# MERGING GEOGLOWS MODEL AND DISCHARGE DATA FOR BIAS-CORRECTED CHARACTERISATION OF HYDROLOGY FOR SURVIVING STURGEON HABITAT ON RIVER RIONI IN GEORGIA, EASTERN BLACK SEA

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***Abstract:*** *Georgian river Rioni still hosts the last remaining sturgeon habitat in the Eastern Black Sea. WWF Caucasus Programme Office is undertaking efforts to conserve and potentially expand this critically important spawning area. Long-term hydrological data, such as daily discharge time series, is indispensable for characterising the entire river and this ecological site in particular. GEO Global Water Sustainability tool GEOGloWS was applied to derive long term (over 40 years) modelled streamflow time series for the stretch of interest at Rioni. Discharge data kindly provided by Vartsikhe Hydropower Cascade, was successfully used to bias-correct the global dataset and thus significantly expand time coverage against the period of available discharge data (10 years). Experience with merging some other global & local datasets is also reported in this work.*

***Keywords:*** *GEOGloWS, Eastern Black Sea, sturgeon, spawning, river Rioni, daily discharge time series, bias-correction, global hydrologic model, catchment hydrologic modelling, Earth Observations, Geo Data Cube, hydropower impacts.*

## Introduction

The Rioni is the last remaining sturgeon spawning river in Georgia and on the entire eastern basin of the Black Sea, which makes this river a regional and even global hotspot of critical importance for the survival and conservation of sturgeon [1].

According to [2], due to the construction of Hydropower Plants (HPPs) sturgeon spawning areas were reduced to only 9 km habitat on river Rioni, just downstream of the Vartsikhe HPP Cascade at the end of the diversion canal confluence with rivers Rioni and Gubistskali. Cumulatively, from 124 km just 9 km of spawning habitat is reported left in the Georgian Black Sea Catchment basin [2]. The sturgeon populations thus have been dramatically reduced in Georgia and they are under continuing pressure from illegal fishing in the Black Sea and Rioni River, from the impacts of hydropower plants (HPP), sand and gravel extraction from river floodplains, pollution and other harmful activities and processes [1].

This paper was produced within the framework of the project „Strengthening Sturgeon Conservation in Georgia" implemented by WWF Caucasus Programme Office (WWF Caucasus) through the financial support of WWF Switzerland.

Overall, the project is aiming at (i) stakeholder engagement, (ii) development of a sturgeon monitoring programme, (iii) assessment of the impacts of current practices of HPP operations and sand and gravel extraction from the Rioni River and sturgeon spawning grounds, (iv) establishing protected areas on the Rioni River and the marine section adjacent to its estuary, and (v) feasibility study on the restoration of part of the sturgeon's historical spawning grounds.

In this particular communication, we are reporting on the experience with the utilisation of Global Earth Observation (GEO) data resources in characterising the water quantity and quality in the catchment of the river Rioni and utility of these data sources for the characterisation of conditions at the sturgeon spawning areas downstream of the Vartsikhe HPP Cascade.

The structure of the paper is the following – the introductory part is followed by a short presentation of the river Rioni and the HPPs concerned. The next part introduces various Global Earth Observations as applied in the study. Finally, the paper is summarised with conclusions.

**Existing HPPs on Rioni and Lajanuri Rivers**

This section characterises concisely the river Rioni and HPPs that operate on the river with potential impacts on the river's sensitive habitats, including cumulative impacts.

The length of the river Rioni is 327 km, and the area of the catchment basin is 13,400 $km^2$. Rioni is rising on the southern slopes of the Greater Caucasus at 2,960 m ASL and is fed by glacial, snow, rain, and groundwater. From the source, it flows into a deep valley south-east, where it develops a wide branch and then flows south-west into a deep and narrow valley till Kutaisi. Near Vartsikhe river turns westward flowing on Kolkheti Lowland to confluence with the Black Sea.

