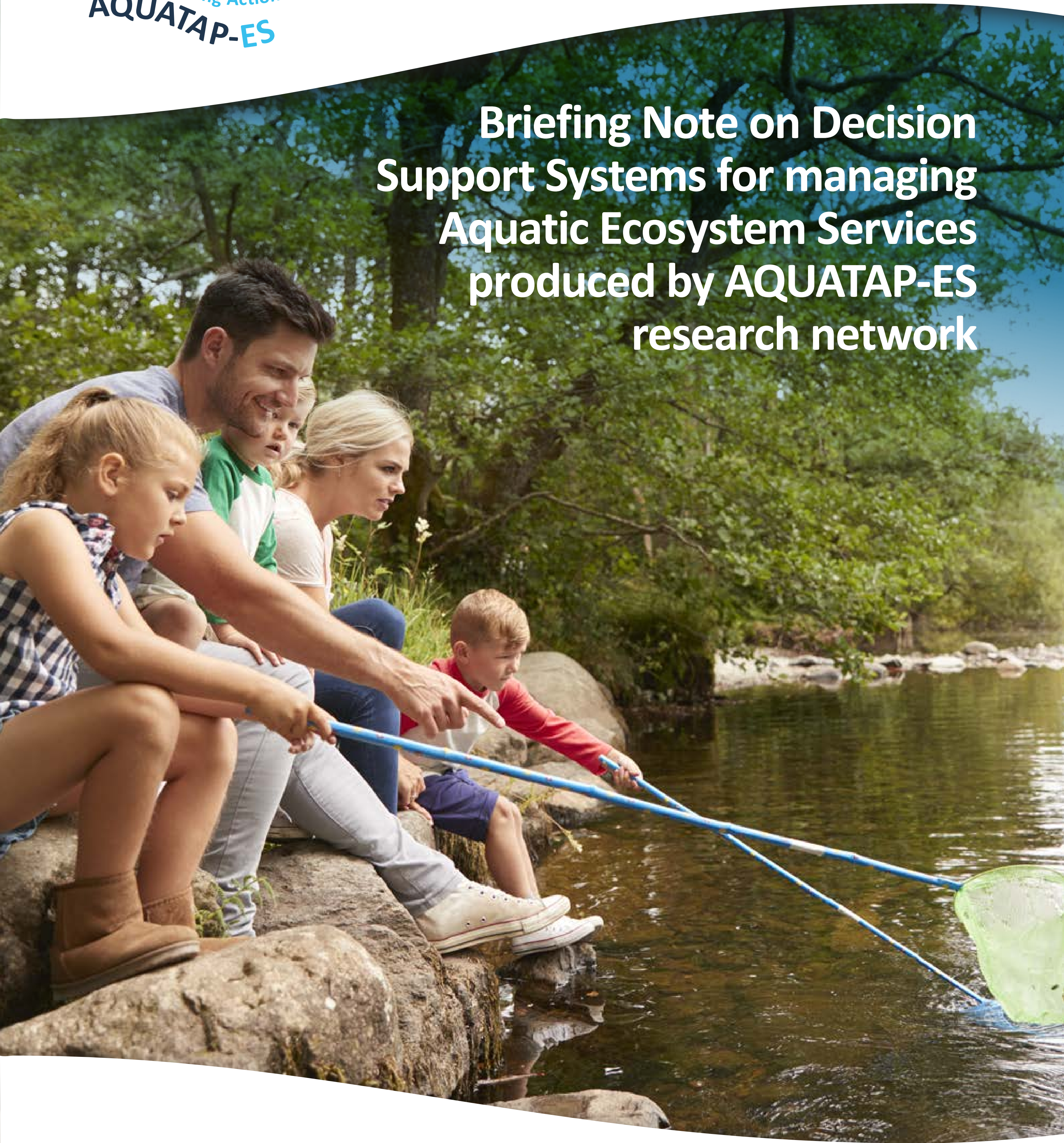
Water JPI
Thematic Annual Programming Action
AQUATAP-ES

Briefing Note July 2021

Briefing Note on Decision Support Systems for managing Aquatic Ecosystem Services produced by AQUATAP-ES research network



European Commission

Water JPI

Water 2015 Works

Briefing Note on Decision Support Systems for managing Aquatic Ecosystem Services July 2021

Disclaimer

Acknowledgments

The Water Joint Programming Initiative (JPI) has received funding from the European Union's Horizon 2020 programme for research, technological development and demonstration under Grant Agreement No. 689271 (**WaterWorks2015**). We wish to acknowledge the invaluable contribution from the authors Micheal Bruen, Christian Feld, Marcin Penk and Mona Soroudi, AQUATAP-ES scientific coordinators, researcher network members, steering committee members and Water JPI Secretariat and Coordinator, the **WaterWorks2015** ERA-Net Cofund partners and the Water JPI Governing Board (GB), and funding from the European Commission.

