Towards recovery of Europe's waters

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Results from the MARS project addressing multiple pressures in river basin management

Presentation at the Nordic WFD conference

21-23 May 2019, Vaasa, Finland

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The MARS project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 603378.

Content

- Overview of multiple pressures reported to WISE
- How has the MARS project worked to provide more knowledge on the impacts of multiple pressures?
- MARS Tools and recommendations for managing multiple stressors
- Future of the WFD: How to improve?

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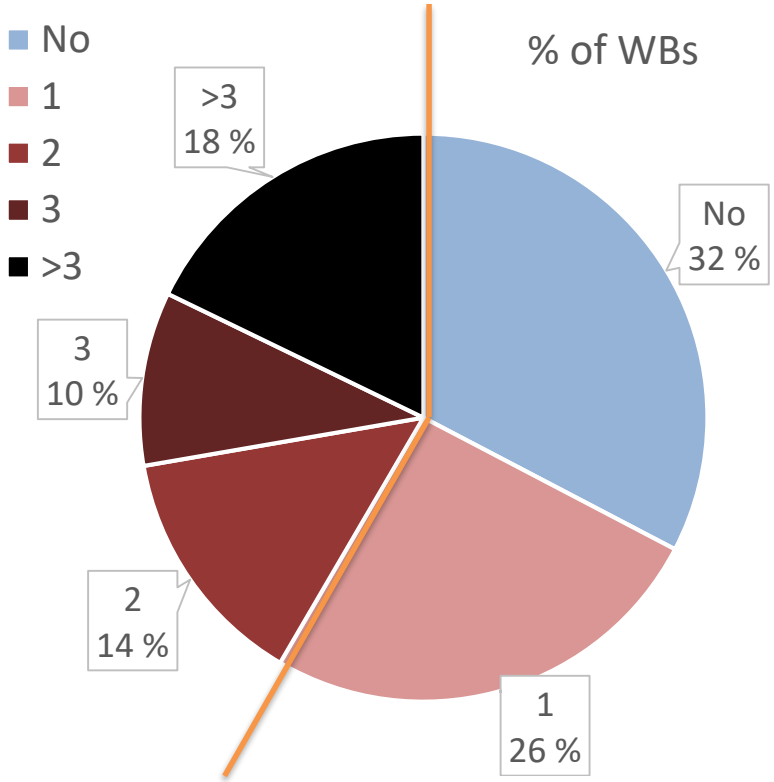
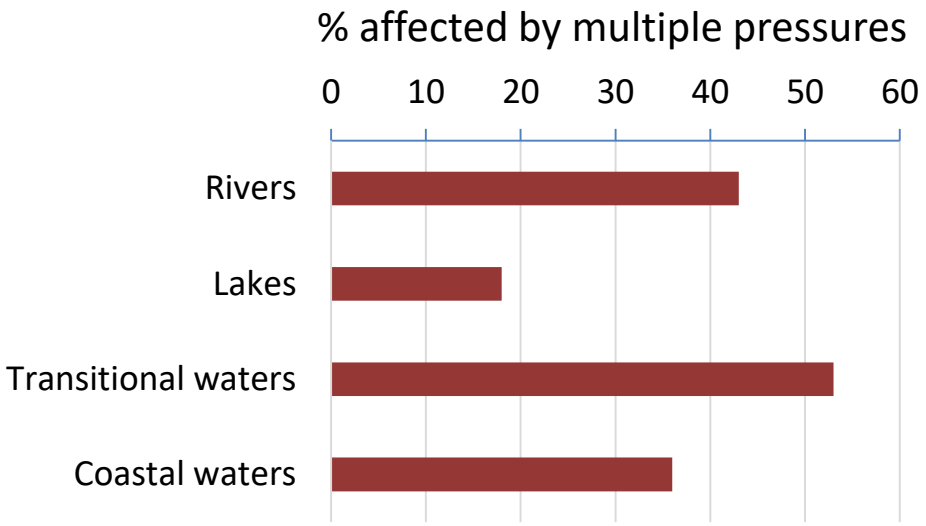
Multiple pressures reported to WISE with the 2nd RBMPs

