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WHITEFISH, *COREGONUS LAVARETUS* (L.), IN THE FISHERIES MANAGEMENT OF LAKE GOŁDOPIWO (NORTHEASTERN POLAND) FROM 1950 TO 2005

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ABSTRACT. The aim of this study was to analyze the growth rate of whitefish, *Coregonus lavaretus* (L.), in Lake Gołdopiwo in the 1932-1999 period. The magnitudes of catches and stocking during the 1950-2005 period were also determined. Once the studied population reached the maximum density, the growth rate diminished distinctly but commercial catches remained at a very high level for the subsequent 21 years at an annual mean of 8181 kg, and 9.5 kg ha^{-1}. Throughout the entire study period, no significant relationship was noted between the magnitudes of catches and stocking. The cause of the collapse in whitefish exploitation in Lake Gołdopiwo must be sought for in disadvantageous changes in the environment and decreasing fisheries exploitation.

Key words: WHITEFISH, LAKE GOŁDOPIWO, GROWTH RATE, CATCHES, STOCKING, EXPLOITATION INTENSITY

INTRODUCTION

The whitefish, *Coregonus lavaretus* (L.), population inhabiting Lake Gołdopiwo played an important role in the fisheries in both an economic and reproductive sense. Lake Gołdopiwo was widely regarded as one of the most valuable whitefish spawning grounds in Poland (Gąsowska 1953). The history of whitefish exploitation in Lake Gołdopiwo extends back to 1880. This species began to be introduced to many lakes in 1879 in the region of then East Prussia (Wiese 1937). The stocking material originating from Middle and Eastern Europe consisted of several forms of the species that differed with regard to the number of gill rakers. The whitefish from Lake Selentersee had very few gill rakers, those from Lake Miedwie had a median number of them, and the fish from Lake Constance had either one or the other of the preceding types. The fish from the Curonian Lagoon and Lake Peipus had gill sieves that were dense with rakers

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(Wiese 1937, Gąsowska 1953, Kaj 1955, Szczerbowski 1970, Heese 1988, 1992, Himberg and Lehtonen 1995).

According to Wiese (1937), the stocking conducted from 1905 to 1917 nearly exclusively with material from Lake Peipus had a decisive impact in shaping the populations of the lakes in East Prussia. In her studies of the impact stocking material type had in 14 Mazurian lakes (northeast Poland), Gąsowska (1953) noted variation in overall body shape, snout build, and the number of gill rakers. According to this author, no basis existed for designating a typical Mazurian lake whitefish (Gąsowska 1953). Nevertheless, it can be hypothesized, similarly to Szczerbowski (1970), that in the lakes of Warmia and Mazury the most commonly occurring whitefish, which have dense gill rakers, are those identified as *Coregonus lavaretus generosus*. Among researchers investigating the Lake Gołdopiwo whitefish population, the prevailing opinion is that the fish there with dense gill rakers are representatives of *Coregonus lavaretus maraenoides* (Wiese 1937, Gąsowska 1953, Szczerbowski 1970, Falkowski 1991).

Initiated in 1966, the introduction of peled, *Coregonus peled* Gmelin, to lakes inhabited by whitefish led to the joint, long-term exploitation of these two species and the resulting unintentional hybridization of them, which has further complicated the study of the types of whitefish in the lakes of Warmia and Mazury (Mamcarz 1987, Falkowski and Łuczyński 1988, Łuczyński et al. 1992). The records in management logs confirm that peled was never introduced into Lake Gołdopiwo.

Wiese (1937) reported that during the period of intense whitefish stocking of East Prussian lakes, material originating from Lake Piepus was released into Lake Gołdopiwo 14 times. In later years (1922-1934), when a total of 25 million whitefish individuals were stocked into the Prussian lakes, Gołdopiwo was already the main spawning grounds in this region. The aim of the present work is to present the growth rate and long-term exploitation history of whitefish in Lake Gołdopiwo and to determine the cause of the total collapse of the whitefish fishery in recent years.

