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# HYDROACOUSTIC MONITORING OF VENDACE IN SELECTED MAZURIAN LAKES

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ABSTRACT. Hydroacoustic monitoring (SIMRAD EY 500 split beam echosounder, 120 kHz) was performed in four coregonid lakes in which commercial catches of vendace, *Coregonus albula* (L.) decreased dramatically over the last decade. It has been shown that in two of the lakes the hypolimnion, which is the natural habitat of vendace, is devoid of fish. In another the fish is abundant, but its body size is too small to be caught. In yet another there is a healthy population of vendace, but the abundance of cyprinid fishes is ten fold higher than that of vendace. The competition for food probably limits natural reproduction, and thus the biomass of adult vendace. Oxygen deficits in deeper layers, especially during fall, are responsible for the disappearance of the fish from the lakes.

Key words: VENDACE, HYDROACOUSTICS, FISH BIOMASS, LAKE QUALITY

## INTRODUCTION

Vendace, *Coregonus albula* (L.), is one of the most valuable species in Polish lakes that are subject to fishery management. Thanks to its very tasty meat and mass occurrence, their economic and marketing value has increased continuously, and by the end of the 1970s vendace landings reached the maximum level of about 570 tons (Wołos 1998). Unfortunately, commercial catches of vendace have declined over the last two decades (Falkowski and Wołos 1996, Doroszczyk et al. 2007). Coregonids have long been considered as a good indicator of water quality, and there are number of studies showing that they tend to disappear along with progressing eutrophication (Leopold et al. 1986, Bnińska 1994). However, Bnińska and Wołos (1998) did not find any statistically significant correlations between vendace yields and the physicochemical parameters of lake water that are measured during standard lake monitoring such as Secchi disc visibility, phosphorus, nitrogen, and chlorophyll content in the surface layer, $BOD_5$ in the epilimnion, or oxygen saturation in the hypolimnion. Similar results were

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reported by Bnińska et al. (1988), who analyzed the effectiveness of vendace stocking in Polish and Finnish lakes. The lack of any significant correlation between vendace yield and lake quality is quite surprising. Various reasons may contribute to this; on the one hand, apart from environmental factors, yield depends on other factors such as fishing effort or stocking rates. On the other hand, the ranking of lake quality based on physicochemical parameters might not adequately reflect the real status of the ecosystem or its functioning. The primary aim of the present paper is to answer the question of why vendace catches are low. Is it due to a lack fish? Or is there another reason they are not being caught? If there are no fish, then a second question arises of why they have disappeared from the lake. If the fish are present in the lake, then the question is why are they not being caught by fishermen. To answer these questions, hydroacoustic monitoring, accompanied by control catches and measurements of temperature and oxygen profiles, was performed in four good quality Mazurian lakes that were once abundant in vendace but are not anymore.

## MATERIALS AND METHODS

### STUDY SITE

Lakes Łanskie, Pluszne, Maróz, and Mielno, located in the Warmiński Lake District in eastern Poland, are known to be coregonid lakes and were chosen for hydroacoustic monitoring. Vendace catches in theses lakes were very high in the 1970s and 1980s, but landings, if there are any, are currently very low (Doroszczyk et al. 2007). Based on water quality monitoring performed by Cydzik et al. (1995), all four lakes were classified as class II water quality and class I resistance to degradation. Two of the lakes are large, with surface areas of about 1000 ha, and two are small, around 300 ha, with maximum depths of about 50 m in the large lakes and 40 m in the small ones (Table 1). Thermoclines were present in all the lakes throughout the season which divided the water masses into two distinct layers of the warm epilimnion and cold hypolimnion. The vendace inhabited the hypolimnion, while the epilimnion was inhabited mainly by cyprinids. The watersheds of all the lakes were primarily forested, but there was also a significant amount of recreational activity around the lakes, and the surrounding villages were not equipped with sanitation facilities.

