Steps Towards Integrated Water Management in the Sava River Basin

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Abstract

The aim of this paper is to review data and activities related to water management within the Sava River Basin and contribute to more effective management practices within the basin. The particular focus was given to monitoring of ecological status, availability of biological data and the design of a biological database as part of an information system established within the frame of activity of the International Sava River Basin Commission. The main goal is to provide the basis for establishment of basin wide actions for cooperation on data collection and effective sharing of information. Based on the review of the development of routine water quality monitoring procedures and ecological status assessment methodology within the Sava River Basin, it can be concluded that during the last ten years considerable progress has been achieved. There is a general lack of high quality data needed for river basin management planning within the SRB. This is specifically the case for biological data. Combining results on measurements of biological and parameters with physico-chemical, chemical and hydromorphological parameters, is of crucial significance for the decision making process in water management. The proposal of a conceptual database for biological records was also presented as a basic step for designing a functional information system for environmental data.

Keywords: Sava River Basin, water management practice, international cooperation, biological data, water quality, ecological status.

Introduction

Pressures to aquatic ecosystems are becoming more and more pronounced with the growing needs of human society. The level and diversity of pressures are not the only consequence of constant production growth, but also a reflection of the dynamics of changes in industry and production of new substances. In order to properly react and protect the aquatic ecosystems, the effective and adaptable management practice is needed. It has to be in line with the EU Water Framework Directive (WFD, Directive 2000/60/EC). Moreover, understanding of large, complex river systems such as the Sava River Basin (SRB) is an important task in setting up effective water management, including the protection of aquatic ecosystems. Natural and socio-economic heterogeneity greatly contributes to management complexity of this transboundary river basin.
Providing accurate information is of crucial importance in order to provide successful water management solutions.

The aim of this paper is to briefly review available data and activities related to water management and to offer the ideas that could contribute to the more effective management practices within the basin. Particular focus was given to monitoring of ecological status, availability of biological data and the design of a biological database as part of an information system established within the frame of activity of the International Sava River Basin Commission (ISRBC). The main goal is to provide the basis for establishment of basin wide actions for cooperation on data collection and effective sharing of information. Taking advantage of the rich natural, cultural and human resources, effective and harmonized planning could be a policy driver and governance innovator fostering European integration among countries in the SRB.

The details on transboundary cooperation within the SRB are presented by Komatina and Grošelj (2015). The effective collaboration of countries and institutions in the area covered by the study is the basic precondition for integrated management of water resources and all basin wide actions. In the SRB, the cooperation framework has been provided by the development of the Framework Agreement on the Sava River Basin (FASRB) and the establishment of the International Sava River Basin Commission (ISRBC), as a joint body with responsibility to coordinate the implementation of the FASRB.

Geographic Coverage of the Study and the Main Characteristics

The analyses provided here are focused on a wide geographic area - the Sava River Basin (SRB) (Fig. 1). It is a macroregion, an area that includes the territories of six countries - Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro, with a minor part of the basin area also extending to Albania.

![Figure 1: Geographic coverage and ecoregions of the SRB.](image)

The SRB is an important river basin for South-Eastern Europe, covering a total area of about 97,713 km² and hosting a population of about 8.5 million inhabitants. It is one of the most significant sub basins of the Danube River Basin, with a share of 12%. The landscape within the SRB is diverse, the elevation varying between approx. 71 m above sea level (m a.s.l.) at the mouth of the Sava River in Belgrade (Serbia) and 2,864 m a.s.l. (Triglav, Slovenian Alps). Mean elevation of the basin is approximately 545 m a.s.l. In
terms of land cover/land use, most of the basin is covered by forest and semi-natural areas (54.7%) and agricultural surfaces (42.4%), while the share of artificial surfaces is 2.2%. Four ecoregions (concept presented by Illies 1978) are represented within the SRB - Alps (ER 4), Dinaric Western Balkan (ER 5) Hungarian Lowlands (ER 11) and Hellenic Western Balkan (ER 6).

Study Design

The results presented in this paper are based on the review of available information related to water management within the SRB throughout a ten year period 2005-2015. The evaluation includes data for Slovenia, Croatia, Bosnia and Herzegovina, Montenegro and Serbia. The data from Albania is not taken into consideration since it shares only a minor part of the basin area.

