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# REGULARITIES OF VENDACE MANAGEMENT AND METHODICAL ASPECTS OF ITS ASSESSMENT ON A LONG-TERM BASIS

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A B S T R A C T. Analyses were performed of the records pertaining to vendace management in 60 lakes of total area 29.8 thousand ha and the period of 42 years. The lakes were arranged according to decreasing effectiveness of this management, and then divided into 3 groups characterised by different intensity of vendace management, viz. high, moderate and low. Trends of stockings and catches as well as the effectiveness of stocking with vendace were determined for all lakes and for the distinguished groups. Correlation was calculated between stocking with vendace and vendace landings. The most effective stocking rates have been determined, and possibilities of optimising vendace management have been discussed.

Key words: VENDACE, MANAGEMENT INTENSITY, TRENDS OF STOCKING AND CATCH, METHODS OF ASSESSING EFFECTIVENESS

## INTRODUCTION

Two methodical approaches can be used to assess the effectiveness of vendace management, which have been previously defined as horizontal and vertical (Bnińska 1994, Wołos 1994). The first is based on an analysis of the mean values, usually for a long-term period, such as the mean fish yield, level of stocking, stocking effectiveness index etc., that characterise particular lakes or groups of lakes. Sample size in this case consists of the number of lakes. The other approach is based on an analysis of the same parameters but in time, so that sample size is the number of years, while the results are in form of statistically significant trends of catches, stockings or other variables.

The two approaches may be used simultaneously. It should be, however, understood that in general terms the first approach is especially helpful in analysing larger sets of lakes, e.g. on a national or regional scale (e.g. Bernatowicz 1953, Walczak 1956, Budych 1957, 1959, Radziej 1960, Leopold 1972, Bnińska 1985, Leopold et al. 1986, Wołos, Falkowski, Abramczyk 1995), whereas the other can be used to assess fishery management in particular lakes (e.g. Bernatowicz 1963, Budych and Mastyński 1978, Mastyński and Wasilewska 1989, Wołos, Falkowski, Czerkies 1998). There are some

methodical difficulties in applying the two approaches and especially the „vertical" one; they have been summarised by Wołos (1994).

The objective of this paper, which also takes into consideration the results of other studies presented in this volume (Bnińska and Wołos 1998, Leopold and Wołos 1998, Leopold, Wołos, Mickiewicz 1998, Wołos and Bnińska 1998), was to identify a set of parameters that would characterise broadly understood effectiveness of vendace management. Following this, „horizontal" method was used to define this effectiveness, making it possible to distinguish the 3 lake groups with different management effectiveness, as well as the „vertical" one to analyse the distinguished parameters in particular lake groups. A discussion is also presented on the conditions, values, and practical benefits resulting from correlation calculus in order to optimise vendace management. The results of analyses, based on a relatively large sample of 60 lakes, are fairly representative and enable definition of the character and rate of changes taking place in vendace management on a national scale. Consequently, they are an adequate and practical reference point for various comparisons, either related to particular fishery enterprises, or to single lakes.

## MATERIAL AND METHODS

The paper is based on an analysis of long-term data on vendace management in 60 lakes selected from a set of 132 Polish lakes (see Wołos 1998). Number of years for which full records were available (viz. 42 years) was the only criterion of selecting these lakes; data on stockings pertain to 1952-1993, and on catches - to 1953-1994 (1-year interval between stocking and catch).

Vendace management was characterised with four mean parameters (for a long-term period):

- vendace landings in kg/ha,
- stockings with vendace in number of larvae/ha,
- number of years in which stockings were made,
- stocking effectiveness index, expressed as the number of vendace larvae needed to yield 1 kg of commercial catch (in the next year).

Analyses were carried out for the whole lake sample of 60 lakes, and in the distinguished groups of 20 lakes in each group. The groups were distinguished based on the intensity of vendace management, measured according to a ranking proce-

dure which took into account vendace yield in kg/ha and index of stocking effectiveness, calculated for each lake and arranged according to decreasing effectiveness of vendace management. Then the lakes were divided into 3 groups of high. moderate and low intensity of this management.

Trends of vendace stockings and catches, and correlation (linear and curvilinear) between these two parameters were calculated for the whole lake sample and in the distinguished groups. Trends of stocking effectiveness were also calculated. At the final stage of analysis, 3-year moving averages were used to smooth the series (stockings and catches) characterised by high variability.

Time series (trends) and correlation and regression analyses were made assuming probability level of $p = 0.05$, although majority of the obtained trends and relationships were significant at $p = 0.01$. A computer programme written especially for the research project PO6E 053 08 was used.

## RESULTS AND DISCUSSION

General characteristics of vendace management, and partly also the first results pertaining to the whole lake sample and to the distinguished groups, are presented in Table 1.

Parameters presented in Table 1 allow for a few important conclusions already at the very beginning of the analysis.

Assuming that the intensity of vendace management can be measured with the mean stocking rate (fish larvae/ha/year) and stocking frequency (number of years with stocking), there is a noticeably positive relationship between this intensity and the effects of management.

