence, issues were identified based on query. The results of the survey were used as an additional source of information about problems in water resource management in the Białka River Basin and allowed for the identification of other management barriers, especially in the context of IWRM and AWM. The survey results additionally confirmed that the lack of legal solutions to stimulate cooperation between stakeholders at the lowest level is one of the main barriers to management.

2. Study Area

The Białka River is the right tributary of the Dunajec River, originating in the Tatra Mountains at an altitude of around 1075 m above sea level from the merging of the Rybi Potok, flowing from the Polish part of the Tatra Mountains, and Biała Woda, flowing from the Slovak part of the Tatra Mountains. The length of the Białka River is approximately 42 km [56], including the Biała Woda source stream flowing from the Kacza Valley at an altitude of around 1577 m above sea level. Moving northwards, the Białka River is run by numerous streams flowing from mountainous areas. Its major tributaries include, among others, Roztoka, Jaworowy Potok, Jurgowczyk, and Trybska Rzeka. Białka is a river with typical mountainous characteristics, characterized by a fast current and high dynamics of changes in the hydrological regime [57]. According to Wrzesiński [58], the Białka River is characterized by a pluvial–nival regime. Between September and February, lower than average flows are observed, and from March, snowmelt-related flow increases, which, in the longer term, are combined with summer floods. Data from the Institute of Meteorology and Water Management—National Research Institute (IMGW-PIB) water gauge network for the years 2001–2020 confirm this characteristic. The lowest flows on the Białka River in Trybsz and Łysa Polana occur from January to February (Figure 1), and the highest during the flood period, which is in May. The river flow variability coefficient in both water gauges exceeds 100% (Table 1). Essential flow characteristics in the catchment area are presented in Table 1. The water level in Białka is subject to significant fluctuations, caused by factors such as the intense melting of snow cover or heavy rainfall, especially in mountainous areas. In the upper flow, the river's bed fall reaches around 72‰, while, in the lower flow, it drops to below 20‰ [59]. Spring and summer floods also cause the river to change its bed frequently. The riverbank can be described as steep, rocky, and partially regulated, with sections of a natural character. The river's course is also distinguished by significant terrain height differences—from 530 to 883 m above sea level [60]. The Białka River is one of the few mountainous Carpathian rivers with a natural, anastomosing character [59]. The Białka Valley has been designated as Natura 2000 SOO site (under the Habitats Directive) no. PLH 120024, with an area of 716.03 ha, and as an area of community importance [61]. The site contains eleven natural habitats from Annex I of the Habitats Directive [62]. It is home to many unique habitat types and plant and animal species. At the Białka River, one can observe the region's largest resources of riverside habitats, rare on a national scale, linked to natural mountain rivers, e.g., German tamarisk thickets (Myricaria germanica) on stony river beds and willow thickets (Salix eleagnos). In the area of the Przełom Białki reserve in the vicinity of Krempachy, 457 species of vascular plants have been declared [59]. The fish that live here include brown trout (Salmo trutta m. fario) and barb (Barbus petenyi), while, on land, one can find deer (Cervus elaphus elaphus), wild boar (Sus scrofa), wolf (Canis lupus), European viper (Vipera berus), or bear (Ursus arctos) [63]. The Białka Valley also forms a significant ecological corridor on the north–south line, connecting the Tatra Mountains with the Gorce and Pieniny Mountains. The area of the Polish part of the Białka River Basin is approximately 123.27 km^2, which is 55% of the total area of the basin of around 225.33 km^2 [56] and includes, among others, the areas of the Tatra National Park, involving the whole area of the northern slopes of the High Tatras. The basin has varied physical and geographical locations. It is located within seven mesoregions. Listed from the south side, it belongs to the High Tatras, the Reglowe Tatras, the Podtatrzańska Bruzda, the Podtatrzański Foothills, the Magura Spiska, the Pieniny Mountains, and the Orawsko-Nowotarska Valley [64,65]. Various types of land cover can be observed in the basin. There are [66] anthropogenic areas, agricultural areas, forests, semi-natural ecosystems, and water areas (Table 2). The largest area in the basin is covered by coniferous forests, followed by meadows and pastures, arable land beyond the reach of irrigation equipment, exposed rocks, and land mainly occupied by agriculture, with a large share of natural vegetation. Other land cover classes account for less than 10% of the total catchment area. In the southern part of the catchment area, there are primarily forest and rocky areas (Figure 2). In contrast, the central part is dominated by agricultural areas, with discontinuous urban fabric along the Białka River and its tributaries. The northern part of the basin catchment area, covering a narrow strip of the river valley up to the river mouth, is mainly covered by forest and arable land.

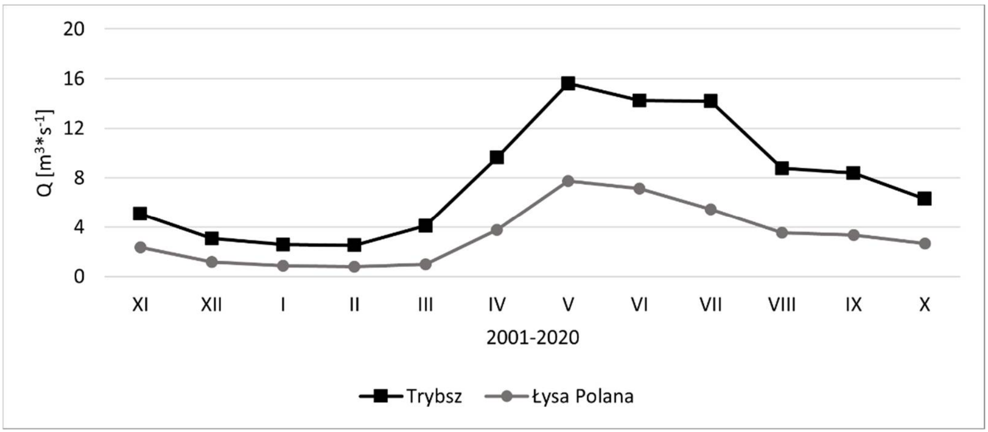

Figure 1. Average monthly water flow in 2001–2020.

Figure 2. Study area based on Corine Land Cover [66].

Table 1. The Białka River flow.

2001–2020	σ	Min	$Q_{25\%}$	Me	Mean	Max	$Q_{75\%}$	*Cv*
				m^3/s				%
Łysa Polana	4.2	0.3	1.0	2.1	3.3	67.4	4.1	138
Trybsz	10.9	0.9	2.9	5.0	7.9	216.0	8.8	126

Table 2. Land cover classes in the Białka River Basin [66].

Type of Land Cover (Level 1)	Area	Area
	km^2	%
Artificial surfaces	5.9	4.8
Agricultural areas	52.2	42.3
Forest and semi-natural areas	62.1	50.4
Water bodies	3.1	2.5
Total	123.3	100

3. Materials and Methods

The study was carried out in two stages. In the first one, an inventory of the issues of the Białka River Basin was made based on a query of available knowledge—scientific publications, press reports, and information posted on the websites of public institutions (Table 3). The Statistics Poland (SP) data on population, tourism, nature protection, and water and sewage management from the years 2014–2020 [67] were used. Land cover classes were determined using the CORINE Land Cover 2018 database [66]. The database containing information on the water-legal permits in the selected river basin was obtained from the National Water Holding Polish Waters. Based on the available materials (literature, analysis of materials published by local media), the issues in the basin in the context of water management were reviewed. For the hydrological characterization of the area, data from the IMGW-PIB for two water gauges—Łysa Polana and Trybsz—were used. The analysis of the current legal situation regarding water management in the Białka River Basin was carried out on the basis of the Water Law Act [52].

In the second stage, a survey was conducted on water management in the Białka River Basin. The study took place from 15 June to 16 July 2021. The questionnaire was addressed to residents, entrepreneurs, and other people associated with the Białka River Basin. The survey was distributed via e-mail and social media (it was made available through the Facebook portal by a person associated with the catchment area). The sources of contact information were: municipal websites, schools, fire brigades, national parks, and other local government organizations. The booking.com portal and the Google search engine were also used. The online query focused on identifying small guesthouses and agrotourism, with the assumption that a significant portion of the people employed there were local residents. The questionnaire consisted of single and multiple-choice questions and, in selected cases, also included the possibility for the respondent's own answers. A total of 22 questions were formulated.

The first part of the questionnaire concerned the respondent's characteristics: age, gender, education, commune of residence, and the type of relationship with the Białka River Basin. In the next part, attempts were made to identify society's awareness related to the river basin in terms of water management. Questions were formulated based on the issues of water management, sources of information on this subject, knowledge of planning documents, institutions responsible for water management, forms of nature protection in the river basin, and the functioning of the river basin over time. The next part aimed to identify the perception of water-related issues in the river basin. The respondents were asked to select from a list of problems their causes and give them a rank. They were allowed to formulate their own statements on selected questions. The last part of the survey was to identify the potential of public involvement in water management. The questions concerned the interest of stakeholder groups in caring for the quality and quantity of water in the river basin, the respondent's direct interest in involvement in the water management process, and the willingness of both individuals and entrepreneurs to cooperate.

Table 3. Categories of identified issues with data sources division.

Category	The Type of Source	References
All	Survey research	-
Urbanization	Database	[66]
Tourism developmnent	Scientific publication	[68–73]
	Website	[74–76]
	Database	[67]
Water pollution from point sources	Scientific publication	[77–80]
	Other	[81]
	Website	[82–89]
	Databese	[67]
Use of water	Legal act	[52]
	Water-legal permits	-
	IMGW-PIB hydrological database	-
Flood risk	Scientific publication	[73,90]
	Other	[91,92]
	Website	[63,93–108]
Context of climate change	Scientific publication	[6,109–116]
Impact of Polish legal forms	Legal act	[52,117]
	Website	[118]

4. Results

The Białka River Basin is one of the most valuable landscape systems in the Polish Carpathians. It is characterized by high natural value—despite the settlement, it has preserved its natural mountainous character [68]. Due to environmental conditions and high economic activity, it is a zone where various issues and interest groups related to water resource management intertwine.

4.1. Tourism Development

One of the main aspects of the economic development of the region is tourism. The development of tourism in the Białka River Basin has a long history. The high natural value of the valley and the surrounding area makes these lands very attractive for tourists. The first ski lifts in Białka Tatrzańska were built in the early 1960s. In the following years, the ski infrastructure was expanded [69]. There are many ski resorts in the catchment area, including Jurgów Ski, Kotelnica Białczańska, Kozieniec Ski, and two large thermal baths—Termy Bania. In 2020, there were 97 tourist accommodation facilities here, including hotels, guesthouses, private accommodation, agrotourism lodgings, holiday centers, and hostels [67]. These facilities had a total of 5384 bed places. According to research carried out in the Tatra National Park, around 30% of the total touristic traffic in the Polish Tatras is concentrated on the route from Palenica Białczańska to Morskie Oko. In August 2009, on average, around 20,000 tourists entered the territory of the Tatra National Park every day [68]. Due to strong tourist pressure, there have been numerous attempts at limiting tourist traffic—for example, the online sale of tickets for the parking lot in Palenica Białczańska [74]. The analysis carried out by the service intermediating in booking accommodation—nocowanie.pl [75]—showed that tourists most often chose Małopolska as their place of rest in 2017. Zakopane dominated (44% of inquiries), followed by Białka Tatrzańska (8% of inquiries), with Bukowina Tatrzańska (4%) in the 6th position. On the other hand, during the winter holidays in 2019, Zakopane was chosen most often (13.5% of inquiries) in the entire country [76], while Białka Tatrzańska was ranked 4th (5.5% of inquiries) among the analyzed towns. Białka Tatrzańska is considered to be the fastest-growing town of Podhale, especially regarding the tourist aspect [70]. The development of mass tourism has caused the intense transformation of the natural environment and landscape of Białka Tatrzańska [71]. A large concentration of ski resorts in a relatively small space leads to extensive degradation of the slopes. The creation of new service facilities negatively impacts the environment and causes the devastation of the traditional aesthetics of the Białka Tatrzańska area [72]. Building on the valley floor also results in the disappearance of ecological corridors, limiting the free migration of animals in the catchment area. The annual influx of tourists during the summer and winter holidays is crucial for water management. Enlarging urbanization could be the cause of the increasing flood risk—impermeable surfaces such as roofs, roads, and parking lots are the cause of increasing runoff [73]. The well-developed tourist base is associated with the abstraction of water for economic purposes, including the snowing of slopes in winter [68]. The increase in the number of people in the tourist season (which now includes both winter and summer) combined with poorly developed infrastructure results in the strong pollution of the river waters. Selected issues related to the tourism are described in Sections 4.2 and 4.3.

