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State-of-the-Lagoon Reports as Vehicles of Cross-Disciplinary Integration

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EDITOR'S NOTE:

The present study represents 1 of 5 review articles generated from 2 research projects funded by the European Union's Seventh Framework Program, ARCH and LAGOONS. The projects aim to develop and apply participative methodologies in collaboration with key stakeholders, to manage the multiple problems affecting European lagoons and estuaries. The articles in this series provide strategies for the sustainable management of these vulnerable ecosystems, which are increasingly threatened by climate change, urbanization, and industrialization.

ABSTRACT

An integrative approach across disciplines is needed for sustainable lagoon and estuary management as identified by integrated coastal zone management. The ARCH research project (Architecture and roadmap to manage multiple pressures on lagoons) has taken initial steps to overcome the boundaries between disciplines and focus on cross-disciplinary integration by addressing the driving forces, challenges, and problems at various case study sites. A model was developed as a boundary-spanning activity to produce joint knowledge and understanding. The backbone of the model is formed by the interaction between the natural and human systems, including economy and governance-based subsystems. The model was used to create state-of-the-lagoon reports for 10 case study sites (lagoons and estuarine coastal areas), with a geographical distribution covering all major seas surrounding Europe. The reports functioned as boundary objects to build joint knowledge. The experiences related to the framing of the model and its subsequent implementation at the case study sites have resulted in key recommendations on how to address the challenges of cross-disciplinary work required for the proper management of complex social-ecological systems such as lagoons, estuarine areas, and other land-sea regions. Cross-disciplinary integration is initially resource intensive and time consuming; one should set aside the required resources and invest efforts at the forefront. It is crucial to create engagement among the group of researchers by focusing on a joint, appealing overall concept that will stimulate cross-sectoral thinking and focusing on the identified problems as a link between collected evidence and future management needs. Different methods for collecting evidence should be applied including both quantitative (jointly agreed indicators) and qualitative (narratives) information. Cross-disciplinary integration is facilitated by functional boundary objects. Integration offers important rewards in terms of developing a better understanding and subsequently improved management of complex social-ecological systems. *Integr Environ Assess Manag* 2016;12:000–000. ©2016 SETAC.

Keywords: Coastal zone Boundary spanning Complex systems Knowledge integration Cross-disciplinarity

INTRODUCTION

The complex character of lagoons and the estuarine system makes it difficult to predict how the system will respond to policy measures. Subsequently, this type of problem can be called a complex policy problem. Complex policy problems are characterized by the systemic and persistent character of the environmental problem, many interdependencies, a diversity of stakeholder interests, and many different views on the problem. For these complex, often called "wicked" problems (Jentoft and Chuenpagdee 2009; Patterson et al. 2013), we need a new approach that is aimed at the integration of scientific knowledge, stakeholder involvement, and collaborative knowledge production (Slob and Duijn 2014).

The present study focuses on the integration of scientific knowledge. The need for this interaction across disciplines is illustrated in integrated coastal zone management (ICZM; introduced in 1992 by the Rio Conference: UN Conference on Environment and Development). A critical overview of the ICZM concept can be found in Billé (2008), whereas an extensive list of publications on ICZM is available at the Directorate-General for Environment (DGE) web site under

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the heading ICZM Bibliography (http://ec.europa.eu/environment/iczm/biblio.htm).

A key aspect of the ARCH research project (http://www.arch-fp7.eu) has been to facilitate the transition from disciplinary science to interdisciplinary science. This means that various scientific disciplines, such as coastal morphology, ecology, economics, spatial planning, and governance studies, should be involved in understanding and describing the lagoon or estuarine system in a holistic way. Interdisciplinary research is based on active interaction across fields (Huutoniemi et al. 2010). This interaction takes place not only in the framing of research problems and coordinating knowledge flows between fields, but also in the execution of research and the formulation and analysis of results. Due to the cultural differences between disciplines, one of the core challenges in realizing interdisciplinarity is to overcome or span the boundaries between the various disciplines involved. In this respect, working toward a common vocabulary is considered to be essential (Klein 1990; Haapasaari et al. 2012). Next, and in relation to this development of shared understanding, participating individuals have to be open and willing to learn from each other and to see the value of other disciplinary frames. How can this be achieved?

A first step in the ARCH project was to connect the various disciplines and to develop an interdisciplinary and integral framework to analyze various case sites and capture the various problems and pressures facing lagoons. The research activities were centered around 10 case study sites (lagoons and estuarine coastal areas, hereafter referred to as lagoons), with a geographical distribution covering all major seas surrounding Europe: the Baltic Sea, Norwegian Sea, North Sea, Atlantic Ocean, Mediterranean Sea, and Black Sea (Figure 1). State-of-the-lagoon (SoL) reports were prepared using this framework for each case study site, an exercise in integrating different disciplines and different fields of expertise. The SoL reports consisted of gathering existing data, integration of data, and presentation in the context of ecosystem services, with an emphasis on minimizing the boundaries between the different scientific disciplines.

Figure 1. Location of coastal lagoons and estuaries included in the ARCH project, covering the interface between land surface and the seas surrounding Europe (see Table 2 for site names).

