The role of hydromorphological information to improve ecological status and provide sustainable hydropower

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Seminar on measurement and data processing techniques for hydro-morphological assessment of regulated rivers, lakes and reservoirs. Trondheim, 9th January 2018
Italian National Institute for Environmental Protection and Research (ISPRA)

- National Research Institute + National Environment Agency
- National coordinator of Regional EA federation
- National Geological Survey
- National node of European Environmental Agency

- Support policies implementation in all environmental fields:
  - Produce standards + methodologies for monitoring + evaluation of env. status, flood hazard etc...
  - Make methodologies applicable
  - Training activity
ISPRA in charge to develop applied research in river hydromorphology (e.g. methods) to analyse and diagnose the impacts of pressures on river hymo processes.

Networking with (the brightest) Italian fluvial scientist since 2007.
To evaluate and prioritize optimal measures we need to understand how a river works, how it reacts to pressures at the different scales.

Hymo information supports WFD, FD, RES...

Integration of objectives in anthropized contexts is THE challenge
The Water Framework Directive (WFD)

WFD aims to achieve the good status of all EU water bodies (WBs), their associated aquatic ecosystems and the services they provide, which sustain society.
Hydromorphology ensures ecological integrity

Good hydromorphological processes are essential to create and maintain habitats and ensure ecosystem integrity, e.g. good ecological status.

Hymo assessment is crucial in order to inform a sustainable and effective management of WBs and so to comply with WFD.
Characterization is not assessment

How does my river work?

Description of the current situation in a river system, from catchment to geomorphic units to understand how it functions.
Tracking changes is not yet assessment

What’s wrong? Why has this transition taken place?

We can track changes over time but not yet sufficient to assess its status: we need to put those information into a spatial and temporal context!
River systems are complex

Bioscience 1996

The Natural Flow Regime
A paradigm for river conservation and restoration

N. LeRoy Poff, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg

Bioscience 2015

The Natural Sediment Regime in Rivers: Broadening the Foundation for Ecosystem Management

Ellen Wohl, Brian R. Bledsoe, Robert B. Jacobson, N. LeRoy Poff, Sara L. Rathburn, David M. Walters, and Andrew C. Wilcox
Rivers are hierarchical systems

Processes and forms at larger scales dominate and determine those at smaller scales.

Each scale can be characterized by a set of parameters/indicators

Controls on river character and behaviour

Dynamic assemblage of units characterizing reach morphology
Reach is the key spatial scale for assessment

At the reach scale, the river has sufficiently uniform boundary conditions to maintain a consistent set of process-form interaction.

River types have similar character and behaviour and similar response to pressures.
Hymo info has to be placed in a catchment context

Evaluation of limiting factors and pressures on future changes and on potential of recovery
Hymo info has to be placed in a temporal context

Rivers evolve in a temporal trajectory adjusting their morphology in response to changes in driving variables. Past evolution informs assessment of current conditions and prediction of future changes.
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

**Spatial context**
- Region
- Catchment
- Landscape unit
- Segment
- REACH
- Geomorphic unit
- Hydraulic unit
- River element

**Temporal context**

**Stage I:** Catchment-wide delineation and spatial characterization of the fluvial system

**Stage II:** Assessment of temporal changes and current conditions

**Stage III:** Assessment of scenario-based future trends

**Stage IV:** Management
Characterizing

DELINEATION OF SPATIAL UNITS
1. Physiographic setting
Physiographic context  M=Mountains, H=Hills, P=Plain
Landscape unit  High plain

2. Confinement
Confinement degree (%)  10-90, >90, 10-90, ≤10
Confinement index  >1.5
Confinement class  PC=Partly confined, U=Unconfined

3. Channel morphology
Aerial photo or satellite image  Aerial Flight Reform Region 2007 (name, year)
Sinuosity index  1-05, 1-05-1.5, >1.5 (applied only to single-thread channels)
Braiding index  ~1.3
Anabranching index  1
River Type (BRT, Basic River Typology)  W
ST=Straight, S=Sinuous, M=Meandering, W=Wandering, B= Braided, A=Anabranching