**TABLE 1**

Morphometric parameters of the studied lakes

| Parameter | Lake Łańskie | Lake Pluszne | Lake Mielno | Lake Maróz |
|---|---|---|---|---|
| Area (ha) | 1042 | 903 | 363 | 333 |
| Max depth (m) | 53 | 52 | 40 | 41 |
| Mean depth (m) | 16 | 15 | 12 | 12 |
| Volume ($10^6$ $m^3$) | 168 | 135 | 44 | 40 |
| Water quality | II class | II class | II class | II class |
| Secchi disc (m) | 3.8-3.9 | 3.4-4.9 | 1.3-1.5 | 2.4-3.0 |
| Watersheds (% of forest) | 80 | 80 | 66 | 79 |

In order to identify the species and size structure of fish, control catches were made at different depths with a pelagic trawl. The fish were measured and weighed individually. Water temperature and dissolved oxygen content were determined twice per season (in June and October) in the deepest part of each lake at 1 m intervals from the surface to the bottom, using an OXI 196 (WTW).

## HYDROACOUSTIC SURVEY TECHNIQUE

Hydroacoustic measurements were conducted from aboard the *Echo*, a 5 m long boat, sailing along zizag transects (Fig. 1) at a constant speed of 8 km $h^{-1}$. The geographical position was recorded with a GPS device connected to the sounder. The transducer was fixed to a special frame in front of the boat at a depth of 0.5 m. A SIMRAD EY500 split beam echosounder at a frequency of 120 kHz was used with a round transducer with a beam angle of 7° at –3 dB points. The pulse duration was set to medium position (0.3 ms), while the repetition rate was set to "as fast as possible". The detection thresholds were fixed at –56 dB (TS) for the discrimination of individual targets (40 log R) and at –50 dB (Sv) for echointegration (20 log R). The criteria used for the discrimination of individual targets were the default criteria recommended by the producer (SIMRAD, 1995) at minimum and maximum returned pulse widths of 0.6 to 1.5 times the transmitted pulse duration, maximum gain compensation at 3 dB, and maximum phase deviation of 3 phase steps. Simrad EP 500 post-processing software was used to analyze the data. Acoustic monitoring was based on the echo integration method. The Elementary Sampling Distance Unit (ESDU) was chosen as 100 m, which was small enough to reveal the distribution pattern, and easy for calculations of the

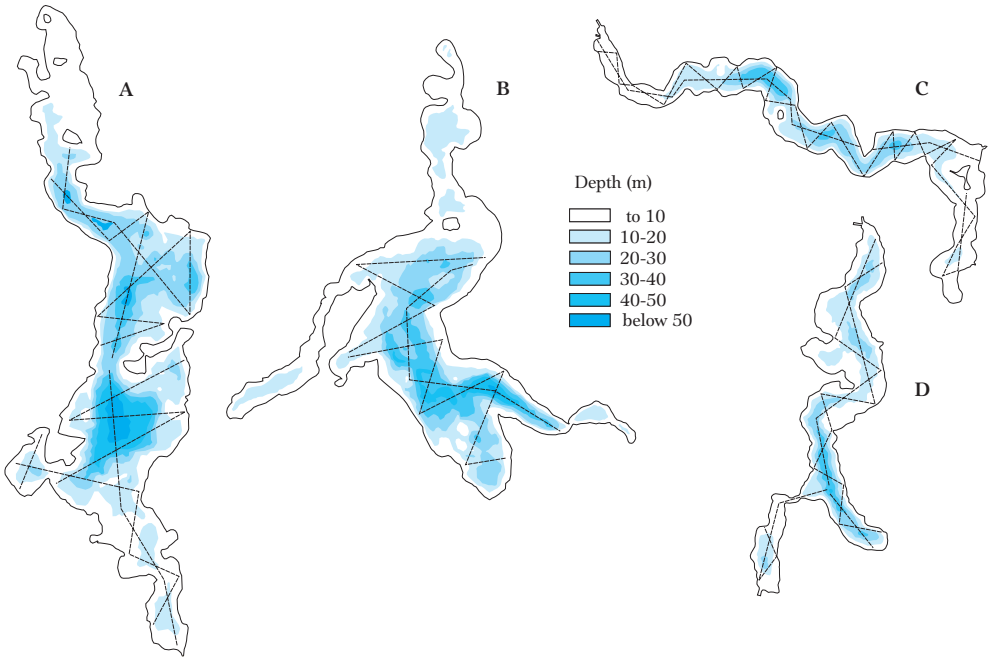


Fig. 1. Bathymetry of and the scheme of hydroacoustic surveys conducted in four lakes: A – Łańskie, B – Pluszne, C – Mielno and D – Maróz.

