PERSONAL ASSESSMENT

1. Name and surname: Michael Nones

2. Education and degrees:

- 2009-2011: Ph.D., School of Civil and Environmental Engineering, University of Padova, Italy. Title of the thesis "*Aspect of riverine hydro-morpho-biodynamics at watershed scale*", supervisor Prof. G. Di Silvio
- 2005-2007: MSc, Faculty of Environmental Engineering, University of Padova, Italy. Title of the thesis: "Sediment balance of the Adige River at watershed scale", supervisor Prof. G. Di Silvio
- 2002-2005: BSc, Faculty of Environmental Engineering, University of Padova, Italy. Title of the thesis: "Analysis and economical-technical comparison of two systems for the re-use of wastewater", supervisor Prof. M.C. Lavagnolo

3. Employment:

- October 2018-present: Adiunkt at the Institute of Geophysics, Polish Academy of Sciences
- October 2018-January 2019: External lecturer, Brandenburg University of Technology, Cottbus, Germany
- May 2018-September 2018: Teaching assistant, Brandenburg University of Technology, Cottbus, Germany
- January 2018-present: External collaborator, start-up ENIHILO, Frankfurt am Main, Germany
- July 2016-March 2018: Research Grant, University of Bologna, Italy
- April 2014-April 2016: Marie Curie Fellowship at the SME gerstgraser, Cottbus, Germany
- February 2012-March 2014: Research Grant, University of Bologna, Italy
- February 2008-December 2008: External collaborator, University of Padova, Italy

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4. Identification of achievement pursuant to Art.16 (2) of the Act of 14 March 2003 on scientific degrees and artistic titles (Journal of Laws no. 65, item 595 as amended) setting the basis for the habilitation procedure:

a) Title of the scientific achievement:

Modelling hydro-morphodynamics in rivers: from the watershed to the reach scale

b) List of scientific publications setting the basis for habilitation procedure:

[1] Nones M., Archetti R., Guerrero M. (2018). *Time-lapse photography of the edge-of-water line displacements of a sandbar as a proxy of riverine morphodynamics*. Water 10(5), 617. doi: 10.3390/w10050617

[2] Maselli V., Pellegrini C., Del Bianco F., Mercorella A., Nones M., Crose L., Guerrero M., Nittrouer J. (2018). *River morphodynamic evolution under dam-induced backwater: An example from the Po River (Italy)*. Journal of Sedimentary Research 88(10), 1190-1204. doi: 10.2110/jsr.2018.61

[3] Nones M., Pugliese A., Domeneghetti A., Guerrero M. (2018). *Po River morphodynamics modelled with the open-source code iRIC*. in Free Surface Flows and Transport Processes, GeoPlanet: Earth and Planetary Sciences, 335-346. Eds. Springer International Publishing. doi: 10.1007/978-3-319-70914-7_22

[4] Franzoia M., Nones M. (2017). *Morphological reactions of schematic alluvial rivers: long simulations with a 0-D model*. Int. Journal of Sediment Research 32(3), 295-304. doi: 10.1016/j.ijsrc.2017.04.002

[5] Nones M., Di Silvio G. (2016). *Modeling of river width variations based on hydrological, morphological and biological dynamics*. Journal of Hydraulic Engineering 142(7). doi: 10.1061/(ASCE)HY.1943-7900.0001135

[6] Nones M., Gerstgraser C. (2016). *Morphological changes of a restored reach: the case of the Spree River, Cottbus, Germany*. in Hydrodynamic and mass transport at freshwater aquatic interfaces, GeoPlanet: Earth and Planetary Sciences, 167-182. Eds Springer International Publishing. doi: 10.1007/978-3-319-27750-9_14

[7] Guerrero M., Latosinski F., Nones M., Szupiany R.N., Re M., Gaeta M.G. (2015). *A sediment fluxes investigation for 2-D modeling of large river morphodynamics*. Advances in Water Resources 81, 186-198. doi: 10.1016/j.advwatres.2015.01.017

[8] Di Silvio G., Nones M. (2014). *Morphodynamic reaction of a schematic river to sediment input changes: analytical approaches*. Geomorphology 215, 74-82. doi: 10.1016/j.geomorph. 2013.05.021

[9] Nones M., Guerrero M., Ronco P. (2014). *Opportunities from low-resolution modelling of river morphology in remote parts of the world*. Earth Surface Dynamics 2, 9-19. doi: 10.5194 /esurf-2-9-2014

[10] Nones M., Ronco P., Di Silvio G. (2013). *Modelling the impact of large impoundments on the Lower Zambezi River*. Int. Journal of River Basin Management 11(2), 221-236. doi: 10.1080/15715124.2013.794144

[11] Guerrero M., Nones M., Saurral R., Montroull N., Szupiany R.N. (2013). *Parana River morphodynamics in the context of climate change*. Int. Journal of River Basin Management 11(4), 423-437. doi: 10.1080/15715124.2013.826234

[12] Ronco P., Fasolato G., Nones M., Di Silvio G. (2010) *Morphological effects of damming on lower Zambezi River*. Geomorphology 115(1/2), 43-55. doi: 10.1016/j.geomorph.2009.09.029

c) Summary of scientific goals and major results of presented publications

Introduction

Despite long-lasting research, the way a river shapes its landscape is still to be thoroughly understood, also because of the several spatial and temporal scale involved and the difficulty in modelling the interactions between water, sediments and vegetation (both riparian and in-channel). These three components, in fact, interplay over a wide range of temporal scales, exhibiting complex, nonlinear spatiotemporal dynamics but, at the same time, they are constituting a whole (Vesipa et al., 2017). Therefore, separating factors that simultaneously influence vegetation patterns and geomorphic processes is very challenging because most of them are interdependent (Hupp & Osterkamp, 2013; Przyborowski et al., 2018) and scale-dependent.

To reduce the real-world complexity in favour of most manageable processes to be modelled at the desired scale, river modellers have made a large use of simplification. Indeed, reduced-complexity models of landscapes evolution showed how even simple rules describing water and sediment interactions (pick-up, transport, deposition) could reproduce the morphodynamics of riverine systems, without accounting for the contribution of the biota. As an example, several approaches have been applied to stream braiding, sorted sediment patterns, bedforms, beach cusps, coastal and estuarine morphology and river deltas. However, simplified representations of the feedbacks between complex small- and large-scale mechanics of flow, sediment motion and biological dynamics (Nones & Di Silvio, 2016; Nones & Varrani, 2016) cannot reproduce complex processes like self-organization that creates intricated patterns because of the crude schematization adopted. Therefore, new physically-based models should be developed, able to: (i) couple large- and small-scale dynamics, capturing the interactions that shape riverbeds at the local scale and the upscaling mechanisms having a feedback at the larger scale, (ii) but also to adequately reproduce the evolution of all the components of a river system, accounting for the required scale (Figure 1).

