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# EFFECTIVENESS OF COREGONID MANAGEMENT VERSUS ENVIRONMENT QUALITY

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A B S T R A C T. Coregonid management was analysed with consideration given to some parameters of environment quality and a ranking system used since 1982 to estimate lake quality. The study comprised 38 lakes, for which catch statistics and management data were collected, embracing a period of 27 years (1968-1994). The lakes were analysed as a whole sample and divided to two groups: „good" and „bad" quality. The latter division was based on the mean rank calculated for the whole sample, amounting to 2.273. Statistically significant differences were found in the two groups. Commercial yields of vendace did not depend on the analysed environment quality parameters, but effectiveness of vendace stockings decreased with increasing lake trophy measured as chlorophyll content in the surface water layer. Yield of whitefish depended on total nitrogen and total phosphorus content in water, with phosphorus having a stimulating and nitrogen a limiting effect. The results of coregonid management have been discussed in relation to environment quality.

Key words: EUTROPHICATION, LAKE QUALITY ASSESSMENT, WHITEFISH, VENDACE, PIKE-PERCH, EFFECTIVENESS OF STOCKING, COMMERCIAL YIELDS

## INTRODUCTION

Coregonids constitute an important component of the ichthyofauna and are considered as economically valuable fish. Unfortunately catches of whitefish (*Coregonus lavaretus* L.) as well as vendace (*Coregonus albula* L.) show a decreasing trend (Mastyński 1978, Leopold, Bnińska, Nowak 1986, Falkowski and Wołos 1996).

Studies on the effect of water eutrophication upon the fish stocks have repeatedly shown that coregonids tend to disappear along with this process (Colby et al. 1972, Hartmann 1977, 1979, Leach et al. 1977, Leopold, Bnińska, Nowak 1986, Bnińska 1994). However, high plasticity of the two species, and especially of whitefish, makes it difficult to reveal direct relationships between physico-chemical conditions and the presence of these fish in the aquatic environment (Bernatowicz 1953, Szczerbowski 1970, Mastyński 1978, Hartmann 1987, Salojärvi and Ekholm 1990). This study presents part of the research conducted within the frames of a complex project on the effectiveness of coregonid management in Poland and the possibilities of its optimisation. Its basic objective was to find out whether it was possible to reveal a relationship between environment quality and the status of aquatic ecosystems (assessed with standard methods used in Poland: Kudelska, Cydzik, Soszka 1981) on the one hand, and the effectiveness of coregonid management on the other. Additionally, the study was supposed to reveal to what an extent a new method of lake quality classification, introduced since 1982 (op. cit.), could be used to undertake management decisions, most of all as regards coregonid management.

## MATERIALS AND METHODS

Analyses comprised 38 lakes of total area 26486.3 ha. They were selected from a sample of 132 lakes with coregonid management based on the availability of environment quality parameters. All lakes were monitored in 1986-1994 by the respective Centres for Environment Monitoring and Control, and the results pertaining to lake quality were published in consecutive Atlases of Polish Lake Quality (Cydzik, Kudelska, Soszka 1992, 1995).

The following environmental parameters were available for each lake:

- average percentage saturation of the hypolimnion waters with oxygen, measured in the peak of summer stagnation;
- BOD5 (in mg $O_2/dm^3$) measured in the epilimnion in the peak of summer stagnation;
- total phosphorus ($P_{tot}$ in $mg/dm^3$) content in the epilimnion layer; a mean value from the measurements made during spring circulation and in the peak of summer stagnation;
- total nitrogen ($N_{tot}$ in $mg/dm^3$) content; a mean value measured in the same way as Ptot;
- chlorophyll (in $mg/dm^3$) content measured in the same way as $P_{tot}$;
- visibility of Secchi's disc (in m); a mean value from the measurements during spring circulation and the peak of summer stagnation;
- point score of lake quality.

Point score of lake quality has been introduced in 1982. It is a resultant value of the scores ascribed to a number of physico-chemical and biological parameters. Details of the ranking procedure are given in Kudelska, Cydzik and Soszka (1981). According to this new method of lake classification, each lake can have a point score from 1 to 4, and is classified into purity classes (categories) in the following manner (op. cit.):

Class (category) I - less than 1.50 points

Class (category) II - from 1.50 to 2.50 points

Class (category) III - from 2.50 to 3.25 points

Polluted and degraded, below any class - more than 3.25 points

Detailed catch statistics were collected for each lake, with consideration given to the species caught as well as their size-classes, together with detailed data on artificial stockings performed in each lake. All data on the fisheries management embraced the period of 27 years (1968-1994).

Relations between environment quality and effectiveness of coregonid management were analysed for the whole lake sample and for two groups i.e. „good" and „low" quality lakes. The two groups were established using a dichotomic division based on the mean point score for the whole lake sample, which amounted to 2.273. Consequently, the group of „good quality" lakes comprised all lakes with the score <2.273, while „low quality" one - those with the score >2.273.

