

The Hydrobiological Institute Ohrid as a Centre of Long-term Hydrobiological Studies in Lake Ohrid Region, Republic of Macedonia

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Abstract: The Hydrobiological Institute Ohrid is one of the few research institutions in the area of hydrobiology in Europe, which has continued its successful work for more than 80 years. It was established in 1935 and since then has become a promoter of the aquatic science, contributing directly to the protection of the natural surface water and biota in the region and in Europe. The mission of the Institute is to conduct fundamental and applied hydrobiological research in the three natural lakes: Ohrid, Prespa and Dojran, in their watersheds, and the other water bodies in the Republic of Macedonia. In the implementation of its mission, the Institute has conducted many research projects and activities in the areas of biodiversity, evolution, biology and ecology of the aquatic flora and fauna, as well as water quality, conservation, fish and fishery. Because of its long-term scientific expertise, the Institute has been authorised to perform different monitoring programmes and analyses in the implementation of national environmental policies of the Republic of Macedonia. With its research activities, education, training, and high expertise, the Institute contributed to the numerous initiatives for development of protection and management strategies and plans for Lake Ohrid and its watershed. The current supplement of *Acta Zoologica Bulgarica* was dedicated to the 80th Anniversary of the Hydrobiological Institute Ohrid. It comprises 15 contributions: 10 research articles and five review articles, covering different topics on which the Institute is working. Here we review the scientific contributions under the following topics: water quality, biodiversity and conservation, and ecosystem functions and services.

Key words: Hydrobiology, history, fundamental and applied research, expertise, scientific contributions

The Hydrobiological Institute Ohrid (HIO) is one of the few research institutions in the area of hydrobiology in Europe, which has continued its successful work for more than 80 years. The Institute is the oldest scientific institution in the Republic of Macedonia. It was established in 1935, following the approach and the example of eminent European scientific institutions at that time, such as the Biological Station Lunz in Austria and the Max Planck Institute for Limnology in Germany. Since its establishment the Institute has become a promoter of the aquatic science, contributing directly to the protection of the natural surface water and biota in the region and in Europe.

The idea of the **establishment** of the Hydrobiological Institute Ohrid had emerged as a result of the long-standing scientific knowledge about the living world of Lake Ohrid accumulated at that time. At the end of the 19th century the Austrian zoologists Franz Steindachner and Rudolf Sturany conducted limnological studies and pointed out the great scientific significance of the lake. Their studies were continued by the famous biologists from the region Zivojin Gjorgjevic and Spiridon Brusina, who published the first more detailed data on the extraordinary world of Lake Ohrid. At the same time, scientists from Austria, Bulgaria, France, and

Germany did some comprehensive hydrobiological studies in the lake. The Serbian academician Sinisha Stankovic devoted much of his life to the study of Lake Ohrid and he managed to summarise all previous studies and to analyse the biogeographical issues related to the Ohrid living world, which has been of great importance for science. Academician Stankovic was the one who initiated the establishment of the Hydrobiological Institute (the Hydrobiological Station at that time) and he mostly contributed to the formation of the initial scientific staff of the Institute.

Historically, the work and achievements of the Hydrobiological Institute Ohrid can be viewed through three main time periods. The first period was from the establishment of the Institute to the end of the Second World War and was characterised by fundamental scientific work related mainly to the inventory of the species in Lake Ohrid. The second period continued from the end of the Second World War to the 1980s and was characterised by intensive research and publishing activities, the development of the hydrobiological science in the Republic of Macedonia, and by promoting the uniqueness and scientific significance of Lake Ohrid. The third period continued from the 1980s until the present, and this has been a period of intensive international cooperation, training and enhancing of the capacity of the scientific staff, applying of modern hydrobiological approaches and methods, and improving of the Institute's scientific structure and equipment.

