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RESEARCH ARTICLE

Opinions of Owners and Managers of Fishing Entities in Central and Eastern Europe on the Impact of Climate Change on Lake Fisheries Management

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Abstract. The study of the impact of climate change on the fish fauna and fisheries management is a relatively young field of scientific research which has yielded very few analytical studies in the Central and Eastern European countries. This paper is the first attempt to examine the impact of this change on lake fisheries management, made based on an extensive and representative survey addressed at managers and owners of the entities authorised to use these waters for fishing and angling purposes. The conducted analyses enabled the determination of their opinions on the issues of climate change impact on the fish, selected hydrological and biological lake parameters, the possibility of use of fishing gear and its efficiency, the length of angling season, the amount of individual fish species caught by anglers and fishermen, and positive phenomena relating to climate change. Of all the phenomena arising from this change and perceived by the respondents surveyed, the growing population of the great cormorant (*Phalacrocorax carbo* (L.)), which is exerting increasing pressure on the fishery resources, and conducive to this change, is definitely at the head of the list. As regards the fish species, the pike (*Esox lucius* L.) is the most vulnerable to this change. The presented results prove that the managers under the study are aware of the ongoing changes and their impact on lake fisheries management, and of the challenges that they will have to face as early as in the coming decades of the 21st century.

Keywords: climate change, lake fisheries management, fisheries entities, questionnaire survey

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Introduction

Lakes are found on every human-inhabited continent, with their total number estimated at 15 million, and a total surface area of approx. 1.5% of the Earth's surface (excluding the Antarctic) (Shiklomanov and Rodda 2003). Poland, the largest country of the Central and Eastern European region, has 7081 lakes with a total surface area of 2,813.77 km^2 i.e. approx. 0.9% of the country's area (Mitchell et al. 2010). Even though in certain countries (e.g. in Central Europe), the biocentric paradigm is predominant in inland fisheries management, the anthropocentric approach still prevails for the most part, as is the case in Central and Eastern European countries (Arlinghaus et al. 2021), including Poland, where the lake-inhabiting fish population is subject to fishing and angling exploitation. However, even with the anthropocentric view of the fish population being held, the main tasks of sustainable lake fisheries management include the proper management of ichthyofaunal resources i.e. balanced commercial and angling exploitation and a rational stocking policy, along with environmental restoration (Vehanen et al. 2002). The implementation of sound strategies for the management and sustainable exploitation of fisheries resources requires a basic knowledge of the waters being managed, e.g. their natural productivity (Brämick 2002). In addition to biological aspects, the socio-economic and ecological factors are also important due to often being crucial in making decisions concerning water management (FAO 1997, Hickley and Tompkins 1998). Improper management of resources as fragile as lakes may lead to environmental degradation in their drainage areas, increase the soil erosion, lake silting, and the nutrient load, and consequently deteriorate water quality (Hecky et al. 2003).

A new problem currently experienced globally is the progressive climate change whose impact on aquatic ecosystems and fishery resources is the subject of a growing body of scientific research carried out throughout the world (Islam et al. 2014, Linderholm et al. 2014, Williams et al. 2015, Himes-Cornell and Kasperski 2015, Kao et al. 2015, Wołos et al. 2017). Climate change mitigation and adaptation are crucial challenges to be faced by the entire fishing industry in the 21st century. What lies at the heart of these challenges is the issue of energy or, more specifically, the total level of energy consumption by humans, and their dependence on fossil fuels (Gielen et al. 2019). The transition from fossil fuels to low-emission solutions will play a crucial role, as carbon dioxide emissions account for two-thirds of all greenhouse gases (IPCC 2014). Fuel consumption during fishing operations is a crucial contributor to the carbon footprint of products derived from commercial and recreational fishing (Ziegler et al. 2016, Avadí and Fréon 2013). The management of lake fisheries, as opposed to marine fisheries, can be referred to as low-carbon (Hornborg and Främberg 2020), and its contribution to climate change is virtually non-existent. However, the global change is bound to affect, and is actually already affecting, the way this management is conducted. The climate change occurring in recent years worldwide has forced the scientists dealing with water management in a broad sense (Arlinghaus et al. 2016, Cooke et al. 2016, Hunt et al. 2016) to incorporate a new research aspect, namely this change's impact on the fishing industry, in the research into lake fisheries management (Trella et al. 2019).