**TABLE 1**

Basic parameters charcterising the analysed lakes

| Lake group | Number of lakes | Total area (ha) | Lake area (ha) | | Stocking rate fish/ha | | Number of years with stocking | | Catch (kg/ha) | | Effectiveness index | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | average | V% | average | V% | average | V% | average | V% | fish/kg | V% |
| I | 20 | 9143 | 457.2 | 65.9 | 6253 | 43.1 | 26.0 | 36.8 | 9.63 | 33.6 | 720 | 63.1 |
| II | 20 | 12037 | 601.9 | 90.3 | 5069 | 36.0 | 23.2 | 39.8 | 4.75 | 33.4 | 1138 | 36.1 |
| III | 20 | 8610 | 430.5 | 120 | 2609 | 57.1 | 15.4 | 48.3 | 1.51 | 53.1 | 2138 | 64.7 |
| Totally | 60 | 29790 | 496.5 | 95.1 | 4721 | 36.6 | 21.5 | 45.9 | 5.31 | 29.9 | 935 | 39.6 |

Viewing vendace management in the distinguished groups in a complex way, group I is the best group, embracing 31% of the total lake area, group II can be defined as „moderate" (40% of lake area), and group III - as the one with unsatisfactory results (almost 29% of lake area). In a practical sense this points to the possibilities of improving vendace management on a large lake area.

## TRENDS OBTAINED FOR THE WHOLE LAKE SAMPLE

Characteristics of basic trends pertaining to vendace management in the analysed lake sample, viz. of stockings (larvae/ha), catches (kg/ha) and stocking effectiveness (number of larvae used per 1 kg of commercial catch), are summarised in Table 2.

**TABLE 2**

Trends of catches, stocking and stocking effectiveness in 1952-1994 (N = 60)

| Parameter | Polynominal of 1st degree | | Polynominal of 3rd degree | |
|---|---|---|---|---|
| | | R | | R |
| Stocking (larvae/ha) | 2364.6 + 109.62x | 0.768 | 3941.3 - 244.55x + 18.095x2 - 0.2568x3 | 0.804 |
| Ctch (kg/ha) | 3.99 + 0.0613x | 0.466 | 4.1708 - 0.2044x + 0.0233x2 - 0.0004x3 | 0.756 |
| Stocking effectiveness (larvae/kg) | 676.41 + 12.013x | 0.394 | 937.44 - 3.5239x - 1.0596x2 + 0.037x3 | 0.629 |

Taking into account the linear trends (polynomials of the Ist degree) and using the mean annual increments of stocking rates, catches and stocking effectiveness, and comparing these to the mean values for the whole period of 42 years (Table 1), it can be stated that the effectiveness of vendace management noticeably decreased in with time. An average increment of stocking rates of 2.32% is connected with an increase of catches by only 1.15% annually, and increasing use of the stocking material (viz. a decrease of stocking effectiveness) by 1.28% annually.

A more detailed approach, based on IIIrd degree polynomials, is presented in Fig. 1a, 1b and 1c. This approach revealed progressing and more and more pronounced changes in vendace management, these changes being of a definitely negative character. An almost linear trend of increasing stocking rates with vendace (Fig. 1a) corresponds to increasing catches (Fig. 1b), but the latter show a theoretical maximum in 1982, and decrease since then at an increasing pace, so that in the recent years this decrease was as high as 10% annually in relation to the mean level.

