

ABSTRACT

Title of Dissertation: THE ROLE OF SOCIO-ENVIRONMENTAL
REPORT CARDS IN TRANSDISCIPLINARY
COLLABORATION AND ADAPTIVE
GOVERNANCE FOR A SUSTAINABLE
FUTURE

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Maryland Center for Environmental Science

Addressing sustainability challenges and overcoming environmental problems requires fundamental societal changes. However, communicating these issues and convincing people to act is challenging. One emerging science communication tool that can accommodate this need is boundary-spanning report cards. Report cards were originally used as a tool for assessing and communicating ecosystem health conditions, but there are a growing number of report cards that incorporate socio-economic values. My dissertation focuses on investigating the role of socio-environmental report cards in addressing sustainability challenges. My research question was centered around whether considering human dimensions and understanding the links between natural and social components of socio-environmental systems can lead to a productive collaboration. This collaboration can lead to positive actions that contribute to a sustainable future. My research has two

major themes: 1) Evaluation of report cards and 2) Evolution of the report card process. First, I found that report cards from a diversity of locations can lead to environmental literacy and promote sustainable actions and positive environmental change. Then, using the Mississippi River Watershed report card as a case study, I demonstrated that report cards are boundary objects that can serve as a platform for transdisciplinary collaboration and serve as a catalyst for collective action. I also established that various report cards in the Chesapeake Bay watershed were able to enhance adaptive governance by facilitating continual learning and cross-scale exchange of information between different organizations. My results highlighted the evolution of report cards from a product created to increase awareness and education about environmental issues, to a process that engages stakeholders. My conclusion is that report cards should include both social and environmental indicators and the process needs to be stakeholder-driven and action-oriented. I developed a framework and a theory of change to guide how socio-environmental report cards can address sustainability challenges and applied it in the Chesapeake Bay watershed. By creating a holistic assessment that balances environmental, economic, and social concerns, socio-environmental report cards incorporate multiple perspectives from multisectoral actors. Thus, socio-environmental report cards can enhance adaptive governance and provide the foundation for collaborative solutions for sustainable resource management.

THE ROLE OF SOCIO-ENVIRONMENTAL REPORT CARDS IN
TRANSDISCIPLINARY COLLABORATION AND ADAPTIVE
GOVERNANCE FOR A SUSTAINABLE FUTURE

by

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Introduction

Addressing sustainable development challenges and understanding the interconnection between our human and natural environments are some of the leading research drivers in our society today. Environmental problems are caused by human behavior (Amel et al., 2017), and solving these issues would require a fundamental change in society. However, communicating these socio-environmental issues and convincing people to act is challenging. While our scientific understanding of biophysical and ecological processes has been increasing, we are often unable to influence outcomes because of our limited understanding of the complex interactions between environment, society, and human activities (Bodin et al., 2011).

Linking knowledge to action in sustainable development requires managing boundaries and cross-scale differences while creating information that is salient, credible, and legitimate (Cash et al., 2004). Multiple scholars have called for a changing approach to complicated environmental problems, the traditional paradigm of management and the role of scientists must be changed (Ludwig 2001). Science must be made accessible to interested laypersons, the importance of ethics and environmental justice must be acknowledged, and traditional knowledge and values should be incorporated (Berkes and Folke 1998; Ludwig 2001). Consensus-based methods are a possible means of achieving such communication.

Progress towards sustainability, therefore, must go beyond research and generation of new knowledge. Employing participatory processes involving

researchers, practitioners, and other stakeholders that could promote the social learning needed towards sustainable development is critical (Kates et al., 2001). Social learning enables the development of a shared understanding among different stakeholders, bridging between and among different knowledge spheres that encompass science, management, policy, and societal values (Roux et al., 2010, 2017; Brandt, 2013; Vilsmaier et al., 2015). A closely linked approach to sustainability is transdisciplinarity, which aims to reconcile the diversity of stakeholder perspectives in understanding socio-ecological systems and to co-produce appropriate knowledge that can lead to action (Jahn et al., 2012; Roux et al., 2010).

Thus, participatory and stakeholder-driven communication strategies that not only consider the accurateness of information but also how human perceptions and cognition, attitudes and behaviors, and cultural values affect how messages are received and internalized are needed. Individuals have their respective mental models that affect their perception and its interpretation and, at the same time, are social animals whose actions are also influenced by social preferences, social networks, social identities, and social norms (World Bank 2015). A balance between communicating scientific findings and engaging the intended audience is needed. Central to this is the ability to draw upon multidisciplinary and transdisciplinary approaches that can link the knowledge generated from the research process and the required actions to manage our natural resources.

One emerging set of tools that can accommodate this need is the boundary-spanning report cards that provide accessible and synthesized information to wider

audiences (Costanzo et al., 2017). Report cards traditionally were used as tools for assessing and communicating environmental conditions (Connolly et al., 2013; Johnson et al., 2015, Fries et al., 2019) but there are a growing number of report cards that incorporate socio-economic values (Pascoe et al., 2016, McIntosh et al., 2019). Although report cards are increasingly used to communicate scientific information and support adaptive management (Connolly et al., 2013; Pascoe et al., 2016; Bunn et al., 2010; Flint et al., 2017; Dauvin et al., 2008), their role in shaping a sustainable future has yet to be evaluated.

Research that focuses on the impacts of the report card process is lacking. Most literature on report cards focuses on scientific framings and technical methodologies (Pantus and Dennison 2005; Williams et al., 2009; Fox, 2014; Fries et al., 2019; S. Johnson et al., 2016; Windle et al., 2017; Pascoe et al., 2016; McIntosh et al., 2019; Harwell et al., 2019). Notable exception, as of this writing, is the dissertation research conducted by Kung (2017) that investigated how the report card process can influence stakeholder relationships through participatory processes in the context of natural resource management. There is also a lack of accountability or a concrete mechanism to improve conditions in how report cards are currently developed (McIntosh et al., 2019). Often, report card initiatives end after the report card is published. Reflections on the process and resulting grades and discussions on how to improve/maintain the grades are almost done as an after-thought.

The motivation for my dissertation is investigating how report cards can move beyond science communication into a process that can influence decision making

towards sustainability. I also studied ways to improve the report card product and development process to broaden its utility by following an ethnographic approach and drawing upon literature on collaborative learning, social network analysis, environmental anthropology and psychology, and complex systems theory-based approaches such as sustainability, socio-environmental systems, and transdisciplinary science.

Therefore, my dissertation has two major themes: (1) Evaluation and (2) Evolution of the report card process and product. My research question was centered around whether considering the human dimensions of ecosystems and effectively incorporating it in the report card process can lead to a sustainable future. My premise was that understanding the link between the natural and social components of socio-environmental systems can lead to a productive collaboration that goes beyond the usual and mostly symbolic call to action to positive actions that will contribute to a sustainable future. I present the results of my research in a series of papers that serves as the main chapters of my dissertation, summarized in Figure 1 with the chapters entitled as follows:

Chapter 1. Addressing sustainability challenges through socioenvironmental report cards

Chapter 2. Using socio-environmental report cards as a tool for transdisciplinary collaboration

Chapter 3. Using socio-environmental report cards to enhance adaptive governance

Chapter 4. Envisioning a sustainable future Chesapeake Bay and watershed through socio-environmental report cards

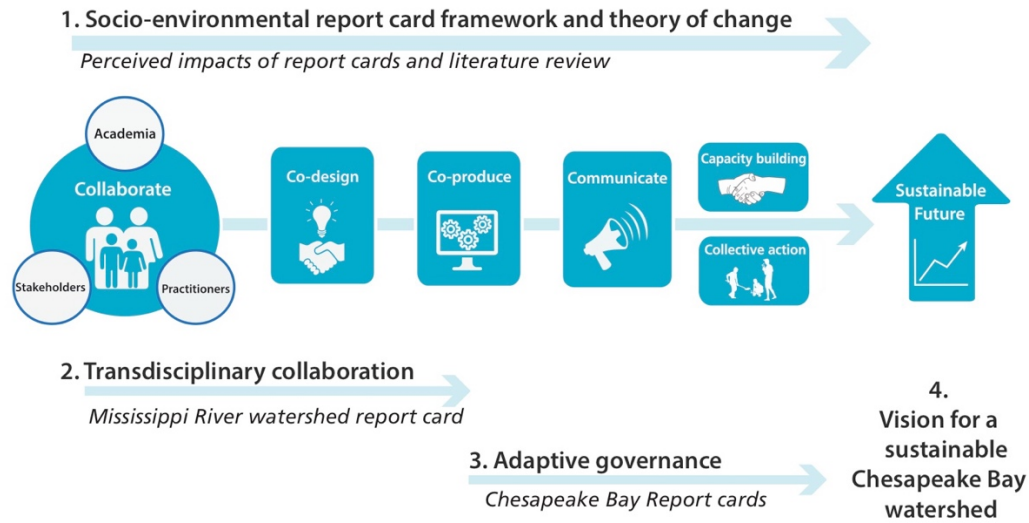


Figure 1. Dissertation research summary

In Chapter 1, I evaluated the impacts of select report cards that the Integration and Application Network (IAN), University of Maryland Center for Environmental Science (UMCES) has helped developed directly or indirectly from 1999-2015 to determine if they can be used in addressing sustainability challenges. I hypothesized that as a science communication tool, report cards can increase environmental literacy and influence decision making towards sustainability. I use a mixed-method approach using an online survey and follow up interviews. My results showed that report cards are useful tools in raising awareness, increasing collaboration, and promoting change and collective action. Evidence suggests that report cards can play an essential role in addressing sustainability challenges. Still, the product, the process, and the approach have to evolve, and the end goal has to be deliberate.

Report cards that can be used in addressing sustainability challenges should include both social and environmental indicators, and the process has to be more stakeholder-driven and action-oriented. Based on my results and literature review, I developed a theory of change, describing how socio-environmental report cards can address sustainability challenges. I also developed a new integrated framework composed of three phases for developing socio-environmental report cards that build on IAN's original 5-step process of conceptualization, choosing indicators, defining thresholds, calculating scores, and communicating results. This new three-phase framework is influenced by transdisciplinary, sustainability and collaborative learning principles and the science of team science and science communication. My research highlighted the evolution of report cards from a product created to increase awareness and education about environmental issues, to a process that engages stakeholders.

In the next three chapters of my dissertation, I applied my proposed theory of change and framework to the Mississippi River Watershed report card and the Chesapeake Bay report card as case studies. These two report cards represent significant milestones in the use of report cards in addressing environmental issues in the United States. The Mississippi River Watershed report card, published in 2015, was the first of its kind, not only in its geographical scope but is also the first socio-environmental report card that IAN-UMCES has helped developed. The Chesapeake Bay report card, the first scientifically rigorous broad ecological assessment of the Chesapeake Bay and its major tributaries, was first published in 2007. Its publication through the years has inspired citizen science groups to create local report cards. As I will show in Chapter 3, there are at least ten report cards published in the Chesapeake

Bay watershed annually since 2011. Both report cards are currently in the process of being revised and updated.

In Chapter 2 of this dissertation, I investigated the validity of my theory of change for socio-environmental report cards using the Mississippi River Watershed report card as a case study. I analyzed written documents such as report cards, reports, web articles, newsletters, and blogs. I also applied an ethnographic approach through my observations and personal experiences during the report card development process and through group meetings and private conversations with key actors after the report card had been published. I evaluated the Mississippi report card development as a transdisciplinary process using the following key features of transdisciplinarity:

- Integration of stakeholders and multidisciplinary researchers to tackle societal challenges (Lang et al., 2012)
- Facilitated by boundary-spanning organizations (Sholz and Steiner, 2015)
- Establishment of communication and engagement pathways such as boundary objects and third places (Roux et al., 2017)
- Co-creation of new knowledge (salient, credible, legitimate) that can lead to solutions and actions (Cash et al., 2003)

I also analyzed the impacts of the Mississippi River watershed report cards in addressing sustainability challenges using Ernstson's (2011) framework of transformative collective action and Kania and Kramer's (2011) Collective Impact model.

In Chapters 3 and 4, I applied my theory of change and my proposed framework in conceptualizing a socio-environmental report card for the Chesapeake

Bay watershed. I used an ethnography through twenty-eight key informant interviews (consent form and interview instrument can be found as Appendix 2 and 3, respectively) and my observations and participation in the annual development of the Chesapeake Bay report card. I also analyzed different written documents such as report cards, reports, scientific literature, books, websites, news articles, and other materials related to the Chesapeake Bay watershed. Unlike the Mississippi River Watershed, the Chesapeake Bay watershed has a long history of different report cards and an existing partnership, The Chesapeake Bay Program partnership, that plays an active part in its governance. Therefore, as part of Phase 1 of my proposed framework in developing a socio-environmental report card, I aimed to understand the current role of report cards in the Chesapeake Bay, identify stakeholders and governance structures, and conceptualize the different existing knowledge, culture, and value in the Chesapeake Bay watershed.

In Chapter 3, I investigated the role of the various report cards in the Chesapeake Bay watershed in adaptive governance. Adaptive governance accounts for the social context and condition for adaptive management (Chaffin et al., 2014; Folke et al., 2005). It is characterized by collaboration, coordination, social capital, community empowerment, capacity building, linking knowledge and decision-making, and governance opportunities (Sharma-Wallace et al., 2018). I hypothesized that report cards, as boundary objects, can facilitate adaptive governance by allowing for cross-scale sharing of information between different organizations leading to informed decision making (Schultz et al., 2015).

In Chapter 4, I identified different perspectives on Chesapeake Bay restoration to conceptualize a Chesapeake Bay watershed socio-environmental report card. I used a bibliometric analysis of scientific literature on Chesapeake Bay restoration, sustainability, and resilience in addition to key informant interviews. Combining these different perspectives, I developed a cultural model and a vision for a future Chesapeake Bay watershed. I also identified a potential socio-economic indicator and explored the possible challenges in developing a Chesapeake Bay watershed socio-environmental report card.

In this dissertation, I present the process of co-developing socio-environmental report cards as an effective platform towards sustainability by promoting transdisciplinary collaboration and adaptive governance. By incorporating conceptual frameworks and research tools from the natural and social sciences, my research will help advance the field of applied and action-oriented science and assist in analyzing the complex relationships between effective governance, resilience, and sustainability. I concluded that socio-environmental report cards, as outlined in my dissertation, can be used in any system and can provide a foundation for collaborative solutions by creating a holistic assessment that balances environmental, economic, and social concerns and incorporates multiple perspectives from multi-sectoral stakeholders.

Chapter 1: Addressing sustainability challenges through socio-environmental report cards

Abstract

Addressing sustainability challenges and overcoming environmental problems requires fundamental societal changes. However, communicating these issues and convincing people to act is challenging. One emerging science communication tool that can address this need is a boundary-spanning report card that provides accessible and synthesized information to wider audiences. Report cards originally were used as tools for assessing and communicating ecosystem health conditions, but there is a growing number that incorporates socio-economic values. In this chapter, I investigated how socio-environmental report cards can be used to advance the science and practice of sustainability. First, I evaluated the impacts of report cards co-developed with the Integration and Application Network between 1999-2015. Using an online survey and follow-up interviews, I found that report cards usually lead to environmental literacy and promote behavior and environmental change. Results also show that report cards from different regions (North America, Australia, and Asia) differ in their objectives, utility, and impact. My results highlighted the evolution of report cards from a document created to increase awareness and education about environmental issues, to a process that engages stakeholders. This stakeholder engagement presents increased opportunities for report cards to influence positive environmental and social change towards a sustainable future. However, these report cards should include both social and environmental indicators, and the process has to be more stakeholder-driven and action-oriented. Thus, I revised the standard report

card process by drawing upon social science literature and using system-based approaches, with a greater emphasis on collaboration, co-design, and co-production. Finally, I offer a Theory of Change to guide how socio-environmental report cards can address sustainability challenges.

Introduction

Addressing sustainability challenges and understanding the interconnection between our human and natural environments are some of the leading research drivers in our society today. In the past twenty years, various frameworks and research needs have been identified (e.g., Polk 2014; Brandt et al., 2013; Kates et al., 2001; Kates, 2011), new institutions and global and regional networks have been formed (e.g., SESYNC, Stockholm Resilience Institute, Future Earth), and new funding infrastructure is being implemented (e.g., Belmont Forum). However, most environmental problems are caused by human behavior (Amel et al., 2017); thus, solving these issues would require a fundamental change in society and the recognition that environmental and social policies should be intertwined (Wallimann, 2013). Progress towards sustainability, therefore, must go beyond disciplinary research and the generation of new knowledge.

Employing participatory processes involving researchers, practitioners, and other stakeholders that could promote the social learning needed towards sustainable development is critical (Ludwig 2001; Kates et al., 2001). Social learning enables the development of a shared understanding among different stakeholders, bridging between and among different knowledge spheres that encompass science,

management, policy, and societal values (Roux et al., 2010; Roux et al., 2017; Brandt et al., 2013; Vilsmaier et al., 2015). A closely linked approach to sustainability is transdisciplinarity, which aims to reconcile the diversity of stakeholder perspectives in understanding socio-ecological systems and to co-produce appropriate knowledge that can lead to action (e.g., Polk 2015; Jahn et al., 2012; Roux et al., 2010).

Linking knowledge to action in sustainable development requires managing boundaries and cross-scale differences while creating information that is salient, credible, and legitimate (Cash et al., 2003). Thus, participatory and stakeholder-driven communication and engagement strategies that consider both the accurateness of information and how individual and social perceptions are needed. In addition, these strategies need to understand how cultural values affect how messages are received and internalized. Individuals have mental and cultural models that affect their perception and the interpretation of their surroundings (Lynam and Brown, 2012). Furthermore, people are social animals whose actions are also influenced by social preferences, social networks, social identities, and social norms (World Bank, 2015). This growing recognition of the importance of effectively communicating science to drive social change has led to a consensus report from the National Academies of Science (NAS, 2017), advocating for a framework to advance both the research and practice of science communication by using principles from the social sciences and “team science.”

The “essence of sustainable development is to meet the demands of the current generation without compromising the ability of future generations to meet

their needs” (Kates et al., 2001). Sustainability should explicitly account for the interconnectedness among systems, the United Nations, for instance, has set 17 interconnected global goals or Sustainable Development Goals (SDGs) that are designed to be a "blueprint to achieve a better and more sustainable future for all" (UN, online). The “Pillars of Sustainability” or the triple bottom line of economy, society, and environment, is the commonly used standard in assessing sustainability goals (2005 World Summit Outcome, UN General Assembly). A more recent approach used in urban development is what is termed as the “Circles of Sustainability” that uses a four-domain model - economics, ecology, politics, and culture (James, 2014).

In this chapter, I present the process of developing socio-environmental report cards as an effective strategy in addressing sustainability challenges by simultaneously advancing transdisciplinary research needs and promoting social learning towards sustainable actions. The report card process of co-design and co-production brings together different stakeholders to develop a shared vision, assess present conditions, and devise adaptive management plans (Costanzo et al., 2017; Vargas-Nguyen et al., 2020; Bunn et al., 2010; Dauvin et al., 2008; Flint et al., 2017). Report cards traditionally were used as tools for assessing and communicating environmental conditions (Connoly et al., 2013; Johnson et al., 2015; Fries et al., 2019) but there is a growing number that incorporates socio-economic values (Pascoe et al., 2016; McIntosh et al., 2019, Vargas-Nguyen et al., 2020). Report cards are increasingly used to communicate scientific information and support adaptive management (Connoly et al., 2013; Pascoe et al., 2016; Vargas-Nguyen et al., 2020),

but both the communication products and the development process need to evolve to address critical sustainability challenges.

Currently, most literature on report cards focuses on scientific framings and technical methodology (Pantus and Dennison, 2005; Williams et al., 2009; Fox 2014; Fries et al., 2019; S. Johnson et al., 2016; Windle et al., 2017; Pascoe et al., 2016; McIntosh et al., 2019; Harwell et al., 2019), but not on the broader societal impacts (Kung 2017; McIntosh et al., 2019; Vargas-Nguyen et al., 2020). Notable exception, as of this writing, is the dissertation research conducted by Kung (2017) that investigated how the report card process can influence stakeholder relationships through participatory processes in the context of natural resource management. Aside from a lack of evaluation, another hurdle in the adoption of report cards is the lack of accountability or a concrete mechanism to improve conditions (McIntosh et al., 2019). Often, report card initiatives end after the report card is published. Reflections on the process and resulting grades and discussions on how to improve/maintain the grades are almost done as an after-thought.

First, I evaluated report cards that were co-created with the Integration and Application Network, University of Maryland Center for Environmental Science (IAN-UMCES) from 1999 – 2015 using mixed-method approaches. IAN-UMCES is a boundary-spanning organization that has pioneered and facilitated the development of different report cards around the world (Kung, 2016; Vargas-Nguyen et al., 2020). Results show that report cards, although initially intended to communicate and raise awareness of environmental issues, can promote behavior

change and that adding socio-economic components can further increase its societal and environmental impact. Based on this evaluation, and drawing upon social science literature (i.e., environmental anthropology and psychology, social innovation, communication), and using complex system theory-based approaches (i.e., collaborative learning, transdisciplinary science, sustainability science, socio-environmental system), I developed a framework and a theory of change for the co-production of socio-environmental report cards to address sustainability challenges specifically.

Methods

Development and administration of the survey instrument

An online survey was administered through SurveyMonkey from March 8-28, 2016. It was sent to 67 key informants representing the 28 report cards that were developed and completed in partnership with IAN-UMCES between the years 2000 to 2015. The report cards represented by the respondents were mostly from North America (20), Australia (4), Asia (3), and Europe (1), as shown in Figure 1. The key informants were primarily local convener/organizer or active participants/data providers during the development of their own report cards. It was felt that these active participants would be the best source of information on the challenges, benefits, and impacts of their report cards. The survey was comprised of 19 close-ended questions to quantify perceived outcomes and two open-ended questions. The responses were confidential,

and at the end of the survey, respondents were asked if they would be willing to participate in follow-up interviews.

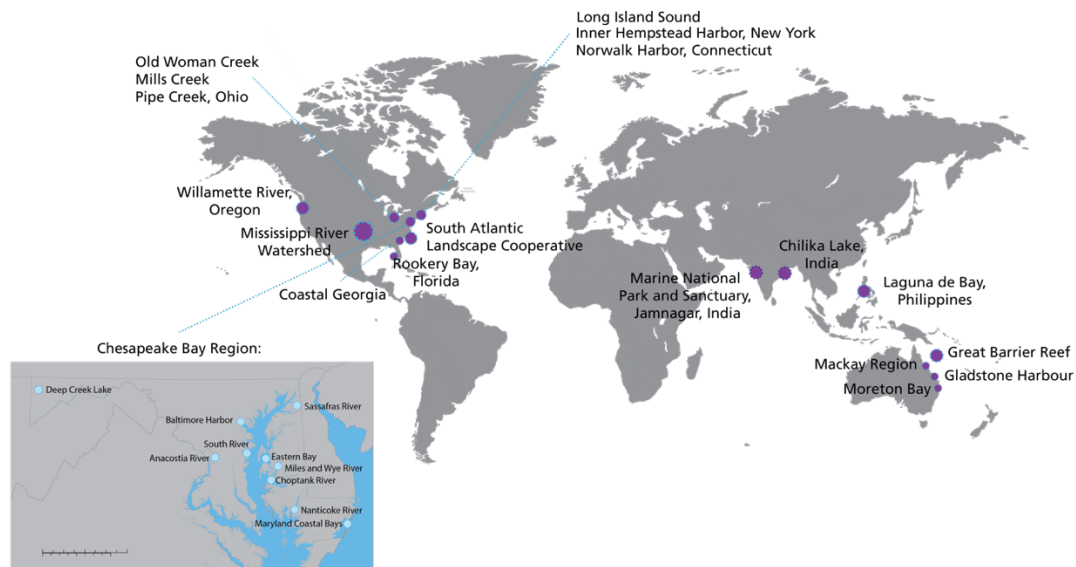


Figure 1. Report Cards evaluated in the study. Twenty-eight report cards from North America (21), Australia (4) and Asia (3) were represented in the study

Follow-up Interviews

Ten follow-up interviews were conducted from December 2016 to March 2017. Survey and interview responses were analyzed using the software MaxQDA 2018.

Results

Report cards represented in the study

Of the 67 key informants contacted to participate in the study, forty responded to the survey (60% response rate). Respondents represented 24 report cards, seventeen of which are located in North America, four in Australia, and three in Asia. Respondents were generally organizers and participants, primarily from government agencies and non-governmental organizations (NGOs). The time to complete the report card for the first time took 1-2 years and cost between \$1,000 and 50,000 dollars. A medium to a high amount of specialized expertise was needed, and pre-existing data were mostly used (Figure 2).

The top three objectives for developing report cards were the following: 1) advocacy and awareness-raising, 2) generating information and knowledge about status, and 3) influencing policy and decision making. Stakeholders who participated in the report card development were primarily from non-profits, government, and university/academia. Representation from the private sector, civil society (general public), and underrepresented populations was also reported. The primary methods for stakeholder engagement used were report card release events, email communication, stakeholder workshops, and one-on-one meetings. Overall, the top users of report cards were non-profit organizations and the general public. There were some significant differences in the top users for each region when the responses were aggregated. In Asia, users were mostly resource managers and government agencies, while in Australia, report cards have been embedded in resource governance and used

in political discussions. Thus, politicians were among the top users in Australia. In North America, report card producers were mostly citizen science groups and non-profit organizations; therefore, their primary target audience was their members and the general public.

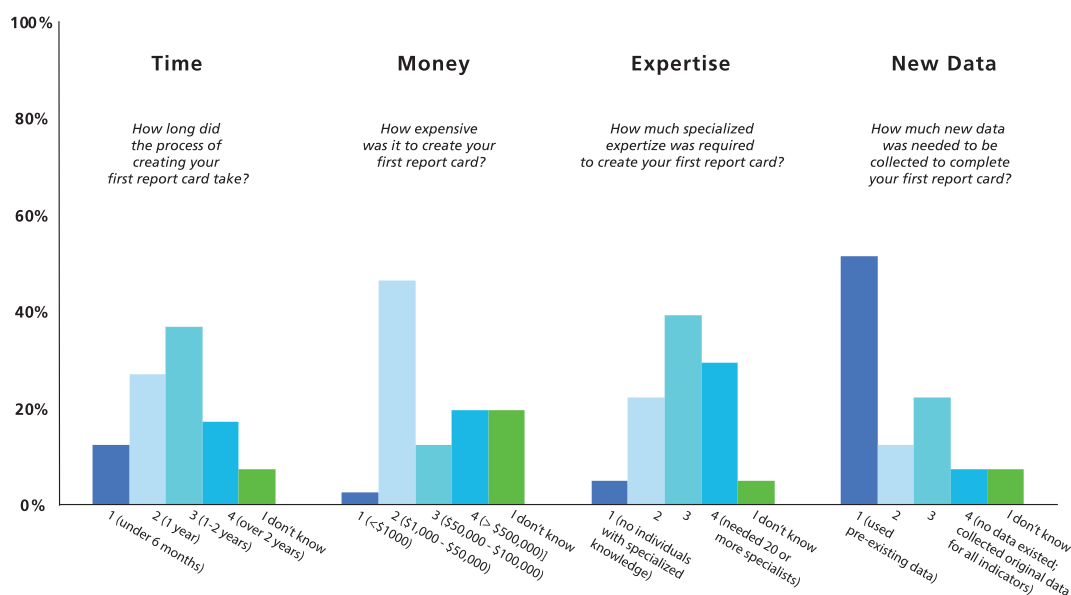


Figure 2. Resources needed to complete first report card. It took 1-2 years to complete the report card for the first time and cost between \$1,000 and 50,000 dollars. A medium to a high amount of specialized expertise was needed, and pre-existing data were mostly used.

Some key regional differences also emerged (Table 1). Behavior change was not a significant objective for Asian report cards, unlike Australians and North American report cards. The stakeholders involved in the report card development were from government agencies and university or academia, and they use stakeholder workshops and report card events as their means of engagement. Report cards from Asia took longer to make, were the least expensive, and mainly used existing data.

The observed use of report cards in Asia was primarily in scientific forums, and the top users were resource managers and researchers or scientists.