STUDY AREA

Lake Gołdopiwo, with a surface area of 862.5 ha, is located in the Mazurian Lake District (northeastern Poland) in the Pregoła River basin. The average depth of the lake is

11.8 m and the maximum is 26.9 m (one central deep). The lake's shoreline is not highly developed (development index – 1.40) and it has a well-developed near-shore bank.

The lake was fished commercially by the State Fisheries Company in Giżycko from 1950 to 1993 and has been under the management of the Polish Anglers' Association since 1994.

MATERIALS AND METHODS

The data for the current analysis of catch and stocking magnitudes in the 1950-2005 period were obtained from fisheries logs. The growth rate of whitefish from Lake Gołdopiwo is based on information from the literature and the authors' own studies conducted in 1999 on a sample of 109 individuals. Fish age was determined by reading scales that had been collected from above the lateral line between the dorsal and adipose fins. All of the back-calculations were performed on the oral side of the scales using the modified Einar Lea formula (Opuszyński 1979):

$$L_n = C + \frac{S_n}{S} - (L - C)$$

L – total body length;

L_n – reconstructed body length in the n^{th} year of life;

S – total scale radius length;

S_n – scale radius length in the n^{th} year of life;

C – constant value, corresponding body length at which the scales were deposited.

In the calculations performed, the value of C was 47.5 mm, which corresponds to the total whitefish length at the moment the third to fifth lines of scales are deposited above and beneath the lateral line (Łuczyński et al. 1988). Weighted means were used to calculate the mean growth rate.

Whitefish catches and stocking were analyzed with the time row method using a 2-degree trend for catches in the 1950-2005 period and a 4-degree trend for stocking at a probability boundary limit of $P < 0.05$. Since stocking began in 1958 and was concluded in 2001, the calculation of the trend function was limited to the 1958-2001 period. The relation between overall catches and those of whitefish were calculated using curvilinear correlation and a third-degree variable at a probability boundary limit of $P < 0.05$. Correlation calculations were applied to test the dependence of whitefish

catches on stocking magnitude, in consideration of 2, 3, and 4 year lag times between stocking and catches at a probability boundary limit of $P < 0.05$. Since stocking was performed with various types of material (larvae, summer and fall fry), in order to compare the stocking performed in particular years the numbers of summer and fall fry released were recalculated as larvae assuming that 66.6 hatch individuals = 4 summer fry individuals = 1 fall fry individual as in Szczerbowski (1977).

RESULTS

GROWTH RATE OF BODY LENGTH AND WEIGHT

Analyses of whitefish growth in Lake Gołdopiwo have focused more frequently on total body length based on back-calculations from scale readings and direct measurements than they have on the growth rate of total body weight. The growth rates of total body length of whitefish from year classes I – VI reported by Wiese (1937) were the highest and differed substantially from the results published by all other investigators working in the 1949-1999 period (Fig. 1). Only the results from the studies by Szczerbowski (1970) for age groups I – III and Falkowski (1991) for year classes I and II are similar to the values reported by Wiese (1937). The differences confirmed in mean total length growth in whitefish from year classes III – VI in studies performed from 1949 to 1999, although not substantial, do indicate irrefutably that the growth rate did clearly decrease.

The data in the literature regarding whitefish growth rate in Lake Gołdopiwo are not numerous and difficult to interpret due to the various ways in which they are presented (Table 1). Data from 1979 and 1999 that refer to the range of body weight variation in whitefish year classes IV – V are close to the results of Gąsowska (1953), who investigated just 14 individuals in 1951. The comparison of the current authors' own results with those of Wiese (1937) indicates a decided deceleration in the growth of body weight in particular years; however, it is not known whether Wiese's data on year classes IV – VII are mean values or if they refer to individual specimens. Szczerbowski (1970) investigated the growth rate of total body length and reported that not until the IX year class do some whitefish in Gołdopiwo attain a weight of 1200 g. Only two specimens collected in 1999 were older than six years; the 7+ female weighed 1067 g, while the 9+ female weighed 1527 g.

