POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 28(2): 283–294, Y. 2013

# VERTICAL DISTRIBUTION AND ABUNDANCE OF PELAGIC FISH IN TWO DEEP STRATIFIED LAKES IN LATVIA*

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Key words: hydroacoustics, Lake Svente, Lake Dridzis, fish density, vertical distribution of fish.

Abstract

Vertical distribution and abundance of pelagic fish were studied in two deep and stratified lakes in south-eastern Latvia. Features of vertical distribution and abundance of fish were studied using hydroacoustic methods. Acoustic data were collected by a BioSonics DT-X digital echosounder operating at the frequency of 200 kHz. The results showed significant differences in acoustic estimates of fish density between day and night surveys. The vertical distribution of fish was markedly heterogeneous in Lake Svente and Lake Dridzis during the day and night. The characteristics of vertical distribution and abundance of fish were different between the two lakes. Spatial segregation of larger and smaller fish was observed in Lake Svente during the day.

## ROZKŁAD PIONOWY I LICZEBNOŚĆ RYB W JEZIORACH SVENTE I DRIDZIS NA ŁOTWIE

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Słowa kluczowe: hydroakustyka, Jezioro Svente, jezioro Dridzis, zagęszczenie ryb, rozkład pionowy ryb.

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* This study was supported by the ESF Project *Formation of interdisciplinary research group for securing the sustainability of salmonid lakes in Latvia* No. 2009/0214/1DP/1.1.1.2.0/09/APIA/VIAA/089.

Abstrakt

Badano rozkład pionowy oraz liczebność ryb w dwóch głębokich, stratyfikowanych jeziorach w południowo-wschodniej części Łotwy. Użyto metod hydroakustycznych. Dane akustyczne gromadzono za pomocą cyfrowej echosondy BioSonics DT-X ustawionej na częstotliwość fal 200 kHz.

Wyniki badań wskazują na występowanie istotnych różnic w szacunkowych ocenach akustycznych zagęszczenia ryb między pomiarami w nocy i w dzień. Pionowy rozkład ryb był znacząco niejednorodny podczas dnia i nocy w jeziorach Svente i Dridzis. Cechy charakterystyczne opisujące rozkład pionowy i liczebność ryb były odmienne w dwóch badanych jeziorach. W Jeziorze Svente zaobserwowano segregację przestrzenną większych i mniejszych ryb występującą podczas dnia.

## Introduction

Lakes are an important group of freshwater habitats, which people generally consider attractive. The Water Framework Directive requires all member states of the European Union to achieve a sound ecological status of surface waters as defined by different groups of biota (European Commission 2000). Understanding of freshwater ecosystem functions is important for effective lake management. However, the spatial distribution of fish in water ecosystems is a complex issue. There are external and internal factors that determine the spatial distribution of fish populations. These factors influence migration, feeding, predator avoidance, reproduction and habitat selection of fish. Traditionally, the environmental background is mentioned as a major factor that correlates with the spatial heterogeneity of fish (LAEVASTU and HAYES 1981, PLANQUE et al. 2011). Abiotic factors especially strongly shape vertical gradients in deep lakes (ŚWIERZOWSKI 2001, EILER and EILER 2004). It is assumed also that the pattern of space use is a complex result of individual species making decisions based on the trade-off between foraging behaviour and predation risk (ROJAS and OJEDA 2010). Light regime is one of the important factors that contribute to vertical and horizontal migrations of fish. Thus, it is assumed that the vertical distribution of fish populations in the lake is unstable through the time (ŚWIERZOWSKI 2001, ŚWIERZOWSKI 2003, DRAŠÍK et al. 2009). The main objective of this study was to evaluate vertical distribution and abundance of fish in two deep lakes in south-eastern Latvia, taking into account vertical gradients of physicochemical parameters, acoustic fish size, and diel cycle.

## Materials and Methods

The lakes are located in the south-east of Latvia. Lake Dridzis (55°58'N, 27°17'E) is the deepest lake of Latvia (maximum depth 63 m, mean depth 12.8 m) and its surface area is 7.5 km$^2$. The lake lies in the Lake Dridzis Nature

Park. Lake Svente (55°51'N, 26°21'E) is a relatively deep, slightly eutrophic lake of 7.35 $km^2$ in surface area. The lake is situated in the region called Augshzeme and its surroundings make a complex area of protected landscapes (POIKANE et al. 2001, BRAKOVSKA and ŠKUTE 2007). The mean depth of the lake is approximately 7.7 m and the maximum depth 38 m. The northern part of the lake is 20–35 m deep and has a strongly marked depression (35 m). Lake Svente is the ninth deepest lakes in Latvia (BRAKOVSKA and ŠKUTE 2007). Both lakes are popular tourists sites, also attracting many fishermen.

