ECOLOGICAL RESTORATION OF THE DANUBE DELTA WETLAND FRAGMENTED ECOSYSTEMS. ŞONTEA-FORTUNA AREA CASE STUDY

*EUGENIA CIOACĂ, MARIAN MIERLĂ, MIHAI DOROFTEI, MIHAI MARINOV, ALEXANDRU DOROŞENCU, VASILE ALEXE, GABRIEL LUPU, AUREL NĂSTASE, MIHAELA TUDOR, ORHAN IBRAM**

Eugenia Cioacă, Marian Mierlă, Mihai Doroftei, Mihai Marinov, Alexandru Doroşencu, Vasile Alexe, Gabriel Lupu, Aurel Năstase, Mihaela Tudor, Orhan Ibram: Ecological restoration of the Danube Delta wetland fragmented ecosystems. Şontea-Fortuna area case study. Geomorphologia Slovaca et Bohemica, 18, 2018, 1, 6 figs., 2 tabs., 20refs.

The Danube River sediment transport leads to alluvial sedimentation of the Danube Delta Biosphere Reserve inner hydro-graphical network which, in some upstream zones, is high. As a result of this fluvial process, wetland ecosystems get fragmented due to their disconnection from the main channels, especially, in the Danube River low water level condition. This hydrological condition lasting 2-3 months in the year lead to a negative impact on flora and fauna species. In order to improve and maintain an optimum water flow regime inside the aquatic ecosystems, ecological restoration is performed. Thus, fragmented migration routes of wild species are restored and their feeding and breeding conditions are improved. The paper presents the Şontea-Fortuna zone ecological restoration case study. As main action, three secondary channels have been subject to dredging works. Channels morphology has been reshaped and the bottom elevation from about + 1.20 m a. s. l. reached post-restoration state - 1.50 / - 2.00 m a. s. l. Within the study area, the 7 wetland habitat types and 1,116 wild flora and fauna species have been studied and their pre and post-restoration state were presented in this paper to emphasize the improvements as a result of ecological restoration (a prerequisite measurement for biodiversity conservation and protection).

Key words: wetland fragmented ecosystems, ecological restoration, Danube Delta

INTRODUCTION

Before reaching the Black Sea, the Danube River bifurcates in three major arms and constructs its own Danube Delta (DD) due to high sediment transport (average 2,138 kg s^{-1}), which corresponding to the discharge 6,570 $m^3 s^{-1}$ (BONDAR 1994). It covers, in Eastern Europe, an area of 4,180 km² shared between Romania (84 %, 3,510 km^2) and Ukraine (16 %, 670 km^2) (**Fig. 1**). The Danube's main arms (271 km) together with the 3,500 km of channels connect the 500 lakes (approximately 200,000 ha), create a complex pattern of land cover types and ecosystems, including extensive cover of semi-natural wetlands, inland marshes and natural grasslands, sand dunes, beaches, broadleaved forests, and large areas converted for aquaculture and agriculture (ROMANESCU 1999, BONDAR and BLENDEA 2000, GÂŞTESCU and ŞTIUCĂ, eds. 2008, POPESCU et al. 2015).

Danube Delta area 3,510 km^2, the Danube River (13 km^2) with its upstream floodplain between rkm 81 and 103 (102 km^2), the Razim-Sinoie lake complex (1,145 km^2), and the Black Sea coastal zones up to 20 m water depth (1,030 km^2) were declared in 1990 as Biosphere Reserve (DDBR).

The DDBR (5,800 km^2, Romanian part) inner hydrographical network (main and secondary channels, fishery brooks, and lakes) is naturally structured in 7 hydrographic units (HU)/ aquatic complexes (**Fig. 2**) with own inlets and outlets. These are identified based on their hydrologic regime and morpho-hydrographical dynamics depend on the Danube River water flow regime and sediment transport and the human interventions.