The **mission** of the Hydrobiological Institute Ohrid is to conduct fundamental and applied hydrobiological research in the three natural lakes: Ohrid, Prespa and Dojran, in their watersheds, and the other water bodies in the Republic of Macedonia. This research is part of the long-term work and development programme, which is funded by the Ministry of Education and Science of the Republic of Macedonia. The programme foresees a continuous study of the aquatic ecosystems in terms of physical and chemical characteristics of water, as well as diversity, endemism, relictness, speciation, biology, and ecology of the aquatic flora and fauna, using different approaches at the molecular, organism, population, and ecosystem level.

The Institute has carried out numerous national and international **research projects** in the areas of biodiversity, conservation, water quality, invasive alien species, etc., related to the implementation of the European Union (EU) legislation, such as the EU Water Framework Directive (EU 2000), Directive 92/43/EEC (EU 1992), Directive 2009/147/EC (EU 2009), Regulation 1143/2014 (EU 2014), and others.

Some of the recent projects are as follows: 'Developing of ecological tools for monitoring according to the EU Water Framework Directive' (2009–2013); 'Conservation and sustainable use of the biodiversity of lakes Prespa, Ohrid and Skadar' (2012–2017); 'Restoration of Lake Prespa Ecosystem' (2013–2016); 'Climate change and invasive alien species – growing threats to biodiversity and ecosystem functionality in ancient Lake Ohrid and its watershed' (2012–2014); ESENIAS-TOOLS project 'East and South European Network for Invasive Alien Species – A tool to support the management of alien species in Bulgaria', with a case study on 'Assessment of the impact of alien species on the biodiversity and endemism of ancient Balkan lakes' (2015–2017; www.esenias.org); ECOPOTENTIAL 'Improving future ecosystem benefits through Earth observations' (2015–2019); and 'Assessment of the ecological status according to the EU Water Framework Directive – intercalibration among Western Balkan countries' (2015–2019). With its expertise, the Institute played an essential role in the preparation and implementation of the Feasibility study for the 'Lake Ohrid Conservation GEF Project (Albania/FYR Macedonia)' (1998–2004, www.projects.worldbank.org), funded by the World Bank. The Institute has also been involved in the implementation of large international projects with a significant contribution to development of the contemporary hydrobiological and earth sciences, such as the project 'Subaquatic springs in ancient Lake Ohrid – assessment of ecological importance and anthropogenic change' (2005–2008) in cooperation with the Swiss Federal Institute of Aquatic Science and Technology, Switzerland, and the interdisciplinary project for determination of the age of Lake Ohrid: SCOPSCO 'Scientific collaboration on past speciation conditions in Lake Ohrid' (2013–2017; <http://www.ohrid-drilling.org>) led by the Institute of Geology and Mineralogy, University of Cologne, Germany.

In addition to the fundamental research, the Hydrobiological Institute Ohrid has been conducted **applied research activities** directed towards the improvement of water quality and preservation of the endemic aquatic flora and fauna in the Republic of Macedonia. At national level the Institute is involved in the conservation of the endemic Ohrid trout (*Salmo letnica* Karaman, 1924). Since the construction of the hatchery installations with the establishment of the Institute in 1935, incubation and cultivation of larvae and regular stocking of the Ohrid trout in the lake has been performed in order to preserve the optimum density of the endemic

population. Until now, the Institute has conducted stocking of Lake Ohrid with over 800 million fish offspring.

The long-term **scientific expertise** of the Institute in the areas of water quality, biodiversity, fish and fishery has been recognised by the national authorities in the Republic of Macedonia. Since 1992, the Institute has been authorised by the Ministry of Health of the Republic of Macedonia to perform biological analyses of the drinking water supplies in the country. The Institute has been given also a 'status' of an authorised institution to perform the National Monitoring Programme for Lakes by the Ministry of Education and Science of the Republic of Macedonia. Furthermore, the Institute has been given a leading position in the creation of the national fishery policy through preparation of the Fishery grounds.

Another activity of the Institute is **education**. In 2005 the Institute was accredited for postgraduate studies (according to the Bologna Convention) and in terms of this type of education it belongs to the 'St. Kliment Ohridski' University in Bitola. The Institute organises summer schools in the areas of hydrobiology and environmental protection.