The objective of the present study was to identify weak and strong points of such an approach for cross-disciplinary integration to evaluate its applicability in other regions where the land–sea interface is crucial.

BACKGROUND

Complex social-ecological systems

The focus of ARCH has been on lagoon systems as model examples of social-ecological systems. The simplest definition states that "a social-ecological system can be considered as a system composed of organized assemblages of humans and non-human life forms in a spatially determined geophysical setting" (Halliday and Glaser 2011, p. 2). The societal component also encompasses the political one (Stokols et al. 2013). Its core is in human–nature interactions (Becker 2011). Thus, the concept itself blurs the boundaries between social and ecological systems (Berkes et al. 2000) and highlights interdependencies between them (Gallopin 2003; Glaser et al. 2008; Stokols et al. 2013). Addressing these systems requires interdisciplinary collaboration because they are beyond the scope of any single discipline.

Boundary spanning

Boundary-spanning processes are among the few promising solutions to cross knowledge boundaries, enhancing knowledge integration. Knowledge integration can be defined as a "process in which members of different fields work together over extended periods to develop novel conceptual and methodologic frameworks with the potential to produce transcendent theoretical approaches" (Klein 2008, based on Rosenfield 1992, p. 117). According to Slob and Duijn (2014), knowledge boundaries can be spanned or crossed through the collaborative generation, integration, and application of so-called boundary objects. Boundary objects are defined as "tangible artefacts or object-like forms of communication that inhabit several intersecting social worlds and satisfy the information requirements of each of them" (Star and Griesemer 1989, p. 393). Boundary objects help to establish a shared context (Carlile 2002). They are generated, integrated, and applied by professionals working on either side of the boundaries of a designated community. Bechky (2003, p. 326) notes that boundary objects not only contain knowledge but also lead to action "in ways other than sharing understanding." Such an object must be capable of provoking collaborative practice, which is more easily achieved by identifying the challenge for a specific group and being able to conceptualize that issue (Duijn 2009). Examples of boundary objects used in regional management are models, maps, action plans, policy, or research notes. Table 1 presents the most important concepts of boundary spanning.

Boundary objects are produced in the course of the boundary-spanning processes that deliver the context, time, and place to create such objects. Boundary-spanning processes help to cross the boundaries, facilitate the collaborative production of knowledge, and generate meaningful results for the researchers involved. Boundary-spanning activities can in addition enhance trust and performance in collaborative research and policy processes, as is shown in research on interactive policy making (Van Meerkerk and Edelenbos 2014). Boundary objects thus are a sort of arrangement that allows different groups to work together without necessarily achieving consensus. As mentioned previously, the ARCH

Table 1. The most important concepts of boundary-spanning theory[a]

Concept	Description
Premise	Communities are separated through boundaries that hamper communication and joint action.
Boundaries	Perceived boundaries between communities can be of a different nature (organizational, cultural, geographical, etc.).
Boundary spanning	Activities are undertaken to cross boundaries such as communication or joint activities.
Boundary objects	Tangible products of joint activities that satisfy the communities involved, like maps, action plans, policy notes, among others. They contain knowledge and provoke action.
Boundary spanners	People who cross the boundaries and intermediate between communities. They are accepted in this role by the communities involved, for instance, because they are "part" of the different communities.
Boundary-spanning processes	These processes are needed to produce the boundary-spanning objects with the communities involved.

[a]Slob and Duijn 2014.

project has implemented 2 concepts for enhancing knowledge integration with regard to lagoons and estuaries. These 2 boundary concepts were: 1) the codevelopment of a model for integrated analysis as a boundary-spanning activity, and 2) the SoL reports functioning as boundary objects. Although interrelated, both processes should be treated as separate boundary-spanning activities.

METHODOLOGY

The ARCH project focused on specific examples of social-ecological systems in 10 lagoon systems throughout Europe. A long-lasting tradition exists to research such regions within the framework of ICZM (Gilbert 2008). Nowadays one can find various approaches to ICZM, from the sectoral ones (Berkes 2011; Nayak 2014) to more complex and comprehensive ones (e.g., SPICOSA 2011). The 10 cases selected by ARCH were of a very diverse nature as a result of the relevant interactions in these regions, their surroundings, and the key challenges faced by them (Table 2; for more details, see Zaucha and Breedveld 2013). The key issues at stake at the various case study sites indicate that understanding and subsequently managing these different sites requires an integrated knowledge approach that reflects their complexity and takes into consideration the high degree of uncertainty caused by the ever-present state of transition at the land–sea interface. Focusing only on selected issues and challenges would result in a misleading picture because the issues and processes influencing development in these regions are mutually interdependent and closely interlinked.

Model for integrative analysis

The ARCH project has codeveloped a model for the integrated analysis of the social-ecological systems of a lagoon (Figure 2). Zaucha and Breedveld (2013) present an in-depth description of the model. In brief, the interaction model provides an integrated social-ecological framework for describing the structure of a land–sea interface region and its internal relations. In the model, the region is described as a system composed of 2 interrelated parts: the natural system and the human system that together comprise the "socioeconomic system" and the governance system. Both systems are linked by different types of flows and interactions.

