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ANALYSIS OF FISHERY EXPLOITATION PARAMETERS OF LAKES AND ASSESSMENT OF THEIR SUITABILITY FOR OBSERVATION OF TRENDS IN FISH CATCHES

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ABSTRACT

Long-term studies on catches from 757 lakes in northeastern Poland served to analyse fishery exploitation parameters available from the records in lakes books. Yield ($kg \cdot ha^{-1}$), annual frequency of exploitation and relative catch ($kg \cdot ha^{-1} \cdot month^{-1}$) were analysed in five size classes of lakes, together with the relations occurring between these parameters. Linear correlation was determined between yield versus the number of months of exploitation when the catches were made and relative catch. The latter parameter was characterised by a slightly smaller variability of real values and consequently by a higher concentration along the adjusted trend line compared to the catch per lake area unit.

Key words: fishery exploitation, yield, frequency of exploitation, relative catch, intensity of exploitation, lakes, northeastern Poland.

INTRODUCTION

Analysis of fishery exploitation and its effects is performed, among other purposes, to find out the species composition and quantitative ratios of exploited fish populations [12]. Observation of results of long-term commercial catches often forms a basis for drawing conclusions on changes taking places within the exploited fish stocks [6, 13] or whole lake ecosystems [3, 8, 11, 35].

The system of organising inland fishery management which was established in Poland in the late 1940s functioned until 1994. It comprised a method for recording the effects of fishery exploitation, which made such analyses possible [17, 24]. In 1959 an instruction was issued containing guidelines on data collection for the purpose of lake exploitation analysis [10]. Several reports and publications appeared which specified principles underlying performance of fishery exploitation analysis, ways of reaching conclusions as well as their practical applications [4, 12, 13, 14, 15, 16, 20, 21].

A classical model of complete fishery exploitation analysis was based on three principal parameters: yield ($kg\cdot ha^{-1}$), intensity of exploitation ($jm\cdot ha^{-1}$) and effectiveness of exploitation ($kg\cdot jm^{-1}$). The term "jm" represents a coefficient of relative efficiency of a standard unit of various fishing gears [4]. A conventional fishing gear, catching one kg of fish daily, was taken as a standard unit of fishing effort for comparison. Then, based upon long-term catch data from different types of fishing gear and collected in various parts of Poland from hundreds of lakes, the average daily catch of the different types of fishing gear, expressed in kg of fish per day, was calculated. The values thus obtained were considered as standard fishing effort for each fishing gear. Thus, the fishing intensity of a given fishing gear is the product of its standard fishing effort multiplied by the number of days during which it is used. Subsequently, the catch per unit of area, or intensity per unit of area (standard units per ha), can be derived [20].

These principal parameters of fishery exploitation, which must be considered over the same time span, remain in a strong mutual relationship, thus creating the so-called exploitation system, which is analysed on different levels of detailedness [14]. Nonetheless, a full-scale analysis of exploitation requires detailed and properly gathered data, especially on fishing effort. The information necessary to determine intensity of exploitation, which was not included in lakes books, was technically very difficult and time consuming to reproduce, even for a short time period in the recent past [17]. Today it is absolutely impossible.

With incomplete data on intensity of exploitation in hand, the researchers have emphasised the possibility of using the so-called indices of exploitation intensity changes in comparative analyses. One of such indices, known as the utilisation of the fishing season, has been demonstrated to be a simple tool which in many cases facilitates good assessment of the changes in exploitation intensity [14]. It was derived from the number of months of exploitation in the fishing season assuming that a higher number of months corresponded to a larger total effect of catches and usually a larger and less monodirectional intensity of exploitation [12]. An undisputed advantage of the utilisation of the fishing season was, and still is, that this index is available from lakes books. The number of months of catches per year appeared as an element of analyses in reports on different aspects of eel management in Polish lakes [17, 19]. It was treated as an indirect index of the intensity of fishery exploitation (fishing effort) [17] or else as a reflection of the intensity of catches [19]. This simplified model for estimating intensity has been applied on the grounds that commercial catches are carried out regularly under stable conditions, and that the estimate is based on indices obtained from water reservoirs of similar size [17].

