Fish and Fisheries in the Lakes of Northeastern Poland

Andrzej Kapusta, Elżbieta Bogacka-Kapusta, and Arkadiusz Wołos

Contents

Abstract In this article, we present the most comprehensive and up-to-date assessment of freshwater fish diversity in the lakes of northeastern Poland, and we use these data to characterize patterns of fish diversity and characterize the fisheries. The northeastern region of Poland is home to the country's largest complex of lakes, with the deepest (Hańcza) and largest (Śniardwy) lakes in Poland. To date, 43 species belonging to 15 families are confirmed to occur in the lakes of northeastern Poland. Among these, the cyprinids are dominant. Most of the fish species noted in this region occur commonly in Poland; however, as many as 27% of the species are classified as highly endangered and are under species conservation. A substantial part of the fish fauna of northeastern Polish lakes is comprised of alien species, of which nine are noted in the region. For centuries, this region was the center of lake fisheries in the southern Baltic Sea basin. Currently, 70 different types of enterprises conduct fisheries in the region, but, in the face of progressing lake eutrophication, changes in catch structure are occurring, and the fisheries yield is decreasing.

A. Kapusta (✉) · E. Bogacka-Kapusta
Department of Ichthyology, Hydrobiology, and Aquatic Ecology, Inland Fisheries Institute in Olsztyn, Olsztyn, Poland
e-mail: a.kapusta@infish.com.pl

A. Wołos
Department of Fisheries Bioeconomic, Inland Fisheries Institute in Olsztyn, Olsztyn, Poland

E. Korzeniewska, M. Harnisz (eds.), *Polish River Basins and Lakes – Part II*,
The Handbook of Environmental Chemistry 87,
https://doi.org/10.1007/978-3-030-12139-6_11

Common bream (*Abramis brama*), pike (*Esox lucius*), roach (*Rutilus rutilus*), and eel (*Anguilla anguilla*) are commercially the most important fish species in commercial catches in the lakes of northeastern Poland.

Keywords Fish composition · Freshwater ecosystems · Inland fisheries · Lake fisheries

1 Introduction

The northeastern region of Poland conjures up images of forests and waters, and it is home to the largest complex of lakes in Poland. There are approximately 2,700 lakes of a surface area greater than 1 ha covering an area of 1,450 km^2, which is nearly 30% of the number of lakes and 45% of lake surface area in Poland [1, 2]. This is where the largest (over 100 km^2) and deepest (over 100 m) lakes are located. This region was also the center of lake fisheries in the southern Baltic Sea basin for centuries.

Studies of riverine fish fauna include most river systems [3, 4]. In comparison to that of rivers, the state of knowledge about the fish fauna of lakes is much worse. Fish fauna studies of lakes are rendered difficult because, in comparison to rivers, they have a significantly wider range of habitats and surface areas are usually large. The species composition of fish inhabiting lakes is most frequently determined during studies focusing on the biology of commercial species [5] or during monitoring catches [6], or it is based on commercial catches and information obtained from professional fishermen [7, 8]. Studies of fish in Polish lakes more frequently concentrate on describing biological or ecological traits [9, 10], than on assessing the entire fish assemblage qualitatively or quantitatively [11]. There are relatively few studies that describe the fish assemblages of individual lakes and even fewer studies that describe the fishes of a few or a dozen or more lakes in a single area [12, 13]. Consequently, relatively little is known about the composition of fish assemblages in lakes. Knowledge of the composition of fish assemblages in many aquatic basins is based exclusively on knowledge obtained from the fisheries that are associated with either commercial or recreational catches.

2 Historical Data Regarding Fishes

Lakes located in the region of northeastern Poland have been the subject of more or less detailed studies regarding fishes and fisheries management [7, 14–16]. Nevertheless, no publication has addressed in detail the species composition or quantitative structure of assemblages in the lakes in this area. Historical publications contain summary information on the occurrence of some species in the Masurian region [14, 17–19], while more detailed studies analyze fisheries management

[15, 16]. Historical materials and fisheries documentation permit making generalizations about the fish species composition of the area. In comparison with other regions of Poland, Masuria remains one of the least investigated areas with regard to fish assemblage species composition and quantitative structure.

