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# EFFECTIVENESS OF FISHERIES MANAGEMENT IN EUTROPHIC LAKES NEAR MRĄGOWO (NORTHEASTERN POLAND)

*Maciej Mickiewicz, Arkadiusz Wołos, Marian Leopold*

The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn, Poland

ABSTRACT. Data from a forty year period on catches and stocking from 25 selected lakes located in the Mrągowski Lake District were analyzed. The results of the analyses of catches and stocking indicate that, as a whole, the studied lakes underwent significant eutrophication and their environmental state declined during the studied period. These changes were manifested by changes in the quality of table fish catches and decreases in fishery effectiveness. The study results also indicated that positive changes occurred in the fishery of these lakes following the ownership transformation of the former State Fisheries Enterprises.

Key words: FISHERIES, STOCKING, CATCHES, LAKE EUTROPHICATION

## INTRODUCTION

Progressing changes in the quality of the environment, especially continuous and unavoidable eutrophication, are the most influential factors which shape the state and perspectives of lake fishery. The pattern of changes in fish populations (species succession) caused by eutrophication and the subsequent changes in fish catches is well described and documented in the scientific literature. These changes are characterized by regularity and are significant enough to be regarded as highly reliable indexes of the degree of water eutrophication (Colby et al. 1972, Leach et al. 1977, Hartmann 1977, 1979, 1987, Leopold et al. 1986).

In fishery, eutrophication is manifested by decreases in the production of commercially and ecologically valuable fish species and size classes. This, in turn, is clearly reflected in decreased catch yields and catch species structure and in economic effectiveness (Leopold 1996). It follows that the priority of rational fishery management is to focus management strategies on counteracting the effects of adverse changes caused by eutrophication. The basic tasks facing the lake fishery user are to adjust fishery and protection measures to a level appropriate to the fish population in the lake and to conduct stocking programs. The significance and intensity of exploitation, stocking and protection change as eutrophication progresses (Bnińska 1996). Depending on the trophic

level of the lake, these practices can help fishery to overcome the results of eutrophication to a greater or lesser extent, and they can become an element of the protection of lake ecosystems. With respect to the latter, it is worthwhile mentioning that fishery is the only lake user which, by catching fish, eliminates a certain amount of nutrients responsible for progressing eutrophication (Leopold et al. 1998).

The aim of this paper is to identify and test the long-term patterns exhibited by the fishery of 25 lakes in the Mrągowski Lake District. These lakes were exploited by the State Fisheries Enterprise Mrągowo until 1993, and then by the private Fisheries Enterprise Mrągowo Ltd. following ownership transformation in 1994. The results of the studies were used to identify the most important changes which took place in fish catches in the studied populations in the lakes and patterns in stocking practices with different species as well as to determine the economic effectiveness of stocking. The patterns presented in the paper are connected with progressing lake eutrophication and changes in fishery following ownership transformation.

## MATERIAL AND METHODS

The analyzed materials were comprised of data from a period of 40 years (1958-1997) on annual catches of particular fish species (including size-classes – commercial size-classes for roach and bream) and data on stocking practices during the same period.

The following species were analyzed:

- eel *Anguilla anguilla* (L.),
- whitefish *Coregonus lavaretus* (L.),
- vendace *Coregonus albula* (L.),
- pikeperch *Sander lucioperca* (L.),
- perch *Perca fluviatilis* L.,
- pike *Esox lucius* L.,
- smelt *Osmerus eperlanus* (L.),
- silver carp *Aristichthys nobilis* Rich.,
- grass carp *Ctenopharyngodon idella* (Val.),
- roach *Rutilus rutilus* (L.),
- bream *Abramis brama* (L.),
- silver bream *Abramis bjoerkna* (L.),
- carp *Cyprinus carpio* L.,
- tench *Tinca tinca* (L.),
- crucian carp *Carassius carassius* (L.),
- bleak *Alburnus alburnus* (L.).

Data on both catches and stocking in 25 selected lakes were retrieved from management logs made available by the Fisheries Enterprise Mrągowo Ltd.

In order for a lake to be chosen for analysis, there had to be a full record for the 40 year study period, and the lake had to have a minimum area of 20 ha.

The average fish and stocking material prices used in this work are from 1998 and 1999 and were calculated using data obtained from 12 lake fish farms in different regions of Poland.

The collected data was analyzed in two variants:

- the total of all catch data from the 25 studied lakes and in selected fish population fractions (see below);
- in two lake groups divided according to environmental state - the division was based on the relation in these lakes between the average long-term catch of species and size-classes, referred to in this paper as "increasing" and "decreasing".

The first group is comprised of species and size-classes which are caught more frequently due to eutrophication, while the second is comprised of those whose share in the catch decreases as a result of this phenomenon. The "increasing" species were bream S and M (commercial size-class - small and medium), roach S (commercial size-class - small), silver bream and pikeperch. The "decreasing" species were coregonines (vendace and whitefish), perch, littoral species (pike, tench and crucian carp), bream L (commercial size-class - large) and roach L (commercial size-class: large) according to the methodology proposed and applied by Leopold and Wołos (1996, 1997, 1998, 1999).

The average relation between "increasing" and "decreasing" groups was calculated for each of the studied lakes. Those which were above the calculated average were classified as "less eutrophic" (better in terms of the environmental state or the degree of eutrophication), while those which were lower than the average values were classified as "more eutrophic".