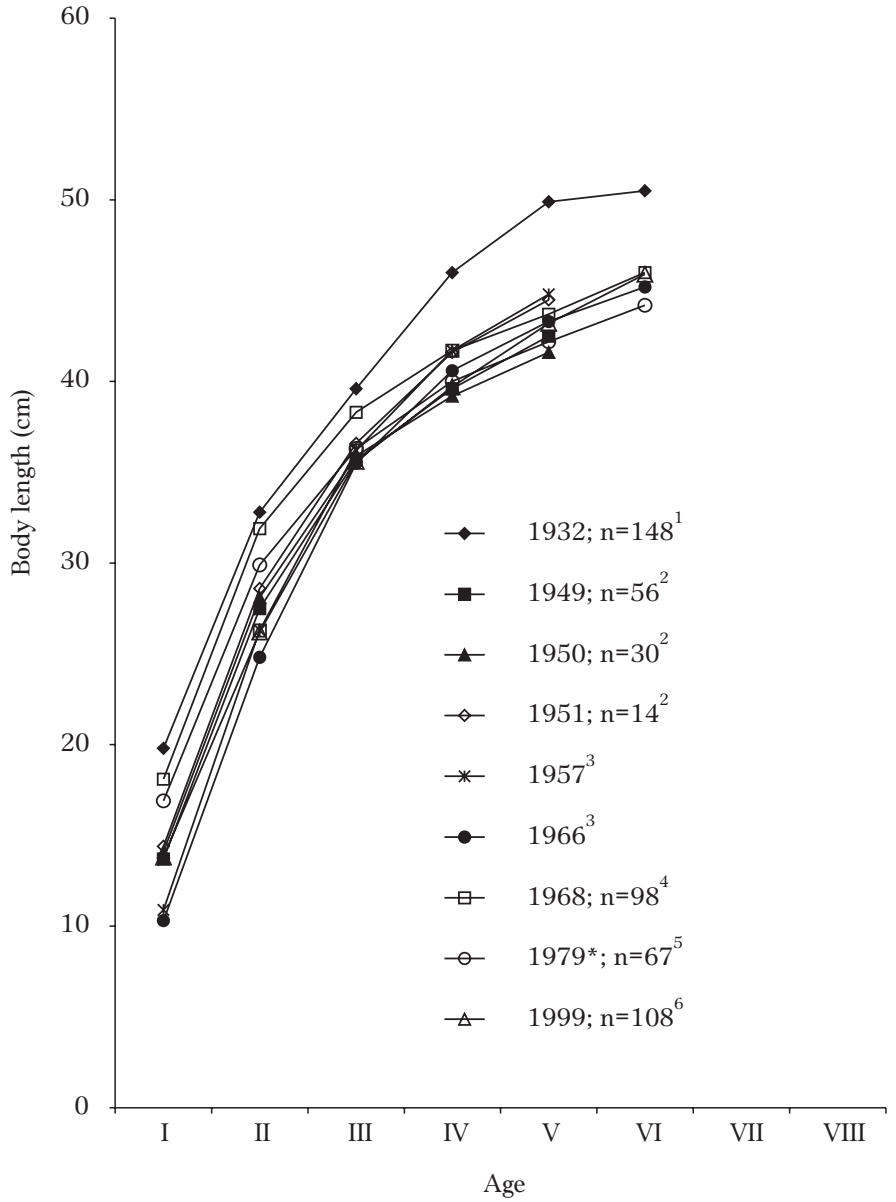

Fig. 1. Total body length growth rate (Lt in cm) of whitefish from Lake Gołdopiwo according to various authors in particular study years. *– data refer exclusively to female whitefish. Data according to: 1 – Wiese (1937), 2 – Gąsowska (1953), 3 – Marciak (1967), 4 – Szczerbowski (1970), 5 – Falkowski (1991), 6 – current study.

