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EFFECTIVENESS OF WHITEFISH (*Coregonus lavaretus* L.) MANAGEMENT IN LAKES WITH THE HIGHEST YIELDS OF THIS FISH IN POLAND

Stanisław Falkowski

The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn

ABSTRACT. Commercial catch statistics were used to analyse the landings, stocking rates and their effectiveness in a group of 12 lakes with the highest commercial yields of whitefish in the period 1967-1994. Attention was paid to the type of stocking material as well as stocking rates, the latter varying from 3 to 12480 fish/ha in the case of larvae, from 4 to 3445 fish/ha in the case of summer fry, and from 4 to 1924 fish/ha in the case of autumn fry. Mean effectiveness of stocking, expressed in terms of autumn fry, ranged from 2.35 to 55.66 fish/kg of the catch. Most of the lakes were stocked with a variety of stocking material and no data were available on the intensity of whitefish exploitation. This hampered the analysis and reliable estimates of the effectiveness of whitefish production in lakes. It was found that a rapid decrease of whitefish landings in the recent years was related not only to lower stocking rates, but also to low intensity of exploitation.

Key words: WHITEFISH, YIELDS, STOCKING MATERIAL, EFFECTIVENESS OF PRODUCTION, INTENSITY OF EXPLOITATION

INTRODUCTION

An inventory of Polish lakes with whitefish, made for the period 1972/73-1976/77, coupled with an analysis of whitefish landings and stocking rates, showed that only 14 lakes of total area 10757 ha had annual landings of this fish of more than 1000 kg, with the mean yield of more than 2 kg/ha (Uryn and Falkowski 1979). These lakes supplied in 1975-1985 over 60% of total whitefish landings in Poland.

Analysis carried out for 107 lakes and the period 1967-1994 confirmed that 12 lakes were quite exceptional as regards whitefish yields (both totally and annual means). They supplied 63.8% of total whitefish landings in this period. Irrespective of the years taken into account there were always the same 10 lakes with the highest whitefish landings.

In the 70-ies, when only 5-year period was taken into account, the mentioned group comprised additionally lakes Głuszyńskie, Serwy, Kownatki and Rumian.

A much longer survey (28 years) showed that these four lakes were replaced by lakes Sniardwy and Szeląg Duży, so that the group comprised 12 lakes.

Highly significant role played in whitefish production in Poland by these few lakes justifies a more closer analysis of coregonid management in this group. Definition of at least some mechanisms affecting whitefish landings should be very helpful in practical determination of the further strategy for managing whitefish stocks in Polish lakes.

MATERIAL AND METHODS

Materials consisted of the statistics related to whitefish management in 12 lakes with the highest yields of this fish in Poland. Level of whitefish landings and stocking rates were analysed for the period of 28 years (1967-1994), while earlier data were used as a background for the discussion.

Mean annual landings of whitefish were calculated for each lake together with the standard deviation ($\pm s$), coefficient of variability (v) and share of whitefish in overall fish landings, as well as whitefish yields from 1 ha. Based on the stocking data the mean stocking rates with whitefish larvae, summer and autumn fry were calculated for each lake in the number of fish/ha.

Effectiveness of stocking, measured as the number of fish released per 1 kg of commercial catch, was presented for each lake in form of the mean value for the three types of the stocking material used, and recalculated to standard autumn fry. The recalculation was done using a model based on the current market prices of the stocking material (83 whitefish larvae = 5 fish in summer fry stage = 1 fish in autumn fry stage).

When it was possible to distinguish a period in which only one form of stocking material was released, the real effectiveness of stocking was calculated for this form in this period.

Very high differences in the stocking rates (from a few to several thousand fish/ha), and the fact that all forms of the stocking material were used in each lake, made it impossible to construct a common model for the 12 lakes that would clearly show the dependence between stocking and yield. Due to this only a descriptive form is used when discussing the results.