The period of evaluation was selected based on the starting point of the implementation of the WFD. Namely, intensive implementation of the WFD in the SRB started in the period between 2003 and 2004 and already in 2005 countries provided early results.

The evaluation has been focused on data important for preparation of river basin management plans, particularly on biological data. The data from national routine water quality/status monitoring has been evaluated, together with information gathered from recent international projects. Additionally, information provided in the Sava River Basin Management Plan (ISRBC 2013), as well as extensive discussion made available in Milačić et al (eds. 2015), were also taken into consideration.

The evaluation of the development of ecological status assessment procedures within the SRB was done based on the review of the development of national water monitoring systems.

The following datasets have been collected and evaluated, in respect to frequency and parameters of monitoring: water quality data; sediment quality data, hydrological data (both for the 2005-2013 period); biological data (2010-2015); available GIS datasets. Also, data on concentration pollutants in biota tissue has been addressed in accordance with the Directive on Priority Substances (EU, 2013).

The outcomes of the discussion from the workshop “Towards the assessment of ecological status of water bodies in the Sava River Basin”, jointly organised by the STAWA Project (Danube START - Danube Region Project Fund, No. 09_PA04-C1) and GLOBAQUA (the European Communities 7th Framework Programme Funded under Grant agreement no. 603629-ENV-2013-6.2.1-Globaqua, Navarro-Ortega et al., 2015) projects (Ljubljana 10-12. February 2016), were also used to identify major shortcomings of the water monitoring practice, water quality and biological data availability and general data quality.

The activities related to the information review are presented in Figure 2.

Results

The following issues have been identified as the major challenges to be addressed in water management practice within the SRB:

- Providing confident information for effective river basin management planning;
- Preservation of natural values;
- Sustainable management of hazards in the basin (i.e. floods, droughts, ice and accidents involving water pollution); and
- Ensuring an international regime of navigation on the Sava River and its navigable tributaries.

As underlined by Komatina and Grošelj (2015) the general challenge for water management in the SRB originates from two contrasting needs – conservation of environmental values and water use. Therefore, a balanced approach is needed to use the potential and preserve the values simultaneously, and thus provide a basis for sustainable development of the region. Managing water resources on the basin level is an important prerequisite to applying such an approach in an efficient manner.

Based on the review of the development of routine water quality monitoring procedures and ecological status assessment methodology within the SRB, it can be concluded that considerable progress...
has been achieved during the last ten years. Biological quality elements, together with supporting parameters (as required by the WFD) were recognized as crucial segments of assessment of the status of water bodies. All countries within the SRB use biological elements for the assessment of the ecological status in monitoring practice.

Based on the review of ecological status assessment systems and monitoring practices in Slovenia, Croatia, Bosnia and Herzegovina, Montenegro and Serbia the following outcomes could be highlighted:

• In general, systems of ecological status assessment should be further upgraded;
• Systems using Macroinvertebrates are the most developed in all countries;
• Saprobiic indexes are widely used metrics and historical data are available, as well;
• Fish monitoring was found to be one of the major problems in a majority of countries within the SRB;
• The identification of Heavily Modified Water Bodies (HMWB) is still an open issue and further work on their identification is needed;
• There is general lack of methodology for assessment of ecological potential for HMWBs and Artificial Water Bodies (AWB);
• Monitoring of hydromorphological (HYMO) degradation is still pending issue in all countries within the SRB and further work is needed; and
• There is an obvious need for harmonization of monitoring methodologies, particularly in respect to Biological Quality Elements.

Further development of systems of ecological status assessment should include design of stressor oriented indicators (metrics). Involvement of all biological quality elements is needed to provide systems of ecological status assessment fully compliant with the WFD requirements. Parameters based on the fish communities have not been included in ecological status assessment in some countries within the SRB (e.g. Serbia, Bosnia and Herzegovina and Montenegro).

The process of designation of HMWB, as well as design of assessment of ecological potential systems for HMWBs and AWBs is still an open issue for the SRB.

