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OCCURRENCE OF PIKEPERCH (*SANDER LUCIOPERCA* (L.)) AND ITS HABITATS IN NORTHEASTERN POLAND IN 1951-1994

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ABSTRACT. The study was conducted based on data from lake management books. Pikeperch, *Sander lucioperca* (L.), was present at various time intervals in 619 lakes in northeastern Poland that covered a total area of 116.2 thousand ha. Based on the frequency of occurrence of this fish species in commercial catches, three categories of habitats were distinguished. The morphologic and morphometric parameters of these three categories of lakes were compared. For each category, the dynamics of temporal changes was characterized in the lakes in which pikeperch lived, and the trend lines of these changes were plotted. An increase in the number of habitats of this predatory fish species appeared in 1951-1965 and was directly connected with its natural migration. The range of fish stocking measures and the time when they began were determined for the three categories of lakes analyzed.

Key words: PIKEPERCH (*SANDER LUCIOPERCA*), HABITAT, LAKES, NORTHEASTERN POLAND, OCCURRENCE

INTRODUCTION

Poland lies near the western border of the natural distribution of pikeperch, *Sander lucioperca* (L.), (Nagięć 1977), and this fish is considered as a native species here (Witkowski 1996). With its specific habitat requirements, pikeperch is, both biologically and commercially, a valuable component of the ichthyofauna of lakes (Nagięć 1961). Data from the sixteenth century revealed that pikeperch inhabited several lakes of the Mazurian Lake District, whereas observations conducted in the late nineteenth and early twentieth centuries and in the interwar years indicated that this species was withdrawing from many habitats (Staff 1950). The low status of pikeperch in the interwar years resulted from a number of economic conditions (Skrzypczak and Mamcarz 2001). In the early years of the development of commercial fisheries, larger numbers of pikeperch were reported in very few Mazurian lakes (Bernatowicz 1947), so suggestions were made that at least 30% of the total

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lake area should be stocked with this fish species (Kostrowicki 1946). In the early 1950s, action was taken to increase the production of pikeperch stocking material for the stocking of open waters (Skrzypczak and Mamcarz 2001).

Studies of exploited pikeperch populations that enhanced the knowledge of the presence of this fish species were conducted mainly by Nagięć (1961, 1977) and Bonar (1977). Changes in the number of pikeperch populations at increasing rates of lake eutrophication were also indicated in the studies on coregonid management (Wołos and Bnińska 1998). The presence and expansion of pikeperch populations in the complex of the Great Mazurian Lakes were reported by Skrzypczak and Mamcarz (1995).

The aim of this paper was to investigate temporal changes in the distribution of pikeperch habitats in the area under study as well as to try to determine the underlying reasons for such changes. The paper also contains a description of the habitats where pikeperch lived in 1951-1994.

MATERIALS AND METHODS

Based on records in management books for the lakes of northeastern Poland from the 1951-1994 period, the authors selected a group of reservoirs in which pikeperch occurred in the fishing statistics or in which this species was stocked. The lakes were categorized as pikeperch habitats according to the frequency of occurrence of this fish species in commercial catches. This index was expressed as a ratio between the number of years when pikeperch was present in catches to the total number of the years it was exploited. The index served to divide the lakes into three categories of pikeperch habitats: A (≥ 0.75) – permanent; B (0.74-0.25) – temporary; C (< 0.25) – incidental.

The morphological and morphometric parameters of the lakes analyzed come from morphometric cards prepared according to data provided by the Inland Fisheries Institute in Olsztyn. Mean depth, depth index, relative depth, and shore development are the generally accepted parameters which characterize water bodies (Szczerbowski 1993). The size of the pelagic zone was determined according to the isobath of 5.0 meters. The size parameters of Lake Śniardwy and the depth of Lake Hańcza were excluded from the analysis of pikeperch habitat characteristics due to their outlying values. When analyzing temporal changes in the number of pikeperch in stocked lakes, eighteen lakes in which no pikeperch were caught despite stocking were categorized as category C (725.1 ha).

