| Arch. Pol. Fish. | Archives of Polish Fisheries | Vol. 9 | Fasc. 2 | 147-156 | 2001 |
|---|---|---|---|---|---|

# DIEL VARIATIONS IN THE VERTICAL DISTRIBUTION AND DENSITY OF VENDACE *Coregonus albula* (L.) IN PLUSZNE LAKE

*Andrzej Świerzowski*

The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn, Poland

ABSTRACT. Pluszne Lake, with an area of 903 ha and a maximal depth of 52 m, is located in northeastern Poland. It is a typical mesotrophic lake, and its resources of pelagic fish are dominated by vendace and smelt. A Simrad EY-M research echosounder (70 kHz, single beam) and a complementary HADAS computer data analysis system were used for fish distribution and density estimation. Control catches were carried out to identify species and to verify hydroacoustic data. A pelagic trawl with an entrance area of S = 10.8 $m^2$ and a filtration coefficient of F = 903.4 $m^3$ $min^{-1}$ was used for these catches. In August, thirteen acoustic surveys were conducted at one hour intervals along the same transect of the depth profile. Surveying was begun at 19.00, one hour before sunset, and was concluded at 07.00, two hours after sunrise. Thirteen maps were obtained illustrating the hourly variations of fish dispersion and aggregation. Three indices were used to analyze these changes: mean fish densities; number of echoes from single fish; % of the smallest fish (TS < -44 dB). The optimal night period for estimating pelagic fish resources with the echocounting method at TVG 40 log R was determined. In August, this period fell between 22.00 and 04.00, i.e. approximately two hours after sunset and before sunrise. The results of control catches made with the pelagic trawl, fish distribution and behavior are discussed.

Key words: VENDACE, HYDROACOUSTICS, VERTICAL DISTRIBUTION, VERTICAL DENSITY, PELAGIC TRAWL

## INTRODUCTION

The first echosounding studies on vendace *Coregonus albula* (L.) distribution in Pluszne Lake were carried out in 1961-1963 (Dembiński 1965, 1971). Since then, fisheries acoustics have progressed from qualitative assessments to the development of techniques that allow quantitative estimates of pelagic fish abundance to be made (Johannesson and Mitson 1983, Lindem 1983, Rudstam et al. 1988, Jurvelius 1991). Despite many valuable investigations with acoustics (Dembiński 1965, 1971, Jurvelius et al. 1984, Jurvelius and Heikkinen 1987, 1988, Jurvelius and Louhimo 1991), the factors which affect vendace migrations under different conditions and in various lakes remain unclear. Reliable abundance estimates of the short-lived vendace are difficult due to considerable population fluctuations as well as seasonal and diel variations in the distribution and density of this species (Auvinen 1995, Świerzowski, unpublished data).

