Communications

The diurnal migration pattern of plankton in the Gulf of Gdańsk during storm-induced onshore – offshore bottomwater transport

OCEANOLOGIA, No. 38 (1)
pp. 143–149, 1996.
PL ISSN 0078–3234

Marine acoustics
Hydrology
Gulf of Gdańsk

Zygmunt Klusek,
Krzysztof Poraziński
Institute of Oceanology,
Polish Academy of Sciences,
Sopot

Abstract

This paper describes a front carrying warm and salt water, changing the depth of the thermocline and halocline in the Gulf of Gdańsk, measured by *in situ* (CTD) and remote sensing (acoustic sounding) methods.

During six days at the end of August and the beginning of September 1995, the diurnal migrations of nekton were surveyed acoustically at 30 and 210 kHz frequencies simultaneously from on board r/v 'Oceania'. The survey area was located in the vicinity of the Hel Peninsula (Fig. 1).

During this cruise the meteorological situation was an unusual combination of windy conditions leading to intense water exchange between the Gulf of Gdańsk and Puck Bay. Water exchange in this area after storms had been observed and recorded in a few cases on CTD and current records (T. Wojewódzki – Sea Fisheries Institute – personal information), and predicted during theoretical model investigations (Jankowski, 1984). The situation we came across, although rather rare, seems worthy of publication because CTD profiles and echo intensities at two different frequencies were measured simultaneously.

The acoustic system consisted of two simultaneously working echosounders – an ELAC 4700 at 30 kHz, and a Polish 60/120/210 kHz

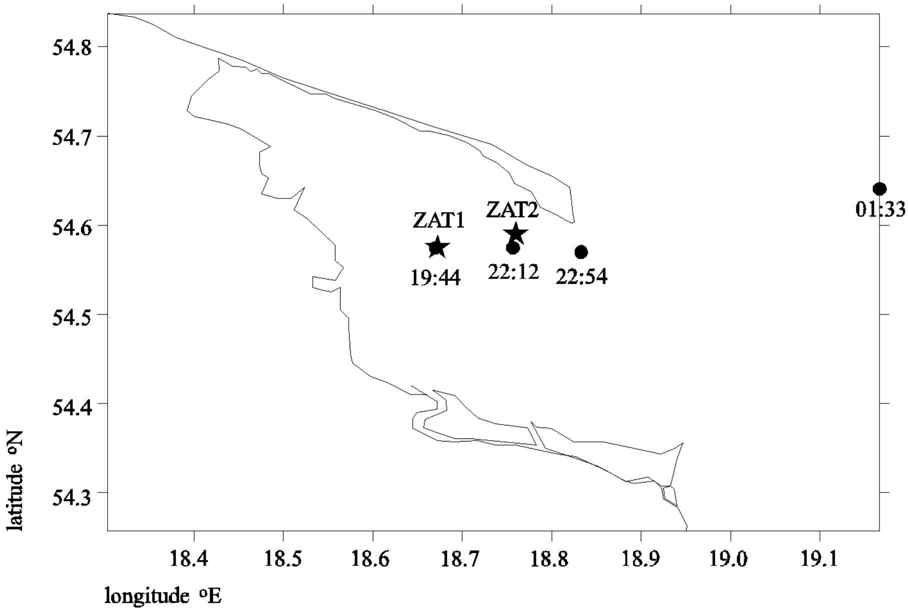
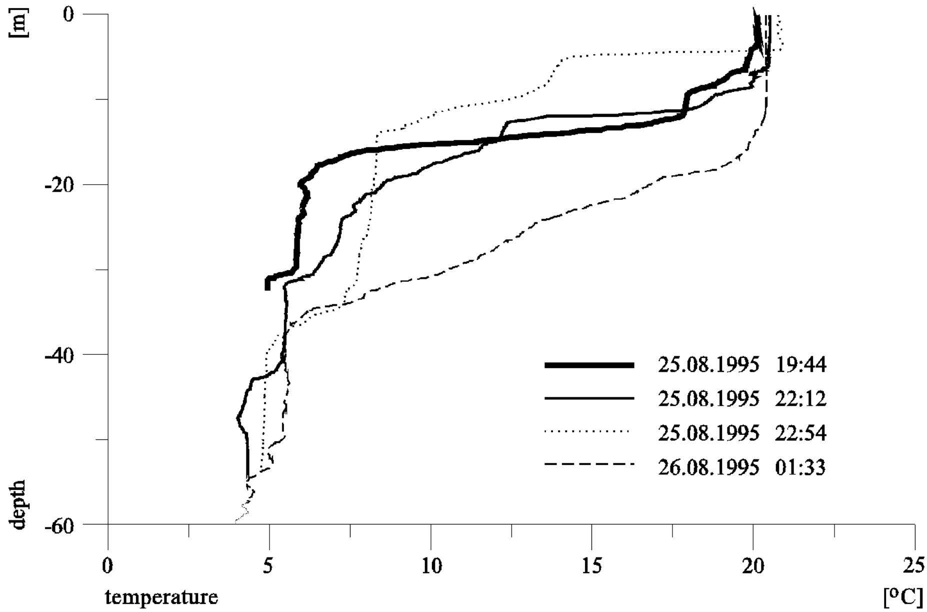