The aim of the study was to present and discuss the results of a survey addressed at managers and owners of lake fisheries entities in order to identify the fisheries management determinants associated with the ongoing climate change.

Materials and methods

The analyses were conducted based on collected detailed survey questionnaires that had been sent to fishing users who conducted fishing and angling management on lakes. The questionnaires were collected from a total of 101 entities (including 18 Polish Angling Association (PAA) districts), and analysed. They concerned lakes with a total surface area of 223,876 ha (Table 1), which accounts for almost 83% of the total surface area of lakes used for fishing purposes in Poland, estimated at 270,000 ha (Wołos et al. 2015).

Based on the obtained responses, the following issues relating to the determinants of lake fisheries management conduct under the influence of climate change were defined and analysed:

- the impact of climate change on ichthyofauna;
- the impact on selected hydrological and biological lake parameters;
- the impact on the possibility of using fishing gear, and on its effectiveness;
- the impact on the angling season's duration;
- the impact on the amount of individual fish species caught by anglers and fishermen;
- positive phenomena relating to climate change.

In the questions in which the scale of impact could be indicated (the so-called Likert scale), it was expressed within the range of 0-5, where 0 indicated 'no impact', 1 – a very low impact, 2 – a low impact, 3

Table 1
General characteristics of the fisheries entities under the study

Entity type	Number of entities (n)	Surface area of lakes (ha)	Average surface area of lakes in 1 entity (ha)	% of the surface area
Fisheries enterprises	67	151,333	2,259	67.6
Polish Angling Association districts	18	48,844	2,714	21.8
Private firms and institutions	13	10,893	838	4.9
National parks	3	12,805	4,268	5.7
Total	101	223,876	2,217	100

– a medium impact, 4 – a high impact, and 5 indicated a very high impact. In the rank questions, the awarded points were analysed depending on the obtained responses, thus creating the percentage distribution of the awarded points according to the selected degree of the impact.

The study used basic statistical parameters e.g. percentages, rank-sums (RS), means (M), standard deviation (SD), median (Me), and mode (Mo). All calculations and drawings were made in the Microsoft Excel program.

Results

Most (92%) of the users, who have been conducting fisheries management on lakes for years, have recently noticed the impact of climate change on fish fauna and management, which demonstrates the heightened awareness of fisheries entity managers/owners in this regard. According to fishing users, the fish species most vulnerable to the climate change's impact in terms of the natural spawning efficiency is the pike (as indicated by 92% of the respondents, RS = 250 points) (Table 1). The distribution of responses concerning the pike shows that most respondents indicated the medium impact and awarded 3 points (Table 2). The pike was followed by the vendace (*Coregonus albula* (L.)) indicated by 63% of the respondents (RS = 180 points). 50% of the points awarded by the respondents indicated a high and very high impact, and slightly more than 20% indicated 'no impact'. Similar indications were true for the European whitefish (*Coregonus lavaretus* (L.)), where over 40% of the awarded points also indicated a high and very high impact. However,

Table 2
Adverse impact on the effects of selected fish species' natural spawning

	Distribution of responses (%) 0 – no impact, 5 – very high impact						Statistical parameters					
Species	0	1	2	3	4	5	RS	M	SD	Me	Mo	Users (%)*
Pike	10.8	9.7	18.3	31.2	21.5	8.6	250	2.7	1.4	3	3	92
Vendace	20.3	10.9	6.3	12.5	29.7	20.3	180	2.8	1.9	3.5	4	63
Perch	18	22.5	25.8	21.3	6.7	5.6	172	1.9	1.4	2	2	89
Tench	20.9	19.8	19.8	23.3	10.5	5.8	172	2	1.5	2	3	86
Pikeperch	15.3	13.9	20.8	27.8	15.3	6.9	169	2.3	1.5	2.5	3	72
European whitefish	19.3	12.3	7	19.3	21.1	21.1	156	2.7	1.8	3	4	56
Bream	28.7	20.7	19.5	14.9	9.2	6.9	153	1.8	1.6	2	0	86
Roach	25.3	26.4	21.8	10.3	11.5	4.6	148	1.7	1.5	1	1	86