According to the fisheries data on Lake Dridzis, almost 50% of the lake's fish fauna consisted of roach (*Rutilus rutilus*), bream (*Abramis brama*), and tench (*Tinca tinca*). Predators were represented by pike (*Esox lucius*) (24%) and perch (*Perca fluviatilis*) (23%) (*Fisheries Logbooks of Lake Dridzis* 1998). Almost 70% of the fish fauna of Lake Svente consisted of roach (*Rutilus rutilus*) and tench (*Tinca tinca*), whereas predators were represented by perch (*Perca fluviatilis*) (9%) and pike (*Esox lucius*) (13%). Also present, although in low abundances, were bream (*Abramis brama*) and carp (*Carassius carassius*) (*Fisheries Logbooks of Lake Svente* 2001).

Acoustic backscattering data were collected by a BioSonics DT-X digital echosounder operating at the frequency of 200 kHz, split-beam 6.8° transducer and a pulse duration of 0.4 msec. The device was calibrated by the standard sphere method (FOOTE et al. 1987). The hydroacoustic technique has an obvious advantage of being non-lethal and allows for acquiring high-resolution spatio-temporal data with a relatively small sampling effort (SIMMONDS and MACLENNAN 2005). Fish were sampled on the same line transect both during the day (1:00 PM) and night (1:00 AM) in each lake in August 2011. Line transects were situated in the deepest parts of the lakes. The total length of a transect in each lake was approximately 1000 m. The transducer of the echosounder was placed 0.5 m below the surface at the back of the boat and tilted slightly downward. The boat speed was maintained at 2 m $sec^{-1}$. The hydroacoustic acquisition threshold was set at – 90 dB and the ping rate was 5 per second. Hydroacoustic and positional data were visualized and continuously stored on a Getac M230 portable computer running the BioSonics Acquisition® program (version 6.0). Physicochemical parameters of the water column (water temperature, concentration of dissolved oxygen, pH, and concentration of chlorophyll- $\alpha$) were measured consequently at the deepest locations of transects by a calibrated HATCH™ DS5 multi-parameter probe, which allowed for the data capture every 1 m from the lake bottom to the surface.

Raw acoustic data were imported to Echoview® (version 4.9) software. Hydroacustic data were calibrated and echograms were scrutinized to exclude unwanted reverberation and echo traces in the water column that were not fish. Sound speed and absorption coefficients were calculated in Visual Acquisition®

and entered in Echoview® to find out the effects of temperature and salinity on the achieved acoustic data (HAGGINBOTTOM et al. 2009). Hydroacustic data of the transect were divided vertically into 5 m depth zones, and fish density was calculated in each strata. Fish density was obtained using the echo integration method. The target strength (TS) and volume back scattering strength (Sv) thresholds used in the analysis were -64 dB and -70 dB, accordingly (PARKER--STETTER et al. 2009). Values of the target strength were generated in Echoview® for single targets within each analysis cell identified by the split-beam single target detection algorithm (HAGGINBOTTOM et al. 2009). The target strength (TS) frequency distributions were compared between the epilimnion and hypolimnion. These two zones of the water column were defined with respect to the thermocline in both lakes.

Data of the physicochemical parameters were exported from the HATCH™ DS5 multi-parameter probe to the Microsoft Excel® software for visualization and further analysis.

The data on fish densities were first checked for normality and homogeneity of variances, using Kolmogorov's and Bartlett's tests. Analysis of variance (ANOVA) tested the time and depth effect on fish density estimates. Prior to ANOVA testing, square root transformation was applied to variables (MCDONALD 2009). All statistical tests were considered significant at the 0.05 significance level. Data analyses were performed using SPSS® (version 11.5.0).