The most exhaustive study of fish is the combined results of research work that focuses on the fish from lakes in the vicinity of Węgorzewo [5]. A team from the Inland Fisheries Institute conducted research focusing on the productivity of the lakes and the impact of environmental factors on fish growth. Catches of fish using nets of various mesh sizes and electro-fishing also permitted fairly precise determinations of the species composition and quantitative structure of more than a dozen lakes [5, 20].

3 Species Richness

The occurrence of at least 43 species belonging to 15 families was noted in the lakes of northeastern Poland (Table 1). The most species are from the cyprinid family, while the other families are represented by single species. Species that prefer riverine habitats occur in the littoral zone of some lakes. Among these, the rarest species is *Barbus barbus*, which was noted in Lake Śniardwy in the mid-twentieth century [23], but it has not been confirmed in this area for many years. The lake form of the species *Salmo trutta* currently occurs in lakes Hańcza and Szurpiły, while formerly it also occurred in lakes Wigry, Białe Wigierskie, Sajno, and Sajenek [24]. The lakes of northeastern Poland are the primary distribution area of *Osmerus eperlanus* in Polish inland waters. Generally, species that prefer cold water and require well-oxygenated water are noted with the least frequency in the lakes of this area.

The occurrence of some species is associated with fisheries management and particularly with deliberate or accidental stocking. Asian carp species (*Ctenopharyngodon idella* and *Hypophthalmichthys* spp.) do not reproduce in the inland waters of Poland [25], which is why their occurrence depends on stocking. Fortunately, the trend of stocking lakes with *Coregonus peled* has stopped, and the further occurrence or even hybridization with indigenous species of the genus *Coregonus* appears to be quite improbable [26]. *Umbra krameri* was introduced along with *Tinca tinca* stocking material from Hungary [27], but it did not establish local populations.

4 Conservation Status

Most fish species noted in this region occur commonly in various types of inland waters in Poland, and they are characterized by broad tolerance to environmental factors [28]. It must also be noted that species that are classified as threatened or are under species conservation are also observed. In total, 27% of the species confirmed

Table 1 List of fish species confirmed in the Masurian Landscape Park

Family	Scientific name	Reproductive guilds	Origin	IUCN category
Anguillidae	*Anguilla anguilla* (L.)	Pelagophil	N	CR
Salmonidae	*Salmo trutta* L.	Lithophil	N	CD
	Coregonus peled Gmelin	Litho-pelagophil	I	–
	Coregonus albula (L.)	Litho-pelagophil	N	VU
	Coregonus lavaretus (L.)	Lithophil	N	VU
Osmeridae	*Osmerus eperlanus* (L.)	Litho-pelagophil	N	VU
Lotidae	*Lota lota* (L.)	Litho-pelagophil	N	VU
Esocidae	*Esox lucius* L.	Phytophil	N	LC
Umbridae	*Umbra krameri* Walbaum	Phytophil	I	–
Cyprinidae	*Cyprinus carpio* L.	Phytophil	I	–
	Carassius carassius (L.)	Phytophil	N	NT
	Carassius gibelio (Bloch)	Phytophil	I	–
	Rutilus rutilus (L.)	Phyto-lithophil	N	LC
	Scardinius erythrophthalmus (L.)	Phytophil	N	LC
	Leusciscus idus (L.)	Phyto-lithophil	N	LC
	Squalius cephalus (L.)	Lithophil	N	LC
	Leucaspius delineatus Heckel	Phytophil	N	LC
	Abramis brama (L.)	Phyto-lithophil	N	LC
	Blicca bjoerkna (L.)	Phyto-lithophil	N	LC
	Leuciscus aspius (L.)	Lithophil	N	NT
	Alburnus alburnus (L.)	Phyto-lithophil	N	LC
	Tinca tinca (L.)	Phytophil	N	LC
	Barbus barbus (L.)	Lithophil	N	VU
	Vimba vimba (L.)	Lithophil	N	CR
	Rhodeus amarus (Bloch)	Ostracophil	N	VU
	Pseudorasbora parva (Temminck and Schlegel)	Phyto-lithophil	I	–
	Gobio gobio (L.)	Psammophil	N	LC
	Ctenopharyngodon idella (Val.)	Pelagophil	I	–
	Hypophthalmichthys molitrix (Val.)	Pelagophil	I	–
	Hypophthalmichthys nobilis (Richardson)	Pelagophil	I	–
Nemacheilidae	*Barbatula barbatula* (L.)	Psammophil	N	LC
Cobitidae	*Cobitis taenia* L.	Phytophil	N	LC
	Misgurnus fossilis (L.)	Phytophil	N	VU
Ictaluridae	*Ameiurus nebulosus* (Lesueur)	Speleophil	I	–
Siluridae	*Silurus glanis* L.	Phytophil	N	NT
Percidae	*Perca fluviatilis* L.	Phyto-lithophil	N	LC
	Sander lucioperca (L.)	Phytophil	N	LC
	Gymnocephalus cernuus (L.)	Phyto-lithophil	N	LC

