BONUS RETURN

Reducing Emissions by Turning Nutrients and Carbon into Benefits

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X	PU	Public.
	PP	Restricted to other project partners.
	RE	Restricted to a group specified by the consortium.
	CO	Confidential, only for members of the consortium.

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EXECUTIVE SUMMARY

This deliverable provides an overview of the publication **"Rethinking the praxis of measure selection and assessment: co-designing a serious game system to navigate wicked sustainability issues"** (Powell et al., 2020).

In this paper, we deploy a serious game system as an innovative mode of praxis to enable no/low-regret actions as a means to navigate the "wicked" context of nutrient emissions in the Baltic Sea Region. The serious game system was co-developed with a diverse group of stakeholders from the three case settings in Sweden, Finland and Poland in the BONUS RETURN project. Our study suggests that the serious game system is a promising approach to support knowledge co-production processes in a creative, safe and inclusive space. It also serves as a communication platform for different constellations of actors to come together, which in turn leads to the emergence of a community of practice. Furthermore, it supports reflection on the implementation of governance actions in "wicked" contexts. Most importantly, the playfulness and inconsequential space of the game environment alleviate the distorting role of power that would otherwise orchestrate the outcomes in all three domains by separating the respective acts of knowledge production, communication of knowledge and implementation of governance action. This paper makes a methodological contribution in terms of operationalising knowledge co-production through serious game system to address "wicked" sustainability issues.

The full manuscript of the scientific publication can be found in the Appendix of this report.

1 INTRODUCTION

The degradation of the Baltic Sea is an ongoing problem, despite investments in measures to reduce external inputs of pollutants and nutrients from both diffuse and point sources. Available technological and management measures to curb eutrophication and pollution flows to the sea have not been adapted adequately to the contexts in which they are being applied. Furthermore, measures are often designed based on single objectives, thereby limiting opportunities for multiple benefits.

In addition, there is a general sense that measures to address the deterioration of the Baltic ecosystem are primarily technologically-driven and lacking broader stakeholder acceptance – the "experts" who define these measures have little engagement with industry, investors, civil society and authorities. This problem is magnified by governance and management, taking place in sectoral silos with poor coordination across sectors.

As a result, research shows that regional institutional diversity is presently a barrier to transboundary cooperation in the Baltic Sea Region (BSR) and that actions to achieve national environmental targets can compromise environmental goals in the BSR (Powell et al. 2013). The regional dimension of environmental degradation in the BSR has historically received weaker recognition in policy development and implementation locally. However, developments in recent years suggest a new trend with growing investments in environmental protection supporting social, economic, and territorial cohesion.

The BSR is an environmentally, politically and economically significant region and like other regions globally, its rapid growth needs to be reconciled with the challenges of sustainable development in a global setting that demands unprecedented reductions in GHG emissions. This poses a truly wicked problem exacerbated by the fact that many of the challenges in the BSR will also magnify in a changing climate. In order to navigate the uncertainties and controversies associated with a transformation towards a good marine environment, BONUS RETURN will enact an innovative trans disciplinary approach for identifying and piloting systemic eco-technologies.

The focus is on eco-technologies that generate co-benefits within other interlinked sectors, and which can be adapted according to geophysical and institutional contexts. More specifically, emphasis is placed on eco-technologies that reconcile the reduction of present and future eutrophication in marine environments with the regional challenges of policy coherence, food security, energy security, and the provision of ecosystem services.

1.1 Project Objectives

The **overall** aim of BONUS RETURN is to improve the adaptation and adoption of eco-technologies in the Baltic Sea Region for maximum efficiency and increased co-benefits.

The **specific objectives** of the project can be divided into six categories presented below. These categories are interlinked but for the purpose of providing a step-wise description, the following overview of each category proves useful. BONUS RETURN is:

1) Supporting innovation and market uptake of eco-technologies by:

- Contributing to the application and adaptation of eco-technologies in the BSR through an evidence-based review (systematic map) of the developments within this field.
- Contributing to the development of emerging eco-technologies that have the capacity to turn nutrients and carbon into benefits (e.g. bio-energy, fertilizers), by providing an encompassing framework and platform for rigorous testing and analysis.
- Developing decision support systems for sustainable eco-technologies in the BSR.
- Contributing to better assessment of eco-technology efficiency via integrated and participatory modelling in three catchment areas in Finland, Sweden and Poland.
- Contributing to methodological innovation on application and adaptation of eco-technologies.

2) Reducing knowledge gaps on policy performance, enabling/constraining factors, and costs and benefits of eco-technologies by:

- Assessing the broader socio-cultural drivers linked to eco-technologies from a historical perspective.
- Identifying the main gaps in the policy environment constraining the implementation of emerging eco-technologies in the catchments around the Baltic Sea.
- Informing policy through science on what works where and under which conditions through an evidence-based review (systematic map and systematic reviews) of eco-technologies and the regional economic and institutional structures in which these technologies evolve.

3) Providing a framework for improved systematic stakeholder involvement by:

- Developing methods for improved stakeholder engagement in water management through participatory approaches in the case study areas in Sweden, Finland and Poland.
- Enacting a co-enquiry process with stakeholders into opportunities for innovations in eco-technologies capable of transforming nutrients and pollutants into benefits for multiple sectors at different scales.
- Bringing stakeholder values into eco-technology choices to demonstrate needs for adaptation to local contexts and ways for eco-technologies to efficiently contribute to local and regional developments.
- Disseminating results and facilitating the exchange of learning experiences, first within the three catchment areas, and secondly across a larger network of municipalities in the BSR.
- Establishing new cooperative networks at case study sites and empowering existing regional networks by providing information, co-organizing events and engaging in dialogues.

4) Supporting commercialization of eco-technologies by:

- Identifying market and institutional opportunities for eco-technologies that (may) contribute to resource recovery and reuse of nutrients, micro-pollutants and micro-plastics (e.g. renewable energy).
- Identifying potential constraints and opportunities for integration and implementation of eco-technologies using economical models.
- Facilitating the transfer of eco-technologies contributing to win-win solutions to multiple and interlinked challenges in the BSR.
- Linking producers of eco-technologies (small and medium enterprises – SMEs), to users (municipalities) by providing interactive platforms of knowledge exchange where both producers and users have access to BONUS RETURN's envisaged outputs, existing networks, and established methodologies and services.

5) Establishing a user-driven knowledge platform and improved technology-user interface by:

- Developing an open-access database that maps out existing research and implementation of eco-technologies in the BSR. This database will be intuitive, mapped out in an interactive geographical information system (GIS) platform, and easily managed so that practitioners, scientists and policy-makers can incorporate it in their practices.

- Developing methodologies that enact the scaling of a systemic mix of eco-technological interventions within the highly diverse contexts that make up the BSR and allows for a deeply interactive medium of knowledge.

1.2 Project Structure

BONUS RETURN is structured around six Work Packages that will be implemented in three river basins: The Vantaanjoki river basin in Finland, the Słupia river basin in Poland, and Fyrisån river basin in Sweden.

Work Package 1: Coordination, management, communication and dissemination.
Work Package 2: Integrated Evidence-based review of eco-technologies.
Work Package 3: Sustainability Analyses.
Work Package 4: Environmental Modelling.
Work Package 5: Implementation Support for Eco-technologies.
Work Package 6: Innovative Methods in Stakeholder Engagement.