4.2. Water Pollution from Point Sources

The increasing pressure resulting from tourism development in the catchment area necessitates water and sewage infrastructure development. In the territory of the Bukowina Tatrzańska community, the number of industrial and sewage treatment plants has doubled in recent years. In 2020, there were six such treatment plants [67]. Their capacity in 2014–2020 increased more than three times (Table 4). The number of residents who benefit from the treatment plant is also gradually increasing. The number of septic tanks (more than five times) and household sewage treatment plants (more than four times) has increased significantly in recent years. The municipality has also systematically recorded an increase in water consumption since 2014 (except for 2018 and 2020, when a decrease was noted compared to the previous year). A similar trend also occurs in the share of industry in overall water consumption [67]. Water quality monitoring is carried out by the Regional Inspectorate for Environmental Protection (WIOŚ), which has two measurement points on the Białka River—in Łysa Polana and Dębno (Białka estuary to the Czorsztyn reservoir) [81]. Information contained in the Classification and Assessment of the Condition of Surface Waters Bodies in 2019 (analysis based on data from 2014 to 2019) shows that the Białka River at the tested measurement points is characterized by a moderate ecological and good chemical state. The overall assessment of the surface water body indicates poor water conditions.

Table 4. Water and sewage management in the Bukowina Tatrzańska commune based on Statistics Poland [67].

Statistics Poland Data Subgroup	Unit	2014	2015	2016	2017	2018	2019	2020
Number of industrial and municipal sewage treatment plants	Number of units	3	3	4	4	4	6	6
Number of household sewage treatment plants		7	7	30	30	30	30	no data
Number of septic tanks		540	540	540	540	2804	2765	no data
People using the sewage treatment plants	people	6624	6690	7203	7453	7691	7713	7855
Capacity of industrial and municipal sewage treatment plants	m^3/d	835	1790	2150	2150	2150	2410	2410
Water consumption for the needs of the national economy and population during the year	dam^3	840.3	872.5	1001.3	2041.2	1152.9	1309.4	1021.2
Industry share in water consumption	%	64.1	65.8	66.9	83.2	69.0	72.2	70.3

Despite the measures taken, the intensive development of tourism adversely affects water quality, especially in terms of microbiology [77,78]. Along the course of the river, the impact of point and diffuse sources of water pollution increases. Moreover, sewage treatment in plants has low efficiency [79]. The water is treated mainly in terms of physicochemical indicators, while bacteriological contamination and high concentrations of antibiotics are observed below the discharges of treated sewage [80]. This problem is also the subject of public discussion in the media, which appears in the context of extreme events or the lack of an adequate sewage system [82–84]. There are reports in the local media about the contamination of the Białka River in the area of Białka Tatrzańska, where there is a lack of sewage, especially during peak tourism periods. The local government and the inhabitants of Białka Tatrzańska have drawn attention to the growing problem of illegal sewage discharge by, among others, owners of small- and medium-sized guesthouses or small farms with rooms for rent. On the other hand, the construction of the sewage system causes resistance from the owners of the plots through which the pipeline would run, which, in 2014, led to the blocking of local government activities leading to the sewerage of Białka Tatrzańska [85,86]. Another cause of water quality problems in the Białka River, which has been noticed by residents, tourists, and pro-environmental organizations, is the inefficient operation of the sewage treatment plant in Czarna Góra [87–89].

4.3. Use of Water in the Białka River Basin

One of the tools for managing water resources in Poland is water-legal permits—they are necessary to obtain a water law approval, which is a type of administrative decision authorizing the use of water or affecting the water environment [52]. Data on water-legal permits have been collected in the PGW WP databases since 2018. The current resources are not yet complete and require further arrangement with regard to the new provisions of the Water Law Act. In June 2021, information was obtained from PGW WP on all applicable water permits in the Białka River catchment area. The shared raw database was then prepared and developed for further work. As a result of the selection, those water-legal permits were rejected that did not apply to any water activity, water services, or use in the catchment area, but were only corrections, instructions, remissions, etc. A total of 203 water-legal permits were finally used for further analyses. They all have the status of writing as up to date. For 83 water permits (41%), water users are private persons, while the remaining are private and public enterprises, companies, and local governments. Water permits in the Białka catchment area were obtained for various types of activities, water services, or water use. They concern such categories as (some permits fall into more than one category): regulations (6), power plants (2), surface intakes (6), protection zones of surface intakes (1), groundwater intakes (62), protection zones of intakes underground (26), sewage treatment plants (10), wastewater discharges (62), pre-treatment facilities (2), crossing by watercourses (44), periodic surface intakes (1), fish ponds (1). A total of 38 water permits were issued between 1998 and 2010 and are still valid today. In the last decade (2011–2020), 165 such permits were issued, the most (20 and more permits) in 2016, 2017, 2019, and 2020. There was also a sharp increase in wastewater discharge permits granted between 2011 and 2020. During this period, 59 of the 62 permits currently in force were issued. Table 5 shows the general distribution of water-legal permits granted and in selected categories in 1998–2020.

According to the analysis of the database, it should be assumed that at least 32 permits in the detailed description have direct reference to the tourist function (guesthouse, hotel, restaurant, recreational function, ski, sports and recreation resort, etc.). Seven water-legal permits concerning the abstraction of surface waters (including one periodical) apply currently in the area of the Białka River Basin. Four permits were issued to entrepreneurs for snowmaking on ski slopes, while the others were issued for the needs of small hydroelectric power stations and for supplying waterworks. Water intake for skiing purposes exceeds 15,000 m^3 per day (Table 6). The permits provide for the abstraction of water from the Białka River in the following locations: Czarna Góra Grapa, Bukowina Tatrzańska, Białka

Tatrzańska, and Jurgów. Out of all water-legal permits related to wastewater discharge, only 14 were classified as discharges of treated domestic sewage or domestic sewage, with information on the permissible discharge. In total, on the basis of the information contained in the obtained database of the permits in force, their discharge is allowed in the amount of Qśr = 231 m^3/d (Table 7).

Table 5. Number of water-legal permits issued in 1998–2020 in the Białka River Basin.

Year	Number of Water-Legal Permits Issued (Currently Valid)	Type of Water-Legal Permit	
		Surface Water Abstractions (Including Periodic Intakes)	Sewage Discharges
2020	23	-	4
2019	20	-	7
2018	14	1	6
2017	21	2 (1)	10
2016	21	1	6
2015	19	-	7
2014	17	-	5
2013	10	-	5
2012	11	-	7
2011	9	-	2
2010	7	1	1
2009	1	-	-
2008	7	-	-
2007	3	-	-
2006	7	1	1
2005	5	1	1
2004	2	-	-
2003	1	-	-
2002	3	-	-
2001	1	-	-
2000	0	-	-
1999	0	-	-
1998	1	-	-
TOTAL	203	7 (1)	62

Table 6. Purposes of water abstractions.

Purpose	Acceptable Quantity	
	Q_{mean} m^3/d	Q_{max} m^3/s
Artificial snowmaking of slopes (the Białka River)	16,950	-
Small hydroelectric power stations	-	2.3
Waterworks	no data	

Table 7. Sewage discharges.

Sewage Discharge Site	Acceptable Quantity
	Q_{mean} m^3/d
Czerwonka	67.8
Bryjów Potok	60
Rybi Potok	9.5
Unnamed stream	51.3
To the ground	42.3
Total	230.9

Over 40% of all water-legal permits in the catchment area were issued for Białka Tatrzańska (84 water-legal permits). According to the information obtained, 52% of users are private individuals (44 permits). The issued decisions concern, among others, wastewater discharge (35 permits), underground intakes (27), protection zones of underground intakes (11), exceedances (11), treatment plants (6), and surface intakes (1). According to the data, wastewater (including treated domestic sewage, rainwater, and snowmelt) is most often discharged to the ground, mainly using absorbent wells and sewage outlets to the Czerwonka stream. In the other major towns located in the catchment area (Czarna Góra, Bukowina Tatrzańska, Brzegi, Trybsz, Jurgów), 103 water-legal permits apply in total, out of which 36 permits (35%) are for private individuals. The permits issued in these towns include wastewater discharges (21 permits), exceedances (30), underground intakes (31), surface intakes (4, including one periodical), and sewage treatment plants (2). Wastewater is most often discharged into ditches and streams without names, representing the tributaries of other rivers, and to the ground using absorbent wells. Apart from water permits, which specify the volume of abstraction, discharge, or other environmental effects, information about the volume of water resources and how it changes over time in different parts of the catchment area is an integral part of water resource management. Currently, apart from two water gauges on the Białka River, the Institute of Meteorology and Water Management—National Research has a water gauge on the Morskie Oko Lake. Between 1967 and 1979, there was also a water gauge on the Wielki Staw Lake (Roztoka) in the Valley of the Five Polish Ponds (Table 8).

Table 8. IMGW-PIB measurement network in the Białka River Basin.

Type	Gauge Name	Date of Starting the Measurements	Date of Termination of the Station
Lake	Wielki Staw (Roztoka)	1967	1979
Lake	Morskie Oko	1951	Active
River	Białka	1917	Active
River	Białka	1994	Active
River	Młynówka (Białka)	1942	2000

4.4. Flood Risk

Floods in the Białka River Basin are a permanent manifestation of its hydrological regime [73]. This is related to the mountainous nature of the catchment area—the diverse morphology of the terrain and the significant height differences, which, combined with high rainfall, often of a torrential nature, result in the rapid development of floods, especially in the southern part of the catchment area. In addition, the spatial distribution of the population is uneven and concentrated in the central and northern parts of the catchment area, in the valley axis—along rivers and streams. This is another characteristic of this area that contributes to the development of floods, threatening the health and lives of residents. The first mentions of floods in Podhale date back to the early 19th century. The floods in 1934, 1970, 1997, and 2010 are considered extremely catastrophic events [90]. According to the inhabitants of the Białka catchment area [91], starting from 1997 and in the years 2001, 2002, 2004, 2005, 2008, 2010, 2014, and 2018, as a result of the floods, numerous roads, bridges, power transmission lines, and water supply systems were destroyed; moreover, drinking water intakes, sports fields, and houses were flooded. In 1965–2008, the bridge over the Białka River between Nowa Biała and Krempachy was broken three times. Flood losses between 2007 and 2012 in the community of Bukowina Tatrzańska amounted to over PLN 10 million [92]. The issue of flood risk, particularly the regulation of the Białka river bed, is the subject of a conflict between stakeholders representing the local and regional authorities, the inhabitants of the area, and the Regional Directorate for Environmental Protection in Cracow. This issue is reflected in the local media publications, similarly as in the case of water pollution [63,93–105]. At the lowest level, the inhabitants of the area demand effective regulation of the river bed through the construction of embankments and weirs and consent to the deepening and thus narrowing of the river bed, also in the area of a Natura 2000 nature reserve. Representatives of the local administration, such as the major of Nowy Targ, present a similar position. At the regional level, there is a conflict between the above stakeholders, the conservator of nature protection, and environmental organizations, which indicate that the proposed solutions are short-term and do not consider the nature of the Białka River [106]. In such circumstances, conflicts escalate, including protests. Flood risk is currently under discussion between the public administration and the local community [107]. Representatives of the local administration (commune heads, district governors, village chiefs), as part of consultations on regulatory works carried out on the Białka River in 2018, indicated that the protection of residents against the effects of floods is one of the management priorities in districts, communes, and towns. According to the information posted on the National Water Holding Polish Waters (PGW WP) website, in 2009, the first attempt was made to implement a flood protection project, taking into account the protection of the unique nature of the Białka River environment [108]. However, the proposed solutions met with the reluctance of the local community. Work is currently underway on a multidirectional flood protection project from the border of the Tatra National Park to the mouth of the Białka River to the Czorsztyn Reservoir. The Program for Białka is intended to protect valuable habitats and ensure corridors of free migration for aquatic and water-dependent organisms.

4.5. The Białka River Basin in the Context of Climate Change

When analyzing climate change, we will use two projects' results based on scenario analyses that form its basis. The scenarios relate to the specific emission of gases that retain solar energy in the Earth's atmosphere, known as greenhouse gases, and contribute to positive radiative forcing. In such a situation, there is an increase in energy absorbed by the climate system, which leads to climate warming. The scenarios included in the Special Report of Emission Scenarios (SRES) [109] are defined by families (A1, A2, B1, and B2) designed on the basis of a set of consistent assumptions. In turn, the Representative Concentration Pathways (RCP) scenarios [6] are classified according to the change in radiative forcing (+2.6 to +8.5 W/m^2) that will occur by 2100. The four proposed scenarios are called RCP2.6, RCP4.5, RCP6.0, and RCP8.5. They estimate the approximate radiative forcing in 2100 against 1750. The year 1750 is the reference year as the conventional end of the pre-industrial era. In the second half of the 21st century, the SRES A2 has a similar trajectory to RCP8.5. Both trajectories will reach around 8 W/m^2 by 2100. SRES A2 is also similar to RCP8.5 in terms of changes in mean global temperature [110].