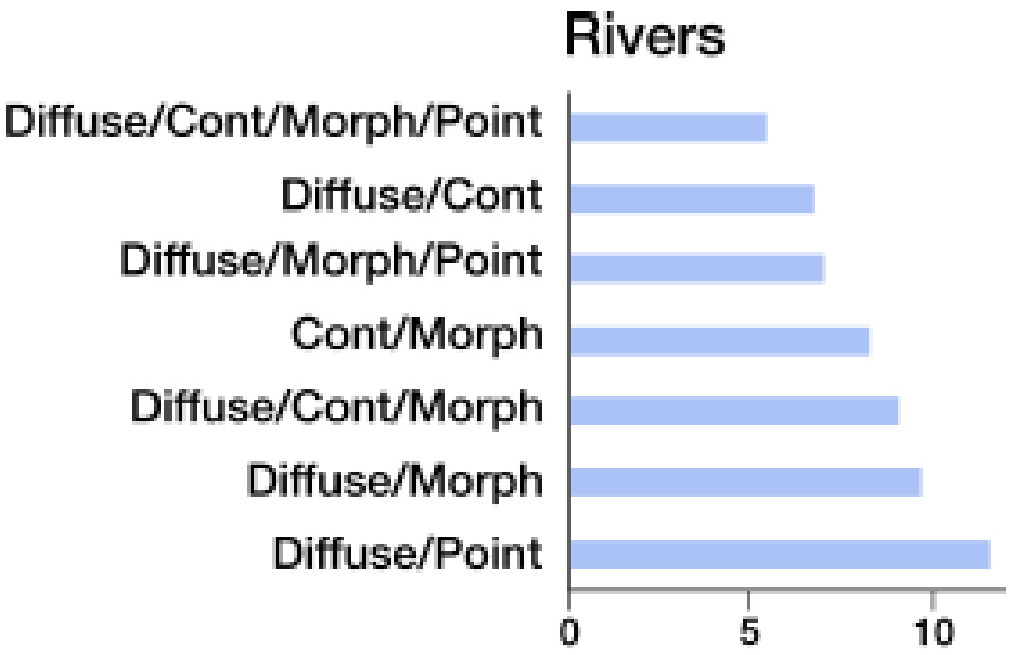
Multiple pressures affect 42% of all surface water bodies

(based on EEA State-of-Water report 2018)





Most common pressure combinations in rivers



% of water bodies with 2 or more pressures

Diffuse: Diffuse source pollution
Point: Point source pollution
Cont: Continuity broken
Morph: Morphology changed

What are the challenges to manage multiple pressures?

- **How to produce enough food and energy without degrading water status in a changing climate?**
  - There are conflicting policy objectives
  - Is it possible to agree on some common multi-benefit measures reducing the footprint on water?

- **How to find and implement the right combination of measures to close the gap between current status and good status?**
  - Knowledge on multi-pressure impacts on different BQEs
  - Link the gap between current and good status to the measures, addressing the different pressures
  - Predict the response time to recovery (can be > 10 years)

- **Will multiple pressures increase the need for measures?**
  - This depends on the presence of pressures interactions (none, synergistic or antagonistic?)

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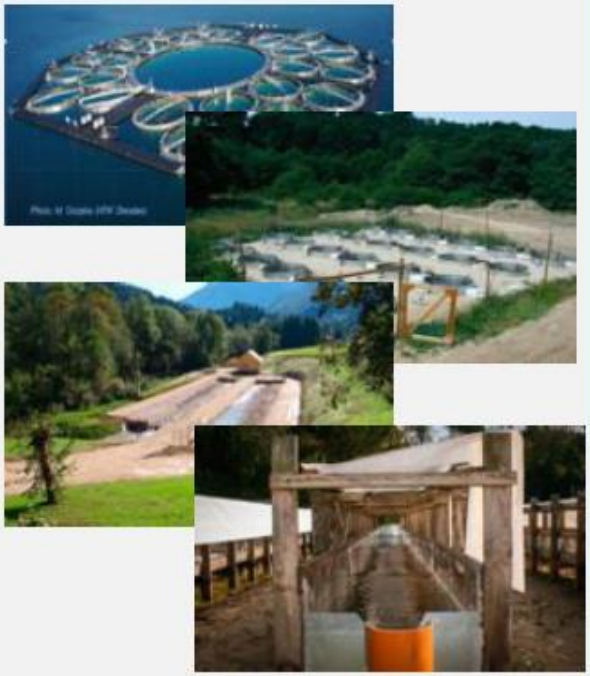
MARS objective and partnership

- Key objectives:
  - provide knowledge on impacts of multiple pressures on ecological status and ecosystem services
  - provide tools and recommendations to improve the programme of measures in the RBMPs
- Partnership:
  - 20 European research institutes, incl NIVA, SYKE, JRC
  - 4 national WFD authorities (AT, PT, RO, UK) + ICPDR (Danube commission)
- Web-site: http://mars-project.eu

Generating data from three spatial scales

Experiments

7 flume and mesocosm factorial experiments



Combined effects of DOC, flow, water abstraction, temperature, precipitation, nutrients, fine sediments, habitat morphology

River basins

16 case study basins

Statistical analysis of combined effects of water abstraction, flow regulation, morphological alteration, water quality, warming, land use

Europe

Europe-wide data analysis of large lakes and rivers and of fish across rivers, lakes and and estuaries

Statistical analysis of relationships between drivers, pressures, biological impacts, ecosystem processes and ecosystem services

