

Can popular systems of trophic classification be used for small water bodies?

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Abstract

The aim of the study was to evaluate the trophic conditions of the waters of twelve small ponds based on the analysis of their physical and chemical parameters according to Carlson's Trophic State Index and OECD. Great differentiation in the trophic status of ponds located in different varieties of landscape was observed and ranged from mesotrophic to weak eutrophic conditions in mid-forest ponds and clay-pits, eutrophic conditions in pastoral ponds, and hypertrophic conditions in urban water bodies. Throughout the analysis, a number of limitations in the classification methods of trophic conditions in the examined water bodies were noted. The specific problems were the shallow depth of ponds, which often corresponded with the depth of the Secchi disc transparency, or the complete overgrowing of the pond water column by macrophytes.

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INTRODUCTION

Evaluating the quality of surface waters, for which the process of eutrophication is often the main threat, is usually related to evaluating the state of trophic conditions (Kajak 1975). Even though large water bodies and rivers are monitored constantly, with the periodically repeated registration of chosen features and parameters of habitat and waters (Hillbricht-Ilkowska 2005), in the case of small water bodies (less than 1 ha in area) such research is carried out only occasionally.

Poznań Lakeland is one of the driest regions in Poland and also in Europe. Considerable amounts of water are stored in lakes and small water bodies, which, in Wielkopolska, are distributed unequally mainly in the northern (the Wałecki Lakeland) and central parts (the Poznańskie and Gnieźnieńskie lakelands) of the region (Lewandowski 1992). A serious threat to the Wielkopolska surface waters lies in the continental climatic conditions, and particularly in certain features such as severe winters, hot summers, and low precipitation rates in the transitional climatic seasons. The systematic decrease in surface and ground water levels is a direct result of the drainage works that were conducted intensively in the eighteenth and, especially, the nineteenth centuries. Already at this time, Wielkopolska had been transformed from a well-irrigated land, rich in running waters and old river beds, into an area which was beginning to dry out (Czubiński 1947). In relation to lakes and ponds, the effect of the above environmental transformation is an increase in the concentration of nutrients in the waters and the transformation of the macrophyte cover. Thus, it seems obvious that determining the quality of waters of small water bodies within agricultural and forest landscapes should provide a basis for the elaboration of strategies for their protection.

Many classification systems are used to assess the quality of surface waters, e.g., Carlson (1977) and OECD (1982), in which classic trophic terminology refers to the numerical values of chosen parameters. Research aimed at establishing quantitative categories has already been undertaken in order to identify the biological indicators of water quality which would be based on the structure of organisms or on the characteristics of macrophyte communities. The question of the applicability of using physicochemical indicators of water quality in relation to small water bodies that are not only morphologically different but which are also located in differentiated catchment areas, was undertaken in the present study. The methods adopted to evaluate trophic conditions allowed relationships as well as their contradictions to be discussed.

The aim of this study was to characterize trophic conditions within small water bodies representative of different aspects of human impact based on analyzing physicochemical parameters in open waters.

MATERIALS AND METHODS

The study area is located in the neighborhood of the Poznań agglomeration in the macroregion Wielkopolska Lakeland (Kondracki 1998). This area is characterized by a dense river network and postglacial lakes and small water bodies of various sizes. The annual amount of precipitation is among the lowest in Poland with an average in the region of Poznań of only 513 mm, which, in the summer months, does not exceed 310 mm. There are several small, shallow ponds within the area of the city of Poznań and its surroundings. The study examined twelve such reservoirs in the western Wielkopolska Region which included: clay-pits (no. 1, 2, 3), urban (no. 4, 5, 6), mid-field (no. 7, 8, 9), and mid-forest (no. 10, 11, 12) reservoirs. All of the reservoirs were of areas between 0.5 and 5 ha and of maximum depths of between 0.2 and 4 m. Most of the reservoirs had no inflows or outflows.

