3-D Visualization and analysis of the pollution sources in the Lake Ohrid

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Abstract. Our work is related to the ecological state of Lake Ohrid. Tectonic by origin, Lake Ohrid is situated in the south-western part of the Republic of Macedonia. The size of the lake is 358 squared kilometres. Its average depth is 151m and the maximum depth is 289m. "Man-made" eutrophication, in the absence of control measures, proceeds much faster than the natural phenomenon and it is the major reason for pollution of this lake.

A Dynamic Integrated Monitoring System (DIMS) was previously presented in another paper. Monitoring system is based on on-line measurements. One of the main objectives of DIMS is to provide a real-time monitoring and efficient protection of the environment.

In this paper, a 3-D based analysis of the data from DIMS is given. The main objective of the paper is to show how the critical pollution sources in the Lake Ohrid can be presented and analysed by using visualization methods.

ESRI 3-D software (ARC/INFO, ArcView Spatial Analyst & Arc View 3D Analyst) for virtual modelling and visualization was used in our work.

Keywords. Pollution, 3-D visualization.

1. Introduction

The Institute for Computer Science and Informatics at the Faculty of Electrical Engineering from "Sts Cyril and Methodius" University in Skopje in cooperation with the Hydrobiological Institute from Ohrid has been working since 1996 on ecological state of water resources. The long-term objectives of our research activities were:

- On the basis of previous research results, to provide an analysis of different parameters for estimation of the eutrophication status of the Lake Ohrid.
-To develop a complete mathematical model taking into accounts all relevant processes in the Lake.
-To apply fuzzy logic for eutrophication analysis and estimation of the Lake.
-To provide multimedia 2D/3D modelling, visualization and analysis of the Lake Ohrid ecosystem.
-To put all measured and calculated data on the Web and in this way to provide an advanced decision support information- monitoring system.

An ecological model for Lake Ohrid has been developed [1], [2], [3] and [4], that gives a general picture of the level of eutrophication in the Lake Ohrid and shows general trends of the lake behavior. The specific nature of the lake has been taken into consideration and embodied in the model. Such dynamic model, which tends to predict future eutrophication and trophic state lake-wide, is the first attempt undertaken in describing the ecological state of Lake Ohrid.

Fuzzy logic is applied in order to obtain more realistic picture about the status of the lake and its prediction [5] and [6]. Fuzzy rule-based models have some advantages over classical models: they use less parameter, they are less sensitive to parameter change, and they are less complicated.

In [7], we presented our scheme for a Dynamic Integrated Monitoring System (DIMS) for the Lake Ohrid. A concept and some preliminary design for a web application for handling the data for Pollution Monitoring System (PMS) are presented in [8]. Data acquisition and analysis is performed by DBMS server and then presented in HTML format in regular pre-defined time intervals.

In [9], we presented a Web-based information system that gives an overview of activities, theory and results of the monitoring, prediction and resolution of ecological problems particularly connected with water bodies. The case example of our work is the Lake Ohrid and its characteristics.

The paper is organized as follows. Section 2 gives the design and implementation of 2-D visualization and analysis of the pollution sources for the Lake Ohrid. Section 3 gives the design and implementation of 3-D visualization and analysis of the pollution sources for the Lake Ohrid, while section 4 will conclude the paper.

2. 2-D Visualization and analysis of the pollution sources in the Lake Ohrid.

By using ESRI GIS software and some selected data from our PMS, we visualized the pollution in the littoral zone of the Lake for different possible situations (cases), as shown on Fig.1. Four main tributaries-rivers Sateska, Koselska, Velgoska and Cerava are shown a model of phosphorus pollution with value classification is presented. It's a case when the influence of all rivers is given with different themes.

