Funded by the European Union within the
7th Framework Programme, Grant Agreement 603378.
Duration: February 1st, 2014 – January 31th, 2018

Deliverable 8.4: Fact sheets including a set of illustrations

Version 3 (Month 48)

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Due date of deliverable: Month 18, 26, 48
Submission date: **Month 18 (v1), Month 26 (v2), Month 48 (v3)**

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Content

Introduction

Europe’s surface waters are affected by multiple stressors, ranging from water pollution of urban point and agricultural diffuse sources to habitat alteration by river engineering and maintenance management. Effective multi-stressor mitigation not only requires in-depth knowledge on the causal pathways to convey practical management solutions, but also appropriate dissemination and communication strategies to impart the existing knowledge, to generate understanding and to distribute relevant evidence.

Multi-stressor settings and their effects on the ecosystem are complex and often complicated to grasp, even for the experts familiar with this topic. When, for instance, multiple stressors act simultaneously, interactions often occur that either exacerbate the impact on the ecosystem compared to the sum of the single stressor effects (so-called “synergistic effects”), or weaken the impact on the ecosystem (so-called “antagonistic effects”). Insights into these interactions are of paramount importance to water managers as the choice of appropriate management strategies depends on this knowledge.

The MARS project thus puts emphasis on practical outputs and the dissemination of scientific findings, allowing to establish strong linkages between the scientists and the practitioners 'on the ground'. One particular aim of the MARS communication and dissemination strategy is to encourage the scholars to leave their ‘ivory tower’ and to propagate their knowledge in a digestible format. Especially the freshwater blog run by the project already proved effective in this regard.

The report at hand forms an essential part of the MARS strategy to communicate the project’s key-approaches and -messages generated from the various research strands conducted in MARS. The fact sheets that constitute the core of this report are designed as “quick feeds” for a diverse target-audience, including academics, administrators, practitioners and policy-makers. Each fact sheet is written in a non-technical language of brief and concise style, not exceeding two pages in length. A set of high-resolution illustrations relevant in the particular context accompanies each fact sheet. These illustrations either visualize thematic contents or generate corporate design for specific MARS products.

The fact sheets are placed at a central position on the MARS public website (http://mars-project.eu/index.php/fact-sheets.html) to allow for easy internet access. The publication of this deliverable will be featured in a post on the freshwater-blog. Furthermore, the individual fact sheets will be circulated via email to the MARS consortium and external contacts, including members of the target-audience specified above.

This deliverable version covers the following fact sheet topics:

- MARS fact sheet #01: *Multiple stresses and freshwater ecosystem service provision: the MARS 'cookbook' methodology*
- MARS fact sheet #02: *Freshwater Information Platform – www.freshwaterplatfrom.eu*
- MARS fact sheet #03: *MARS scenarios and storylines*
- MARS fact sheet #04: *Multiple stresses on Europe's freshwaters: emerging challenges for science, policy and management*
- MARS fact sheet #05: *Freshwater Blog – a tool for wide range dissemination*
- MARS fact sheet #06: HyTEC: investigating the effects of pulse releases of water from hydropower on aquatic life
- MARS fact sheet #07: Provisioning Freshwater Ecosystem Services
- MARS fact sheet #08: Regulating and Maintaining Freshwater Ecosystem Services
- MARS fact sheet #09: Cultural Freshwater Ecosystem Services
- MARS fact sheet #10: Storylines: writing the future for effective water management – Fragmented World
- MARS fact sheet #11: Storylines: writing the future for effective water management – Consensus World
- MARS fact sheet #12: Storylines: writing the future for effective water management – Techno World
- MARS fact sheet #13: The MARS Diagnostic Analysis Tool (DAT
- MARS fact sheet #14: Four key messages of the MARS project

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MARS fact sheet #01

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Multiple stresses and freshwater ecosystem service provision: the MARS 'cookbook' methodology

The MARS project assesses the impacts of multiple stressors on the provision of ecosystem services from freshwater ecosystems, under different climatic and land-use scenarios. The European Union FP7 funded project has developed an innovative new assessment methodology – termed a 'cookbook' – to allow scientists, environmental managers and policy makers to quantify the relationships between multiple stresses and ecosystem service provision and value. The cookbook provides an invaluable tool to support the implementation of the Water Framework Directive in Europe.

Ecosystem Services and MARS

Ecosystem services are the benefits that people obtain from ecosystems, which contribute both directly and indirectly to human well-being. Their designation helps highlight and value the key roles that biodiversity and ecosystem functions play in providing multiple benefits to humans, such as food, clean water and sanitation. This in turn, helps support, legitimate and strengthen environmental policy and conservation.

The MARS cookbook is a new integrated assessment methodology that allows users to assess how the impacts of multiple stresses affects the services that freshwater ecosystems can provide. Increasingly complex 'cocktails' of multiple stresses such as nutrient pollution, water abstraction and flooding affect Europe's freshwater ecosystems. Such multiple stressors can interact in an ecosystem to potentially intensify or weaken their individual, additive effects, posing new challenges for environmental management. In collaboration with a number of other European Union projects, MARS is undertaking experimental and modelling analyses to better understand the effects of multiple stressors on freshwaters, particularly in terms of the ecosystem services that they provide.

Service capacity, flow and benefits

Building on the expertise of project partners and insights from wider scientific and economic research, the MARS cookbook uses a cascade model methodology that links the structure and function of an ecosystem to its service provision. This methodology includes the *capacity* of an ecosystem to provide a service (assessed using biophysical data), the actual *flow* of the services used by humans (assessed using socio-economic data), and finally the *benefits* that ecosystem services provide.

By assessing both the capacity of an ecosystem to provide services, and the actual use of these services, the MARS cookbook methodology allows assessments on the *sustainability* of ecosystem use to be made. The unsustainable use of ecosystem services may become an additional stressor of the ecosystem's health and status.

The MARS service cookbook

The MARS cookbook methodology is split into four steps. The first is *scoping*, the process by which the aquatic ecosystem and ecosystem services of interest are selected and mapped, and the spatial and temporal scale of analysis are defined. The second step is to develop the *assessment framework*, through which multiple stressors and ecosystem services are linked in a stressor-ecological status-ecosystem service series. A key step here is to check whether the ecological indicators used (e.g. biodiversity, ecological status) capture the effects of the stressors, and can be linked to the ecosystem services of interest.

The third step is *assessment*, where biophysical indicators are organised according to the ecosystem's capacity to deliver a service, its actual use, and the resulting human benefits provided. Indicators are organised in three categories: capacity (e.g. biomass of commercial fish species); flow (e.g. fish catch); and sustainability (e.g. % of catch within sustainable limits). Their ability to indicate ecosystem stress and / or service provision is quantified through the computer modelling of existing ecological data.

The fourth step is *valuation*, to identify the benefits provided by ecosystem services and aggregate them at three scales: water body, catchment and European continent. The valuations are undertaken at appropriate scales to support decision making in River Basin Management Planning. In the valuation process, the ecosystem service, benefit and value are separated, because a service (e.g. water purification) can provide numerous societal benefits depending on the location (e.g. drinking water; swimming areas). The economic value of the ecosystem services provided can then be valued through revealed and stated preference methodologies, and cost-based and benefit transfer approaches.

Further reading

Grizzetti B., Lanzanova D., Liquete C., Reynaud A. (2015) Cook-book for ecosystem service assessment and valuation. JRC Science and Policy Report EUR 27141 EN. Luxembourg Publication Office of the European Union. 136 pp.

Maes J., Hauck J., Paracchini M., Ratamäki O., Hutchins M., Termansen M., Furman E., Pérez-Soba M., Braat L., Bidoglio G. (2013) Mainstreaming ecosystem services into EU policy. Current Opinion in Environmental Sustainability, 5, 128–134.

Figures

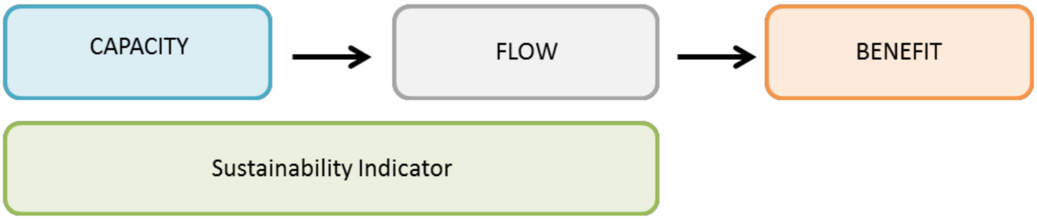

Figure 1: The cascade model - quantifying the capacity, flow and benefits of ecosystem services

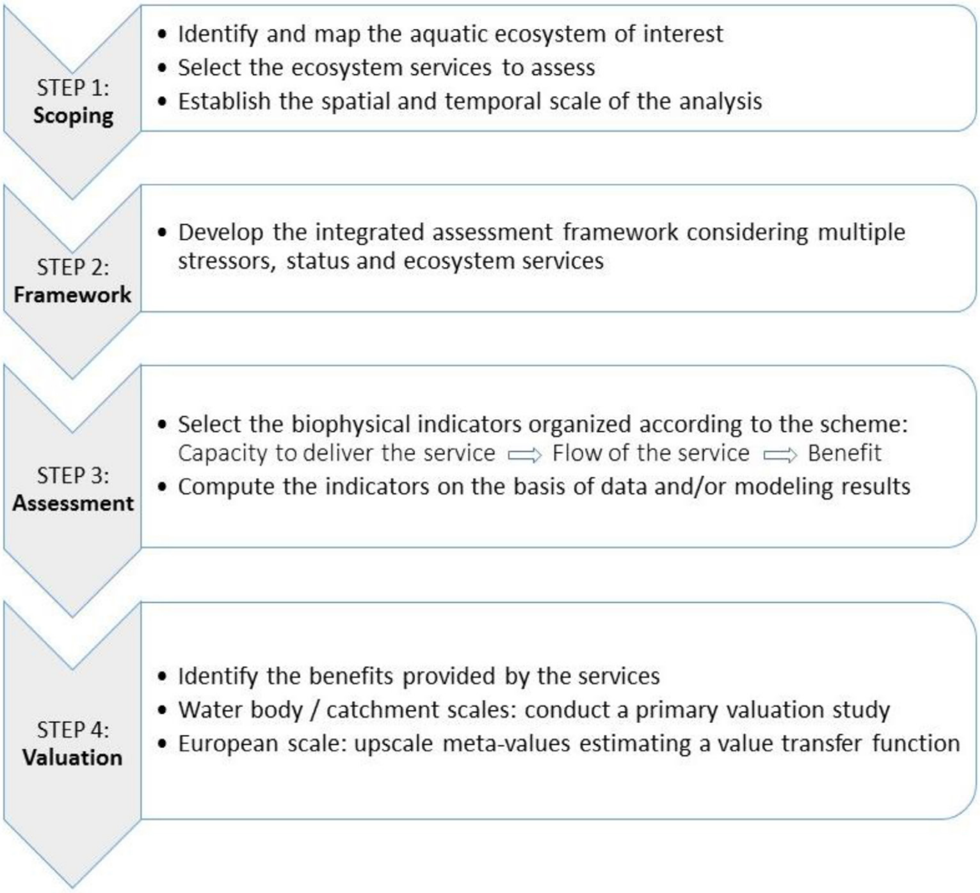

Figure 2: The four steps of the MARS 'cookbook' methodology

MARS fact sheet #02

Freshwater Information Platform – www.freshwaterplatform.eu

Over recent years, many European Union funded research projects have investigated freshwaters – ranging from biodiversity related projects to others focusing on pressures and their effects on European inland waters, including appropriate rehabilitation strategies. However, the data generated by these projects is often difficult for water managers, policy makers, scientific communities and the general public to access and use. In order to make this detailed and wide-ranging knowledge of freshwater ecosystems accessible to all, the Freshwater Information Platform was launched: an interactive website integrating results and original data stemming from finished, on-going, and future freshwater research projects.