The same approach was applied to analyze the data on the stocking of the studied lakes with particular fish species. The so-called index of stocking frequency (Bnińska and Leopold 1983, Moriarty et al. 1990, Leopold 1998) was used in this part of the analysis. It describes the ratio of the number of years certain lakes were stocked with given fish species with the number of years of the entire study period and the magnitude of stocking (in terms of value) and the surface area of the stocked lake. The so-called index of long-term stocking effectiveness was also applied. This index describes the magnitude of the effort expended (in PLN) during the studied period to stock a given species or species group versus the catch magnitude of the same species during the same time period (in kg).

The time series method with second degree polynomials ($P > 0.05$) was used to statistically analyze the catch data.

## DESCRIPTION OF THE STUDY AREA

The studied lakes are located in the Mrągowski Lake District, which is part of the Masurian Lake District located in northeastern Poland.

These lakes are characterized by significant morphometric diversity with respect to area (22.5 ha - 475.5 ha), maximum depth (2.5 m - 56.6 m), average depth (1.0 m - 12.9 m), depth index (0.22 - 0.56) and shoreline development (at an index range of 1.0 to 3.2) (Table 1).

**TABLE 1**

Morphometric parameters of the analyzed lakes (according to data from the Inland Fisheries Institute in Olsztyn)

| Lake | Area (ha) | Maximum depth (m) | Average depth (m) | Total shore-line length (m) | Shoreline development index[1] | Depth index[2] |
|---|---|---|---|---|---|---|
| Białe | 341.0 | 31.0 | 7.0 | 18100 | 2.7 | 0.23 |
| Czarne | 76.3 | 23.3 | 7.9 | 3900 | 1.3 | 0.34 |
| Czos | 279.1 | 42.6 | 11.1 | 14960 | 1.3 | 0.26 |
| Dłużec | 123.1 | 19.8 | 6.3 | 8000 | 2.0 | 0.32 |
| Gielądzkie | 475.5 | 27.0 | 6.8 | 20225 | 2.6 | 0.25 |
| Juno | 380.7 | 33.0 | 11.9 | 16850 | 2.4 | 0.36 |
| Karw | 54.0 | 8.7 | 2.6 | 6400 | 2.4 | 0.30 |
| Kiersztanowskie | 148.6 | 32.5 | 12.2 | 8975 | 2.0 | 0.38 |
| Kołowin | 78.2 | 7.2 | 4.0 | 4150 | 1.3 | 0.56 |
| Kot | 44.0 | 21.0 | 7.2 | 2850 | 1.2 | 0.34 |
| Krzywe | 155.5 | 22.5 | 5.0 | 13900 | 3.1 | 0.22 |
| Kujno | 24.0 | 6.0 | 2.8 | 2700 | 1.6 | 0.47 |
| Lampackie (+ Lampasz) | 286.8 | 38.5 | 9.2 | 19450 | 3.2 | 0.24 |
| Pierwój | 134.1 | 26.0 | 7.7 | 6575 | 1.6 | 0.30 |
| Piłakno | 259.0 | 56.6 | 12.9 | 12850 | 2.2 | 0.23 |
| Probarskie | 201.4 | 31.0 | 9.2 | 9475 | 1.9 | 0.30 |
| Ruskowiejskie | 29.1 | 11.5 | 5.5 | 2200 | 1.1 | 0.48 |
| Rydwągi | 62.0 | 9.1 | 5.0 | 3750 | 1.3 | 0.55 |
| Salęt Wielki (+ Salęt Mały) | 327.7 | 17.2 | 4.9 | 19115 | 3.0 | 0.28 |
| Sarż | 76.7 | 15.0 | 5.9 | 5100 | 1.6 | 0.39 |
| Stromek | 116.8* | 2.5 | 1.0 | 9900 | 2.3 | 0.40 |
| Sutapie Wielkie | 22.5 | 8.1 | 4.4 | 1615 | 1.0 | 0.54 |
| Uplik | 60.6 | 9.2 | 2.8 | 6450 | 2.3 | 0.30 |
| Wągiel | 176.8 | 13.3 | 4.2 | 13250 | 2.8 | 0.32 |
| Zaleckie | 39.9 | 8.6 | 3.5 | 3900 | 1.7 | 0.41 |
| Total: | 3973.4 | | | | | |

**data from Fisheries Enterprise Mrągowo Ltd.*

[1] *(according to Szczerbowski 1995):*, $Wp = \frac{L}{2\sqrt{\pi A}}$,

*where: $W_p$ – shoreline development index; L – shoreline length (m); A – lake area (ha).*

[2] *(according to Szczerbowski 1995): $D_{s.g.} = D_{av.} / D_{max.}$, where: $D_{s.g.}$ – depth index; $D_{av.}$ – average depth [m]; $D_{max.}$ – maximum depth (m).*

The values of these indexes, determined as described in Szczerbowski (1995), indicate that 73% of the total shoreline of the analyzed lakes is either well- or highly-developed, and that 96% of the bottom area is either diverse or highly diverse. These factors indicate that fishery conditions are generally good, at least in terms of lake morphometry.

A noteworthy fact is that depth exceeds 20 m in a relatively high percentage of the lakes, and these constitute over 70% of the area studied. The average depth of over 9.2 m indicates that these lakes are significantly resistant to degradation.

## RESULTS

### CATCHES

The overall catch trend for all the studied lakes in the 1958–1997 period shows that, following an initial increase, there was a decline in catches until approximately the middle of the studied period (Fig. 1). Presumably, this trend, especially during the period of decrease, was linked to adverse environmental changes in the lakes caused by progressing eutrophication. This is also supported by the tendencies of catches of "decreasing" versus "increasing" species and size-classes (Fig. 2).