TABLE 19

Lake		Total landings in 1967-1994 (tons)	Mean annual catches				Share in total fish landings (%)	Effectiveness of stocking in 12 lakes in 1967-1994			
area (ha)	average depth (m)		kg	σ	V%	kg/ha		larvae	summer fry	autumn fry	standard fry
Gołdopiwo 963	11.8	178.8	6383	3909	61.2	7.40	23.88	251	7	1.6	6.02
Mielno 363	12.1	87.4	3120	2555	81.9	8.60	21.60	138	51	41.5	53.36
Łańskie 1042	16.0	80.6	2878	2584	89.8	2.76	7.45	176	27	4.7	12.22
Mamry Płn. 2711	11.7	72.6	2594	2623	101.5	0.96	3.53	60	22	0.9	6.12
Maróz 333	11.9	69.2	2471	1965	79.5	7.43	14.89	252	40	4.8	15.78
Wigry 2118	66.9	66.9	2390	2638	110.4	1.13	4.28	3.19	4.6	-	4.76
Pluszne 903	14.9	65.9	2346	1945	82.9	2.60	8.29	197	86	32	51.57
Śniardwy 9880	5.8	53.8	1920	2816	146.7	0.19	0.66	7	-	-	-
Rospuda 342	14.5	50.9	1816	1813	99.8	5.32	13.74	195	-	-	2.35
Wulpińskie 707	10.6	44.6	1592	1423	89.4	2.25	6.18	144	112	10.4	34.53
Szeląg Duży 599	13.5	43.8	1563	1292	82.7	2.61	7.56	229	125	26.9	54.66
Isąg 396	14.2	42.5	1519	1332	87.7	3.84	10.67	153	165	8.6	43.44

RESULTS

Average annual whitefish landings in 1967-1994 in the 12 lakes were characterised by very high variability (tab. 1). In the biggest lakes Śniardwy, Wigry and Mamry Płn. variability coefficient exceeded 100%. In the remaining 9 lakes it ranged from 61.2% (Lake Gołdopiwo) to 99.8% (Lake Rospuda).

The highest annual yield from a unit of area was observed in Lake Mielno (8.60 kg/ha). Very high mean yields were also found in lakes Maróz and Gołdopiwo (7.43-7.40 kg/ha). Slightly lower yields, 5.32-3.84 kg/ha, were found in lakes Rospuda and Isąg. In the group of other lakes the mean annual yield from 1 ha ranged from 2.76 kg in Lake Łańsk to 0.19 kg in Lake Śniardwy.

The highest mean percentages of whitefish in the fish catch were found in lakes Gołdopiwo and Mielno (23.88% and 21.60%). In other lakes whitefish landings represented on the average from 14.89% in Lake Maróz to 0.66% in Lake Śniardwy (tab. 1).

LAKE GOŁDOPIWO

This lake is characterised by the highest whitefish landings in Poland, both on an overall scale and on the average, as well as the highest percentage of this fish in total fish landings and one of the best effectiveness of stocking (tab. 1). In 1950-1966 the mean annual catch of whitefish amounted to 2286 kg (2.65 kg/ha). In this period the lake was only twice stocked with whitefish larvae (in 1958 - 590 larvae/ha, in 1961 - 348 larvae/ha). Next stocking took place as late as 1968, so until 1970 whitefish landings from this lake must have been determined by natural reproduction of this fish and by the exploitation. Very high landings in 1967-1972 (9982 kg or 11.6 kg/ha on the average) were, on the other hand, due to a change in the legal size of whitefish, introduction of new, more effective gill nets, and to a lesser extent - stockings with whitefish larvae (348 fish/ha) and autumn fry (160 fish/ha) made in 1968, although these could have affected the yields only in 1971-1972.

The highest whitefish catch obtained from Lake Gołdopiwo in 1978 (14133 kg; 16.4 kg/ha) could have resulted from the first stockings with summer fry made in 1972 and 1973 (133 and 122 fish/ha), and some stockings with autumn fry (15 and 34 fish/ha), as well as very high stocking with larvae in 1972 (1855 fish/ha).

Stockings performed in Lake Gołdopiwo in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	19	348 - 10435	2740
Summer fry	5	7 - 870	289
Autumn fry	4	15 - 160	86

Next period of very high yields of whitefish took place in Lake Goldopiwo in 1982-1986 (annual mean: 9444 kg, 10.9 kg/ha). It was due to the highest in the history of this lake release of summer fry in 1979 (870 fish/ha) and two very high stockings of larvae in 1978 and 1981 (10435 and 7480 fish/ha respectively). Since 1980 the lake was stocked exclusively with whitefish larvae. Landings of this fish decreased since 1987, with a noticeable drop in 1992-1995, notwithstanding high stocking rates used in 1989 and 1990 (5526 and 4174 larvae/ha). Effectiveness of stocking with the larvae in 1981-1991, calculated based on the landings in 1985-1995, amounted to 597 fish/kg (tab. 2) and was only slightly higher than the recalculated theoretical effectiveness estimated for the whole period (tab. 1).

LAKE MIELNO

Whitefish caught in Lake Mielno in 1960-1970 originated exclusively from stockings with autumn fry, performed in 1956-1966. During this period, 97 fish fry were needed to produce 1 kg of the catch (tab. 2).