Website http://www.waterjpi.eu/

Water JPI AQUATAP-ES website http://www.waterjpi.eu/implementation/thematic-activities/water-jpi-tap-action

Briefing Note on Decision Support Systems for managing Aquatic Ecosystem Services July 2021

What are Ecosystems Services?

Ecosystems Services (ES) are the goods and benefits that ecosystems provide to people and society. They are included in the concept of "Nature's contribution to people" described by IPBES (2018). The ES approach seeks to understand and use this relationship between nature and people to support decisions contributing to global sustainability. Here we focus on freshwater aquatic ecosystems, so the decisions we talk about relate to freshwater ecosystems protection and management. However, much of the material can be readily adapted for other types of ecosystems. AQUATAP-ES has produced a separate briefing note to underpin that the "Integration of the ecosystem services approach into policy & practice is key for the sustainable management of aquatic resources".[1]

What are Decision Support Systems (DSS)?

A DSS is a collection of (i) models (usually mathematical), (ii) its underlying data, (iii) appropriate analysis methods, (iv) relevant knowledge and (v) users that individually or in concert can assist in making informed decisions. In the case of AQUATAP-ES, these decisions relate to the management of water related ecosystems and the services they provide. The distinction between "decision support" and "decision making" is important as normally DSS do not make decisions, but rather provide information and analysis that may assist a "decision maker". Note that the use of a computer is not a necessary part of the definition of a DSS as humans, for example, have always had to make decisions and adopt strategies to live and survive. Nevertheless, many modern decision support systems are based on computers.

Why use Decision Support Systems?

1. Modern environmental management decision making situations have some of the following characteristics:

a. system complexity, diversity, interconnectedness (some connections not yet known or understood).

b. data-rich or data-scarce or a combination of both, compounded by dynamic spatial and temporal aspects, e.g., remote sensing (including drones).

c. multiple objectives / multiple stakeholders / issues about who should decide.

d. uncertainty (in all measurements).

e. stochastic nature of natural systems.

All of these are difficult to process without the use of organised, directed, computing power and this requires DSS, although the levels of complexity, modelling components and related data needs can be different in each individual application, Figure 1. The simplest may be used for status reporting or data analysis, including investigations of unusual incidents. The more complex can include economic models, multi-criteria decision analysis (MCDA) and tools for communication with stakeholders (including citizen science tools) from the Information technology domain (IT). Some of these are listed below:

Figure 1: Some possible uses of Decision Support Systems.

		GIS + Data	
LEVELS	1	Reporting	
	2	General Analysis	+ Technical Models
	3	Investigative Analysis	+ Technical Models
	4	Assessment of Management Options	+ Economic Models
	5	Communication: Facilitating Stakeholder involvement	+ IT
	6	Negotiation and Compromise: Stakeholder participation	+ MCDA