1.3 Deliverable context and objective

The current deliverable (D 6.10) is part of WP6. The objective of WP6 is to serve as a platform to enable a co-enquiry process between stakeholders and the project. At the regional level the 40 municipalities connected to the Race for the Baltic will act as a sounding board to provide input to the Evidence-based Review in WP2. Stakeholder platforms have been established at the case study sites to support the identification of eco-technologies for analysis in WP3, WP4 and WP5. These platforms have served as opportunities to further test, develop, adapt and use the eco-technologies based on the assumption that their effectiveness and relevance depends on context, as defined by institutional, economic, social and bio-physical barriers and opportunities. Thus, WP6 has contributed to understanding historical drivers, policy instruments, governance structures and local needs in order to ensure that selected eco-technologies are possible to implement in the three case study sites.

The task connected to this deliverable is T 6.2 – Serious Game System Development. The aim of the Serious Game System (SGS) is to draw on empirical insights generated by the BONUS RETURN project, in a creative, safe and inclusive learning space that invites deliberation over the feasibility of different constellations of eco-technologies. Furthermore, it will support a participatory evaluation of the systemic impact different constellations of eco-technologies have on the Baltic Sea Region (BSR). It is intended that the SGS will serve as a platform to foster systemic awareness of the biophysical, cultural and socio-economic status of the BSR in order to enhance agility and adaptive capacity when selecting eco-technologies and responding to disaster risks from unexpected nutrient and pollution emissions.

The objective of this deliverable is to summarize the key conclusions of the scientific publication that drew on the work with serious game system and stakeholder co-inquiry process throughout the course of the BONUS RETURN project.

1.4 Outline of the report

This report provides the main conclusions from the scientific publication submitted to the Sustainability Science journal.

2 RETHINKING THE PRAXIS OF MEASURE SELECTION AND ASSESSMENT: CO-DESIGNING A SERIOUS GAME SYSTEM TO NAVIGATE WICKED SUSTAINABILITY ISSUES

The paper argues that nutrient pollution in the Baltic Sea is characterized by complexity, uncertainty and high decision stakes, a “wicked” situation that cannot simply be resolved by applying traditional scientific methods and sectorally bound policies. In order to capture the multi-dimensional narrative of nutrient governance and foster intersubjective rigor in the selection and assessment of measures and action, there is a need for an open and dynamic approach that involves a broader constellation of stakeholders who bring on board a rich diversity of perspectives in problem framing and navigational choices. In this paper, we deploy a serious game system as an innovative mode of praxis to enable no/low-regret actions as a means to navigate the “wicked” context of nutrient emissions in the Baltic Sea Region. The intersubjective narrative fostered by a serious game system leads to self-organisation without imposing a “burden” of epistemic inquiry or convergence of awareness among stakeholders as a premise for concerted action. Instead, it shifts the emphasis to co-engage in joint tasks and praxis as a community of practice through which more sustainable and legitimate actions and assessment methodologies can be enacted.

The main conclusions from the paper are summarized as follows:

1) The serious game system is a promising approach to support knowledge co-production processes in a creative, safe and inclusive space.
2) The serious game system serves as a communication platform for different constellations of actors to come together, which in turn leads to the emergence of a community of practice.
3) The serious game system supports reflection on the implementation of governance actions in "wicked" contexts.
4) The playfulness and inconsequential space of the game environment alleviate the distorting role of power that would otherwise orchestrate the outcomes in all three domains by separating the respective acts of knowledge production, communication of knowledge and implementation of governance action.

The paper is submitted to the Sustainability Science journal (https://www.springer.com/journal/11625/). The full manuscript can be found in the Appendix.

3 REFERENCES

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Powell, N., Do, T., Bachelder, S., Tattari, S., Koskiaho, J., Hjerppe, T., Väisänen, S. 2020. Rethinking the praxis of measure selection and assessment: co-designing a serious game system to navigate wicked sustainability issues. *Sustainability Science*. (Manuscript in Appendix)

4 APPENDIX

Rethinking the praxis of measure selection and assessment: co-designing a serious game system to navigate wicked sustainability issues

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Abstract

This paper makes a methodological contribution in terms of operationalising knowledge co-production through a serious game system to address “wicked” sustainability issues. The management of nutrient enrichment from diffuse sources, like many other sustainability issues, is characterized by complexity, uncertainty and power asymmetries, a “wicked” situation that cannot simply be resolved by applying normal scientific methods. “Wickedness” calls for an open and dynamic approach to bring on board a diversity of perspectives from a broader constellation of stakeholders. This paper reports on the co-design of a serious game system, SELECT ECOTECH; and examines its potential as an innovative mode of praxis, to surface no/low-regret actions to systemically address nutrient enrichment of the Baltic Sea. The serious game system was co-developed with a diverse group of stakeholders from three case settings in Sweden, Finland and Poland in the BONUS RETURN project. Our findings suggest that the serious game system is a promising approach to support knowledge co-production in a creative, safe and inclusive space. It also serves as a communication platform for different constellations of actors to come together, which in turn supports the emergence of an "extended peer community". Furthermore, it fosters reflection on the implementability of governance actions in "wicked" contexts by bridging the dichotomy between the acts of knowing and doing. Most importantly, the playfulness and inconsequential space of the game environment alleviates the distorting role of power that would otherwise collapse the multiple and fluid boundaries emerging from pluralistic knowledge production processes into a one-dimensional operating space.

Keywords: water governance, wicked situations, legitimacy, knowledge co-production, serious games, environmental assessment

Introduction

Decades after Rittel and Webber's (1973) seminal paper there is growing consensus that sustainability issues are wicked problems. Wicked problems are multifaceted and the nature of the problem and preferred solutions are strongly contested by stakeholders who hold diverging values and interests. In face of these indeterminate problems, normal science is unable to deliver definitive solutions (Head et al. 2016). There is growing recognition that working with wicked problems requires process orientated approaches that are participatory, systemic and anticipatory (Poli 2019). This is reflected in the mainstreaming of new modes of knowledge production which transgress the fixed explanatory frameworks that bound the regular scientific work of theorizing, observation, experimentation and modelling (Kuhn 2012). These include, for example, mode 2 science, post normal science, transdisciplinarity, social learning, participatory and systemic action research, knowledge co-production, etc. (Ravetz 2004; Burns 2007; Sharp et al. 2011; Ison et al. 2015)

Whilst we are experiencing a radical transformation in the modes of knowledge production in the face of wicked sustainability challenges, the inertia within pre-existing sectoral and hierarchical governance structures makes them resistant to change. The dominant sustainability narratives from normal science, articulated as expert defined system boundaries, states and targets (e.g. the planetary boundaries framework (Steffen et al. 2015)) are well aligned to discrete sectors and can be readily translated into the goals and performance indicators that enable policy implementation. In contrast, the systemic knowing that narrates problems under a wicked framing cannot be reconciled within existing governance structures. Thus, the multiple and fluid boundaries emerging from pluralistic knowledge production processes need to be collapsed into a one-dimensional operating space. The tradeoffs required to reconfigure this knowing tends to be a deeply political process, and inherent power imbalances often result in outcomes that are shaped by dominant positionholders (Westberg and Powell 2015; Knight et al. 2019).

