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THE EFFECT OF LAKE MORPHOMETRY ON THE EFFECTIVENESS OF VENDACE MANAGEMENT

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ABSTRACT. Analyses were carried out of long-term data on vendace management in 114 lakes of total area 59.1 thousand ha and on morphometric characters of these lakes. Statistical methods were used to determine the relationships between lake morphometry and the effectiveness of fishery management. Four morphometric parameters were taken into consideration: lake area, average depth, maximal depth and development of the shore line. It was found that the effects of vendace management, expressed as vendace yield and effectiveness of stocking, were most strongly related to average lake depth. Multiple regression equation was obtained, which related vendace yields to stocking rates and average lake depth. The equation was used to construct a table helpful in undertaking management decisions as to the allocation of vendace stocking material.

Key words: LAKE MORPHOMETRY, VENDACE, YIELDS AND STOCKING, EFFECTIVENESS OF MANAGEMENT

INTRODUCTION

Vendace stockings, an essential fishery practice in managing this species, are performed in a variety of lakes differing as to their morphometric features. This is best illustrated in the paper characterising vendace management in Poland (Wołos 1998), based on a representative sample of 132 lakes, as well as becomes fairly evident when reviewing the source materials used in preparing the papers published in this volume. It is fairly obvious that lakes in which vendace stock is still (or was) managed represent different categories, both as regards their area and depth, as well as development of the shore line. It is enough to mention here that area of particular lakes with such management ranges from as little as 25 to over 10000 ha, and that the smallest lakes (of less than 100 ha) represent 22.7%, while the biggest (over 1000 ha) - 9.9%.

A number of authors discussed possibilities of producing vendace in lakes of different depth and trophy (Pokrovskij 1964, Zawisza and Backiel 1970, Mastyński 1978, Leopold 1972), but there are no papers available in the Polish literature that would use statistical methods to establish the relationship between the effects of vendace management and basic morphometric parameters. In view of this, the objective of the present study was to find out if, and to what an extent, these parameters determined the success of vendace management, and especially the effects of stocking.

MATERIAL AND METHODS

Studies comprised data recorded in the so-called lake books of 114 lakes (vendace stockings made with larvae only) totalling 59.1 thousand ha. The lakes are used by 21 fishery enterprises. The records embraced level of vendace catches in each lake from a period of minimum 20 and maximum 46 lakes (38.6 years on the average for 1 lake), and on stockings made a year before.

Morphometric data were collected from the lake data base of the Inland Fisheries Institute.

The following parameters were available for each lakes:

1) Lake area (water surface) in ha,
2) Maximal depth in m,
3) Average depth in m,
4) Development of the shore line, i.e. the ratio between shore length and length of the circumference of a circle of the same area,
5) Mean annual yield of vendace in kg/ha,
6) Mean annual stocking with vendace larvae in number of larvae/ha.

Parameters 1-4 were treated as independent variables. Parameters 5 and 6 characterise vendace management, but since vendace yield depends on stocking, it was treated as a dependent variable, while stocking rates were an another independent variable. Such an approach implied the method of analysis, consisting of an attempt to identify and quantify significant relationships taking advantage of multiple correlation and regression. At the same time, all statistical analyses were simplified as much as possible, so as to obtain the results of a directly practical nature.

RESULTS

Characteristics of the lake under study, resulting from ascribing management parameters (vendace yields and stockings) to morphometric parameters lower or higher than the respective mean (x) values, are presented in Table 1.

TABLE 1

b - values higher than the mean value for the given parameter

Morphometric parameter		$\bar{x}$		Relation to $\bar{x}$	Number of lakes	Total area of lakes	Vendace yield (kg/ha)	Stocking rate (larvae/ha)	Index of stocking effectiveness (larvae/kg of commercial catch)
Area (ha)	518.4	a	191.4	a	82	15699.0	3.61	3844	1065
		b	1356.4	b	32	43403.2	5.29	3904	738
Index of shore line development	2.35	a	1.73	a	60	15251.5	3.43	3588	1046
		b	3.03	b	54	43850.7	4.80	4164	868
Maximal depth (m)	2.35	a	23.2	a	65	31515.1	2.72	3165	1164
		b	44.1	b	49	27587.1	5.89	4783	812
Average depth (m)	9.78	a	7.36	a	57	27519.4	2.07	2965	1432
		b	12.20	b	57	31582.8	6.00	4756	780
Mean							4.08	3860	946

This table reveals that from among the morphometric parameters under study, lake depth, and especially average depth, was the one which most strongly differentiated management parameters. Depth parameters yielded two lake classes. When maximal depth was taken into account, there were „deeper" lakes, in which the average vendace yield was 5.89 kg/ha, and „shallower" ones, with vendace yield of 2.72 kg/ha, whereas if attention was paid to average depth, vendace yield in „deeper" lakes was 6.00 kg/ha on the average, and in „shallower" ones - 2.07 kg/ha. This implies that both parameters are likely to affect the results of vendace management.