According to the calculated trend, catches of the former exhibited a decline beginning in the fourteenth year of the studied period, while in the latter this tendency was not observed until the twenty-sixth year. If the above-mentioned tendencies are accepted as criteria, then the study period can be divided into three qualitative periods for analytical purposes (Table 2):

**TABLE 2**

Production characteristics for three time periods from the analyzed 40 year period

| | Years | | |
|---|---|---|---|
| | 1 – 14 | 15 – 26 | 27 – 40 |
| Total catches (kg $ha^{-1}$) | 24.80 | 27.31 | 24.60 |
| Increase or decrease (%) | +2.29 | +0.04 | -2.22 |
| "Decreasing" species (kg $ha^{-1}$) | 10.67 | 9.92 | 8.92 |
| Increase or decrease (%) | +0.62 | -0.61 | -2.12 |
| "Increasing" species (kg $ha^{-1}$) | 8.75 | 12.41 | 12.38 |
| Increase or decrease (%) | +5.13 | +1.02 | -1.56 |
| Other species (kg $ha^{-1}$) | 5.38 | 4.98 | 3.30 |
| Increase or decrease (%) | +0.99 | -1.10 | -4.97 |
| Species "Decreasing" / "increasing" (%) | 121.9 | 79.9 | 72.0 |

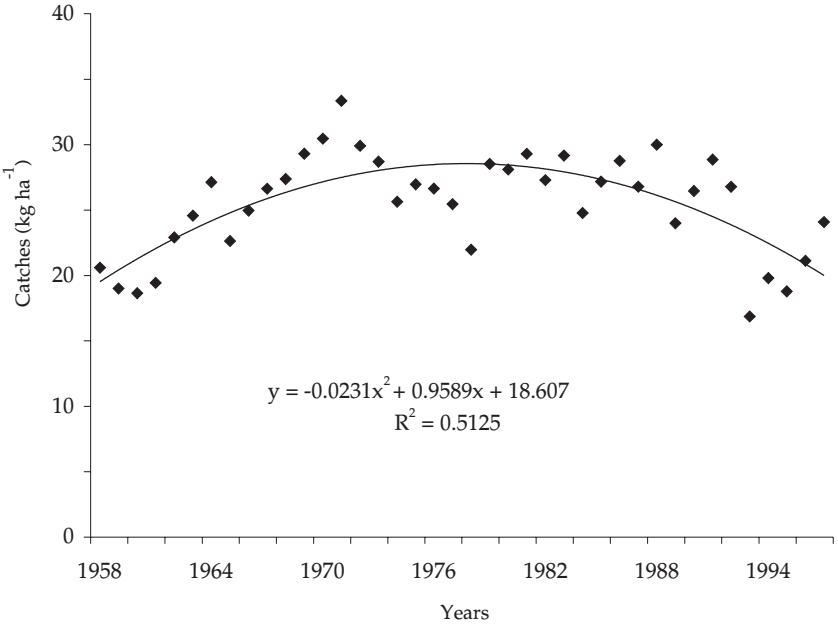


Fig. 1. Total catches in 1958-1997.

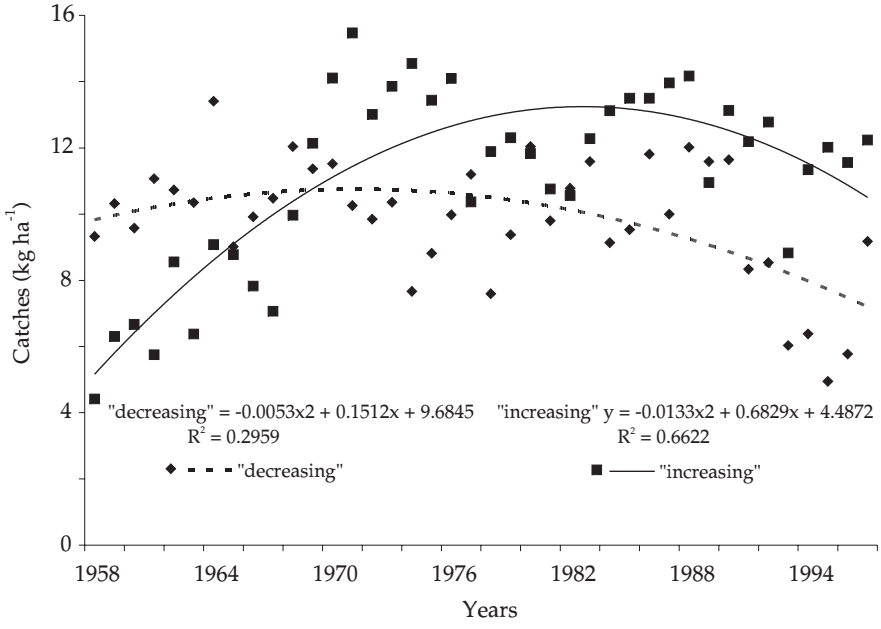


Fig. 2. Catches of "decreasing" and "increasing" species in 1958-1997.

Period I – 14 years - catches of both groups grew;

Period II – 12 years - catches of "decreasing" species and class-sizes fell, while catches of "increasing" species and size-classes continued to rise;

Period III – 14 years - both groups exhibited declining tendencies.

Table 2 presents the parameters of the degree of catch decrease in both groups and confirms the assumption that the environment of the studied lakes had a significant impact on the analyzed catches.