Taking into account the described similarity of the A2 scenario to the RCP8.5 scenario, to illustrate the changes in water resources, the figures below show the percentage change in the mean annual flow and mean seasonal flows in rivers between 2071 and 2100 compared to the period 1961–1990 for the A2 scenario [110,111]. For the Tatra Mountains and Podhale region, the forecasted flow change is within the range of -5 to 5% in terms of mean annual flows (Figure 3).

In turn, a detailed analysis of the results of the Chase-PL project shows that, in the south of Poland, the number of hot days has increased, and winters are becoming milder—the number of very cold and extremely cold days is decreasing. In high mountain areas (such as the southern part of the Białka River Basin), a decrease in annual precipitation is observed, while, in the foreland of the Tatra Mountains, the opposite trend is observed. In the Podhale region, the ratio of winter precipitation to summer precipitation changes [112]. Both in the station located in the high mountain region and in the foreground of the Tatra Mountains, the mean seasonal precipitation decreases in winter and summer, while, in spring and autumn, it increases. A particularly unfavorable phenomenon is the change in the type of precipitation from snow to rain in winter. As a result, the water retained by plants during the summer quickly escapes beyond the catchment area. Additionally, the lack of snow cover may reduce the retention capacity of the soil as a result of soil freezing. The climate scenarios based on the radiative forcing in the RCP 4.5 and 8.5 variants for the time horizons 2021–2050 and 2071–2100 for the empirical–statistical downscaling (ESD) and dynamic downscaling (DD) models clearly forecast an increase in air temperature [113]. The DD projections indicate that the mountainous areas of Southern Poland will be exposed over a longer time horizon to temperatures above 2 °C per year in the RCP 8.5 scenario. The most significant change will take place for the winter months (both RCP 8.5 and 4.5). According to the DD method, precipitation in both time horizons and emission scenarios will increase from a few to several percent per year (Table 9). The highest increases are forecast for the winter months. In the case of ESD projections for the Podhale region, a decrease or a slight increase in annual precipitation is forecast. In winter and autumn, a weaker decrease for the RCP 4.5 scenario and stronger for RCP 8.5 (multi-year 2021–2050) is expected. The decrease in precipitation total is carried over to the spring and summer months for a longer time horizon. In addition, the authors of the study point out that the appearing divergences in the projection results for various types of models introduce high uncertainty of the obtained results. The results of the SWAT model for RCP 4.5 and 8.5 in the time horizons 2024–2050 and 2074–2100 for the value of river outflow do not show statistical significance of the projected changes [114]. Climate change will also affect aquatic organisms in the Białka River. Okruszko et al. [115] analyzed three groups of fish species: settled, partially migratory, and migratory. For the first group, the impact of the change on the rivers in the Podhale region will be medium for both RCP 4.5 and RCP 8.5 in the near and far future. Similarly, for the second and third groups, there will be slight deviations towards high and low impact. The IHA index [116] was used for the analyses, including identifying changes in parameters affecting fish habitat conditions. These included features such as water temperature, flow velocity, and vegetation changes.

4.6. Legal Forms—Polish Water Law in the Context of the Stakeholders' Participation

The current legal framework for water management in Poland is defined in the new Water Law Act, which entered into force in 2018 [52]. According to its content, water management in Poland should be carried out according to the principle of sustainable development, particularly regarding the development and protection of water resources, water use, and water resource management, including a wide and open process of consultation. For water management purposes, a system of management units with different spatial resolutions has been established. At the highest level of generality, the Białka River Basin is classified as the Vistula river basin, then to the Upper-Western Vistula water region. In the current text of the Act, the minister responsible for water management, the President of Polish Waters, the directors of the regional water management board in Cracow of Polish Waters, the management of the water catchment in Nowy Sącz, the head of the Water Supervision Zakopane, the Małopolska voivode, the governor of the Tatra and Nowotary district, and commune mayors (Bukowina Tatrzańska, Nowy Targ, Łapsze Niżne) are mentioned as the governing bodies in the context of the Białka catchment area [118]. It is understood through the principle of common interests based on the cooperation of various stakeholders groups to obtain the maximum benefit with minimum environmental costs. According to this Act, stakeholder participation at the national level of responsibility is assured by the State Council for Water Management. For a specific case, the President of Polish Waters also has the opportunity to appoint a consultative team consisting of experts and representatives of the public administration. However, the Act does not further define which rights such teams would have. The new Act has a direct impact on the management of water resources at lower levels of responsibility, through the limited possibilities of stakeholder participation. The previous water act established "water region councils", whose members were stakeholders representing economic, agricultural, fisheries, and community organizations and representatives of water users [117]. The current Act has abolished such councils.

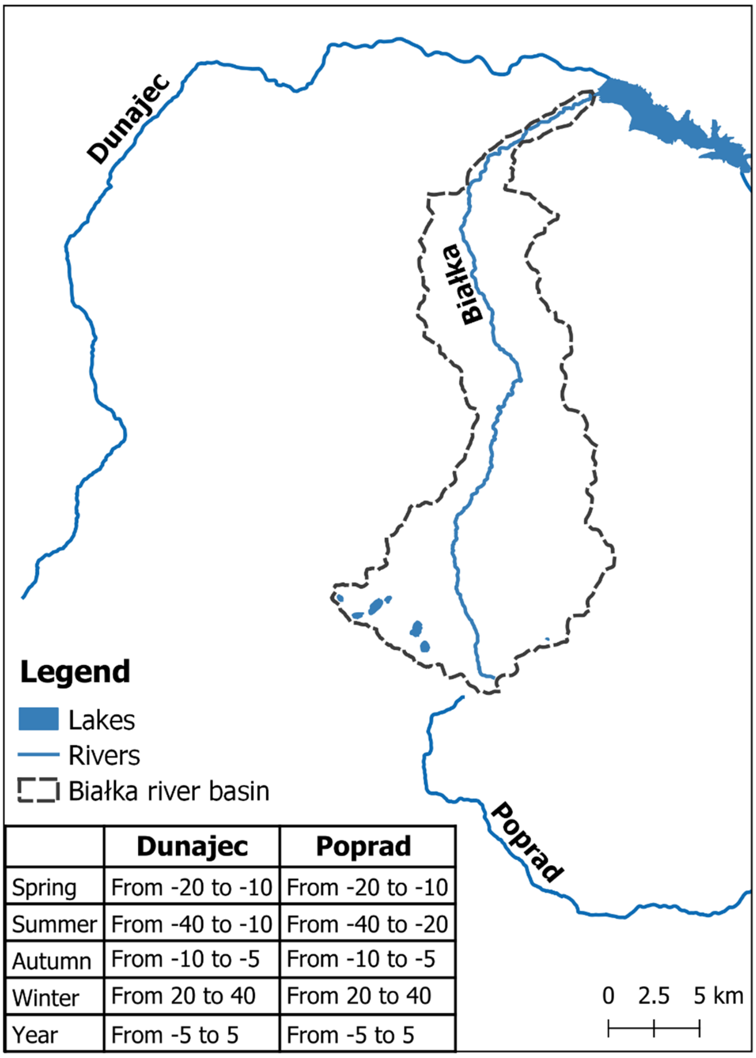

Figure 3. Projected changes (%) in the annual flow for the time horizon 2071–2100 in relation to the multi-year period 1961–1990 based on Majewski and Walczykiewicz [111].

Table 9. Projected changes in annual precipitation for the Podhale region—modeled by empirical–statistical downscaling (ESD) and dynamic downscaling (DD) based on Mezghani et al. [113].

Downscaling Method		RCP Scenario	Range of Changes (%)
DD	2021–2050 2071–2100	4.5	from 0 to 5 from 5 to 10
	2021–2050 2071–2100	8.5	from 0 to 5 from 5 to 10
ESD	2021–2050 2071–2100	4.5	from 0 to 5 from 0 to 5
	2021–2050 2071–2100	8.5	from −5 to 0 from 0 to 5

4.7. Survey Results

A total of 371 respondents took part in the survey. People with a Master's degree and secondary education prevailed. This trend was maintained for all age groups (except for "up to 18"). The older the age category, the fewer people participated in the study. In total, 63.6% of the respondents came from the Nowy Targ commune, 17.3% from Bukowina Tatrzańska, and 12.4% from Łapsze Niżne. The remaining 7.0% were respondents from other communes. A significant fraction of the respondents—85.2%—declared that they were associated with the Białka River Basin as a resident, and approximately 14% were entrepreneurs (Table 10). Other responses did not exceed 10%.

Table 10. Links between respondents and the Białka River Basin.

Type of Connection	Number of Answers	%
I live here	316	85.2
I run a business	53	14.3
I work in a non-governmental organization (NGO)/association	21	5.7
I work in public administration	28	7.5
Tourism	18	4.9
Other	14	3.8

4.7.1. Knowledge of Water Management and the Environment in the Białka River Basin

More than 80% of respondents indicated internet portals as the primary source of knowledge on water management. Radio and television were ranked lower—37%—while the remaining sources did not exceed 35% of all respondents. In their own responses, the respondents most often cited their experience and observation of the environment as the source of knowledge (20 responses—5.3% of all respondents). The survey respondents' knowledge of planning documents was relatively low—63.6% answered that they were not familiar with the planning documents related to water management (Figure 4). Awareness of documents did not exceed 30% of all respondents. Understanding the definition of water management was different—almost 60% of the respondents answered this question correctly, choosing the answer based on the definition of water management from the Water Law Act [52].

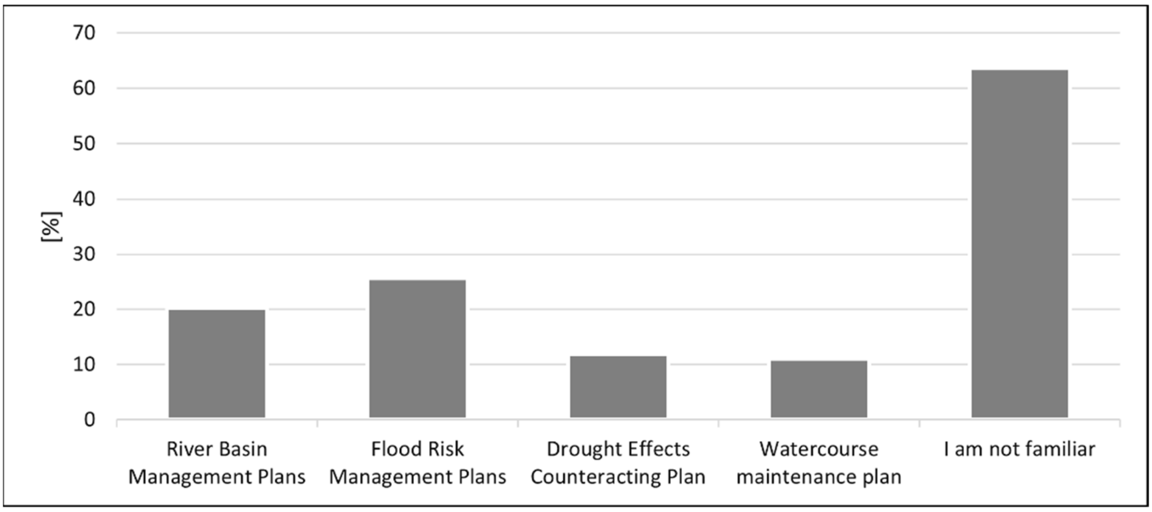

Figure 4. Knowledge of planning documents.

The high percentage (20.5% of respondents) of responses identifying the regulation of rivers and streams with the process of water management is also puzzling. The respondents noticed the variability of the water flow in the Białka River Basin during the year. Overall, 74.1% of people believed that the quantitative status of the waters in the basin had deteriorated. The answer to the question regarding what forms of nature protection exist in the Białka River Basin was quite surprising. Only 15.1% of people indicated the national park (a significant part of the basin is the Polish and Slovak Tatra National Park).

The vast majority (73.6%) pointed to Natura 2000 sites. Almost half of the respondents (49%) pointed to nature reserves and approximately 7.0% replied that they did not know the forms of nature protection in the Białka River Basin. Approximately 12.0% pointed to a landscape park but, in the Białka River Basin, such a form of nature protection does not exist.

4.7.2. Issues in the Białka River Basin

The survey included two questions on the issues surrounding the Białka River Basin and their causes. The number of responses to the questions varied from 330 to 361 for the question concerning the problems and from 288 to 342 for the question related to the causes of the issues. More than one answer was possible for the question, but few respondents made such a choice—in Tables 9 and 10, they are marked as "other". When asked about the issues in the Białka River Basin, the respondents indicated the flood risk and poor quality of water in rivers and streams as huge problems. In both cases, the responses amounted to more than 50% (Table 11). The most frequently cited cause of flood risk issues was the variability of the course of the river bed throughout the year. Subsequently, building on floodplains was mentioned as the cause (Table 12). Although water shortage was not the most crucial problem, many respondents believed that excessive water abstraction for tourist purposes, artificial snowmaking of slopes, and a lack of precipitation were significant causes of issues in the Białka River Basin. More than 40% of respondents identified this issue as very important. For the problem of poor water quality in rivers and streams, the respondents' highlighted the following as essential reasons: discharge of untreated sewage to surface water bodies, lack of sewage system, leaky septic tanks, excessive discharge of untreated sewage during the tourist season. For all four of these reasons, the answer "very important" was chosen by more than 60% of the respondents.