For basic calculations, descriptive statistics were used, such as arithmetic means, standard deviation (SD), and standard mean error (SE). In order to analyze potential differences in the parameters that describe pikeperch habitats, analysis of variance (ANOVA) and *post-hoc* comparison of means (T-Tukey test) were performed. Groups of variables were pre-tested in order to check whether they fulfill the basic requirements of ANOVA tests and were therefore applicable to perform certain statistical analyses (Leven's test, Brown and Forsythe's test, W Shapiro-Wilks' test) (StatSoft 1997). The significance of the tests and analyses was determined at a level of significance of $\alpha = 0.05$.

RESULTS

Pikeperch was present at different time periods between 1951 and 1994 in 619 lakes covering a total area of 116.2 thousand ha in northeastern Poland. Permanent populations, associated with category A lakes, were present in 116 lakes (46246 ha). More temporary habitats, designated as category B lakes, were identified in 215 lakes (40526 ha). The most numerous group of lakes, 288 reservoirs with a total area of 29454 ha, belonged to category C, in which pikeperch occurred only sporadically and incidentally. Figure 1 shows the distribution of the 331 category A and B lakes that were the most important for the presence of pikeperch in northeastern Poland. The mean (± SD) of the frequency of pikeperch occurrence in commercial catches in category A, B, and C habitats was 0.91 (± 0.08), 0.49 (± 0.16) and 0.11 (± 0.12), respectively.

Analysis of morphological and morphometric traits of pikeperch habitats showed some significant differences in the following parameters: lake area, pelagic zone area, relative depth, and shore development (Table 1). Such differences were most evident at the average lake area, which decreased as the status of the lakes as pikeperch habitats declined. For the pelagic zone area, differences were found between category C lakes versus the other two categories. The differences in parameters such as relative depth and shore development appeared between the permanent habitats (category A) and the other two habitat categories. These differences were statistically highly significant ($P < 0.0001$).