The field research was carried out during the summer season of 2004. Samples for physicochemical analyses were collected using sampling equipment in the open water zone (unvegetated area). Temperature, dissolved oxygen, pH, conductivity (Sension 156 Hach), and water transparency (Secchi disc) were measured in situ. The laboratory analyses included total phosphorus and total phosphates (Hermanowicz et al. 1999). The determination of chlorophyll *a* was carried out spectrophotometrically in homogenized samples after extraction with 90% acetone (Wetzel and Likens 2000). The trophic conditions were estimated using the trophic state index (TSI) as described by Carlson (1977), where the mean values of total phosphorus concentration (TSI_{TP}), chlorophyll *a* (TSI_{Chl}), and water transparency (TSI_{SD}) were taken into consideration. To establish the trophic conditions, the mean value of TSI was compared to the ranges of each trophic stadium as proposed by Kraska et al. (1999). Additionally, trophic condition classification according to the OECD (1982) based on the same parameters was also applied.

RESULTS

The evaluation of trophic conditions of water using classifications based on physical and chemical parameters revealed great qualitative differentiation between the examined water bodies. According to the Carlson's Trophic State Index (l.c.) seven of the twelve ponds were eutrophic; however, in several of these it was mainly TSI_{SD} which contributed to obtaining such values. Only in the case of the clay-pits and mid-forest ponds were trophic conditions identified as between α - or β -mesotrophy. The analysis of the results of the OECD classification indicated hypertrophic conditions in most of the investigated ponds, and water transparency also had a decisive effect. Only with regard to

the chlorophyll *a* concentration were ultra-oligotrophic conditions noted (Table 1) in two water bodies in completely different types of landscape.

Furthermore, the analysis of the trophic conditions in particular types of landscapes indicated that only in the case of the ponds located within the woody areas were trophic conditions lower than hypertrophy (Table 2). According to the OECD index (l.c.), the concentration of phosphorus in the examined water bodies represented mesotrophic, eutrophic, and hypertrophic conditions. The TSI_{TP} index usually had higher values than TSI_{SD} and TSI_{Chl}. The index based on the chlorophyll *a* concentration generally had considerably lower values

Table 1

Trophic conditions of water bodies according to Carlson's index (1977) and OECD (1982). Symbols: U-ol – Ultra-oligotrophy, O – Oligotrophy, α-M – α-mesotrophy, β-M – β-mesotrophy, M – Mesotrophy, E – Eutrophy, H – Hypertrophy.

No	Pond	depth	Carlson's Index					OECD		
			TSI _{TP}	TSI _{Chl}	TSI _{SD}	TSI _{Mean}	Trophic state	TP	Chl <i>a</i>	SDV
1	Clay-pit 5	4	47.4	23.8	40	37.1	β-M	M	U-ol	M
2	Clay-pit 10	2.2	72.4	43.2	48.6	54.7	α-M	H	M	E
3	Mankol	1.4	65.2	49.7	55.2	56.7	α-M	E	M	H
4	Św. Jerzy	0.8	80.3	68.7	63.2	70.7	E	H	H	H
5	Bajkowy	0.25	43.2	72.9	80	65.4	E	M	H	H
6	Batorowo	0.1	85.2	88.4	93.2*	88.9	E	H	H	H*
7	Dąbrówka	0.7	75.3	44.3	65.2*	61.6	E	H	M	H*
8	Pałędzie	1.5	78.2	52.1	54.2*	61.5	E	H	E	H*
9	Piotrowo	0.2	60.6	60.1	83.2*	68	E	E	E	H*
10	Gazbruchy Małe	0.2	54.2	1.2	83.2*	46.2	β-M	M	U-ol	H*
11	Gazbruchy Wielkie	0.35	59.4	31.2	75.2*	55.3	α-M	E	O	H*
12	Sycyn	0.4	63	51.4	73.2*	62.5	E	E	E	H*

* value of TSI_{SD} when depth = SDV

Table 2

Characteristics of the trophic status of water bodies according to type of landscape. (α-M – α-mesotrophy, β-M – β-mesotrophy, M – Mesotrophy, E – Eutrophy, H – Hypertrophy).

n	Group	Carlson's Index					OECD		
		TSI _{TP}	TSI _{Chl}	TSI _{SD}	TSI _{Mean}	Trophic state	TP	Chl <i>a</i>	SDV
3	Clay-pits	61.7	38.9	47.9	49.5	β-M	E	M	E
3	Urban	69.6	76.7	78.8	75	E	H	H	H
3	Mid-field	71.4	52.2	67.5	63.7	E	H	E	H
3	Mid-forest	58.9	27.9	77.2	54.7	α-M	E	M	H

compared to other indexes, which was especially apparent in clay-pits and mid-forest ponds. Similarly, according to the OECD this parameter strongly differentiated trophic conditions from ultra-oligotrophy to hypertrophy (Table 2).

