Restoring the Lower Danube River's wetlands: a short report on the hydrological effectiveness of completed projects

Gabriela Ioana-Toroimac [‡]

‡ University of Bucharest, Faculty of Geography, Bucharest, Romania

Corresponding author: Gabriela Ioana-Toroimac (gabriela.toroimac@geo.unibuc.ro)

Abstract

Our report synthesizes information on (i) restoration projects along the Lower Danube River in order to show their hydrological effects and (ii) reference conditions of sites in order to better understand the evolution of riparian wetlands under present-day conditions.

Our report (i) concluded on the difficulty to successfully restore the hydrology of the Lower Danube wetlands and (ii) pointed out restrictive factors for the terrestrialization of wetlands and islands in reference conditions.

Overall, the report is a state of the art that shows a general picture of the present-day hydrological conditions of the Lower Danube's wetlands.

Keywords

riparian wetlands, islands, restoration, Danube, hydrology, state of the art

Introduction

The Lower Danube River (corresponding to the downstream sector of the river, from the Iron Gates gorge to the outflow in the Black Sea through a delta) was subject of restoration planning. After being severely embanked and drained for agriculture for more than half a century (Constantinescu et al. 2015), the objective of the Lower Danube River restoration was to recreate riparian wetlands and reconnect them with the river (Hein et al. 2016). A large-scale plan relied upon the idea of restoring the lost wet paradise from the beginning of the 20th century; it further took into account the present-day topography and finally identified areas prone to restoration versus water storing or agriculture (Nichersu et al. 2022). Other scientific papers were also largely in favour of restoring the

Lower Danube River ecosystem services (Funk et al. 2019). In practice, only small-scale projects were implemented, with various restoration solutions. All the projects were independent initiatives as funding and they were conducted by various actors of environment and water domains (Ioana-Toroimac et al. 2024), which is rather common among river restoration projects in the European Union member states (Szałkiewicz et al. 2018). All the projects reported good results, but only few post-restoration data were published and the scientific literature lacks a critical analysis of their effects and effectiveness, as well as of restrictive factors in implementation and results.

Our report inventories restoration projects along the Lower Danube River in order to show their hydrological effects, as well as reference conditions sites in order to better understand the evolution of riparian wetlands under present-day conditions. The report is a state of the art on the hydrological issues of the Lower Danube's wetlands based mostly on satellite remote sensing survey.

Hydrological effects of completed case studies of wetland restoration

Fig. 1 regroups 14 completed restoration projects along the Lower Danube River. They can be classified as follows:

1. ten in Romania and three in Bulgaria; among them, eight projects are in the Danube Delta, six in the floodplain and two on islands;
2. the majority had levees for agriculture that were later opened during the restoration actions, while the others had various features (such as fishing or navigation as drivers for pressure and channel dredging as measure of restoration).

Our study is focused on wetlands with water surface area that were restored by opening levees. Conclusions concerning the evolution of the surface water area are based on the analysis of Landsat imagery (30 m of resolution, one image per year during high waters for the time interval 1984-2020). The methodology is described by Ioana-Toroimac et al. (2022).

Pilot projects were those on the Babina and Cernovca islands along the Chilia arm in the north of the Danube Delta, in Romania. These islands were dammed in 1985 to be transformed into rice fields, but the latter were never productive (Dorondel et al. 2021). In 1990, the Danube Delta became a Biosphere Reserve. In 1994, the first restoration project of Babina Island (22 km^2) began. And in 1996, the second restoration project was completed on Ostrovul Cernovca (17.8 km^2). In both cases, the dikes were opened in the 1990s to restore the connectivity with the river, and for the islands to benefit from its quasi-natural hydrological regime. On both islands, the maximum water surface area was synchronous to the restoration (Fig. 2, respectively Fig. 2a). Post-restoration, the water surface area decreased. In the case of the Babina Island, a significant change point corresponded to the flood of 2006 when the openings in levees were clogged. Since then, the humidity area statistically decreased while the drought area statistically increased (Ioana-Toroimac et al. 2022).