*percentage of users who indicated a particular species in the question concerning the adverse impact of climate change on the effects of spawning of selected fish species under natural conditions

Table 3
Adverse impact on the effects of selected fish species' spawning under controlled conditions

Species	Distribution of responses (%) 0 – no impact, 5 – very high impact						Statistical parameters					Users (%)*
	0	1	2	3	4	5	RS	M	SD	Me	Mo	
Pike	13.5	16.2	21.6	23.0	16.2	9.5	178	2.4	1.5	2	3	73
Vendace	20.0	12.7	5.5	21.8	20.0	20.0	148	2.7	1.8	3	3	55
European whitefish	23.1	11.5	7.7	19.2	19.2	19.2	134	2.6	1.9	3	0	52
Pikeperch	22.6	17.0	17.0	24.5	15.1	3.8	108	2.0	1.5	2	3	53
Other	24	22	28	10	10	6	89	1.8	1.5	2	2	50

*percentage of users who indicated a particular species in the question concerning the adverse impact of climate change on the effects of spawning of selected fish species under controlled conditions.

only 56% of the respondents indicated this species, resulting in such a low RS value of 156 points. On the other hand, the low-scoring species i.e. the bream (*Abramis brama* (L.)) and roach (*Rutilus rutilus* (L.)) were indicated by 86% of users. However, over 60% of the awarded points show either no impact or a low or very low impact. Species such as the perch (*Perca fluviatilis* L.), tench (*Tinca tinca* (L.)), and pikeperch (*Sander lucioperca* (L.)) were most similar to each other in terms of the awarded ranks and the distribution of the awarded points (Table 2).

On the other hand, as regards spawning efficiency under controlled conditions, fishing lake users pointed out that climate change again had the highest impact on the pike (73% of the respondents indicated this species and awarded 178 RS points (Table 3). The distribution of responses concerning this species shows that most respondents indicated the low and medium impact, and awarded 2 and 3 points (Table 3). The pike was followed by the vendace indicated by 55% of the respondents (RS = 148 points). 40% of managers indicated the high and very high impact, while 20% indicated 'no impact'. Similar indications were true for the European whitefish, with over 40% of the respondents indicating the high and very high impact. However, 52% of managers indicated this species, and the RS value amounted to 134 points. On the other hand, the low-scoring species of pikeperch (RS = 108 points) was indicated by 53% of the users. However, almost 60% of the awarded points show either no impact or a low or very low impact. Other species were indicated by 50% of the respondents, and scored a total of 89 RS points. Over 70% of the awarded points prove that the impact of climate changes on these species was low (Table 3).

The question concerning the impact of climate change on larval and fry survivability was answered by 89.1% of the respondents, who awarded 226 RS points. The highest number of awarded points indicated that the impact of climate change was medium (40%), and only 8.9% of points were awarded to the 'no impact' option (Table 4). In turn, with regard to adult fish mortality, the results were completely different, as 88% of the respondents who answered this question stated that climate change had no significant impact on adult fish mortality (29.5%), hence such a low RS value of 134 points (Table 4).

Shifting seasons were indicated by 92.1% of the respondents who awarded this phenomenon with a total of 312 RS points. Most of them agreed that the phenomenon had a very high impact on fisheries management, with more than 47% of awarded points indicating either a high or very high impact (Table 4).

