Application of state-of-the-art geomathematical methods in water protection

- on the example of the data series of the Kis-Balaton Water Protection System -

by

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Ph.D. dissertation summary

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Introduction

Water is perhaps our most precious common resource, and with urbanization and the spread of agriculture and industry it has become, and is becoming more and more exposed to contamination and misuse and lakes are no exception. They are sensitive to environmental changes and anthropogenic effects. Lake Balaton being, the largest shallow freshwater lake in Central Europe, also is vulnerable to these impacts. To protect it (and primarily Keszthely Bay) against elevated nutrient loads, the Kis-Balaton Water Protection System (KBWPS) was constructed as a mitigation wetland at the mouth of the River Zala, the largest tributary of the lake (Kárpáti ed., 1980; Tátrai et al., 2000). The construction of the KBWPS was planned in two phases. Phase I (18 km^2 Upper Reservoir) was inundated and began operating in 1985, it became an open lake dominated by algae. Phase II (the Lower Reservoir, total area 51 km^2), however, is still under construction. A part of it (16 km^2), which is covered by reed-dominated macrophytes, was inundated at the end of 1992, and the rest is planned to be completed in 2013-2014.

The present work has three main aims:

(1) to demonstrate the applicability of the proposed methods in water quality evaluation; in particular, on the example of the long term data series of the Kis-Balaton Water Protection System (KBWPS),

(2) to describe the processes evolving in the KBWPS over three decades of water quality samples using explorative data analysis methods, and provide excess information to support the better understanding of the system.

(3) to suggest a means of recalibrating the (monitoring) system, meaning that it could be fine-tuned to follow the evolving processes.

Furthermore, the study aims to deal with a segment of the paradox: "In general we are rich in data, but poor in information" (Clement, 2013). This is particularly true for Hungary, where hundreds of thousands of data "lie around" without being assessed in sufficient depth. In the case of the study area the more than 250,000 data assessed represented the fruit of approx. 30 years of hard work and monitoring. This fact urged me to try to extract as much excess information as possible with the aid of stochastic modeling. This study (and more generally the approach used in it) could hopefully help scientists to gain a broader perspective on processes evolving in such water systems as the KBWPS; and with regard to the study area, when it comes to finishing the

second phase of the reservoir system (2013-2014), more knowledge will be available on what can be expected regarding the quality of the water entering Lake Balaton, and the conservation of the nature preserve wetland area.

Materials and methodology

In the course of the research the time series of a total of 24 weekly and 3 daily sampled natural parameters (variables) were used from 12 sampling sites of the KBWPS and one each from the River Zala and Keszthely Bay for various time intervals, out of which the longest was 1977-2009. The analyzed dataset comprised approximately 250,000 data.

The methods used comprised the following:

- *descriptive statistics and "elementary" time series analyses* to get an overview on the data at hand and point out the key events in the history of the KBWPS;
- *cluster-, discriminant-, principal component analyses with Wilks' lambda statistics* to
    - find those water quality parameters which give rise to the factors driving their relationships,
    - find similar spatial water quality patterns,
    - shed light on the new "stabile state" of the system (Scheffer et al., 1993);
- *dynamic factor analysis* (Kovács et al., 2004) to determine which external influences (latent effects) dominated in determining the long-term behavior of the River Zala;
- *variogram analysis* to suggest a sampling frequency for the KBWPS that is suitable to calculate annual nutrient loads without significant information loss;
- *wavelet spectrum analysis* to give an overall picture of the parameters capability of following the seasonal changes in the different habitats of the KBWPS.

Results

1) The separation of the point and non-point nutrient loads is extremely difficult. However, despite this, with the aid of dynamic factor analysis, changes in the governing processes of the River Zala were determined, specifically the decreased role of diffuse-, and the increased role of point source nutrient loads, as well as biological activity, as indicated by the role of water temperature.

2) By means of cluster analysis it was found that the border between Phase I and Phase II changes dynamically, the most explicit change being after 1997, when SS 202i disconnected from the cluster group covering Phase II and connected to the one covering most of the SSs of Phase I. This happened as a result of water management issues (constant water level), which degraded the macrophyte vegetation in the vicinity of SS 202i.

3) The use of input-output analysis enabled a discussion of the P retention capacity of the KBWPS in which the decreased overall output to Lake Balaton could be demonstrated. This was due to the economic changes, the water quality ameliorating measures taken, and the beneficial effects of the KBWPS. Furthermore, it becomes clear that since the publication of the work of Somlyódy et al. (2003) the nutrient retention capacity of the system has not changed.

4)

a) Using cluster- and principal component analysis with Wilks' lambda statistics, it was found that the adverse decrease of nutrients was responsible for Keszthely Bay forming a cluster group alone in the low runoff years from the perspective of the KBWPS.

b) With reference to the determining role of runoff, it was found that as far as the stochastic relations are concerned, in the years with low runoff, Kszt was not the SS where the most influential parameters underwent a change. On the contrary before the year 2000 - when runoff was low - the inorganic parameters were those which dominated the water body of Phase II to the greatest extent, which after the year 2000 became co-dominated by the parameters describing eutrophication and the nutrient cycle. This was the period when Keszthely Bay formed a distinct area with regard to the KBWPS.

5) Using periodicity analysis a new perspective was gained on the vulnerability of wetlands. As seen from the input-output analysis, 40% extra runoff and approx. 25-30% extra nutrient input is brought by the canals coming from Somogy County. These disrupt the capacity of the water quality parameters measured in Phase II to follow annual periodicity. Therefore, if the buffer capacity of the wetland were to be increased against the extra nutrient loads with the inundation of the remaining areas it would presumably be able to follow the seasonal changes (i.e. indicate annual periodicity) to a higher degree. In terms of periodic behavior it would be less influenced by sudden nutrient loads.

6) Based on the elementary time series and cluster results it has been suggested that, in order to preserve the wetland area of Phase II, its water-level management should be altered so that it is able to follow the seasonal fluctuations.

7) Using cluster-, principal component- and Wilks' lambda analyses the new stable state of Keszthely Bay was determined, where the KBWPS functions as the location of intensive planktonic eutrophication, which facilitates the movement of the eutrophication processes upstream to Phase I(*After the after reaching the partially finished state of the KBWPS (1992), neither the changes in the background processes of Phase II nor the changes in runoff and loadings were able to influence the solid state of the stochastic interdependences at Kszt, while its trophic processes (observable in their continuous decrease 1981-1984 & 1985-1992) moved upstream from Keszthely Bay to Phase I).*

8) Based on the coded cluster result it has been proven, from the perspective of Lake Balaton, that both the outlet of the KBWPS and Keszthely Bay form separate water quality areas (water-bodies) of Lake Balaton after 1998.

9) Using semivariograms it was determined that the present daily sampling could be rarefied to three days regarding TN & TP, if the aim is nutrient load estimation. Such a step would result in a reduction in water management costs and the more economic function of the monitoring network. This principle could have wider applicability in the management of other water bodies as well.

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