4. Other elements for reach delineation
Upstream  Tributary
Downstream

FURTHER CHARACTERIZATION
Drainage area (at the downstream limit) (km²)  760
Mean bed slope  S 0.0033
Mean channel width, W (m)  42
Bed sediment (dominant)  G-C
C=Clay, SH=Shit, S=Sand, G=Gravel, C=Cobbles, B=Boulders
Bed configuration  BR=Bedrock, C=Cascade, SP=Step Pool, PB=Plane bed, RP=Riffle Pool, DR=Dunefield
A=Artificial, NC=not classified (high depth or strong alteration)
River Type (ERT, Extended River Typology)  from 0 to 22 (GF=Groundwater-Fed)
Unit stream power (w=Q/S/W) (when available) ≥10 ≤10, >10 W m⁻¹
Energy setting  LE=Low Ene

Additional available data / information
Sediment size, D₅₀ (mm)  85
Discharges  E
M=measured, E=estimated, NA=not available
Gauging station (if M)  Mean annual discharge (m³/s)  24
Q₁₅ or Q₉₅ (m³/s)  235
Maximum discharges (indicate year and Q when known)  Intense flood in 2009
Characterizing
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

In WFD

- Delineation of river types
- Identification of water bodies
- Analysis of pressures
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

Stage I: Catchment-wide delineation and spatial characterization of the fluvial system

Stage II: Assessment of temporal changes and current conditions

Stage III: Assessment of scenario-based future trends

Stage IV: Management

Temporal context

Spatial context
Past and recent evolution of rivers
WFD hymo assessment: the MQI

Assessment is based on understanding the relationship between pressures (artificiality) and responses (functionality) in the light of temporal long term channel changes.

1. Continuity
   A. Longitudinal
   B. Lateral

2. Morphology
   A. Channel planform
   B. Cross-section configuration
   C. In-channel configuration and substrate

3. Vegetation

Geomorphological Functionality

Artificiality

Channel adjustment

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Sub-indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functionality</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>Longitudinal continuity in sediment and wood flux</td>
</tr>
<tr>
<td>F2</td>
<td>Presence of modern floodplain</td>
</tr>
<tr>
<td>F3</td>
<td>Hillslopes – stream connection</td>
</tr>
<tr>
<td>F4</td>
<td>Processes of bank retreat</td>
</tr>
<tr>
<td>F5</td>
<td>Presence of a potentially erodible corridor</td>
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<tr>
<td><strong>Morphology</strong></td>
<td></td>
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<tr>
<td>Channel pattern</td>
<td></td>
</tr>
<tr>
<td>F6</td>
<td>Bed configuration – valley slope</td>
</tr>
<tr>
<td>F7</td>
<td>Forms and processes typical of the channel pattern</td>
</tr>
<tr>
<td>F8</td>
<td>Presence of typical fluvial forms in the alluvial plain</td>
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<tr>
<td>Cross-section configuration</td>
<td></td>
</tr>
<tr>
<td>F9</td>
<td>Variability of the cross-section</td>
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<tr>
<td>Bed substrate</td>
<td></td>
</tr>
<tr>
<td>F10</td>
<td>Structure of the channel bed</td>
</tr>
<tr>
<td>F11</td>
<td>Presence of in-channel large wood</td>
</tr>
<tr>
<td><strong>Vegetation</strong></td>
<td></td>
</tr>
<tr>
<td>F12</td>
<td>Width of functional formations in the fluvial corridor</td>
</tr>
<tr>
<td>F13</td>
<td>Linear extension of functional vegetation</td>
</tr>
<tr>
<td><strong>Artificiality</strong></td>
<td></td>
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<tr>
<td>Upstream alteration of longitudinal continuity</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>Upstream alteration of channel-forming discharges</td>
</tr>
<tr>
<td>A2</td>
<td>Upstream interception of sediment transport</td>
</tr>
<tr>
<td>Alteration of longitudinal continuity in the reach</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>Alteration of channel-forming discharge in the reach</td>
</tr>
<tr>
<td>A4</td>
<td>Interception of sediment transport in the reach</td>
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<tr>
<td>A5</td>
<td>Crossing structures</td>
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<tr>
<td>Alteration of lateral continuity</td>
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<tr>
<td>A6</td>
<td>Bank protections</td>
</tr>
<tr>
<td>A7</td>
<td>Artificial levees</td>
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<tr>
<td>Alteration of channel morphology and/or substrate</td>
<td></td>
</tr>
<tr>
<td>A8</td>
<td>Artificial changes of river course</td>
</tr>
<tr>
<td>A9</td>
<td>Other structures of alteration of channel profile and/or substrate</td>
</tr>
<tr>
<td>Interventions of removal</td>
<td></td>
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<tr>
<td>A10</td>
<td>Sediment removal</td>
</tr>
<tr>
<td>A11</td>
<td>Wood removal</td>
</tr>
<tr>
<td>A12</td>
<td>Vegetation cutting</td>
</tr>
</tbody>
</table>

| Channel adjustments | |
| CA1 | Adjustments in channel pattern |
| CA2 | Adjustments in channel width |
| CA3 | Bed-level adjustments |