area density. At the beginning of the study the whole system was calibrated *in situ* according to the procedure described by Foote et al. (1987). Fish abundance was estimated by interpolating the data by kriging (Surfer software). Detailed descriptions of this method can be found in Petitgas (1993) and Rivoirard et al. (2000). Surfer software was also used to produce maps of fish density spatial distribution.

## RESULTS

### LAKE ŁAŃSKIE

The comparison of maps of fish distribution in the epilimnion and hypolimnion of Lake Łańskie (Fig. 2) clearly depicts the enormous difference in the density of fish populations inhabiting these two layers. The epilimnion is densely populated throughout with over 9,000 fish per hectare, while in the hypolimnion fish concentrate along the

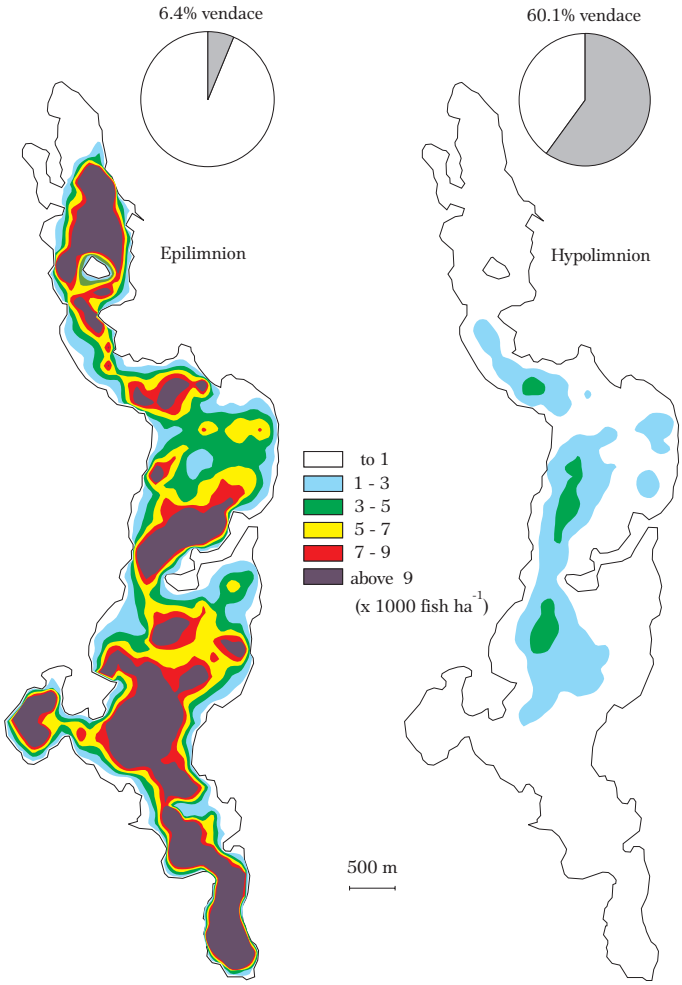


Fig. 2. Distribution of fish density in the epilimnion and hypolimnion of Lake Łańskie. Population composition is based on pelagic trawl control catches.

western coast at densities of 1,000 to 3,000 fish per hectare, exceeding the larger figure only in a few spots. The total abundance of fish in the epilimnion is in excess of an order of magnitude higher than that in the hypolimnion. The comparison of the fish population structure from the control catches (Świerzowski and Doroszczyk 2005), in which vendace comprised 60% of the fish in the hypolimnion and 6% in the epilimnion, clearly shows that this species represents only 10% of the total population (in numerical abundance). Thus, low landings of vendace in Lake Łańskie are fully understand-