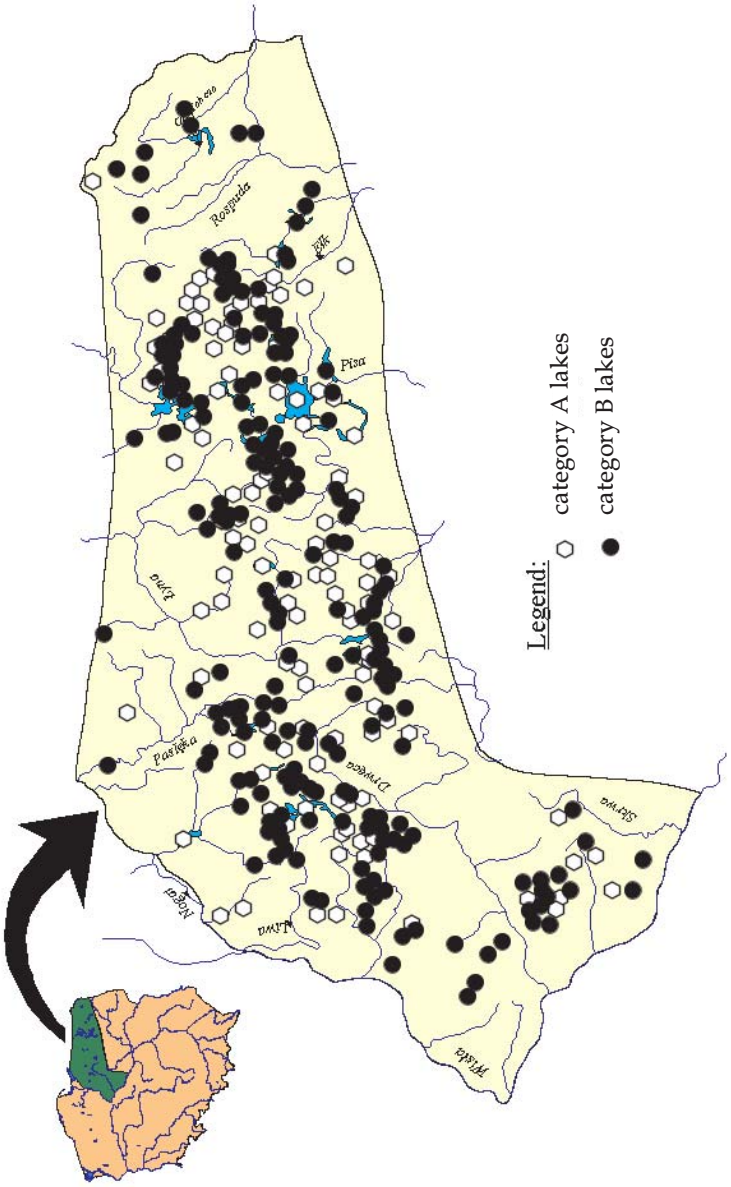

Fig. 1. Distribution of permanent (category A) and temporary (category B) pikeperch habitats in northeastern Poland in 1951-1994.

TABLE 1

Results of comparisons of the morphological and morphometric traits of pikeperch habitats (categories A, B, C – see Materials and Methods) in northeastern Poland in 1951-1994 (mean ± SE)

Parameters	F-ratio	Category of pikeperch habitats		
		A	B	C
Lake area (ha)	18.15*	$315.40^{a} \pm 42.99$	$188.49^{b} \pm 24.12$	$102.27^{c} \pm 12.93$
Pelagic zone area (ha)	4.43*	$147.57^{a} \pm 26.89$	$116.24^{ac} \pm 18.24$	$59.78^{bc} \pm 15.46$
Share of pelagic zone (%)	4.17*	$34.19^{a} \pm 2.48$	$41.91^{a} \pm 1.98$	$34.40^{a} \pm 2.41$
Maximal depth (m)	1.16	$14.49^{a} \pm 1.10$	$16.56^{a} \pm 0.89$	$16.41^{a} \pm 0.81$
Mean depth (m)	2.92	$4.80^{a} \pm 0.26$	$5.68^{a} \pm 0.24$	$5.63^{a} \pm 0.23$
Depth index	0.84	$0.40^{a} \pm 0.01$	$0.38^{a} \pm 0.01$	$0.38^{a} \pm 0.01$
Relative depth	22.39*	$0.01^{a} \pm 0.00$	$0.02^{b} \pm 0.00$	$0.02^{b} \pm 0.00$
Shore development	11.35*	$2.17^{a} \pm 0.08$	$1.90^{b} \pm 0.05$	$1.77^{b} \pm 0.05$

Critical value F=3.01 (df 2; 616; α=0.05). Indexed (*) F test statistic values are statistically significant (P < 0.05). Mean values in the same row with different letter superscripts are statistically different (P < 0.05)

The number of lakes in which pikeperch was fished continued to increase in all the three categories of lakes until the mid-1960s (Fig. 2). The most dynamic growth was recorded in category B habitats between 1955 and 1965. At the beginning of this period, pikeperch was present in approximately 20% of the exploited lakes, whereas ten years later this species was caught in over 60% of the lakes. In the late 1970s and early 1980s, a decrease in the number of lakes with pikeperch was observed. From the mid-1980s the trend line describing changes

