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Post-Construction, Hydromorphological Cumulative Impact Assessment: An Approach at the Waterbody Level Integrating Different Spatial Scales

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Abstract: The environmental impact assessment is a process required in many countries. It highlights future activities with a significant impact on the environment. Water, as an environmental factor, needs adequate methods for quantifying cumulative impact of hydrotechnical works. In most cases, for new developments, baseline data is collected before the beginning of the construction, but for waterworks already in place, a different approach is needed. In line with the EU Water Framework Directive (Directive 2000/60/EC), the overall purpose of the research is to develop an approach for the hydromorphological cumulative impact assessment integrating different spatial scales for existing water intakes with transversal barriers on mountain rivers in Romania. Being a research study developed for a specific issue—post-construction impact assessment, some innovative actions were required. Lack of information in the pre-construction phase was an important constraint. Customizing formulas of certain indicators established within the Romanian method for hydromorphological status assessment of rivers proved to be a practical solution to show both local and waterbody hydromorphological impact. Upscaling the impact from the local scale to the river sector and the waterbody allows awareness of the spatial extent of the impact and understanding of the importance of the thresholds of significant impact for a broader audience. In order to better highlight the approach, this paper shows practical examples. The whole chain of the drivers–pressures–state–impacts–responses (DPSIR) framework is applied in the case of two river water bodies with hydropower generation facilities in place. In addition, some recommendations for actions are provided.

Keywords: hydromorphological indicators; hierarchy of spatial scales; local impact; quantifying the impact

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1. Introduction

The essential change introduced by the Water Framework Directive (WFD) in Europe's water management is the management of the negative impact from an ecological point of view due to waterworks. The waterworks are regarded as hydromorphological "pressures" and may lead to changes in the structure and functioning of aquatic ecosystems (both abiotic and biotic elements of the Water Framework Directive) in multiple ways: modification of hydrological regimes (low flows); loss of lateral and longitudinal continuity of rivers, which affects the migration of aquatic organisms and sediment transport; changes in river water depth and width; changes in structure and substrate of the riverbed as well as modification of the riparian zone [1–4].

A better knowledge of the pressures (e.g., type and magnitude, cumulative effects) and their assessment as a part of sustainable river basin management could be a basis for designing appropriate restoration measures to reduce/mitigate these pressures [5].

The relationship between pressures, impact and the necessary measures that should be taken are put together in the well-known framework of the DPSIR (driver–pressure–

state–impact–response) concept. This concept was developed in the late 1990s by experts from the Organization for Economic Cooperation and Development (OECD) and the European Environmental Agency (EEA) as a framework for the analysis of the cause–effect relationships between environmental and human systems [6,7]. Today, the concept is widely applied by EU member states, being incorporated in the Water Framework Directive for the impact and cost-effectiveness analyses [8]. The DPSIR framework divides a given environmental issue into five components: diver, pressure, state, impact and response. For aquatic ecosystems, human activities (e.g., agriculture, industry, hydropower generation) are “driving forces” or “drivers” that may become “pressures” (like a direct effect of the driver) on the water’s “status” (physical, chemical and biological conditions) and therefore indicate a problem (an alteration) that translates as an “impact” in need of a “response”. The response should mitigate the impact or even eliminate it and consists of structural or non-structural measures, for example, a change in policy concerning a certain driving force for a specific issue (Figure 1).

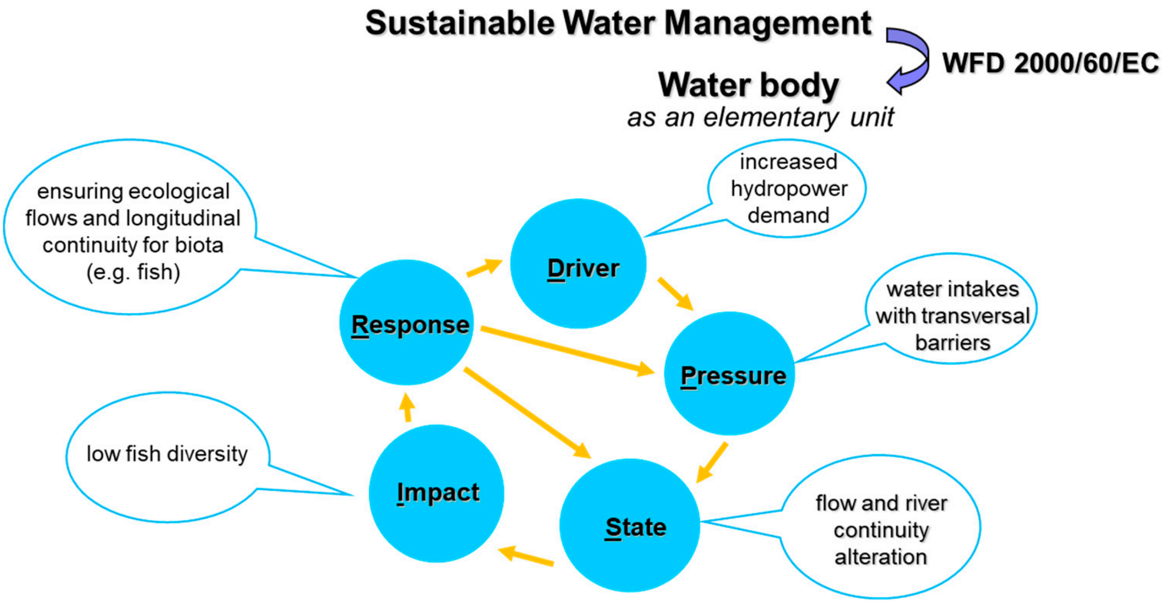

Figure 1. An illustration of the drivers–pressures–state–impacts–responses (DPSIR) analytical framework using as example hydrotechnical works.

The DPSIR framework has considerable potential to provide policymakers meaningful explanations of cause-and-effect relationships and to support the decision-making process [9]. DPSIR has often been criticized for focusing on the causal chain, one-to-one relationships, rather than addressing complex interactions between multiple pressures, activities, the environment and society [10–12]. Another criticism is a non-standardized use of terms, as the use of the five components is wide-open to interpretation, [13] therefore being difficult to compare between different studies, even if they are similar [14]. For example, the term “pressure” is commonly replaced by “activity” or “driving force” and vice versa [13]. Similarly, state change and impact are both commonly used in the context of impacts on the environment [15] whereas impact also commonly refers to the impact on society due to the state change of the environment [12].

Sometimes it is difficult to make a difference between the results of the status assessment and the impact assessment, as the pressures’ effects are often combined. As many of the impacts are difficult to measure, the status is often used as an indicator of the impact [16] (pp. 13–14). As the pressures often act simultaneously within a river basin [17,18] and for a long time, it becomes more difficult to assess the impact. The lack of baseline data and information (reference conditions) are mentioned as a constraint for the impact assessment [19].

While the knowledge base on multiple pressures is developing, there still remains a challenge for water managers to use this information to establish a practical "pressures-hierarchy", which can be helpful in deciding which pressure is the most important and has to be tackled first, or when it is necessary to tackle multiple pressures simultaneously [20].

Usually, the highlighted impact generated by the water intake works with transversal barriers (e.g., for drinking water supply, energy production) is limited to the interruption of longitudinal connectivity for fish fauna and the decreased flow on a river sector. However, the whole range of alteration is much broader, from physical alteration of the aquatic habitats upstream of the barrier [21–24] to river morphology and sediment regime modification due to low flows downstream of the barrier [25] and alteration of riparian vegetation [26–28].

Although the impact assessment of the pressures is stated in Article 5 of the Water Framework Directive and general guidelines have been developed by the European Commission, there is currently no single tool capable of performing a complete pressure and impacts analysis for all types of water bodies [16] (p. 51). The guidelines emphasize that the impact assessment should use, for example, information about the existing pressures (pressure inventories), monitoring data (field survey), numerical tools (e.g., modelling), expert judgement or a combination of these [29] (p. 36).

In Romania, recent legislation requires waterbody impact assessment (including the cumulative impact) for future projects. It underlines the need to identify the time and spatial scale of the impact occurrence and if the impacts occur as a direct result of an activity or changes in other quality elements (indirect impact). No specifications on assessing and quantifying the impact is provided, and the practitioners who carry out the waterbody impact assessment cannot rely on only the "expert judgement".

As the Water Framework Directive defines the waterbody as the elementary unit for water management, an approach involving a hierarchy of spatial scales (e.g., river section, river sector) could be helpful in highlighting and explaining the impact on both local and waterbody level.

Moreover, an approach for quantifying hydromorphological cumulative impact for a particular existing pressure (e.g., transversal barriers related to small hydropower plants in the operation phase) is needed at the waterbody level, especially when limited information about the situation before the pressure is available.

The original contributions of the paper are clarifying and refining the approach for hydromorphological cumulative impact assessment at the waterbody level, integrating different spatial scales for waterworks in place on mountain rivers in the context of previous research [30].

The following issues are addressed: defining an approach for cumulative hydromorphological impact assessment based on DPSIR analytical framework; quantifying the hydromorphological local impact due to the water intakes and transversal barriers; quantifying the spatial extension of hydromorphological cumulative impact (upscaling from local to waterbody level) in case of already predefined river water bodies; quantifying the hydromorphological impact of waterworks in place when no specific measurements of hydromorphological parameters before construction are available.