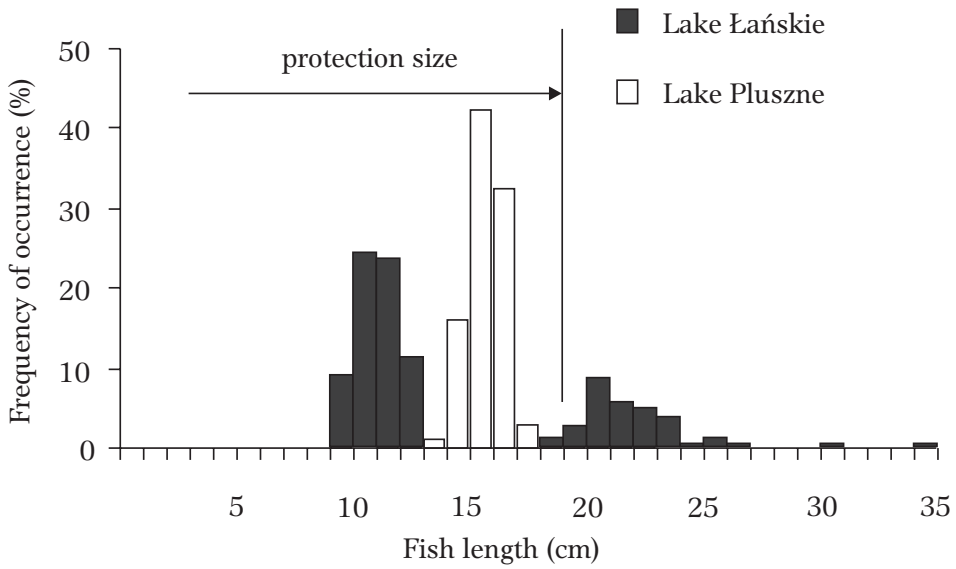


Fig. 3. Vendace size distribution in lakes Łańskie and Pluszne from control catches.

able. However, as can be seen from the fish size distribution (Fig. 3), 70% of fish come from the 0+ age group. It can be anticipated that increased landings will be noted in the near future once these fish mature.

## LAKE PLUSZNE

The situation in Lake Pluszne is completely different from that in Lake Łańskie (Fig. 4). Foremost, the total fish abundance in the hypolimnion slightly exceeds that in the epilimnion, and overall amount of fish, in spite of nearly the same lake size, is nearly twice smaller than that in Lake Łańskie. In the hypolimnion, high fish density exceeding 9,000 fish per hectare are concentrated in the southeast, while in the epilimnion the most dense concentrations are located in the northern part of the lake. Vendace is present in both the hypolimnion (99%) and epilimnion (63%) and it constitutes over 83% of the fish population in the lake in numerical abundance. Theoretically, this fish could be caught by fishermen, but the fish size distribution (Fig. 3) clearly shows that even the largest fish do not exceed the minimum landing length, which means the mesh size of the gill nets deployed is too large to catch this fish.