For a number of subsequent years Lake Mielno was subject to both whitefish and peled management. The yields of the two species, reaching 24.6 kg/ha in 1974 and 25.4 kg/ha in 1978, were the highest ever recorded in Polish lake fisheries.

The price of whitefish and peled is exactly the same. The two species are also seldom distinguished by the fishermen. Due to this they are often reported together, either as whitefish or as peled. Hence, it is impossible to establish yields of either of these species in Lake Mielno, so they were analysed as one.

In the period 1970-1986 Lake Mielno was stocked with summer fry at very high rates (1315 fish/ha on the average), used simultaneously with high rates of autumn fry (684 fish/ha on the average). Also the yields were the highest in this period, but it is impossible to state which of the two forms of the stocking material was more

Stockings performed in Lake Mielno in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	11	413 -10526	3016
Summer fry	15	17- 3445	822
Autumn fry	15	41 - 1924	666

TABLE 2

Real effectiveness of stocking with whitefish larvae, summer and autumn fry, calculated for some lakes in the periods when there was only one kind of the stocking material used

Lake Kind of the stocking material	Years of stocking Years of catches	Total number of fish stocked Total catch in kg	Number of stockings	Mean stocking rate (number of fish) Mean catch in kg	Mean stocking rate fish/ha Mean yield kg/ha	Effectiveness of stocking fish/kg of commercial catch
Gołdopiwo larvae	1981-1991 1985-1995	25 556 400 42 833	8	3 195 800 3894	3705 4.51	597
Wigry larvae	1972-1983 1975-1986	10 955 000 55 516	11	995 909 4626	470 2.18	197
Rospuda larvae	1967-1991 1970-1994	8 711 000 50 792	18	483 950 2032	1416 5.95	172
Isąg summer fry	1977-1985 1981-1989	4 189 400 22 867	9	465 488 2541	1176 6.42	183
Mielno autumn fry	1956-1966 1960-1970	1 662 000 17 085	6	277 00 1553	764 4.28	97
Łańskie autumn fry	1958-1968 1962-1972	1 558 000 23 826	10	155 800 2176	149 2.08	63
Maróz autumn fry	1951-1965 1954-1968	1 352 000 12 345	13	104 000 823	313 2.48	110
Pluszne autumn fry	1952-1971 1954-1973	3 736 000 26 806	16	233 500 1340	258 1.48	139
Wulpińskie autumn fry	1955-1965 1958-1968	561 000 11 405	5	112 200 1037	159 1.47	49
Szeląg Duży autumn fry	1960-1966 1963-1969	585 000 4 737	5	117 000 677	195 1.13	123
Isąg autumn fry	1955-1966 1959-1969	456 000 1800	6	76 000 164	192 0.41	253

effective. Whitefish catches commenced to decrease since 1982; this might have been connected with decreasing stockings with autumn fry. After 1988, notwithstanding regular stockings with larvae which had started two years earlier (1283 larvae/ha on the average), catches decreased sharply, reaching in 1993-1994 as low levels as 0.2-0.4 kg/ha.

Since 1978 Lake Mielno was regularly stocked with vendace larvae, the stocking rates being from 12430 to 35860 larvae/ha (22650 larvae/ha on the average). Vendace catches amounted in 1985-1987 to 12254 kg on the average (33.8 kg/ha annually). In the last period (1988-1994) mean annual yield of vendace amounted to 3207 kg (8.7 kg/ha).

Notwithstanding very high yields achieved during intensive stockings with summer and autumn fry, from an economic point of view Lake Mielno is in reality characterised by an unfavourable index of stocking effectiveness (tab. 1).

LAKE ŁAŃSKIE

The first regular stockings with whitefish were made in Lake Łańskie in 1956-1968. Only autumn fry was stocked. Stocking rates were from 48 to 379 fish/ha (149 fish/ha on the average). Effectiveness of these stockings, calculated based on the yields in 1962-1972 (which amounted on the average to 2166 kg i.e. 2.08 kg/ha annually) was 63 autumn fry per 1 kg of whitefish catch (tab. 2).

The highest whitefish landings from Lake Łańskie were recorded in 1975-1978 (8190 kg and 7.85 kg/ha on the average), and it would be possible to ascribe these landings to the first stockings with summer fry made in 1971-1975 (from 37 to 179 fish/ha), but there was also one stocking with whitefish larvae (768 fish/ha) and one with autumn fry (240 fish/ha) made in the same period. These two stockings make it impossible to conclude on the effectiveness of stocking with summer fry.