1 Water JPI AQUATAP-ES - Policy and Practice

i. To facilitate collaborative group-decision making and provide a trusted negotiation framework. A reliable decision support system can provide answers to "What if ???" questions that would allow participants in group-decision making or negotiation situations to explore the consequences of agreeing or compromising on management options or policy or balancing benefits against negative impacts. The use of a single, trusted, DSS means that all parties have access to the same information and modelling capabilities. Sometimes, the collaborative use of a DSS to explore options and consequences reveals the commonalities in the concerns of diverse groups and facilitates compromise.
ii. To help with communicating the reasons for decisions and demonstrating the expected outcomes, for example with illustrations or animations. Computer based DSS can produce simulations of the consequences of the options being considered by the decision makers, not only in terms of quantitative outputs, but also as graphs, maps, and animations. These can be extremely useful for explaining the DSS recommendations to decision makers and to the public.
iii. To help plan data gathering and design monitoring network and strategies. DSS can investigate the sensitivity of the ecosystems being managed to both natural influences and to management options and changes in these. By identifying the most sensitive inputs, the DSS can point out which data streams have most influence on the operation of the system so that resources can be applied to ensuring adequate data collection for the sensitive inputs. Conversely, by identifying which inputs have little influence on the operation of the ecosystem, the DSS can reveal which management options are unlikely to be effective.
iv. To assist with up-scaling, down-scaling and dynamic responses. If the modelling tools typically incorporated in a DSS are flexible they can assist with up-scaling or down-scaling and thus applying the DSS to different domains. While the catchment (watershed) is a natural domain for use in aquatic water resources management, when combined with socio-economic considerations, the most suitable domain of analysis may be quite different.
v. To link with socio-economic decision-making models. Because ES are ecosystem goods and benefits for people and societies there is a natural link with socioeconomics and with governance considerations. Thus, there is interest in linking DSS that focus on the ecosystems aspects with systems that capture the social/economic/governance contexts. The ecosystems DSS (or some of its parts) becomes a component of a larger DSS used at larger scales.

What types of decisions are supported and how?

Decision Support Systems have a place in every aspect of policy formulation, implementation and in the operational management, including of aquatic systems. They can be used in both top-down and bottom-up configurations.

1. Typically, top-down contexts are related to policy formulation. Policy makers require tools and knowledge to help them estimate the potential consequences of the options they are considering at national or regional scales. In such applications, the spatial extents tend to be large (national or regional) and the timescales tend to be mid- to long-term (many years to decades). DSS for this purpose tend to be broad in scope with more but simpler modelling components. As the options being considered tend to be quite different the problem is usually a discrete choice one and high quantitative accuracy is not always required to differentiate between the available options.
2. In contrast, typical bottom-up decisions are the frequent, operational, decisions made in relation to specific management options in specific rivers / catchments. For these, managers need to know how effective each available option is likely to be and what other consequences the options might have. DSS for this purpose tend to have a tighter focussed scope with fewer, but more complex, modelling components (in some cases just single models). Some of the management options can have a quantitative nature, e.g., how much water to release from (or store in) a reservoir or wetland, how much water can be abstracted from a river (or aquifer), dosage of chemicals to be added for water treatment, length of bankside to be managed. Thus, a greater quantitative accuracy is usually demanded than for a top-down policy DSS. A notional trade-off of spatial and modelling detail is shown in Figure 2. Note that no combination is considered completely useless, and no existing combination is yet considered excellent. The "caution" assessment is applied to combinations that may be either (i) too simplistic to capture the important phenomena, or (ii) too complex to be widely implemented or even adequately calibrated.
3. Other stakeholders/public/media need access to the outputs from modelling tools to allow them to form their own options on the desirability of options or policy. True public participation in decision making should give all participants the capability to interrogate datasets and get answers to "What if?" type questions. This is especially true in situations involving negotiation and/or compromise.
4. Real-time decisions are also made in dealing with emergencies/hazards/environmental change and the response/recovery of ecosystems to these and other shocks. For instance, the effects of pollution incidents can travel through ecosystems rapidly and the DSS must be able to assist with rapid diagnosis of the problem as well as recommendations of responses and where and when they should be applied.

Notes:

i. there are no combinations shown that are judged to be completely useless or none judged excellent

ii. "Caution" implies there may be some usable results, but it may not be clear which ones)