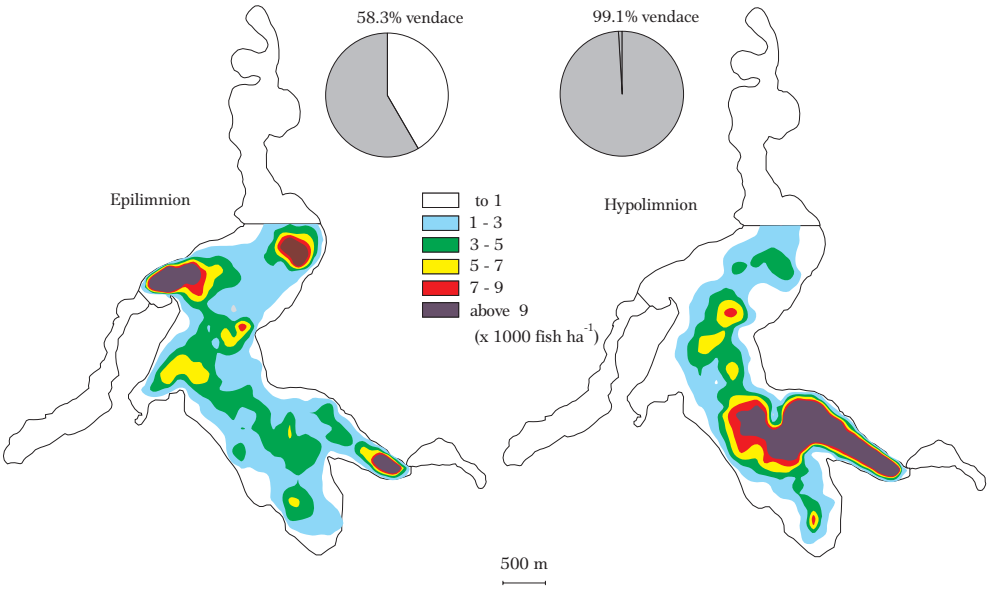


Fig. 4. Distribution of fish density in the epilimnion and hypolimnion of Lake Pluszne. Population composition is based on pelagic trawl control catches.

## LAKES MIELNO AND MARÓZ

The conditions in these two smaller lakes are nearly identical (Fig. 5 and 6) and differ from the larger lakes. In both the hypolimnion is nearly devoid of fish, while the distribution of fish in the epilimnion is very patchy, amounting to about one million fish in total. In Lake Maróz, not a single vendace individual was caught by trawling. In Lake Mielno vendace comprised 4.6% of the fish population in the epilimnion, but similarly to Lake Maróz, no fish were caught in the hypolimnion.

## TEMPERATURE AND OXYGEN STRUCTURE OF THE LAKES

In June there is already a strong thermocline dividing the water column into two layers; the warm epilimnion with temperatures above 15°C, and the cold hypolimnion with temperatures below 10°C (Fig. 6). Oxygen conditions in June are good in four lakes with concentrations above 5 mg $O_2$ $dm^{-3}$, decreasing slightly below this value

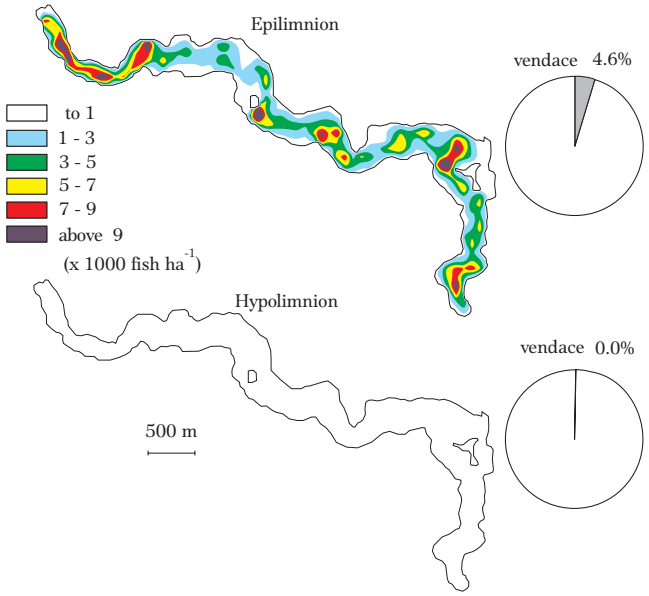


Fig. 5. Distribution of fish density in the epilimnion and hypolimnion of Lake Mielno. Population composition is based on pelagic trawl control catches.

