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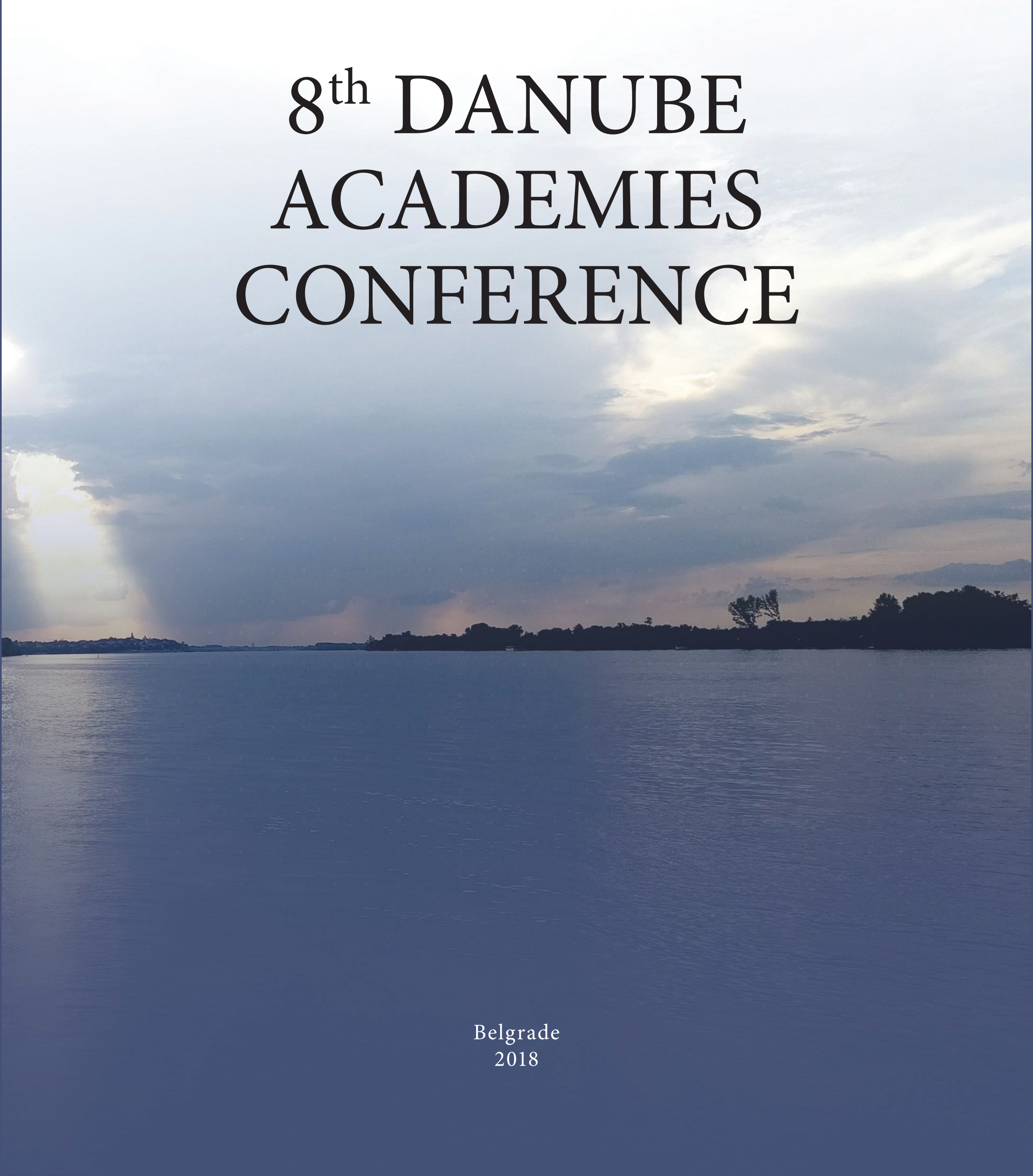
8th DANUBE ACADEMIES CONFERENCE



Belgrade
2018

8th DANUBE ACADEMIES CONFERENCE

8. КОНФЕРЕНЦИЈА АКАДЕМИЈА
ПОДУНАВСКЕ РЕГИЈЕ

СРПСКА АКАДЕМИЈА НАУКА И УМЕТНОСТИ

П Р Е Д С Е Д Н И Ш Т В О

8. КОНФЕРЕНЦИЈА АКАДЕМИЈА ПОДУНАВСКЕ РЕГИЈЕ

Београд, 21–22. септембра 2017. године

Примљено на IV седници Председништва Српске академије наука
и уметности 4. јуна 2018. на основу рецензија академика
Владимира Стевановића и академика *Дејана Поповића*