For the next six years (1976-1981) there were no whitefish stockings in this lake, this being well noticeable in the catches of 1983 (0.9 kg/ha). Stocking with summer fry was again undertaken in 1982, and since 1985 there were regular stockings made with whitefish larvae. Notwithstanding this, whitefish catches decreased since 1986, reaching as little as 0.1 kg/ha in 1994. On the other hand, vendace catches increased considerably in this time. In 1985-1994 average annual landings of vendace amounted to 20325 kg i.e. 19.5 kg/ha.

Stockings performed in Lake Łańskie in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	10	96 - 4221	1363
Summer fry	13	37 - 384	159
Autumn fry	3	48 - 240	120

LAKE MAMRY PŁN.

In 1967-1994 Lake Mamry Płn. was sporadically stocked. The highest whitefish landings of 1974 (8147 kg or 3.0 kg/ha) and 1975 (10906 kg or 4.0 kg/ha) could have been related to two stockings with summer fry made in 1970 (297 fish/ha) and 1972 (44 fish/ha), as well as the two low stockings with autumn fry made in the same years (4 and 8 fish/ha respectively). Effectiveness of these stockings was 48 summer fry and 1.5 autumn fry per 1 kg of the catch obtained in 1974-1975. On the other hand, however, a similar stocking with summer fry made in 1979 (2598 fish/ha) had no effect on the catch whatsoever. On the contrary, 1983 and 1984 were characterised by the lowest landings of whitefish (only 27 and 353 kg respectively). In 1988-1991 whitefish landings increased slightly (1693 kg or 0.62 kg/ha on the average), to decrease again in 1992-1994 (to 612 or 0.22 kg/ha on the average), this decrease being accompanied by a similar drop in vendace landings (to 11943 viz. 4.4 kg/ha annually on the average).

Stockings performed in Lake Mamry Płn. in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	5	37 - 922	325
Summer fry	4	4 - 297	151
Autumn fry	4	4 - 11	6

LAKE MARÓZ

Whitefish was released to Lake Maróz for the first time in 1951. Until 1965 only autumn fry was used. Effectiveness of these stockings was 110 fish per 1 kg of commercial catch (tab. 2).

The first very high landings of whitefish were recorded in 1970 (4788 kg viz. 14.4 kg/ha) and 1971 (5428 kg or 16.3 kg/ha), following the first stockings with larvae made in 1966, 1968 and 1969 (2600, 887 and 355 larvae/ha), and stockings of 1968 made with summer fry (115 fish/ha) and of 1966 made with autumn fry (159 fish/ha). 1974-1978 was the period of the highest whitefish landings (5755 kg or 17.3 kg/ha annually). These high yields resulted from the stockings made with summer fry in 1971, 1973 and 1974 (300, 60 and 630 fish/ha respectively) as well as one stock-

Stockings performed in Lake Maróz in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	13	150 - 12481	4042
Summer fry	20	24 - 2286	413
Autumn fry	3	30 - 662	331

ing with autumn fry (300 fish/ha) made in 1970. Since 1982, notwithstanding earlier intensive stockings with summer fry, whitefish catches decreased noticeably. In 1982-1990 average annual catches amounted to 1508 kg (4.5 kg/ha). In subsequent years even the highest stocking rates (2286 summer fry/ha and 3610 larvae/ha in 1986, and 12480 larvae/ha and 429 summer fry/ha in 1988) did not affect the catches which showed a decreasing trend, and in 1991-1994 amounted on the average to 500 kg annually (1.5 kg/ha).

LAKE WIGRY

In Lake Wigry there were no stockings made in 1952-1967, but whitefish was always caught, suggesting its effective natural reproduction.

Regular stockings with whitefish larvae beginning from 1968 resulted in a noticeable increase of commercial catch. The highest whitefish landings were recorded in 1975-1980 (6968 kg or 3.29 kg/ha annually on the average); they can be related to the stockings made in 1972-1977 (average annual rates: 792.5 thousand larvae i.e. 374 larvae/ha). Effectiveness of stockings made in the period 1972-1983, calculated based on the catches of 1975-1986, amounted to 197 larvae per 1 kg of the catch (tab. 2).

In 1979-1988, notwithstanding considerable increase of average stocking rates (to 1462.5 thousand larvae annually, viz. 690 larvae/ha) and two additional stockings

Stockings performed in Lake Wigry in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	24	3 - 1511	420
Summer fry	2	71 - 76	73

with summer fry, whitefish landings systematically decreased beginning from 1981. In 1987-1994 their average annual level was 242 kg viz. 0.11 kg/ha, dropping in the last years to several kilograms annually.