At present, in the vast majority of reports on observations of qualitative and quantitative changes in the exploited ichtiofauna components on the basis of long-term catch statistics, expressed in kg or $kg\cdot ha^{-1}$, the question of exploitation intensity is ignored following the assumption that its value has not changed.

The present paper reviews these exploitation parameters which are possible to be calculated and assessed on the basis of the data included in lakes books. Beside yield ($kg\cdot ha^{-1}$) and number of exploitation months per year, indicating the frequency of catches, relative catch was considered, which had previously been used in research on changes in distribution of pikeperch [27]. The objective of this study was to determine variability and mutual relationships between the above parameters and to assess their suitability for observation of time events in the exploited components of ichtiofauna.

MATERIALS AND METHODS

The initial material for the research comprised the exploitation data from 757 lakes in northeastern Poland, collected in 1951-1994. The lakes books contained information on total annual fish catches expressed in kilograms and the number of months of exploitation in each year. The data on catches recorded in commercial years were converted to calendar years. The key factor that allowed the conversion lay in the association of a particular calendar year with the summer and autumn fishing season in a given commercial year. The number of exploitation months as a parameter of frequency of catches was assigned to this set. Yield ($kg \cdot ha^{-1}$) was calculated for each lake in every year. After dividing the yield by the appropriate number of months, the parameter of relative catch ($kg \cdot ha^{-1} \cdot month^{-1}$) was computed. The area of the lakes for computations was taken from the IRŚ database after Choiński [5].

All relations were analysed within five lake size categories established during the initial analysis of the lake size structure (Table 1). In the process of the analysis, values of the analysed parameters in each year of exploitation and for each lake were taken as cases within groups of variables. For the parameter of yield, outliers (infrequent observation), which have a profound influence on the power of relationships between groups of variables, were identified and removed according to the analysis of scatterplots and standard deviation of variables [31]. In practice, this procedure applied to the cases of yield exceeding 100 $kg \cdot ha^{-1}$, which were potentially burdened with the biggest random error. The years in which no catches were done were excluded from the analysis as invalid cases.

Table 1. Division and specification of the data sets included in the analysis of exploitation parameters

Size class of lakes (ha)	Category of lakes	Number of lakes	Outliers	
			Number of cases	Share (%)
< 50	I	359	387	3.8
50 - 100	II	149	111	2.1
100 - 200	III	116	35	0.8
200 - 500	IV	86	24	0.7
> 500	V	47	3	0.2

When elaborating the results of the analyses, Statistica 6.0 PL and Microsoft Excel 2000 software packages were applied. The basic statistical computations relied on descriptive statistics such as an arithmetic mean, standard deviation and mean standard error. In order to compare the significance of statistical differences of exploitation parameters between the lake size categories, analysis of variance (ANOVA) and *post-hoc* comparison of means (Tukey's t-test) were performed. Preliminary tests were done on groups of variables to determine whether they fulfilled the basic requirements of ANOVA and were therefore suitable for performing the necessary statistical analyses. A hypothesis on homogeneity of variances in the groups of variables was tested using Levene and Brown-Forsythe tests. Although the hypothesis was discarded on the basis of the significance of these tests ($p<0.05$), the results obtained by ANOVA were not undermined [31]. Parametric tests were applied, hence the hypothesis of the conformity of variables to the normal distribution was tested in each case with the help of Shapiro-Wilks' W test, which is a preferable and powerful test of normality [31]. In none of the cases significant values of W statistics were attained ($p<0.05$), which entitled us to accept the hypothesis that the distribution of variables was normal [31].

The power of relations between the analysed parameters was determined by linear regression analysis and Pearson's correlation coefficients [30]. The validity of tests and analyses was accepted at the level of significance $\alpha=0.05$.

Approximation of time changes of mean annual values of exploitation parameters was done using functions of 2-degree and 3-degree polynomials. The values of the coefficient of determination (R-squared) constituted a measure of trend line adjustment [32].