TABLE 1

Body weight growth rate of whitefish from Lake Gołdopiwo

Author, year of study	N	Age III range (g)	III mean	IV range (g)	IV mean	V range (g)	V mean	VI range (g)	VI mean	VII range (g)	VII mean
Wiese 1931	13	513-697	626	-	-	-	-	-	1150	-	1190
Wiese 1932	148	420-750	538	-	843	-	1111	940-1333	1096	942-1364	1172
Gąsowska 1951	14	-	-	460-610 510-710	-	490-650 570-925	-	-	-	-	-
Falkowski 1979[1]	67	-	-	450-890	608	570-940	701	620-1000	851	-	-
Falkowski 1999	108	393-545	470	582-673	615	583-829	702	622-1030	786	1067[2]	-

[1] *data refer only to female whitefish*
[2] *data refer to one individual*
- no data

COMMERCIAL WHITEFISH CATCHES

In the 1950-1965 period, the mean annual catch of whitefish was 1,704 kg (from 312 kg to 3673 kg) while the mean annual total catch was 26,894 kg (from 14,682 kg to 32,709 kg; Fig. 2). In the 1966-1986 period, the corresponding numbers were 8,191 kg of whitefish (from 3,073 kg to 14,133 kg) at an overall catch of 29,765 kg (from 15,788 kg to 44,853 kg). The highest whitefish catches in Lake Gołdopiwo were noted in 1978 at 14,133 kg (16.3 kg ha^{-1}). Since 1987 there has been a distinct decline in the magnitude of whitefish catches, and in the 1993-2000 period the mean annual catch was just 891 kg (from 122 kg to 1,926 kg), and since in 2001, when 40 kg were caught, whitefish did not occur.

WHITEFISH STOCKING

During the studied period, Lake Gołdopiwo was stocked 22 times with whitefish larvae, 9 times with summer fry, and 4 times with fall fry (Fig. 3). In the 1950-1967 period, the lake was stocked twice (in 1958 and 1961) with small quantities of larvae. In 1966-1986, when the highest whitefish catches were noted, the lake was stocked fairly regularly with larvae (13 times) and sporadically with summer and fall fry (4 times). In 1987-1993, when the decline in whitefish catches was already notable, the