In 1986 exceptionally high catch of vendace was recorded in Lake Wigry: 32486 kg or 15.3 kg/ha. Vendace catches remained on a high level also in the subsequent years, amounting on the average to 13318 kg viz. 6.29 kg/ha annually.

LAKE PLUSZNE

Until 1970 Lake Pluszne was stocked with autumn fry only. In 1954-1973 catches of whitefish amounted on the average to 1340 kg annually (1.48 kg/ha). The effectiveness of stocking was 139 fish in summer fry stage per 1 kg of commercial catch (tab. 2). A noticeable increase of whitefish landings in the period 1974-1980 (on the average 5190 kg or 5.75 kg/ha annually) was due to stockings with summer fry, which began in 1971, and to high stocking rates with autumn fry used in 1969-1973. After 1978 there were no stockings made with autumn fry, but only with summer fry. Since 1984 also stockings with larvae were introduced. Whitefish landings in 1981-1992 amounted on the average to 1374 kg annually (1.52 kg/ha), i.e. they decreased to the level recorded in 1954-1973, when the lake was stocked with autumn fry only. Subsequent decrease of whitefish landings took place in the last two years of the analysed period (on the average to 678 kg or 0.75 kg/ha), but exceptionally high landings of vendace were recorded in 1994: 21853 kg or 24.2 kg/ha.

Lake Pluszne is characterised by one of the worst indices of stocking effectiveness (tab. 1), meaning that a lot of fish were needed to produce 1 kg of catch.

Stockings performed in Lake Pluszne in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	11	55 - 4495	1306
Summer fry	19	12 - 981	330
Autumn fry	10	6 - 597	232

LAKE ŚNIARDWY

Until 1967 whitefish was sporadic in Lake Śniardwy, but in 1968-1978 its average annual landings amounted to 373 kg. The highest catches were recorded in the subsequent years 1981-1987 (on the average 5767 kg annually). The lake was stocked only once with whitefish larvae released at a rate of 2 million fish (about 200 larvae/ha) in 1983, a year after commercial whitefish landings exceeded 10 tons. More than 10 tons of whitefish were caught also in 1986, but although apparently this catch may be related to the mentioned stocking, it would be a mistake to consider it as resulting from stockings only. Whitefish catches began to increase in Lake Śniardwy already since 1979, when this fish was released into the neighbouring interconnected lakes of the Great Mazurian Lakes complex. It is well known that whitefish can migrate for considerable distances, so it is not difficult to explain its appearance in Lake Śniardwy.

In mid-eighties the intensity of stockings with whitefish decreased noticeably in the majority of lakes. Landings of whitefish in Lake Śniardwy show a downward trend since 1988. This confirms the suggestion that migrating whitefish gather in this lakes.

Stockings performed in Lake Wulpińskie in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	8	283-3113	1134
Summer fry	19	35 - 1344	373
Autumn fry	5	21-282	131

LAKE ROSPUDA

The lake was stocked for the first time in 1953 with autumn fry (79 fish/ha), and whitefish appeared in the catch in the sixties, the level of its landings being from a few to several kg per ha.

Another stocking was performed in 1967, with whitefish larvae (878 fish/ha). Thus, whitefish landings until 1969 have probably originated from natural reproduction. Regular stockings with whitefish commenced in 1974. The highest catch

(8717 kg, 25.5 kg/ha) was obtained in 1982. Average annual landings amounted in the whole period to 1816 kg (5.32 kg/ha) and were a result of 20 stockings with whitefish larvae, the stocking rates being from 293 to 3219 fish/ha (1450 fish/ha on the average).

Effectiveness of stockings amounts on the average to 172 larvae per 1 kg of commercial catch and is the highest from among all lakes (tab. 2).

LAKE WULPIŃSKIE

Whitefish caught in Lake Wulpińskie in 1958-1968 (1037 kg annually or 1.47 kg/ha on the average) originated from 5 stockings with autumn fry performed in 1955-1965. The effectiveness of stocking amounted in this period to 49 fish/kg (tab. 2). The two periods of noticeably higher whitefish landings from Lake Wulpińskie are: 1969-1971 (annual average: 2779 kg or 3.93 kg/ha) and 1974-1982 (3076 kg or 4.35 kg/ha).

The first period of high catches can be related to stockings with summer and autumn fry, the second - to stockings with summer fry and whitefish larvae. Stockings with autumn fry came to an end in 1978, with summer fry - in 1982, and with larvae - in 1984. There were no noticeable effects of very high stocking rates with summer fry in 1979-1982 (annual average 495 fish/ha), the reasons of this being quite unclear.

