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EXPLOITATION AND PROTECTION OF THE POLISH SOUTHERN BALTIC COASTAL ZONE LAKES AND THEIR POTENTIAL FOR RECREATION

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A b s t r a c t

There are about 30 lakes located on the Polish coast. They vary in terms of use. They are used for many purposes: energetic, fisheries, economic, educational, as receiver surpluses water from the polders, as receiver of social welfare pollutants. Also, some of them are good place for development of specific plant and animal ecosystems. Most of these lakes have very high potential for recreation. Evidence of this include conducting annual sports competitions, setting bike paths around the lakes, creating a pedestrian educational paths, development of technical and social infrastructure.

WYKORZYSTANIE I OCHRONA JEZIOR POLSKIEJ STREFY BRZEGOWEJ POŁUDNIOWEGO BAŁTYKU ORAZ ICH POTENCJAŁ REKREACYJNY

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S ł o w a k l u c z o w e: strefa brzegowa, jeziora, ochrona, funkcje, wykorzystanie, potencjał rekreacyjny.

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Abstrakt

Na polskim wybrzeżu zlokalizowanych jest około 30 jezior. Pod względem wykorzystania są one mocno zróżnicowane. Wykorzystuje się je m.in. do celów energetycznych, rybackich, gospodarczych, edukacyjnych, jako odbiornik nadwyżek wód z polderów, jako odbiornik zanieczyszczeń socjalno-bytowych. Niektóre z nich stanowią również dobre miejsce do rozwoju specyficznych ekosystemów roślinnych i zwierzęcych. Większość z tych jezior ma bardzo duży potencjał rekreacyjny. Świadczy o tym m.in. coroczne przeprowadzanie zawodów sportowych, wytyczenie ścieżek rowerowych wokół jezior, stworzenie ścieżek edukacyjnych dla pieszych, rozbudowa infrastruktury technicznej i społecznej.

Introduction

Lakes are an indispensable part of the landscape in which they have an important function. They are vacation spot for people, satisfying their needs of both recreation and esthetic. Influencing local climate, lakes are habitat for numerous species of flora and fauna what is crucial in maintaining biodiversity (ŚWIERK, SZPAKOWSKA 2009). Interactions between human activity, tourism, recreation and natural environment are varied. This results in measurable changes in the human – nature relations, which enter into interactive relationships most strongly (KRZYMOWSKA-KOSTROWICKA 1997).

One of the main components of natural environment where these relationships are very clear are water reservoirs. Often, human or recreation activities carried out too intensively can result in environment degradation and adversely affect the conditions for an optimal relaxation (ZWOLINSKI 1979). Also, improper protection of these objects instead of improving their condition, may negatively impact on their development and persistence in the environment. Among lakes, particular attention should be paid to reservoirs located on the coast. The Southern Baltic Sea area is a place where the primary water relations have evolved under the influence of Scandinavian glacier and its meltwaters, and then underwent a further transformation under the influence of climate change (CIEŚLIŃSKI 2011). Nowadays coastal zone is still characterized by complex water relations, affected by both the water inflow from the land and the proximity to the main drainage base, which is the Baltic Sea, as well as the impact of direct basin and intensive human activity, both in aspect of use and protection. Currently, also local and regional hydrometeorological and hydrographical conditions have strong impact on water conditions.

The main objective of this paper is to determine scope and forms of lakes use on the Polish southern Baltic coastal zone, effects of their use and forms of protection. An additional objective is to investigate their potential for tourism and recreation.

Methods

The main studies were based on fieldwork, including an inventory of the direct catchment of lakes selected to analysis in the hydrographic, quality and economy context. Also during expedition works the water quality measurements were carried out (to determine the physical and chemical composition of water) and morphometric work, including identifying overgrowing areas of each reservoir. In addition to field work the source materials query has been performed. The query was supposed to define the functions and use of each lake. Also, limited to determine concentration levels of indicators such as chlorides, nitrates and phosphates laboratory analysis was performed. The first indicator was intended to determine the degree of sea water's influence on the analyzed lakes, while two others were to specify the impact from the catchment.

