Understanding linkages between habitat dynamics and morphodynamics in rivers for setting environmental flows

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FHARMOR Project Meeting, 13 Oct 2017 Bolzano
Outline

• Introduction: Habitat modeling
• Research questions
• State-of-the-art and case studies
• Some (preliminary) results
• What has been done so far?
• What’s next?
Habitat modeling

Hydro-morphology

Species distribution models

Abiotic and biotic par.
- Velocity
- Depth
- Substrate
- Cover
- Vegetation
- Connectivity
- ...

Quantify spatial-temporal HABITAT variations

Type of models:
- Expert-based
- Univariate o multivariate
- Micro-, Meso- o Macroscale

Modified from: Vezza et al. 2017
Spatial scales: Macro → Meso → Micro

- Cachment
- Segment
- Reach
- Macro
- Meso
- HMU
- Micro
- U, D, d50

modified from Rinaldi et al., 2016
Hydro-Morphological-Units (HMUs)
Spatial scales: Meso - Micro

<table>
<thead>
<tr>
<th>Model</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MesoCasimir</td>
<td>Eisner et al. 2005</td>
</tr>
<tr>
<td>Norwegian Mesohabitat Classification Method</td>
<td>Borsanyi et al. 2003</td>
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<tr>
<td>MEM</td>
<td>Hauer et al. 2009</td>
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<td></td>
<td>Hauer et al. 2011</td>
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<td>River Habitat Survey</td>
<td>Hawkins et al. 1993</td>
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<td>Maddock et al. 2001</td>
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<tr>
<td>MesoHABSIM</td>
<td>Parasiewicz 2007</td>
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<td></td>
<td>Parasiewicz et al. 2013</td>
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<td></td>
<td>Vezza et al. 2014a</td>
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<td>Vezza et al. 2014b</td>
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<td>Vezza et al. 2015</td>
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</table>

PHABSIM, RHABSIM, RYHABSIM, EVHA, RSS, CASIMIR, HARPHA, ...
Habitat models: MesoHABSIM

Habitat mapping

Other parameters (vegetation, cover, ...)

Substrate

Velocity, depth

Flow time series

Habitat time series

Habitat Integrity Index

<table>
<thead>
<tr>
<th>IH</th>
<th>CLASSE</th>
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<tbody>
<tr>
<td>IH ≥ 0.80</td>
<td>ELEVATO</td>
</tr>
<tr>
<td>0.60 ≤ IH &lt; 0.80</td>
<td>BUONO</td>
</tr>
<tr>
<td>0.40 ≤ IH &lt; 0.60</td>
<td>SUFFICIENTE</td>
</tr>
<tr>
<td>0.20 ≤ IH &lt; 0.40</td>
<td>SCADENTE</td>
</tr>
<tr>
<td>IH &lt; 0.20</td>
<td>PESSIMO</td>
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</table>
MesoHABSIM for non-wadable rivers?
\[ v \cdot d = 1 \]
Research question(s)

From the perspective of a mesoscale approach (i.e., geomorphic units used as mesohabitats)

1) How can 2D hydraulic modelling be used to quantify fish habitat availability at different spatial resolutions?

2) How does the morphological pattern of gravel-bed rivers affect habitat availability for a target fish species?

3) How can 2D hydraulic modelling be integrated into a mesohabitat modeling framework that combines complementary approaches (including field work, remote sensing) to be applicable to a broad range of hydro-morphological conditions?
Literature review: State-of-the-art in mesohabitat hydraulic modeling

| MEM          | Mesohabitat Evaluation Model | Hauer et al. 2009  
|             |                             | Hauer et al. 2011  
|             |                             | Martinez-Capel et al. 2016 |
| NMCM        | Norwegian Mesohabitat Classification Model | Borsányi et al. 2004  
|             |                             | Roser Casas-Mulet et al. 2014 |
|             | 2D hydrodynamic delineation of river forms | Wyrick et al. 2014  
|             |                             | Pasternack 2011 |

- **Parametric classification**
- **Clustering**
- **Framework to evaluate hydraulic patches**: Wallis et al. 2010
- **Fuzzy logic classification**: Legleiter and Goodchild 2004

*Validation lacking!*
No modeling.
Field survey: ok

Modeling and field survey.
But: Field survey not possible at all discharges!