The model was built as a joint collaborative effort of scientists representing various disciplines: marine biology, marine chemistry, climatology, geology, ecotoxicology, economy, spatial planning, sociology, and even information technology sciences at some point of the work. The entire group was composed of 22 to 25 researchers (their number varied in different stages of the project) from 10 countries, with a core group of scientists with policy experience. The elaboration of the model was carried out through an iterative process. The core group first discussed the main assumptions, subsequently the outline, and finally the complete model was discussed with the entire ARCH project team. This resulted in feedback that fueled consecutive rounds of discussions. The elaboration of the model and subsequent preparation of reports based on it took 9 months and required 3 in-person meetings plus extensive Internet communication for the entire team. Despite the extensive work on indicators, the wide multidisciplinary background of the team made it difficult to comply with all the standards in each discipline. The ambition was not to achieve precise consensus on the model details but rather to enhance cooperation among various disciplines through collaboration in the model preparation and elaboration.

Preparation of SoL reports

For each of the 10 case study sites, SoL reports were prepared using the presented model. The 11 ARCH project partners covering at least 8 different disciplines acted as team leaders during the development of the SoL reports; they developed and elaborated the reports creatively in a mutual learning process because the entire ARCH methodology was based on the "learning by doing" paradigm. The SoL reports provided a holistic picture of present lagoon systems from an integrated social, economic, and ecological point of view. Therefore, the process of developing the reports was directed toward: 1) problem identification, 2) sharing knowledge, and 3) the identification of desired solutions. The main elements describing the lagoon system and the main points of analysis are presented in Table 3.

Each element of the model and type of relation were described using descriptors and narratives. Some key descriptors and the most important types of narrative were proposed for each field of analysis. Altogether 93 descriptors were proposed (Supplemental Table S1) for all categories listed in Table 3, even though it was clear that some of them might be hard to quantify for some case study sites. Their choice was based on the best available knowledge and experience within the ARCH team (the key criterion was relevance of data). The descriptors and narratives selected were intended to outline the structure, state, and dynamics of the lagoon system (details are

Table 2. Key issues at stake at the various ARCH case study sites[a]

Case study site	Engineered lagoons	Urban development, quality of life	Lack of social capital	Lack of management	Nature protection and development	Institutional borders	Fisheries	Harbor development	Climate change and sea level rise	Sediments and eutrophication	Pressures of tourism	Freshwater flows
1. Vistula lagoon, Baltic Sea			X	X	X	X	X	X	X	X	X	X
2. Göta älv, Kattegat		X			X	X			X	X	X	X
3. Byfjorden, Norwegian Sea		X						X	X	X	X	
4. Elbe estuary, North Sea	X	X			X	X		X	X	X		X
5. Rhine estuary, North Sea	X	X			X	X		X	X	X		X
6. Broads, North Sea	X				X	X			X	X	X	
7. Òbidos lagoon, Atlantic Ocean	X		X	X			X		X	X	X	
8. Lesina lagoon, Mediterranean Sea			X	X	X	X	X		X	X		
9. Amvrakikos lagoon, Mediterranean Sea			X	X	X	X	X		X	X		X
10. Razelm-Sinoe estuary, Black Sea	X		X		X	X	X		X	X	X	X

[a]Zaucha and Breedveld 2013.

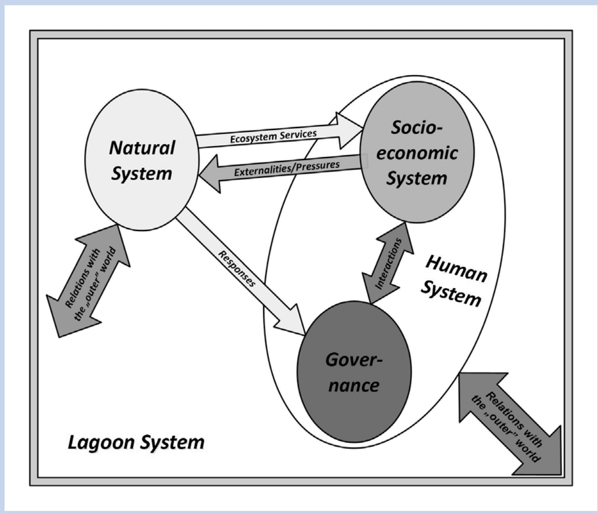

Figure 2. The ARCH model as a knowledge integrator (adapted from Zaucha et al. 2012).

given by Zaucha et al. 2012). A narrative was understood as a phenomenon described in qualitative terms, whereas a descriptor usually meant a word, phrase, or alphanumeric character used to identify an item in a storage system. For instance, in the case of the Marine Strategy Framework Directive of the European Union (EU), descriptors identified key elements of the "good status of the marine environment." ARCH followed this example by collecting descriptors that were sufficiently general to be applicable to different cases and situations across Europe, but that were also specific enough to be operationalized by a set of specific numerical indicators, or measures, that permitted the practical evaluation of the status of the marine environment. This requirement explains why popular indicators of sustainable development (e.g., United Nations 2007; Economic and Social Council 2011) were not included and why, instead, there was a greater use of ICZM (Gilbert 2008) and Marine Strategy Framework Directive indicators.