In addition, some recommendations are provided as responses/actions to mitigating the hydromorphological cumulative impact.

2. Materials and Methods

The research was carried out within a complex study that aimed to assess the impact of 17 small hydropower plants (in operation on the ecological status of 14 river water bodies and the conservation status of species and natural habitats of community interest in the potentially affected natural protected areas [30]). The research was conducted over a short period of time and was a specific requirement of the Romanian Ministry of Environment, Water and Forests referring to the impact assessment on the environment of the construction and operation of the waterworks dedicated to the exploitation of the hydropower potential through small hydropower plants.

The hydromorphological cumulative impact assessment was performed based on the principles of the Romanian method of hydromorphological status assessment—methodology for the hydromorphological assessment of Romanian rivers [31–33]—which is in line with the Water Framework Directive and part of the Romanian River Basin Management Plan. Formulas of certain hydromorphological indicators were customized (for details please see Section 2.4) for the specific requirement of the above-mentioned research in order to capture the hydromorphological local impact and upscaling it to waterbody level in the context of scarce general information available before construction.

For the purpose of this paper, two river water bodies were selected as examples. Each of them comprises one main river and its tributary, with water intakes for energy production (small hydropower plants) being the main pressure for biota, particularly fish (according to other studies, e.g., [34–36]). This serves to highlight the applicability of the cumulative impact assessment approach.

2.1. The Case Studies

The two river water bodies located within the central part of Romania, at high altitudes in the Fagaras Mountains (Southern Carpathians), are the first water bodies designated for the Arges and Targului rivers, from their headwaters to the Vidraru Reservoir (on the Arges River) and, respectively, the Rausor Reservoir (on the Targului River) (Figure 2).

The Capra River and its tributary (the Modrugazu River), cover a drainage area of about 81.4 km^2, with an elevation ranging from 899 to 2140 m and a high mean slope (>80 ‰) [37]. With a drainage area of about 65.2 km^2, the Targului River and the Batrana River (Waterbody 2) have headwaters at over 1900 m altitude and a high mean slope of about 177 ‰. The climatic regime is temperate-continental alpine, with short and cool summers and long, cold, snowy winters [23]. The average multiannual (1960–1990) rainfall, within the drainage area of Waterbody 1 is between 37 and 152 mm, with higher values in May (125 mm), June (133 mm) and July (122 mm); slightly higher values were recorded for the second waterbody, between 41 and 149 mm, peaking in May (111 mm), June (135 mm) and July (127 mm) [38].

According to the updated National Management Plan (2021) the two water bodies, namely Argeş: headwater—Vidraru Reservoir and tributaries—Waterbody 1 and Râul Târgului: headwater—Râuşor Reservoir and tributaries—Waterbody 2 belong to a high land river typology (Romanian river typology code: RO 01), with a substrate consisting mostly of rocks, boulders and gravel and providing habitat for a specific potential aquatic fauna, with the Brown Trout (*Salmo trutta*) as dominant fish species. The study areas are located entirely within natural protected areas (sites of community importance), as part of the European Natura 2000 network.

The main anthropic activity within the study area is represented by hydropower generation through small hydropower plants (SHPs). Two field monitoring campaigns were carried out in June and August of 2019, during heavy rainfall. The campaigns were important bearing in mind the lack of information, mainly before the construction of SHPs. A specific procedure for survey has been developed. The data were used as input for hydromorphological cumulative impact assessment.

2.2. The Survey Approach

The survey activity aimed at:

- Measurements of some parameters that are the basis for the hydromorphological assessment and also for the local and waterbody cumulative impact assessment;
- Identification of all hydromorphological pressures and the activities that can generate such pressures (e.g., transversal structures, water intakes);
- Filling in the gaps of data before construction by current measurements in the upstream section conventionally unaltered.

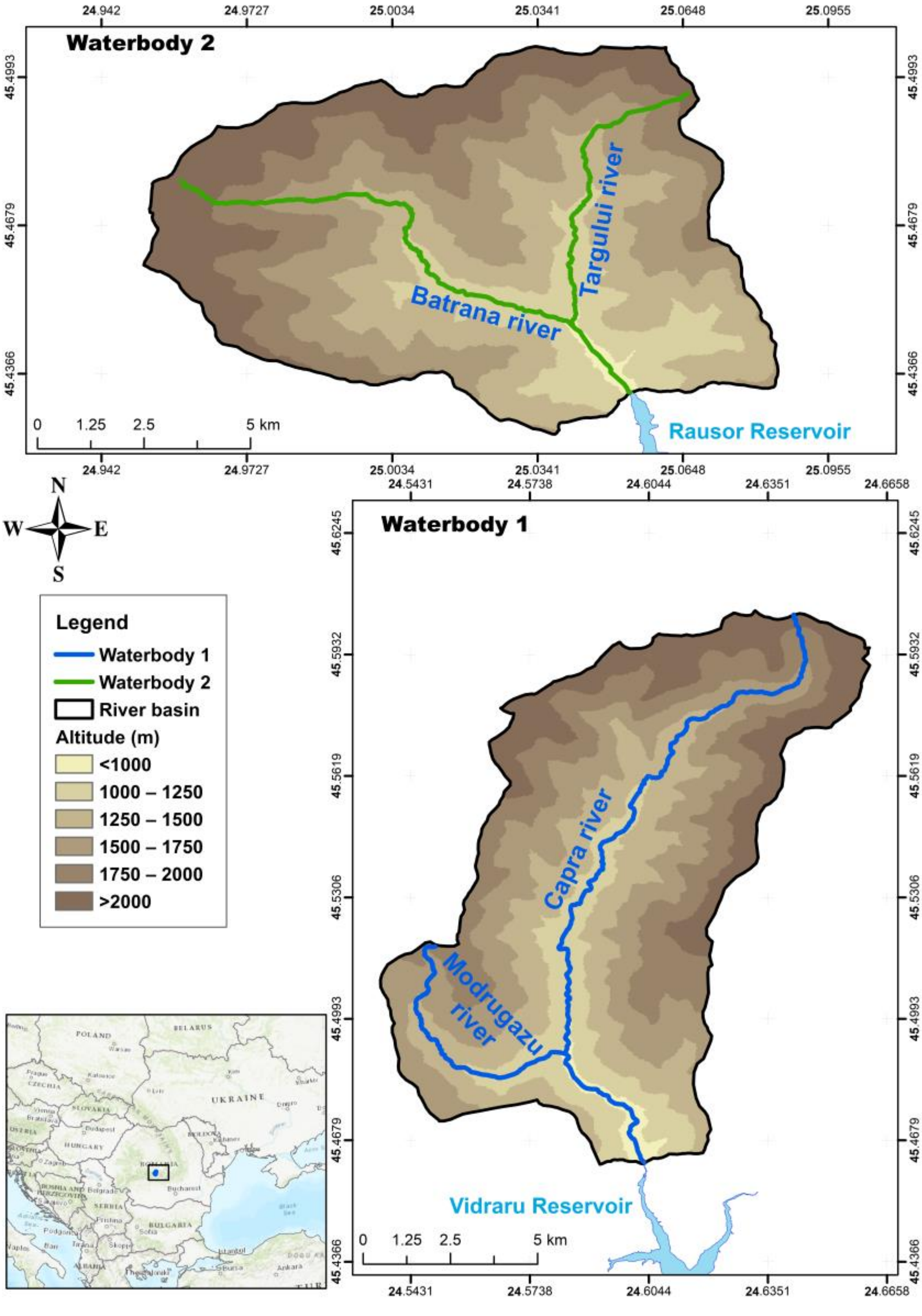

Figure 2. The location of the study areas in Romania.

As the impact should be assessed at different spatial scales in order to be quantified at the waterbody level, the monitoring focused on two levels of analysis: river section (within river unit) and river sector (Figure 3). The length of the river unit was 100 m along the river. A characteristic cross-section (river section) was established along the river unit for the morphometric measurements (water depth, the width of the river channel at the current water level). The location of the characteristic cross-section (upstream and downstream) was established at a certain distance from each water intake so that the results of the measurements capture the specific characteristics of a lotic ecosystem, especially upstream where the river looks like a small lake due to the impoundment/transversal barrier related to the water intake. Usually, the river sector is between the water intake and the restitution point (Figure 3—Waterbody 2). In case of a succession of water intakes (e.g., small hydropower plants operating in cascade), the river sector is from the first water intake to the restitution point of the last water intake (Figure 3—Waterbody 1). The results of the measurements and visual survey were collected on a predefined field protocol. In order to avoid subjectivism, the field activity was carried out by the same experts in both field campaigns.