Effectiveness of coregonid management was assessed based on the yield of vendace and whitefish (commercial catch in kg/ha) and an index of the effectiveness of vendace stockings (number of stocked vendace larvae needed to obtain 1 kg of commercial catch). This index was calculated for the whole period of 27 years (1968-1994) and all lakes ($E_0$), and for the 10 years in which the lakes were subject to quality controls ($E_1$; 1985-1994). In the latter case it was assumed that in view of progressing environmental changes, assessment of the ecosystem state made in a given year would reflect this state in a few preceding and a few subsequent years, totally no more than 10. Simple (linear and curvilinear) and multiple correlations were calculated (for the same period of 10 years) between environment quality parameters and parameters characterising coregonid management. The dependent variables were: average vendace catch per 1 ha, index of vendace stocking effectiveness ($E_1$, number of larvae per 1 kg of catch), and mean whitefish catch per 1 ha. The independent variables were: parameters of environment quality (as above) and the point score. In the case of vendace, also stocking rates were taken into account as an independent variable.

Index of the effectiveness of stocking with whitefish was not calculated. This was due to the fact that a variety of different stocking material was used in the lakes under study (from feeding larvae to autumn fry), so that no direct comparisons could be made, and it was not possible to find a common denominator.

Basic statistics were also calculated (mean values, ranges, variability), and time series approach was used to assess the trends. Significance of the differences between the two lake groups was checked against a null hypothesis using one- and two-way t-test (Blalock 1977, Loftus and Loftus 1987). All statistical analyses were carried out using the programme STATISTICA, Version 5.

# RESULTS AND DISCUSSION

## STATE OF LAKE ENVIRONMENTS AS BASED ON OFFICIAL INDICES

The group of „good quality" lakes, in which the point score did not exceed 2.273, comprised 22 lakes of total area 15519.8 ha. Mean point score for this group was 1.94, ranging from 1.40 to 2.20 (Table 1). According to the criteria of lake quality (Kudelska, Cydzik, Soszka 1981), four lakes in this group were classified as class I, the remaining ones - as class II, but within the range close to the lower limit for this class.

The group of „low quality" lakes embraced 16 lakes of total area 10966.5 ha. The mean point score was 2.73 in this group, ranging from 2.31 to 3.33. The difference in the mean score between the two groups was statistically very highly significant ($p=0.0000$, Table 1). Four lakes in this group had the point score within the upper limit for class II lakes, and one lake was classified as strongly polluted and degraded, beyond any category. The remaining lakes belonged to class III.

Significant difference in the point score between the two groups is quite obvious as this score was used as a criterion to divide the lakes into „good" and „low" quality. Attention should rather be given to particular physico-chemical parameters. All of them were of worse quality in the group of „low quality" lakes compared to „good" ones. And thus, in the group of „good quality" lakes water saturation with oxygen in the hypolimnion was higher, visibility of Secchi's disc was also higher, while content of total phosphorus, total nitrogen and chlorophyll was lower and so was $BOD_5$ compared to „low quality" group, and the differences were very highly significant (Tab. 1). Only in the case of two-way t-test for the mean content of Ptot the statistical significance of the difference was a little lower than the accepted level of 0.05 (it amounted to $p=0.06$), but one-way test showed that this difference was statistically significant at the level $p = 0.03$ (tab. 1).

**TABLE 1**

Characteristics of lake environment in the distinguished groups

| Parameter | „Good quality" lakes N=22 area 15519.8 | N=16 area 10966.5 | Significance of the differences between the groups |
|---|---|---|---|
| $O_2$ (%) in the hypolimnion<br>Mean<br>Range | 14.1<br>0.0 - 35.2 | 3.69<br>0.0 - 12.9 | p(t1)* ≤ 0.001<br>p(t2)** ≤ 0.003 |
| $BOD_5$ ($mg\ O_2/dm^3$)<br>Mean<br>Range | 1.98<br>1.1 - 4.2 | 4.00<br>1.4 - 7.7 | p(t1) ≤ 0.0003<br>p(t2) ≤ 0.0006 |
| $P_{tot}$ ($mg/dm^3$)<br>Mean<br>Range | 0.091<br>0.031 - 0.233 | 0.159<br>0.080 - 0.290 | p(t1) ≤ 0.03<br>p(t2) ≤ 0.06 |
| $N_{tot}$ ($mg/dm^3$)<br>Mean<br>Range | 0.901<br>0.43 - 1.35 | 1.528<br>0.87 - 2.39 | p(t1) ≤ 0.0000<br>p(t2) ≤ 0.0000 |
| Chlorophyll ($mg/dm^3$)<br>Mean<br>Range | 11.43<br>2.4 - 87.1 | 31.26<br>5.7 - 114.4 | p(t1) ≤ 0.007<br>p(t2) ≤ 0.01 |
| Visibility of Secchi's disc (m)<br>Mean<br>Range | 2.83<br>1.3 - 5.6 | 1.56<br>1.0 - 3.3 | p(t1) ≤ 0.0001<br>p(t2) ≤ 0.0002 |
| Point score<br>Mean<br>Range | 1.40 2.20 | 2.73<br>2.31 - 3.33 | p(t1) ≤ 0.0000<br>p(t2) ≤ 0.0000 |

**level of significance with one-way t-test*
***level of significance with two-way t-test*

High significance of the differences in the analysed parameters of water quality between the two groups suggests that point score used to assess the status of lake environment reflects in an adequate way differences in water quality.

Point score method is certainly more useful than the former methods of lake classification. Until 1981 lakes were classified into classes based on a variety of physico-chemical and biological indices, and the most extremal value determined the lake class. Due to this it happened that an incidental lake pollution, which for abrief period changed e.g. faecal coliform counts, would result in classifying quite a good lake into the class of polluted or even degraded water bodies. There were also cases when different parts of the same lake were classified as belonging to different purity classes (Cydzik and Soszka 1988) against all principles of ecology.