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SERBIAN ACADEMY OF SCIENCES AND ARTS

PRESIDENCY

8th DANUBE ACADEMIES CONFERENCE

Belgrade, 21–22 September, 2017

Accepted at the 4th meeting of the Presidency of the Serbian Academy of Sciences and Arts, on 4th June 2018, on the basis of reviews by academician *Vladimir Stevanović* and academician *Dejan Popović*

BELGRADE 2018

Published by
Serbian Academy of Sciences and Arts
Belgrade, 35 Kneza Mihaila St.

Proof-readers for English
Tatjana Ćosović
Žarko Radovanov

Prepared for printing by
Mira Zebić

Text assembly
Nikola Stevanović

Number of copies
400

Print
Službeni glasnik, Belgrade

ISBN 978-86-7025-779-5

Издаје
Српска академија наука и уметности
Београд, Кнеза Михаила 35

Лектори за енглески језик
Татјана Ћосовић
Жарко Радованов

Технички уредник
Мира Зебић

Прелом
Никола Стевановић

Тираж
400

Штампа
Службени гласник, Београд

ISBN 978-86-7025-779-5

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TOPIC 1:

Endangered Danube: What can we do?

HIPPO EFFECTS ON BIODIVERSITY CHANGES IN DANUBE ACCUMULATIONS

Vladimir STEVANOVIĆ*

A b s t r a c t. – Biodiversity is not only a renewable resource for various human needs, but an invaluable ecosystem service without which it is difficult to imagine the functioning of the biosphere and the human population. Biodiversity is also a remarkable bio-indicator of changes in the environment. There is no better way to determine the state of an ecosystem than the composition of biodiversity. The composition of biodiversity cannot show the current state of the environment, but the cumulative effects that have led to its disturbance and/or changes. In this way, changes in the structure of biodiversity provide reliable estimates of the actual and predictable state of the environment in the future. In this context, we will consider the state of biodiversity along the right bank of large sections of the Danube watercourse which include two hydro-accumulations (reservoirs). The identical changes are on the Romanian side of the reservoirs.

Already today, 45 years since accumulations were formed, their littoral zones in length of over 250 km of the river course are characterized by the distribution of macrophytes similar to the shallow lakes and/or marsh ecosystems. These changes of biodiversity, as valuable bio-indicators of the ecosystem stage in accumulations, will be discussed in regard to negative and positive HIPPO effects on biodiversity.

Keywords: Danube reservoirs, biodiversity changes, HIPPO effects

INTRODUCTION

In the 1970–1972 period, the construction of the Đerdap (Iron Gate) I hydroelectric power station was finished at 943 km of watercourse and a hydro-accumulation (reservoir) long c. 200 km was formed. Almost 15 years later,

* Serbian Academy of Sciences and Arts

in 1984, the second hydropower Đerdap II was formed at 864 km of the river course. The new reservoir is 79 km long. There have been gigantic changes with the numerous consequences of the regime and the alluvial flat water regime, including those related to the increase in groundwater, flood regulation and the like, over 250 km of the Danube watercourse. Changes in reservoirs are more pronounced with their aging and gradual conversion into the lake ecosystem with a characteristic littoral zonation of vegetation. It is important to determine the current ecological state of the accumulations in order to establish the biota monitoring and to make a prediction of the state of the reservoirs in the future.

Summarizing the negative human impacts on biodiversity, the famous ecologist Edward O. Wilson [19] has proposed the acronym **HIPPO**: **H** – Habitat destruction; **I** – Invasive species; **P –** Pollution; **P** – Growth of the human population and **O** – Overexploitation. In the assessment of the state of each ecosystem on earth, this acronym can be applied. It is understandable that the listed impacts are mutually related and dependent. In the case of two accumulations, we will consider how the HIPPO effect reflects the biodiversity of this section of the Danube.

H – HABITAT DESTRUCTION AND/OR ALTERATION

The destruction of natural ecosystems along the Danube River basin began with the construction of embankments and drainage of wetland nearly 100 years ago. Flooding zones are reduced to the belts between riverbeds and embankments, usually between 300 and 500 m wide, rarely between 1 and 5 km. The reduction of former floodplains was reflected in the restoration of the biota in the Danube. This should be added to the drying of swamps behind embankments and their conversion into agricultural land. How much construction of the embankments and narrowing of the flooded zones affected the fishing potential of the Danube was detected very soon after the embankment was built [8].