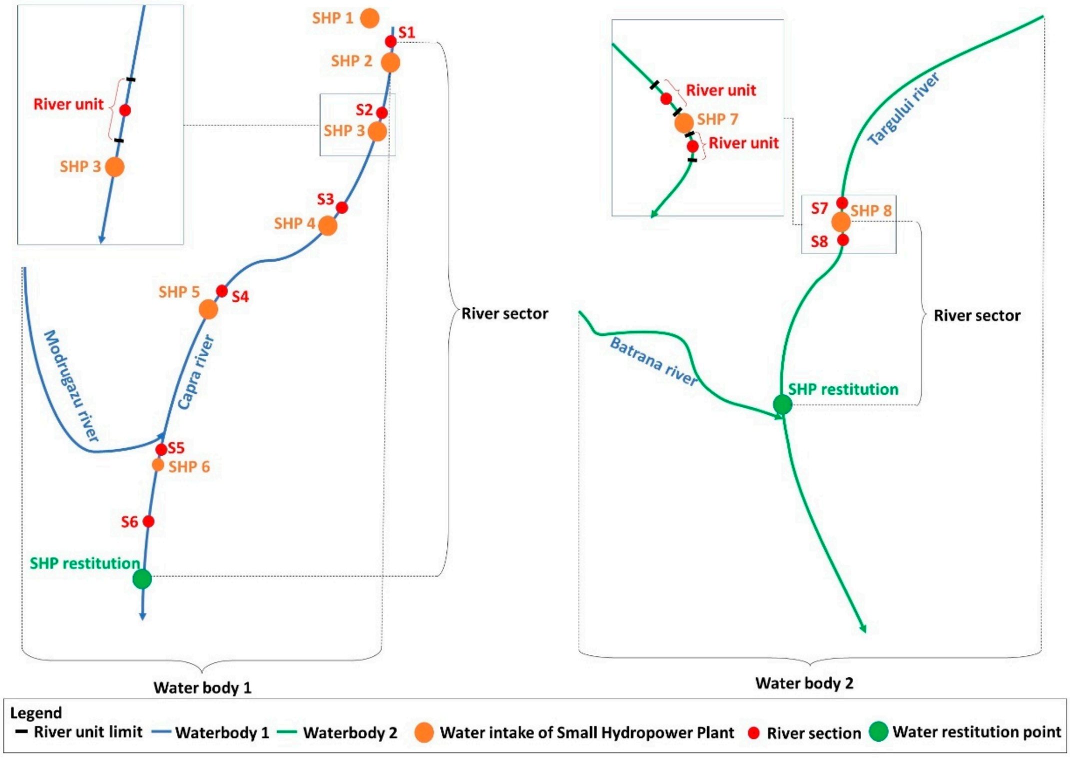

Figure 3. The schematic representation of the river unit, characteristic river cross-sections and the river sector for hydromorphological measurements in the case of the analyzed water bodies.

In addition, a visual overall survey was performed at the waterbody level.

As there are no information/measurements available before the construction and operation of the SHPs in the analyzed water bodies, we have assumed that the upstream section is conventionally unaltered.

Therefore, the aim of the upstream section is to allow a comparison of the downstream conditions (modified) to the upstream conditions (natural or quasi-natural condition). In case of small hydropower plants operating in cascade (e.g., the water intakes on the Capra River) the downstream section of the first abstraction point became the upstream section for the second abstraction point and so on until the last water abstraction.

The equipment needed for the field survey includes maps with the location of the water intakes with transversal barriers, security equipment, a camera, OTT C31 Universal Current Meter for discharge measurements, IMH 2 current meter.

To ensure the objectivity of the monitoring results all the necessary operations for determining the river bed geometry are done taking into account the national guidance harmonized with the recommendations of the World Meteorological Organization (WMO-No. 1044:2010, Manual on Stream Gauging, vol. I, Fieldwork; WMO-No. 168:2008, Guide to Hydrological Practices, vol. I, Hydrology—From Measurement to Hydrological Information; ISO 748:2007, Hydrometry—Measurement of Liquid Flow in Open Channels using Current-Meters or Floats).

2.3. Hydromorphological Data

The collected/measured hydro-morphological data are data related to the hydro-morphological pressures and the values of the measured/computed hydrological and morphometric parameters (Table 1).

Table 1. The type and the sources of collected data.

Data Type	Scale	Source	Description
Hydrological	Local	NIHWM database	The multiannual average natural flow computed within a cross section at the end of the waterbody (2 values) and also in case of each SHP (7 values).
	Local (river section)	NARW	The values of abstracted flow in case of each SHP.
Transversal barriers	Local, waterbody	NARW, field monitoring campaigns	The height of barrier, the number of barriers/km of river length.
Water depth	Local (characteristic cross-section)	Field monitoring campaigns	Measurements according to the national instructions harmonized with the recommendations of the World Meteorological Organization
Water width	Local (characteristic cross-section)	Field monitoring campaigns	

The type of hydromorphological pressures used within the paper are the water intakes related to SHPs and the transversal structures that interrupt the longitudinal continuity of the river.

In case of water intakes, the following hydrological parameters were used: the average abstracted flow, the multiannual average natural flow (computed in the case of each water intake and also at the end of the waterbody). The morphometric parameters measured in the upstream and downstream cross-sections are the water depth and width.

The monthly average of abstracted flow and monthly average of returned flow in case of all SHPs was provided by the National Administration "Romanian Waters" (NARW) for 2019 [30]. Based on daily mean flows extracted from the National Institute of Hydrology and Water Management (NIHWM) database, the multiannual average natural flow was computed for all recorded data. Moreover, the multiannual average natural flow was computed in case of each abstraction point of the SHPs.

2.4. Hydromorphological Cumulative Impact Assessment Approach

The hydromorphological cumulative impact assessment approach took into account the types of pressures, including water intakes with transversal barriers, and the related hydromorphological conditions/parameters possibly affected by these pressures. The approach is in line with the Water Framework Directive's (WFD) aim: to maintain or achieve good ecological status/good ecological potential for all surface water bodies and non-deterioration of the ecological status/ecological potential.

The hydromorphological impact assessment was based on the results of the monitoring activity (post-construction) and relied on the principles of the Romanian hydromorphological status assessment [16–18]. The main principle is to assess the anthropogenic alterations to the values of the hydromorphological elements from those under undisturbed conditions. As the hydromorphological assessment methodology classifies the severity of the anthropogenic alterations into five classes and it is known to be difficult to distinguish among the results of status assessment and the impact (see Figure 1), it can be emphasized that the hydromorphological assessment can mainly provide an impact assessment.

Taking into account the overall purpose of the research required by Romanian central national water authority, the type of hydromorphological pressures identified during the two field monitoring campaigns and the related impacts cited by the literature (e.g., the alteration of longitudinal connectivity, the decrease of the flow, the alteration of morphological conditions), the indicators that allow analysis of flow, longitudinal continuity and variation in river depth and width have been selected out of the Romanian hydro-morphological status assessment methodology and further customized to assess the impact at different scales. Some indicators (noted $I1_{wb}$ and $I2_{wb}$ in Table 2) were used to assess the water status at waterbody scale, such as in the status assessment methodology, and the other indicators were customized to assess local and cumulative impact. Table 2 presents the formulas/criteria for assessing the hydromorphological status and the hydromorphological local and cumulative impact, the scale of application and the classification system.

Table 2. The hydromorphological indicators used for the status assessment and cumulative hydromorphological impact assessment.

Indicator (Description)	Formula/Criteria	5 Class System According to Methodology for Hydromorphological Assessment of Romanian Rivers					Scale of Application
		Class I	Class II	Class III	Class IV	Class V	
$I1_l$ Average consumed flow (Identifies a potential local flow modification)	$\frac{Q_{mean\ abstracted}}{Q_{natural\ or\ renaturalized\ multiannualmean}} * 100$ $Q_{mean\ abstracted}$—mean abstracted flow by each water use averaged over 1 year $Q_{natural\ or\ renaturalized\ multiannual\ mean}$—multiannual average natural or renaturalized discharge averaged for all data recorded computed in the case of each water use in the water intake cross-section	≤10%	11–30%	31–50%	51–70%	≥71%	Local (l)
$I1_{wb}$ Average consumed flow (Identifies a water deficit at waterbody level)	$\frac{\sum_{i=1}^{j} Q_{mean\ abstracted} - \sum_{i=1}^{k} Q_{mean\ return}}{Q_{natural\ or\ renaturalized\ multiannualmean}} * 100$ $Q_{natural\ multiannual\ mean}$—multiannual average natural discharge averaged for all data recorded computed at the end cross-section of the waterbody; Q_{mean_return} = mean return flows averaged over 1 year; j = number of water intakes; k = number of users which return flows						Waterbody (wb)
$I2_{wb}$ Longitudinal continuity/connectivity of the riverbed [2] (Indirectly assesses the impact of transversal structures on the mobility of fish species)	The maximum height of the barriers	≤50 cm		50–70 cm	71–200 cm	>200 cm	Waterbody (wb)
$I3_l$ Mean water depth variation (based on the data collected during monitoring campaigns within the characteristic, upstream and downstream, cross-sections for all water intakes)	$\frac{h_m^{ds} - h_m^{us}}{h_m^{us}} * 100$ h_m^{ds}—mean water depth measured downstream (current conditions); h_m^{us} —mean water depth measured upstream (reference conditions/natural or quasi-natural condition conventionally unaltered).	<20%	21–40%	41–60%	61–80%	≥81%	Local (l)
$I3_{wb}$ Mean water depth variation (based on the arithmetic average of the mean water depths measured within the characteristic, upstream and downstream, cross-sections for all water intakes)	$\frac{h_m^{ds} - h_m^{us}}{h_m^{us}} * 100$ h_m^{ds}—mean water depth measured downstream (current conditions) [1]; h_m^{us} —mean water depth measured upstream (reference conditions/natural or quasi-natural condition conventionally unaltered) [1].	<20%	21–40%	41–60%	61–80%	≥81%	Waterbody (wb)