Many researchers (e.g., Sponseller et al., 2013) argue that the traditional vision of water acting as a resource/habitat for biota, a vector for connectivity and exchange of energy, materials and organisms, and as an agent of geomorphic change and disturbance, should be surpassed. To advance the scientific understanding of the feedbacks of local scale processes on the large-scale imprint of rivers, research needs to go further than these water-related mechanisms, extending beyond the land surface to explore river phenomena within the atmosphere and in the subsurface, and to extend beyond physical processes to the full array of biological, biogeochemical, ecological processes that

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are a product of the river impact on the landscape and its feedback (Gurnell et al., 2016), accounting for their variability in space and time. Following this vision, the study of riverine landscapes as macrosystems requires integrated approaches, incorporating the challenge of processing large data sets through statistical tools and combining data coming from several sources to force numerical and analytical models.

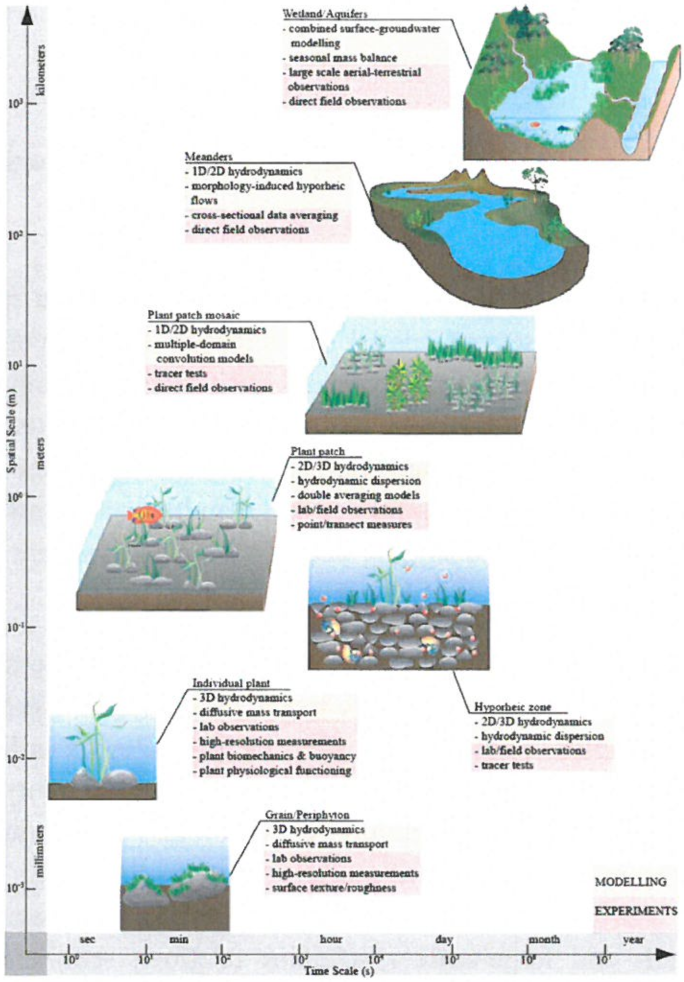

Figure 1: Key domains and fundamental processes in riverine environments (adapted from Marion et al., 2014).

Based on the previous consideration, my research is focussed on developing and applying numerical models having different scales to reproduce the fluvial dynamics observed at such scales. As described in the following, each code is calibrated and validated on monitored data, accounting for real case studies combined with theoretical considerations. On the one side, in fact, I am interested in developing new approaches and numerical codes for reproducing phenomena having several spatiotemporal scales. On the other side, I am also interested in monitoring fluvial environments by means of old and new techniques, coupling traditional theoretical hydraulics with other sciences like remote sensing imagery.

0-D modelling

Mutual interactions among deposition and erosion cycles, driven by long-term river morphodynamics and tectonic and climate-driven processes, create the setting for contemporary geomorphological and ecological river evolution. By acting at the spatial scale of the entire valley to floodplain depth and width, these mutual, long-term interactions fundamentally influence present river dynamics, especially for the largest river systems on Earth (Latrubesse, 2008; Di Silvio & Nones, 2014).

At the very long temporal horizons (geological scale) natural (e.g., tectonic uplift, climate change) and anthropogenic (e.g., damming, erosion-control works, sediment mining, water extraction) alterations do not have an appreciable impact on the long-term averaged quantity of sediments conveyed by the rivers and to the consequent evolution of their bed morphology. At the geological scale, indeed, the present configuration of alluvial rivers is solely determined by the time of the orogenesis, after which the time-averaged input of water and sediments can be assumed constant. Apart from localized discontinuities (knickpoints) connected to hard-rock formations, actual alluvial reaches typically exhibit a consistent decrease in the downstream direction of both the slope and the grainsize composition of their bottom (Rice, 1999), and many scientists tried to reproduce it, mostly at the local scale, accounting for different mechanisms (e.g., Mackin, 1948; Paola et al., 1992; Blom et al., 2016; Franzoia et al., 2017).

However, an established conceptual framework of the problem which can explain the very large variety of fining and concavity profiles exhibited at the watershed scale by actual alluvial rivers is still missing, and I am working in providing additional insights in this direction, developing a schematic (but physically based) model. Preliminary results (Franzoia et al., 2017; Franzoia and Nones, 2017) and submitted works pointed out the capability of the model in replicating, with satisfactory accuracy, the fining and concavity of large watercourses. Moreover, these results showed the predominance, in the developing process of fining and concavity, of the selective transport mechanism due to the different intrinsic mobility of the different grainsize classes. Written in non-dimensional form to allow for a comparison between streams having largely different characteristics, the model equations indicate that any river basin, regardless of its size and morphoclimatic conditions, may be sufficiently well described by a rather limited set of dimensionless parameters. The most important among these parameters appears to be the so-called filling time of the river (Di Silvio and Nones, 2014), which represents the basic scaling quantity of time as far as the morphological evolution at geological scale is concerned, but additional research in this sense in necessary. Indeed, these preliminary conclusions were based on some assumptions that can be eventually relaxed, leading to new findings in the evaluation of the control parameters of fluvial evolution at the watershed scale.