The platform contains several complementary sections, either providing access to original data or summarising research results in an easily digestible way. All sections are composed as 'living documents' that will be continuously improved and updated. Pressures such as water pollution, intense land use and climate change are increasingly threatening the health and diversity of European freshwater ecosystems. The Freshwater Information Platform also provides a collection of research tools, information about freshwater-related policies and relevant European and global networks relating to freshwater science and policy.

Scientists are invited to add their data to the platform, publish their research results and share it with other users inside and outside the scientific community. We also invite other research projects to be part of the platform. As a connecting element we have developed a corporate design and a "member sticker", which forms a linking element across different websites.

Member of the
Freshwater
Information
Platform

Platform sections

The "*Freshwater Biodiversity Data Portal*" provides access to data on the distribution of freshwater organisms (such as fishes, insects and algae), both in Europe and worldwide. The portal helps scientists to advertise and publish their data(base) and to provide tools for the discovery, integration and analysis of open and freely accessible freshwater biodiversity data.

Freshwater Biodiversity Data Portal facts	
Number of species:	> 900.000
Total occurrences:	>16millions
Georeferenced occurrences:	>13millions
Visitors per month (first half 2015):	950-1400

The "*Global Freshwater Biodiversity Atlas*" provides a series of interactive maps with different data-layers on freshwater biodiversity richness, threats to freshwaters and the effects of global change on freshwater ecosystems.

Global Freshwater Biodiversity Atlas facts	
Maps online:	35
Maps currently under development	24
Maps data requested/agreed on:	40
Map data-layers:	92
Visitors per month (first half 2015):	2300-3100

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MARS fact sheet #02

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

The "*Freshwater Species Traits Database*" integrates the knowledge on the ecology of about 20,000 species inhabiting European freshwater ecosystems, including information on their ecological preferences (e.g. species' habitats, nutrition, pollution tolerance).

Freshwater Species Traits Database facts

	Taxa	Ecological pref.
Fish:	654	21
Macroinvertebrates:	8586	40
Macrophytes:	1083	5
Diatoms:	8868	36
Phytoplankton:	1976	4
Registered users > 800		

The "*Freshwater Metadata*" section provides an overview of hundreds of major data sources related to freshwater research and management and offers the option to publish such data in the Freshwater Metadata Journal.

This easy way of publishing freshwater (biodiversity) related metadata is aiming to change the perception about data publishing in the freshwater scientific community.

Freshwater Metadatabase facts

Publications (2015):	8 (incl. 4 MARS publications)
Metadata:	314 databases
Publicly available:	212 databases (incl. 19 MARS databases)

The vibrant and widely-read "*Freshwater Blog*" publishes features, research highlights, interviews and podcasts on freshwater science, policy and conservation.

Freshwater Blog facts

Blog posts:	> 310
Overall readers:	> 200.000 (90.000 wthin MARS)
Readers per month: (Jan-Jun 2015)	5000 - 12.000

Further reading

Schmidt-Kloiber A., & Hering D. (2015) www.freshwaterecology.info – An online tool that unifies, standardises and codifies more than 20,000 European freshwater organisms and their ecological preferences. Ecological Indicators, 53, 271–282.

Schmidt-Kloiber A., Vogl R., De Wever A., & Martens K. (2014) Editorial - Launch of the Freshwater Metadata Journal (FMJ). Freshwater Metadata Journal, 1, 1–4.

St. John, R. "The Freshwater Information Platform is launched." The Freshwater Blog, May 6, 2015.

St. John, R. "Freshwaterecology.info: an online database for European freshwater species." The Freshwater Blog, July 6, 2015.

St. John, R. "A new way of publishing information on freshwater datasets." The Freshwater Blog, October 22, 2014.

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MARS fact sheet #02

MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

Corporate design

Logo

Freshwater Information Platform

Freshwater Information Platform

Button for websites

Member of the Freshwater Information Platform

Simple icon for websites or other uses

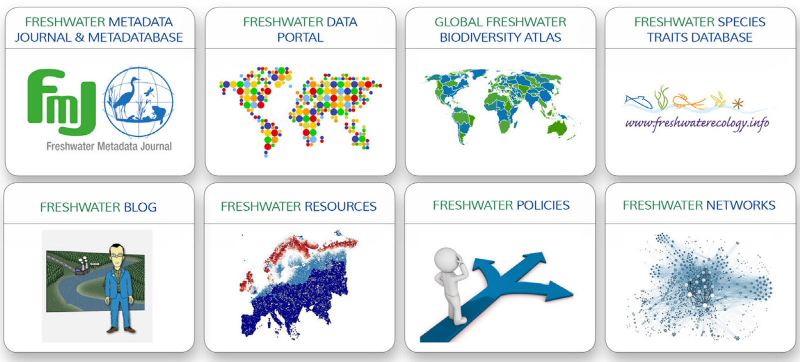
Colors

RGB: 0 60 143
CYMK: 98 85 1 0
HEX: #003d90

RGB: 37 126 79
CYMK: 82 28 78 10
HEX: #257E4F

RGB: 151 191 13
CYMK: 50 0 99 0
HEX: #97BF0D

Iconset for website



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MARS fact sheet #03

MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

MARS scenarios and storylines

The multiple combinations of drivers and pressures for a given aquatic system for the current situation are shaped by its historical and present climatic, managerial and socio-economic conditions. The future combinations of drivers and pressures depend on the future climatic and socio-economic scenarios considered plausible for this system. Within MARS, scenarios and storylines are used to project the impacts of multiple stressors on aquatic ecosystems. They deliver a qualitative framework and, where possible, quantitative data for modellers to run simulations.

Various future climatic and socio-economic scenarios have been chosen within MARS to define three storylines at European level. Each storyline frames the conditions leading to certain combinations of drivers and pressures for Europe. These storylines have been downscaled to case-study catchment-level using the expert knowledge of the scientists working on the 16 MARS case-study catchments, and the stakeholders of these catchments.

What are storylines and scenarios within MARS?

A storyline is a narrative about a fictive sequence of events that could take place in the near future. Within MARS, storylines describe several aspects of economic, environmental, political and climatic developments and are mainly defined focusing on the different fashions to manage and regulate drivers and pressures impacting aquatic systems.

A scenario is a coherent description of alternative hypothetical futures that reflects different perspectives on past, present and future developments. Within MARS, we used climatic and socio-economic projections as scenarios that served as the basis to define our storylines.

Development of MARS storylines

Storylines in MARS are built on scenarios. The combination of certain climate scenarios and socio-economic scenarios set the basis for the narratives. We used the Representative Concentration Pathways (RCPs) and the Shared Socioeconomic Pathways (SSPs) to define our storylines.

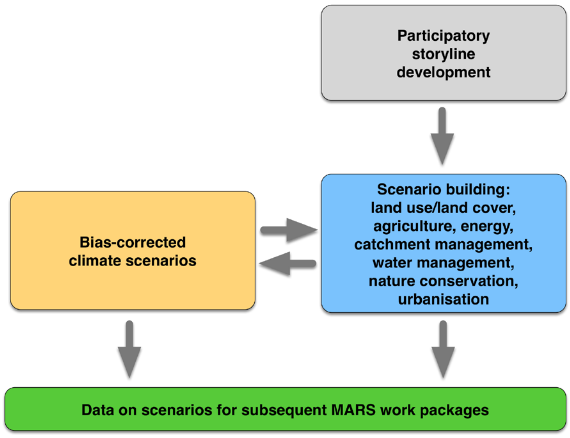

Figure 1: Development of the MARS storylines

MARS storylines

The time-horizon for the storylines of MARS is 2030 and 2060.

Storyline 1: 'Techno world' or 'Economy rules'

This is a world driven by economy. A fast economic development increases the use of energy. Policies are not focused on the environment but on enhancing trade and benefitting the economic growth. Climate is changing rapidly. This world is based on a combination of SSP5 and climate scenario 8.5.

Storyline 2: 'Consensus world'

Economy and population grow at the same pace as now. Policies to protect the environment are continued after 2020, and the preservation of nature is regulated by the government. This world is based on a combination of SSP2 and climate scenario 4.5.

MARS fact sheet #03

Storyline 3: 'Fragmented world'

This world is characterized by an unequal development of the different countries. International trade agreements are stopped and each country needs to fight for its own survival. Environment is just protected by rich countries at a local scale, but in general no attention is paid to the preservation of nature. This world is based on a combination of SSP3 and climate scenario 8.5.

MARS quantitative storylines

These qualitative storylines have been translated to quantitative data. Grids of 0.5 x 0.5 degrees resolution were provided for several parameters (e.g. temperature, precipitation, water abstraction, run off, flood risk areas, nitrate losses), covering Europe for the three storylines and the two time-horizons. The quantitative values used in predictive modelling were derived from existing projects and modelling tools (e.g. ISI-MIP, SCENES, CLIMSAVE).