Chloride was marked by argentometric titration (Mohr method) nitrate(V) of silver to chromate(VI) of potassium as an index in neutral or slightly alkaline reaction (pH 6.5–10). Nitrates and phosphates were marked by using Photoflex TurbSet photometer and WTW Merck spectrophotometer.

The study area covered the Polish part of the southern Baltic coast between Władysławowo and Wolin Island and also the delta of Vistula. This area is classified as the Coasts of the Southern Baltic (KONDRACKI 2000), which are the hydrographic unit of hydrological conditions different from the rest of the country (CHOIŃSKI 1988).

The following lakes were selected for analysis: Kołczewo, Żółwińskie, Domysławskie, Czajcze, Wisełka, Koprowo (all situated on the Wolin Island), Liwia Łuza, Resko Przymorskie, Jamno, Bukowo, Kopań, Wicko, Modła, Gardno, Smołdzińskie, Dołgie Wielkie, Dołgie Małe, Łebsko, Sarbsko, Kopalińskie, Żarnowieckie (located in the coastal zone of open sea), Pusty Staw, Ptasi Raj, Karaś, Druzno (located in the delta of Vistula). The study period covered the decade of 2001–2011.

Analysis of the lake's recreational values was performed according to the methodology proposed by DEJA (2001). The analysis included morphometric parameters (area, depth), shoreline development index, lake elongation, shores overgrowing, lake surface overgrowing of water vegetation and shores afforestation. Complement to this method was to define the lakes degradation resistance, water quality and tourism activity for each reservoir.

Morphometric lake diversification

Lakes selected for analysis are characterized by morphometric variation (Table 1). As a rule, those reservoirs are shallow, the average depth is 0.6 m (Pusty Staw Lake) to 3.6 m (Wisełka Lake), and the maximum

of 1.7 m (lakes: Liwia Łuza, Smołdzińskie, Dołgie Małe) to 6.3 m (Łebsko Lake). Only in the case of Żarnowieckie Lake its average and maximum depth differs significantly from other reservoirs and amounts to 8.4 m and 19.4 m (Table 1). The area of studied lakes is within the range of 5.6 ha (Kopalińskie) to 7020 ha (Łebsko).

Length of coastline is within the range of 1150 m (Pusty Staw Lake) to 55 400 m (Łebsko Lake), and shoreline development index from 1.13 (Żółwińskie Lake) to 2.44 (Kopalińskie Lake) – Table 1.

Table 1

The main coastal lakes morphometric data

Name of lake	P [ha]	H_{max} [m]	H_{sr} [m]	L [m]	R	A [km^2]
Kołczewo	49.2[6]	4.0	2.2	3675	1.48	1.1
Żółwińskie	41.7[6]	3.0	2.1	2580	1.13	1.0
Domysławskie	43.5[6]	3.1	2.1	3000	1.28	1.3
Czajcze	71.5[6]	4.6	2.9	4970	1.66	1.6
Wisełka	20.0[6]	6.1	3.6	1980	1.25	0.5
Koprowo	486.8[8]	3.1	1.6	9800	1.25	51.1
Liwia Łuza	210.8[8]	1.7	0.9	6500	1.26	160.7
Resko Przymorskie	559.0[1]	2.5	1.3	11700	1.38	315.2
Jamno	2231.5[1]	3.9	1.4	28300	1.69	510.6
Bukowo	1644.0[1]	2.8	1.8	23200	1.57	102.8
Kopań	786.5[1]	3.9	1.9	12350	1.24	38.5
Wicko	1031.0[1]	6.1	2.7	21350	1.85	107.7
Modła	45.1[2]	2.6	1.2	3163	1.76	26.9
Gardno	2337.5[1]	2.6	1.3	23000	1.33	964.4
Smołdzińskie	28.0[2]	1.7	1.3	3075	1.64	0.8
Dołgie Wielkie	131.0[1]	2.9	1.4	6675	1.51	3.2
Dołgie Małe	7.3[1]	1.7	0.7	1197	1.35	0.2
Łebsko	7020.0[1]	6.3	1.6	55400	1.87	1594.0
Sarbsko	614.0[1]	3.2	1.2	15550	1.72	213.3
Kopalińskie	5.6[7]	3.0	1.6	2050	2.44	0.2
Żarnowieckie	1425.0[1]	19.4	8.4	18650	1.39	259.8
Pusty Staw	7.5[3]	3.0	0.6	1150	1.19	0.7
Ptasi Raj	51.8[4]	2.6	1.3	4551	1.78	1.4
Karaś	8.8[4]	2.5	0.7	2145	2.03	1.0
Druzno	1450.0[5]	3.0	1.2	32200	2.39	1084.0