Fig. 1. The CTD casting points: before the storm •, and after ⋆; ZAT1, ZAT2 – names of measurement points; 19:44, 22:12, 22:54, 01:33 – times and sites of CTD probing

echosounder operating at 210 kHz only – connected to 12 bit A/D converters and computers. Working at two very different frequencies, the system should at least theoretically distinguish between echoes of different origin – from nekton at 30 kHz (*e.g.* mature herring and sprat) to zooplankton at 210 kHz. The tranducers were placed at a depth of about 2 m.

The maximum full beam width (± 3 dB) of each transducer did not exceed 16° o at 30 kHz and 7° at 210 kHz. The envelope of the echosignal produced by the hardware was digitised at the rate of 3 kHz. Each sequence of 64 consecutive pings provided a block of data which was taken as the unit for averaging and computing other parameters. The duration of the transmitted signal was 0.6 ms, but the time of pulse repetition was different at the two frequencies – 0.53 s at 30 kHz and 1 s at 210 kHz. The blocks of registered data alternated with pauses corresponding to 128 or 256 pings during the day and at night. During the sunset and sunrise periods registration was continuous. CTD profiles were taken each hour using a 'Guildline 8770' probe.

The TS situation, registered in Puck Bay five days before the storm, is shown in Fig. 2, which gives the set of temperature and salinity profiles recorded on 25–26 August. The symbol '•' shows the CTD casting points in Fig. 1. The subsurface zone was characterised by a thick, 20 m upper layer of