Table 2. *Cont.*

Indicator (Description)	Formula/Criteria	5 Class System According to Methodology for Hydromorphological Assessment of Romanian Rivers					Scale of Application
		Class I	Class II	Class III	Class IV	Class V	
$I4_l$ Water width variation (based on the data collected during monitoring campaigns within the characteristic, upstream and downstream, cross-sections for all water intakes)	$\frac{b_m^{ds}-b_m^{us}}{h_m^{us}} * 100$ b_m^{ds}—water width measured downstream (current conditions); b_m^{us}—water width measured upstream (reference conditions/natural or quasi-natural conventionally unaltered).	<20%	21–40%	41–60%	61–80%	≥81%	Local (l)
$I4_{wb}$ Water width variation (based on the arithmetic average of the water widths measured within the characteristic cross-sections (upstream and downstream) for all water intakes with artificial barriers)	$\frac{b_m^{ds}-b_m^{us}}{h_m^{us}} * 100$ b_m^{ds}—water width measured downstream (current conditions) [1]; b_m^{us}—water width measured upstream (reference conditions/natural or quasi-natural conventionally unaltered) [1].	<20%	21–40%	41–60%	61–80%	≥81%	Waterbody (wb)

Notes: [1] in case of the assessment at the waterbody level, the values of the two campaigns have been averaged. [2] the threshold values are specific for salmonids zone.

The thresholds values among the classes in the case of all hydromorphological indicators listed within the Table 2 are the same as within the Methodology for hydromorphological assessment of Romanian rivers [31–33]. Apart from the indicators $I1_{wb}$ and $I2_{wb}$, used as in the Methodology, in case of the indicators $I1_l$, $I3_l$, $I3_{wb}$, $I4_l$, $I4_{wb}$, the formulas were customized taking into account the challenges for hydromorphological impact assessment at different spatial scales and lack of data to perform cumulative impact assessment post-construction. The indicator I1wb reflects the water deficit at the waterbody level but it cannot identify the river sectors with potential local flow modification within the waterbody. Therefore, indicator $I1_l$ was derived from indicator $I1_{wb}$ to capture the local impact due to the water intakes. The original formulas used to assess variation in river depth and width are the relative error or deviation from natural or undisturbed conditions of the mean water depth and width corresponding to multiannual mean discharge averaged over the last six years of the WFD cycle. The original formulas were intended for use on rivers with historical measurements. Since specific measurements of hydromorphological parameters before construction of small hydropower plants (SHPs) were not available, the original formulas were customized to meet the objectives of the study using data collected during monitoring campaigns. Therefore, indicators $I3_l$, $I3_{wb}$, $I4_l$ and $I4_{wb}$ were derived using these data (See Table 2 for details).

The cumulative impact assessment was carried out starting from local impact upscaling to river sector and river waterbody (Figure 4).

The Romanian Water Law (No. 107/1996 with subsequent amendments and additions) mentions that the impact is significant if it leads to deterioration or compromising the achievement of good ecological status assessed at waterbody level, meaning class II within Table 2. The classification system showed in Table 2 is related to the 5 WFD status classes. It was assumed that, at local level, class I and II within Table 2 mean No impact.

Four classes of the impact significance have been established at waterbody level: low, moderate, significant and no impact. At local level, the impact is either significant or there is so impact. The approach for gathering the information from the local to river sector and waterbody level taking into account the specific hydromorphological features relevant for each level and the establishment of the significance of the impact is shown below.

2.4.1. River Section (Local Level)

Water flow alteration together with morphological conditions expressed by current water depth and river width and flow were considered as relevant hydromorphological features at local level. Establishing the significance of the impact at the river section (local) level is the first step for the impact assessment of the water intakes with structural barriers. The following approach was used: the river section is considered to be significantly affected (a significant local impact) if the hydromorphological indicators listed within Table 2 ($I1_l$, $I3_l$, $I4_l$) are classified as having moderate (class III), poor (class IV) or bad (class V) status. If the indicators classify in classes I (high status) or II (good status) it was considered to be no impact, as the environmental objective is achieved (class II).

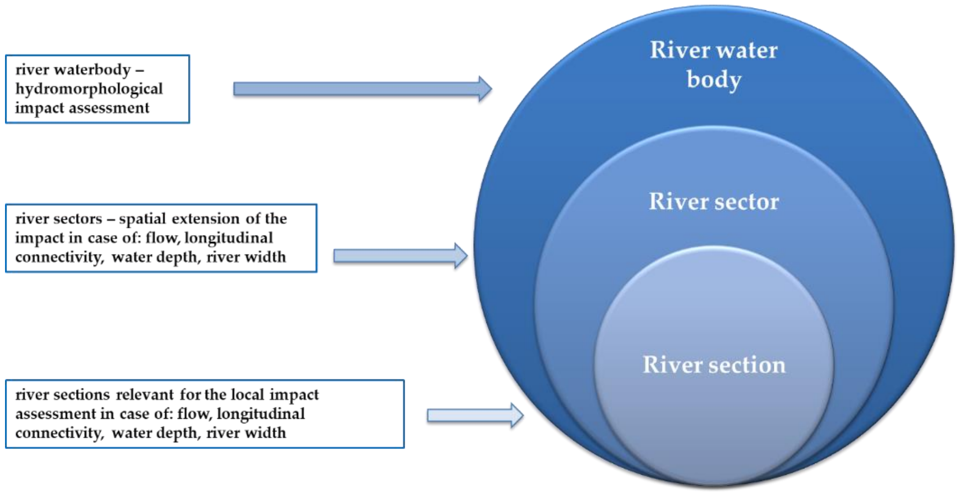

Figure 4. The levels of hydromorphological cumulative impact assessment—schematic representation.

The significance of the impact for longitudinal connectivity was assessed considering that each barrier generates a significant local impact.

2.4.2. River Sector Level

In order to establish the significance of the impact at the river sector level (spatial extension of the impact), it was considered that the significative hydromorphological impact at the section level (classes III, IV and V) is the same for the river sector associated to that section (the sector between the abstraction point and restitution point).

Related to longitudinal connectivity, the river sectors with interrupted connectivity were considered between first barrier and the headwaters, which may overlap the waterbody level in some cases.

2.4.3. Waterbody Level

A matrix (Table 3) was used to assess the hydromorphological cumulative impact. It takes into account both the local impact and the spatial extension of the impact. Conventionally, it is considered that if a significant impact on a local scale exceeds 20% of the total length of the waterbody, the impact is significant at body level.

Table 3. The matrix for establishing the impact significance at the waterbody level based on the spatial extension of the impact.

Significance of the Hydromorphological Impact at Local Scale	Spatial Extension of the Impact (Waterbody Scale)		
	<5%	5–20%	>20%
Significant	Low	Moderate	Significant
No impact	No impact	No impact	No impact

The significance of the impact at the waterbody level is established by summing the length of the river sectors for which the results of the indicators $I1_l$, $I3_l$, $I4_l$ classify in classes III, IV or V and by summing the river sectors with interrupted connectivity; the total length of the river sectors is divided to the length of the waterbody and expressed as a percentage. The spatial extension of the impact from local to waterbody scale (Table 2) was assessed based on the following assumptions:

- If the significant impact at local/river sector is affecting less than 5% of the total length of the waterbody, the impact is low at waterbody level and with no risk of deterioration or compromising the achievement of environmental objectives;
- If the significant impact at local/river sector is between 5 and 20% of the total length of the waterbody, the impact is moderate at waterbody level but with no risk of deterioration or compromising the achievement of environmental objectives;
- If the significant impact at local/river sector represents more than 20% of the length of the waterbody, it could lead to the deterioration of the condition of the entire waterbody and therefore to the registration of a significant impact at the level of the waterbody. Based on the precautionary principle, it was considered that the value of 20% is a precautionary one, allowing a better identification of the impact at waterbody level.

3. Results

An approach to assessing the cumulative hydromorphological impact based on the Driver–pressure–state–impact–response analytical framework has been developed for a particular case—post-construction of hydrotechnical works—by identifying the drivers and the pressures during field monitoring campaigns using a specific survey approach; assessing the cumulative hydromorphological impact considering the difficulty in making a difference between the results of state assessment and the impact as effect and providing recommendations for appropriate response in order to mitigate the hydromorphological cumulative impact. A hydromorphological cumulative impact assessment approach derived for the WFD water management unit by customizing some already available formulas is shown (see Section 2.4). This approach clarifies the way of calculus for the hydromorphological indicators taking into account the limited information available about the pre-construction situation. Moreover, certain assumptions for spatial extension of the impact from local to waterbody scale have been made. The approach to and results of the hydromorphological cumulative impact assessment are distinctively shown in Figure 5, which is the core of the paper. The following sub-chapters present the results of applying this cumulative approach to the two water bodies.

