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ANALYSIS OF TEMPERATURE CONDITIONS AND DISSOLVED OXYGEN CONCENTRATIONS IN THE PILWA BAY (LAKE DOBSKIE)

ANALIZA WARUNKÓW TERMICZNO-TLENOWYCH WÓD W ZATOCE PILWA (JEZIORO DOBSKIE)

Abstract: This study was carried out in the Pilwa Bay of Lake Dobskie located in the mesoregion known as the Land of Great Masurian Lakes, Gizycko district. Temperature and oxygen conditions in the western, central and eastern (connected to Lake Dobskie) parts of the Pilwa Bay were studied by analyzing the vertical distribution of temperature and dissolved oxygen concentrations in the winter and summer seasons of three consecutive years (2005–2007). Measurements were performed using the WTW OxiTop OC 100 system with automatic temperature compensation.

During winter stagnation, the highest dissolved oxygen content was noted in the top water layer under ice cover, and oxygen concentrations varied widely between years. An analysis of temperature and oxygen profiles revealed an insignificant temperature difference of approximately 1–2 °C between the surface and bottom layers of water, which indicates that the studied bay was not characterized by a summer stratification pattern typical of deep water bodies.

Keywords: temperature and oxygen profiles, thermal stratification, bay

Introduction

Water heats and cools slowly, and it exhibits smaller changes in temperature than air. The above implies that lake ecosystems provide a more supportive environment for the growth of aquatic organisms than land habitats.

The temperature of surface (standing) waters is determined by the depth of the water body, the movement and mixing of waters. Temperature is a key factor conditioning the metabolic activity of aquatic organisms. It affects the solubility of chemical compounds in water, and it supports thermal stratification. The accumulation of thermal energy in

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lakes is determined by various processes, mostly direct absorption of solar radiation, transfer of energy from the sediment layer, transfer of energy from the surrounding land and the metabolic activity of organisms.

During summer stagnation, surface waters in the epilimnion zone are mixed by the wind, and they are characterized by relatively uniform temperature and oxygen concentrations. The thickness of the epilimnion layer is determined mostly by weather conditions in a given year, the size of the water body and its location relative to wind direction. At a certain depth of the metalimnion (transition zone), temperature and oxygen concentrations decrease rapidly to form meta- and oxycline zones. Temperature and oxygen levels decrease fairly uniformly with an increase in depth. The highest water density is noted at 4 °C, but such temperatures are observed only in deep lakes. In the benthic zone, oxygen concentrations approximate zero. In shallow and highly eutrophic water bodies, an absence of oxygen may be observed already at smaller depths. A reverse temperature gradient is noted in the winter. Water is cooler in the surface layer, its temperature increases with depth, along with a simultaneous drop in oxygen concentrations. In transitional periods between direct stratification and inverse stratification in the winter, homothermia, the vertical mixing of the water column takes place in the spring and fall [1].

The aim of this study was to determine the effect of winter and summer seasons on selected physicochemical properties of water in the Pilwa Bay.

Materials and methods

This study was carried out in the Pilwa Bay of Lake Dobskie located in the mesoregion known as the Land of Great Masurian Lakes, Gizycko district. Lake Dobskie constitutes the western part of the Mamry Lake complex, and it is a typical ground moraine formation. The lake has an area of more than 1776 ha, and the bay occupies 52.98 ha with an average depth of 1.36 m and a well-developed shoreline ($K = 1.88$). The shoreline development index (K) is the quotient of shoreline length (l) and the circumference of a circle with an area equal to the lake's area (A_0):

$$K = \frac{l}{2\sqrt{\pi A_0}}$$

The index is a denominate number equal to or higher than 1 [2]. In its present shape, the bay is a only a remnant of the former section of Lake Dobskie that spanned an area of more than 100 ha. The western part of the Pilwa Bay is supplied by watercourses draining catchment areas which are semi-intensively farmed and intensively fertilized. Sections of Lake Dobskie's catchments are exposed to nitrogen runoffs from farmland.

The Pilwa Bay was selected for the study because it receives outflow water from agricultural catchments and functions as an ecotone by preventing the penetration of undesirable contaminants into the main basin of Lake Dobskie. However, long-term human pressure has led to intense eutrophication in the bay.