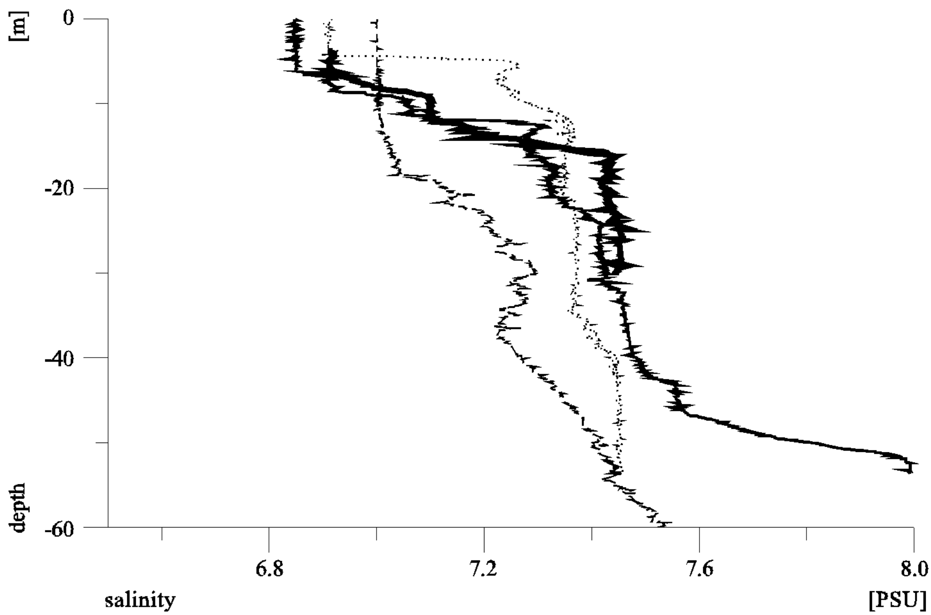


Fig. 2. The TS situation in the study area, recorded five days before the storm

rather homogeneous water with typical summer values of temperature and salinity. Following the north-easterly storm lasting two days with winds up to Force 10, important changes took place in the Gulf of Gdańsk.

The strong winds caused surface water from offshore to pile up in the Gulf, and this was probably associated with coastal downwelling (Szczucka *et al.*, 1994). The CTD time record carried out after the storm at the point marked in Fig. 1 by '$\star$' is illustrated in Figs. 3a, 3b. Comparison of Figs. 2 and 3 shows that in the meantime all the isotherms were displaced significantly. The seasonal thermocline was depressed to a depth of about 48 m, very close to the sea floor (the sea depth at this point was 50 m).

The ship was then moved from the point marked by '+' on Fig. 1 to deeper water where the pycnocline was farther from the bottom.

When the wind relaxed, the onshore – offshore transport responded quickly (in a matter of hours) and this time warm, less saline Baltic water started to spread seaward and denser bottom water flowed into Puck Bay. A moderate E and SE wind of Force 4° to 7° B was blowing all the time during the period of acoustic observations. Within about 24 hours the thermohaline situation at that point had returned to the pre-storm state. At the same time the thermocline and the halocline rose by about 23 m and became less diffuse.

Numerous observations of the migration of acoustic scattering layers in the southern Baltic were made by the Marine Acoustics Laboratory, especially at station P116 ($\varphi = 54°39'$N, $\lambda = 19°17'$E) (Szczucka *et al.*, 1994). However, there are no repeated records of diurnal behaviour in the late summer – early autumn. Nevertheless, some consistent patterns could be identified – a rapid rise around sunset, dense layers at the thermocline persisting during the night, a scattering maximum before sunrise and dispersion at sunrise.

The results of observations at point ZAT2 are presented as compressed echograms averaged over 64 pings in Fig. 4. The colour scale in these echograms represents the echointensity expressed in square voltage of the averaged samples. The colourless (white) areas on the echograms are the temporary breaks in recording.

At the beginning of the observation, during the morning hours, when the pycnocline was pressed to the bottom, as it were, the peak concentration of echo intensity, most probably from plankton, was centered around the maximum temperature gradient. In the upper homogeneous layer echosounder records at both frequencies show layers made up of group scatterers. The traces consist of discrete scatterers or schools of fish, probably small schools of sprat and/or herring, vanishing or dispersing towards evening. In the afternoon hours, typically during this season, echosignal intensity decreased