RESULTS

Analysis of the mean values of the fishery exploitation parameters of lakes in the years 1951–1994 revealed their variation within the lake size categories (Table 2). The mean total yield varied in the range of values from 21.87 $kg \cdot ha^{-1}$ in lake size category III to 28.4 $kg \cdot ha^{-1}$ in lake size category V. Statistical differences ($p<0.05$) between the mean values of this parameter were not found within the first three size categories of lakes. All the size categories significantly differed from each other in the annual number of months of exploitation. The larger the lake size, the higher the mean value of this parameter, rising from 2.64 for lakes of size category I to 10.25 for reservoirs over 500 ha large. A reverse distribution was obtained for the mean relative catch. The lowest relative catch value was determined for lakes in category V (2.77 $kg \cdot ha^{-1} \cdot month^{-1}$), being slightly higher for lakes in category IV (3.4 kg·ha^{-1}·month^{-1}), with no statistically significant differences found between these two groups of lakes. The highest mean relative catch was characteristic of lakes measuring less than 50 ha, for which it amounted to 10.81 kg·ha^{-1}·month^{-1}.

Table 2. Results of comparisons of the means of lake exploitation parameters obtained in 1951 – 1994 (mean±SEM). Critical value *F*=2.37 (*df* 4, 24988; α=0.05). Indexed (*) *F* test statistics valu-es are statistically significant at p<0.05. Means of the parameters marked with different letter superscripts (in rows) are statistically different at p<0.05

Parameters	*F*-ratio	Category of lakes				
		I	II	III	IV	V
Yield (kg·ha^{-1})	69.46*	22.45^{a} ±0.21	22.23^{a} ±0.26	21.87^{a} ±0.25	25.90^{b} ±0.28	28.40^{c} ±0.31
months of exploitation	6633.19*	2.64^{a} ±0.02	4.10^{b} ±0.03	5.72^{c} ±0.04	7.84^{d} ±0.04	10.25^{e} ±0.05
relative catch (kg·ha^{-1}·month^{-1})	807.93*	10.81^{a} ±0.13	6.55^{b} ±0.10	4.31^{c} ±0.06	3.47^{d} ±0.05	2.77^{d} ±0.03

The mean annual number of months of exploitation was compared for consecutive 11-year-long periods of exploitation (Table 3). The results of the analysis reveal a general tendency for the mean values of this parameter in each size category of lakes to decline from 1951 to 1994. In all the five size classes there were statistically significant differences (p<0.05) between the penultimate and ultimate time period compared. Moreover, for the lakes in size classes I, II, III and IV a statistically proven decrease in the means of the analysed parameter was observed as early as between the second and third 11-year-long period of analysis, while for the smallest lakes (size less than 50 ha) such a decline also occurred between the first two periods. At each stage of the analysis, a higher annual number of months of exploitation was typical of a higher size category of lakes.

Table 3. Results of comparisons of the mean annual number of exploitation months of the analy-sed lakes in eleven-year-long periods in 1951-1994 (mean±SEM). Critical values *F*=2.61 (*df* 3, 10248-1915; α=0.05). Indexed (*) *F* test statistics values are statistically significant at p<0.05. Means of the parameters with different letter superscripts (in rows) are statistically different at p<0.05.

Category of lakes	*F*-ratio	Years			
		1951-61	1962-72	1973-83	1984-94
I	143.09*	3.21^{a} ±0.05	2.87^{b} ±0.04	2.56^{c} ±0.04	2.13^{d} ±0.03
II	123.75*	4.82^{a} ±0.08	4.60^{a} ±0.06	4.02^{b} ±0.07	3.14^{c} ±0.06
III	195.16*	6.68^{a} ±0.08	6.43^{a} ±0.07	5.56^{b} ±0.08	4.26^{c} ±0.07
IV	132.79*	8.46^{a} ±0.09	8.55^{a} ±0.08	8.00^{b} ±0.08	6.50^{c} ±0.09
V	51.77*	10.78^{a} ±0.08	10.58^{ab} ±0.08	10.37^{b} ±0.08	9.34^{c} ±0.11

Table 4. Results of the estimation of linear regression analysis of the dependent variable (y) total annual yields (kg·ha^{-1}) and independent variable (x) number of exploitation months per year. Critical value *t*=1.96 (*df* 9852-1917; α=0.05). Indexed (*) *F* test statistics values are statistically significant at p<0.05. Values of the correlation coefficient marked with different letter super-script (in the column) are statistically different at p<0.05.