The current **structure** of the Institute has been conceptualised in a way that enables the synergy between the fundamental and applied research activities. The Institute consists of 10 departments that fully cover the physical, chemical, and biological components of aquatic ecosystems, giving a priority to biological components. Currently, there are 29 employees, of them 17 are scientific staff (13 PhD, 3 MSc, and one young researcher), and the rest are technical and administrative staff. Many of the researchers have gained their education, training, and expertise in eminent foreign institutions, with which the Institute has established close cooperation.

During the last decades, the Institute has been equipped with modern field **equipment** and lab facilities in order to implement its research activities. Currently, it is equipped with a research vessel with cranes and winches, radar and echo-sounder with GPS, water profiler (t°C, pH, conductivity, O₂), PAR (photo active radiation), sediment corers, water samplers, plankton nets, etc.

With its research activities, education, training, and high expertise, the Institute has **contributed** to the numerous initiatives for development of protection and management strategies and plans for Lake Ohrid and its watershed. Thus, the continuous scientific promotion of the unique flora and fauna of Lake Ohrid by the Institute at prestigious national and international scientific forums contributed to the

designation of Lake Ohrid together with the town of Ohrid as a World Natural and Cultural Heritage site by the United Nations Educational, Scientific and Cultural Organization (UNESCO) since 1979. Later (in 2014), based on the data collected with the participation of the Institute, showing the value and peculiarity of the whole region, Lake Ohrid and its sister Lake Prespa were declared as an 'Ohrid-Prespa Transboundary Biosphere Reserve' under the Man and Biosphere Programme of UNESCO. Another benefit arising from the work and efforts of the Institute in its scientific history is the initiative for the construction of the communal and industrial wastewater collecting and treatment system with their extraction outside of the lake watershed. The Institute has also actively contributed to the improvement of the water legislation in the Republic of Macedonia, such as the prohibition of the use of detergents with phosphorous components in the watershed of Lake Ohrid.

The **current supplement of *Acta Zoologica Bulgarica*** was dedicated to the 80th Anniversary of the Hydrobiological Institute Ohrid. This Anniversary is a pride for all those who have had the opportunity to contribute to and invest in the development of the hydrobiological science: from the initiators of the idea of the aquatic ecosystem protection, through the followers who developed continuously and maintained this idea, to the present generation of scientists who have been working and contributing vigorously and consciously to the development of the modern hydrobiology and protection of the unique flora and fauna and natural freshwater resources in the Republic of Macedonia.

The supplement comprises 15 contributions: 10 research articles and five review articles, covering different topics related to water quality, biodiversity and conservation, and ecosystem functions and services.

Six of the articles present results from the assessment of quality and trophic state of water in the lakes Ohrid and Prespa, using different indicators: physical, chemical, and biological (bacteria, diatoms, macrophytes). VASILEVSKA et al. (2019) determine the water quality of the following tributaries of Lake Prespa: Golema, Istocka, Kranska, and Brajcinska, based on physical, chemical and microbiological parameters. Their results indicate organic and faecal pollution of the water in the investigated rivers in 2014, the highest organic and nutrient loading being registered in the Golema River. For the same period (2014), LOKOSKA et al. (2019) assess the water quality of Lake Ohrid and its tributaries, using microbiological and chemical indicators. Based