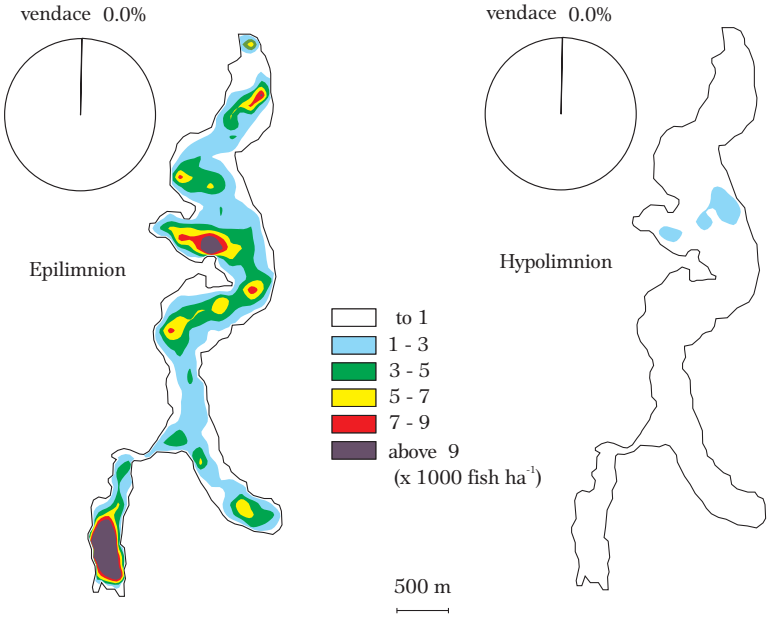


Fig. 6. Distribution of fish density in the epilimnion and hypolimnion of Lake Maróz. Population composition is based on pelagic trawl control catches.

only within the thermocline. However, in fall high oxygen concentrations persist only in the epilimnion, while in the hypolimnion they are comparatively good only in Lake Łańskie. In Lake Pluszne oxygen concentrations approach lethal values for fish, below 3 mg $O_2$ $dm^{-3}$, while in lakes Mielno and Maróz they are either very close to or practically equal to zero.

## DISCUSSION

It seems that with regard to the four lakes studied, the answers to the basic questions posed are quite straightforward. In lakes Mielno and Maróz vendace landings are negligible because there are no fish (Fig. 5). This species is absent due to a lack of oxygen in the hypolimnion (Fig. 6), the natural habitat of vendace, which prefers cold, well-oxygenated waters (Bernatowicz et al. 1975, Aku and Tonn 1995, Świerzowski 1999, 2001). The intensive development of recreation around the lakes without the implementation of the necessary sanitation facilities has led to the rapid deterioration of environmental conditions and oxygen depletion in deeper waters (Lossow et al. 2006). Although recently shut down, the pig farm in the vicinity of the lakes increased considerably the nutrient load transported to the lakes. Without serious measures to improve the environmental conditions there is no chance of increasing vendace landings in these lakes.

The situation in Lake Łańskie is much more optimistic. Since oxygen concentrations in both the epilimnion and hypolimnion are good throughout the year (Fig. 6), there is potential for vendace to inhabit the hypolimnion, assuming that natural reproduction is not affected. There are number of publications showing that poor feeding conditions might affect the success of natural reproduction in the lake (Ciepielewski 1974, Auvinen 1988, 1995). Thus, although control catches indicate that 70% of the vendace in Lake Łańskie is from the 0+ age group (Fig. 3), the survival rate is probably not high since juveniles are particularly sensitive to poor food conditions. Since the total fish biomass in Lake Łańskie estimated by Świerzowski and Doroszczyk (2005) at 195 kg $ha^{-1}$ in the pelagic zone is very high, there must be strong competition for food. According to the same authors (Świerzowski and Doroszczyk 2005), the abundance of cyprinids in the epilimnion increased dramatically between 2001 and 2004. Undoubtedly, this is the result of anthropogenic pollution from recreational facilities and trout