Table 11. Issues related to water in the Białka River Basin.

Scale of the Issue	Flood Risk (n = 361)	Water Shortage (n = 330)	Poor Water Quality in Rivers and Streams (n = 347)
	%		
Huge issue	53.7	14.8	56.2
Big issue	19.7	20.3	25.4
Moderate issue	18.0	37.3	12.7
Very small issue	3.6	15.2	3.2
There is no such issue	2.2	9.4	1.4
Other	2.8	3	1.2

Both questions enabled respondents to enter their own statements. Since the first question concerned the identification of issues in the Białka River Basin, and the second concerned the causes of these issues, respondents gave similar answers to both questions in the "other" category. Therefore, it was decided to group thematically the answers assigned to this category for both questions together. The result of grouping responses was to create eight categories of issues, the order of which was determined based on the most frequent responses among respondents. The results of this analysis are presented in Table 13. The comments included in the "other" category show that "poor water quality" (33.0%) is the most significant issue in the Białka River Basin. Among the other responses of respondents were "riverbed regulations" (18.0%), "formal and legal conditions, education" (14.0%), "digging up gravel and stones from the river bed " (10), and "flood risk" (9.0%). Problems related to "protected areas" (6.0%) and "water abstraction" (2.0%) were the least relevant, according to respondents.

Table 12. Causes of water issues in the Baiłka River Basin.

Cause	Total Number of Responses	Very Important	Important	Moderately Important	Unimportant	Negligible	I Don't Know	Other
	n				%			
Building on floodplains	288	26.4	28.8	18.1	14.2	8.3	2.8	1.3
Variability of the course of the riverbed during the year	342	52.3	21.6	13.5	7.6	2	0.9	2.1
Excessive water abstraction for tourist purposes	305	36.7	18.0	19.0	16.7	8.2	1.0	0.3
Artificial snowmaking of slopes	314	44.9	16.2	17.5	12.7	7.0	1.3	0.3
Discharge of untreated sewage to surface water	328	76.2	13.4	4.3	1.2	1.2	3.0	0.6
No precipitation, drought	297	23.6	30.0	24.6	13.1	5.7	1.7	1.2
No sewage system	333	76.6	12.0	3.6	2.1	1.2	3.6	0.9
Leaky septic tanks	320	64.7	15.9	7.2	3.8	3.4	4.4	0.6
No water supply network	295	41.4	18.0	16.9	9.2	9.5	4.1	1.0
Excessive discharge of sewage during the tourist season	336	76.8	8.6	4.8	2.4	2.1	4.8	0.6

4.7.3. Social Potential

When asked about the local community's interest in maintaining the quality and quantity of water in the Białka River Basin, 36% of respondents said that the local community was very interested in such activities, and 21% stated that this was moderately the case. The remaining 43% responded "Yes, slightly" (25%), "No" (17%), and "I don't know" (1%). In terms of the question regarding the selection of social groups that should be involved in the water management process, representatives of the residents were dominant (88%). Other social groups questioned, i.e., "entrepreneurs" and "representatives of organizations and associations related to nature protection", received 55% and 50% of responses, respectively. When asked about their willingness to cooperate in water management, 53% of respondents expressed their willingness to get involved, 17% stated that they would not like to get involved, while the rest did not have an opinion. In terms of the activities that the respondents wished to undertake, the most dominant was participation in the identification of water quality endangering sites (53%). Meanwhile, 20% wished to be involved in co-organizing training and workshops related to water management, while a similar number wished to help in carrying out measurements (23%), while assistance in the preparation of training and promotional materials was the least popular option.

The final part of the survey concerned entrepreneurs. The number of people who defined themselves as entrepreneurs (110 responses) differed from those who introduced themselves as a person running a business in the river basin at the beginning of the survey (53 people). The first question aimed to identify the possibility of incurring the costs of maintaining the measurement and observation infrastructure to support business activity. The number of affirmative responses was 50%, 21% were not interested in maintaining the measuring devices, and 29% had no opinion. Moreover, among entrepreneurs, 14% answered that they maintained the measurement infrastructure, while 50% of the respondents indicated that they would be willing to incur such costs. The last issue concerned establishing a hierarchy of water users—41% of the responses agreed to the creation of such a structure, while 36% disagreed, and others did not have an opinion.

Table 13. Respondents' own statements.

Issue Category	Description of the Category
Poor water quality	Direct and indirect responses related to poor water quality: • information on discharge of pollutants to surface water/water bodies from tourist centers in Białka Tatrzańska, Bukowina Tatrzańska, and Czarna Góra. • high-temperature water discharge from thermal baths. • illegal discharge of pollutants by residents. • information relating to the broadly understood contamination of the river basin, e.g., garbage and debris removal to the river, landfills along the riverbed. • no sewage system in Białka Tatrzańska.
Riverbed regulation	Responses concerning the issues related to the lack of regulation of the Białka River: • information on the lack of reinforcements of the banks and the river bed in critical places, i.e., in the sections of the river's regular flooding during floods.
Formal and legal conditions, education	Responses on formal, legal, and educational aspects related to the proper understanding of water management: • information on the lack of solutions regarding charges for land taken up by the flood. • improper river basin management, lack of knowledge of water retention, no compromise between the needs of the environment and local communities, improperly functioning administration. • lack of cooperation between the river basin managers and the inhabitants of towns threatened by the river, improper management of financial resources.
Digging up gravel and stones from the river bed	Responses to the illegal digging up of gravel and stones from the Białka river bed and the resulting problems: rising of the river bed due to the accumulation of transported rock material in the downstream river, thus contributing to flooding.
Flood risk	Responses concerning: • information on the frequency of floods and related damage. • activities related to reducing of flood risk, the impact of an anastomosing river on the flood risk.
Other	Responses of respondents that could not be assigned to any of the other categories. The statements were in the form of deliberations, assessments, or statements: • "Why and with whom the Slovaks agreed that they cut off one tributary of this stream" • "Rushing flow" "The problem is people who have nothing to do with our region and are fighting against the regulation of the river, allegedly . . . ".

5. Discussion

The results of the analyses show that the Białka River Basin requires a multifaceted and comprehensive approach to water management. It is an area of interest for many groups of stakeholders due to the region's high natural value. It is a place of residence for many people and, additionally, a zone of development of intensive tourism, both summer and winter. This phenomenon is confirmed by the significant number of water-legal permits granted to tourist facilities. Due to the valuable mountain and river ecosystems in the catchment area, there are many forms of nature protection, including water-oriented ones, which remain an integral part of the water management process in this area. The Białka River, because of its mountainous nature—high flow dynamics and the flood-like nature of the river—affects various aspects of the functioning of the communities associated with the catchment area. Due to the fact that the Białka River Basin is a transboundary area, it may require cooperation between the Polish and the Slovak governments in the future. As Hussein [119] points out, transboundary issues in the context of water resources are a common problem in regions where there are frequent water shortages, and the group of stakeholders at the country level is large. However, the current situation in the management of the Białka River's resources is not of strategic importance for these countries and is not the subject of conflict.

5.1. Water Issues in the Białka River Basin

Analyses of the obtained questionnaire surveys, the information contained in the literature on the subject, and the media indicated that the main risks related to water management in the catchment area are the phenomena of flooding and water pollution. The causes of these problems were most often indicated as inadequately organized water and sewage management and, in the event of flood risk, the variability of the course of the river bed. Much less frequently, the respondents indicated the development of floodplains. The tourist significance of the region means that stakeholders related to the accommodation network, ski slopes, and restaurants have and will have strategic importance in water management in the Białka River Basin. Anthropopressure related to tourism has a negative impact on the quality of the water in the area. Due to the region's attractiveness, it is burdened with a year-round influx of tourists, which also results in an increased supply of sewage to the waters of both Białka and its tributaries. According to the permits, there are sites of discharge of domestic, treated domestic, rainfall, and snowmelt sewage in the catchment area. They are discharged into rivers, streams, or with absorbent wells to the ground. The occurrence of negative phenomena related to inefficient water and sewage management is confirmed by research conducted by A. Lenart Boroń and her team [77–80] in the field of microbiology. They indicate that the water from the treatment plant itself is not sufficiently purified. These studies also confirm the observations of the inhabitants of the Białka River Basin expressed in the survey, as well as the information available in the media. However, it should be remembered that this is a subjective assessment, often of people not involved in water management. The activities of entrepreneurs in the tourism industry now also generate increased water abstraction throughout the catchment area. Abstraction for snowmaking of the ski slopes in Białka Tatrzańska, Bukowina Tatrzańska, Jurgów, and Czarna Góra is becoming particularly significant. Based on the data from the permits, it appears that they can collect in total approximately 0.2 m^3/s (while the minimum flow in the multi-year 2001–2020 in Trybsz is 0.9 L/s—taking into account that this measurement is burdened with the abstractions mentioned above). As in the case of water quality, the location of IMGW-PIB measurement points does not allow for the monitoring of water abstraction because the distance between the stations is too large. However, it should be remembered that the Water Law in pp. 316–320 requires [52] that the method of monitoring the quantitative and qualitative parameters of the abstracted water is specified in the water law consent. Nonetheless, there is no publicly available database that contains data on water abstraction and the quality and quantity of discharged sewage. As a result, there is no information flow in this regard between the stakeholders. As a consequence, those who abstract water for snowmaking also do not know its quality parameters.

Due to the increase in the number of permits issued for the abstraction of surface waters (four permits have been issued for snowmaking of ski slopes since 2010—a two-times increase compared to previous years), the uncertainty of the results obtained from the above-mentioned measurement networks is also increasing. Climate change analyses do not clearly indicate an increase or decrease in water resources. In the Białka River Basin, a change in the precipitation structure is expected during the year. It will increase the time uncertainty, which may necessitate appropriate adaptation measures. The climatic scenarios for the southern regions of Poland indicate an increase in rainfall at the expense of snowfall, which may disrupt the river's natural regime and water availability in different seasons of the year. At the same time, the divergent results of climate models in terms of the various components of the water balance indicate that they are fraught with uncertainty, which significantly hinders the development of an appropriate water management strategy. Many authors point out that the uncertainty of climate projections is an important challenge for entities responsible for managing various areas of life, including water resources [120–125]. This uncertainty hampers policy-making, reduces public and management confidence in research results, and may increase investment costs. Moreover, according to Refsgaard et al. [126], uncertainty is a major obstacle to the efficient management of water resources and a key obstacle to the development of adaptation measures.

5.2. Barriers to Water Management in the Białka River Basin

5.2.1. Involving Stakeholders

It should be emphasized that even the full availability of data and the full ability to forecast changes in the aquatic environment are not enough to ensure the correctness of the water management process. It requires a socialization aspect of the decision-making process by ensuring stakeholder participation. This is a challenging task that requires involved stakeholders to influence different elements of the decision-making process in line with the common objective of adequate water management, taking into account needs, uncertainties, and conflicts [127,128]. It is crucial to move from imposing optimal solutions developed by experts to supporting experts in developing appropriate solutions considering stakeholders [129]. Public consultation in Sweden showed that the public was interested in participating in the water management process [130]. However, non-expert stakeholders indicated that they were overwhelmed by an overload of information and expressed doubts as to whether they should be involved at all phases of the process due to a poor level of knowledge. Moreover, many of them indicated that they would be more willing to engage in the problems of "their own backyard" than the entire catchment area, the impact of which on their lives they do not see. In the Białka River Basin, social potential in terms of willingness to participate in the water management process was also observed as a result of the survey. At least half of the respondents were interested in participating. As with the Swedish consultations, respondents claimed that they would prefer to be involved in local issues such as the localization of sources of pollution, while participatory activities, such as cooperation in the information exchange process, aroused much less interest among them. It is worth noting that, in the studies by Jacobs et al. [131], it is confirmed that positive effects of these activities can be observed, especially in terms of consensus building and conflict resolution in the catchment areas of Mexico, the USA, Brazil, and Thailand, where stakeholders were involved in the water management process. At the same time, the authors note that participatory processes generate huge financial and time costs.