Long-term data regarding commercial catches was used to designate the lakes as either "less eutrophic" or "more eutrophic" based on their environmental state The "less eutrophic" group numbered 11 lakes with a total area of 1677.3 ha, while the "more eutrophic" group was comprised of 14 lakes with a total area of 2296.1 ha.

**TABLE 3**

Catches of commercial fish (kg) and yields (kg $ha^{-1}$) in "less eutrophic" and "more eutrophic" lakes

| Species /size-class | "Less eutrophic" lakes (1677.3 ha) | | "More eutrophic" lakes (2296.1 ha) | |
|---|---|---|---|---|
| | Average annual catch | | Average annual catch | |
| | kg | kg $ha^{-1}$ | kg | kg $ha^{-1}$ |
| Eel | 102571 | 1.53 | 241192 | 2.63 |
| Whitefish | 35710 | 0.53 | 28343 | 0.31 |
| Vendace | 247933 | 3.70 | 59986 | 0.65 |
| Pikeperch | 8742 | 0.13 | 126897 | 1.38 |
| Perch | 84516 | 1.26 | 88403 | 0.96 |
| Pike | 160269 | 2.39 | 121634 | 1.32 |
| Tench | 160465 | 2.39 | 58557 | 0.64 |
| Crucian carp | 8571 | 0.13 | 10799 | 0.12 |
| Roach L | 76678 | 1.14 | 103748 | 1.13 |
| Roach S | 216991 | 3.23 | 519000 | 5.65 |
| Roach (together) | 293669 | 4.38 | 622748 | 6.78 |
| Bream L | 106869 | 1.59 | 210183 | 2.29 |
| Bream M | 174850 | 2.61 | 413585 | 4.50 |
| Bream S | 30803 | 0.46 | 85515 | 0.93 |
| Bream (together) | 312522 | 4.66 | 709283 | 7.72 |
| Silver bream | 31628 | 0.47 | 159289 | 1.73 |
| Carp | 12486 | 0.19 | 10724 | 0.12 |
| Silver carp | 14549 | 0.22 | 1240 | 0.01 |
| Grass carp | 824 | 0.01 | - | - |
| Smelt | 15534 | 0.23 | 169421 | 1.84 |
| Bleak | 11682 | 0.17 | 5789 | 0.06 |
| Trash fish | - | - | 1101 | 0.01 |
| Other | 72308 | 1.08 | 60896 | 0.66 |
| Total | 1573979 | 23.46 | 2476385 | 26.96 |

The catch structure of the two lake groups is presented in Table 3. There were huge differences between the two groups with regard to the ratio of "decreasing" to "increasing" species and size-classes in the "less eutrophic" lake group (1:1.9) in comparison to that from the "more eutrophic" lake group (1:0.5). This results largely from the criteria applied for selecting these groups. The tendencies of the overall catches in both groups of lakes during the studied period are very significant. Catches in the "less eutrophic" group ranged from 15.21 kg $ha^{-1}$ in 1995 to 34.84 kg $ha^{-1}$ in 1988. The average annual yield over the study period was 23.46 kg $ha^{-1}$ (there is no statistically significant tendency), although in the "more eutrophic" lakes a clear increasing tendency was observed, followed by a significant decrease (Fig. 3). The differences between these two groups clearly indicate that the changes in the environmental state of the lakes are responsible for such dissimilar tendencies.

## STOCKING

The intensity with which stocking with various fish species and with all species combined was performed in particular lakes, expressed as the stocking frequency index (the

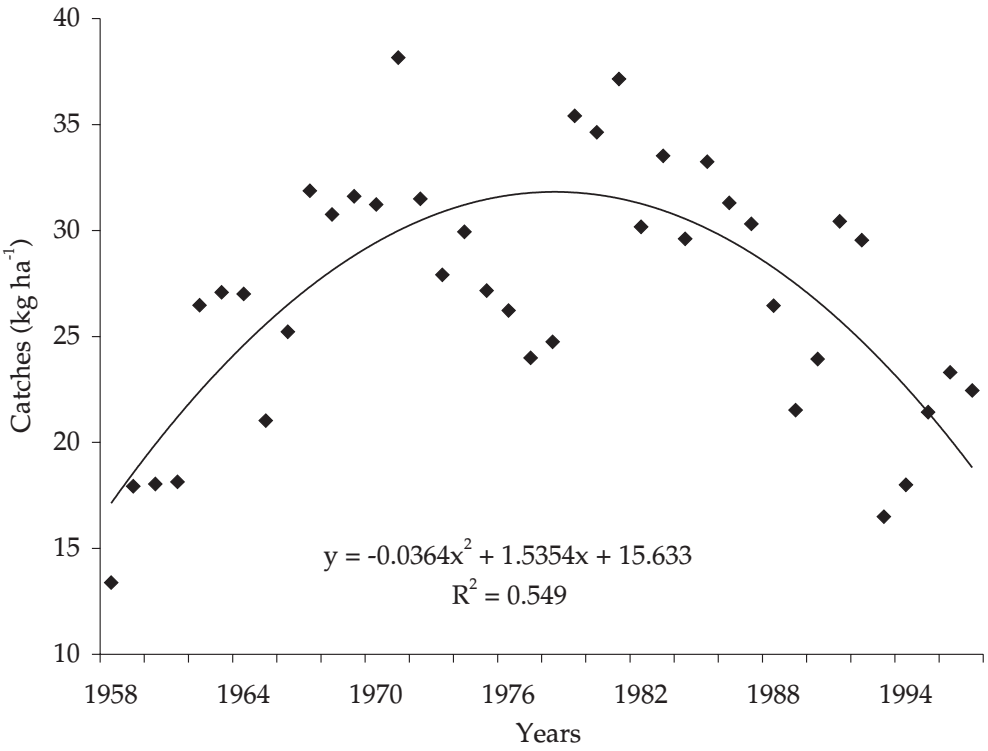


Fig. 3. Total catches in "more eutrophic" lakes in 1958-1997.

