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Methodology for Identification of Areas with Possible Risk for Sturgeon Species Migration Disruption on The Lower Danube

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Abstract. In the context of the continuing decline of the species belonging to the order *Acipenseriformes* on a global level, the anadromous sturgeon species sturgeon species in the Lower Danube have been affected by a significant reduction in historical migration routes and fragmentation of breeding habitats. This paper presents the stages of the methodology for identifying areas that present a possible risk of interruption of sturgeon migration in correlation with satellite images and daily values for discharge/water level databases. In order to determine the two ranges of values that characterize the extreme phenomena (high/low flows), a hydrological statistical analysis was carried out for the most extensive period of time covered by recorded data (January 2011 – May 2023) in the hydrometric station located in Calarasi, Romania. Based on the 4524 values from the series of average daily discharge values, the discharge hydrograph, the empirical curve of insurance/exceedance probability and the frequency and duration curves using 200 m3/s discharge steps were determined and represented. Correlated with satellite imagery recorded during the determined time intervals with extreme phenomena, there were identified areas with possible risk for sturgeon species migration disruption.

1 Introduction

Black Sea sturgeons are anadromous fish [1], migrating upstream on the Danube River for reproduction, and the distance covered in the migration process varies depending on each species, from tens to hundreds of kilometers [2] [3]. According to the global assessment conducted by the International Union for the Conservation of Nature - Sturgeon Specialist Group (IUCN-SSG) in 2010, all 27 species belonging to the order *Acipenseriformes* are classified as Vulnerable or Critically Endangered and the 2022 updated version of the same report [4] highlights the continuing decline of this taxonomic group on a global level. The sturgeon species currently extant in the Lower Danube (*Acipenser stellatus* - the stellate sturgeon, *Huso huso* - the beluga sturgeon, and *Acipenser gueldenstaedtii* - the russian sturgeon) maintain their previous classification, as Critically Endangered, with a consistent population decline trend. The expert team of the National Institute for Research and

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Development for Environmental Protection Bucharest (INCDPM), through more than a decade of research on the migratory behavior of ultrasonic tagged wild sturgeons monitored using telemetry techniques, determined that the anadromous sturgeon species have been affected by a significant reduction in historical migration routes and fragmentation of breeding habitats [3,5,6].

Although the interruption of migration routes, the causative factor of blocking the access of anadromous sturgeons to the historical spawning habitats, is often cited as an element of major importance in the decline of sturgeons in the Ponto-Danubian space, however, until now, this hydromorphodynamic aspect has not been quantified or spatially located, indicating areas of potential risk. INCDPM uses the specialized Acoustic Doppler Current Profilers technique [7,8,9,10,11] to record bathymetry profiles, water velocity vectors and water discharge values for over eleven years.

This paper presents the stages of the methodology for identifying areas that present a possible risk of interruption of sturgeon migration in correlation with databases with satellite images, respectively with discharge/water level (D/WL).

For a wider hydrologic timeframe context, statistical analysis is carried out [12] [13] on chronological data series of average D/WL for a number of 17 hydrometric stations [14] with data recorded between January 2011 and May 2023.

2 Materials and method

Aiming to identify areas with possible risk of interruption of sturgeon migration, databases were created with pairs of average daily D/WL values for a number of 17 points covering the Danube sector located downstream from the fluvial kilometre 793 and represented in Fig. 1.

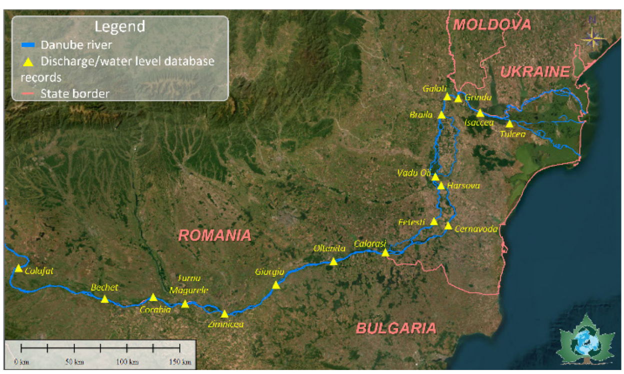


Fig. 1. Location of D/WL record points.

In order to determine the two ranges of values that characterize the extreme phenomena (high and low flows), a hydrological statistical analysis was carried out for the most extensive period of time covered by recorded data (January 2011 – May 2023) for the hydrometric station located in Calarasi. Based on the 4524 values from the series of average daily flow values, the discharge hydrograph, the empirical curve of the insurance/exceedance probability and the frequency and duration curves, using 200 m^3/s discharge steps, were determined and represented.