In 1990, overall 97,408 ha of the DD (22 %) were dammed and transform to agriculture, forestry or fish ponds land use. In 1993, according to the Ramsar CONVENTION (1971), reverse action started in DD by ecological restoration works (GÂŞTESCU and ŞTIUCĂ 2008, SCHNEIDER et al. 2008, CIOACĂ 2002, CIOACĂ 2004, DDNI 2008-2016). Within the DDBR, some zones of wetland ecosystems get fragmented due to the hydrographical network disconnection from the main channels and changes of the Danube River natural flooding regime. Channels siltation occurs in some se-

* Danube Delta National Institute for Research and Development, Babadag 165, 820112, Tulcea, Romania, e-mail: eugenia.cioaca@ddni.ro (corresponding author)

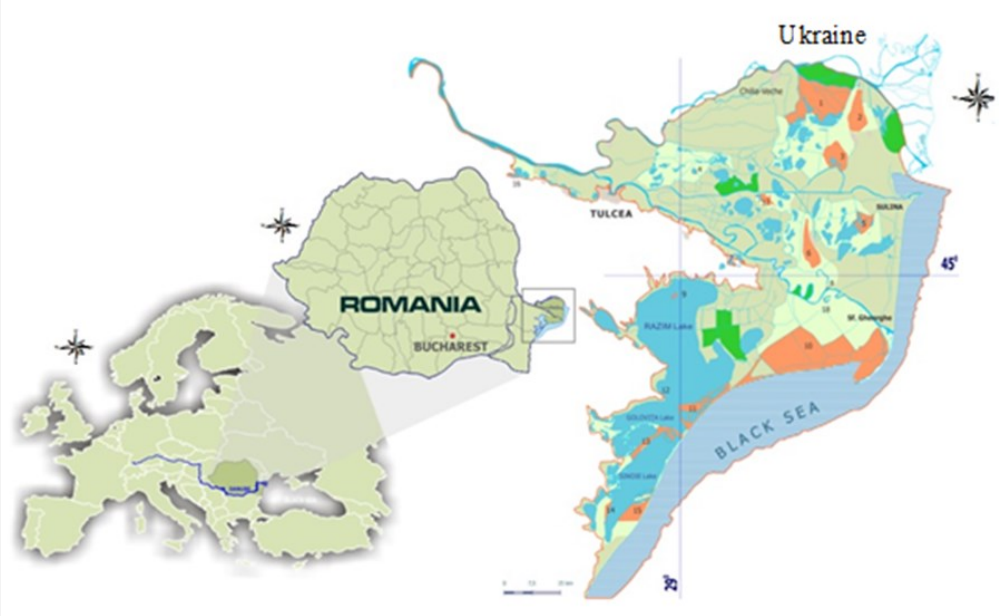

Fig. 1 Location of the Danube Delta Biosphere Reserve (DDBR) in Eastern Europe and Romania.

condary channels/sectors, where the fluvial process of alluvial sedimentation has a medium-high intensity. Low water level conditions with duration up to 2-3 months in the year, lead to disconnection, desiccation and degradation of channels and sectors with negative impact on flora and fauna species. The depositional zones create obstacles in the migration routes of aquatic species. Data from morpho-hydrographical field measurements, carried out in areas ecologically reconstructed, show significant morphology changes of the channels' bottom elevation uplift ranging between 0.50 – 1.00 m from the ecological restoration works execution (1994-2007) to the present (DDNI 2008-2016).

The DDBR aquatic habitats produce the support services for feeding and reproduction of most wild species of flora, zoo-benthos, aquatic macro-invertebrates, molluscs, birds, fish, mammals, amphibians, reptiles, insects, closely linked to each other in the framework of the Functional Feeding Groups relationships.

Their survival, preservation and maintenance of a favourable state depend on the upper water level extent during the water circulation regime within the DDBR and their inner hydrographic network. To assure an optimum water circulation, supply and freshening of water for all aquatic ecosystems, especially, under the Danube River low level conditions, ecological restoration works have been performing since 1994 to present, in order to restore or improve the water flow regime by re-connecting those anthropic degraded wetland (dammed zones) and silted secondary channels to the main channels (**Fig. 3**).

STUDY AREA

Among the 7 hydrographical units (HU) of the DDBR belongs Șontea-Fortuna (24,636 ha) as it is most upstream located within the fluvial delta, which is exposed to fluvial processes, erosion and, especially, alluvial sedimentation. The IRS Satellite Images (**Fig. 4**) show the sediment transport dispersion among the DDBR hydrographical unit. Within the Șontea-Fortuna area the upper sectors of secondary channels and the connected lakes are exposed to siltation and disconnection from the main (supply) channels during the Danube River low water level conditions. It leads to habitats and aquatic species migratory routes fragmentation. In this area, ecological restoration is the only option to ensure an improved hydrological regime by biodiversity protection and conservation measurement.