(continued)

Table 1 (continued)

Family	Scientific name	Reproductive guilds	Origin	IUCN category
Gasterosteidae	*Gasterosteus aculeatus* L.	Ariadnophil	N	LC
	Pungitius pungitius (L.)	Ariadnophil	N	LC
Gobiidae	*Neogobius fluviatilis* (Pall.)	Lithophil	I	–
Cottidae	*Cottus gobio* (L.)	Speleophil	N	VU
	Cottus poecilopus Heckel	Speleophil	N	VU

Reproductive guilds [21], IUCN [22]: CR, critically endangered; EN, endangered; VU, vulnerable; NT, near threatened; CD, conservation dependent; LC, least concern. Origin: N, native; I, introduced

in this region are classified as the highest level of critically endangered according to the International Union for Conservation of Nature (Table 1). *Anguilla anguilla* is a critically endangered species throughout its range of occurrence, while *Vimba vimba* is a critically endangered species throughout Poland. In turn, *Coregonus albula*, *C. lavaretus*, *O. eperlanus*, *Lota lota*, *B. barbus*, *Rhodeus amarus*, *Misgurnus fossilis*, *Cottus gobio*, and *C. poecilopus* are classified as vulnerable species, and *Carassius carassius*, *Leuciscus aspius*, and *Silurus glanis* are classified as near threatened (Table 1). *R. amarus*, *M. fossilis*, *C. gobio*, *C. poecilopus*, *Barbatula barbatula*, and *Cobitis taenia* are under partial species conservation. Additionally, *R. amarus*, *C. taenia*, *C. gobio*, and *M. fossilis* are listed in Annex II of the Habitat Directive, and *C. albula*, *C. lavaretus*, *B. barbus*, and *L. aspius* are listed in Annex V of the same directive.

The majority of autochthonous fish species in Poland have been severely affected by years of human pressure and have reacted with the collapse of local populations [22]. The situation of fish assemblages in the lakes of northeastern Poland is similar. The confirmation of *V. vimba* in the food of *Phalacrocorax carbo* nesting on the island in Lake Warnołty certainly qualifies as a curiosity [29]. For many years *V. vimba* had not been registered in fisheries catches, and the specimens found probably originated from the local form of this species that occurs in Lake Roś. In Poland, *V. vimba* is classified as critically endangered. Of its former range of occurrence, which included most of the Vistula and Oder river tributaries, currently only a small fragment remains. Freshwater populations have formed in a few river systems, and within the region analyzed, this species occurs in lakes Roś (the Pisa–Vistula river system) and Maróz (Łyna–Pregoła river system).

5 Alien Species

A significant part of the fish fauna of the lakes of northeastern Poland are alien species, of which nine have been noted (Table 1). To date, approximately 40 alien fish species have been noted in Polish inland waters [30]. Most of these alien species occur as the result of intentional or accidental stocking. The process itself of the

spread of alien fish species is very poorly documented. *Cyprinus carpio* and *Carassius gibelio* occur in lakes as a result of intentional stocking. While Asian carps have not been permitted to be released into lakes for a few years, they are commonly expanding their distribution naturally from ponds and are released into open waters along with stocking material of other cyprinid species. Most of the alien species confirmed in Polish waters do not reproduce in these latitudes [28]; however, they do have a disadvantageous impact on native fauna and flora and sometimes on the ecological and trophic statuses of waters. When the large numbers of *C. carpio* released into lakes feed, they release nutrients that accumulate in the sediments, and this increase the trophic status of the waters. The groups of alien fish species reproducing in the region analyzed include *C. gibelio*, *Pseudorasbora parva*, *Ameiurus nebulosus*, and *Neogobius fluviatilis*. All of these species are invasive species in Poland [25]. *C. gibelio* occurs in most lakes, and its spread is linked to stocking. In the mid-twentieth century, *A. nebulosus* occurred sporadically in the region studied [20], but in recent years, its distribution has increased [31]. This species is noted at dispersed sites throughout nearly the entire area of northeastern Poland, although the occurrence of this species was noted previously [20]. The expansion of *N. fluviatilis* is progressing from the Vistula River through the Narew and Pisa rivers. In recent years, *N. fluviatilis* has settled in the southern part of the Masurian Lakeland.