Multiple correlation and regression were calculated between vendace yield in kg/ha (dependent variable 1) and all other parameters treated as independent variables. Very highly significant ($p<0.01$) correlation was found between these variables. Coefficient of multiple correlation $R_{1.23456} = 0.7367$, where:

1 - average vendace yield in kg/ha,

2 - average stocking rate in larvae/ha,

3 - average depth in m,

4 - maximal depth in m,

5 - lake area in ha,

6 - index of shore line development.

Analysis of the determination coefficient $R_{21.23456} = 0.5427$ revealed that practically there was no effect of the variables 4, 5 and 6 on vendace yields in kg/ha. What is more, inclusion of these variables into the model had a „disturbing" effect, as illustrated by the coefficients of multiple correlation $R_{1.23} = 0.7406$ and determination $R_{21.23} = 0.5485$, obtained when independent variables 4, 5 and 6 were eliminated. As can be seen, correlation coefficient increased considerably, thereby increasing reliability of predicting the dependent variable.

Hence, it appeared that from among the analysed morphometric parameters, only average lake depth had a significant effect on vendace yields. Determination coefficient $R_{21.23}$ showed that the obtained model explained 54% of the variability of vendace yields (in kg/ha), out of which 37% were explained by stocking rates (larvae/ha) and 17% by average lake depth (in m).

The respective equation of multiple regression is:

$$X1 = -2.22 + 0.62\ X_2 + 0.40\ X_3$$

where:

X_1 - vendace yield in kg/ha

X_2 - stocking rate in thousand larvae/ha

X_3 - average depth in m.

Practical implications of the revealed effect of average lake depth on vendace yields are quite obvious: the same stocking rate in lakes „1 m deeper" will increase vendace yield by 0.4 kg/ha, decreasing use of the stocking material per 1 kg of vendace catch (see Table 2).

For example, mean stocking rate of 6 thousand larvae/ha in a lake with average depth 6 m results in an average vendace yield of 3.90 kg/ha, and 1538 larvae are used to produce 1 kg of the catch. In a lake with average depth 10 m the same stocking rate will result in vendace yield of 5.50 kg/ha, and only 1091 larvae will be used per 1 kg of this catch.

It should be noted that the lower the stocking rate, the relatively higher the effectiveness of stocking in deeper lakes. And thus, taking the same average depth as above, viz. 6 and 10 m, stocking rate of 3 thousand larvae/ha corresponds in the first case to vendace yield of 2.04 kg/ha and 1470 larvae are used for 1 kg of the catch, while in the second case it corresponds to 3.64 kg/ha and only 824 larvae are used to produce 1 kg of commercial catch.

In the first example, vendace yield in „deeper" lake is 41% higher than in „shallower" one, at almost 30% lower use of the stocking material, while in the second example the yield is higher by 78% and the use of stocking material decreased by 44%.

DISCUSSION

In view of unfavourable changes observed in coregonid management since mid-eighties, and accentuated by political and economic changes at the turn of 80-ies and 90-ies (Falkowski 1994, Falkowski and Wołos 1996), there needs to be a change in management policies as regards these species. Although the negative trends have been somewhat slowed down in 1995 and 1996 (Leopold and Wołos 1996, Leopold and Wołos 1997, Wołos 1996, Wołos and Mickiewicz 1997) thanks to successful transformation in the inland fisheries sector, proper allocation of the available stocking material, especially of vendace, seems to be the optimal solution, and in many fishery enterprises became of vital importance.

Management and economic consequences of paying attention to average lake depth need no commenting. Importance of this issue results from considerable variety of lakes used for coregonid management, but also from high variability of the stocking rates (Wołos 1998). Table 2 illustrates this quite well; it is also a specific summary of the current studies that may be helpful in undertaking proper management decisions, and especially in allocating the stocking material of vendace.