The problem of a shorter ice cover duration was indicated by as many as 95.1% of the respondents. Moreover, almost 40% of the awarded points showed that the impact of climate change on this phenomenon was exceptionally high, which resulted in as many as 351 RS points. Only 5.2% of points were

Table 4
The impact of climate change on selected phenomena, noted by fishing lake users

	Distribution of responses (%) 0 – no impact, 5 – very high impact						Statistical parameters				
Phenomenon	0	1	2	3	4	5	RS	M	SD	Me	Mo
Impact on extending the period of cormorants' stay in selected seasons	5.1	6.1	2	11.2	22.4	53.1	391	4	1.5	5	5
Impact on the shortening of the permanent ice cover duration	5.2	8.3	7.3	13.5	26	39.6	351	3.7	1.5	4	5
A change in the duration of seasons (shifting seasons) – seasonal temperature anomalies	3.2	3.2	17.2	29	25.8	21.5	312	3.4	1.3	3	3
Impact on a reduction in larval and fry survivability	8.9	14.4	16.7	40	16.7	3.3	226	2.5	1.3	3	3
Impact on an increase in adult fish mortality	29.5	28.4	15.9	15.9	6.8	3.4	134	1.5	1.4	1	0

awarded to 'no impact' (Table 4). The shorter ice cover duration, i.e. an effect of higher temperatures during the winter season, provides perfect conditions for cormorants to stay longer on lakes. Therefore, it is not surprising that this option was indicated as an adverse phenomenon by 97% of the fishing lake users, with more than 50% of points awarded to the highest category of 'a very high impact', resulting in such a high RS value of 391 points.

The respondents were asked how the particular phenomenon i.e. an overall temperature rise and extreme (rapid) jumps in temperatures affected the conduct of lake fisheries management in specific seasons. In their opinion, extreme jumps in temperatures were most severe in the spring and summer, with the RS of 27.7 and 28.7%, respectively, when considering all seasons. As regards the overall temperature rise, the highest impact is observed in the winter and summer, with the RS of 27.3 and 27.2% respectively, when considering all seasons (Table 5). An analysis of the response distribution shows significant differences in the awarded points, with the most extreme (i.e. either a very high or very low) score having been awarded in the wintertime, which means that for many users during this season, climate change was of either no significance or of particular significance. In other seasons, the distribution of points was more averaged, with the respondents selecting ranks within the range of 2-4 points (Table 5).

As regards the impact of climate change on selected hydrological parameters, the respondents answered the question concerning the impact on water level lowering or fluctuations. In both cases, the respondents concluded that climate change had the highest impact on hydrological changes during the spring and summer. Low water levels for the spring are 24.9%, and for the summer, 29.2% RS, when considering all seasons, while water level fluctuations for the spring are 26.0% and for the summer, 28.9% RS, when considering all seasons. In contrast, as regards the temperatures, there were no extremes in the awarded ranks. It can be noticed that the majority of respondents expressed an opinion that hydrological changes were affected by climate change, while the minority believed that there was no such impact or that it was negligible (Table 5).

Oxygen depletion i.e. a considerable reduction in the amount of oxygen dissolved in the water of a lake or its part, which occurs in both winter and summer, was indicated by 94% of the respondents. An analysis of the response distribution shows that this problem is much more burdensome in the summer,

Table 5
The impact of climate change on the phenomena noted by fishing lake users in selected seasons