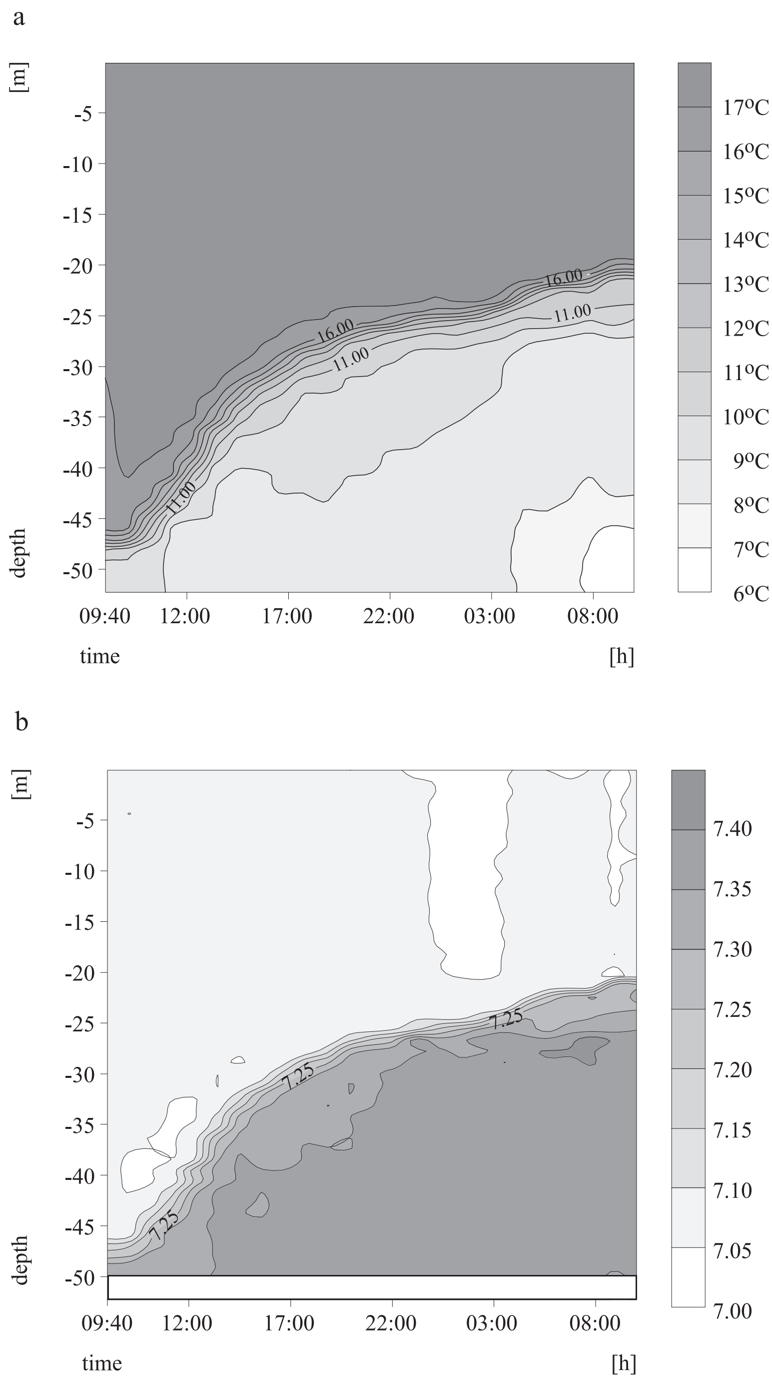


Fig. 3. Time records of temperature (a) and salinity (b) after the storm at point ⋆ in Fig. 1