The Srebarna wetland (600 ha) located in the Danube floodplain in Bulgaria has been dammed and the connectivity with the river has been cut off. The area of the wetland has narrowed and started to have water quality problems. Consequently, the area was restored in the period 1994-1998 by opening the dike towards the Danube. Despite these works, the wetland was still affected by eutrophication (Central Laboratory of General Ecology 2001). Post-restoration, the water surface area registered variations, but no statistical change point or trend.

The Brashlen Kalimok Marsh (2000 ha) in Bulgaria was embanked in the 1950s to be transformed into agricultural fields. A restoration project that started in 2001 aimed to open levees in order to reconnect the riparian marsh to the Danube. This site is considered to be one of the most interesting areas from biodiversity protection perspective (Valchev et al. 2006). Hence, post-restoration, no water surface area was detected.

Persina Island (Belene, Bulgaria) is the largest on the Bulgaria-Romania border, with an area of almost 50 km^2. The island was dammed mainly for agricultural purposes. Between 2001 and 2008, dikes were opened on a local scale to maintain the wetlands on the eastern side of the island. Kalchev et al. (2010) consider that the results obtained from the restoration were less significant than those announced by the objective of the original project. The water surface area did not statistically change pre- versus post-restoration.

The Carasuhat polder near the town of Mahmudia (Sf. Gheorghe branch of the Danube Delta) was restored by opening a levee previously used for protection of an agricultural area. The project was carried out between 2012-2015 with the aim of reconnecting 924 ha with the river, with good ecological results (Suliman et al. 2022). In the case of Carasuhat, the polder was flooded post-restoration which means that the objective of the project was achieved. Yet, a flood in 2023 created a breach in the levee, therefore the restored polder was overflowed on a larger area when compared to the goal of the restoration.

Evolution of wetlands and islands in reference conditions

Other case studies were analyzed in order to better understand the evolution of islands and wetlands under present-day conditions, without restoration works. Our conclusions concerning the evolution of areas with various land cover are based on the analysis of Landsat imagery (30 m of resolution, one image per year during high water flow and one image per year during low water flow for the time interval 1984-2020).

The Kosava Island (0.5 km^2, in the vicinity of Kosava village in northern Bulgaria) is currently merging with the bank. The alluvial point bars located north of the island and on the riverbank suffered erosion or accumulation processes during the studied time interval. Both point bars are being colonized by vegetation post-2010 (for details – Dorondel et al. (2024)).

The Danube islands located along two river reaches recorded a similar pattern of evolution. One river reach is located between the mouths of Jiu and Olt tributaries (95 km in length). We counted 18 relatively stable islands and a mean area per island of approximately 2.2 km^2. Out of the total area of islands, the vegetated part represents 85.3% while the bare sediment forms the balance of 14.7%. The other river reach is located between the cities of Giurgiu and Călărași in Romania (135 km in length). The in-stream land is divided into vegetated islands (mean = 22.3% of the total area) and alluvial bars (mean = 10.1% of the total area). During the studied time interval, the area of the islands maintained itself but it recorded a change of land cover: while the area of alluvial bars decreased, the area covered by vegetation statistically increased (for details – Ionita-Scholz et al. (2024)).

The Small Island of Brăila (206 km^2) is one of the remaining Danube wetlands in pristine hydromorphological conditions without human pressures at local scale and is protected according to the Convention of Ramsar. Within its boundaries, the water surface area maintained at approximately 32.3% of the total area during the studied time interval. Yet, the humidity area statistically decreased while the dry area statistically increased especially after 2009 (for details – Ioana-Toroimac et al. (2022); Ionita-Scholz et al. (2024)).

Discussion

Our report inventoried case studies of riparian wetlands and islands along the Lower Danube River in Romania and Bulgaria. We showed different patterns of evolution under restoration works or under present-day conditions. The study syntheses information from previous publications and scientific reports.