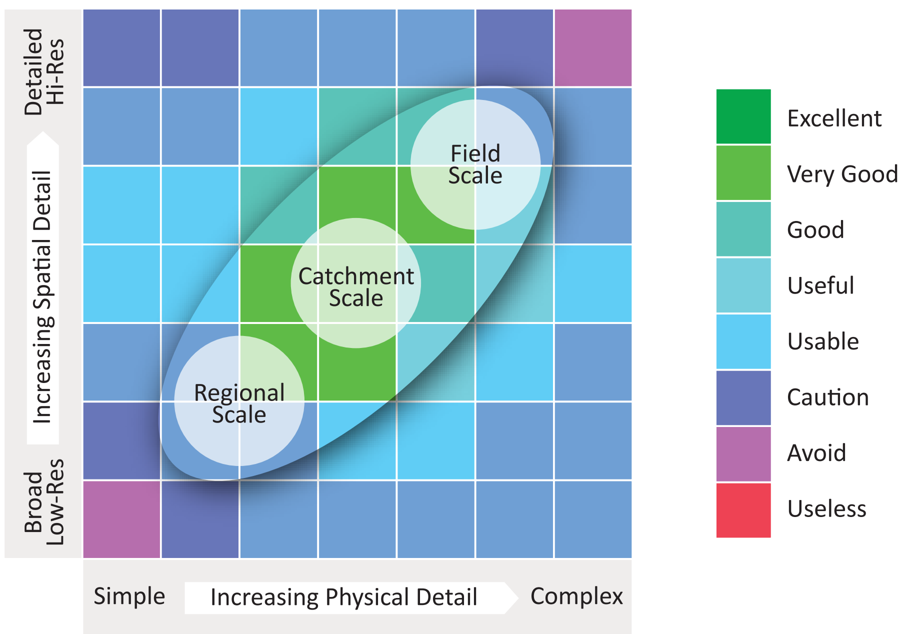


Figure 2: Trade-off of spatial detail (scale) with modelling (physical) detail.

Some Examples of Decision Support Systems

FABM (https://github.com/fabm-model/fabm)

Framework for Aquatic Biogeochemical Models (FABM) is a framework holding a collection of biogeochemical models of marine and freshwater systems. It is not a stand-alone DSS but contains components from which a DSS can be built. It is mature, supported by the authors and has been widely used, mainly in research institutions and has been linked with GIS systems that provide a user interface. It is generally used with external hydrodynamic models of estuaries, lakes, or rivers. The code is available for GITHUB and a short description can be accessed at https://github.com/fabm-model/fabm/wiki

InVEST (https://naturalcapitalproject.stanford.edu/software/invest)

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is a collection of models used to map and value the goods and services provided by nature for use by people. It is spatially explicit, i.e. produces maps of the distribution of services and their valuation and can work at different scales. The models tend to be used with a supporting GIS system and cover a wide range of ES, including components for modelling habitat quality, recreation, sediment retention, water yield nutrients and purification, and fisheries.

ARIES (https://aries.integratedmodelling.org/)

Artificial Intelligence for Environment and Sustainability (ARIES) is a United Nations (Economics and Social Affairs -UNDESA and Development Programme - UNDP) project based at the Basque Centre for Climate Change. It is based on a knowledge hosting program called k.Lab and has a semantically based user interface (k.EXPLORER) that provides decision makers with access to information, data and models that have been shared by other users.