In order to address the failure of existing governance structures to effectively draw on pluralistic knowing, Knight et al. (2019) argues that more attention needs to be given to bridging the dichotomy between the acts of knowing and doing. The notion of praxis challenges the divide between science and policy (knowing and doing) by embracing the dualities through traditions such as science in action and systemic action research (Pfeffer and Sutton 1999; Larsen 2013). “Good” praxis can be attentive to those that are often marginalised on account of power asymmetries, and by way of iterations between learning and doing, it is possible to experiment with governance actions that can address entrenched path dependencies (Freire 2000; Pielke Jr 2007).

In recent years, serious games have emerged as an innovative mode of praxis. Serious games can represent real-world issues whilst simultaneously providing a safe and inclusive space where stakeholders are encouraged to challenge their existing beliefs, cross knowledge boundaries, think outside of the box, co-create alternatives and test actions to address sustainability issues (Medema et al. 2016; Gugerell and Zuidema 2017; Jean et al. 2018)

Building on the aforementioned potential benefits, a serious game system entitled SELECT ECOTECH was co-designed with stakeholders in three river basins in the Baltic Sea Region (BSR); namely Fyrisån in Sweden, Słupia in Poland and Vantaanjoki in Finland in the BONUS RETURN project (www.bonusreturn.eu). Several other decision support tools were used within the project, including the river basin model SWAT (Soil and Water Assessment Tool) (Arnold et al. 1998), multi-criteria analysis (MCA), and cost effectiveness analysis (CEA). The aim of the serious game system was to complement these tools by addressing the "wicked" domain within the research context. More specifically, the aim of the serious game system was to provide a safe and inclusive learning space to support the selection and assessment of different constellations of eco-technologies (measures and actions) that tackle both diffuse sources of nutrient emissions and provide local co-benefits.

This paper presents the co-design process of SELECT ECOTECH and assesses its potential as a mode of praxis to tackle diffuse nutrient enrichment in the Baltic Sea.

The Research Context

The Baltic Sea is considered as one of the world's most polluted seas. The eutrophication of the sea, precipitated by nutrient enrichment from anthropogenic emissions of nitrogen (N) and phosphorous (P), is often used as a case to exemplify the Anthropocene (Crutzen 2002; Steffen et al. 2015; Zalasiewicz et al. 2018). Nutrient enrichment, like many other sustainability issues, is characterized by complexity, uncertainty and power asymmetries (Patterson et al. 2013; Powell et al. 2017). It is nested in complex systems that are dynamic and exhibit non-linear properties, as demonstrated by the extremes of droughts and floods. Similarly, the systemic nature of nutrient enrichment leads to complex interdependencies between the biophysical and socio-economic domains. Interdependency compounds and moves this problem between: upstream and downstream, terrestrial and marine contexts, societal intersections, and nation states. Moreover, other existing pressures such as climate change are projected to amplify enrichment (Bartosova et al. 2019) and flow-on effects to other sustainability issues such as food security, renewable energy, biodiversity and the provision of other essential ecosystem services.

Many of the scientific sustainability narratives that have led to the development of the sectorally bound EU environmental directives have generally performed poorly in fostering collective action within their specific sectoral domain let alone in terms of complex systemic issues which transcend sectors and stakeholder groups. Some progress has been achieved in improving the management of water quality and hydrological flows at regional scales under policy directives such as the Nitrates Directive (Directive 91/676/EEC 1991), the Urban Waste Water Directive (Directive 91/271/EEC 1991), the Water Framework Directive (WFD) (Directive 2000/60/EC 2000), and more recently the Marine Strategy Framework Directive (Directive 2008/56/EC 2008).

The enactment of the WFD can be viewed as a turning point in EU environmental legislation; a recognition that the implementation of water governance actions takes place in local contexts where there are multiple and conflicting interests. Under such conditions, in order to ensure that governance actions are both legitimate and implementable, the process of defining good water quality, and actions designed to meet these, need to be negotiable (Jager et al. 2016). Thus, the WFD stipulates that the chemical and ecological status of water shall be achieved by context-specific and stakeholder defined measures, and by way of consultation in the development and enactment of River Basin Management Plans (RBMPs) (Kochskämper et al. 2016).

In the absence of having earmarked funding to implement governance actions under the nutrient centred EU directives, the Baltic Sea countries have leaned heavily on the resources allocated to them under the EU's rural development programme and EU contributions to waste water and collection projects. For example, during the programming period 2007-2013, EU support amounted to 4.6 billion euro for wastewater actions and 9 billion in agri-environmental actions (European Court of Auditors 2016). In spite of EU's substantial investments to tackle nutrient emissions in the BSR, and in particular diffuse pollution, in a comprehensive EU audit undertaken in 2016, it is concluded that the RBMPs, which are the basis for HELCOM nutrient reduction targets *"lack ambition as they focus only on 'basic measures' for implementing EU directives in relation to the specific activities causing nutrient* *pollution, mainly urban waste water and agriculture. Less focus is put on measures for the control of diffuse sources of pollution as set out in the WFD." (ibid)*

The failure to address diffuse sources of pollution in the BSR is also reflected in the HELCOM's latest assessment of nutrient loads from 2014 (Sonesten et al. 2018), which indicates that there is decline in N and P from point sources, whereas inputs from diffuse sources have remained stable or even increased (Räike et al. 2020). This trend is expected to be magnified on account of climate change; namely increased demand for "locally produced" food and biofuels (Wulff et al. 2014); and increasing frequency and intensity of extreme precipitation episodes which leads to increases in nutrient leaching (Bartosova et al. 2019), and makes many of existing measures deployed to address diffuse pollution perform less effectively (Kynkäänniemi et al. 2013).

In the following section we will introduce and motivate the choice of the theoretical approaches used for this study in order to obtain a better understanding of the water governance praxis in the BSR and the shortcomings of models as decision support in wicked situations. Thereafter we will present the potential of serious games as an innovative method to support knowing and acting in wicked water management contexts.

Different sense making traditions in water resource management

In order to understand how sustainability narratives shape the selection of measures to tackle nutrient enrichment, we draw on a sense making framework that was originally presented in Powell and Larsen (2013) (see Fig. 1). Under reductionist sensemaking (A), the desirable state of the system is elicited by identifying the building blocks by way of iterations between reduction, classification and analysis. The policy environment aligns the building blocks to discrete sectors which deploy actions to optimise their state by means of policy instruments i.e. the Nitrates and Urban Waste Water Directives.

Expert sensemaking (B), emphasises the whole system, and the interconnections between its components. Here the hard boundaries that circumscribe water bodies become the unit of analysis for science and the administrative space for policy (i.e. the RBMPs under the WFD and the Baltic Sea Action Plan). The desirable system state is articulated as one-dimensional targets such as good ecological and good chemical status.

Epistemic sensemaking (C), views system boundaries as soft, permeable and fluid. Here sustainability is considered as negotiable and depends on the purpose a particular stakeholder ascribes to the system. Here governance actions are no longer prescriptive and legitimacy grows out of their capacity to meet the demands from a diverse set of interests and ongoing and unforeseen socio-ecological dynamics. Measures that are applied under epistemic sensemaking can be referred to as no/low-regret actions or measures. Within climate governance, low/no regret actions are considered as a "precautionary" approach to climate change adaptation, and foster "win-win" situations by addressing present multi-sectoral vulnerabilities and future risks (IPCC 2014; David et al. 2016). They can produce a whole host of co-benefits such as livelihood improvement, human well-being, biodiversity conservation and are considered to minimize the risk of maladaptation (Field et al. 2012).