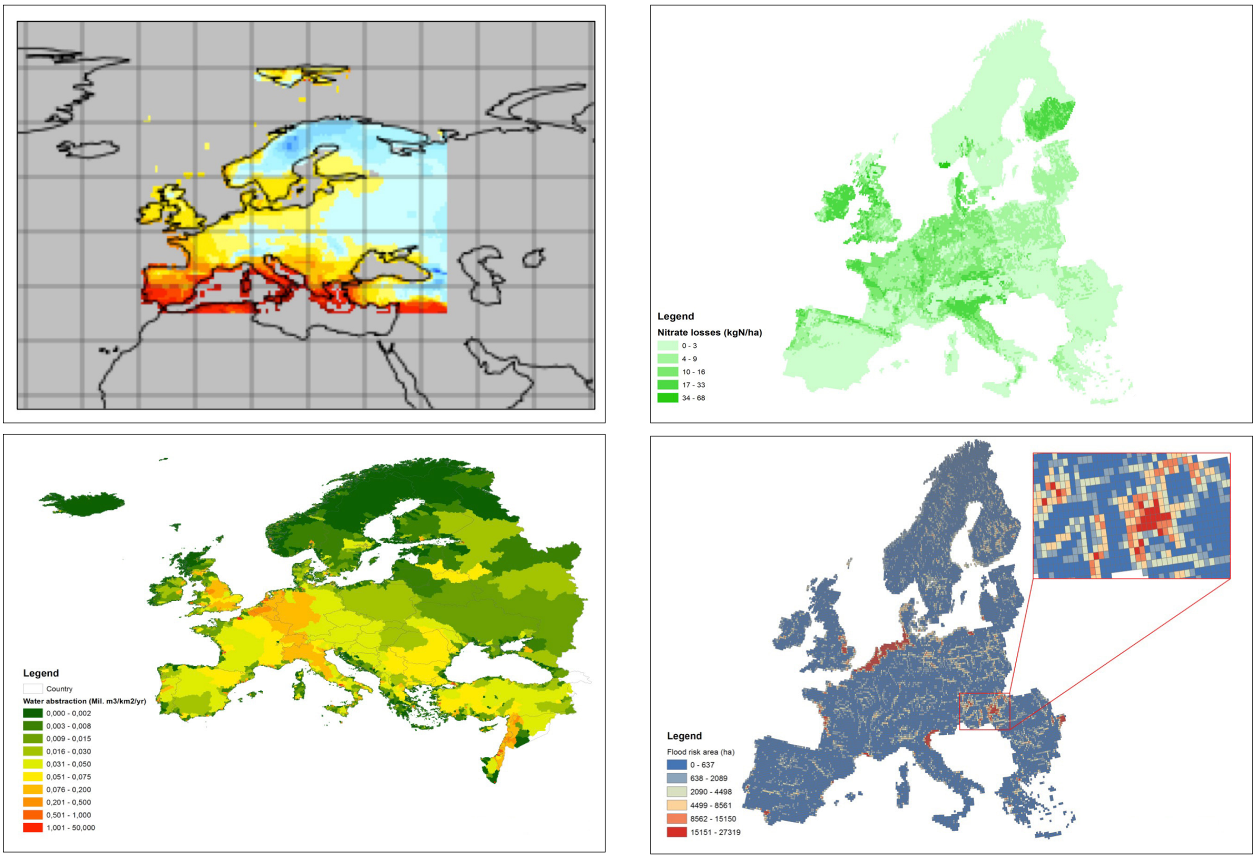

Figure 2: Grids showing quantitative storyline data for the time-horizon 2030

Further reading

Faneca Sanchez, M. et al. (2015) Report on the MARS scenarios of future changes in drivers and pressures with respect to Europe's water resources. Part 4 of MARS Deliverable 2.1: Four manuscripts on the multiple stressor framework.

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MARS fact sheet #04

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Multiple stresses on Europe's freshwaters: emerging challenges for science, policy and management

The interactions and impacts of multiple stressors on aquatic ecosystems is one of the key challenges for freshwater science, policy and conservation. Whilst there are many success stories of pollution being reduced on rivers and lakes across the continent, Europe's freshwaters are still subject to multiple stresses, many of which are complex and poorly understood. In order to safeguard the health and diversity of Europe's freshwaters, and the ecosystem services that they provide to humans, we need to better understand and manage the challenge of multiple stressors.

Multiple stressor combinations in European freshwaters

A 2012 report by the European Environment Agency 'European Waters - Assessment of Status and Pressures' outlines how multiple stressors such as water pollution, water scarcity, flooding, water abstraction and flow modifications increasingly affect Europe's surface waters (i.e. rivers, lakes, transitional and coastal waters). From data collected as part of the Water Framework Directive monitoring, it is evident that more than 40% of European water bodies are negatively impacted by multiple stressors.

In European lakes and rivers, the most common two-stressor combination is diffuse water pollution combined with hydromorphological pressures. For example, this might describe a river fragmented by weirs and dams and subject to nutrient pollution from agricultural fertilisers. In transitional and coastal environments, the most common stressor combination is diffuse pollution with a group of 'other' stressors including overfishing, the impact of alien species and waste disposal.

Similarly, a 2015 literature review by MARS scientist Peeter Nõges and colleagues dealing with multistressor effects found that most scientific studies also address the combined impact of nutrient pollution and hydrological alteration.

Interactions and impacts of multiple stressors: synergism and antagonism

New scientific research suggests that such stressors can interact in complex and dynamic 'cocktails' to potentially intensify or neutralize their individual and additive effects on the environment. However, these interactions are not yet fully understood: a knowledge deficit which poses challenges for the management of aquatic environments and the ecosystem services they provide, particularly in the context of on-going climatic change. The cumulative impact of multiple stressors on the environment does not always equal the sum of the individual parts. Instead, synergistic and antagonistic interactions between multiple stressors are increasingly being observed.

Synergistic interactions between multiple stressors create effects that are greater than the sum of the individual stressor effects. Synergistic interactions can be expressed in a formula as 1+1=3. *Antagonistic interactions*, on the other hand, occur when certain stressors cancel out the impacts of others. Antagonistic interactions can be expressed in a formula as 1+1=1.

The interactions and impacts of multiple stressors: challenges for aquatic science, policy and management

Both interactions pose challenges for the management of aquatic systems. Synergistic interactions mean that ecosystem change and decline might be underestimated if assessed on the cumulative sum of individual stressors. Similarly, new stressors in an ecosystem may have unpredictable effects as a result of such synergistic interactions. Antagonistic interactions mean that environmental management of a single stressor may have the unintended effect of worsening detrimental ecosystem effects, because the antagonistic, nullifying between-stressor effects are removed.

There are additional uncertainties about the variable impacts of multiple stressors in different types of aquatic ecosystems. Peeter Nõges and colleagues found that in lakes, the impacts of multiple stressors had more significant impacts on ecological change than single stressors. However, in transitional and coastal waters, single stressors were more damaging than multiple combinations.

The MARS project: addressing the challenge of multiple stressors

Multiple stressor conditions in aquatic environments are no longer the exception, but the norm. However, scientific knowledge on their interactions and impacts is still incomplete and inconclusive. The European Union FP7 MARS project is designed to address the shortfall in knowledge, and to provide policy-relevant information on multiple stressors at a range of scales necessary to inform the Water Framework Directive and River Basin Management Planning.

Further reading

European Environment Agency (2012) European waters – assessment of status and pressures. EEA Report n°8. EEA, Copenhagen.

Nõges P., Argillier C., Borja Á., Garmendia J. M., Hanganu J., Kodeš V., Pletterbauer F., Sagouis A., Birk, S. (2015) Quantified biotic and abiotic responses to multiple stress in freshwater, marine and ground waters. Science of The Total Environment. doi:10.1016/j.scitotenv.2015.06.045

Figures

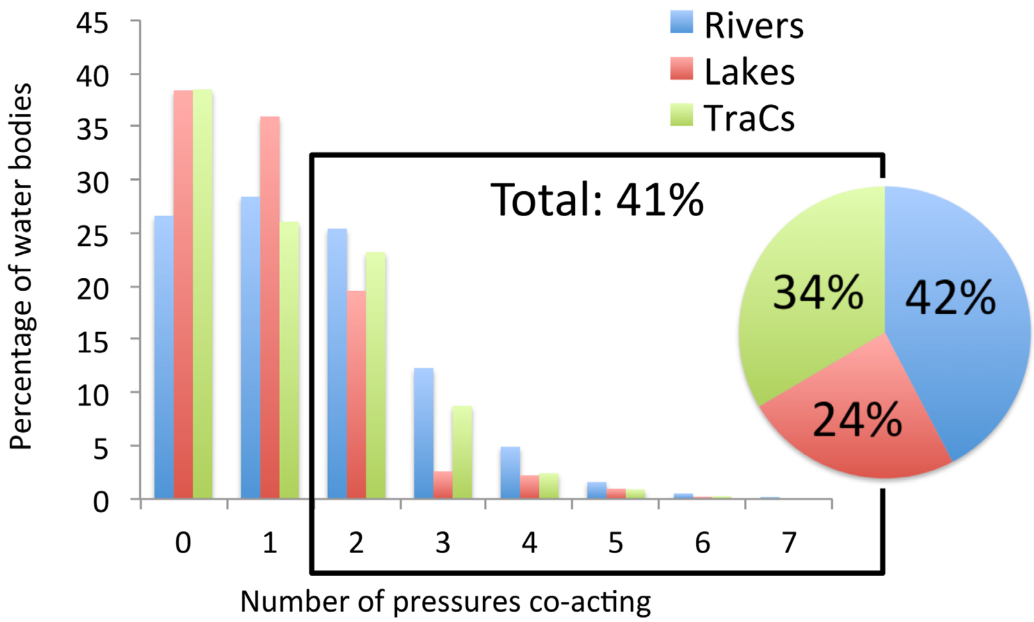

Figure 1: Multiple pressures acting on EU surface waters
Data source: WISE WFD database (EEA 2015; n = 108,130 water bodies of 26 EU Member States)
TraCs: Transitional and Coastal waters

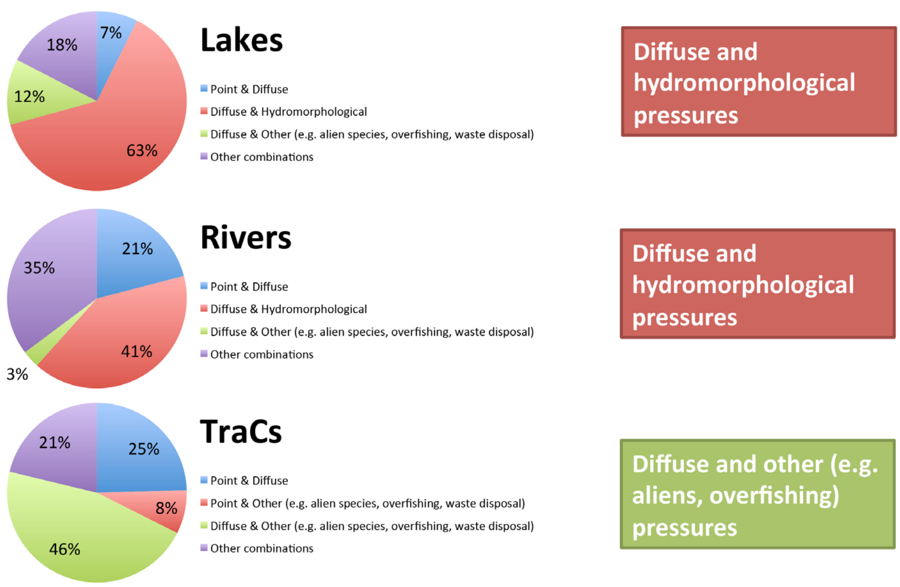

Figure 2: Two-pressure combinations acting most frequently
Data source: WISE WFD database (EEA 2015; n = 26,345 water bodies of 26 EU Member States)
TraCs: Transitional and Coastal waters

MARS fact sheet #05

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Freshwater Blog - a tool for wide range dissemination

With the start of MARS one of the first tasks was to transition the blog from the BioFresh project to the MARS project, involving a renaming and rebranding of the site and associated social media. Since then, one blog post on freshwater science, policy or conservation was published on a weekly basis. The blog is an excellent tool for a wide spread dissemination and communication and to reach a large group of readers all over the world on a regular base.

Editorial framework

We have assigned writing the blog posts to a native speaker with biological and journalistic background. He has devised an editorial framework for publishing, which effectively targets different audiences relevant to the work of MARS, comprising four broad types of posts. This framework ensures that there is a diverse, topical and engaging range of material on the blog at all times, which can be accessed and enjoyed by a variety of different target audiences.

1. MARS and related projects

These are posts that directly communicate and profile the work of the MARS project and individual scientists; or of related EU projects such as DESSIN and GLOBAQUA. Such posts provide an in-depth and engaging look 'behind the scenes' of the project, and provide simple explanations of the project's key (and often complex) focuses. Some examples:

The MARS 'Meet the Team' Series

Reflecting on the Symposium for European Freshwater Sciences in Geneva

Introducing the MARS river and lake experiments

2. New and relevant freshwater science and policy

These are posts that offer analysis and invite debate on new and important scientific publications and policy topics relating to freshwaters. They are designed to attract an interested audience of freshwater scientists, water managers and policy makers. Some examples:

Microplastic pollution: an emerging freshwater stressor

Underwater sound pollution leaves juvenile European eels vulnerable to predators

Why are global crayfish populations declining?