6 Fisheries Management

Fisheries in the lake region of northeastern Poland has a very long tradition. Despite ownership and structural changes, it remains the central region of lake fisheries in Poland. Approximately 70 enterprises of various types are active in the fisheries sector of this area. As a rule, these enterprises each exploit a few lakes with surface areas of a dozen or so hectares [32]. The largest fisheries enterprises exploit lakes of a combined surface area exceeding 12,000 or so hectares. Thirteen fisheries enterprises exploit over 3,000 ha, and another 4 exploit lakes with a combined surface area exceeding 1,000 ha.

Traditionally, the fisheries sector in Poland is divided into four types. The previously dominant type of commercial fisheries has been replaced by recreational fisheries, which is now the dominant type of fisheries, at least in terms of area. The second most important type of fisheries is angling, which is usually conducted in fisheries districts exploited by the Polish Anglers Association. The least common type of fisheries is specialized fisheries conducted by scientific institutions (Inland Fisheries Institute, University of Warmia and Mazury) or fisheries that specialize in fish culture. It should be underscored here that the division of the fisheries sector is often arbitrary. In the case of many lakes, fish populations are regularly exploited by anglers, while catches are also made with professional fishery, and the decided majority of lakes are stocked more or less intensely.

7 Fisheries Yield

Following World War II, almost all the lakes in northeastern Poland were exploited by state commercial lake fish farms, which were legally required to conduct rational fishery management [33]. These farms were also required to keep detailed catch statistics and to record management practices. In the early 1950s, fisheries and biological studies were initiated in over 2,000 lakes, which corresponded to most Polish lakes. In the early period, the aim was to increase catches of commercially important fish species [20]; however, as the eutrophication of lakes progressed, changes were noted in the structure of the catches, and their yield decreased [34]. Catches of commercially important fishes have also decreased in recent years (Fig. 1). In the 2004–2016 period, annual yield decreased by approximately 300–880 tons in 2016. The three most significant species in terms of biomass (*Abramis brama*, *Esox lucius*, *Rutilus rutilus*) comprise 50–60% of the total catches. The species groups that contributed a 5–10% share of the catches are *C. albula*, *Perca fluviatilis*, *Blicca bjoerkna*, *T. tinca*, *A. anguilla*, and *Sander lucioperca*. However, the economic ranking of these species is different, with *A. anguilla* accounting for about 30% of the value of professional catches followed by *E. lucius* – 20%, *C. albula* – 13%, and *S. lucioperca* – 10% [32, 35].

Decreases in fish catches were also noted in catch efficiency. In the 1950s and 1960s, the mean commercial catch efficiency was 26 kg/ha [20]. In recent years catch efficiency has decreased by nearly 13–7.2 kg/ha (Fig. 2). Considering, however, the most important of the species caught, the trend in changes of fishing

