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EFFECTIVENESS OF COREGONID MANAGEMENT ON THE BACKGROUND OF FISH YIELD CHANGES IN 25 POLISH LAKES

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ABSTRACT. Analyses were performed of 33-year data on fish catches and coregonid management in 25 lakes of total area over 25 thousand ha, in which the fish stock had undergone significant changes under the effect of eutrophication. Time series was taken advantage of to determine the character and rate of these changes in the whole stock of lake fish, with special attention given to three economically valuable species: whitefish, vendace and pike-perch. The analyses embraced also the effectiveness of stocking with coregonids. Mutual economic relations were examined between catches of coregonids and those of pike-perch. Practical implications of the results in the decision-making process have been discussed.

Key words: EUTROPHICATION, CHANGES IN THE FISH STOCK, VENDACE, WHITEFISH, PIKE-PERCH, EFFECTIVENESS OF COREGONID MANAGEMENT

INTRODUCTION

The effect of eutrophication on the fish stocks has been quite well documented in the literature (Colby et al. 1972, Leach et al. 1977, Hartmann 1977, 1979) as well as its effects on the fisheries management, both on an overall scale (Bnińska 1985, Leopold, Bnińska, Nowak 1986, Leopold et al. 1987) and in single lakes (Bnińska 1984, Falkowski 1996, Wołos 1996, Wołos, Falkowski, Czerkies 1998). The results of these studies agree on one point: that eutrophication affects negatively whitefish (*Coregonus lavaretus* L.) and vendace (*Coregonus albula* L.) management. The two species, and especially vendace, have so far represented in many lakes the major species from an economic point of view, but their importance gradually decreases, and in some lakes this decrease can be very rapid (Wołos 1996), their place being taken by „growing” species (in the sense of increasing numbers). These changes affect the economic performance of the fishery management in lakes (Leopold 1996), the more so that prospects for further development of eel management, another economically important fish, seem to be rather grim (Moriarty 1997). Due to this, proper estimates of the ecosystem status and of management effectiveness, in this especial-

ly of the relations between state of the exploited fish stock and the effects of management, become more and more important. In this context, it is worth noting that estimates of the effectiveness of stocking with coregonid fish are *per se* very difficult from the methodical point of view (Wołos 1994) and change with changes taking place in the fish stocks, while monitoring of the latter is very costly and complicated if traditional methods are used (Bnińska and Wołos 1998).

These limitations, as well as the conclusions resulting from Bnińska and Wołos (1998), have affected the aim and the methods used in this study. It analyses long-term changes in coregonid management on the background of other fish species in those lakes in which eutrophication process was the most rapid, so that also the fish stock changes took place more rapidly than elsewhere. The increase of pikeperch landings was used as the criterion to select these lakes (Bnińska and Wołos 1998). Effectiveness of vendace and whitefish management was assessed in these lakes on the background of long-term changes in the exploited fish stock.

MATERIALS AND METHODS

This study is based on an analysis of 33-year records (1962-1994) of fish landings (all species), and of stockings with vendace and whitefish in 25 lakes of total area 25043.8 ha, selected from 132 lakes with coregonid management, totalling 65961.5 ha.

The lakes were selected based on the level of pikeperch landings. Only these lakes were selected in which there was no pikeperch at the beginning of the analysed period, or if its catches were negligible, and then this fish appeared at an increasing rate.

When assessing the changes in commercial fish catches, viz. indirectly also in the state of the lake ecosystems, two fish groups were basically distinguished:

- A) „disappearing” species and sizes, the share of which in commercial landings decreases along with progressing eutrophication (pike, tench, crucian carp, perch, large bream, large roach), and
- B) „increasing” species and sizes, the share of which in commercial fish landings increases with progressing eutrophication (medium and small bream, small roach, white bream).

Vendace and whitefish have been excluded from group A, and pikeperch from group B in order to define mutual relations between these species in a more precise way.

The following indices were used in the analysis:

- percentage of species, groups of species and fish sizes in the catches;
- fish yield in kg/ha,
- variability of catches expressed as coefficient of variability (V%) related to the long-term mean catch,
- per cent of catch increase or decrease in relation to the multi-year mean, calculated from statistical equations of linear trends,
- index of the effectiveness of stocking with vendace, expressed in number of vendace larvae needed to produce 1 kg of commercial catch,
- average prices of: vendace (9.1 zł), whitefish (9.9 zł) and pikeperch (11.7 zł) calculated on the basis of fish prices in October 1997 in 6 lake fishery enterprises (3 from Mazurian and 3 from Pomeranian lakelands).

The materials were analysed with statistical methods using time-series approach (trends), calculating polynomials up to the 4th degree, and assuming their statistical significance at the level of $p = 0.05$. Computer programme STATISTICA Version 5 was used as well as a programme made especially for this study project.