The most visible manifestation of ecological and hydrological changes in the accumulation is the massive occurrence of macrophytes and establishing the vegetation zonation that is characteristic for littoral zones of lakes and marshes. The occurrence of macrophytic vegetation is the reliable bio-indicator of the state of the river-lake ecosystem: 1. Rapid shallowing of a reservoir, i.e. sedimentation rate speed; 2. Degree of littoral eutrophication; 3. Changes in the type of benthos and their communities; 4. Efficient retaining of suspended particles in the river; 5. Prediction of vegetation succession in littoral zones could indicate a general state of reservoirs in the future; 6. Massive production of macrophytes due to large amounts of nutrients in sediment.

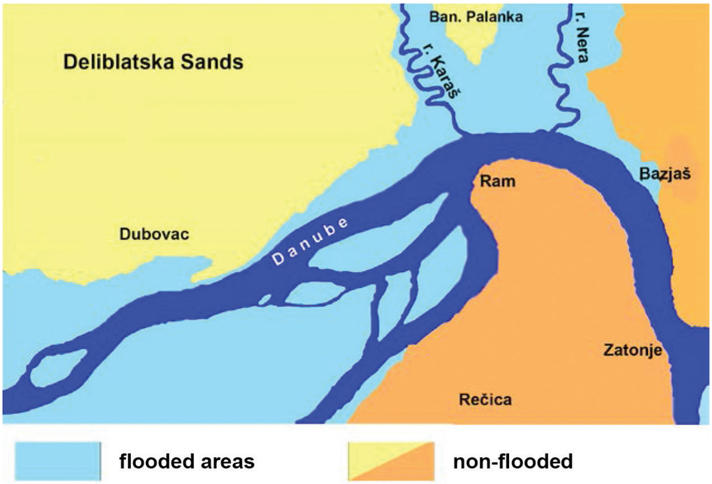

Fig. 1. How wide the flooded zones were along the Danube before the construction of the embankment – the reconstruction of one section of the 15km-long watercourse from Ada Žilovo to the village of Zatonje before 1920 (orig.)

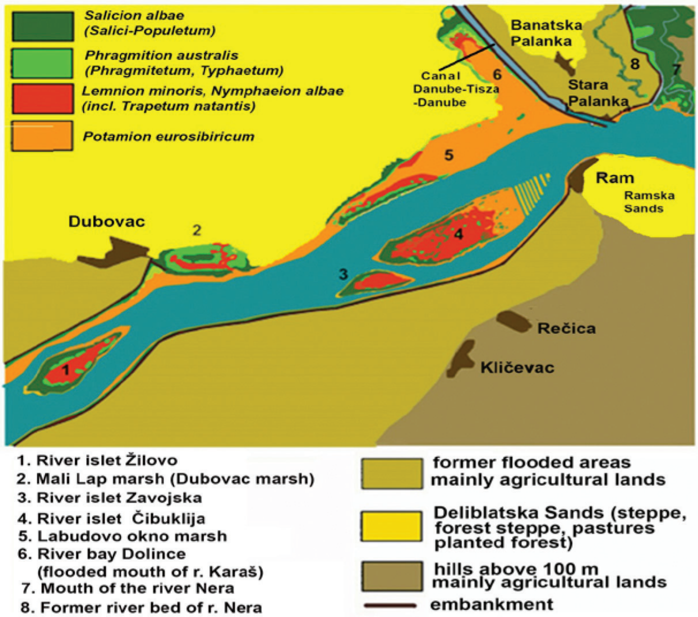

Fig. 2. Positive effects on wetland biodiversity after construction of Đerdap reservoirs. The current map of vegetation and distribution of agricultural land after the construction of the reservoir of the hydropower plant Đerdap I. Forming new wetland habitats along almost the entire river littoral at permanent flooded river islands (1, 3, 4), flooded mouths of Danube tributaries (6), flooded seminatural wetlands (2,5) and flooded banks of the river (5) (orig.)

Fig. 3. Forming new wetland habitats along almost the entire river littoral at permanent flooded river islands – islet Ada Ćibuklija (1), flooded mouths of Danube tributaries – near Mihajlovac (2), flooded semi-natural wetlands – Mali Lap marsh (3) and flooded banks of river – vicinity of Veliko Gradište (4) (photo: Stevanović)

The occurrence and spreading of macrophytes in the Danube is well-documented thanks to numerous papers and studies [7, 9, 10, 14, 16, 17, 18].