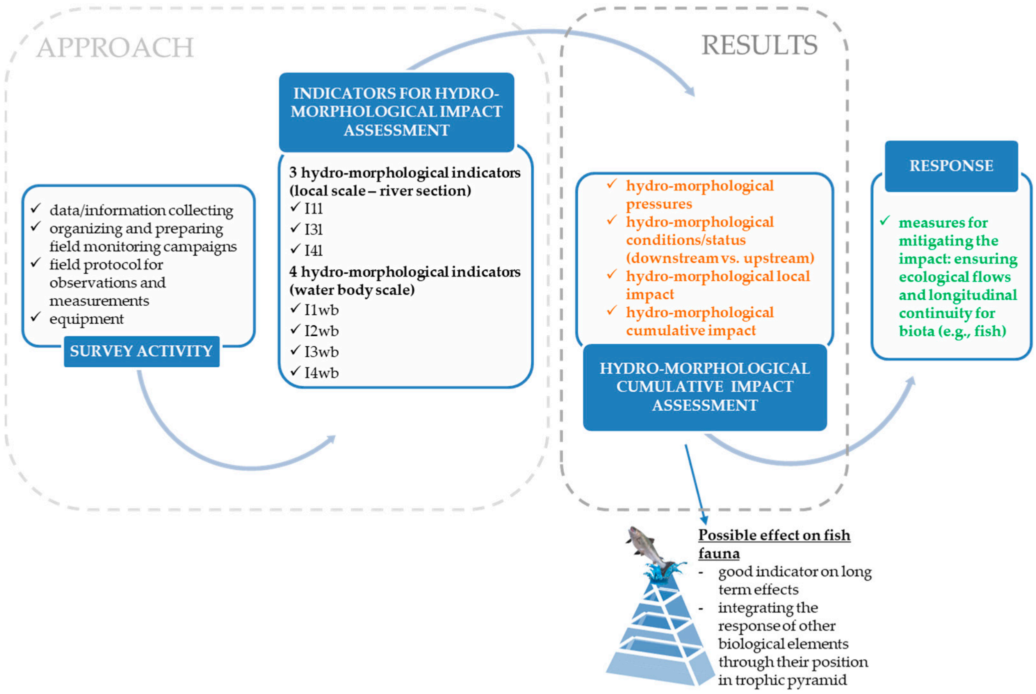

Figure 5. Diagram for the process of the cumulative hydromorphological impact assessment approach following the DPSIR analytical framework—waterworks in place.

The Results of the Survey Approach and the Hydro-Morphological Cumulative Impact Assessment

During the field campaigns, hydromorphological pressures were identified, such as the water abstraction for hydropower generation and the presence of related barriers, as well as other barriers. Three transversal structures not related to SHP with a height of about 2 and 8 m were identified on the Capra River and the Modrugazu River (Table 4 and Figure 6). Moreover, several natural barriers with heights 0.25–1.1 m were identified between SHP2 and SHP4. In the case of the Targului River and the Batrana River 18 and, respectively, 21 transversal structures (sediment weirs) with heights 0.5–3.5 m were identified.

Table 4. Transversal artificial and natural barriers within the study areas.

No.	River	Barriers (Transversal Structures and Natural Barriers)	Barriers Height (m)	Fish Aids	Flow Direction
		Waterbody 1			
1	Capra	Culvert	2	No	
2	Capra	SHP 2	1.45	Yes	
-	Capra	Natural barrier	0.4	-	
-	Capra	Natural barrier	1.1	-	
5	Capra	SHP 3	1.45	Yes	
-	Capra	Natural barrier	0.25	-	
6	Capra	SHP 4	1.45	Yes	
7	Capra	Sediment Weir	8	No	
8	Capra	SHP 5	1.45	Yes	
9	Capra	SHP 6	1.45	Yes	
1	Modrugazu	Sediment Weir	8	No	
		Waterbody 2			
1,2	Targului	Sediment Weir	2.5	No	
3, 5–8	Targului	Sediment Weir	3.5	No	
4	Targului	SHP 8	1.45	Yes	
9–18	Targului	Sediment Weir	0.5	No	
1–4	Batrana	Sediment Weir	1.2	No	
5, 9–10	Batrana	Sediment Weir	1.0	No	
6	Batrana	Sediment Weir	2.0	No	
7	Batrana	Sediment Weir	1.7	No	
8, 11, 13–16	Batrana	Sediment Weir	1.5	No	
12, 17	Batrana	Sediment Weir	1.1	No	
18, 20	Batrana	Sediment Weir	1.7	No	
19	Batrana	Sediment Weir	1.6	No	
21	Batrana	Sediment Weir	0.5	No	

All the barriers related to SHPs are equipped with fish aids except in case of SHP1 where the water abstraction is made by using a siphon inlet.

The results of indicator $I1_{l,}$ and for comparison those of indicator I1wb (the original indicator) are shown in Table 5.

In case of Waterbody 1, the mean abstracted flow ranged from 0.028 to 1.61 m^3/s, always equal to the returned flow after passing through turbines; the multiannual average natural flow at abstraction point ranged from 0.068 to 2.36 m^3/s. The results of applying indicator $I1_l$ showed moderate status (Class III) in case of SHP1 and SHP2 and poor status (Class IV) for the other SHPs. The mean abstracted flow and the mean returned flow of SHP8 located on Waterbody 2 was 0.36 m^3/s and the results of applying indicator $I1_l$ indicated poor status (Class IV). The assessment of the waterbody level ($I1_{wb}$) by taking into account the multiannual average natural flow (computed at the end of the water bodies) indicated high status (Class I) in both cases, as all the abstracted flow was returned within the same waterbody.

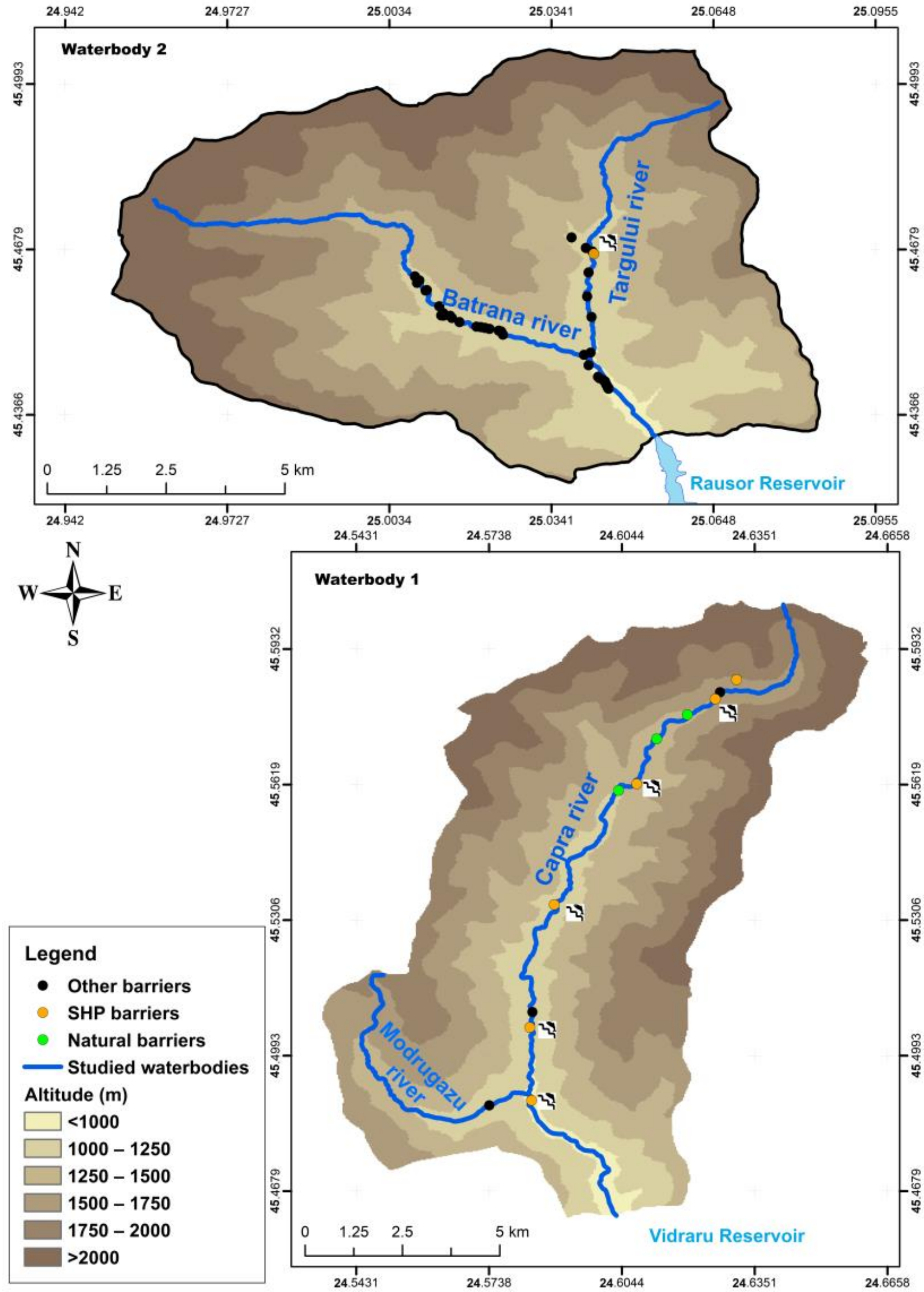

Figure 6. The location of the barriers within the study areas.

The results of indicator $I1_1$ showed a significant local impact in case of all SHPs.

