Transboundary River Hydrodynamic Conditions Assessment in Sustainable Development Context. A Case Study of Danube River: Chilia Branch – Bystroe Channel Area

Georgeta Tudor¹, Deák György¹, Constantin Cîrstinoiu¹, Marius Raischi¹, Tiberiu Dănălache¹², Gabriel Cornățeanu¹ and Edward Bratfanof³

¹National Institute for Research and Development in Environmental Protection Bucharest, Romania
²University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania
³Dunărea de Jos University of Galați, Romania

E-mail: gyorgy.deak@incdpm.ro

Abstract. Located in the Danube Delta Biosphere Reserve, the Chilia branch serves as country boundary between Romania and Ukraine. The former state started in 2004 a project intended to increase the navigability capacity of Bystroe Channel, the environmental impact of the works carried out being discordantly considered by the Romanian and Ukrainian authorities. The Inquiry Commission established under the Espoo Convention, of which both countries are part of, delivered its final opinion that the project was likely to have a significant adverse transboundary impact on the hydrodynamic local conditions and habitat loss for fish and birdlife. Statistical analysis was operated on daily and monthly averaged water discharge values and the results were graphically displayed as hydrographs and probability curves and distribution. Addressing the in situ data measurements deficit for the Chilia branch – Bystroe Channel Area, measurement campaigns have been carried out in order to monitor the alterations of the hydrodynamic parameters. Using the specialized Acoustic Doppler Current Profilers technique, there have been recorded water flow parameters (water discharge and water current velocity vectors) and the data used for analysis and 2D and 3D representation of the hydrodynamic conditions.

1. Introduction
Two of the main objectives of the EU Water Framework Directive 2000/60/EC consist of prevention of the aquatic ecosystems deterioration and achievement of at least good status for the water bodies within EU, the hydrodynamic parameters are considered key elements for both aims. The Danube Biosphere Reserve is declared as UNESCO World Heritage Natural Reserve and RAMSAR wetland of international importance, due to its rich and diverse biodiversity. Notably, for sturgeon species that are sensitive to habitat changes, the Chilia branch – Bystroe Channel area is important due to the key habitats and migration routes from/to the Black Sea, migration that was found to be at risk of decrease with 67 % [1, 2].
For a wider hydrologic time frame context, statistical analysis is carried out [3] on chronological data series of averaged (daily, monthly, yearly) discharge values recorded in gauge stations. INCDPM uses the specialized Acoustic Doppler Current Profilers technique [4,5,6,7,8] to record bathymetry profiles, water velocity vectors and water discharge values for over nine years. The measured river sector is located in the Bystroe Channel area of Chilia branch (Figure 1), the northernmost of the three main Danube distributaries that form the delta before meeting the Black Sea and that serves as country boundary between Romania and Ukraine [9].

![Figure 1. Location of the measured river sector.](image)

The Bystroe Channel has been the subject of intense debate due to the works carried out by Ukraine in order to transform it into a navigational channel for large ships. Under the provisions of the Espoo Convention, the Inquiry Commission reported in 2006 the unanimous conclusion that there will likely be a significant adverse transboundary impact and still, in 2019 the request to full compliance and the need to inform Romania about the existing monitoring results is active.

2. Experimental

2.1. Water discharge

Using daily averaged discharge values recorded in the Tulcea and Isaccea gauging stations, for Chilia branch there has been generated the discharge hydrograph for January 1st 2018 – 30th May 2020 in order to determine the hydrological conditions reference status. To broaden the perspective on the general hydrology of the Chilia branch, statistical analysis was used on recorded data from 1987 – 2020, in the form of a homogenous monthly averaged discharge time series. For the probability computation a Weibull distribution (1939) was considered due to the nature of the data used, the discharge parameter being related to natural phenomena that implies a random factor, thus the 100% probability cannot be reached. The statistical analysis was used to draw the discharge probability distribution curve and discharge cumulative frequency for Chilia branch.

2.2. Water velocity

In July 2019, INCDPM carried out an ADCP single-beam measurement campaign (Figure 2).
Addressing the in situ data measurements deficit for the Chilia branch – Bystroe Channel Area, the campaign covered a 9.8 km river sector. The raw water velocity recorded data was processed and analysed, resulting velocity distributions for the measured river sections.

3. Results and Discussions

3.1. Water discharge
On the Chilia branch discharge hydrograph shown in Figure 3 in green have been marked the seasonal milestones in order to assess the behaviour of the spring high and autumn low water levels.

| Discharge, (m$^3$/s) | 2018 | 2019 |
|----------------------|------|------|
| minimum              | 1150 | 1190 |
| average              | 3268 | 2777 |
| maximum              | 8399 | 7310 |

Figure 2. ADCP single-beam measurements campaign – July 2019.

Figure 3. Chilia Branch hydrograph.

Table 1. Representative discharge values for Chilia branch.
For the considered time interval (January 2018 - May 2020), in Figure 3 we can see two spring high water levels, for 2019 the values are offset towards the summer and smaller than the ones recorded in 2018. As for the autumn low water level periods, the minimum values are comparable, the water deficit being stretched on a longer time interval in 2019. As seen in Table 1, the yearly averaged discharge value for 2018 is higher than the one for 2019. Using monthly average discharge values grouped in 200 m$^3$/s intervals, we computed the frequency for every discharge step and drawn the probability distribution curve presented in Figure 4 (A).

![Figure 4](image)

**Figure 4.** Discharge probability distribution curve (A) and cumulative frequency (B) for Chilia branch.

The highest probability values are noted for discharge values between 1800 - 4200 m$^3$/s, with a maximum of 7.62 % for the 2200 – 2400 m$^3$/s interval. The flow-duration curve from Figure 4 (B) shows the percentage of time discharge values were equaled or exceeded. The graph highlights the inversely proportional relation between the discharge value and its duration/frequency, in the considered series the minimum value of 1200 m$^3$/s has a 100% cumulative frequency and the lowest frequency value of 0.28% represents the only existent value over 8000 m$^3$/s.

### 3.2. Water velocity

Considering the length (9.8 km) of the measured river sector on Chilia branch in the Bystroe Channel area, the 3D representation of the water velocity distributions on sections transversal on the river flow has been divided in four areas, shown in Figure 5. For each of the four areas, we computed the representative values for water velocity vectors, resulting maximum values from 0.98 to 1.30 m/s and average values from 0.40 to 0.51 m/s.
As seen in Figure 5 and resulting from the computed water velocity values, the highest ones were recorded in area 4.

4. Conclusions
The Chilia branch – Bystroe area has a strategic importance given the specific conditions of the Danube Delta, as point of concentration of water and sediment flow collected from the entire Danube basin, the transboundary hydromorphological pressure of the works carried out on the Bystroe Channel and the economic implications of increasing channel navigability to the detriment of Sulina Branch. For the year 2019, the statistical analysis on water discharge values series shown a slight water deficit considering an average hydrological year, with an offset towards the summer of the seasonal high water levels. From the sections that divided the measured river sector, the highest water velocity vectors values have been recorded in the downriver area. In situ measurements campaigns are further required in order to address the present data deficit in the Bystroe Channel area. A sustainable management of the entire area requires a solid scientific basis on local hydrodynamic processes, access to relevant and updated data on local environmental conditions and mitigation of the risk to discontinue the sturgeon migration routes from/to the Black Sea using the Stambulul Vechi branch. The results presented in this paper were obtained thanks to the research conducted by INCDPM in the development of the project entitled “Research on the morphological and hydrodynamic evolution tendencies in the Chilia – Bystroe transboundary area”, financed by Ministry of Education and Research, Romania (2019-2022).

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