However, the construction of two large reservoirs in a total length of over 250 km established new wetland habitats such as permanently flooded river islets, the mouths of the Danube tributaries and the river banks. In this way, the loss of the former flooded zones is compensated (Fig. 2, 3).

The newly formed habitats in the reservoirs have become suitable for the reproduction of fish populations and other aquatic organisms, as well as a feeding base and a nesting place for aquatic birds. In this respect, newly formed aquatic habitats significantly influenced the increase in biodiversity.

INVASIVE SPECIES

Invasive species produce one of the most significant negative effects on biodiversity, especially in tropical ecosystems that are distinguished not only by high biodiversity, but also by a high percentage of endemic species of specific ecology and distribution. Allochthonous (non-indigenous) species that can be defined as unintentional, or deliberately entered from other biogeographical areas, have established a self-renewing population in natural, semi-natural or artificial ecosystems maintained by various human activities. It is important to emphasize that all allochthonous species are not invasive, as can often be read and heard. The invasion rate is directly correlated with the rate of spread of those species. Also, one should always keep in mind that the appearance of non-indigenous species is directly related to changes in natural habitats generated by human impacts of different intensity. Hence, the largest number of allochthonous species, some of which are invasive, inhabits extremely anthropogenic habitats such as agricultural and ruderer surfaces, edges of roads of all types and railroads, planted and/or intensively used natural forests, newly created ponds and lakes, etc. In fact, any human activity that leads to disorders in autochthonous ecosystems contributes to the spread of non-indigenous species.

The massive spreading of allochthonous species is often very rapid and unpredictable. Acclimatization and the successful establishment of self-renewing populations of allochthonous species will depend on reproductive biology and ecology, but also on the biogeographical region from which they originated. In almost all groups of aquatic organisms, especially among the invertebrates, there are mostly allochthonous species. The following alien or/ and invasive species of molluscs and crustacean are recorded in the part of the Danube stretch in Hungary: Mollusca – Bivalvia (5 species): Corbiculidae *Corbicula fluminea* (Asia) and *Corbicula fluminalis* (Middle East, Africa); Dreissenidae *Dreissena polymorpha* and *D. rostriformis bugensis* (both from Ponto-Caspian region), Unionidae *Anodonta woodiana* (Asia); Gastropoda (6 species), Hydrobiidae *Potamopyrgus antipodarum* (New Zealand), Neritidae *Theodoxus fluviatilis* (Lower Danube, Rhine), Physidae *Haitia acuta* (North America), Planorbidae *Ferrissia fragilis* (North America), Melanopsidae *Melanoides tuberculatus* (North Africa, South Asia), Lithoglyphidae *Lithoglyphus naticoides* (Ponto-Caspian region); Crustacea (16 species): Decapoda: Cambaridae *Orconectes limosus* (North America), Varunidae *Eriocheir sinensis* (Asia); Astacidae *Pacifastacus leniusculus* (North America); Amphipoda: Corophidae *Chelicorophium sowinskyi, Ch. curvispinum, Ch. Robustum,* Pontogammaridae *Dikerogammarus bispinosus, D. haemobaphes* and *D. villosus,* Gammaridae *Echinogammarus ischnus* and *E. trichiatus,* Pontogammaridae *Obesogammarus obesus,* Mysidae *Limnomysis benedeni, Hemimysis anomala* and *Katamysis warpachowskyi*; Isopoda: Janiridae: *Jaera sarsi* (all from Ponto-Caspian region) [2]. Similar data on the number and extensions of alien species of invertebrates are given for the entire category [5].

Some of them, such as certain types of molluscs (shells, snails and crabs), represent the most invasive species in almost the entire Danube watercourse.

Among them, several species of shells (*Corbicula fluminalis*, *C. fluminea*, *Dreissena polymorpha* and *Anodonta woodiana*) [4, 5] and amphipoda crabs (*Chelicorophium curvispinum* and *Dikerogammarus villosus*) [5] are most frequent, while a reduction in the number of these invasive species is a major and, so far, a solvable problem.