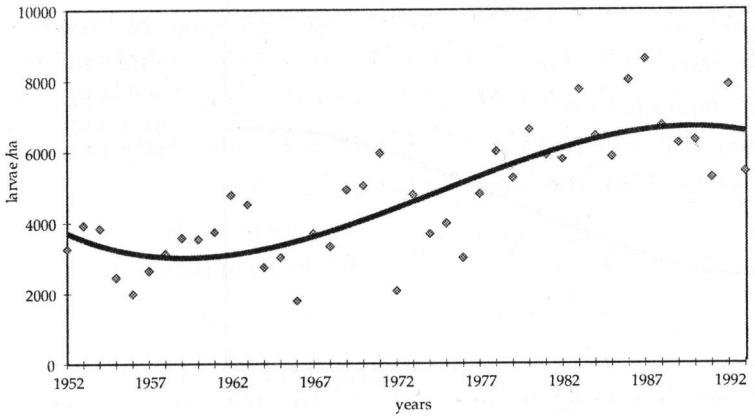


Fig 1a. Trend of stockings with vendace larvae in 60 lakes in 1952-1993

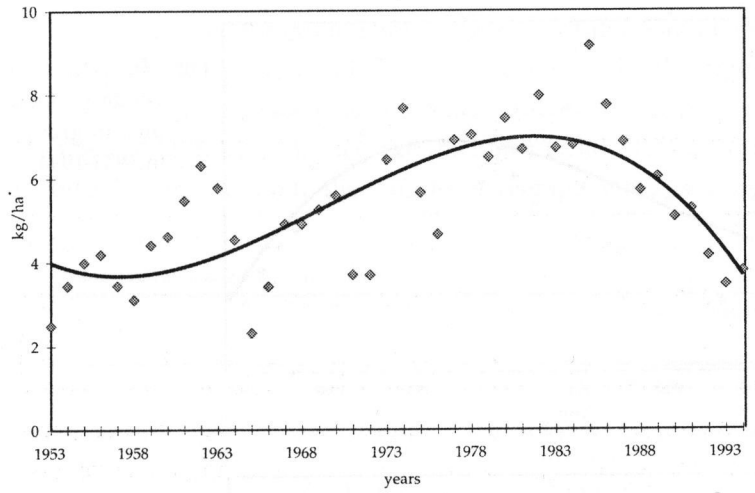


Fig. 1b. Trend of vendace landings in 60 lakes in 1993-1994

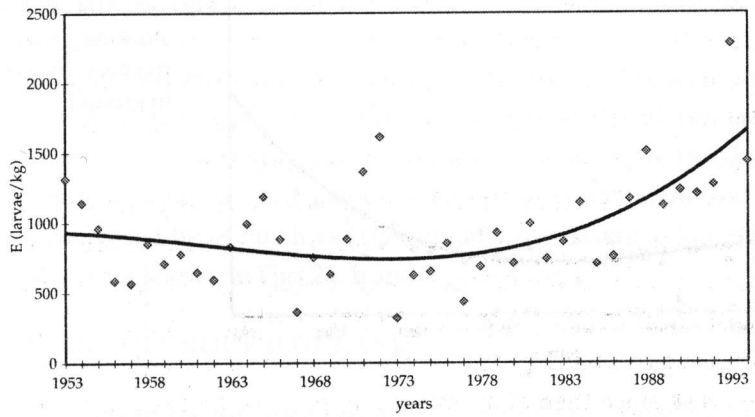


Fig. 1c. Trend of stocking effectiveness index in 60 lakes

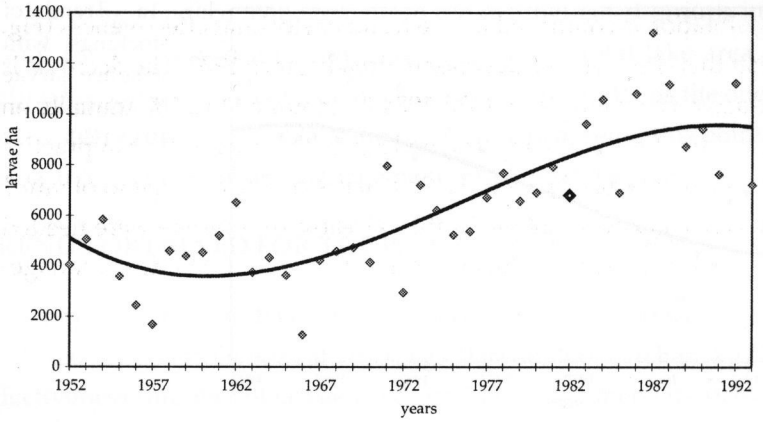


Fig. 2a. Trend of stocking with vendace larvae in group I in 1952-1993

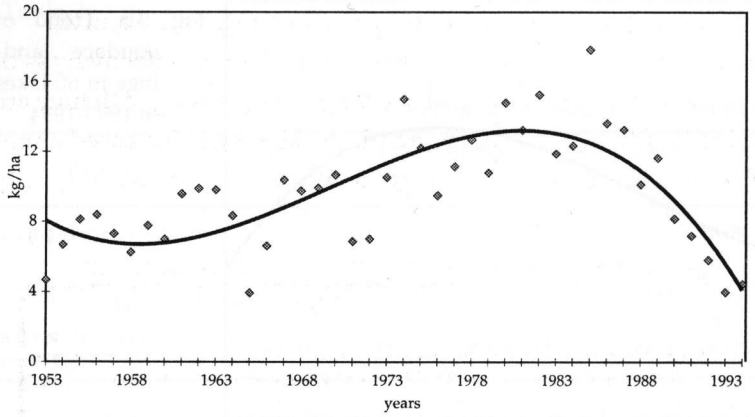


Fig. 2b. Trend of vendace landings in group I in 1953-1994

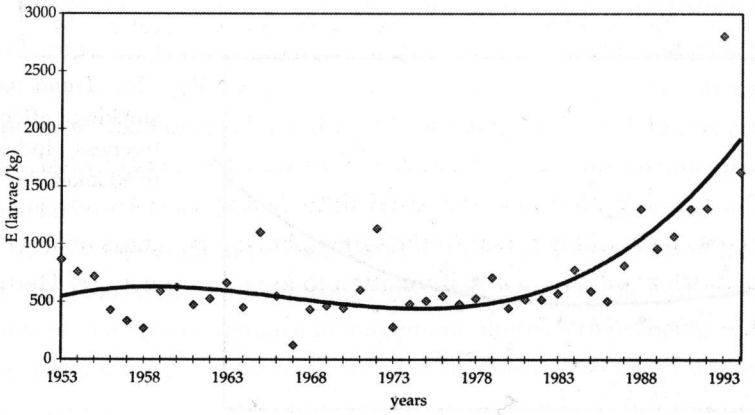


Fig. 2c. Trend of stocking effectiveness index in group I

This disturbing situation is confirmed by the trend of stocking effectiveness (Fig. 1c), which shows that this effectiveness decreased already since 1973. The decrease is of a curvilinear character. For example, in 1975-1984 it amounted to 2.5% annually on the average, while in 1985-1994 it already reached 5.7%. This means that in practice in 1980 the fishery manager needed to release 820 larvae on the average to obtain 1 kg of marketable vendace next year, while in 1994 already 1662 larvae were needed to produce the same effect. Obviously this increases the costs of vendace management.

## TRENDS IN GROUP I OF LAKES

Trends obtained for group I are presented in Table 3 and Figs 2a, 2b and 2c.