Vertical distributions of temperature and dissolved oxygen levels were measured in the Pilwa Bay in the winter and summer seasons of the three-year experiment (2005–2007). Measurements were performed using the WTW OXI Top OC 100 oxygen sensor with automatic temperature compensation. In the summer, the Secchi disc method was used to monitor water transparency. Additional measurements were performed to determine electrolytic conductivity, oxygen saturation and pH of water. To account for Pilwa Bay's bathymetric features, shape and varied character, the analyzed water body was divided into three sections based on the direction of water flow: western (554), central (554A) and eastern part which is connected to the main basin of Lake Dobskie (553) (Fig. 1).

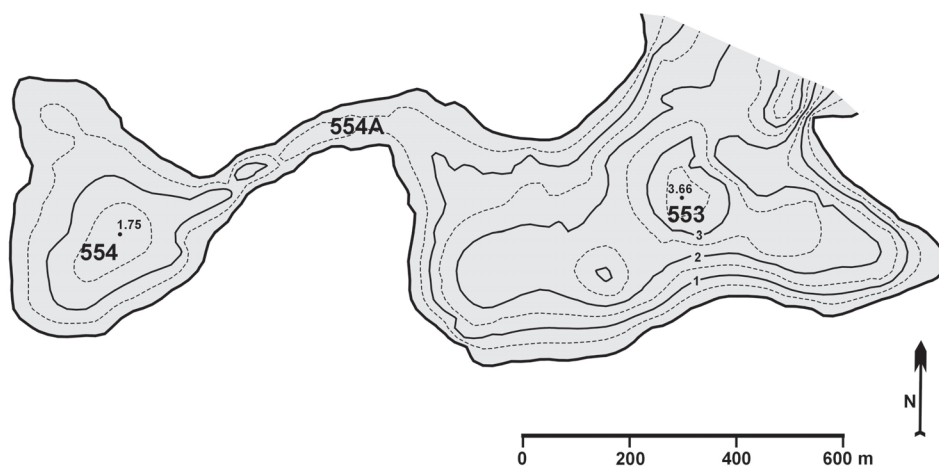


Fig. 1. Sampling sites

Results and discussion

Dissolved oxygen concentrations varied widely due to changes in weather conditions, including temperature of ambient air and water. Inverse stratification was observed in the winter when the temperature of surface water approximated $0\text{ }^{\circ}\text{C}$, and it increased gradually below the depth of 0.5 m to reach around $2\text{ }^{\circ}\text{C}$ at the bottom (Fig. 2–4). Since water circulation is the main source of oxygen supply in lakes, dissolved oxygen concentrations were generally consistent with water mixing dynamics [3]. During winter stagnation, the highest dissolved oxygen levels were noted in the upper water layer under ice cover, and oxygen concentrations varied extensively between years. In the milder winters of 2005 or 2007 (average January temperatures of 0.6 and $2.6\text{ }^{\circ}\text{C}$, respectively), oxygen concentrations in the surface layer fluctuated between 3.68 and $13.21\text{ mgO}_2 \cdot \text{dm}^{-3}$. In the winter of 2006 when average January temperature reached $-4.3\text{ }^{\circ}\text{C}$, oxygen concentrations in the western and central parts of the bay were determined in the range of 0.27 to $0.32\text{ mgO}_2 \cdot \text{dm}^{-3}$, *ie* below the minimum temperatures for fish survival. The critical concentrations of dissolved oxygen