By summing the length of the river sectors related to the river sections with significant local impact, it results a total length of 16.2 km in the case of Waterbody 1, representing 62% out of the total waterbody length. In the case of Waterbody 2, the river sector with poor status (class IV) meaning local significant impact, represents about 12% out of the total waterbody length.

According to the matrix within Table 3 the spatial extend of the impact showed a significant impact at waterbody level in the case of Waterbody 1 and moderate for Waterbody 2.

Despite the fact that the WFD requires to highlight the impact of anthropogenic pressures, the natural barriers higher than 0.5 m were taken into consideration in the analyses because the literature mentions them as obstacles for fish movement and implicitly have to be considered when planning measures [39]. Therefore, out of the eleven barriers

(Figure 6 and Table 4) identified within the Waterbody 1, only four (one being a natural barrier and three transversal structures) of them were considered a hindrance for fish mobility and have been included in the assessment. All the identified barriers were considered within the hydromorphological assessment in case of Waterbody 2. The result of applying the indicator $I2_{wb}$ are shown in Table 6.

Table 5. The results of the indicator average consumed flow (local and waterbody level).

SHP	Mean Abstracted Flow (m^3/s) in 2019	Mean Returned Flow (m^3/s) in 2019	Multiannual Average Natural Flow (Waterbody Section) (m^3/s)	Multiannual Average Natural Flow (Abstraction Point) (m^3/s)	Local Level Assessment		Waterbody Level Assessment	
					$I1_l$ Value (%)	$I1_l$ Class [1]	$I1_{wb}$ Value (%)	$I1_{wb}$ Class [1]
				Waterbody 1				
1	0.028	0.028	2.64	0.068	41.2	III	0	I
2	0.195	0.195		0.4	48.7	III		
3	0.405	0.405		0.7	57.8	IV		
4	0.771	0.771		1.42	54.3	IV		
5	0.976	0.976		1.94	50.3	IV		
6	1.61	-		2.36	68.2	IV		
7	-	1.61		-				
				Waterbody 2				
8	0.36	0.36	2.13	0.64	56.25	IV	0	I

Notes: [1] Blue—class I (high ecological status); Yellow—class III (moderate ecological status); Orange—class IV (poor ecological status).

Table 6. The results of the indicator longitudinal continuity/connectivity of the riverbed (waterbody level).

Length of the Waterbody (km)	No. of Transversal Structures	Maximum Height of the Transversal Structure (m)	Transversal Structures Density on the Waterbody	I2 Class [1]
		Waterbody 1		
27.3	8	8	0.29	V
		Waterbody 2		
17.92	39	3.5	2.18	V

Notes: [1] Red—class V (bad ecological status).

The river sectors with interrupted connectivity considered from the first barrier (from downstream to upstream) to the headwaters area are about 6.8 km on the Modrugazu River and, respectively, 16.2 km on the Capra River. As the river sectors represent about 85% out of waterbody length the impact is significant in the case of Waterbody 1 (see Table 3). In the case of Targului River and Batrana River, the river sectors with interrupted connectivity are about 7 km and, respectively, 9 km, representing more than 20% of waterbody length. Therefore, the impact of the barriers on river connectivity results in also being significant for Waterbody 2.

The results of applying the indicators $I3_{l/wb}$ and $I4_{l/wb}$ are provided in Tables 7 and 8.

The results presented in Tables 7 and 8 indicate a local impact on the water depth for SHP 6 (as indicator $I3_l$ falls in class IV—poor status) and a local impact on width for SHP 2 and 3 (as indicator $I4_l$ falls in class III—moderate status). Although applying the indicators I3 and I4 at waterbody level reveals good status (classes I—high status and II—good status), the extension of the local impact showed a moderate impact in case of Waterbody 1 as the river lengths with class IV and III represent approx. 7% (I3) and, respectively, 15% (I4) of the total waterbody length.

As indicator I3 was classified in class I (high status) at both local and waterbody level, in the case of Waterbody 2, there was no impact. In terms of width variation, although the local impact was significant within the waterbody level, the impact was moderate, as the river sector represented approx. 12% out of the total length of Waterbody 2.

Table 7. The results of the indicator mean water depth variation (local and waterbody level).

SHP	$H_{med\ upstream}$		$H_{med\ downstream}$		Δ_h (%)		$I3_l$ (2019)		$I3_{wb}$
	C1	C2	C1	C2	C1	C2	C1 [1]	C2 [1]	(2019) [1]
Waterbody 1									
1	-	-	0.34	0.25	-	-	-	-	
2	0.34	0.25	0.38	0.21	11.76	−16	I	I	
3	0.38	0.21	-	0.17	-	−19.05	-	I	
4	-	0.17	-	0.16	-	−5.88	-	I	
5	-	0.16	-	0.19	-	−18.75	-	I	
6	-	0.19	-	0.32	-	68.42	-	IV	
Waterbody 2									
8	0.21	0.13	0.21	0.14	0.00	−7.69	I	I	I

Notes: C1—monitoring campaign 1; C2—monitoring campaign 2. [1] Blue—class I (high ecological status); Orange—class IV (poor ecological status).

Table 8. The results of the indicator width variation (local and waterbody level).

SHP	$B_{upstream}$		$B_{downstream}$		Δ_B (%)		$I4_l$ (2019)		$I4_{wb}$
	C1	C2	C1	C2	C1	C2	C1 [1]	C2 [1]	(2019) [1]
Waterbody 1									
1	-	-	5.95	5.50	-	-	-	-	
2	5.95	5.50	6.30	3.00	5.88	−45.45	I	III	
3	6.30	3.00	-	4.70	-	56.67	-	III	
4	-	4.70	-	4.70	-	0.00	-	I	
5	-	4.70	-	4.00	-	−14.89	-	I	
6	-	4.00	-	4.50	-	12.50	-	I	
Waterbody 2									
8	7.00	12.00	3.50	3.50	−50	−70.83	III	IV	III

Notes: [1] Blue—class I (high ecological status); Green—class II (good ecological status); Yellow—class III (moderate ecological status); Orange—class IV (poor ecological status); Red—class V (bad ecological status).

4. Discussion

This paper illustrates a conceptual and practical approach to hydromorphological cumulative impact assessment by following the general steps of the DPSIR analytical framework.

This paper addresses a highly relevant challenge for practitioners and decision makers in water management by developing an approach to assessing the cumulative hydromorphological impact integrating different spatial scales by upscaling from local to water bodies such as the WFD water management unit. Usually, environmental impact assessments are conducted during the design phase, prior to construction, based on qualitative assessments.

The innovative approach demonstrated in this paper shows the potential to highlight and explain the hydromorphological impact (at both the local and waterbody levels) of existing waterworks, even with limited information about the situation before the pressure. This paper also suggests in this section possible mitigation measures based on the impact results of the case studies presented.

Following the steps of DPSIR, two main types of impact/alterations were revealed: the decrease in flow within river sectors and the interruption of the longitudinal connectivity.

As indicator $I1_{wb}$ is assessing the status in class I (no change of flow), the indicator $I1_l$ showed a totally different situation as it falls into classes III (moderate status) and IV (poor status) in case of waterbody 1 and in class IV in case of waterbody 2 (Table 5). Therefore, the results indicate that there is a local impact on flow within the river sectors between abstraction and restitution points.

With regard to the results of the indicators $I3_l$ and $I4_l$, which assess the morphological status (mean water depth variation and width variation), they are similar, with results of flow alteration in some cases (Tables 7 and 8). These results suggest that the assessment at waterbody level cannot capture the local impact by applying Romanian hydromorphological water status assessment methodology. Assessing hydromorphology at local level seems to be an appropriate approach to identifying the local impact and then using the results as starting point for upscaling and cumulating the impact at waterbody level (see Table 3).

Bearing in mind that the objective of the WFD is good water status ($\geq$class II), the assumption for defining the significant local impact proved to be a good manner for the purpose of this study. Therefore, the indicators classifying on Class III, IV and V suggest hydromorphological impact at local level.

The threshold of 20% used for spatial extension of the impact from local to waterbody could be adjusted by in-depth studies that also consider the changes of biological and physiochemical quality elements.

Quantifying from downstream (the first barrier) to upstream (the headwaters), the spatial extent of the impact related to the interruption of the longitudinal connectivity is in line with ICPDR approach for prioritization of barrier locations where fish aids should be implemented [39].

Having in mind the DPSIR concept, as a response, the ecological flow implementation was identified as a mitigating action. The ecological flow should be computed downstream of each abstraction point according to the RoEflow method, which has been approved by the Governmental Decision no. 148/2020 on the approval of the method of determining and calculating the ecological flow. However, in order to be implemented, studies to justify technical infeasibility or disproportionate costs of the ecological flow might be carried if this is the case.

As all of the SHPs are equipped with fish aids (except SHP1, which is located in a river sector without fish fauna in natural conditions), the flow should be ensured in such a way that the fish aids are fully functional ensuring appropriate conditions (water velocity, water depth) for fish fauna [40].

As the impact on longitudinal continuity is significant at waterbody level due to other barriers than those that belong to SHPs, taking into account only the hydromorphological issues, the measure for ensuring the longitudinal continuity should be implemented in case of all sediment weirs, especially those not passable by the dominant fish species (e.g., *Salmo trutta*). In-depth studies focusing on fish behavior to overcome the barriers and the barrier heights passable by trout [41] should be carried out in correlation with other important parameters related to migration (e.g., temperature, discharge flow).