Table 1. Description of Respondents and their Report Cards

	<i>Overall</i>	<i>North America</i>	<i>Asia</i>	<i>Australia</i>
<i>N</i>	40	29	6	5
<i>Report Card Objective</i>				
<i>Engage stakeholders</i>	3%	3%	0%	0%
<i>Improve ecosystem health</i>	65%	55%	100%	80%
<i>Policy and decision making</i>	73%	69%	100%	60%
<i>Funding and resource allocation</i>	50%	48%	50%	60%
<i>Generate information</i>	80%	83%	100%	40%
<i>Behavior change</i>	65%	66%	67%	60%
<i>Advocacy and awareness-raising</i>	80%	83%	100%	40%
<i>Participants</i>				
<i>General public</i>	15%	17%	17%	0%
<i>Civil society</i>	23%	10%	67%	40%
<i>[general public listed twice] general public</i>	15%	17%	17%	0%
<i>Private sector</i>	38%	34%	33%	60%
<i>Underrepresented populations</i>	15%	10%	33%	20%
<i>Academia</i>	80%	72%	100%	100%
<i>Nonprofit</i>	85%	90%	67%	80%
<i>Government</i>	83%	76%	100%	100%
<i>What types of indicators were included in your report card?</i>				
<i>Governance/Management</i>	23%	14%	33%	60%
<i>Water Quality and Quantity</i>	100%	100%	100%	100%
<i>Ecological</i>	75%	66%	100%	100%
<i>Economic</i>	20%	10%	17%	80%
<i>Social and cultural</i>	28%	24%	0%	80%
<i>Report Card Users</i>				
<i>Media</i>	70%	62%	83%	100%
<i>Advocacy groups</i>	65%	62%	50%	100%
<i>Planners</i>	43%	28%	83%	80%

<i>Private sectors</i>	28%	24%	17%	60%
<i>Researchers</i>	58%	48%	100%	60%
<i>Non-profit</i>	80%	79%	67%	100%
<i>Politicians</i>	58%	48%	67%	100%
<i>Managers</i>	63%	52%	100%	80%
Where have you observed the use of your report card in discussions?				
<i>Targeted outreach</i>	15%	14%	33%	0%
<i>None</i>	3%	3%	0%	0%
<i>Social Media</i>	3%	3%	0%	0%
<i>TV</i>	50%	52%	0%	100%
<i>Newspaper</i>	65%	59%	67%	100%
<i>Radio</i>	40%	38%	0%	100%
<i>Political discussions</i>	40%	34%	17%	100%
<i>Scientific forums</i>	73%	66%	100%	80%
<i>Conversations</i>	83%	86%	83%	60%
How has your report card been used?				
<i>Too early to tell</i>	3%	3%	0%	0%
<i>Educate the public</i>	78%	79%	50%	100%
<i>Inform or modify a policy</i>	50%	41%	50%	100%
<i>Public engagement</i>	73%	72%	67%	80%
<i>Raise awareness</i>	88%	86%	83%	100%
<i>Influence dialogue</i>	60%	59%	33%	100%
<i>Inform or modify management</i>	53%	45%	67%	80%
<i>Modify monitoring programs</i>	40%	34%	50%	60%
<i>Inform behavior</i>	35%	38%	0%	60%
<i>Resource allocation</i>	45%	38%	50%	80%
Topics of interest that were stimulated				
<i>Trash</i>	3%	3%	0%	0%
<i>Biodiversity</i>	3%	0%	17%	0%
<i>Embayment</i>	3%	3%	0%	0%
<i>Fisheries</i>	14%	14%	17%	0%
<i>Improvement of indicators (add new ones)</i>	19%	21%	17%	0%
<i>Monitoring quality/gaps</i>	5%	7%	0%	0%
<i>Bacteria</i>	8%	10%	0%	0%
<i>Conservation</i>	5%	7%	0%	0%
<i>Management</i>	30%	17%	50%	60%
<i>Water Quality</i>	51%	48%	33%	60%

Report cards from Australia were developed to help improve ecosystem health. The main stakeholders were also from the government and university/academia. In addition to stakeholder workshops and report card release events, they used one-on-one meetings as a primary means of engagement. All respondents indicated that their report cards had been repeated yearly between 3 to 15 years. These report cards were also the most intensive in terms of money and expertise. All report cards have reported trends in water quality, and new indicators have been added over time. Report card use had been observed in political discussions, TV, newspaper, and radio, and the primary users were politicians, the media, non-profit, and advocacy groups.

Report cards from North America were used to generate information and for advocacy and awareness-raising. Report card producers were mostly citizen science groups and non-profit organizations, so their primary audiences were their members and the general public. North America was the only region that did not report that stakeholder workshops as a form of engagement in their top 4 responses. The engagement method used was primarily through email. Only 48% said that their report cards were repeated yearly. Sixty-four percent indicated their report card did not show any trend. The use of their report card has been observed primarily from conversation with friends and used mainly by the general public and non-profits.

Perceived Impacts of Report Cards

1. Environmental Literacy

“We have been surprised and pleased by the interest shown by state and local elected officials. They appreciate the product, understand the message, and are asking more questions to learn more about the resources in their communities.”

Report cards appear to be useful and practical tools for public engagement and awareness. Awareness, education, and civic engagement were the most common uses of the report card, as identified by respondents. Additionally, respondents identified a wide range of report card user types and observed use in a variety of media and social settings. These factors suggest that report cards are very versatile and useful awareness-raising tools. The levels of awareness and user types vary from each region (Figure 3). In Asia, eighty-three percent indicated that report cards increased public education, public awareness, and political awareness of their issues. In Australia, all respondents indicated ‘Agreement/Strong Agreement’ that reports cards increased public education, public awareness, and political awareness of their problems. In North America, the majority of the respondents indicated that report cards increased public education, public awareness, and political awareness of their problems.

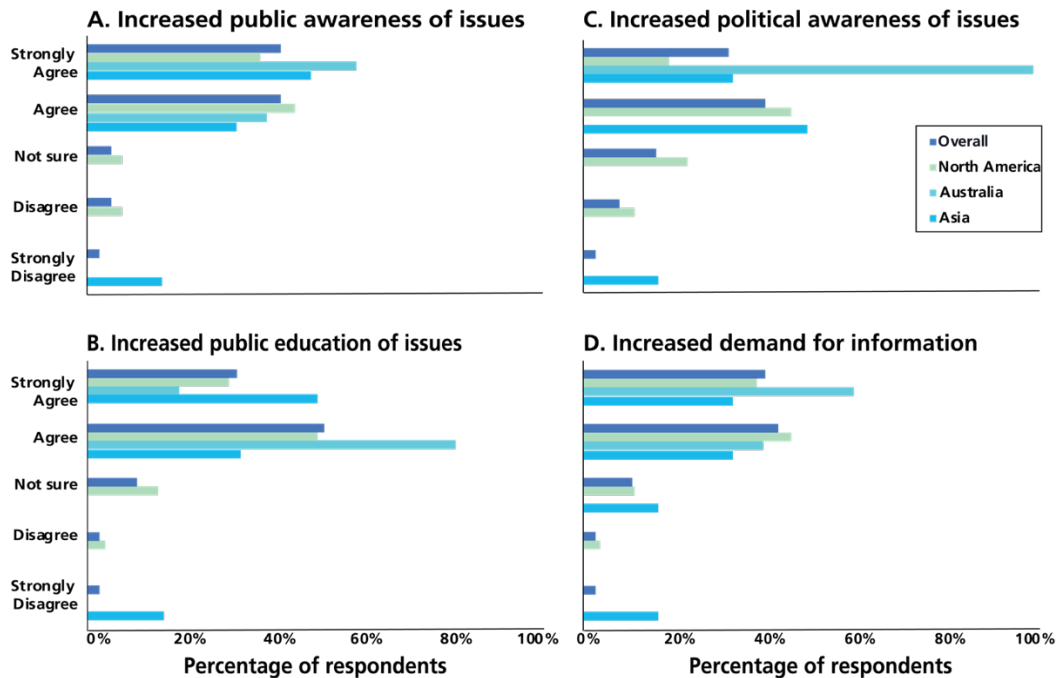


Figure 3. Report Cards increased environmental literacy. Survey respondents strongly agreed/agreed that their report cards increased (A) public awareness, (B) public education, (C) political awareness, and (D) demand for additional information.

“We monitored our streams for four years before implementing the report cards. Before, no one remembered what the data was telling us (possibly because the presentation was foreign or complex for the general public). Now several months after the release, people can comment on specifics of scores related to sites and years.”

Using the Pearson Chi-Square statistical analysis function of MaxQDA 2018, report cards that have been repeated over time were significantly correlated with increases in public awareness (p value<0.005), public education (p value<0.007), and political awareness (p-value <0.03). Increase in awareness also was correlated with certain reported user groups: private sector (political awareness, p-value <0.02), advocacy groups (public education, p value<0.04), and civil society (public

awareness, p value <0.03). Increases in public education (p value <0.05) and public awareness (p -value < 0.005) were also correlated with report cards that have been publicized in the newspapers. Report cards that have release events (p value <0.03) were similarly correlated with the perceived increase in public education.

“When performing outreach at community events, people are aware of the report card and issues in the watershed. They ask about trends and are curious about local water quality.”

Interviewees shared various examples of how their report cards have been used awareness-raising. The State of South Atlantic report card, for instance, is actively being used as greeting points to talk with new people who just move into the area. In Pipe Creek and Old Woman Creek in Ohio, the US, the report card initiative started as a way to engage further monitoring volunteers and to communicate the importance of what they’re collecting to motivate the changes that need to be done in the watershed. Once they started mailing printed copies of their report cards to their community members, they had an instance where a landowner that was close to one of their monitoring locations called them and asked if there was anything on their farm that could be contributing to the report card score. And they wanted to know who could come out and talk to them about some conservation changes that they could implement to help the watershed.

“It revealed gaps in our monitoring and our reporting. We added more stations to our monitoring program and incorporated more data in our annual report.”

Almost all respondents strongly agreed or agreed that their report card increased the demand for additional information. Table 1 shows that 80% of respondents reported that generating knowledge and information was a goal of their

report card; 63.6% of the repeated report cards have added indicators over time, and 50% have said that sampling sites have increased (only 18.2% reported a decrease in sampling sites). Also, 40% overall reported that report cards had been used to modify their monitoring program, but this does not seem to necessarily correlate with responses on changes to indicators or sampling sites.

2. Behavioral and environmental change

“1 - Changes in the mindset of people and their perceptions on conserving an ecosystem; 2 - Coastal managers are taking a keen interest in the improvement of ecosystem health.”

Report cards have been used to inform or modify management, policy, and allocation of resources, with 45% of respondents reporting that their report cards were used to inform or modify the allocation of resources (Table 1). Influencing funding and resource allocation was only an explicit objective of about 50% of the overall responses. Interestingly, however, it was only the objective of about 60% of the surveys that observed this as an actual outcome of their report card — implying that it may be an unintended benefit of the process. The responses also tended to have a higher representation from report cards that have been repeated over time (75%), which may point to the benefit of sustained repetition of report cards. The regional representation of these responses was reasonably representative of the overall respondents. Generally speaking, there seemed to be slightly higher information reporting for repeated report cards, which could be representative of more aggressive

communication strategies. A noticeable outlet for the report cards that have influenced resource allocation is the use of this information in political discussions (61% of the “changed allocation of resources” responses versus 40 % of the overall reactions). Reported use of report cards to inform or modify policy also seems to be correlated with report cards that include indicators for governance/management (p value<0.02) and report cards that have been observed in the political discussions of issues (p value<0.004).

“The condition of waterways is of political interest at least once a year, and we have the opportunity to give cabinet ministers one-on-one briefings on the key issues and what they could do to improve things.”

In Southeast Queensland, where various report cards have been developed in the past 16 years, funding has been allocated to all the different catchments over the years as a result of their report cards. The first report card in Moreton Bay in 1999 and 2000, led to *“AUS \$1 billion of investment in sewage treatment plants across the region which became a significant source of funding for improvement in ecosystem health”*. Report cards had also been used as a prioritization tool to focus particular actions in different catchments to reduce diffuse sediment and nutrients.

“The report card (and water quality data) has also informed our other programs and has broadened grant and other funding options by allowing us to target problem sites/areas.”

Various respondents had indicated that they had used the results of their report cards in funding justifications and grant proposals. A representative from the South Atlantic Landscape Cooperative reported that new conservation dollars were acquired as a direct result of their report card. Fifty percent of respondents said that their report card was used to inform or modify a policy, 53% said that it was used to inform or

modify management. About 45% said that it was used to inform the allocation of resources (Table 1). These responses suggest that the report cards have been useful in the discussions about specific types of decisions at the management and policy levels, but the outcomes were not necessarily clear. In summary, it was not clear whether report cards resulted in any changes to decision making or were just used as part of the discussion.

“Has brought more science into the political debate, which is good for improving policy settings based on evidence.”

Influencing policy and decision-making was indicated as one of the top objectives for report cards in Asia (100%) compared to Australia (60%) and North America (69%). Resource managers were also one of the top users of report cards in Asia (100%), while in Australia, politicians were among the top users (100%). Australia indicated that both influencing dialogue (100%) and informing policy (100%) were among the top uses of their report cards while both Asia and Australia indicated that informing management was the number two observed use of their report cards (Asia, 67%; Australia, 80%). Results imply report cards had some utility in decision-making, particularly in Asia and Australia.

“Increased pressure for the industry to do better, faster. Some have taken this on & are being more proactive in trying to address issues (they were sick of getting 'red' on the report card)”

About 58% of respondents agreed or strongly agreed that their report card had changed stakeholder behavior, and about 35% of respondents observed that their report card was used to inform civil society behavior (Figure 4). Levels of agreement again varied per region. For Asians, 17% strongly agreed, and 50% agreed that report

cards affect behavior; for Australians, 60% strongly agreed, and 20% agreed, while North Americans 15% strongly agreed, and 35% agreed. Influencing behavior change was not the top objective for any of the regions (67% Asia, 60% Australia, 69% North America). Most interview participants indicated that they have no definitive metrics on whether their report cards were able to change stakeholder action and behavior, other than observations and conversations. For example, when conservation groups have outreach events, there would be people that would come and make rain barrels, but they have no way of knowing if these devices were actually used.

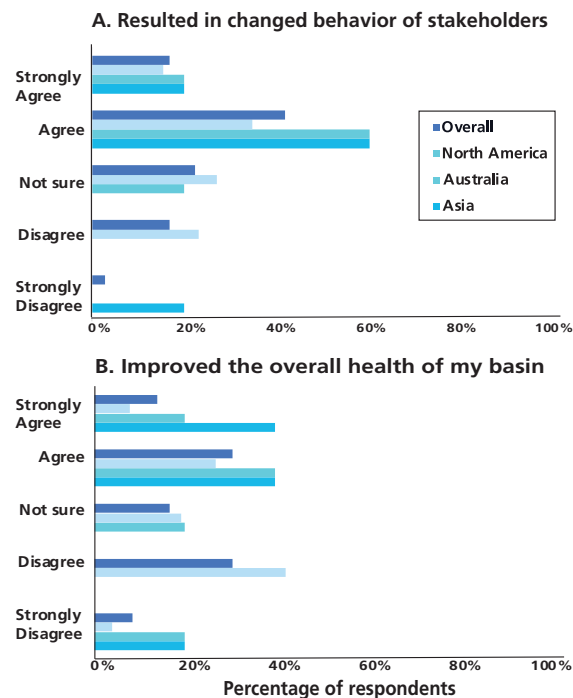


Figure 4. Report Cards resulted in (A) behavior change and (B) improvement of ecosystem health.

“Reduction in estuarine nutrient concentrations and now a shift towards a collective desire by water utilities to invest in catchment management to offset point source pollutant.”

Half of the respondents strongly agreed or agreed that their report card improved overall health. It is important to note that the majority of these report cards mostly include ecological indicators and their primary objective was to use report cards as science communication tools and not so much for individual behavior change or even improving ecosystem health. As mentioned previously, the report card as a communication tool led to a significant reduction in nutrients, both total phosphorus and nitrogen, and from sewage treatment plants over the past 15 years in Southeast Queensland. The state government has also used the report card as a platform for their water policies, particularly environmental water policies in and around the waterways in Southeast Queensland and the Great Barrier Reef.

Stakeholder Engagement as most important change

“The most important change as a result of our report card is the interaction among resource managers who provide data. The process of developing the report card seems to have increased understanding across different agencies and areas of responsibility.”

A surprising impact of report card development is the level of stakeholder engagement and reaction (both positive and negative) that it created. Only one survey respondent indicated that stakeholder engagement was part of the objective of their report cards. Yet, several respondents reported that their report cards had increased understanding, cooperation, and collaboration across different agencies and among local organizations. In the Laguna Lake in the Philippines, fishers have expressed willingness to get and share information on fisheries. Stakeholders and local officials

also showed an increased awareness of the impacts of too much nitrates and phosphates in the lake. Interview participants have repeatedly emphasized the importance of the process, which brought together different stakeholders to co-create the report card and, in turn, resulted in collective action. The best example of this was the Mississippi River watershed report card that brought together over 400 different businesses, organizations, trade associations, academic institutions, and agencies throughout the watershed. In the next chapter of this dissertation, I used the Mississippi Report Card development as a case study to show that developing report cards can be used as a tool for transdisciplinary collaboration.

Several interviewees reported that after their report card came out, groups from the NGOs and academia had come out asking why they were not consulted in the report card development. A survey respondent reported that some stakeholder groups were angry because they thought that the report card did not reflect the health of their system.

Challenges and limitations of Report Cards

“The report card is an excellent tool to synthesize information and make it relevant to stakeholders. But you need to ensure that the issues that are important to stakeholders are clearly represented in the report card. It is not always a simple simplification/summary of the data. From my experience, if the synthesized message fails to appeal to the stakeholders' key drivers - then it could be negative in producing appropriate behavior change.”

Two significant issues or pitfalls that could arise in the long-term were further explored in the follow-up interviews. First is “report card fatigue,” which one respondent estimated to occur about five years from when they first started their report card program. It usually happens when stakeholders lose interest when they

don't see progress. Being able to adjust the process and implement new programs to reflect the changing priorities of stakeholders becomes very critical. As another respondent noted, environmental conditions are deemed as part of history, and its protection is most often a lower priority compared to job security and growth. It becomes essential, then, to be able to link environmental conditions to benefits that people care about before change can happen. After the initial excitement of mobilizing stakeholders and resources to develop a report card, and the novelty of the idea wears off, report cards have the tendency to fall into a "business as usual" trap. It happens when stakeholders complain if they get a bad grade - but do little to change future grades through modifying actions.

Another potential danger in the long term is the idea that anything that is not in the report card becomes unimportant. A majority of survey respondents and interviewees have said that their report cards had increased demand for additional information, especially in the first few years. In the same way that report cards can highlight issues that need more attention, it can also reduce resource allocation to issues that were not represented in the report card. Based on the experience of one of the interviewees, indicators that do not influence the report card grade were dropped from their monitoring program, leading to a reduction in information. Once the report card program is underway, stakeholders become more interested in getting a deeper understanding of a particular report card indicator or a specific set of issues. Creating new information then becomes limited to the scope of the report card. In the long term, there is a tendency that the perception of the ecosystem status and the direction

that it should become too synonymous with the report card, and anything that is not on it becomes forgotten.

From ecosystem health report cards to socio-environmental report cards

“Our water bodies are not just natural resources, and report cards need to be expanded to assess all their uses and contributions.”

“Would recommend more inclusion of 'progress to management targets' in other report cards - this is key to driving political pressure and providing feedback on the effectiveness of programs to enact change. Just reporting on 'condition' which is variable with the weather is not enough to engender change.”

Ecosystem health can be defined as the integration of ecological, economic, and human processes, as well as measures of sustainability and system resilience (O’Brien et al., 2016). While the majority of the report cards represented in this study and the literature are generally characterized as “ecosystem health report card,” the previously stated definition of ecosystem health is not reflected in the indicators that are included in their report card (Table 1). One hundred percent of respondents had water quality/quantity indicators, and 75% had ecological indicators, but only 23%, 10%, and 18% of respondents had governance/management indicators, economic indicators, and social/cultural indicators, respectively. When aggregated by region, report cards with socio-economic and governance/management indicators were mostly from Australia. In the follow-up interview, it was disclosed that socio-cultural indicators were only added later on, as part of efforts to promote change. The majority of survey respondents also recognized the need to include the human and economic dimensions of ecosystem health in their report cards. Issues related to human health indicators, conservation, biodiversity, governance and management,

policy changes, and investment were some of the topics of interest that were stimulated as part of their report cards.

Thus, to differentiate from traditional report cards, I will be using the term socio-environmental report cards to refer to the type of report cards that can be used to address sustainability challenges.

Developing socio-environmental report cards using a three-phase framework

Based on my survey and interview results, report cards have evolved from a document created to increase awareness and education about environmental issues, to a process that engages stakeholders. This presents increased opportunities for report cards to influence positive environmental and social change towards sustainable development. However, for report cards to drive social and environmental change, the process has to be stakeholder-driven and action-oriented and builds on transdisciplinary principles of collaboration, co-design, and co-production. Therefore, I have conceptualized a three-phase framework for developing socio-environmental report cards (Figure 5). This proposed framework can potentially address some of the issues in the use of report cards that were raised by research participants in Table 2.

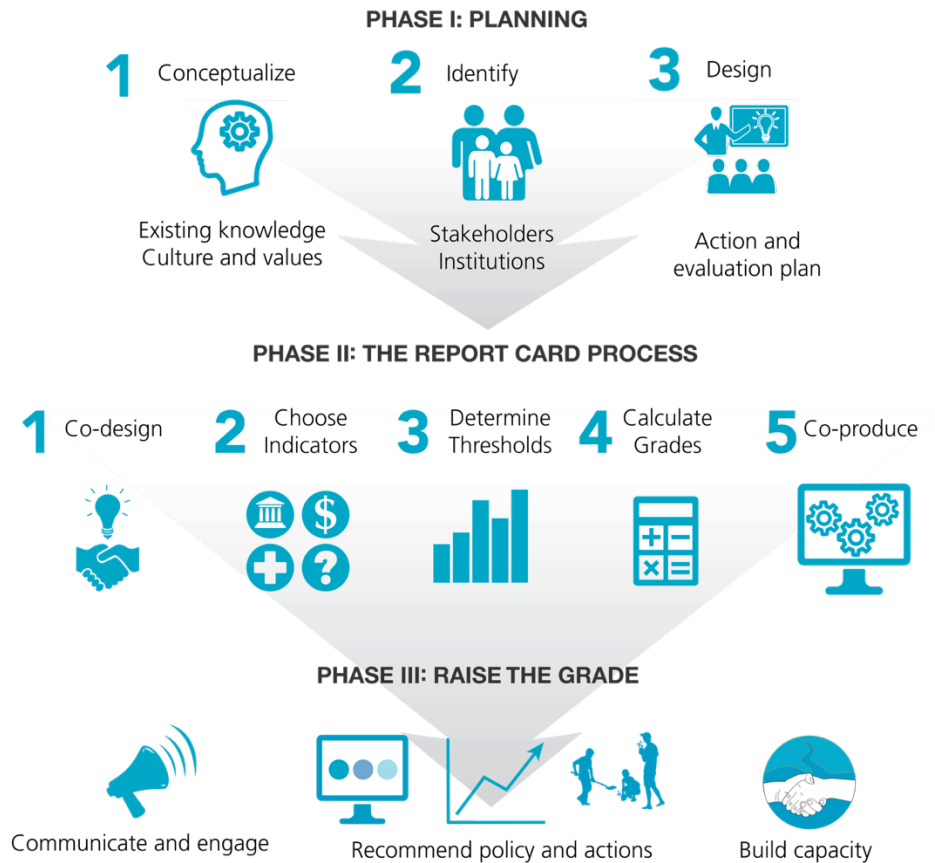


Figure 5. Three-phase framework for developing socioenvironmental report cards

Phase 1 is the planning stage and should ideally be conducted before the first stakeholder workshop. One of the crucial aspects of the Mississippi Watershed socio-environmental report card was that prior to the report card development, conceptualization of the different stakeholder values in the watershed was conducted, and only then was the report card chosen as a tool to create their shared vision. Phase 1 addresses multiple concerns in the report card development process, such as insufficient stakeholder representation and expertise, lack of local and traditional knowledge, and unrealistic plans and expectations. Phase 2 emphasizes co-design and co-production in the actual development of the report card and builds on IAN-

UMCES five-step process of conceptualization of values and threats, indicator selection, threshold and reporting region determination, calculation of scores, and finally, communication (Costanzo et al., 2017, Fries et al., 2019, Hartwell et al., 2019).

Phase 2 ensures community ownership of the product and minimizes a specific agenda to inadvertently be pushed. Emphasizing co-development could also potentially minimize conflicts over data quality, thresholds, and grading methodology used. The discourse around report cards can be influenced by the expertise involved in the process and the kinds of data that are available. Even in the traditional ecosystem, health report cards, indicator selection, thresholds, and grading are a major concern and often, the cause of conflict (Table 2). Several reports and papers (i.e., Connolly et al., 2013; Logan et al., 2020) discuss this in detail. In contrast to natural systems where indicator data usually exist but might be inappropriate or incompatible with report card needs, data needed for socio-cultural indicators are usually not readily available. Some social data can be obtained from ethnographic approaches, such as interviews and surveys. In identifying thresholds or tipping points, the socio-environmental report card should also consider social values, interconnection and vulnerability to tipping points, and climate change; hence, experts from different fields of knowledge should be consulted. Methods for calculations, selection of spatial and temporal scale, and degree of uncertainty should be communicated, and resulting grades should have consensus from both scientific and stakeholder perspectives.

Phase 3 is the ‘Raise the Grade’ stage and ensures that the process is action-driven. A major shortcoming of standard report card cards is that they lack any substantial action agenda at the end of the process. There should be a mechanism that is built in to ensure that the momentum that was created during the process leads to action. Optimizing the collaboration formed during the process can build capacity, and advancement in socio-environmental modeling can help with recommending policy and management action and assessing future scenarios.

Table 2. Issues that were raised by respondents

REPORT CARD PROCESS	REPRESENTATIVE STATEMENTS OF ISSUES
PHASE 1. PLANNING	
DEVELOP	"In-kind costs for sponsors should be discussed at the outset. Mutual expectations should also be made as explicit as possible in early discussions between prospective client and IAN."
IDENTIFY	"Vetting processes vary by the governmental body. Our state government was not open to the idea of grading the health of our waters in any way, but it would be a great tool for NGOs and nonprofits."
CONCEPTUALIZE	"our parties have some disparate visions of what this report card is/will be, and that could be a source of future issues, as in order to be a broadly reaching outreach and advocacy tool, this necessitates reducing scientific rigor."
PHASE 2. REPORT CARD PROCESS CO-DESIGN	
CHOOSE INDICATORS	"The broader the participant base is, the stronger the product will be" "challenge to use data available to communicate the full spectrum of ecosystem conditions that the public is most interested in..."
DETERMINE THRESHOLDS	"Include more indicators in the report card and develop threshold limits applicable to the region."
CALCULATE GRADES	"Grading methodology and parameters need to be agreed upon at the outset by all parties."

CO-PRODUCE	"Our stakeholders were very angry about the report card because they felt that it did not accurately reflect the health of the harbor."
PHASE 3. RAISE THE GRADE	
COMMUNICATE RESULTS	"Aside from the initial launching of the report card, which was attended by few representatives from different stakeholder groups, it has to be presented to a wider audience of sectoral groups for better understanding, discussion, and call to action."
RECOMMEND POLICY AND MANAGEMENT ACTIONS	"...while the key Natural Resources agency staff were involved through the whole process; there has been no follow up action to even consider the recommendations made."
BUILD/ENHANCE CAPACITY AND COLLABORATION	"Capacity building of local technical staff in the preparation of future report cards."