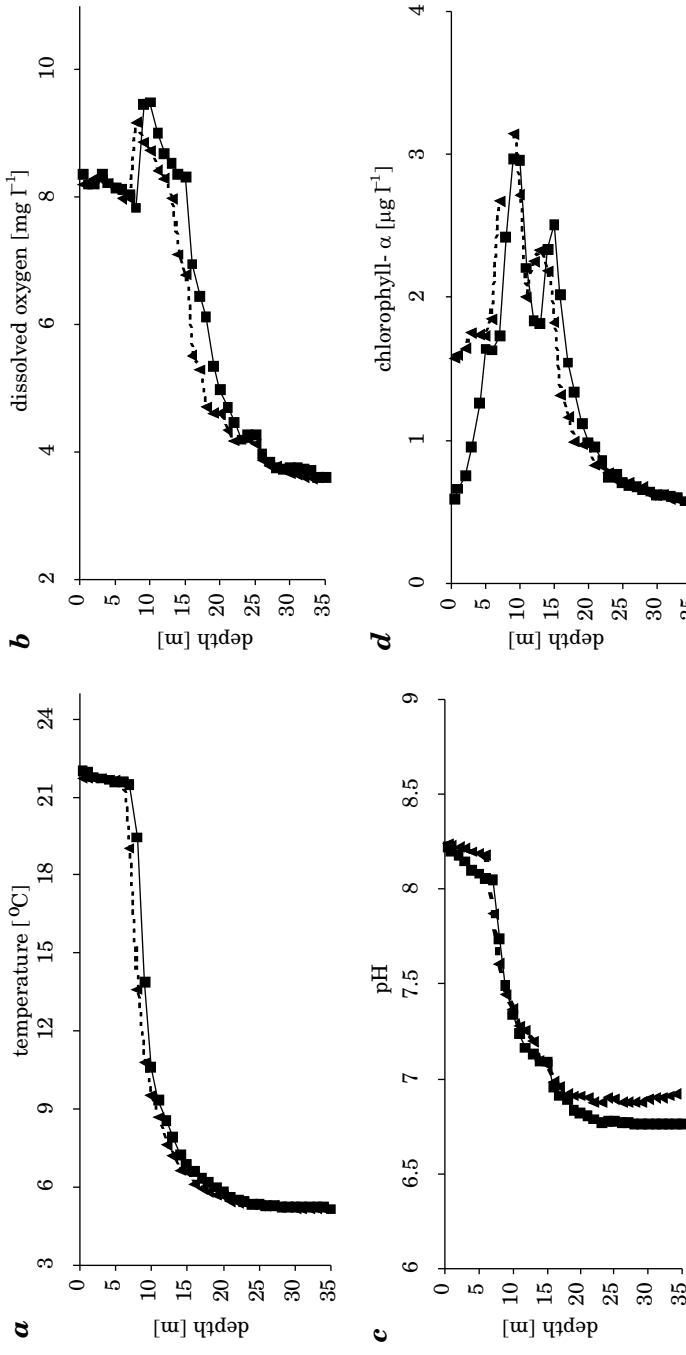
## Results and Discussion

Consistent with our expectations, the profiles of physicochemical parameters were found to be relatively uniform in the temporal dimension, but obviously varied in the spatial dimension. The values of water temperature varied from 5.15°C at the bottom to 22°C at the surface, dramatically decreasing at the depth of 6–12 m. The thermocline in Lake Svente was observed at this depth (Figure 1 a). The pH profiles were similar to the temperature profiles. The values of pH varied from 6.8 at the bottom to 8.2 at the surface (Figure 1 c). The values of chlorophyll- α concentration varied from 0.6 $\mu g\ l^{-1}$ to 3.1 $\mu g\ l^{-1}$ at the depth of 10 m (Figure 1 d). The highest values of dissolved oxygen were observed at the depth of the thermocline. Marked depletion of dissolved oxygen concentration was seen in the hypolimnion of Lake Svente (Figure 1 b). Statistical analysis indicated that the estimated fish density differed between day and night surveys (ANOVA, $P < 0.05$) in the 5 m depth zones of Lake Svente, except for the 30–35 m depth zone (ANOVA, $P = 0.975$). This difference was especially pronounced in the upper part of the water column (Figure 2 a). The results showed that fish were not distributed evenly along the