Modeling.
Field survey possible: boat!
Case study: Mareit (measurements)

Upstream: \( Q = 1.7 \text{ m}^3/\text{s} \) 15/12/2016
Downstream: \( Q = 2.4 \text{ m}^3/\text{s} \) 20/03/2016
Case study: Mareit (measurements)

HMU distribution

1.7 (upper) 2.4 (lower)
Case study: Noce and Avisio rivers

Noce, \( Q = 1.6 \ m^3/s \)

Avisio, \( Q = 2.13 \ m^3/s \)
Framework: Integration of remote sensing and hydraulic simulation into mesohabitat methodology

- Remote sensing
  - RGB
  - DEM
  - Wadable
  - Non-wadable
  - Habitat mapping
  - Other parameters (vegetation, cover, ...)
  - Substrate
  - Velocity, depth
  - Velocity, depth
  - Habitat mapping

Field survey

2D modeling

Expected outcome
What’s next?

• Testing various clustering techniques: kmeans, fuzzy-c, ...
• Unsupervised and semi-supervised (constrained)

• How do modeling parameters affect results?
• Different case studies (morphology + hydrology)
What has been done so far?

<table>
<thead>
<tr>
<th>Activities</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
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<tbody>
<tr>
<td>WP1.1 Field based mesohabitat mapping (UNITN, FUB)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP1.2 Biological multivariate model for grayling (UNITN)</td>
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<tr>
<td>WP2.1 Hydrodynamic model calibration for the study sites (UNITN, UIBK)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP2.2 Extraction of model-predicted mesohabitat metrics (UNITN, UIBK)</td>
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<td>WP2.3 Morphodynamic modeling of habitat variability (UNITN)</td>
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<td>WP2.4 Optimal bathymetric resolution for mesohabitat modeling (UIBK)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
</tr>
<tr>
<td>WP3.1 Remote sensing data acquisition (UIBK)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP3.2 Data processing of airborne bathymetric lidar and UAV hyperspectral surveys (UIBK)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
</tr>
<tr>
<td>WP3.3 Remote sensing analysis of habitat attributes (FUB)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP4.1 Integrated mesohabitat assessment method (FUB, UNITN)</td>
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<tr>
<td>WP4.2 Habitat as a metric to link hydro-morphological quality to biotic communities (UNITN,FUB)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP4.3 Future scenarios of habitat availability in the Eisack River (UNITN, FUB)</td>
<td>1-6</td>
<td>6-12</td>
<td>12-18</td>
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<tr>
<td>WP5 Project management and dissemination</td>
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</tr>
</tbody>
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Survey: Mareit – low flow
Postponed to 2° and 3° year
Work in progress
Literature review
What’s next? Measurements

Flow time series Mareit – 2010 - 2016
What’s next? Measurements

Flow time series Mareit – 2010 - 2016

<table>
<thead>
<tr>
<th>Quantiles:</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q (m3/s):</td>
<td>2.27</td>
<td>2.75</td>
<td>3.47</td>
<td>5.46</td>
<td>6.51</td>
</tr>
</tbody>
</table>
Thank you!
References:
- Eisner et al. 2005: MesoCASiMiR – new mapping method and comparison with other current approaches
- Borsányi et al., 2004: A Meso-scale Habitat Classification Method for Production Modelling of Atlantic Salmon in Norway
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- Vezza et al. 2015: Random forests to evaluate biotic interactions in fish distribution models
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- Hauer et al. 2011: Variability of mesohabitat characteristics in riffle-pool reaches: Testing an integrative evaluation concept (FGC) for MEM-application
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- Roser Casas-Mulet et al., 2014: A cost-effective approach to predict dynamic variation of mesohabitats at the river scale in Norwegian systems
- Wallis et al., 2010: A framework for evaluating the spatial configuration and temporal dynamics of hydraulic patches
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- Pasternack, 2011. 2D modeling and ecohydraulics analysis
- Vezza et al. 2017, «Manuale tecnico-operativo per la modellazione e la valutazione dell’integrità dell’habitat fluviale»