Although this group of lakes was characterised by the highest effectiveness of vendace management (see Table 1), unfavourable changes progressing with time are very noticeable. Taking into account the linear trend, stocking rates increased annually by 2.74% in relation to the long-term average, while catches increased by only

**TABLE 3**

Trends of catches stocking and stocking effectiveness in 1952-1994 in group I of lakes (N = 20)

| Parameter | Polynominal of 1st degree | R | Polynominal of 3rd degree | R |
|---|---|---|---|---|
| Stocking (larvae/ha) | 2564.0 + 171.56x | 0.772 | 5528.1 - 454.89x + 30.313x2 - 0.4101x3 | 0.823 |
| Ctach (kg/ha) | 7.86 + 0.0824x | 0.309 | 8.6379 - 0.6433x + 0.0608x2 - 0.0011x3 | 0.785 |
| Stocking effectiveness (larvae/kg) | 304.08 + 19.325x | 0.516 | 507.63 - 40.871x - 3.9937x2 + 0.091x3 | 0.798 |

0.86%, and effectiveness of stocking decreased by 2.68%. More detailed analysis based on polynomials of the IIIrd degree showed that vendace catches attained maximum level in 1981 (13.2 kg/ha), and decreased since then by 1.5-8.4% annually notwithstanding increasing stocking rates. At the same time, effectiveness of stocking decreased by as much as 10% annually in relation to long-term average. These changes are shown in Figs 2a, b and c.

## TRENDS IN GROUP II OF LAKES

Trends of the analysed parameters in this group are presented in Table 4 and Figs 3a, b and c.

**TABLE 4**

Trends of catches, stocking, and stocking effectiveness in 1952-1994 in group II of lakes (N = 20)

| Parameter | Polynominal 1st degree | R | Polynominal 3rd degree | R |
|---|---|---|---|---|
| Stocking (larvae/ha) | 2733.6 + 108.64x | 0.721 | 4347.9 - 205.01x + 13.919x2 - 0.1725x3 | 0.759 |
| Catch (kg/ha) | 2.78 + 0.0918x | 0.700 | 3.1795 - 0.077x + 0.012x2 - 0.0002x3 | 0.736 |
| Stocking effectiveness (larvae/kg) | ns | - | ns | - |

*ns - statistically not significant*

Vendace management in this group has been defined as moderately intensive (Table 1). Patterns of changes taking place in time are presented in Table 4 and Figs 3a, b and c. They differ from those revealed for group I. This refers to both: stockings, which practically do not show a decreasing trend, as well as catches, the trend of which is very slight. The most pronounced differences are noted as regards the effectiveness of stocking, which shows no statistically significant trend. As a result, effectiveness of stocking in the recent years was not only close to that in group I, but even became more satisfactory. In the last 5 years (1990-1994) real values of this index were 1624 larvae needed to produce 1 kg of commercial catch in group I, and only 1307 larvae/kg in group II. Hence, in reality the effectiveness of vendace management in group II improved with time, contrarily to group I, in which it decreased. An attempt to explain this is presented in the discussion.

## TRENDS IN GROUP III OF LAKES

Table 5 and Figs 4a, b and c present trends of the analysed parameters in group III. They confirm the statement on unsatisfactory vendace management in these lakes. Apart from very high variability of all parameters (reflecting inconsistency in management policies), and weak trends (the lowest values of the correlation coeffi-

**TABLE 5**

Trends of catches, stocking, and stocking effectiveness in 1952-1994 in group III of lakes (N = 20)

| Parameter | Polynominal 1st degree | R | Polynominal 3rd degree | R |
|---|---|---|---|---|
| Stocking (larvae/ha) | 1637.2 + 45.202x | 0.368 | 1687.4 - 76.32x + 10.95x2 - 0.2116x3 | 0.481 |
| Catch (kg/ha) | ns | - | $0.8233 - 0.0801x + 0.0005x^2 - 0.00005x^3$ | 0.485 |
| Stocking effectiveness (larvae/kg) | 1277.5 + 40.009x | 0.351 | $1893.7 - 39.373x + 1.5168x^2 - 0.0086x^3$ | 0.402 |