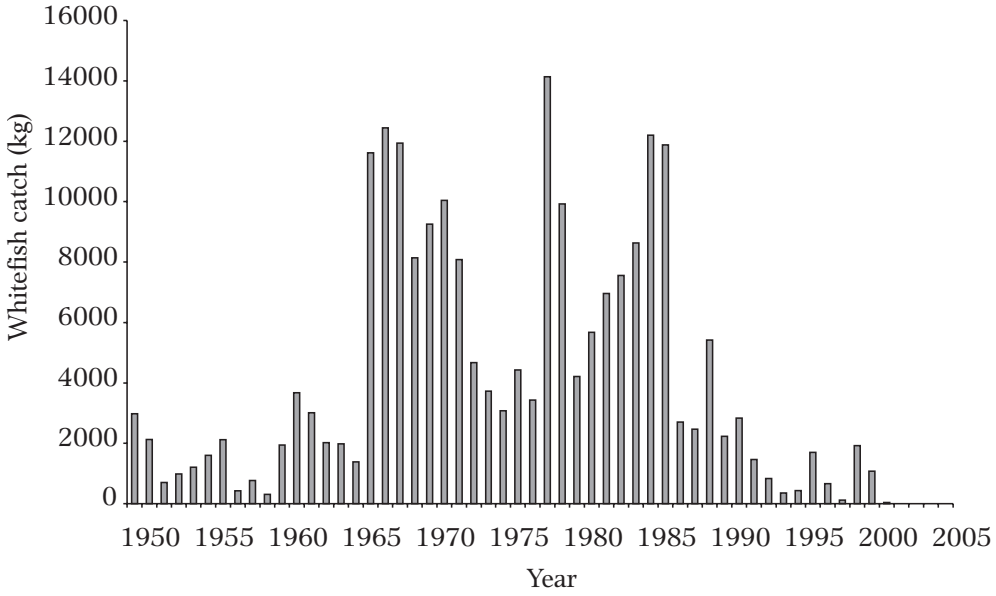

Fig. 2. Whitefish catches in Lake Gołdopiwo in the 1950-2005 period.

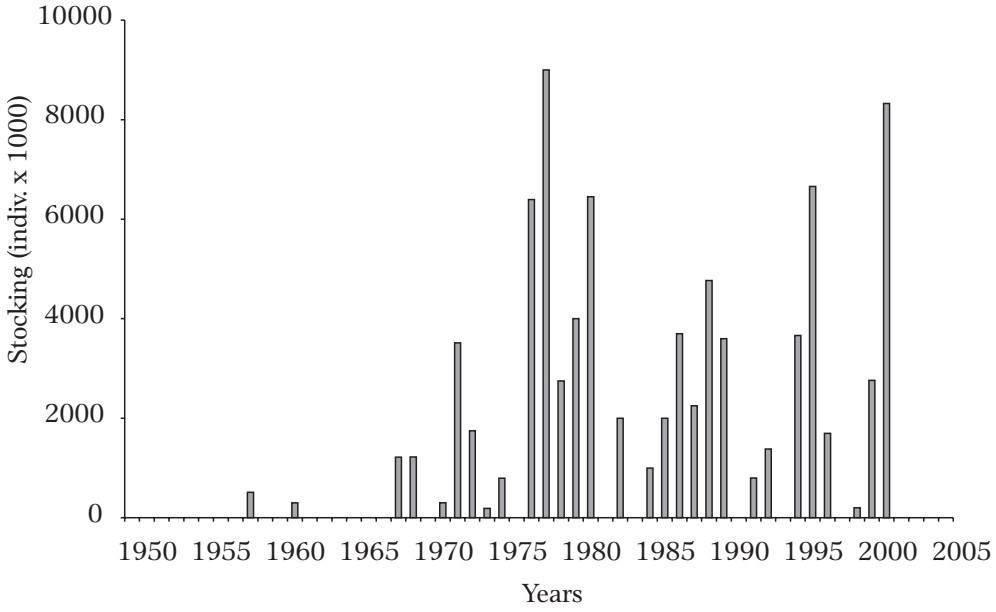

Fig. 3. Stocking Lake Gołdopiwo with whitefish larvae in the 1950-2005 period.

lake was stocked six times with larvae. During the 1994-2001 period, when catches of whitefish declined drastically, the lake was stocked twice with larvae and five times with summer fry. No whitefish stocking was conducted in the lake in the 2002-2005 period.

Correlation calculations performed between the stocking of whitefish and the catch magnitude of this species, in consideration of 2, 3, and 4-year time lags between catches and stocking, did not indicate a statistically significant relationship between the studied variables ($P > 0.05$). The comparison of stocking trends in 1958-2001 (Fig. 3) with catches in 1950-2001 (Fig. 2) indicates that in the first period from the mid 1970s increasing stocking was accompanied by increasing catches, while in the later period there was a distinct decline in catches despite increased stocking.

RELATIONSHIP BETWEEN EXPLOITATION INTENSITY AND WHITEFISH CATCHES

A statistically significant relationship was confirmed between total catches and whitefish catches in Lake Gołdopiwo ($R = 0.6821$, $P < 0.001$; Fig. 4). The curve indicates that as total catches increased, so did those of whitefish. Since 1991, a very distinct decline in total catches has been noted; the annual mean in 1991-2005 was 17.02 kg ha^{-1}, which was two times lower than the figure for the 1966-1986 period which was 34.51 kg ha^{-1}. Nevertheless, this provides no explanation for the disappearance of whitefish from the catches in the past four years.