MARS outcomes - overview

- **Tools** (http://www.freshwaterplatform.eu/index.php/tools.html)
  - Freshwater Information System (DPSIR, case studies)
  - Diagnostic tool (why has status deteriorated?)
  - Scenario analysis tool (how will status change with future land use change and climate change?)
  - Other useful tools (modelling, assessment, GIS, R)

- Policy briefs, Freshwater Blog (https://freshwaterblog.net/)

- Stakeholder workshops:
  - need for guidance expressed

- **MARS Recommendations**

- > 200 papers (more to come)
- 4000 pages of deliverables

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MARS Tools - overview

MARS FRESHWATER INFORMATION SYSTEM - FIS

Find background information on the effects of multiple stressors and options to mitigate them as well as example case studies in all kinds of freshwater ecosystems

MARS DIAGNOSTIC TOOLS - DAT

Identify and diagnose multiple stressors and their effects on waterbodies with an interactive tool, which also suggests potential management measures

MARS SCENARIO ANALYSIS TOOL - SAT

Provide a catchment-scale perspective of the multiple stressor situation and estimate the effects of changing multiple stressor combinations due to changes

Background information

Evidence & potential management measures

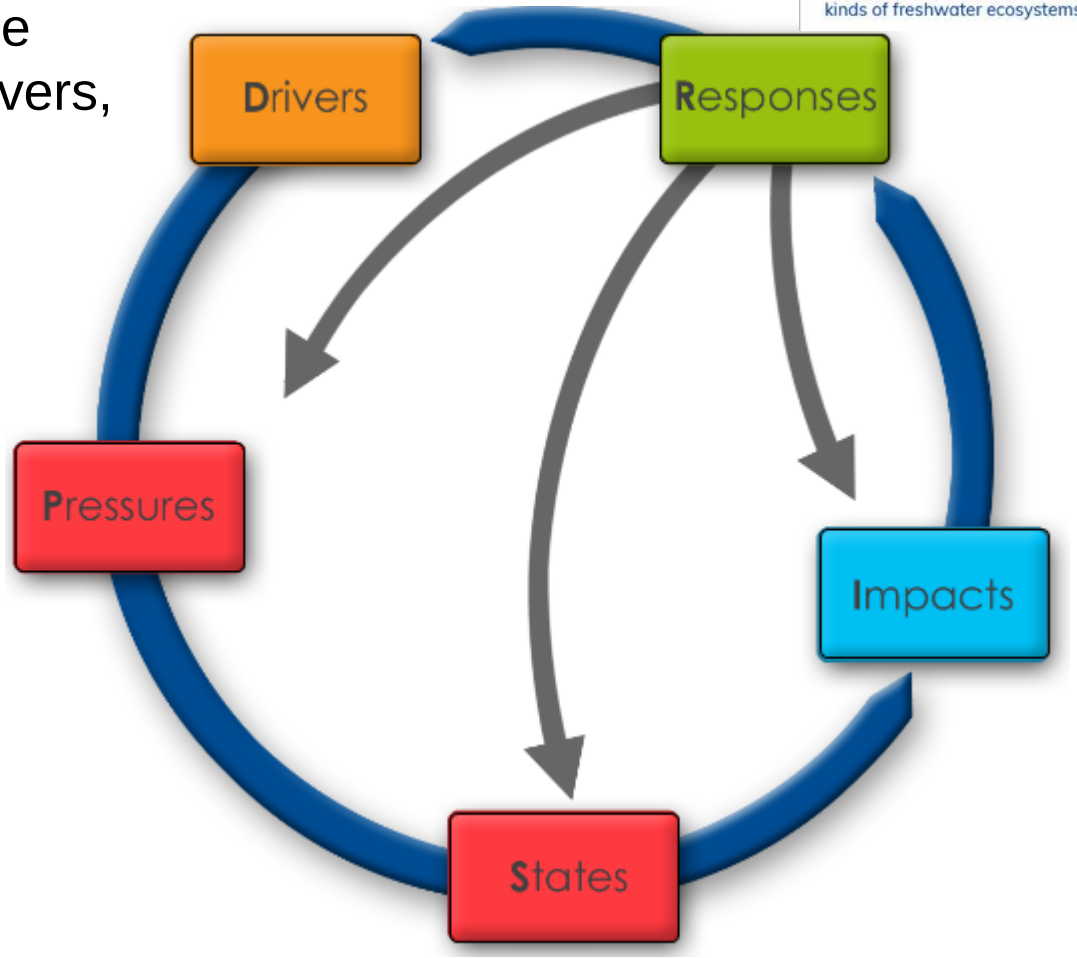
Prediction/Catchment scale perspective for future planning of measures

Tools: Freshwater Information System

MARS FRESHWATER INFORMATION SYSTEM - FIS

Find background information on the effects of multiple stressors and options to mitigate them as well as example case studies in all kinds of freshwater ecosystems