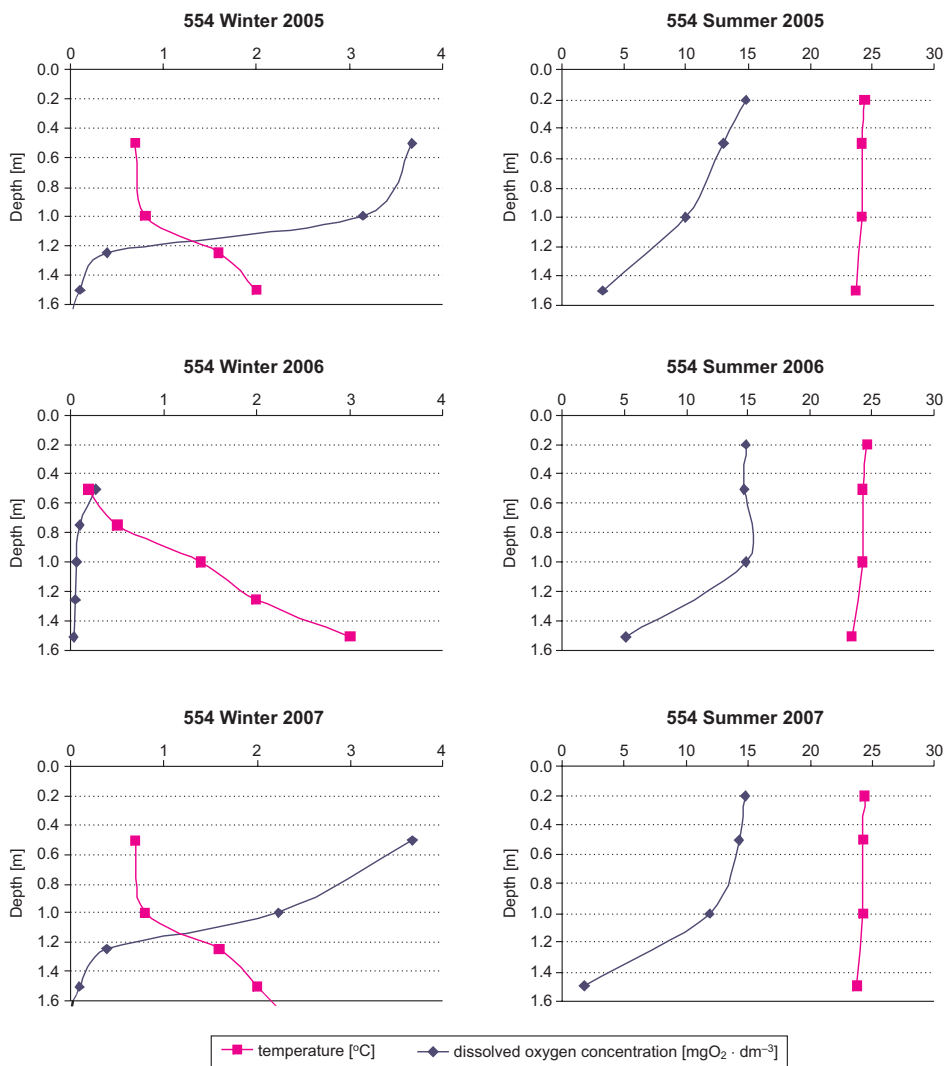


Fig. 2. Vertical distribution of temperature and dissolved oxygen concentrations ($\text{mgO}_2 \cdot \text{dm}^{-3}$) in the western part of Pilwa Bay during the winter and summer seasons of 2005–2007

for aquatic biocenoses are set at $2 \text{ mgO}_2 \cdot \text{dm}^{-3}$ [4]. In the winter of 2006, the thickness of ice cover reached 60 cm, and oxygen could not be absorbed into water by direct diffusion from the atmosphere [5]. Photosynthesizing phytoplankton, mainly diatoms, may be a source of oxygen, but only under sufficient exposure to light. Light is able to penetrate the ice layer in the absence of snow cover, but the winter of 2006 was characterized by abundant snowfall. In the eastern part of the bay which is connected to the main lake basin, severe winter conditions did not decrease oxygen concentrations which reached $15.95 \text{ mgO}_2 \cdot \text{dm}^{-3}$ in the surface layer.