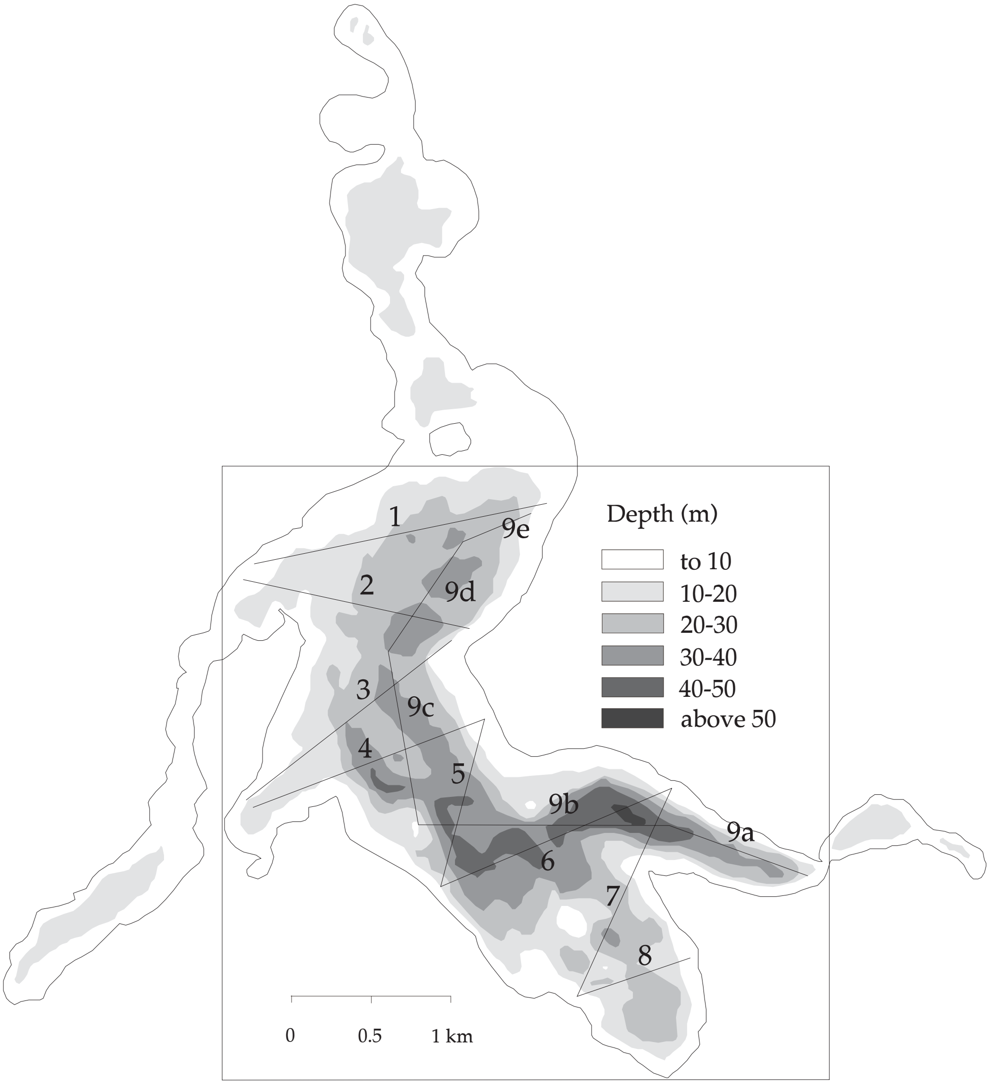


Fig. 1. Bathymetric map and location of acoustic transects in Pluszne Lake.

The 1994 studies carried out in Pluszne Lake were designed to examine diel distributions of pelagic fish, with a focus on vendace. Understanding these patterns will aid in the design of acoustic assessments of vendace. Reliable estimates are needed to manage commercial vendace fisheries.

## MATERIAL AND METHODS

Pluszne Lake, with a surface area of 903 ha and a maximum depth of 52 m, is located in the Mazurian Lake District in northeastern Poland. It is a typical mesotrophic lake that supports a fish community predominated by vendace. Since 1991, hydroacoustic assessments have been carried out in the lake's main basin (580 ha in area). A bathymetric map and the location of acoustic surveying are presented in Fig. 1.

On the night of 22 August 1994, repetitive hydroacoustic surveys were conducted hourly along transect number 6, located in the deepest part of the lake (Fig. 1). The transect was well marked with floats. Monitoring was begun at 19.00, one hour before sunset, and was concluded at 07.00, two hours after sunrise, for a total of 13 separate runs.

Acoustic data were obtained using a SIMRAD EY-M research echosounder and a 70 kHz single beam transducer that was deployed in a towfin. The echosignals were registered simultaneously on echogram paper and magnetic tape. The recorded echosignals (40 log R TVG) were transformed and analysed using HADAS. This system is based on the Craig and Forbes (1969) algorithm that was modified by Lindem (Lindem 1983, Rudstam et al. 1988). Over 100,000 echoes were collected from individual fish during the study. Details of this method are described by Johannesson and Mitson (1983), Lindem (1983), Bayona (1984), Jurvelius et al. (1984) and Rudstam et al. (1988).

In order to determine fish species composition and size distribution, three hauls were made with a pelagic trawl in the same region of the acoustic monitoring on 23 August 1994. The tows were made in the lower epilimnion (6-9 m), and upper (13-16 m) and middle (21-24 m) hypolimnion. Additional tows were made in the lower epilimnion in transect 9d (Fig. 1).

A one-boat pelagic trawl with otter boards was used to collect fish. The net mesh size ranged from 80 mm at the mouth to 5 mm in the codend. Its fishing area was 10.8 $m^2$ and its filtration was 903.4 $m^3$ $min^{-1}$ at a tow speed of 83.3 m $min^{-1}$. Each tow lasted 15 min. All fish collected were weighed to the nearest 0.1 g and measured (total length) to the nearest 0.1 cm. The water temperature and oxygen content were measured from the surface to the bottom at meter intervals.