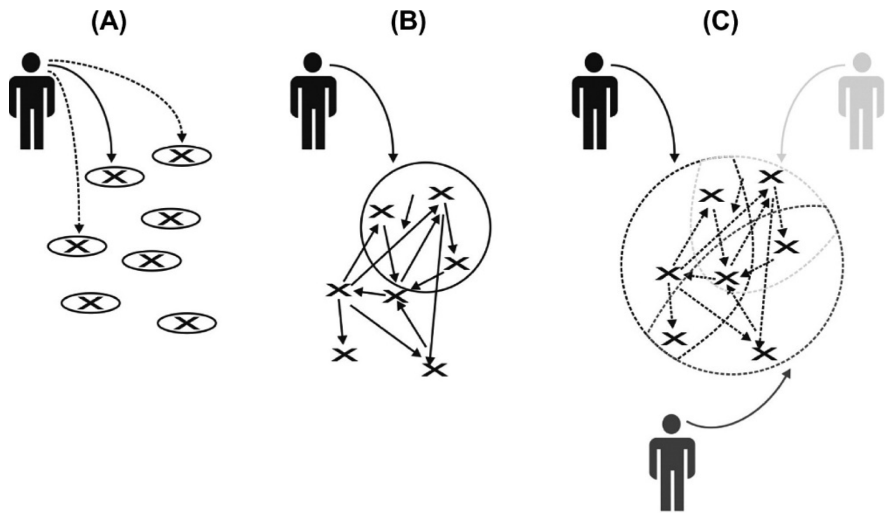

Figure 1. Diagrammatic representation of the three sensemaking perspectives: (A) Reductionist sensemaking; (B) Expert sensemaking; (C) Epistemic sensemaking (Powell and Larsen 2013)

The use of models as decision support tool in water governance and their limitations in wicked contexts

In the BSR, hydrological, water quality and economic models such as Cost-Effectiveness Analysis (CEA) are used as a sensemaking tool to support the selection and assessment of the most appropriate measures to achieve good water status (Directive 2000/60/EC 2000).

Hydrological and water quality modelling supports the direct measurement of flows, and the emissions and transport of waterborne pollutants at different scales. The "proxy" data derived from these models is particularly important for simulating the emissions from non-point source pollution, as generating data from the direct measurement of diffuse sources is considered extremely expensive. In the BSR, hydrological models, such as HYPE, SWAT, BALTSEM, etc. have been used to create nutrient budgets and optimize the costs of management solutions (Savchuk 2018). For instance, they have generated data for HELCOM's Baltic Sea pollution load compilations for the implementation of the Baltic Sea Action Plan (Sonesten et al. 2018). Moreover, they are able to assess the effectiveness of various measures such as buffer strips, constructed wetlands, and catch crops, in order to support the selection of the Program of Measures included in the RBMPs (Piniewski et al. 2015; Arheimer and Pers 2017). In BONUS RETURN for example, SWAT, a catchment-level hydrological, soil and water quality model, provided the data on the nutrient loading as well as on the effectiveness of eco-technologies and agri-environmental Best Management Practices (BMPs) to reduce emissions in the 3 case study catchments (Koskiaho et al. 2020).

CEA is grounded in the economic rationale that the removal of a given amount of nutrients should be done at the lowest possible cost. Conducting a CEA of mitigation measures has become a prerequisite in formulating a Programme of Measures for all river basins (Balana et al. 2011). Most CEA methods used in water management are based on results from models for the quantification of effectiveness indicators manifest in the reduced transport of nutrient loads (ibid), which suggests that conducting CEA will become challenging in the event that some measures cannot be modelled.

The knowledge traditions underpinning hydrological, water quality and economic models are closely aligned with the dominant science tradition, embodied within a techno-centric worldview where social and ecological systems are treated as a dualism (Ison et al. 2011). Models exhibit limitations in representing the complexities underpinning nutrient enrichment in qualitative terms (Beven 2010) and are unable to display the value-laden assumptions and the uncertainties in their outputs (Van der Sluijs 2002). As models are generally calibrated to accommodate a limited number of dimensions i.e. nutrient emissions, they have difficulties incorporating local practices which tend to be multifunctional and have values which cannot be quantified within a single model. Moreover, based on the premise that scientific knowledge is objective, models are unable to recognize the role of agency and power that shapes the choice of actions, the motivation, goals, and navigational tools affecting the implementation of those actions.

In order to get a better sense of the efficacy of models in supporting decision-making in different contexts, we draw on the Cynefin framework (Kurtz and Snowden 2003) (see Fig. 2). Here four strategic approaches to decision-making are identified according to the level of complexity and urgency to respond. In simple or complicated contexts, when the relationship between cause and effect are observable or can be determined by analysis and/or expert knowledge, models have proven to be effective for assessing actions to tackle problems. However, in complex situations, when cause-effect can only be determined retrospectively (post action) and; in chaotic situations when causal relationships cannot be determined and there is an urgent need to act, the data generated by models is no longer valid.

Figure 2. The Cynefin decision-making framework (Kurtz and Snowden 2003) shows the spectrum of situations from simple, complicated to complex and chaotic that require different approaches to decision-making.

Complex and chaotic situations are characterized by a high degree of uncertainty. The critique of models often points to their lack of capacity to deal with uncertainty at many levels. Maier et al. (2016) discuss two types of uncertainty in relation to models: aleatory uncertainty and epistemic uncertainty. Aleatory uncertainty refers to the intrinsic uncertainty of natural fluctuations. Existing models struggle to represent dynamics of change as a consequence of their structures. Uncertainty is inherent in these dynamics, as future system behaviour is shaped by many multifaceted components that cannot be quantified or observed. Epistemic uncertainty on the other hand, grows out of the ambiguity arising from contested views in terms of causal relationships, the degree of uncertainty, or the preference of interventions on account of underlying motivations and goals (Dewulf et al. 2005). Rather than acknowledging the multi-dimensional nature of sustainability issues, in order to operationalise models, tradeoffs are required to reduce their dimensionality. This one-dimensional narrative is also reproduced by the widespread use of economic models, such as CEA. CEA again only represents a single dimension, i.e. nutrient reduction rather than accounting for diversity of ecosystem services and livelihood benefits manifest in local contexts. In fact, measures that are preferred by local stakeholders because they can help achieve multiple goals, such as increased biodiversity, better connectivity for fish migration, or improved flood mitigation are often excluded in the assessment (Carolus et al. 2020).

Post Normal Science and the potential of serious games to support knowing and acting in wicked contexts

The critique of models is part of a wider debate on the legitimacy and credibility of science and the dominion of expert knowledge in supporting decision-making. It surfaces the need to transcend the boundary of science to include other actors in knowledge generation processes to form an "extended peer community" (Saltelli et al. 2009). The extension of the peer community can enrich scientific inquiry processes and enhance the rigorous quality of scientific outputs and the legitimacy of policy decisions that are derived from them (Funtowicz and Ravetz 1993). The process by which an expanded peer community fosters legitimacy through validation and generation of data and insights builds intersubjectivity (Peker 2008; Husserl 2012; Leavy 2012). This led to the emergence of a different research tradition, post normal science that emphasizes knowledge co-production between stakeholders and scientists, in order to bring about changes. This approach emphasises interactive dialogue rather than formalised scientific deduction and embraces uncertainty and divergence of values instead of omitting them (Funtowicz and Ravetz 1993).