Factsheets illustrate impacts of multiple pressures and provide overview of most common drivers, and responses (measures) to mitigate impacts

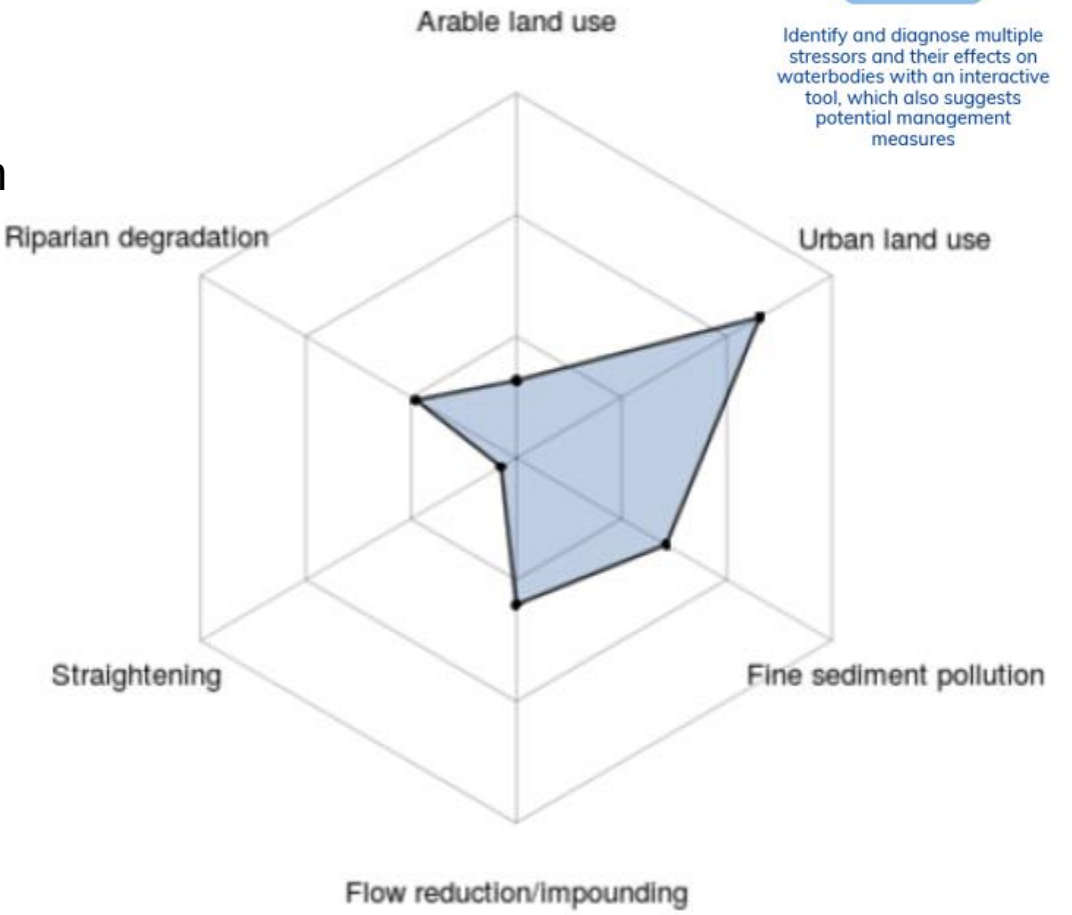


Tools: Diagnostic tool to assess relative importance of several pressures

Identify and diagnose multiple stressors and their effects on waterbodies with an interactive tool, which also suggests potential management measures

- Based on the status for a BQE, the tool calculates the contribution of each pressure to the deterioration.

- The example shows urban land use as most important, while fine sediment pollution and flow reduction also contributes to deteriorate the ecological status of benthic fauna in a river.