number of years stocking was performed during the study period), is presented in Table 4. The lakes are listed in descending order of the value of this index. Higher average stocking intensity was noted in lakes with greater areas. This is confirmed by the average area of the ten most intensively stocked lakes (as described above) at 275.71 ha, in comparison to the average area of the remaining 15 lakes at only 81.07 ha.

**TABLE 4**

Number of years stocking various fish species was performed in different lakes in 1958 – 1997

| Lake | Area (ha) | Eel | Vendace | Pike | Whitefish | Carp | Pikeperch | Tench | Crucian carp | Herbivorous fish | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gielądzkie | 475.5 | 17 | 12 | 5 | 10 | - | 9 | 1 | - | - | 54 |
| Juno | 380.7 | 22 | 4 | 3 | 15 | - | 2 | 1 | - | - | 47 |
| Probarskie | 201.4 | 8 | 20 | 3 | 15 | - | - | - | - | - | 46 |
| Lampackie | 286.8 | 17 | 25 | 2 | - | - | - | 1 | - | - | 45 |
| Czos | 279.1 | 19 | 13 | 10 | - | - | - | 2 | - | - | 44 |
| Białe | 341.0 | 22 | 9 | 6 | 2 | - | - | 3 | - | - | 42 |
| Salęt | 327.7 | 23 | 1 | 9 | 1 | 4 | 3 | 1 | - | - | 42 |
| Ruskowiejskie | 29.1 | 3 | 1 | 5 | 16 | 10 | 2 | 1 | - | - | 39 |
| Wągiel | 176.8 | 19 | - | 1 | - | 2 | 4 | 5 | 6 | 1 | 37 |
| Piłakno | 259.0 | 10 | 17 | 6 | 1 | - | - | - | - | - | 34 |
| Pierwój | 134.1 | 9 | 14 | 4 | 6 | - | - | - | - | - | 33 |
| Czarne | 76.3 | 3 | 1 | 11 | 5 | 2 | 5 | 2 | - | - | 29 |
| Kołowin | 78.2 | 6 | - | 8 | 1 | 5 | - | 6 | - | 3 | 29 |
| Rydwągi | 62.0 | 8 | - | 4 | 7 | 4 | 1 | - | 3 | 1 | 28 |
| Dłużec | 123.1 | 17 | - | 4 | - | - | 1 | 1 | 1 | - | 24 |
| Stromek | 116.8 | - | - | 17 | - | 2 | - | - | - | - | 19 |
| Krzywe | 155.5 | 6 | 1 | 6 | 1 | - | 3 | - | - | - | 17 |
| Kujno | 24.0 | 2 | - | 7 | - | - | - | 1 | 1 | - | 11 |
| Uplik | 60.6 | 6 | - | 3 | - | - | - | 1 | - | - | 10 |
| Sutapie Wlk. | 22.5 | 1 | - | - | 1 | 1 | 2 | 2 | 3 | - | 10 |
| Kiersztanowskie | 148.6 | 1 | 4 | - | 2 | - | - | - | - | - | 7 |
| Karw | 54.0 | 2 | - | 1 | - | 3 | - | 1 | - | - | 7 |
| Sarż | 76.7 | 3 | - | 1 | 2 | - | - | - | - | - | 6 |
| Kot | 44.0 | 1 | - | 1 | - | - | - | - | - | - | 2 |
| Zaleckie | 39.9 | - | - | - | - | 1 | 1 | - | - | - | 2 |
| Total | 3973.4 | 205 | 122 | 117 | 85 | 34 | 33 | 29 | 14 | 5 | 644 |

Eel, vendace, pike and whitefish, listed in order of preference, were especially favored. This also becomes apparent when taking into consideration the areas of the lakes stocked with particular fish species in particular years and throughout the study period (Table 5).

Throughout the analyzed period, over 80% of the area of the studied lakes was stocked with eel (35%), vendace, pike and whitefish, while only 11% of the area was stocked with all the other species.

The comparison of the areas of stocked lakes illustrates the basic changes which occurred in the management system during the ownership transformation period (c.1990-1993) and after the newly formed enterprises had leased them (c.1994).