Based on our case studies and methodology via satellite remote sensing, the strategy of opening levees to reconnect the riparian wetland to the river was effective in 50% of the inventoried case studies and in the short term. In the long term, the effectiveness of restoration works decreased. The hydrological effectiveness of restoring the Danube wetlands is not obvious in spite of various actions. Other fluvial processes occurred post-restoration and were probably not foreseen by restoration planners.

Concerning the evolution of wetlands and also islands under present-day reference conditions, without restoration works, we found a general trend of terrestrialization. Vegetation colonized previous alluvial sand bars on the Bulgaria-Romania border and dry areas increased as was the case on the Small Island of Brăila especially in the last decade, without major floods on the Lower Danube River.

Therefore, we suggest three main causes of reduced effectiveness of riparian wetland restoration.

- Inappropriate planning. Planning issues are specific for each project. At this point, planning issues cannot be further investigated given the lack of access to the project information and expertise of the project managers. As a general statement, we point out that independent works outside the site may have affected the restoration effects and effectiveness (Ioana-Toroimac et al. 2023).
- Climatic conditions. Evapotranspiration registered an increasing trend in south-eastern Europe (Cheval et al. 2017). Precipitation recorded a negative summer trend at Tulcea weather station (Ioana-Toroimac et al. 2023). The Danube has not recorded major floods after 2010. Climate scenarios predict a decrease in runoff in the Lower Danube region (Ionita-Scholz et al. 2024), more pronounced in spring and summer (Stagl and Hattermann 2015). In conclusion, the lack of water resource could be a restrictive factor of wetland restoration.
- River channel incision. WRI & project partners 2020 showed a degradation of the Danube's riverbed along the lower course by an average of 3-4 m and locally up to 6-9 m in the last half century. This process could affect the connectivity of the river with its floodplain and islands, preventing an effective restoration.
- Feedback loops. Various feedbacks and nonlinear behavior could emerge as it is impossible to predict a river's trajectory (Wohl 2017). As an example, while floods are responsible for clogging in the case of the restored Babina Island, the lack of floods allowed vegetation to colonize alluvial bars as was the case of sites in reference conditions.

Our report concluded on the difficulty of successfully restoring the Lower Danube's wetlands via classic strategies due to natural restrictive factors such as climate change at regional scale and riverbed incision or trajectory at local scale. Other human-induced factors may be responsible for the hydrological and morphological effectiveness of river and wetland restoration. The report gathered information from various sources and showed an overall picture of the present-day hydrological conditions of the Lower Danube's wetlands.

Acknowledgements

Methodological details and other in situ observations are available in the scientific reports (in Romanian) of the project ”Methodology to evaluate the effectiveness of hydromorphological restoration of rivers in Romania” (PN-III-P1-1.1-TE-2021-0600, grant of the Ministry of Research, Innovation and Digitization, CNCS - UEFISCDI, within PNCDI III).

Funding program

National Research-Development and Innovation Plan for the period 2015 - 2020 (PNCDI III), Programme 1: Development of the national research-development system, Sub-programme 1.1. Human Resources (Young Teams).

Grant title

Methodology to evaluate the effectiveness of hydromorphological restoration of rivers in Romania (PN-III-P1-1.1-TE-2021-0600, 2022-2024).

Hosting institution

University of Bucharest, Research Center Water Resources and Water Related Risks Management

Ethics and security

NA

Conflicts of interest

The authors have declared that no competing interests exist.