Serious games have emerged as a promising approach within the sustainability discourse owing to their potential in crossing knowledge boundaries and supporting knowledge co-production (Gugerell and Zuidema 2017; Jean et al. 2018; Medema et al. 2019). Serious games are often defined as games used for purposes beyond entertainment. These purposes can range from teaching and training, research and data collection, facilitating social learning and change of practice (Flood et al. 2018; Rodela et al. 2019).

Serious games can serve as a creative method for engaging with stakeholders, capturing and harnessing their local knowledge and experience in order to determine appropriate actions (Salvini et al. 2016; Medema et al. 2019; Rodela et al. 2019). Moreover, they can provide an arena for stakeholders to reflect and challenge their existing beliefs, deliberate, negotiate and resolve conflicts (Flood et al. 2018). Furber et al. (2018) outline three contexts where serious games have the potential to serve as tools for supporting decision-making, namely: i) contexts characterized by complex systems and high levels of uncertainty, which can neither be fully understood nor mathematically modelled; ii) contexts involving multiple stakeholders with divergent perspectives and iii) contexts with a high degree of urgency where decisions have to be made under time constraints. In these contexts where the knowing is indeterminate, the conventional methodologies that drive decision-making can lead to maladapted outcomes. Furber et al. (2018) posit that serious games can be harnessed to navigate decision-making in such contexts by identifying multi-dimensional solutions through testing alternative courses of action, enhancing the recognition of diverse perspectives and developing their capacity and agile use of knowledge and experience for swift assessment in response to urgent situations.

Another crucial benefit of serious games, that has enabled them to gain traction in sustainability research, is their ability to provide a safe space for exploration and experimentation (de Suarez et al. 2012; Schulze et al. 2015; Rumore et al. 2016). Serious games represent real-world issues and capture their complexity, but at the same time, offer greater freedom to think outside the box in order to explore different pathways for sustainability transformation (Gugerell and Zuidema 2017; Jean et al. 2018). Within this setting, co-production of knowledge and real empowerment take central place (de Suarez et al. 2012; Flood et al. 2018), which in turn can lead to improvement of systems understanding and identification of novel solutions and approaches (Gugerell and Zuidema 2017).

Methods and Materials

Case Studies

Case study analysis is a powerful approach to elicit contextual lessons and engage decision makers in learning towards improved governance (De Stefano 2010). The cases were drawn on from a diverse set of country contexts. This allowed for in-depth and multi-faceted exploration of complex nutrient-related issues in the BSR, which supported the development of the serious game system SELECT ECOTECH. Three case study catchments were included, namely Fyrisån in Sweden, Vantaanjoki in Finland, and Słupia in Poland. They were selected on account of their similar size (1000-2000 km^2) and the presence of a variety of water resource problems, e.g. diffuse pollution from agriculture, urban runoff and point source pollution. Table 1 summarizes an overview of the case study contexts.

Table 1. Basic descriptions of the case studies

Catchment	Fyrisån (Sweden)	Vantaanjoki (Finland)	Słupia (Poland)
Size (km^2)	1982	1688	1623
Land use (% of total area)	60% forestry, 32% agriculture, 2% urban areas	56% forestry, 23% agriculture, 17% urban areas	42% forestry, 54% agriculture, 3% urban areas
Stakeholders involved	Academia, agriculture, wastewater, energy, municipality, regional authority	Academia, agriculture, wastewater, forestry, environmental protection, municipality, regional authority	Academia, agriculture, wastewater, aquaculture, forestry, energy, biodiversity, environmental protection, regional administration

Co-designing a serious game system

The main method employed for the development of SELECT ECOTECH was co-design (also known as participatory design). This approach embraces stakeholders as "co-designers". Their participation in co-design activities contributes real-world knowledge, values, perceptions and interest, which in turn will lower the risk of failure due to blind spots, designer bias or misinterpretation of context specific content (Khaled and Vasalou 2014; Ampatzidou and Gugerell 2018). More importantly, co-design approaches support the enactment of a learning environment that allows for the interplay of different kinds of knowledge from scientists and stakeholders from different backgrounds.

Stakeholders can be engaged in game design processes in different ways and at different levels, namely stakeholders as users of the game, as testers of playable prototypes, as informants providing consultation to the game design team, and as design partners who are fully involved in game design processes (Mildner and Mueller 2016). SELECT ECOTECH followed the fourth design strategy which embraces the highest level of stakeholder engagement, recognising stakeholders as equal partners in the co-design process. The co-designers from the case study settings represented a diversity of sectors, including wastewater, agriculture, forestry, energy, aquaculture and environmental protection (see Table 1). 36 stakeholders participated, including local and regional authorities, academics, interest organisations, advisory associations and businesses.

SELECT ECOTECH was developed as a board game as this format was able to support a co-design process that would facilitate learning, exploration and experimentation to a greater extent. Unlike digital games, the rules underpinning a board game are generally explicit and can be modified easily and rapidly, allowing for flexibility and swiftness that is desirable in iterative game design processes. Another advantage of board games is their transparency, exposing players to the various mechanics and data that create complex and dynamic situations (Castronova and Knowles 2015).

The co-design process underpinning SELECT ECOTECH was made up of three main phases: concept design phase, co-design phase and final co-development phase (see Fig. 3).