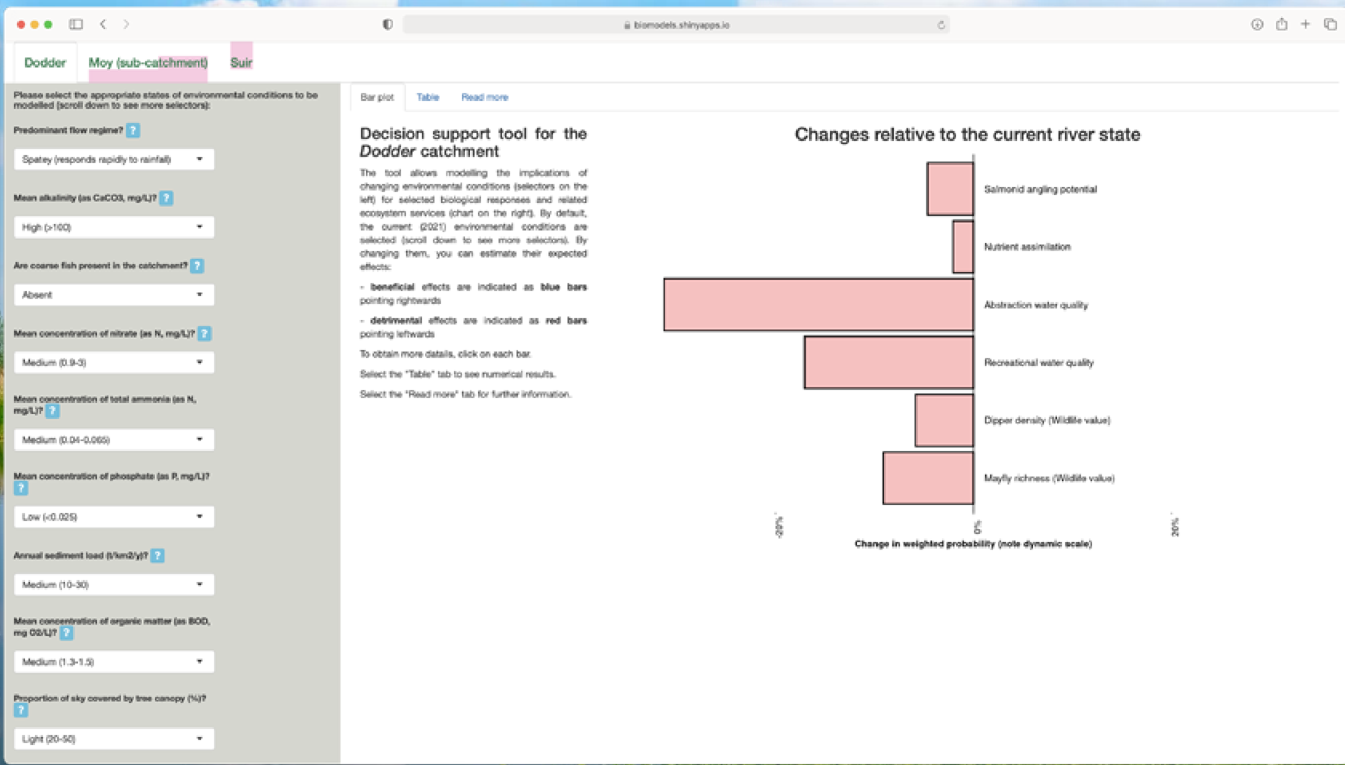


Figure 3 Screenshot of ESDecide DSS

ESDecide DSS (https://biomodels.shinyapps.io/IC_Combine/)

The ESDecide DSS is an interactive online tool that links management-related environmental changes with consequences for biodiversity and ES in three Irish catchments. The DSS runs a model in the background that calculates the probabilities of individual biological implications based upon the user's selection of environmental changes, Figure 3. The DSS helps estimate and compare consequences and aids decisions on management options to take, to achieve the desired biodiversity and ES targets.

CE-QUAL-W2 (http://www.ce.pdx.edu/w2/)

CE-QUAL-W2 is a two dimensional (vertical and longitudinal, i.e. width-averaged) hydrodynamic and water quality model than can be used for estuaries, rivers, lakes and reservoirs. It can simulate sediment, nutrients, dissolved oxygen, organic matter, eutrophication, shading and bacteria. A GUI based pre- and post-processer is available for preparing inputs and displaying outputs.

MARS Diagnostic tools (http://www.freshwater-platform.eu/index.php/mars-diagnostic-tools.html)

The MARS diagnostic comprises a set of online interactive applications that help users estimate potential causes of deterioration in rivers. The tools run diagnostic models in the background that link selected biological symptoms with a set of candidate environmental causes. Based on the selection of symptoms, the models calculate probabilities of the causality of each pressure, which allows to identify primary pressures and to separate them from less likely ones. The MARS diagnostic tools hence can help better link river monitoring results with programs of measures and inform decisions about suitable management options (incl. its sequential order) towards good ecological status achievement according to the EU Water Framework Directive (WFD).

Sustainability, confidence, and trust

The area of DSS is rapidly expanding, not only in relation to the availability of data, models and other tools, but also in relation to tools for model integration (e.g. k.LAB) and output visualisation (e.g. GIS and video hosting platforms). This raises the issue of longer-term sustainability of the DSS. The scientific literature is full of articles on unused, single-use or "proposed" models of decision support systems. What are the characteristics of a successful system?

i. Maintenance – Ownership and responsibility are important factors. In particular, is maintenance the responsibility of a single developer or is there a long-term team behind the system? Is there an established system for keeping up to date (data and models)? For example, the GITHUB platform is an established general purpose software development and dissemination platform. Another possibility is a dedicated set of webpages (ideally with a linked Wiki to establish a user query forum) hosted by an established organisation.