HYMO assessment is an action that has to be performed in a coherent way in the SRB. It is a challenging, complex issue where numerous and different methodologies are available (Gurnell et al., 2014, Rinaldi et al., 2015a 2015b), and it is important to select the appropriate procedure. Also, the relevant standards are available (CEN 2004 and 2010). As in the case of other elements required for assessment of WB status, harmonization is required for HYMO assessment. It should be underlined that improving of HYMO status of water bodies is a demanding issue, having in mind the level of pressures in Europe. Moreover, some parameters of HYMO assessment are extremely hard to monitor, which is particularly true for large rivers. Based on the review of the data from the Sava River Basin Management Plan (ISRBC, 2013), the most significant HYMO pressures are related to hydropower use, navigation and flood defense measures.

Based on the outcomes from the workshop “Towards the assessment of ecological status of water bodies in the Sava River Basin” (Ljubljana, 10-12 February 2016, organised by the STAWA and GLOBAQUA projects), the following priority actions aimed at improving the monitoring practice, data availability and quality have been identified:

• Harmonization of sampling, material and data processing methodology, as well as assessment systems is crucial in order to provide high quality and comparable data;
• Involvement of biological data into a water related logical and physical database is necessary in order to fully explore the relations between abiotic and biotic factors; and
• Future work is required in order to define effective sampling methodology for large lowland rivers (this is particularly true in the case of macroinvertebrates, but also in the case of fish and phytobenthos);

The discussions from the workshop also pointed out that:

• It is important to cover all key taxa groups in both, monitoring and research;
• There is a general lack of taxonomical knowledge;
• Effective sampling is necessary for confident assessment of ecological status;
• Sampling design highly depends on the scope of the study – different resolution is needed for monitoring and for research; and
• The organization of training courses on identification of biological material and sampling methodology for biological quality elements is highly desirable in the region.

Monitoring of the fate of stressors in multistressor situations is of extreme importance to assess the influence of complex interactions on ecological and chemical status (Navarro-Ortega et al., 2015). It is important acquire knowledge on the fate of stressors in key hydrological situations, such as extremely low water levels and flooding conditions. A holistic approach is needed to properly cover the issue of pollution of complex aquatic ecosystems, including water quality, biodiversity and ecosystems (Navarro-Ortega et al., 2015).
Although collection of data on environmental status in the SRB is performed through national monitoring, most of the programmes are limited to certain river sections, and do not cover all parameters required by the EU Water Framework Directive (WFD 2000) and other related documents. Activities are focused primarily on water and much less on sediment and biota, while biodiversity is not sufficiently addressed. The data on new emerging pollutants, the significance of which has recently been elucidated at the EU level, are scarce (available only from a few research projects). Due to unsatisfactory monitoring practices, insufficient institutional cooperation and use of non-harmonized methodologies, a substantial amount of data is missing or unreliable. No common database and data exchange mechanism has been established within the SRB. There is a lack of comparability among existing data and insufficient assessment of pollutants’ fate in water-sediment-biota compartments.

In respect to the assessment of institutional competence in the area, it was confirmed that research potential is high, but organizational capacity for management of large scale projects and actions is absent in the region.

Harmonization of data quality that includes the sampling, analytical procedures (in the case of chemical parameters) and sampling protocols and taxonomical resolution (in the case of biological quality elements) is a crucial action towards designing effective water management within the SRB.

The general impression is that insufficient information is available for proper water and environmental management within the SRB. Scientific knowledge about the fate and effects of pollutants in water has progressed significantly over recent years and consequently our capability for modelling complex relations and predicting have evolved. For modelling and prediction of water and environment-related processes, availability of accurate data is a crucial issue. To ensure accessibility of such accurate data, the whole procedure starting from material/sample collection, through material processing and data assessment to reporting have to be harmonized and standardized.

Conceptual Model for Biological Data

As it was previously emphasized, one of the priority objectives towards effective use of biological data is to provide input for designing a database for different types of environmental data. This complex topic covers:

1. Preparation of solutions for a background taxonomic database with a relevant taxacoding system (for each biological quality element),

2. To initiate resolving of the issue of uploading the data and "user friendly" reporting tools.

Those activities should be realized by selection of "best available practice" from different platforms designed for similar purposes (e.g. the ICPDR database) and based on the experience of project partners in using different databases, and in line with the results of the project “C4-Establishment of the Sava GIS core functionalities” (coordinated by the ISRBC – started in January 2015). The overall objective of this project is to support the establishment of the Sava GIS as a common platform aimed at facilitating sharing and dissemination of information and knowledge concerning the protection of the water resources and water management activities in the SRB.

