Hydrological connectivity, structural and ecological functionality of a meandering ecosystem of the Danube Delta

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Abstract

The pressure control of the climate change and anthropogenic factors have consequences on the ecological systems, generating structural changes. The abiotic (i.e., water hydrology and hydraulics, sediment load, water physic-chemistry) and biotic (i.e., biodiversity, structure and functionality of food webs) characteristics of river-channels-lakes from deltas depend on several factors; however, the main driver of these characteristics is represented by the hydrologic connectivity with the main stem of the river. Floodplain lakes can be permanently, temporarily or disconnected with the main stem of the river producing interruptions in the transfer of fresh water and thus affecting benthic macroinvertebrates, by decrease in their population, diversity and even loss of sensitive taxa. Multidisciplinary investigations (hydrodynamics, sedimentological and ecological measurements and analyses) were made to investigate a river-channel-lake site type situated on the St. George branch formed by a cutoff meander (Mahmudia meander), a connective channel (Uzlina Canal) and a lake (Uzlina Lake) to observe how much the fresh water and sediment input to the delta depressions is affected by the structural changes of the meander physiography. The Mahmudia meander was rectified 40 years ago and the response of the channel consisted in a very fast silting of the former meander, currently receiving less than 5% of the upstream water and sediment discharge. The lateral connectivity with the deltaic depressions thought the lateral canals is compromised.

Keywords: hydrological connectivity, structural and ecological functionality, meander, ecosystem, Danube delta

Introduction

Human activities, such as groins, embankments, jetties, meander cut-off represent important factors in the sedimentary processes by segmentation or even interruption of the sedimentary flow [1].

Located in the south-eastern part of Romania, the Danube Delta is the largest delta in the European Union covering about 5640 km^2 with a very complex network of canals and lakes [2]. Multiples series of human works have been influenced the sedimentological processes in the Danube Delta area. In the last 40 years, the cut-offs programme of the St. George branch brought a redistribution of water and sediment discharges among the delta distributaries [3, 4]. The artificial canals were intensively eroded while the former meanders are going to be progressively sedimented [5, 6] (Figure 1).

The former Mahmudia free meander is located in the middle part of the St. George branch, between KM 84 and KM 64 (Figure 1). This meander results from the river impingement against the Mahmudia hills that deflected the St. George channel into a large meander loop named the Mahmudia-Uzlina meander bend [2]. The mahmudia meander is the largest and the most complex meander of the St. George branch [7].

The concept of hydrological connectivity was widely used in different environments and defines the water-mediated transfer of matter, energy and organism within the hydrological cycle [8, 9]. The loss of the connectivity produces the diminish of the fresh transfer in the fluvial networks. The longitudinal connectivity is important for the nutrients transport and the migration of aquatic organism [9].

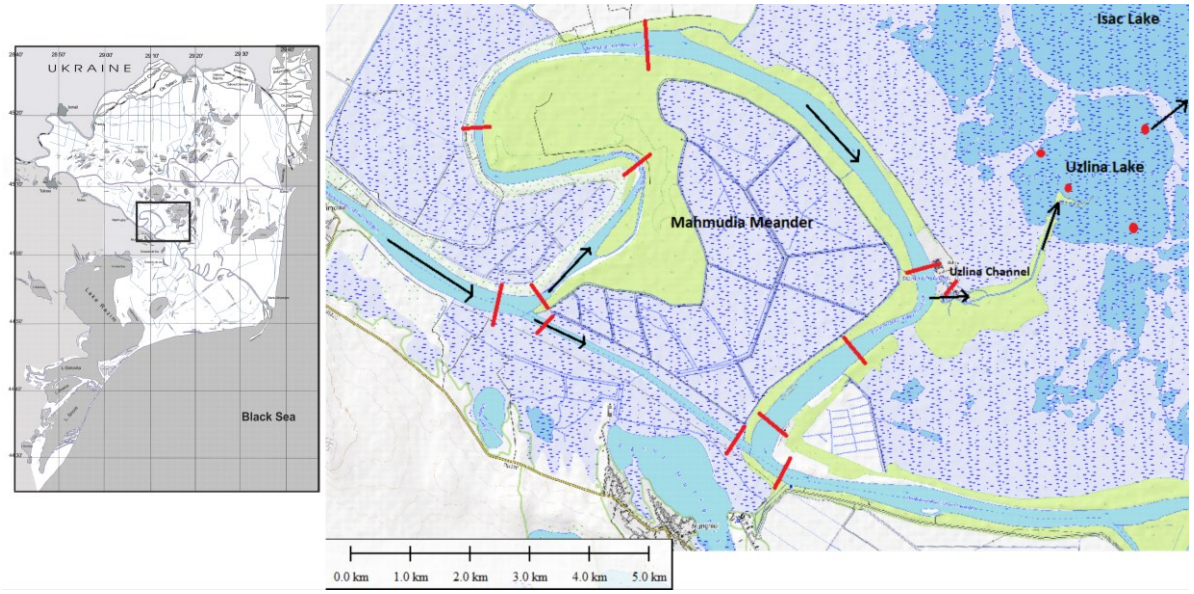


Fig. 1. The Danube Delta with the location of the Mahmudia meander and the investigated cross-sections