## RESULTS AND DISCUSSION

Aggregations of pelagic fish that are present in the middle hypolimnion in the daytime, begin to disperse an hour before sunset. This process lasts for over two hours (Fig. 2). At the same time, some fish migrate towards the surface, and then probably to and from the littoral. Afterwards, changes in fish densities were observed hourly. About an hour before sunrise, dense schools of fish began to form in their daytime location in the middle hypolimnion at an average depth of 25 m.

Data on fish densities (fish $ha^{-1}$), numbers of echoes from single fish, and the proportion of fish less than 44 dB (Fig. 3) was used to analyze the dynamics of hourly changes in fish densities during the night, and, thus, of fish migrations. The highest density and echocount values were observed at night between 22.00 and 04.00. The fish densities observed in this period depended most of all on the percentage of the smallest fish. The hourly variability of the analysed indices reflected mostly the horizontally fish migrations. According to Rudstam et al. (1988) and Jurvelius and Luohimo (1991), strong horizontal migrations of vendace may affect the density estimates.

The pelagic trawls made at night indicated various species compositions at different depths. Smelt, *Osmerus eperlanus* (L.) dominated in the lower epilimnion (6-9 m). Catches in the upper hypolimnion (13-16 m) were a mixture of vendace and smelt. Vendace dominated the catch in the middle hypolimnion (21-24 m) (Table 1). There were no one-year-old vendace in the catches as they usually appear in the upper hypolimnion only in September. This pattern has been observed many times by the author as well as by Dembiński (1965) in the same lake and in Wulpińskie Lake (Świerzowski, unpublished data).

**TABLE 1**

Fish numbers and percentages in trawl catches made in different layers in Pluszne Lake

| Depth layer (m) | Tow No. | Vendace | | | | Smelt | | | | Others | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | indiv. | % | mean total length ± SD (cm) | mean body weight ± SD (g) | indiv. | % | mean total length ± SD (cm) | mean body weight ± SD (g) | indiv. | % | indiv. | % |
| 6 – 9 | 1 | 1 | 0.5 | - | - | 181 | 96.8 | 12.9±1.5 | 9.7±4.1 | 5 | 2.7 | 187 | 100 |
| | 2 | 4 | 3.3 | 12.1±0.2 | 10.0 ±0.0 | 116 | 95.1 | 12.8±1.8 | 10.4±4.9 | 2 | 1.6 | 122 | 100 |
| 13 – 16 | 3 | 187 | 86.2 | 18.1±4.7 | 52.0±34.3 | 28 | 12.9 | 12.7±1.6 | 9.3±4.7 | 2 | 0.9 | 217 | 100 |
| 21 – 24 | 4 | 370 | 99.2 | 21.6±2.2 | 78.4±28.9 | 2 | 0.5 | - | - | 1 | 0.3 | 373 | 100 |