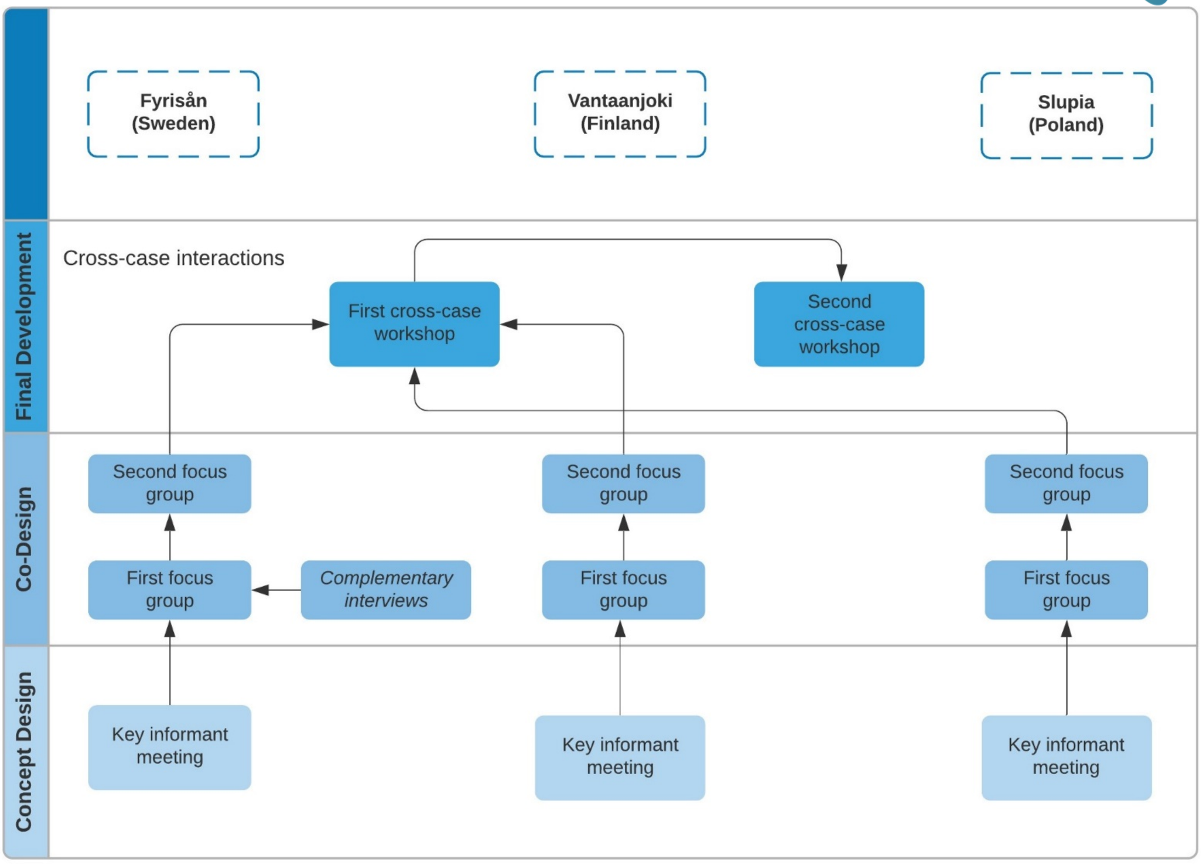

Figure 3. The co-design process of the serious game system in three case study settings in BONUS RETURN

Concept design phase: Surfacing issues and stakeholders

This phase was conducted to elicit a preliminary understanding of the issues manifest in the three case studies by actors who have a stake in those issues. An understanding of the baseline conditions in the cases was partly obtained through the initial findings from the modelling and multi-criteria analysis work in the project (Johannesdottir et al. 2019). TWOCAGES mnemonic (see Box 1) was used to identify those stakeholders who would be invited to participate in the co-design process (Checkland and Poulter 2006). Key informants and a snowballing approach were employed at the outset of the identification process. Key informants were the initial set of stakeholders, identified through the BONUS RETURN researchers' pre-existing networks, local knowledge, a desk review, and media screening. Snowballing is an iterative approach for identifying stakeholders on the basis of established networks. In this respect, each stakeholder we encountered served as an informant for identifying other stakeholders (Colvin et al. 2016).

Those may be people whom they have worked with or have been in contact with, whom they feel have affected or been affected by their work in some way.

T – Transformation: The desired change or desired future state of a situation

W – Worldview: The values and ethical justifications for proposing transformation

O – Owner: Those who control or own the transformation (who can start or stop it)

C – Clients: The beneficiaries and victims of the transformation

A – Actors: Those who carry out the activities required to achieve the transformation

G – Guardians: Those who can inform the unintended consequences of the transformation

E – Environment: Influences outside the control of the owners that may help or hinder the transformation

S – System: All the activities that must be initiated and coordinated to achieve the transformation

Box 1. TWOCAGES mnemonic (Checkland and Poulter 2006)

During the key informant meetings, stakeholders were invited to develop rich pictures to frame the issues they face in their respective river basins. Rich pictures is a graphical technique to represent complex situations, problems or concepts with the use of pictures, texts, symbols, and icons (Scholes and Checkland 1990). Based on the analysis of the rich pictures, it was possible to identify those who had a stake in eco-technologies designed to reduce nutrient enrichment. Furthermore, it supported our understanding of what co-benefits would be desirable to derive from the implementation of eco-technologies in addition to nutrient reduction, for instance, biodiversity, crop productivity, local economic development, fishery and tourism. At the end of this phase, a diverse constellation of stakeholders emerged who expressed their interest in partaking in the co-design of SELECT ECOTECH. The results of this phase also provided a basis for the initial structure of a board game that facilitated the co-design process in subsequent phases.

Co-design phase: Crafting responses to a dynamic socio-ecological system

The co-design phase for SELECT ECOTECH was characterized by a dynamic co-inquiry process into the feasibility and impacts of different constellations of eco-technologies in agriculture, forestry, urban and marine contexts. 36 stakeholders (see Appendix 1) participated in this phase from the three cases by way of interviews and focus groups. Eight interviews were conducted in the Fyrisån case study to increase buy-in from key stakeholders before the co-design phase officially took place. The first round of focus groups helped foster critical reflection on the dilemma's stakeholders faced in their respective contexts and surfaced numerous local approaches to address these. Insights from these sessions further supported the initial design of the board game structure. In the second round of focus groups, the first iteration of SELECT ECOTECH was introduced to mediate stakeholder dialogue pertaining to eco-technology preference and appropriate modes of implementation. These sessions were designed as a free-form activity with an initial rule set, rather than having a strictly standardized procedure enforced on players (Deterding et al. 2013). In this regard, the act of playing, creating game content and validating game mechanics were interwoven to allow for open and dynamic co-design sessions (Gugerell and Zuidema 2017). New ideas for game rules and components were proposed by players and subsequently tested on the spot.

Final co-development phase: Navigating shocks and the governance environment

The results of the second phase were analysed in order to refine the board game content, mechanics and functions, which led to the second iteration of SELECT ECOTECH (see Fig. 4). This was used to mediate stakeholder dialogue in an interactive cross-case workshop in Uppsala (Sweden) where a selected number of stakeholders from the three cases were brought together to explore how different constellations of eco-technologies perform in the face of disaster risks and threats (see Appendix 2) that are presently manifest within the BSR, whilst revealing similarities and differences within and between contexts. The insights from this session were consolidated to support continuous improvement and validation of SELECT ECOTECH. The third version was introduced in another cross-case workshop in Helsinki (Finland) where it facilitated fruitful discussions as to how the existing policy environment enables or hinders the implementation of different eco-technologies in agriculture, forestry and urban areas. The co-design process resulted in a final board game prototype that supported learning processes and decision-making regarding the selection and implementation of constellations of eco-technologies that have the capacity to address nutrient emissions, whilst remaining cognisant of the need to reconcile multiple demands at the local context (see Appendix 3).

Figure 4. Co-designing SELECT ECOTECH to support decision-making about the selection and implementation of different constellations of eco-technologies for nutrient reduction and other local co-benefits

The board game can be played between two players or two teams. SELECT ECOTECH includes the main board, six hexagon tiles for three different land use systems (two for Agriculture, two for Forestry and two for Urban area) and a number of game tokens, including eco-technology tokens (white), development tokens (grey), resource tokens (green) and emission tokens (red). The board game is set up at the beginning of a play session as illustrated in Fig. 5.