3. Institutional networking

These are posts that intentionally engage with other institutions working on freshwater topics: partly as a means of keeping the blog populated with current, cutting-edge information; and perhaps more importantly as a means of networking with important individuals and institutions, and ensuring the Freshwater Blog and MARS links are circulated around their networks, and in so doing raising the visibility of the MARS project. Examples:

WWF Living Planet Report suggests 76% decline in freshwater biodiversity globally since 1970

Do anglers make good conservationists? An interview with Mark Lloyd of the Angling Trust

4. General public topics

These are posts on topics that are likely to have wide public appeal. These are always targeted to subtly introduce MARS topics (e.g. multiple stress, ecosystem services) but within a wider topic that is easy to engage with, and has the potential to be widely shared. Examples:

Of Soil and Water: outdoor swimming in a naturally filtered urban pool

Beneath the Waterline: an interview with underwater filmmaker Jack Perks

MARS fact sheet #05

Freshwaterblog

In 2014, 52 blog posts were published from February onwards (archive 2014), in 2015, 30 blog posts have been published to the end of July (archive 2015).

Within MARS more then 90.000 visitors have been to the blog website (220.000 visitors in total since the blog is online). In 2015 the number of visitors per month was growing from 4.000 to 12.600 (Jan-June). Readers are coming from all over the world.

MARS social media communications metrics

Aside the blog we use all social media channels for dissemination and communication.

Twitter

The Freshwater Blog twitter is predominantly followed by water scientists, conservationists, managers and other professionals around the world, and has 1.730 followers who receive each post.

LinkedIn

The Freshwater Blog LinkedIn group has 242 members, largely drawn from water scientists, researchers and managers. It is used to post updates from the Freshwater Blog, and to facilitate discussions amongst members.

Soundcloud

The Freshwater Blog Soundcloud page is used to host the project podcasts, which users can then stream, embed and download. The first MARS podcast, an interview with MARS scientist Steve Ormerod, has been streamed 262 times.

Facebook

The Freshwater Blog facebook page was transitioned from the BioFresh Cabinet of Freshwater Curiosities page, and has 284 followers. It is used to share Freshwater Blog posts, and to facilitate discussion amongst an audience of predominantly freshwater and conservation students, researchers and professionals.

MARS fact sheet #05

Figures

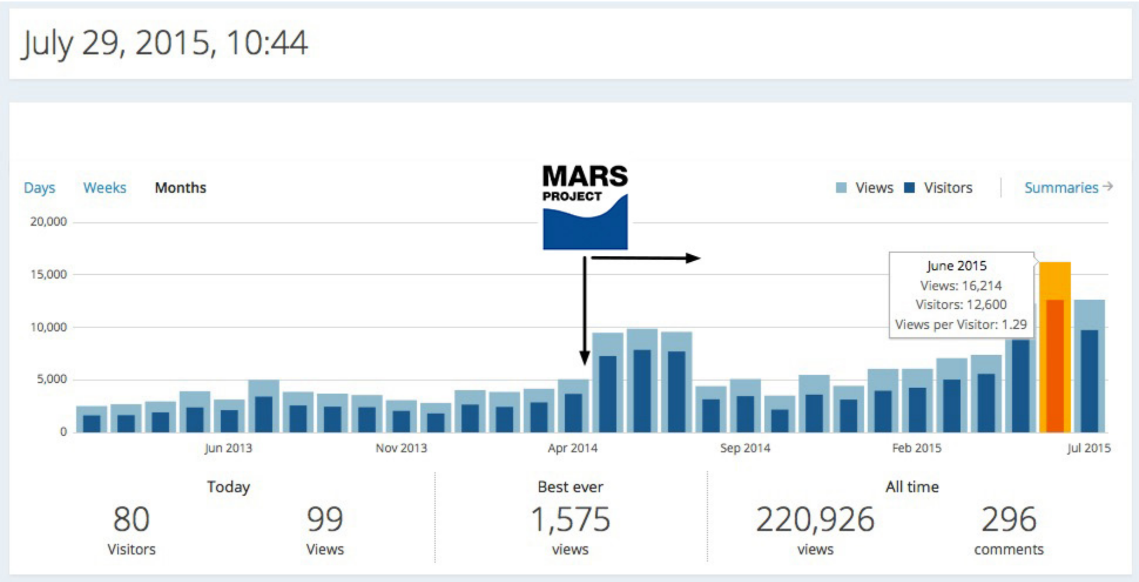

Figure 1: Blog statistics. Development of readers.

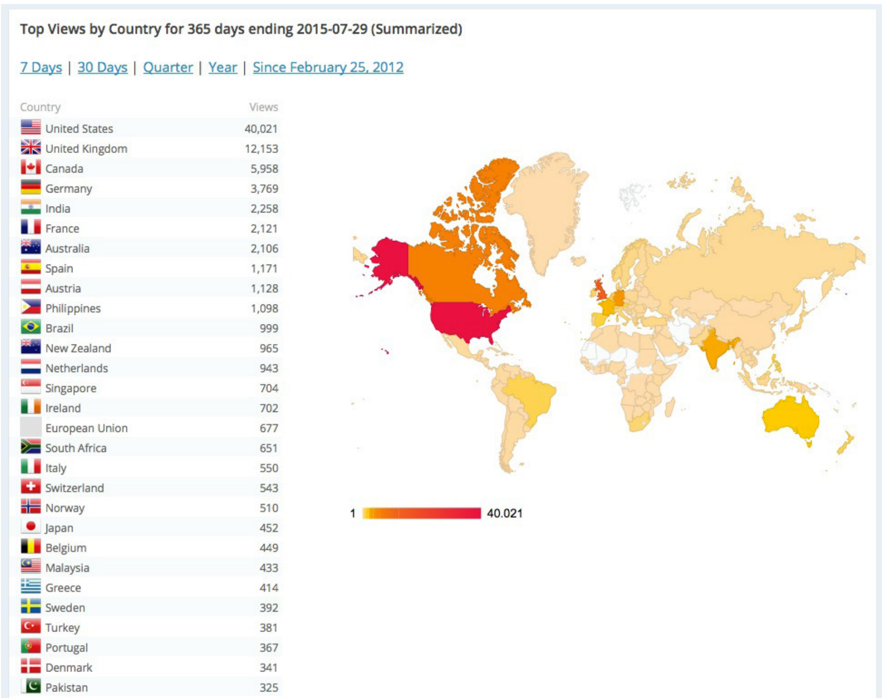

Figure 2: Blog statistics. Readers' origins.

MARS fact sheet #06

MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

HyTEC: investigating the effects of pulse releases of water from hydropower on aquatic life

Hydropeaking and Thermopeaking

Hydropower plants often produce electricity in response to energy demands. This means that their energy production can be intermittent and changeable, which in turn causes pulse releases of water downstream into river systems. This causes rapid and short-term fluctuations in water speed, depth and quantity downstream – a process termed hydropeaking – which can affect the ecology and hydromorphology of the rivers exposed to such changeable and often unpredictable regimes. Fluctuations in water flow caused by releases from hydropower reservoirs can also alter the temperature of the river downstream – causing reductions in summer and increases in winter – a process termed thermopeaking. Hydropeaking and thermopeaking from hydropower releases are now widespread and common occurrences in many European mountain rivers and streams.

HyTEC experiments in the Austrian Alps

A team of researchers from the European Union MARS Project are carrying out ongoing experiments on the effects of hydropeaking and combinations of hydropeaking and thermopeaking on aquatic life at a facility known as HyTEC close to Lake Lunz in the Austrian Alps.

HyTEC site near Lake Lunz, Austria

The team have studied how algae, macroinvertebrate and fish populations are impacted by hydropower releases, using a series of experimental channels where variables such as water flow and temperature can be controlled and ecological responses monitored.

The effects of hydropeaking and nutrient addition on benthic algae growth

Benthic algae are a key component of aquatic food webs. They are useful indicators of stream water quality, and their short lifecycles mean that algae populations can provide ongoing, responsive records of environmental change. Frequent hydropeaking events can affect the growth of benthic algae and affect their community structures and ability to colonise new habitats. Algae can be washed away in floods, or left exposed in areas close to the shoreline drying up after a flood. The MARS team simulated hydropeaking events for one hour each day for a month in four experimental channels. One channel was kept as a control, one had nitrogen added, one had phosphorous added, and one had both phosphorous and nitrogen added. These nutrient additions were used to investigate the multiple stress effects of hydropeaking in stream ecosystems affected by nutrient pollution.

Antagonistic relationships between hydropeaking and nutrient addition

After a month, where no nutrients were added, algal growth was significantly higher in the channels with no hydro- or thermopeaking, compared to those where it was simulated. Where no hydro- or thermopeaking was simulated, algal growth was highest in the channels where phosphorous had been added. A shift in the assemblage was observed in these high growth channels from diatom-dominated to non-diatom algae (chlorphyta)-dominated.

However, where both hydro- and thermopeaks were simulated and nutrients were added, there were no significant differences in algal growth between the different channels. This means that one hour of hydro- and thermopeaking each day cancelled out any potential algal growth following nutrient addition, most likely because nutrient concentrations were diluted and washed away. This is termed an antagonistic relationship between stressors.

The effects of hydropeaking and thermopeaking on macroinvertebrate drifting

Macroinvertebrates are animals without a backbone that can be seen with the naked eye: taxa such as mayflies, beetles, caddisflies, dragonflies, worms and crustaceans. They are important links in the food web between producers (such as algae) and consumers (such as fish). Many macroinvertebrates are sensitive to water quality and so their populations provide excellent indicators for environmental change.

Some macroinvertebrate species 'drift' across and along a stream's course throughout their lifecycles, (re)colonising habitats. This drifting behaviour is increasingly recognised by scientists as an important process in shaping ecosystem structure and function in rivers and streams.

The MARS team used experimental channels to study how hydropeaking and thermopeaking affected drifting behaviour of marcoinvertebrate taxa, and how this behaviour differed during the day and during the night.

Drifting highest at night under hydropeaking and thermopeaking

The first results from their experiments indicate significant differences between macroinvertebrate drifting behaviour in response to hydropeaking, thermopeaking and time of day.

Drifting behaviour was highest where only hydropeaking was simulated, and was lower under combined hydropeaking-thermopeaking conditions. For both simulations, drifting behaviour was highest at night, and significantly higher than drifting behaviour of macroinvertebrates in the control experiments under normal conditions.

The team identified specific drifting traits for macroinvertebrate species. Those that were likely to drift tended to be swimming surface taxa with small body sizes and cased caddisflies. On the other hand, those less likely to drift were clinging or burrowing interstice taxa, with large body sizes and caseless caddisflies.

Initial results for ongoing research at HyTEC

This initial research from the HyTEC experiments has indicated that hydropeaking and thermopeaking have significant effects on the growth of benthic algae and on the drifting behaviour of macroinvertebrates in stream ecosystems.