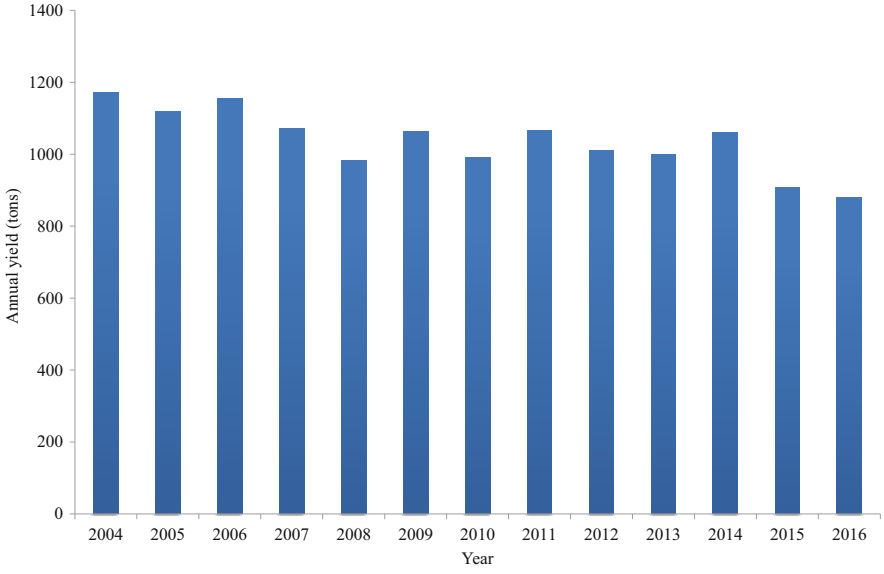

Fig. 1 Fisheries yield (tons) of professional fisheries in lakes in northeastern Poland in 2004–2016

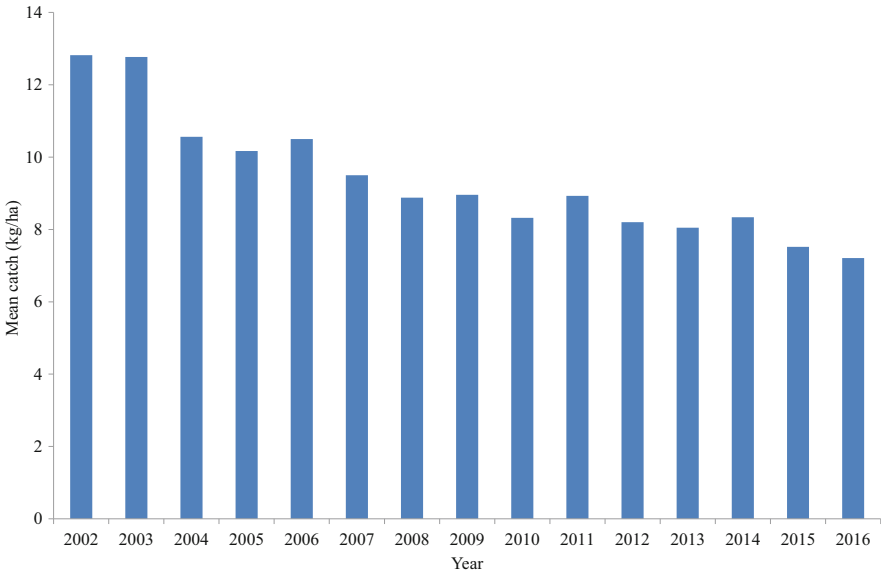

Fig. 2 Changes in mean catch efficiency (kg/ha) of catches of professional fisheries in lakes in northeastern Poland in 2002–2016

efficiency was not as unequivocal. The catch efficiency of *C. albula* exhibited substantial fluctuation (from 0.5 to 1.1 kg/ha), which is characteristic of this species. Decreases in catch efficiency were noted for *A. anguilla*, *A. brama*, and *R. rutilus*, while increases were noted for *E. lucius*, *T. tinca*, and *S. lucioperca*. It must be underscored that catch efficiency does not necessarily reflect fish biomass or species composition since only commercially valuable species are subjected to intense exploitation.

8 Conclusions

Fish inhabiting lakes form characteristic assemblages that are generally linked with lake limnological type. Similarly, in rivers the fish fauna structure depends largely on environmental conditions. The species richness and biological diversity of fish fauna is a reflection of interactions among local species groups and environmental conditions. The species composition and quantitative structure of assemblages inhabiting the lakes of northeastern Poland are subject to long-term ecological succession. The occurrence of fish in lakes is conditioned by many factors, and the natural processes that shape the structure of fish assemblages have been aggravated by anthropogenic factors [36]. Despite very clear changes caused by water pollution, habitat transformation, and fisheries management (catches, stocking), the fish fauna of the lakes of northeastern Poland is characterized by considerable species richness in comparison

to other areas of the country. A large segment of the species occurring here are subject to legal conservation and are classified as threatened according to IUCN categories. The main threats to indigenous fish fauna include habitat transformation, water eutrophication, and the spread of alien fish species.

Acknowledgments This study was supported by statutory project No. S009 and No. S014 of the Inland Fisheries Institute in Olsztyn (Poland).