MATERIAL AND METHODS

Field measurements have been carried out for pre- and post-restoration state and evaluate the morpho-hydrographical changes and the ha-

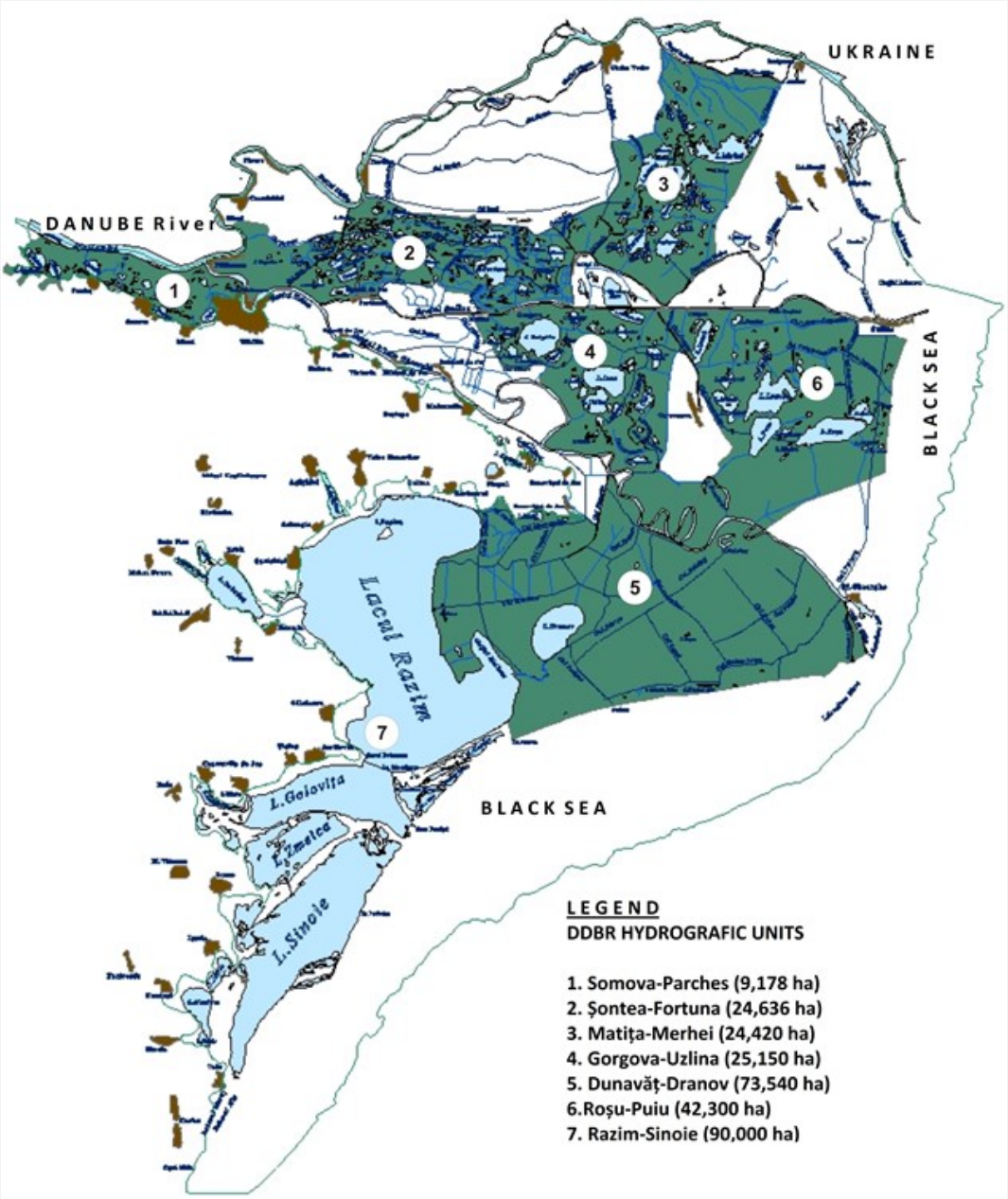

Fig. 2 The 7 hydrographic units of the Danube Delta Biosphere Reserve.

bitats and wild flora and fauna species status improvement. This reflect the study area inner hydrographical network dredging works execution, which lead to re-connection it to the main/ supply channels, especially, during the Danube River low water level conditions (less than +1.5 m a. s. l. as recorded at the Tulcea-port gauging station).