RESULTS

LONG-TERM CHANGES IN THE CATCHES

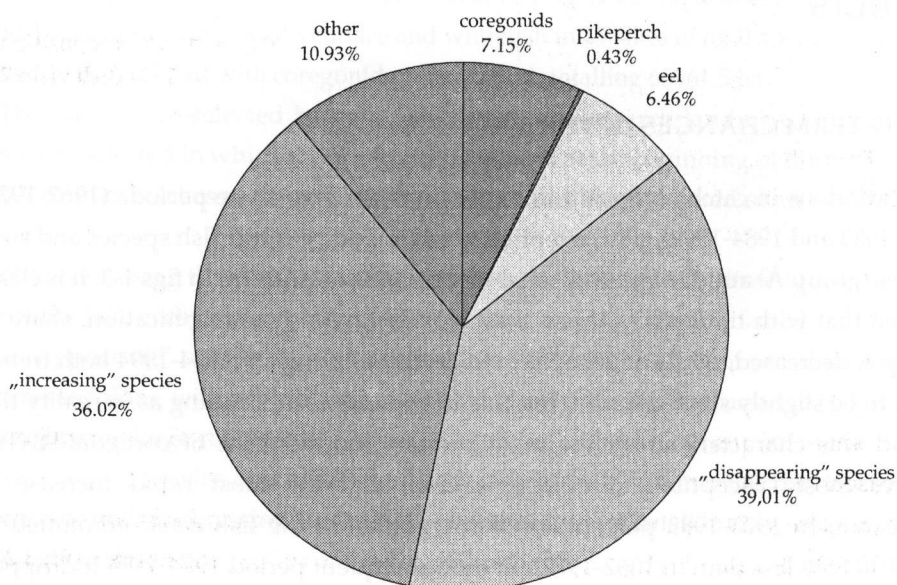
Variations in catch composition in the distinguished three periods (1962-1972, 1973-1983 and 1984-1994), with attention given to „decreasing” fish species and size-classes (group A) and „increasing” ones (group B) are presented in figs 1-3. It is clearly seen that with time, and - thus - also with progressing eutrophication, share of group A decreased, while of group B - increased. Although in 1984-1994 both trends seem to be slightly slowed down, but this impression is misleading as in reality this period was characterised by the most pronounced decrease of coregonids (viz. species most susceptible to eutrophication), and the most rapid increase of pikeperch. In 1973-1983 percentage of coregonids in the fish catch amounted to 6.50% (0.65% less than in 1962-1972), in the subsequent period 1984-1994 it dropped to 4.29%. At the same time share of pikeperch increased from as little as 0.43% in the first period to 3.48% in the third. Taking into consideration the last 5 years (1990-

TABLE 1

Catch parameters for selected species and size-classes in 1962-1994 (n = 25)

Species/ size classes	Yield (kg/ha)	Variability (V%)	Increment/decrease (%)
A „disappearing”			
Vendace	1.31	60.4	-4.26
Whitefish	0.44	61.0	ns
Perch	1.81	36.5	-2.80
Pike	1.65	37.8	-3.24
Tench	0.33	60.7	-5.16
Large bream	2.25	40.1	-2.26
Large roach	3.82	35.0	ns
B „increasing”			
Pikeperch	0.43	84.5	+7.84
Medium-sized bream	3.00	19.6	+1.30
Small bream	0.53	110.3	ns
Small roach	7.12	31.3	ns
White bream	1.40	64.9	ns

ns - linear trend not significant



tion in 1962-1972 (fish yield 31.2 kg/ha)

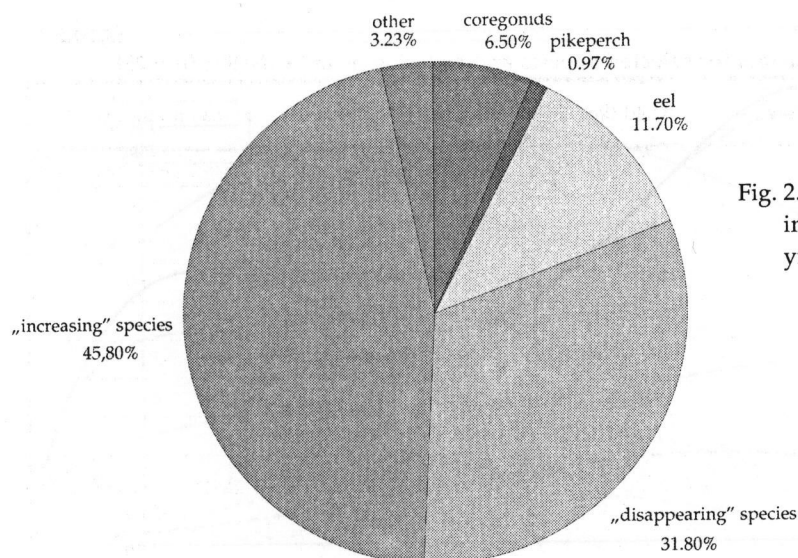


Fig. 2. Catch composition in 1973-1982 (fish yield 31.2 kg/ha)