For some descriptors related to the natural environment, indicators are even missing because they are case specific. This means that different indicators can be selected to characterize the same descriptor in different case studies. When this was the case, the indicators were examined by the project partners to assess their relevance and feasibility in relation to each case study. Surprisingly, collecting socioeconomic indicators proved to be a challenge in many cases. The main reason was the differences in the geographical scales of the terrestrial analysis. Thus, existing data, usually available at the Nomenclature of Territorial Units for Statistics (NUTS) 2 or 3 level (NUTS is a geocode standard for referencing the subdivisions of EU countries for statistical purposes; NUTS 2 and 3 are subcountry units, and each NUTS 2 unit encompasses several NUTS 3 units) should be adjusted to lower tier administrative areas. Therefore, it was not possible to complete all of the indicators for all of the different lagoon regions. Consequently, indicators were treated mainly as a source of inspiration, whereas the descriptors and narratives provided the backbone of the analyses for each of the SoL reports.

Evaluation

The analytical methodology used for evaluation of the boundary-spanning activities is composed of 2 steps. Initially the process of preparation of the model for integrated analysis and the elaboration and the use of the SoL reports have been analyzed against rigorous requirements specified in the literature on boundary-spanning processes (e.g., Klein 2008). Subsequently, ARCH researchers have been subject to examination with regard to their experiences related to the elaboration of the model and preparation of the SoL reports. This was achieved through questionnaires, group discussions involving all project partners, and in-depth semistructured telephone interviews with 9 (out of 10) ARCH site team leaders. Interviews were conducted by an external researcher who did not participate in the ARCH project. They lasted about 45 minutes each and took place when the SoL reports were finalized. The list of questions is presented in the Supplemental Data (Table S2). In the final stage of the project an additional 12 researchers were interviewed by e-mail to examine the change of their attitudes toward other disciplines and the role of the model and the SoL reports in this process. The questionnaire used is presented in the Supplemental Data (Table S3).

All of this information has allowed identification of the most important conditions for success of knowledge integration applied to lagoon systems.

RESULTS

Model for integrative analysis

As pointed out by Gari et al. (2015), several frameworks have been developed and used for the adaptive management of

Table 3. Structure of the state-of-the-lagoon report

Main elements to be described	The natural system, its environmental status, its resilience, and main direction of change	The human system and its ability to maintain and develop evolutionary resilience	The human–nature relationship and relations between the lagoon system and the outside world
Key points for description	• Hydromorphological status (separately for rivers and lagoons) • Biological status • Physicochemical status • Harm by specific pollutants • Dynamics and the vulnerability of the natural system	• The place and its history • Developmental drivers within the human system • The social structure • Governance and the institutional structure • Vulnerabilities • Resources • Adaptive capacities	• Main pressures and drivers affecting the natural system, exposure of the natural system • Forms of nature protection • Ecosystem services provided for the benefit of the "human system" • Relations between the lagoon region and the outer world

Key points of description are explained in detail in Zaucha et al. (2012). For an explanation of the resilience concept, see Davoudi et al. (this issue).

social-ecological systems. The most popular among them are the Driver-Pressure-State-Impact-Response (DPSIR) model, introduced by the European Environmental Agency, and the Ecosystem Services approach, introduced by the Millennium Ecosystem Assessment (MEA 2005). The core of the DPSIR model is a causal relationship among its 5 elements: driving forces, pressures, state, impact on environment, and responses to the negative impacts. The DPSIR approach has been extensively described in the literature (see Gari et al. 2015). The Ecosystem Service approach is an attempt for more systematic identification of benefits that human beings receive from ecosystems. An in-depth description is given in numerous publications, but the original concept comes from MEA (2005).

The ARCH model draws a lot on the DPSIR approach; however, it encapsulates 2-way relationships (e.g., influence of human beings on environment, but also impact of changes in environment on development of the human component of the lagoon system). Thus, it fills in an important gap of the DPSIR approach. The Ecosystem Service concept is part of the ARCH logic and serves for emulation of the impact of environment as described earlier. Moreover, the ARCH model draws attention to the impacts from outside, being of regulative, environmental, or societal nature. In comparison with other models encapsulating development on different geographical scales (i.e., the Economic and Social Council [2011] model), the ARCH model focuses more attention on mechanisms, relations, and driving forces than on the measurement of development outcomes in terms of the satisfaction of needs or levels of well-being. The complexity of the ARCH model adds to both its strengths and its weaknesses. In comparison with the DPSIR approach, it might be less appealing and straightforward to the policy actors by integrating various policies and policy objectives. These weaknesses became clear when the ARCH consortium started to define which indicators were necessary to populate the model.

Model as scientific discipline integrator: the process of cocreation

The application of the model as a disciplines integrator refers mainly to the following features: 1) elaboration on system boundaries; 2) reflections on policy context issues and contextual factors; 3) development of a common language; and 4) mutual learning between disciplines and fostering an understanding of their research apparatus, possibilities, and limits.