Discussion

Developing socio-environmental report cards

Sustainability should explicitly account for the interconnectedness among systems, such as between air, land, and sea. Sustainability should also integrate ecological, social, economic, and human processes and their strong interdependences. Table 3 describes the unique considerations for each phase that are required for developing a socio-environmental report card for sustainability and some suggested activities and literature to guide each step. In developing stakeholder-driven socio-environmental assessments, it is imperative to incorporate systems thinking approach. Systems thinking has been defined as an "approach to problem-solving that attempts to balance holistic thinking and reductionist thinking" (Stroh, 2015). As part of the conceptualization step of Phase 1, it is important to have a systems understanding of how a particular system works by engaging key stakeholders, identifying the values, threats, possible solutions, trade-offs, and leverage points. Understanding the system

is important in the next step of developing a plan for continuous learning and expanded engagement through transdisciplinary collaborations initiated in Phase 2. In managing different researchers from various disciplines, strategies for team science collaboration should be applied (Hall et al., 2019; Bennett & Gadlin, 2012).

A key aim in Phase 2 of the report card process is to use principles of transdisciplinarity to reconcile the diversity of stakeholder perspectives in understanding socio-ecological systems or complex societal problems and to co-produce appropriate knowledge that can lead to sustainable actions (Roux et al., 2017). Successfully engaging stakeholders can achieve knowledge co-production in report card development through social learning, knowledge integration, and accountability (Roux et al., 2010; Jahn et al., 2012). Social learning enables the development of a shared understanding among different stakeholders, bridging between and among different knowledge spheres that encompass science, management, policy, and societal values (Roux et al., 2010; 2017).

Another framework that can guide the report card process is ‘collaborative learning’ that was developed by Daniel and Walker (2001) as an approach to resolve environmental conflict. Collaborative learning can be used to bridge science, management, and policy to improve outcomes. Collaborative learning, then, becomes a more fluid process that requires engaging people with diverse and conflicting viewpoints to collaboratively develop a vision of desired future outcomes that integrate ecological, social, economic, cultural, and organizational perspectives (Feurt, 2018). Collaborative science also promotes the exchange of cultural and

environmental knowledge and expertise among individuals who previously had no sustained interaction, resulting in social networks that can enhance socio-ecological resilience (Paolisso et al., 2019).

The common barriers that collaborative learning can help bridge are perceptual, institutional, and disciplinary barriers (Feurt, 2018). Social science tools that can be used to overcome these barriers are stakeholder analysis and social network analysis, institutional analysis, and cultural analysis that can be used in Phase 1 of the report card process. Another tool in collaborative learning that can be used in the co-design step in Phase 2 is situation mapping, which facilitates discussion and enables the group to “get on the same page.” The purpose of situation mapping is to build a shared understanding of the situation and the diversity of ways people see the issue, what they value, and what they perceive as threats and barriers. Participants are divided into small groups, and each person is asked to answer the following questions in colored sticky notes: 1 – what is valued by stakeholders in your situation; 2 – What are threats impacting what people care about; 3 – How their work contribute to protecting what people care about. This exercise makes the issues more personal because it helps the participants see that they are part of the system. Situation mapping is one way to reveal the mental models that people are using to think about a problem, its cause, and potential solutions (Feurt, 2018). Mental models are a simplified representation of the world used by people to interpret observations, to infer from what is known to unknown, and to solve problems ultimately.

Mental models that are shared within a culture or social group are called cultural models (Kempton et al., 1995). Knowing the existing mental models of the different stakeholders can facilitate better communication that can inform Phase 3 of the report card process. According to Jones et al., (2011), mental models are elicited in the context of natural resource management for the following reasons: explore similarities and differences to improve communication, integrate different perspective to improve overall understanding of a system and improve decision making, support social learning processes, overcome knowledge limitations and misconceptions, among others.

A challenge for report cards has been the ability to provide quantitative recommendations to improve conditions reflected by report card grades. Generic recommendations based on findings and best practices are included, but the impacts on the functionality of complex systems and interactions with other factors are not fully described. The introduction of ethnographic approaches in Phase I of the process and the use of systems and socio-ecological modeling approaches in Phase III to formulate recommendations will help bridge this gap. These additions will be converting qualitative information into quantitative recommendations and help determine how actions should be implemented most cost-effectively and by whom. In Phase 3, socio-environmental and complex systems modeling approaches can be utilized, such as System Dynamics, Bayesian Belief Networks, Agent-Based Modelling (see Letcher et al., 2013 for comparison of these approaches) and Socio-ecological network analysis (Sayles and Baggio, 2017). These different approaches also have their versions of participatory processes that can be used during Phase 2.

Table 3. Considerations for developing socio-environmental report cards

REPORT CARD PROCESS	CONSIDERATIONS FOR A SOCIOENVIRONMENTAL REPORT CARD	ACTIVITIES/METHODS/ SELECT REFERENCES
PHASE 1. PLANNING	This phase should be conducted before the first workshop and in close coordination with the primary partner/s, but the facilitators/boundary organizations/researchers should conduct independent preliminary systems analyses	Collaborative learning (Daniel and Walker, 2001; Feurt 2018); Strategies for team science collaboration (Hall et al., 2019; Bennett and Gadlin, 2012); System's Theory (Senge, 2006, Meadows, 2009; Stroh, 2015)
DEVELOP	Develop project management plan with critical partner/s, clarify roles, expectations, and budget	Activities, milestones; risk assessment; evaluation/theory of change (Anderson et al., 2016)
IDENTIFY	Identify key stakeholders, institutions and governance structure, devise plans for engagement	Stakeholder mapping and stakeholder analysis (Reed et al., 2009)
CONCEPTUALIZE	Identify socio-ecological components, different knowledge streams, key issues	Conduct key informant interviews, literature review
PHASE 2. REPORT CARD PROCESS	Similar to IAN's original 5-step process and initiated during the first stakeholder workshop, but with more emphasis on the co-creation process to enhance social learning and stakeholder buy-in	For a review of the different analytical frameworks in indicator selection, weighing, etc. currently used for ecosystem health report card development (see Logan et al., 2020)
CO-DESIGN	During the first workshop, develop shared understanding and vision through participatory activities involving researchers from different disciplines, practitioners, and various stakeholders	Lessons learned from co-design (Moser 2016); Examples of participatory activities: SNAP (values and threats); role-playing games; participatory mapping, participatory modeling (i.e., causal loop diagram); stakeholder mapping
CHOOSE INDICATORS	One of the biggest well-documented challenges in any assessment is the selection of indicators. In contrast to natural systems where indicator data usually exist but might be inappropriate or incompatible with report card needs, data needed for socio-cultural indicators are usually not readily available. Some can be obtained from ethnographic approaches such as interviews and surveys	Example of SES ¹ indices: ecosystem health (Cairns et al., 1993); (Flint et al., 2017); ocean health (Halpern et al., 2012); freshwater health (Vollmer et al., 2018); Ethnographic approaches such as surveys can be used to generate socio-cultural indicators (Windle et al., 2017) and emergent technologies or frameworks such as spatial analysis (i.e., NEON ²) and ecosystem services (Pascoe et al., 2016) can also be used

DETERMINE THRESHOLDS	Identifying targets for each chosen indicator is usually based on management objectives or ecological values. The socio-environmental report card should also consider social values, interconnection and vulnerability to tipping points, and climate change; hence, experts from different fields of knowledge should be consulted.	SES thresholds, SES tipping points (Horan et al., 2011, Lauerburg et al., 2020); Climate change (Liu et al., 2015); Social Values (Smyth et al., 2007)
CALCULATE GRADES	Aggregating and assigning scores from different types of indicators from different sources of varying degrees of uncertainty can pose a challenge. Methods for calculations, selection of spatial and temporal scale, and degree of uncertainty should be clearly communicated, and resulting grades should have consensus from both scientific and stakeholder perspectives.	Bayesian Belief Networks (BBN) (S. Johnson et al., 2016; Pascoe et al., 2016), Probability Weight Index (Fox, 2014); Fuzzy logic (Birch et al., 2016)
CO-PRODUCE	Co-produce new knowledge through integration and synthesis, identification of knowledge gaps, and development of boundary objects; knowledge co-production for sustainability should be context-based, pluralistic, goal-oriented, and interactive.	Examples of boundary objects: maps, conceptual diagrams, SES indicator framework, newsletters, report card product, system models/scenarios; Principles of knowledge co-production (Norström et al., 2020)
PHASE 3. RAISE THE GRADE	Socioenvironmental report cards should be action-oriented	
COMMUNICATE RESULTS	Report cards release events are usually held and covered by media. Printed report cards and online versions are available and disseminated in social media.	Costanzo et al., 2017; Vargas-Nguyen et al., 2020
RECOMMEND POLICY AND MANAGEMENT ACTIONS	Advancement in SE modeling can help with recommending policy and management action and assessing scenarios.	See Letcher et al., 2013 for comparison modeling approaches, i.e., System Dynamics, BBN, Agent-Based Modelling; Socio-ecological network analysis (Sayles and Baggio, 2017)
BUILD/ENHANCE CAPACITY AND COLLABORATION	The optimizing collaboration formed during the process can build capacity and lower transaction costs for collective action.	Social network analysis (Groce et al., 2018; Bodin and Prell, 2011); Socio-ecological network analysis (Sayles and, Baggio 2017)

¹SES – Socioecological Systems;

²NEON - National Ecological Observatory Network (<https://www.neonscience.org>)

Evaluating the impacts of socio-environmental report cards

Assessing the broader accountability of participants and evaluating impact is one of the biggest challenges in developing socio-environmental report cards through transdisciplinary collaboration. Much of the literature involving transdisciplinary approaches are mostly researcher-driven and still within the framework of academic discourse. Impact evaluation and co-reflection can be seen under the lens of research users, research providers, and research funders, and when these three align, progress towards their collective goal can be achieved (Roux et al., 2010). Different frameworks for evaluating transdisciplinary research have been suggested (Stokols et al., 2003; Roux et al., 2010; Brandt et al., 2013; Belcher et al., 2016). However, these are not sufficient for assessing user-driven transdisciplinary collaboration where collective action, not research in the traditional sense, is the main driving force.

A commonly used tool in the Development discipline that can be used as part of the planning and evaluation process of report card development is the theory of change. A theory of change explains how activities are understood to produce a series of results that contribute to achieving the final intended impacts (MacQueen et al., 2018). Theory of change can be used to identify the current situation, the intended situation, and what needs to be done to move from one to the other. A theory of change explains how a program or intervention is understood to work. At a minimum, we should have the following: the context for the initiation, long term change, process or sequence of change, assumptions about how the changes may happen, and diagram and narrative summary (Stein and Valters, 2012). Garcia and Zazueta (2015) also

propose that beyond an intervention's theory of change, a systems perspective must be applied so that the appropriate evaluation methods can be used. Essential elements to be evaluated are the process, outputs, outcome, and both the ecological and social impacts (Holzer et al., 2017). Figure 6 is my proposed general framework for a theory of change in how socioenvironmental report cards can contribute to a sustainable and resilient socio-environmental system.

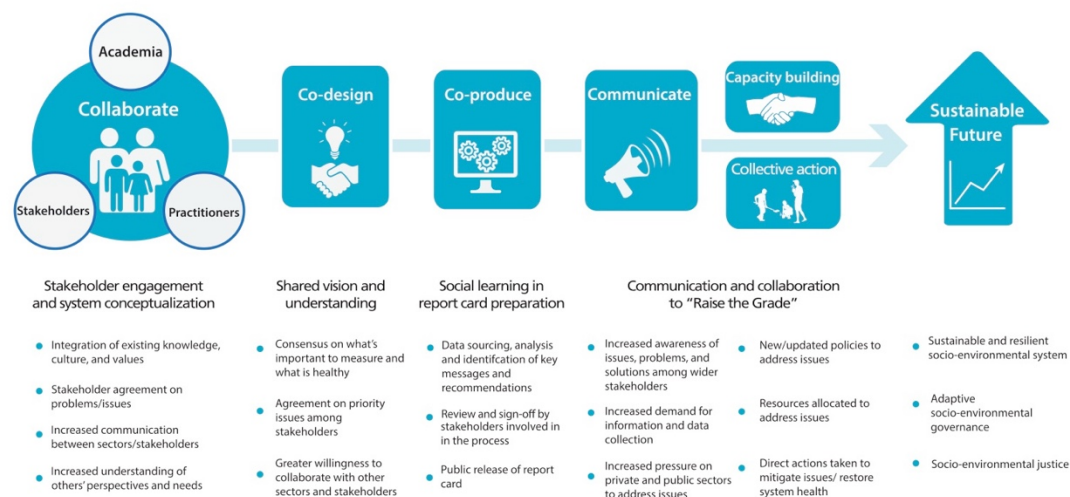


Figure 6. Socio-environmental report card theory of change

Report cards and social learning

Report cards increase cooperation between and among stakeholders. Thus, stakeholder participation is critical in the report card process; careful stakeholder selection should be done right from the start of the project and continues throughout the three phases of report card development. Involving the "right" stakeholders are not only crucial in Phase I: Planning but also in co-producing the report card in Phase II and in raising the grade in Phase III. Successful identification and engagement of

stakeholders can be achieved using stakeholder analysis. Different typologies and methods are available (Reed et al., 2009), but which ones to use depends on the system. The co-development of report cards can become a catalyst for stakeholders to come together, forming a social network of governance actors and contributing to the social capital of a particular watershed through social learning that was facilitated through the co-creation of the report card.

Social learning is defined as ‘learning that occurs when people engage one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action’ (Schusler et al., 2003). Features of social capital that can increase through social learning include the following: trust; reciprocity and exchanges; common rules, norms, and sanctions; obligations, and expectations; values and attitudes; culture, information, and knowledge; and connectedness in networks and groups (Pretty and Ward, 2001). Social learning can lead to the development of new partnerships, strengthening of existing collaborations, and even transformation of adversarial relationships (Schusler et al., 2003; Stringer et al., 2006).

While it is easier to communicate and share knowledge within individuals that have a shared understanding, diffusion of new information might only occur within a similar group (as reviewed by (Prell et al., 2010). It has even been suggested that diversity is more likely to facilitate adaptive management, while homophily may reduce communities’ resilience to environmental change (Newman and Dale, 2006). Determining diversity, however, is not as straightforward. While getting people from

different organizations in one room is already a big step, selecting stakeholders from different organizations, categories, or stakes is not enough (Prell et al., 2010). Instead, it is the existing social network or the structure of social ties between individual stakeholders that plays an important role (Prell et al., 2009; Prell et al., 2010). For institutional change through collective action to occur, a whole network of individuals and organizations is needed to continuously share information, unite their collective effort, and sustain the pressure for change (Ernstson, 2011). Using social network analysis (SNA) in the report card process can be a powerful tool.

Network Analysis can also potentially show the interconnection between ecological, socio-cultural, economic, health, and governance indicators in one assessment. Also, specific characteristics of social networks can also be used as indicators that can be used in report cards. Potential indicators are network density and fragmentation, centrality measures, and the type of network structure formed. SNA can also be used to design targeted communication strategies to have broader reach and behavior change impacts. SNA can identify the flow of information in the system, identify who the public turns to for information, and the different belief and value system that exists within the network, among others. Change in network structure during the process can also be used in the evaluation.

Collective impact is a growing social movement characterized by “the commitment of a group of important actors from different sectors to a common agenda for solving a specific social problem” (Kania and Kramer, 2011). Collective impact can be seen as an amalgamation of two important principles – 1) collective

action and 2) social innovation. Collective action, or the common and voluntary actions taken by a group to pursue shared interests (Vanni, 2014), can be achieved through social learning by improving the social capital and enabling “participants to act together more effectively to pursue shared objectives” (Putnam 1995). Once this is achieved, social innovation or the creation of long-lasting outcomes that aim to address societal needs can follow. Both collective action and social innovation emphasized encouraging active participation through an open process of engagement, exchange, and collaboration with relevant stakeholders, including end-users, to address issues in natural resource management by crossing organizational boundaries and jurisdictions. One mechanism for active participation in the co-creation or co-production of knowledge (Voorberg et al., 2015), which is a key feature of transdisciplinarity.

Report cards and the adoption of sustainable actions

Based on my results, report cards help raise awareness of issues and promote behavior change (Figure 3). In essence, they help promote “environmental literacy” that is the needed pre-cursor for enhancing “environmentally responsible behavior” and encouraging “conservation behavior.” As cited in Monroe (2003), environmental literacy means “having knowledge, attitudes, skill, and behaviors to be competent and responsible.” Conservation behaviors are activities that support a sustainable society. Stern (2000) defines environmentally significant behavior by the extent to which it changes the availability of resources or alters ecosystems. Socio-environmental report cards can be used as a vehicle to promote behavior change by reinforcing messages

that influence pro-environmental behaviors and addressing how to overcome barriers to their adoption. Based on environmental psychology (Gifford et al., 2011), influences on pro-environmental behaviors include: knowledge and education, perceived behavioral control; values, attitudes, and various kinds of worldviews, felt the responsibility and moral commitment, place attachment and other emotional connection, norms and habits, goals, and many demographic factors.

There are two general ways that the overall impact of a report card project can be improved to adapt to the changing needs of the users. The first is to make sure that the information presented would influence the users to adopt pro-environmental behaviors. Second, engage the public in the development of the report card. Expanding report card assessments to integrate the ecological, socio-cultural, and economic creates a more inclusive, holistic, and robust report card. Highlighting the ecosystem services that benefit users most would reinforce place attachment, moral responsibility, and sense of obligation (Masterson et al., 2019; Halpenny 2020). Report cards can be designed to account for the difference in stakeholders' levels and stages of adoption (Rogers 1995) and the different levels of influence (Amel et al., 2017) that are needed for literacy and behavior change.

One of the most popular theories in social science is the diffusion of innovation, which describes how an idea or new technology spreads in society (Rogers 1995). Rogers identified five different types of stakeholders in his bell curve, which I adapted for report cards. Figure 7 illustrates how these stakeholders can be engaged in the report card process. The naming classification I used is adapted from

Moore (2002): Enthusiasts (innovators), Visionaries (early adopters), Pragmatists (early minority), Conservatives (late minority), and Skeptics (laggards). Enthusiasts and visionaries are in the green zone; they are more willing to participate in the process and thus should be involved in the co-design phase. Pragmatists and conservatives are in the yellow and orange zone, respectively, and they have medium to low-interest levels. Engaging the Pragmatists and conservatives in the co-production phase could promote product ownership and thus would make them more willing to collaborate. The Skeptics, in the red zone, generally are the general public that is either uninterested or uninformed and thus should be a focus of communication efforts aimed at educating and information sharing.

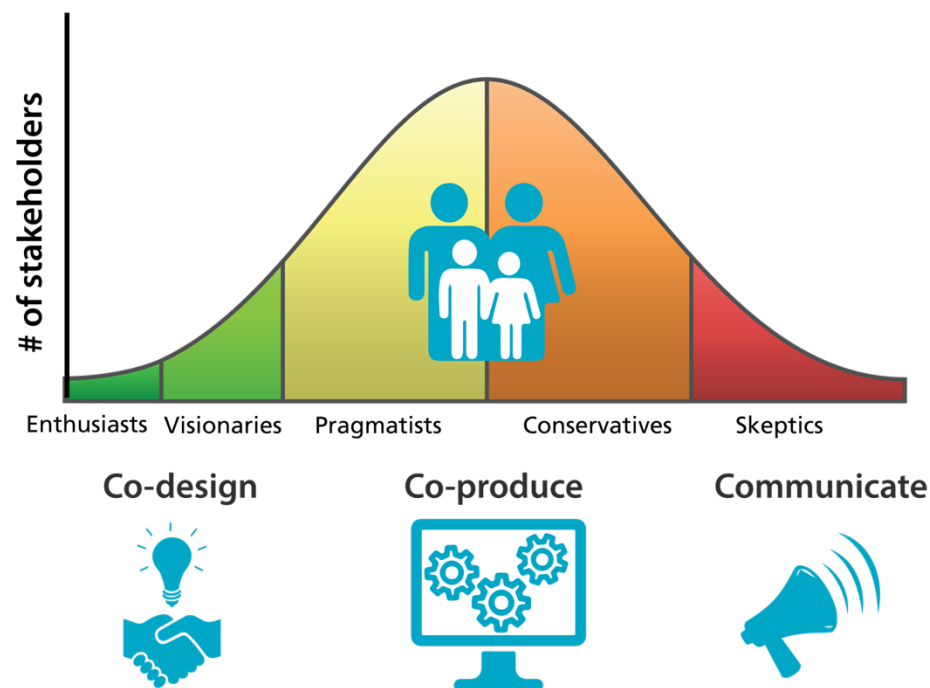


Figure 7. Diffusion of innovation model for engaging stakeholders in the report card process

In the collaborative learning framework, behavior change can be achieved. It can be evaluated by moving decision-makers from awareness to concerted action, mostly on issues that relate to ecosystem services (Feurt 2018). In the same manner, report cards should highlight the kind of ecosystem services that users benefit most from their environment. Why the ecosystem is vital to the users, how it affects their daily lives, and what roles they play in the process are some of the information that should be highlighted.

Another way to improve content is to highlight that actions are being done to address the problems. For example, a management plan is in place or in the works by the relevant institutional bodies. If applicable, highlighting cooperative actions among the government, the different sectors, and the community should be highlighted (Gifford et al., 2011; Gifford and Nilsson, 2014). Doing this will promote the trust of the institution and motivation that any actions can lead to positive results. If possible, a report card should also reflect the cultural norms of a particular place to increase ownership of the product and stakeholders' connection with nature (Scholte et al., 2015; Hinds and Sparks, 2008). Highlighting pro-environmental stories can slowly change the social norms towards environmentalism. The idea that others are doing it too and that our right actions are recognized could increase a person's intention to act (Amel et al., 2017). Similarly, offering specific projects that people can participate in can eliminate the lack of behavioral control and promote self-efficacy (Fielding et al., 2008).

Conclusion and future directions

Report cards have evolved from a document created to increase awareness and education about environmental issues, to a process that engages stakeholders. This evolution presents increased opportunities for report cards to influence positive environmental and social change towards sustainable development. What is and is not in the report card is important to explore, there is a potential that report cards can reinforce a specific knowledge type, and make it difficult for new forms of knowledge and concerns and needs to find space and legitimacy. Therefore, considering social and environmental concerns is critical in developing report cards to address sustainability challenges.

The report card process should be characterized by transdisciplinary collaboration, co-design, and co-production. Knowledge co-production, however, is not enough to translate to effective environmental governance; what is needed is to foster collaborative approaches to social learning (Berkes 2017). It is essential to understand what affects behavior change - the capabilities, motivation, and opportunities of the people and addresses them (Langer et al., 2016). The proposed three-phase framework and theory of change can potentially address these challenges. However, they also need to be continuously evaluated; the various conceptual frameworks that are used should be validated in practice, to ensure that the process evolves to address the challenges of sustainability and global change effectively. There is an implicit bias in the perceived impacts of report cards since their adoption

has been voluntary or based on a specific need. Therefore, a broader evaluation strategy should be designed.

It is also important to emphasize that developing an actual report card product should not be the end goal. Instead, the experiences and collaborative and social learning shared by stakeholders through the three-phase process is the most important. In the proposed framework, different participatory processes can be used on top of the typical report card approach. There is flexibility in what boundary objects or products can be co-produced. Other products that can be more appropriate locally and culturally can be chosen or co-produced in addition to the report card. Examples of these boundary objects are models, maps, websites, reports, videos, animations, comics, newsletters, training protocol, adaptation strategies, or books (photobook, e-book). In this manner, the process of developing socio-environmental report cards can be an effective strategy in addressing sustainability challenges by simultaneously advancing transdisciplinary research needs and promoting social learning towards sustainable actions.

Chapter 2: Using socio-environmental report card as a tool for transdisciplinary collaboration

ABSTRACT

The process of developing a socio-environmental report card through transdisciplinary collaboration can be used in any system and can provide the foundation for collaborative solutions for sustainable resource management by creating a holistic assessment that balances environmental, economic, and social concerns that incorporates multiple perspectives from multisectoral actors. We demonstrated this in the Mississippi River Watershed with the ultimate goal of promoting holistic management of the region's natural resources. But, working at the scale of the Mississippi River watershed presents the challenge of working across geographical, organizational, and disciplinary boundaries. The development of a socio-environmental report card served as the focus for efforts to foster a shared vision among diverse stakeholders in the watershed and to promote transdisciplinary collaboration. The process engaged over 700 participants from environment, flood control, transportation, water supply, economy, and recreation sectors, from over 400 organizations representing local, state, and federal government agencies, businesses and trade associations and private, non-profit, and academic institutions. This broad engagement in the selection of important themes, indicators, measures, and assessment methods as part of the co-creation of boundary objects aimed to foster social and mutual learning and develop common understanding and shared visioning among stakeholders with differing perspectives. The process was facilitated by boundary spanning organizations, creating an atmosphere of trust by utilizing 'third

places' for knowledge exchange and integration. This transdisciplinary process also led to collective action through collaboration and selection of restoration and management activities that could improve conditions for multiple sectors simultaneously and/or recognize potential tradeoffs for informed decision making.

Key words: Mississippi River, Socio-environmental, Report Card, Transdisciplinary collaboration, Integrated Management

Introduction

Transdisciplinary collaboration in the context of integrated management (Allen et al., 2011) allows for multisectoral stakeholders to reconcile a diversity of perspectives and act together more effectively to pursue shared objectives (Putnam 1995) leading to collective action (Vanni, 2014) and collective impact (Kania and Kramer, 2011). Transdisciplinarity promotes social learning or mutual learning through the use of “third places” and the co-development of “boundary objects” (Jahn et al., 2012; Vilsmaier et al., 2015; Roux et al., 2017). Third places are learning spaces where diverse stakeholders meet and share experiences with an equal voice (Roux et al., 2017) allowing for knowledge exchange, integration, and production to occur. Examples of boundary objects include models, indicators, and maps that allow for different groups to share meaning and incorporate individual perspectives while still maintaining an identity that is recognized by all (Star and Griesemer, 1989; Fox, 2011; Jahn et al., 2012; Roux et al., 2017). Ideally, transdisciplinary processes are facilitated by boundary spanning organizations that help increase the legitimacy of

science by fostering trust and sustaining interaction and engagement among the participants (Scholz and Steiner, 2015; van Kerkhoff and Pilbeam, 2017; Bednarek et al., 2018).

The co-development of boundary objects is key in sustaining stakeholder engagement by enabling participants to develop a shared understanding, fostering trust in the collaboration process. Facilitating the creation of boundary objects can be daunting however; requiring capacity in planning, facilitation, and communication. The objective of this paper is to illustrate how a socio-environmental report card is a boundary object that can serve as a platform for transdisciplinary collaboration and a catalyst for collective action. We illustrate the co-development process as a practical solution for achieving stakeholder engagement, providing opportunities for collective action in complex systems. We describe the process here as a guide for others, using the Mississippi River Watershed Report Card as a case-study.

Report cards are assessment and communication products that compare a region's ecological, social, and economic status with predefined goals or objectives (Costanzo et al., 2017). They can synthesize large quantities of complex information into comprehensive letter-grade scores that can be easily communicated to decision-makers and the public. Although the use of ecosystem health report cards has been increasing (Williams et al., 2009; Harwell et al., 2019), the Mississippi River watershed report card was the first of its kind, not only in its geographical scope and the inclusion of both ecological indicators and socio-economic indicators, but also in the stakeholder engagement approach that was utilized. The co-design and co-production process for the report card is unique and has allowed for the engagement

of a diverse multi-sector group of stakeholders through multiple workshops that served as “third places” and the co-development of boundary objects such as conceptual diagrams and maps, newsletters, and the report card product itself. This process has since been applied in diverse locations and contexts world-wide, resulting to socio-environmental report cards that were co-designed by stakeholders to reflect their values and interests.

The Mississippi River watershed is the third largest watershed in the world, covering over 41% of the continental United States and including parts of 31 states and 2 Canadian provinces (Mississippi River Corridor Study Commission 1996). Many different users depend on the watershed but this diversity of interests also leads to competition and conflict over the use of the river’s natural resources. Increasingly, stakeholders throughout the watershed recognize the need to extend the scope of existing cooperation in the management of natural resources to incorporate a broader scope of interests and larger geographical scale (Walsh and Mulcahy, 2010; Meridian Institute 2010). This, however, is challenging because in addition to the diversity of management objectives, constituencies and decision-makers, there are also significant geographic, environmental, economic, and social differences across the watershed (Mississippi River Corridor Study Commission, 1996).