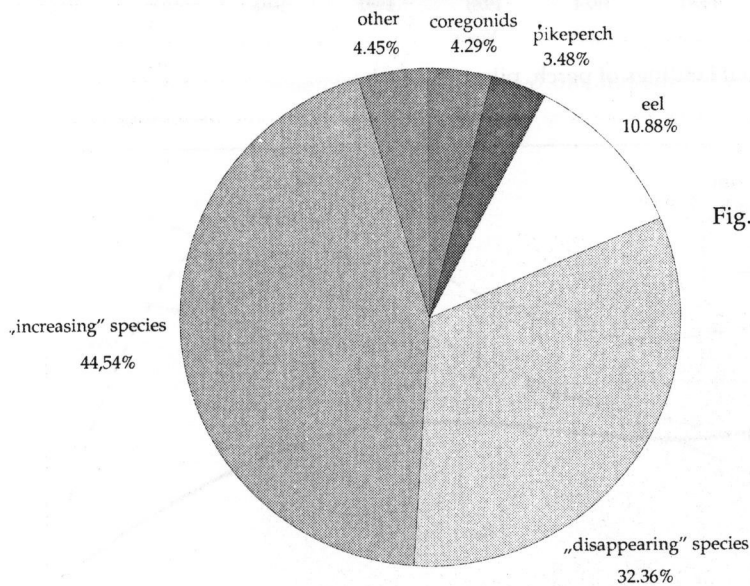


Fig. 3. Catch composition in 1984-1994 (fish yield 25.2 kg/ha)

1994), share of pikeperch increased even more - to 5.4%, while of coregonids decreased to 2.5%.

Time series approach applied to fish catches in the distinguished groups A and B revealed statistically highly significant trends of a curvilinear character (Figs 4-6), which can be taken advantage of to assess state of the lake environments more precisely. Decreasing trends of perch catches, as well as of littoral fish: pike and tench,