The key feature that enabled the model to work properly as a boundary object was its capacity not only to encompass different scientific disciplines, but also to link them very dynamically. For instance, the model helped to understand that in the case of Vistula lagoon, increased socioeconomic inequalities could lead to the deterioration of the natural environment through overexploitation (e.g., insufficient number of nongovernmental organizations monitoring the ecological situation or silent approval of illegal fishing by the general public). At the Swedish coast, innovative ways of sustainable exploitation of natural capital can result in innovations and extension of the regional knowledge base, for example, by prompting the local society to acquire relevant skills and knowledge on green technologies. This, in turn, can influence the development of human capital in the region and improve the attitude of local people to their environment.

Indeed, the model kicked off various debates, stimulated engagement, and promoted cross-disciplinary discussions. The first important learning experience provided by the elaboration of the model concerned the boundaries of the lagoon systems. The project partners noted that defining the boundaries of the analyzed areas was very difficult because these boundaries were not necessarily geographically defined. The boundaries were process dependent and created a complicated pattern of mutually overlapping functional areas. Problems with identifying these boundaries were also related to the different data sets available and the disciplinary perspective that was considered. For instance, available data did not always allow for tracing ecological impacts back to their origin. Neither of the production chains of local products could be easily traced. Sometimes analysis of the functional region appeared infeasible. In the case of Hamburg and the Elbe estuary, the economic region is of a global magnitude, whereas the ecological region encompasses the entire catchment of the Elbe and the adjacent sea. Therefore, some arbitrary decisions were taken on how far in spatial terms the analysis should be extended. Natural sciences are usually in a better position to find some objective criteria for such a limit. Social sciences, dealing with powers, stakes, and conflicts, face the challenge of high volatility of the researched processes; thus, they usually opt for a broader geographical scope of analysis. In the case of ARCH, the solution was to accept those differences and to accept different geographical ranges of analyzing different influences and interdependencies. However, for the delimitation of the impacted region, the local administrative units were used, because policy measures and policies are usually conducted within arbitrarily defined jurisdictions.

The model also opened up discussions on contextual issues. An important element of regulations and policies is that many are decided outside the lagoon regions in national capitals or on a European level in Brussels. For example, the European Commission (EC) recently introduced maritime spatial planning (EC 2014) as a cross-cutting integrative tool for the management of sea areas within the EU Integrated Maritime Policy (Zaucha 2014). Another example is EU regulations concerning environmental quality such as the Marine Strategy Framework Directive or the EU Water Framework Directive (EC 2000). An example of the influence of the implementation of national policies can be found in the case of the Broads, in which nature conservation provided a framework for all other types of analysis including those normally reserved for economics, agriculture, spatial planning, and local governance.

The importance of the role of ecosystem services to achieve knowledge integration in the model is noteworthy (Zaucha et al. 2016). These services are a type of boundary object in and of themselves, and their very nature requires input from different scientific disciplines (Fisher and Turner 2008; Fisher et al. 2009; Haines-Young and Potschin 2011; Egoh et al. 2012; Depellegrin and Blažauskas 2013; Turner et al. 2014). Ecosystem services link biology and oceanography, or knowledge of ecosystems, with economics and regional science. They raise important axiological questions regarding the intrinsic values and use values of the marine environment and illustrate trade-offs among different temporal scales. They also prompt thinking in terms of panarchy and dynamic persistence (broader description of those concepts is provided by Davoudi et al., this issue). Thus, they provide an additional step toward operationalizing the ecosystems into public policy.

One product of joint model building was the evolution of a common language. This was observed as the ARCH group progressed in articulating the similarities and differences among the various case studies. The participants themselves stated that this would not have been possible without working jointly on the model.

The model development process presented earlier indicates that the interactive model proved to be a sound investment in knowledge integration. It allowed each discipline to perceive its strengths and weaknesses with regard to analyzing complex lagoon systems. As mentioned previously, the ARCH project incorporated a learn-by-doing paradigm, and the development of the model stimulated an important process of mutual learning, while fostering an understanding of the research apparatus, its key concerns, the strengths and weaknesses of other disciplines, and identifying main linkages among them. It led to knowledge brokerage and research component integration and prompted fundamental axiological discussions. Thus, the model was a vehicle for improving a shared understanding among researchers, establishing a common vocabulary, and laying down a common research ground.

SoL report development as a boundary activity

The process of preparing the scientific SoL reports for each of the 10 lagoons was important for building trust and a community feeling. A clear decision at the beginning of the elaboration process was not to limit the size of the SoL reports. This was a good choice because it provided the possibility for all contributors from different disciplines to contribute to the inventory process with their entire available knowledge. This process contributed to building trust, which has several connotations in the ARCH project. Trust was related mainly to augmenting confidence in the competences of other participants (disciplines) to add valuable input to analyses of the complex problems of the lagoon system. Trust has been seen as a factor enhancing cooperation, information sharing, and problem solving (for details on trust, see Castelfranchi and Falcone 2001; Lewicki and Tomlinson 2003).

The SoL reports structure permitted focus on the complexity of the lagoon system. None of the contributors had the impression that his or her concerns was disproportionately reduced or omitted. As 1 of the project leaders noted: "The state-of-the-lagoon reports became an enormous compendium of data. People feel comfortable with this. You do not want to reduce this kind of energy. People need something in which their knowledge can manifest itself. That is also where the state-of-the-lagoon report was useful" (Slob and van Meerkerk 2014, p. 32–33).