Whitefish landings show a downward trend since 1982, while total lack of stockings becomes noticeable since 1986. Re-introduction of stockings with summer fry in 1988-1993 (390 fish/ha annually) did not result in an increase of catches in 1991-1994 (0.1-0.4 kg/ha). In 1990, 1991 and 1994 whitefish landings from Lake Wulpińskie exceeded 8 kg/ha, this being a noticeable increase compared to the previous years (1983-1989).

Stockings performed in Lake Wulpińskie in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	8	283-3113	1134
Summer fry	19	35 - 1344	373
Autumn fry	5	21-282	131

LAKE SZELAĞ DUŻY

Average annual whitefish landings from Lake Szeląg Duży in 1963-1968 (567 kg or 0.95 kg/ha) resulted from stockings with autumn fry in 1960-1965. The effectiveness of stocking was not satisfactory, however, as the respective index amounted in this period to 123 fish/kg (tab. 2). Since 1967 the lake was simultaneously stocked with larvae and autumn fry, and since 1972 - summer fry was added as well.

Whitefish landings in 1975-1976 (2833 kg or 4.73 kg/ha on the average) could have originated from all forms of the stocking material released into the lake in the preceding period. Also in the subsequent years 1977-1979 (average landings 2745 kg or 4.58 kg/ha) and 1983-1984 (average landings 2835 kg or 4.73 kg/ha) it is not possible to distinguish which form of the stocking material was the most effective. The highest landings of whitefish, noted in 1987 (6314 kg or 10.54 kg/ha), were probably the result of very high stocking rates with summer fry in 1982-1984 (1390 fish/ha on the average), although even in this case it is not possible to exclude the effects of a single stocking with autumn fry in 1982 (412 fish/ha).

In the period 1967-1994 this lake was characterised by the highest costs of stocking when recalculated per 1 kg of commercial catch (tab. 1).

Stockings performed in Lake Szeląg Duży in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	15	300 - 2462	1115
Summer fry	16	33 - 1503	573
Autumn fry	5	83 - 668	393

LAKE ISAĞ

Level of whitefish catches in Lake Isağ recorded until 1969 (164 kg annually) was related to the first irregular stockings with autumn fry, carried out in 1955-1966, with stocking rates varying from 68 to 354 fish/ha. Effectiveness index for these stockings was the highest from among all lakes under study, amounting to as many as 253 fish needed per 1 kg of commercial catch (tab. 2).

In 1967-1976 Lake Isag was regularly stocked with whitefish larvae, and sometimes also summer and autumn fry were released. Noticeable increase of the landings occurred in 1974 (2021 kg or 5.11 kg/ha); most probably this catch resulted from a very high stocking with autumn fry performed in 1970 (821 fish/ha), although the effect of simultaneous stockings with larvae cannot be excluded. The highest whitefish landings from Lake Isag were recorded in 1981-1982 (on the average 4883 kg or 12.34 kg/ha annually). High landings persisted for 15 years, until 1988 (on the average 2466 kg or 6.23 kg/ha). In 1976-1987 Lake Isag was stocked each year with summer fry, so it was possible to calculate the effectiveness of this material. Based on the catches obtained in 1981-1989, effectiveness of stockings with summer fry amounted to 183 fish needed to produce 1 kg of commercial catch (tab. 2). Since 1989 whitefish catches noticeably decreased notwithstanding earlier stockings with larvae and summer fry, so whitefish landings in 1993-1994 were only 33 kg per year. This was probably caused by low intensity of exploitation in this period.

Stockings performed in Lake Isag in 1967-1994

Stocking material	Number of stockings	Stocking rates fish/ha	
		from-to	mean
Larvae	10	253 - 2780	1643
Summer fry	15	178 - 2230	1182
Autumn fry	2	108 - 821	465

DISCUSSION

Stocking policies in the twelve lakes under study and the period 1967 - 1994 differed considerably. Lake Śniardwy was stocked with some whitefish larvae only once in the whole period. Lake Rospuda was stocked exclusively with larvae, and whitefish larvae were systematically released to Lake Wigry, but in the latter case summer fry was also released although only twice. The remaining 9 lakes were stocked with all three types of the stocking material, and stocking rates varied considerably, so it was not possible to reliably calculate the effectiveness of this practice for particular types of the stocking material.

Suitability of larvae used to stock the lakes has been questioned for a number of years, this resulting in working out methods of rearing whitefish stocking material in cages (Bryliński et al. 1979, Dembiński and Falkowski 1983, Mamcarz and Nowak 1987).