**TABLE 5**

Area (ha) of the studied lakes stocked with various fish species in 1958–1997

| Year | Eel | Vendace | Whitefish | Pike | Tench | Crucian carp | Pikeperch | Carp | Silver carp + Grass carp |
|---|---|---|---|---|---|---|---|---|---|
| 1958 | 327.1 | 259.0 | - | - | - | - | - | - | - |
| 1959 | 404.4 | 201.4 | - | - | - | - | - | - | - |
| 1960 | 1078.6 | 762.3 | - | 380.7 | - | - | - | - | - |
| 1961 | 286.8 | - | 730.7 | - | - | - | 367.6 | - | - |
| 1962 | 2564.3 | 1236.8 | 460.4 | 332.3 | - | - | 930.9 | 107.3 | - |
| 1963 | 2191.3 | 1743.0 | - | - | - | - | 660.0 | 78.2 | - |
| 1964 | - | 1402.0 | - | - | - | - | - | 29.1 | - |
| 1965 | 2584.0 | 1370.5 | 76.3 | - | 255.0 | - | - | 169.3 | - |
| 1966 | 2927.4 | 1095.0 | 582.1 | - | 100.7 | 22.5 | - | 238.8 | - |
| 1967 | 2927.4 | 1854.7 | 201.4 | 76.3 | 1487.5 | 176.8 | 176.8 | 189.9 | - |
| 1968 | 1926.6 | 1501.8 | 307.2 | 457.8 | 1131.4 | - | 475.5 | 138.3 | - |
| 1969 | 176.8 | 1583.8 | 700.7 | 286.8 | 881.1 | 176.8 | 155.5 | 78.2 | - |
| 1970 | 2267.6 | 1556.0 | 457.0 | 380.7 | 380.7 | - | 76.3 | - | - |
| 1971 | 2267.6 | 983.2 | 380.7 | 341.0 | 78.2 | - | 76.3 | 54.0 | - |
| 1972 | 138.8 | - | 475.5 | - | - | - | - | - | - |
| 1973 | 1908.3 | - | 471.8 | - | 299.9 | 322.4 | - | - | - |
| 1974 | 2041.4 | 808.4 | 947.3 | - | - | - | - | - | 29.1 |
| 1975 | 237.4 | - | 29.1 | - | - | - | - | - | - |
| 1976 | 1783.9 | - | 1268.4 | - | - | - | - | - | - |
| 1977 | 1873.1 | 1431.1 | 1394.6 | - | - | - | - | - | - |
| 1978 | 1794.9 | 714.5 | 1019.4 | 404.0 | - | - | - | - | - |
| 1979 | 380.7 | - | 380.7 | 849.0 | 24.0 | 200.8 | - | - | - |
| 1980 | 1091.9 | 747.2 | 1297.1 | 341.0 | 176.8 | 176.8 | - | - | - |
| 1981 | 2802.2 | 1478.5 | 409.8 | 627.7 | - | - | - | - | - |
| 1982 | 1881.2 | 488.2 | 502.9 | - | - | - | - | - | - |
| 1983 | 140.2 | 1169.9 | 829.8 | 1008.1 | - | 238.8 | - | - | - |
| 1984 | 201.3 | 594.5 | 370.7 | 1288.8 | - | - | - | - | 140.2 |
| 1985 | 3263.3 | 679.9 | 475.5 | 445.5 | - | - | - | - | - |
| 1986 | 3442.2 | 1376.9 | 706.0 | 1211.7 | - | - | - | - | - |
| 1987 | 2698.1 | 881.3 | 706.0 | 1065.6 | - | - | - | - | - |
| 1988 | 134.1 | 881.3 | 1755.4 | 715.6 | - | - | - | - | - |
| 1989 | 450.8 | 622.3 | 380.7 | 1575.0 | - | 62.0 | 560.0 | - | - |
| 1990 | - | 761.9 | 230.5 | 253.7 | - | 84.5 | 123.1 | - | - |
| 1991 | 62.0 | - | - | - | - | - | 76.3 | - | - |
| 1992 | - | 1222.3 | - | 280.0 | - | - | 475.5 | 522.7 | - |
| 1993 | - | 881.3 | - | 685.5 | 78.2 | - | 856.2 | 744.3 | - |
| 1994 | - | 279.1 | - | 972.6 | - | - | 879.5 | 29.1 | 78.2 |
| 1995 | 2595.8 | 679.9 | - | 2029.5 | - | - | 856.2 | 356.8 | - |
| 1996 | 2213.9 | 700.0 | - | 3588.6 | - | - | 504.6 | 83.1 | 78.2 |
| 1997 | 2649.7 | 901.4 | - | 2263.8 | - | - | 544.1 | 356.8 | - |
| Annual average | 1393 | 821 | 439 | 547 | 122 | 37 | 195 | 79 | 8 |

The most spectacular of these changes, with the exception of the reinstatement of eel stocking, the increase in the area stocked with pikeperch and the cessation of whitefish stocking, is the very significant increase in the areas of lakes stocked with pike. The average in 1958-1989 was 368 ha, followed by a drop to 305 ha in 1990-1993 and then an increase to as much as 2214 ha in 1994-1997.

The data presented in Tables 4 and 5 indicate that the analyzed lakes as a whole were stocked intensively. Table 6 presents the average stocking effort (in PLN ha $^{-1}$) for all the lakes and for the "less eutrophic" and "more eutrophic" lakes separately during the analyzed period.

**TABLE 6**

Value of the stocking material (PLN ha$^{-1}$) released into the studied lakes in 1958–1997

| | Entire lake sample (3973.4 ha) | "Less eutrophic" lakes (1677.3 ha) | "More eutrophic" lakes (2296.1 ha) |
|---|---|---|---|
| TOTAL | 35.91 | 34.91 | 36.63 |
| Eel | 19.37 | 13.18 | 23.88 |
| Whitefish | 3.42 | 2.05 | 4.42 |
| Vendace | 7.93 | 14.47 | 3.16 |
| Pike | 1.18 | 1.66 | 0.82 |
| Tench | 1.07 | 0.83 | 1.24 |
| Carp | 1.53 | 1.92 | 1.24 |
| Pikeperch | 1.00 | 0.27 | 1.54 |
| Silver carp + Grass carp | 0.27 | 0.53 | 0.08 |
| Crucian carp | 0.14 | - | 0.25 |
| Together (excluding eel) | 16.54 | 21.73 | 12.75 |

The data presented in Table 6 permit the following conclusions to be drawn:

- the overall stocking effort, independent of various species structures, does not significantly vary in either the "more eutrophic" or "less eutrophic" lakes;
- the preceding allows for the conclusion that eel and coregonines are the absolute dominant species, as their joint contribution to the total stocking effort, both combined and in particular groups, exceeded 85%;
- the structure of the stocking effort in "less eutrophic" and "more eutrophic" lakes was drastically divergent, as Fig. 4 illustrates – this refers mainly to commercially important species, especially eel and vendace;
- the structure of the stocking effort indirectly indicates that the environmental state of "more eutrophic" lakes is significantly worse than that of "less eutrophic" lakes.