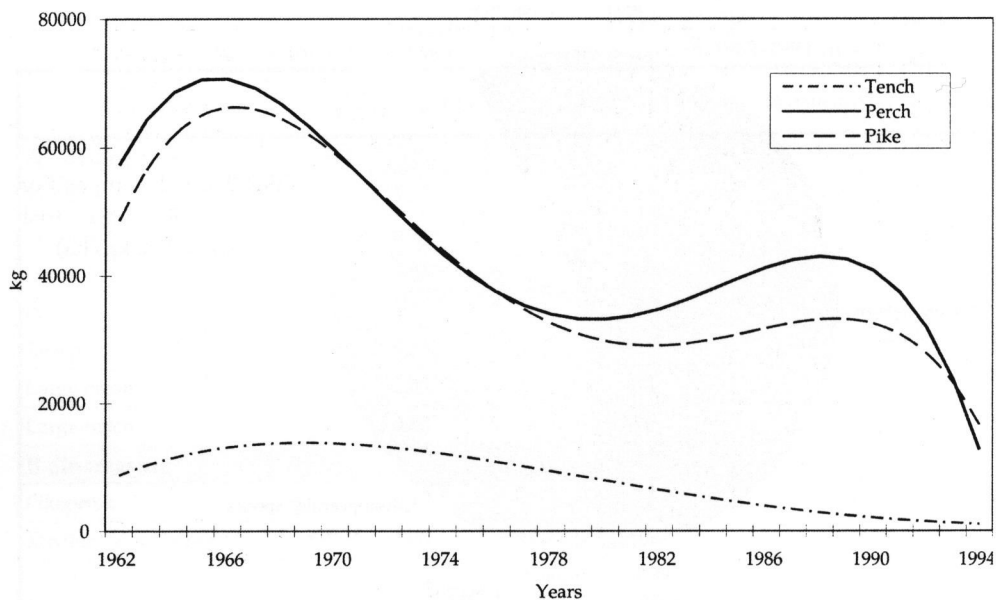


Fig. 4. Trends of commercial landings of perch, pike and tench

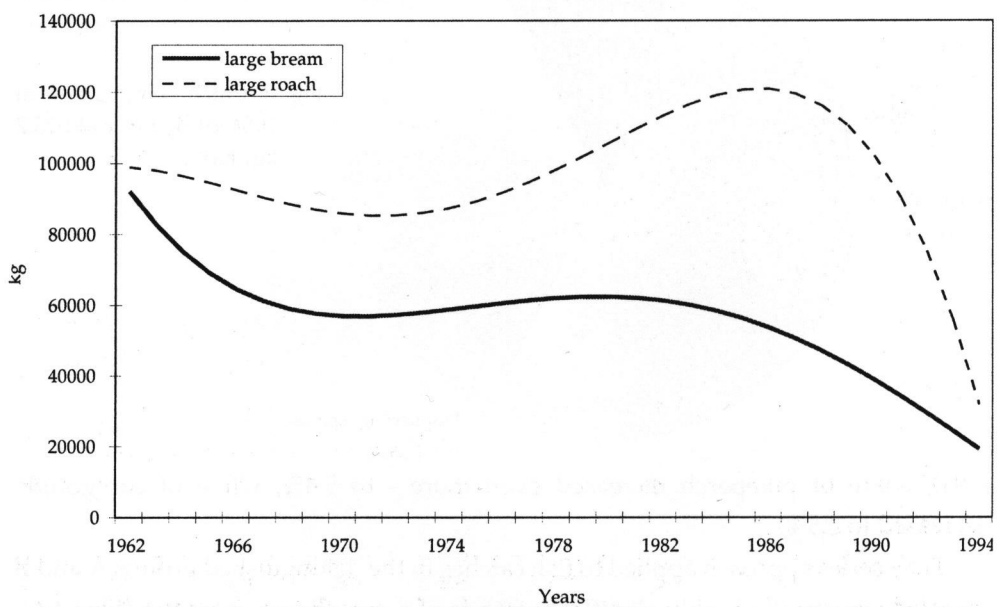


Fig. 5. Trends of commercial landings of large bream and roach

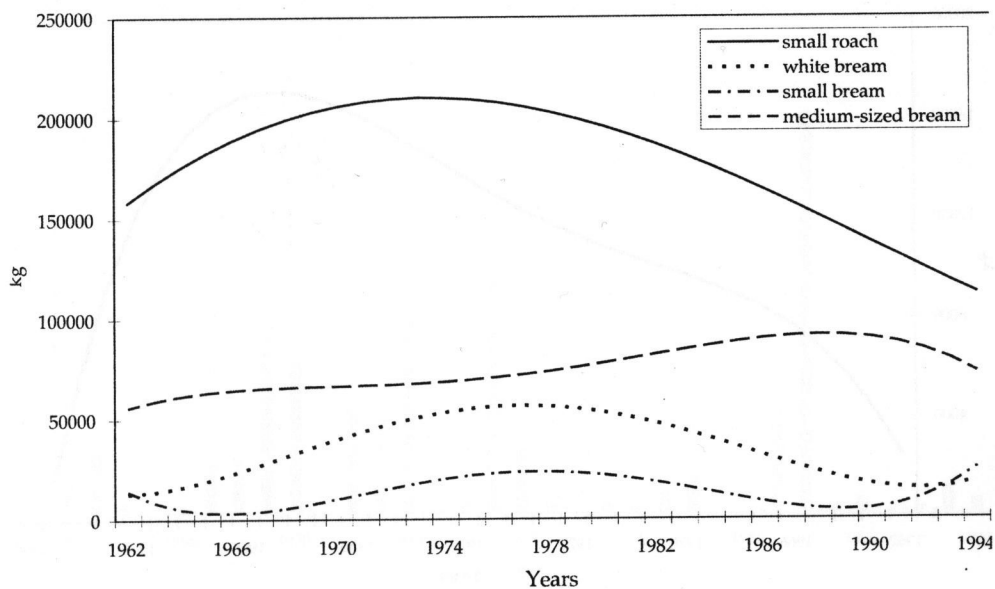


Fig. 6. Trends of commercial landings of medium and small-sized bream, small roach and white bream