P – area of lakes ([1] – Choiński 2006, [2] – Cieśliński et al. 2009, [3] – Tylmann 2003, [4] – Raśkiewicz, Cieśliński 2007, [5] – Lumberjack 2002 – the area of lake at the water level of 500 cm, [6] – Kubiak, Chojnacki, Tórz 2002, [7] – Cieśliński, Olszewski 2012, [8] – Tórz, Kubiak 2006), H_{max} – maximum depth (Jańczak 1997, Choiński 2006), H_{sr} – average depth (Jańczak, 1997, Choiński 2006), L – coastline length, R – shoreline development.

The lakes catchment area is firmly variable. Among them there are both very small catchment with an area of 0.2–1.6 km^2, and very large catchment with an area over 1,000 km^2. The size of total catchment of studied lakes is within the range of 0.2 km^2 (lakes: Dołgie Małe, Kopalińskie) to 1594.0 km^2 (Łebsko Lake) (Table 1).

Lakes overgrowing

The problem of overgrowing lakes located in the coastal zone of the southern Baltic Sea is fairly important. This includes not only to the coastal zone, where it is possible to grow swamps intensively, but also water depths, where it is possible to grow aquatic vegetation. Mainly reed rushes contribute to lakes overgrowing. They cause the water receding at the rate of 0.3–3.0 m per year (PIOTROWSKA 1997). According to SCHECHTL (1984) rushes cover about 650 ha of Łebsko Lake. According CHOIŃSKI and KANIECKI (2003) rushes in lakes Łebsko and Gardno cover zone width up to several hundred meters, while in terms of area it is covering 9.1% of Łebsko Lake water surface and 4.1% of Gardno Lake. Liwia Łuża Lake reed zone is wide from 5 to 60 m.

Excluding lakes mentioned above, rushes overgrowing problems concerns on most of analyzed lakes. Only in case of lakes located on Wolin Island (except Koprowo Lake) and lakes Żarnowieckie and Pusty Staw reed expansion in their coastal zone is not observed.

Second place of lakes overgrowing is water depths. Most of analyzed lakes have eutrophic waters with near zero transparency, which limits the growth of large submerged vegetation patches. Stronger winds causes intensive mixing of water and sediment resuspension. Permanently submerged in the water depths considerable amount of abioseston effectively limits light diffusion into the water and is an inhibitor of submerged vegetation spread (KRASKA 2003). Łebsko lake water transparency according to KRASKA (1997) varied from 0.4 to 0.7 m and the Gardno Lake from 0.5 to 0.8 m, which results in limited the growth of submerged vegetation. According KRASKA (1997) transparency of Łebsko lake water varied from 0.4 to 0.7 m, and Gardno Lake from 0.5 to 0.8 m, which in consequence limited the growth of submerged vegetation. In the other reservoirs water transparency is less than 1 m. Among the underwater vegetation most noteworthy are *Chara* phytocenoses. *Chara* grow in shallow waters (it is much easier to grow species of vegetation with floating leaves or emergent), in areas less exposed to strong waving, where the water depth varies from 10 to 100 cm (DĄBSKA 1978).

The biggest problem with lakes overgrowing of emergent vegetation relates to following lakes: Modła, Karaś, Gardno, Liwia Łuża, Koprowo. The area

covered by emergent vegetation varies from 1% to 60%. Particular attention should be paid to Druzno Lake with overgrown area covering about 80% of water depths during summer. Fetal lakeside includes not only water route across the lake, which is related to keeping its patency by human activity. Typical reed islands are formed on the surfaces of lakes Modła and Liwia Łuża. In the case of Liwia Łuża Lake they cover 20% of the water surface, but in case of Modła Lake even 60%. In turn, this problem does not apply to the lakes without outflow, where generally this occurrence is not observed.

The following table presents estimated values of area overgrown with rushes and emergent vegetation, given in absolute values and percentages (Table 2).