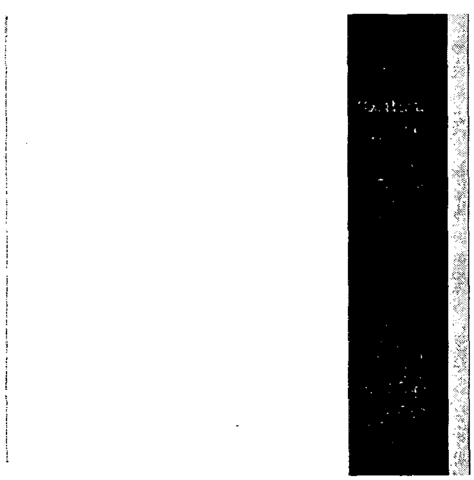

Figure 1. 2-D visualization of the phosphorus pollution in the littoral zone

On Fig.2-7, the virtual models of the Lake Ohrid are presented. Fig. 2 shows present state of pollution of Lake Ohrid. Fig. 3 shows virtual model in the case when the river Sateska doesn't enter the Lake Ohrid, i.e. it is redirected or the river is totally cleaned from the phosphorus. Fig. 4, 5, and 6 shows virtual models in the case when the rivers Velgoska, Koselska and Cerava, do not enter the Lake Ohrid respectively. Fig. 7 shows virtual models in the case when the rivers Velgoska and Koselska (together) are totally cleaned from the phosphorus.

The virtual model shows that if the influence of rivers Velgoska and Koselska are minimized, or if they are totally cleaned from phosphorus, the average pollution of the lake will be evidently decreased, especially in the littoral zone.

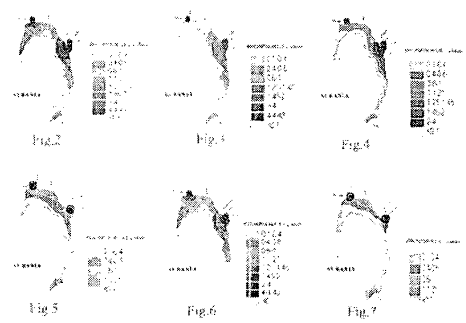

Figure 2-7. 2-D virtual models of the phosphorus pollution in the littoral zone

3. 3-D Visualization and analysis of the pollution sources in the Lake Ohrid

We have used selected data from PMS and ESRI 3D Analyst software for 3-D virtual modelling and visualization. The 3D Analyst provides two types of surfaces models, grids and TINs (triangulated irregular networks), for modelling continuous data. Surfaces can be created from a wide variety of data sources. Triangulating features represented by points, lines, and poligons or from grids can create TINs.

Measurements were held in several previously determined places (deeps) both for phosphorus and temperature changes and in same time intervals. Every month there were measuring held in following deeps: 0m, 5m, 10m, 30m, 50m, 70m, 100m, 120m, 150m, 200m, 210m, 220m, 230m, 240m, 250m, 260m, 270m. Results of those measurements are placed in separate tables showing an annual review of temperature and phosphorus changes through every month reports.

On Fig.8, 3-D virtual model of phosphorus and temperature for the Lake Ohrid is presented for the period of one month. In the first picture we can see all elements, which are present and used for these analysis. In the centre we have table of temperature changing and phosphorus concentration according to lake deeps. In right upper corner there is TIN model of temperature changing with legend on the left explaining the feature. The TIN model is coloured for better visualisation and understanding. In the bottom half we can see two 3D model of temperature changing and phosphorus concentration in colours and legend by each side for explanation.

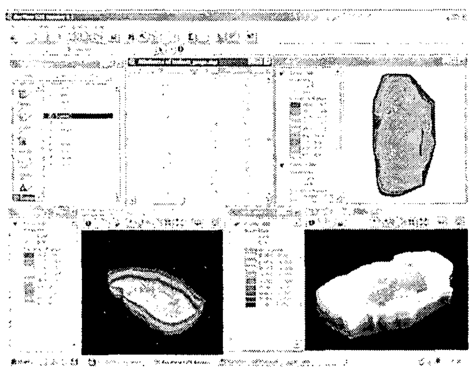

Figure 8. 3-D virtual model for the phosphorus and temperature for the period of one month

This reports are the base of analysis, which was created in ArcView GIS. First we have model of Lake Ohrid consisted of isohipses. Then using temperature and phosphorus concentration chart we created models of equivalent features of Lake Ohrid but now showing temperature changing and phosphorus concentration. For better understanding the nutrient cycles, we created seasonal dynamics of phosphorus concentration and temperature changing. On Fig.9&10, 3-D virtual model of phosphorus concentration and temperature changing for the period of six months is presented. The virtual model will generate dynamically 3-D graphical presentation from the database for all measured parameters.