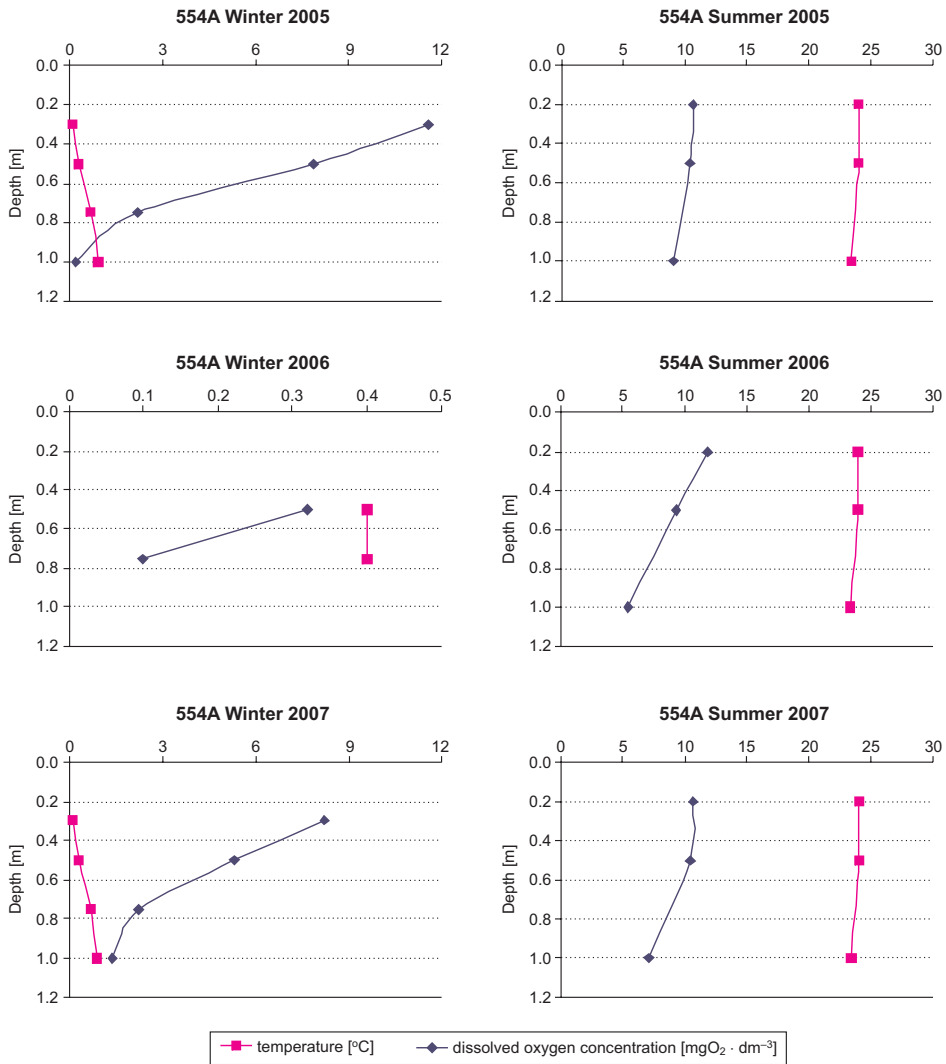


Fig. 3. Vertical distribution of temperature and dissolved oxygen concentrations ($\text{mgO}_2 \cdot \text{dm}^{-3}$) in the central part of Pilwa Bay during the winter and summer seasons of 2005–2007

During summer stagnation, the bay was characterized by incomplete thermal and oxygen stratification which is typical of shallow water bodies. The temperature of the surface layer varied between 22.3 and 24.4 $^{\circ}\text{C}$. An analysis of temperature and oxygen profiles revealed an insignificant temperature difference of approximately 1–2 $^{\circ}\text{C}$ between surface and bottom layers, which indicates that the examined bay was not characterized by a summer stratification pattern typical of deep water bodies. In the three-year period of the study, oxygen distribution patterns were correlated with temperature curves.