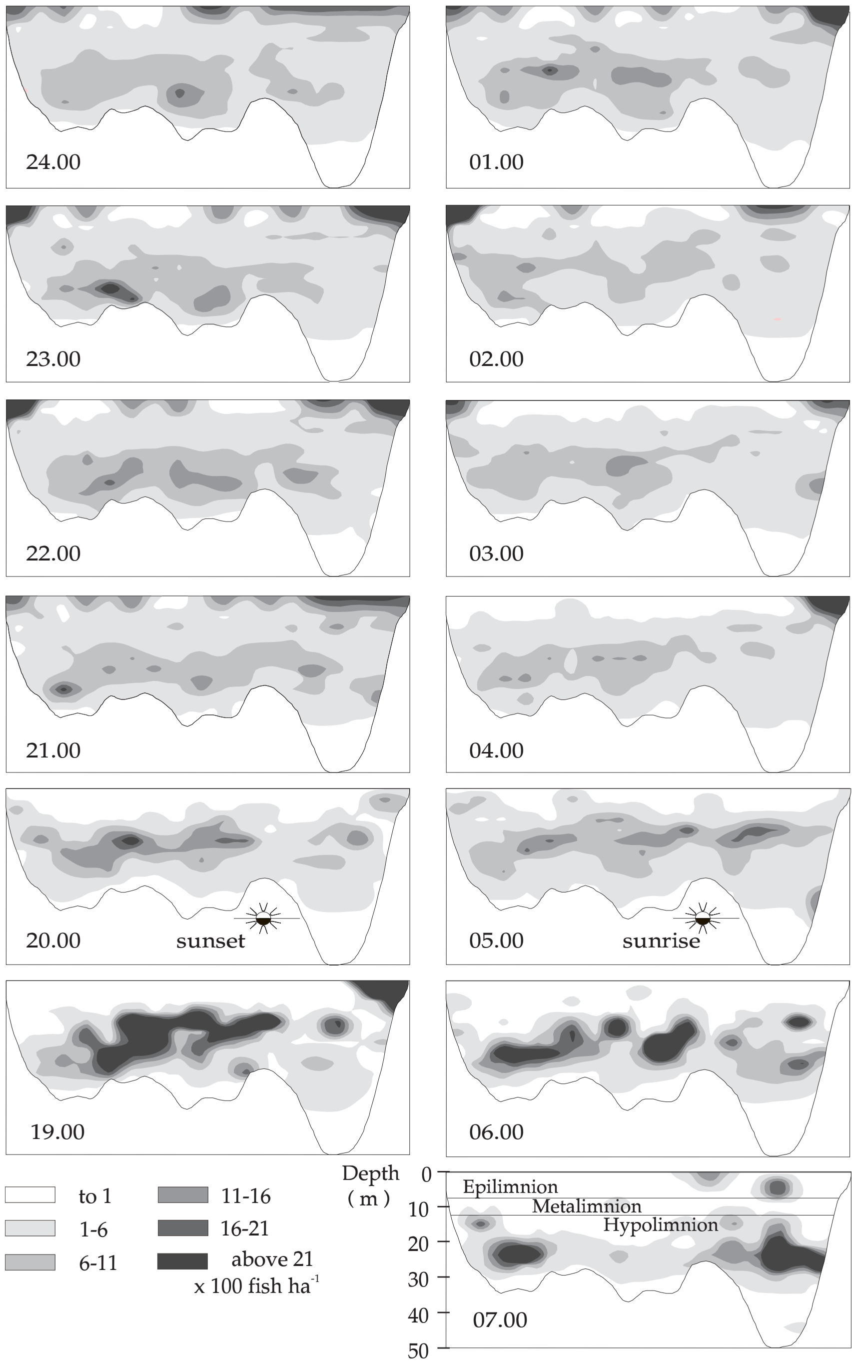


Fig. 2. Diel vertical distribution of pelagic fish (mostly vendace and smelt) in Pluszne Lake.

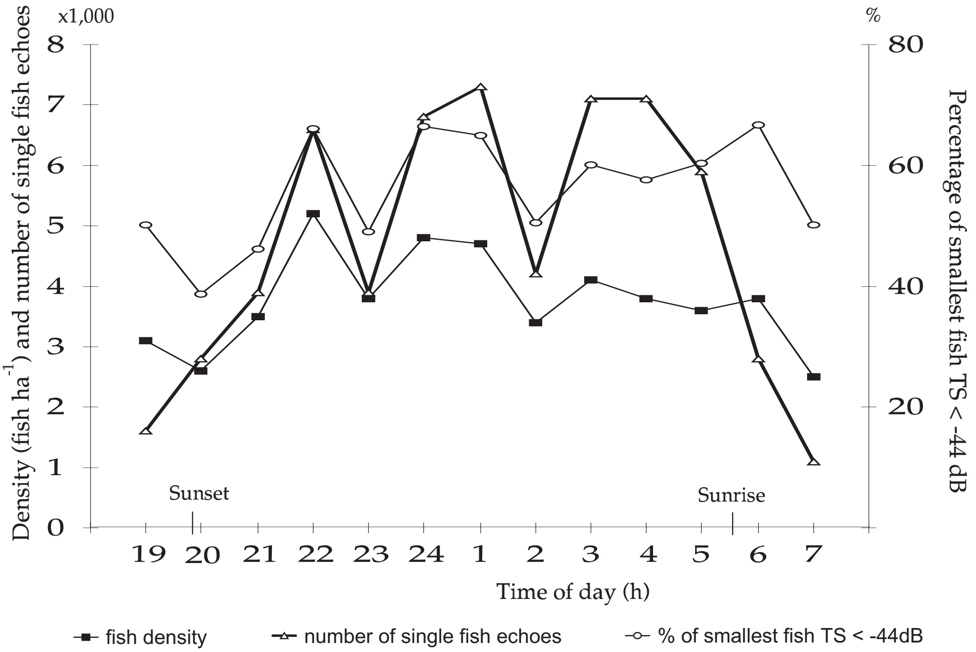


Fig. 3. Comparison of the indices the estimating the density of pelagic fish in different diel periods in Pluszne Lake.