Looking at the very large scale (both temporal and spatial) permits me to have an estimation about the future trend of entire river systems, possibly suggesting management strategies. Indeed, even if based on by some means strict assumptions, long-term modelling of alluvial rivers can indicate criticalities in the present situation, showing how far are the actual watercourses, in terms of bed composition and longitudinal profile, from an idealized natural condition, and what are the main drivers affecting its evolution. The temporal scale of this process of self-adjustment should be considered when planning any further activity on disturbed watercourses but estimates on this time

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are not always available or easily computable with traditional numerical models. Moreover, recognising the importance and the spatiotemporal scale of the interplay between both natural and engineering drivers is paramount to adequately manage large fluvial systems, suggesting specific problems that should be studied using 1-D or 2-D approaches.

1-D modelling and quasi 2-D modelling

At the scale of the whole river basin, water flows mobilize, transport, and deposit sediment particles ranging in size from boulders and cobbles to silts and clays. Coarser sediment particles underpin the landforms of the river channel and floodplain, while finer sediments are retained within the matrix of coarser particles or become stabilized by plants roots and other organisms. Many studies adopted a 1-D description of the river channel to evaluate the timing, magnitude and quality of sediment moving at the reach scale, allowing assessment of reactions to disturbances in sediment connectivity arising from natural events like floods or human activities such as dam removal, reservoir sediment flushing or dredging (e.g., Ronco et al, 2010; Nones et al., 2013; Maselli et al., 2018).

River modelling should consider the interactions between hydrodynamics, morphodynamics, and biodynamics (growth and mortality of riparian vegetation), which have, in principle, 3-D (Li and Zeng, 2009) or, at least, 2-D (Bockelmann et al., 2004; Abu-Aly et al., 2014) features. While 3-D and 2-D models have to be obviously ruled out, even 1-D codes appear to be hardly compatible, from a numerical point of view, with long-term and large-scale morphodynamic description of an entire river system. Therefore, appropriate simplifications of the 1-D model based on the local uniform flow (LUF) hypothesis (e.g., Verhaar et al., 2008; Fasolato et al., 2011) have been introduced to permit its application at historical and even geological scale to very large watersheds. On the one part, simplified 1-D codes can efficiently simulate, under the hypothesis of stationary river width, the changes of bottom elevation and grainsize composition of a riverbed without describing, however, the corresponding evolution of the transverse profile (Ronco et al., 2010). To remove the hypothesis of stationary width and in order to account for the crucial interactions between morphology, hydrology, and biology occurring across a river, in my PhD thesis I proposed a quasi 2-D sub-model providing a synthetic description of the transverse profile based on the carrying capacity of the riparian plants.

Generally, in small rivers, the transverse profiles are provided by occasional bathymetric surveys, while, for large watercourses, especially in ungauged basins, cross-section profiles can be detected by repeated satellite images associated to different flow discharges (Ronco et al., 2009; Nones et al., 2014). In both cases, however, the detected cross-sections are partially colonized by riparian vegetation, which cannot be easily distinguished from the wetted surface at the banks. On the other hand, what is significant for hydrological and morphological models is the so-called active width (the width available for sediment transport), which needs to be properly estimated by subtracting from the wetted surface the vegetation density as a function of the water flow variations and the shape of the cross-sections.

While the temporal variability of the river hydrology plays a crucial role in the riparian vegetation evolution (Steiger et al., 2005), the transverse spatial variability of the morphology acts in the same

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way, involving a difficult estimate of the single contributions. The effect of a transient hydrology on the fluvial bio-morphology at the reach scale is still poorly understood, especially with reference to real cases and large watercourses, and my research will address this gap by combining a simplified 1-D approach (long-term evolution at the watershed scale) with a more detailed description of the active cross-section (quasi 2-D sub-model). Thanks to the relatively low computational effort required, this kind of model on the one side provides reliable results at the large scale and, on the other side, furnishes input data for more detailed codes, able to describe the 2-D (or 3-D) evolution of fluvial bio-morphodynamics more specifically but involving a bulky workload.

2-D modelling

The application of large-scale, simplified models (0-D and 1-D) permits the long-term description of fluvial changes on longitudinal profile and grainsize composition but does not allow for a detailed description of the river bio-morphodynamics, which have typically a 2-D or even a 3-D behaviour. Downscaling from the watershed scale towards the reach (and smaller) scale, I have applied both commercial and freeware 2-D and 3-D codes to evaluate the impact of hydraulic infrastructures like bridges and groynes on the riverine hydro-morphodynamics.

In applying numerical codes for reproducing the observed phenomena and possibly forecast the future trends of a river, one should work with reliable and case study-based input data, which are not generally available, especially regarding sediment transport and grainsize composition. To enlarge the database, I applied different techniques spanning from aerial images (Nones and Gerstgraser, 2016) for the tracking of edge-of-line displacements (Nones et al., 2018), demonstrating the field of validity of each approach and proposing future improvements. The application of different software permitted to highlight the performance of each code, besides giving possible solutions to real-world problems.

Given the increased human pressure on fluvial environments, for the future an increase of challenges posed by the combination of anthropogenic and natural drivers is forecasted (Vitousek et al., 1997). Therefore, to react to them towards more sustainable management strategies, it is necessary to improve our knowledge about the water-sediment-biota interactions, their mathematical description and the numerical issues necessary to describe the complexity of a river system. In this sense, I am working in developing specific routine to describe hydro-morpho-biodynamics at the reach scale, aiming to improve some software already available on the market.

The subject of modelling sediment transport in rivers looking at different spatial scales and accounting for several processes by means of adequate simplifications was the subject of many research projects performed in Italy and Germany and is still the main topic of my research. Aside from improving my research skills, the involvement in these projects and the continuous exchange of experience with other scientists and practitioners resulted in several publications and a set of presentations made at international conferences, which constitute the basis of my habilitation procedure entitled "Modelling hydro-morphodynamics in rivers: from the watershed to the reach scale".