Category of lakes	Parameters	Estimate B	Standard Error *B*	*t* value	Correlation Coefficient *r*	Std. Error of Estimation
I *n*=9854	Intercept	12.8819	0.3361	38.3232*	0.3327[a]	19.4213
	Slope (*x*)	3.6168	0.1033	35.0124*		
II *n*=5287	Intercept	8.2940	0.4575	18.1305*	0.4396[b]	17.1946
	Slope (*x*)	3.3945	0.0954	35.5775*		
III *n*=4463	Intercept	6.8085	0.5061	13.4531*	0.4439[bc]	14.7166
	Slope (*x*)	2.6382	0.0797	33.0958*		
IV *n*=3467	Intercept	5.7915	0.8159	7.0980*	0.4033[de]	15.0178
	Slope (*x*)	2.5638	0.0988	25.9416*		
V *n*=1919	Intercept	1.6826	1.4254	1.1805	0.3992[bce]	12.1861
	Slope (*x*)	2.6003	0.1364	19.0619*		

Based on the model of linear regression analysis, a relationship between total yield as a dependent variable (y) and number of months of exploitation as an independent variable (x) within the size categories of lakes was determined (Table 4). In each case, a statistically significant (p<0.05) positive correlation was obtained, in which an increase in the number of exploitation months caused an increase in the mean annual yield. The values of estimation (*B*) of the intercept and coefficient of regression (slope) allowed us to construct a regression equation describing the analysed relationship for each size category:

- I $y = 12.88 + 3.62x$
- II $y = 8.29 + 3.39x$
- III $y = 6.81 + 2.64x$
- IV $y = 5.79 + 2.56x$
- V $y = 1.68 + 2.60x$

These equations imply that one-month extension of the period of exploitation (in an interval of 1 to 12 months) caused an average increase in total yield in the range of 2.56 kg·ha^{-1} in lakes from size category IV to 3.62 kg·ha^{-1} in lakes measuring less than 50 ha. Comparison of the significance of statistical differences (p<0.05) in the values of the correlation coefficient showed no differences between the largest lakes (size class V) versus the lakes from categories II, III and IV, or between the lakes from category II versus category III. Coefficient r in the interval of values from 0.33 and 0.44 suggests that the correlation level of the analysed relations is on an average level.

It was found that yield was statistically significantly correlated with relative catch in all the size categories of the analysed lakes, and the values of Pearson's linear correlation coefficient (r) obtained from the analysis confirmed that this relation was positive (Table 5). Strong correlation between the two parameters was observed for lakes in categories I, II, III and IV, where r coefficient was contained in the interval between 0.567 and 0.673. On the other hand, a very strong relation between yield and relative catch (r=0.864) was found for the largest lakes (area over 500 ha). Analysis of the regression equation constructed for this size category of lakes reveals that an increment in relative catch by 1 kg·ha^{-1}·month^{-1} was accompanied by the largest mean increase in yield equal 9.13 kg·ha^{-1}. As regards the other four size categories of lakes, an increment in the mean value of this parameter was smaller for smaller lakes down to 1.10 kg·ha^{-1} for lakes less than 50 ha large. No statistical differences were found in the recorded values of Pearson's coefficient between categories I and IV or II and III.

Table 5. The coefficient of linear correlation r (Pearson's) between the variable (y) total annual yields (kg·ha^{-1}) and the variable (x) relative catch (kg·ha^{-1}·month^{-1}). Critical value t=1.96 (df 9852-1917; α=0.05). Indexed (*) t test statistics values are statistically significant at p<0.05. Values of the correlation coefficient r marked with different letter superscripts (in the column) are statistically different at p<0.05.