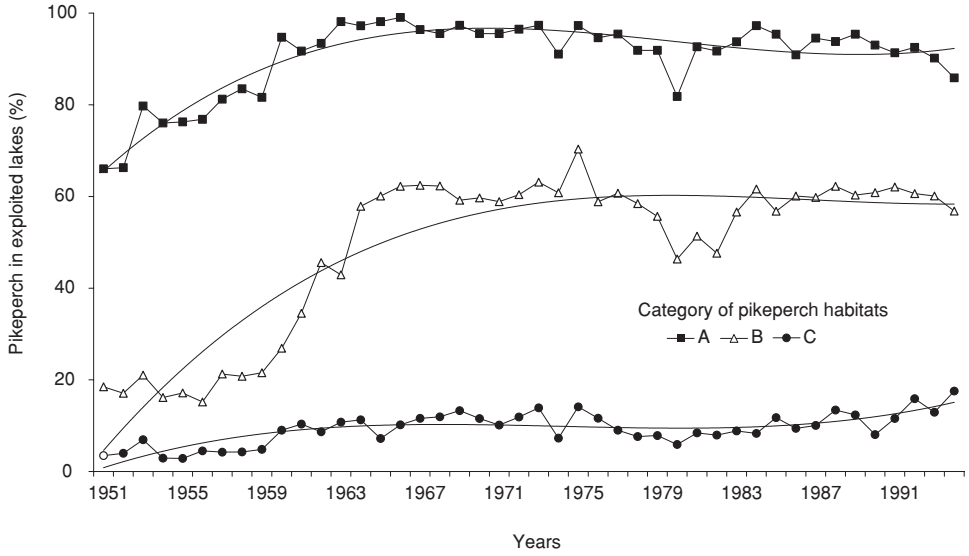

Fig. 2. Occurrence of pikeperch in commercial catches from lakes (categories A, B, C – see Materials and Methods) in northeastern Poland in 1951-1994.

in the occurrence of pikeperch in category C lakes exhibited an increasing tendency, but the trends were the opposite in the other two categories. The regression equations and determination coefficients for the plotted curves are presented in Table 2.

TABLE 2

Regression equation coefficients ($Y=ax^3+bx^2+cx+d$) and determination coefficients (R^2) in the three-degree polynomial adjustment of trend lines at approximation of time series changes in the occurrence of pikeperch in fisheries catches of exploited lakes (categories A, B, C – see Materials and Methods) in northeastern Poland in 1951-1994

Category of pikeperch habitats	R^2	Equation coefficient			
		a	*b*	*c*	*d*
A	0.817	0.0017	-0.1553	4.1727	61.5000
B	0.825	0.0014	-0.1499	5.2985	-0.5537
C	0.610	0.0009	-0.0666	1.5037	-0.6097

TABLE 3

Distribution of pikeperch populations in the lakes (categories A, B, C – see Materials and Methods) of northeastern Poland in 1951 with the time distribution of the first stocking treatments

Specification		Category of pikeperch habitats								
		A			B			C		
		No. of lakes	Area		No. of lakes	Area		No. of lakes	Area	
			(ha)	Share in category (%)		(ha)	Share in category (%)		(ha)	Share in category (%)
Total		75	34753	75.2	42	7652	18.9	25	4885	16.6
Non-stocked lakes		25	15823	34.2	17	5221	12.9	21	4764	16.2
First stockings	1951-1961	22	10106	21.9	6	621	1.5	-	-	0.0
	1962-1972	15	5175	11.2	11	602	1.5	1	6	0.0
	1973-1983	4	1349	2.9	5	450	1.1	1	65	0.2
	1984-1994	9	2301	5.0	3	758	1.9	2	50	0.2

In the early years of the analyzed period, pikeperch was present in 142 lakes in northeastern Poland. The lakes covered a total area of 47.2 thousand ha (Table 3). The largest number of pikeperch habitats was found in category A lakes: 75 lakes (34753 ha). Twenty-five of these lakes had not been stocked with pikeperch until 1994. In the other lakes pikeperch stocking started mainly between 1951 and 1972.

While analyzing the records, the authors found that after 1951 pikeperch appeared in 477 water reservoirs with a combined area of 68.9 thousand ha (Table 4).