Phenomenon	season	Distribution of responses (%) 0 – no impact, 5 – very high impact: 0	1	2	3	4	5	Statistical parameters: RS	%*	M	SD	Me	Mo
Overall temperature rise	spring	11.0	17.6	15.4	24.2	20.9	11.0	236	23.7	2.6	1.5	3	3
	summer	10.4	11.5	22.9	14.6	21.9	18.8	271	27.2	2.8	1.6	3	2
	autumn	17.6	17.6	13.2	23.1	17.6	11.0	217	21.8	2.4	1.6	3	3
	winter	18.8	9.4	11.5	12.5	26.0	21.9	272	27.3	2.8	1.8	3	4
Rapid temperature rise	spring	10.5	17.9	13.7	20.0	22.1	15.8	259	27.7	2.7	1.6	3	4
	summer	11.8	14.0	12.9	20.4	17.2	23.7	268	28.7	2.9	1.7	3	5
	autumn	16.3	23.9	18.5	18.5	15.2	7.6	198	21.2	2.2	1.5	2	1
	winter	19.8	20.9	15.4	14.3	13.2	16.5	209	22.4	2.3	1.8	2	1
Water level fluctuations	spring	11.6	9.5	16.8	18.9	21.1	22.1	280	26.0	2.9	1.6	3	5
	summer	7.3	11.5	11.5	18.8	21.9	29.2	311	28.9	3.2	1.6	4	5
	autumn	9.7	14.0	19.4	23.7	16.1	17.2	255	23.7	2.7	1.6	3	3
	winter	12.2	21.1	15.6	22.2	8.9	20.0	229	21.3	2.5	1.7	3	3
Low water levels	spring	7.4	8.5	20.2	11.7	18.1	34.0	307	24.9	3.3	1.6	4	5
	summer	5.1	10.2	4.1	15.3	24.5	40.8	359	29.2	3.7	1.5	4	5
	autumn	7.4	11.6	13.7	21.1	25.3	21.1	293	23.8	3.1	1.5	3	4
	winter	7.5	16.1	16.1	21.5	14.0	24.7	272	22.1	2.9	1.6	3	5
Oxygen depletion	summer	13.8	17.0	7.4	22.3	22.3	17.0	257	59.4	2.7	1.7	3	3
	winter	30.9	21.3	6.4	22.3	9.6	9.6	176	40.6	1.9	1.7	1	0
Shorter angling season	spring	30.0	24.4	11.1	17.8	6.7	10.0	159	21.0	1.8	1.7	1	0
	summer	30.8	28.6	16.5	11.0	5.5	7.7	141	18.6	1.5	1.5	1	0
	autumn	24.7	25.8	16.9	20.2	3.4	9.0	159	21.0	1.8	1.5	1	1
	winter	13.0	13.0	8.7	9.8	13.0	42.4	298	39.4	3.2	1.9	4	5

*percentage of points obtained in each category

which is why as many as 62% of the awarded points fell within the range of 3-5 points, with as many as 257 RS points awarded in total, which means that climate change has an impact on this phenomenon. On the other hand, in the wintertime, where the RS was at a much lower level (176 points), almost 31% points were awarded to the option of the lack of any impact of climate change on winter oxygen depletion (Table 5).

90% of the respondents answered the question concerning the contribution of climate change to the shortening of the angling season. According to fishing lake users, the highest impact on this phenomenon can be observed in the winter (RS = 298 points) (Table 5). An analysis of the distribution of awarded points shows clearly that over 40% of them concerned the winter season, which appears to have a strong logical connection to the lack of ice cover and the impossibility of practising ice fishing. As regards other seasons, the vast majority of the awarded points indicates that climate change has no impact, or a minimum impact on the shortening of the angling season.

Issues relating to the impact of climate change on the use of specific fishing gear were described by 81.1% of the respondents. Most RS points i.e. 212 were awarded to the double-winged fyke nets, which accounted for as much as 31.6% of all the points awarded in this category (Table 6), while the dragged gear i.e. trawls and seine nets scored 25.3% points.

Table 6
The effect of climate change on the use of fishing gear in all entities

	Distribution of responses (%) 0 – no impact, 5 – very high impact						Statistical parameters					
Fishing gear type	0	1	2	3	4	5	RS	%*	M	SD	Me	Mo
Double-winged fyke nets	29.4	7.1	8.2	17.6	15.3	22.4	212	31.6	2.5	2	3	0
Trawls and seine nets	27.8	10.1	20.3	13.9	16.5	11.4	170	25.3	2.2	1.7	2	0
Traps	32.9	12.2	13.4	24.4	9.8	7.3	154	23.0	1.9	1.7	2	0
Gill nets	36.8	18.4	16.1	14.9	9.2	4.6	135	20.1	1.6	1.6	1	0

*percentage of points scored

Table 7
The impact of climate change on the use of fishing gear in Polish Angling Association districts

	Statistical parameters				
Fishing gear type	RS	M	Me	Mo	no response (%)
Gill nets	11	0.6	0.5	0	27.8
Trawls and seine nets	19	1.1	1.5	0	27.8
Traps	22	1.2	1	0	27.8
Double-winged fyke nets	35	1.9	3	0	22.2