ii. Trust – how to establish and maintain trust in the outputs to prevent unjustified overreliance on DSS. The complexity of methods such as Artificial Intelligence and Machine learning used in some DSS means that most users do not fully understand how they work, and this can reduce the users' trust in the DSS's outputs. Conversely, this has been countered in many systems by giving the DSS the ability to better explain the reasons for its recommendations and a relatively new field of Explainable AI (XAI) has emerged to address some to these issues. Such DSS can give quite detailed information on how their recommendations were derived. In addition, confidence or uncertainty measures can be associated with recommendations.

iii. Access to the system, its input data, models and/or its outputs. This issue relates to security as well as confidence and trust. A user should know what types of access to the DSS, and its components are allowed and how to implement changes such as corrections, new features and to provide access to new data (almost certainly this requires a secure web interface and multiple degrees of access). Thus, the degree of access and the ability to make changes should depend on the knowledge, competence and position of the user and could vary significantly between maintainers/developers of the system to non-expert, but interested, users.

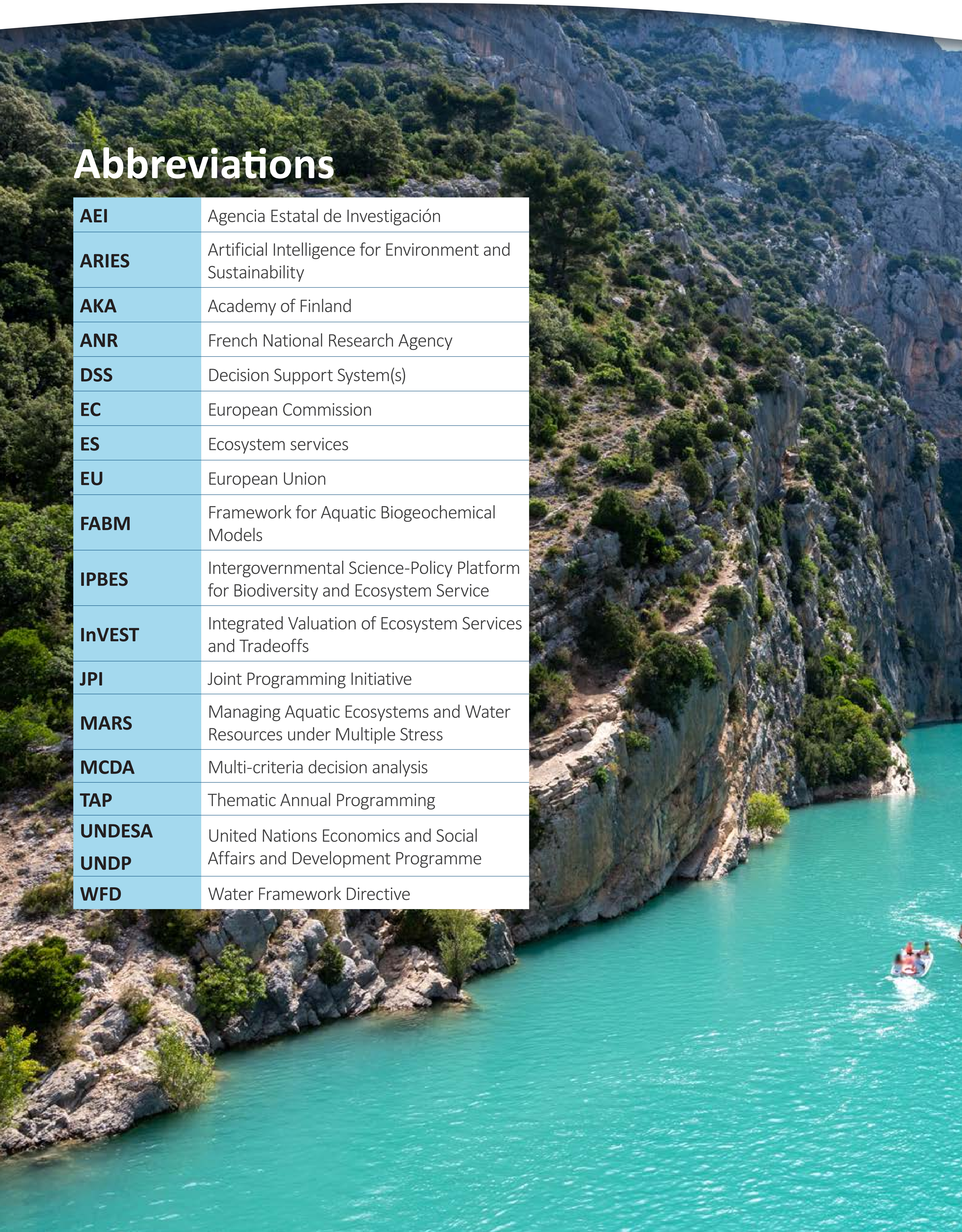
Where to from here? Future directions and possibilities.