Some of the more active sectors engaged in management include conservation, navigation, industry, agriculture, water supply, recreation, flood control & risk reduction, and energy (coal and gas extraction and hydroelectric power generation). Protection, conservation, and restoration of water quality, wildlife habitat, water quantity and allocation, navigation infrastructure, flood control and risk

reduction, water treatment and supply are interconnected, and have significant local and watershed wide impacts (Mississippi River Corridor Study Commission, 1996, Turner and Rabalais, 2003, Camillo and Percy 2004, National Research Council, 2008, White et al 2014). Thus, many stakeholders have reported widespread challenges to their interests and an inability to address their issues and meet their objectives without developing broader coalitions and partnerships (Walsh and Mulcahy, 2010; Meridian Institute 2010).

The challenge is to implement new management approaches for these sectors that recognizes their impacts on other sectors. For example, how can ecosystem health, water supply, hydropower, economic vitality, and recreational opportunities be maintained or improved while also preserving the navigation and flood risk reduction improvements created through the Mississippi River and Tributaries Project (MR&T) that is implemented by the U.S. Army Corps of Engineers (Camillo and Percy, 2004; Camillo, 2012). Traditional natural resource management approaches are bounded by human-made jurisdictional borders while ecological processes operate across various spatial and temporal scales (Sayles and Baggio, 2017; Cumming et al., 2006). These differences often lead to ineffective natural resource management (Cumming et al., 2006; Folke et al., 2007; Bodin and Prell, 2011; Ratner et al., 2013).

One approach to addressing these types of multi-scale and multi-sectoral issues, and the disconnect between management activities and societal outcomes, is through integrated management that is grounded on transdisciplinary collaboration such as watershed-based approaches (National Research Council 1999), integrated

river basin management and integrated catchment management (Allen et al 2011). In the Mississippi Watershed, this has been addressed to some extent at the basin level through the formation of basin compacts such as the Ohio River Valley Water Sanitation Commission, Tennessee Valley Authority, the Mississippi River Commission, Missouri River Commission and the Red River Compact. However, a watershed-wide integrated and holistic management effort has not been initiated for the whole Mississippi Watershed (Hooper 2012).

The process of developing a holistic socio-environmental report card for the Mississippi River Watershed fostered a shared vision among diverse stakeholders. This was achieved through transdisciplinary collaboration by 1) managing boundaries, 2) actively engaging diverse stakeholders, and 3) creating a shared understanding through the co-creation of boundary objects. The paper is structured as follows: first, we discussed the events that led to the decision to use a report card as a tool to develop a shared, long-term vision for the Mississippi watershed. Second, we evaluated the strategies that were used for developing the report card, which centered around two important transdisciplinary principles: stakeholder engagement and co-development of boundary objects. We then discuss the results achieved through the report card process in building social networks and as a rallying point for collective action and collective impact. Finally, we give our reflection on the report card process as a transdisciplinary collaboration, the lessons learned, and our recommendations.

Toward a shared vision for the Mississippi watershed

The Mississippi River watershed includes the Mississippi River and major tributaries including the Missouri, Ohio, Arkansas, and Red Rivers (Figure 1). It has a rich history for multi-sectoral, transboundary management under the rubric of Integrated River Basin Management. However, these existing entities operate at the basin level and employ a mostly top-down management approach. In 2008, a National Research Council report went so far as to call the Mississippi River an “orphan” because no agency, program or entity oversees the entire river (National Research Council 2008). In 2009, a series of interviews with diverse geographic and sector stakeholders were completed to gather information about support for developing a long term, intergenerational vision for the Mississippi River watershed (Meridian Institute, 2010). A consistent result in the interviews was the need to develop a shared, holistic vision for the future of the Mississippi River watershed that integrated ecological, social, and economic concerns. The respondents wanted this vision to help create commonly accepted priorities for the watershed. This information helped shape the agenda for the 2010 America’s Inner Coast Summit in St Louis, MO. At the conclusion of the summit, the participants asked The Nature Conservancy and the U.S. Army Corps of Engineers to convene a steering committee of stakeholders to support developing a shared future vision and seeking solutions for meeting the multiple demands placed on the Mississippi watershed system by integrating issues, partners and ideas at the full watershed scale (Walsh and Mulcahy, 2010). This became the America’s Watershed Initiative steering committee.



Figure 1. The Mississippi River Watershed. The Mississippi River Report Card was built in five major basins, including the Upper Mississippi River, Lower Mississippi River, Missouri River, Arkansas and Red River, and Ohio River basins. Workshops and summits were conducted throughout the watershed to solicit feedback from experts from these regions.

The Nature Conservancy, as a member of the steering committee, secured and allocated the funding needed to hire a director and begin the process to advance America's Watershed Initiative. The steering committee then organized a series of high-level stakeholder watershed summits to identify a tool to help define and shape a common long-term vision and to identify goals shared by stakeholders for the future of the watershed. Following these summits, a report card assessment was chosen as the best tool for establishing baseline conditions and developing the shared, long-term vision for the watershed, which would be based around 6 goals: (1) Maintain supply of abundant clean water; (2) Provide reliable flood control and risk reduction; (3) Support local, state and national economies; (4) Support and enhance healthy and

productive ecosystems; (5) Provide world-class recreation opportunities; and (6) Serve as the nation's most valuable river transportation corridor. A seventh goal, national security, was initially selected, but later dropped as impractical.

The AWI steering committee partnered with Integration and Application Network, University of the Maryland Center for Environmental Science to help develop this report card. IAN-UMCES has been instrumental in the development of ecosystem health report cards globally, most notably in the Chesapeake Bay (Williams et al, 2009), the largest estuary in the USA, and the Great Barrier Reef in Australia (State of Queensland, 2011), among many others. IAN-UMCES generally follows a 5-step process (Figure 2) in creating report cards: Step 1– developing the conceptual frameworks to understand ecosystem processes, environmental values and threats, etc.; Step 2 - choosing indicators that can be measured; Step 3 - defining thresholds to establish benchmarks, a color coding scheme of green-yellow-red is used to convey scale of values; Step 4 - calculating scorecards, by combining different indicators and presenting it in a way that make sense to decision makers, resource managers, and the public; and Step 5 - communicating results through mass media with supporting material in technical or web based venues (Costanzo et al., 2017).



Figure 4. The University of Maryland Center for Environmental Science Integration and Application Network follows a five-step process when developing report cards.

Four foundations for the Report Card were essential in its creation: (1) *The report card was to be built in the basins* – the Report Card would gather data and provide grades at the scale of the 5-Basins (Upper Mississippi River, Ohio River, Lower Mississippi River, Arkansas and Red Rivers, and the Missouri River Basins) through multiple workshops that served as third places and integrating the results to create the watershed report card; (2) *The report card was to be built with partners* – the report card development process would recruit leading stakeholders and partners in each of the five basins who in turn would help to recruit stakeholders to participate in workshops and meetings to provide the foundational information for the co-

creation of the report card; (3) *The report card was to be built with diversity* – the report card needed to have active engagement from a diversity of stakeholders and perspectives including business, basin associations, civic organizations, local, state and federal governments, academic institutions, and others; and (4) *The report card was to be built with transparency* – the report card data sources, methodology, and evaluations would be shared with the participants and public to allow for review and feedback while under development and after completion. The last three foundations were achieved through the co-development of boundary objects creating information products that are salient, credible and legitimate.

Developing the Mississippi river watershed report card

The report card process emphasized active participation through an open process of engagement, exchange, and collaboration with stakeholders who crossed jurisdictional and organizational boundaries in order to address key issues in the Mississippi River watershed. Frequent communication and active participation was facilitated through the development of boundary objects such as conceptual diagrams, workshop newsletters, and the report card product.

Stakeholder selection and engagement

Report card development was guided by several important transdisciplinary principles, which were intended to achieve the most diverse stakeholder input and active engagement possible. The report card incorporated information and advice provided by leaders, stakeholders and experts from more than 400 businesses,

organizations, agencies and academic institutions from every major river basin in the watershed and from key stakeholder groups (**Figure 3**). More than 700 diverse participants participated in workshops, summits, webinars and meetings to gather data, provide feedback and give advice throughout the process. This allowed the project to be guided by a shared vision for the Mississippi River watershed with an open line of communication for active exchange of ideas and concerns.

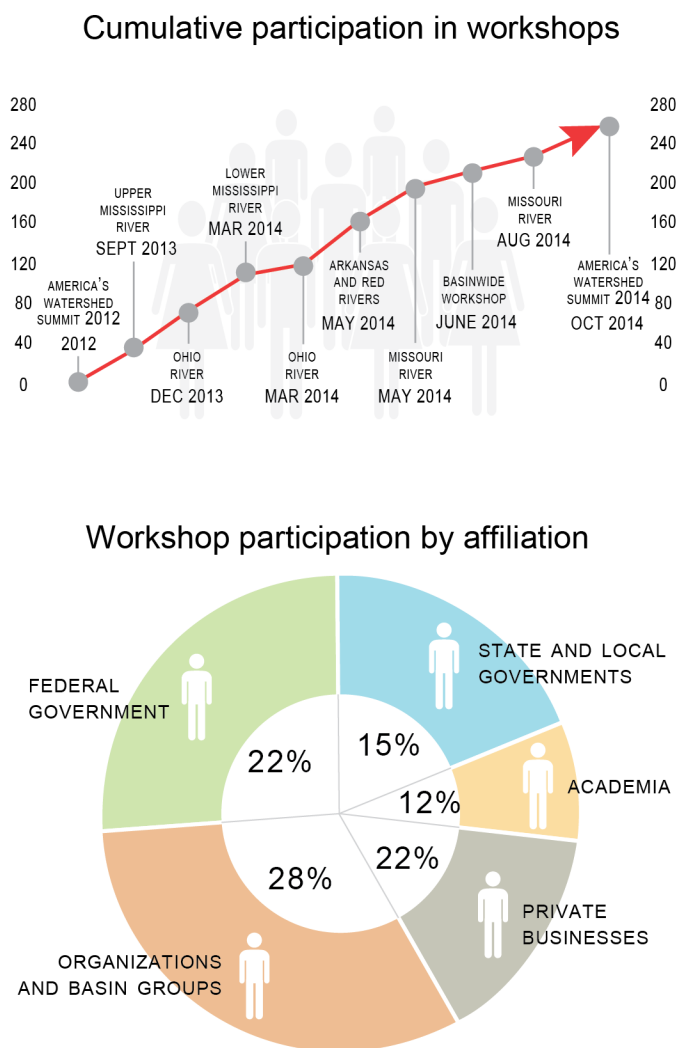


Figure 3. The Mississippi River Report card was built with partners and with diversity. (A) More than 400 organizations were engaged throughout the development of the Report Card. (B) These participants represented stakeholder groups from the

federal, state and local governments and agencies, private businesses, academic institutions, and various organizations from every major river basin in the watershed.

Regional Workshops

Workshops that served as “third places” were held in each of the five basins to gather information for potential indicators and solicit advice from stakeholders with regional knowledge on the sectors involved in the six management goals (**Figures 1**).

Transdisciplinary and participatory processes require skilled facilitation performed by boundary-spanning organizations (Reeds 2008, Scholz and Steiner 2015, van Kerkhoff and Pilbeam 2017, Bednarek et al., 2018) and in this case, workshop planning and implementation was coordinated by the AWI staff and facilitated by IAN-UMCES personnel. The workshops included high-level participation from multiple stakeholders from local government units, federal agencies, academia, non-governmental organizations, and the private sector. These stakeholders were chosen carefully to ensure that each of the six management goals and its diversity of issues were well represented through multiple diverse perspectives. The regional workshops were held for two days and were characterized by both formal and informal engagement, designed to enhance cooperation and promote knowledge exchange among the participants. Each workshop and meeting was different, but the importance of the rivers and waters in each basin and from every stakeholder group was clear. After each basin workshop a newsletter documenting the information gathered was produced.

On the first day of the regional workshops, participants developed a conceptual diagram through participatory mapping. Conceptual diagrams are self-

contained visual representations of key ecosystem processes that make use of symbols to summarize the features and threats of an ecosystem (Dennison et al, 2007). This exercise helped foster stakeholder empowerment and product ownership by allowing participants to represent features and processes that are relevant and familiar to them. Participatory maps are planned around a common goal; in this exercise, participants were divided into small groups and were given blank maps of their region. They were then tasked to use their local knowledge and expertise to spatially identify what they value in their region and what they think are the threats that their region is facing. Each map was presented to the whole group and the succeeding discussion served as the basis for the creation of the conceptual diagram (Figure 4). The final conceptual diagram was created using symbols from the IAN Symbols library and underwent several revisions as part of the workshop newsletter. A key component of the conceptualization process is that the facilitated discussion among multiple stakeholders helped synthesize regional issues while developing a shared understanding of these issues and a common language to describe them (Dennison et al., 2007). Further, breaking out in smaller groups builds opportunities for socialization, enhanced relationships between participants, and served as a venue to overcome issues of trust and power inequality (Prell et al., 2010).

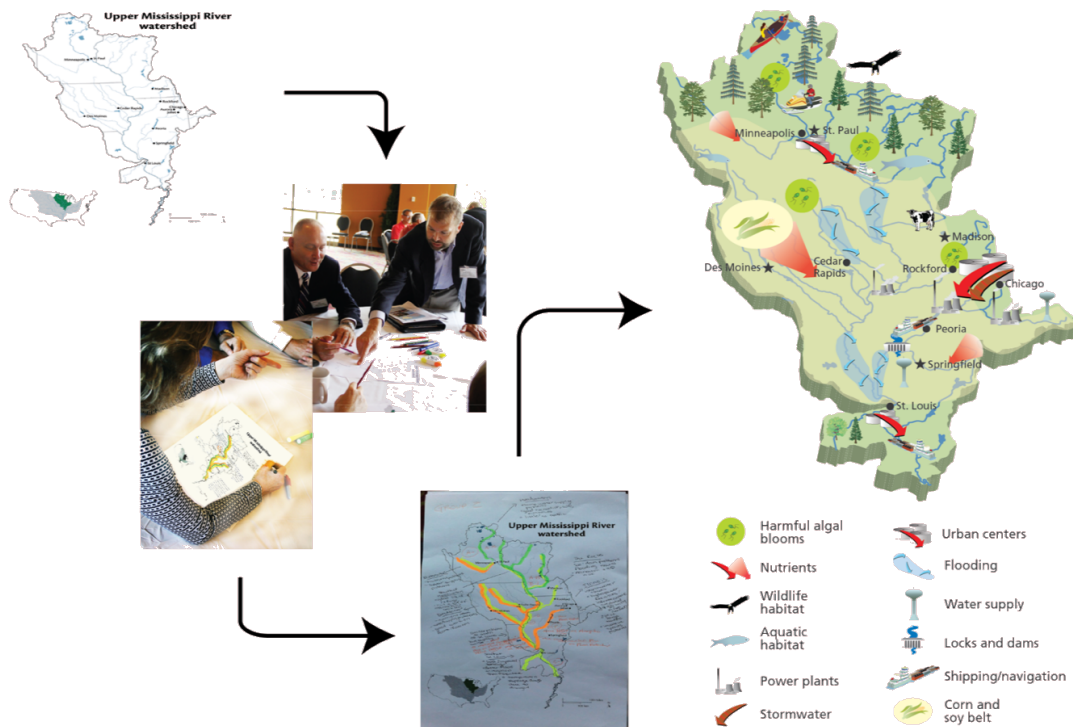


Figure 4. Participants co-developed conceptual diagrams through participatory mapping. In each of the five basins, workshop participants used their regional expertise to map the values and threats of their basin. These conceptual maps served as boundary objects that helped in developing a shared understanding among participants. Symbols used for the final conceptual maps are available at the Integration and Application Network, University of Maryland Center for Environmental Science Symbol library (<https://ian.umces.edu/symbols/>).

Upon development of a shared narrative and understanding through the conceptualization exercise, breakout groups then established a list of indicators that could be used to assess each of the six goals. In some of the regional workshop, a new survey tool was used that allowed for each participant to log into a web interface in order to create a ranked order of preference for each indicator. What is unique about this technology is that different weight was assigned for votes coming from an expert in the specific goal area compared to other participants that have expertise elsewhere. Some indicators were highly preferred, but others were relatively equally ranked. Data availability were discussed and potential data providers were identified.

At the end of each workshop, a newsletter draft was co-produced that featured the basin's conceptual diagram, values and threats, suggested indicators, and a group photo of the participants with their names and affiliations. Finalization of the newsletter took about 4-6 weeks after each workshop, with constant engagement of all participants throughout. The newsletters served as documentation of the progress that was made during the workshop, consensus that was reached on the key messages, and the potential indicators that could be used to measure progress toward the six goals. At the outset of the meetings, participants were assured that a printed document would be produced that represents their combined efforts.

Some basins (i.e. Missouri, Ohio and Lower Mississippi) required more than one visit to improve stakeholder engagement from that area (Figure 1). For example, because of practical and historical issues, the Tennessee River is often considered to be separate from the Ohio River Basin even though it is a tributary of the Ohio River. Thus, an additional workshop was held in Nashville, TN in addition to the one held in Cincinnati, OH. The series of regional workshops in the five basins was concluded with a meeting in Arlington, Virginia to discuss the integration of basin results into the overall watershed results. This meeting built on the results of the regional workshops over the previous year. The meeting also addressed issues that were applicable at the scale of the entire watershed, but that were not considered in the individual basin workshops.

In all, more than a dozen major workshops and meetings brought together diverse experts with broad perspectives to help develop the report card. The original intent for the workshops was to identify the measures that would be appropriate for

each goal and region by seeking expert opinion and local knowledge to select the indicators that could best reflect the status of the goals. However, it quickly became apparent that the workshops created value beyond that narrow objective. Participants routinely mentioned how unusual and refreshing it was to work together with other stakeholders, sometimes with perspectives very different than their own. The single-issue advocacy model that interest groups have been following for decades had precluded close collaboration prior to the AWI workshop. In addition, the production of the newsletter after each workshop was particularly valuable to the participants because it gave them the feeling that they had already made important progress, and that the time spent at the workshop was an investment in a tangible product that could be disseminated. Because of the regional workshops and the production of newsletters afterwards, there was trust in the co-creation initiative and participants had clear incentive to participate.

Development of the report card

Sustaining the momentum and the collaboration that was formed among the different stakeholders was another important aspect of the report card development process. This was achieved through the co-creation of new knowledge and understanding of the interconnectedness of the different values within the Mississippi watershed. This integrated knowledge was documented and communicated not through typical scientific publications and project reports but through a Report Card and a suite of supporting science communication products that served as boundary objects. Unlike traditional scientific publications that generally have restricted access,

report cards allow for the delivery of concise, data-driven information in a timely manner to broad audiences.

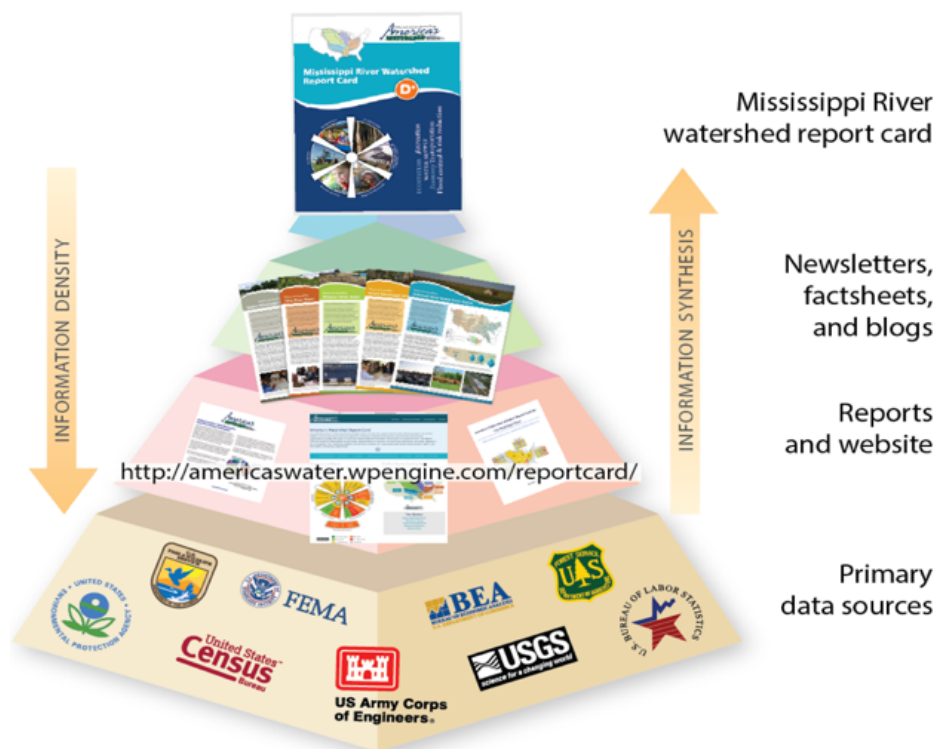


Figure 5. The Mississippi River report card was built with transparency and sits atop an information pyramid supported by primary data sources. The scoring methodologies that were used underwent extensive stakeholder consultations and expert reviews and were made available through a dedicated website. The results of the workshops, summits and meetings were well-documented through the publication of newsletters, factsheets and blogs.

Preliminary report card release and the revision process






Indicators for the preliminary report card were chosen based on recommendations from the basin-level workshops and their relevance to measuring the goal, consistency with other basin indicators, data availability, and the ability to develop a relevant scoring method. The report card utilized national, regional, and state level



data to report on over 20 indicators for Flood Control and Risk Reduction, Transportation, Water Supply, Economy, Recreation, and Ecosystems goals, in five basins within the Mississippi River watershed, as well as key impacts to the Northern Gulf of Mexico. Results of the report card were calculated for the Upper Mississippi River, Ohio & Tennessee Rivers, Lower Mississippi River, Arkansas & Red Rivers, and Missouri River basins and results from these five basins were summarized in an overall watershed score.

The preliminary report card underwent multiple revisions based on the feedback of the AWI steering committee, the report card working group and other key stakeholders. The preliminary draft was presented during the 2014 America's Watershed Initiative Summit in Louisville, Kentucky in October 2014. External facilitators organized the meeting as a series of structured interactions designed to solicit constructive feedback about the report card from summit participants. The preliminary results generated many constructive suggestions, which guided a comprehensive revision of report card indicators, data sources, analyses, and presentation. Expert review panels and working groups were formed to consider more than 250 specific suggestions. Some indicators included in the preliminary report card were dropped, new indicators were added, and all of the scores were recalculated. In addition to the goals and basin results, watershed-wide indicators were also included (Table 1, Figure 6). All measurements were standardized to a 0-100 scale to enable aggregation of individual indicator results to the goal score. It is important to note that the scoring scheme is not a reflection of a curve or a lenient grading system; the working group for each goal area and expert advisors determined through data

analysis what data values represented good and bad grades, and those were translated to the final scoring scheme distributed into the 0-100 scale in 20-point increments.

Table 1 Indicators used for the Mississippi River Watershed Report Card¹

Goals	Indicators	Description	Source of Data
 Maintain supply of abundant clean water	Water Treatment Violations	Percent of the population served by community water systems that did not report any violations in 2013.	2013 Government Performance and Results Act of Total Water Systems.
	Water Depletion	Water use compared to the total amount of water naturally available from precipitation and stream flow (minus losses from natural evaporation).	2010 (Water Stress Index) WaSSI model results for HUC8 watersheds
 Provide reliable flood control and risk reduction	Floodplain Population Change	Change in number of people living in areas most at risk for flooding compared to the change in number of people living in a basin.	US Census and FEMA Special Flood Hazard Area
	Levee condition	Status of levees inspected by the U.S. Army Corps of Engineers	US Army Corps of Engineers 2013 National Levee Database
	Building Elevation Requirements	Community adoption of requirements to elevate structures above mapped flood levels.	Association for State Floodplain Managers
 Support local, state and national economies	River-Dependent Employment	Number of people employed in river-dependent sectors in each state in 2013 compared to the national average.	Bureau of Labor Statistics 2013
	GDP by Sector	Gross domestic product (GDP) for river-dependent industries in each state for 2013 compared to the national average.	Bureau of Labor Statistics 2013
	Median income	2013 per capita income by state compared to the national average	Bureau of Economic Analysis 2013
 Support and enhance healthy and productive ecosystems	Living Resources	Condition of aquatic animal communities living in the ecosystem.	US Environmental Protection Agency National Rivers and Streams Assessment 2008-2009.
	Water Quality	Nutrient (nitrogen and phosphorus) levels in rivers and streams in the watershed.	
	Habitat Index	Condition of stream and river habitat in the ecosystem.	
	Wetland Area Change	Percent change in wetland area in each basin.	Multi-Resolution Land Characteristics data
 Provide world-class recreation opportunities	Outdoor Participation	Recent hunting, fishing, and birding activity and national park visitation compared to the 20-year historical range.	US Fish and Wildlife Service survey by US Census Bureau, and National Park Service
	Hunting and Fishing Licenses	Recent sales of licenses, tags, stamps, and permits for hunting and fishing compared to the 10-year historical range.	US Fish and Wildlife Service

 Serve as the nation's most valuable river transportation corridor	Lock delays	Amount of time in 2013 that locks in a basin were unavailable compared to the best performing year between 2000 and 2012.	US Army Corps of Engineers (USACE) 2013
	Infrastructure Condition	Condition of critical infrastructure at locks and dams.	US Army Corps of Engineers 2010
	Infrastructure Maintenance	Adequacy of maintenance funding for navigation infrastructure on a pass/fail basis.	Office of Management and Budget, USACE, Congressional Research Service, and National Research Council
 Maintain a functioning, sustainable Mississippi River watershed	Gulf Dead Zone	Annual maximum extent of the Northern Gulf of Mexico's dead zone compared to the restoration goal set by the Hypoxic Task Force.	Mississippi River/Gulf of Mexico Watershed Nutrient Task Force
	Coastal Wetland Change	Net rate loss of wetland in Coastal Louisiana average over the last 11 years.	US Geological Survey

¹See the Mississippi River Report Card Methods Report (IAN Press, 2015b) for comprehensive discussion

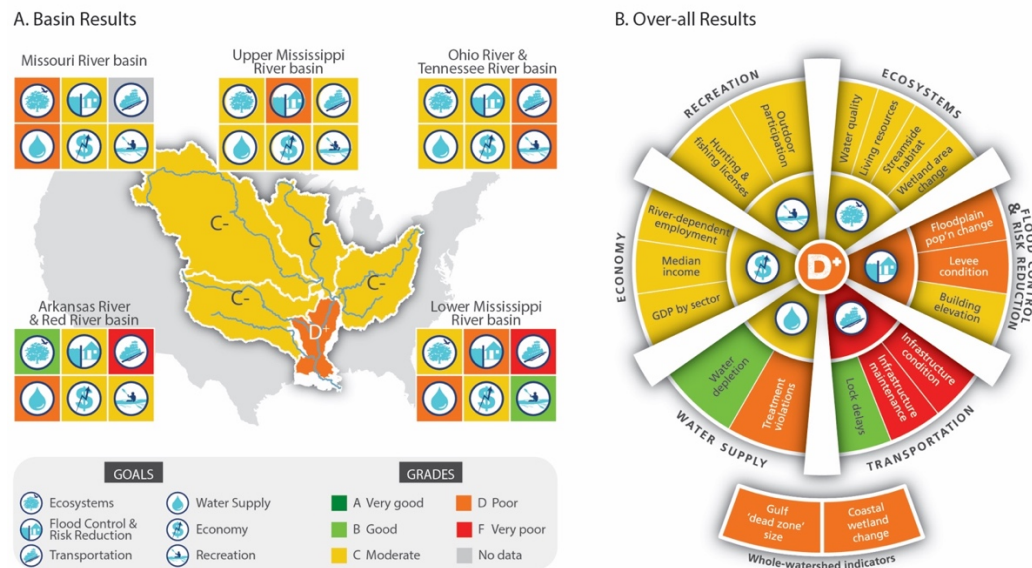


Figure 6. Results of the Report Card for the Mississippi River Watershed. (A) The report card (IAN, 2015a) measured the status and trends of the six goals throughout the 31 state and five major river basin – Upper Mississippi River, Ohio River, Lower Mississippi River, Arkansas & Red Rivers, and Missouri River basins. (B) Results from these five basins were then summarized in an overall watershed score. In addition to the goals and basin results, watershed wide indicators (the size of the Gulf of Mexico hypoxic/dead zone and the rate of coastal wetland loss in Louisiana) were also included. How scores were calculated is documented in a separate Report Card methodology report (IAN, 2015b).