Table 2

Volume of lakes overgrowing with rushes and emergent vegetation

Name of lake	*P* [ha]	Rushes overgrowing [ha]	Rushes overgrowing [%]	Emergent vegetation overgrowing [ha]	Emergent vegetation overgrowing [%]
Kołczewo	49.2	0.0	0.0	0.0	0.0
Żółwińskie	41.7	0.0	0.0	0.0	0.0
Domysławskie	43.5	0.0	0.0	0.0	0.0
Czajcze	71.5	0.0	0.0	0.0	0.0
Wisełka	20.0	0.0	0.0	0.0	0.0
Koprowo	486.8	48.7	10.0	0.0	0.0
Liwia Łuza	210.8	10.5	5.0	42.0	20.0
Resko Przymorskie	559.0	28.0	5.0	11.2	2.0
Jamno	2231.5	223.1	10.0	0.0	0.0
Bukowo	1644.0	82.0	5.0	0.0	0.0
Kopań	786.5	31.0	4.0	0.0	0.0
Wicko	1031.0	30.0	3.0	0.0	0.0
Modła	45.1	0.5	1.0	27.0	60.0
Gardno	2337.5	117.0	5.0	93.0	4.1
Smołdzińskie	28.0	2.8	10.0	0.0	0.0
Dołgie Wielkie	131.0	0.0	0.0	0.0	0.0
Dołgie Małe	7.3	0.0	0.0	0.0	0.0
Łebsko	7020.0	0.0	0.0	632.0	9.1
Sarbsko	614.0	0.0	0.0	0.0	0.0
Kopalińskie	5.6	0.1	2.0	0.4	8.0
Żarnowieckie	1425.0	0.0	0.0	7.2	0.5
Pusty Staw	7.5	0.0	0.0	0.0	0.0
Ptasi Raj	51.8	2.6	5.0	0.0	0.0
Karaś	8.8	2.5	30.0	0.4	5.0
Druzno	1450.0	0.0	0.0	1160.0	80.0

Hydrochemical differentiation of lakes

Coastal lakes are usually characterized by a small average and maximum depth and a large area. These attributes in relation with the location decide of high values of expose index. Expose index, is defined by intensity of the impact of wind on each reservoir. It can be assumed that waters in these lakes are fully mixed by waves. Stratification may occur only in Żarnowieckie Lake. In other lakes In the other lakes, waters are completely mixed (polymictic lakes). Therefore, later in this work evaluation of hydrochemical composition variation was decided to perform only for the surface layer of these lakes.

By analyzing the variability of chloride concentrations (Table 3) it was observed that there are lakes, where the water was characterized by constantly high concentration levels – more than 500 mg Cl^- dm^{-3} (lakes: Koprowo, Ptasi Raj, Karaś, Resko Przymorskie, Łebsko, Bukowo i Gardno). There are also lakes where the chloride concentration increases followed only periodically, usually rapidly. These increases included whole lakes basins, or just their parts (lakes Jamno and Druzno). There are also lakes in which waters high concentrations of these indicators (above 200 mg Cl^- dm^{-3}) were never observed (lakes: Kołczewo, Żółwińskie, Domysławskie, Czajcze, Wisełka, Liwia Łuża, Wicko, Kopań, Modła, Smołdzińskie, Dołgie Wielkie, Dołgie Małe, Sarbsko, Kopalińskie, Żarnowieckie i Pusty Staw).

Analysis of the nitrates(V) and phosphorus(V) revealed that concentrations of both substances in these lakes waters, as well as the variability of concentrations observed over time were very similar. In the case of phosphorus(V) not high mean concentrations of this ion in analyzed lakes waters were observed. The range of variation fluctuated from 0.021 mg PO43 – dm – 3 (Bukowo Lake) to 0.17 mg PO_4^{3-} dm^{-3} (Dołgie Wielkie Lake). Only in the case of lakes Druzno and Liwia Łuża, higher levels of phosphate(V) in relation to the other lakes were observed. In the first case, the average concentration was 0.85 mg PO_4^{3-} dm^{-3}, while the other mg PO_4^{3-} dm^{-3}.