References

1. Kondracki J (1965) A geomorphologic and hydrographic outline of the Mazurian Lakeland. In: Patalas K (ed) Mazury. Part I. XVI Limnologorum Conventus in Polonia MCMLXV. Polish Academy of Sciences, Hydrobiological Committee, Cracow, pp 21–37
2. Jokiel P, Marszalewski W, Pociask-Karteczka J (2017) Hydrology of Poland. Wydawnictwo PWN, 342 pp (in Polish)
3. Witkowski A, Kotusz J (2008) Status of ichthyofauna inventory research in Polish rivers. Rocz Nauk PZW 21:23–60. (in Polish)
4. Przybylski M, Głowacki Ł, Grabowska J, Kaczkowski Z, Kruk A, Marszał L, Zięba G, Ziułkiewicz M (2019) Riverine fish fauna in Poland. In: Korzeniewska E, Harnisz M (eds) Polish River basins and lakes – Part II: biological status and water management. Springer, Cham
5. Zawisza J (1961) The growth of fish in the lakes of the Węgorzewo district. Rocz Nauk Rol 77-B-2:681–748. (in Polish)
6. Kapusta A, Morzuch J, Bogacka-Kapusta E, Pająkowski J (2012) Ichthyofauna of Lake Mukrz in the Leon Wyczółkowski Cisy Staropolskie nature reserve in Wierzchlas. Chrońmy Przyr Ojcz 68:435–442. (in Polish)
7. Chybowski Ł, Białokoz W (1992) Analysis of fish catches from the Krutynia River lake complex. Komun Ryb 1:9–11. (in Polish)
8. Boroń A, Szlachciak J (2011) The ichthyofauna of Olsztyn. In: Jankun M, Furgała-Selezniow G, Woźniak M, Wiśniewska AM (eds) Assessment and biodiversity of waters. Wydział Ochrony Środowiska i Rybactwa UWM, Agencja Wydawnicza Argi S.C., Olsztyn and Wrocław, pp 179–189 (in Polish)
9. Czarkowski TK, Martyniak A, Kapusta A, Wójcik A, Bowszys M, Wziątek B, Szymańska U, Kozłowski J (2007) Feeding ecology of vendace, *Coregonus albula* (L.), in Lake Wigry (Northeastern Poland). Arch Pol Fish 15:117–128
10. Kozłowski K, Kozłowski J, Poczyczyński P, Martyniak A (2010) Age and growth of vendace, *Coregonus albula* (L.), from Lake Wigry (northeast Poland). Arch Pol Fish 18:239–245
11. Hutorowicz A, Kapusta A, Krzywosz T, Hutorowicz J (2005) The ichthyofauna of the dystrophic Lake Smolak (northern Poland) in light of selected physical and chemical water conditions thirty years after the conclusion of liming and fertilization. Arch Pol Fish 13:207–225
12. Białokoz W, Krzywosz T (1992) Ichthyofauna structure in the lakes of Wigry National Park. In: Zdanowski B (ed) The lakes of Wigry National Park: Eutrophication status and conservation. Polska Akademia Nauk, Komitet Naukowy przy Prezydium PAN „Człowiek i Środowisko" PAN, 3, Zeszyty Naukowe 3, Wydawnictwo Zakład Narodowy im. Ossolińskich, Wrocław, pp 153–162 (in Polish)
13. Martyniak A, Wziątek B, Szymańska U, Osewski M, Hliwa P (2004) Ichthyofauna composition and age and growth rates of fish in lakes Suchar Wielki, Sucharek, and Klonek. Rocz Augustowsko-Suwalski 4:131–136. (in Polish)
14. Benecke B (1881) Fische, Fischerei und Fischzucht in Ost- und Westpreussen. Hartungsche Verlag, Königsberg