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Description of specific papers

[1] Nones M., Archetti R., Guerrero M. (2018). *Time-lapse photography of the edge-of-water line displacements of a sandbar as a proxy of riverine morphodynamics*. Water 10(5), 617. doi: 10.3390/w10050617

The main aim of this research was the presentation of a simple methodology to track the displacements of a sandbar from a fixed video camera, extracting its morphological features and deriving the associated fluvial morphology, using a small reach of the Po River in Italy as a case study. The tracking results were compared with a 2-D numerical simulation performed using the freeware code iRIC to quantify the local fluvial morphodynamics.

A camera fixed on a bridge pier acquired images every twelve hours while hourly water levels are derived from a radar hydrometer located upstream of the study area. The quantification of the fluvial bathymetry is achieved through the mapping of multiple edge-of-water lines of a sandbar before and after high flow conditions in December 2017, while the model, based on a Digital Elevation Model, was forced with the local hydrology. Both time-lapse photography and numerical results showed that, in this region, flood waves can easily remove sediments that accumulated at bars during low flow conditions, redistributing them across a wider cross-section, reshaping the deepening and narrowing of the main channel typically observed during dry periods and described by previous studies.

The paper demonstrated that monitoring the riverine edge-of-water line displacements with a fixed camera can be an economical and reliable method for reproducing the river morphodynamics by detecting the changes of emerged morphological features due to flooding happenings, thus offering novel evidence for the calibration of numerical models. Even if preliminary and based on few images, this application pointed out the feasibility of the approach and suggested its application to larger periods to track the long-term evolution of alluvial rivers with a higher resolution with respect to satellite imagery, requiring a limited effort in terms of workforce.

[2] Maselli V., Pellegrini C., Del Bianco F., Mercorella A., Nones M., Crose L., Guerrero M., Nittrouer J. (2018). *River morphodynamic evolution under dam-induced backwater: An example from the Po River (Italy)*. Journal of Sedimentary Research 88(10), 1190-1204. doi: 10.2110/jsr.2018.61

Integrating field observations and numerical modelling results, this work quantified the sedimentary and morphological changes of the Po River (Italy) upstream of the Isola Serafini dam to investigate the impact of dam-induced backwater on river morphodynamics.

The combination of field observations and modelling simulations highlighted that the effects of the dam-induced backwater propagated upstream of the dam for up to 30 km, given that the dam interrupted the river continuity and generated a new base level, forcing a retrogradation of alluvial lithofacies and a change in the planform geometry. At the transition from normal flow to backwater flow a strong decrease in water-surface slope and associated bed shear stress promoted the

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deposition of coarse-grained material and the emergence of the gravel-sand transition typical of this river. Along the 30-km-long reach of the river affected by the backwater, lateral migration rate of the meanders progressively decreased approaching the dam, with a general fining of river-bed sediment and an increase in dune spacing. Closer to the dam, M1 and M2 water surface profiles were modelled in response to low-flow and high-discharge events, respectively, by means of the freeware code Hec-Ras. In essence, using the largest river in Italy, this study showed the evolution of a reach after the construction of a dam, highlighting the effects of base-level rise, and backwater and drawdown processes, in controlling fluvial hydro-morphodynamics and sediment transport processes.

[3] Nones M., Pugliese A., Domeneghetti A., Guerrero M. (2018). *Po River morphodynamics modelled with the open-source code iRIC.* in Free Surface Flows and Transport Processes, GeoPlanet: Earth and Planetary Sciences, 335-346. Eds. Springer International Publishing. doi: 10.1007/978-3-319-70914-7_22

This research was focussed on the application of the freeware software IRIC to reproduce the hydro-morphological evolution of a 10-km reach of the Po River, in Italy, where both man-made structures (two bridges) and natural features (bars, islands) are present. The outcomes of the research represented a part of the Italian-funded project INFRASAFE, during which numerical modelling tools of fluvial dynamics were used to support monitoring information acquired with non-invasive techniques, as described in other articles.

Starting from a non-detailed description of the studied area and using synthetic hydrological data, the reach has been modelled adopting the 2-D solver MFLOW_02, which solves the riverine morphodynamics by means of an unstructured grid having triangular meshes, based on a Digital Elevation Model of the area acquired in 2005. As for the boundary conditions, to speed up the simulations the model was forced with a synthetic hydrograph at upstream and the corresponding water elevations at downstream, while the sediments grainsize referred to samples acquired close to the studied zone. The choice of adopting a synthetic approach was evaluated with respect to the adaptation time and the inertia of the river, and following a sensitivity analysis.

Even if based on some assumptions, the first results obtained showed a promising capability of the 2-D model in reproducing the behaviour of the reach, both in terms of liquid flow and morphodynamics, if compared with historical data measured along the watercourse and reported in the literature, as well as up-to-date field information. In detail, the flow velocity resulted in the order of 0.4-0.8 m/s, similar to the one measured with an ADCP during a recent field survey. The reproduced sediment dynamics were proper of this reach of the Po River: deposition of sediments on bars and banks during low flow conditions, accompanied by an excavation of the main channel, and redistribution of the sediments across the whole cross-section because of flooding events. These results were also used to better contextualize future studies and field campaigns.

[4] Franzoia M., Nones M. (2017). *Morphological reactions of schematic alluvial rivers: long simulations with a 0-D model.* Int. Journal of Sediment Research 32(3), 295-304. doi: 10.1016/j.ijsrc.2017.04.002

A 0-D model of an alluvial watercourse schematized in two connected reaches, evolving at long time-scale and under the hypothesis of local uniform flow was presented and discussed in this article. Each reach was defined by its geometry (constant length and width, time-changing slope) and grainsize composition of the bed, while the sediment transport was computed using a sediment rating curve. The temporal changes of bed slope were computed by a 0-D mass balance, while the evolution of the bed composition was simulated by means of a 0-D Hirano equation. The proposed mathematical system resulted implicit and non-linear and, therefore, it was not possible to find an analytical solution as for the model proposed by Di Silvio and Nones (2014). For this reason, a numerical evaluation based on a predictor-corrector scheme was developed in Matlab, showing the potential of the approach despite the several simplifications involved. The application reported in the paper pointed out that solving such 0-D models is much simpler and faster than solving a complete 1-D hydro-morphodynamic model, with a reduced loss of details at the large spatial and temporal scale.