This is confirmed by the long-term stocking effectiveness indexes of both groups of lakes (Table 7). This index describes the stocking effort (in PLN) of various fish spe-

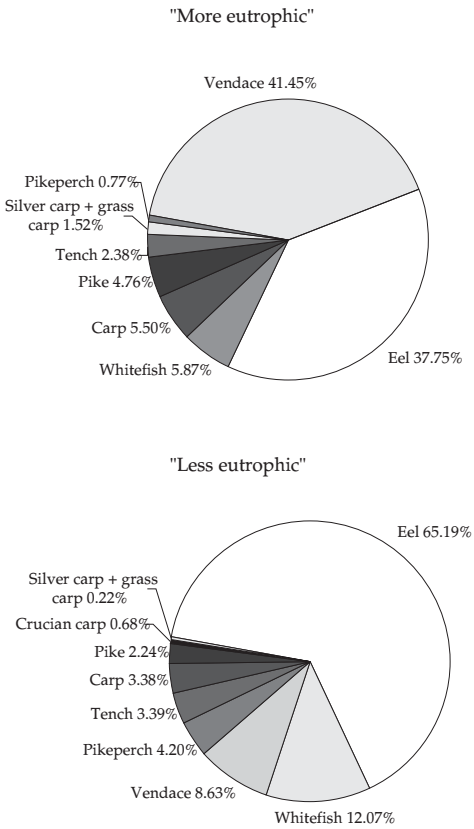


Fig. 4. Value of stocking in "more eutrophic" and "less eutrophic" lakes.

cies and species groups in comparison to catches (in kg) of them at the same times throughout the studied period.

**TABLE 7**

Comparison of the index of multi-year stocking effectiveness (PLN $kg^{-1}$) in "less eutrophic" and "more eutrophic" lakes

| | "Less eutrophic" lakes | "More eutrophic" lakes |
|---|---|---|
| Eel | 8.61 | 9.08 |
| Coregonines | 3.90 | 7.90 |
| Littoral fish species | 0.51 | 1.11 |
| Carp + herbivorous | 5.83 | 10.15 |
| Pikeperch | 2.08 | 1.12 |
| Together | 3.11 | 5.10 |

The clearly lower stocking effectiveness of coregonines and littoral species, i.e. those which are most affected by eutrophication, in the "more eutrophic" lakes in comparison with that in the "less eutrophic" lakes, clearly confirms the preceding evaluations. Another fact which confirms this is the higher stocking effectiveness of pikeperch, a species which finds optimum conditions in more eutrophic waters, in the "more eutrophic" lakes.

## DISCUSSION

According to the definition of water eutrophication, this process ultimately leads to "*... waters becoming degraded to the extent that they cannot be exploited for any purpose...*" inclusive of conducting fishery (*Definition of Issues in Environmental Protection*, GUS 1993). The analyses of the fish catches in the studied lakes clearly indicate that, although eutrophication did not reach levels which would render the lakes useless for fishery, production results declined progressively during the analyzed period. This phenomenon is seen in the majority of Polish lakes, and though their environmental states are generally not acceptable, rarely are they degraded to the point that all functions, including fishery, are destroyed (Leopold et al. 1994). Evidence that progressing eutrophication has impacted fishery production is seen in the tendencies throughout the analyzed period of catches of "increasing" and "decreasing" species. The parameters of the degree of decline of both groups confirm the hypothesis that the environmental state of the lakes has a heavy impact on the catches.

The division of the lakes into "more eutrophic" and "less eutrophic" groups appears to be acceptable since fishery was analyzed with regard to the environmental state. This is confirmed by the differences in catch tendencies, average long-term efforts and the areas of the lakes from the two groups. It is plausible that the same methodology can be applied to any group of lakes to divide them into relatively "more eutrophic" and "less eutrophic" groups and then to evaluate the quality of the entire group. Currently, fishery analyses are often used as a basis for evaluating the environmental quality factor of lake ecosystems where fishery is conducted since fish indicate that changes, including those in the rate of eutrophication (Leopold et al. 1986), are occurring in a system (Bnińska 1994).

Stocking, which is analyzed in this work as an element of fishery management, can also describe the quality of lake environments. The structure of the stocking effort indicates that the environment of the "more eutrophic" group of lakes is worse in

comparison with the "less eutrophic" lakes. The total vendace stocking effort varies greatly between the "less eutrophic" and "more eutrophic" lakes. This is due to the understandable policy of stocking vendace in lakes which provide better environmental conditions. The effectiveness of vendace stocking in "less eutrophic" lakes as reflected in the multi-year stocking effectiveness index, i.e. stocking value per catch unit, is definitely higher than in "more eutrophic" lakes. A similar situation was noted with regard to littoral species (pike, tench and crucian carp), but with pikeperch the opposite was noted; higher stocking effectiveness indexes were recorded for "more eutrophic" lakes.