The appearance of allochthonous species of fish in the Danube is not new and was recorded in the early 20th century. A gradual increase in the number of allochthonous fishes was recorded after the Second World War, while the new increase in the number of these species occurred in the period from 1970 onwards, which coincides with the formation and subsequent changes in the accumulations. To date, 20 species of allochthonous fish species have been identified in the Danube, and the main causes are aquaculture and, with regard to it, the spontaneous spread of such species into surrounding aquatic ecosystems and river traffic [20]. In the Danube section through Hungary, 14 allochthonous fish species were recorded [2]. The invasive fish species belong to the Gobiidae family from the Ponto-Caspian region whose expansion undoubtedly coincides with the construction of two Đerdap accumulations [5, 6].

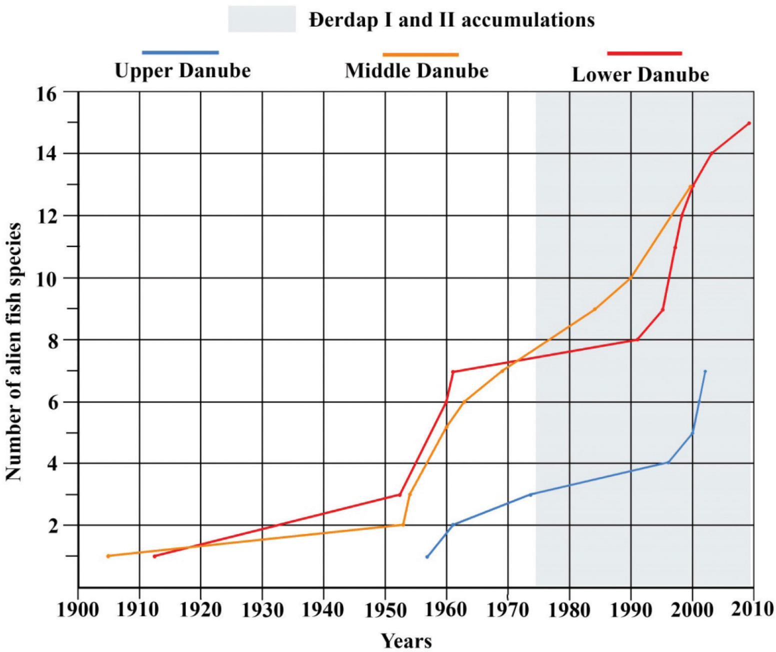

Fig. 4. Increase in the number of allochthonous fish species in the three Danube sections from 1900 to 2010. The Danube section in Serbia includes parts of the middle and lower river watercourse. The rapid increase in the number of species in the last 20 years coincides with the formation of two Danube reservoirs – gray shaded (data compiled from Zorić et al., 2014 [20])

Fig. 5. The South American aquatic grass *Paspalum paspalodes* occupies vast areas in the zones between the embankments and the main river stream, as well as flooded river islets along more than 250 km of the river course. There are flooded *Paspalum paspalodes* meadows in length of more than six kilometres between Dubovac and Malo Bavanište (photo: V. Stevanović)

Paspalum paspalodes originating from South America is certainly one of the non-indigenous vascular plants that have been extensively spreading along the Danube accumulation over the last 20 years. This grass forms floristically uniform grassland in large areas of shallow water of the flooded mouths of Danube tributaries and river islets, as well as areas between the river bed and embankments (Fig. 5). This phenomenon has been reported [11], while spreading of *P. paspalodes* along the reservoirs is the subject of current research.

The following invasive macrophytes originating from North America is *Elodea nuttallii*, which is particularly common in the eutrophized shallow river littoral, channels and ponds. Other allochthonous hydrophytes such as *Azola filicauloides, A. caroliniana, Elodea canadensis*, and *Lemna turionifera* are mostly localized.

In addition to the new allochthonous species of vascular flora, many populations of North American species, which were conquered by the islands of the Danube, were established earlier. Among the most invasive is certainly a hillock (*Amorpha fruticosa*) that occupies numerous wetland habitats, especially those located in the zone of autochthonous poplar and willow forests. The invasiveness or fast and efficient spreading of *A. fruticosa* was given on the example of the Great War island at the mouth of the river Sava into Danube in

Belgrade [15]. In addition to this species, there are very common other North American tree species *Acer negundo*, *Fraxinus lanceolata*, *F. pennsilvanica*, as well as some types of herbaceous climbers *Echinocystis lobata* and *Sycios angulatus*. The spreading of North American species in indigenous alluvial flooded forests along almost the entire Danube watercourse has been strongly supported by the widespread plantation of fast-growing hybrids of North American poplars.