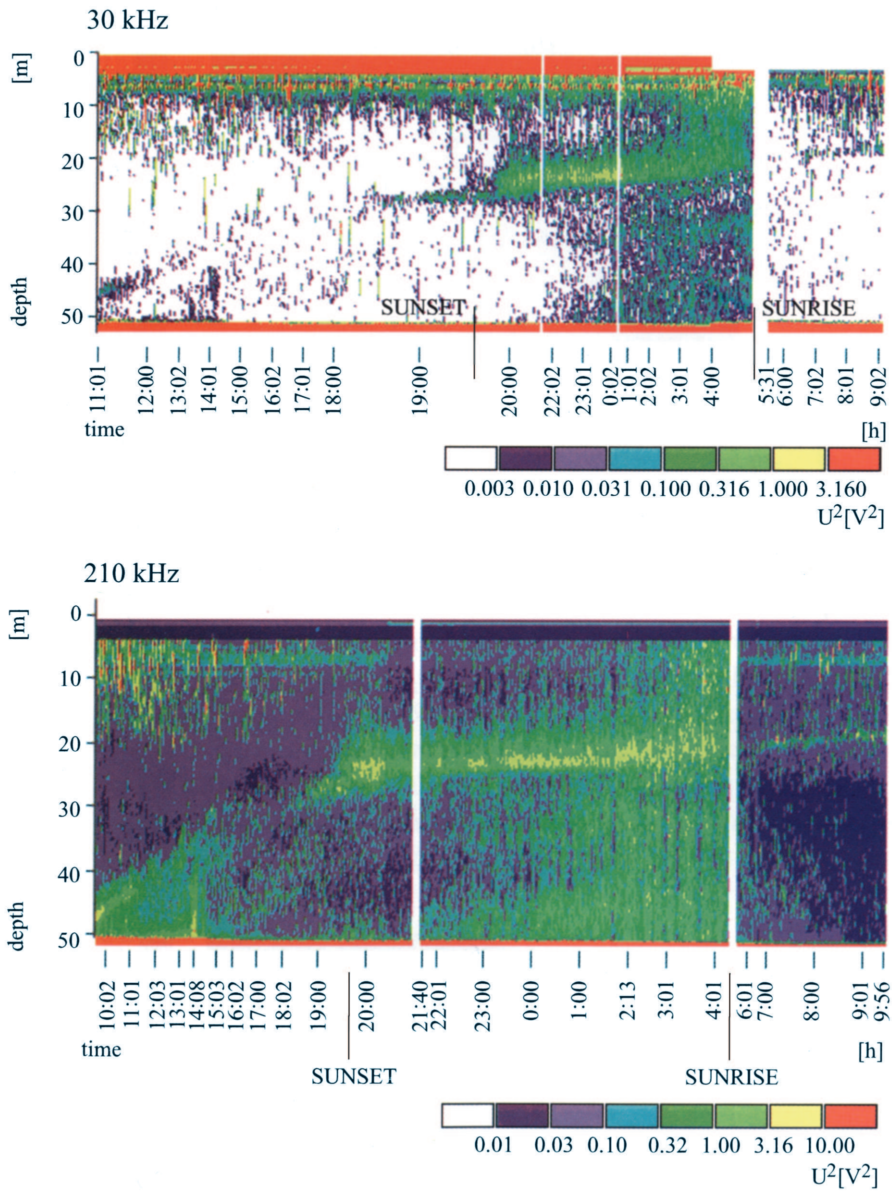


Fig. 4. Compressed echosounder record of diurnal variations in echointensity from scatterers at 30 and 210 kHz

upwards from the pycnocline. This decrease tends to extend into the sunset period. Before sunset, at a higher frequency, the upward migration of plankton could be distinguished as a distinct layer. At sunset, migration to the pycnocline from the layers above and below is quite rapid. The two fluxes from the upper and lower layers meet within 15 minutes. The echointensity maximum is above 7.5°C with a steeper gradient at the lower pycnocline boundary.

A similar pattern of behaviour has frequently been observed in September at station P116 with a stable, deep pycnocline at 50–60 m depth. It can be seen in Fig. 4 that during the night increasing echointensity from the whole water column was observed within the pycnocline. A thick, backscattering layer of unknown origin persisted almost all night and caused night-time backscattering levels to be higher than during the daytime. At the time, the reason was not well understood. Shortly before sunrise the pycnocline dispersed. At this time, the backscattering levels were less intensive than the day before, when the pycnocline was depressed, although the overall agreement between pycnocline gradient and maximum acoustic echo is quite good. It is interesting to note that there were several distinct scattering layers below the thermocline, not connected with the theromohaline situation, moving upwards before sunset. These layers were more clearly apparent on the record at 210 kHz, which supports the hypothesis that they are of planktonic origin.

Quantitative biological sampling is the most urgent requirement in our acoustic observations. When linked with the appropriate enviromental measurements, such acoustic and biological data would provide a basis for an insight into the identification of species and their behaviour.

References

Jankowski A., 1984, *Dynamics of the steady wind-driven circulation in the Gulf of Gdańsk*, Stud. i Mater. Oceanol., 43, 5–79, (in Polish).

Szczucka J., Klusek Z., Śliwiński A., 1994, *Seasonal and diurnal changes of biological patterns in the Southern Baltic Sea*, Proc. 2nd European Conf. on Underwater Acoustics, European Commiss., Luxembourg, 1, 273–278.