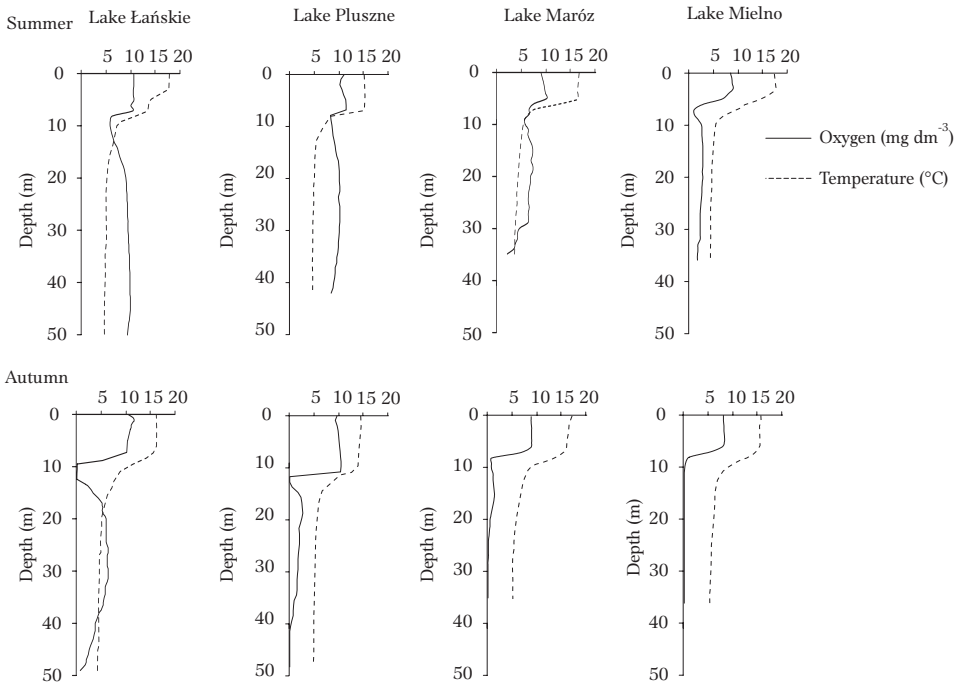


Fig. 7. Profiles of temperature and oxygen concentrations in the four studied lakes during summer (June) and fall (October).

cultivation in the upper reaches of the Łyna River, which transports highly fertilized waters to the lake (Teodorowicz et al. 2006). Therefore, in order to increase vendace catches in the lake, the pollution reaching the lake must be controlled strictly, and some removal of cyprinids is necessary.

A large population of vendace exists in Lake Pluszne; however, it is not caught because of its small body size (Fig. 3). The fact that adult vendace do not reach the normal size is probably the effect of overcrowding, which leads to competition for food and a decrease in reproductive effectiveness. Świerzowski and Godlewska (2001) have shown that in October the density of vendace in Lake Pluszne is 20 times higher than in June due to limited habitat, the upper limit is set by the thermocline and lower one by the lack of oxygen. The whole population of vendace is limited to a layer of about 10 m in the period preceding spawning, which must have an effect on the reproductive abilities of this species. The lack of 0+ individuals in the vendace size distribution in Lake Pluszne (Fig. 3) confirms that either there is no natural reproduction or that it is ineffec-

tive. This situation is very dangerous since the death of adult vendace may cause the disappearance of this species from the lake. Therefore, some fish removal should be undertaken to ensure good conditions for growth and development for those fish that are left. Additionally, some control of environmental parameters is necessary to sustain sufficient oxygen concentrations in the hypolimnion through the year.

The results of the monitoring performed within the scope of the current study indicate that hydroacoustic methods are a very useful tool for fisheries managers and that they provide them with a good basis for making optimal decisions at the right time.

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## STRESZCZENIE

MONITORING HYDROAKUSTYCZNY W WYBRANYCH JEZIORACH SIELAWOWYCH POJEZIERZA MAZURSKIEGO

Celem badań było określenie zagęszczenia sielawy, *Coregonus albula* (L.) w czterech głębokich jeziorach sielawowych: Łańskie, Pluszne, Mielno i Maróz, położonych w północnej Polsce (rys. 1). Na podstawie wyników badań hydroakustyczno-połowowych przeanalizowano aktualny stan zasobów, podjęto próbę wyjaśnienia przyczyn tendencji spadkowej połowów sielawy oraz dokonano prognozy zmian obfitości populacji sielawy. Pomiary hydroakustyczne były prowadzone za pomocą echosondy z rozszczepioną wiązką EY500 firmy SIMRAD, o częstotliwości 120 kHz. Badania wykazały, że w jeziorach Maróz i Mielno sielawy prawie nie ma, prawdopodobnie ze względu na obserwowane w okresie jesiennym deficyty tlenowe w hypolimnionie. W jeziorze Pluszne zasoby sielawy są na wysokim poziomie, ale jest to sielawa o małych rozmiarach, nie przekraczających wymiaru ochronnego. Stosunkowo najlepsza jest sytuacja w Jeziorze Łańskim, ale ze względu na bardzo duże zagęszczenie ryb karpiowatych, można się spodziewać pogorszenia warunków bytowania sielawy.