The channels morphology changes have been evaluated based on morpho-hydrographical field measurements. Topographical station, an ADCP – Acoustic Doppler Current Profiler (both equipped with GPS antenna) and specialised software for field data collection (*WinRiver II*) have been used and processing in ArcGIS and QGIS software. *WinRiver II* is a real-time discharge data collection program, which creates a measurement file for operation the ADCP, checks each command, and verifies that the ADCP has received these commands. Also, the georeferenced position of each point target by the ADCP in the channel profile is recorded as

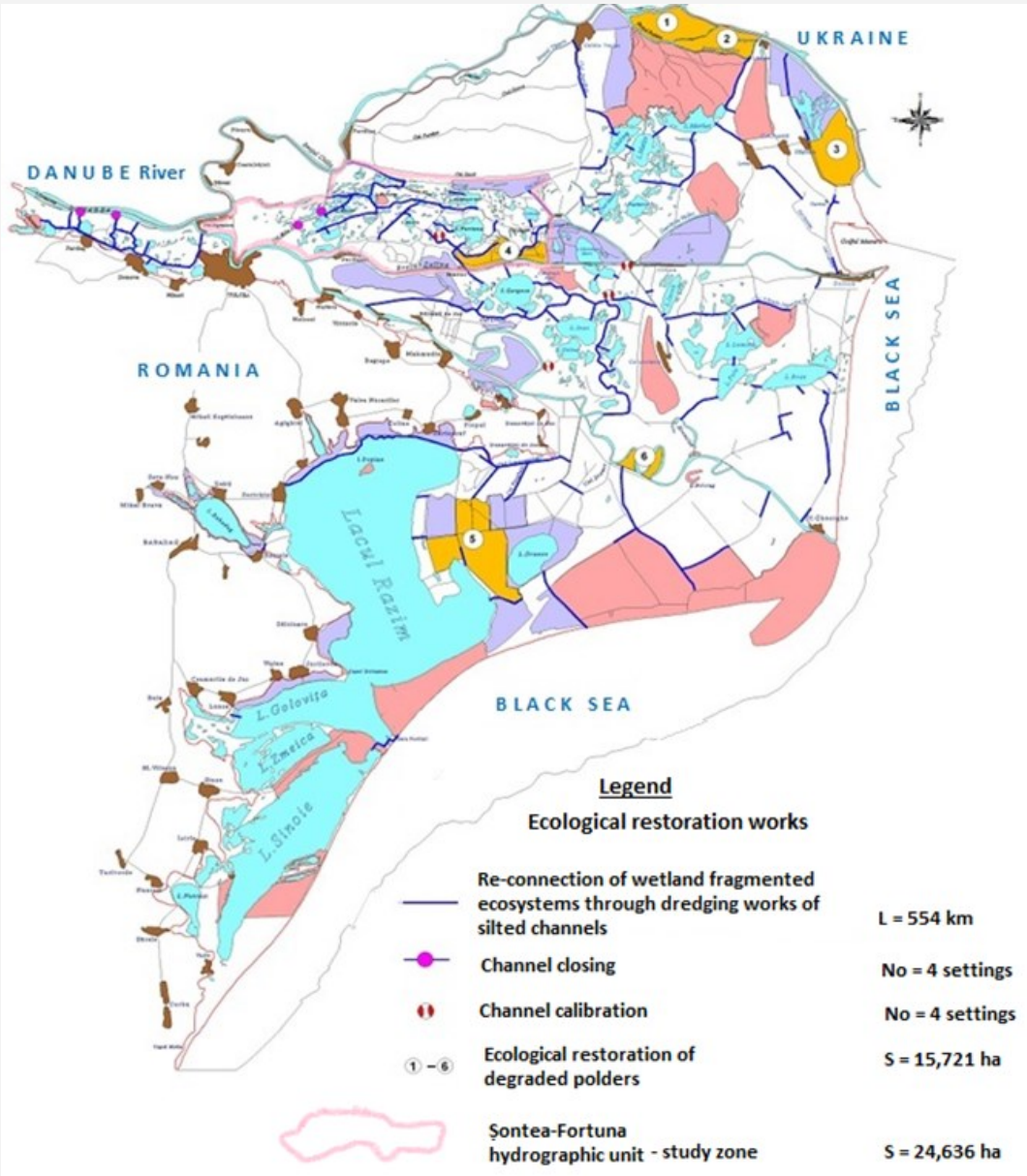

Fig. 3 Ecological restoration types implementation within the Danube Delta Biosphere Reserve wetland fragmented ecosystems since 1994 to present.