on the results, the lake parts, which are far from settlements and river inflows, are classified as pure waters. The worse water quality has been reported in the area of Grashnica locality, where relatively high organic and faecal pollution is registered, as well as in the rivers Velgoska and Cherava, due to the inflow of communal and industrial waste water rich with pollutants and nutrients. VELJANOSKA-SARAFILOSKA et al. (2019) make a comparative analysis of data on water quality in the littoral and pelagic zones of lakes Ohrid and Prespa based on the results of monitoring of certain physical, chemical and biological parameters, for the period 2013–2014. According to the numeric values of the Carlson's Trophic State Index, calculated based on the total phosphorus, Secchi depth and chlorophyll *a* concentration, Lake Ohrid is determined in a stable oligotrophic state, while Lake Prespa is in a mesotrophic state, with a tendency towards an eutrophic state. VASILESKA & LOKOSKA (2019) determine the microbial phosphatase activity as an indicator of water quality in the rivers Cherava and Velgoshka and the littoral area of Lake Ohrid, where the rivers inflow into the lake, for the period 2013–2014. The water at the studied localities has been classified from satisfactorily clean to slightly and very polluted. The statistically significant correlation between phosphatase activity and microbiological parameters reveals the phosphatase activity in the water as a good indicator of the available organic matter and the degree of eutrophication. Other authors (LOSHKOSKA et al. 2019) assess for the first time the ecological status of some tributaries of Lake Ohrid (Macedonian part) based on benthic diatoms as defined by the EU Water Framework Directive. The Trophic Diatom Index ranges from mesotrophic status in the upper flow of the Sateska River and the middle flow of the Koselska River to eutrophic status in the inflow of the Velgoshka River. The rivers Velgoshka and Cherava show the highest pollution and negative influence on Lake Ohrid. TRAJANOVSKA et al. (2019) study the macrophyte composition and determine the level of nutrient pollution in the littoral of the Macedonian part of Lake Prespa through calculations of the macrophyte index. The authors report 15 macrophytes represented by emergent and submerged species. The nutrient pollution is mainly moderate-immense, immense and massive. The pollution has been found to be heavy and very low only at single sites. Most of the above cited authors recommend certain preventive measures, mainly rehabilitation of the communal waste waters and regular monitoring of the water and sediments in order to prevent further worsening

of the ecological state of the lakes Ohrid and Prespa and their tributaries.

Six of the contributions focus on diversity of some taxonomic and ecological groups, endemic species and conservation issues in the lakes Ohrid and Prespa. PATCEVA & LESHOSKI (2019) present results on the qualitative and quantitative composition of phytoplankton and characteristics of phytoplankton community in the Macedonian part of Lake Prespa for 2013. The phytoplankton assemblages of Lake Prespa and their spatial and temporal distribution are typical of mesotrophic lakes. Bacillariophyta and Cyanophyta are the dominant divisions within the phytoplankton assemblage, showing distinct seasonal variations. Bacillariophyta predominates in spring, while Cyanophyta in summer. According to the Trophic State Index based on chlorophyll *a* concentration, all sampling points at Lake Prespa indicate mesotrophic conditions. TASEVSKA et al. (2019) summarise available field and published data and compile a list of the monogonont rotifers in Lake Ohrid. The authors report the presence of 73 species, representing 27 genera and 17 families. Sixty-one species have been recorded in the littoral zone and only 12 species in the pelagic zone. The highest number of species is observed in the genera *Lecane*, *Trichocerca* and *Cephalodella*. The rotifers of Lake Ohrid have created taxonomically rich composition due to the wide variety of habitats they can inhabit. GUSESKA et al. (2019) analyse the trends in biomass dynamics of the Crustacea (Cladocera and Copepoda) in the pelagic zone of Lake Ohrid through the period 2000–2009. The values of the Crustacea biomass are the highest in the summer and autumn periods, when the values of the Copepoda and Cladocera biomass are similar. Considerable increase in the Crustacea biomass has been recorded during the summer period 2004, which has resulted from the relatively high biomass values of the Copepoda, especially the Calanoida. High values of the Crustacea biomass have been found also in the summer and autumn period 2008–2009, when the biomass of the Cladocera considerably increase in comparison with the other studied periods that imply considerable changes in zooplankton community. Another review (TALEVSKA & TRAJANOVSKA 2019) presents results from long-term studies on the main belts of macrophyte vegetation in Lake Ohrid: the belt of *Phragmites*, the belt of *Potamogeton*, and the belt of *Chara*. The analysed data confirm that these three belts play a significant role in the circulation of materials in the littoral zone and Lake Ohrid as a whole. BUDZAKOSKA GJORESKA et al. (2019) focus their study on the endemic and endangered gastropod