The development of the hydropower potential on Rioni River dates back to the 1930s and since then the hydro-ecological characteristics of Rioni are significantly disrupted. The location of the existing HPPs is depicted on the map in Fig. 1 and their list and characteristics are given in Table 1. Vartsikhe cascade is described next as the most relevant one for this paper.

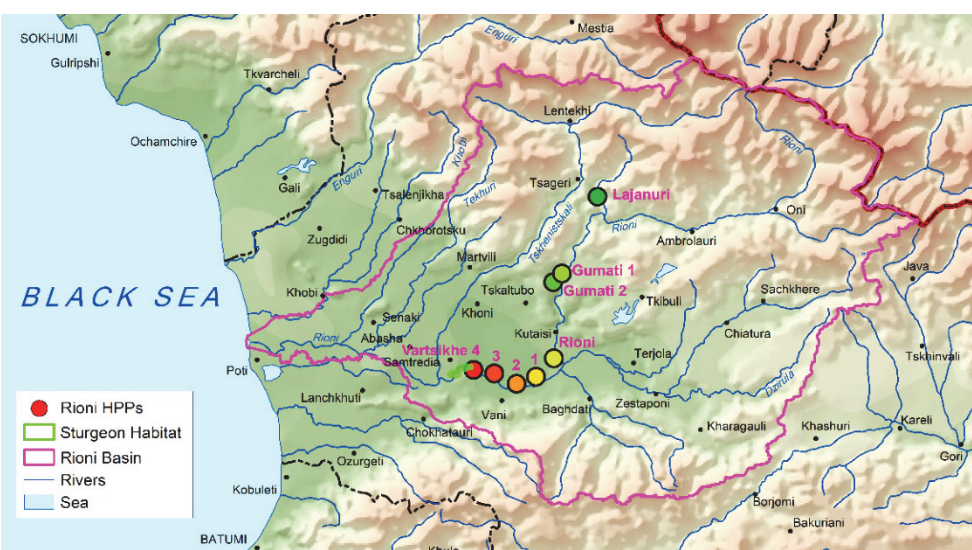



*Fig. 1. Existing hydropower plants and cascades on r. Rioni and r. Lajanuri.*

**Table 1.** Existing hydropower plants on the rivers Rioni and Lajanuri.

| Hydroelectric Power Plants | Gumati I | Gumati II | Rioni | Vartsikhe I, II, III, IV | Lajanuri |
|---|---|---|---|---|---|
| River | Rioni | Rioni | Rioni | Rioni | Lajanuri |
| Power (MW) | 44 | 22.8 | 48 | 184 (total) | 112.5 |
| Turbines | 4 x 11 | 3 x 7.6 | 4 x 12 | 4 x 2 x 23 | 3 x 37.5 |
| Year of commissioning | 1958 | 1956 | 1933 | 1976-1988 | 1960 |
| Generation (million kWh/year) | 256 | 138 | 325 | 1000 | 505 |

**Vartsikhe HPP Cascade**

Vartsikhe HPP Cascade consists of the dam on river Rioni (Fig. 2), Vartsikhe reservoir and the diversion system, with 4 HPPs installed along the canal (Vartsikhe 1, 2, 3 and 4) (Fig. 3).