TABLE 4

Increasing distribution of pikeperch and time analysis of the first stocking in habitats (categories A, B, C – see Materials and Methods) of northeastern Poland settled after 1951 (BS – first catch before first stocking, AS – first catch after first stocking)

Specification			Category of pikeperch habitats								
			A			B			C		
			No. of lakes	Lake area		No. of lakes	Lake area		No. of lakes	Lake area	
				(ha)	Share in category (%)		(ha)	Share in category (%)		(ha)	Share in category (%)
Total			41	11494	24.8	173	32874	81.1	263	24569	83.4
First catch	1951-1961	BS	15	7428	16.1	68	20597	50.8	57	5559	18.9
		AS	20	2665	5.7	21	1670	4.1	8	743	2.5
	1962-1972	BS	4	268	0.6	38	4198	10.4	83	10344	35.1
		AS	2	1133	2.4	33	3423	8.4	17	883	3.0
	1973-1983	BS	-	-	0.0	8	2629	6.5	40	2545	8.7
		AS	-	-	0.0	5	357	0.9	6	454	1.5
	1984-1994	BS	-	-	0.0	-	-	0.0	43	3795	12.9
		AS	-	-	0.0	-	-	0.0	9	246	0.8
Non-stocked lakes			7	2816	6.1	65	14810	36.5	207	17701	60.1
First stocking	1951-1961		25	3854	8.3	58	6502	16.0	22	1628	5.6
	1962-1972		7	2170	4.7	30	7857	19.4	17	1750	5.9
	1973-1983		1	2600	5.6	8	303	0.8	6	364	1.2
	1984-1994		1	54	0.1	12	3402	8.4	11	3126	10.6

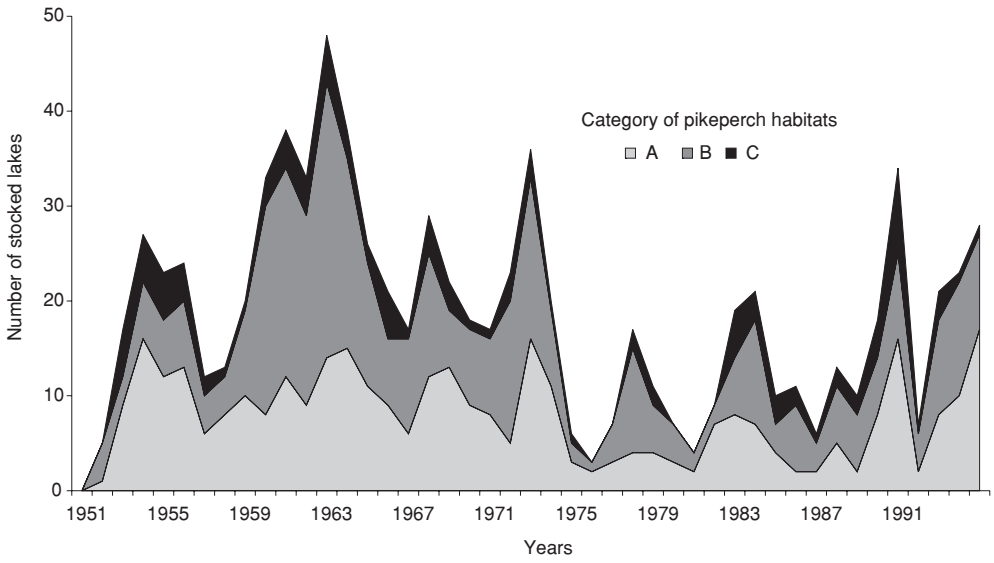

Fig. 3. Number of lakes (categories A, B, C – see Materials and Methods) in northeastern Poland stocked with pikeperch in 1951-1994.

The permanent (category A) and temporary (category B) habitats deserve special attention. These two categories were composed of 41 and 173 lakes, respectively, which comprised a total of 44.3 thousand ha. Among these 214 lakes, pikeperch was caught in 133 (35120 ha) prior to the first stocking. Some sporadic occurrence of pikeperch in category C lakes (263 lakes) after 1951, noted only forty times, may have been related to pikeperch stocking in these water reservoirs.