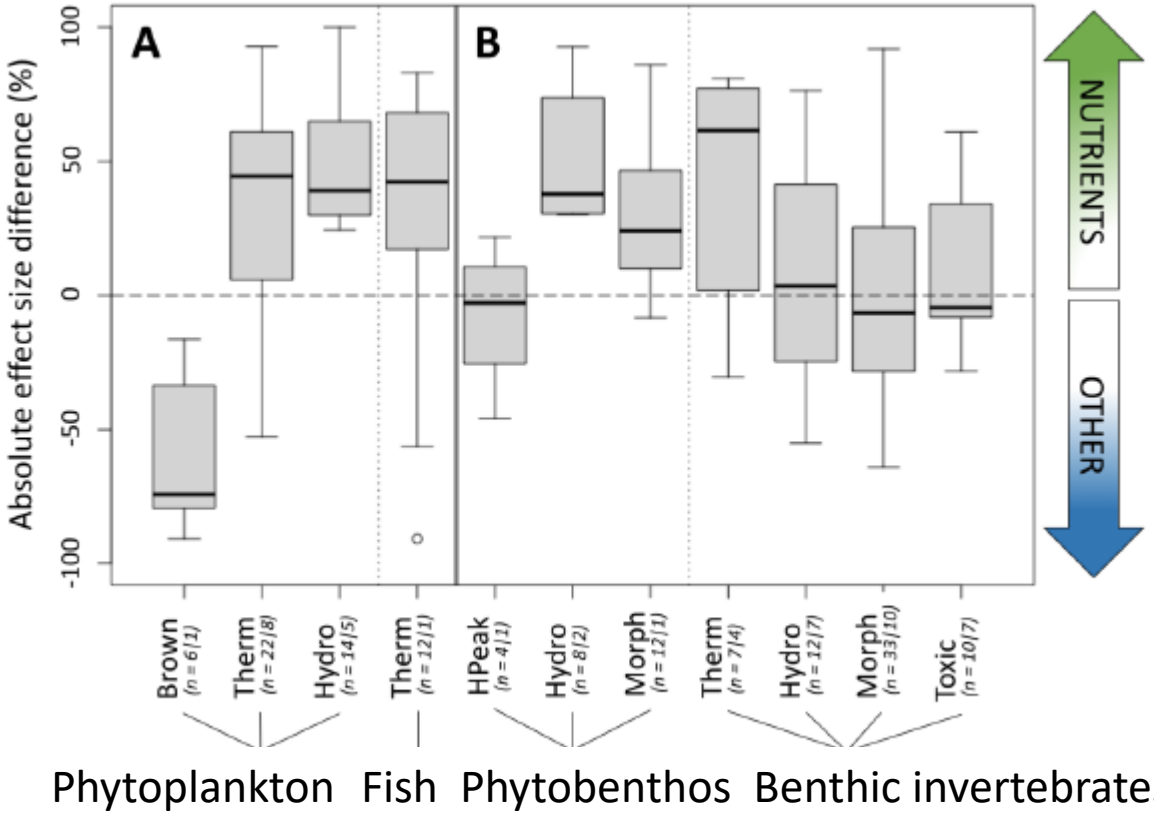
Tools: Diagnostic tool

- An illustrated cookbook available here: http://www.freshwaterplatform.eu/index.php/mars-diagnostic-tools.html *MARS Deliverable 7.1*.
- The tool is implemented with *Shiny*, a freeware graphical user interface that interactively links to the freeware statistical software program *R* *https://shiny.rstudio.com/* .
- Contact: Christian Feld, University of Duisburg-Essen (UDE)

Relative importance of nutrient pressure versus other pressures on biological quality elements

Nutrients are the primary pressure in most of the MARS studies

A. Lakes B: Rivers



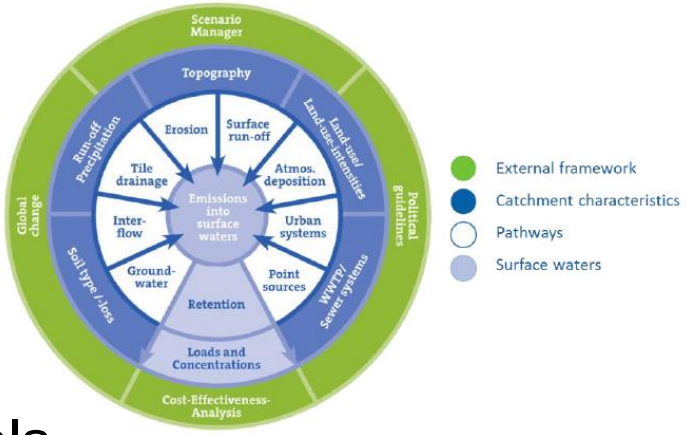
Positive %AES (y-axis) indicate stronger effects by nutrient pressure,
Negative %AES indicate stronger effects by the other pressure

Scenario Analysis Tool

MARS
SCENARIO ANALYSIS TOOL - SAT

Provide a catchment-scale perspective of the multiple stressor situation and estimate the effects of changing multiple stressor combinations due to changes