Some indicators are applied/not applied in specific cases e.g. F3,F6 are applied only to C
The Morphological Quality Index (MQI)
The Morphological Quality Index (MQI)

Artificiality

<table>
<thead>
<tr>
<th>A10</th>
<th>Sediment removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Absence of recent (last 20 years) and past (last 100 years) significant sediment removal activities</td>
</tr>
<tr>
<td>B1</td>
<td>Sediment removal activity in the past (last 100 years) but absent during last 20 years</td>
</tr>
<tr>
<td>B2</td>
<td>Recent sediment removal activity (last 20 years) but absent in the past (last 100 years)</td>
</tr>
<tr>
<td>C</td>
<td>Sediment removal activity either in the past (last 100 years) and during last 20 years</td>
</tr>
</tbody>
</table>
The Morphological Quality Index (MQI)

Channel adjustments

<table>
<thead>
<tr>
<th>CA3</th>
<th>Bed-level adjustments</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Negligible bed-level changes (≤0.5 m)</td>
</tr>
<tr>
<td>B</td>
<td>Limited to moderate bed-level changes (0.5÷3 m)</td>
</tr>
<tr>
<td>C1</td>
<td>Intense bed-level changes (&gt;3 m)</td>
</tr>
<tr>
<td>C2</td>
<td>Very intense bed-level changes (&gt;6 m)</td>
</tr>
</tbody>
</table>
The Morphological Quality Index (MQI)

Geomorphological functionality

<table>
<thead>
<tr>
<th>F2</th>
<th>Presence of a modern floodplain</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Presence of a continuous (&gt;66% of the reach) and wide modern floodplain</td>
</tr>
<tr>
<td>B1</td>
<td>Presence of a discontinuous (10÷66%) but wide modern floodplain or &gt;66% but narrow</td>
</tr>
<tr>
<td>B2</td>
<td>Presence of a discontinuous (10÷66%) and narrow modern floodplain</td>
</tr>
<tr>
<td>C</td>
<td>Absence of a modern floodplain or negligible presence (≤10% of any width)</td>
</tr>
</tbody>
</table>
The Morphological Quality Index (MQI)

Synthesis and visualization of results
The Morphological Quality Index (MQI)

Scoring system

1. High
   \( (MQI = 0.85 - 1.0) \)

2. Good
   \( (MQI = 0.70 - 0.85) \)

3. Moderate
   \( (MQI = 0.50 - 0.70) \)

4. Poor
   \( (MQI = 0.3 - 0.5) \)

5. Bad
   \( (MQI = 0 - 0.3) \)
Hymo information for habitat integrity and e-flows evaluation

(i) GU for different flow conditions

(iv) Historic habitat series

Vezza et al, 2013
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hymo assessment framework.

In WFD

- Pressure/Impacts analysis
- Assessment of hydromorphological status
- Identification of HMWB

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What if? Hymo info to evaluate future scenarios

Piave river, upper reach. Surian, 2009
Hymo information to identify flood hazard areas
Diagnosis of present conditions and evaluation of future scenarios require a multiscale hygro assessment framework.

In WFD

• Design of measures
• Evaluation of measure efficiency

Stage II: Assessment of temporal changes and current conditions

Stage III: Assessment of scenario-based future trends

Stage IV: Management
How can we use hymo info for WFD and HP,....

We need a common approach envisaging characterization, assessment of current conditions and future scenarios.
These approaches already exist!
(e.g. River Styles, MQI, IDRAIM)

Such methods drive us to know what to monitor at the different scales both for characterization and assessment:
- Spatial scales of segmentation
- Type specific indicators
- Historical analysis

The data needs for these methods can be satisfied by a combined use “traditional” data and remote sensed information.

RS gives opportunity on HOW to monitor in a more cost-effective way
Thank you

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Past and recent evolution of river systems can be explained by conceptual models developed by quantitative geomorphological analysis.
WFD hymo assessment

It must analyze the relationship between processes and related features

Are the features we observe consistent with the typical character and behaviour of that type?