5.2.2. Dialogue and Knowledge

Nevertheless, given the respondents' interest in participation, it can be assumed that implementing this type of management would improve the quality of water management processes in the Białka River Basin. Social participation allows for the development of thoughtful, open solutions that consider the change in knowledge concerning the water system in the future. The need to implement a new management model in the Białka River Basin is also reflected in the low communication assessment between stakeholders. Both the survey results and the literature query indicate that, currently, in the Białka River Basin, there is no proper dialogue between the public administration, stakeholders using water, and the inhabitants of the catchment area. This is reflected in a social sense of poor resource management (both in media reports and the survey, there are accusations that water management is insufficiently conducted). The implementation of a participatory management model would facilitate the flow of information and make stakeholders aware of the difficulties in reconciling all sides of the issues. These communication problems also translate into the level of knowledge. The survey results partially confirm this. Every fifth respondent believed that water management is based on the regulation of rivers and streams. Although the respondents perceived the river's variability throughout the year, they did not know about the forms of nature protection in the catchment area or about planning documents related to water management. Respondents also identified the internet as their main source of knowledge. The PGW WP is responsible for disseminating information on water management, whose principal medium of communication is the website www.wody.gov.pl (accessed on 15 October 2021). By analyzing the respondents' responses, it was found that the existing methods of communication used by public institutions do not meet the needs of society.

A worrying phenomenon is the increasing negative assessment of the Natura 2000 program and legal regulations in environmental protection, particularly regarding flood protection. In many cases, the respondents perceived nature protection as a tool for the unfounded repression of the local inhabitants. The situation is aggravated by the fact that the responsible institutions are unable to implement the assumptions of the environmental protection program, taking into account the needs of the inhabitants of the Białka River Basin (in particular, the Nowa Biała and Krempachy regions). This points to an imperfection in the functioning of the water management process (especially in terms of communication and knowledge transfer), which is intended to ensure the common interest of the whole of society. According to the inhabitants, the strong and fast current of the Białka River, during heavy rainfall, brings huge amounts of rubble, which causes the bed's grade line to rise continuously. Presumably, the grade line has been increased in some places by at least 2 m for 80 years, and thus the Białka river bed, in some sites, reaches 200–250 m wide [91].

In the survey and media reports, people associated with the region indicated that the most appropriate solution is artificially deepening the river bed and building flood embankments. Significantly, such activities would lead to the destruction of the unique character of the Białka River Basin, and, from a broader perspective, it would not improve flood safety. This problem reveals the low level of knowledge of society—in this case with regard to the development of the river bed and natural floodplain terraces. At the same time, a certain contradiction appeared in the results of the survey. Some respondents expressed a desire to deepen the riverbed on their own, while a large group indicated that one of the area's problems is the digging up of gravel and stones from the Białka River's bed. This is defined as an unequivocally negative phenomenon. There are also no legal permits for this type of activity in the catchment area. Flood risk is a sphere where the poor quality of communication plays a very negative role. Residents do not know which public administration bodies they should address. They acquire knowledge about flood protection from uncertain sources, which often do not consider the broader perspective. One example is the perception of an anostomotic river bed as a flood risk factor. This leads to conflicts between the residents, the administration, and organizations dealing with nature protection. Purkey et al. [132] indicate that conflicts of stakeholder needs and different perceptions of reality are premises for implementing a participatory management model. This is one of the more complex elements of the process because reaching a consensus is long and arduous. It is impossible to satisfy all parties to the conflict entirely. Furthermore, developing optimal solutions through social participation requires a willingness to cooperate, thoughtful and reasonable actions, precise and efficient communication, and the building of positive relations based on respect between stakeholders [129]. An essential element of this model is the exchange of knowledge and information, which is most effective through social learning, which is crucial for initiating changes and building and maintaining water management systems' adaptive capacity [133]. Effective social learning leads to new knowledge, a common understanding of the processes taking place in the environment, the transparent exchange of information between stakeholders, and increased trust in the managing authorities [134]. As a result, there is a change in practices and behaviors, the system of values is restructured, institutional changes take place, and the policy is adapted to the needs of the water management process.

5.2.3. Policy

The wide range of stakeholders and barriers and conflicts related to the management of water resources in the Białka River Basin requires the implementation of appropriate operational rules. It is worth noting that despite the low level of knowledge in nature protection forms and planning documents, a significant percentage of respondents were interested in cooperating in the development of the water management process, especially in identifying the risks and issues related to water resources. This potential can be used to implement the IWRM's principles in the studied area. IWRM's objectives are complementary at the national level, river basin level, and sub-basin levels [135]. It is optimal in this respect to achieve such a balance in activities that support the IWRM process from all parties involved. A holistic, integrated objective means that all aspects of water management, soil maintenance, spatial planning, land use, agriculture, transport, urban development, and nature conservation should be considered at the appropriate scale and administrative level [136]. Within a river basin or sub-basin, the integration of water management with spatial planning is not an easy process because aspects of spatial planning are related to, among others, agriculture, urban policy, transport, and industry, supervised by various administrations guided by their own policies [137]. Depending on the level of activities in the IWRM, three levels can be distinguished. At a local level, problems in the catchment area, water supply, and water protection plans are analyzed. Second, the implementation level covers the river basin scale or a separate administrative unit. Third, the political level is where national and international problems are resolved, and legislation is created to regulate water management issues. This requires the creation of an appropriate management structure with a network of connections, which will include public structures, including ministry offices responsible for water management in a strategic dimension; organizations, agreements, and agencies operating at the river basin level or its parts; local authorities and local governments; associations of communes and catchment unions; associations of water users; and non-governmental organizations. The local level is mainly responsible for the practical implementation of all measures while being their direct beneficiaries. At this level, the real, local problems of water management are known. The local level should form the IWRM based on the correlation between two complementary activity groups [138]. The first group should focus on the development of natural resources to ensure, among others, economic development, while the second group includes activities in the field of resource management, protection, and restoration. Both groups of activities require the participation and interaction of the operational level (users and society) to ensure balance and correctness in the management process. Given the numerous identified areas of uncertainty in water management in the Białka River Basin and the low level of public knowledge about the water management process, it seems that a necessary complement is the implementation of the Adaptive Water Management (AWM) principles into the IWRM. The AWM rules aim to build a resilient management system based on always incomplete information about the system, considering the uncertainty of its results [139]. AWM considers the complexity of the managed systems and the limitations in anticipating and controlling them. It assumes a comprehensive approach to all issues and the relations between them. The key tool for developing AWM is social learning, which should include the cooperation and exchange of knowledge of laypeople with experts and scientists, developing an understanding of key issues related to water resource management. AWM strives to build capacity through training and information distribution at every stage of the management process and shape stakeholders' conscious attitudes in the water resource management process. Properly built public awareness is intended to help broaden knowledge of the system and reduce uncertainty. From this perspective, AWM ensures greater resistance to unexpected and uncontrolled conditions in the system, reducing the negative environmental impact of its activities, building and strengthening the dialogue between stakeholders and area managers, including building positive communication relationships. Considering the barrier to the development of adequate water resource management, which is the low level of knowledge and measurement uncertainty, the AWM concept is probably the best way to achieve balance, resolve conflicts, and deal with the low spatial resolution of measurement networks and the uncertainty of climate projections for the Białka River Basin.

Both the IRWM and AWM need to develop an appropriate legal framework that will support the transition of all management stages to a local scale. Do the changes to the Water Law introduced in Poland in 2018 create the conditions for such support? The Act, in its current form, has maintained an opinion-making and advisory body at the national level as the State Water Management Council. It is of strategic importance, and its role is mainly based on issuing opinions on strategic documents or formal and legal solutions on a national scale. The water region councils have been abolished, and advisory committees have been proposed instead. Pursuant to Article 250 para. 1 of the above Act, the President of Polish Waters appoints consultative committees as opinion-making and advisory teams composed of governors, voivodeship marshals, representatives of the local government of the Joint Government and Local Government Commission, and directors of inland navigation offices. These committees are established for one or more water regions. However, is such a solution sufficient from a local point of view? Certainly not, because the act should also allow for the formal appointment of river basin committees and their operation at the local level, which is significant because of the aforementioned interactions. Thus, it is a barrier to the implementation of both IWRM and AWM. Table 14 shows how the current legal framework in Poland fits into the IWRM concept. The ideas of the concept are reflected at the political and implementation level. The legislation has the appropriate solutions here. On the other hand, the problem is the local level, theoretical assumptions of which are presented in the table, and which, in the current legislation, has not been defined (except for the spatial development plan). Local stakeholders, such as inhabitants and entrepreneurs associated with the Białka River Basin, are not included in the water management process. Their only tool is applications and petitions to the public administration managing the catchment area. The local level is crucial for AWM. The implementation of social learning must involve the exchange of knowledge between all stakeholders. Moreover, there are conceptual inconsistencies in the current Water Law, which make it difficult to understand the issue of water resource management. According to the first article of the current Water Law (in p. 1) [52], water management consists of water resource management, water development and protection, and water use. On the other hand, Article 10 of the Water Law (in p. 3) defines the following elements of water resource management: meeting the needs of the population and economy, the protection of waters, and the protection of the environment associated with these resources [52]. The emerging inconsistencies and lack of appropriate tools in the Water Law are some of the main barriers to the implementation of AWM, as well as IWRM. This is a basic problem, but the fragmentation of the management stages into many stages will generate further issues that the current legislation cannot minimize. For example, Saravanan et al. [140] indicate that although the decentralization of management is necessary, there is a particular risk of uncontrolled behavior, such as unfair selection of stakeholders for political reasons. It also confirms that a significant obstacle to engaging society in the water management process in many countries is unfavorable legal solutions that do not provide tools for building social participation.

Table 14. A concpetual framework for catchment management in the context of IWRM for the Białka River Basin.

Assumption/Premises of IWRM	Political Level	Implementation Level	Local Level
The type of river basin organization	International River Basin Committee	PGW WP National Water Management Board, regional water management boards, committees, associations, etc.	Local group, an association of communes, catchment union, the association of catchment users
Strategies and plans for the river basin	Agreement for the international catchment, management plan	River basin management plan	Local water plan, land use plan, local water and sewage management plan, local flood and drought protection plan
Decision-making level	Highest political level	Voivodeship, district, commune	Local administration, user associations, producer associations
The existing system of natural resources	A delimited geographical area, river basin, or part thereof, lake	A regional ecological system, catchment, groundwater reservoir, aquifer	Areas with relatively uniform ecological and hydrological conditions

6. Conclusions

The water resource management in the Białka River Basin is facing many difficulties. The most significant are river basin issues such as flood risk and water pollution, and, to a lesser extent, the risk of water scarcity. The causes of these problems are complex. They result from natural conditions (the seasonal variability of the hydrological regime of the Białka River, the flood-like nature of the river) and anthropogenic conditions (intense tourist pressure resulting in excessive discharge of municipal sewage and increasing water abstraction). The low emphasis on education in terms of water management results, among others, in the emergence of conflicts between the stakeholders and institutions responsible for water resource management. The low level of knowledge also leads to a considerable diversification of attitudes towards current methods of nature protection, and, in some cases, a strongly anthropocentric approach, especially in terms of the area's flood safety. Poor communication between stakeholders is the cause of, and, at the same time, the solution to this issue. The hydrological and socio-economic complexity of the river basin requires appropriate management methods such as IWRM, which will strive to preserve the unique value of the area, taking into account the needs of its inhabitants. Due to the low level of knowledge, high uncertainty of forecasts of changes in water resources, and uncertainty of measurements, the Białka River Basin needs a solution that will focus on the social aspects of management in order to reduce the negative effects of the uncertainty of system elements. The AWM seems to be the answer to these needs, which emphasizes social learning and knowledge exchange in adapting to changes in the water and economic system. In order for IWRM and, in the broader context, for AWM to be able to exist at all levels within the river basin, appropriate legislation is necessary. The current legal framework in Polish law covers the political and implementation level at the public administration level. However, at the local level, which is crucial for AWM, there is no defined framework for action and functioning in the context of developing the water management process.

Author Contributions: Conceptualization, M.B., T.W., M.S., M.Ż.; Methodology, M.B., T.W., M.S., M.Ż.; Software, M.B., T.W., M.S., M.Ż.; Validation, M.B., T.W., M.S., M.Ż.; Formal Analysis, M.B., T.W., M.S., M.Ż.; Investigation, M.B., T.W., M.S., M.Ż.; Resources, M.B., T.W., M.S., M.Ż.; Data Curation, M.B., T.W., M.S., M.Ż.; Writing—Original Draft Preparation, M.B., T.W., M.S., M.Ż.; Writing—Review and Editing, M.B., T.W., M.S., M.Ż.; Visualization, M.B., T.W., M.S., M.Ż.; Supervision, M.B., T.W.; Project Administration, T.W.; Funding Acquisition, T.W. All authors have read and agreed to the published version of the manuscript.

Funding: Subsidy from the Minister of Education and Science, Government of Poland. Project DS-6, 2021 "Adaptive planning and management of water resources in the light of climate change".