Another important element of the SoL reports was the need to perform a full-scale analysis for each case study site, regardless of the composition of the scientific team responsible for the SoL report. As a result, biologists were required to conduct socioeconomic analysis, and economists and planners were challenged to gather ecological and oceanographic information. This was a rich learning and mind-opening process.

Special topic coaches were appointed (i.e., those members of the ARCH project team with strong experience in specific types of analysis) to secure the proper level of analysis to assist nonprofessionals in gathering and interpreting their data. Finally, each SoL report was subject to peer review at the project level by a team composed of representatives of different disciplines.

The SoL reports have been used for many purposes other than knowledge integration. They have served as an important starting point for discussions with stakeholders on management plans, which is actually the most frequently listed use of the reports at the case study sites. They were treated as a source of existing knowledge, including lists of useful references such as scientific bases for the elaboration of scenarios, and they were used as background for suggested changes in policies. For example, in the Broads case study, the SoL in its various draft phases contributed to the refinement of a preliminary version of the official management plan that was submitted to the United Kingdom government by the Broads Authority. Finally, the SoL reports were considered as a gift by local stakeholders, which they could disseminate for free to visitors as encyclopedias of the site. Examples of maps and data were also available from SoL reports being uploaded on the WebGis Web site (http://www.webgis.com) and subsequently maintained through the volunteer work of local stakeholders.

SoL reports as vehicles for knowledge integration

Preparation of the SoL reports changed attitudes of the ARCH researchers. Of 12 scientists interviewed, 7 assessed that their main focus at the beginning of the project was on their own discipline, whereas all of them confirmed importance of other disciplines after elaboration of the reports (Table 4).

Contextual factors played an important role in determining the ultimate scope and way of examination of the sites with regard to involved disciplines and related theoretical and methodological preferences for the analysis. It seems that this choice was partially related to the main challenges faced by the analyzed regions or key developmental drivers. For instance, in the Broads, ecological perspectives prevailed in line with the overall ambition to sustain the Broads' ecological uniqueness and biodiversity. In the Elbe estuary, conflicts between development of the port of Hamburg and protection of the river's habitats paved the way to a strong ecological bias. Socioeconomic implosion in the Vistula lagoon led to a strong focus on the economic dimension in the regional analysis. Oceanographic problems in the Òbidos lagoon, dominated by coast dynamics and sediment transport coupled with a low economic status of the region, gave the framework for the analysis, dominated by the discussion of the relations between geomorphology and provisioned ecosystem services. However, it is beyond the scope of the present study to analyze to what extent the choice of the sites themselves (and consequently the key problems that were analyzed) was biased by the mix of disciplines represented in each case study site team.

Concrete examples from case study sites illustrate how the elaboration of the SoL reports has worked as a spanning object in practice and helped in preparation of the management plans, the final objective of ARCH. For instance, in the case of the Òbidos lagoon, the report prompted putting hydrological conditions at the front of the socioeconomic analysis as a key prerequisite for ensuring regional development. Thus, economists and spatial planners should incorporate hydrology and biology into their analytic framework. The opposite was found in the case of the Vistula lagoon; a comprehensive analysis of the historical, sociological, and political aspects was required to understand the environmental problems of this lagoon. The current, not encouraging state of environment is a result of huge hydrotechnical engineering in the 19th century and a total change of the local population in the 20th century

Table 4. Changes in attitudes of ARCH researchers toward other disciplines

Key facts on the scientists taking part in the ARCH project and how their vision has changed during the preparation of the SoL reports	
Specialization of ARCH researchers	• Marine biology • Climate change impact assessment • Marine chemistry • Applied geology • Ecotoxicology • Ecological economics • Maritime spatial planning
Number of scientists examined	12
Number of scientists focusing on their own disciplines at the beginning of the project	7 of 12
Number of scientists reporting importance of other disciplines after elaboration of SoL reports	12
The most interesting comments on the role of the SoL report as an boundary object	
"The SoL provided me with another opportunity to expand my thinking, especially with regard to the various environmental indicators in economics and governance."	
"This exercise helped me to see the case study area from the perspectives of different scientific disciplines and to develop a more complete picture of the system."	
"Ecosystem services were also more clear after listening to colleagues from economics and the social sciences."	
"[Joint work has...] Introduced important, new aspects to the scientific process and in particular, administration failures, lack of vision and plans, non-existence of authorities, and political interventions that alter the actual effectiveness of scientific advice and lead to environmental mismanagement."	
"I have realized the importance of stakeholder involvement and their awareness to the success of the lagoon management."	
"At the time [beginning of the project], I did not consider the social part to be very import for defining the State of the Lagoon. I actually considered that part to be of utmost importance only after the first Workshop."	
"No change in my way of thinking, but I learned much more about the socioeconomic aspects of the estuary, which are equally important as the environmental, but I was not that familiar with it."	
"Major experience (and most difficult one as well) – gathering the social and economic data (very scarce and/or outdated) and developing new understanding in this category of sciences."	

