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# Establishing reference conditions for Polish lakes – preliminary results

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## Abstract

Establishing reference conditions is essential for performing ecological status assessments of surface waters according to the EU Water Framework Directive. Ecological status is described as the deviation from undisturbed (reference) conditions. This paper presents the process of establishing preliminary reference values for chlorophyll *a*, total phosphorus, and Secchi disc readings in different types of Polish lakes. This was done by selecting potential reference lakes and performing statistical analysis of the values of the main eutrophication parameters. The preliminary reference values for total phosphorus, chlorophyll, and Secchi disc depth were defined as 0.033 mgP $dm^{-3}$, 3.75 µg $dm^{-3}$, and 3.6 m for stratified lakes, and 0.048 mgP $dm^{-3}$, 5.80 µg $dm^{-3}$, and 2.5 m. for polymictic lakes, respectively.

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## INTRODUCTION

The Water Framework Directive (European Commission 2000) introduces a new approach to surface water assessment and classification that requires assessing ecological status, which is the expression of the quality of the structure and functioning of aquatic ecosystems in terms of so-called biological elements (assemblages of organisms inhabiting waters) and the supporting physicochemical and hydromorphological elements. At a high ecological status, the values of the quality elements reflect those normally associated with that ecosystem type when conditions are undisturbed and show no or only very minor evidence of distortion. High status, also referred to as reference status, is the basis for the ecological assessment of water bodies and depends on the deviation of values of quality elements from those observed in reference conditions, which are type-specific. They are defined for each biological and physicochemical element indicator as a numerical value which enables comparing monitoring data with them in order to assess the ecological status of the water body being monitored. All European countries are at the moment in the course of establishing reference conditions for biological elements in different types of waters in order to develop WFD-compliant classification tools. Establishing reference conditions based on macroinvertebrates for selected types of European rivers was discussed within the STAR project completed under the 5$^{th}$ FP EU (Verdonschot 2006). The current REBECCA project (6$^{th}$ FP EU) is working to establish reference conditions in different types and categories of water bodies (Lyche Solheim 2005).

The aim of the paper is to present different approaches to establishing reference conditions for surface waters and the initial results of establishing preliminary reference values for chlorophyll *a*, total phosphorus, and Secchi disc depth for two broad lake types in Poland (stratified and polymictic).

## METHODS FOR ESTABLISHING REFERENCE CONDITIONS

According to the guidance document on establishing reference conditions and ecological status class boundaries for inland surface waters (European Commission 2003a), the main options for establishing reference conditions are:

- the spatially-based method using data from existing undisturbed or minimally disturbed sites (the best existing);
- predictive modeling using data available within a region/type or "borrowing" the data from other similar regions/types;
- temporally-based method using either historical data or paleoreconstruction or a combination of both; this method is usually site-specific and, hence, may be of limited use for establishing type specific values;

- expert judgment.

The reference value for biological or physicochemical indicators (metric) is a suitable statistic (e.g., median or arithmetic mean) of the values pertaining to reference conditions or high status.

The spatial method was adopted to define reference conditions for Polish lakes. In order to identify existing potential reference lakes, a set of pressure screening criteria and water quality criteria were elaborated. They were:

- land use in the catchment area (no urban areas, low population density, high share of forests and wetlands, lack of villages in direct contact with the shoreline);
- recreation use (not intensive);
- sources of pollution (no point sources of pollution);
- high water quality according to the Lake Quality Evaluation System (LQES) (Kudelska et al. 1997).

It was assumed that potential reference lakes should be classified to quality class I or II with a maximum score of 1.80 for stratified lakes and 2.00 for polymictic ones.

## RESULTS AND DISCUSSION

According to Polish lake typology and based on several abiotic criteria described by Kolada et al. (2005), there are 13 types of lakes with a surface area exceeding 50 ha. Monitoring data are too scarce to select a pool of potential reference lakes for each type. That is why establishing preliminary reference values for eutrophication parameters much more simple and rough was adopted based on a few criteria only, namely: altitude (one class – lowland lakes); mean depth (two classes – deep lakes >3 m and shallow lakes <3 m), and alkalinity as the expression of catchment geology (high >1 meq $dm^{-3}$, low <1 meq $dm^{-3}$). Such a harmonized approach was decided on in a pan-European intercalibration exercise for lakes in the central part of Europe (European Commission 2003b). Thus, for Polish lowland lakes preliminary reference values of eutrophication parameters were established for high alkaline shallow lakes (polymictic) and high alkaline deep lakes (stratified).