A comment to Table 2: the most reliable area comprises average lake depths within the range of 6 - 15 m (93% of the analysed lakes), and mean stocking rates up to 15 thousand larvae/ha (96.5% of the lake number). It can be assumed that within this range, probability of achieving the expected results is the highest.

Methodical approach adopted in this analysis revealed some general, statistically highly significant relationships which can be taken advantage of in practice. It is, however, based on a „horizontal" approach, so it pays no attention to changes taking place with time, so to a certain extent it disregards the effect of changing environmental conditions as well as of changing management systems. The effect of environment, and especially of the eutrophication process, on coregonid management is discussed in other papers of this volume (Bnińska and Wołos 1998, Wołos and Bnińska 1998), and these should also be taken into consideration when undertaking practical decisions based on table 2.

TABLE 2

Mean vendace catches (in kg/ha) corresponding to different stocking rates in lakes of different average depth

Stocking with larvae in th. fish/ha	Yield of vendace kg/ha																
20.0	11.78	12.18	12.58	12.98	13.38	13.78	14.18	14.58	14.98	15.38	15.78	16.18	16.58	16.98	17.38	17.78	18.18
19.5	11.47	11.87	12.27	12.67	13.07	13.47	13.87	14.27	14.67	15.07	15.47	15.87	16.27	16.67	17.07	17.47	17.87
19.0	11.16	11.56	11.96	12.36	12.76	13.16	13.56	13.96	14.36	14.76	15.16	15.56	15.96	16.36	16.76	17.16	17.56
18.5	10.85	11.25	11.65	12.05	12.45	12.85	13.25	13.65	14.05	14.45	14.85	15.25	15.65	16.05	16.45	16.85	17.25
18.0	10.54	10.94	11.34	11.74	12.14	12.54	12.94	13.34	13.74	14.14	14.54	14.94	15.34	15.74	16.14	16.54	16.94
17.5	10.23	10.63	11.03	11.43	11.83	12.23	12.63	13.03	13.43	13.83	14.23	14.63	15.03	15.43	15.83	16.23	16.63
17.0	9.92	10.32	10.72	11.12	11.52	11.92	12.32	12.72	13.12	13.52	13.92	14.32	14.72	15.12	15.52	15.92	16.32
16.5	9.61	10.01	10.41	10.81	11.21	11.61	12.01	12.41	12.80	13.21	13.61	14.01	14.41	14.81	15.21	15.61	16.01
16.0	9.30	9.70	10.10	10.50	10.90	11.30	11.70	12.10	12.50	12.90	13.30	13.70	14.10	14.50	14.90	15.30	15.70
15.5	8.99	9.39	9.79	10.19	10.59	10.99	11.39	11.79	12.19	12.59	12.99	13.39	13.79	14.19	14.59	14.99	15.39
15.0	8.68	9.08	9.48	9.88	10.28	10.68	11.08	11.48	11.88	12.28	12.68	13.08	13.48	13.88	14.28	14.68	15.08
14.5	8.37	8.77	9.17	9.57	9.97	10.37	10.77	11.17	11.57	11.97	12.37	12.77	13.17	13.57	13.97	14.37	14.77
14.0	8.06	8.46	8.86	9.26	9.66	10.06	10.46	10.86	11.26	11.66	12.06	12.46	12.86	13.26	13.66	14.06	14.46
13.5	7.75	8.15	8.55	8.95	9.35	9.75	10.15	10.55	10.95	11.35	11.75	12.15	12.55	12.95	13.35	13.75	14.15
13.0	7.44	7.84	8.24	8.64	9.04	9.44	9.84	10.24	10.64	11.04	11.44	11.84	12.24	12.64	13.04	13.44	13.84
12.5	7.13	7.53	7.93	8.33	8.73	9.13	9.53	9.93	10.33	10.73	11.13	11.53	11.93	12.33	12.73	13.13	13.53