The HyTEC experiments on hydropeaking continue, with ongoing research questions including: 1) whether macroinvertebrate drift behaviour effects juvenile fish populations; and 2) whether hydropeaking and thermopeaking affects the top-down control of macroinvertebrates on benthic algae.

Links

http://hydropeaking.boku.ac.at/hytec.htm

http://mars-project.eu/

MARS fact sheet #07

MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

Provisioning Freshwater Ecosystem Services

What are ecosystem services?

Ecosystem services describe the benefits that people obtain from ecosystems (MA, 2005). They outline the direct and indirect contributions that ecosystems make to human well-being. Ecosystem services are directly linked to the underlying ecosystem functions, processes and structures that generate them (CICES, 2012).

Why are ecosystem services important?

Ecosystem services help make visible the vital roles that ecosystems play in supporting human lives. By clearly linking ecological and socioeconomic systems, the ecosystem service concept is intended to foster enhanced appreciation and protection of global ecosystems.

However, there is still uncertainty about how ecosystem services are related to ecosystem structure, functioning, habitat type, size and condition. The EU MARS project is investigating how multiple stresses (e.g. pollution, overabstraction) affect the ecosystem services that Europe's freshwaters can provide.

What are provisioning ecosystem services?

Provisioning services encompass all the outputs of materials, nutrients and energy from an ecosystem. These might include food and water supplies, raw materials for construction and fuel, genetic resources, medicinal resources and ornamental resources.

Irrigation (photo: Brad Smith, Flickr.com, CC licence)

Human use of provisioning services is therefore usually extractive, and ranges from subsistence hunting, fishing and gathering to industrial agri- and aqua-cultural systems.

What provisioning ecosystem services do freshwater ecosystems provide?

Surface waters in rivers and lakes can provide:

- Clean water for drinking;
- Water for domestic uses such as washing and cleaning;
- Water for use in industry and agriculture, for example cooling and irrigation;
- Water flows or falls for low-carbon, renewable hydropower generation,
- Navigable rivers, canals and lakes for transport and shipping;
- Fish populations to be harvested, providing both nutritional and economic value. Fish may be caught from wild populations, farmed in aquaculture systems, or collected for ornamental display in aquariums.
- Other freshwater animals, plants and algae may be harvested for food – e.g. molluscs and crustaceans – and medicinal purposes.
- Genetic resources for scientific research and development of medicines, for example the use of zebrafish in cancer research.

Groundwater present under the Earth's surface and abstracted from underground aquifers through pumps and wells can provide water for drinking, domestic use, agriculture and industry.

Freshwater provisioning services are not only limited to lakes and rivers.

• Riparian zones along river banks can provide woodland for firewood and edible plants.

• Floodplains and wetlands support edible plants and animals which may be harvested, for example reeds, herbs and waterfowl.

• Wetlands are often sources of valuable biofuels for energy production and peat for horticulture, and provide grazing, silage and hay for dairy and beef cattle.

How do ecosystem services relate to freshwater ecosystem management?

An ecosystem service approach has the potential to strengthen freshwater management which aims to coordinate the conservation, management and sustainable development of water, land and resources across entire river basins.

Such integrated approaches are designed to maximise the social and economic outputs of freshwater ecosystems whilst preserving and restoring their ecological status. By explicitly linking ecological status with human benefits, the ecosystem service approach offers the potential for ecosystem health and functioning to be better valued within environmental policy making and management.

What are the policy and management challenges for valuing provisioning ecosystem services?

The extractive use of provisioning ecosystem services means that there are trade-offs between their use and the maintenance of healthy and diverse freshwater ecosystems, which have 'good ecological status' as measured in the European Union Water Framework Directive.

Maintaining sufficient water quantities for abstraction and use means that dams and reservoirs are often constructed where demand is high. Such structures often have negative impacts on the quantity, timing and speed of water flows downstream, can change sediment and nutrient flows throughout a river basin, and block fish migrations.

For many provisioning services, water is treated more as resource to be abstracted, channelled and stored, than as a medium for life. This means that many provisioning 'ecosystem' services are now significantly supported by human intervention and management, for example through the construction of dams and reservoirs, irrigation channels, and the straightening and dredging of river channels for navigation.

Over-abstraction of surface and ground waters can have negative impacts on ecosystem health and function, and cause lakes and rivers to become seasonally dry, with potentially negative impacts on human livelihoods, and reduce the provision of other ecosystem services.

Over-harvesting of wild populations of freshwater fish, animals and plants depletes their numbers and potentially their resilience and sustainability. Aquaculture can also have negative effects on the wider environment, through pollution from feed and waste and the genetic and behavioural impacts of escaped (sometimes non-native) fish on wild, breeding populations.

Further reading

Freshwater Ecosystem Services (2005), Millenium Ecosystem Assessment, Chapter 7:

http://tinyurl.com/hsv4o7e

Common International Classification of Ecosystem Services (CICES) (2012), European Environment Agency:

http://tinyurl.com/hepdfsd

Cookbook for water ecosystem service assessment and valuation (2015), European Commission Joint Research Centre:

http://tinyurl.com/z4atgzu

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MARS fact sheet #08

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Regulating and Maintaining Freshwater Ecosystem Services

What are ecosystem services?

Ecosystem services describe the benefits that people obtain from ecosystems (MA, 2005). They outline the direct and indirect contributions that ecosystems make to human well-being. Ecosystem services are directly linked to the underlying ecosystem functions, processes and structures that generate them (CICES, 2012).

Why are ecosystem services important?

Ecosystem services help make visible the vital roles that ecosystems play in supporting human lives. By clearly linking ecological and socioeconomic systems, the ecosystem service concept is intended to foster enhanced appreciation and protection of global ecosystems.

However, there is still uncertainty about how ecosystem services are related to ecosystem structure, functioning, habitat type, size and condition. The EU MARS project is investigating how multiple stresses (e.g. pollution, overabstraction) affect the ecosystem services that Europe's freshwaters can provide.

What are regulating and maintaining ecosystem services?

These are services that regulate and maintain ecosystem processes, and in so doing, support ecosystem functioning and productivity. Regulating and maintaining services describe the ways in which living organisms can mediate or moderate their environments in ways that benefit human well-being.

Constructed reed bed lagoon
(photo: Natural England/Paul Glendell, CC licence)

What regulating and maintaining ecosystem services do freshwater ecosystems provide?

Freshwater systems provide a range of vital regulating and maintaining ecosystem services through processes that move water, energy, nutrients, organisms and sediment across different landscapes and habitats, linking atmospheric, terrestrial, groundwater and marine systems.

• Water purification: freshwater ecosystems can maintain sufficient water quality for drinking and domestic use. Freshwater plants and ecosystems can trap, breakdown, process and transform pollutants, toxins and heavy metals present in water.

• Decomposition and cycling of nutrients: through freshwater and terrestrial systems, for example by aquatic plants and algae.

• Carbon sequestration: carbon accumulates in living plant tissue and decomposed vegetation in waterlogged conditions. This 'locks up' carbon stores which helps regulate the amount of carbon dioxide in the atmosphere.

• Flood protection: natural freshwater systems can control the frequency and magnitude of runoff and flooding through water interception and storage. River channel alterations and floodplain development can reduce the ability of ecosystems to provide this buffering effect. •
Aquifers and other unsaturated soils and rocks can provide capacity to store extreme rainfalls as groundwater, providing buffers to flood risk and drought.

• Erosion prevention: bankside vegetation, reed beds, riparian zones and wetlands can cover plays an important role in soil retention and the prevention of erosion and landslides.

• Maintaining populations and habitats: natural ecosystem processes shape ecological structure, health and function, maintaining their ecological status and the services they provide for future generations.

• Local climate regulation: evaporation over freshwaters and wetlands can cool the surrounding atmosphere and increase humidity, creating microclimates.

• Pollination: floodplain meadows provide habitat for pollinating insects such as bees.

• Fire breaks: bodies of water can act as breaks for regulating the spread of wildfires.

How do ecosystem services relate to freshwater ecosystem management?

An ecosystem service approach has the potential to strengthen freshwater management which aims to coordinate the conservation, management and sustainable development of water, land and resources across entire river basins.

Such integrated approaches are designed to maximise the social and economic outputs of freshwater ecosystems whilst preserving and restoring their ecological status. By explicitly linking ecological status with human benefits, the ecosystem service approach offers the potential for ecosystem health and functioning to be better valued within environmental policy making and management

What are the policy and management challenges for valuing regulating and provisioning ecosystem services?

Regulating and maintaining services cannot be easily measured in terms of production. Instead, they are measured by monitoring an ecosystem's capacity to regulate a particular service. For example, if a river system is modified to the extent that it can no longer naturally buffer floods, then its flood prevention service will be diminished.

Another consideration is that for ecosystem services to have value, human end users are required. This means that adequately valuing the importance of services such as nutrient cycling or pollination can be difficult, as they can take place over large spatial and temporal scales, often without a easily definable 'end user'.

Changes to land use such as intensified agriculture and urban growth provide some of the key threats to freshwater regulating and maintaining services, by preventing the natural cycling, transformation and storage of water, nutrient, sediment and pollutant flows through freshwater systems.

However, humans are increasingly creating new freshwater systems in an attempt to enhance the regulating and maintaining services they can provide. A key example of this is wetland creation and expansion, in an effort to encourage natural water purification and carbon storage.

Further reading

Freshwater Ecosystem Services (2005), Millenium Ecosystem Assessment, Chapter 7:

http://tinyurl.com/hsv4o7e

Common International Classification of Ecosystem Services (CICES) (2012), European Environment Agency:

http://tinyurl.com/hepdfsd

Cookbook for water ecosystem service assessment and valuation (2015), European Commission Joint Research Centre:

http://tinyurl.com/z4atgzu

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MARS fact sheet #09

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Cultural Freshwater Ecosystem Services

What are ecosystem services?

Ecosystem services describe the benefits that people obtain from ecosystems (MA, 2005). They outline the direct and indirect contributions that ecosystems make to human well-being. Ecosystem services are directly linked to the underlying ecosystem functions, processes and structures that generate them (CICES, 2012).

Why are ecosystem services important?

Ecosystem services help make visible the vital roles that ecosystems play in supporting human lives. By clearly linking ecological and socioeconomic systems, the ecosystem service concept is intended to foster enhanced appreciation and protection of global ecosystems.

However, there is still uncertainty about how ecosystem services are related to ecosystem structure, functioning, habitat type, size and condition. The EU MARS project is investigating how multiple stresses (e.g. pollution, overabstraction) affect the ecosystem services that Europe's freshwaters can provide.

What are cultural ecosystem services?

Cultural ecosystem services are the non-material benefits that people obtain from ecosystems through recreation, tourism, intellectual development, spiritual enrichment, reflection and creative and aesthetic experiences.

Anglers seek freshwaters with healthy and diverse fish stocks to catch. (photo: jenkinson2455, Flickr.com, CC licence)

What cultural ecosystem services do freshwater ecosystems provide?

Recreation and tourism: Healthy, clean and biodiverse freshwater ecosystems attract a range of different user groups. Walkers and sightseers may use bankside paths, trails and viewpoints, drawn by a landscape's aesthetic appeal, histories and iconic species, often in national parks or other protected areas.