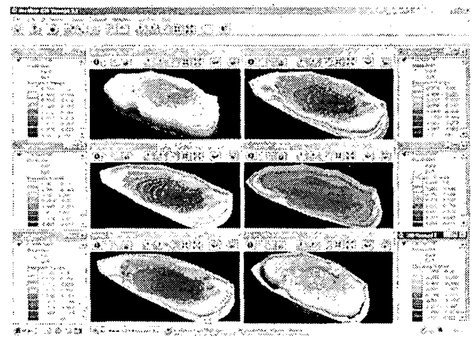

Figure 9. 3-D virtual model for phosphorus for the period of six months

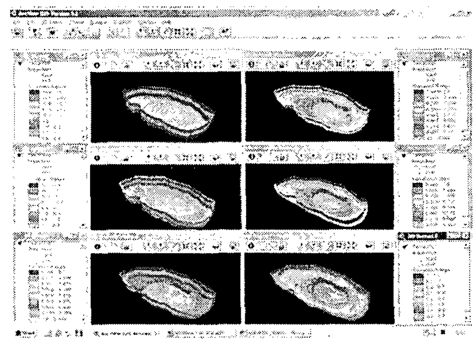

Figure 10. 3-D virtual model for temperature for the period of six months

On Fig.11&12, 3-D virtual model of phosphorus concentration and temperature changing for the period of next six months is presented.

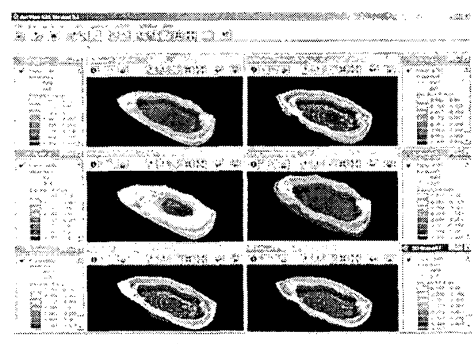

Figure 11. 3-D virtual model for phosphorus for the period of six months

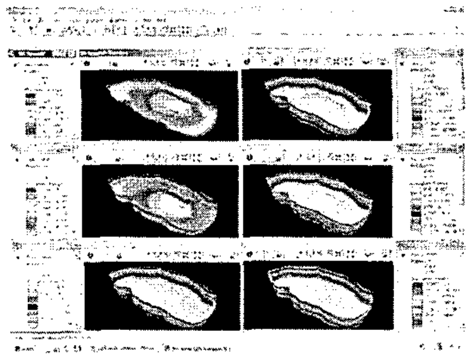

Figure 12. 3-D virtual model for temperature for the period of six months

Also for better annual presentation and understanding of certain processes we can gather up together all models selected and classified according their theme (temperature changing and phosphorus concentration) and time (date) of that situation. Here we can see temperature changing and phosphorus concentration gather up in groups of six months showing the nature and character of those intervals.

Nutrient visualization is necessary because nutrients are the components controlling much of the system behaviour, and specifying future nutrient conditions is extremely difficult. One important aspect of nutrient-phytoplankton dynamics and control of the process of eutrophication is nutrient availability. Some modelling studies [3] on large lake systems suggested that seasonal nutrient dynamics are almost completely controlled by nutrient cycling rather than by external loads. Recycling has been suggested as the major reason why large lakes do not respond immediately to alterations in inputs.
Our ecological model for the Lake Ohrid [4] also was compared with empirical data from the PMS and simulated with ArcView 3D Analyst.

4. Conclusion

In this paper, a 2-D/3-D based analysis of the data from DIMS is given. The main objective of the paper is to show how the critical pollution sources in the Lake Ohrid can be presented and analysed by using visualization and simulation.

Using 2-D visualization, the pollution in the littoral zone of the Lake for different possible situations was analysed. 2-D virtual models shows that if the influence of rivers Velgoska and Koselska are minimized, or if they are totally cleaned from phosphorus, the average pollution of the Lake will be evidently decreased, especially in the littoral zone.

3-D virtual model of phosphorus concentration and temperature changing for the period of one year explain nutrient-phytoplankton dynamics. Nutrient visualization is necessary because nutrients are the components controlling much of the ecosystem behaviour.

2-D/3-D visualization also provides a better and broader presentation of our research results, and easier access to information from any place and at any time.

5. References

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