The evolution of the river morphology studied by the present two-reach model with non-uniform grainsize resulted slower than the one analyzed by Di Silvio and Nones (2014). In fact, their model neglected the variability of the bed composition and did not consider the fundamental role played by the bottom composition, as recognizable from the analyses of the river reaction to the perturbation of the initial conditions and of the very long-term evolution. Even if the proposed model did not operate directly on the grainsize parameters, the bottom composition reacted very rapidly to any perturbation, changing the behaviour of the system itself via the morphodynamic parameter. After an initial state, the evolution slowed down, following the evolving time of the slopes, i.e. reaching the equilibrium in about four times the characteristic filling time of the longer reach. In this sense, the model represented a significant improvement of the previous approach (Di Silvio and Nones, 2014), especially for its capability to reproduce the observed behaviour of alluvial watercourses with a reduced computational effort.

[5] Nones M., Di Silvio G. (2016). *Modeling of river width variations based on hydrological, morphological and biological dynamics.* Journal of Hydraulic Engineering 142(7). doi: 10.1061/(ASCE)HY.1943-7900.0001135

Along the research, a 1-D model was developed and applied to simulate the long-term and large-scale morphodynamics of two large rivers, namely the Parana River in Argentina and the Zambezi River in Africa. The model was based on the local uniform flow hypothesis, coupled with a synthetic description of the transverse profile, which provided the changes of the active (transport) river width by analysing the total and the vegetated widths of a watercourse, assumed as variables of the water flow. The overall density of the riparian vegetation, here expressed in terms of biological carrying capacity, was predicted as a function of the local climate and some stresses due to the interactions between hydrology, morphology and biology.

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Even if based on several simplifications like the implicit hypothesis of long-term stationary hydrological conditions, this work confirmed the opportunity to deal with hydro-morpho-biodynamic river modelling at large spatiotemporal scale through an efficient mixed 1-D + quasi 2-D approach. On the one part, the 1-D model permitted reasonably fast computations at the watershed scale extended for very long periods (up to several centuries) of the river longitudinal evolution (bottom slope and grainsize composition). On the other part, the quasi 2-D sub-model provided the transversal representation of the watercourse in terms of active (non-vegetated) width and vegetation density, which in its turn reflected on the 1-D computations.

Apart from the necessity to test the model under different climatic and geomorphological conditions and from the possible improvements of its present structure, the applications reported in this paper showed that the basic concepts utilized have a general validity. Among others: i) the combination of two extremely different timescales for the longitudinal and the transversal sub-models; ii) the adoption of a productory to express the aggregate carrying capacity of the riparian vegetation.

[6] Nones M., Gerstgraser C. (2016). *Morphological changes of a restored reach: the case of the Spree River, Cottbus, Germany*. in Hydrodynamic and mass transport at freshwater aquatic interfaces, GeoPlanet: Earth and Planetary Sciences, 167-182. Eds Springer International Publishing. doi: 10.1007/978-3-319-27750-9_14

This research was performed within the ITN HYTECH, in a work package devoted to point out the importance of considering sediment transport and hydro-morphological elements during the application of the European Water Framework Directive (WFD) in fluvial environments. Looking at the law, indeed, the WFD considers hydro-morphological elements only as supporting elements for watercourses at good or lower status, while biological elements are considered fundamental. Nonetheless, various scientific studies have demonstrated that rivers need to be considered in a more holistic way, involving all their characteristics, principally water, sediment and biota.

To give a practical example, the case study of a restored reach of the Spree River near the city of Cottbus, Brandenburg, Germany, was chosen. The proposed analysis utilized aerial images, DGMs and cross-section profiles for the pre- and post-project periods, giving information about the morphological changes due to the restoration works by tracking the edge-of-water lines and computing morphological parameters like thalweg and total sinuosity.

The preliminary results described in this paper pointed out that the river restoration along the study reach did not restore the fluvial environment to natural/pristine conditions. Habitat diversity and morphological heterogeneity, in fact, are related to the variability of flow conditions and substrate composition, therefore the increase in the number of channels, the redesign of their form and the addition of coarser sand were not sufficient to improve the river status. Another outcome regarded the temporal horizon: the lack of studies about the long-term impact of fine sand transport along the Spree River can threat the restoration project goals. To overcome such limitations, the study suggested that improved monitoring data and detailed field measurements, combined with additional information of reference conditions typical of this riverine environment and new studies

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on the impact of fine sand transport on macrophyte habitats and macroinvertebrate communities were paramount for addressing the goal.

[7] Guerrero M., Latosinski F., Nones M., Szupiany R.N., Re M., Gaeta M.G. (2015). *A sediment fluxes investigation for 2-D modeling of large river morphodynamics*. Advances in Water Resources 81, 186-198. doi: 10.1016/j.advwatres.2015.01.017

Along the research the focus was posed on combining monitoring and modelling tools for reproducing the dynamics of a bifurcation of the Parana River near Rosario, Argentina. As for the measured data, the backscatter estimations from Acoustic Doppler Currents Profilers (ADCPs) provided the suspended load of the sediment forming the riverbed, while an echo-sounder was applied to track the dunes yielding the bedload estimation. A commercial 2-D numerical code (Mike21C) was applied to the 10-km long and 2-km wide Rosario reach using the measured data as boundary conditions. The morphodynamic module was uncoupled from the hydrodynamics assessment, enabling for a long-term prediction of the river morphology that accounts for the hydrological yearly variation with a quasi-steady approach. A sensitivity analysis of the adopted parameters and of the spatiotemporal scale discretization was made to evaluate the stability of the code and the validity field of the performed simulations.

Using the particles scattering at the two well-spaced frequencies of 600-1200 kHz ADCPs, the suspended-load was estimated and a relatively good correspondence with the sediment fractions observed in the riverbed was found. Simultaneously, the dune-tracking technique using a single-beam echo-sounder was applied to investigate the bed and capture the bedload dynamics. These field-related estimations of the sediment fluxes were applied to calibrate the 2-D numerical model, providing a reliable simulation of the observed erosions and depositions in the river channels, as well as of the bedload and suspended load fluxes.

[8] Di Silvio G., Nones M. (2014). *Morphodynamic reaction of a schematic river to sediment input changes: analytical approaches*. Geomorphology 215, 74-82. doi: 10.1016/j.geomorph. 2013.05.021

This research investigated the morphodynamic reaction of a schematic river to a perturbation of the sediment input imposed at its upstream end. The consequent evolution of the initially equilibrium river was studied by means of various models (0-dimensional; 1-D parabolic and 1-D hyperbolic with uniform sediments; 1-D hyperbolic with graded sediments), depending on the more or less simplified differential equations applied for describing the water and sediment motion.