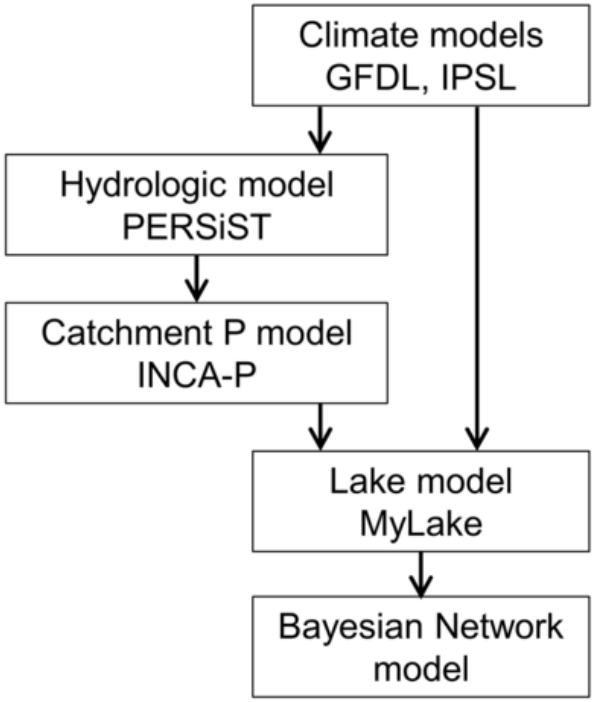
- Estimates the impact of multiple pressures on ecological status for different climate and land-use scenarios:
  - Techno-world (TW)
    - max focus on growth, low sustainability
  - Fragmented world (FW)
    - Inequality, less international regulations and trade
  - Consensus-world (CW)
    - more balanced priorities of growth and sustainability
- Combines hydrological and nutrient models, focus is on nutrient emissions
- Includes the effect of measures on status in the different scenarios

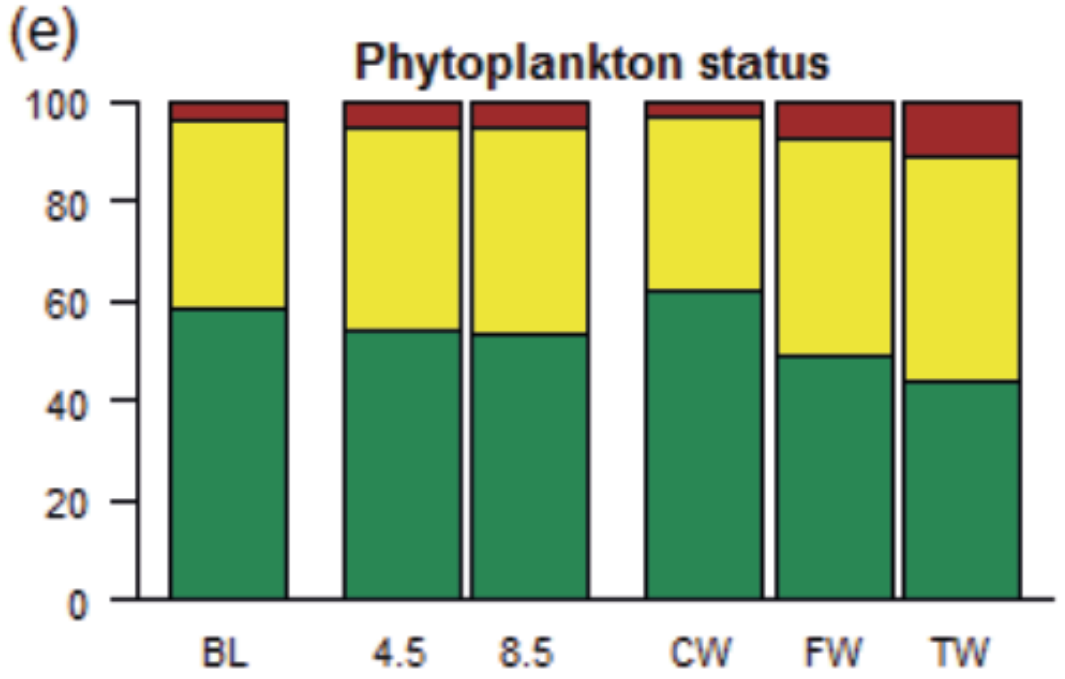


Predicting future change using chained models : Example: Nutrients and climate impacts on phytoplankton

Lake phytoplankton, impact of nutrients and climate change on ecological status (Good, Moderate, Poor/Bad) for phytoplankton in the future (2050-2070).

(Lake Vansjø, Norwegian case study from MARS WP4: Couture et al., 2018)





BL: Baseline Climate Nutrient pressure (TP)

CW: less P, FW: more P, TW: even more P

Climate change has a small negative impact on phytoplankton status, but nutrient management is more important than climate

Multi-pressures interactions

- ***None (Additive)***: Multi-pressure effects equal the sum of single pressure effects.
- ***Synergistic*:** Multi-pressure effects are larger than the sum of single pressure effects
  - One pressure **enhances** effects of the other pressure
- ***Antagonistic*:** Multi-pressure effects are smaller than the sum of single pressure effects.
  - One pressure **dampens** effects of the other pressure

Management implications of interactions

- **Interactions can give** *"Ecological surprises":*

- **Synergistic** *(e.g. Nutrients & Temperature)*
  - Combined effect is *larger* than sum of single effects.
  - May require more protective nutrient standards.

- **Antagonistic** *(e.g. Nutrients & Hydropeaking in rivers)*
  - Combined effect is *smaller* than sum of single effects.
  - Requires combined stressor mitigation to avoid worsening.