Bearing in mind the social, cultural, economic and environmental importance of fish fauna [42–44] and taking into account the local conditions and the height of the barriers, some types of options/alternatives might be considered for improving longitudinal connectivity in case of the sediment weirs. The literature has recommended the following hierarchy in the process of selecting the appropriate option [45]: (i) the analyses of fulfillment of designed role of the barriers in order to identify if the removal might be an option for restoring longitudinal connectivity; (ii) the implementation of natural solutions like a succession of rock ramps (as the river slope is high and the slope of a single ramp would be too steep); (iii) technical solutions such as fish passes (e.g., Denil pass, slot pass, pool passes). These recommendations should be cross-checked by biological and physicochemical monitoring and assessments to see if the investment is worth making (e.g., no sustainable fish population upstream barriers, adequate water quality to sustain fish population). Maintenance works should be foreseen for their functionality.

Within this paper, we are solving a practical problem: hydromorphological cumulative impact assessment for waterworks in place.

Even though the pressures in our case studies are water intakes for hydropower generation, the approach might be applied to all type of uses with transversal barriers in place and little baseline information, and it might be adjusted for future waterworks in the design phase.

The cumulative impact assessment is required at waterbody level—the reporting unit of the Water Framework Directive. In the process of implementing the Water Framework Directive in Romania, it was observed that the direct application of the hydromorphological status assessment methodology that carries out a waterbody-level assessment, cannot capture the changes at local level.

Therefore, the hydromorphological impact assessment approach using appropriate scales of analyses developed within a study [30] was refined for the current paper. Starting from local impact (river cross-sections, small survey units and measurements), upscaling to river sector and waterbody level proved to be a viable option in order to quantify spatial extension of hydromorphological impact. Integrating different spatial scales in analyzing hydromorphological conditions of the predefined river water bodies was an appropriate approach to drive the cumulative hydromorphological impact on waterbody level in the context of water intakes for hydropower generation as a main pressure and diverse transversal barriers. The approach was used with good results for 14 waterbodies across the entire study [30].

Nevertheless, the results of the hydromorphological impacts were based on short term data (two monitoring campaigns in 2019) collected within a period of abundant precipitation therefore long series of monitoring data are required to capture the hydrodynamics of the rivers. In general, it is difficult to identify the difference between the effects of anthropogenic pressures and the natural modifications, this being one of the limitations of our research.

Another challenge was the lack of baseline data (no specific measurements of hydromorphological parameters before the construction). This aspect was one major limitation of our study making the impact quantification difficult. Moreover, the results of systematic measurements (long data series) for an extended period of time may improve the level of confidence of the impact assessment. Some of the instantaneous data (i.e., water width, depth) are subject to certain natural variation and thus severe hydrological events such as floods and droughts that might influence the results.

Using the hierarchy of spatial scale (river section–river sector–waterbody) and assessment of hydromorphological conditions in characteristic cross-sections upstream and downstream of each water abstraction was the only option for the short period of time of the entire study and few monitoring campaigns, but detailed enough for the WFD requirements and for the purpose of the original research [30]. Similar studies have indicated that water intakes for hydropower generation (SHP) have an impact on rivers as hydromorphological conditions downstream compared to upstream are changed [46,47]. It should be mentioned that the hydromorphological elements are supporting elements for biological elements. However, more in-depth studies for hydromorphological analyses and also for other purposes (e.g., investments for fish aids) may be carried out by using hydrological and hydraulic modelling (e.g., using the digital terrain model). Bearing in mind that the results of hydromorphological status assessment and the impact of the hydromorphological pressures (e.g., transversal artificial barrier) are closely linked, customizing some indicators of an existing method for hydromorphological status assessment to identify the local impact at a certain moment of time proved to be a good solution. The formulas of some indicators that assess the hydrological impact on water flow and a rapid and simplified morphological impact assessment expressed by mean water depth and width variation upstream–downstream the water intakes with transversal barriers (knowing there is a lack of information before construction) helped to identify the local impact.

Another limitation of this study is tackling sediment issues and large-scale embankments. More attention should be paid to sediment management downstream water intakes for hydropower generation, especially in alpine rivers with naturally high rates of sediment delivery and sediment transfer [48]. For example, Xie et al. [49,50] analyzed the cumulative impacts of the large-scale embankment in the Qiantang Estuary and Hangzhou Bay, China by means of a long-term morphodynamic model as well as field data. As a result of the large-scale embankment, significant morphological responses have occurred in the estuary; for example, the large bar in the inner estuary has moved seaward by about 16 km [48]; the accumulation rate in the Hangzhou Bay has been increased from several cm/a to more than 10 cm/a [50].

5. Conclusions

In this paper, we highlighted an approach for assessing the hydromorphological pressures and their cumulative impact on water status, showing the results of its application to four rivers. Our results, which are also supported by our previous research, demonstrated that a combination of spatial scales of investigations could provide an overview of the relationship between hydromorphological pressures, namely water intakes with transversal barriers and hydromorphological cumulative impact.

A case-by-case analysis of hydromorphological conditions reveals the locations where actions are required in order to improve longitudinal continuity and water flow modification. In addition, recommendations for types of options/alternatives for improving longitudinal continuity might be provided. The functionality of existing fish aids should be assessed. Stakeholder involvement is important within the whole process of establishing measures.

Further research with an improved design of spatial and temporal survey may better clarify the complex nature of the relationship between pressures, alterations and biological impact (cause–effect relationship), and also where the appropriate investments are to be made.

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References

1. Rieman, B.E.; Dunham, J.B. Metapopulations and Salmonids: A Synthesis of Life History Patterns and Empirical Observations. *Ecol. Freshw. Fish.* **2000**, *9*, 51–64. [CrossRef]
2. Hughes, F.M.R.; Rood, S.B. Allocation of River Flows for Restoration of Floodplain Forest Ecosystems: A Review of Approaches and Their Applicability in Europe. *Environ. Manag.* **2003**, *31*, 12–33. [CrossRef]
3. Sindelar, C.; Schobesberger, J.; Habersack, H. Effects of weir height and reservoir widening on sediment continuity at run-of-river hydropower plants in gravel bed rivers. *Geomorphology* **2016**, *291*, 106–115. [CrossRef]
4. Kuriqi, A.; Pinheiro, A.N.; Sordo-Ward, A.; Bejarano, M.D.; Garrote, L. Ecological impacts of run-of-river hydropower plants—Current status and future prospects on the brink of energy transition. *Renew. Sustain. Energy Rev.* **2021**, *142*, 110833. [CrossRef]
5. Golfieri, B.; Surian, N.; Hardersen, S. Towards a More Comprehensive Assessment of River Corridor Conditions: A Comparison between the Morphological Quality Index and Three Biotic Indices. *Ecol. Indic.* **2018**, *84*, 525–534. [CrossRef]
6. European Environmental Agency (EEA). *Environmental Indicators: Typology and Use in Reporting*; EEA internal working paper; European Environment Agency: Copenhagen, Denmark, 2003; pp. 6–7.
7. Organisation for Economic Co-Operation and Development (OECD). *OECD Core Set of Indicators for Environmental Performance Reviews: A Synthesis Report by the Group on the State of the Environment*; OECD: Paris, France, 1993.
8. Vannevel, R. Using DPSIR and Balances to Support Water Governance. *Water* **2018**, *10*, 118. [CrossRef]
9. Tscherning, K.; Helminga, K.; Krippner, B.; Sieber, S.; Gomez y Paloma, S. Does research applying the DPSIR framework support decision making? *Land Use Policy* **2012**, *29*, 102–110. [CrossRef]