DSS are going to be more widely used in future in a wide variety of areas and confidence and trust in their performance is likely to increase. This increases the possibility of them being manipulated unscrupulously, so the issue of security must be developed in parallel and integrated into operational DSS. As the number and complexity of the models included in DSS increases, the issues of scale, validation, stability and resilience will also increase in importance. In addition, users may struggle to judge their overall reliability of the DSS or of its individual components. It may be useful to have some sort of standardised convention for documenting the important aspects of DSS or the underlying models. Some examples of mandatory information in this documentation are:

- what kind of information and simplifying assumption are they based on?
- how many sources/layers of uncertainty?
- how were the models calibrated/tested?
- what are the limits of the settings and scales at which they can be applied?

Annex 1. AQUATAP-ES Members and Steering Committee

AQUATAP-ES TAP membership	First name	Surname	Organisation
Scientific Coordinator 2020-2021	José María	Bodoque del Pozo	University of Castilla-La Mancha, Spain
Scientific Coordinator 2019-2020	Mary	Kelly-Quinn	University College Dublin, Ireland
Member	Michael	Bruen	University College Dublin, Ireland
Member	Marieke	de Lange	Rijkswaterstaat, the Netherlands
Member	Joost	Backx	Rijkswaterstaat, the Netherlands
Member	Anna	Kuparinen	University of Jyväskylä, Finland
Member	Vicenç	Acuña	Catalan Institute for Water Research, Spain
Member	Anne Marie	Power	National University of Ireland Galway, Ireland
Member	Kathryn	Schoenrock-Rossiter'	National University of Ireland Galway, Ireland
Member	Christian K.	Feld	University of Duisburg-Essen, Germany
Member	Craig	Bullock	University College Dublin, Ireland
Member	Marcin	Penk	Trinity College Dublin, Ireland
Member	Michael	Christie	Aberystwyth University, UK
Steering committee Chair & AQUATAP-ES Facilitator	Lisa	Sheils	Environmental Protection Agency (EPA), Ireland
Steering committee	Harri	Hautala	Academy of Finland (AKA)
Steering committee	Miguel Ángel	Gilarranz Redondo	Agencia Estatal de Investigación (AEI), Spain
Steering committee	Esther	Chacon	Agencia Estatal de Investigación (AEI), Spain
Water JPI	Véronique	Briquet-Laugier	French National Research Agency (ANR)/Water JPI Coordinator)
Water JPI	Juliette	Bettus	French National Research Agency (ANR)/WW2015 Coordinator)
Water JPI	Armelle	Montrose	French National Research Agency (ANR)/WW2015 Coordinator)



Abbreviations

AEI	Agencia Estatal de Investigación
ARIES	Artificial Intelligence for Environment and Sustainability
AKA	Academy of Finland
ANR	French National Research Agency
DSS	Decision Support System(s)
EC	European Commission
ES	Ecosystem services
EU	European Union
FABM	Framework for Aquatic Biogeochemical Models
IPBES	Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Service
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
JPI	Joint Programming Initiative
MARS	Managing Aquatic Ecosystems and Water Resources under Multiple Stress
MCDA	Multi-criteria decision analysis
TAP	Thematic Annual Programming
UNDESA UNDP	United Nations Economics and Social Affairs and Development Programme
WFD	Water Framework Directive

Briefing Note on Decision Support Systems for managing Aquatic Ecosystem Services July 2021

Water JPI
Thematic Annual Programming Action
AQUATAP-ES

Water JPI website
www.waterjpi.eu/

Water JPI AQUATAP-ES website
www.waterjpi.eu/implementation/thematic-activities/water-jpi-tap-action