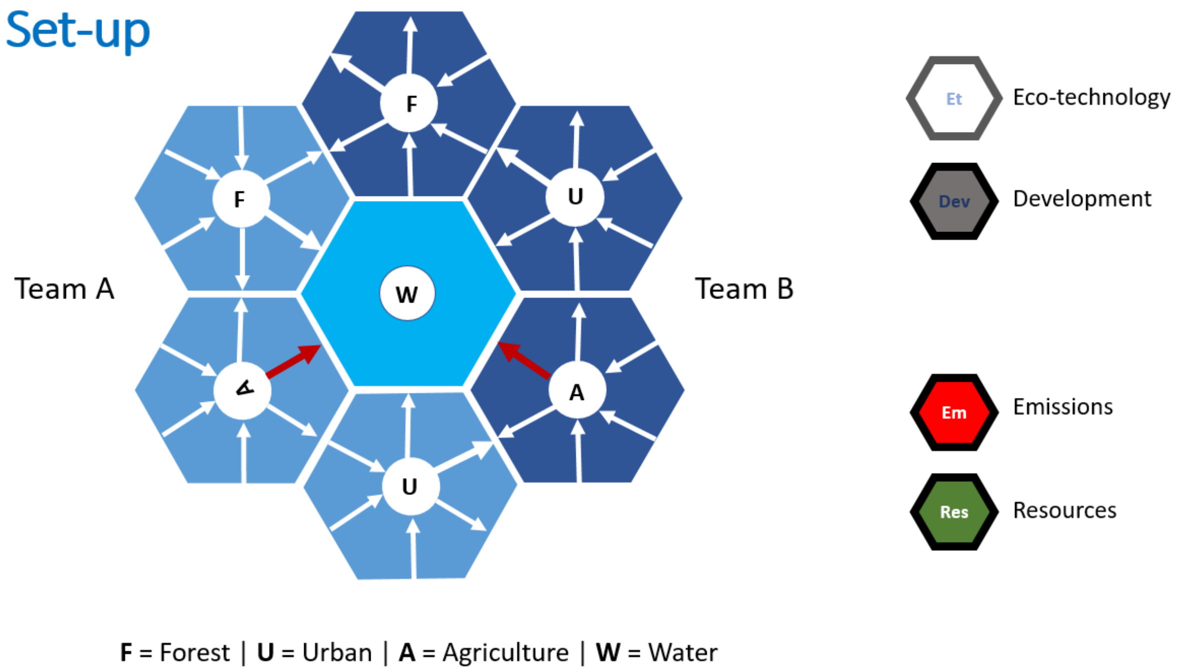

Figure 5. Setup of the board game SELECT ECOTECH

The players' objective in the board game prototype SELECT ECOTECH is threefold: i) to reduce emissions from their respective land use systems (urban areas, forestry, and agriculture); ii) to increase the productivity of these systems; and iii) to increase the adaptive capacity of their land use systems. The players must use resources to purchase both eco-technologies and development interventions in order to achieve those objectives. When deploying eco-technologies and development interventions, they need to navigate the checks and balances from a dynamic policy environment; the potential conflicts of interests with other players, as well as the shocks and risks they may encounter in a dynamic socio-ecological system.

Emergent insights from the co-design sessions were recorded through photographic documentation and note-taking. After each session, the notes were reviewed, consolidated and interpreted jointly by the research team. Moreover, feedback and suggestions for improvement provided by the co-designers (stakeholders) were discussed as a basis for implementing changes in the serious game system.

Discussion

In this section, we reflect on the insights emerged from the development process of SELECT ECOTECH and subsequently discuss the potential of a serious game system to support the selection of no/low regret actions that are considered more legitimate in the face of complex and urgent situations.

Serious game system as a complement to modelling in decision support

Experiences from the BONUS RETURN project exemplified the difficulties of models in supporting measures and action to tackle wicked sustainability issues. During the process of developing SELECT ECOTECH, we intended to use the data generated by the SWAT model as input into the serious game system. However, out of 35 eco-technologies identified by our stakeholders from the three cases, only five eco-technologies, i.e. wetlands, retention ponds, buffer strips, catch crops, and crop rotation could be modelled in SWAT within the timeframe of the project. Whilst the main aim of BONUS RETURN was to support synergistic constellations of eco-technologies in order to tackle nutrient emissions and bring about co-benefits for local stakeholders, however, the conventional approach is to model one eco-technology at a time and subsequently aggregate their effects to calculate the total nutrient loading. Thus, it was not possible to gain a systemic understanding of the synergies or conflicts for a constellation of eco-technologies as the emphasis was put on discrete technical solutions, rather than interconnections.

The shortcomings of the SWAT model were magnified when we worked towards developing the serious game system that would enhance the adaptive capacity of stakeholders to respond to nutrient emissions under complex and chaotic situations characterized by disasters and shocks in the BSR. This involved devising new constellations of eco-technologies in the absence of evidence to support their effectiveness from the models. Thus, we drew on proxy values that grow out of embodied knowledge from stakeholders who had experience in working with those eco-technologies. As opposed to the rigid structures of models, the iterative and open structures of the serious game system made it possible to develop responses even in the face of uncertainty. As Mayer (2009) also argues, one of the weaknesses of models is the “black box” filled with assumptions and calculations that most stakeholders struggle to make sense of, whereas games are much more transparent and easier to interact with. Furthermore, games have great flexibility as they can be shaped into many different forms and directions (ibid). Evidently, what we observed during the development process of SELECT ECOTECH was that the game content and mechanics increasingly took shape as a result of stakeholder participation. More importantly, as the focus of the serious game system was the development process rather than a full-fledged game artefact, the assumptions and values underlying the game structure were made explicit for stakeholders to evaluate and modify as they were playing.

The use of proxy values again emphasised the importance to recognise different ways of knowing, rather than an overreliance on evidence-based knowledge, in order to guide our actions in times of complexity and uncertainty manifest in “wicked” contexts. Feedback from most of the stakeholders involved in the co-design process suggests that the serious game system showed great potential in expanding the boundaries of a normal scientific process to foster knowledge co-production where multiple types of knowledge and ways of knowing are appreciated in a safe and inclusive setting. Within this setting, perspectives can be bridged, and shared understanding and trust among various stakeholders can be built, which is crucial for supporting purposeful and concerted actions in local contexts (Ison et al. 2011; Patterson et al. 2013).

Serious game system as an innovative method to foster intersubjectivity in order to enable no/low-regret actions

Much of the literature on transdisciplinary research discusses how to conceptualise co-production and elucidates its importance and benefits. In contrast, our research focused on how to operationalise co-production through the employment of a serious game system. The serious game system is not a model for obtaining new facts but rather is an alternative mode of praxis to rethink and enact them.

Within the game setting, stakeholders as players were faced with challenging situations, referred to as “system shocks”, such as flooding, drought, changes in the policy environment, market conditions or public awareness. The players responded by devising an appropriate constellation of eco-technologies that could adapt to the shocks while best serving their multiple interests. The safe space evoked by SELECT ECOTECH levelled the playing field, allowing them to openly share and discuss why barriers to implementation of certain eco-technologies persist or are amplified in their own contexts. This further opened up an opportunity to learn about how these situations could be transformed by developing no/low-regret practices and legitimate assessment methodologies that are resilient in “wicked” situations.

Many participatory approaches aim at building consensus to resolve conflicts and enable collective action. Rather than relying on reified scientific narratives, the serious game system allowed for the coexistence of different perspectives and actions, as a response to multifaceted nutrient-related issues. In so doing, a specific narrative was not advocated. Rather, multiple narratives were empowered in order to improve governance performance in uncertain and wicked situations; situations where scientific and policy-oriented narratives that would otherwise ultimately shatter and be reconstituted through local practice and agency (Powell et al. 2014).