A comparison of the acoustic data (Figs. 2 and 3) with net catches (Table 1) indicates that vendace dispersed at sunset and aggregated at dawn in the sufficiently oxygenated (Fig. 4) water strata of the hypolimnion at depths from 12 to 36 m. Dembiński (1965, 1971) set suspended gill nets in «steps» and found that night distributions of vendace were associated with the thermocline and those of smelt were associated with the epilimnion. This vertical distribution pattern confirms earlier observations by Dembiński (1971) and Jurvelius et al. (1984).

Multiple-mesh gill net (13 panels, mesh bar size from 10 to 65 mm) assessments in the littoral areas (inaccessible to trawls) indicated the near-shore fish aggregations were composed of bleak *Alburnus alburnus* (L.) and bream *Abramis brama* (L.) juveniles, roach *Rutilus rutilus* (L.) and perch *Perca fluviatilis* L..

The typical layering of pelagic fish appears to confirm Gause's rule of one species per food niche (Dembiński 1971). In lakes of this type, the major part of the adult, i.e. exploitable, vendace population are usually found in the greatest densities in the middle hypolimnion. This distribution allows for fishing with special pelagic trawls which target only the desired adult vendace, while protecting young-of-the-year fish.

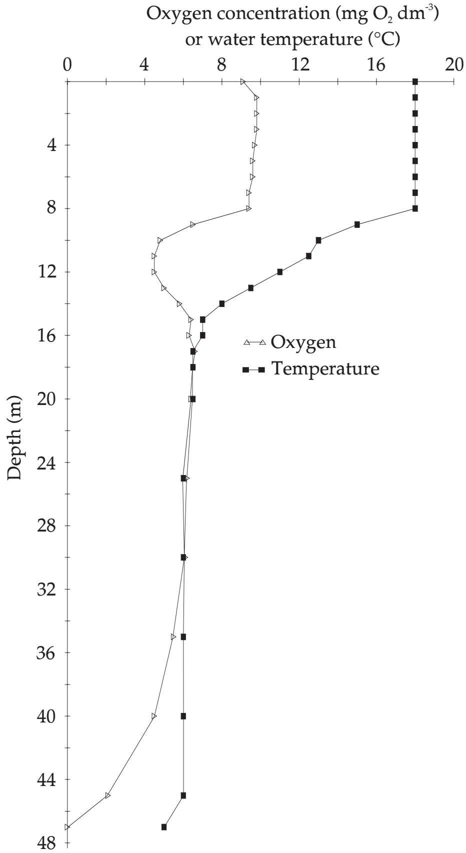


Fig. 4. Water temperature and oxygen content in Pluszne Lake.

Suuronen (1995) also reported avoiding juvenile vendace when catches were carried out at night with trawls.

The comparison of estimates of fish densities from the hydroacoustic surveys with pelagic trawl catches indicated differences in trawl efficiency (Table 2). In the epilimnion, which is inhabited by smelt, the effectiveness of trawl catches ranged between 48.6 and 48.9%, while in the hypolimnion (dominated by vendace) it reached 80.2 and 83.1%. These differences were probably caused by the different ways the trawl and its movements are perceived by the two fish species at night and their size relationship to the trawl mesh size. Similar differences in response to trawls were observed by Enderlein and Appelberg (1992) for vendace and whitefish, *Coregonus lavaretus* (L.). The increased effectiveness of pelagic trawls in the deeper areas might have also been due to the herding effect of trawl boards which increased the fishing area in relation to the inlet area.