Consistent interactions of two pressures, example 1

#1a Nutrients and temperature effects on phytoplankton

Category	Type	BQE	Stressor 1	Stressor 2
Lakes and rivers	Nutrient-limited lakes and rivers	Phyto-plankton	Nutrients	Temperature

Interaction: *Synergistic*

Reason: *Accelerated primary production of opportunistic phytoplankton species*

Management: *The ambition level of nutrient reduction measures should be enhanced.*

Consistent interactions of two pressures, example 2

#2 Nutrients and browning effects on phytoplankton

Category	Type	BQE	Stressor 1	Stressor 2
Lakes	Northern stratified lakes	Phyto-plankton	Nutrients	Browning

Interaction: *Antagonistic*

Reason: *Changes in the light quality (lack of blue light) and/or adsorption of phosphorus to humic substances*

Management: *The ambition level of nutrient reduction measures can be decreased, as the risk of cyanobacterial blooms are less in humic lakes.**

* Potential risk for blooms of other harmful algae (e.g. *Gonyostomum semen*) should also be taken into account.

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Consistent interactions of two pressures, example 3

#5 Nutrients and morphological alterations (channelization) on benthic invertebrates and fish

Category	Type	BQE	Stressor 1	Stressor 2
Rivers	Any type of river	Benthic invertebrates and Fish	Nutrients	Channeli-zation

Interaction: *Antagonistic*

Reason: *Faster current velocity and better oxygen exchange*

Management: *If morphological restoration measures are applied nutrient reduction measures still are needed.*

Consistent interactions found in MARS: Impacts (**syn:+/ant:-**) and implications for measures (↑↓)

Multi-pressures	Rivers	Lakes	Transitional
Nutrients & warming	Phytobenthos, + Measures: ↑	Phytoplankton + Measures: ↑	
Nutrients & browning		Cyanobacteria – Measures: ↓	
Nutrients & High flow	Phytobenthos – Measures: ↓	Phytopl – shallow ↓ Phytopl + deep ↑	
Flow variation & morph pressures	Fish + Measures: ↑	Macrophytes + Measures: ↑	
Low flow & warming	Fish + Measures: ↑		
Nutrients & morph pressures (channelisation)	Benthic fauna – Measures: ↓		

Recommendations on management strategies

- Multi-pressures, but no interactions:
  - Plan measures for each pressure separately
  - Prioritise measures to reduce dominating pressure first

- Antagonistic multi-pressures
  - e.g. hydropeaking dampens effects of nutrients in rivers
  - Prioritise measures against the non-antagonist (e.g. nutrients)
    - Reducing the antagonist (e.g. hydropeaking) without prior mitigation of the other pressure (e.g. nutrients) would result in aggravated pressure effects of the other pressure (e.g. nutrients)

- Synergistic multi-pressures
  - e.g. climate change and nutrients in lakes
  - requires increasing mitigation efforts (e.g. tightening nutrient standards and/or putting additional measures in place to reduce nutrients).

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Future of WFD: How to improve?

- Web-conference and questionnaire collecting inputs from 100 experts in autumn 2017 on three major topics:
  - Monitoring and assessment systems
  - Management measures
  - Policy integration
- Article with major results published (Carvalho et al. 2019)

Science of the Total Environment 658 (2019) 1228–1238

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Protecting and restoring Europe's waters: An analysis of the future development needs of the Water Framework Directive

Laurence Carvalho [a,*], Eleanor B. Mackay [b], Ana Cristina Cardoso [c], Annette Baattrup-Pedersen [d], Sebastian Birk [e], Kirsty L. Blackstock [f], Gábor Borics [g], Angel Borja [h], Christian K. Feld [e], Maria Teresa Ferreira [i], Lidija Globevnik [j], Bruna Grizzetti [c], Sarah Hendry [k], Daniel Hering [e], Martyn Kelly [l], Sindre Langaas [m], Kristian Meissner [n], Yiannis Panagopoulos [o], Ellis Penning [p], Josselin Rouillard [q], Sergi Sabater [r], Ursula Schmedtje [s], Bryan M. Spears [a], Markus Venohr [t], Wouter van de Bund [c], Anne Lyche Solheim [m]

https://www.sciencedirect.com/science/article/pii/S004896971835126X.

Future of WFD:
How to improve monitoring and status assessment?