Release of the Final Report card

The final Mississippi River Watershed Report Card (IAN, 2015a) was released on October 14, 2015 in St. Louis, Missouri. About 75 participants from the Americas Watershed Initiative Steering Committee, US Army Corps of Engineers, municipal, state and local governments, and academic and non-governmental organizations involved with the process attended the event. Immediately upon release, the Report Card generated significant media coverage including more than 3000 local, state, and national media placements, nearly 3 million twitter impressions and substantial web visits to the americaswatershed.org and other sites hosting the information. One key to the media success was the effort to recruit AWI Steering Committee member organizations and partners who collaborated in developing the report to post stories and use social media to advance the Report Card messaging. Substantial effort was spent prior to the event to work with and engage the different stakeholders to help leverage media outreach. When the report card was released, many of the stakeholder groups also issued press releases and disseminated information through their own networks. The report card release generated substantial media interest and penetrated different media sectors and markets because of the ownership demonstrated by the diverse stakeholders engaged in the development process. For example, press releases from the National Corn Growers Association, and press interviews with the Ingram Barge Company executives and the Waterways Council, Inc., likely generated interest from agricultural and navigation related news outlets and publications.

The publication of the report card symbolizes the concrete realization of the collective efforts of the various stakeholders that participated in the process. Stakeholders were not only guided by a unified vision for the watershed, but they also actively co-designed the assessment, and co-produced the report card, which created a sense of shared ownership of the project outcome.

Results and impacts of the report card process

The transdisciplinary process of developing of a socio-environmental report card resulted in consensus building and capacity building (Scholz and Steiner 2015). A vision for the Mississippi River watershed, which was shared by participants representing diverse perspectives, was generated. Additionally, the process fostered collaboration and collective action that can lead to more sustainable management of the watershed. This shift to a more integrated approach of natural resource management which places emphasis on the action of whole network of individuals and organizations to bring about change can be referred to as *transformative collective action*. It is characterized by: (i) development of new knowledge that highlights ecosystem interconnectivity; (ii) formation of social networks; (iii) emergence of leaders with synthetic and integrative vision; and (iv) new opportunities that can bring change (Ernstson, 2011).

Creating new knowledge by synthesizing information and identifying gaps

The report card generated awareness of the importance of the watershed and key issues, but also highlighted important knowledge gaps as well as key current and

future challenges in the watershed (IAN, 2015a). Regional results varied across the watershed, but the Mississippi River Watershed earned a D+ overall grade; a poor result (Figure 6). The results revealed several challenges—the Transportation, Flood Control & Risk Reduction, and the watershed-wide indicators for Coastal Wetlands Loss and the Hypoxic “Dead Zone” in the Gulf of Mexico all received D scores. These results highlighted key issues related to the contribution of nutrients that lead to the Gulf of Mexico hypoxic zone, losses of sediment required to maintain coastal wetlands in Louisiana, the gap in maintenance funding for locks and dams, and areas where populations are disproportionately increasing in the flood plain, creating higher risk for flood damages. Participants in the report card process also cited the need for better coordination among regional programs directed at ecosystem restoration and economic development across the watershed.

The results and information gaps highlighted in the report card were important outputs of the process, which created a common understanding of key issues and data needs in the watershed. A detailed discussion of the report card results can be found on the Report Card methodology report (IAN, 2015b). Key knowledge and information gaps were identified in the report card process. These included needs for:

- More spatial, temporal, and methodological consistency in data for water quality, living resource health and diversity, and streamside habitat. Existing data on these factors is either inconsistently analyzed or has poor spatial and temporal resolution.
- Greater spatial resolution of census data related to populations in the flood plains and understanding of flood damage prevented by control structures. Existing

census data are not bounded by floodplain boundaries, and interpolation methods must be used to estimate the fraction of population in census blocks that are within the floodplain.

- Better information related to funding distribution and shortfalls for transportation infrastructure maintenance and repair, and economic impacts of transportation system disruptions. Information on the amount and distribution of funds requested and allocated to infrastructure repair and maintenance is opaque.
- Better information on depletion of groundwater, especially on depletion rates in the Ogallala Aquifer. Water demand shortfalls are made up with groundwater, but little is known about the ability of the aquifer to maintain this shortfall in the long term, especially considering projected precipitation changes.
- Better information linking watershed condition to economic status. Readily available economic data that are not easily disaggregated to generate information relevant to watershed condition.
- More comprehensive information on recreation participation and resulting economic impact. These data are not collected consistently (both spatially and temporally) and can be difficult to access.
- Detailed linkages of regional and coastal nutrient sediment delivery, as well as needs and control options. Nutrient loads to the Gulf of Mexico are too high, creating the hypoxic zone in the northern gulf, and the sediment load is not delivered to wetlands affected by sea level rise and subsidence to reverse the enormous loss of wetland area in coastal Louisiana, especially considering sea level rise projections.

Building social networks and emergence of social leaders

Creating common knowledge in and of itself is not sufficient for successful collective action; generated knowledge must be internalized and shared among community members (Ishihara and Pascual, 2009). The *America's Watershed Initiative's* goal is to build and implement a vision based on collaboration and mutually beneficial outcomes in contrast to single purpose advocacy, while utilizing the strong leadership already present in the Mississippi watershed. Creating shared measures through the report card prompted partner recruitment and network formation to strengthen the collaboration within the watershed. Enhanced relationships among the stakeholder groups generated during the report card development process was instrumental in creating viable pathways for improving integrated management.

The report card process contributed to increases in social capital within the Mississippi River watershed through knowledge exchange and the social learning that was facilitated through the co-creation of the report card and other boundary objects. Social capital is defined as the 'features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit' (Putnam 1995). Features of social capital that can increase through social learning include trust; reciprocity and exchanges; common rules, norms and sanctions; obligations and expectations; values and attitudes; culture, information and knowledge; and connectedness in networks and groups (Pretty and Ward, 2001).

Social learning has the potential to develop new partnerships, strengthen existing collaborations, and even transform adversarial relationships (Schusler et al.,

2003, Stringer et al., 2006), and these effects were seen in the case of the Mississippi River watershed stakeholders. Social and mutual learning were enhanced through the establishment of third places and the co-creation of boundary objects. One of the barriers overcome by the report card process, as reported by workshop participants, was skepticism about the ability of a multisectoral approach that could lead to concrete outcomes, given that some participant organizations and sectors are naturally in dynamic tension with each other. The workshops and report card development process created an atmosphere of trust and shared visioning. Through interactive social and mutual learning, individuals are able to learn about the character of other group members and begin to understand and appreciate the legitimacy of each other's views (Stringer et al., 2006).

Seizing opportunities for collective action

For institutional change through collective action to occur, a network of individuals and organizations are needed to continuously share information, unite their collective effort and sustain the pressure for change (Ernstson, 2011). An example of this was seen in the October 2016 "Raise the Grade" conference in Moline Illinois, which was organized by River Action, Inc as a response to the score given to the Upper Mississippi River Basin in the 2015 Mississippi River Watershed Report Card. The conference brought together over 200 participants from 95 organizations to develop solutions and prioritize specific actions to overcome the many challenges identified in the report card, in which the Upper Mississippi River basin received a C grade. This resulted in an Action Agenda that was released in

December 2016 and presented to the US Congressional Representatives for the States of Illinois and Iowa in January 2017. The Action Agenda identified seven objectives that address ecosystem resilience, nutrient reduction, monitoring and assessment, watershed planning and management, transportation infrastructure, recreation opportunities, and hydropower (IAN 2016). For each objective, specific actions were identified that could be taken to improve conditions in the Upper Mississippi River Watershed.

Aside from developing a coordinated and shared action agenda to “Raise the Grade” for the Mississippi Watershed, one of the goals is to achieve collective impact through strategic investments, leveraging the efforts by the different stakeholder groups to improve decision-making in the watershed. Collective impact refers to collaborative projects that addresses complex and intransigent problems through collective vigilance, learning, and action (Kania and Kramer, 2013). This process, which is initiated by the development of the Mississippi River Watershed Report Card, requires multiple stakeholders to change their behavior and pursue a shared goal, rather than pursuing the singular objectives represented by their professional perspectives and single-issue advocacy.

The Report card has been the focus point for many significant presentations about challenges and opportunities in the Mississippi River watershed. Presentations focused not only on the report card process and grades but most importantly on the opportunities to collaborate to “Raise the Grade” for the Mississippi River watershed. Specifically, different groups want to know how their goals fit with the other sectors in the environment and how the whole system work. Businesses, organizations and

agencies involved in developing the report card continue to work together to seek specific actions to improve the watershed and support efforts to improve the outcomes in the transportation, ecosystem, recreation goals in the report card. The report card had also been used to support watershed-scale decision making in meetings and presentations to the Mississippi River Commission, USACE, Mississippi River Congressional Caucus, NOAA and many other public and private stakeholders.

Conclusion and recommendations

The Mississippi River Watershed Report Card represents a significant milestone in the ability to integrate information and perspectives from multiple sectors toward holistic assessment for multiple objectives, in one of the largest and most important river systems in the world. The project leveraged principles of transdisciplinarity by engaging diverse participants in a co-design and co-production process from the outset of the project, through the creation of boundary objects. Boundary spanning organizations facilitated the process using principles of knowledge exchange and integration and social and mutual learning to improve understanding among participants with diverse perspectives and opinions. The report card process created an atmosphere of trust by utilizing ‘third places’ that fostered new collaborations and partnerships and potential for collective action and collective impact.

The development of the Mississippi River Watershed Report Card satisfied the five pre-conditions for collective impact (Kania and Kramer, 2011). The

collective impact model requires a shared vision for change that is developed through an inclusive process involving all stakeholders, a common system of measures to assess progress toward achieving goals, mutually reinforcing activities, continuous and open communication, and backbone support. The workshops, the newsletters, the report card as the ultimate product, and efforts to raise the grade provided rallying points for working together, creating a common vision, common measurements for progress, a common language, and a new level of trust among the participants. AWI and UMCES-IAN served as backbone support by coordinating and facilitating the process. To make Collective Impact work, however, it is important to establish a long term regional “home” for the report card that can continuously and consistently function as a backbone organization and provide six essential functions: guide overall strategic direction, facilitate dialogue between partners, manage data collection and analysis, handle communications, coordinate community outreach, and mobilize funding (Hanleybrown et al., 2012). AWI is taking on this role, as it is currently leading the effort to update the report card, with the expected release in 2020.

Additionally, the report card results highlighted key issues that are important to sustainable management of the watershed and identified important information gaps and data needs. Data quality, consistency, and availability are major issues in such a large regional assessment. Assumptions about data utility were challenged and required flexibility and revision of assessment methods to account for best available and surrogate data. Data useful for supporting holistic decision-making over the entire watershed and across multiple sectors are simply not adequate in some cases. The report card was specifically created at the scale of the Mississippi River watershed

and the five major basins within it, but most citizens experience conditions at the scale of small streams and watersheds, and state, local and county administrative boundaries. Thus, improving the resolution of report card results could allow for more locally generated data to be used increasing its relevance. Data at this scale were not used in this first report card largely because it was not consistent across basins. There is also a need to explore the intricate linkages between report card goal areas and between indicators within goal areas. Exploring these linkages will improve understanding of actions that could improve the status of multiple goals.

It is also important to create a pathway to better leverage the report card process to generate collaborative action and collective impact to improve holistic management. An important next step is to increase our understanding of the social networks within the Mississippi River watershed and use this understanding of social dynamics to influence management and identify local leaders. It is important to actively maintain and seek out diversity in knowledge and viewpoints, especially in natural resource management where development of alternative options is crucial (Prell et al., 2010). However, selecting stakeholders from different organizations, categories or sectors might not be enough. Rather, it is the existing social network or the structure of social ties between individual stakeholders that potentially plays a bigger role (Prell et al., 2010). There is a need to evaluate regional participant networks and identify potential collaborations that can be leveraged to create collective action and identify potential collaborative opportunities.

The process of creating the first-ever report card for the Mississippi River Watershed built a foundation for collective action by creating a shared understanding

of, and vision for, the Mississippi River watershed. The process reinforced the importance of stakeholder engagement at all stages and the utility of high-quality data and effective communication for decision-makers. It also provided access to information at various levels of detail for different user needs, and creates credibility through transparency of data, methods, and results. The multi-stakeholder driven process created the opportunity for engagement of multiple users, managers, and researchers throughout the 5 basins on prioritizing issues using third places and co-creating boundary objects. This allowed for high level visioning across disciplines and interests, which supports the idea of transdisciplinary activity to implement solutions. This process of developing a report card through transdisciplinary collaboration can be used in any system and can provide the foundation for collaborative solutions by creating a holistic assessment that incorporates multiple perspectives from multi-sectoral actors.

Chapter 3: Using socio-environmental report cards to enhance adaptive governance

Abstract

Report cards are emerging tools for science communication that are being used to bring together diverse stakeholders to create a shared vision, assess present conditions, and develop adaptive management plans for their respective ecosystem. In the Chesapeake Bay watershed, several bay-wide and tributary report cards have been developed by different organizations since the early 2000s. In particular, the Chesapeake Bay Report Card by the University of Maryland Center for Environmental Science, the first scientifically rigorous broad assessment of the Bay and its major tributaries, was first published in 2007. Its publication through the years has inspired citizen scientist groups to create local report cards and catalyzed a myriad of positive actions from federal and state agencies and advocacy groups. However, its role in engaging a diverse group of stakeholders (including watermen, farmers, community groups and public and private companies, and the general public) within the Chesapeake Bay and its overall societal impact has not been evaluated. I reviewed publicly available documentation and resources to analyze the history and evolution of report cards in the Chesapeake Bay. Then, using an ethnographic approach through content analysis of key informant interviews, I identified how Chesapeake Bay stakeholders perceived the management impacts, benefits, and limitations of report cards. I also explored the possible role of report cards in the Chesapeake Bay watershed as boundary objects that are able to enhance adaptive

governance by facilitating continual learning and cross-scale exchange of information between different organizations and stakeholders.

Introduction

Managing complex environmental problems requires flexibility and capacity for change in the planning and implementation process (Sharma-Wallace et al., 2018). Adaptive governance has been the proposed solution that accounts for the social context and condition for the adaptive management of ecosystems (Chaffin et al., 2014; Schultz et al., 2015; Folke et al., 2005). Adaptive governance is characterized by collaboration, coordination, social capital, community empowerment, capacity development, linking knowledge and decision-making, leadership, and governance opportunities (Sharma-Wallace et al., 2018). Generation of new knowledge through social learning and collaboration and the diffusion of knowledge and best practices across boundaries is of crucial importance in achieving collective action (Bodin 2017). Boundary objects are often the product of such engagement and collaboration allowing for different groups to share meaning and incorporate individual perspectives while still maintaining an identity that is recognized by all (Star and Griesemer, 2016; Fox, 2011; Jahn et al., 2012; Roux et al., 2017). Boundary objects are often transportable representations that can bridge social worlds and facilitate communication, especially when they are perceived to be credible, salient, and legitimate (White et al., 2010). In the Great Barrier Reef, Australia, for example, the co-production of a boundary object, the “Reef Water Quality” report, facilitated

adaptive governance by allowing for cross-scale sharing of knowledge leading to informed decision making (Schultz et al., 2015).

Report cards are similar boundary objects that can serve as a platform for transdisciplinary collaboration and a catalyst for collective action. In the Chesapeake Bay watershed, several bay-wide and tributary report cards have been developed by different organizations since the early 2000s. In particular, the Chesapeake Bay Report Card by the University of Maryland Center for Environmental Science (Figure 1), the first scientifically rigorous broad assessment of the Bay and its major tributaries, was first published in 2007. Its publication through the years has inspired citizen scientist groups to create local report cards and catalyzed a myriad of positive actions from federal and state agencies and advocacy groups. However, its role in Chesapeake Bay governance and its overall societal impact has not been systematically evaluated.

The Chesapeake Bay is managed through the Chesapeake Bay Program partnership, an intergovernmental coalition representing the signatories of the Chesapeake Bay Watershed Agreement (the State of Maryland, Commonwealth of Virginia, District of Columbia, State of Delaware, Commonwealth of Pennsylvania, State of West Virginia, State of New York, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency representing the federal government) as well as the various stakeholders (local governments, businesses, watershed organizations, and other non-governmental organizations) who participate in the different levels of the organization and the development and implementation of management strategies

(CBP, online). The Chesapeake Bay Program uses “an adaptive management approach to respond to changing conditions and better information, the structure and governance of the program will change and evolve over time to better plan, align and assess partner activities and resources to meet Chesapeake Bay Program goals” (CBP, 2019).

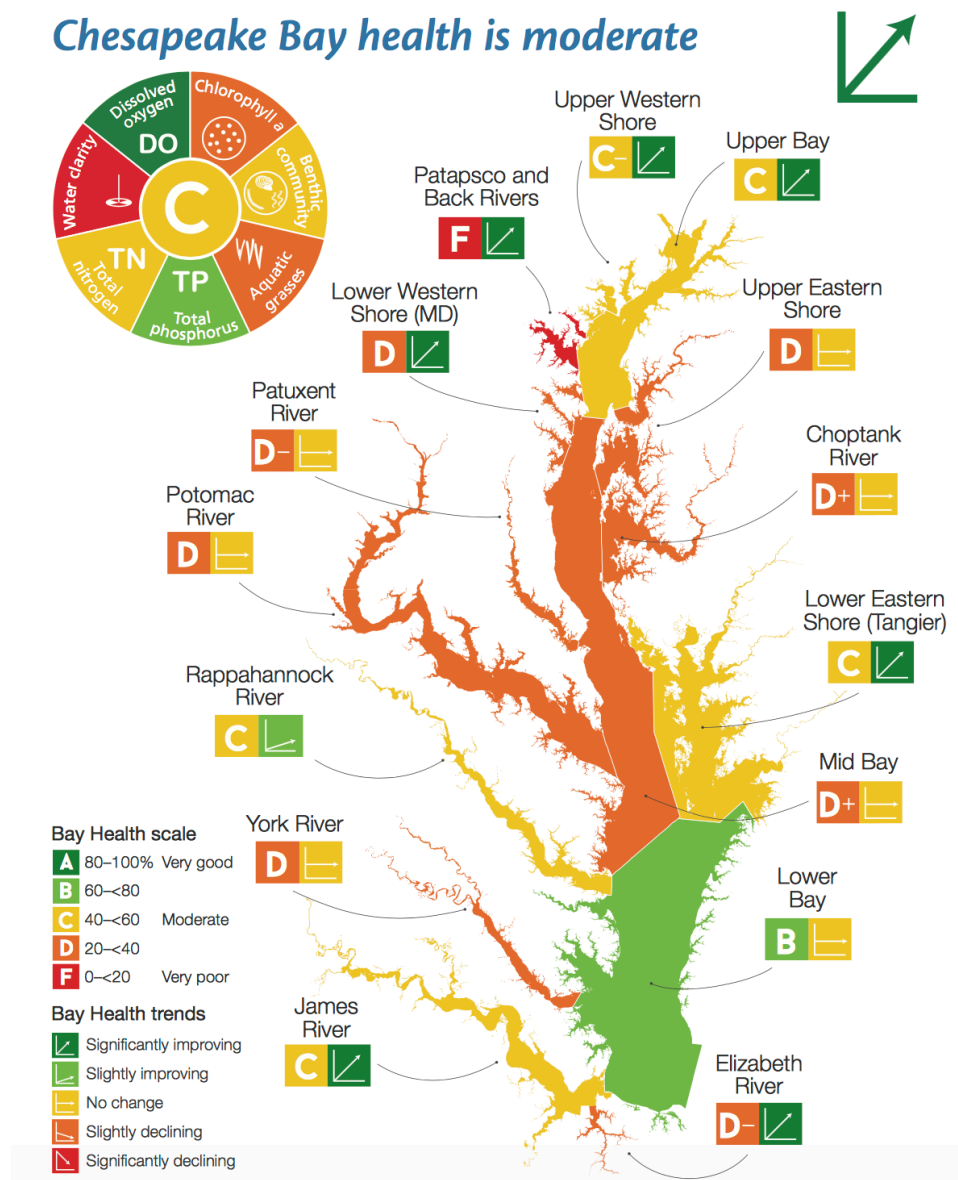


Figure 1. The 2018 Chesapeake Bay report card.

As noted by Boesch (2001), while the CBP is viewed as an example of adaptive management, there are shortcomings in assessing progress leading to less responsiveness in adaptation due to the weak connection between the programs within the CBP. Strengthening the interlinkages among the three Chesapeake Bay Program backbone - monitoring, modeling, and management, is very important to be more adaptive. There is also a need to develop adaptive capacity at the institutional and community level and maintain open communication among the different agencies, management, scientists, policymakers, and stakeholders

In this chapter, I discuss the evolution of report cards in the Chesapeake Bay, with a particular focus on the Chesapeake Bay report card developed by the University of Maryland Center for Environmental Science. I also explore the possible role of report cards in the Chesapeake Bay watershed as boundary objects that can enhance adaptive governance by facilitating continual learning and cross-scale exchange of information between different organizations and stakeholders. The UMCES report card has been annually produced since 2007 using indicators of water quality and biodiversity collated from the Chesapeake Bay Program and its network of data providers.

The need for report cards in the Chesapeake Bay

The Chesapeake Bay is the largest estuary in the United States, defined by a wide range of ecological and physical features. It supports a diverse and dynamic ecosystem that displays not only remarkable evolutionary traits but also a reflection

of human history. The Chesapeake Bay and its watershed, once populated with submersed aquatic vegetation (SAV) and covered with the forested landscape, has changed with increasing human population and changing needs (Brush, 2008). Increased nutrient inputs and sedimentation led to eutrophication, hypoxia, loss of SAVs, and a shift from a benthic to a planktonic population (Kemp et al., 2005). Attempts to reverse eutrophication and anoxia centered on reducing nutrient loading. Studies have correlated recent reduction efforts to decreasing hypoxia and increasing SAVs in some areas (Orth et al., 2010; Murphy et al., 2011; Lefcheck et al., 2018). However, due to the complicated nature of the Bay, both rapid and slow recovery of functions has been observed (Kemp et al., 2005).

Modern estuarine science had its origins in the Chesapeake Bay. Still, it was only in 1972, after the devastating effects of Tropical Storm Agnes, that the degrading conditions of the Bay were recognized. From a primary model system for estuarine research, studies on the Bay shifted to eutrophication processes (1970-1983), modeling and monitoring (1983-2003), to restoration and accountability (2003-present). Chesapeake Bay management has been conducted independently by the adjacent states for over one hundred years. In 1983, an extensive water quality monitoring and modeling program were coordinated by the federal government through the Chesapeake Bay Program. Various other governmental and non-governmental organizations have been created to focus on management, advocacy, and education, such as the Chesapeake Bay Commission, Chesapeake Bay Foundation, Chesapeake Bay Trust, and the Alliance for the Chesapeake Bay.

The intensive management of the Bay started the accountability phase, and with it, a greater need to report the status of the Bay to a broader audience. A free monthly newspaper called the Bay Journal is available, and the Chesapeake Bay Program also publishes its annual report called the Bay Barometer. In addition, the Chesapeake Bay Foundation, the largest regional non-governmental organization, produces a State of the Bay report that started in 1998, using numerical ranking as percent, with conditions from early 1600 as recounted by European explorer John Smith as the benchmark. The Chesapeake Bay Foundation (CBF) goal is to achieve a "Saved" Bay by 2050, rated as 70% on the State of the Bay index. According to CBF, a saved Bay is "resilient enough to withstand the storms of nature and humankind, and it is rich enough to nurture diverse cultures and contribute abundantly to our economy (CBF, online)."

In 2003, a newspaper account in the Washington Post stated that pollution progress in the Chesapeake Bay is overstated, which prompted Congress to call for a review of this oversight. The Government Accountability Office undertook an intense study. It concluded that improved strategies are needed to guide restoration efforts better and that the Bay program should revise its reporting approach to prove its effectiveness. Hence, the University of Maryland Center for Environmental Science proposed to develop a Chesapeake Bay report card that is spatially explicit and with data and results that are robust, defensible, and responsive.

Development of the UMCES Chesapeake Bay Report Card.

The development of the UMCES report card started in 2005, and the process is still continually evolving (Figure 2). UMCES initially created a partnership with NOAA Chesapeake Bay office - EcoCheck, and built a framework for a new report card involving the major resource managers in the Bay. They turned to the Chesapeake Bay Program for possible indicators to use. The Bay Program at that time had 101 indicators that were collected without any hierarchy of importance. Ultimately, they focused on Bay Health and divided it up into water quality, habitat, and living resource indicators. After a thorough selection process, three water quality indicators (chlorophyll, dissolved oxygen water clarity) and three biotic indicators (aquatic grasses, benthic biotic index, phytoplankton) were selected. The water quality index and the biotic index were then combined to an overall index.



Figure 2. Evolution of the University of Maryland Center for Environmental Science Chesapeake Bay Report Card

The first UMCES report card was developed in 2006, but the launch was delayed for another year because there was not enough buy-in from the Chesapeake Bay Program and scientists and managers around the Bay. In that year that followed,

UMCES tested the sensitivity of their methodology using high and low flow years (Williams et al., 2010). They calculated scores from previous years to show that it is responsive and explained their methods and results in different workgroup meetings and subcommittees in the Chesapeake Bay.

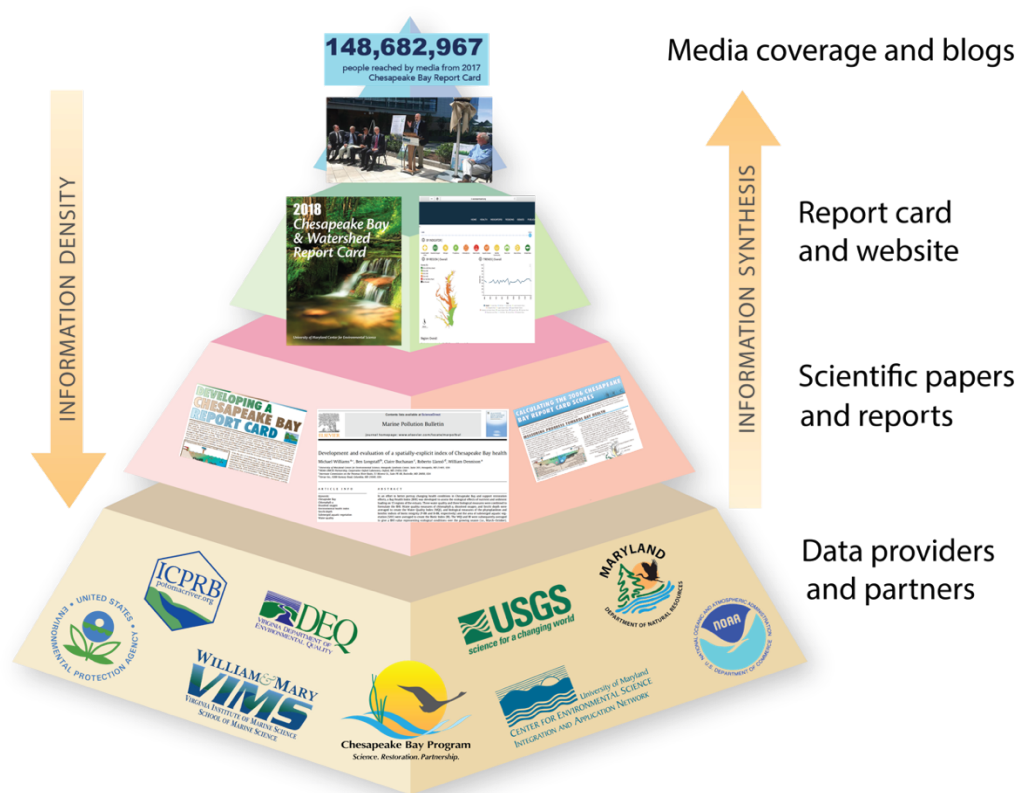


Figure 3. The Chesapeake Bay report card synthesized information and allowed for linking knowledge and decision making. The Chesapeake Bay report card is the first scientifically rigorous broad assessment of the Bay and its major tributaries that is being used to communicate the condition of the Bay to a diverse audience. The data is from the Chesapeake Bay program and its network of data providers. Scientific experts have also reviewed the process.