Material and Methods

The measurements were made in September 2020, during the average autumn waters. Eleven transversal profiles were completed at relevant sections (Figure 1). An ADCP River Ray 600 kHz mounted on a power boat was used for the hydrological data acquisition. The sediment grain size analysis were done by diffractometry using the granulometric laser analyzer „Mastersizer 2000E Ver.5.20 (Malvern Instruments Ltd.-Malvern UK). Suspended sediment concentrations were measured and analysed in each investigated cross-sections (sampling with 5 L horizontal Niskin-types bottle and filtration with a Millipore filtration unit, using 4.7 cm acetate cellulose filter membranes of 0.45 μ porosity, according to STAS 6953-81). In order to estimate the amount of the total organic matter, the total carbonates and the minerogenic content within the bed-sediment samples, the Loss on Ignition (LOI) method was used. Sixteen quantitative and qualitative zoobenthos samples have been collected with a Van Veen grab and a limnological net, in order to gather, as much as possible, the diversity of the analysed ecosystem. Geochemical analyses of collected samples of superficial sediments were done using a slight modification of the analytical procedures described in detail by Secrieru and Secrieru [10].

Results

Along the Mahmudia meander the water flow was unequally distributed between the former meander (receiving a very small part of the upstream flow, 14 $m^3 \cdot s^{-1}$, representing 1% of the upstream flow of 1330 $m^3 \cdot s^{-1}$). At the bifurcation (P09) very low velocities are found (between 0.01 – 0.04 $m \cdot s^{-1}$ on the natural channel of the former meander and between 0.52 şi 0.58 $m \cdot s^{-1}$ along the artificial canal (P07) (Figure 2).

The sediments of the natural channel are composed mostly of fine sediments (clay and silt) while those of the artificial canal are composed of fine and medium sand. In the Uzlina lake the predominant fraction is silt and clay.

The studied area is characterized by terrigenous, non-carbonated and low-calcareous sediments ($CaCO_3$ within 5.11-16.25%), relatively poor in organic matter (TOC within 0.002-2.60%). Only few of TOC concentrations were > 1. Hg concentrations exceeding the quality criteria in effect in Romania (Order 161/2006) were observed metals presented the highest concentrations on the former meander (V, Zn, and Pb). The average value of the lithological components is as follows: siliciclastic fraction between 40.08 and 89.36 (% SIL), total carbonates between 5.26 and 10.84 (CAR%) and total organic matter between 1.66 and 52.09 (TOM%) (Figure 3a and Table 1).

From the sedimentary discharge of 14.7 $kg \cdot s^{-1}$ at the upstream bifurcation (cross-section P06), a very small part, 0.2 $kg \cdot s^{-1}$ passes through the natural course of the meander. On the cut-off channel (between P06 and P15) the sedimentary flow in suspension is significantly enriched (from 14.7 $kg \cdot s^{-1}$ to 21.9 $kg \cdot s^{-1}$) showing erosion processes along the artificial canal (Figure 3b).

The faunistic research performed in the studied sector highlighted the presence of 52 taxa of invertebrates belonging to 20 major taxonomic groups. In the area of the meanders, the oligochaetes were the most numerous with an average abundance of 11652.4 $ind.m^{-2}$.