DISCUSSION

The results of studies of the body length growth rates of whitefish inhabiting Lake Gołdopiwo in the 1932-1999 period have been analyzed by several authors. It must be borne in mind that the period during which research materials were collected, the total number of fish collected and the number of them in various year classes, the sex distribution in the sample studied, and, most significantly, the method applied for back-calculating growth rings and corrections for compensating for fish growth prior to the deposition of scales all have a significant impact on the results obtained. Each of the publications differed significantly with regard to each of the preceding points. The study material was collected in February 1932, in November 1949, 1950, 1951, 1968,

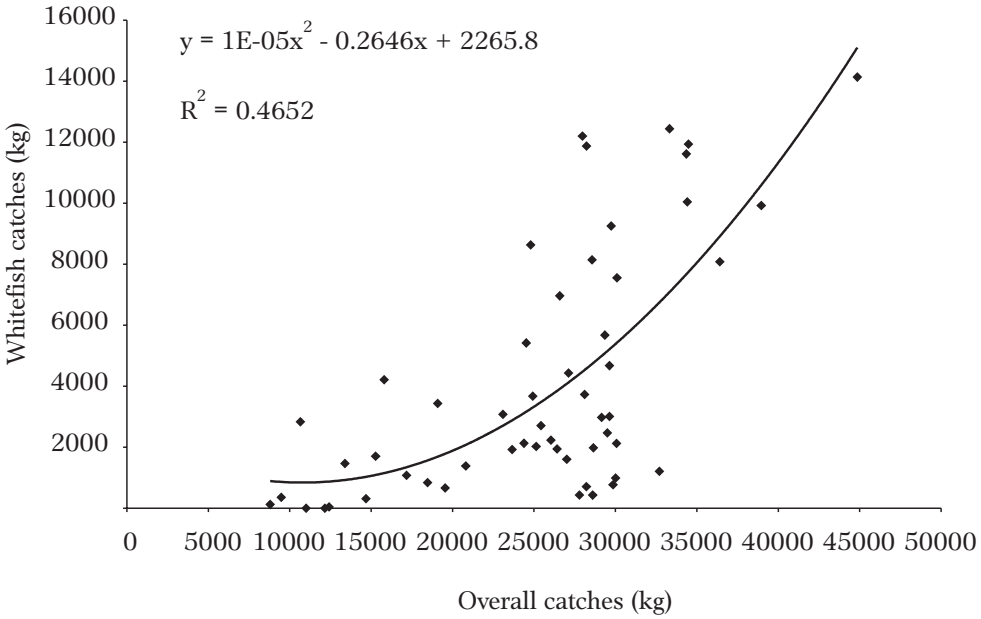

Fig. 4. Relationship between overall catches and whitefish catches in Lake Gołdopiwo.

and 1979, and October 1999. The number of individuals ranged from 14 to 148, while the number of them in the year classes was often insufficient. The sex distribution was proportional only in the work of Szczerbowski (1970) and in the current study. No information regarding study methodology is provided in the work by Marciak (1967).

The greater differences in body length growth in age groups I and II must be explained by the various methods applied for calculating the corrections. Szczerbowski (1970) and Falkowski (1991) calculated corrections using a coefficient developed by Einsel for Mecklenburg lakes (Szczerbowski 1969). It is reasonable to assume that applying a correction developed for whitefish from a fairly distant geographical region resulted in higher calculated values. On the other hand, Marciak (1967) probably did not apply any correction at all, which is why the results presented for age groups I and II are the lowest. When direct measurements (those performed on year classes III-VI) are included in the calculation of mean growth, the differences in calculated growth decrease distinctly and can be considered to be insignificant, similarly to the way Marciak (1967) did this in the studies from 1957 and 1966.