References

- Central Laboratory of General Ecology (2001) Management Plan for the Srebarna Managed Nature Reserve. Ministry of Environment and Water, Sofia.
- Cheval S, Dumitrescu A, Birsan M (2017) Variability of the aridity in the South-Eastern Europe over 1961–2050. CATENA 151: 74-86. https://doi.org/10.1016/j.catena.2016.11.029
- Constantinescu Ş, Achim D, Rus I, Giosan L (2015) Embanking the Lower Danube: From Natural to Engineered Floodplains and Back. Geomorphic Approaches to Integrated Floodplain Management of Lowland Fluvial Systems in North America and Europe265-288. https://doi.org/10.1007/978-1-4939-2380-9_11
- Dorondel S, Șerban S, Ioana-Toroimac G (2024) Underground and Underwater Mining: State Extractivism and the Socio-ecological Transformations of Rural Bulgaria. Science, Technology, & Human Values forthcoming.
- Dorondel Ș, Şerban S, Tudor M (2021) Ecological Restoration in “Liquid Societies”. Nature and Culture 16 (2): 86-117. https://doi.org/10.3167/nc.2020.160205

- Funk A, Martínez-López J, Borgwardt F, Trauner D, Bagstad K, Balbi S, Magrach A, Villa F, Hein T (2019) Identification of conservation and restoration priority areas in the Danube River based on the multi-functionality of river-floodplain systems. Science of The Total Environment 654: 763-777. https://doi.org/10.1016/j.scitotenv.2018.10.322
- Hein T, Schwarz U, Habersack H, Nichersu I, Preiner S, Willby N, Weigelhofer G (2016) Current status and restoration options for floodplains along the Danube River. Science of The Total Environment 543: 778-790. https://doi.org/10.1016/j.scitotenv.2015.09.073
- Ioana-Toroimac G, Zaharia L, Moroșanu G, Grecu F, Hachemi K (2022) Assessment of Restoration Effects in Riparian Wetlands using Satellite Imagery. Case Study on the Lower Danube River. Wetlands 42 (4). https://doi.org/10.1007/s13157-022-01543-9
- Ioana-Toroimac G, Stoica C, (Oprea) DC, Moroșanu GA, Șandor IA (2023) Râurile - o abordare interdisciplinară. Editura Transversal, Târgoviște.
- Ioana-Toroimac G, Stoica C, Moroșanu GA, Șandor IA, Constantin DM (2024) Assessing the role of actors in river restoration: A network perspective. PLOS ONE 19 (4). https://doi.org/10.1371/journal.pone.0297745
- Ionita-Scholz M, Ioana-Toroimac G, Șandor IA, Nagaviuc V (2024) Hydrology and Hydromorphology. In: IAD (Ed.) Ecohydrology from catchment to coast: Danube River and Western Black Sea Coast: Complex Transboundary Management. Academic Press, Amsterdam, forthcoming pp.
- Kalchev R, Beshkova M, Pehlivanov L (2010) First records on effect of renewed flooding of three wetlands from Belene Island (Lower Danube, Bulgarian stretch). In: IAD (Ed.) 38th IAD Conference. Dresden
- Nichersu I, Nichersu I, Constantinescu A, Nichersu A (2022) A Transdisciplinary Approach Using Danube River Multi-connectivity in Wetland Management. The Lower Danube River405-442. https://doi.org/10.1007/978-3-031-03865-5_14
- Stagl J, Hattermann F (2015) Impacts of Climate Change on the Hydrological Regime of the Danube River and Its Tributaries Using an Ensemble of Climate Scenarios. Water 7 (11): 6139-6172. https://doi.org/10.3390/w7116139
- Suliman I, Tudor I, Ibram O, Burada A, Despina C, Seceleanu-Odor D, Tofan L (2022) Zooplankton and water quality of Carasuhat and Zaghen wetlands, Danube Delta Biosphere Reserve. Scientific Annals of the Danube Delta Institute (27)117-128.
- Szałkiewicz E, Jusik S, Grygoruk M (2018) Status of and Perspectives on River Restoration in Europe: 310,000 Euros per Hectare of Restored River. Sustainability 10 (1). https://doi.org/10.3390/su10010129
- Valchev V, Georgiev V, Ivanova D, Tsoneva S, Janauer G (2006) Conservationally important macrophytes in the Bulgarian stretch of the Danube river and the near water bodies. In: IAD (Ed.) 36th IAD Conference. Vienna
- Wohl E (2017) Connectivity in rivers. Progress in Physical Geography: Earth and Environment 41 (3): 345-362. https://doi.org/10.1177/0309133317714972
- WRI & project partners (2020) Long-term morphological development of the Danube in relation to the sediment balance. https://www.interreg-danube.eu/danubesediment
- WWF (2016) Lower Danube green corridor: floodplain restoration for flood protection. https://climate-adapt.eea.europa.eu/en/metadata/case-studies/lower-danube-green-corridor-floodplain-restoration-for-flood-protection