SoL = state-of-the-lagoon.

resulting in a low regional identity and insufficient care for the future of the region. Also, political tension between Poland and Russia adds to the problems. Consequently, placing strong emphasis on good environmental status in this case would be premature without first changing the attitudes of people and the behavior of local governments.

An important conclusion is that in the course of preparing the SoL reports, the process itself was more important than the outcome or the need for producing complete reports. Unrestricted and only lightly structured stock taking, as dictated by the model, gave room for full-scale expression and narrowed dominating attitudes, which was conducive for laying a foundation for implementing a collaborative approach. Step-by-step mutual respect for one another's expertise and the recognition of the mutual need to deliver project outcomes overcame initial communication barriers. The inclusion of various scientific disciplines on equal footing and the possibility of comparing the approaches and results of various cases were instrumental in this. This transformation was also facilitated by the iterative approach and the collectiveness of preparing SoL reports. Parallel to the preparatory effort, the interim results and difficulties encountered were constantly identified, discussed, and analyzed. This provided a constant feedback loop during the compilation process. The project setup was flexible enough to accommodate this. All of these steps led to the creation of a new interdisciplinary knowledge pool on lagoons and estuarine systems, and promoted a joint understanding of the nature of the researched phenomena.

The-story-we-want-to-tell

A disadvantage of this approach was the scope of the SoL reports themselves and the lengthy time required for preparation. The reports were long, full of scientific jargon, and slightly unbalanced, with usually more in-depth elaboration of issues closer to the professional profile of the authors. Hence their use for communication purposes was limited, such as launching debates with stakeholders and decision makers. The SoL reports were translated into stories—short, concise documents focusing on key findings and policy issues—to overcome these shortcomings. Communication with stakeholders forced the contributors to conduct reverse decomposition from complexity to simplicity and from interdisciplinary results into more sectoral-oriented findings. Due to existing mandates and the responsibilities of stakeholders, this was far away from an integrated pattern. This required the selection of short messages and the careful selection of the information presented while avoiding superficial simplicity. This exercise was considered as a final check of the quality of knowledge integration and the validity of the preparation process of the SoL reports as a boundary object. In the ARCH case, the simplification required for stakeholder communication worked well. The storytelling reports were balanced and dynamic, and focused on interactions and interdependencies. This was made possible as a result of the achieved level of joint understanding and trust, and the lack of competition among the scientific disciplines.

Evaluation of the compilation of the model and SoL reports as a boundary-spanning process

Interviewed ARCH partners (for details, see Slob and van Meerkerk 2014) indicated the following benefits of the joint work on the model and the reports: 1) learning about the framing of other disciplines (including language and concepts) and about different interdisciplinary concepts such as social-ecological system thinking and ecosystem services; 2) reflecting on and discussing boundaries of lagoon systems; and 3) discovering the importance of governance structures and levels of regulation and information available regarding lagoon systems. They also indicated the importance of integrating knowledge on ecosystems, governance systems, and economic structures, and the benefits of using interdisciplinary frameworks for cultivating an understanding of the dynamics of lagoon systems.

ARCH partners also identified several constraints and problems (Slob and van Meerkerk 2014), such as "this is not my discipline," data mining and processing, formulating an overarching story from the various disciplinary data, identifying a complex system of overlapping boundaries, finding the right scale for analysis, and combining different data sets.

In general (Slob and van Meerkerk 2014), the interlocutors were of the opinion that the model based on the concept of a social-ecological system worked well as a boundary concept. Every project partner was able to put their knowledge in this framework, but they also had to deliver the data and analysis of indicators coming from different disciplines. The respondents pointed out that the framework provided by the model and the structure of the SoL report allowed people to populate it with particular questions that were important to them, which largely came from disciplinary knowledge. The preparation of the SoL reports was considered to be an important knowledge integrator. One of the respondents noted: "[T]he state-of-the-lagoon report became an important term in itself, as did the notion of the-story-we-want-to-tell [...] These are things the whole group recognized/.../, this is where we were all working on" (Slob and van Meerkerk 2014, p. 32).

IMPLICATIONS AND RECOMMENDATIONS

The preparation of the SoL report at the 10 case study sites permitted identification of the main obstacles to conduct holistic research of complex human-natural systems and conceptualize the main problems. The participants of the ARCH project listed several lessons learned to be shared with other research and policy-oriented groups striving for integration of multiple disciplines. The conceptual model and the subsequent SoL reports functioned well as boundary-spanning objects. Scientists from different backgrounds and disciplines could add their knowledge to the model and to the reports. Although full consensus has not been reached on the importance of various development drivers and obstacles, the model and the reports allowed for increased transdisciplinary cooperation and building of respect for the competences and knowledge of the other disciplines. This is underpinned by the following observations:

- During the elaboration of the SoL reports, the first, most overwhelming feeling was the growing understanding of the importance of working with other disciplines. The different "disciplines" met together and acknowledged the importance of being open to each other.
- The importance of equally addressing the 3 aspects of the model when analyzing a complex system was observed. Thus, the joint use of knowledge of different disciplines plays an important role in this type of research.
- The participants underlined the importance of not only including the various disciplines, but also of ensuring strong interaction among them. Without such mechanisms, cross-disciplinary integration could remain shallow and insufficient.
- The interlocutors also underscored the fact that integrated approaches are resource intensive. Joint work encompassing several scientific disciplines helped to reveal the true complexity of the lagoon systems and set standards for further work while also opening up management plans to a multidisciplinary approach.
- Quantitative description as an illustration of narratives was experienced as very useful. The summary indicators provided a brief, accurate view of the system under study and served as a point of departure for many discussions within the research groups and subsequently with stakeholders. They worked as a kind of a separate "integrator" through scales and disciplines.
- Access to data from national monitoring points was considered to be extremely valuable for preparation of the SoL reports.