The introduction and spread of allochthonous species and the degree of their invasiveness are a major threat to the original biodiversity of the Danube watercourses and its floodplains. As long as the habitats are created under direct or indirect strong anthropogenic impacts, the number of allochthonous species will increase, including the degree of their invasiveness. Already today, reducing and regulating the populations growth of invasive allochthonous plant and animal species in the Danube and its flooded zones seems to be an impossible mission.

Increasing the area under marsh vegetation in the littoral of reservoirs creates favourable habitats for the reproduction of various species of mosquitoes, among others those that are vectors of dangerous diseases. Vectors of the West Nile virus are the alien Asian tiger mosquito (*Aedes albopictus*) and native *Culex pipiens*. The incidence of transmission of diseases (West Nile fever, malaria) by mosquitos could not be excluded in near future. Some cases of West Nile fever have already been recorded at several localities along the Danube. This fact must be accepted as a potential health problem in the future and requires field and *ex-situ* investigations.

POLLUTION AND POPULATION GROWTH

The Danube is the main waterway that flows through central and southeastern Europe for 2,000 km. The Danube is the main stream of the Black Sea Basin catchment in Europe. The Rhine–Danube Canal is connected with the Baltic and its tributaries by the canal network and the river Tisa. Along all these watercourses there are numerous cities and settlements with accompanying industries.

There are about 80 million people in the Danube basin today, while over ten towns with a population of over 100,000 inhabitants from Regensburg in Germany to Galați in Romania are located on the banks of the Danube. Among them are Vienna, Budapest and Belgrade with a total of over six million inhabitants who directly or indirectly gravitate to the main river stream in terms

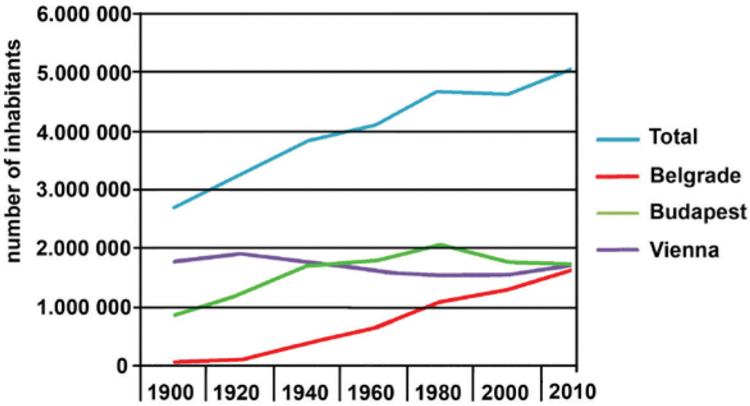

Fig. 6. Increase in the number of inhabitants in the three largest cities on the Danube since the beginning of the last century (source of data: Wikipedia)

of water supply, transport, recreation, but also significantly contribute to discharges of wastewaters of varying degrees of purification (Fig. 6).

Along the Danube and its tributaries, there are numerous plants of the chemical, petrochemical and metal industries, refineries, thermal power plants, nuclear power plants, shipyards, ports, etc. All these human settlements and the accompanying industry are the source of water pollution. In addition, during the NATO bombing of Serbia huge amounts of chemical pollutants were discharged into the Danube and Sava (for example, the petrochemical industry in Pančevo and Novi Sad, the chemical industry in Barič), which additionally burdened the sediment pollution in the reservoirs.

The Danube's ecological capacity is not so great that it could receive ever-increasing amounts of solid, organic and chemical pollution. From the beginning of the last century until today, pollution has been constantly increasing both qualitatively and quantitatively, while the ecological capacity has decreased due to regulation of the watercourse.

Accelerated sedimentation and concentration of various pollutants that fall into the accumulations, as the distribution of newly established ecosystems, are the basic characteristics of the changes caused by the construction of these two great reservoirs. On the largest part of the hinterland of the Danube there are agricultural areas where fertilizers and pesticides are treated, which through canals and tributaries come to the Danube watercourse and significantly contribute to the increase in pollution.

