Insights into the demand side of the socio-ecological system from a pressure-oriented, freshwater view – experiences from the FP7 MARS project

Sebastian Birk
Universität Duisburg-Essen (DE)
Multiple stressors, ecological status and ecosystem services
–
How is this all related?

Sebastian Birk
Universität Duisburg-Essen (DE)
Content

- Multiple stressors acting on European surface waters
- Relationships between ecological status and ecosystem services (ESS)
Multiple stressors acting on European surface waters
Percentage of water bodies at lakes, rivers, transitional and coastal waters affected by no, one or several significant pressures

Data reported for 103,130 water bodies by 25 EU member states (excl. IE, GR, LT) within the 2nd WFD RBM cycle 2009-2015. Pressure categories cover point source pollution, diffuse pollution*, water abstraction, physical alteration, hydrological alteration, continuity disruption and other pressures (including introduced species and diseases = 1.6%; exploitation or removal of animals or plants = 0.6%; groundwater recharges or alteration = 0.2%; litter or fly tipping < 0.1%). [*excluding atmospheric deposition]
From pressures to stressors

Ecosystem response

Drivers

Pressures
Examples: Point sources, Diffuse sources

Stressors
directly affecting habitats and biota
Examples:
• Oxygen depletion
• Nutrient enrichment
• Siltation
Multiple stressors

MORPH
Rip. land use

HYDRO
Mean and base flow

NUTR
Total N and P

TOX
msPAF

MODELLING

Empirical modelling:
*Boosted Regression Trees* analysis

Ecological status
(SOLUTIONS sub-catchments, n > 12,000)

12 Broad River Types

Lemm et al., in prep.
Multiple stressors acting on European rivers

Effects of multiple stressors in Europe

- **HABITAT**
  - Urban
  - Agriculture
  - Mean flow
  - Base flow

- **WATER QUALITY**
  - Total N
  - Total P
  - msPAF

Explanatory power (%):

- Urban: 35%
- Agriculture: 19%
- Mean flow: 46%
- Base flow: 100%
- Total N: 35%
- Total P: 19%
- msPAF: 46%

Lemm et al., in prep.
What is the (combined) effect of stressors?

**Dominance** \((1 + 0 = 1)\) \(\text{or}\) **Additive** \((1 + 1 = 2)\)

**Interactions** \(\rightarrow\) “Ecological surprises”

**Synergistic** \((1 + 1 = 3)\) \((e.g.\ Nutrients \& Temperature)\)
\(\rightarrow\) Requires, for instance, more protective nutrient standards.

**Antagonistic** \((1 + 1 = 1)\) \((e.g.\ Nutrients \& Hydropeaking)\)
\(\rightarrow\) Requires combined stressor mitigation to avoid worsening.
Paired-stressor effects

Ecosystem response

\[ f(x) = a \cdot x_1 + b \cdot x_2 + c \cdot x_1 \cdot x_2 \]

Stressor 1

Stressor 2

Interaction-term

Birk et al., in prep.
Paired-stressor effects: *data basis*

European lakes and rivers

9 mesocosm experiments
13 basin studies
22 cross-basin studies

→ 18,000 samples
Paired-stressor effects: data basis

Ecosystem response

Plants

Animals

Bioassessment metrics
(Biodiversity, Functional traits, Functions)
Paired-stressor effects: data basis

Stressor pairs

- Nutrient | Morphological
- Nutrient | Thermal
- Nutrient | Hydrological
- Hydrological | Thermal
- Nutrient | Toxic
- Nutrient | Chemical
- Hydrological | Morphological
- Morphological | Toxic
- Hydrological | Chemical
- Morphological | Chemical
- Chemical | Toxic
- Morphological | Morphological

Number of analytical cases

n = 180 cases
Paired-stressor effects: interactions

Share of interactions across lakes and rivers

LAKES (n= 58 cases)
- Additive: 60%
- Interactive: 23%
- Dominance: 17%

RIVERS (n = 122 cases)
- Additive: 38%
- Interactive: 32%
- Dominance: 30%

Birk et al., in prep.
Paired-stressor effects: *interactions*

**Interaction strength**
Change in models’ explanatory power due to interaction effects (n = 59 cases)

- Median = 17%
- Range = 99.5%

INCREASING “SURPRISES”
Multiple stressors: *summary*

Multiple stressors are acting on European surface waters, with **highly case-specific** ecological impacts.

Effective water management is challenged by **interaction effects** which can evoke “ecological surprises”.
Relationships between ecological status and ecosystem services (ESS)
‘Tapping’ and ‘replenishing’ types of ecosystem services
Ecological status ~ ESS: empirical proof

Ecological status
River Basin Management Planning
of the European Water Framework Directive
Ecological status ~ ESS: empirical proof

<table>
<thead>
<tr>
<th>ESS category</th>
<th>Indicator</th>
<th>Spatial data</th>
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<tbody>
<tr>
<td>Water provisioning</td>
<td>Water Exploitation Index (-)</td>
<td></td>
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<tr>
<td>Regulating services:</td>
<td>Sediment Removal Efficiency (+)</td>
<td>Danube basin</td>
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<tr>
<td>Erosion prevention</td>
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<tr>
<td>Cultural services:</td>
<td>Recreation Potential Index (+)</td>
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Ecological status ~ ESS: empirical proof

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**Cultural services:**

| Recreation |
| Potential Index (+) |

Kruskal-Wallis: p<0.05

Grizzetti et al., 2017
Rough-scale evidence (not always) supports assumed relationships between ecological status and provision of different ESS.

Synergies and conflicts between ecological status and ESS yet to be further evaluated at operational scales (e.g. water body, sub-basins).
Conclusions

“PRESSURE – RESPONSE – SHORTCUT”
WHEN SELECTING MITIGATION MEASURES
Conclusions

“PRESSURE – RESPONSE – SHORTCUT”

WHEN SELECTING MITIGATION MEASURES

Driver ➔ Pressure ➔ State ➔ Impact ➔ Response

Multi-stressor effect understanding is indispensable in ecosystem-based management.