However, many participants complained about similar problems associated with obtaining accurate, relevant information, while trying to be brief and concise. This appeared to be a difficult task when describing complex systems, and it was very important for the success of the work. Although the information existed, it was not easily retrieved. There are some severe problems with data storage systems (e.g., database) that, if corrected, would facilitate their use and integration. Problems with data comparability on different geographical scales, data deficits at local levels, and the need to adjust data selection to the specific settings of a given lagoon or estuary region were also present. Some of the interlocutors also underlined the importance of including local and small-scale studies on environmental status in SoL reports because larger national studies cannot replace this kind of information.

Many natural scientists were of the opinion that it was difficult for them to gather relevant, current socioeconomic information. The only solution was to engage in discussions with authorities involved at the case study site. Thus, combining data with narratives was considered to be a great help in solving these problems. But the result is that the SoL reports differ in terms of attention put to various aspects of the lagoon system. This should be taken as evidence that boundary spanning rarely leads to consensus. Taking the number of pages as a simple indicator, one can easily note that description of the natural system prevails in some reports (e.g., 67% and 60% of the report for Òbidos and Lesina, respectively) prepared under the leadership of natural scientists, whereas the opposite situation is observed when the lead was in the hands of social scientists (34% and 19% of the report for Vistula and Rhine, respectively). Details are given in the Supplemental Data (Table S4). It seems that a strong focus remains on the importance of one's own field of knowledge, despite the aim of cross-disciplinarity.

Despite numerous discussions during elaboration of the model, some participants were dissatisfied with placing equal importance on the natural and human systems. With regard to working with stakeholders, it seems that the summary of the SoL reports (the-story-we-want-to-tell), translated to the local language, was equally or even more important than the original report with regard to increasing stakeholder awareness and disseminating information. For instance, in the Elbe case, a Microsoft PowerPoint summary of the SoL in German was used frequently and worked well for stakeholder dissemination.

Experiences with the model developed in ARCH and its implementation during preparation of SoL reports at the case study sites forms the basis for several recommendations of how to ensure cross-disciplinary integration while analyzing complex social-ecological systems with a focus on lagoons, estuaries, and other land–sea regions.

Cross-disciplinary integration is initially resource intensive and time-consuming; one should set aside the required resources and invest efforts at the forefront. It is important to allow sufficient time for preparing templates for the inventory documents that are to be prepared for each case study. Good representation of the various disciplines is required for the system analysis. The report templates should be prepared by a mixed team covering the various areas of knowledge and expertise.

It is crucial to create engagement among the group of researchers by focusing on a joint, appealing overall concept that will stimulate cross-sectoral thinking. In ARCH, this was the model showing the interplay between natural and human capital. Such a concept should ensure integration of the socioeconomic and natural parts of the site analysis. In the SoL reports this was achieved by the structure that included a separate chapter on the interplay between human and natural capital.

One should focus on the identified problems as a link between collected evidence and future management needs. This limits the size of the inventory and should prevent bias by the knowledge of the author team in charge of report preparation because the authors will devote too much time to information gathering in their specific fields of expertise.

Different methods for collecting evidence should be applied. The stock-taking should be based on collecting both quantitative (jointly agreed indicators) and qualitative (narratives) information. Collecting indicators outside the field of expertise of a given author might become too challenging and evolve into a discouraging exercise hampering the quality of the inventory process.

A few test cases should be discussed in-depth by the entire project team comprising different experts and scientists to establish a proper correction mechanism, exclude errors, and stimulate cross-disciplinary dialogue. The team should be asked to identify the most important developmental problems at the site and the links and relations among them, as a problem-mapping exercise. The same can be achieved through a peer-review process. However, the reviewers should represent different scientific perspectives and backgrounds to guarantee cross-disciplinarity.

The preparation of SoL reports proved that cross-disciplinary integration is crucial in building joint knowledge. To be successful, it requires appropriate scientific resources and appropriate boundary objects. Integration offers important rewards in terms of developing a better understanding and subsequently improved management of complex social-ecological systems.

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SUPPLEMENTAL DATA

Supplemental Table S1. Descriptors included in the analysis of the state-of-the-lagoon (Zaucha et al. 2012).

Supplemental Table S2. Questionnaire used for the semi-structured interview conducted by telephone (Slob and van Meerkerk 2014).

Supplemental Table S3. Questions used in the interviews conducted by e-mail at the end of the project.

Supplemental Table S4. Overview over the number of pages devoted to the description of the natural and social system in the ARCH state-of-the-lagoon reports.

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