OVEREXPLOITATION

It has already been said that the forming of two reservoirs on the Danube established new aquatic habitats or ecosystems (submerged islets, river mouth and banks) that are favorable for the colonization of indigenous and allochthonous species. These recently formed habitats in the accumulations were, in a certain way, compensation for the former decreasing of flooded zones along the river. These changes are directly related to the increase in biodiversity of almost all groups of organisms. Macrophytic vegetation, which has been massively developed in both reservoirs, has become a suitable breeding place for aquatic organisms, but also a food base for both herbivores and predatory species of invertebrates, fish and birds. There is no doubt that due to habitat changes the fish fund in the Danube has increased, and there has been the massive occurrence of waterfowl during both nesting and migration and wintering. All this has led to increased anthropogenic pressures on fish resources and hunting wetland birds. These pressures now become so strong and worrying in terms of their extent (almost everywhere and without respect of the seasonal fishing ban), and in terms of unallowed methods of exploitation, such as the use of electricity stunning of fish, the nets of inadequate mesh size and even explosives. In this respect, there is a noticeable discrepancy between the speed of exploitation and natural regeneration of economically important fish populations. One of the most striking examples is the sterlet (*Acipenser ruthenus*), one of the most economically important fish species in the Danube, which is becoming increasingly vulnerable to changes in habitats in accumulations and uncontrolled catch [3]. Uncontrolled and non-selective fishing, accelerated deposition of sediments and the input of various pollutants, synergistically lead to changes in the composition of almost all components of benthic communities and support the spreading of alien species.

Hydrographic and ecological changes caused by the construction of reservoirs on the Danube influenced the composition of the breeding, migratory and wintering ornithofauna. These changes can be considered positive, and this is indicated by the increase in the number of breeding bird species and those temporarily staying on the Danube and surrounding habitats. Submerged river islands (Ada Čibuklija, Smederevska ada, Ada Žilovo etc.), as well as shallow littoral zones transformed into swamps, are today especially important for the preservation of birdlife. Winter counting of water habitats in the 1999–2003 period showed that the water sector from the mouth of the Morava to the HP Đerdap I dam is the most important for winter waterfowls. In this stretch of the Danube, 127,036 specimens are recorded on average, with the largest number of

181,414 individuals, while in both reservoirs the number of recorded specimens was between 137,722 and 194,977 individuals within 30 species [1]. Recent data on winter counting of waterfowl in 2012 and 2013 confirm that the Danube, in particular flow reservoirs, is the most important wintering place for birds in Serbia [12, 13]. A large number of birds are attracted by a huge number of domestic and foreign hunters, so the hunting pressure and disturbance of birds in the winter months are very strong. Unfortunately, these negative impacts are most pronounced in or nearby the protected part of the watercourse from Ada Žilovo to the mouth of Nera. Newly developed habitats favor the increase in breeding ornithofauna. Colonies of herons, small and large cormorants are now in the protected areas of Ada Čibuklija, Ada Žilovo and Mali Lap, as well as Smederevska ada. Undoubtedly, the migratory route and wintering of birds of water habitats are important for the Danube watercourse in Serbia, and especially the sector from Smederevska ada to Veliko Gradište. Bearing this in mind, it is also the responsibility of the state, in accordance with the Bonn Convention on Migratory Species and the Ramsar Convention on the Protection of Wetland Habitats, to protect and implement measures, which implies, first and foremost, a permanent ban on hunting in protected areas. It is also necessary to reduce the disturbance of birds during the reproductive period, which is usually done by fishing activities nearby the nesting sites.

INSTEAD OF CONCLUSION

All five HIPPO effects on the example of the Danube reservoirs work synergistically and can be separated from each other only conditionally. In the presented scheme of intensities and interconnection of HIPPO effects in two time segments – before and after the construction of accumulations, there are noticeable differences in the intensity of effects and their impacts on the present state of biodiversity in the accumulations. In a certain way, this scheme may indicate the directions of changes in accumulations in the future, provided that the intensity of the HIPPO effect continues with the same or higher intensity.

What has generated the care of scientists are all the listed effects that have been intensively lasting for more than a century and are increasingly accelerating and becoming more and more intense. Scientists question whether the ecological capacity of the Danube is large enough to accept all these synergistic human impacts. The answer to this question largely depends on the state of biodiversity along the watercourse – because it is always necessary to keep