In 2007, the Chesapeake Bay program was still not on-board, so UMCES decided to release the report card, calling it the UMCES Chesapeake Bay Report

Card. The initial report card release gained local media attention, and this broad media coverage was helpful because it focused on what needed to be done. There were in-depth follow-up media, many requests from educators from universities and even high schools. One of the essential things that differentiated the UMCES report card was that it ranked the health of the tributaries, which promoted peer pressure. There were also two surprising primary results from the report card. One is the best water quality, or the health of the bay was not the lower Bay, near the mouth, as was expected but, in fact, in the Upper Bay. Secondly, the report card showed that degradation was not only occurring near the big cities, like Washington D.C. and Baltimore on the western shore, but also on the eastern shore - the less densely populated, mostly rural and agricultural areas, also had terrible scores. It was a wakeup call to the Eastern Shore communities that mainly were agriculture; although it was not densely populated, there were millions of chickens. Chicken manure, combined with fertilizer from the crops to feed the chickens, contributed significantly to the amount of nutrients in the Eastern Shore tributaries.

Methods

A review of publicly available documents and resources such as report cards, peer-reviewed publications, white papers, and other technical documents, reports, web resources, videos, lectures, and news articles related to report cards and other assessments of the Chesapeake Bay and its tributaries were conducted to analyze the history and evolution, and the benefits and limitations of report cards in the region. Interviews were conducted to determine stakeholder's perception of the benefits and

limitations of report cards in the Chesapeake Bay region. The methodology is described in detail in the next chapter.

Results and discussion

Impacts of the Chesapeake Bay report card

Adaptive Management

In 2007, the new governor of Maryland, Governor Martin O'Malley, implemented StateStat, a performance measurement and management tool that used data analysis to identify areas of concern and support improvement strategies. When he saw the UMCES report card, he decided to create BayStat that focused on nutrient reductions in the Chesapeake Bay. He used the report card to track the health of the bay and used the results to prioritize management actions to help improve it (O'Malley and Goldsmith, 2019). Governor O'Malley also wasn't satisfied with the indicators, stating that he didn't manage water clarity or dissolved oxygen but did manage nitrogen and phosphorus. UMCES then went from six to seven indicators, dropping phytoplankton because the CBP curtailed the phytoplankton monitoring program, but adding nitrogen and phosphorus. Chesapeake Bay fisheries indicators were also added, which included blue crabs, bay anchovies, and striped bass. Governor O'Malley held monthly BayStat meetings to establish accountability and drove actions towards reducing the flow of pollutants into the tributaries of the Bay (O'Malley and Goldsmith, 2019). Science, through UMCES, was represented in these BayStat meetings.

One shortcoming of the initial report card framework was the lack of information on whether Bay health was improving or declining. Hence, starting in the 2012 report card, trends in Bay health were determined by analyzing data from the Chesapeake Bay Program for the whole Bay and each reporting region from 1986–2012. Overall, Bay health showed no specific trajectory, but some of the reporting regions did. Four out of the fifteen regions had significantly improving trends - the Upper Western Shore, Upper Bay, James River, and Elizabeth River. The Mid Bay region was the only one that showed a significantly decreasing trend. This emergent property that became evident from the trend analyses of the report card scores is hypothesized to be due to positive and negative feedback. In some areas where nutrient reductions due to sewage upgrades resulted in the resurgence of aquatic grasses, there is positive feedback. The aquatic grasses slow down water motion, allowing for sediments to deposit and improve water clarity; at the same time, the nutrients are absorbed by the aquatic grasses and their epiphytes. Negative feedback, in contrast, occurred when the bottom water oxygen dropped to zero or near zero, allowing the sediments to be completely anoxic. Instead of being captured either chemically or biologically at the surface, nutrients remain in the water column fueling algal growth and oxygen consumption, resulting in a negative feedback loop.

Another critical issue that the UMCES report card tackled was climate change. From 2013-2015, analysis on Chesapeake Bay's climate change resilience was conducted using coastal wetlands, aquatic grasses, fisheries, pathogens in shellfish beds, and swimming beach closures as indicators. Results suggest that with current sea level rise rates of 4 mm/year, the majority of the regions in the

Chesapeake Bay have moderate to very good coastal wetlands resiliency scores. However, under future sea-level rise rates of 6+ mm/year, coastal wetlands will be less resilient. While climate change resiliency in numerous small-scale habitats (e.g., segments of tributaries) was projected, it was not observed at the scale of the whole Chesapeake Bay.

In 2018, the Chesapeake Bay report card for 2017 showed improving trends for the whole watershed. This finding was important because it was the first time that the overall Bay has shown a statistically significant improving trajectory. These trajectories can be viewed as an indication of progress and that the investments on Bay restoration are working. Another major story that was highlighted in the report card was the resurgence of aquatic grasses that have been shown to be directly related to the reduction of nutrient discharge in the Chesapeake Bay (Lefcheck, 2018). Media placement and reach calculated by a public relations group (GreenSmith PR) immediately after the release of the report card were as follows: online reach - 67,885,855; radio reach - 1,304,000; print reach - 641,233 and TV - 105,818 (GreenSmith, 2018). The estimated total number of people reached through the media in 2018 was at least 148.7 M (IAN Press 2018).

UMCES has an on-going project with the National Fish and Wildlife Foundation (NFWF) to expand the Chesapeake Bay report card to include social and economic indicators across the entire watershed (2018-2021). The goal is to make the report card more inclusive by expanding the regional scale and indicator scope. New indicators will be added to correspond to the goals and outcome of the 2014

Chesapeake Bay Watershed Agreement, which includes goals for watershed health, fisheries, stewardship, and other socioeconomic issues.

The Bay Barometer, on the other hand, aids in the CBP's adaptive management strategy. The Bay Barometer and Chesapeake Progress report on indicators that support the CBP's adaptive management-based decision-making process (CBP, online). It also provides transparency, better coordination of actions, and timely access to data and information (Islam and Jorgensen, 2018), which are important for adaptive management (Boesch 2006).

Public Participation and engagement

One of the strengths of the UMCES report card is it is simple, visually appealing, and easily understandable format making it a useful science communication tool. Over the years, the report card has evolved to improve its utility and engagement (Fig 4). For instance, photo contests for the report card cover were held to increase interest since 2011. A section on recommendations for how stakeholders can help in improving the Bay was also added. Aside from the traditional print and broadcast media, social media platforms were also used in disseminating the results of the report card. A dedicated website was created (<https://ecoreportcard.org/report-cards/chesapeake-bay/>) that people can access if they want more information on all the indicators, the different regions, and other information such as scoring methodologies and results (Fig 5).

The annual report card release events have generated significant media attention over the years. To significantly broaden the reach of the report card,

UMCES enlisted GreenSmith Public Affairs, a public relations and business development firm based in the Washington, DC area, to get the information out directly to the media. For the 2016 event, wherein the grade for the Chesapeake Bay in 2015, at 53% (C), was one of its highest grades received, it was estimated that the total audience reach was at least 124.65 million people across the world in 2016 (GreenSmith, 2016). Also, video materials and storyboards were prepared in advance to help in structuring and emphasizing the report card message.



Figure 4. UMCES has been producing the report card annually since 2007

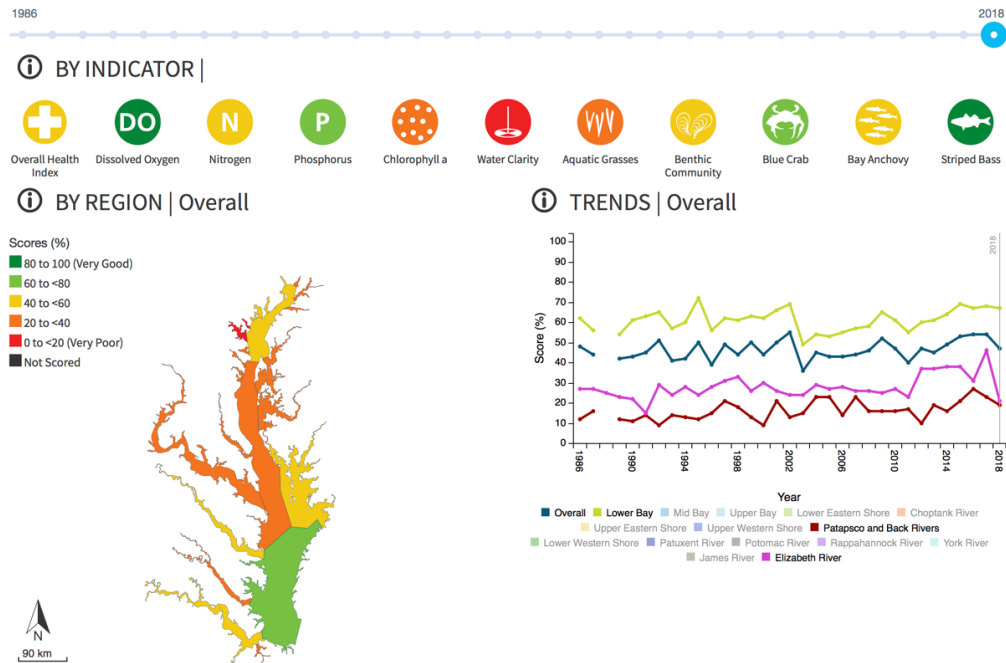


Figure 5. Chesapeake Bay report card reports on trajectories, as seen in this screenshot of the Chesapeake Bay report card website.

Coordination and Community Empowerment

UMCES also led The Mid-Atlantic Tributary Assessment Coalition (MTAC), a “group of watershed organizations interested in advancing the use of environmental data from local organizations and citizen scientists for use in report cards and assessments.” At least eight local watershed organizations were part of this coalition and had planned to produce some version of a report card by 2010. These groups have found that report cards are essential outreach tools for generating community interest and increasing citizen understanding of ecosystem health, water quality, and watershed issues. The MTAC coalition established methods and a set of core indicators that all mid-Atlantic tributary groups will monitor, creating a common framework for obtaining and analyzing data for ecosystem health assessments (Wicks

et al., 2011, 2013) . In 2018, there were 12 tributary report cards published in the Chesapeake Bay watershed (Figure 6), inspiring place attachment, and local ownership.

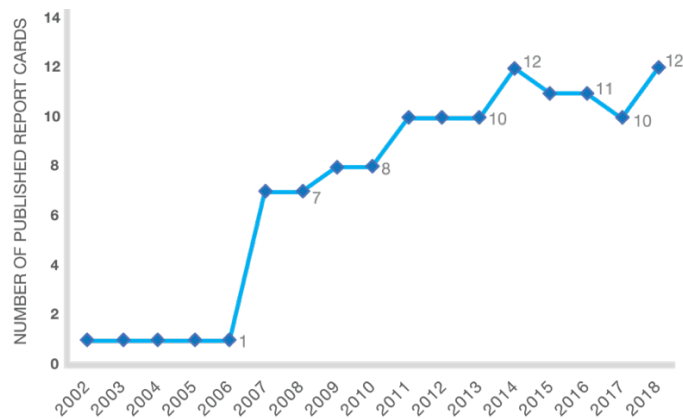
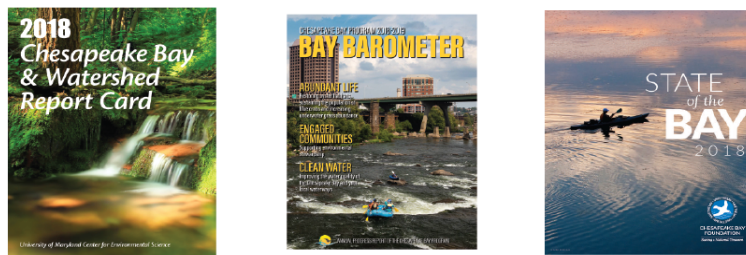


Figure 6. Expansion of the use of tributary report cards in the Chesapeake Bay

The report cards in the Bay are popular tools used by NGOs, community groups, and riverkeepers. Several interview participants from such organizations highly valued the report cards' role in engaging their volunteers and coordinating actions of their members. For instance, the Chesapeake Bay Foundation uses the State of the Bay to engage their members and in fundraising. Report card release events are seen as opportunities for community members to come together and discuss the current status of their tributary and how they can help to improve it. Report cards were used to provide useful and timely information on environmental issues to local decision-makers and highlight actions that residents can take to become involved in the improvement and protection of their communities.

A. Bay-wide report cards



B. Regional report cards

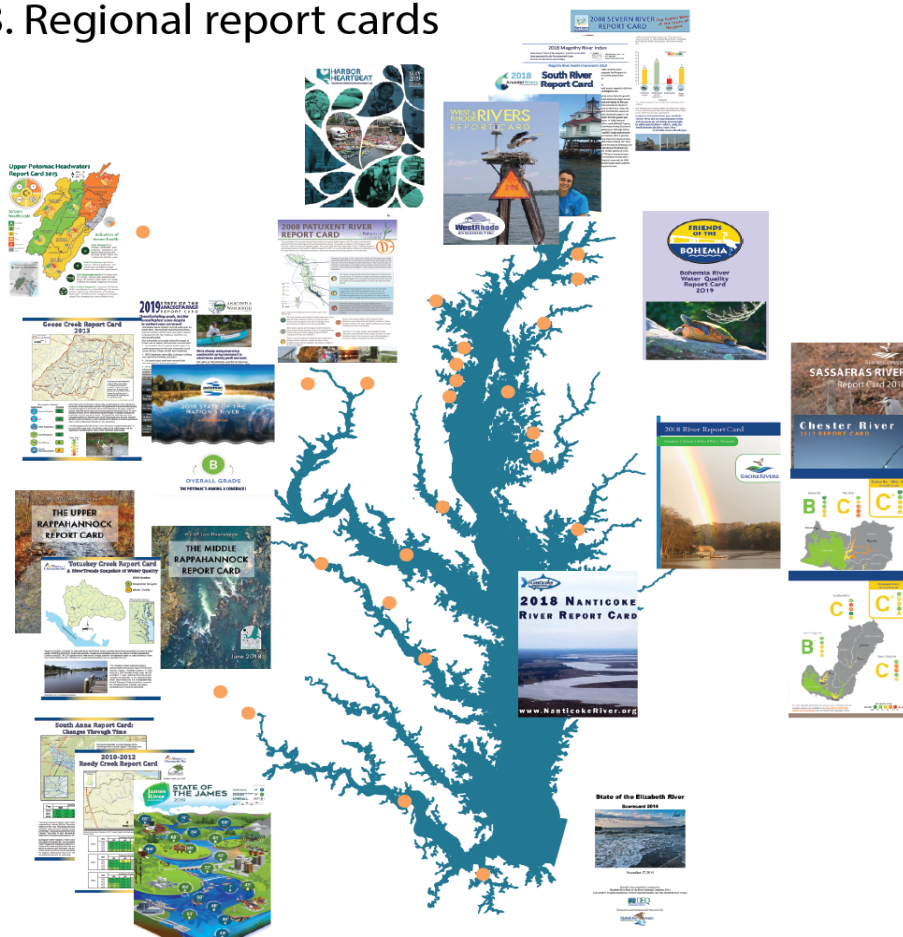
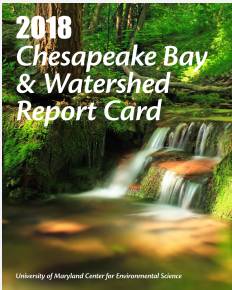


Figure 7. Distribution of tributary report cards published between 2002 to 2019 in the Chesapeake Bay watershed.

Report cards in the Chesapeake Bay watershed and their perceived impacts

For an adaptive governance approach to be successful, effective communication and continuous learning are needed (Folke et al., 2005; Boesch 2019). Modeling and monitoring are a big part of the program, and both make use of highly integrated data of various scales (spatial and temporal), ecosystems (species interactions and controls), and media (atmospheric, terrestrial, freshwater, and estuarine) (Boesch and Goldman, 2009). Maintaining these intersectoral connections are essential for Chesapeake Bay management and governance. There is a disconnect between taking action and seeing results; thus, here is a need to ensure that tangible benefits can be communicated among different stakeholders. Report cards are a popular tool that is being used in the Chesapeake watershed. The Chesapeake Bay Trust (CBT) has funded over 50 projects related to report cards from 2008-2019 (CBT, personal communications). Currently, several report cards are published for the Chesapeake Bay (Figure 7). Table 1 compares these different report cards.

Table 1. Comparison of Report cards in the Chesapeake Bay Watershed

	DESCRIPTION	ASSESSMENT METHOD	PRIMARY AUDIENCE
UMCES CHESAPEAKE BAY REPORT CARD 	Scientifically rigorous annual assessment with 15 reporting regions. Seven indicators are integrated into a Bay Health Index: Dissolved oxygen, total nitrogen, total phosphorus, chlorophyll-a, water clarity, aquatic grasses, and benthic community. In addition, three fisheries indicators, the abundances of blue crabs, bay anchovies, and striped bass, are rolled up into a fisheries index. Water	Data are expressed on a 100-point scale relative to agreed thresholds for the desired state. Back-calculating Bay Health Index scores to the beginning of standardized Bay-wide monitoring allows for trend analysis to accompany annual condition assessment. Methods and data are provided on an annually updated website (www.ecoreportcard.org). Data collection, analysis, and processing lead to this report card being released in the	Political leadership in the Bay community and an increasingly national audience reached through traditional and social media.

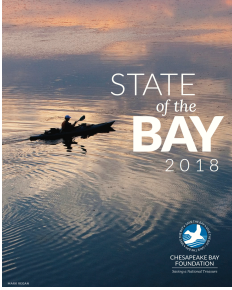
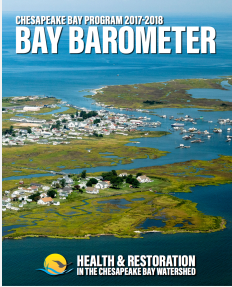
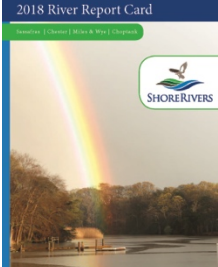
	quality data collected on monthly monitoring cruises, with annual surveys of aquatic grasses and benthic communities.	spring of the subsequent year of reporting.	
CBF STATE OF THE BAY 	Annual assessment of the Bay as a whole, measured against the pre-European settlement conditions. Thirteen indicators grouped into three categories are assessed: pollution (nitrogen, phosphorus, water clarity, toxics), habitat (forested buffers, wetlands, underwater grasses, resource lands), and fisheries (rockfish, blue crabs, oysters, shad).	Data are expressed on a 100-point scale, with 100 representing historical conditions, and 70 is the goal for a restored Bay. Data gleaned from preliminary reports and in-the-field observations, with the State of the Bay release shortly following the year of reporting. The State of the Bay represents an early indication of results before the more rigorous assessment by the Chesapeake Bay report card that comes later in the year. The State of the Bay reflects on the various initiatives to improve the Bay.	Chesapeake Bay Foundation membership, with extensive public dissemination.
CBP BAY BAROMETER 	Annual assessment of the Bay as a whole, evaluated against the goals established in the 2014 Chesapeake Bay Watershed Agreement. Indicators include both condition assessments as well as restoration progress.	The annual Bay Barometer report is not comprehensive, with data and methods available on www.ChesapeakeProgress.com website. Clean water is assessed as water quality (watershed implementation plans, water quality standards attainment), toxic contaminants (toxic contaminant research, toxic contaminant policy, and prevention) and healthy watersheds. Conserved lands are measured as land conservation. Engaged communities measured as public access (site development), environmental literacy (literacy planning, students, and sustainable schools) and stewardship (citizen stewardship, diversity, local leadership). The Bay Barometer is released in the spring of the year following reporting.	Resource managers and decision-makers in the Bay restoration community.
REGIONAL REPORT CARDS 	Annual assessments of Chesapeake Bay regions and tributaries, using a wide diversity of indicators.	Citizen scientists collect most of the data, often coordinated by riverkeepers and waterkeepers. The release dates of regional report cards vary and can occur throughout the entire year, often coordinated with local events. Data protocols and reporting standardization occurred through the Mid-Atlantic Tributary Coalition, and currently, the Chesapeake Monitoring a cooperative provides training and methodologies.	Members of the regional NGOs, but local elected officials also targeted.

Table 2. Report Cards in the Chesapeake Bay Watershed

	YEARS ACTIVE	NUMBER PUBLISHED	ORGANIZATION	INDICATORS REPORTED IN THE MOST RECENT VERSION
BAY-WIDE				
CHESAPEAKE BAY REPORT CARD	2007 - present	13	University of Maryland Center for Environmental Science	Bay Health, Fisheries, Watershed Health
STATE OF THE BAY REPORT	1998 - present	15	Chesapeake Bay Foundation	Pollution, Habitat, Fisheries
BAY BAROMETER	2009 - present	10	Chesapeake Bay Program (before 2009, the annual report was " State of the Chesapeake Bay")	Abundant life, Clean Water, Conserved Lands, Engaged Communities, Climate Change
SUB-REGIONS				
POTOMAC	2007 - present	10	Potomac Conservancy	Pollution (N, P, Sediment, Bacteria), Fish (American Shad, Striped Bass, White Perch, Smallmouth Bass, Blue and Flathead Catfish, Northern Snakehead), Habitat, Land, People
PATUXENT	2007 - 2008	2	Patuxent Riverkeeper	Ecological
JAMES	2007 - present	6	James River Association	Fish and Wildlife, Habitat, Pollution Reductions, Protection and restoration actions
CHOPTANK/EASTERN BAY/MILES AND WYE	2010 - present	8	Choptank Riverkeeper and Miles-Wye Riverkeeper	Water Quality (DO, TN, TP, Chl, Clarity)
ELIZABETH	2014	1	Virginia Department of Environmental Quality and The Elizabeth River Project	River Health (includes contaminants, bacteria)
PATAPSCO	2014 - present	4	Waterfront Partnership of Baltimore	Fecal Bacteria, Sewer Repairs, Pollution Tracking, Litter and Debris, Restoration Projects, Ecosystem Health, Volunteers
MIDDLE RAPPAHANNOCK	2018 - present	1	Friends of the Rappahannock	Human Health, Land Use, Stream Ecology, Community Engagement
TRIBUTARIES				
MAGOTHY (RIVER INDEX)	2002 - present	16	Magothy River Association	River Health, Bacterial Water Quality
SOUTH RIVER	2007 - present	12	Arundel Rivers Federation	Water Quality (DO, Bacteria)
CHESTER	2007 - present	12	Chester RiverKeeper	Water Quality (DO, TN, TP, Chl, Clarity)

NANTICOKE	2007 - present	12	Nanticoke Watershed Alliance	Water Quality (DO, Conductivity, TN, TP, Chl a, Clarity)
SEVERN	2008	1	Severn Riverkeeper	Water Quality (DO, SAV, Clarity), Fisheries
SASSAFRAS	2009 - present	9	Sassafras Riverkeeper	Water Quality (DO, TN, TP, Chl, Clarity)
WEST AND RHODE	2009 - present	10	Arundel Rivers Federation	Water Quality and Bacteria
TOTUSKEY CREEK	2011 - 2013	2	Alliance for the Chesapeake Bay/ RiverTrends	DO, Water Clarity
ANACOSTIA	2012 - present	6	Anacostia Watershed Society	Water Quality, Remediation
REEDY CREEK	2012	1	Alliance for the Chesapeake Bay and Reedy Creek Coalition	Ecological Health and Human Health (Bacteria, how safe for swimming)
HAZEL RUN	2012	1	Alliance for the Chesapeake Bay and Friends of the Rappahannock	Ecological Health and Human Health (Bacteria, how safe for swimming)
SOUTH ANA	2013	1	Alliance for the Chesapeake Bay and South Anna Monitoring Project	Ecological Health and Human Health (Bacteria, how safe for swimming)
GOOSE CREEK	2014	1	Alliance for the Chesapeake Bay and Goose Creek Association	Ecological Health (water quality is from 2013 monitoring, IBI 2000-2010)
UPPER POTOMAC	2015	1	UMCES - MEES Class	Stream Health (TP, TN, TSS, IBI)
BOHEMIA	2015 - present	4	Friends of the Bohemia	Water Quality

Table 3 lists the perceived benefits of report cards in the Chesapeake Bay.

Report cards served as boundary objects for continuous learning that are easy to comprehend. A common perception is that the concept of grading is universal. However, several interview participants raised the idea of the appropriateness of giving letter grades when even schools are re-thinking its use. The report cards in the Bay also show how local tributary or subwatershed links to the broader picture and convey how the pieces of the bay work together. They also enhance adaptive governance by providing accountability, community empowerment, building capacity by linking knowledge and decision making through social learning (Sharma-Wallace

et al., 2018; Folke et al., 2005). According to interview participants, report cards have multiple purposes, and they are good policy tools. In terms of accountability, local jurisdictions might be put in some kind of fun competitive advantage with another, enabling them to act more decisively.

Table 3. Perceived impacts of report cards in the Chesapeake Bay

IMPACTS	REPRESENTATIVE STATEMENT
SOCIAL LEARNING	<i>“I think people like the idea of giving a report card. I think the concept of grading is universal. Everyone understands what an A is. Everyone understands what an F is. Everyone understands what that all means. It makes sense.”</i>
	<i>“So the more widely available we can make it, I think there's lots of value in showing how local tributary or subwatershed links to the broader picture.”</i>
	<i>“With donors, you know, really trying to convey how the pieces of the bay work together, the pollutants affect dissolved oxygen affects, you know, fish and crabs and things like that, and trying to tell that story and also tell sort of what, how things are improving or not improving”</i>
LINKS KNOWLEDGE AND DECISION MAKING	<i>“I think report cards have multiple purposes. They have a purpose informing appropriators and lawmakers, and they have a purpose with the general public. I think it's both. If it were only for experts, you wouldn't need the numbers...”</i>
	<i>“I think they're really good policy tools. I think a lot of people who are making decisions about how to protect the Bay take those things into consideration.”</i>
	<i>“I also think that it's really healthy and useful that UMCES does a report card outside of the Chesapeake Bay program process. So having something that can be held up as objective, you know, it's not being, the partnership is not producing it, having it even though UMCES is part of the partnership,</i>

<p>PROVIDES</p> <p>ACCOUNTABILITY</p>	<p><i>having that sort of third party feel to it, I think is it's helpful. It sorts of feels more authentic, then grading ourselves."</i></p> <p><i>"I like report cards. I like the accountability. I like the idea that one local jurisdiction might be put in some kind of fun competitive advantage with another."</i></p>
<p>COMMUNITY</p> <p>EMPOWERMENT</p>	<p><i>"...and so it seems that the report card has this incredible ability to deliver facts and to open conversation and to get people thinking, and then it's up to everybody to build on that and to take that somewhere to drive people towards involvement, or individual behavior change...."</i></p> <p><i>"the smaller watershed organizations are having ownership in promoting those, but also promoting them in a way that is consistent with the science."</i></p> <p><i>"Then the trend line over time is also extremely important to demonstrate because people are always very curious about that are well, are things getting better, you know, so being able to demonstrate those trends."</i></p>

One of the issues with having multiple report cards, though, is the notion that they're dueling with one another. It has been a point of confusion and even frustration, and most people don't understand the difference between the two Bay-wide report cards, especially in the indicators and metrics that are being used. One interviewee even stated that *"I don't find that helpful. And so that's part of my dilemma, which is, if we really are going to do a report card, we should be doing one report card, somehow"*. This idea of a single report card for the Chesapeake Bay has been considered, but ultimately was not pursued. Having these different report cards that work across different scales and can target different audiences offers flexibility.

These various report cards also allow for cross-scale multi-actor collaboration that promotes adaptive governance (Edwards et al., 2019). However, at the very least, there should be coordination between the different report cards, especially the UMCES, CBF, and Bay Barometer.