species *Gocea ohridana* Hadžišiče, 1956. The authors assess the current status of the species based on population parameters, such as density changes and dynamics over time, and its habitat preferences for different substrate types, i.e. vertical and horizontal distribution. This endemic species has been reported only from two localities (Velidab and Sveti Zaum), at two depths, on a sandy-stony bottom. The species was not found in other types of habitats, which points out to the high 'selectiveness' or low ecological tolerance as one of the factors that limit the species only to this region in Lake Ohrid. The main threats are mentioned and measures for conservation of this endangered gastropod species are discussed and recommended. TRAJANOVSKI et al. (2019) make a complete inventory of species of benthic diatoms, macrophytes and benthic macroinvertebrates in 2017 at the Velidab locality, recognised as the most important hotspot of biodiversity, at the same time harbouring many endemic species. Furthermore, they assess water quality and ecosystem services. The authors study two alternatives: 1) the Velidab locality is not managed and/or protected in any way (the current situation), and 2) the site is designated as a Strict Nature Reserve and appropriate conservation measures are taken. Twenty-three species of benthic diatoms, 11 macrophytes and 33 benthic invertebrates have been reported. Of them 28 species are endemic, the highest percentage of endemism being recorded in Gastropoda (95%). The ecological status based on water physical, chemical and biological parameters varies in a wide range from oligotrophic to eutrophic conditions, showing a decrease in some parameters and unstable conditions compared to previous study periods. The designation of Velidab as a Strict Nature Reserve has been proposed and appropriate conservation measures are recommended. The results of this and the above cited articles demonstrate the high species diversity and endemism in Lake Ohrid and the urgent need of proper management and protection of the endangered species and habitats.

One of the contributions deals with the assessment of major threats to biodiversity as the invasive alien species and water pollution. In order to evaluate the potential threats to the benthic macroinvertebrate fauna in Lake Ohrid watershed (lake littoral, its tributaries and outflow), TRAJANOVSKI et al. (2019) assess ecological status of the water based on the composition and structure of benthic macroinvertebrate community and examine the occurrence of alien macrozoobenthic species. A total of 79 taxa have been recorded. The highest number of taxa belongs to Insecta, which is presented mostly

in the tributaries, followed by Gastropoda, presented in the lake littoral. All taxa are native, there is no any alien species recorded either in the lake or in its tributaries and outflow. The most abundant are taxa tolerant to pollution, such as *Tubifex tubifex* (Müller, 1774), *Chironomus plumosus* (Linnaeus, 1758), and *Gammarus roeselii* Gervais, 1835. The ecological status of the lake littoral sites is significantly lower (bad and poor) in comparison with that of the sites along the tributaries (from poor to very good) and the Crni Drim River (good). The authors assume that these results indicate a general decrease in the stability and functionality of the lake ecosystem, which may consequently reduce its natural resilience and resistance capacity against introduction and spread of invasive alien species.

One of the article deals with the assessment of ecosystem functions and services. ZDRAVESKI et al. (2019) provide the first economic valuation of the two endemic species *S. letnica* and *G. ohridana* in Lake Ohrid and their protection and conservation. Using a questionnaire and the contingent valuation method, the authors determine the total economic value of the two species and clarify the willingness to pay for the protection of the animals among the residents of the area in Ohrid, the Republic of Macedonia, and Pogradec, the Republic of Albania. The results show that the majority of the respondents are willing to pay for the protection of the two species. The willingness to pay is positively correlated with the income and educational level of the respondents and the best mode of payment is supposed to be an annual tax collectable by the local tax offices in the respective towns. The total economic value of *S. letnica* and *G. ohridana* for the population living near Lake Ohrid for both the Republic of Macedonia and the Republic of Albania has been estimated at 800,249.34 Euro and 699,268.08 Euro per year, respectively. This study clearly demonstrates that local people have highly valued the native aquatic biodiversity, they are concerned about its conservation and are interested to support financially the protection of the endemic species in Lake Ohrid.

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