vertical gradient during the day (ANOVA, $P < 0.05$) and during the night (ANOVA, $P < 0.05$). The 0–10 m depth zone of Lake Svente was the most densely populated at night. Nevertheless, the highest fish density during the daytime was observed in the deepest part of the hypolimnion. The values of fish density varied from 0.23 ind. · 1000 $m^{-3}$ to 55 ind. · 1000 $m^{-3}$ during the daytime and from 24 ind. · 1000 $m^{-3}$ to 146 ind. · 1000 $m^{-3}$ during the night. The target strength data implicitly provide information on the fish size. The values of target strength in Lake Svente varied from -62.5 dB to -20.5 dB. It should be noted that smaller fish were mostly represented in the epilimnion during the daytime, whereas larger fish occupied the hypolimnion (Figure 3 a). However, spatial segregation of larger and smaller fish was not so marked during the night in Lake Svente (Figure 3 b).

In lake Dridzis values of water temperature varied from 4.7°C at the bottom to 20.6°C at the surface, decreasing abruptly at the depth of 5–10 m (Figure 1 e). The values of pH varied from 7 at the bottom to 8 at the surface. The values of chlorophyll- α concentration varied from 0.8 μg $l^{-1}$ to 2.6 μg $l^{-1}$, (Figure 1 h). Profiles of dissolved oxygen concentration showed that the hypolimnion of Lake Dridzis was sufficiently oxygenated. However, an abrupt decrease of dissolved oxygen concentration from 8.2 mg $l^{-1}$ to 5.8 mg $l^{-1}$ was observed at the depth of 5–10 m (Figure 1 f). The results showed that the values of fish density differed between day and night surveys (ANOVA, $P < 0.05$) in all depth zones of Lake Dridzis, except for the 45–50 m depth zone (ANOVA, $P = 0.459$). It should be noted that the depth zones below 35 m were almost uninhabited regardless of the time of day (Figure 2 b). Fish density estimates differed across 5 m depth zones both during the day (ANOVA, $P < 0.05$) and night (ANOVA, $P < 0.05$). The highest fish density was observed in the 5–10 m depth zone both during the day and night. The values of fish density in Lake Dridzis varied from 0.1 ind. · 1000 $m^{-3}$ to 53 ind. · 1000 $m^{-3}$ during the daytime and from 0.2 ind. · 1000 $m^{-3}$ to 155 ind. · 1000 $m^{-3}$ during the night. The patterns of target strength distributions did not show marked differences in vertical distribution of smaller and larger fish in Lake Dridzis (Figure 3 c, d).

The results showed that both lakes were strongly stratified in August. The summer stratification of water was observed in Lake Svente and Lake Dridzis during previous surveys and during several surveys in other lakes in this region, similar in depth (BRAKOVSKA and ŠKUTE 2007, JUREVIČS 2008). The vertical profiles of dissolved oxygen markedly differed between the lakes below the depth of 6 m. These opposite patterns of dissolved oxygen distribution could be explained by different trophic levels of the lakes. The metalimnetic peak of chlorophyll- α concentration could be explained by the marked presence of phytoplankton at this depth. Thus, abiotic factors showed spatial variations strongly influenced by the water stratification. However, light