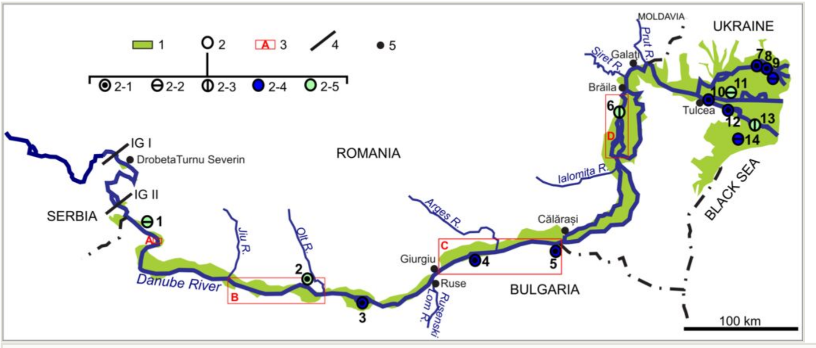

Figure 1.

The Lower Danube River: river restoration actions: 1 – plan of the Lower Danube Green Corridor (based on WWF 2016); 2 – river restoration completed project; 2–1 – agriculture as driver for pressure; 2–2 – fishing as driver for pressure; 2–3 – navigation as driver for pressure; 2–4 – opening levees as restoration solution; 2–5 – reshaping canals as restoration solution; 3 – case study of islands; 4 – dam (IG I – Iron Gates I; IG II – Iron Gates II); 5 – city > 50,000 inhabitants. Site numbers: 1 – Gârla Mare Fish Farm; 2 – Gerai Marsh; 3 - Persina Island; 4 – Brashlen Kalimok Marsh; 5 - Srebarna Lake; 6 - Small Island of Brăila; 7 - Babina Island; 8 - Cernovca Island; 9 - Popina Polder; 10 – Zaghen Lake; 11 – Fortuna Lake; 12 – Carasuhat Polder; 13 – Saint George Arm; 14 – Holbina-Dunavăț Fishpond; A – Koșava Island; B – Jiu-Olt reach; C – Giurgiu-Călărași reach; D – Small Island of Brăila.

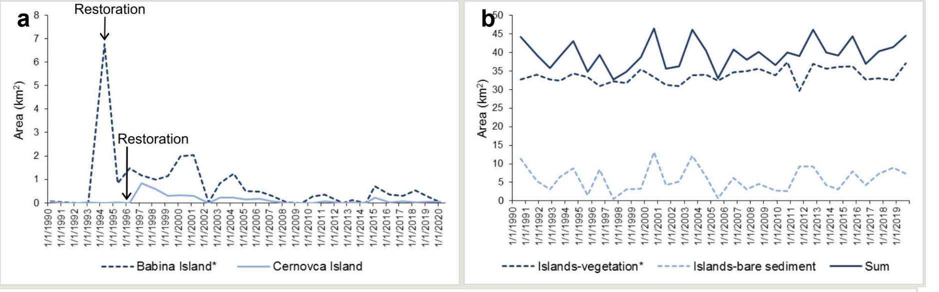

Figure 2.

Temporal variations

a: Area of the water surface on Babina and Cernovca islands (*up trend, p = 0.01)

b: Area of islands along the Jiu-Olt reach (*up trend, p = 0.05)