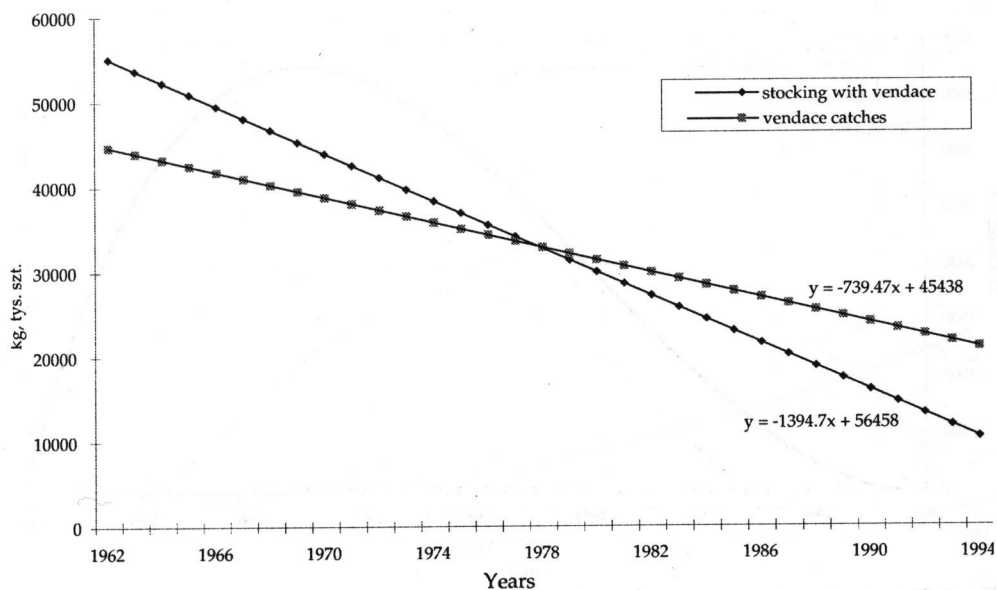


Fig. 7. Trends of vendace catches and stockings with larvae

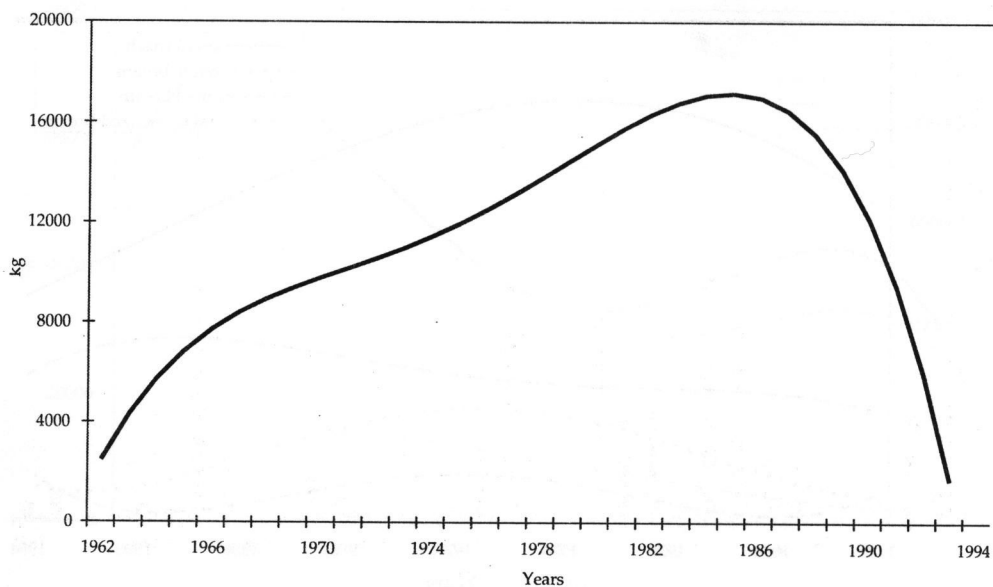


Fig. 8. Trend of whitefish catches

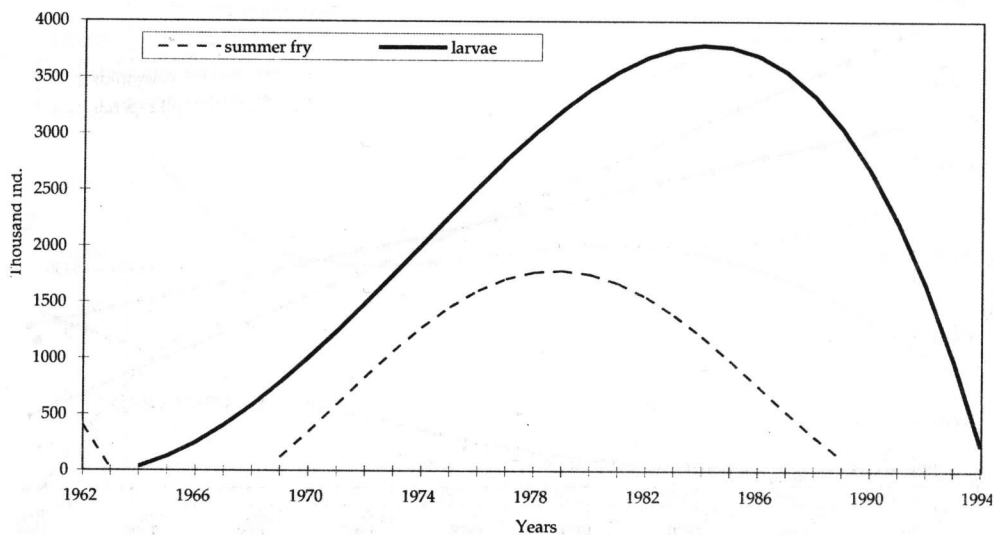


Fig. 9. Trends of stockings with whitefish larvae and summer fry

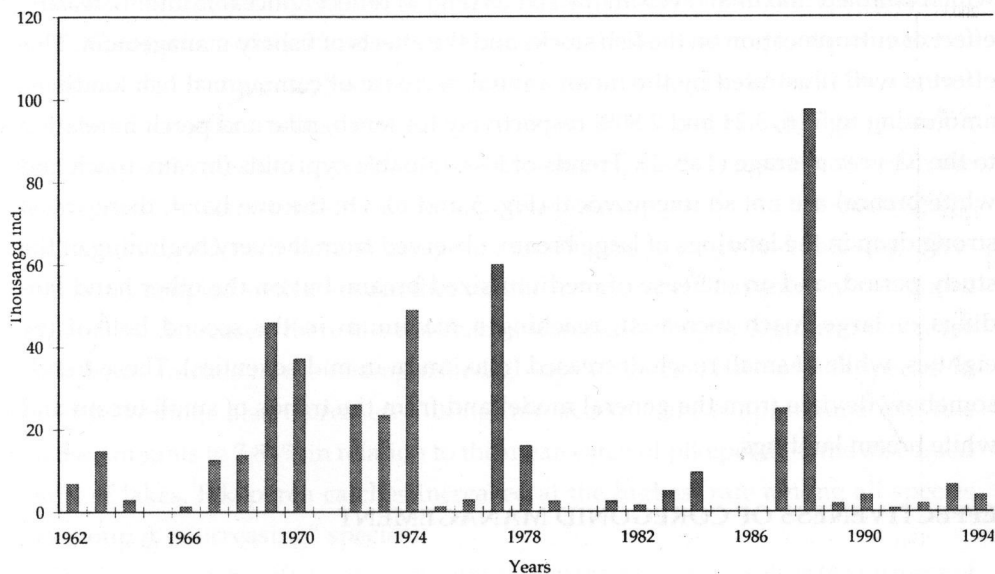


Fig. 10. Stockings with autumn fry of whitefish

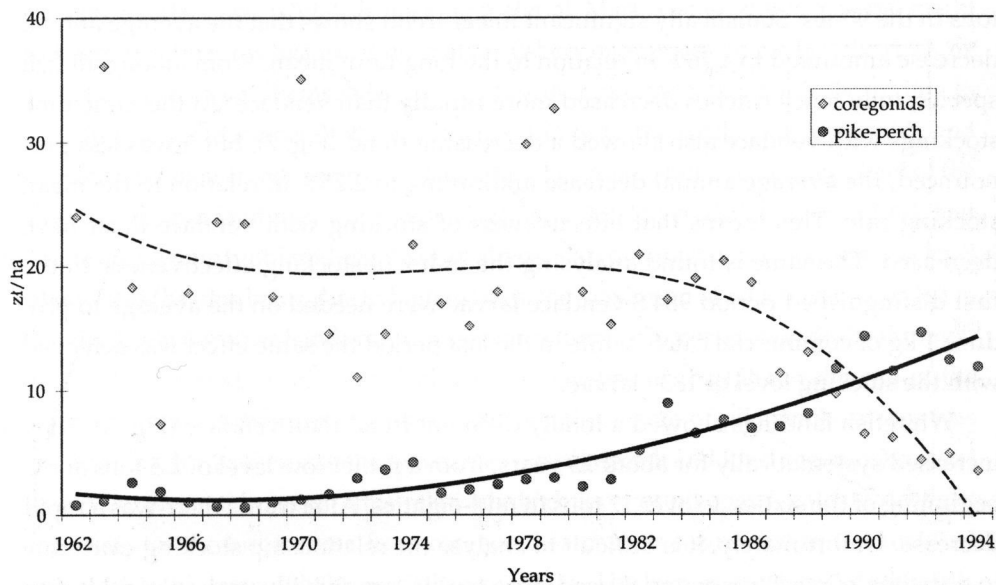


Fig. 11. Value of commercial landings of coregonid fish and pikeperch

which attained maximal levels in the sixties (Fig. 4) reflect noticeable and increasing effect of eutrophication on the fish stocks and the effects of fishery management. This effect is well illustrated by the mean annual decrease of commercial fish landings, amounting to 5.16, 3.24 and 2.80% respectively for tench, pike and perch in relation to the 33-year average (Tab. 1). Trends of less valuable cyprinids (bream, roach and white bream) are not so unequivocal (Fig. 5 and 6). On the one hand, there was a strong drop in the landings of large bream, observed from the very beginning of the study period, and an increase of medium-sized bream, but on the other hand landings of large roach increased, reaching a maximum in the second half of the eighties, while of small roach decreased (maximum in mid-seventies). These trends somehow deviate from the general model and from the trends of small bream and white bream landings.

EFFECTIVENESS OF COREGONID MANAGEMENT

Coregonid landings also show statistically significant regularities (Figs 7, 8, 11, Tab. 1). Vendace catch shows a decreasing trend practically since the beginning of the analysed period, from about 60 tons at the beginning of the 60-ies, to less than 10 tons in the 90-ies. Statistically significant linear trend shows that the average annual decrease amounted to 4.26% in relation to the long-term mean. From among all fish species, only tench catches decreased more rapidly than vendace. At the same time stockings with vendace also showed a decreasing trend (Fig. 7), but it was less pronounced, the average annual decrease amounting to 2.25% in