The selection of potential reference lakes was based on the analysis of lake monitoring data collected in the JEZIORA database (Cydzik 2005) at the Institute of Environmental Protection in Warsaw under the auspices of the commission of the Chief Inspectorate for Environmental Protection. From the list of hundreds of lakes monitored in recent years in Poland within regional and national (benchmark) networks (Cydzik et al. 2005), a total of 26 deep water bodies and 14 shallow ones were selected as references. They represent all lakelands in Poland and meet screening criteria adopted for reference sites. The

catchment areas of the majority of them are densely forested. Even if agricultural use constitutes a significant share of the structure of catchment land use, the cultivated fields are isolated and have no direct impact on lake waters. There are neither urban areas nor point sources of pollution discharging wastewater into the lake or its inflows. Some other characteristics of the lakes selected as reference sites are listed in Table 1.

**Table 1**

Characteristics of lakes selected as potential reference sites

| Feature | Range of values | |
|---|---|---|
| | Stratified lakes (n=26) | Polymictic lakes (n=14) |
| Surface area (ha) | 51.4 – 903.3 | 58.5 – 416.8 |
| Mean depth (m) | 3.9 – 38.7 | 1.2 – 6.0 |
| Alkalinity (meq $dm^{-3}$) | 1.1 – 3.3 | 1.5 – 2.8 |
| Scoring acc. to LQES | 1.13 – 1.80 | 1.27 – 2.00 |

Preliminary reference values of chlorophyll content, total phosphorus concentration, and Secchi disc depth (means from surface waters in spring and summer) are represented by the median values of these eutrophication indicators within the reference lake population (Table 2). They are considered to be robust because relatively few data served as the basis for calculation and confidence may be insufficient. The population of potential reference lakes consists of water bodies with rather small catchment areas and low Schindler ratio values (ratio of the sum of lake and catchment area to lake volume), which can be use as a measure of the intensity of catchment area impact on the lake (Schindler 1971). This ratio does not exceed 2 in the case of 90% of the stratified lakes,

**Table 2**

Concentration of eutrophication parameters in reference lakes (range of values, standard deviation) and preliminary reference values (median) for two broad types of Polish lakes

| Parameter | Stratified lakes (n=26) | | | Polymictic lakes (n=14) | | |
|---|---|---|---|---|---|---|
| | range | SD | median | range | SD | median |
| Chlorophyll *a* (µg $dm^{-3}$) | 0.5 – 9.4 | 2.38 | **3.75** | 2.5 – 19.8 | 5.54 | **5.8** |
| Total phosphorus (mg $dm^{-3}$) | 0.014 – 0.079 | 0.016 | **0.033** | 0.026 – 0.124 | 0.032 | **0.048** |
| Secchi disc depth (m) | 2.4 – 6.9 | 1.32 | **3.6** | 1.3 – 4.3 | 0.82 | **2.5** |

while in the case of polymictic lakes some 80% are characterized by a ratio below 4. This may limit the use of established reference values for lakes with larger catchments. Thus, the next step should be to refine the derived reference values for eutrophication parameters while taking into account the more detailed typology of Polish lakes. When establishing reference conditions using the

spatially based method, the differentiation of values considered as the reference within one water body type should be analyzed. On the one hand, strong differentiation can be regarded as the effect of insufficiently refined typology and, on the other, it can indicate that the metric itself needs improvement or refinement (e.g., increased sampling frequency).

Reference values obtained for chlorophyll are in line with those calculated for Central European dimictic lakes (mean depth 3-15 m) as part of the EU-funded project REBECCA (Carvalho and Moe 2005) and for Danish polymictic lakes (Søndergaard 2005). Reference values of phosphorus in Polish lakes are relatively high in comparison to lakes affected only to a small degree by anthropogenic pressure in other geographical regions, especially northern or alpine, not exceeding 0.020 mgP $dm^{-3}$. This is related to the different geology of the catchment areas which influences the natural characteristics of waters (Vighi and Chiaudani 1985).

Comparing preliminary reference values for eutrophication parameters with limit values adopted in the trophic classification by OECD (Vollenweider 1989), it is clear that the reference state of lowland lakes in Central Europe can also represent eutrophic conditions. This indicates the necessity of establishing reasonable and attainable goals in water management plans by considering not only public expectations but also the limnological features of lakes.

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