Birdwatchers are often drawn to freshwater sites – often in nature reserves – to see rare and charismatic bird species, whilst anglers may seek freshwaters with healthy and diverse fish stocks to catch. Wild swimmers, windsurfers and boaters are likely to seek freshwaters with good water quality and aesthetic appeal for their pursuits

Intellectual and aesthetic appreciation: Many freshwaters are important sites of early settlement, subsistence and travel, and so are often important sites for archeological studies. Freshwaters provide important outdoor laboratories for students and the wider public to engage with nature, for example, through citizen science schemes and outdoor education centres. Aquatic sediments and deposits can provide important paleo-ecological records of environmental history.

The aesthetic, ecological and historical characteristics of freshwaters are often important to the construction of the overall character of a landscape. This 'sense of place' often influences the values, opinions and aspirations that people attach to a landscape, and the ways it is represented to the world, and how it is managed.

Spiritual and symbolic appreciation: Freshwaters are important sacred sites in many religions and spiritual belief systems, and water is central to many religious and spiritual practices.

Freshwaters shape the way that people live, work, create and relax. This means that freshwaters are often important influences on cultural diversity, artistic and literary forms and practices, architecture, folk stories, and so can shape local and regional identities. When combined, these factors may help emphasise the preservation of the heritage value of cultural freshwater landscapes.

How do ecosystem services relate to freshwater ecosystem management?

An ecosystem service approach has the potential to strengthen freshwater management which aims to coordinate the conservation, management and sustainable development of water, land and resources across entire river basins.

Such integrated approaches are designed to maximise the social and economic outputs of freshwater ecosystems whilst preserving and restoring their ecological status. By explicitly linking ecological status with human benefits, the ecosystem service approach offers the potential for ecosystem health and functioning to be better valued within environmental policy making and management.

What are the policy and management challenges for valuing cultural ecosystem services?

Cultural services are inherently challenging to quantitatively measure and monitor. Perceptions of the value of cultural ecosystem services may differ amongst individuals and communities, be locally specific, and change through time.

This difficulty in measuring the value of cultural ecosystem services may mean that the least prominent or visible services are overlooked in decision making, particularly when compared to provisioning services.

An emphasis on the aesthetic value of freshwaters may conceal reductions in their ecological health or diversity – shifting baselines that may be invisible to the naked eye – or even be the basis for opposition to changes in landscape aesthetics through conservation and restoration projects.

Anglers may stock non-native fish species at unnaturally high levels to provide sport. Recreation and tourism at popular freshwater sites may lead to problems such as water pollution, bank erosion and littering.

Further reading

Freshwater Ecosystem Services (2005), Millenium Ecosystem Assessment, Chapter 7:

http://tinyurl.com/hsv4o7e

Common International Classification of Ecosystem Services (CICES) (2012), European Environment Agency:

http://tinyurl.com/hepdfsd

Cookbook for water ecosystem service assessment and valuation (2015), European Commission Joint Research Centre:

http://tinyurl.com/z4atgzu

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MARS fact sheet #10

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Storylines: writing the future for effective water management – Fragmented World

The future is uncertain. Depending on both human actions and the scale of climatic changes, we can expect any number of potential changes in freshwater ecosystems between now and 2060. In response to this uncertainty, MARS scientists and stakeholders have collaboratively developed a range of different scenarios, each based on climate and socioeconomic predictions.

Using these scenarios, three 'storylines' were written to explore the potential future impacts of multiple stressors on the ecosystems and basin regions studied by MARS. Two time horizons are used for scenarios: 2030 (to inform the update of the Water Framework Directive in 2027) and 2060 (to show the impacts of climate change).

This scenario methodology has been used by many organisations to present unpredictable futures, including UNEP and the IPCC. Traditionally, these scenarios have been simple, linear predictions, with sequential and predictable relationships between socio-economic actions and climatic and environmental outcomes.

In recent years, however, scientists have pointed out that the interactions between humans and the environment are more complex than such a sequential approach gives credit for, and a more responsive methodology is used here, in which emissions and socio-economic scenarios are developed in parallel.

Manure desertification farming (photo: werktuigendagen, Flickr.com, CC licence)

Analytical priority is given to changes in emissions and greenhouse gas concentrations over time (termed 'Representative Concentration Pathways'). Scenarios can then be created based on these emission pathways alongside parallel (and plausible) 'Socio-Economic Pathways' and policy scenarios.

Scenarios and water management

As water management is usually site-specific, global data and predictions currently tells us little about water management in the future. Projections and data do tell us, however, about aggregate global demand and availability.

The storylines designed by MARS scientists use this data and create further predictions around potential changes such as technologies for irrigation, changes in river discharges, changes in pesticide use (and thus pollution), technologies like dikes and dams, water use in industry and energy production, and use of surface and groundwater.

Fragmented World

In the Fragmented World, we envision a future with rising emissions and significant climatic change (Representative Concentration Pathway 8.5). Technological developments are slow, and fossil fuel dependence is high; international cooperation is poor and significant pockets of poverty persist (Shared Socio-Economic Pathway 3). The Fragmented World storyline features a future world with the following features:

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Economy

In the Fragmented World, the economy grows in some European countries (particularly in Northern and Western Europe) and decreases in others (primarily the South). Security concerns have led many countries to limit trade and focus on their internal economies and national, rather than international, development. There are few international trade agreements.

Economic growth is slow, as is technological innovation, and industry is very resource intensive, with high dependence on fossil fuels. Inequality is rife, particularly in poorer countries, where resources are scarce.

Energy

Energy use is high in the Fragmented World, and largely dependent on fossil fuels. Barriers to trade mean the international energy markets are complex, and energy security is a priority for most states.

Poor international cooperation and knowledge transfer means technological development and energy efficiency are low, and industry and power generation are resource intensive. There is investment in developing renewable energy, but this only happens when sufficient financial resources are available and there are no cheaper alternatives.

Environment

Environmental protection is not a priority in the Fragmented World. Some national governments implement local scale solutions to environmental problems, but the lack of international cohesion means that large-scale and trans-boundary problems are rarely addressed. Many currently existing habitats are lost, and deforestation, soil erosion and desertification increase in vulnerable areas.

Poor technological progress means and the low priority of the environment means that pesticide use increases, and as a result, water pollution and nutrient load increases in freshwater ecosystems. Water resources are overexploited, and the ecosystem health of freshwater systems is ignored.

Poor technological and economic development, coupled with weak international institutions, mean that climate change mitigation is difficult. Unfortunately, poverty, uneven development and a lack of international cooperation mean that adaptation to climate change is also difficult.

Policies

Current environmental commitments are not met in a Fragmented World future. European environmental policies expire or are broken before 2030, and are not renewed. Each state plans its own policies in isolation.

The majority of these policies favour economic development over environmental protection. Some local solutions are implemented in rich countries, but any diffuse environmental problems occurring over larger scales are neglected.

Water Management Strategies

In the Fragmented World, water management is not strategic. All interventions in freshwater are reactive, and respond only to limited short-term aims: that people in the present and immediate future have enough water to drink and to service agriculture and industry, and that areas with high levels of economic activity are protected against floods.

Links

Shared Socio-Economic Pathways:

http://tinyurl.com/jcuhq4h

Representative Concentration Pathways:

http://tinyurl.com/hrnlx9s

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MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

Storylines: writing the future for effective water management – Consensus World

The future is uncertain. Depending on both human actions and the scale of climatic changes, we can expect any number of potential changes in freshwater ecosystems between now and 2060. In response to this uncertainty, MARS scientists and stakeholders have collaboratively developed a range of different scenarios, each based on climate and socioeconomic predictions.

Using these scenarios, three 'storylines' were written to explore the potential future impacts of multiple stressors on the ecosystems and basin regions studied by MARS. Two time horizons are used for scenarios: 2030 (to inform the update of the Water Framework Directive in 2027) and 2060 (to show the impacts of climate change).

This scenario methodology has been used by many organisations to present unpredictable futures, including UNEP and the IPCC. Traditionally, these scenarios have been simple, linear predictions, with sequential and predictable relationships between socio-economic actions and climatic and environmental outcomes.

In recent years, however, scientists have pointed out that the interactions between humans and the environment are more complex than such a sequential approach gives credit for, and a more responsive methodology is used here, in which emissions and socio-economic scenarios are developed in parallel.

Wind energy at a lake (photo: Conor Dupre-Neary, Flickr.com, CC licence)

Analytical priority is given to changes in emissions and greenhouse gas concentrations over time (termed 'Representative Concentration Pathways'). Scenarios can then be created based on these emission pathways alongside parallel (and plausible) 'Socio-Economic Pathways' and policy scenarios.

Scenarios and water management

As water management is usually site-specific, global data and predictions currently tells us little about water management in the future. Projections and data do tell us, however, about aggregate global demand and availability.

The storylines designed by MARS scientists use this data and create further predictions around potential changes such as technologies for irrigation, changes in river discharges, changes in pesticide use (and thus pollution), technologies like dikes and dams, water use in industry and energy production, and use of surface and groundwater.

Consensus World

The Consensus World storyline is based on a scenario where future development follows similar patterns to the recent past: the economy grows well in some countries and poorly in others, and inequality between rich and poor countries continues.

Despite this disparity, the world tends towards being relatively politically stable (Shared Socio-Economic Pathway 2).

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This occurs alongside a stablising and relatively low level of climatic change (Representative Concentration Pathway 4.5).

The Consensus World storyline features a future world with the following features:

Economy

In the Consensus World, the global economy and world population are growing at a rate similar to today. Governments worldwide aim to achieve both economic growth and sustainable and efficient use of resources. Investments tend to be low-risk, and technology improves over time, but without any fundamental breakthroughs. While the economies of some countries grow, others perform poorly and global poverty is not eradicated.

Energy

Energy is produced using a mixture of renewable and fossil fuel sources in the Consensus World. Between now and 2030, fossil fuel dependence decreases slowly, but this does not impact on the growth of renewables. The use of bio-energy crops increases significantly. The reproduction rate levels off in the second half of the century, so pressures on energy resources are not increased too significantly by population growth. Regulations are in place to save energy and reduce emissions.

Environment

In Consensus World, there is public and political interest in environmental conservation. This is largely in line with existing regulations, though these have been extended and strengthened over time. Greening measures that are currently being proposed within the EU are being implemented.

As now, global and national institutions are making some progress towards sustainable development goals, but this progress is slow. The environment continues to be degraded over time, but there are some improvements. Resource and energy use declines. Continued poverty in some countries and areas means that many people are left vulnerable to environmental change.

Policies

Current European environmental policies (such as the EU strategy on Adaptation to Climate Change, the EU Biodiversity Strategy, the Habitats and Birds Directives, the Directive on Industrial Emissions, the Regulation on European Pollutants, Floods Directive, Directive on Environmental Quality Standards and Dangerous Substances and the Water Framework Directive) are continued beyond 2020 in an improved and more integrated manner. The objectives and targets are well designed and their achievement is realistic.

Water Management Strategies

European water management strategies are designed in line with the continuing suite of strong regulations. Moderate economic growth means that cheap solutions that are sustainable over the moderate to long-term are the preferred choice, but there is a trend towards solutions that are more sensitive to ecosystem health, and green environmental solutions that work sympathetically with natural processes and functions.