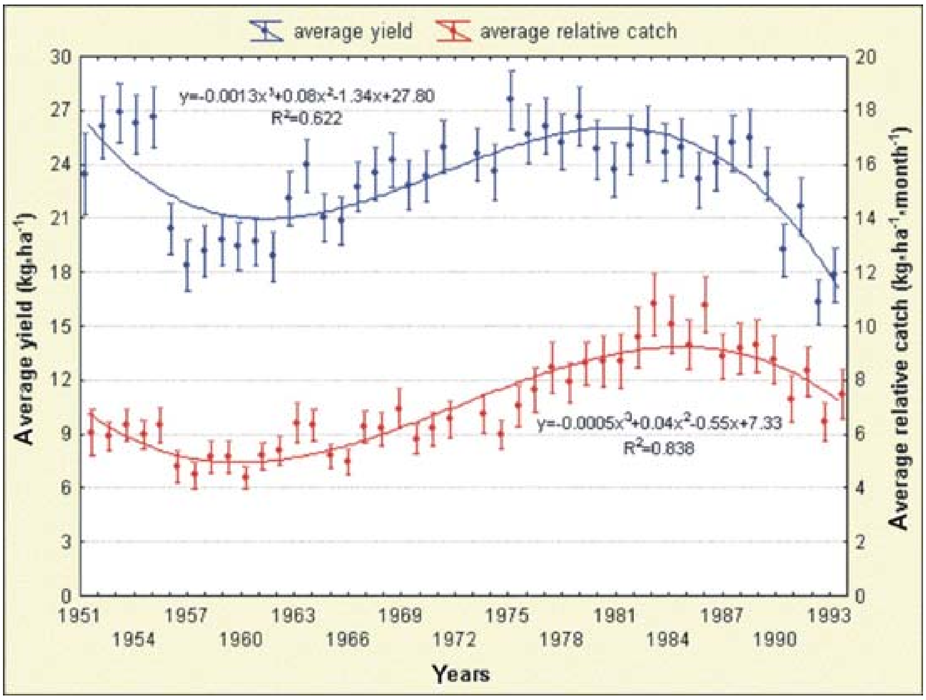
Category of lakes	N	t value	Coefficient r	Regression equation
I	9854	90.2666*	0.6729^a	y=10.56 + 1.10x
II	5287	50.0608*	0.5672^b	y=12.80 + 1.44x
III	4463	46.2026*	0.5689^b	y=11.84 + 2.33x
IV	3467	50.8644*	0.6538^a	y=12.28 + 3.93x
V	1919	75.2595*	0.8642^c	y=3.11 + 9.13x

Based on the mean annual values of total yield and relative catch, simulated approximation of time series changes in these parameters for each size category of the analysed lakes in 1951–1994 was conducted. Curvilinear regression equations for virtual trend lines were obtained by adjusting 2-degree and 3-degree polynomial functions. Appropriate formulas of equations and values of their R-squared determination coefficients are presented in Table 6. The smallest function adjustment was observed at the second order regression equation for yield in category I lakes (R^2=0.001), while the highest determination coefficient (0.797) and the best adjustment appeared at the third order equation for relative catch parameter in category III lakes. The values of R-squared coefficient at all levels of analysis were statistically different (p<0.05). Naturally, better adjustment of a polynomial function to actual values at a higher value of determination coefficient was obtained for 3-order equations. However, for either form of the polynomial, approximation of changes in fish catches based on relative catch generally resulted in a higher value of R-squared coefficient for nearly all the size categories of lakes except the largest lakes (size over 500 ha), where the 2-degree polynomial function was slightly better adjusted to total yield rather than to relative catch.

Table 6. Regression equation and determination coefficient in the polynomial adjustment of trend lines at approximation of time series changes in annual values of exploitation parameters for the analysed lakes in 1951–1994