To determine the intervals for low discharge and high discharge, the values with assurance of Q95% and Q5%, respectively were considered as limits. According to the results of the hydrological statistical analysis, these values correspond to flows of 2630 m^3/s and 9960 m^3/s, respectively.

The values that satisfy the criteria for Q95% and Q5%, were grouped by time intervals in order to identify satellite images recorded in periods with low/high discharge values. In order to monitor the expansion of some islands that present a possible risk of interrupting the migration of sturgeon species, 13 representative areas have been identified. For these areas, satellite images recorded during Q95% and Q5% flow periods were downloaded from the Landsat 8 OLI and Sentinel 2A satellite product databases and selected according to the degree of cloud cover and resolution criteria.

The present study outlines a systematic methodology for the identification of regions that may be susceptible to potential disruptions in the migratory patterns of sturgeon species (Fig. 2.)

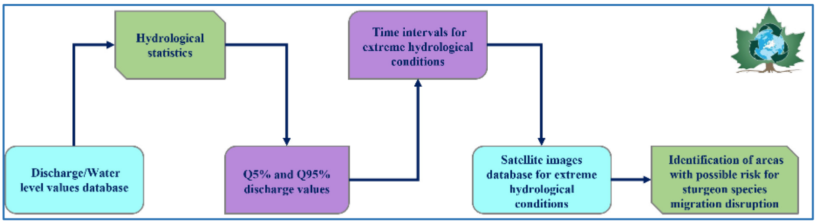


Fig. 2. Methodology diagram for identifying areas with possible risk of interruption of the migration of sturgeon species.

3 Results and discussion

The characteristic hydrological elements of a river course are the water level H (the water surface elevation at a considered point, at a given time) and the water discharge Q in a river section (the volume of water flowing per unit time through cross section considered).

The hydrography of levels and flows includes the graphical representation procedures by which their characteristic values are highlighted, useful both in establishing the hydrological conditions for a certain time interval, for forecasting the hydrological data, as well as for the design and dimensioning of hydrotechnical constructions.

The discharge hydrograph shows a chronological representation of the variation of flow values. The set of average daily values from the Calarasi station database was used to represent the hydrograph found in Fig. 3.

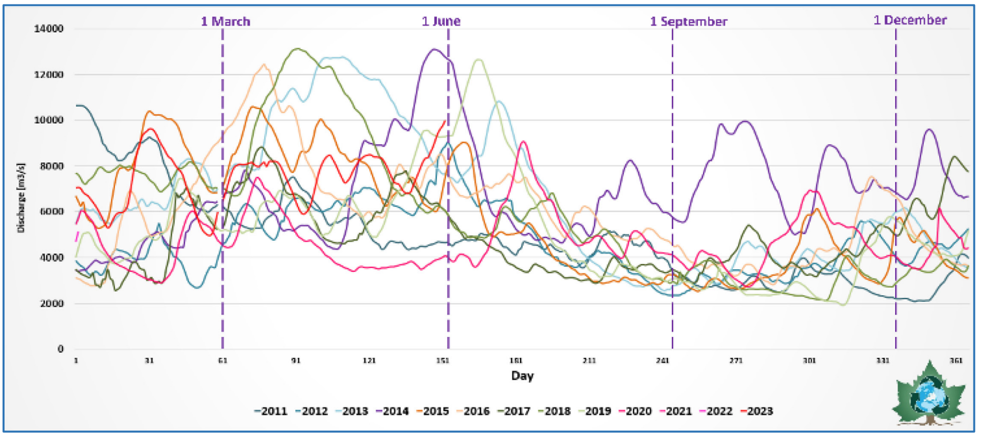


Fig. 3. Calarasi Hydrograph January 2011 – May 2023.

The discharge hydrograph highlights the spring peak and the period of low flows in autumn for most of the years included in the analysis, except for 2014, in which an autumn characterized by high flow values was recorded.

Another atypical behaviour is also presented for 2020, which shows a first spring peak with low discharge values, followed by a dry period with the lowest discharge values in the series of values analysed and another peak, shifted in the period of summer.

The methods of mathematical statistics were applied to determine the behaviour of the sets of homogeneous hydrological characteristics that constitute chronological series. This way of processing can be called one-dimensional temporal statistical analysis because it is a single element that varies over time.

For the statistical analysis, a series of 4524 average daily discharge values recorded in Calarasi was used, covering the interval January 2011 – May 2023.