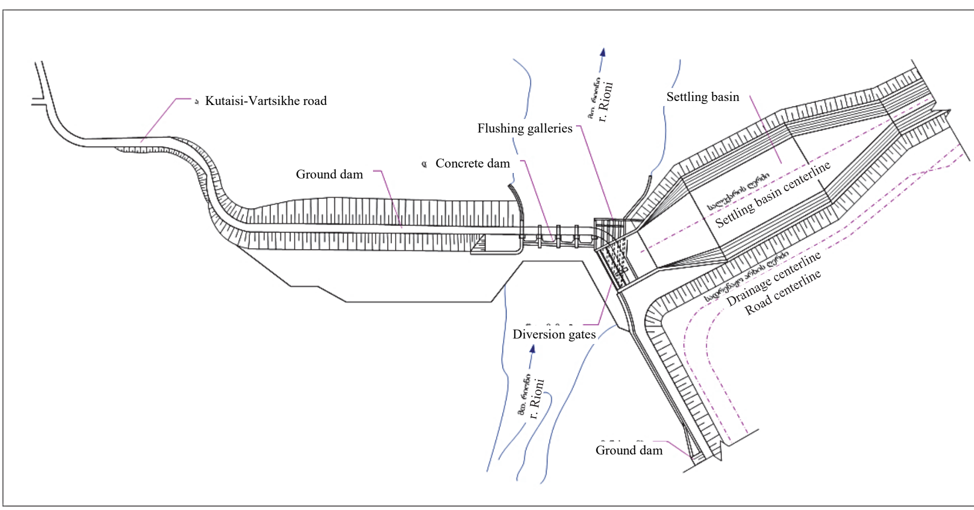



*Fig. 2. Scheme of Vartsikhe HPP cascade dam and headworks [3].*

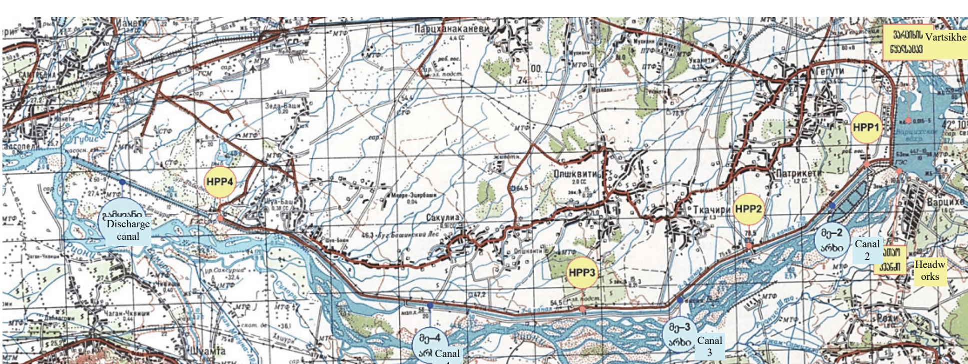



*Fig. 3. Vartsikhe HPP cascade layout depicted on a topographic map [3].*

Vartsikhe-1 was put into operation in 1976, Vartsikhe-2 in 1978, Vartsikhe-3 in 1980, and the construction of the last Vartsikhe-4 HPP started in 1982 and was put into operation in 1987. HPPs are diversion type hydropower plants of identical capacity and output, located on a single diversion canal with a designed water flow rate of 350 $m^3/s$. The total installed capacity of the cascade is 184 MW: each HPP is equipped with a pair of vertical turbines with a total rated capacity of 46 (2 x 23) MW. Each HPP with two hydraulic units is located on the diversion channel with a design head/pressure of 15 m. All cascade HPPs are located on the 27 km diversion canal section along the right bank of the Rioni River.

**Global Earth Observations characterising r. Rioni and its sturgeon habitat**

In this section, several examples of practical utilisation of Global Earth Observations (see e.g. https://earthobservations.org and search for data sources at https://geoportal.org) are applied to characterise river Rioni and its critical habitats both in terms of site condition assessment, water quantity and quality, as well as physical characterisation, such as water/land surface temperatures.

**Flushing.** Per HPP management (personal communication), headworks are opened and sediments are flushed downstream every year and sometimes twice a year. Such an event, which took place on the Vartsikhe HPP reservoir on September 8-10, 2016 is illustrated with a Landsat-8 satellite image, emptied during the flushing of the Vartsikhe Reservoir, as shown in

Fig. *4*.