*ns - statistically not significant*

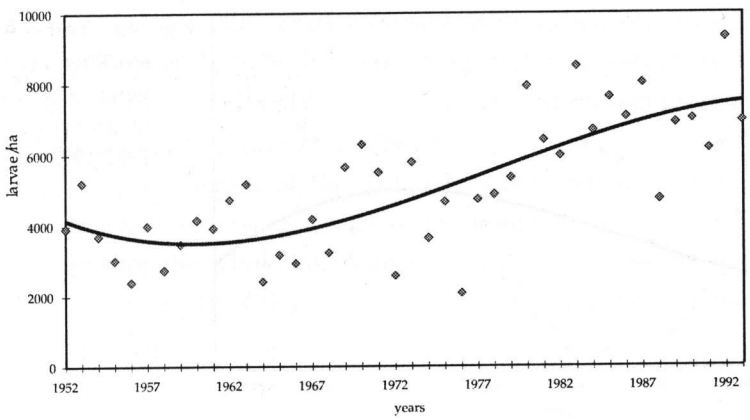


Fig. 3a. Trend of stocking with vendace larvae in group II in 1952-1993

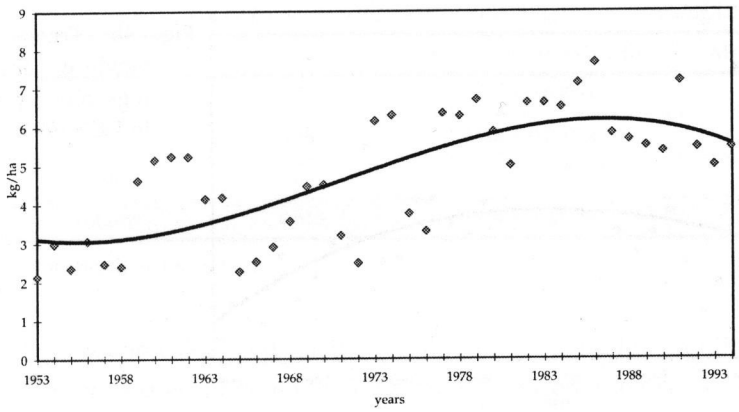


Fig. 3b. Trend of vendace landings in group II in 1953-1994

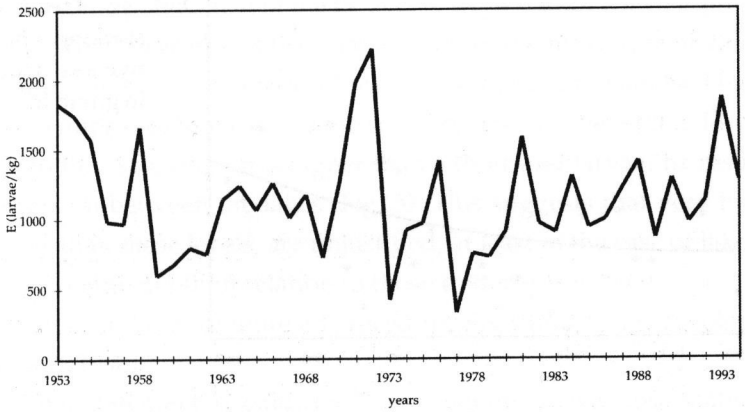


Fig. 3c. Stocking effectiveness index in group II (linear approximation not significant)

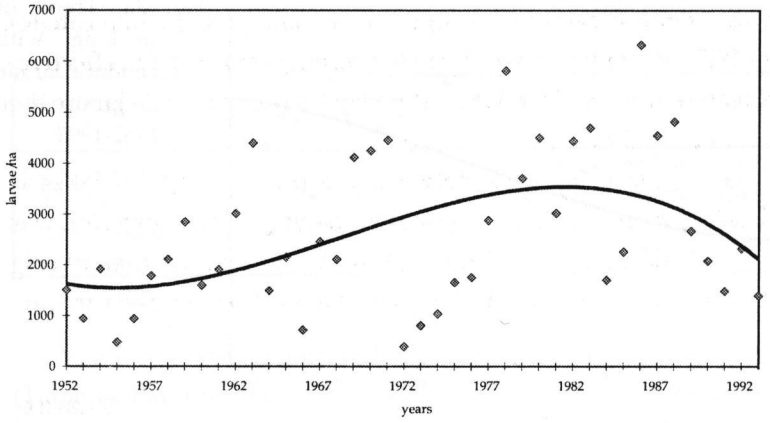


Fig. 4a. Trend of stocking with vendace larvae in group III in 1952-1993

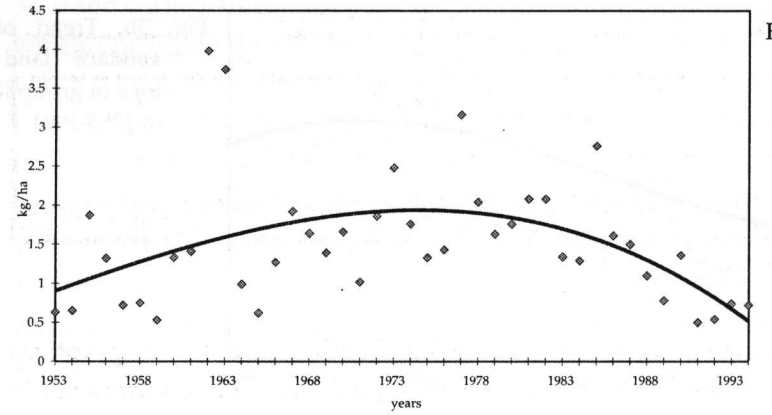


Fig. 4b. Trend of vendace landings in group III in 1953-1994

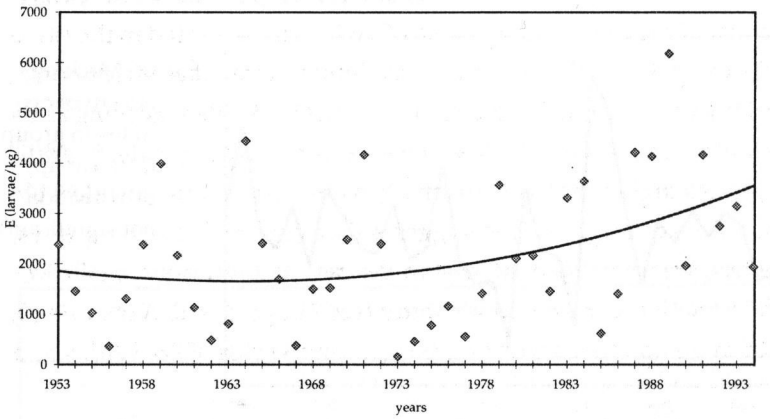


Fig. 4c. Trend of stocking effectiveness index in group III

cients), stockings with vendace decreased progressively since 1982, while catches began to decrease in 1975, at an increasing rate in the recent years, and the effectiveness of stocking decreased already since 1964. At present more than 3000 larvae are used for each kg of commercial catch.