The total number of lakes stocked with pikeperch in subsequent years varied substantially from 48 lakes in 1963 to 3 in 1975 (Fig. 3). Until the end of the 1950s, stocking was mainly conducted in category A lakes. The increase in the number of stocked pikeperch, which appeared in the early 1960s, was associated predominantly with temporary habitats (category B). A rapid decrease in the number of pikeperch-stocked lakes took place in the mid-1970s.

DISCUSSION

The analysis of morphometric and morphological traits of pikeperch habitats indicates that this fish species prefers larger water bodies. Similar observations were reported by Toivonen (1966), although the size of lakes was not always connected with the requirements of this fish species (Mikulski 1964). It should be assumed that the pikeperch type of lake, as included in the fishing typology (Korycki 1976), was characterized on the basis of water reservoirs which would belong to category A. With only scarce information on pikeperch stocking measures in lakes during the 1946-1950 period (Nagięć 1961), native populations of pikeperch should be looked for mainly in this group of lakes.

The size of water reservoirs is usually positively correlated with their maximum and average depth (Różycki 1971). At the same time, shallower lake depth together with larger area will theoretically increase the chance that the lakes in question are polymictic (Choiński 1995). Next to low water clarity, important traits typical of pikeperch habitats include rather low average depth and the absence of thermal stratification in summer (Mikulski 1964, Nagięć 1977). Due to the large variation in the parameters observed, these assumptions were not confirmed by the significance of the statistical analysis, although the average depth of category A lakes was shallower. The fact that they were shallower was also indicated by the similar percentage of area that

was in the pelagic zones of all the lakes studied, which varied considerably in their total area. The high level of statistical significance of the differences for the relative depth parameter and shore development implies that pikeperch prefers habitats permanent in character, such as category A lakes.

In the interwar years pikeperch was present in 76 lakes in the Mazurian Lake District (Staff and Rudnicki 1950). This figure is smaller versus the number of lakes in which pikeperch was observed in the early 1950s (142 lakes), but in general it is congruent with the number of category A habitats (75 lakes).

The analysis of the distribution of pikeperch populations should be based on the observations of category B lakes. Slightly over 80% of those lakes are water reservoirs in which pikeperch appeared for the first time three years after recorded fishing exploitation had begun. Assuming that morphometric and morphological characteristics of lakes as well as habitat preferences of pikeperch do not change, the occurrence of pikeperch in new habitats should be related to other events, of which the most important are increasing eutrophication (Hartmann and Nümann 1977, Leach et al. 1977), stocking (Nagięć 1961, Lehtonen et al. 1984), and some tendency of the fish to migrate and settle in whole river systems (Nagięć 1972, Winkler and Thieme 1978).

Some researchers have reported that this predatory fish species has appeared in new habitats that are different from typical pikeperch lakes (Wołos and Bnińska 1998). In the majority of category B lakes (65.9%), pikeperch occurred in catches prior to the first stocking. Disregarding the dubious relationship between stocking and the occurrence of pikeperch (the first catch either in the same year pikeperch stocking began or five or more years afterwards), this percentage would increase by over 12.5%. Further confirmation that pikeperch can migrate is provided by some data on category C lakes. Although the distribution of pikeperch in those lakes has little zoogeographical importance, its presence in nearly 85% of category C lakes had no relationship with direct stocking treatments (after disregarding dubious cases, the percentage would rise to 92.7%).