Traps (different fyke-net types) are among the most effective fishing methods without injuring the fish. Difficulties in their use can have a major impact on sustainable fisheries management. The use of gill nets and traps was regarded by the respondents as the least vulnerable to the climate change's impact. However, it is worth mentioning here that the PAA entities awarded a total of very few points in this category (Table 7). In 18 districts under the study, an average of 0.6-1.9 points was awarded depending on the fishing gear type, with the vast majority awarding 0 points to each type. 27.8% of the PAA entities under the study provided no response to the question concerning the impact on gill nets, trawls, seine nets, and traps, and 22.2% provided no response to the question concerning double-winged fyke nets.

The final question answered by the respondents was the one concerning the impact of climate change on the amount of individual fish species caught. It is noteworthy that almost 4% of the respondents declared no catches. According to the respondents, climate change has the highest impact on the amount of the following fish caught: the European eel (*Anguilla anguilla* (L.)) (RS = 242 points), followed by the vendace (RS = 173 points), the pike (RS = 161 points), the pikeperch (RS = 147 points), and the European whitefish (RS = 139 points). The fewest RS points, i.e. 91 and 76, were awarded to the crucian carp (*Carassius carassius* (L.)) and smelt (*Osmerus eperlanus* (L.)), respectively. It is also worth mentioning that, of all the species mentioned, the pike as well as the bream and white bream (*Blicca bjoerkna* (L.)) (81.2%), and the roach (80.2%), were indicated by most respondents, while the smelt was indicated by the fewest respondents, which also explains its such a low RS value (Table 8).

The positive impact of climate change was mentioned by only 12% of the respondents who indicated the following phenomena: longer feeding times; increased amounts of spring zooplankton during stocking with the European whitefish and vendace; extended fishing season; increased tourism rates; better natural reproduction of certain fish species (the pikeperch, tench, and crucian carp); and less

Table 8
The impact of climate change on the catches of individual fish species in lakes

Species	Distribution of responses (%) 0 – no impact, 5 – very high impact						Statistical parameters					Percentage (%) of the entities which indicated a species in the catches
	0	1	2	3	4	5	RS	M	SD	Me	Mo	
European eel	12.5	6.3	15.0	21.3	22.5	22.5	242	3.0	1.6	3	4	79.2
Vendace	21.0	6.5	14.5	12.9	21.0	24.2	173	2.8	1.9	3	5	61.4
Pike	17.1	22.0	26.8	20.7	8.5	4.9	161	2.0	1.4	2	2	81.2
Pikeperch	16.4	14.9	22.4	29.9	11.9	4.5	147	2.2	1.4	2	3	66.3
European whitefish	25.0	10.7	12.5	14.3	17.9	19.6	139	2.5	1.9	3	0	55.4
Perch	20.0	26.3	31.3	15.0	3.8	3.8	134	1.7	1.3	2	2	79.2
Tench	23.8	31.3	16.3	17.5	5.0	6.3	134	1.7	1.5	1	1	79.2
Roach	30.9	24.7	22.2	14.8	3.7	3.7	119	1.5	1.4	1	0	80.2
Bream and white bream	36.6	22.0	19.5	12.2	3.7	6.1	117	1.4	1.5	1	0	81.2
Crucian carp	35.3	27.9	17.6	10.3	4.4	4.4	91	1.3	1.4	1	0	67.3
Smelt	50.0	0.0	7.9	5.3	15.8	21.1	76	2.0	2.2	1	0	37.6

frequent cases of winter oxygen depletion. However, due to the sample being so small, no analysis was conducted.