**TABLE 2**

Effectiveness of pelagic trawls compared to the acoustic estimates of fish density at night in Pluszne Lake

| Depth layer (m) | Tow No. | % of catch by species | | | Density (fish 1000 $m^{-3}$) | | Effectiv.of trawl catch (%) |
|---|---|---|---|---|---|---|---|
| | | Vendace | Smelt | Others | Acoustic | Trawl | |
| 6 – 9 | 1 | 0.5 | 96.8 | 2.7 | 61.0 | 29.6 | 48.6 |
| | 2 | 3.3 | 95.1 | 1.6 | 18.4 | 9.0 | 48.9 |
| 13 – 16 | 3 | 86.2 | 12.9 | 0.9 | 18.7 | 15.0 | 80.2 |
| 21 – 24 | 4 | 99.2 | 0.5 | 0.3 | 33.1 | 27.5 | 83.1 |

Catches made with pelagic trawls are more reliable than those made with gill nets; this is significant when estimating the density of particular species at specific strata in lakes. Concurrent acoustic pelagic trawl surveys are short in duration compared to gill net surveys. The latter typically lasts from sunset to dawn. During this time, different fish migrate to varying degrees and intensity not only horizontally but also vertically, so gill nets catches are greater at night than during the day. Jurvelius and Louhimo (1991) and Enderline and Appelberg (1992) reported better correlation of the fish density data obtained between hydroacoustic studies and trawl catches than between the former and gill net catches.

A similar layering of fish resources in August-September had been observed earlier in Pluszne Lake, and was also recently reported in Wulpińskie Lake (Świerzowski, unpublished data). This phenomenon allows the fish to be exploited in the best possible manner as specific species and ages or sizes can be targeted. Data reported by Dembiński (1965, 1971), among others, indicate that this period is also optimal for vendace exploitation since this species has attained its maximal size and is at its best food quality.

## CONCLUSIONS

The nightly dispersion of pelagic fish in late summer, when fish numbers in pelagic waters are at their highest, appears to be a good period for concurrent acoustic studies and mid-water trawl assessments of vendace and smelt. The period from two hours after sunset to one and a half hours before sunrise was the best time to assess pelagic distributions of vendace. This is especially important when planning surveys in large water bodies, as both acoustic surveys and the associated trawls must be carried out in this period on the same night.

It was found that the diel distribution of smelt and vendace observed during the late summer provided an opportunity to optimize vendace exploitation with pelagic trawls. At this time, the vendace schools which are present have completed their most intensive growth, attained the highest individual weight and the best meat quality and they are accessible to fishing.

## ACKNOWLEDGEMENTS

*I wish to thank my co-workers Mr. L. Doroszczyk M.Sc., Mr. B. Długoszewski, Eng., Mrs. E. Kanigowska and Mr. A. Cielewicz for their assistance in collecting and analyzing the data, and Dr. M. Bnińska for preparing the English version of the text.*

## REFERENCES

Auvinen H. 1995 - Intra - and interspecific factors in the dynamics of vendace (*Coregonus albula* L.) populations - Finnish Fish. Res. 15: 87-96.

Bayona J.D.R. 1984 - Comparison of acoustic survey systems for use in developing countries. In: Mitson, R.B. (Ed.) Acoustic systems for the assessment of fisheries. FAO Fish. Circ. 778: 1-19.

Craig R.E., Forbes S.T. 1969 - Design of sonar for fish counting - Fiskeridr. Skr. Ser. Havunders. 15: 210-219.

Dembiński W. 1965 - Echosounder investigation of the distribution of pelagic fish in Lake Pluszne - Ph.D. thesis, Agricultural University, Olsztyn, Poland 120 pp. (in Polish).

Dembiński W. 1971 - Vertical distribution of vendace *Coregonus albula* L., and other pelagic fish species in some Polish lakes - J. Fish Biol. 3: 341-357.

Enderlein Q., Appelberg M. 1992 - Sampling stocks of *Coregonus lavaretus* and *C. albula* with pelagic gillnets, trawls and hydroacoustic gear - Pol. Arch. Hydrobiol. 39: 771-777.

Johannesson K.A., Mitson R. B. 1983 - Fisheries acoustic. A practical manual for aquatic biomass estimation - FAO Fish. Tech. Pap. 240: 249 pp.

Jurvelius J. 1991 - Distribution and density of pelagic fish stock, especially vendace (*Coregonus albula* L.), monitored by hydroacoustics in shallow and deep southern boreal lakes - Finnish Fish. Res. 12: 45-63.