In the case of nitrates(V) high average concentrations of this ion in waters of throughflow lakes were observed. For example, the average concentration of nitrates(V) in the waters of Druzno Lake was 1.74 mg NO_3 dm^{-3}, and in the waters of Kopań Lake 2.39 mg NO_3^- dm^{-3}. In the case of lakes without outflow the nitrate(V) concentrations were low. For example, in the waters of Pusty Staw mean concentrations of nitrates(V) were 0.34 mg NO_3^- dm^{-3}, while in the waters of Żółwińskie Lake 0.31 mg NO_3^- dm^{-3}. The range of variation for all of analyzed lakes varied from 0.18 mg NO_3^- dm^{-3} (Czajcze Lake) to 3.29 mg NO_3^- dm^{-3} (Liwia Łuża Lake).

Considering the variability range of phosphorus(V) concentrations of in waters of all analyzed lakes it can be concluded that it was not very varied

(Table 3). Just in case of some lakes, large variations in their concentrations levels were observed. On the other hand, in the case of nitrate(V), as for the mean values, the high concentrations of this ion was observed in the waters of throughflow lakes (Table 3).

Table 3
Maximum and minimum values for chloride ion, nitrate and phosphate (mg dm^{-3}) in the waters of analyzed lakes

Name of lake	Chloride		Nitrate		Phosphate	
	maximum value	minimum value	maximum value	minimum value	maximum value	minimum value
Kołczewo	14.0	8.0	0.48	0.03	0.210	0.030
Żółwińskie	14.0	10.0	0.56	0.03	0.140	0.010
Domysławskie	13.0	6.0	0.67	0.02	0.110	0.008
Czajcze	13.0	9.0	0.28	0.01	0.180	0.009
Wisełka	15.0	8.0	0.77	0.06	0.150	0.010
Koprowo	780.0	320.0	2.87	0.09	0.190	0.003
Liwia Łuza	160.0	90.0	5.66	0.89	0.689	0.040
Resko Przymorskie	2700.0	1560.0	1.19	0.04	0.160	0.002
Jamno	698.0	70.0	2.31	0.09	1.480	0.008
Bukowo	1188.0	531.0	2.12	0.06	0.122	0.005
Kopań	112.1	85.2	5.72	0.86	0.110	0.010
Wicko	66.6	38.2	5.52	0.92	0.118	0.009
Modła	152.0	26.4	2.54	0.11	0.520	0.020
Gardno	1512.0	13.9	2.18	0.08	0.139	0.001
Smołdzińskie	240.0	81.7	5.38	0.79	0.090	0.010
Dołgie Wielkie	18.9	13.0	0.98	0.02	0.510	0.040
Dołgie Małe	11.9	9.1	0.66	0.01	0.340	0.010
Łebsko	1970.0	409.0	2.00	0.07	0.253	0.001
Sarbsko	87.7	21.0	7.20	0.20	0.080	0.040
Kopalińskie	21.0	11.0	2.12	0.07	0.090	0.040
Żarnowieckie	28.6	8.3	1.11	0.09	0.360	0.006
Pusty Staw	40.9	33.4	0.82	0.06	0.230	0.020
Ptasi Raj	4090.0	2311.0	3.22	0.96	0.139	0.016
Karaś	2703.0	1830.0	4.28	1.13	0.111	0.021
Druzno	652.0	39.0	5.60	0.06	2.000	0.130

The water quality and evaluation of degradation resistance

The Polish southern Baltic coastal lakes analyzed in terms of the physicochemical and biological quality of their waters are characterized by poor quality. There were 8 lakes (32% of all analyzed reservoirs) with NON

class water quality. 10 lakes (40%) are from the scope of III class water quality and 7 lakes (28%) are from II class. There were no lakes with I class waters quality (Table 4).