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Vörösmarty, C.J. Global water assessment and potential contributions from Earth Systems Science. *Aquat. Sci.* **2002**, *64*, 328–351. [CrossRef]
2. Vörösmarty, C.J.; McIntyre, P.B.; Gessner, M.O.; Dudgeon, D.; Prusevich, A.; Green, P.; Glidden, S.; Bunn, S.E.; Sullivan, C.A.; Reidy Liremann, C.; et al. Global Threats to Human Water Security and River Biodiversity. *Nature* **2010**, *467*, 555–561. [CrossRef]
3. Parish, E.S.; Kodra, E.; Steinhaeuser, K.; Ganguly, A.R. Estimating Future Global per Capita Water Availability Based on Changes in Climate and Population. *Comput. Geosci.* **2012**, *42*, 79–86. [CrossRef]

4. Vörösmarty, C.J. Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science* **2000**, *289*, 284–288. [CrossRef]
5. Kundzewicz, Z.W.; Mata, L.J.; Arnell, N.W.; Döll, P.; Jimenez, B.; Miller, K.; Oki, T.; Şen, Z.; Shiklomanov, I. The implications of projected climate change for freshwater resources and their management. *Hydrol. Sci. J.* **2008**, *53*, 3–10. [CrossRef]
6. Pachauri, R.K.; Allen, M.R.; Barros, V.R.; Broome, J.; Cramer, W.; Christ, R.; Church, J.A.; Clarke, L.; Dahe, Q.; Dasgupta, P.; et al. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Intergovernment Panel on Climate Change (IPCC): Geneva, Switzerland, 2014.
7. Azhoni, A.; Holman, I.; Jude, S. Adapting water management to climate change: Institutional involvement, inter institutional networks and barriers in India. *Glob. Environ. Chang.* **2017**, *44*, 144–157. [CrossRef]
8. Dai, A.; Trenberth, K.E.; Qian, T. A global dataset of Palmer Drought Severity Index for 1870–2002: Relationship with soil moisture and effects of surface warming. *J. Hydrometeorol.* **2004**, *5*, 1117–1130. [CrossRef]
9. Sivakumar, M.V.K. Agricultural Drought—WMO Perspectives. In *Agricultural Drought Indices, Proceedings of the Expert Meeting, Murcia, Spain, 2–4 June 2010*; Sivakumar, M.V.K., Motha, R.P., Wilhite, D.A., Wood, D.A., Eds.; World Meteorological Organization: Geneva, Switzerland, 2011; pp. 22–34.
10. Sheffield, J.; Wood, E.F.; Roderick, M.L. Little change in global drought over the past 60 years. *Nature* **2012**, *491*, 435–438. [CrossRef]
11. Spinoni, J.; Naumann, G.; Carrao, H.; Barbosa, P.; Vogt, J. World drought frequency, duration, and severity for 1951–2010. *Int. J. Climatol.* **2014**, *34*, 2792–2804. [CrossRef]
12. Gustafson, E.J.; Sturtevant, B.R. Modeling forest mortality caused by drought stress: Implications for climate change. *Ecosystems* **2013**, *16*, 60–74. [CrossRef]
13. Ghimire, Y.N.; Shivakoti, G.P.; Perret, S.R. Household-level vulnerability to drought in hill agriculture of Nepal: Implications for adaptation planning. *Int. J. Sustain. Dev. World Ecol.* **2010**, *17*, 225–230. [CrossRef]
14. Udmale, P.D.; Ichikawa, Y.; Kiem, A.S.; Panda, S.N. Drought impacts and adaptation strategies for agriculture and rural livelihood in the Maharashtra State of India. *Open Agric. J.* **2014**, *8*, 41–47. [CrossRef]
15. Sugg, M.; Runkle, J.; Leeper, R.; Bagli, H.; Golden, A.; Handwerger, L.H.; Magee, T.; Moreno, C.; Reed-Kelly, R.; Taylor, M.; et al. A scoping review of drought impacts on health and society in North America. *Clim. Chang.* **2020**, *162*, 1177–1195. [CrossRef]
16. Mehta, L. Whose scarity? Whose property? The case of water in western India. *Land Use Policy* **2007**, *24*, 654–663. [CrossRef]
17. Petersen-Perlman, J.D.; Veilleux, J.C.; Wolf, A.T. International water conflict and cooperation: Challenges and opportunities. *Water Int.* **2017**, *42*, 105–120. [CrossRef]
18. Ahmed, S.A.; Hoque, B.A.; Mahmud, A. Water management practices in rural and urban homes: A case study from Bangladesh on ingestion of polluted water. *Public Health* **1998**, *112*, 317–321. [CrossRef]
19. Ashraf, M.A.; Maah, M.J.; Yusoff, I.; Mehmood, K. Effects of polluted water irrigation on environment and health of people in Jamber, District Kasur, Pakistan. *Int. J. Basic Appl. Sci.* **2010**, *10*, 37–57.
20. Cazcarro, I.; López-Morales, C.A.; Duchin, F. The global economic costs of the need to treat polluted water. *Econ. Syst. Res.* **2016**, *28*, 295–314. [CrossRef]
21. Hussein, H.; Menga, F.; Greco, F. Monitoring Transboundary Water Cooperation in SDG 6.5.2: How a Critical Hydropolitics Approach Can Spot Inequitable Outcomes. *Sustainability* **2018**, *10*, 3640. [CrossRef]
22. Marsalek, J. Overview of flood issues in contemporary water management. In *Flood Issues in Contemporary Water Management*; NATO Science Series: Series 2, Environment Seciurity; Marsalek, J., Watt, W.E., Zeman, E., Sieker, F., Eds.; Springer: Dordrecht, The Netherlands, 2000; Volume 71, pp. 1–16. [CrossRef]
23. Zhang, S.; Li, Y.; Ma, M.; Song, T.; Song, R. Storm water management and flood control in sponge city construction of Beijing. *Water* **2018**, *10*, 1040. [CrossRef]
24. Huntjens, P.; Pahl-Wostl, C.; Rihoux, B.; Schlüter, M.; Flachner, Z.; Neto, S.; Koskova, R.; Dickens, C.; Nabide Kiti, I. Adaptive water management and policy learning in a changing climate: A formal comparative analysis of eight water management regimes in Europe, Africa and Asia. *Environ. Pol. Gov.* **2011**, *21*, 145–163. [CrossRef]
25. Martínez-Santos, P.; Varela-Ortega, C.; Hernández-Mora, N. Making Inroads Towards Adaptive Water Management Through Stakeholder Involvement, the NeWater Experience in the Upper Guadiana basin, Spain. In Proceedings of the International Conference on Adaptive and Integrated Water Management (CAIWA), Basel, Switzerland, 12–15 November 2007.
26. King, A.B.; Thornton, M. Staying the course: Collaborative modeling to support adaptive and resilient water resource governance in the Inland Northwest. *Water* **2016**, *8*, 232. [CrossRef]
27. Mutahara, M.; Warner, J.F.; Wals, A.E.; Khan, M.S.A.; Wester, P. Social learning for adaptive delta management: Tidal River Management in the Bangladesh Delta. *Int. J. Water Resour. Dev.* **2018**, *34*, 923–943. [CrossRef]
28. Tran, T.A.; Pittock, J.; Tuan, L.A. Adaptive co-management in the Vietnamese Mekong Delta: Examining the interface between flood management and adaptation. *Int. J. Water Resour. Dev.* **2019**, *35*, 326–342. [CrossRef]
29. McLoughlin, C.A.; Thoms, M.C.; Parsons, M. Reflexive learning in adaptive management: A case study of environmental water management in the Murray Darling Basin, Australia. *Riv. Res. Appl.* **2020**, *36*, 681–694. [CrossRef]
30. Mysiak, J.; Henrikson, H.J.; Sullivan, C.; Bromley, J.; Pahl-Wostl, C. *The Adaptive Water Resource Management Handbook*; Routledge: London, UK, 2010; pp. 17–32. [CrossRef]

31. Meran, G.; Siehlow, M.; von Hirschhausen, C. Integrated Water Resource Management: Principles and Applications. In *The Economics of Water: Rules and Institutions.*; Springer International Publishing: Cham, Switzerland, 2021; pp. 23–121. [CrossRef]
32. The Need for an Integrated Approach. 2020. Available online: https://www.gwp.org/en/About/why/the-need-for-an-integrated-approach/ (accessed on 26 August 2021).
33. Akhmouch, A.; Clavreul, D. Stakeholder Engagement for Inclusive Water Governance: "Practicing What We Preach" with the OECD Water Governance Initiative. *Water* **2016**, *8*, 204. [CrossRef]
34. Dillon, P.; Bellchambers, R.; Meyer, W.; Ellis, R. Community perspective on consultation on urban stormwater management: Lessons from Brownhill Creek, South Australia. *Water* **2016**, *8*, 170. [CrossRef]
35. Mott Lacroix, K.E.; Megdal, S.B. Explore, synthesize, and repeat: Unraveling complex water management issues through the stakeholder engagement wheel. *Water* **2016**, *8*, 118. [CrossRef]
36. Megdal, S.B.; Eden, S.; Shamir, E. Water governance, stakeholder engagement, and sustainable water resources management. *Water* **2017**, *9*, 190. [CrossRef]
37. Van der Keur, P.; Lloyd, J.G. Integrated Water Resources Management (IWRM). In *Adaptive Water Resource Management Handbook*; Mysiak, J., Henrikson, J.H., Sullivan, C., Bromley, J., Pahl-Wostl, C., Eds.; Earthscan: London, UK, 2010; pp. 4–6.
38. Mehta, L.; Movik, S.; Bolding, A.; Derman, B.; Manzungu, E. Introduction to the Special Issue: Flows and practices—The politics of Integrated Water Resources Management (IWRM) in southern Africa. *Water Altern.* **2016**, *9*, 389–411.
39. Allouche, J. The birth and spread of IWRM—A case study of global policy diffusion and translation. *Water Altern.* **2016**, *9*, 412–433.
40. Michalak, D. Adapting to climate change and effective water management in Polish agriculture—At the level of government institutions and farms. *Ecohydrol. Hydrobiol.* **2020**, *20*, 134–141. [CrossRef]
41. McMillan, H.K.; Westerberg, I.K.; Krueger, T. Hydrological Data Uncertainty and Its Implications. *WIREs Water* **2018**, *5*, e1319. [CrossRef]
42. Sordo-Ward, Á.; Granados, I.; Martín-Carrasco, F.; Garrote, L. Impact of Hydrological Uncertainty on Water Management Decisions. *Water Resour. Manag.* **2016**, *30*, 5535–5551. [CrossRef]
43. Loch, A.; Adamson, D.; Mallawaarachchi, T. Role of Hydrology and Economics in Water Management Policy under Increasing Uncertainty. *J. Hydrol.* **2014**, *518*, 5–16. [CrossRef]
44. Pandey, C.L.; Bajracharya, R.M. Climate adaptive water management practices in small and midsized cities of Nepal: Case studies of Dharan and Dhulikhel. *Sustain. J. Rec.* **2017**, *10*, 300–307. [CrossRef]
45. Cosens, B.; Brian, C.; Chaffin, B.C. Adaptive Governance of Water Resources Shared with Indigenous Peoples: The Role of Law. *Water* **2016**, *8*, 97. [CrossRef]
46. Casiano Flores, C.; Vikolainen, V.; Bressers, H. Water governance decentralisation and river basin management reforms in hierarchical systems: Do they work for water treatment policy in Mexico's Tlaxcala Atoyac Sub-basin? *Water* **2016**, *8*, 210. [CrossRef]
47. Rouillard, J.J.; Spray, C.J. Working across scales in integrated catchment management: Lessons learned for adaptive water governance from regional experiences. *Reg. Environ. Chang.* **2017**, *17*, 1869–1880. [CrossRef]
48. Ashofteh, P.S.; Bozorg-Haddad, O.; Loáiciga, H.A. Role of adaptive water resources management policies and strategies in relieving conflicts between water resources and agricultural sector water use caused by climate change. *J. Irrig. Drain. Eng.* **2017**, *143*, 02516004. [CrossRef]
49. Pahl-Wostl, C. Adaptive and sustainable water management: From improved conceptual foundations to transformative change. *Int. J. Water Resour. Dev.* **2020**, *36*, 397–415. [CrossRef]
50. Derepasko, D.; Peñas, F.J.; Barquín, J.; Volk, M. Applying Optimization to Support Adaptive Water Management of Rivers. *Water* **2021**, *13*, 1281. [CrossRef]
51. Pahl-Wostl, C.; Craps, M.; Dewulf, A.; Mostert, E.; Tabara, D.; Taillieu, T. Social learning and water resources management. *Ecol. Soc.* **2007**, *12*, 5. [CrossRef]
52. Act of 20 July 2017, Water Law (Journal of Laws 2017, Item 1566). Available online: http://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20170001566/U/D20171566Lj.pdf (accessed on 15 October 2021).
53. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000, Establishing a Framework for Community Action in the Field of Water Policy. Available online: https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF (accessed on 15 October 2021).
54. Kubiak-Wójcicka, K.; Machula, S. Influence of climate changes on the state of water resources in Poland and their usage. *Geosciences* **2020**, *10*, 312. [CrossRef]
55. Więckowski, M. Tourism development in the borderlands of Poland. *Geogr. Pol.* **2010**, *83*, 67–81. [CrossRef]
56. Mapa Podziału Hydrograficznego Polski w Skali 1:10 000 (MPHP10k), Państwowe Gospodarstwo Wodne Wody Polskie. Available online: https://dane.gov.pl/pl/dataset/2167,mapa-podzialu-hydrograficznego-polski-w-skali-110 (accessed on 15 October 2021).
57. Kulesza, K.; Woźniak, Ł.; Walczykiewicz, T. Czynniki Determinujące Funkcjonowanie Korytarza Ekologicznego Doliny Białki na tle Możliwych Zmian Klimatu. In *Nauka Tatrom, Tom III—Człowiek i Środowisko*; Chrobak, A., Zwijacz-Kozica, T., Eds.; Wydawnictwa Tatrzańskiego Parku Narodowego: Zakopane, Poland, 2015; pp. 79–88.