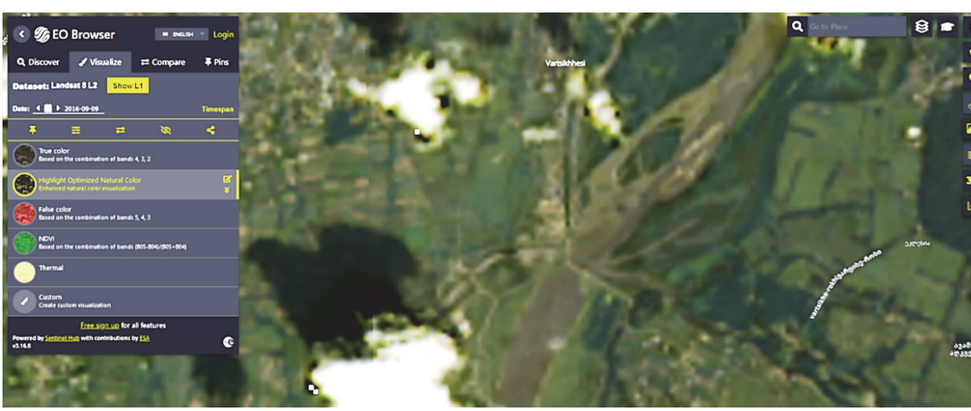
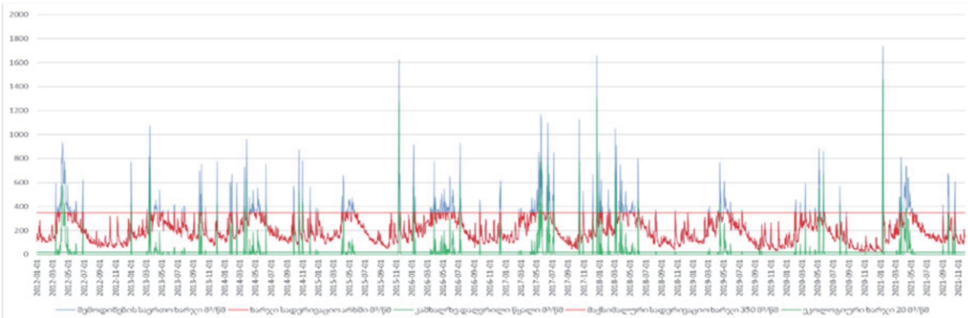


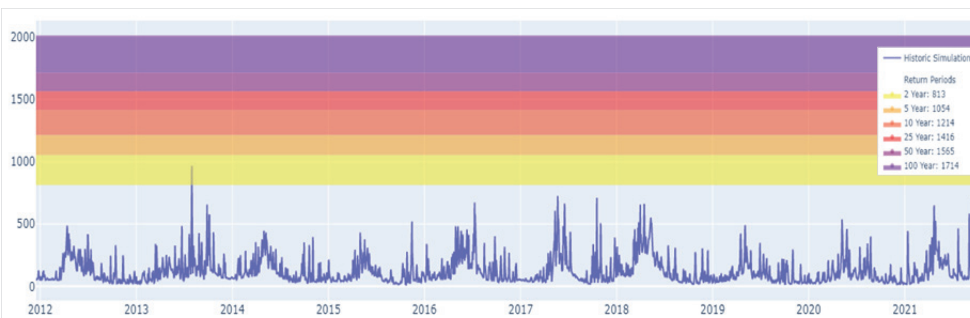

*Fig. 4. Vartsikhe Reservoir emptied during the flushing event of September 8-10, 2016. (Landsat-8, 2016-09-09, source https://sentinelshare.page.link/r1hw)*

**Discharge.** Hydrological daily time series data is necessary to establish critical operational and environmental functions in river catchments, including to characterise impacts of hydropower in terms of riverine data quantity and quality. With respect to the rivers, daily discharge is critical data to build the catchment models, including for the rivers in the Black Sea Catchment, and such methods were successfully applied, as described in references [4], [5], [6], others.