relation to the mean stocking rate. This means that effectiveness of stocking with vendace must have decreased. The same is found analysing the index of stocking effectiveness: in the first distinguished period 984.8 vendace larvae were needed on the average to produce 1 kg of commercial catch, while in the last period the same effect was achieved with the stocking level of 1839 larvae.

Whitefish landings showed a totally different trend than vendace (Fig. 8). They increased systematically for about 25 years, from a rather low level of 2.5 tons at the beginning of the sixties, to over 17 tons in mid-eighties. Afterwards there was a rapid decrease. Unfortunately, it is difficult to analyse the relationship stocking-catch due to a variety of stocking material used. Due to this, graphic illustration of whitefish stockings comprises all types of the stocking material; in the case of larvae and summer fry we deal with curvilinear trends (Fig. 9), whereas stockings with autumn

fry showed no statistically significant trend, so the real data have been presented in Fig. 10. Comparison of the trends of stockings with the dominating forms of material (viz. larvae and summer fry) with the trend of whitefish catches shows that, contrarily to vendace, effectiveness of stocking with whitefish did not change in such a drastic way as in the case of vendace notwithstanding the decrease of catches in the last 7-8 years. In fact, whitefish catches decreased almost parallel to the stockings.

Changes noted with time in coregonid landings, stockings and stocking effectiveness are coupled with a yet another regularity: as the effectiveness of coregonid management decreases, there is a noticeable, statistically highly significant increase of pikeperch catches in the distinguished groups of lakes. Share of this species in total fish landings also increases. Taking into account linear approximation, this increase amounts to 7.84% in relation to the mean catch of pikeperch in the discussed groups of lakes. Pikeperch catches increased at the highest rate among all species from group A („increasing” species).