12.0	6.82	7.22	7.62	8.02	8.42	8.82	9.22	9.62	10.02	10.42	10.82	11.22	11.62	12.02	12.42	12.82	13.22
11.5	6.51	6.91	7.31	7.71	8.11	8.51	8.91	9.31	9.71	10.11	10.51	10.91	11.31	11.71	12.11	12.51	12.91
11.0	6.20	6.60	7.00	7.40	7.80	8.20	8.60	9.00	9.40	9.80	10.20	10.60	11.00	11.40	11.80	12.20	12.60
10.5	5.89	6.29	6.69	7.09	7.49	7.89	8.29	8.69	9.09	9.49	9.89	10.29	10.69	11.09	11.49	11.89	12.29
10.0	5.58	5.98	6.38	6.78	7.18	7.58	7.98	8.38	8.78	9.18	9.58	9.98	10.38	10.78	11.18	11.58	11.98
9.5	5.27	5.67	6.08	6.47	6.87	7.27	7.67	8.07	8.47	8.87	9.27	9.67	10.07	10.47	10.87	11.27	11.67
9.0	4.96	5.36	5.76	6.16	6.58	6.96	7.36	7.76	8.16	8.56	8.96	9.36	9.76	10.16	10.56	10.96	11.36
8.5	4.65	5.05	5.45	5.85	6.25	6.65	7.05	7.45	7.85	8.25	8.65	9.05	9.45	9.85	10.25	10.65	11.05
8.0	4.34	4.74	5.14	5.54	5.94	6.34	6.74	7.14	7.54	7.94	8.34	8.74	9.14	9.54	9.94	10.34	10.74
7.5	4.03	4.43	4.83	5.23	5.63	6.03	6.43	6.83	7.23	7.63	8.03	8.43	8.83	9.23	9.63	10.03	10.43
7.0	3.72	4.12	4.52	4.92	5.32	5.72	6.12	6.52	6.92	7.32	7.72	8.12	8.52	8.92	9.32	9.72	10.12
6.5	3.41	3.81	4.21	4.61	5.01	5.41	5.81	6.21	6.61	7.01	7.41	7.81	8.21	8.61	9.01	9.41	9.81
6.0	3.10	3.50	3.90	4.30	4.70	5.10	5.50	5.90	6.30	6.70	7.10	7.50	7.90	8.30	8.70	9.10	9.50
5.5	2.79	3.19	3.59	3.99	4.39	4.79	5.19	5.59	5.99	6.39	6.79	7.19	7.59	7.99	8.39	8.79	9.19
5.0	2.48	2.88	3.28	3.68	4.08	4.48	4.88	5.28	5.68	6.08	6.48	6.88	7.28	7.68	8.08	8.48	8.88
4.5	2.17	2.57	2.97	3.37	3.77	4.17	4.57	4.97	5.37	5.77	6.17	6.57	6.97	7.37	7.77	8.17	8.57
4.0	1.86	2.26	2.66	3.06	3.46	3.86	4.26	4.66	5.06	5.46	5.86	6.26	6.66	7.06	7.46	7.86	8.26
3.5	1.55	1.95	2.35	2.75	3.15	3.55	3.95	4.35	4.75	5.15	5.55	5.95	6.35	6.75	7.15	7.55	7.95
3.0	1.24	1.64	2.04	2.44	2.84	3.24	3.64	4.04	4.44	4.84	5.24	5.64	6.04	6.44	6.84	7.24	7.64
2.5	0.93	1.33	1.73	2.13	2.53	2.93	3.33	3.73	4.13	4.53	4.93	5.33	5.73	6.13	6.53	6.93	7.33
2.0	0.62	1.02	1.42	1.82	2.22	2.62	3.02	3.42	3.82	4.22	4.62	5.02	5.42	5.82	6.22	6.62	7.02
1.5	0.31	0.71	1.11	1.51	1.91	2.31	2.71	3.11	3.51	3.91	4.31	4.71	5.11	5.51	5.91	6.31	6.71
1.0	0.00	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00	4.40	4.80	5.20	5.60	6.00	6.40
0.5	0.00	0.09	0.49	0.89	1.29	1.69	2.09	2.49	2.89	3.29	3.69	4.09	4.49	4.89	5.29	5.69	6.09
Average depth (m)	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**

REFERENCES

Bninska M., Wołos A., 1998 – Effectiveness of coregonid management versus environment quality – Arch. Ryb. Pol. Vol. 6, Fasc. 2: 295-314

Falkowski S., 1994. - Stan i perspektywy gospodarki sieją: 71-78 - In: Aktualne Problemy Rybactwa Jeziorowego (Ed.) A. Wołos, Wydawnictwo IRS, Olsztyn.

Falkowski S., Wołos A., 1996. - Stan gospodarki koregonidami: 57-60 - W: Rybactwo Jeziorowe. Stan, Uwarunkowania, Perspektywy. Materiały I Krajowej Konferencji Rybackich Użytkowników Jezior, Uroczysko Waszeta, 23-25 czerwiec, Wydawnictwo IRS, Olsztyn.