Category of lakes	Polynomial	Parameters of exploitation			
		yield (kg· ha^{-1})		relative catch (kg· ha^{-1}· month^{-1})	
		Equation	R-squared	Equation	R-squared
I	2-degree	y = -0.0009x^2+0.04x+27.78	0.001	y = -0.0009x^2+0.25x+8.10	0.524
	3-degree	y = -0.0019x^3+0.13x^2-2.26x+36.86	0.457	y = -0.0011x^3+0.07x^2-1.12x+13.49	0.764
II	2-degree	y = -0.0055x^2+0.26x+22.54	0.038	y = 0.0018x^2+0.04x+4.97	0.487
	3-degree	y = -0.0016x^3+0.10x^2–1.72x+30.38	0.441	y = -0.0008x^3+0.06x^2–0.92x+8.79	0.797
III	2-degree	y = -0.0076x^2+0.33x+20.27	0.099	y = 0.0002x^2+0.06x+2.98	0.537
	3-degree	y = -0.0014x^3+0.09x^2–1.43x+27.23	0.524	y = -0.0004x^3+0.03x^2–0.39x+4.76	0.785
IV	2-degree	y = -0.0120x^2+0.48x+23.65	0.185	y = 0.0002x^2+0.02x+3.02	0.231
	3-degree	y = -0.0014x^3+0.08x^2–1.25x+30.51	0.453	y = -0.0003x^3+0.02x^2–0.30x+4.27	0.582
V	2-degree	y = -0.0115x^2+0.45x+25.90	0.174	y = -0.0009x^2+0.05x+2.35	0.122
	3-degree	y = -0.0014x^3+0.09x^2–1.31x+32.87	0.439	y = -0.0002x^3+0.01x^2–0.16x+3.16	0.557

Fig. 1. Mean fishery yield and relative catch in all the analysed lakes (757) in northeastern Poland in the years 1951-1994. Error 'whiskers' represent standard deviation (SD) of the mean values of the lake exploitation parameters in the consecutive years. Trend lines were determined by adjusting the 3-degree polynomial function



Function of 3-degree polynomial was used for approximation of time series changes in total yield and relative catch from all 757 lakes in the years 1951–1994 (Fig. 1). Due to a very large amount of actual data used to construct curvilinear regression equations (24 990 for each series of variables), means and standard deviation (SD) values were used for graphic interpretation of the analysed phenomena. The trend line delineated on the basis of relative catch was characterised by better adjustment to actual values at the determination coefficient equal 0.838.

DISCUSSION

The differences in mean yields and number of exploitation months between lake size categories observed in the present study are typical and have been demonstrated in reports by other authors [16, 25]. According to Nowak [25] the yield from 600 Polish lakes (excluding lakes of crucian carp type) ranged from 24 $kg \cdot ha^{-1}$ to 29 $kg \cdot ha^{-1}$ and was therefore lower than the yield assumed when creating fishing typology of lakes (30-40 $kg \cdot ha^{-1}$ without crucian carp lakes) [33]. Yield depends on lake fertility and exploitation intensity. Smaller reservoirs are characterised by lower levels of exploitation, which is due to the fact that they have been assigned lesser importance in the fishing economy [25]. Leopold [16] reported that an average yield obtained in reservoirs of an area >500 ha was higher than in lakes measuring <100 ha, although smaller lakes were demonstrated to show the largest range of differences in values of this parameter. According to this author, small lakes were also characterised by the largest range of exploitation intensity at the highest long-term mean value of this parameter (32 jm<$\cdot ha^{-1}$). This parameter for lakes of an area >500 ha was 22 $jm \cdot ha^{-1}$. In the light of these observations, the fishing management in lakes sized <100 ha was described as unstable, consisting of irregular catches executed with great fishing effort [16]. Assuming that the number of months of exploitation served as a fishing frequency index in the present report, a decrease in this parameter noticed for smaller lakes confirms the conclusions contained in the reports published by Leopold [16] and Nowak [25]. Months of exploitation for lakes in different size categories have been used to formulate conclusions about different levels of fishery exploitation [17].

Distribution of the computed mean values of relative catch, which is indicative of the mean volume of catch obtained per month of annual exploitation, reflects variation in frequency of fishery exploitation in size categories of lakes.