Finnish lakes are almost exclusively stocked with autumn fry reared in ponds (Salojarvi 1992c), while stocking with whitefish larvae had been stopped already at the beginning of the seventies due to their questionable effectiveness. In the group of the discussed 12 lakes, the best effects of stockings were certainly noted in lakes Rospuda and Wigry (tab. 1 and 2), in which whitefish larvae were used almost exclusively. It can be assumed that natural reproduction of whitefish in these lakes is still fairly effective, and stockings with larvae only enhance natural population, giving positive results in form of commercial landings. It is, of course, possible to conclude that whitefish landings in these lakes are related exclusively to stockings with larvae, but in this case it would be necessary to verify common views on the suitability and effectiveness of this stocking material. Stockings with larvae obviously enhanced natural reproduction also in Lake Gołdopiwo. In addition to these three lakes, also in Lake Mamry Płn. natural reproduction of whitefish must play an important role, as can be judged from stocking rates and intensity. Lakes Gołdopiwo and Mamry Płn. show only a slightly worse index of stocking effectiveness than lakes Rospuda and Wigry (tab. 1), this being the result of low stocking rates with bigger fish (fry).

Index of stocking effectiveness, expressed as the number of autumn fry needed to produce 1 kg of commercial catch, amounted in lakes Szczęg D., Mielno, Pluszne, Isąg and Wulpińskie to from 54.6 to 34.5 (tab. 1), and exceeded the limits of economic profitability of whitefish production despite high yields from the unit of lake area. High costs of whitefish production in these five lakes were due to high stocking rates, mostly with summer and autumn fry.

Stocking rates used in 1967-1994 in the analysed lakes ranged from 3 to 12480 fish/ha in the case of larvae, from 4 to 3445 fish/ha in the case of summer fry, and from 4 to 1924 fish/ha in the case of autumn fry. These ranges suggest that there was no consistent stocking policy, and that stocking rates depended on the availability of the material rather than on consistent planning.

It has been often stressed that in the case of fish with short life span, regularity of stockings is very important (e.g. Szczerbowski 1977) and affects the results of fishery management.

With the exception of lakes Śniardwy and Mamry Płn., the lakes under study were stocked rather systematically, but the stocking material used varied considerably, and this must have had a negative effect on the overall results of this practice.

The effectiveness of stocking with whitefish larvae, summer and autumn fry, calculated in some lakes and for the periods when only one type of stocking material was used (tab. 2), seems economically profitable only when larvae are used. Values obtained for autumn fry, ranging from 49 to 253 fish needed per 1 kg of commercial catch, refer to earlier years which have not been analysed in this study. Unsatisfactory effectiveness of stockings with this type of material was at that time due to an unrealistic protective size in force for this fish species, which amounted to 1 kg (Rożniakowski 1967, Szczebowski 1970), but it can also be assumed that stocking rates used then were too high - they amounted in particular lakes to from 149 to 764 fish/ha on the average (tab. 2). In lake Śremskie, in a comparable period 1953-1977, only 76 fish/ha were stocked (Budych and Mastyrński 1978), and the effectiveness of stocking was 17 fish in autumn fry stage to produce 1 kg of commercial catch, the practice being very effective.

From among the lakes under study, only in Lake Isąg it was possible to distinguish a 9-year period in which stockings with summer fry were responsible for the level of whitefish landings (tab. 2). Notwithstanding high yields (6.42 kg/ha), economic effects of stockings seem questionable as 183 fish (about 37-45 when recalculated to standard autumn fry) were needed to produce 1 kg of commercial catch.

Effectiveness of stockings calculated by Szczebowski (1977) for 96 lakes of north-west Poland (in the period 1953-1972), recalculated to standard autumn fry, ranged from 12 to 438 fish/kg (on the average 29 fish/kg). In 73 lakes of north-west Poland (years 1951-1973) it also varied within a wide range of from 3 to 497 fish/kg, but the mean value was much lower (9 fish/kg).

Węgliński and Marciak (1980) examined 14 lakes of Varmia and Mazuria which were stocked with autumn fry of whitefish. Data presented by these authors were from 3 to 722 fish/kg, on the average 96 fish/kg. These authors calculated that in 11 lakes stocked with summer fry of whitefish, the effectiveness of stocking ranged from 27 to 1268 fish/kg (259 fish/kg on the average). When recalculated to standard autumn fry, these values correspond to from 7 to 317 fish/kg (65 fish/kg on the average). In lakes stocked by Grzywacz (1981) with summer fry of whitefish, at stocking rates from 120 to 784 fish/ha, the effectiveness of stocking varied from 76 to 472

fish/kg (147 fish/kg on the average), corresponding to 19-118 standard autumn fry/kg (or 37 fish/kg on the average).