primary data. These data are processed and presented in this paper as graphics to show the bottom elevation post-restoration, compared to the pre-restoration one, as well as the height of alluvial sedimentation deposits, along the channel's longitudinal profile.

The evaluation of the 7 types of Natura 2000 habitats' status, from the study area, was performed according to the European Habitat Directive.

The wild flora and fauna species status assessment from IUCN Red List of Threatened Species categories (version 3.1/2001: EX-Extinct, CR-Critically Endangered, EN-Endangered, VU-Vulnerable, NT-Near Threatened, LC-Least Concern, DD-Data Deficient, and NE-Not Evaluated) was performed within the study area (7,000 ha) in 1995 - 2016 and compared to the entire DDBR aquatic and terrestrial ecosystems area (580,000 ha).

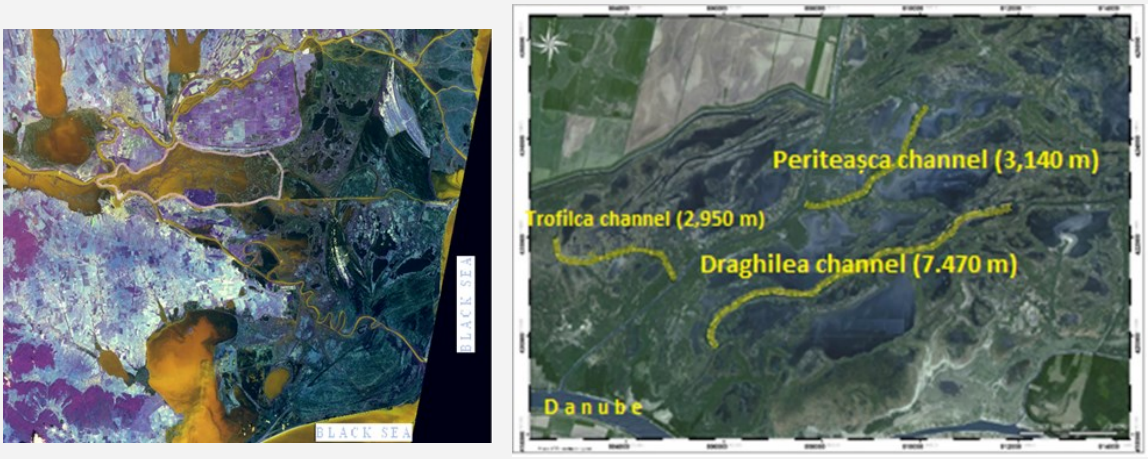

Fig. 4 Location of the study area: Șontea-Fortuna hydrographic unit (24,636 ha). IRS Satellite Image from May 2006 (left), a year with long-duration, 5 months flood conditions and suspended load dispersion into the DDBR. A detail image of the secondary channels zone (right) which was object of ecological restoration in 2015 - 2016.