When applying the whitefish growth evaluation criteria proposed by Szczerbowski (1981), the population from Lake Gołdopiwo must be categorized as slow growing. The exception to this is the results obtained by Wiese (1937). The mean body weight achieved by specimens from year classes III-VI is also evidence of slow growth. The cause of decelerating growth rates should be sought for in the high population density that occurred in various periods. Comparing her study results with those of Wiese (1937), Gąsowska (1953) confirmed that there had been a very distinct decline in growth and suggested that the whitefish population in Lake Gołdopiwo had reached the saturation limit (whitefish catches in this period were approximately 2-3 kg ha^{-1}). Marciak (1967) and Szczerbowski (1970) alike attributed the sudden increase in whitefish catches in 1966 to increased population abundance, while overlooking the radical change that occurred in how the fishery was exploited (Rożniakowski 1967). Until 1966, age classes III-VI, which were the basis of the exploited stock in subsequent years, were not fished, and, due to the minimum legal size of 1 kg, the exploited stock consisted mainly of older year classes in which there were substantial losses due to parasite infection (Rożniatowski 1960, 1967) and natural mortality. The results of the study by Marciak (1967), in which no significant differences were noted in the growth of the studied fish in the 1957-1966 period, indicated that the increase in the population density of younger year classes in Lake Gołdopiwo had occurred much earlier.

Marciak (1967) and Szczerbowski (1970) concluded that in Lake Gołdopiwo whitefish growth ceased in age groups 3 and 4 following the first spawning. Marciak (1967) maintained that this phenomenon was typical of many whitefish populations with dense gill rakers inhabiting lakes in northern Poland. Some authors emphasized that the weak condition of the older whitefish year classes in Lake Gołdopiwo was probably related to parasitic infections and proposed that there was a decidedly disadvantageous relation between whitefish density and the quantity and availability of food (Rożniakowski 1960, 1967).

The analysis of the quantity of stocking and the magnitude of catches of whitefish did not reveal any significant dependence. After fifteen years of practically no stocking, the period of the highest whitefish catches began, and Lake Gołdopiwo had one of the highest mean whitefish catch efficiencies in Poland (Falkowski 1998). The whitefish population inhabiting Lake Gołdopiwo in the 1950-1970 period probably originated

from natural spawning. The relatively larvae stocking with hatch performed in the 1986-1990 period, when catches began to decline, and with summer fry in the periods of 1995-1996 and 2000-2001, when catches were already markedly smaller, did not stop the disappearance of whitefish from the lake.

The cause of the whitefish fishery collapse in Lake Gołdopiwo must be sought for in disadvantageous environmental changes and management strategies. In the 1981--1995 period, the decline in catches of whitefish and vendace, *Coregonus albula* (L.), were accompanied by distinct declines in the catches of littoral species and perch, *Perca fluviatilis* L., and an increase in catches of small cyprinids (Falkowski 1996, Wołos et al. 1998). Although this undoubtedly attested to environmental changes, it did not yet signal a fundamental change in fisheries exploitation based on consciously discontinuing whitefish and supporting pikeperch, *Sander lucioperca* (L.), fisheries. In 1999, catches of silver bream, *Abramis bjoerkna* (L.), reached 12,305 kg, which is confirmation of the increased density of small cyprinids. In the 2003-2004 period the lake was stocked with 180,000 pikeperch summer and 20 kg of pikeperch fall fry. The effects of this stocking have yet to be noted.

The different quantities and types of stocking material released (larvae from 300,000 to 900,000 individuals; summer fry from 6,300 to 500,000 individuals, and fall fry from 1,200 to 13,000 individuals) is evidence that the effectiveness of stocking has never been analyzed nor has the optimum form of material or its quantity been determined. This was probably due to the fact that successful natural spawning was observed in this lake, and this was largely responsible for the magnitude of commercial whitefish catches.