The probability of insurance/exceedance for a certain flow value was determined with Weibull's formula (1939):

$$p = \frac{m}{n+1} \times 100 \tag{1}$$

(m) the sequence number in the ordered data string
(n) the number of elements in the string

Fig. 4 shows the representation of the empirical curve of insurance/exceedance probability for average daily discharge values.

The low probability for high flow values is observed and also, the high probability of exceeding low flow values.

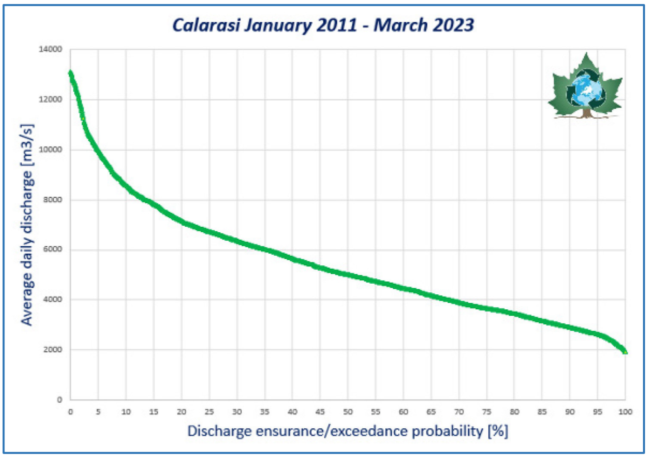


Fig. 4. Insurance/exceeding curve for average daily discharge values – Calarasi.

An element that contributes to a better knowledge of the behaviour of natural phenomena data strings is the establishment of their frequency and duration within the respective strings.

Thus, the values of the average daily flows were framed in 200 m^3/s interval-steps and the number of occurrences was calculated for every step, determining the frequencies [%] for each interval, the result being shown in Fig. 5.

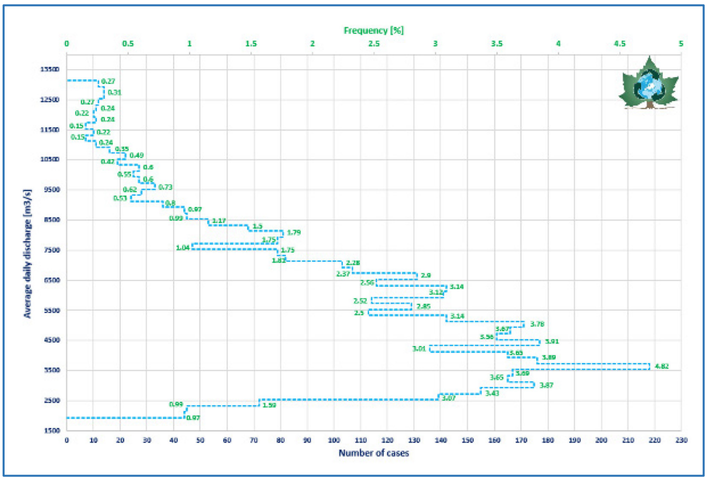


Fig. 5. The frequency curve on characteristic steps - average daily discharge – Calarasi.

It is observed that the highest frequencies have the flow rates in the range of 2730-5130 m^3/s, with a maximum frequency (4.82%) for the step of 3530-3730 m^3/s.

For the same discharge interval-steps, the number of occurrences with higher values of average monthly flows were added up, determining the duration (Fig. 6).

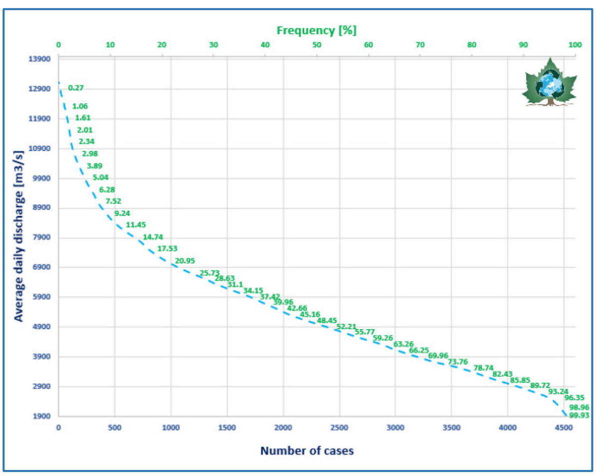


Fig. 6. Duration curve - average daily discharge values – Calarasi.

The representation highlights the link between the duration and the frequency of the discharge values, thus, 99.93% of the cases are greater than the lower limit of the flow range (1930 m^3/s), and 12 values were recorded above the threshold of 12930 m^3/s, with the minimum frequency of 0.27 %.