15. Bernatowicz S (1947) On the threshold of managing the Masurian lakes. Prz Ryb 7/8:259–263. (in Polish)
16. Staff F, Rudnicki A (1949) Fisheries of Polish Prussia. Masurian Lake District. In: Staff F (ed) Fisheries of the recovered territories. Wyd. PIWR, Warsaw, pp 1–37 (in Polish)
17. Bernatowicz S (1953) Distribution and growth of vendace (*Coregonus albula* L.) in Masurian Lakes and environmental conditions. Rocz Nauk Rol 67-B-1:1–20. (in Polish)
18. Bernatowicz S (1953) The actual state of distribution of vendace (*Coregonus albula* L.) in the Masurian and Suwałki district lakes. Rocz Nauk Rol 67-B-1:61–80. (in Polish)
19. Rembiszewski JM, Rolik H (1975) Lampreys and fishes – Cyclostomata et Pisces. Catalog of Polish Fauna. 38. PWN, Warsaw, 252 pp (in Polish)
20. Zawisza J (1965) Fisheries in Mazury. In: Patalas K (ed) Mazury. Part I. XVI Limnologorum Conventus in Polonia MCMLXV. Polish Academy of Sciences, Hydrobiological Committee, Cracow, pp 53–63
21. Balon EK (1975) Reproductive guilds of fishes: a proposal and definition. J Fish Res Board Can 32:821–864
22. Witkowski A, Kotusz J, Przybylski M (2009) Degree of threat to Polish freshwater ichthyofauna: red list of lampreys and fish – state in 2009. Chrońmy Przyr Ojcz 45:33–52. (in Polish)
23. Patalas K (1965) Mazury. Part II. XVI Limnologorum Conventus in Polonia MCMLXV. Polish Academy of Sciences, Hydrobiological Committee, Cracow, p 70
24. Chybowski Ł, Białokoz W, Krzywosz T (1994) Lake trout in the waters of the Suwałki region. In: Wołos A (ed) Current issues in lake fisheries. Wydawnictwo IRS, Olsztyn, pp 141–149. (in Polish)
25. Grabowska J, Kotusz J, Witkowski A (2010) Alien invasive fish species in Polish waters: an overview. Folia Zool 59:73–85
26. Popović D, Szczepkowski M, Heese T, Weglenski P (2016) Introgression of peled (Coregonus peled) into European whitefish (*C. lavaretus*) in Poland. Conserv Genet 17:503–508
27. Ejsmont L, Słoniewski B (1969) On the accidental record of the European mudminnow (*Umbra krameri* Walbaum, 1792) in Poland (Osteichthyes, Esociformes). Przegląd Zoologiczny 13:215–219. (in Polish)
28. Brylińska M (2000) The freshwater fishes of Poland. PWN, Warsaw, 521 pp (in Polish)
29. Krzywosz T, Traczuk P (2010) Local populations of vimba in Masuria? Komun Ryb 1:29. (in Polish)
30. Witkowski A, Grabowska J (2012) The non-indigenous freshwater fishes of Poland: threats to the native ichthyofauna and consequences for the fishery: a review. Acta Ichthyol Piscat 42:77–87
31. Kapusta A, Morzuch J, Partyka K, Bogacka-Kapusta E (2010) First record of brown bullhead, *Ameiurus nebulosus* (Lesueur), in the Łyna River drainage basin (northeast Poland). Arch Pol Fish 18:261–265
32. Wołos A (2009) Diagnosis of the current state and perspectives for the development of inland and coastal fisheries areas in the Warmian-Masurian Voivodeship. Wydawnictwo IRS, Olsztyn, 352 pp (in Polish)
33. Bnińska M, Leopold M (1990) Fisheries management in Polish lakes. In: van Densen WLT, Steinmetz B, Hughes RH (eds) Management of freshwater fisheries. Proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweden, 31 May-3 June 1988. Pudoc, Wageningen, pp 406–436
34. Leopold M (1986) Status and prospects of freshwater fisheries in Poland. Expert assessment for the Ministry of Agriculture, Forestry and Food. Instytut Rybactwa Śródlądowego, Olsztyn, p 44. (in Polish)
35. Wołos A, Draszkiewicz-Mioduszewska H, Mickiewicz M (2015) Magnitude and characteristics of lake fisheries production in 2009–2014. In: Mickiewicz M, Wołos A (eds) Exploiting fisheries resources in 2009–2014. State, changes, trends. Wydawnictwo IRS, Olsztyn, pp 9–16. (in Polish)

36. Mamcarz A, Skrzypczak A (2011) Between the ichthyofauna biodiversity of Masurian waters and their management: theory, problems, and hope. In: Jankun M, Furgała-Selezniow G, Woźniak M, Wiśniewska AM (eds) Managing the ichthyofauna of diversified aquatic environments. Wydział Ochrony Środowiska i Rybactwa UWM, Agencja Wydawnicza „Argi" S.C., Olsztyn and Wrocław, pp 7–38 (in Polish)