A decline in frequency of lake exploitation, demonstrated for all the five size categories of lakes, was most evident in the years 1973-1994. It is difficult to state categorically whether this event was connected with a depressed exploitation intensity. Should the number of months of exploitation be treated as an indirect index of fishing intensity [17, 19], such correlation ought to be accepted. Nevertheless, such an approach must account for the fact that no data are available on fishing effort in a particular month. In contrast, it needs to be emphasised that the general annual intensity of exploitation in the classical model depends directly on the number of type of fishing gears and frequency of their use [12, 13, 14, 15, 16, 20]. Irrespective of the fact that no detailed studies on the intensity of fishing exploitation in 1970s and 1980s have been conducted, some theories on causes of the general decline in exploitation intensity have been put forth while observing changes in catches of several fish species [33]. The decrease in the number of months of annual exploitation was most probably triggered by the change in lake management enforced by changes in lake ecosystems, associated with more intense anthropogenic pressures on the aquatic environment, of which the most important one was rapid eutrophication of water bodies [9]. Eutrophication contributed to changes in species composition of the ichtiofauna of Polish lakes, which has been broadly described in many publications [2, 22, 23, 28, 29].

As a rule, the restructuring of qualitative and quantitative composition of ichtiofauna is associated with a modification of exploitation type [12]. Eutrophication also has an effect on economic aspects of lake management and is connected with numerous obstacles to fishing exploitation, including inferior effectiveness of some fishing gears and their limited use [18]. Changes in fishing exploitation and extent of fishing season utilisation may have also been affected by the climatic changes observed. Studies carried out worldwide have determined that the effect of global warming on water environment mainly consists in elevated thermal capacity of lakes and is associated with warm, ice-free winters [7, 26]. Climatic changes resulting in shorter ice cover and higher temperature of surface water layers in summer have also been recorded in Poland [1]. Weather anomalies can disrupt proper use of fishing gears drawn in late autumn and winter catches. That is precisely when they can be most effective [13]. The current studies on results of fishing exploitation of lakes have pointed to a considerable effect that, for instance, early and unstable ice cover can have on effects of annual catches [34].

The power of the relation between the total yield and number of months of exploitation during which the given catch was obtained varied within the size categories of lakes. The highest increase in mean yield attained at a one-month extension of exploitation time was observed for lakes of an area to100 ha, that is for the reservoirs in which the extent of fishing season utilisation counted in months of exploitation was the lowest. Studies on relations between the effectiveness and intensity of exploitation versus the surface area of lakes were carried by Leopold [14, 16], who concluded that exploitation intensity maintained on an unchanged level resulted in better yield in larger lakes. Moreover, the researcher found out that as the intensity of exploitation increased, yield increment per unit of intensity decreased. Furthermore, the relation between the number of months, reflecting intensity of catches, and the catch obtained was analysed while studying the question of effectiveness of eel stocking [19]. The results then achieved revealed positive correlation at which a one-month increase in fishing intensity resulted in a mean increase in eel catches by 0.38 $kg \cdot ha^{-1}$.

Conversion of yield obtained by referring yield to the number of months of exploitation when this catch was obtained and expressing it in the form of relative catch brings distinct advantages for the process of analysis. Relative catch shows strong and very strong correlation with fishery yield in each size category of lakes, describing the analysed events on a lower level of absolute values. It accounts for time changes in the way fishery exploitation is executed, which is reflected by depressed annual frequency of exploitation. Consequently, the values of this parameter can correct possible large variations in the catch, the variability of which is connected with a higher or lower number of months in which the exploitation took place. As a result, the actual values of relative catch in the course of years are characterised by a higher level of concentration along curvilinear trend lines and better adjustment. Analyses of long-term time changes in fish catches and the interpretation of these changes are not infrequently performed without dividing water reservoirs into size categories. Whichever parameter is then analysed, it is always burdened with additional variability. Nevertheless, relative catch shows a much smaller level of variability and better adjustment of the trend line.

CONCLUSIONS

1. Lakes in the particular size categories were significantly different in annual exploitation frequency, which proves that they varied in the extent of fishery management of waters and the way of conducting commercial catches.
2. The decrease in annual fishery exploitation observed in the years 1950-1994 may have been caused by the changed lake fishery management enforced by the changes in the aqueous environment of natural water reservoirs.

3. Linear correlation was determined between yield and number of months of catches during an annual exploitation cycle, with the power of the relationship being highly variable within the size categories of the analysed lakes.
4. Strong correlations appeared between yield and relative catch, which is characterised by lower variability and higher concentration along the time trend line.

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