In order to determine the ranges of flows that characterize extreme phenomena (low/high flows), the Q95% and Q5% values were considered as limits. According to the results of the hydrological statistical analysis presented above, these values correspond to flows of 2630 m3/s, respectively 9960 m^3/s. In Fig. 7 these intervals are shown graphically overlayed on the insurance curve for Calarasi.

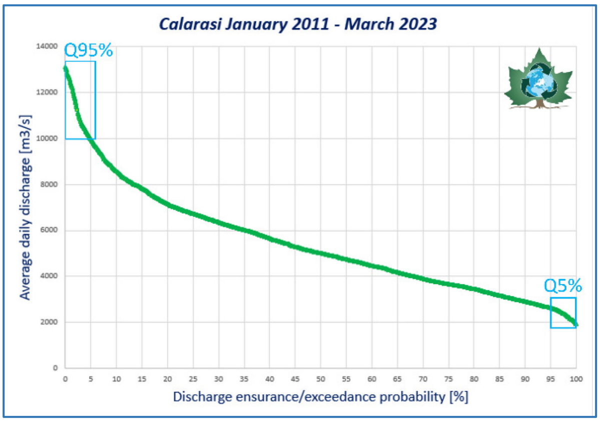


Fig. 7. Value ranges for Q95% and Q5% - Calarasi.

From the database with all the values for the Calarasi point, using the determined limits, the 2 databases with daily values for D/WL pairs on the investigated section for the two extreme hydrodynamic phenomena were extracted.

The values that satisfy the criteria for <Q95%, respectively >Q5% were grouped by time intervals in order to identify satellite images recorded during periods with extreme hydrodynamic phenomena (Table 1).

Table 1. Time intervals – <Q95% and >Q5%.

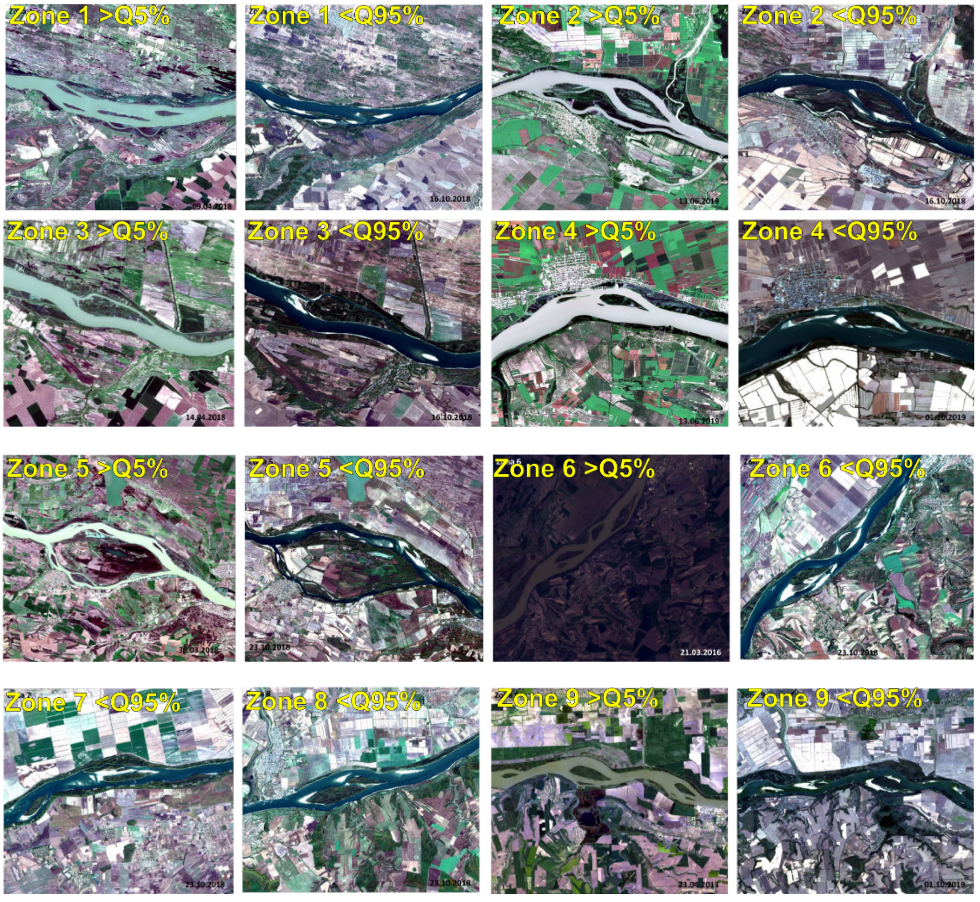
<Q95%				>Q5%			
Year	**Month**	**Days**	**Average flow [m³/s]**	**Year**	**Month**	**Days**	**Average flow [m³/s]**
2011	09	23-27	2600	**2011**	01	01-08	10482
	10	11-17	2536	**2013**	03, 04, 05	20.03-15.05	11590
	11,12	19.11-18.12	2273		06	19-26	10545
2012	08, 09	25.08-08.09	2436	**2014**	05, 06	10.05 – 08.06	11972
2013	08	28-31	2597	**2015**	01, 02	29.01-09.02	10187
2015	09	10-12	2547		03	11-19	10374
2017	01	17-18	2583	**2016**	03	07-31	11183
2018	09, 10, 11	29.09-05.11	2419	**2018**	03, 04	15.03 – 28.04	11759
2019	09	12-13	2605	**2019**	06	05-22	11521
	09,10,11	29.09-13.11	2303	**2021**	02	12-25	10279
2021	11	01-10	2539				
2022	07, 08, 09	23.07-06.09	2149				
	09	14-24	2404				
	10,11	31.10-17.11	2533				