Effective international cooperation has been recognized as the only option for progress in complex assignments, such as designing an effective monitoring and data exchange platform.

Here we describe the proposal for a conceptual model of biological data which can be used to create a logical and physical database model when establishing a monitoring system for biological data.

The Conceptual model is designed and based primarily on collected lists of biological data. These examples contain lists of different biological taxa groups (algae, higher plants, aquatic macroinvertebrates and fish) along with descriptive attributes and measured values. For certain types of taxa there are databases with available coding systems (e.g. OMNIDIA diatom database etc.). The database formed on the conceptual model can comprise all known and available species together with their attributes and codes defined from known databases or other sources. There is unlimited ability to add new species thereby generating their own identification codes (Taxa data segment). The enumerated lists of taxa and data can be used for initial database loading and establishment.

The Conceptual model for biological data is separated into three main segments. Each segment is shown in different color:

- Orange - Monitoring point data (6 tables/entities);
- Blue - Measuring data (7 tables/entities); and
- Green - Taxa data (5 tables/entities).

The Conceptual model of the Biological data is presented in the Entity-relationship (ER-model) model diagram (Figure 3). The ER-model is a data model for describing the data or information aspects of a business domain or its process requirements and is ultimately being implemented in a database such as a relational database. The boxes represent the entities while lines show the relations between them. A dot or circle at the end of relation marks the “many” sides of one-to-many relation.
The following entities/tables have been divided by segments:

- Monitoring point data segment:
  - monitoring_point
  - monitoring_point_code
  - river
  - riverbasin
  - country
  - station classification

- Measuring data segment:
  - measured_parameter
  - sample
  - dataset
  - substrate
  - sampling method
  - parameter_class
  - measured_value

- Taxa data segment:
  - species
  - species_code
  - genus
  - family
  - taxagroup

Mark PK and FK in entities/tables are constraints and mean PK - Primary Key and FK - Foreign Key. Constraints are used to limit the type of data that can go into a table.

Primary Key Constraint is used to uniquely identify each row in the table. A primary key cannot be NULL, as it does not make sense to use the NULL value to uniquely identify a record. Therefore, the column that is set as a primary key or as part of a primary key cannot be NULL.

Foreign Key Constraint is used to ensure referential integrity of the data. It is a column (or columns) that reference a column (most often primary key) of another table. The purpose of the foreign key is to ensure that only values that are supposed to appear in the database are permitted.

Figure 3: ER Model of biological data.
Conclusions

There is a general lack of high quality data required for river basin management planning within the SRB. This is specifically the case for biological data. Combining measurement results of biological and chemical parameters is of crucial significance for the decision making process in water management. For proper linking of biological data with water quality information and results of HYMO assessment, a consolidated database that covers all environmental data is needed.

In this paper we presented the proposal how to include biological data in an already existing logical database platform established by the ISRBC. Based on the presented review of the data availability and quality, assessment of water monitoring practices within the SRB, as well as by a general overview of the water management, the following conclusion could be emphasized:

• Fully comparable water related data are needed for proper water management;
• Considerable progress in routine monitoring has been achieved during the last ten years;
• In general, systems of ecological status assessment should be further upgraded;
• It is important to provide high identification skills in laboratories dealing with routine monitoring, with the aim of achieving high taxonomical resolution of the data;
• Harmonization of sampling, material and data processing methodology is crucial in order to provide high quality and comparable data;
• Involvement of biological data in water related databases is necessary to be able to explore the relations between abiotic and biotic factors;
• Future work is required to define effective sampling methodology for large lowland rivers (this is particularly true in the case of macroinvertebrates, but also in the case of fish and phytobenthos);
• The identification of HMWB is still an open issue and further work on their identification is needed;
• There is a general lack of methodology for assessment of ecological potential for HMWBs and AWBs;
• As in the case of other elements for the assessment of WB status, harmonization is required for HYMO assessment;
• Monitoring of the fate of stressors in multistressor situations is of extreme importance, to assess the influence of complex interactions on ecological and chemical status;
• A holistic approach is needed to properly cover the issue of degradation of complex aquatic ecosystems, including water quality, biodiversity and ecosystems, with effects on socio economical regional development.

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