Even when one does not pay any attention to such drastic examples, a definite class of lake quality always contained lakes differing as to their state. Having this classification plus a variety of indices which could not be interpreted in an unequivocal manner, there was no possibility of comparing the lakes in a meaningful way. The score point is based on the same physico-chemical and biological indices, but ranking procedure enables a certain quantification of the environmental quality, thereby allowing for direct comparisons between the lakes. In the distinguished group of „good quality" lakes there were 18 lakes belonging to the same class (class II), but their scores differed, so they could be compared as required.

It should be, however, pointed out that although the discussed ranking procedure reflects differences in lake water quality, this does not automatically imply that it reflects also the state of an ecosystem as a whole, or the efficiency of ecosystem functioning.

## STATE OF ENVIRONMENT AND COREGONID MANAGEMENT

A general characteristic of coregonid management in the two lake groups and the 27-year period (1968-1994) is presented in Table 2, while the same data for the period of 10 years corresponding to environment quality monitoring are presented in Table 3.

TABLE 2

Characteristics of coregonid management in the two lake groups in 1968-1994 (n = 27 years)

| Parameter | „Good quality" lakes<br>N=22<br>area 15519.8 | „Low quality" lakes<br>N=16<br>area 10966.5 | Significance of the differences between the groups |
|---|---|---|---|
| Catch of vendace (kg/ha)<br>Mean<br>Range | <br>5.71<br>0.49 - 9.56 | <br>5.26<br>1.00 - 9.80 | <br>not significant |
| Catch of whitefish (kg/ha)<br>Mean<br>Range | <br>1.20<br>0.33 - 2.35 | <br>0.60<br>0.11 - 1.23 | <br>p(t1)* ≤ 0.0000<br>p(t2)** ≤ 0.0000 |
| Stocking with vendace (ind./ha)<br>Mean<br>Range | <br>5457.1<br>2506.5 - 8899.3 | <br>4057.8<br>1236.4 - 6083.3 | <br>p(t1) ≤ 0.0000<br>p(t2) ≤ 0.0001 |
| Effectiveness of stocking<br>Mean<br>Range | <br>1155.7<br>439 - 2882 | <br>1253.2<br>320 - 2861 | <br>not significant |

*level of significance with one-way t-test
**level of significance with two-way t-test

**TABLE 3**

Characteristics of coregonid management in the two lake groups in the period corresponding to environmental surveys (1985-1994)

| Parameter | „Good quality" lakes N=22 area 15519.8 | „Low quality" lakes N=16 area 10966.5 | Significance of the differences between the groups |
|---|---|---|---|
| Catch of vendace (kg/ha)<br>Mean<br>Range | 6.27<br>4.78 - 7.82 | 3.63<br>1.00 - 7.63 | p(t1)* ≤0.0003<br>p(t2)** ≤ 0.0006 |
| Catch of whitefish (kg/ha)<br>Mean<br>Range | 0.88<br>0.33 - 1.50 | 0.52<br>0.11 - 0.98 | p(t1) ≤ 0.0002<br>p(t2) ≤ 0.0005 |
| Stocking with vendace (ind./ha)<br>Mean<br>Range | 5869.4<br>2506.5 - 8899.3 | 4179.0<br>1434.4 - 5687.6 | p(t1) ≤ 0.0003<br>p(t2) ≤ 0.00 |
| Effectiveness of stocking<br>Mean<br>Range | 1994.9<br>121 - 7527 | 2751.3<br>213 - 14080 | not significant |

**level of significance with one-way t-test*
***level of significance with two-way t-test*

Vendace management. Based on the results presented in Table 2 there is no possibility of assessing the relationship between state of lake environment and effectiveness of vendace management. Notwithstanding highly significant difference in the rate of artificial stockings between „good quality" and „low quality" lakes, average vendace yield per 1 ha did not differ (Tab. 2). Moreover, one could even advocate that stockings with vendace were more effective in the group of „low quality" lakes compared to the „good quality" ones. Statistically significantly lower level of stockings in the „low quality" lakes, amounting on the average to 4058 larvae/ha compared to 5457 larvae/ha in „good quality" group, corresponded to a more or less the same level of catches in both groups (the difference in vendace catch was statistically insignificant, Tab. 2). This suggestion, however, is not confirmed by the average index of stocking effectiveness, which in the whole period of 17 years showed no statistically significant differences between the two groups (Tab. 2). This suggests that when the whole period of 27 years is taken into account, the differences in environment quality between the two groups might not be so readily noticeable. It can be easily assumed that lake status defined on the basis of environment monitoring reflects the real situation in a period of a few years before and after this monitoring, but it cannot be adequate for the very first years of the 27-year period. In view of rapidly progressing lake eutrophication, it is quite certain that significant changes took place in the environment between 1968 and the second half of the 80-ties, viz. the period of environment monitoring. Hence, the mean data presented in Table 2 for the 27-year period cannot be treated as fully meaningful.