Jurvelius J., Heikkinen T. 1987 - The pelagic fish density, biomass and growth of vendace, *Coregonus albula* L., monitored by hydroacoustic methods and trawling in a Finnish lake - Aqua Fennica 17(1): 27-34.

Jurvelius J., Heikkinen T. 1988 - Seasonal migration of vendace, *Coregonus albula* (L.) in a deep Finnish lake-Finnish Fish. Res. 9: 205-212.

Jurvelius J., Lindem T., Heikkinen T. 1988 - The size of vendace, (*Coregonus albula* L.), stock in a deep lake basin monitored by hydroacoustic methods - J. Fish Biol. 32 (5): 679-687.

Jurvelius J., Lindem T., Louhimo J. 1984 - The number of pelagic fish in Lake Paasivesi, Finland monitored by hydroacoustic methods - Fish. Res. 2: 273-283.

Jurvelius J., Louhimo J. 1991 - The impact of lake morphometry, illumination, water temperature and eutrophication on the distribution of pelagic fish. (manuscript).

Lindem T. 1983 - Successes with conventional in situ determinations of fish target strength. In: Nakken O., Venema S. C. (Eds.) Selected papers of the ICES/FAO Symposium on fisheries acoustics. Bergen Norway, 21-24 June 1982. - FAO Fish. Rep. 300: 104-111.

Rudstam L., Lindem T., Hansson S. 1988 - Density in situ target strength of herring and sprat: a comparison between two methods of analyzing single-beam sonar data - Fish. Res. 6: 305-315.

Suuronen P. 1995 - Conservation of young fish by management of trawl selectivity - Finnish Fish. Res. 15: 97-116.

## STRESZCZENIE

DOBOWA ZMIENNOŚĆ PIONOWEGO ROZMIESZCZENIA I ZAGĘSZCZENIA SIELAWY, *Coregonus albula* (L.) W JEZ. PLUSZNE

Celem badań wykonanych na Jez. Pluszne (pow. 903 ha, maksymalna głębokość 52 m) była optymalizacja metody hydroakustycznego monitoringu ryb pelagicznych głównie sielawy, a także ich połowów.

Dane akustyczne uzyskano przy pomocy badawczej echosondy Simrad EY-M (70 kHz). Zapisane na taśmie magnetofonowej echosygnały przetwarzano i analizowano przy pomocy komputerowego systemu HADAS. Do połowów ryb zastosowano włok pelagiczny o powierzchni wlotu S = 10,8 $m^2$ i filtracji F = 903,4 $m^3$ $min^{-1}$przy szybkości holowania 83,3 m $min^{-1}$.

Wykonano 13 cogodzinnych przeszukiwań akustycznych wzdłuż transektu nr 6 zlokalizowanego w najgłębszej części jeziora (rys. 1). Przeszukiwania akustyczne rozpoczęto na godzinę przed zachodem, a zakończono w dwie godziny po wschodzie słońca. Na kolejnych mapach przedstawiono cogodzinną zmienność dyspersji i agregacji ryb (rys. 2). Do analizy tych zmian zastosowano trzy wskaźniki: - średnie zagęszczenie ryb; - liczebność echa ryb pojedynczych; - % udział ryb najmniejszych (TS < -44 dB).

Optymalnym okresem doby dla prowadzenia monitoringu hydroakustycznego zasobów sielawy i innych ryb pelagicznych jest ich nocne rozproszenie, pozwalające na zastosowanie metody zliczania echa ryb przy zakresowej regulacji wzmocnienia TVG 40 log R. W sierpniu największe rozproszenie ryb w toni wody przypada w godzinach od 22.00 do 4.00, tzn. w 2 godziny po zachodzie i 2 godziny przed wschodem słońca (rys. 2 i 3).

Stwierdzone o tej porze roku i doby warstwowe rozmieszczenie ryb jest szansą na prowadzenie optymalnych, z ekologicznego i gospodarczego punktu widzenia, połowów sielawy przy pomocy aktywnych narzędzi sieciowych.

CORRESPONDING AUTHOR:

Dr Andrzej Świerzowski
Instytut Rybactwa Śródlądowego
ul. Oczapowskiego 5
10-719 Olsztyn
Tel./Fax: +48 89 5241064, +48 89 5240505; e-mail: a.swierzowski@infish.com.pl