The paper discussed a number of analytical solutions obtained with two types of boundary conditions: i) stepwise change of the sediment input, very often connected to anthropogenic actions, ii) sinusoidal input variation with prescribed period, typically associated to the meteorological cycles (short period) or to the geological and climate change (long period). While for stepwise disturbance is the so-called response time that give a clear idea about the rapidity of the entire river

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to adapt to the change, it was demonstrated that, for a periodical disturbance, the river reaction was substantially a function on the period of the disturbance itself. In this latter case, the so-called attenuation length, representing the extent downstream of the origin of the disturbance required by the watercourse for damping out the disturbance itself, was especially significant. This extension, indeed, was generally much smaller than the river itself for meteorological periodicities, but it may covered the entire watercourse for geological processes.

The performed comparison between different models highlighted that, for most practical cases, the type of differential equations (0-D, 1-D parabolic, 1-D hyperbolic with uniform material) did not affect the magnitude of the response time and the attenuation length in a relevant way, while more complex became the response of the river when non-uniform grainsize sediments were considered. In addition, the paper pointed out that, as all the models are dependent on the fundamental morphological parameters of the schematic river, the numerical results were inevitably affected by the very same definition of the relevant morphological parameters with respect to the real river (river relief, probably different from the watershed relief; river width, extremely variable along the watercourse; equivalent river length, very likely depending on the density of the river network). In other words, the paper showed that, even if the application of the analytical solutions to a schematic river may certainly give some useful insight into the reaction behaviour of the real fluvial systems, especially from a comparative point of view, the quantitative analysis of a specific problem requires the application of a more complex but relaibale numerical code.

[9] Nones M., Guerrero M., Ronco P. (2014). *Opportunities from low-resolution modelling of river morphology in remote parts of the world.* Earth Surface Dynamics 2, 9-19. doi: 10.5194 /esurf-2-9-2014

This research was focussed in providing and testing simplified tools for handling long-term modelling of large rivers located in remote areas, where field information and detailed data are missing. In this paper, a 1-D approach coupled with a quasi 2-D description of the river cross section was presented and applied to the Lower Zambezi River in Mozambique and the Parana River in Argentina. In the first case, the model was used for analysing the long-term evolution of the reach after the construction of two reservoirs, while, in the second case, the same code was applied to study the evolution of the Middle and Lower Parana River forced by a changing hydrology as a result of the climate variability.

The results indicated the potential of non-detailed models in analysing the long-term impact of anthropogenic and natural pressures, especially in the case of rivers located in remote parts of the world, for which detailed field data are usually not available, and in providing input data to 2-D models, which depend on processes parameterization and calibrations based on detailed field information. As for the case studies, the code pointed out the riverbed aggradation and delta erosion observed during the last century as a response of the dam construction along the Zambezi River, while showed the importance of considering the future climate variability in simulating the morphological evolution of the Parana River.

[10] Nones M., Ronco P., Di Silvio G. (2013). *Modelling the impact of large impoundments on the Lower Zambezi River*. Int. Journal of River Basin Management 11(2), 221-236. doi: 10.1080/15715124.2013.794144

This research was focussed on simulating the fluvial dynamics observed along the Lower Zambezi River by means of an own-developed 1-D hydro-morphodynamic model capable to deal with the scarcity of available data, combined with a quasi 2-D description of the cross-section evolution to account for a changing river width. This river reach is highly influenced by the presence of two very large hydropower impoundments, which have modified the natural seasonal flows, the sediment balance, the morphology of the river and the pattern of the riparian vegetation. Downstream of these large impoundments, appreciable local effects are reported to take place, such as scour, bank collapse and shoreline degradation, ultimately changing both the bed profile and the river planform towards a single-reach channel. Besides the systematic flow records at the dam gauging station and few occasional measurements of turbidity and grai size of the river bed, only a Digital Elevation Model and a few recent satellite images of the river have been used as the input data of the model to compute the sediment transport and the associated fluvial morphodynamics.

A combination of a simplified 1-D hydro-morphodynamic model and a quasi 2-D sub-model permitted to reproduce the observed hydro-morpho-biodynamics in a relatively fast way, allowing for long-term simulations referred to possible management strategies of the two dams. As far as the longitudinal profile is concerned (1-D model), the main results basically confirm the findings of a previous fixed-width model (Ronco et al., 2010). The new application (2-D sub-model), however, pointed out a much more evident and relevant impact of the dams on the planimetric configuration of the river, given that the reservoirs altered the flow and sediment discharges and consequently changed the pattern of the vegetation, reducing the active width, narrowing and deepening the main channel, increasing the vegetated area and eventually obliterating the braided structure of the river.

[11] Guerrero M., Nones M., Saurral R., Montroull N., Szupiany R.N. (2013). *Parana River morphodynamics in the context of climate change*. Int. Journal of River Basin Management 11(4), 423-437. doi: 10.1080/15715124.2013.826234

This paper presents the outcomes of the EU-funded project CLARIS-LPB, constituted by an analysis of the sediment dynamics that take place at different scales within the Middle and the Lower Parana River in the La Plata Basin. The aim of this study was to provide a multi-disciplinary and multi-scale approach for the prediction of river future morphology in the context of climate change, the intended use of which is the prognosis of river morphodynamics' long-term impact on manmade structures and activities over or near the river.

The study was based on three levels of mathematical modelling, with the output of wider-scale models providing the input conditions for more specific ones. Climate models gave the input ensemble, i.e. future precipitation and temperature over La Plata Basin. The semi-distributed macroscale variable infiltration capacity hydrological model simulated the flow discharge time series that were then applied to an own-developed 1-D morphodynamic model already tested over large rivers like the Zambezi. The 1-D model outputs were handled for providing the future rate of

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sediment transport and corresponding bed level changes at the watershed scale that were used as boundary conditions for a commercial 2-D model. Indeed, local-scale changes like streamflow divagations and active channel dynamics were simulated by means of the Mike21C code developed by the Danish Hydraulic Institute.