Based on the analyses of long-term stocking policy, conclusions can be drawn with regard to the generally understood concept of fishery management quality and the impact ownership transformation had on it.

The data suggest that all of the lakes were stocked intensively during the analyzed 40 year period. Thus, the fishery management quality of the analyzed lakes, at least with respect to stocking practices, was high. The most important species included eel, vendace, pike and whitefish, and over 80% of the analyzed lake areas were stocked with these species.

Following the period of ownership transformation of the former State Fisheries Enterprises in 1990 – 1993, fundamental changes occurred in the lake fishery management system in Poland. These included, among others, shifting the priority of stocking policy from established eel targeted fishery to the introduction of other species, especially pike (Mickiewicz and Wołos 1999a). Unquestionably, this has been the most important species in the stocking policy of Polish lakes for the past several years (Mickiewicz 2001). The role of pike in the stocking of the lakes analyzed in this work has also increased dramatically as a result of ownership transformation. The average area stocked in 1958-1989 was 368 ha; this figure increased to 2214 ha in 1994–1997. Additionally, eel stocking was reintroduced in the group of analyzed lakes, whereas fishery company interest in stocking this species is declining year by year. In light of the foregoing, the impact of the transformation on the stocking policy in the studied lakes, and thus on the whole of fishery management, must be evaluated positively.

The comparison of the amount of stocking material released into the studied lakes during the 40 year study period to that for the 1998 lake fishery stocking effort, which varied from 21.4 to 30.4 zł $ha^{-1}$ depending on the region (Mickiewicz and Wołos 1999b), indicates that stocking in the former was more intense in both the entire group of lakes as well as in the "less eutrophic" and "more eutrophic" groups. Coregonines

(vendace and whitefish) and eel comprised a total of 85% of the stocking material released in the "less eutrophic" and "more eutrophic" lakes; this differed from the stocking structure in Poland in 1998 when coregonines and eel constituted only about 50% of the material released (Mickiewicz 1999).

In summary, the following conclusions can be drawn:

1) The morphometric features, environmental state, size and species structure of catches and stocking as well as the intensity and effectiveness of management varied tremendously among the 25 analyzed lakes (total area of 3973.4 ha).
2) The methods applied to analyze catches and stocking revealed that eutrophication was clearly noted in throughout the studied lakes during the 1958 - 1997 period and that the environmental state of the lakes worsened, as was reflected by changes in the species structure of the catches and decreases in fishery effectiveness.
3) The conclusions derived from the applied analysis of catch time series for selected species groups and size-classes of fish and for all fish which were either stimulated ("increasing") or limited ("decreasing") by eutrophication were verified and fully confirmed by the complementary stocking studies.
4) Studies of the "more eutrophic" and "less eutrophic" lake groups, which were divided based on relations between catch groups, not only confirmed and strengthened the obtained conclusions, but also justified the use of the applied methodology and demonstrated its reliability and cognitive value.
5) The analyses revealed that, despite long-term negative tendencies which were observed in all the analyzed lakes, the environmental state of the lakes and especially the level of fishery are much better than the Polish average.
6) The studies revealed that there were positive changes in the fishery of the analyzed lakes after the liquidation of the former State Fisheries Enterprises and the transformation of ownership.

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## STRESZCZENIE

EFEKTYWNOŚĆ GOSPODARKI RYBACKIEJ W EUTROFICZNYCH JEZIORACH OKOLIC MRĄGOWA (POLSKA PÓŁNOCNO–WSCHODNIA)

Poddano analizie 40-letnie dane (1958-1997) o odłowach i zarybieniach 25 wybranych jezior Pojezierza Mrągowskiego (tab. 1). Analizę przeprowadzono sumarycznie dla wszystkich danych (tab. 2, rys. 1) oraz w dwóch grupach jezior, wyodrębnionych w oparciu o relacje, jakie zachodzą pomiędzy średnim wieloletnim odłowem gatunków i sortymentów, których liczebność wzrasta, oraz odwrotnie – maleje w miarę

postępowania procesu eutrofizacji (rys. 2, 3, tab. 3). Zgodnie z tym układem analizowano zarybienia, wykorzystując wskaźnik częstotliwości zarybień, wielkość zarybień w ujęciu wartościowym, wielkość zarybianej powierzchni oraz wskaźnik wieloletniej efektywności zarybień (tab. 4, 5, 6, 7, rys. 4).

Wyniki analizy odłowów i zarybień wskazują, że badane jeziora jako całość podlegały w rozpatrywanym okresie wyraźnemu procesowi eutrofizacji i pogarszania się stanu środowiska, czego wyrazem były zmiany jakościowe w odłowach ryb towarowych i spadek efektywności gospodarki rybackiej.

Przeprowadzone badania ujawniły też pozytywne zmiany, jakie zaszły w rybackim gospodarowaniu na rozpatrywanych jeziorach po okresie transformacji własnościowej byłych państwowych gospodarstw rybackich. Uzyskane wyniki wykazały też zasadność, wysoką przydatność i duże walory poznawcze zastosowanej metody badawczej.

CORRESPONDING AUTHOR:

Mgr inż. Maciej Mickiewicz
Instytut Rybactwa Śródlądowego
Zakład Bioekonomiki
ul. Oczapowskiego 10
10-719 Olsztyn
Tel./Fax: +48 89 5240171, +48 89 5240505