It is generally accepted that composition of fish catches reflects state of lake ecosystems (e.g. Leopold, Bnińska, Nowak 1986, Bnińska and Leopold 1990, Bnińska 1992, 1994). Having this in mind, analyses of commercial catches were performed to find out whether the lakes in the two groups did differ as to the state of their environments already at the beginning of the analysed period of 27 years. To achieve this, catch composition was established for the first 10 years, i.e. 1968-1977, and the results are presented in Fig. 1 a and b. It is readily seen from these figures that at that time the quality of lake ecosystems was definitely satisfactory in both groups. Coregonids and predators represented as high percentage as 38.1 % in the „good quality" group and 28.7 % in the „low quality" one. Share of less valuable cyprinids (bream, roach, white bream) was 43.9 and 50.4 % respectively, viz. much less than in eutrophic lakes, and the share of small-sized specimens of these fish was 24.9 % and 24.1 % respectively in the two groups, being at the level characteristic of well functioning ecosystems (e.g. Bnińska and Leopold 1990, Bnińska 1996, Bnińska et al. 1997). Notwithstanding this, it is also obvious that lakes included into the group of „low" quality were characterised by higher trophy than those included into „good" quality group, as reflected in a slightly lower percentage of coregonids and predators, higher of eel and less valuable cyprinids, especially small-sized ones (Fig 1 a, b). Suggestion on higher trophy of „low" quality lakes already at the beginning of the 27-year period is confirmed also by the differences in total fish yield, which in 1968-1977 amounted to 27.8 kg/ha in „good" quality group and 33.2 kg/ha in „low" quality one, this difference being very highly significant (p=0.0000).

In view of the above, only the last 10 years (corresponding to environment quality surveys) were taken into consideration in order to assess the effect of environment quality on coregonid management. The results are presented in Table 3.

Average vendace catches in the group of „good" quality lakes was 1.7 times higher than in the „low" quality lakes, while stocking rates were only 1.4 times higher in the first group (Tab. 3). Hence, it can be assumed that higher vendace catches in better quality lakes were connected with better quality of their ecosystems. This is confirmed by the results of fish catch analysis presented in Fig. 2a, b. Compared to the picture of 1968-1977 (Fig. 1a, b), environment quality definitely deteriorated in

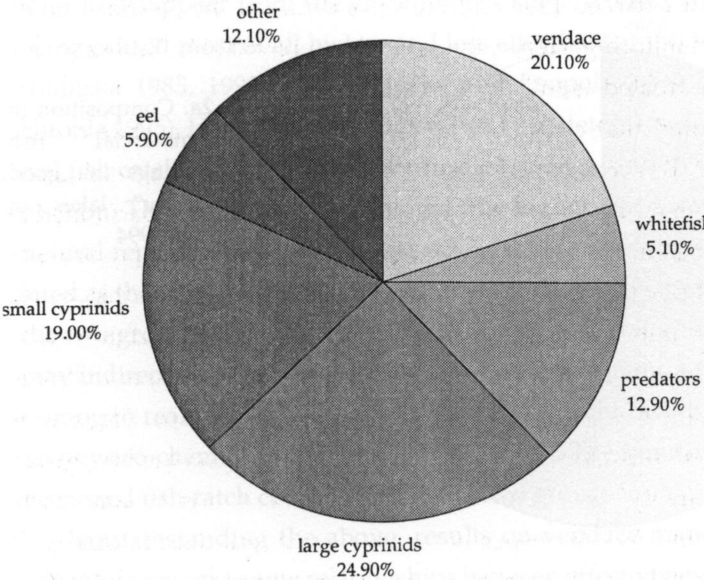


Fig. 1a. Composition of commercial fish landings in „good quality" lakes in 1968-1977

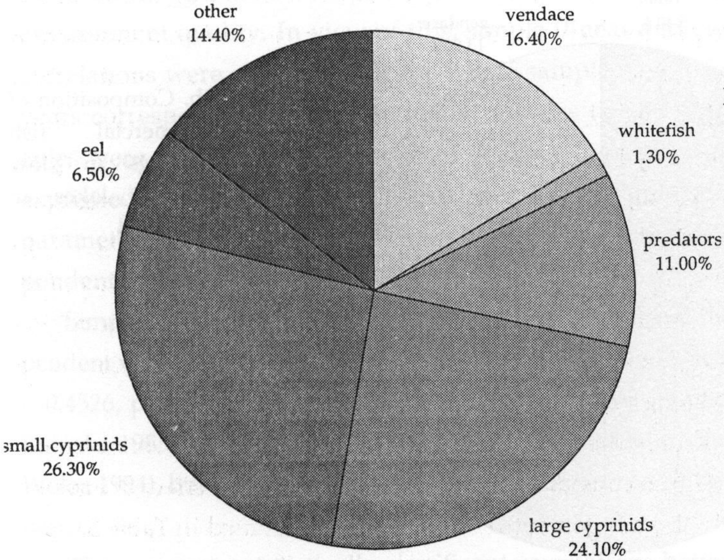


Fig. 1b. Composition of commercial fish landings in „low quality" lakes in 1968-1977

the „low" quality group, this being reflected in a decrease of coregonid fraction and an increase of less valuable cyprinids, small-sized cyprinids most of all (Fig. 2a, b). Total fish catch was still significantly (p=0.001) higher in „low" quality group compared to „good" quality one (26.3 and 22.7 kg/ha respectively). On the other hand, however, high percentage of predators (10.3%), and the overall picture of catch composition in „low quality" lakes suggest that their ecosystems are still functioning