Limitations and suggestions for future research

Despite the positive feedback about the serious game system, certain limitations of our study need to be acknowledged. During the game development process, we were faced with the challenge of balancing the complexity of real-world issues, i.e. the richness of the knowledge and experience brought by our stakeholders and the playability and fun elements of the game. This suggests that the game structure must not be overly complex whilst still allowing for nuanced discussions to take place. As Ampatzidou and Gugerell (2018) also point out in their work with serious game design, it is crucial to create a balanced game prototype that accommodates both the complexity needed to address the issue at hand and the playability expected from any game.

It is evident that serious game systems can open up new possibilities for engagement and contribute to the diversification of methods and tools for facilitating transdisciplinary research processes (Ampatzidou et al. 2018; Andreotti et al. 2020). However, critical questions remain unanswered, which can pose a challenge for a wider application of this method. Can the learnings (e.g. knowledge, skills, empathy…) gained within the game environment be carried into the real world? How does one's experience in the game space impact their knowing and doing in real-world situations? Future research should explore these questions in order to increase the adoption of serious game system as an alternative mode of praxis to support decision-making in wicked contexts.

Conclusion

The epistemology underpinning serious game systems can be distinguished from existing serious games as they are emergent and non-prescriptive. Rather than communicating scientific narratives as educational outcomes, they can serve as a mode of praxis to develop and assess the potential of actions to qualify as a no/low regret approach to navigate "wicked" contexts. The approach facilitated by the serious game system can be seen as an alternative to the tradeoffs that are inevitably required to collectively act in the face of "wicked" sustainability issues, as they can foster self-organisation without imposing convergence of awareness among stakeholders as a premise for concerted action. Here the emphasis becomes co-engagement in praxis through which more sustainable and legitimate measures and assessment methodologies can be enacted. In so doing, consequential actions can be agreed upon in the inconsequential game environment where different kinds of knowledge and ways of knowing and acting are not distorted by power asymmetries.

The serious game system served as a novel and innovative approach to support intersubjective perspectives and actions. In the absence of scientific evidence, on account of epistemic and aleatory uncertainty, the serious game system surfaced proxy data, embodied in multiple ways of knowing. It is noteworthy that these data serve to complement rather than substitute other types of data generated from normal science. Inherent in this approach was a shift in the mode of knowledge production and the distribution of agency, from a group of experts to an extended peer group. Our findings suggest that the constellations of measures that emerged through their enactment in the serious game system are arguably more legitimate and adaptive under wicked conditions, as they embody a multi-dimensional narrative, which does not need to be collapsed by way of a tradeoff process in order to allow for their implementation.

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Appendices

Appendix 1. List of contributors to the co-design of SELECT ECOTECH

No.	Organisation	Case study
1.	Federation of Swedish Farmers (LRF)	Fyrisån, Sweden
2.	Vansta Lantbruk	Fyrisån, Sweden
3.	Uppsala municipality	Fyrisån, Sweden
4.	Uppsala Vatten	Fyrisån, Sweden
5.	County Administration Board Uppsala (Länsstyrelsen)	Fyrisån, Sweden
6.	Lövsta biogas plant	Fyrisån, Sweden
7.	Swedish University of Agricultural Sciences	Fyrisån, Sweden
8.	Uppsala municipality	Fyrisån, Sweden
9.	Linköping University	Fyrisån, Sweden
10.	Skogvision	Fyrisån, Sweden
11.	Finnish Environment Institute (SYKE)	Vantaanjoki, Finland
12.	Finnish Environment Institute (SYKE)	Vantaanjoki, Finland
13.	Finnish Environment Institute (SYKE)	Vantaanjoki, Finland
14.	Finnish Environment Institute (SYKE)	Vantaanjoki, Finland
15.	Helsinki Region Environmental Services Authority Water Services	Vantaanjoki, Finland
16.	Centre for Economic Development, Transport and the Environment	Vantaanjoki, Finland

17.	Finish Forest Centre	Vantaanjoki, Finland
18.	University of Helsinki	Vantaanjoki, Finland
19.	University of Helsinki	Vantaanjoki, Finland
20.	Helsinki Region Environmental Services Authority Water Services	Vantaanjoki, Finland
21.	Organic farmer	Vantaanjoki, Finland
22.	City of Hyvinkää	Vantaanjoki, Finland
23.	Warsaw University of Life Sciences	Słupia, Poland
24.	Warsaw University of Life Sciences	Słupia, Poland
25.	Warsaw University of Life Sciences	Słupia, Poland
26.	Słupsk Waterworks	Słupia, Poland
27.	Pomeranian University in Słupsk	Słupia, Poland
28.	Słupsk Waterworks	Słupia, Poland
29.	Słupsk Waterworks	Słupia, Poland
30.	Pomeranian Agricultural Advisory Center	Słupia, Poland
31.	Farmer in the Słupia Catchment	Słupia, Poland
32.	Energa Production	Słupia, Poland
33.	Polish Waters, Słupsk Supervision of Water	Słupia, Poland
34.	POMINNO, Gdynia	Słupia, Poland
35.	Pomeranian University in Słupsk	Słupia, Poland
36.	Koszalin University of Technology	Słupia, Poland

Appendix 2. List of shocks generated by stakeholders in SELECT ECOTECH

Fyrisån, Sweden	Vantaanjoki, Finland	Słupia, Poland
- Change of chemicals legislation: all new chemicals supplied to society must be investigated before import and use - Wastewater as a resource would feel "safer" for the public - Prohibition of sewage sludge use - Highly increased transportation costs (for water) - Fast cost reduction on decentralised and mass produced wastewater treatment technology - New legislation on drainage - Ecological tax reform on electricity - Subsidies/support for technical development in biogas	- Warming climate (mild winter and rainfall) - Extreme drought - Massive flood episodes - No ground frost during the whole winter - Strict nitrogen budget in the EU's Common Agricultural Policy (CAP) - Only EU's developing countries are entitled to receive subsidies from CAP - Decrease of animal manure due to an increase in vegetarian diets - Heath problem(s) caused by the use of sludge on agricultural lands - Profitability in farming increases dramatically - Permits for peatland management, drying peatlands	- Rapid increase in prices for fuels (oil, gas, electric energy) - Long period of dry years (severe drought) due to climate change - Accident at the Composting Plant – no possibility to collect and compost the organic waste - Lack of energy supply – industrial catastrophe - Infrastructure damage caused by flood - Quick and dramatic climate change followed by change in agricultural policy - Change in regulations which prohibit any new damming constructions in the catchments - Long-lasting rainfall (flooding)

Appendix 3. List of synergistic constellations of eco-technologies and developments in SELECT ECOTECH

1. Small scale district heating

   Combined with: Incineration and phosphorus recovery from ash

2. Greenhouse

   Combined with: District heating, biochar, compost or irrigation from nutrient-rich retention ponds

3. Hunting tourism

   Combined with: Riparian zones, wetlands and buffer strips

4. Building houses for rent

   Combined with: District heating with renewable energy, urine-diversion toilets, source separation of waste from scattered settlements.

5. Slaughterhouse

   Combined with: Biogas plant and biochar production

6. Biogas plant

   Combined with seaweed farm, mussel farm and buffer strips