A number of works have been devoted to whitefish management in Finland (Salojärvi 1988, 1990, 1991, 1992a, b, c, 1994). They all underlined that the effectiveness of stockings varied within a wide range (from 4 to 500 fish/kg), with the mean values being 16-18 fish/kg. Average effectiveness of stockings with standard autumn fry, calculated for 106 Polish lakes in 1967-1994 (Falkowski and Wołos 1998), was 20 fish/kg, viz. only a little worse than in Finnish lakes.

Stocking rates used for autumn fry in Finnish lakes (lakes Oulujärvi, Sotkamo and Inari) ranged from a few to a few tens of fish/ha, and in the paper devoted to Lake Kiautajärvi (Salojärvi 1992b), the author suggested that due to economic reasons the stocking rates should not be higher than 10 fish/ha. In other lakes (Salojärvi 1988, 1991) they were much higher (100-200 fish/ha), but never as high as in Poland.

There are no data whatsoever on the intensity of whitefish exploitation in the discussed 12 lakes, and this limits the possibility of assessing whether the fishery management conforms to the standards of rationality, as well as to determine the effectiveness of stockings in a reliable way.

Drastic decrease of whitefish landings recorded in 1990-1994 in lake fishery enterprises corresponds to the period of economic and political transformation, in which a number of negative factors and conditions could have been observed (Leopold 1994, Leopold and Wołos 1995). In the case of whitefish, this decrease is not due exclusively to the decrease in stocking rates. In almost all lakes stockings performed in the late eighties seem totally ineffective notwithstanding a variety of the stocking material used. It seems that the observed drop in fish landings was related to very low exploitation intensity in this period. Vendace landings from such lakes as Łańskie, Pluszne, but also Mielno, Wulpińskie, Wigry and Mamry Płn. were also low in this period, confirming the suggestion on improper exploitation. They also negate claims that environment quality deteriorated to the extent affecting effectiveness of stocking with whitefish. As regards the discussed 12 lakes, only Lake Maróz deteriorated in the recent times due to long-term inflow of pollutants from the catchment basin.

Whitefish landings from an unstocked Lake Śniardwy, recorded in 1982 and 1986, suggest high productive potential for this fish, on condition that stockings are carried out according to a proper programme. In the remaining lakes, stocking

„policy” should be verified. Results presented in this paper reveal considerable management difficulties when the manager tries to couple intensive whitefish and vendace management in the same lake. Vendace, which is by nature a much more catchable fish than whitefish, causes that whitefish is not caught with appropriate intensity. Also financial issues are important in this respect. Fishery exploitation not adapted to the stocking rates results in the fact that stockings with whitefish become useless from an economic point of view.

If whitefish is to be a desired species in the discussed lakes, for each of them there should be an overall management strategy worked out based on the experience and data gathered so far. This refers most of all to the selection of an appropriate type of the stocking material, stocking rates, as well as dates and methods of fish release to the lake. These are basic criteria of a rational management and their fulfilment should improve the situation in the most valuable Polish lakes with whitefish.

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STRESZCZENIE

EFEKTYWNOŚĆ GOSPODAROWANIA SIEJĄ (*Coregonus lavaretus* L.) W JEZIORACH O NAJWYŻSZYCH ODŁOWACH TEGO GATUNKU W POLSCE

W pracy na podstawie danych gospodarczych prześledzono wysokość odłowów, zarybień i ich efektywność w grupie 12 jezior o najwyższych w Polsce odłowach siei na przestrzeni lat 1967-1994. Ocenie poddano zarówno używane w tym okresie do zarybień rodzaje materiału jak i wysokość stosowanych dawek zarybieniovych, które w przypadku wylęgu wahały się od 3 do 12480 szt./ha, narybku letniego od 4 do 3445 szt./ha i narybku jesiennego od 4 do 1924 szt./ha. Średnia efektywność zarybień, wyrażona za pomocą narybku jesiennego przeliczeniowego wynosiła w poszczególnych jeziorach od 2,35 do 55,66 szt./kg. Zarybianie większości badanych jezior kilkoma rodzajami materiału zarybieniovego jednocześnie jak również brak danych o intensywności eksploatacji siei, utrudniają przeprowadzenie rzetelnej oceny efektywności produkcji siei w tych jeziorach. Stwierdzony gwałtowny spadek odłowów siei w ostatnich latach wiąże się nie tylko ze znacznym zmniejszeniem zarybień ale wynika również z niskiej intensywności eksploatacji.

ADRES AUTORA:

Instytut Rybactwa Śródlądowego
Zakład Rybactwa Jeziorowego
10-719 Olsztyn-Kortowo
ul. Oczapowskiego 10