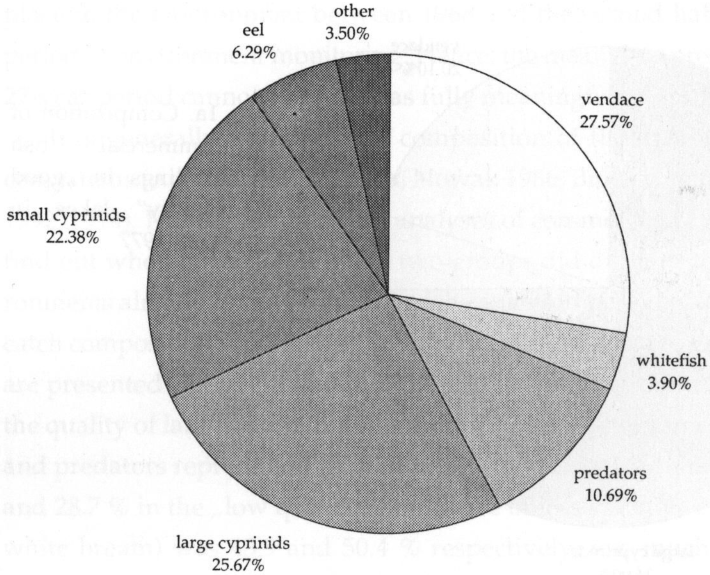


Fig. 2a. Composition of commercial fish landings in „good quality" lakes in 1985-1994

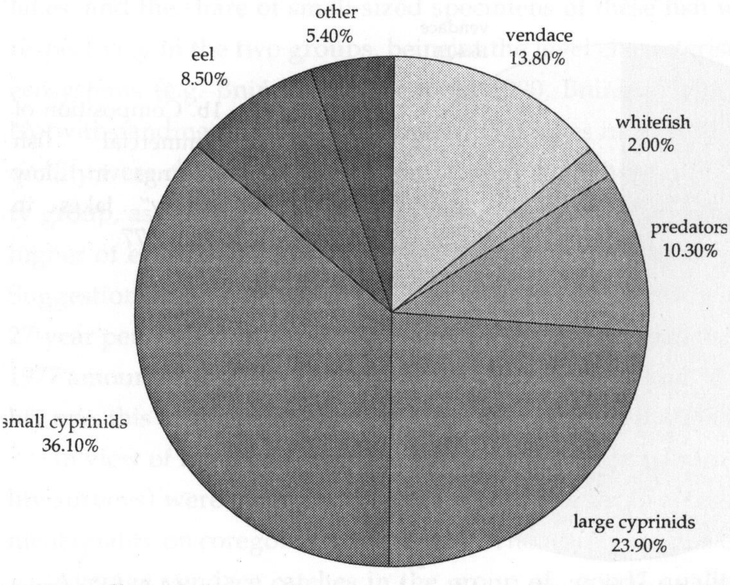


Fig. 2b. Composition of commercial fish landings in „low quality" lakes in 1985-1994

quite well, and that environment quality in these lakes is definitely better than it would result from the respective environmental indices (Tab. 1).

No significant differences were found in the effectiveness of vendace stocking in the two groups (Tab. 3), similarly as for the whole period of 27 years (Tab. 2). This is probably due to low accuracy of the index as calculated in this study. Coregonids tend to disappear from the environment subjected to eutrophication process, this being caused most of all by less and less effective natural reproduction of these fish (Bnińska 1985, 1992, 1994, Bnińska and Leopold 1990, Marjomaki, Kirjasniemi, Huolila 1995). Hence, it would be necessary to determine to what an extent commercial fish catch originated from artificial stockings, and to what from natural reproduction. The better the environment, the higher catch fraction will originate from natural reproduction, and the less adequate the stocking effectiveness index calculated as the ratio between stocking and catch. Lack of significant difference between the two groups in the effectiveness of vendace stocking in the last 10 years (Tab. 3) may indirectly suggest that state of the lake ecosystems and efficiency of their functioning in reality do not differ so much as it would result from the estimates based on physico-chemical parameters of lake water. The same can be concluded from the discussed fish catch composition in the two groups.

Notwithstanding the above, results on vendace management in the two lake groups do suggest some relationships between effectiveness of this management and environment quality. In view of this, simple (linear and curvilinear) and multiple correlations were calculated for the whole sample of 38 lakes and the period of 10 years corresponding to environmental surveys (1985-1994). Two dependent variables were used i.e. average catch of vendace (kg/ha), and stocking effectiveness expressed as number of larvae used per 1 kg of vendace catch. Environmental parameters and stocking rates (number of larvae stocked/ha) were used as independent variables.

Simple correlation between vendace catches (kg/ha) and the above mentioned independent variables revealed that level of catches depended solely on the stocking rates ($r = 0.4526$, $p<0.004$). The same result was obtained in a number of earlier studies (e.g. Bnińska 1985, 1994, Leopold and Bnińska 1987, Bnińska, Salojärvi and Leopold 1988, Wołos 1994), but this point shall not be discussed here as being outside the scope of this paper.

There were no statistically significant correlations between vendace yields and physico-chemical parameters of lake water (hypolimnion saturation with oxygen, $BOD_5$ in the epilimnion, phosphorus, nitrogen and chlorophyll content in surface layer, visibility of Secchi's disc). Similar results were obtained by Bnińska, Salojärvi and Leopold (1988) who analysed effectiveness of vendace stocking in Polish and Finnish lakes. They found that vendace catches in Finnish lakes depended in a significant way on total phosphorus content in water, while there was no such a relationship in Polish lakes. These authors concluded that in poor, oligotrophic lakes of Finland phosphorus might have been the limiting factor, whereas in fertile, strongly eutrophic lakes of Poland there was no such an effect. The results obtained in course of this study confirmed this suggestion.