Table 4

Water quality classes of the Polish southern Baltic coastal lakes

S.n.	Name of lake	Class
1	Kołczewo	II
2	Żółwińskie	II
3	Domysławskie	II
4	Czajcze	II
5	Wisełka	II
6	Koprowo	NON
7	Liwia Łuża	NON
8	Resko Przymorskie	III
9	Jamno	NON
10	Bukowo	III
11	Wicko	NON
12	Kopań	III
13	Modła	NON
14	Gardno	III
15	Dołgie Wielkie	III
16	Dołgie Małe	III
17	Smołdzińskie	III
18	Łebsko	III
19	Sarbsko	III
20	Kopalińskie	II
21	Żarnowieckie	II
22	Pusty Staw	III
23	Ptasi Raj	NON
24	Karaś	NON
25	Druzno	NON

One of the reasons why this happens may be a natural resistance to degradation of these lakes. The natural predisposition to water pollution is possible because of the small depth and strong pressure from the catchment. On the other hand, the influence of the Baltic Sea has a negative impact on water quality (increased salinity). However, the location of lakes in the lower part of the catchment or river basin and the capacity of waters pollutants retention and their accumulation in sediments have negative impact on the

water quality. Based on the obtained results it can be concluded that in most cases the analyzed lakes are low resistant to degradation. 8 lakes were included into the group outside of class, and 10 lakes to the III class group. Only Kopalińskie and Żarnowieckie lakes were included into II class.

Use of lakes

Lakes located in the coastal zone of the southern Baltic were and are used for different purposes. Frequently, these purposes are related to human activities. Kopalińskie Lake in the past, before it was actually a lake, was the site of the peat extraction, used for energy purposes. Human activities initiated its creation, by forming the basin. Nowadays it is a place of human recreation and relaxation. Żarnowieckie Lake is also used by humans. In the 80s of the 20th century, pumped storage Żarnowiec power plant was built. It is located on the south side of Żarnowieckie Lake. It includes, among others artificial lake with an area of 122 ha and a total capacity of 13.6 million m^3, located on the plateau, placed 100 m above the average water level in the lake. Primary, before starting Żarnowiec power plant, hydrological lake attributes indicated stability (DRWAL LANGE 1991), where the annual change in water volume was up to 5%, and the amplitude of water level was up to 50 cm (MIKULSKI 1983). Starting pumped – storage power plant resulted in the transformation of water exchange conditions. Daily variations of water level in the lake after starting the power plant grew to 95 cm. In such conditions, natural annual cycle of water level changes readable before became completely undetectable (MAJEWSKI 1996).

Jamno and Liwia Łuża lakes in the past were used as a place of discharge waters from sewage treatment plant in Koszalin (Jamno Lake) and in Pobierowo (Liwia Łuża Lake). As a result, their waters were heavily polluted and water quality (outside class) evidently indicates that. Currently, despite the lack of waste water discharges into the Jamno Lake it is still heavily polluted. This pollution is a result of large amounts of dirt deposited in the sediments. In periods of re – suspension pollutants are lifted from the bottom of the lake and mixed with water depths, what is the cause of deterioration of its water quality. Another reason for periodic changes in water quality of many lakes can be water discharge from polders surrounding the lakes. Lakes: Koprowo, Liwia Łuża, Resko Przymorskie, Jamno, Bukowo, Wicko, Kopań, Modła, Gardno, Łebsko and Druzno are water receiver from several polders. Druzno Lake is a receiver of water from 12 polders. Waters from polders are characterized by large biogenic compounds pollution, which is the result of pumping by polders water from fields and meadows. This water often very long

stagnate in the fields, before being pumped to each lake. This is confirmed by the results of nitrates and phosphates recorded on a few selected polders of lakes: Łebsko, Gardno and Sarbsko (Table 5).

Table 5
Average concentrations of chemical indicators in waters discharged by selected pumping stations to coastal lakes in the period 2002–2007

Name of lake	Name of pumping station	Nitrates(V) [mg dm^{-3}]	Phosphates(V) [mg dm^{-3}]
Łebsko	Lisia Góra	0.63	0.046
Łebsko	Łokciowe	0.89	0.072
Łebsko	Kluki	0.92	0.081
Gardno	Gardna V–VI	0.91	0.047
Gardno	Gardna VII	0.78	0.033
Sarbsko	Nowęcin	0.55	0.021