An overall picture of the differences between the three groups of lakes is obtained when regression of catch on stocking rates is analysed. This regression was calculated for the whole lake sample and the distinguished groups, after having smoothed the trends with the 3-year moving average. The results of analysis are presented in Table 6.

**TABLE 6**

Regression of catch on stocking rates (y - catch kg/ha, x - stocking larvae/ha)

| Lake group | $r_{xy}$ | Regression equation a + bx | Mean increment (%) |
|---|---|---|---|
| I | 0.431 | 6.8729 + 0.0005x | + 5.2 |
| II | 0.763 | 1.4412 + 0.0007x | + 14.7 |
| III | ns | - | - |
| Totally | 0.613 | 2.8804 + 0.0005x | + 9.4 |

ns - statistically not significant

Regression calculated for the whole sample is highly significant. Its graphical illustration is presented in Fig. 5. As can be noticed, the regression line does not fit well the real data at the highest and the lowest stocking rates. This has been corrected using the polynomial of the IV degree ($r_{xy} = 0.642$), which is presented in the same figure. This curve shows that in reality there is a maximum of vendace yields corresponding to the stocking rate of some 7-8 thousand larvae/ha. Higher stocking rates do not improve the yield - on the contrary, they even result in lower yields. In addition to this, stocking rates higher than 6 thousand larvae/ha result in considerable dispersion between the lakes (Fig. 5). This suggests that very high stocking rates, higher than these levels, are unjustified, at least in the case of lakes being shallower or of average depth in relation to those under study (see Leopold and Wołos 1998), as well as in lakes of more advanced trophy (Bnińska and Wołos 1998, Wołos and Bnińska 1998).

This statement is confirmed by a slightly lower, but statistically significant dependence between vendace stockings and yield in lakes belonging to group I (with the highest stocking rates), and especially its character (Fig. 6a). As can be seen, there

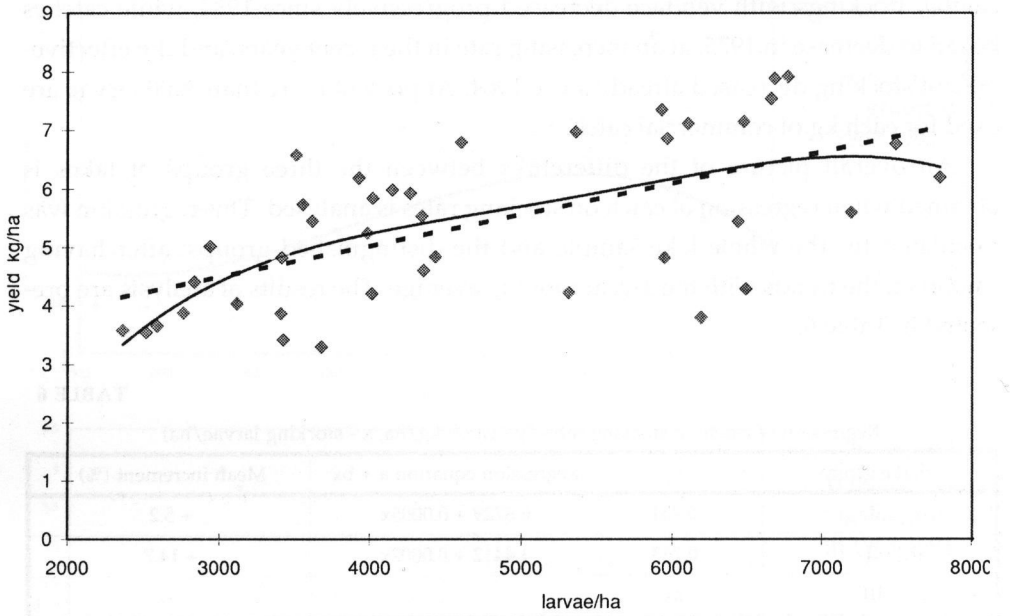


Fig. 5. Regression of vendace yield on stocking in 60 lakes

are two qualitatively different areas of the dependence between stockings and catches: first with stocking rates up to some 8000 larvae/ha, where there is a very strict dependence between the two variables, and another one, at higher stocking rates, where there is no such relationship. Regression calculated for the first area only (Fig. 6b) is of a linear character, with very high correlation coefficient $r_{xy} = 0.803$, expressed by the equation:

$$y = 2.73 + 0.0014\,x$$

It should be noted that lack of the dependence in the second area (at stocking rates higher than 8000 larvae/ha) explains relatively low value of the correlation coefficient obtained for the whole group I, viz. taking into account also the lakes with very high stocking rates. Abstracting from the reasons for less effective stocking at very high stocking rates, it must be stressed that although this group was defined as characterised by satisfactory vendace management, the use of these high stockings was not always justified from an economic point of view. This is also confirmed by considerable decrease of stocking effectiveness observed in the recent years in this group of lakes (Fig. 2c).