Links

Shared Socio-Economic Pathways:

http://tinyurl.com/jcuhq4h

Representative Concentration Pathways:

http://tinyurl.com/hrnlx9s

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MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

Storylines: writing the future for effective water management – Techno World

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Using these scenarios, three 'storylines' were written to explore the potential future impacts of multiple stressors on the ecosystems and basin regions studied by MARS. Two time horizons are used for scenarios: 2030 (to inform the update of the Water Framework Directive in 2027) and 2060 (to show the impacts of climate change).

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In recent years, however, scientists have pointed out that the interactions between humans and the environment are more complex than such a sequential approach gives credit for, and a more re-sponsive methodology is used here, in which emissions and socio-economic scenarios are developed in parallel.

Tysso Hydroelectric Plant, Norway
(photo: Dag Endre Opedal. Flickr.com, CC licence)

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Scenarios and water management

As water management is usually site-specific, global data and predictions currently tells us little about water management in the future. Projections and data do tell us, however, about aggregate global demand and availability.

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Techno World

The Techno World storyline is based on a scenario of high greenhouse gas emissions and rising global temperatures (Representative Concentration Pathway 8.5) in combination with a strong, carbon-based global economy in which many currently pressing social concerns, such as inequality and population growth, have been ameliorated (Shared Socio-Economic Pathway 5).

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Managing Aquatic ecosystems and water Resources under multiple Stress

The Techno World storyline features a future world with the following features:

Economy

In the Techno World, the global economy is strong and growing. Governments worldwide (in the vast majority) prioritise this economic growth and the creation of financial capital, supporting innova-tions in technology, expansion of businesses and the opening up of new markets. This growth is positive socially, and is accompanied by a rising quality of living conditions and decreases in global inequality.

Energy

Industry is growing, and people are getting wealthier and consuming more, so Techno World has a high demand for energy. This demand is met in whatever is the most cost efficient way in the short term. Newer technologies like hydropower and biofuels are further developed, but so is the use of fossil fuel. Better technologies mean previously inaccessible gas, oil and coal stores can now be exploited, and so CO_2 emissions increase.

Environment

In Techno World, there is a broad consensus between government officials and business leaders that environmental regulation is economically inefficient and hinders development. Governments and international organisations tend to focus their eco-activity on win-win policies that improve economic as well as environmental performance (like energy efficiency), but environmental policies without an obvious financial benefit are weak.

Members of the public are concerned about the environment, and Techno World's campaigning charities and non-governmental organisations are well funded, but these tend to focus most on popular issues (such as local green spaces). Less visible or lucrative environmental goods, or those that require integrated regulation (such as river-basin management) are neglected.

Policies

As we move towards a Techno World future, existing international agreements that protect the environment are either not renewed when they expire or significantly weakened during reform. International agencies are focused on stimulating economic growth, and international law prioritises removing trade barriers, which reduces national governments' abilities to implement strong environmental policies.

By 2060, government intervention to protect ecosystems is virtually nil. The few policies that do exist tend to focus on the recreational value of "nature" as something for humans to enjoy.

Water Management Strategies

The primary focus of water management in the Techno World is to benefit humans. Freshwater is seen primarily as a commodity that is necessary for human health and economic development, and policies focus on having access to water for drinking, agriculture and industry.

Watercourses are primarily managed to reduce hazards to humans like floods, droughts or health risks. These aims tend to be met by technology and engineering like dams, sluices or floodgates. Management thinking is focused on the short term, with little attention given to ecological health and long-term sustainability.

Links

Shared Socio-Economic Pathways:

http://tinyurl.com/jcuhq4h

Representative Concentration Pathways:

http://tinyurl.com/hrnlx9s

MARS fact sheet #13

MARS PROJECT

Managing Aquatic ecosystems and water Resources under multiple Stress

The MARS Diagnostic Analysis Tool (DAT)

An approach to diagnose the causes of ecological degradation of water bodies

What is it about?

Water bodies are subject to multiple man-made stressors with individual or combined adverse effects on the ecological status. This results in a loss of biodiversity – sensitive species disappear and tolerant species, such as neobiota, thrive. In consequence, many water bodies are of poor ecological status.

To improve ecological status and to derive appropriate management and restoration options, it is necessary to know the causes of ecological degradation. Yet, often the ecological assessment does not identify the causes itself. Here, the MARS DAT provides a tool to fill this gap. It is a diagnostic tool that aims to help water body managers identify and rank potential causes of ecological degradation at the scale of individual water bodies.

What is the DAT?

The DAT is a statistical approach that combines probabilities and knowledge rules of cause-effect relationships. A knowledge rule might be: "it is impossible to achieve good status for this stream water body, if riparian shading is completely absent". The probability then comes in to better account for the strength of this knowledge rule, as there might exist exceptional cases where good status is achievable even without riparian shading: "it is 95% impossible to achieve good status for this stream water body, if riparian shading is completely absent". The knowledge rules and probabilities are then combined using a Bayesian network. The network statistically combines all probablilities and allows of a backward diagnosis from ecological status to the potential causes of degradation.

The DAT also provides a prognostic tool that allows of estimating probabilities of ecological status effects conditional on the user's indication of the status of selected causes of deterioration.

How does DAT work?

The DAT is accesible through the Freshwater Information Platform (FIP) via a graphical user interface. The user is asked to indicate values or ranges of selected biological diagnostic metrics, which represent ecological status. The underlying Bayesian network then calculates the probabilities of selected causes of degradation and provides both a graphical and tabular representation of the results. Additional textual information is provided to help identify the causes and derive appropriate management options.

MARS has developed several prototypes including phytoplankton, benthic invertebrates and fish and representing lowland and alpine rivers. The prototypes are applicable only to the respective water body types, for which they have been developed. The application beyond these types is not recommended without verification and adaptation of the underlying knowledge rules.

The methodology is described in the MARS Deliverable 7.1, available for download here: http://www.mars-project.eu/files/download/deliverables/MARS_D7.1_suite_of_tools_1.pdf.

You can access the MARS DAT here:

http://www.freshwaterplatform.eu/index.php/mars-diagnostic-tools.html

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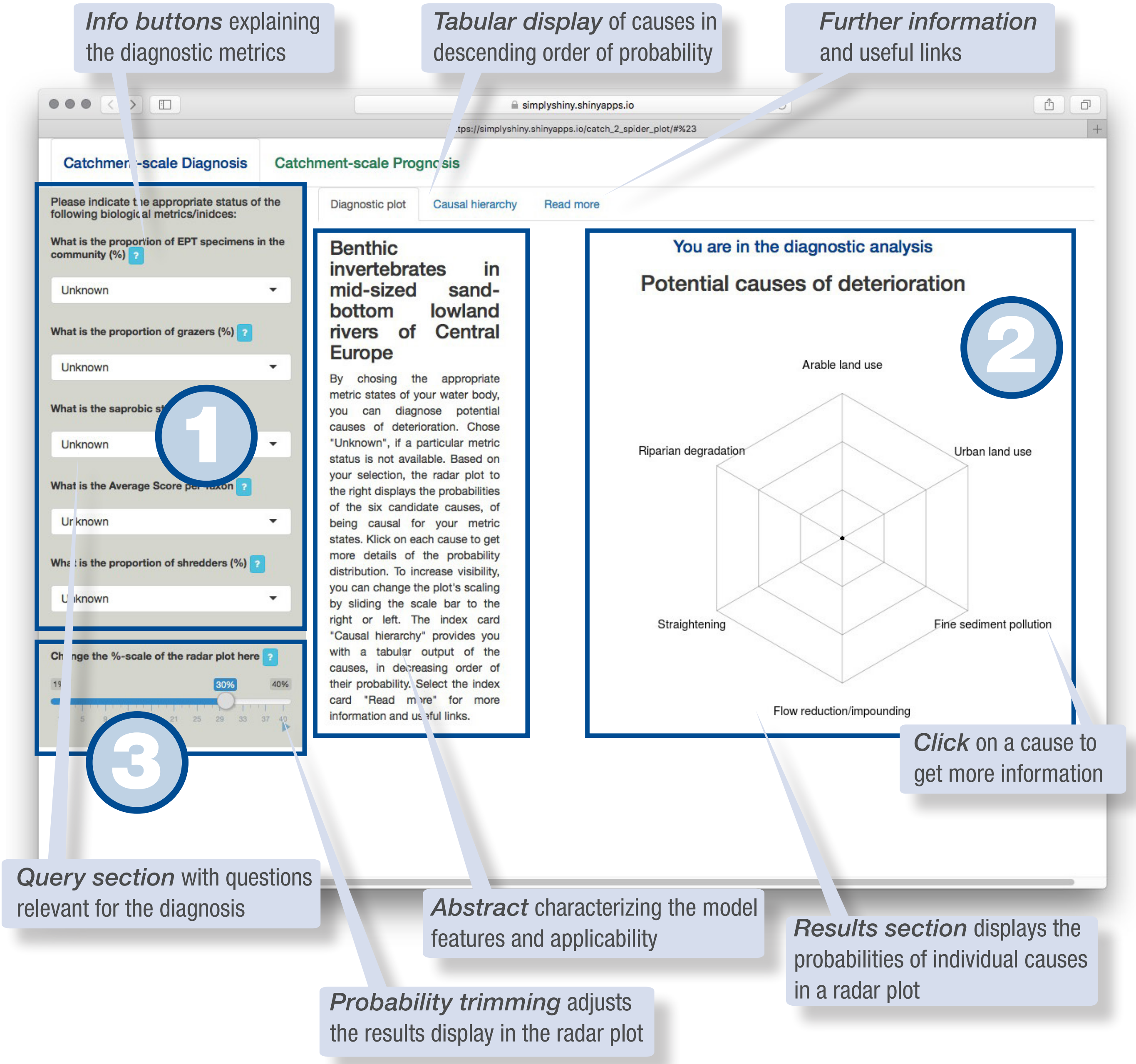
Three steps to diagnose using the DAT

1. Answer to the diagnostic questions one by one. Unknown answers can be left *unknown*.
2. Read of the probabilities of the potential causes of deterioration.
3. Adjust the display of probabilities to allow for best representation of the potential causes.



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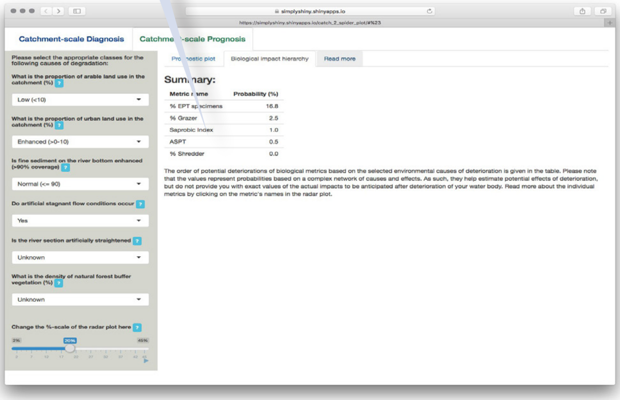
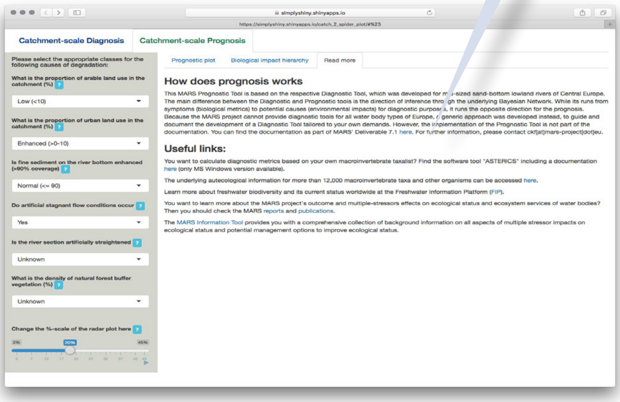
Besides the graphical display of the probabilities of the causes, there is a tabular output showing the causes in hierarchical order. Under "*Read more*", the user is provided with useful links that may help diagnose the causes of deterioration, for instance, at the broader catchment scale, and calculate the diagostic metrics based on a list of species.