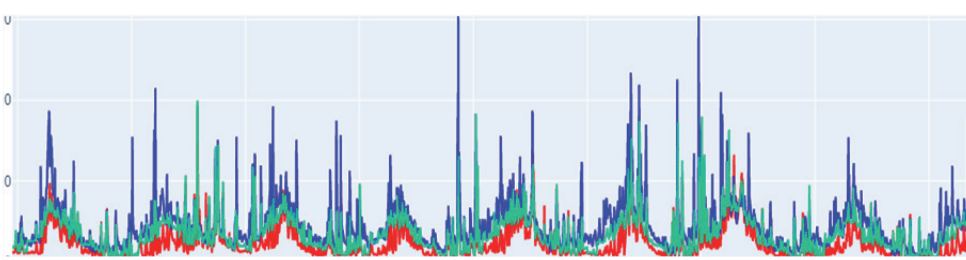
Bottleneck for catchment model calibration and validation indeed is the availability and/or quality of the *in situ* river discharge data. This data gap for r. Rioni can be filled by utilising the global streamflow data made available recently via Hydrologic Modeling as a Service (HMaaS) [7], delivered through the GEO Water Sustainability (GEOGloWS) Hydroviewer tool [8].



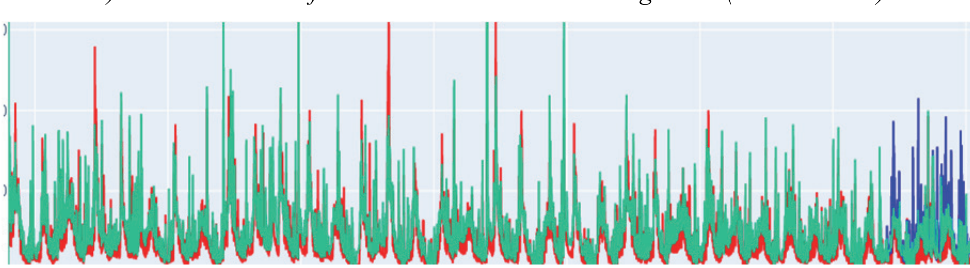
*a) In situ water discharge data at the dam. Source: Vartsikhe HPP Cascade Administration.*




*b) Ex situ water costs in the downstream of the dam. Source: Global Hydrological Model, https://apps.geoglows.org/apps/geoglows-hydroviewer [8], Rioni River, Reach # 601182.*



*c) Bias-correction of model with measured discharge data (same sources).*



*d) Rioni daily discharges per bias-corrected model data for the period 1979-2021.*

*Fig. 5. Hydrological time series of daily discharges of Rioni near Vartsikhe HPP dam.*

Bias-correction of the globally sourced data was performed by utilising excellent in-situ daily discharge data, provided by Vartsikhe HPP with respect to total inflows into and outflows from the Vartsikhe Reservoir. Data quality was indeed confirmed by clear correlation and satisfactory bias-correction achieved with the global model discharge data (Fig. 5 above), thus significantly expanding the availability of daily discharge time series from 10 years up to 40 years.

**Temperature.** Water temperature is another critical parameter for sturgeon spawning success, as confirmed and described in the r. Rioni sturgeon study conducted by FFI-Caucasus with EBRD support [9], visualising the strong impact of water temperature (and sedimentation) patterns from Rioni HPPs, in particular, the Vartsikhe Reservoir Dam operations, as well as annual flushing events on the ecology of floodplain habitats and the early life cycle of sturgeons.