58. Wrzesiński, D. Identyfikacja cech reżimu odpływu rzek w Polsce na różnych poziomach grupowania. *Bad. Fizjogr.* **2017**, *68*, 265–278. [CrossRef]
59. SDF of the Natura 2000 Białka River Valley. Available online: http://n2k-ws.gdos.gov.pl/wyszukiwarkaN2k/webresources/pdf/PLH120024 (accessed on 29 October 2021).
60. Hełdak, M. Rzeka Białka w krajobrazie wsi podhalańskiej. *Archit. Kraj.* **2010**, *2*, 39–46.
61. Commission Decision of 12 December 2008, Adopting, Pursuant to Council Directive 92/43/EEC, a Second Updated List of Sites of Community Importance for the Alpine Biogeographical Region, (2009/91/EC). Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:043:0021:0058:EN:PDF (accessed on 15 October 2021).
62. Council Directive 92/43/EEC of 21 May 1992, on the Conservation of Natural Habitats and of Wild Fauna and Flora. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0043&from=PL (accessed on 15 October 2021).
63. Bożek, K. Jak Udrożnić Rezerwat. Dzikie Życie 3/177. 2009. Available online: https://dzikiezycie.pl/archiwum/2009/marzec-2009/jak-udroznic-rezerwat (accessed on 29 October 2021).
64. Kondracki, J. *Geografia Regionalna Polski*; Wydawnictwo Naukowe PWN: Warsaw, Poland, 2002.
65. Solon, J.; Borzyszkowski, J.; Bidłasik, M.; Richling, A.; Badora, K.; Balon, J.; Brzezińska-Wójcik, T.; Chabudziński, Ł.; Dobrowolski, R.; Grzegorczyk, I.; et al. Physico-geographical mesoregions of Poland: Verification and adjustment of boundaries on the basis of contemporary spatial data. *Geogr. Pol.* **2018**, *91*, 143–170. [CrossRef]
66. Copernicus Land Monitoring Service, CORINE Land Cover (CLC). 2018. Available online: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018 (accessed on 22 October 2021).
67. Statistics Poland (GUS), Local Data Bank. 2021. Available online: https://bdl.stat.gov.pl/BDL/start (accessed on 15 October 2021).
68. Krąż, P. Problemy w zarządzaniu systemem krajobrazowym Doliny Białki. *Probl. Ekol. Kraj.* **2012**, *33*, 229–234.
69. Krzesiwo, K.; Mika, M. Ocena atrakcyjności turystycznej stacji narciarskich w świetle zagadnienia ich konkurencyjności-studium porównawcze Szczyrku i Białki Tatrzańskiej. *Prace Geogr.* **2011**, *125*, 95–110.
70. Kruczek, Z. Wykorzystanie Wód Geotermalnych w Polsce w Celach Rekreacyjnych i Uzdrowiskowych. Studium Przypadku-Białka Tatrzańska. In *Wybrane Aspekty Zarządzania Zakładem Uzdrowiskowym*; Szromek, A., Ed.; Proksenia: Kraków, Poland, 2016; pp. 157–173.
71. Duda, E.; Ziaja, W. Wpływ turystyki i rekreacji na środowisko przyrodnicze i krajobraz białki tatrzańskiej. *Problemy Ekol. Kraj.* **2010**, *27*, 131–140.
72. Heldak, M.; Szczepanski, J. Wpływ rozwoju turystyki na transformację krajobrazu wsi Białka Tatrzańska. *Infrastrukt. I Ekol. Teren. Wiej.* **2011**, *1*, 151–161.
73. Janecka, K.; Lempa, M.; Czajka, B. Przyczyny i Skutki Powodzi w Tatrach i Na Podhalu. In *Z Badań Nad Wpływem Antropopresji na Środowisko*; Machowski, R., Rzętała, M.A., Eds.; Studenckie Koło Naukowe Geografów UŚ, Wydział Nauk o Ziemi UŚ: Sosnowiec, Poland, 2014; Volume 15, pp. 111–119.
74. Tatra National Park—Online Ticket Website. Available online: https://tpn.pl/zwiedzaj/e-bilety (accessed on 22 October 2021).
75. Stępień, K. Małopolskie Interesuje Turystów Najbardziej. Available online: https://www.nocowanie.pl/malopolskie-interesuje-turystow-najbardziej.html (accessed on 22 October 2021).
76. Ferie Zimowe 2019 w Polsce—Raport Nocowanie.pl. Available online: https://www.nocowanie.pl/ferie-zimowe-2019-w-polsce--raport-nocowanie-pl.html (accessed on 22 October 2021).
77. Lenart-Boroń, A.; Wolanin, A.; Jelonkiewicz, Ł.; Chmielewska-Błotnicka, D.; Żelazny, M. Spatiotemporal variability in microbiological water quality of the Białka River and its relation to the selected physicochemical parameters of water. *Water Air Soil Pollut.* **2016**, *227*, 1–12. [CrossRef]
78. Bojarczuk, A.; Jelonkiewicz, Ł.; Lenart-Boroń, A. The effect of anthropogenic and natural factors on the prevalence of physicochemical parameters of water and bacterial water quality indicators along the river Białka, southern Poland. *Environ. Sci. Pollut. Res.* **2018**, *25*, 10102–10114. [CrossRef]
79. Lenart-Boroń, A.; Prajsnar, J.; Krzesiwo, K.; Bojarczuk, A.; Jelonkiewicz, Ł.; Jelonkiewicz, E.; Żelazny, M. Diurnal variation in the selected indicators of water contamination in the Białka river affected by a sewage treatment plant discharge. *Fresenius Environ. Bull.* **2016**, *25*, 5271–5279.
80. Lenart-Boroń, A.; Prajsnar, J.; Guzik, M.; Boroń, P.; Chmiel, M. How much of antibiotics can enter surface water with treated wastewater and how it affects the resistance of waterborne bacteria: A case study of the Białka river sewage treatment plant. *Environ. Res.* **2020**, *191*, 110037. [CrossRef]
81. Program Państwowego Monitoringu Środowiska Województwa Małopolskiego na lata 2016–2020. WIOŚ, Kraków, Poland, 2015. Available online: http://www.krakow.pios.gov.pl/Press/monitoring/pms/wpms_2016_2020.pdf (accessed on 22 October 2021).
82. Kuraś, B. Białka Tatrzańska. Turystów Przybywa, a Kanalizacji Jak Nie było, Tak Nie Ma. Trza Skończyć z Tym Szambem". 2020. Available online: https://krakow.wyborcza.pl/krakow/7,44425,25782184,trza-skonczyc-z-tym-szambem.html (accessed on 15 October 2021).
83. Będzie Oczyszczalnia, Kanalizacja i Nowa Droga. 2021. Available online: https://podhale24.pl/aktualnosci/artykul/75699/Bedzie_oczyszczalnia_kanalizacja_i_nowa_droga.html (accessed on 15 October 2021).
84. Starmach, P. Podhalański Śmierdzący Problem. Turystów Przybywa, Sieci Kanalizacyjnej Nie Ma. 2021. Available online: https://zakopane.wyborcza.pl/zakopane/7,179294,27098979,podhalanski-smierdzacy-problem-turystow-przybywa-sieci-kanalizacyjnej.html (accessed on 15 October 2021).

85. Podhale. Kiedy Ruszy Budowa Kanalizacji w Białce Tatrzańskiej? 2020. Available online: https://gazetakrakowska.pl/podhale-kiedy-ruszy-budowa-kanalizacji-w-bialce-tatrzanskiej/ar/c15-14888421 (accessed on 15 October 2021).
86. Zubek, A. Białka Tatrzańska na Kanalizację Musi Poczekać Do 2027 Roku? Pytamy w Gminie. 2021. Available online: https://podhaleregion.pl/index.php/z-podhala/33168-bialka-tatrzanska-na-kanalizacje-musi-poczekac-do-2027-roku-pytamy-w-gminie (accessed on 15 October 2021).
87. Białka Tatrzańska: Płyną Ścieki Do Rzeki. 2014. Available online: https://24tp.pl/?mod=news&id=21987 (accessed on 15 October 2021).
88. Włodarczyk, K. Czarna maź w Białce Tatrzańskiej Wypływa z Oczyszczalni Ścieków w Czarnej Górze. Czy ABW też Będzie Badało tą Sprawę? 2019. Available online: https://gazetaplus.pl/czarna-maz-w-bialce-tatrzanskiej-wyplywa-z-oczyszczalni-sciekow-w-czarnej-gorze-czy-abw-tez-bedzie-badalo-ta-sprawe/8695/ (accessed on 15 October 2021).
89. Podhale. Ekolodzy w Szoku! Wodę w Rzece Białce Zanieczyściły bobry? 2019. Available online: https://zakopane.naszemiasto.pl/podhale-ekolodzy-w-szoku-wode-w-rzece-bialce-zanieczyscily/ar/c8-7436941 (accessed on 15 October 2021).
90. Stoffel, M.; Wyżga, B.; Niedźwiedź, T.; Ruiz-Villanueva, V.; Ballesteros-Cánovas, J.A.; Kundzewicz, Z.W. Floods in Mountain Basins. In *Flood Risk in the Upper Vistula Basin. GeoPlanet: Earth and Planetary Sciences*; Kundzewicz, Z.W., Stoffel, M., Niedźwiedź, T., Wyżga, B., Eds.; Springer: Berlin, Germany, 2016; pp. 23–37. [CrossRef]
91. Waniczek, K. Petycja w Sprawie Białki. 2019. Available online: https://krempachy.pl/2019/03/20/petycja-w-sprawie-bialki/ (accessed on 15 October 2021).
92. Odpowiedź Podsekretarza Stanu w Ministerstwie Administracji i Cyfryzacji na Zapytanie nr 3074 w Sprawie Określenia Wysokości Środków Finansowych Przekazanych Do Tej Pory na Usunięcie Skutków Powodzi, z Uwzględnieniem Szacunków i Wyceny Zgłoszonych i Udokumentowanych Strat, Jakie Powstały w Wyniku Powodzi w Latach 2007–2012 w gm. Bukowina Tatrzańska. 2013. Available online: https://www.sejm.gov.pl/sejm7.nsf/InterpelacjaTresc.xsp?key=09288B00&view=null (accessed on 15 October 2021).
93. Słowik, J. Wody Białki Opadły. Pozostało Oburzenie. 2008. Available online: https://gazetakrakowska.pl/wody-bialki-opadly-pozostalo-oburzenie/ar/30317 (accessed on 15 October 2021).
94. Ludzie Przegrali z Wodą. 2008. Available online: https://dziennikpolski24.pl/ludzie-przegrali-z-woda/ar/2474868 (accessed on 15 October 2021).
95. Rzeka Białka Znowu Postraszyła. "Na Spiszu" 2(75). 2010. Available online: http://kacwin.com/nowe/naspiszu/2010_2/?rok=2010&nr=2&wydanie=75&strona=44,data (accessed on 15 October 2021).
96. Kaźmierczak, P. Powódź Przez Urzędników? (updated). 2016. Available online: https://interwencja.polsatnews.pl/reportaz/2011-02-08/powodz-przez-urzednikow_853131/ (accessed on 15 October 2021).
97. Para, M. Jurgów: Zdążyć Przed Powodzią. 2012. Available online: https://24tp.pl/n/17151 (accessed on 15 October 2021).
98. Giżycka, A.; Szkaradzińska, B. Ochrona Siedzib Ludzi, a Ochrona Przyrody. 2013. Available online: https://podhaleregion.pl/index.php/z-podhala/3936-ochrona-siedzib-ludzi,-a-ochrona-przyrody (accessed on 15 October 2021).
99. Ciężki Sprzęt Dewastuje Rezerwat Przełom Białki! 2018. Available online: https://www.wwf.pl/aktualnosci/ciezki-sprzet-dewastuje-rezerwat-przelom-bialki (accessed on 15 October 2021).
100. Breczko, B. Mieszkańcy Kontra Ekolodzy Kontra Państwo. A Rzeka Płynie Jak Chce. 2018. Available online: https://tech.wp.pl/mieszkancy-kontra-ekolodzy-kontra-panstwo-a-rzeka-plynie-jak-chce-6327138770130561a?nil=&src01=f1e45&src02=isgf (accessed on 15 October 2021).
101. Pałahicki, M.; Potocka, J.; Wiosło, M. Protest Ekologów Przeciwko Pracom Na Chronionej Rzece Białka. 2018. Available online: https://www.rmf24.pl/fakty/polska/news-protest-ekologow-przeciwko-pracom-na-chronionej-rzece-bialka,nId,2731131#crp_state=1 (accessed on 15 October 2021).
102. Rzeka Białka Niszczona Ciężkim Sprzętem. 2018. Available online: http://eko.org.pl/index_news.php?dzial=2&kat=20&art=2206 (accessed on 15 October 2021).
103. Topiński, P. Piotr Topiński: Protest nad Białką. 2018. Available online: https://studioopinii.pl/archiwa/190156 (accessed on 15 October 2021).
104. Wody Polskie o Regulacji Białki: "Chronimy Mieszkańców przed Powodzią". 2018. Available online: https://podhale24.pl/aktualnosci/artykul/60844/Wody_Polskie_o_regulacji_Bialki_quotChronimy_mieszkancow_przed_powodziaquot.html (accessed on 15 October 2021).
105. Słowik, J. Białka Znowu Groźna. Mieszkańcy Chcą Udrożnienia Koryta i Zabezpieczenia Brzegów. 2020. Available online: https://podhale24.pl/aktualnosci/artykul/71175/Bialka_znowu_grozna_Mieszkancy_chca_udroznienia_koryta_i_zabezpieczenia_brzegow.html (accessed on 15 October 2021).
106. Skowron, G. Kraków. Protest Przeciwko Regulacji Rzeki BIAŁKI. 2018. Available online: https://dziennikpolski24.pl/krakow-protest-przeciwko-regulacji-rzeki-bialki/ar/c3-13741932 (accessed on 15 October 2021).
107. Wody Polskie Zabezpieczają Białkę Przed Powodzią. 2018. Available online: https://www.kzgw.gov.pl/index.php/pl/aktualnosci/699-wody-polskie-zabezpieczaja-bialke-przed-powodzia (accessed on 15 October 2021).
108. Ochrona Przeciwpowodziowa Doliny Rzeki Białki w Zgodzie z Przyrodą. 2021. Available online: https://krakow.wody.gov.pl/aktualnosci/1837-ochrona-przeciwpowodziowa-doliny-rzeki-bialki-w-zgodzie-z-przyroda-2 (accessed on 15 October 2021).
109. Nakicenovic, N.; Alcamo, J.; Davis, G.; Vries, B.; Fenhann, J.; Gaffin, S.; Gregory, K.; Grubler, A.; Jung, T.Y.; Kram, T.; et al. *Special Report on Emissions Scenarios*; Cambridge University Press: Cambridge, UK, 2000.