On the other hand, lack of significant correlation between yields of vendace and point score of lake quality is quite surprising. This is probably due to the fact that the discussed ranking procedure reflects quality of lake water rather than of the ecosystem. The same can be implied from the analysis of fish catch composition.

Also multiple correlation showed that in eutrophic lakes vendace yields were to some an extent independent of the chemical composition of water. When all water quality indices were taken into account, the obtained coefficient of correlation was barely significant (p=0.06). Consecutive elimination of the least significant variables yielded a statistically significant model (R=0.5166, p<0.004), but only two independent variables remained in the model which proved to be statistically significant. They were: stocking rate and $BOD_5$ in the epilimnion. Moreover, even in this case the effect of $BOD_5$ on vendace yields appeared to be very little significant, its significance level being p<0.1 which is sometimes accepted in applied biology (Romanowski 1951), but considered as low. The discussed model revealed that commercial yield of vendace (kg/ha) increased with increasing stocking rates, and decreased with increasing $BOD_5$ levels, with stocking rates explaining 22% and $BOD_5$ only 8% of the variability of vendace catches. Almost 70 % of catch variability remained unexplained. Hence, yield of vendace in eutrophic lakes must be affected by some other factors.

Slightly different results were obtained when the effectiveness of stocking was taken into consideration. Simple correlation revealed that this effectiveness depended on one environmental parameter only, viz. chlorophyll content in the epilimnion. The dependence was very highly significant and best approximated by a 3rd degree curve (r=0.7432, p<0.0001). It showed that the effectiveness of stocking decreased with increasing chlorophyll content in water, i.e. the higher the chlorophyll levels, the more larvae were needed to produce 1 kg of vendace catch. Chlorophyll content explained over 55 % of the variability of stocking effectiveness.

Chlorophyll concentration in water can be treated as an index of primary production, thus - indirectly - also as a measure of lake trophy (Brylinsky and Mann

1973, Dillon and Rigler 1974, Kudelska, Cydzik, Soszka 1981). Hence, it can be concluded that while vendace yield in our lakes does not depend on environment quality parameters, the effectiveness of stocking with vendace depends on lake trophy and decreases with increasing lake fertility. It also seems that the new method of ranking lake quality does not adequately reflect the real status of the ecosystem and its functioning.

Whitefish management. Although in the whole period of 27 years there were no statistically significant differences in vendace catches in „good" and „low quality" lakes, catches of whitefish were twice lower in „low quality" group compared to the „good" one (0.60 and 1.20 kg/ha, Tab. 2). Considering, however, the discussed state of lakes at the beginning of this period, it seems that this difference was more related to the differences in stocking rates than to habitat quality. Table 2 does not contain data on whitefish stockings due to the mentioned difficulties in bringing them down to a comparable form. It is generally known that whitefish catches, similarly as catches of vendace, are strictly related to stockings (Bnińska, Salojärvi, Leopold 1988, Salojärvi 1988, 1991, Mattina and Moccia 1989, Moccia and Mattina 1990, Salojärvi and Ekholm 1990, Bnińska 1994, Salojarvi and Mutenia 1994). In the analysed period of 27 years 8699 whitefish larvae/ha were totally released into the „good quality" lakes as compared to only 3020 larvae/ha in „low quality" ones. The respective data for other forms of the whitefish stocking material were: actively feeding hatchlings - 240.1 and 1043.6 ind./ha, summer fry - 1910 and 2177 ind./ha, autumn fry - 923 and 353 kg/ha. Hence, levels of stocking with larvae and autumn fry were three times lower in „low quality" lakes than in „good quality" group, while the opposite was true of feeding hatchlings. Assuming, however, that mortality of larvae and feeding hatchlings is more or less the same (Szczerbowski et al. 1993), these two types of stocking materials can probably be summed up. It appears then that level of stocking with whitefish larvae and hatchlings was 2.2 times higher in „good quality" lakes than in „low quality" ones, of stocking with summer fry at a more or less the same level in both groups, and of stocking with autumn fry - 2.6 times higher in „good" quality lakes. There is no doubt that in the whole period of 27 years (1968-1994) the difference in whitefish yield between the two groups (Tab. 2) resulted from the differences in stocking rates, and not from the differences in lake quality.

Commercial yields of whitefish in the last ten years (1985-1994) were also significantly lower in lakes of low quality compared to the good ones (Tab. 3). But also in this case stocking rates were lower in „„„worse" lakes. In the whole period of 10 years there were 5326 larvae released per 1 ha in „good quality" lakes, and only 1684 larvae/ha in „low quality" group. Stockings with summer fry were slightly higher in good quality lakes (650 versus 550 fish/ha), while the same amounts of autumn fry were released in both groups (77 and 71 kg/ha). Hence, it seems that also in the case of whitefish the commercial catch was more related to stocking rates than to the differences in environment quality between the two lake groups. Notwithstanding this, there was a statistically significant correlation between whitefish yield (in kg/ha) and phosphorus content in surface water layer. Correlation coefficient for the linear regression was highly significant ($p<0.002$) and amounted to $r = 0.4965$. Multiple correlation proved to be even more interesting. Whitefish yields appeared to depend in a significant way on two factors: total phosphors content ($p<0.0001$) and total nitrogen content ($p<0.009$) in surface water layer. Multiple correlation model was highly significant ($R=0.6167$, $p<0.0002$) and explained 38% of the total variability of whitefish yields. An unexpected result was the fact that the two factors had a totally opposite effect on whitefish yield; an increase of phosphorus content in water stimulated whitefish production whereas of nitrogen content - decreased it. The relationship was described by the equation:

$$y = 1.33227 + 11.98552x - 1.5136z$$

where:

y - commercial yield of whitefish in kg/ha

x - total phosphorus content in water ($mg/dm^3$)

z - total nitrogen content in water ($mg/dm^3$).

It should be noted that whitefish yield proved to depend on the two major factors responsible for the eutrophication process in lakes. The obtained model suggests that as regards lakes characterised by the trophic status as those analysed in this study (with still relatively well functioning ecosystems, Fig. 2), nitrogen content in water limits whitefish production, while phosphorus stimulates it, the stimulating effect of phosphorus being much stronger than the limiting effect of nitrogen. It can be, thus, concluded that it is still possible to increase whitefish production.

It should be also pointed out that almost 60% of the variability of whitefish yields remained unexplained, and that this variability was most probably related to the variability of stocking rates, which had not been taken into account in the statistical

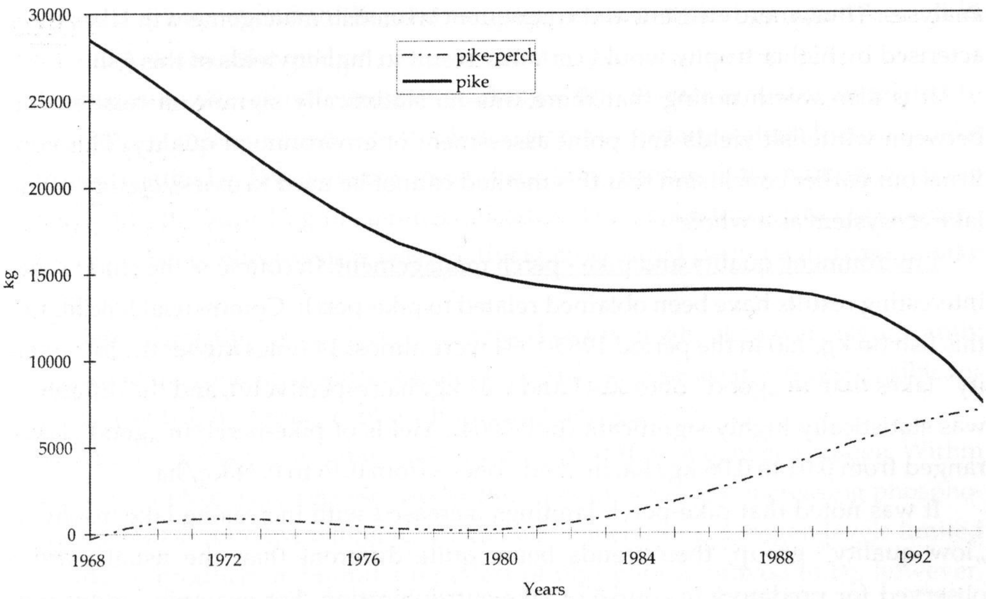


Fig. 3a. Trends of pike and pike-perch landings in „low quality" lakes in 1968-1994

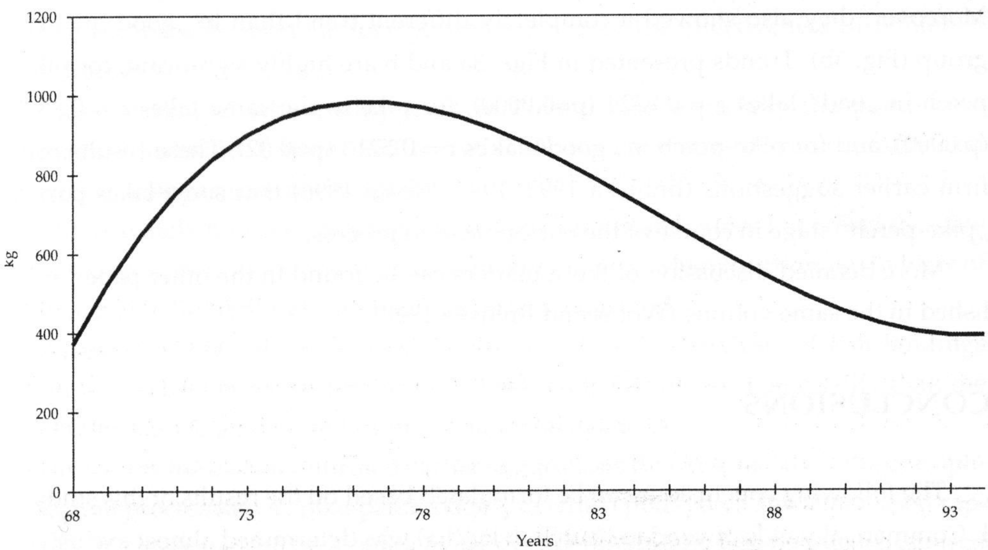


Fig. 3b. Trend of pike landings in „good quality" lakes in 1968-1994

analyses. Thus, more efficient and consequent whitefish management in lakes characterised by higher trophy would certainly result in higher yields of this fish.