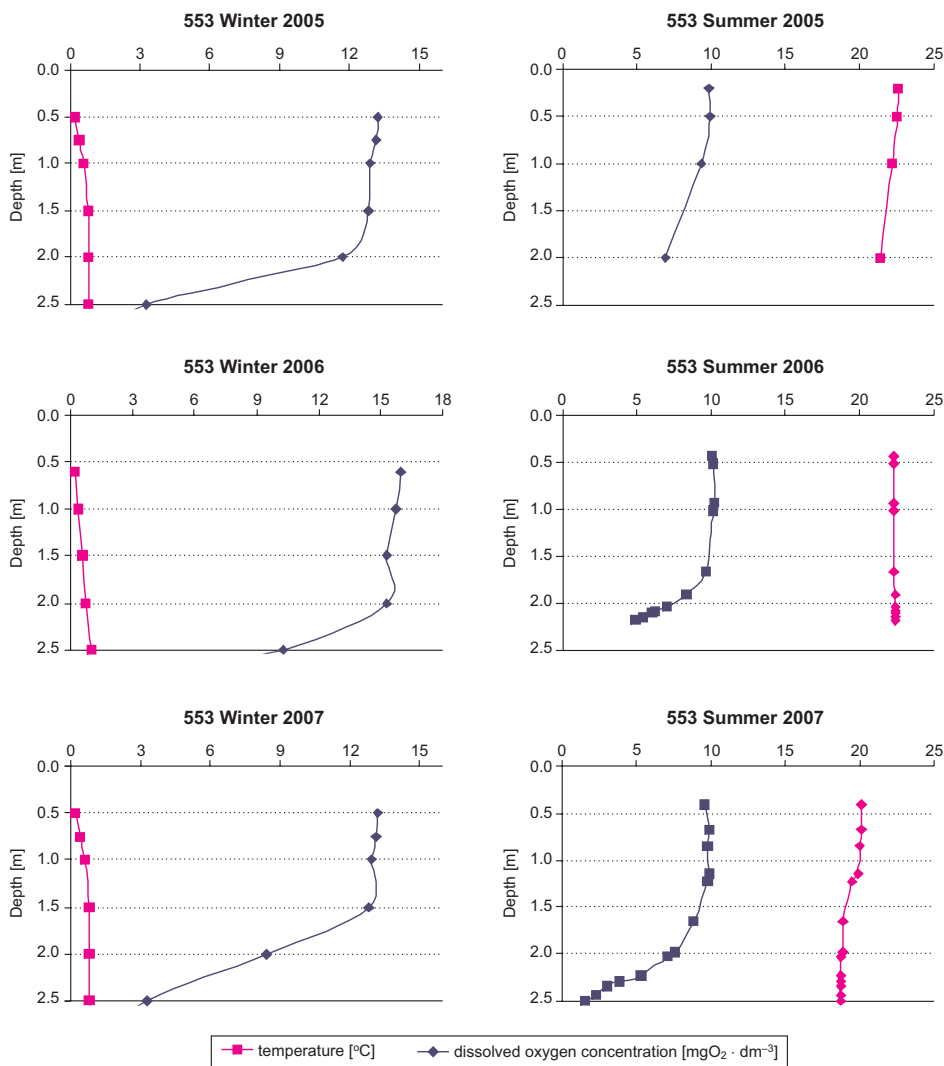


Fig. 4. Vertical distribution of temperature and dissolved oxygen concentrations ($\text{mgO}_2 \cdot \text{dm}^{-3}$) in the eastern part of Pilwa Bay during the winter and summer seasons of 2005–2007

Oxygen concentrations decreased with an increase in depth. A sudden drop in dissolved oxygen levels was noted in the depth range of 1 to 1.5 m. Shallow lakes have polymictic thermal-dynamic regime, and complete circulation of water contributes to uniform temperatures and free distribution of oxygen [6].

The electrolytic conductivity of the studied water body varied significantly between seasons (Table 1). In the winter, maximum electrolytic conductivity in the surface layer reached $810 \mu\text{S} \cdot \text{cm}^{-1}$ in the central part (554A), and the lowest EC value of $370 \mu\text{S} \cdot \text{cm}^{-1}$ was reported in the eastern section of the bay (553) which is connected to the

main basin of Lake Dobskie. In the summer, the highest electrolytic conductivity of $476 \mu\text{S} \cdot \text{cm}^{-1}$ was noted in the western part of the bay (554) which is supplied by two polluted watercourses. Elevated electrolytic conductivity values in runoffs from farmed areas were also reported by [7].