a
temperature [°C]
depth [m]
b
dissolved oxygen [mg l-1]
depth [m]
c
pH
depth [m]
d
chlorophyll- α [µg l-1]
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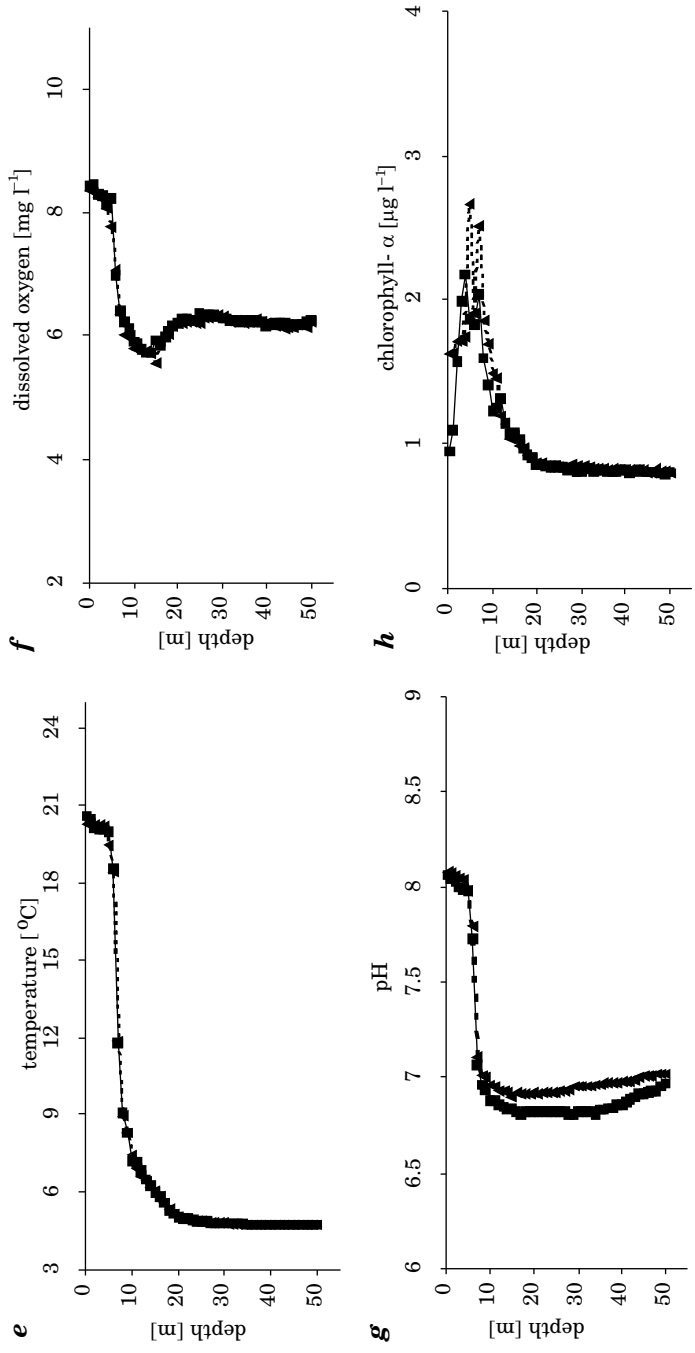


Fig. 1. Profiles of the water temperature, dissolved oxygen concentration, pH and chlorophyll- α concentration in Lake Svente (*a–d*) and Lake Dridzis (*e–h*) for each of the two sampling periods