10. Niemeijer, D.; De Groot, R.S. Framing environmental indicators: Moving from causal chains to causal networks. *Environ. Dev. Sustain.* **2008**, *10*, 89–106. [CrossRef]
11. Svarstad, H.; Kjerulf Petersen, L.; Rothman, D.; Sieple, H.; Wätzold, F. Discursive biases of the environmental research framework DPSIR. *Land Use Policy* **2008**, *25*, 116–125. [CrossRef]
12. Atkins, J.P.; Burdon, D.; Elliott, M.; Gregory, A.J. Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. *Mar. Pollut. Bull.* **2011**, *62*, 215–226. [CrossRef]
13. Patrício, J.; Michael, E.; Mazik, K.; Papadopoulou, K.-N.; Smith, C.J. DPSIR—Two Decades of Trying to Develop a Unifying Framework for Marine Environmental Management? *Front. Mar. Sci.* **2016**, *3*, 177. [CrossRef]
14. Cooper, P. Socio-ecological accounting: DPSWR, a modified DPSIR framework, and its application to marine ecosystems. *Ecol. Econ.* **2013**, *94*, 106–115. [CrossRef]
15. Eastwood, P.D.; Mills, C.M.; Aldridge, J.N.; Houghton, C.A.; Rogers, S.I. Human activities in UK offshore waters: As assessment of direct, physical pressure on the seabed. *ICES J. Mar. Sci.* **2007**, *64*, 453–463. [CrossRef]
16. European Environmental Agency. Available online: https://www.eea.europa.eu/policy-documents/wfd-cis-guidance-document-no-3 (accessed on 25 November 2022).
17. Ormerod, S.J.; Dobson, M.; Hildrew, A.G.; Townsend, C.R. Multiple stressors in freshwater ecosystems. *Freshw. Biol.* **2010**, *55*, 1–4. [CrossRef]
18. Kalogianni, E.; Vourka, A.; Karaouzas, I.; Vardakas, L.; Laschou, S.; Skoulikidis, N.T. Combined effects of water stress and pollution on macroinvertebrate and fish assemblages in a Mediterranean intermittent river. *Sci. Total Environ.* **2017**, *603–604*, 639–650. [CrossRef] [PubMed]
19. Appiah-Opoku, S. Environmental impact assessment in developing countries: The case of Ghana. *Environ. Impact Assess. Rev.* **2001**, *21*, 59–71. [CrossRef]
20. Carvalho, L.; Mackay, E.B.; Cardoso, A.C.; Baattrup-Pedersen, A.; Birk, S.; Blackstock, K.L.; Borics, G.; Borja, A.; Feld, C.K.; Ferreira, M.T.; et al. Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive. *Sci. Total Environ.* **2019**, *658*, 1228–1238. [CrossRef]
21. Walter, R.; Merritts, D. Natural Streams and the Legacy of Water-Powered Mills. *Science* **2008**, *319*, 299–304. [CrossRef]
22. Wolter, C.; Lorenz, S.; Scheunig, S.; Lehmann, N.; Schomaker, C.; Nastase, A.; Diego García de Jalón, D.; Marzin, A.; Lorenz, A.; Kraková, M.; et al. Review on Ecological Response to Hydromorphological Degradation and Restoration, REFORM Project (Restoring Rivers FOR Effective Catchment Management). 2013. Available online: https://www.reformrivers.eu/system/files/1.3%20Ecol%20response%20to%20HyMo%20changes_final.pdf (accessed on 28 November 2022).
23. Csiki, S.; Rhoads, B. Hydraulic and Geomorphological Effects of Run-of-River Dams. *Prog. Phys. Geog.* **2010**, *34*, 755–780. [CrossRef]
24. Mueller, M.; Pander, J.; Geist, J. The Effects of Weirs on Structural Stream Habitat and Biological Communities. *J. Appl. Ecol.* **2011**, *48*, 1450–1461. [CrossRef]
25. Anderson, D.; Moggridge, H.; Warren, P.; Shucksmith, J. The impacts of 'run-of-river' hydropower on the physical and ecological condition of rivers. *Water Environ. J.* **2015**, *29*, 268–276. [CrossRef]
26. Jansson, R.; Nilsson, C.; Dynesius, M.; Andersson, E. Effects of River Regulation on River-Margin Vegetation: A Comparison of Eight Boreal Rivers. *Ecol. Appl.* **2010**, *10*, 203–224. [CrossRef]
27. Malm Renöfält, B.; Jansson, R.; Nilsson, C. Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshw. Biol.* **2010**, *55*, 49–67. [CrossRef]
28. Greet, J.; Webb, J.; Downes, B. Flow Variability Maintains the Structure and Composition of In-Channel Riparian Vegetation. *Freshwat. Biol.* **2011**, *56*, 2514–2528. [CrossRef]
29. Eionet Central Data Repository. Available online: https://cdr.eionet.europa.eu/help/WFD/WFD_715_2022/Guidance%20documents/WFD%20Descriptive%20Reporting%20Guidance.pdf (accessed on 28 November 2022).
30. Ministry of Environment, Waters and Forests—Romania. Available online: http://www.mmediu.ro/articol/studiul-privind-evaluarea-impactului-asupra-mediului-a-constructiei-si-exploatarii-lucrarilor-de-amenajare-pentru-valorificarea-potentialului-hidroenergetic-prin-microhidrocentrale-amplasate-pe-cursurile-de-apa-capra-buda-otic-izvorul-mircea-cuca-cartisoar/4742 (accessed on 14 September 2022).
31. Moldoveanu, M.; Galie, A.; Radulescu, D. Methodology for hydromorphological assessment of Romanian rivers—Results of testing. In Proceedings of the 15th International Multidisciplinary Scientific Geoconference, Albena, Bulgaria, 18–24 June 2015; Book 3—Volume 1, pp. 427–436.
32. Galie, A.C.; Moldoveanu, M.; Antonaru, O. Hydro-morphological assessment of atypical lowland rivers—Romanian Litoral basin case study. *Carpathian J. Earth Environ. Sci.* **2017**, *12*, 161–169.
33. Moldoveanu, M.; Sarbu, D.; Galie, A.C.; Bojan, V.; Mezdroiu, I. Assessment of river water quality using an integrated hydromorphological, physico-chemical and biological approach. *AES Bioflux* **2017**, *9*, 158–172.
34. Banaduc, A.; Banaduc, D.; Ursu, L.; Rachita, R. Historical human impact on the Capra Stream macroinvertebrates and fish communities (Southern Romanian Carpathians). *Acta Oecologica Carp.* **2014**, *VII*, 111–152.
35. Banaduc, A.; Pauli, S.; Banaduc, D.; Didenko, A.; Sender, J.; Marić, S.; Del Monte, P.; Khoshnood, Z.; Zakeyuddin, S. Environmental aspects of implementation of micro hydro power plants—A short review. *Transylv. Rev. Syst. Ecol. Res.* **2015**, *17*, 179–198. [CrossRef]

36. Costea, G.; Pusch, M.T.; Banaduc, D.; Cosmoiu, D.; Banaduc, A. A review of hydropower plants in Romania: Distribution, current knowledge, and their effects on fish in headwater streams. *Renew. Sustain. Energy Rev.* **2021**, *145*, 111003. [CrossRef]
37. AQUAPROIECT S.A. Bucharest, Cadastral Water Atlas of Romania. Unpublish. 1992.
38. WordClim. Available online: https://www.worldclim.org/data/v1.4/worldclim14.html (accessed on 28 December 2022).
39. International Commission for the Protection of the Danube River (ICPDR). Available online: http://www.icpdr.org/main/sites/default/files/nodes/documents/drbmp_update_2021_final_annex_17_-_ecological_prioritisation_approach.pdf (accessed on 30 December 2022).
40. International Commission for the Protection of the Danube River (ICPDR). Available online: http://www.icpdr.org/flowpaper/viewer/default/files/nodes/documents/icpdr_fish_migration_final.pdf (accessed on 5 December 2022).
41. Utzinger, J.; Roth, C.; Peter, A. Effects of environmental parameters on the distribution of bullhead *Cottus gobio* with particular consideration of the effects of obstructions. *J. Appl. Ecol.* **1998**, *35*, 882–892. [CrossRef]
42. Weeratunge, N.; Béné, C.; Siriwardane, R.; Charles, A.; Johnson, D.; Allison, E.H.; Nayak, P.K.; Badjeck, M.C. Small-scale fisheries through the well-being lens. *Fish Fish.* **2014**, *15*, 255–279. [CrossRef]
43. Cooke, S.J.; Cowx, I.G. The Role of Recreational Fishing in Global Fish Crises. *BioScience* **2004**, *54*, 857–859. [CrossRef]
44. Lynch, A.J.; Cooke, S.J.; Deines, A.M.; Bower, S.D.; Bunnell, D.B.; Cowx, I.G.; Nguyen, V.M.; Nohner, J.; Phouthavong, K.; Riley, B.; et al. The social, economic, and environmental importance of inland fish and fisheries. *Environ. Rev.* **2016**, *24*, 115–121. [CrossRef]
45. Armstron, G.; Apahamian, M.; Fewings, G.; Gough, P.; Reader, N.; Varallo, P. *Environment Agency Fish Pass Manual: Guidance Notes on the Legislation, Selection and Approval of Fish Passes in England and Wales*; Environment Agency Rio House, Waterside Drive, Aztec West Almondsbury: Bristol, UK, 2010; p. 51.
46. Wiatkowski, M.; Tomczyk, P. Comparative Assessment of the Hydromorphological Status of the Rivers Odra, Bystrzyca, and ’Sleza Using the RHS, LAWA, QBR, and HEM Methods above and below the Hydropower Plants. *Water* **2018**, *10*, 855. [CrossRef]
47. Tomczyk, P.; Willems, P.; Wiatkowski, M.J. Comparative analysis of changes in hydromorphological conditions upstream and downstream hydropower plants on selected rivers in Poland and Belgium. *J. Clean. Prod.* **2021**, *328*, 129524. [CrossRef]
48. Babbud, C.; Lane, S.N. Ecosystem impacts of Alpine water intakes for hydropower: The challenge of sediment management. *WIREs Water* **2016**, *3*, 41–61. [CrossRef]
49. Xie, D.; Wang, Z.B.; Van der Wegen, M.; Huang, J. Morphodynamic modeling the impact of large-scale embankment on the large bar in a convergent estuary. *Mar. Geol.* **2021**, *442*, 106638. [CrossRef]
50. Xie, D.; Pan, C.; Wu, X.; Gao, S.; Wang, Z.B. Local human activities overwhelm decreased sediment supply from the Changjiang River: Continued rapid accumulation in the Hangzhou Bay-Qiantang Estuary system. *Mar. Geol.* **2017**, *392*, 66–77. [CrossRef]