It is also worth noting that there was no statistically significant relationship between whitefish yields and point assessment of environment quality. This confirms our earlier conclusion that this method cannot be used to assess quality of the lake ecosystem as a whole.

<u>Environment quality and pike - perch management.</u> In course of the study some interesting results have been obtained related to pike-perch. Commercial landings of this fish (in kg/ha) in the period 1985-1994 were almost 14 times higher in „low quality" lakes than in „good" ones (0.41 and 0.03 kg/ha respectively), and the difference was statistically highly significant ($p<0.0004$). Yields of pike-perch in „good" lakes ranged from 0.01 to 0.06 kg/ha, in „bad" ones - from 0.16 to 0.74 kg/ha.

It was noted that pike-perch landings increased with increasing lake trophy in „low quality" group, their trends being quite different than the usual pattern observed for predators in course of lake eutrophication. For example, contrary to pike yields which show a typical trend, viz. an initial increase and then a decrease as the lake trophy increased, yields of pike-perch continued to increase (Fig. 3a). Moreover, they also showed a completely different trend than in „good quality" group (Fig. 3b). Trends presented in Figs. 3a and b are highly significant: for pike-perch in „bad" lakes $r = 0.9324$ ($p=0.0000$), for pike in the same lakes $r = 0.9325$ (p.0000), and for pike-perch in „good" lakes $r = 0.5213$ ($p=0.02$). These results confirm earlier suggestions (Bnińska 1992, 1996, Wołos 1996) that some lakes pass a „pike-perch" stage in course of the eutrophication process.

More detailed discussion of these matters can be found in the other paper published in the same volume (Wołos and Bnińska 1998).

## CONCLUSIONS

The following conclusions can be formulated based on the results of this study:

1. Commercial yields of vendace (catch in kg/ha) was determined almost exclusively by the stocking rates. Progressing eutrophication does not seem to affect much vendace yield, at least within the range of trophy as represented by the lakes under study, i.e. with effectively functioning ecosystemic mechanisms. Vendace

yields did not depend in these lakes on the environmental parameters used in Poland to assess lake quality.

2. Contrarily to this, effectiveness of stocking with vendace was strictly related to lake trophy measured with chlorophyll content in surface waters. Increased lake trophy resulted in lower effectiveness of stocking in terms of the number of larvae needed to produce 1 kg of commercial catch. The dependence was curvilinear - the decrease of effectiveness was relatively more rapid than the increase of lake trophy.
3. In contradistinction to vendace, commercial yields of whitefish were significantly related to the content (in surface water layer) of two basic elements responsible for the lake eutrophication, i.e. phosphorus and nitrogen.
4. The effect of phosphorus on whitefish yield was different than of nitrogen. Within the range of trophy as represented by the lakes under study, increasing phosphorus content stimulated whitefish yields, while increasing nitrogen levels limited whitefish production. Stimulating effect of phosphorus proved to be, however, stronger than the limiting effect of nitrogen. This suggests that whitefish production in eutrophic lakes can still be increased.
5. Methodical difficulties in bringing down the different whitefish stocking materials to a comparable form hamper proper analysis of the effectiveness of whitefish stockings.
6. Classification of lake quality used in Poland, and especially the point-score method introduced since 1982 is useful for the estimates of water quality and enables comparisons of this quality.
7. Unfortunately however, this method of lake classification does not reflect the state of the ecosystem as awhole, nor the efficiency of ecosystem functioning. In view of this, it is of limited usefulness for the fishery managers.
8. Analysis of the fish stock composition based on the analysis of fish landings proved to be a much better method of assessing lake ecosystem quality than the official classifications used by environmental agencies.
9. The results have also confirmed earlier suggestions that in some lakes the eutrophication process had a „pike-perch stage", in which pike-perch stock increased rapidly. To define which lakes were likely to pass through this stage one would need to carry out proper studies.

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## STRESZCZENIE

EFEKTYWNOŚĆ GOSPODARKI KOREGONIDAMI W ŚWIETLE WSKAŹNIKÓW JAKOŚCI ŚRODOWISKA

Przeanalizowano gospodarkę koregonidami w odniesieniu do parametrów jakości środowiska oraz stosowanej od 1982 r. punktowej oceny stanu czystości jezior. Badaniami objęto 38 jezior, dla których zebrano dane o gospodarce rybackiej w latach 1968-1994 (27 lat). Jeziora przeanalizowano łącznie oraz w podziale na grupę jezior "dobrych" i "złych". Podziału dokonano opierając się o średnią ocenę punktową jakości środowiska, wynoszącą 2.273 dla analizowanej próby jezior. Stwierdzono statystycznie istotne różnice między grupami. Wydajność sielawy nie zależała od rozpatrywanych parametrów środowiska, natomiast efektywność zarybień tym gatunkiem spadała wraz ze wzrostem trofii mierzonej zawartością chlorofilu w powierzchniowej warstwie wody. Wydajność gospodarcza siei zależała od zawartości fosforu i azotu ogólnego w wodzie, przy czym fosfor stymulował wydajność, zaś azot ograniczał ją. Omówiono szczegółowo wyniki gospodarki koregonidami w odniesieniu do jakości środowiska.

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