One issue that is prevalent in the report cards that have been consistently being produced annually is the idea of “report card fatigue.” Often, report card grades remain the same or even decreases with severe storm events despite or regardless of the actions of people and organizations. It makes it difficult then to continuously engage people when it seems that their actions are not making any difference. Several regional report cards have addressed this by adding indicators, changing their communication strategy, and even forming collaborations. For instance, the Shore River report card is composed of report cards from 4 different riverkeeper groups that decided to coordinate their actions for maximum impact.

Report cards can be communicated easily, but they are understood and valued differently across stakeholder groups. Most interview participants that are not directly related to report card development are indifferent about report cards. They hear them in the news and appreciate the media coverage, but other than that, it has no impact on their decision-making and actions. Other participants generally have a positive perception of report cards in terms of simplifying and communicating environmental issues. Still, when pressed for possible negatives, they concede that there is an implicit bias in that report cards are being used to engage the already interested and invested group of stakeholders. There is an agreement that there is a need to engage

key community leaders to help in communicating report card results and a need to identify indicators that community members value.

Another challenge in the use of report cards is that it can frame and create environmental knowledge in such a way that what is not in the report card can be perceived as not important and left out in the environmental discourse. Several interview participants expressed the need for report cards to be connected to the local communities and even to management actions. Report cards in the Chesapeake Bay tend to only talk about the Chesapeake Bay in terms of water quality and residential and recreational value. Several regional report cards are recognizing this, such as Baltimore's Harbor Heartbeat (Waterfront Partnership of Baltimore, online), formerly Healthy Harbor Report Card, that shifted its focus from water quality to restoration efforts. The State of the James (James River Association, online) and Upper and Middle Rappahannock report cards (Friends of the Rappahannock, online) are similar, having indicators for human health, land use, stream ecology, community engagement, and restoration efforts.

Conclusion and recommendation

The evolution of the use of report cards in the Chesapeake Bay reflects the growing need to go beyond communicating scientific information and engaging stakeholders to influencing decision making to inspire people to act and change their behavior. Similar to the three adaptive governance case studies that were examined by Schultz et al. (2015), an awakening crisis, Hurricane Agnes triggered the

emergence of adaptive governance in the Chesapeake Bay. The Chesapeake Bay report card was able to enhance adaptive governance by linking science and decision-making through data collection and monitoring (Edwards et al., 2019). Additionally, because experts from the academic, state and federal agencies back the Chesapeake Bay report card (Williams et al., 2009), it was used by both formal (BayStat) and informal (NGOs) governance to facilitate coordination, negotiation, and collaboration (Schulz et al., 2015).

The different report cards in the region serve as boundary objects that can facilitate adaptive governance by promoting continual learning and cross-scale exchange of information between various organizations and stakeholders (Schultz et al., 2015). These report cards are also able to enhance adaptive management, facilitate collaboration and coordination of actions by providing accountability and community empowerment (Sharma-Wallace et al., 2018). The tributary report cards, in particular, are being used by regional organizations to promote participation, collaboration, and social learning, all of which are essential features of adaptive governance (Plummer et al., 2017).

Currently, the UMCES report card is in the process of expansion to include socio-cultural-economic indicators. A socio-environmental report card can potentially address the existing limitation of the report card in engaging the diverse stakeholders in the Chesapeake Bay watershed. However, this comes with its own set of issues. The development of such a socio-environmental report card requires a broader collaboration and understanding of the different environmentalism that exist in the

Chesapeake Bay watershed (Paolisso 2006). It is crucial, therefore, to understand how these cross-scale collaborations among organizations that use report cards enhanced Chesapeake Bay governance (Berkes 2017). According to Epstein et al. (2015), there are three general types of fit between institutions: (1) Ecological fit, or the fit between institutions and ecological problems; (2) Social fit, or the fit between institutions and social systems; and (3) Social-ecological system fit, or the fit between institutions and contexts that contribute to success. However, some collaborations do not produce any tangible action and only produce symbolic outcomes that have no forms of accountability (Bodin, 2017).

Research has shown that stakeholders only collaborate to advance their agenda while having little interest or having the limited individual capacity to contribute towards solutions (Bodin, 2017). One of the most common questions in this context is, “*why do people choose to collaborate with certain others to solve shared/common environmental problems?*” Bodin (2017) hypothesized that people’s choice for collaborators could depend on three things: (1) basic social preference (i.e., similarity); (2) desire to solve the common problem (i.e., perceive effectiveness to achieve the goal); (3) perceived risk of collaboration or collaboration uncertainty. Understanding what drives (or impedes) collaboration can optimize relationships that can potentially lead to collective action and behavior change (Plummer et al., 2017, Bodin 2017).

One way of addressing the collaboration issue is by studying the relational patterns of the different stakeholders using Social Network Analysis and Socio-

ecological Network Analysis, which is an emerging field in natural resource governance (Bodin and Prell, 2011). It has been used and applied in many systems around the world in the context of coupled human and natural systems, social-ecological systems, sustainability and resilience, and collaborative governance, among others. For example, in Puget Sound, USA, a social-ecological network analysis framework has been developed and used to analyze the collaboration patterns among local and regional organizations working in estuary restoration (Sayles and Baggio, 2017). Functioning social networks are essential for adaptive governance to be successful (Chaffin et al., 2014). Report card development can lead to network formation, and the interaction and interconnection among the different networks of people (experts, organizations, citizens, local community groups, etc.) and natural resources are critical. A deep understanding of all these in the Chesapeake Bay will be vital in overcoming socio-environmental problems at different scales.

Chapter 4: Envisioning a sustainable future Chesapeake Bay and watershed through socio-environmental report cards

Abstract

Several report cards or similar bay-wide assessments are published for the Chesapeake Bay, in addition to several tributary report cards within the watershed. These report cards can enhance adaptive governance in the watershed by serving as boundary objects that can facilitate the cross-scale exchange of information and learning. However, developing a watershed-wide socio-environmental report card can be challenging because different stakeholder groups in the watershed hold diverse socio-environmental values. They may use different cultural models of the environment to understand and value natural resources and support or oppose policies and programs. In this chapter, I identified how different stakeholder groups define an “improved” or a “restored” Chesapeake Bay watershed through content analysis of key informant interviews. I then used this understanding to create a vision for a future sustainable Chesapeake Bay watershed. I proposed a framework for a socio-environmental report card that can support this vision. Identifying potential indicators for what people value can improve the utility of report cards in supporting Chesapeake Bay governance. Considering both scientific information and the human dimensions of ecosystems promotes more effective communication that can translate into positive actions towards a resilient and sustainable Chesapeake Bay watershed.

Introduction

Multiple scholars have called for a changing approach to complex environmental problems, wherein the traditional paradigm of management must be changed (e.g., Ludwig 2001). Science needs to be made accessible to interested laypersons, the importance of ethics and environmental justice must be acknowledged, and traditional knowledge and values should be incorporated (Berkes and Folke 1998; Ludwig 2001). Similarly, Martin (2017) opined that the definition of “ecological restoration” should be revised and that decision-makers, scientists, and other restoration professionals and practitioners should follow a structured, hierarchical goal-setting process that is guided by a simple question: “Why?”. Indicators used to evaluate the success of restoration programs should be revisited to support system resilience and ensure sustainability. In the past twenty years, novel transdisciplinary strategies that recognize the inherent coupling between human societies and natural environments, also referred to as socio-ecological systems, is growing (Polk, 2015; Roux et al., 2017; Scholz and Steiner 2017; Schauppenlehner-Kloyber and Penker, 2015; Frescoln and Arbuckle, 2015). However, the actual integration of social and natural science in practice remains to be seen.

The Chesapeake Bay, the largest and most productive estuary in the United States, was the first estuary in the United States targeted by the U.S. Congress for restoration and protection (CBP, Online). It is currently widely regarded as one of the best examples of successful environmental restoration using adaptive management in

the world (Boesch 2019). The Chesapeake Bay is managed through the Chesapeake Bay Program, an intergovernmental coalition of the federal government, and the different states within the region. Since the CBP was formed in 1983, there have been several written agreements that have guided the CBP Partnership's efforts to reduce pollution and restore the ecosystem (Stokstad, 2009).

However, social science research in the Chesapeake Bay has not been fully integrated into Chesapeake Bay management. In 2011, Paolisso et al. (2011) identified critical social science research needs in the Chesapeake Bay. These are the following: behavior change research, economic research, cultural landscape, research to address communication barriers, and research to understand institutional change. Groups of Bay stakeholders may use different cultural models of the environment to understand and value Bay's natural resources and support or oppose Bay restoration policies and programs. According to Jones et al. (2011), cultural models are elicited in the context of natural resource management for the following reasons: explore similarities and differences to improve communication, integrate different perspectives to enhance the overall understanding of a system and improve decision making, support social learning processes, overcome knowledge limitations and misconceptions. Several studies in the Chesapeake Bay utilized cultural analysis in the context of fisheries (Paolisso, 2007), oyster restoration (Paolisso and Dery, 2010), and climate change (Hesed and Paolisso, 2015; Paolisso et al., 2012).

Developing a watershed wide socio-environmental report card for the Chesapeake Bay

As discussed in the previous chapter, report cards are popular tools for communication that have been used in the Chesapeake Bay to enhance adaptive governance. These existing report cards, however, are lacking to effectively support Chesapeake Bay restoration and fail to consider the diversity of environmental beliefs held by the various stakeholder groups within the Bay. Integrating the social science perspective into the Chesapeake Bay report card could lead to the development of indicators that can be used to assess the “multiple” Chesapeake Bays (Paolisso, 2006) at the cultural level and identify key individuals within the Bay.

Different stakeholders have different things that they value in the Chesapeake Bay; this may or may not be wholly reflected in the report card. Highlighting these values would reinforce place attachment, moral responsibility, and sense of obligation. Targeted communication and engagement strategies for different stakeholders are needed. The socio-environmental report cards can be designed to account for the difference in stakeholder’s levels and stages of adoption, and the different levels of influence needed. Understanding this can give insight on potential indicators, and initiate discussion and future projects to help develop these indicators, if not yet available. Thus, a new framework for a Chesapeake Bay report card involving more involved and deliberate stakeholder engagement should be considered

so as not just to reinforce the status quo but to promote collective action and shared governance.

In this chapter, I investigated if stakeholders involved in Chesapeake Bay restoration view how the restored Chesapeake Bay lines up with the Chesapeake Bay Program's priorities, and if this is reflected in the scientific literature. Using these different views on the future of Chesapeake Bay, I conceptualize a socio-environmental report card that can assess a future sustainable and resilient Chesapeake Bay watershed. Semi-structured interviews and text analysis were used to address the research question: "What is a restored Chesapeake Bay and watershed?". I also developed a cultural model and conceptualization of how different stakeholder groups define "success" and a "restored" Chesapeake Bay.

Methods

Interviews

Cultures are shared understandings based on shared experiences that are primarily taken for granted but are drawn upon in forming expectations, reasoning, and other cognitive tasks (Quinn, 2005). In the same manner, most mental and cultural models emerge in society through shared experiences, and they can be passed down across generations (World Bank, 2015). One of the best available windows in analyzing a person's mental and cultural model is through interviews by teasing out the implicit

meaning in their words that are rarely explicitly stated (Quinn, 2005). Other sources of information are written documents, such as books, reports, web pages, scientific papers, meeting minutes, and others.

Twenty-eight individuals from researchers (private companies and academic institutions, both natural and social scientists), managers, and decision-makers (federal, state, local) and non-profit groups (advocacy groups) working on the Chesapeake Bay related issues were interviewed. Content analysis and visualization of the interview transcripts and other related documents were conducted using MaxQDA. Consent forms and interview guide questions are attached as Appendix 1 and 2.

Analysis of written documents

In this chapter, I analyzed documents available online to help in developing a vision for what a future Chesapeake Bay and watershed is. The Chesapeake Bay is one of the most studied systems in the United States and thus has a rich history and body of knowledge already written down. I looked at four primary sources: (1) Web of Science for scientific publications; (2) Chesapeake Bay Program website and other CBP Partners (i.e., Chesapeake Bay Commission, Chesapeake Bay Foundation, IAN-UMCES, Alliance for the Chesapeake Bay, etc.); (3) Books, dissertations, and other reports; and (4) Web pages that resulted from Google search on “Chesapeake Bay” and related keywords.

I also used the web to investigate potential indicators for socio-ecological assessments. In particular, I used the CDC's Social Vulnerability Index to illustrate a possible socio-ecological indicator that can be used for the Chesapeake Bay watershed.

Visualizing bibliometric networks or science mapping

For the web of science search results, I used bibliometric network analysis to systematically analyze scientific publications related to Chesapeake Bay management and restoration. A bibliometric network consists of nodes and edges (Waltman and van Eck, 2012). The nodes can be publications, journals, researchers, or keywords, while the edges indicate relations between pairs of nodes. The most commonly studied types of ties are citation relations, keyword co-occurrence relations, and co-authorship relations.

I created maps from keywords of co-occurrences network extracted from Web of Science using the VOSviewer application (van Eck and Waltman, 2010). Search words included: (1) "Chesapeake Bay" and "management"; (2) "Chesapeake Bay" and "restoration"; (3) "Chesapeake Bay" and "sustainability"; and (4) "Chesapeake Bay" and "resilience." VOSviewer is a program developed for constructing and viewing bibliometric maps (Van Eck and Waltman, 2012) using the VOS or visualization of similarities mapping technique (Van Eck and Waltman, 2007). VOSviewer constructs a map based on a co-occurrence matrix (Van Eck and

Waltman, 2010). Items that have a high similarity are located close to each other, while issues that have a low similarity are far from each other. The number of articles in which both keywords occur together in the title, abstract, or keyword list determines the number of co-occurrences of two keywords (Van Eck and Waltman, 2014). The cutoff for included keywords was between 50-75 words. If multiple words are similar, such as oyster and oysters, or SAV and submerged aquatic vegetation, only the word with the highest co-occurrence score was included.

Results and Discussion

Chesapeake Bay restoration in the scientific literature

The top research clusters that are closely associated with Chesapeake Bay restoration were the following: submerged aquatic vegetations, oyster restoration, water quality, watershed management, and climate change (Fig. 1A). This clustering supports the perception that water quality and oysters are the two most important values in the Chesapeake Bay. Research on submerged aquatic vegetation is also directly linked with the restoration as they are considered sentinel species of Chesapeake Bay ecosystem recovery (e.g., Orth et al., 2017; Lefcheck et al., 2018). Figure 1A could also suggest that recent successes in water quality improvement, oyster restoration, and SAV recovery in the Chesapeake Bay can be attributed to strong support in scientific research in these topic areas in the past.

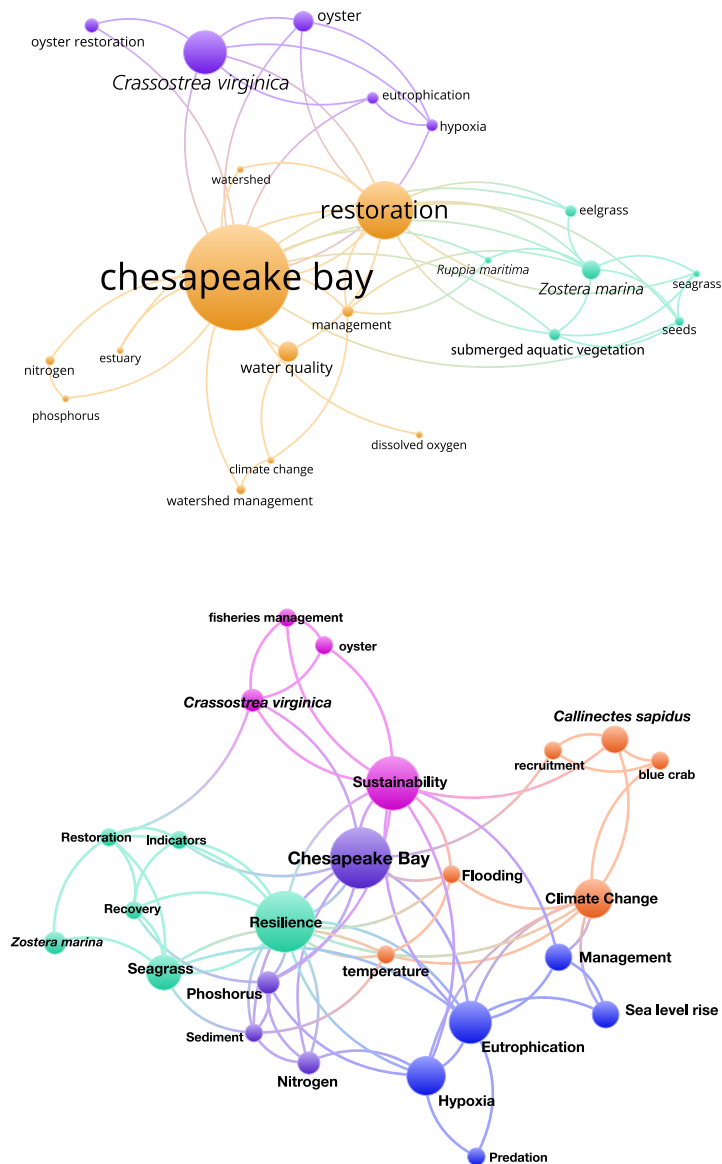


Figure 1. Chesapeake Bay Restoration (top) and Chesapeake Bay resilience and sustainability (bottom) in the scientific literature

In addition to Chesapeake restoration, I also created a bibliometric map for scientific literature on Chesapeake Bay resilience and sustainability. In this map, relationships become more prominent. Chesapeake resilience is mostly associated

with seagrass and nutrients. Chesapeake sustainability is mainly related to fisheries management, oysters, and blue crabs. Surprisingly, the keywords related to blue crabs only appeared in this bibliometric network and are clustered together with climate change. Other issues in this cluster are flooding and temperature. Another group related to climate change seems to be eutrophication/hypoxia, and sea-level rise management.

Climate change and the Chesapeake Bay

Bibliometric analyses in Figure 2 revealed that issues related to climate change such as flooding, temperature, and sea-level rise management are some of the new topics in Chesapeake resilience and sustainability. The impacts of various climate change scenarios will need to be modeled to anticipate changes. In addition, the synergistic effects of a variety of changes (e.g., temperature, salinity, and chemical composition of seawater) need to be modeled, integrating results of specific experiments and observations. Modeling can also help discern the changes observed due to climate change vs. those changes due to changes in land use and increased population pressures (people and domesticated animals). The implications of climate change on the Bay's living resources will be a critical factor in determining management strategies.

Several features of Chesapeake Bay have already been altered by climate change, documented in a suite of previous Chesapeake Bay Program's Science and

Technical Advisory Committee reports. Satellite analyses of sea surface temperatures over the past thirty years show that waters adjacent to urban developments and power plants have increased temperatures due to runoff from impervious surfaces and cooling water discharges, respectively (Ding and Elmore, 2015). Relative sea-level rise, which is the combination of land subsidence and sea-level height, has been about 30 cm (1 ft) over the past one hundred years, accelerating over the past few decades (Boesch et al., 2013; Boesch et al., 2018). This relative sea-level rise has increased the cross-sectional area of the mouth of Chesapeake Bay. It is allowing more tidal excursion into and out of the Bay, resulting in saltier water. Also, sea-level rise has inundated coastal salt marshes. The low relief along much of Chesapeake's shoreline means that landward migration of the salt marshes is occurring at about one meter per year. Vast tracts of salt marsh have been converted to open water as a result. It is particularly pronounced in southern Dorchester County and Blackwater Wildlife Refuge, where annual changes in open water vs. salt marshes can be readily observed.

The increase in atmospheric carbon dioxide results in higher $p\text{CO}_2$ dissolved in the Chesapeake Bay. Transformations of dissolved inorganic carbon lead to changes in concentrations in carbonic acid, bicarbonate, and carbonate. Ocean acidification can happen that could negatively affect organisms that produce calcium carbonate (e.g., oysters, clams, snails). In contrast, SAV thrives under higher dissolved inorganic carbon conditions and may be enhanced (Zimmerman et al., 2015). The effects of altered carbon cycles on phytoplankton and other living

resources are mostly unknown. The warmer, wetter winters that regional climate models are predicting will have implications in the timing and delivery of sediments, nutrients, and toxicants into the Chesapeake Bay (Boesch et al., 2013). Earlier spring runoff has already been observed with less snowmelt and more runoff events in late winter/early spring (Murphy et al., 2011). The establishment of a stratified water column will occur earlier as the freshwater lens creates a pycnocline, which can accelerate the establishment of seasonal hypoxia and anoxia in bottom waters.

The flashier runoff patterns of mini-droughts punctuated by extreme rain events will have implications in the Chesapeake Bay. Sediment mobilization occurs following mini-drought conditions due to lack of vegetative cover, combined with severe storms, can wash these sediments and associated nutrients and toxicants into the Bay. Organisms that can withstand pulsed events will thrive, like the increasingly abundant SAV *Ruppia*, but organisms sensitive to these events, like the declining SAV *Zostera*, will suffer (Lefcheck et al., 2017). There is much speculation about the frequency and intensity of tropical storms and hurricanes in future climate scenarios. The significant impacts of previous tropical storms (e.g., Tropical Storms Agnes in 1972; Isobel in 2003; Lee in 2011) on Chesapeake Bay biota means that if there is a change in the frequency and severity of tropical storms, there could be dramatic impacts on the Chesapeake Bay.

Chesapeake Bay Program goals

The most recent Chesapeake Bay Watershed Agreement was signed in 2014, establishing ten goals and 31 outcomes to restore the Bay, its tributaries, and the lands that surround them. The CBP partnership vision is “*an environmentally and economically sustainable Chesapeake Bay watershed with clean water, abundant life, conserved lands and access to the water, a vibrant cultural heritage, and a diversity of engaged citizens and stakeholders*” (Chesapeake Bay Watershed Agreement, 2014). Progress towards this vision is supported by robust monitoring networks and modeling frameworks that provide the best available accurate representations of the Chesapeake Bay and watershed processes in the natural science perspective.

Table 1. Chesapeake Bay Program goals and 2018 progress ¹

Chesapeake Bay Program Goals	Indicators	Chesapeake Progress
Sustainable Fisheries		Progress Increased
	Blue Crab Abundance	Progress Increased
	Blue Crab Management	Progress Completed
	Fish Habitat	Progress Even
	Forage Fish	Progress Even
	Oysters	Progress Increased
Vital Habitats		Progress Increased
	Black Duck	Progress Increased
	Brook Trout	Progress Even
	Fish Passage	Progress Increased
	Forest Buffers	Progress Increased
	Stream Health	Progress Even
	Submerged Aquatic Vegetation	Progress Increased

	Tree Canopy	Progress Even
	Wetlands	Progress Increased
Toxic Contaminants		Progress Even
	Toxic Contaminant Research	Progress Even
	Toxic Contaminant Policy and Prevention	Progress Decreased
Water Quality		Progress Increased
	2017 Watershed Implementation Plans	Progress Completed
	2025 Watershed Implementation Plans	Progress Increased
	Water Quality Standards Attainment and Monitoring	Progress Increased
Healthy Watersheds		Progress Even
	Healthy Watersheds	Progress Even
Land Conservation		Progress Increased
	Land Use Methods and Metrics Development	Progress Even
	Land Use Options Evaluation	Progress Increased
	Protected Lands	Progress Increased
Public Access		Progress Increased
	Public Access Site Development	Progress Increased
Environmental Literacy		Progress Even
	Environmental Literacy Planning	Progress Increased
	Student	Progress Even
	Sustainable Schools	Progress Increased
Stewardship		Progress Even
	Citizen Stewardship	Progress Even
	Diversity	Progress Even
	Local Leadership	Progress Even
Climate Resiliency		Progress Even
	Climate Adaptation	Progress Even
	Climate Monitoring and Assessment	Progress Increased

¹Synthesized from 2018 Bay Barometer and chesapeakeprogress.org

Future Chesapeake Bay watershed from stakeholder perspectives

I constructed a cultural model of stakeholder's perception of Chesapeake Bay restoration by creating a word cloud from all interview responses related to perception restoration using MaxQDA (Figure 2). Based on this analysis, a healthy and restored Chesapeake Bay according to my interviews is not restoring the Bay to conditions similar to John Smith's time, and it is not just about whether or not goals in water quality or oysters, fish, crabs, trees, watershed and stream health are met. It is also about the people and communities that people are able to access the Bay, swim safely, and their livelihood and economic needs are supported. It was evident that Chesapeake Bay stakeholders can understand and balance different perspectives and can transform their inherent love of the Bay and their appreciation of its importance to sustainable actions.

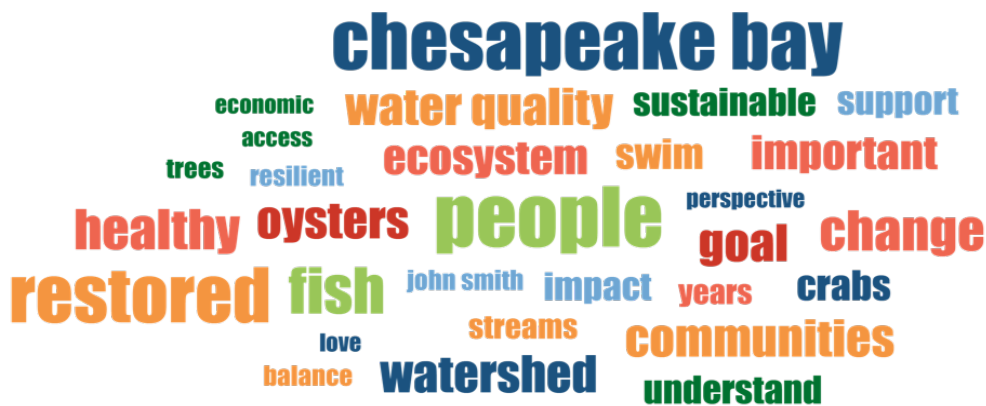


Figure 2. A cultural model of a restored Chesapeake Bay

The majority of the people that I interviewed were born in the Chesapeake Bay watershed have either or both spent a significant portion of their professional career and personal life in the Chesapeake Bay and have indicated that the Bay provides for them a unique sense of place. The people that are born in the Chesapeake Bay watershed, in particular, have a direct and meaningful experience with the Chesapeake. Almost everyone that I interviewed was very proud of the Chesapeake Bay and the work that they do in preserving the “most extraordinary estuary in the world.” Practitioners that are part of the CBP Partnership viewed the Chesapeake Bay as a “unifying force,” indicating that “it is a great example of a resource that has forced people to work across state lines and jurisdictions.” One social scientist echoed a similar sentiment, calling it a “poster child of how humans interact with the natural world.”

The majority of my interviewees worked in organizations that are part of the Chesapeake Bay Program Partnership. So a number of them referred back to the Chesapeake Watershed Agreement goals when talking about the future Chesapeake Bay. Several of them also made it clear that it is not just clear water and bountiful fish and more trees along the shoreline. Instead, it is also in terms of how the restored Chesapeake Bay influences local and regional communities. Interviewees viewed the future Bay from an economic, social, and recreational perspective with the caveat that these are things that the CBP Partnership has not figured out yet on how to achieve and measure.

Natural vs. social science perspective of a restored Chesapeake Bay

“...it has oysters and crabs and fish, and you can see through the water... and more about implementing best management practices.”

-Natural scientist

Natural and social scientists had two different perspectives, and it was apparent in how they define a restored Chesapeake Bay and in the words that they use. Stakeholders with more of a scientific background equated a restored Chesapeake Bay to meeting the CBP program goals, application of best management practices and innovative technological solutions, resilience, and sustainable development (environmental, economic, social). Water quality, nutrient reduction, aquatic grasses, fish, and other living resources were commonly mentioned in terms of environmental sustainability. The social component, however, was mostly limited to recreation, human health, diversity, and stewardship, while the economic component was mainly related to aquaculture and agriculture. Most of these topics are already part of the Chesapeake Bay Watershed Agreement (Table 1).

“...have a really engaged citizenry that understands that we have this multiple environmentalism for how we understand the Bay.”

-Social scientist

Social scientists, on the other hand, associated a restored Chesapeake Bay to issues related to social vulnerability. Common themes were social and environmental justice, especially the inclusion of rural communities and other vulnerable populations in the conversation on Chesapeake restoration. Another essential aspect

was respecting different environmental beliefs, cultural identity, and heritage in promoting and striving for Chesapeake restoration.