Leopold M., 1972. - Metodyka prognozy i oceny połowów ryb o krótkim cyklu życiowym w jeziorach polskich (na przykładzie sielawy - *Coregonus albula* (Linnaeus)) - Rocz. Nauk Roln. 94-H-4: 9-98

Leopold M., Wołos A., 1996. - Analiza stanu jeziorowej produkcji rybackiej w 1995 roku: 35-41 - In: Rybactwo Jeziorowe. Stan, Uwarunkowania, Perspektywy. Materiały I Krajowej Konferencji Rybackich Użytkowników Jezior (Ed.) A. Wołos, Uroczysko Waszeta, 23-25 czerwiec, Wydawnictwo IRS, Olsztyn.

Leopold M., Wołos A., 1997. - Analiza stanu jeziorowej produkcji rybackiej w 1996 roku: 31-37 - In: Rybactwo jeziorowe. Znaczenie, zarządzanie, gospodarowanie. Materiały II Krajowej Konferencji Rybackich Użytkowników Jezior, Stare Jabłonki, 18-20 czerwiec, Wydawnictwo IRS, Olsztyn.

Mastyński J., 1978. - Sieja (*Coregonus lavaretus* L.) i sielawa (*Coregonus albula* L.) w jeziorach Polski zachodniej. Roczniki Akademii Rolniczej w Poznaniu, Rozprawy Naukowe, 85: 1-26.

Pokrovskij V.V., 1964. - Osnovnye faktory sredy, opredeljajuscie cislennost rjapuski: 228-234 - In: Tr. sovescanij ichtiologiceskoj komissii Ak. Nauk SSSR, vyp. 13, 1961, Sovescanie po dinamikie cislennosti ryb.

Wołos A., 1996. - Gospodarka zarybieniowa w 1995 roku: 51-55 - In: Rybactwo Jeziorowe. Stan, Uwarunkowania, Perspektywy. Materiały I Krajowej Konferencji Rybackich Użytkowników Jezior (Ed.) A. Wołos, Uroczysko Waszeta, 23-25 czerwiec, Wydawnictwo IRS, Olsztyn.

Wołos A., Bnińska M., 1998 – Effectiveness of coregonid management on the background of fish yield changes in 25 Polish lakes – Arch. Ryb. Pol. Vol. 6, Fasc. 2: 315-328

Wołos A., Mickiewicz M., 1997. - Charakterystyka zarybień przeprowadzonych przez użytkowników jezior w 1996 roku: 45-52 - In: Rybactwo jeziorowe. Znaczenie, zarządzanie, gospodarowanie. Materiały II Krajowej Konferencji Rybackich Użytkowników Jezior, Stare Jabłonki, 18-20 czerwiec, Wydawnictwo IRS, Olsztyn.

Wołos A., 1998. General characteristics of coregonid management in 132 Polish lakes. Arch. Ryb. Pol., Vol. 6, Fasc. 2: 265-278

Zawisza J., Backiel T., 1970. - Płodność sielawy. Broszura IRS Olsztyn 40: 8-19.

STRESZCZENIE

WPŁYW MORFOMETRII JEZIOR NA EFEKTYWNOŚĆ PROWADZONEJ W NICH GOSPODARKI SIELAWOWEJ

Poddano analizie wieloletnie dane o gospodarce sielawowej w 114 jeziorach o łącznej powierzchni 59.1 tys. ha, dane o cechach morfometrycznych tych jezior, oraz przy użyciu stosowanych metod statystycznych określono związki między morfometrią jezior a efektami gospodarowania. Spośród czterech anal-

izowanych parametrów morfometrycznych tj. powierzchni, głębokości średniej, głębokości maksymalnej i rozwinięcia linii brzegowej, najsilniejszy wpływ na efekty gospodarowania sielawą - wyrażone wydajnością tego gatunku oraz wskaźnikiem efektywności zarybień - ma średnia głębokość jezior. Uzyskano równanie regresji wielokrotnej, wiążące wydajność sielawy z dawkami zarybieniowymi i średnią głębokością jezior. Na jego podstawie opracowano tabelę, która może być pomocna przy podejmowaniu decyzji gospodarczych dotyczących alokacji materiału zarybieniowego.

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