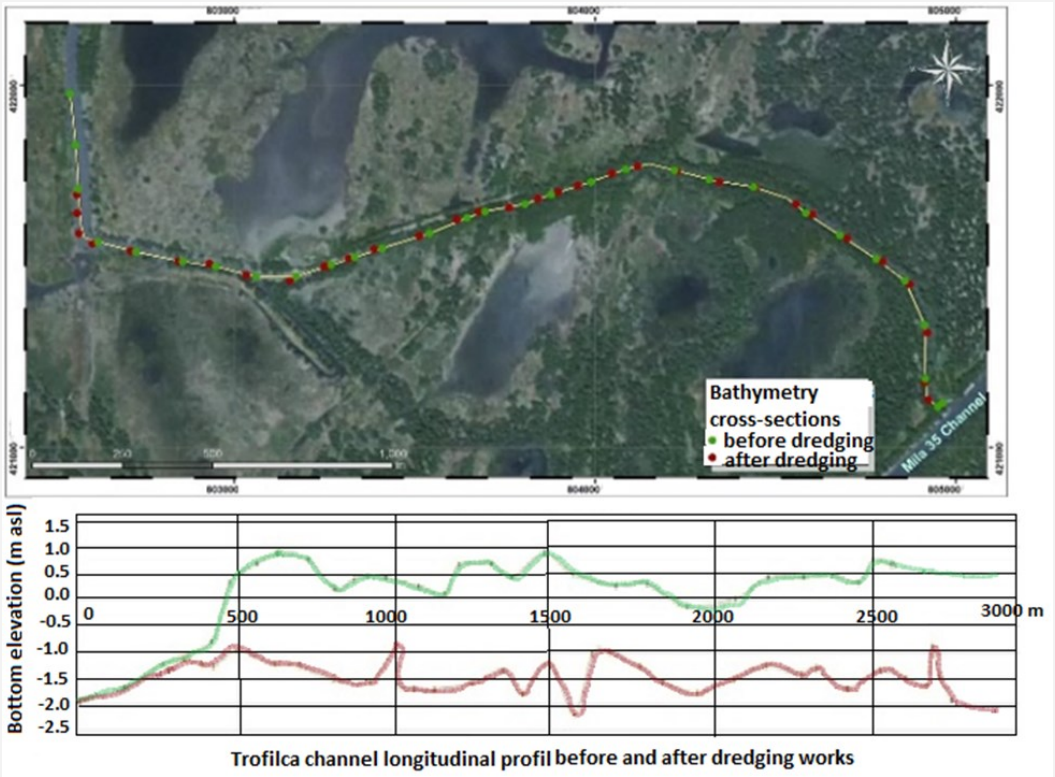

Fig. 5 Longitudinal profiles of the dredged secondary channels. The lines in the graphs represent the channel's thalweg as the line joining the lowest elevations of the channels' bottom in the pre-restoration (upper line) and post-restoration state (lower line). The channel bottom elevations ranging in the profile in pre-restoration state are positive (between 0.00 ÷ +1.20 m a. s. l.) and leading to disconnection of the system from the main channel during the Danube River low water level conditions. In the post-restoration state, the channel bottom elevations ranging is negative (between - 1,0 ÷ - 2,00 m a. s. l.) and leading to system re-connection with the main channel, especially, during low water level discharges.



Fig. 6 Pre- and post-restoration morpho-hydrographical conditions. First image is from September 2015 and second and third images are from June 2016.

RESEARCH RESULTS

Within 2015-2016, ecological restoration works were executed in the Șontea-Fortuna area, in order to restore some wetland fragmented habitats by their re-connection to the main channels. This was achieved by execution of dredging works of silted secondary channels, for a total length of 13.56 km (**Tab. 1**). The water flow regime within the inner habitats and, implicitly, the aquatic species migration routes have been improved, especially, during the Danube River low water level conditions.

Post-restoration results, compared to the pre-restoration ones, related to physical parameters of the secondary channels subject to dredging works (**Tab. 1., Fig. 5** and **Fig. 6**), wetland habitats conservation status (**Tab. 2**) and wild flora and fauna species status description are presented in this section

HABITATS CONSERVATION STATUS

Pre- and post-restoration conservative status assessment of the 7 habitats from the study area, and their vegetation associations conservative

Name of channels	**Length of channels (m)**	**Channels' bottom elevation pre/post -restoration (m a.s l.)**	**Channels' width pre /post restoration (m)**
Trofilca	2.950	0.00 ÷ +1.00/-1.00 ÷ -1,50	0.00/10.00
Periteaşca	3.140	0.50 ÷ +1.20/-1.00 ÷ -1,50	0.00/10.00
Draghilea	7.470	0.50 ÷ +1.20/-1.50 ÷ -2,50	4.00/12.00
Total	**13. 560**		

Tab.1 Parameters of the secondary channels subject to dredging works.