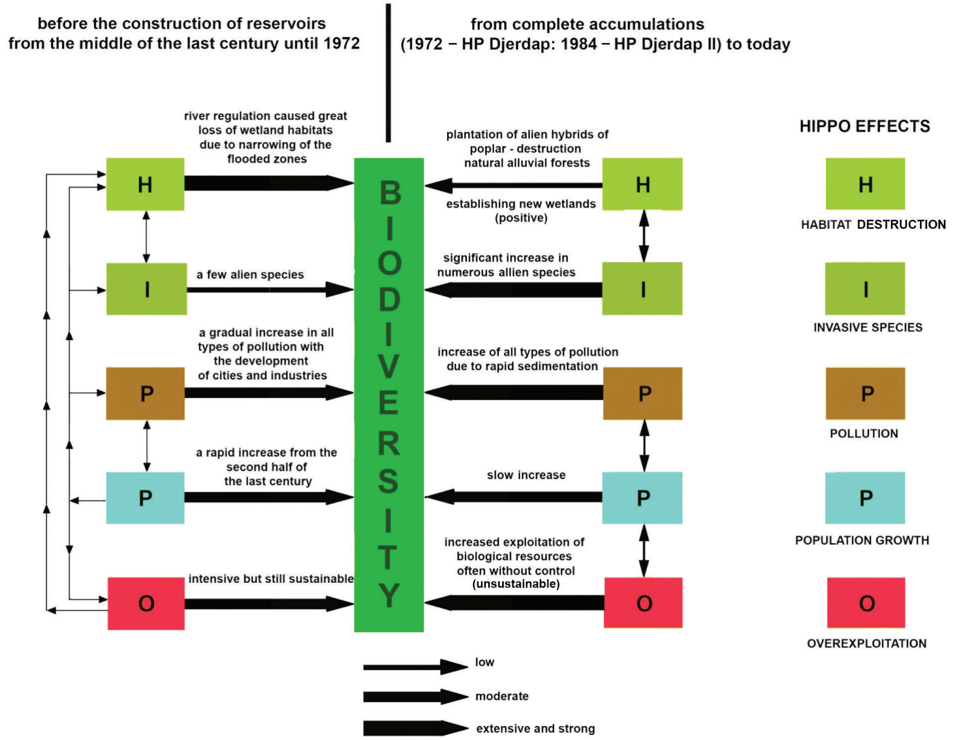

Fig. 7. Scheme of interdependence, causes and intensities of HIPPO effects on biodiversity before and after the construction of reservoirs (orig.)

in mind that biodiversity is essential for every human population, not only as a biological resource, but as powerful and unwilling free ecosystem services that compensate for, among other things, pollution and other negative human impacts.

In this respect, the determination of the state of the biodiversity of the Danube and its reservoirs cannot be limited only to the riverbed, but must take into account the flooded zone where the majority of river biota are being renewed and reproduced.

Given the current stage and increasing anthropogenic pressures, we must ask ourselves whether Danube ecosystems will be able to respond to all these challenges in the future. Therefore, the scientific community is concerned that these negative trends will continue in the future with unpredictable consequences for the people living along the Danube banks. The attitude towards the growing ecological and hydrological problems in the accumulations cannot be ignored, but it is necessary to raise awareness and education not only in the society, but also among decision makers.

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ХИПО (HIPPO) ЕФЕКТИ НА ПРОМЕНЕ БИОДИВЕРЗИТЕТА У ДУНАВСКИМ АКУМУЛАЦИЈАМА

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Р е з и м е

Биодиверзитет не представља само обновљиви извор за различите људске потребе, већ и драгоцену услугу екосистема без које је тешко замислити функционисање биосфере и људске популације. Биодиверзитет је такође изузетан биоиндикатор промена у животној средини. Нема бољег начина да се утврди стање екосистема од анализе састава биодиверзитета. Састав биодиверзитета не може показати тренутно стање средине, већ кумулативне ефекте који су довели до њеног нарушавања и/или промена. На тај начин, промене у структури биодиверзитета дају поуздане оцене стварног и предвиђеног стања животне средине у будућности. У том смислу, размотрићемо стање биодиверзитета уз десну обалу великих делова водотока Дунава, који садрже дуж две хидроакумулације (резервоара). Идентичне промене постоје на румунској страни резервоара.

Већ данас, 45 година након формирања акумулација, њихове приобалне зоне у дужини од преко 250 km речног тока карактерише распрострањеност макрофита, слично плитким језерима и/или мочварним екосистемима, али и убрзано ширење алохтоних, често инвазивних врста. Биће речи о тим променама биодиверзитета, као вредним биоиндикаторима фазе стања екосистема у акумулацијама, с обзиром на негативне и позитивне *HIPPO* утицаје на биодиверзитет.

Кључне речи: резервоари акумулације на Дунаву, промене биодиверзитета, *HIPPO* утицаји