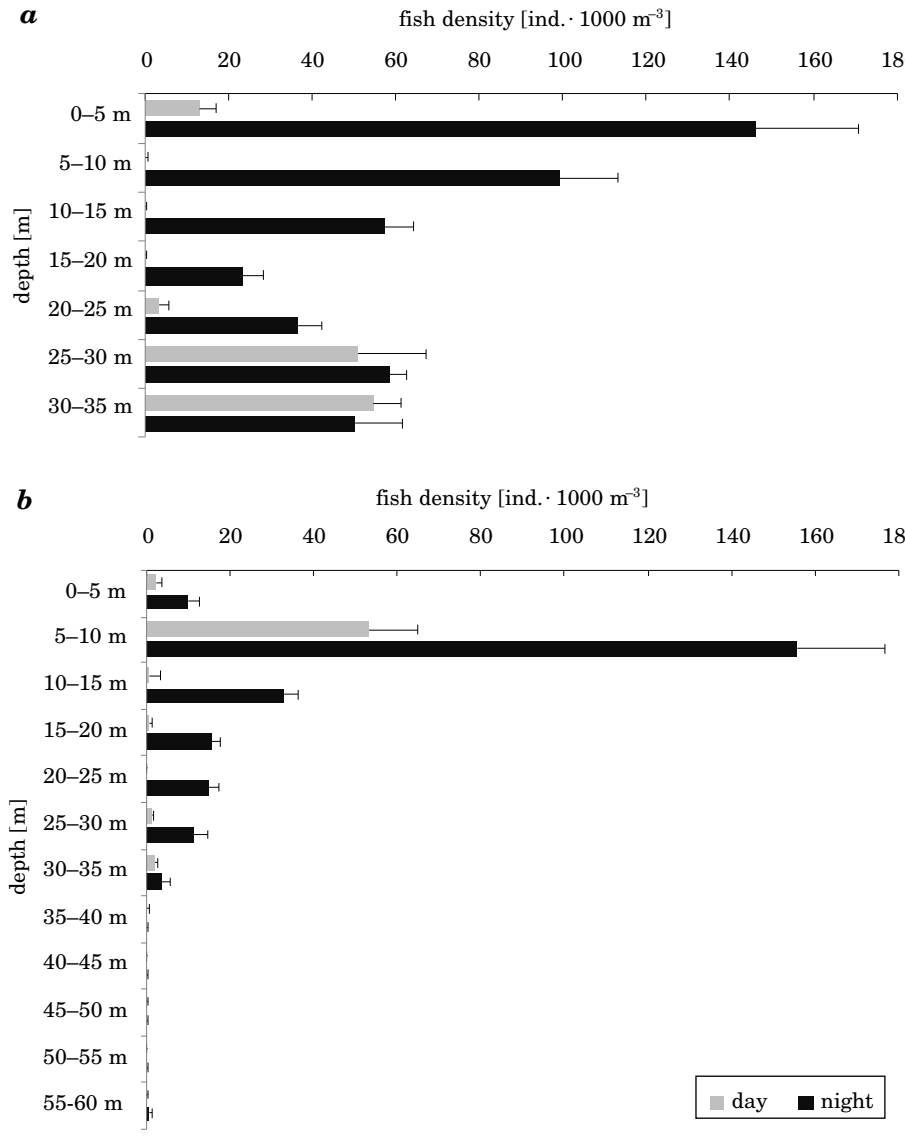


Fig. 2. Mean (+SE) volumetric fish density in Lake Svente (*a*) and Lake Dridzis (*b*) for each of the two sampling periods

intensity was one of the unmeasured changeable factors that should also be taken into account. A relatively high fish density at night in both lakes could have been caused by the horizontal migration of fish to a certain part of the lake or it may have just reflected the movement of fish from the onshore zone into the open water during the night. However, results of this study could not