Cod.	Natura 2000 habitat type	Favorable	Unfavorable		Unknown	Vegetation associations' conservative value			
			inappropriate	bad					
1530*	Pannonian and Ponto-Sarmatian meadows and saltmarshes								
3130	Oligotrophic to mezotrophic Standing waters with vegetation from *Littorelletea uniflorae* and/or I*soëto-nanojuncetea*								
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* vegetation								
3160	Dystrophic Lakes and ponds								
3260	Water courses from the plain zones, up to the mountainous areas, with vegetation from *Ranunculion fluitantis* and *Callitricho-Batrachion*								
3270	Rivers with mudflats sides, with vegetation of *Chenopodion rubri* p.p. and *Bidention* p.p.								
92A0	*Salix alba* and *Populus alba* galleries								
	= Very high								
	= High								
	= Moderat								
	= Low								

Tab. 2 Pre and post-restoration conditions: the matrix of the habitats conservation status.

value assessment was performed according to the European Habitat Directive (DOROFTEI et al. 2011, COVALIOV et al. 2012). There is not any difference between the pre- and post-restoration conditions (**Tab.2**).

WILD FLORA AND FAUNA STATUS

The total number of species, at the DDBR level is 7,705 (2,905 flora species: 1,544 algae, 107 lichens, 38 mushrooms, and 1,361 vascular plants, and 4,655 fauna species: 945 zoo-benthos, 726 macro-invertebrates, 91 molluscs, 2,300 insects, 177 fishes, 10 amphibians, 11 reptiles, 341 birds, and 54 mammals. 732 species are threatened (according to The IUCN Red List of Threatened Species: 15 Molluscs, 382 vascular plants, 12 insects, 205 birds, 59 fishes, 11 reptiles, 10 amphibians and 38 mammals). (OŢEL, ed. 2000, NĂVODARU et al. 2005, CIOACĂ et al. 2007, CIOACĂ et al. 2009, DOROFTEI et al. 2011, NĂVODARU and NĂSTASE 2011, COVALIOV et al. 2012, MARINOV et al. 2012, TÖRÖK 2012, LUPU 2013. DDNI 2008-2016).

At the study area level, pre-restoration /post-restoration 1099 /1116 species have been identified, of which, 195 are threatened, as follows:

– 631/631 species of vascular plants, none included in the IUCN Red List,

– 31/23 species of zooplankton. They are not subject to the IUCN List Red analyses,

– 34/53 species of aquatic macroinvertebrates. They are not subject to IUCN List Red analyses,
– 181/181 species of birds. 133 species are threatened: EX 1, EN 1, VU 2, NT 4, LC 125,
– 169/169 species of insects. 12 species are threatened: EN 2, VU 5, NT 3, LC 2,
– 19/24 fish species. All of them are included in the LC category,
– 24/25 species of mammals. 19 species are threatened: 1 is CR, 1 NT, and 17 LC,
– 7 species of amphibians. 5 species are threatened: 2 are VU, 2 NT, and 1 LC,
– 3 species of reptiles. 2 species are threatened: 1 VU and 1 LC.

ACKNOWLEDGMENTS

This research was funded through a European Economic Area grant (EEA, www.eeagrants.-org,www.eeagrants.ro), in the framework of the "Restoration of aquatic ecosystems in the Şontea -Fortuna area-component of Natura 2000 sites of the Danube Delta Biosphere Reserve" [RESTORATION-DD] project (http://restoration-dd.ddni.ro). The project's objectives have been implemented within 2015-2017. Data were kindly provided by the project research teams, experts in Hydrology, Hydro-morphology, Biology, and Geography, from the Danube Delta National Institute (Tulcea, Romania) in partnership with Norwegian Institute for Nature Research (NINA, Norway) and Danube Delta Biosphere Reserve Authority (Tulcea, Romania)

REFERENCES

BONDAR, C. (1994). Referitor la alimentarea si tranzitul apelor Dunării prin interiorul deltei. *Scientific Annals of the Danube Delta Institute*, 3, 259 – 261.

BONDAR, C., BLENDEA, V. (2000). Water and Sediment Transport by the Danube into the Black Sea During 1840–1995. *Intergovernmental Oceanographic Commission Workshop Report*, No. 145, IOC, UNESCO, Paris, 63 – 85.

CIOACĂ, E. (2002). Ecological reintegration of the Danube Delta Biosphere Reserve degraded ecosystems into the natural ones. *Scientific Annals of the Danube Delta Institute*, 10, 35 – 39.