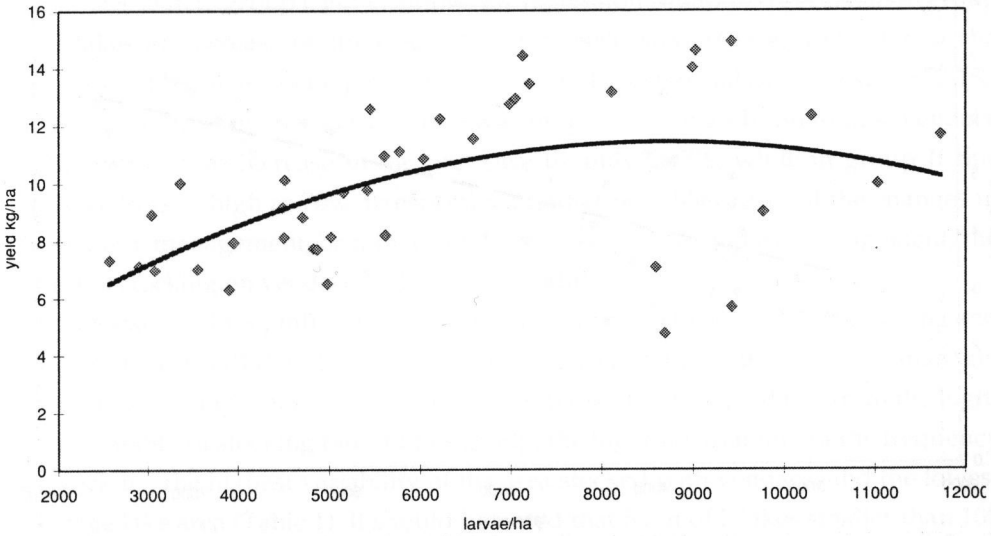


Fig. 6a. Regression of vendace yield on stocking in group I

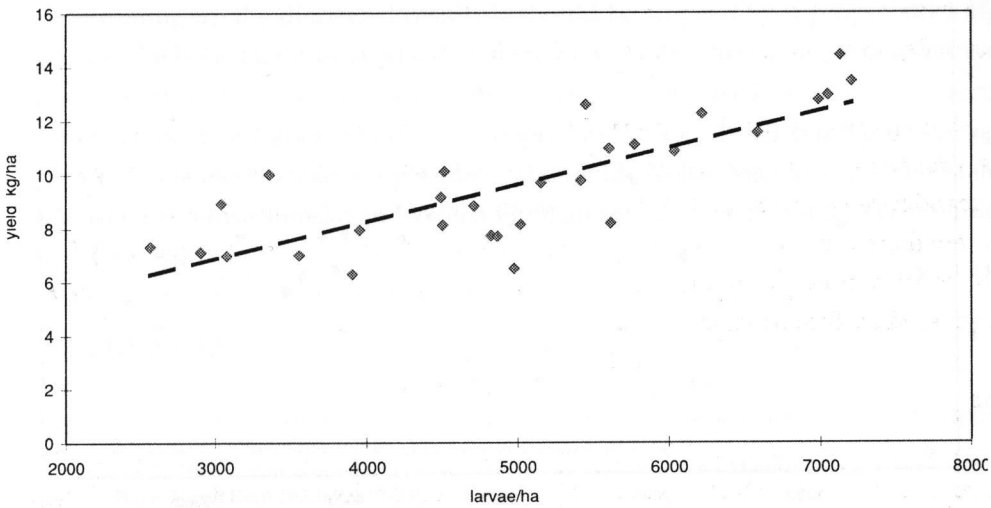


Fig. 6b. Regression of vendace yield on stocking in group I (at stocking rates less than 8000 larvae/ha)

The above conclusions are also confirmed by the dependence between vendace stocking and yield in group II of lakes (Fig. 7). Average stocking rates in this group practically did not exceed 8000 larvae/ha, and correlation between the two parameters proved to be very strict here ($r_{xy} = 0.763$), the regression equation being:

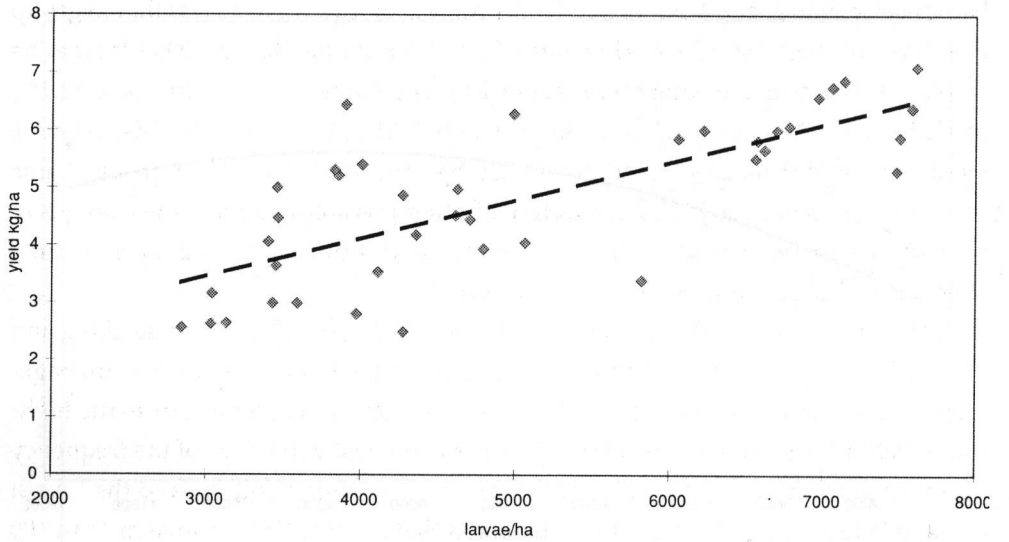


Fig. 7. Regression of vendace yield on stocking in group II

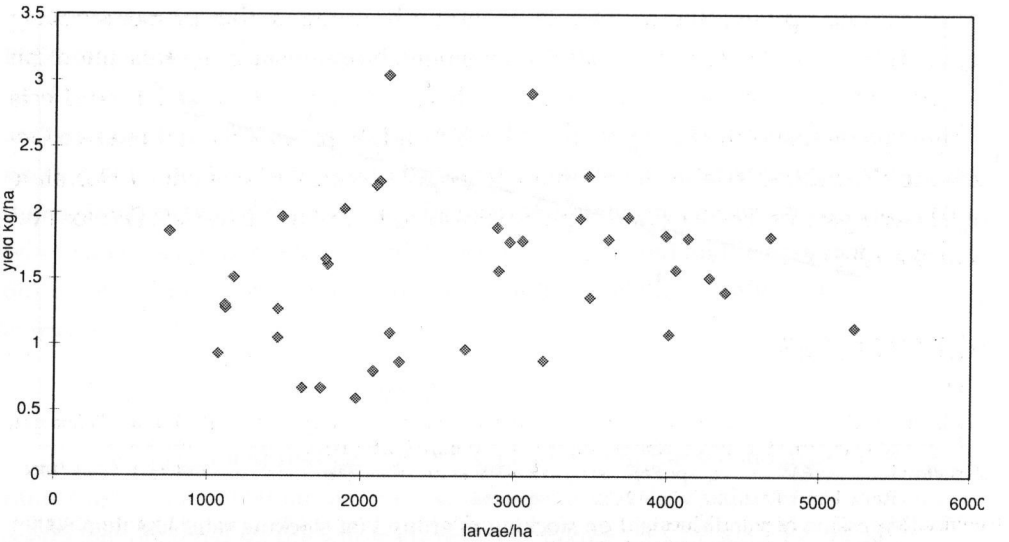


Fig. 8. Relation between vendace yield and stocking in group III

$$y = 1.4412 + 0.0007x$$

Hence, although on a long-term basis this group of lakes was characterised by a less intensive vendace management than group I (see Table 1), progressing unfavourable changes in the stocks of this species and in their management seem to

be slower than in group I. For example, the regression equations reveal that in group I of lakes an increase of stocking rates from 5000 larvae/ha to 10000 larvae/ha increased the use of stocking material per 1 kg of commercial catch by some 52.1%, while in group II the respective value was only 17.1%. In addition to this, vendace yields (in kg/ha) increase in the first case by only 26.7%, while in group II this increase was as high as 70%. Irrespective of other possible causes of the changes in the fishery management, or rather in the effectiveness of vendace management, the effect of stocking on vendace yield is undoubtful.

No statistically significant relationship was found between vendace stocking and catches in group III (Fig. 8). This confirms negative evaluation of vendace management in this group. Lack of such a relationship results, among others, from the highest variability of stocking rates in this group, the highest variability of the frequency of stocking, the highest variability of the area stocked with vendace, and the lowest average lake area (Table 1). It should be noted that 5 out of 7 lakes smaller than 100 ha have been included into this group.

Summing up the discussed results it should be stressed, that proper stocking policy is the basic factor in vendace management. Notwithstanding this, attention should be given to systemic relationships. There is a feed-back between the effects of management and stocking policies (Leopold and Wołos 1998), but these two factors are also related to lake morphometry (Leopold, Wołos, Mickiewicz 1998), state of lake ecosystems (Bnińska and Wołos 1998) and state of the fish stock (Wołos and Bnińska 1998).

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## STRESZCZENIE

PRAWIDŁOWOŚCI GOSPODARKI SIELAWOWEJ I ASPEKTY METODYCZNE JEJ OCENY W UJĘCIU WIELOLETNIM

Poddano analizie 42-letnie dane o gospodarce sielawowej w 60 jeziorach o łącznej powierzchni 29.8 tys. ha. Rozpatrywane jeziora uszeregowano według malejącej efektywności tej gospodarki, a następnie podzielono na 3 grupy charakteryzujące się różnym tj. najwyższym, przeciętnym i najniższym poziomem gospodarowania sielawą. Dla całości jezior oraz w wyróżnionych grupach określono tendencje zarybień, odłowów i wskaźnika efektywności zarybiania, a także związki korelacyjne między zarybieniami a odłowami. Zidentyfikowano najbardziej efektywne przedziały wielkości dawek zarybieniowych, a także zwrócono uwagę na możliwości optymalizacji gospodarki sielawowej.

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