Discussion

The climate change occurring on Earth over a period of many years is becoming increasingly evident, and is of interest not only to scientists from many fields but also to people whose work involves contact with nature. It is also causing concerns among the public who are calling for actions to prevent it (Le Treut et al. 2007). In recent years, the term "climate change" has been identified mainly with the phenomenon of global warming i.e. an increase in temperatures on the Earth's surface, while currently, other scenarios are under consideration, including those involving the cooling of the Earth's surface (Collins et al. 2013). The surveyed lake fishing users are highly aware of the changes taking place in the climate, and similarly to fishing users of damming reservoirs (Trella et al. 2019), they notice the change and feel its impact on lake fisheries management. The major problem highlighted by the lake users was the cormorant's adverse impact related to global warming, namely the bird's longer stay on lakes, which consequently translates into an increased pressure on fisheries resources. In Poland, the cormorant is a major consumer of fish in the inland and coastal lagoons (Krzywosz and Traczuk 2012, Trella, 2017), and a potential threat to many fish populations in Poland and other countries (Švažas et al. 2011, Winkler et al. 2012, Heikinheimo et al. 2016, Trella and Mickiewicz 2016). The problem of cormorants' pressure on lake fishery resources will be increasing with the overall temperature rise (Lehikoinen et al. 2017). Currently, winters in Poland are mild, and frosts are rare and of short duration, which results in the shortening of the permanent ice cover duration, noticed and awarded with the most points by the surveyed managers. Increased lake fertility and increasingly high water temperatures may contribute to an increase in the biomass of fish (Mooij et al. 2005) that are an easy prey to the cormorant, thus extending the period of cormorants' stay on lakes, and increasing their population size (White et al. 2015, Klimaszyk and Rzymski 2016). It is accompanied by a considerable increase in the phosphorus content and chlorophyll a concentration, the occurrence of intense cyanobacterial blooming in lake waters, and, consequently, negative changes in the aquatic ecosystem functioning, demonstrated by Napiórkowska-Krzebietke et al. (2020, 2021), based on the example of a 360-ha Lake Warnołty with the most numerous cormorant colony in the extensive Masurian Lake District (1,491 breeding pairs in 2016).

Another problem that was particularly highlighted by the respondents was that of the issues relating to water level fluctuations and low water level. This may be a consequence of the drought that affected vast areas of Poland in the summer of 2015, and the risk of further droughts. Unfortunately, climate change forecasts and scenarios predict that major changes will specifically occur in hydrology, which may result in a disruption of the hydrological regime, primarily due to an increase in water temperatures (Cammalleri et al. 2020). This, in turn, may results in a drop in oxygen content, which consequently implies a more frequent occurrence of oxygen depletion. Another consequence of mass fish kills will be an increase in water toxicity accompanying an increase in the metabolite concentration in water, including in particular compounds such as ammonia and nitrites (Lewis, 2011), which may result in dramatic and hardly reversible changes in the composition and status of fish fauna. The most endangered species are the cold-water ones with high oxygen requirements, e.g. salmonids and coregonids (Ficke et al. 2007), which may be facing extinction or a reduction in their area of occurrence. The respondents also awarded high scores to the problems arising from noticeable weather changes. The most important ones include raising water temperatures in the summer and spring, extreme jumps in water temperatures in the summer, fluctuating water levels in the spring and summer, low water levels from the spring to autumn, and oxygen losses, particularly in the summer period.

Sustainable fisheries management on lakes requires a rational fishing policy, regardless of whether using fishing gear or a fishing rod, and properly carried out stocking operations (Vehanen et al. 2002). The phenomena described earlier, e.g. jumps in temperatures or changes in water levels during the spawning period, have a significant impact on the development of species and their juvenile stages. According to most respondents, climate change has the most significant impact on pike spawning. The pike is currently the most important species in terms of the stocking policy in Poland, as pike stocking is predominant in all inland waters (lakes, rivers, and dammed reservoirs) (Mickiewicz and Wołos 2012, Mickiewicz and Trella 2016, 2017, Mickiewicz 2018). During the spawning season, this species requires favourable hydrological conditions and, in many lakes, also a longer period of the flooding of waterside meadows where spawning takes place (Łozowski et al. 2014, Foubert et al. 2020). All of this explains why the pike ranks so high in the assessments of the climate change's adverse impact as compared to other fish species, in terms of both the (natural and controlled) spawning and the assessment of the impact of this change on anglers' fishing. The overall position of coregonids (the vendace and European whitefish) in managers' awareness was law, as they were only indicated by 60% of the respondents. This demonstrates that greater significance is being attached to these species by the users who most often conduct fisheries management using these species, while the users focused exclusively on meeting anglers' needs, among others those being members of the vast majority of the PAA districts, do not place such importance on it, as the vendace is not a species of angling significance. An exception in this respect is Finland where recreational fishermen are allowed, under certain conditions, to fish non-commercially using nets for the vendace, smelt, herring (*Clupea harengus* L.), or sprat (*Sprattus sprattus* (L.)) (Pawson et al. 2008). A similar correlation can also be observed in fishing gear use where, for reasons obvious to the users who do not use it, this is not a major problem, and this is why the impact of climate change on the use of fishing gear was awarded so few points by managers. Such users include e.g. the PAA districts, in which increasing pressure exerted by anglers has resulted in the suspension or cessation of commercial fishing in PAA waters. For example, the PAA District in Toruń (178 lakes with a total surface area of approx.