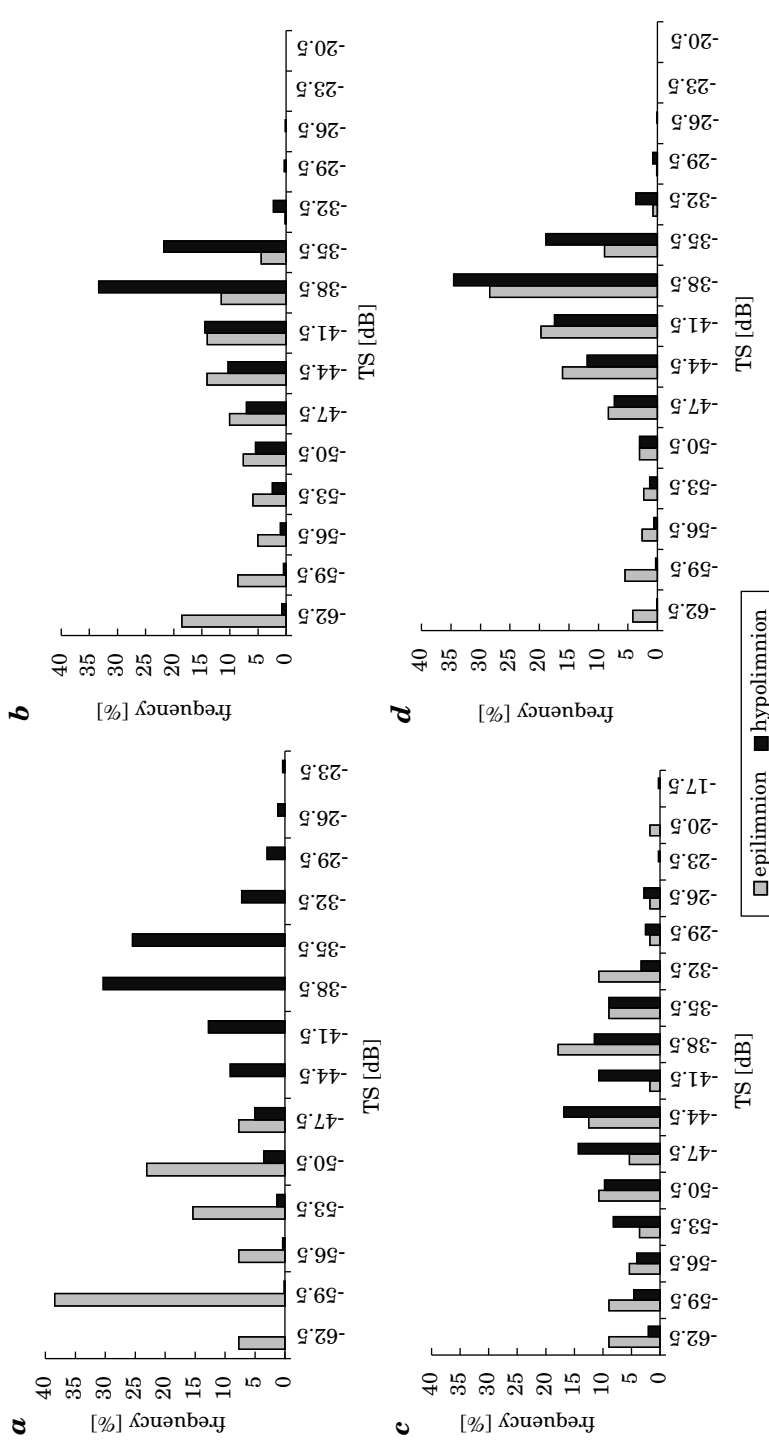


Fig. 3. Distribution of fish targets by target strength (TS) in Lake Svente (*a* – day, *b* – night) and Lake Dridzis (*c* – day, *d* – night) for each of the two sampling periods

sufficiently confirm or reject these assumptions because we had no data about the spatial distribution of fish across the whole lake. An analogous situation of increased fish density in the open water at night was described by MASSON et al. (2001), ŚWIERZOWSKI (2003), EILER and EILER (2004). This pattern of spatio-temporal distribution confirmed a significant time effect on the acoustic estimates of fish abundance in the open water (ŚWIERZOWSKI 2001). Consistent with our expectations and similar studies, fish were not distributed evenly along the vertical gradient in both lakes (DEMBIŃSKI 1971, EILER and EILER 2004, BRIEDIS 2011). Moreover, the characteristics of vertical distribution of fish differed between the lakes. In contrast to Lake Svente, the deepest part of the hypolimnion in Lake Dridzis was almost uninhabited. A significant impact of water temperature and dissolved oxygen concentration on spatial location of fish has been emphasized (EILER and EILER 2004, DOROSZCZYK 2007). The hypolimnion of Lake Dridzis, however, was sufficiently oxygenated. Therefore, the low fish density in the corresponding depth could not be explained by scarcity of oxygen. It should be noted, that Lake Dridzis is much deeper than Lake Svente. Therefore Lake Dridzis has a larger dark hypolimnion zone. Thus, such an important abiotic condition as light regime could probably limit the preferred fish habitat in the hypolimnion of Lake Dridzis. The 5–10 m depth zone of Lake Dridzis was most abundantly inhabited regardless the time of the day. This stratum of the water column approximately corresponded to the metalimnion. The peak of chlorophyll- $\alpha$ concentration was found at that depth in Lake Dridzis. We assumed that it implicitly indicated possible relationships between phytoplankton, zooplankton and fish in Lake Dridzis. The fish density in the metalimnion and upper hypolimnion in Lake Svente at night decreased with increasing depth (Figure 2). Thus, the patterns of vertical distribution of fish in Lake Svente during the night partially could be associated with the water temperature (DEMBIŃSKI 1971). The spatial segregation of larger and smaller fish in Lake Svente during the day could be explained by the predator-prey interactions, taking into account the light regime (SIH 2005, ROJAS and OJEDA 2010). Unfortunately, the hydroacoustic technique does not allow identification of fish species. Thus, this assumption could not be fully confirmed.

## Conclusions

The vertical distribution of fish was markedly heterogeneous in Lake Svente and Lake Dridzis during the day and night. The significant time effect on the acoustic estimates of fish abundance was evident in the open water of both lakes. The results of this study indicated that, despite the similar

geographic location and origin of the lakes, certain differences are possible in vertical distribution and abundance of fish. Profiles of physicochemical parameters were found to be relatively uniform in the temporal dimension. Therefore, the spatio-temporal heterogeneity of vertical distribution of fish could not be fully explained by the measured physicochemical parameters. The scale and methods of this study allow for determination of characteristics of the vertical distribution and abundance of fish in both lakes. However, further studies are needed to elucidate reasons for particular vertical distribution patterns.

Translated by NATALJA MINOVA

Accepted for print 10.05.2013

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