Many lakes catchments are used for agricultural purposes. Only a few lakes have forestry catchments (lakes on the Wolin Island and Pusty Staw) or catchment dominated by natural wasteland (lakes Ptasi Raj and Karaś). The result of the impact of agriculture on these objects is their very strong eutrophication. The volume of biogenic compounds loads delivered directly to lakes basins with the surface inflow from the catchment. For example, on average 40.0 tons per month of total nitrogen and 1.6 tons per month of total phosphorus are discharged into the Gardno Lake from the catchment (CIEŚLIŃSKI 2009a). However, 53.5 tons per month of total nitrogen and 2.3 tons per month of total phosphorus are discharged into the Łebsko Lake from the catchment (CIEŚLIŃSKI 2009b). In the case of both lakes in 2008–2010 CIEŚLIŃSKI (2010) observed larger delivery of total nitrogen and total phosphorus into those lakes basins than the results recorded on their outflows into the sea. In the waters of the Łebsko Lake variations of total nitrogen loads were about 30%, and for total phosphorus it was estimated to be nearly 70%. In case of Gardno Lake amount of total nitrogen loads, remaining in the lake basin was estimated at only 1%, and total phosphorus to over 30%.

In principle, all lakes even though to varying degrees, are used for recreation and tourism. This applies not only for tourism around the lake (Pusty Staw Lake) but also recreational activities at the reservoir in the form of the use of lakes for water sports (Jamno Lake, south – west part of the Gardno Lake), sailing and sunbathing (Bukowo Lake). Of course, some reservoirs are poorly used for tourism purposes, which is due to poor technical nd social infrastructure (lakes Wicko and Kopań).

Lakes are also used as a natural retention reservoir, which is often a receiver for water runoff from entire river basin, as it is in the case of lakes Łebsko and Gardno. As a result, they may provide natural protection against flooding to towns such as Łeba and Rowy.

Coastal zone region is characterized by an exceptionally wide variety of habitats, in combination with a complex system of soil – water relations and the characteristics of the local climate, it is a direct base of specificity, as well as the wide variety of its vegetation. For example, flora of Slowinski National Park actually includes 911 species of vascular plants and 165 species of bryophytes. About 300 algal species were also found there, 424 fungi species, and 225 species of lichens. In the zone of the spit there are dune vegetation communities, including two nationally rare and protected species: the Sea holly (*Eryngium maritimum*) and Fragrant Toadflax (*Linaria loeselii).* At the spit, both in the coniferous forests, as well as within moving dunes, in the hollows between the dunes (deflationary basins) a number of unique hygrophilous vegetation communities can be found.

In turn an open area of lakes is place of occurrence hydrophytes with large floating leaves. Halophytic plant communities, rare in Poland, have interesting meadow character.

Of the 450 species of birds observed in Poland in the coastal zone 270 were found among them. There were more than 180 species, which joined the breeding. Other species occurs during migration, they spend the winter here or arrive irregularly. Through the territory of Slowinski National Park, Modła Lake Nature Reserve, lakes Drużno and Ptasi Raj, there goes one of the main routes of spring and autumn birds migrations.

Recreational potential

Most of the lakes in the Polish coastal zone have a very high potential for recreation. This is confirmed by carrying out annual sports competitions such as on the Jamno Lake, demarcation of bicycle paths around the lakes (Liwia Łuża Lake), creation of educational pathways for pedestrians (Łebsko Lake) or technical and social infrastructure expansion (Gardno Lake). Looking at their recreational potential based on natural conditions such as morphometry and overgrowing, it can be concluded that, in principle, these are objects with high recreational value (according to Deja classification of 2001 – II class). Only cases of lakes such as: Smołdzińskie, Dołgie Małe i Pusty Staw, should be included as III class, which are lakes with an average value of recreation (Table 6). Deja classification (2001) does not reflect completely the actual recreational attractiveness of individual reservoirs and limited to a few selected limnological

indicators, without even analyzing tourism in those lakes catchments. Therefore, it was decided to analyze the size of tourism in catchments of individual lakes and then to estimate the number of people staying by the lake in relation to the size of its catchment.