- Use CIS guidance *Strategic design of monitoring,*
  - ***select representative monitoring sites***
- Monitoring the effects of restoration measures
  - Use early responding indicators, including supporting elements (hydro-morphology , physico-chemistry)
- Apply new monitoring tools:
  - Earth observation, genomics (e-DNA), automated monitoring platforms, citizen science
  - But ensure the links to existing BQE indices

- Making WFD success more visible
  - Display progress of individual BQEs

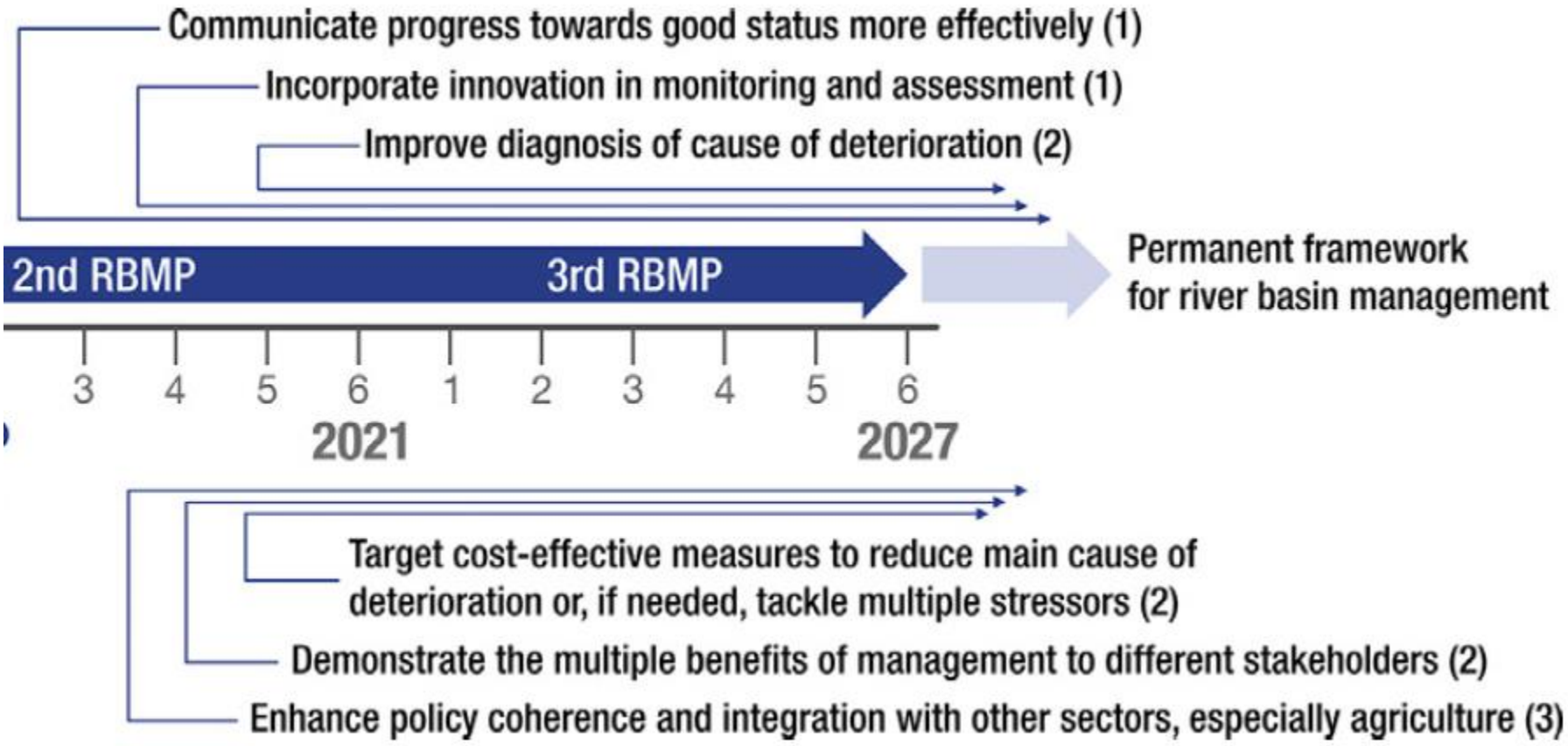
Future of WFD: Selecting management measures

- Check whether management measures are sufficient to cope with multi-pressure interactions
- Evaluate the benefits gained from improving ecological status by using *ecosystem service indicators*
- Prioritise multi-benefit measures, e.g. restoration of riparian zones and floodplains
- Lack of progress towards good status:
  - Insufficient measures or delayed recovery?
  - Communciate to sectors, local politicians and the public that responses to measures takes time (sometimes decades for full recovery)

Future of WFD: Policy integration

- Integration with *Common Agricultural Policy*
  - Enable extensification of agriculture in riparian zones
- Regulating pollution acts:
  - polluter paying not to pollute
- Climate Change, including floods, droughts and water scarcity.
  - Floods Directive to be incorporated into WFD, making synergies in case of natural flood protection measures more explicit
- Ecosystem service approach:
  - Integration of land and water policy goals, make costs and benefits of restoration more explicit.

Future of WFD: How to improve? Summary



Thank you for your attention

Lake Nisser, Telemark, Norway, drought-summer 2018
Photo: Anne Lyche Solheim