110. Melillo, J.M.; Richmond, T.C.; Yohe, G.W. (Eds.) *Climate Change Impacts in the United States: The Third National Climate Assessment*; U.S. Global Change Research Program: Washington, DC, USA, 2014. [CrossRef]
111. Majewski, W.; Walczykiewicz, T. (Eds.) *Zrównoważone Gospodarowanie Zasobami Wodnymi Oraz Infrastrukturą Hydrotechniczną W Świetle Prognozowanych Zmian Klimatycznych*; IMGW-PIB: Warsaw, Poland, 2012.
112. Pińskwar, I.; Kundzewicz, Z.W.; Choryński, A. Projections of changes in heavy precipitation in the northern foothills of the Tatra Mountains. *Meteorol. Hydrol. Water Manag.* **2017**, *5*, 21–30. [CrossRef]
113. Mezghani, A.; Parding, K.M.; Dobler, A.; Benestad, R.E.; Haugen, J.E.; Piniewski, M. Projekcje Zmian Temperatury, Opadów i Pokrywy Śnieżnej w Polsce. In *Zmiany Klimatu i ich Wpływ na Wybrane Sektory w Polsce*; Kundzewicz, Z.W., Hov, Ø., Okruszko, T., Eds.; Narodowe Centrum Badań i Rozwoju: Poznań, Poland, 2017; pp. 94–118.
114. Piniewski, M.; Szcześniak, M.; Kardel, I.; Marcinkowski, P.; Okruszko, T.; Kundzewicz, Z.W. Zasoby wodne. In *Zmiany Klimatu i ich Wpływ na Wybrane Sektory w Polsce*; Kundzewicz, Z.W., Hov, Ø., Okruszko, T., Eds.; Narodowe Centrum Badań i Rozwoju: Poznań, Poland, 2017; pp. 131–147.
115. Okruszko, T.; O'Keeffe, J.; Utratna, M.; Marcinkowski, P.; Szcześniak, M.; Kardel, I.; Kundzewicz, Z.W.; Piniewski, M. Prognoza wpływu Zmian Klimatu na Środowisko Wodne i Mokradła w Polsce. In *Zmiany Klimatu i ich Wpływ na Wybrane Sektory w Polsce*; Kundzewicz, Z.W., Hov, Ø., Okruszko, T., Eds.; Narodowe Centrum Badań i Rozwoju: Poznań, Poland, 2017; pp. 148–167.
116. O'Keeffe, J.; Piniewski, M.; Szcześniak, M.; Oglęcki, P.; Parasiewicz, P.; Okruszko, T. Index-based analysis of climate change impact on streamflow conditions important for Northern Pike, Chub and Atlantic salmon. *Fish. Manag. Ecol.* **2019**, *26*, 474–485. [CrossRef]
117. Act of 18 July 2001, Water Law (Journal of Laws 2001, No. 115, Item 1229). Available online: https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20011151229/U/D20011229Lj.pdf (accessed on 23 November 2021).
118. ISOK. Hydroportal. Available online: https://wody.isok.gov.pl/imap_kzgw/ (accessed on 15 October 2021).
119. Hussein, H. Yarmouk, Jordan, and Disi basins: Examining the impact of the discourse of water scarcity in Jordan on transboundary water governance. *Mediterr. Polit.* **2018**, *24*, 269–289. [CrossRef]
120. Jones, R.N. Managing uncertainty in climate change projections–issues for impact assessment. *Clim. Chang.* **2000**, *45*, 403–419. [CrossRef]
121. Webster, M.; Forest, C.; Reilly, J.; Babiker, M.; Kicklighter, D.; Mayer, M.; Prinn, R.; Sarofim, M.; Sokolov, A.; Stone, P.; et al. Uncertainty Analysis of Climate Change and Policy Response. *Clim. Chang.* **2003**, *61*, 295–320. [CrossRef]
122. Lawler, J.J.; Tear, T.H.; Pyke, C.; Shaw, M.R.; Gonzalez, P.; Kareiva, P.; Hansen, L.; Hannah, L.; Klausmeyer, K.; Aldous, A.; et al. Resource management in a changing and uncertain climate. *Front. Ecol. Environ.* **2010**, *8*, 35–43. [CrossRef]
123. Todd, M.C.; Taylor, R.G.; Osborn, T.J.; Kingston, D.G.; Arnell, N.W.; Gosling, S.N. Uncertainty in climate change impacts on basin-scale freshwater resources–preface to the special issue: The QUEST-GSI methodology and synthesis of results. *Hydrol. Earth Syst. Sci.* **2011**, *15*, 1035–1046. [CrossRef]
124. Kundzewicz, Z.W.; Krysanova, V.; Benestad, R.E.; Hov, Ø.; Piniewski, M.; Otto, I.M. Uncertainty in Climate Change Impacts on Water Resources. *Environ. Sci. Policy* **2018**, *79*, 1–8. [CrossRef]
125. Underwood, B.S.; Mascaro, G.; Chester, M.V.; Fraser, A.; Lopez-Cantu, T.; Samaras, C. Past and present design practices and uncertainty in climate projections are challenges for designing infrastructure to future conditions. *J. Infrastruct. Syst.* **2020**, *26*, 04020026. [CrossRef]
126. Refsgaard, J.C.; Arnbjerg-Nielsen, K.; Drews, M.; Halsnæs, K.; Jeppesen, E.; Madsen, H.; Markandya, A.; Olesen, J.E.; Porter, J.R.; Christensen, J.H. The Role of Uncertainty in Climate Change Adaptation Strategies—A Danish Water Management Example. *Mitig. Adapt. Strateg. Glob. Chang.* **2012**, *18*, 337–359. [CrossRef]
127. Gallego-Ayala, J.; Juízo, D. Integrating stakeholders' preferences into water resources management planning in the Incomati river basin. *Water Resour. Manag.* **2014**, *28*, 527–540. [CrossRef]
128. Basco-Carrera, L.; Warren, A.; van Beek, E.; Jonoski, A.; Giardino, A. Collaborative modelling or participatory modelling? A framework for water resources management. *Environ. Model. Softw.* **2017**, *91*, 95–110. [CrossRef]
129. Langsdale, S.; Beall, A.; Bourget, E.; Hagen, E.; Kudlas, S.; Palmer, R.; Tate, D.; Werick, W. Collaborative Modeling for Decision Support in Water Resources: Principles and Best Practices. *J. Am. Water Resour. Assoc.* **2013**, *49*, 629–638. [CrossRef]
130. Jonsson, A. Public participation in water resources management: Stakeholder voices on degree, scale, potential, and methods in future water management. *AMBIO* **2005**, *34*, 495–500. [CrossRef] [PubMed]
131. Jacobs, K.; Lebel, L.; Buizer, J.; Addams, L.; Matson, P.; McCullough, E.; Garden, P.; Saliba, G.; Finan, T. Linking Knowledge with Action in the Pursuit of Sustainable Water-Resources Management. *Proc. Natl. Acad. Sci. USA* **2016**, *113*, 4591–4596. [CrossRef] [PubMed]
132. Purkey, D.R.; Escobar Arias, M.I.; Mehta, V.K.; Forni, L.; Depsky, N.J.; Yates, D.N.; Stevenson, W.N. A Philosophical Justification for a Novel Analysis-Supported, Stakeholder-Driven Participatory Process for Water Resources Planning and Decision Making. *Water* **2018**, *10*, 1009. [CrossRef]
133. Pahl-Wostl, C.; Sendzimir, J.; Jeffrey, P.; Aerts, J.; Berkamp, G.; Cross, K. Managing change toward adaptive water management through social learning. *Ecol. Soc.* **2007**, *12*, 30. [CrossRef]
134. Lebel, L.; Grothmann, T.; Siebenhüner, B. The role of social learning in adaptiveness: Insights from water management. *Int. Environ. Agreem.* **2010**, *10*, 333–353. [CrossRef]

135. GWP; INBO. *A Handbook for Integrated Water Resources Management in Basins*; Global Water Partnership and International Network of Basin Organisations; Elanders: Mölnlycke, Sweden, 2009.
136. Konieczny, R.; Walczykiewicz, T. *Wstępna Analiza Proponowanych Rozwiązań Zawartych w Projektowanej Dyrektywie Powodziowej i ich Wpływu na Rozwiązania Prawne i Organizacyjne w Polsce*; (Unpublished Work, Typescript); Institute of Meteorology and Water Management, National Research Institute: Kraków, Poland, 2005.
137. Drużyńska, E.; Nachlik, E. (Eds.) *Podstawy Metodyczne i Standardy Zintegrowanego Planowania w Gospodarce Wodnej*; Praca zbiorowa, Politechnika Krakowska im, Tadeusza Kościuszki, Monografia 341; Seria Inżynieria Środowiska: Kraków, Poland, 2006.
138. Dourojeanni, A. Public Policies for Integrated Watershed Management. In *Integrated River Basin Management: The Latin American Experience*; Tortajda, C., Biwas, A., Eds.; Oxford University Press: Oxford, UK, 2001; pp. 58–73.
139. Van der Keur, P.; Jeffrey, P.; Boyce, D.; Pahl-Wostl, C.; Hall, A.; Lloyd, J.G. Adaptive Water Management in Terms of Development and Application within IWRM. In *Adaptive Water Resource Management Handbook*; Mysiak, J., Henrikson, J.H., Sullivan, C., Bromley, J., Pahl-Wostl, C., Eds.; Earthscan: London, UK, 2010; pp. 7–9.
140. Saravanan, V.S.; McDonald, G.T.; Mollinga, P.P. Critical review of integrated water resources management: Moving beyond polarised discourse. *Nat. Resour. Forum* **2009**, *33*, 76–86. [CrossRef]