Despite all the four climatic scenarios applied in this study agreeing on the prediction of an increase in the discharge that most affect the morphology, their distributions were quite different. This variation significantly altered the active-channel morphology (simulated with the 2-D model), while the longitudinal bed profile (reproduced with the 1-D model) was not particularly influenced. In fact, the 1-D simulations of past century hydrology and future scenarios pointed out that the bed profile is stable in the longitudinal direction at the large scale, while the transport capacity resulted mainly correlated with the flow discharge variation. The channel morphology sensitivity to future scenarios was inferred from 2-D simulations of the 2010–2038 period at a 25-km-long section of the Lower Parana, showing the influence of the hydrological variability on the planimetric morphology. Indeed, the simulations demonstrated that the smaller the oscillations, the higher the oversimplifications and the deepening of the main channel. Moreover, such runs pointed out the weight of the flow-resistance parameter distribution in describing the dynamics of active channel, floodplains and islands.

[12] Ronco P., Fasolato G., Nones M., Di Silvio G. (2010). *Morphological effects of damming on lower Zambezi River.* Geomorphology 115(1/2), 43-55. doi: 10.1016/j.geomorph.2009.09.029

The objective of this paper was to predict the present and future effects of the presence of the Kariba and Cahora Bassa dams on the downstream morphology of the Zambezi River, in Mozambique, integrating the few coarse and non-simultaneous data available, somehow improving their overall quality, by means of a simplified own-developed 1-D numerical model.

The model is constituted by the 1-D differential equations of water flow and sediment movement of sediment particles simplified introducing the kinematic propagation of the water flow and the local uniform flow hypothesis to reduce the computation effort, reproducing the long-term evolution of the river assuming a fixed width. This model was developed at the University of Padova and tested in several case studies spanning from large and lowland rivers to steep torrents, pointing out its applicability as a function of the Froude number and the river geometry.

The main results obtained in the study were: i) during the last and the next centuries the largest part of the Lower Zambezi in undisturbed conditions had a continuous and almost constant bottom aggradation and sediment fining; ii) this "natural" trend was affected by the construction of the Kariba (1959) and Cahora Bassa (1975) dams, but only in a relatively minor way; iii) the perturbations created by the impoundments, respectively in terms of water flow and sediment interception, propagated along the river with different celerities and with different consequences on the bottom profile and composition; iv) the construction of the two dams apparently produced an erosion of the delta area. Of course, these outcomes were affected by the scarce and uncertain information utilized for input data and model calibration, but a sensitivity analysis was also performed to corroborate them.

Summary

The results which are the basis of my habilitation procedure "Modelling hydro-morphodynamics in rivers: from the watershed to the reach scale" constitute an important contribution to the representation of fluvial dynamics and associated sediment transport accounting for different scales and drivers.

In this context, of particular importance is the research on:

- the development of a 0-D model to reproduce at the basin scale the longitudinal profile concavity and sediment fining frequently observed in alluvial rivers going from upstream towards downstream, which can be helpful in detecting large spatiotemporal changes of river systems;
- the development of a simplified 1-D model to quantify the sediment yield at the watershed scale, and its coupling with a quasi 2-D description of the fluvial cross-section to mimic the presence of riparian vegetation;
- the calibration and validation of different 2-D numerical codes for reproducing the detailed hydro-morphodynamics of rivers affected by human pressure, aiming to suggest mitigation measures and management strategies to local stakeholders.

5. Discussion of other scientific achievements

5.1 Water-related policies and management of European rivers

The changes to national and international statutory policies in response to emerging priorities of sustainable use of water resources and the challenges of climate change require an advanced understanding of eco-hydrological issues and their practical implementation in environmental management strategies and policies to protect natural aquatic environments (Marion et al., JHR 2014). To tackle these new challenges, an interdisciplinary approach is necessary, involving scientists having a different background to reduce gaps in developing common cultural ground and terminology towards more comprehensive and holistic solutions.

In this aspect, during the last years, I was involved in two different projects dealing with legislations and engineering practices. The first one regarded a WP of the MSC-funded ITN HYTECH, having the title "Strategies combining WFD and Floods Directive" and the goals of providing a recommendation for the compilation of future management plans of rivers accounting for the presence of sediments. I mostly worked on this topic for around two years between 2014 and 2016, and the outputs were published in many international journals (Nones, 2015; Nones, 2016; Nones, 2017; Nones et al., 2017) and presented in conferences worldwide, as detailed in the following. A large part of the presented results came from the analysis of the available literature (articles, database, technical reports) and an own-developed questionnaire sent to the EU water authorities in 2015 to inquire, among other things like flood risk and public participation, about the consideration of sediment transport and hydro-morphological alterations in dealing with fluvial environments. Based on this, the outcomes referred mostly to water management rather than classical fluvial engineering, but, in my opinion, having additional points of view could be paramount in addressing the actual challenges related to water.

Moving from engineering to water management and related policies gave me the opportunity to become in contact with researchers from the UCL London, in particular with the Cascading Disasters Research Group (www.ucl.ac.uk/rdr/cascading), which is focussed on understanding, assess and mitigate the escalation of crises in the globally interconnected system. In an ongoing collaboration with one of the members, we are working on addressing the challenges posed by flooding events but not commonly addressed because of their spatial and temporal scale (the so-called cascading effects). Starting from an informal collaboration we moved towards a more structured one, giving rise to journal papers (Nones and Pescaroli, 2016), conference proceedings (e.g., Pescaroli and Nones, 2016; Nones and Pescaroli, 2016; Nones, 2018) and a recent special issue (Pescaroli et al., 2018). Our work showed that a connection between research fields usually separated like social sciences and engineering is not only necessary nowadays, but, however, desirable.

The outcomes of my research about the topic were reported in journal papers and presented at international conferences, as detailed in the following.