Table 1

Variation in the water parameters of Pilwa Bay in the years 2005–2007

Sampling site	Parameter	Season	Average from the years	Min	Max
Western part (554)	Conductivity [$\mu\text{S} \cdot \text{cm}^{-1}$]	Winter	577	437	716
		Summer	449	426	476
	pH	Winter	7.38	7.13	7.60
		Summer	8.53	7.95	8.80
	Oxygen saturation [%]	Winter	24	2	25
Summer		150	119	178	
Transparency [m]	Summer – 0.3				
Central part (554A)	Conductivity [$\mu\text{S} \cdot \text{cm}^{-1}$]	Winter	713	463	810
		Summer	433	408	474
	pH	Winter	7.25	7.07	7.48
		Summer	8.08	8.12	8.44
	Oxygen saturation [%]	Winter	65	2	79
Summer		113	106	126	
Transparency [m]	Summer – 1.0				
Eastern part connected to the main basin of Lake Dobskie (553)	Conductivity [$\mu\text{S} \cdot \text{cm}^{-1}$]	Winter	329	302	370
		Summer	327	316	359
	pH	Winter	8.39	8.24	8.52
		Summer	8.05	7.55	8.54
	Oxygen saturation [%]	Winter	97	100	109
Summer		120	113	132	
Transparency [m]	Summer – 1.5				

The pH of the analyzed bay varied between 7.07 and 8.80. The maximum pH values were noted in the summer, due to the enhancing effects of photosynthesis. The minimum values were reported in the winter when organic matter decomposition lowered the pH of water.

The oxygen content of water fluctuates on a daily and seasonal basis. The highest oxygen saturation levels at 178 % were reported in the summer. According to [8], oxygen oversaturation may be encountered in eutrophic water bodies with high levels of primary production. The above phenomenon explains high oxygen concentrations in the summer when photosynthesis is intensified by extensive exposure to light and the growth of vascular plants, leading to the production of free oxygen in excess of 100 %.

Secchi disk measurements revealed the highest water transparency (up to 1.5 m) in the eastern section of the bay (553) which is connected to the main lake basin. The

above results can be attributed to low algae content which is an important determinant of turbidity. The lowest levels of water transparency (0.3 m) were noted in the western part of the bay (554) due to the presence of cyanobacteria blooms [9].

Conclusions

1. During winter stagnation, the highest dissolved oxygen content in the Pilwa Bay was noted in the top water layer under ice cover, and oxygen concentrations varied widely between years.

2. Average dissolved oxygen concentrations were higher in the summer than in the winter. Oxygen solubility decreased with depth in the analyzed water body.

3. In the three-year period of the study, electric conductivity values were higher in the western part of the bay which is supplied with runoffs from semi-intensively farmed and intensively fertilized catchment areas than in the eastern section of the bay which is connected to the main basin of Lake Dobskie. Electric conductivity is a reliable indicator of water supply, circulation and dissolved organic matter concentrations, and it supports the identification of incidental events in catchment areas.

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ANALIZA WARUNKÓW TERMICZNO-TLENOWYCH WÓD W ZATOCE PILWA (JEZIORO DOBSKIE)

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Abstrakt: Badaniem objęto zatokę Pilwa jeziora Dobskiego położonego na obszarze mezoregionu Krainy Wielkich Jezior Mazurskich, w powiecie giżyckim. W niniejszej pracy przedstawiono warunki termiczno-tlenowe wód zatoki. Podczas trzyletnich prac badawczych (2005–2007) w okresie zimy i lata wykonano w zatoce (w części zachodniej, środkowej i wschodniej połączonej z głównym akwenem jeziora Dobskiego) pomiary rozkładu pionowego temperatury i tlenu rozpuszczonego. Pomiarów dokonano za pomocą sondy tlenowej z automatyczną kompensacją temperatury (WTW OXI Top OC 100).

W wyniku badań stwierdzono, że w czasie stagnacji zimowej największa zawartość tlenu rozpuszczonego znajdowała się w górnej warstwie pod powierzchnią lodu, a przebieg zmienności stężenia tlenu był bardzo zróżnicowany w poszczególnych latach. Z analizy profilu termiczno-tlenowego wynika, że istnieje niewielka różnica temperatur między powierzchnią lustra wody a dnem i wynosi ona około 1–2 °C, w związku z czym, nie można mówić o typowej stratyfikacji letniej, jaka występuje w akwenach głębokich.

Słowa kluczowe: profile termiczno-tlenowe, stratyfikacja termiczna, zatoka