Table 6

Polish coastal zone lakes recreational value according to DEJA classification (2001)

Name of lake	*P*	*h*	*K*	λ	ZSB	ZPJ	ZB	Total
Domysławskie	2	1	2	3	4	4	1	17
Czajcze	2	1	2	3	4	4	1	17
Żółwińskie	2	1	2	3	4	4	1	17
Wisełka	3	1	2	3	4	4	1	17
Kołczewo	1	1	2	3	4	4	1	16
Koprowo	5	0	2	2	4	4	3	20
Liwia Łuża	5	0	2	2	4	3	4	20
Resko Przymorskie	5	0	2	1	4	4	4	20
Jamno	5	0	2	1	4	4	4	20
Bukowo	5	0	2	1	4	4	3	19
Kopań	5	0	2	1	4	4	3	19
Wicko	5	1	2	2	4	4	3	21
Modła	2	0	2	3	4	2	3	16
Gardno	5	0	2	3	4	4	3	21
Smołdzińskie	1	0	2	2	4	4	2	15
Dołgie Wielkie	4	0	2	2	4	4	1	17
Dołgie Małe	1	0	2	2	4	4	1	14
Łebsko	5	0	2	3	4	4	3	21
Sarbsko	5	0	2	2	4	4	4	21
Kopalińskie	1	0	3	3	4	4	1	16
Żarnowieckie	5	2	2	1	4	4	2	20
Pusty Staw	1	0	2	1	4	4	1	13
Ptasi Raj	3	0	2	2	4	4	5	20
Karaś	1	0	3	1	3	4	5	17
Druzno	5	0	3	2	4	1	4	19

P – lake area; *h* – lake depth; *K* – shoreline development index; λ – lake elongation; ZSB – shores overgrowing; ZPJ – lake surface overgrowing of water vegetation; ZB shores afforestation.
Classes of reservoir attractiveness in terms of recreation: to 10 pts – low recreational value of lake – class IV; 10.1 – 15.9 pts – average recreational value of lake – class III; 16.0 – 21.7 pts – high recreational value of lake – class II; 21.8 – 29.0 pts – very high recreational value of lake – I class.

As a result, a very large tourist traffic was observed for lakes located on the Wolin Island and in the Slowinski National Park. Also, lakes located in the delta of Vistula attracted wide interest. The greatest interest was in the

Druzno Lake (700 000 tourists), while the smallest – in lakes Modła and Kopalińskie (15 000 tourists for each lake). In estimating ratio of the number of tourists visiting one area of the lake catchment area it must be assumed that the results for some part of lakes are too large and should not be taken into account. Due to the lack of actual data for individual lakes, this could not be corrected, and so, in fact, there were tourists from 78.4 (Jamno Lake) to 50 000 (Karaś Lake) per 1 km^2 of catchment. This paper was based on the values for each region.

Conclusions

Reservoirs and their floristic environment have positive impact on holiday makers. The water availability heavily determines their recreational suitability. Due to use of tourism and recreation lakes with clear water and available beaches, which have sandy bottom along the shores are most attractive (ŚWIERK et al., 2003). Large size and forestry in close proximity heavily influence the attractiveness of the reservoir (ŁAPIŃSKA 1998).

The Polish southern Baltic coastal zone lakes definitely stand out in terms of hydrological and hydrographic conditions and water quality from other lakes located inland. Such difference results from the location, but also the interaction of the sea and the lakes catchment at the same time. It is interesting that the sea has the greatest influence on lakes despite the fact that sea affects lakes only periodically (what is noticeable in the size of a water salinity). As a consequence of specific location and impacts of different environments those reservoirs perform different functions and are used by humans for many purposes. They are used for many purposes: energetic, fisheries, economic, educational, as receiver surpluses water from the polders, as receiver of social welfare pollutants, as natural retention reservoir, as a habitat for unique species of flora and fauna etc. At that point it should be considered, if the reservoir can perform so many functions and if that can influence on its attractiveness for recreational purposes. It is known that water quality of many lakes is rather poor (III class water purity and outside class), and due to morphometric conditions resistance to degradation of these lakes is low. Also strong overgrowing of their shores and water depths, and furthermore significant loads of nutrients inflow, does not affect the tourist attractiveness of these lakes. Despite this, based on the calculation of the recreational potential proposed by DEJA (2001) and determining the amount of people staying by the selected lake during the year basically all analyzed lakes must be considered as an attractive place for tourists, with high potential for their use by humans. Another positive aspect for the recreational attractiveness

of discussed lakes is the proximity of the Baltic Sea and the well – developed technical, social and accommodation infrastructure in the towns at their close proximity.

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