The decrease of the effectiveness of coregonid management, as well as the increase of pikeperch importance must result in significant implications for the fishery management. Their quantification is not easy, this being mostly due to the lack of data on the costs of producing vendace and whitefish stocking material. Market price of this material might result in misleading conclusions as most of the fishery enterprises do not buy the stocking material but produce it themselves. Having this in mind, monetary value (according to the mean prices of October 1997) was ascribed only to the catches of coregonids and pikeperch, and their trends were calculated (Fig. 11). A generally decreasing trend of the value of coregonid landings, from some 25 zł/ha in 1962 to statistical zero in 1994, had for quite a long time (until mid-eighties) an almost stable character, remaining at the level of about 20 zł/ha, this being due to high catches, the maximum of which was recorded in 1985 (Fig. 8). On the other hand, value of pikeperch catches increased practically throughout the whole period, from about 2 zł/ha in the sixties to 15 zł/ha at the end of the analysed period. At the turn of eighties and nineties, value of pikeperch catches was about 10 zł/ha. It was then that the two curves (for pikeperch and for coregonids) crossed (Fig. 11). At present, however, this relatively high level of pikeperch catches does not compensate for the lost income from coregonid catches. It seems that in the analysed group of lakes this loss might be partially compensated by increased catches of whitefish. As has been already mentioned, whitefish is not as susceptible to the eutrophication process as vendace.

DISCUSSION

Advantages of using time series analysis, most of all to determine the rate and character of changes taking place in the fish stocks, and to assess the effectiveness of stockings, have been pointed out by many authors (Bnińska 1984, 1985, Leopold, Bnińska, Nowak 1986, Bnińska and Leopold 1990, Bnińska 1994). Papers devoted to lake fishery management showed that as regards the coregonid fish, trends are usually of a curvilinear character, both on a general scale and in particular lakes, catches of these fish reaching a maximum and then decreasing. The same was observed in the 25 lakes under study, but vendace catches showed a decreasing trend since the very beginning, while whitefish landings began to decrease some 20 years later. Comparing catches of these species with stockings it can be readily concluded that vendace must have been affected by the eutrophication process, while as regards whitefish the situation is not so clear. Hence, one should agree with Hartmann (1987) that whitefish is not the best indicator species as regards water eutrophication, this being surely connected with exceptional plasticity of this fish (see the review paper by Falkowski 1991). In an analysis between state of environment and stockings on the one hand, and whitefish landings on the other, Wołos, Falkowski and Czerkies (1998) concluded that the decrease of whitefish catches in Lake Gołdopiwo and a drop of stocking effectiveness was more related to „management” and „economic” factors (among others, high price of eel and incomparably low prices of small cyprinids preventing their proper exploitation, transformation of Polish fisheries sector in the nineties, all resulting in a decrease of exploitation) than to the effects of eutrophication. Also Hartmann (1987) pointed out that in the case of whitefish, exploitation intensity was more important in Lake Constance than environmental factors. Müller (1992), on the other hand, quantified the effect of increasing phosphorus concentration on decreasing effectiveness of whitefish reproduction, but in the analysed 25 lakes this factor could have affected whitefish catches in a few lakes only, so it would not change the general conclusion resulting from time series analysis that whitefish catches were basically determined by stocking rates. The same results from the paper by Falkowski and Wołos (1998).

A few questions can be posed: when, with what catch composition, and at what effectiveness of stockings would coregonid management become totally unprofitable

from an economic point of view? Can mutual relations between catches of whitefish, vendace and pikeperch be helpful in undertaking proper management decisions?

Methodical approach used in this paper was based on the analysis of the species composition of the exploited stock, time series analysis (using linear and curvilinear trends), and of the effectiveness of stockings, with special attention given to pikeperch, not only as a species indicator of the eutrophication process, but also as an indicator of the effectiveness of coregonid management. The obtained trends and graphical illustration of the results point to the changes in parameters characterising economic effectiveness of coregonid management. Among other things, it is possible to assess the „threshold” levels. Fishery manager who can estimate, even very roughly, the costs of producing the stocking material and the costs of exploitation, can use trends and regularities revealed in this paper to find out ranges and threshold values answering the two questions in lakes undergoing the eutrophication process. Or the other way around, as in practical terms we can also deal with the reversal process, Lake Lubie being the example of it, where in the 90-ies vendace population was re-established while pikeperch disappeared (Bnińska, Leopold, Wołos, Grzegorzczak 1997). The observed phenomenon of oligotrophisation cannot be generalised as yet, but it certainly calls for further research.

REFERENCES

- Bnińska M., 1984. - Outdoor recreation - a new factor disturbing lake ecosystems, as exemplified by Lake Gim, Mazurian Lake District. - Verh. Internat. Verein. Limnol. 22: 978-981.
- Bnińska M., 1985. - The possibilities of improving catchable fish stocks in lakes undergoing eutrophication. - J. Fish Biol. 27 (Suppl A): 253-261.
- Bnińska M., 1994. - Praktyczne metody analizy efektywności zarybiania jezior: 51-70 - In: Aktualne problemy rybactwa jeziorowego (Ed.) A. Wołos, Wydawnictwo IRS, Olsztyn.
- Bnińska M., Leopold M., 1990. - Fisheries management in Polish lakes: 406-436 - In: Management of freshwater fisheries (Ed.) W.L.T. van Densen, B. Steinmetz, R.H. Hughes, Pudoc, Wageningen.
- Bnińska M., Leopold M., Wołos A., Grzegorzczak J., 1997. - Operaty urządzeniowe rybackiego gospodarowania w jeziorach dzierżawionych przez Przedsiębiorstwo Rybackie Złocieniec Sp. z o.o. Opracowanie dla Przedsiębiorstwa Rybackiego Złocieniec Sp. z o.o. (maszynopis).
- Bnińska M., Wołos A., 1998 - Effectiveness of coregonid management versus environment quality - Arch. Ryb. Pol. Vol. 6, Fasc. 2: 295-314
- Colby P.J., Spangler G.R., Hurley D.A., McCombie A.M., 1972. - Effects of eutrophication on salmonid communities in oligotrophic lakes. - J. Fish. Res. Bd. Can. 29: 975-983.
- Falkowski S., 1991. - Płodność siewi (*Coregonus lavaretus* L.) w polskich populacjach jeziorowych. - Praca doktorska, IRS Olsztyn.
- Falkowski S., 1996. - „Czekając” na sandacza w Gołdapiwie: 33-39 - In: Sandacz - gospodarka rybacka - eutrofizacja (Ed.) A. Wołos, materiały Seminarium „Sandacz - gospodarka rybacka - eutrofizacja”, Ostrowiec k/Wałcza, 6-7 czerwiec 1995, Wydawnictwo IRS, Olsztyn.