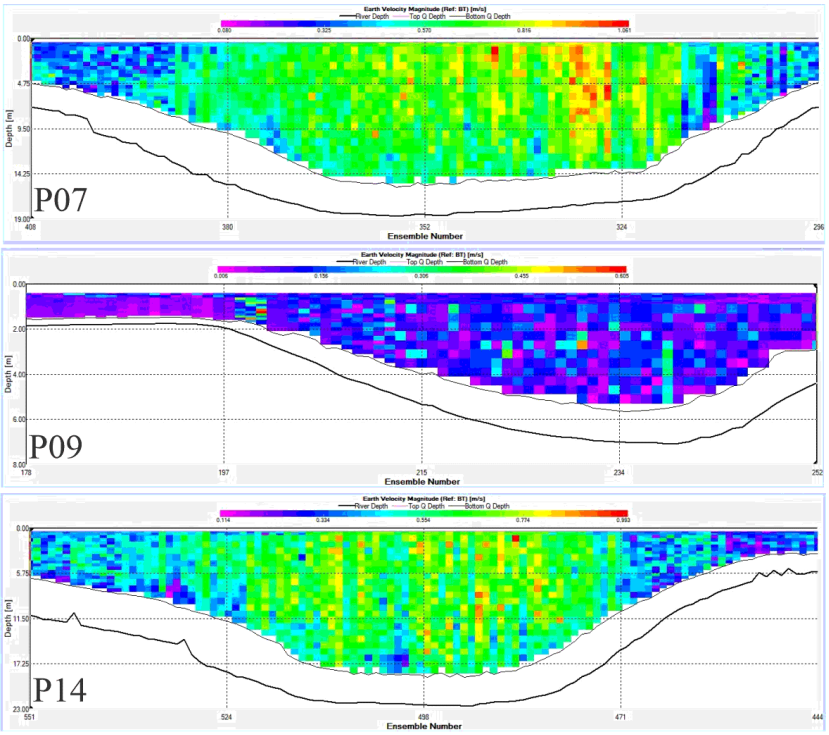
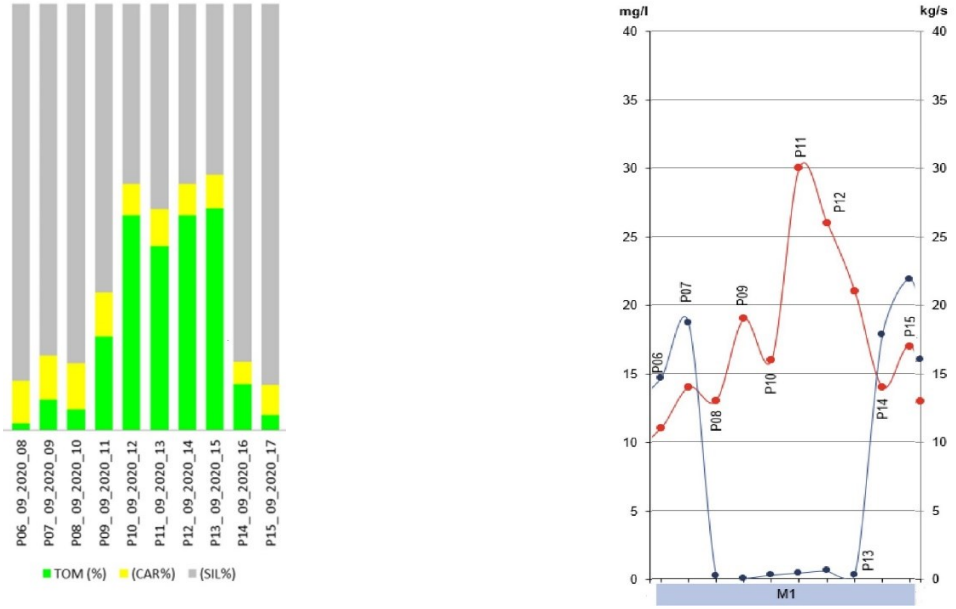


Fig. 2. The velocity distribution on the natural channel (P09) and on the artificial canal (P07 and P14)



(a) (b)

Fig. 3. (a) Percentual distribution of the main lithological compounds in the bed sediments; (b) SSC (mg·l^{-1}) mean values (red line) and the SS fluxes (kg·s-1) (blue line)

Tab. 1. The main physical and chemical indicators of the bed sediments

Sample	Water Content (WC %)	Dry Matter (DM %)	Total Organic Matter (TOM %)	Total carbonates (CAR %)	Siliciclastic fraction (SIL%)
P06_09_2020	19,54	80,46	1,66	10,03	88,31
P07_09_2020	12,81	87,19	7,20	10,31	82,49
P08_09_2020	16,31	83,69	4,91	10,84	84,24
P09_09_2020	23,32	76,68	21,93	10,32	67,75
P10_09_2020	12,70	87,30	50,34	7,42	42,25
P11_09_2020	13,61	86,39	43,19	8,65	48,16
P12_09_2020	29,38	70,62	50,37	7,50	42,13
P13_09_2020	12,04	87,96	52,09	7,83	40,08
P14_09_2020	11,59	88,41	10,87	5,26	83,87
P15_09_2020	14,42	85,58	3,52	7,13	89,36

Conclusion

The study provides recent data on hydrological, sedimentological and ecological of a large multi-impacted meandering channel. The natural channel of the cutoff meander and the newly built channel evolve differently, due to major changes of the sediment transport processes. The results show that the granulometric distribution of sediments on the Mahmudia meander as well as their quality have been segmented by the presence of the rectification canals. The decrease of the water velocity and implicitly of the fluvial energy in the cutoffs has favoured the deposition of the sediment load. The chemical composition corresponds to terrigenous, non-carbonated and low-calcareous, with the very occasional presence of calcareous sediments. Sediment chemistry is largely controlled by their granulometry, with the sand fraction. Generally, the quality of the sediments may be considered as good, although individual values of Cr, Cu and especially Ni exceed frequently the Romanian quality criteria. The hydrotechnical works carried out along the St. George branch to improve navigation produced negative effects on the exchange of water and sediments with the lakes in the delta through the connecting channels. To date, there is still a limited understanding of how alterations in river flow, depositional-erosional processes and hydrological connectivity may affect trophic interactions and flows of energy in food webs along a gradient of lateral hydrologic connectivity, such as the river-channels- floodplain lakes. The natural channel of the Mahmudia rectified meander is currently heavily clogged and the sediments accumulated in the bed create sediment disturbances. Therefore, at low water levels, this area is isolated from the main distributary producing interruptions of the liquid fluxes transfer with consequences on the hydrological connectivity.

Acknowledgments

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