In the 1980s, algal blooms began to appear in the fall, which hampered the deployment of set gear for whitefish catches. Unfortunately, neither the species comprising these blooms nor the cause of their occurrence were investigated.

A distinct decline in exploitation intensity has been noted since 1991, which, in the 1991-1993 period at least resulted from structural transformations in the inland fisheries administration (the state fisheries company was liquidated). Nevertheless, since the Polish Anglers' Association became the administrative body responsible for this lake in 1994, the level of exploitation has continued to decrease, and this may indicate that commercial catches are being curtailed on purpose. Since 1994, fishing gear has been owned by the fishermen and the fear of losing it may contribute to how and where

it is deployed. The decline in whitefish catches is noted in lakes throughout Poland. According to data published by Wołos and Mickiewicz (2006), total Polish catches of this species in 2005 were 7.82 tons, whereas in the 1974-1979 period the highest mean catch of this fish was registered at about 87.5 tons annually (Falkowski and Wołos 1998). Wanzenboeck et. al. (2002), in their analysis of whitefish from two Austrian lakes, concluded that exploitation intensity, as a regulator of whitefish population density, has a greater impact on growth than does lake productivity expressed as the content of phosphorous. Maltsev and Vasilets (1996) also indicated that whitefish biomass fluctuations in the Iriklinskoe Reservoir are tied to the advantageous or disadvantageous environmental conditions during spawning. They do suggest, however, that the overall environmental conditions for coregonids in this reservoir, while not yet critical, were worsening due to pollution.

As is indicated by the results of the present study, the current state of whitefish exploitation in Lake Gołdopiwo is the result of disadvantageous environmental changes in the lake as well as decreasing intensity of exploitation, which, in recent years especially, has had a highly significant impact on the decline in whitefish catches and overall catches in this lake.

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STRESZCZENIE

SIEJA, *COREGONUS LAVARETUS* (L.), W GOSPODARCE RYBACKIEJ W JEZIORZE GOŁDOPIWO (POLSKA PÓŁNOCNO-WSCHODNIA) W LATACH 1950-2005

W pracy przedstawiono dane o tempie wzrostu siei, *Coregonus lavaretus* (L.) z jeziora Gołdopiwo, opracowane przez różnych autorów na przestrzeni lat 1932-1979 i porównano je z wynikami własnych badań z roku 1999. Stwierdzono, że sieja w Gołdopiwie od momentu, kiedy populacja osiągnęła maksymalne zagęszczenie rosła wolno (tab. 1, rys. 1). Lata 1966-1986 to okres najwyższych odłowów siei

w jeziorze (rys. 2). W tym okresie odławiano średnio 8191 kg ryb, a średnia roczna wydajność wynosiła 9,5 kg ha^{-1}.

W badanym okresie jezioro było zarybiane wylęgiem, narybkiem letnim i narybkiem jesiennym siei z różną częstotliwością i intensywnością (rys. 3). Prawdopodobnie populacja siei zasiedlająca jezioro w latach 1950-1979 pochodziła z naturalnego rozrodu. Stosunkowo wysokie zarybienia w latach 1995-2001 nie zahamowały spadku odłowów tego gatunku. Stwierdzono istotną zależność pomiędzy odłowami ogólnymi a odłowami siei (rys. 4). Wzrost odłowów w roku 1966 był spowodowany zaprzestaniem stosowanego do tej pory gospodarczego wymiaru ochronnego oraz zmianą wielkości oczka w wontonach używanych do odłowów siei. Od roku 1966 rozpoczęto eksploatację roczników III-V, wcześniej nie podlegających eksploatacji gospodarczej.

Przyczyn całkowitego załamania się gospodarki sieją w jeziorze Gołdopiwo należy poszukiwać w niekorzystnych zmianach środowiskowych oraz w sposobach i intensywności eksploatacji rybackiej, zwłaszcza w ostatnim dwudziestoleciu.