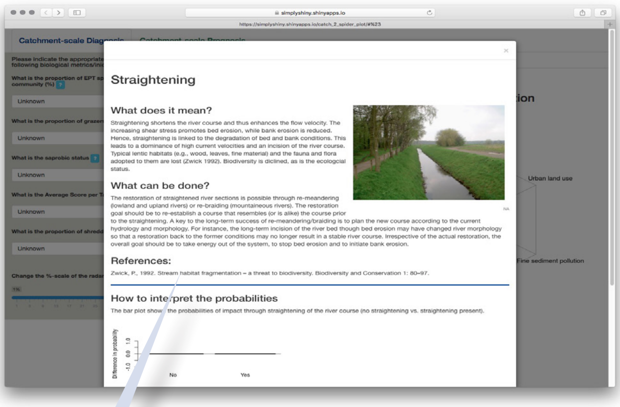
Hierarchical order of causes

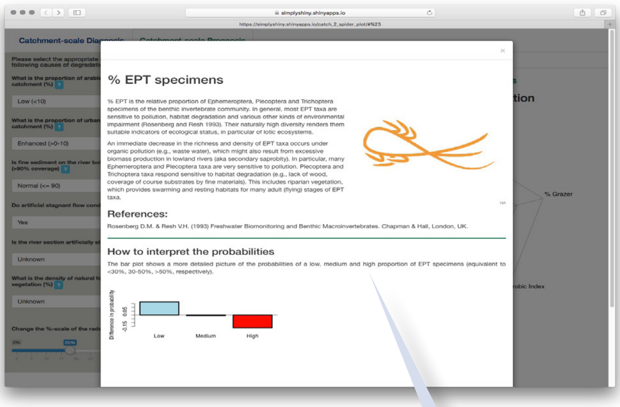
Background information about diagnosis and prognosis





A click on a cause name in the diagnostic part (or a metric name in the prognostic part) of the DAT will open a window with useful background information and potential management options.





Background information about stressors

Background information about used metrics

Interested users, who wish to tailor existing prototypes or develop new diagnostic tools may wish to consult the "cookbook" at http://www.mars-project.eu/files/download/deliverables/MARS_D7.1_suite_of_tools_1.pdf. The cookbook provides a stepwise methodology of the development and implementation of a Bayesian diagnostic network. For further information, please contact christian.feld@mars-project.eu.

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Four key messages of the MARS project

After four years of in-depth research on multiple stressors, the MARS project delivered a large quantity of results, including > 50 scientific reports, > 150 paper publications, various tools and further achievements. Four key messages emanated from the project activities, which provide a quintessential summary of the endeavours.

Message 1: Mitigating pressure-effects on aquatic ecosystems requires an understanding of multi-stressor impacts.

WFD water management is designed using the Driver-Pressure-State-Impact-Response concept. Significant pressures on aquatic ecosystems are identified first. These pressures are assumed to have impacts on ecological status of a river, lake or estuary. Mitigation actions are then selected on the basis of these pressures (known as the "pressure-response shortcut").

This approach may not fully account for the complex interactions and impacts of multiple stressors. As a result, MARS advocates aquatic science research that investigates the direct causes of deteriorated ecological status. Such an approach would allow for more informed management decisions targeting the actual, multi-stressor reasons for ecosystems not reaching good status.

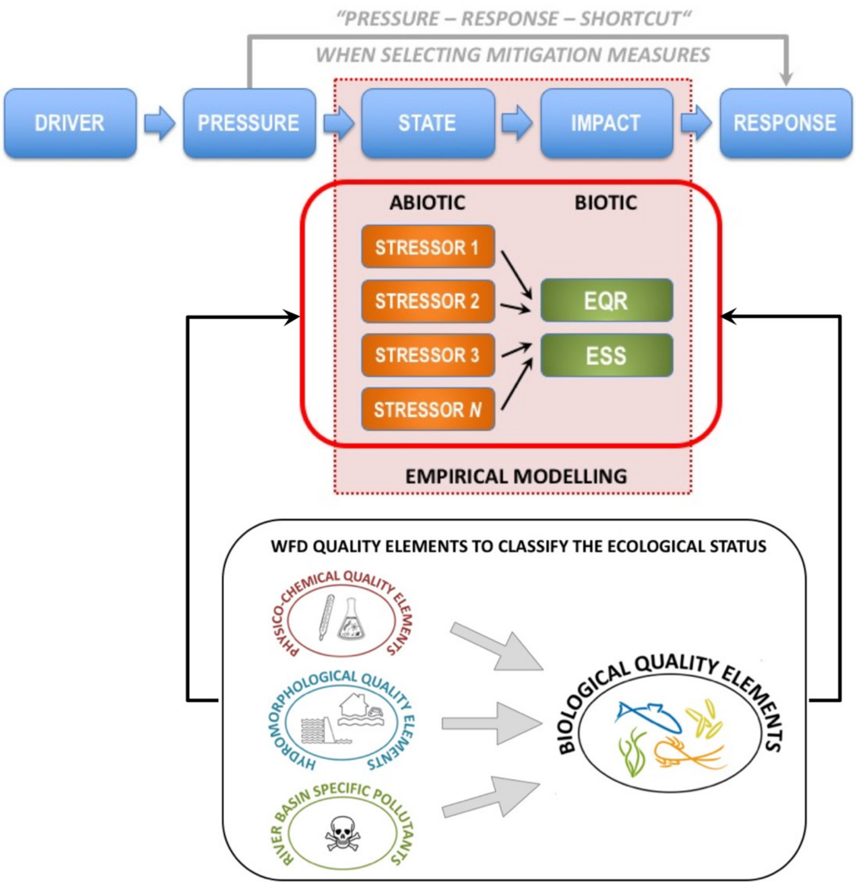

Figure 1: Multi-stressor – impact relationships lie at the heart of informed river basin management. The WFD monitoring programmes generate valuable data sources for such analysis. EQR = Ecological Quality Ratio; ESS = Ecosystem Services.

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Message 2: Environmental 'noise' can obscure evidence from multi-stressor – impact relationships in river basins. Experiments can help unravel multi-stressor interactions and impacts.

Water managers deal with water bodies in the 'real world'. Here, multi-stressor effects on aquatic biology often interfere with other (natural) factors like weather conditions or river flow dynamics. Distinguishing multi-stressor effects from such complex environments is a bit like trying to identify a musical tune played in a noisy room. Nevertheless, water managers need to understand the multi-stressor combinations acting in their basin to devise appropriate mitigation measures.

Multi-stressor experiments (like those conducted by [MARS in the Austrian Alps]) help uncover the 'noise-free' pathways of multi-stressors interactions and impacts, and thus offer valuable insights for informed management decisions.

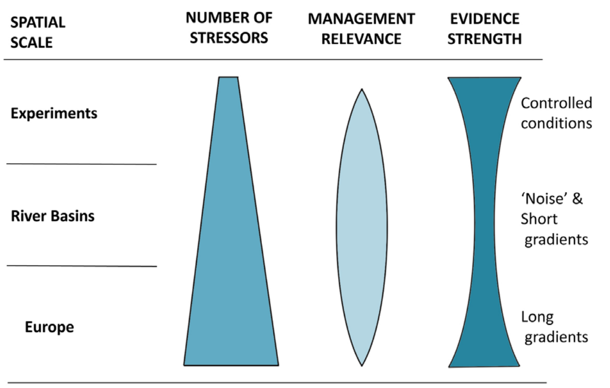

Figure 2: Multi-stressor evidence at the river basin scale (most relevant for water management) is more obscure compared to the evidence gained at experimental scale (under controlled conditions) or European scale (with many and long stressor gradients).

Message 3: Multi-stressor interactions are common in rivers and lakes across Europe and need to be considered in River Basin Management. Interactions are highly context-specific, requiring targeted, localised research to inform management.

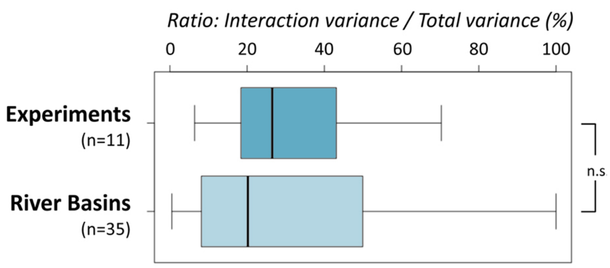

Figure 3: Strength of interaction effects. About one-third of the 156 MARS case studies analysed showed significant interaction effects (in paired-stressor – impact relationships). The strength of interaction effects at river basin scale is as large as at experimental scale (n.s. = non-significant difference).

Message 4: River Basin Management in Europe will benefit from (more) data-driven analyses, modelling and interpretations which are tailor-made for the river basin to be managed.

WFD monitoring data from surface and ground waters across Europe is increasingly available, allowing researchers new opportunities to analyse multi-stressor – impact relationships. This evidence can feed into basin-specific prognostic or diagnostic models that enhance our understanding of aquatic systems, and help facilitate their effective management. Practitioners from applied aquatic science and water management can work together as interdisciplinary 'water body doctors'.

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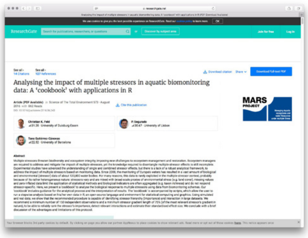
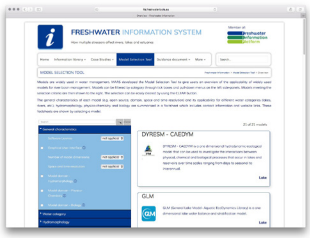
MARS is helping create the conditions for such work by offering these tools:

The Freshwater Information Tool
http://fis.freshwatertools.eu

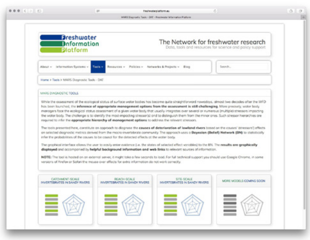
The Multi-Stress Analytical 'Cookbook'
https://goo.gl/L8dSh4 (ResearchGate)



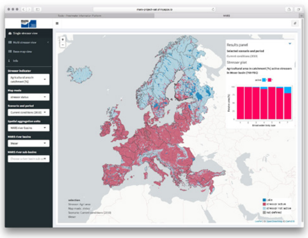
The Model Selection Tool
http://fis.freshwatertools.eu/index.php/mst.html



The Diagnostic Tool
http://www.freshwaterplatform.eu/index.php/mars-diagnostic-tools.html



The Scenario Analysis Tool
http://www.freshwaterplatform.eu/index.php/tools.html



The Guidance for River Basin Management under multiple stress
Available on www.mars-project.eu