- Falkowski S., Wołos A., 1998. - Analysis of whitefish (*Coregonus lavaretus* L.) landings and stockings in 106 lakes in 1967-1994 - Arch. Ryb. Pol., Vol. 6, Fasc. 2: 345-360
- Hartmann J., 1977. - Fischereiliche Veränderungen in kulturbedingt eutrophierenden Seen. - Schweiz. Z. Hydrol. 39(2): 243-254.
- Hartmann J., 1979. - Unterschiedliche Adaptionfähigkeit der Fische an Eutrophierung. - Schweiz. Z. Hydrol. 41(2): 374-382.
- Hartmann, J. 1987. - Whitefish as indicators of cultural eutrophication? - Schweiz. Z. Hydrol. 49: 343-352.
- Leach J.H., Johnson M.G., Kelso J.R.M., Hartmann J., Nümann W., Entz B., 1977. - Responses of percid fishes and their habitats to eutrophication. - J. Fish. Res. Bd. Can. 34: 1964-1971.
- Leopold M., Bnińska M., Nowak W., 1986. - Commercial fish catches as an index of lake eutrophication. - Arch. Hydrobiol. 106: 513-524.
- Leopold M., Bnińska M., Nowak W., Wołos A., Szlażyńska K., 1987. - Gospodarka rybacka w systemie Wielkich Jezior Mazurskich na tle stanu ich środowiska - Opracowanie dla PGRI Giżycko, IRS Olsztyn (typescript).
- Leopold M., 1996. - Ekonomiczne skutki procesu eutrofizacji: 73-79 - In: Sandacz - gospodarka rybacka - eutrofizacja (Ed.) A. Wołos, materiały Seminarium „Sandacz - gospodarka rybacka - eutrofizacja”, Ostrowiec k/Wałcza, 6-7 czerwiec 1995, Wydawnictwo IRS, Olsztyn
- Moriarty Ch., 1997. - Węgorz w Europie: 23-30 - In: Rybactwo jeziorowe. Znaczenie, zarządzanie, gospodarowanie. Materiały II Krajowej Konferencji Rybackich Użytkowników Jezior (Ed.) A. Wołos, Stare Jabłonki, 18-20 czerwiec, Wydawnictwo IRS, Olsztyn.
- Müller, R. 1992. - Trophic state and its implications for natural reproduction of salmonid fish. - Hydrobiologica 243/244: 261-268.
- Wołos A., 1994. - Efektywność zarybień koregonidami: 79-93 - In: Aktualne problemy rybactwa jeziorowego (Ed.) A. Wołos, Wydawnictwo IRS, Olsztyn.
- Wołos A., 1996. - Historia sandacza w 4 jeziorach „sielawowych” z okolic Olsztyna: 23-32 - In: Sandacz - gospodarka rybacka - eutrofizacja (Ed.) A. Wołos, materiały Seminarium „Sandacz - gospodarka rybacka - eutrofizacja”, Ostrowiec k/Wałcza, 6-7 czerwiec 1995, Wydawnictwo IRS, Olsztyn.
- Wołos A., Falkowski S., Czerkies P., 1998. - Changes in whitefish (*Coregonus lavaretus* L.) and vendace (*Coregonus albula* L.) fisheries in Lake Gołdapiwo due to eutrophication and management policies - Arch. Hydrobiol. Spec. Issues Advanc. Limnol., 50: 523-530

STRESZCZENIE

EFEKTYWNOŚĆ GOSPODARKI KOREGONIDAMI NA TLE ZMIAN W ODŁOWACH RYB W 25 JEZIORACH POLSKI

Poddano analizie 33-letnie dane o odłowach ryb i zarybieniach koregonidami 25 jezior o łącznej powierzchni ponad 25 tys. ha, w których połowie ryb uległo istotnym zmianom pod wpływem procesu eutrofizacji. Przy użyciu metody analizy szeregów czasowych określono charakter i tempo tych zmian w odłowach całego połowu ry jeziorowych, w szczególności trzech cennych gospodarczo gatunków: sielawy, siei i sandacza, a także zmian w efektywności zarybiania koregonidami. Zbadano wzajemne, ekonomiczne relacje między odłowami koregonidów i sandacza, a także poddano dyskusji możliwości praktycznego wykorzystania przedstawionych wyników przy podejmowaniu decyzji gospodarczych.

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