[1] Pescaroli G., Nones M., Galbusera L., Alexander D.E. (2018). *Understanding and mitigating cascading crises in the global interconnected system*. Int. Journal of Disaster Risk Reduction 30(B), 159-163. doi: 10.1016/j.ijdrr.2018.07.004

[2] Nones M., Gerstgraser C., Wharton G. (2017). *Consideration of hydromorphology and sediment in the implementation of the EU Water Framework and Floods Directives: a comparative analysis of selected EU Member States*. Water and Environment Journal 31(3), 324-329. doi: 10.1111/wej.12247

[3] Nones M. (2017). Flood Hazard Maps in the European context. Water International 42(3), 324-332. doi: 10. 1080/02508060.2016.1269282

[4] Nones M. (2016). Is public participation an added value for river basin management? European Planning Studies 24(6), 1159-1174. doi: 10.1080/09654313.2016.1164125

[5] Nones M., Pescaroli G. (2016). *Implications of cascading effects for the EU Floods Directive*. Int. Journal of River Basin Management 14(2), 195-204. doi: 10.1080/15715124. 2016.1149074

[6] Nones M. (2015). Implementation of the Floods Directive in selected EU Member States. Water and Environment Journal 29(3), 412-418. doi: 10.1111/wej.12129

[7] Nones M. (2018). *Learning from the past: the Secchia River case study*. 5th IAHR Europe Congress, Trento, Italy. doi: 10.3850/978-981-11-2731-1_163-cd

[8] Pescaroli G., Nones M. (2018). *Integrating cascading effects of floods in policy making: a case study for Emilia Romagna, Italy*. 5th IAHR Europe Congress, Trento, Italy. doi: 10.3850/978-981-11-2731-1_291-cd

[9] Pescaroli G., Nones M. (2016). *Cascading Events, Technology and Floods Directive: future challenges.* 3rd European Conference on Flood Risk Management, Lyon, France. doi: 10.1051/e3sconf/20160707003

[10] Nones M. (2016). *River restoration: the need for a better monitoring agenda.* Proceedings of the 13th Int. Symposium on River Sedimentation, Stuttgart, Germany

[11] Nones M., Pescaroli G. (2016). *Implications of cascading effects for the EU Floods Directive.* 6th International Disaster and Risk Conference, Davos, Switzerland

[12] Nones M., Gerstgraser C. (2016). *Synergies and missing links between the Water Framework Directive and the Floods Directive.* HYTECH Final Conference, Aberdeen, United Kingdom

[13] Schnauder I., Gerstgraser C., Nones M., Schuster M., Giebler S. (2016). *Sediment - ein "missing link" zwischen WRRL und HWRM? Untersuchungen an einem sandgeprägten Tieflandfluss* (Sediments-a "missing link" between WFD and FD? Investigations on a sandy lowland river). 39. Dresdner Wasserbaukolloquim, Dresden, Germany (German Conference on Hydraulic Engineering)

[14] Nones M., Gerstgraser C. (2015). *River restoration and hydromorphological quality elements: a German case study.* 2nd Yalin Memorial Colloquium, Palermo, Italy

[15] Nones M. (2015). *1D long-term morphological evolution of rivers.* Symposium on Environmental Systems Analysis, Tübingen, Germany

[16] Nones M. (2015). *Sediment management of rivers and Water Framework Directive: the case of the Spree River.* 36th IAHR World Congress, The Hague, The Netherland

5.2 Including riparian vegetation in modelling fluvial morphodynamics

The quasi-2-D description of the river cross-section adopted in my modelling applications (e.g., Nones et al., 2014; Nones and Di Silvio, 2016) is based on the assumption of steady conditions for the vegetational carrying capacity. To overcome the limitation set by steady conditions, imposing the vegetational evolution dependent upon the initial plant population and the growth rate, which represents the potential growth of the overall vegetation along the watercourse, additional studies were performed. A sensitivity analysis made on vegetation density and growth rate showed that, regardless of the initial population density, the growth rate can be considered as the main parameter defining the development of riparian vegetation, but it results in site-specific effects, with significant differences for large and small rivers. Despite the numerous simplifications adopted and the small database analyzed, this initial comparison between measured and computed river widths pointed out a quite good capability of the model in representing the typical interactions between riparian vegetation and water flow occurring along watercourses. For the future, the relatively simple structure of the code proposed by Nones and Varrani (2016) requires further developments and additional applications to a wide range of alluvial rivers to be validated, possibly accounting for more detailed field information.

[1] Nones M., Varrani A. (2016). *Sensitivity analysis of a riparian vegetation growth model.* Environments 3(4), 30. doi: 10.3390/environments3040030

5.3 Experimental studies

Aside from modelling fluvial processes, I am also interested in better understanding the physical mechanisms by the means of experimental works. During the two research grants at the University of Bologna (Italy) I had the opportunity to work in the local hydraulic laboratory, mainly performing experiments with acoustic devices. A few outcomes of these experiments are currently under evaluation and will be a possible subject of future publications. By now, however, I edited a Special Issue to summarize the state of-the-art regarding the laboratory measurements, in particular focusing on the use of Particle Image Velocimetry and image-processing techniques to track the behaviour of different grainsize classes.

[1] Nones M. (2018). *Special Issue "Laboratory Geosciences: Modelling Surface Processes".* Geosciences 8(11), 386. doi: 10.3390/geosciences8110386

5.4 Lagoon and estuarine environments

Being formed at the Italian University of Padova, close to Venice, I was also been in contact and stimulated by challenges related to shallow water environments like lagoons. I performed a few studies mostly focussed on Venice, both under a social and a technical point of view, and the outcomes were published in one peer-reviewed article (Varrani and Nones, 2017), in a book chapter (Di Silvio et al., 2011) and presented at international conferences as detailed in the following.

[1] Varrani A., Nones M. (2018). *Vulnerability, impacts and assessment of climate change on Jakarta and Venice.* Int. Journal of River Basin Management 16(4), 439-447. doi: 10.1080/15715124.2017.1387125

[2] Nones M., Di Silvio G. (2017). *Role of Grainsize Sorting in the Long-term Morphodynamics of Sedimentary Systems.* 10th Symposium on River, Coastal and Estuarine Morphodynamics, Padova, Italy

[3] Di Silvio G., Franzoia M., Nones M., Bonaldo D., Zaggia L., Lorenzetti G., Dall'Angelo C. (2011). *Evaluating sediment input of rivers flowing in the Lagoon of Venice.* Corila. Scientific Research and Safeguarding of Venice, Corila VII, 2007-2010 results, 227-235. Eds. Europrint, Treviso, Italy

[4] Di Silvio G., Franzoia M., Nones M., Bonaldo D., Zaggia L., Lorenzetti G., Dall'Angelo C. *Valutazione dell'afflusso di sedimenti fluviali nella Laguna di Venezia* (Estimation of sediment fluxes in the Venice Lagoon). Riunione Annuale Corila, Venezia, Italy (Congress of the Italian Consortium Corila)

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