Following the analysis of satellite images available for the study area, 13 representative areas were determined (Fig. 8) for which it is necessary to monitor the expansion of some islands that present a possible risk of interruption of the migration of sturgeon species.

Fig. 8. Location of areas with islands identified on the basis of satellite images.

For these areas, satellite images recorded during Q95% and Q5% flow periods were downloaded from the Landsat 8 OLI [15] and Sentinel 2A [16] satellite product databases, selected according to the degree of cloud cover and resolution.

Below (Fig. 9) are presented the satellite products, in natural colors, selected for the 13 identified areas, in hydrological conditions of <Q95% and >Q5%.



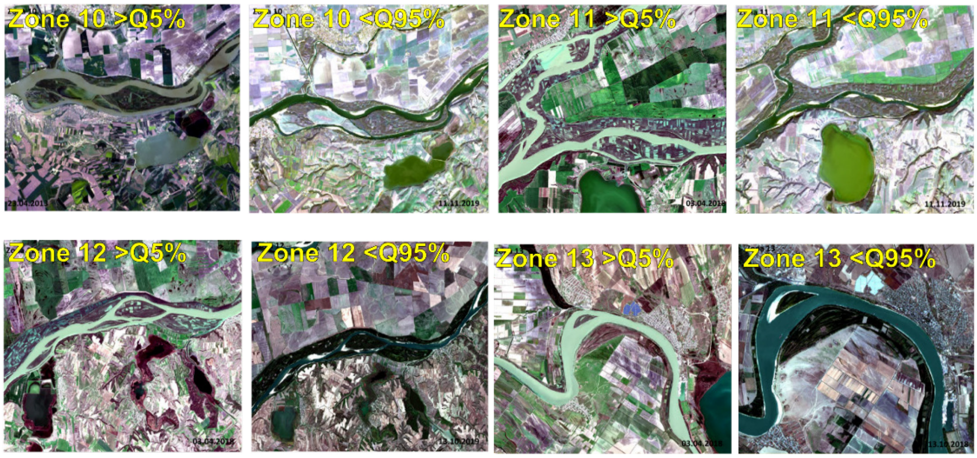


Fig. 9. Areas with islands – satellite images for periods of extreme hydrological conditions.

The algorithm presented for the Calarasi station was also applied to the other 16 recording points, thus creating the 2 databases with daily values for D/WL pairs on the investigated Lower Danube section for the two extreme hydrodynamic phenomena (characteristic values Q95% and Q5%).

4 Conclusion

Following the analysis of the data recorded at the hydrometric stations, it was found that, for Calarasi, the highest frequencies are the flows in the range of 2730-5130 m^3/s, with a maximum frequency (4.82%) for the step of 3530-3730 m^3/s.

Also, the connection between the duration and the frequency of the discharge values was highlighted, thus, 99.93% of the cases are greater than the lower limit of the flow rate series (1930 m^3/s), and above the threshold of 12930 m^3/s were recorded 12 values, with the minimum frequency of 0.27 %.

The presented methodology can be applied every time extreme phenomena occurs, the daily D/WL database being continuously updated and the process of identifying of new areas with possible risks of migration interruption will be carried out in optimal time, providing the base for the in-situ assessment of the real risk for migration routes disruption.

Acknowledgements

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