The problem of water pollution and eutrophication of the Mazurian Lake District and the effect of these events on the ichthyofauna were indicated in the early post-war years (Michalski 1949). The process of eutrophication was also described through some observations of structural changes in fish assemblages (Bnińska and Wołos 1998). An increase in the number of small cyprinid fish is another indication of incre-

asing eutrophication of lakes (Hartmann 1977). Indices of the exploitation of this fraction of fish in lakes of northeastern Poland began to rise evidently from the late 1970s (Skrzypczak 2001). It is difficult, then, to directly associate the migration of pikeperch and the increase in pikeperch habitats in 1951-1965 with the eutrophication of lakes. The effect of eutrophication became more evident more than a decade later when it was considered one of the main reasons why catches of pikeperch from the Great Mazurian Lakes in the 1980s increased rapidly (Skrzypczak and Mamcarz 1995). No relationship was observed then between stocking and the peak in pikeperch catches.

The observations of Skrzypczak and Mamcarz (2001) of the introduction and stocking of pikeperch in lakes of northeastern Poland failed to prove whether these measures had any direct influence on the temporal dynamics in the distribution of this species. The number of stocked lakes was not correlated with the amount of stocking material used. This is proved by the steadily increasing amounts of stocking material introduced from 1965 to 1984 (Skrzypczak and Mamcarz 2001), which were accompanied by a decrease in the number of stocked lakes and a decrease in the pikeperch habitats in the late 1970s and early 1980s. It is difficult to draw conclusions from the above data due to the fact that 34% of the lakes in both categories A and B were not stocked at all.

Successful pikeperch stocking is more strongly linked with the presence of proper habitat conditions for this species rather that the amounts of stocking material introduced to lakes, and the evaluation of the stocking efficiency is often difficult or even impossible (Zakęś and Szkudlarek 1996). Nevertheless, the numerous introductions of pikeperch in the 1950s and 1960s (Skrzypczak and Mamcarz 2001), conducted at different sites in the river catchments located in the lake districts of northeastern Poland are more than likely to have helped create new points on the pikeperch distribution map.

CONCLUSIONS

1. The morphological and morphometric traits of the habitats in which pikeperch was present for the longest periods suggest that this fish species is strongly associated with water reservoirs called pikeperch lakes.
2. Pikeperch settled new habitats most dynamically in the 1951-1965 period.

3. The major role in the increasing distribution of pikeperch in the lakes of northeastern Poland was played by the migration of this fish species, which coincided in time with the development of commercial fisheries and the beginning of fish stocking in river catchments in lake districts.

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STRESZCZENIE

WYSTĘPOWANIE SANDACZA (*SANDER LUCIOPERCA* (L.)) I JEGO SIEDLISKA W PÓŁNOCNO-WSCHODNIEJ POLSCE W LATACH 1951-1994

Badania wykonano w oparciu o dane z ksiąg gospodarczych jezior. Występowanie sandacza, *Sander lucioperca* (L.), w różnym wymiarze czasowym, stwierdzono w 619 jeziorach północno-wschodniej Polski, o łącznej powierzchni ponad 116,2 tys. ha. Na podstawie częstotliwości pojawiania się tego gatunku w połowach komercyjnych wyłoniono 3 kategorie siedlisk i porównano ich parametry morfologiczne oraz morfometryczne. W każdej kategorii scharakteryzowano dynamikę zmian czasowych w liczbie jezior, w których poławiano sandacza oraz wykreślono linie trendu dla tego zjawiska. Określono zasięg zarybień i czas ich rozpoczęcia w wyodrębnionych kategoriach jezior.

Wzrost liczby siedlisk tego drapieżnika zaznaczył się w latach 1951-1965. Główną rolę w rozprzestrzenianiu się sandacza w jeziorach północno-wschodniej Polski odegrały jego wędrówki, które wykazują zbieżność czasową z rozwojem gospodarki rybackiej i rozpoczęciem zarybień w pojeziernych zlewniach rzek. Cechy morfologiczne i morfometryczne siedlisk, w których sandacz występował w najdłuższym wymiarze czasowym, wskazują na najsilniejsze związki tego gatunku ze zbiornikami określanymi w typologii rybackiej mianem jezior sandaczowych.