8,000 ha), which introduced a ban on commercial fishing in 2009, with the only exception of fishing for spawners in order to supply own hatcheries with reproductive material (Wołos and Trella 2017).

The fisheries management conducted in this manner, where fishing operations using fishing gear are being discontinued, can be very unfavourable in the light of ongoing climate change, as cyprinids (e.g. the bream, white bream, and roach) increase their populations when temperatures increase, and pose a real threat to the functioning of lake ecosystems (Ficke et al. 2007). This situation may even deteriorate because approx. 70% of anglers in Poland always, or at least often, release the caught fish including cyprinids (Arlinghaus et al. 2021). It is worth mentioning that the use of groundbaits has been increasing in Poland. In the 1980's, approx. 50% of anglers used groundbaits (Wołos 1984); at the beginning of the 1990's, 53.4% of anglers used 1 kg of groundbaits per angler on a daily basis (Wołos et al. 1992), while ten years later, this amount increased to 2.2 kg, with 66% of anglers using them (Wołos and Mioduszewska 2003). Recent research indicates a further increase in the amount of groundbaits used to a level of 2.7 kg, and an increase in the proportion of anglers using groundbaits to over 80% (Czarkowski et al. 2018, 2021). This increasing tendency towards the use of groundbaits is due to the fact that anglers used groundbaits mainly for baiting cyprinids (Czerniawski et al. 2010), as there is a positive correlation between the amount of groundbaits and the amount of caught fish (Wołos et al. 1992, Arlinghaus and Mehner 2003, Mehner et al. 2019). Such large amounts of nutrients introduced into water bodies with groundbaits, and the increasing anglers' tendency towards releasing all the fish they catch (Czarkowski et al. 2018), may result in an increased eutrophication rate and increased cyprinid spawning. A study by Iho et al. (2017) suggested that optimal fisheries management should also take into account the need for more intensive commercial fishing for species that may pose an ecological hazard, as overstocked populations of zooplankton-eating fish accelerate the eutrophication process. Similarly, the harvesting of fish of low value but high density was suggested by Nielsen et al. (2019) as a way to improve water quality. Small individuals of this group of fish are of no commercial importance. Therefore, the so-called reduction fishing operations are carried out in many countries to significantly reduce the cyprinid density. Such harvesting is carried out e.g. in Sweden, where even the use of this fish fraction for biogas production is currently under consideration (Hornborg and Främberg 2020).

Conclusions

In summary, the obtained responses presented the actual problems faced by lake fisheries managers authorised to conduct fishing operations. Due to the fact that the responses were obtained from entities which use almost 83% of the total area of lakes used for fishing purposes in Poland, it can be concluded that this sample is highly representative for the entire fisheries management conducted in this group of water bodies, not only in Poland but also in other regions of Central and Eastern Europe. As can be seen, managing these water bodies requires a comprehensive approach, and the respondents are mostly aware of the ongoing or future climate change and its impact on their management. This is an overall positive result of the conducted questionnaire survey, as climate change is predicted to intensify and have a significant impact on both recreational and commercial fisheries.

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