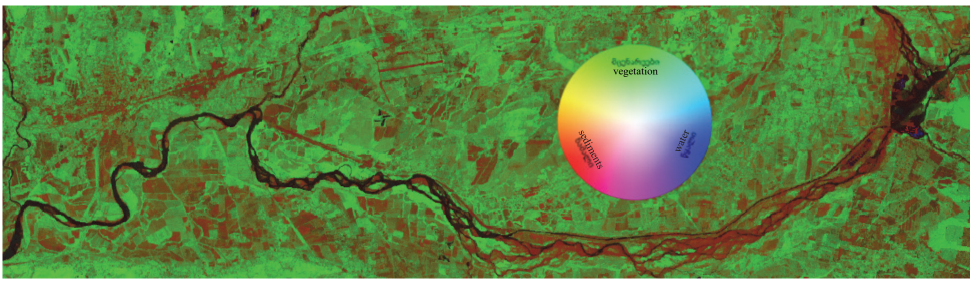
Maintaining the natural dynamics of sediment flows and water temperatures are important factors in mitigating the cumulative impact of the existing and planned HPPs in the basin and along the Rioni. The arguments indeed emphasised by the World Sturgeon Conservation Society (WSCS) in their appeal to Government of Georgia (see [10]) where, among other issues, the following types of impacts were highlighted in the case of large reservoirs versus viability of Rioni spawning habitats, quote: „a) the magnitude and timing of discharge the available habitats in the downstream sections and natural hydro-ecological processes, such as gravel turnover, sediment outwash etc.; b) the annual temperature cycle through deep water discharge from the reservoir; c) the disruption of the ecological flows of the river during the first phase of operation; d) the daily water level fluctuations (hydropeaking) which will affect both the habitats and the faunal elements inhabiting the river sections below the facility; e) the sediment transport into the lower river sections resulting in incision of the river into the landscape and the loss of its connection with its floodplain; f) the migration of the sturgeon species for reproduction; g) the effectiveness of reproduction due to the above-mentioned impacts; and h) the food base for young sturgeon during the early life phases."

According to the two sources above, the water temperature is particularly sensitive for the sturgeon. Below, as an example, is provided the measurement of land and water surface temperatures as sensed fortnightly via openly accessible satellite observations, including for the section of Rioni from Vartsikhe Reservoir to the spawning habitat area, as shown below (

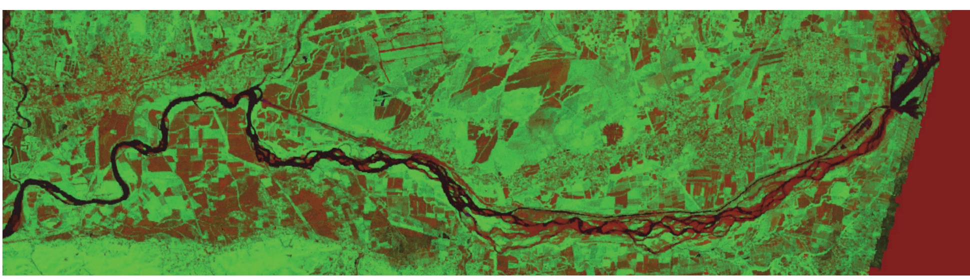
Fig. *6*). The observation period here (early April) roughly corresponds to sturgeon spawning period [9].


*Fig. 6. R. Rioni water surface temperature variabilities in the study area.*
*(Source: https://app.climateengine.com, land surface temperature, Landsat-8, 2017.04.12)*

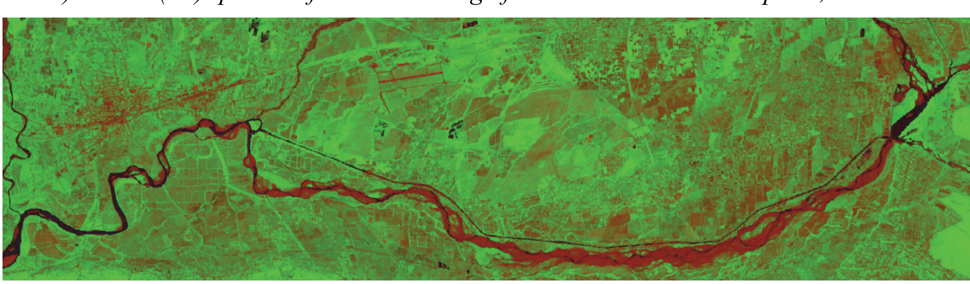
**Sedimentation** patterns in the riverbed and adjacent floodplain areas before and after the construction of the critical 4th stage of the Vartsikhe HPP Cascade, as a proxy for cumulative effects on downstream sturgeon habitats, can be confirmed by reanalysis of water, vegetation and soil cover conditions with satellite observations from 1984 to date, applying Georgian Data Cube (a pilot tool developed with UNEP-GRID support [11]), which clearly demonstrates the degradation of Rioni riverbed section just south of the derivation channel with respect to the spawning area downstream of 4th stage of the cascade after the diversion of the Rioni waters from the main riverbed to diversion canal of the cascade since after 1988 (Fig. 7).