CIOACĂ, E. (2004). Morpho-hydrographic changes within the Danube Delta Biosphere Reserve ecological reconstruction zones – Babina zone case study. *Scientific Annals of the Danube Delta Institute*, 11, 99 – 106.

CIOACĂ, E., BREDEWEG, B., SALLES, P. (2007). Danube Delta Biosphere Reserve Case Study Qualitative Reasoning Model - an Environmental System Sustainable Development Decision Making Support**.** *NaturNet-Redime Newsletter*, 5, 9 – 12.

CIOACĂ, E., LINNEBANK, F. E., BREDEWEG, B., SALLES, P. (2009). A qualitative reasoning model of algal bloom in the Danube Delta Biosphere Reserve. *Ecological Informatics*, 5 – 6, 4, 282 – 298.

COVALIOV, S., DOROFTEI, M., NEGREA, B. M. (2012). Assessment of vegetal resources in Danube Delta, Romania. *AAB Bioflux,* 4, 2, 57 – 72.

DDNI (2008-2016). *Ecological restoration reports*. Danube Delta National Institute for Research and Development.

DOROFTEI, M., OPREA, A., ŞTEFAN, N., SÂRBU, I. (2011). Vascular wild flora of the Danube Delta Biosphere Reserve. *Scientific Annals of the Danube Delta Institute,* 17, 15 – 52.

GÂŞTESCU, P., ŞTIUCĂ, R. eds. (2008). Delta Dunării – Rezervaţie a Biosferei. CD PRESS, Bucureşti, 400 p.

LUPU, G. (2013). Ortopterele din Rezervaţia Biosferei Delta Dunării. *Scientific Annals of the Danube Delta Institute,* 19, 49 – 54.

MARINOV, M., KISS, J. B., TOMAN, A., POLEDNIK, L., ALEXE, V., DOROFTEI, M., DOROSENCU, A., KRANZ, A. (2012). Monitoring of European Mink (*Mustela lutreola*) in the Danube Delta Biosphere Reserve – Romania, 2003 -2011. Current status and setting of goals for the European Mink conservation. *Scientific Annals of the Danube Delta Institute*, 18, 69 – 74.

NĂVODARU, I., NĂSTASE, A. (2011). What fish and how many there are in Danube delta lakes? *Scientific Annals of the Danube Delta Institute,* 17, 71 – 82.

NĂVODARU, I., STARAŞ, M., BUIJSE, A. D., DE LEEW, J. J. (2005). Changes in fish population in Danube Delta lakes: effects of hydrology and water quality change. Review of results and potential for rehabilitation. *Ecohydrology & Hydrobiology*, 5, 3, 245 – 256.

OŢEL, V., ed. (2000). *The Red List of plant and Animal species from Danube Delta Biosphere Reserve Romania*. Danube Delta National Institute, 132 p.

POPESCU, I., CIOACĂ, E., PAN, Q., JONOSKI, A., HANGANU, J. (2015). Use of hydrodynamic models for the management of the Danube Delta wetlands: the case study of Sontea-Fortuna ecosystem. *Environmental Science & Policy,* 46, 48 – 56.

RAMSAR CONVENTION (1971). *Convention on Wetlands of International Importance Especially as Waterfowl Habitat. International Conference on the Wetlands and Waterfowl (Ramsar, Iran, 2 February 1971)*.

ROMANESCU, G. (1999). *The Danube Delta: Some hydro-morpho-dynamic aspects: deltaic changes during the modern and contemporary historical stages.* Suceava University of Suceava Press, 164 p.

SCHNEIDER, E., CERNIŞENCU, I., CIOACĂ, E., COVALIOV, S., DOROŞENCU, A., HULEA, O., IBRAM, O., KRANZ, A., MARINOV, M., MARINOV, M., NĂVODARU, I., OBRDLÍK, P., SCHNEIDER, E., STARAŞ, M., ŞTIUCĂ, R., TÖRÖK, L., TUDOR, M., TUDOR, M. (2008). *Evolution of Babina polder after restoration works. Agricultural polder Babina, a pilot project of ecological restoration.* WWF Germany/DONI, Tulcea, 81 p.

TÖRÖK, Z. C. (2012). Doubtful records of reptile species in some areas of the Danube Delta Biosphere Reserve (Romania). *Scientific Annals of the Danube Delta Institute,* 18, 223 – 232.