In the case of the TSI_{SD} index, high values of distinctly increasing TSI_{Mean} were noted mainly in ponds located within fields and forests and in one urban water body (Table 1). In seven of the investigated ponds a problem arose with the interpretation of the water transparency results obtained due to shallow pond depth and the correspondingly limited water transparency measured by Secchi disc (Table 1).

DISCUSSION

The trophic condition classification systems of surface waters that are commonly used are based on chosen indicators, such as concentrations of nutrient mineral compounds, water transparency, and the concentration of chlorophyll *a*. Despite great simplification, they are good with reference to large reservoirs, where they are applied as a useful instrument for water management (Soszka 2002). Examples of the systems applied in the evaluation of inland water quality, which use numerical values for trophic parameters, are the indexes of Carlson (1977) and OECD criteria (1982).

Under certain circumstances using the parameters mentioned above to assess trophic conditions may be uncertain, especially in relation to small water bodies. The main problem concerns the value of the water transparency measurement. Secchi disc measurements of water clarity, which is commonly applied, provides only an approximate evaluation of water transparency. Standardized measurements of water clarity help in monitoring environment undergoing changes. Even though the Secchi disc measurement may be influenced by a multiplicity of variables, including solar conditions, geographical location, the eyesight of the observer, the diameter of the disc, and its ability to scatter the light (Lampert and Sommer 2001), this method is usually sure. Problems arise only when the depth of the water body corresponds to the water transparency measured by the Secchi disc; in this case the real water clarity may be distorted and false. This contributed to the identification of hypertrophy in one third of the examined ponds in which water transparency had a decisive effect. The measurement of water transparency using this method may also be unreliable in the case of ponds where the water column is fully filled by submerged vegetation (e.g., *Ceratophyllum demersum*) or if an open water zone does not exist. In all, however, a useful feature of hydromacrophytes is that they provide an opportunity for assessing water transparency based on

the occurrence or lack of certain plant communities (Podbielkowski and Tomaszewicz 1996).

Numerous doubts in evaluating trophic conditions also appeared with reference to the total concentration of phosphorus. From a chemical point of view, total phosphorus is the sum of all of the forms of this element, including phosphates, polyphosphates, and organic compounds in dissolved, colloidal, or suspended forms (Kajak 2001). Only dissolved phosphate phosphorus is available for biological assimilation and is useful for primary producers. However, when phytoplankton blooms the amounts of this form of phosphorus are quickly exhausted. The remaining forms of phosphorus, organic and polyphosphates, may transform into the phosphate form; however, this depends on numerous chemical processes (Grobbellar and House 1995) or on the activity of specialized groups of organisms (Piotrowicz et al. 2002). However, when phosphate forms are depleted, the analysis of total phosphorus may still reveal high values. This is also confirmed by the decreasing participation of the phosphate ions in the total phosphorus bank along with the decrease of the trophic state in the investigated water bodies. So, under conditions of high dynamics and a multidirective tendency of transformations in relation to the biocenosis or biotope, which are characteristic of water ecosystems, it is advisable to establish the qualitative composition of this element. Additionally, studies should identify the structure of the biocenoses, especially the relationships between bacterioplankton and phytoplankton.

It can be concluded that the commonly-used classifications of trophic conditions of surface waters (Carlson index and OECD) may only be applied to a restricted degree in small water bodies, especially those which are either shallow and/or fully macrophyte-dominated. The solution to this problem would be to further develop methods combining chemical indices with biological features, which would be based on the participation of indicator species.

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