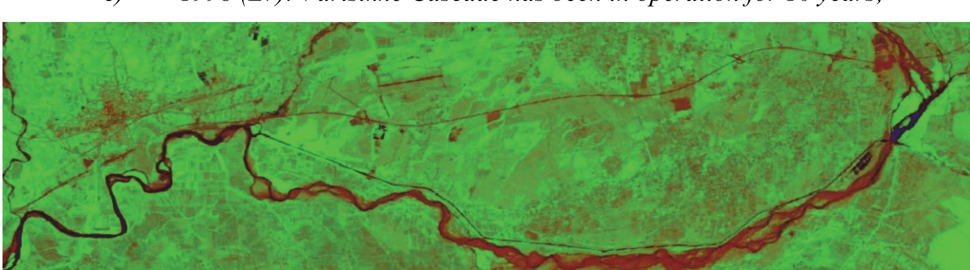

*a) 1985 (L5): Period before commissioning of the 4th HPP and checkpoint;*



*b) 1988 (L5): period of commissioning of the 4th HPP and checkpoint;*



*c) 1998 (L7): Vartsikhe Cascade has been in operation for 10 years;*



*d) 2015 (L8). (Note: L5, L7 and L8 mean Landsat 5, 7 and 8 satellites.)*

*Fig. 7. Degradation of Rioni habitats along the Vartsikhe cascade derivation section. (Source: http://geodatacube.unepgrid.ch urbanization tool, annual median pixel)*

## Conclusions

The results of the analysis are summarized below as the main conclusions of this paper:

- The Rioni is the last remaining sturgeon spawning river in Georgia and on the entire eastern side of the Black Sea, which makes this river a global hotspot of critical importance for the survival and conservation of sturgeon.

- Sturgeon and its juvenile lifecycle are heavily dependent on ecological characteristics of the riverine spawning habitats, such as water flow quantity (daily discharge rates) and water quality (sediments, nutrients, physical and biogeochemical parameters), sediment transport and deposition patterns, river water temperatures and other essential ecological variables.

- Increasingly available ex situ Global Earth Observation (GEO) datasets from various sources and of various types are capable of complementing in situ data via bias-correction and sometimes even supplementing in situ datasets, when not available or available but of poor quality.

- The GEO datasets tested in this communication were, specifically: (i) high frequency and medium resolution satellite observations (such as Landsat and Sentinel 2) to detect sediment flushing events; (ii) modelled river reach daily discharge rates extracted with GEOGloWS tool and bias-corrected with *in situ* data, thus significantly extending the time series with quality data; (iii) applying data cube tool to establish water, sediment and vegetation change patterns in space and time to characterise extent, degradation and/or restoration potential of sturgeon habitats; and to establish water temperature values and variability with 30 m spatial and fortnightly temporal resolution (cloud cover permitting).

- All above data sources, if complemented with other needed types of data, also available from global sources (such as provided in this reference source [12]) could provide for characterisation of the quantity and quality of water in the basin, by building the hydrologic model for upstream and downstream reaches of sturgeon habitat, till the confluence with the Black Sea.

- Data on daily discharge rates provided by Vartsikhe HPPs allowing to bias-correct the flow rates derived from global sources is extremely useful in this regard. It would be important to obtain data from other HPPs in the basin, especially with respect to historical daily discharges.

- Finally, data critical for the sturgeon life cycle (such as river flow rates, environmental and biological monitoring data, etc.), when collected by both governmental agencies and/or by non-governmental actors, including private entities, must be rendered available publicly to safeguard these critical natural resources and to provide for transparent governance.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