“...underserved community voices will be heard more in a restored and resilient Chesapeake Bay; I think there is a lot of environmental justice challenges that we have yet to face.”

-Practitioner

Several practitioners (people working in state and federal agencies) also explicitly emphasized the importance of finding a balanced use of not depleting the resources while still being able to address the growth of the number of people in the watershed. Having people understand how things are connected and how they are connected to the Bay becomes crucial.

Visualizing a sustainable future Chesapeake Bay

“I think we’ve got the right measurements out there, from a scientific perspective of saying, is the Bay restored. And we’ve grappled with what a restored Bay looks like. And we put it in the context of how many seagrasses out there, whatever, the population to keep fisheries out there. What about habitat? What about the landscape itself? So I think we’ve actually done a pretty good job of that... but it’s not just clear water and bountiful fish and more trees along the shoreline. It’s also in terms of how the restored Chesapeake Bay influences local and regional communities, from an economic perspective, from a social, recreation perspective, those I think we haven’t figured out.”

-Federal administrator

Historically, natural resource users with their traditional and local knowledge have shaped the issues and politics around the Chesapeake Bay (Keiner, 2010). The professional environmental scientists and natural resource managers then started to

shape the future of the Bay through the CBP partnership, addressing local and regional issues that stemmed from past actions and behaviors. There are also several community groups, non-profit organizations that support community development. In today's society and towards the future, however, the biggest threat that the Chesapeake Bay is/will be facing is more global, for example, climate change and the broader ecosystem changes that are caused by systemic changes. To be able to address this threat, there should be a true socio-environmental integration in Chesapeake Bay governance. All these different views on the Chesapeake Bay should be combined to develop this vision for the future Chesapeake Bay that is sustainable and resilient.

The Bay has also shown signs of resilience and recovery of certain species, such as SAVs, oysters, and even blue crabs (Lefcheck et al., 2018). Understanding the dynamics of this resilience is very important to determine if management plans in effect are still applicable to the system and if there is a need to shift management priorities. In addition to this ecological resilience, social resilience is also an essential aspect of Chesapeake restoration, in particular, individuals whose livelihoods are dependent on the water (watermen) and other vulnerable communities (Hesed and Paolisso, 2015).

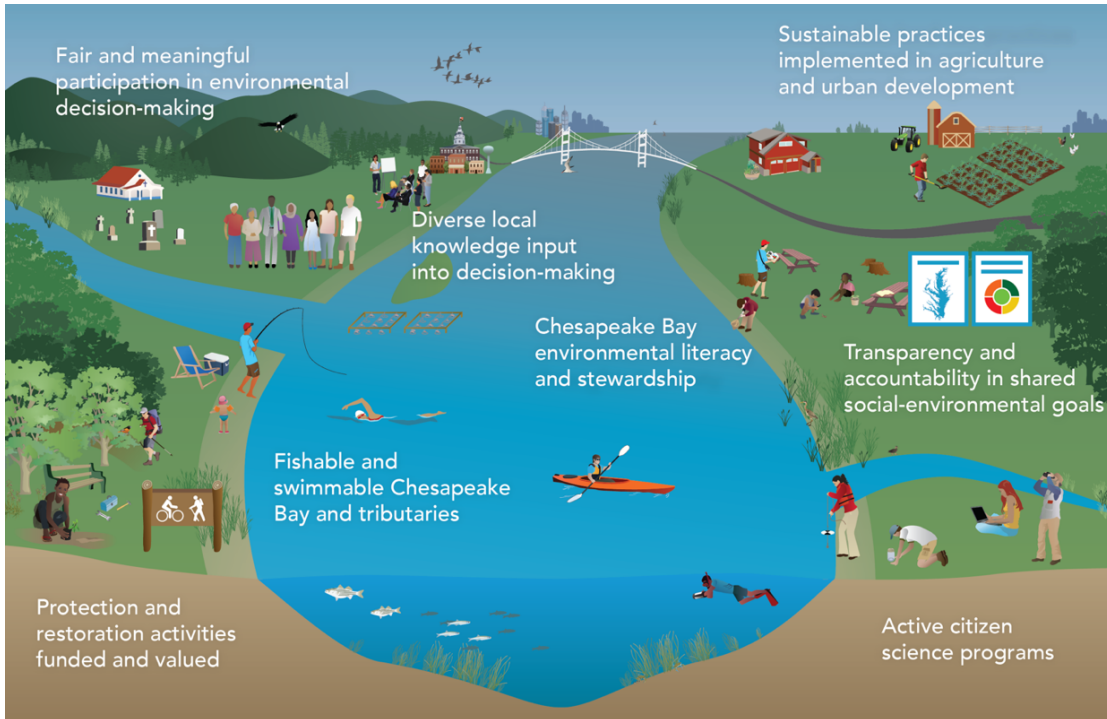


Figure 3. A vision for a sustainable and resilient Chesapeake Bay watershed

Figure 3 represents a visualization of a future Chesapeake Bay watershed that I conceptualized from integrating these different views on Chesapeake Bay’s future. It became apparent to me that people who work in Chesapeake Bay restoration all have some degree of personal connection either to the Bay itself or the many natural resources across the watershed. Furthermore, for them, a future Chesapeake Bay watershed is not separate from people and society. One of their main motivations is for the future generation to be able to enjoy and experience the Chesapeake Bay. It is important than to encourage environmental literacy and stewardship to the younger generation and more citizen science programs. The familiar “fishable and swimmable Chesapeake Bay” was a common theme, and with that comes the importance of funding for protection and restoration activities.

Communities must be able to adapt and function in society amidst climate change and anthropogenic disturbances. Population growth and development cannot be avoided, so sustainable practices and urban development should be observed. Environmental justice and the importance of diversity and traditional knowledge is also a common theme. Finally, there should be transparency and accountability in shared socio-environmental goals, and this will be possible when there is fair and meaningful participation in decision making and a balance implementation of policies.

Conceptualizing a Chesapeake Bay and watershed socio-environmental report card

“... bringing in more human dimensions makes it more relevant, and it will connect people to the Bay in a way that you would not have otherwise... creates a more comprehensive and holistic assessment that would balance things out...”

-Researcher

Co-designing a socio-environmental report card for the Chesapeake Bay watershed with its diversity of stakeholders can be an important first step in moving towards a Chesapeake Bay watershed that is resilient, sustainable, and that fully integrates socio-ecological values. This would simultaneously advance transdisciplinary socio-environmental research needs and promote social learning towards sustainable actions. One aspect of the watershed agreement that is lacking, but is important, are socio-cultural and economic indicators. Therefore, my proposed socio-environmental report card (Figure 4) is composed of four major categories: Ecosystem, People and Culture, Governance, and Economics. These four categories

represent what makes the Chesapeake Bay and its watershed important. Some of the regional report cards in the Bay (i.e., the Middle Rappahannock Report Card, State of the James River Report Card, and the Harbor Heartbeat Report) already incorporate indicators such as human health, community engagement, and restoration efforts.

The first category is the ecosystem, which can include Chesapeake Bay health, watershed health, living resources, and soil health. The goal is to have a resilient Chesapeake Bay and watershed that has healthy water, lands, and living resources. Considering the Chesapeake Bay's spatial scale and the existing resources and expertise within the Chesapeake Bay program, indicators from remote sensing data should be utilized (i.e., Sea surface temperatures, chlorophyll, Bay hypoxia). Indicators for climate change, such as climate change resiliency and coastal vulnerability, should also be pursued. The Chesapeake Bay Program and partnership are continually developing indicators that can be used in this category.

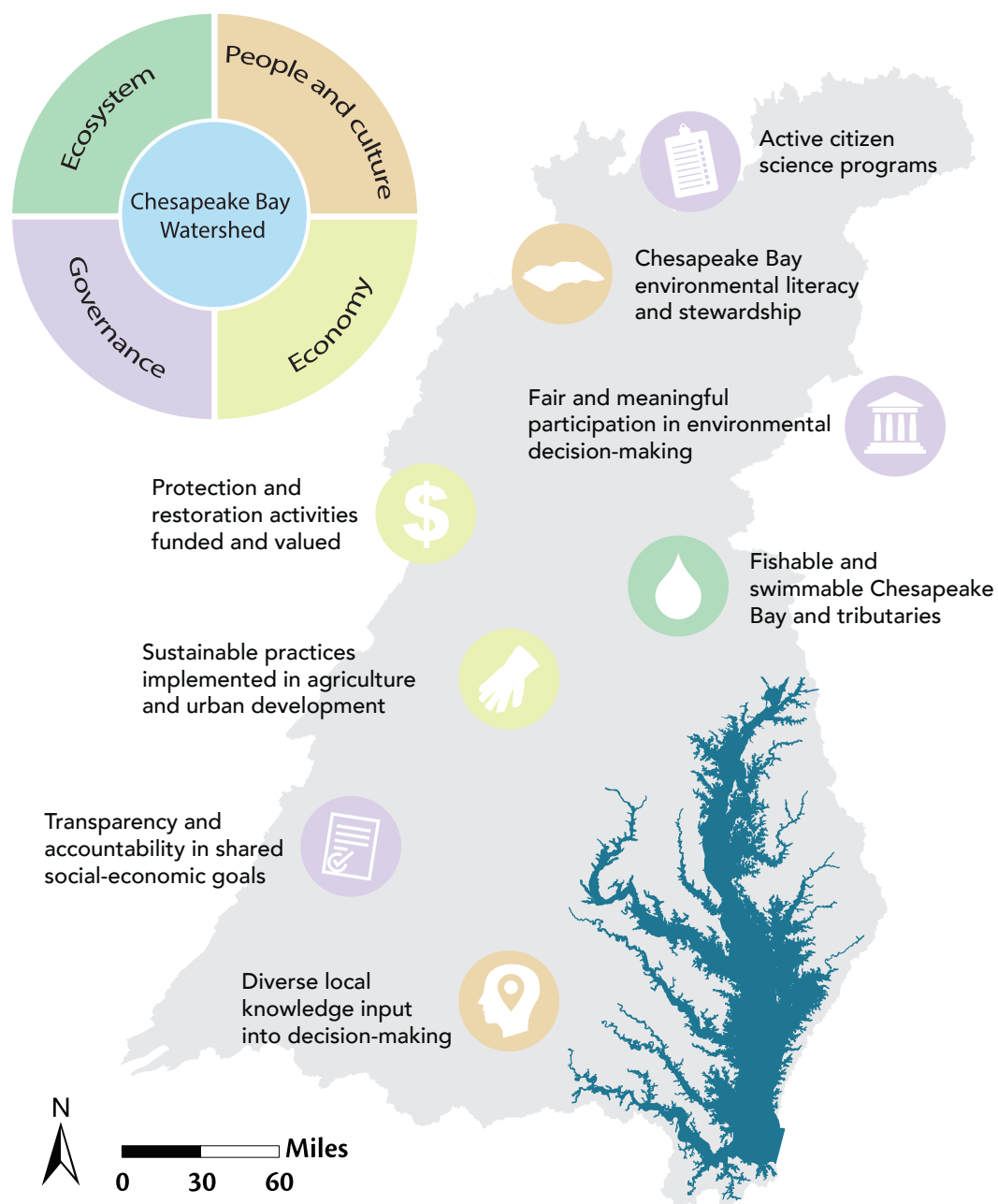


Figure 4. Framework for a Chesapeake Bay watershed socio-environmental report card

“I like the idea of a holistic report card, I think, the socio-economic stuff is the frontier that people are very interested in and excited about, and want to learn more. And I hear that everywhere I go...”

-Coordinator

The second category is the economy, which can include agriculture, fisheries/aquaculture, recreation, and ecosystem services. Indicators relating to ecosystem services – provisioning services, regulating services, cultural services, and supporting services (MEA, Island Press, 2005) are good starting points. Pascoe et al. (2015) have used this framework to develop socio-cultural and economic indicators in Gladstone Harbor in Australia. However, ecosystem services that are typically monetized can also leave information gaps, as demonstrated by (Wainger et al., 2017) in the Chesapeake Bay. The goal for a future Chesapeake Bay and watershed is to have sustainable agriculture, aquaculture, and urban development.

The third category is people and culture, which can include public health, heritage, and culture, sense of place, social vulnerability, increase social resilience and adaptive capacity, and environmental justice. Environmental anthropologists should be engaged in developing indicators for this category, as they specialize in how culture drives the relationship between society and environment (Bennett et al., 2017). The Chesapeake Bay has a rich history and cultural heritage (Van Dolah, 2018; Keiner, 2009; Chambers, 2006) that needs to be preserved or saved. There are vulnerable populations, especially in the coastal areas, that are disproportionately being affected by climate change and environmental degradation. The on-going

collaborative learning program in the Deal Island Peninsula can be a rich resource on potential indicators that can be used in a future socio-environmental report card (K. J. Johnson et al., 2018; Paolisso et al., 2019, among others).

The fourth category is governance, and this is because environmental professionals and resource managers are much ingrained in Chesapeake Bay identity. Governance can include social networks, adaptive management, and stewardship. Potential indicators from social networks are network density and fragmentation, centrality measures, and the type of network structure formed (Prell, 2011). Having a report card with a direct link to management will also aid in adaptive management (McIntosh et al., 2019) and will facilitate a close connection between science, policy, and management. For example, the Great Barrier Reef report card in Australia follows the Pressure-State-Response framework and includes a metric for adaptation of improved management practices (McIntosh et al., 2019). Similarly, the Chesapeake Bay report card could also include metrics for meeting the ten goals and management plans (nutrients, crabs, etc.) or adaption of best management practices.

“...it’s complicated to figure out how to sort of interweave these social and physical indicators. But that’s fun. I mean, we can all think about that together and figure out what we just need to do.”

- Consultant

A stakeholder engagement approach, similar to the Mississippi River watershed report card (Vargas-Nguyen et al., 2020), should be used for the Chesapeake Bay report card to expand its intersectoral and interdisciplinary

integration. UMCES should engage the other members of the Chesapeake Bay Partnership (Reed, 2008), in particular, the Chesapeake Bay Trust, the Alliance for the Chesapeake Bay, the Chesapeake Bay Foundation, and the different Riverkeepers that have their histories of involvement in developing report cards in the Bay. It is also essential to engage the other states in the Chesapeake Bay watershed. It is also critical to engage the various expert groups in the watershed, especially ones that specialize in the social sciences such as anthropology, human geography, political science, Bay history, economy, and socio-environmental synthesis and modeling. More importantly, it is essential to connect with various local groups, community and religious groups, and civic organizations.

Interview participants that are part of the Chesapeake Bay Program partnership recognize that there are still natural science types of indicators, such as watershed, stream health, soil health, that still need to be fully developed. Surprisingly, a number of them had also voiced support in conducting a Bay-wide assessment of stakeholder's values through qualitative measures such as surveys to inform them if their science and efforts are serving the need of the people. There is also an interest in understanding the various social networks in the Bay.

Social vulnerability Index provides potential indicators for a socioenvironmental report card

The Social Vulnerability Index (SVI) indicates the relative vulnerability of every U.S. census tract using 15 social factors grouped into four major themes (Flanagan et al., 2011), and a percentile rank was calculated for each census tract for each variable (Flanagan et al., 2018). The SVI is created by the Centers for Disease Control and Prevention to measure community vulnerability to natural and anthropogenic hazards (Flanagan et al., 2018). I mapped the SVI for the Chesapeake Bay watershed to demonstrate how this can be used as part of the socio-environmental report card. SVI will be particularly useful because the Chesapeake Bay region is facing increased flooding and storms due to climate change. The majority of stakeholders are socially vulnerable (Figure 5 top) and might not have the capacity or motivation to engage in the Chesapeake Bay watershed related issues. Social vulnerability and social justice issues are prevalent in rural Chesapeake Bay coastal region (Paolisso et al., 2012), and this should be represented in a socio-environmental report card.

Additionally, CBP's vision for the Chesapeake Bay includes economic sustainability, cultural heritage, and diversity of stakeholders. However, the only social component in the Bay Barometer is the engaged community theme. Using SVI, it becomes apparent that all its related indicators are only applicable to a small population of Chesapeake Bay watershed stakeholders. Environmental literacy and stewardship would not be the priority for communities that have lower socio-

economic status (Figure 5A). In the same manner, communities that are failing in household composition/disability (Figure 5B) and housing/transportation (Figure 5C) are more vulnerable to climate change (O'Brien et al., 2004). Even the diversity indicator seems to be only relevant to areas closer to the Bay itself (Figure 5D).

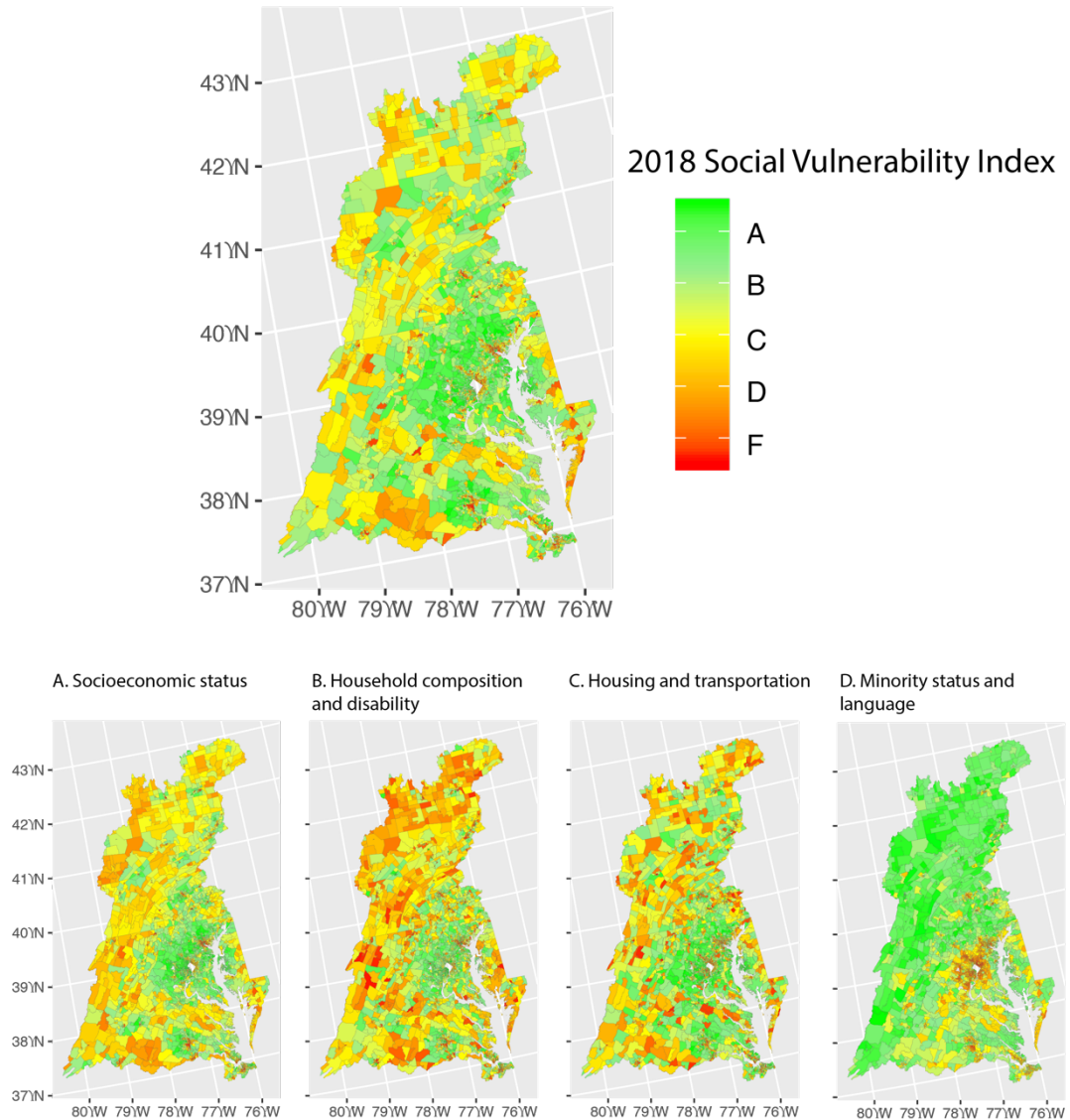


Figure 5. 2018 Social Vulnerability Index of the Chesapeake Bay Watershed. Top- Social Vulnerability Index; Bottom- A. Socio-economic status; B. Household composition and disability; C. Housing and transportation; and D. Minority status and language. Scores are based percentile ranking, census tracts in red color denote greater vulnerability while census tracts in green are the least vulnerable.

Conclusions and Recommendations

“It is not just how you could make this giant report... but is that the right approach to start with? I’m not saying that it is or is not. But it’s worth asking that question...”

-Communication specialist

Creating a socio-environmental report card for the Chesapeake Bay watershed would not be straightforward. The strength of the Chesapeake Bay Program partnership in using “science” will become its weakness in creating such a report card because of its “data-driven” mentality and specialization in the natural sciences. Significant resources have already been allotted to Chesapeake Bay research, and creating a socio-environmental report card would require additional data and different sets of expertise. Also, different organizations and individuals already have a strong perception of their “niche” in Chesapeake Bay restoration, and it might be a more significant challenge to transcend this boundary. A new approach in determining the interconnection among the different aspects of this report card would be needed.

Conceptualizing existing knowledge, culture, and values is an essential first step in developing a socio-environmental report card. It is also essential to understand what affects behavior change - the capabilities, motivation, and opportunities of people and addresses them (Langer et al., 2016). In the Chesapeake Bay watershed, stakeholders share a similar vision for a future sustainable watershed, but priorities may differ. There is a legitimate concern that in the long term, values that are not captured in the report card will be forgotten or deemed unimportant. Having a

suitable representation and employing transdisciplinary and participatory approaches will alleviate this concern by adding legitimacy to the process. Moving forward, getting the right people, and using the appropriate engagement strategy is vital. In the Chesapeake Bay watershed, churches are essential stakeholder partners that needed to be part of this conversation (Paolisso et al., 2012; Hesed and Paolisso 2015; Hesed et al., 2020).

There is still an evident lack of social science research in the Chesapeake Bay (STAC, 2011), including the following: Bay-wide information on behavior-change, addressing communication barriers, and the effects of socio-economic factors. Insights on how to effectively engage and understand the needs of diverse stakeholders are required to be able to initiate robust conversations. This a big challenge for the UMCES watershed-wide Chesapeake Bay report card because of the inherent complexity of the Chesapeake Bay and the diversity of environmental beliefs held by the various stakeholder groups within the Bay watershed (Paolisso, 2006; Paolisso et al., 2013). While knowledge to make informed decisions is essential, empowering stakeholders to take positive actions can lead to the healthy Chesapeake Bay governed by all its stakeholders.

In developing a socio-environmental report card for the Chesapeake Bay, a transdisciplinary approach is needed. The Chesapeake Bay is a multi-use water resource; hence everyone living in the watershed and the people affected by the ecosystem services that are derived from the Chesapeake Bay and watershed are considered as stakeholders. It is crucial to identify these stakeholders and outline their

main concerns on the limitations and benefits of report cards to ensure that the report card is relevant to all. Thus, co-developing this report card with stakeholders should be based on trusted interpersonal relationships (Marzano et al., 2006) and should account for external dynamics such as institutional factors and the political context (Hansson and Polk, 2018). Balancing these differences will lead to a holistic report card that considers both the accuracy of scientific information and the diversity of cultural values and experiential knowledge held by Chesapeake Bay stakeholders.

Next Steps

Moving forward, I will be the project coordinator in a multi-year transnational and transdisciplinary program, funded by the Belmont Forum, that will be piloting my three-phase framework in developing socio-environmental report cards in the Chesapeake Bay, Manila Bay, Tokyo Bay, and Goa Coast (Figure 1). As part of the proposal development of this project, we formed a working project management plan, and Chapter 4 of my dissertation serves as the conceptualization phase for the Chesapeake Bay model. This project, the Coastal Ocean Assessment for Sustainability and Transformation (COAST Card) will be merging social network analysis (Phase 1), socio-environmental assessment and reporting (Phase 2), and system dynamics modeling (Phase 3) to achieve this need. Integrating these three approaches in the COAST Card will enable the assessment of coastal and ocean systems, provide guidance on optimal cost-benefit solutions to maintain or improve the health of these systems, and identify the actors best placed to fund and deliver these solutions.

The COAST Card approach encourages stakeholder engagement and transdisciplinary collaboration to produce cost-effective and balanced pathways toward resilient communities and ecosystems. COAST Cards also provide a mechanism for regular reporting and accounting of global change impacts through indicators that are monitored and assessed periodically. COAST Cards will be useful for practitioners like governmental resource managers and NGOs, and helpful for productive stakeholder engagement. The COAST Card approach can be expanded into other environments and at different scales (e.g., terrestrial, estuarine, national,

global). COAST Cards will be presented through model-based interactive learning environments (ILEs) that will allow users to submit and edit management scenarios and view how these decisions will affect future report card scores.

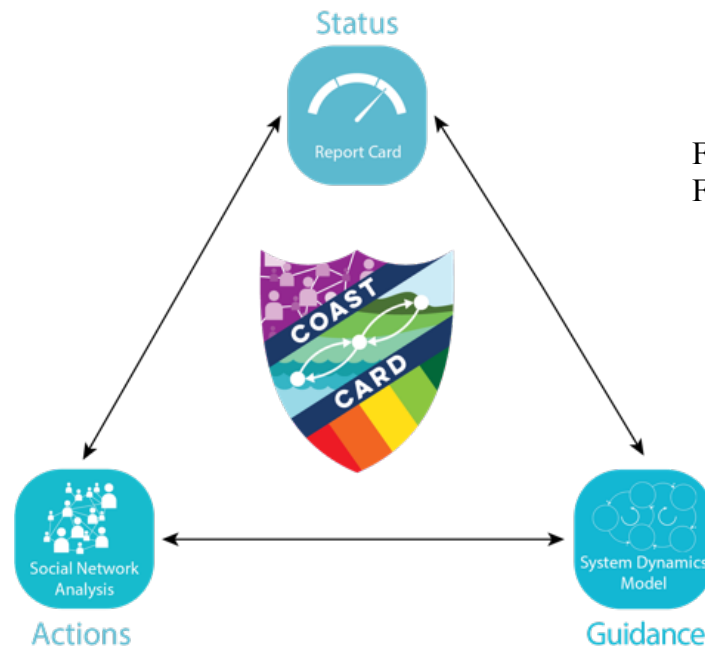


Figure 1. The COAST Card Framework

As part of this project, I will lead the development of training manuals in stakeholder engagement and socio-environmental report card development. We will also be training project partners in the Philippines, India, and Japan.

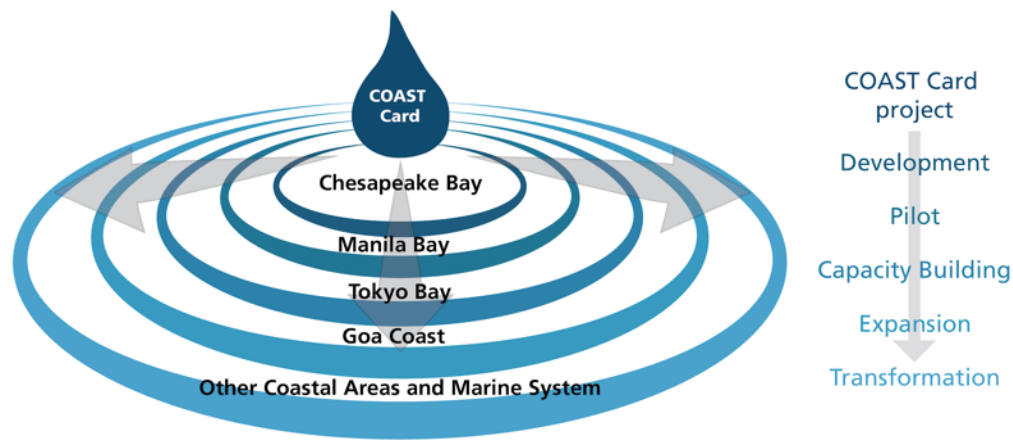


Figure 2. COAST framework for transformation

Getting the right people (social network analysis), armed with publicly available synthesized information (report cards), informed by robust models that provide guidance as to what is needed (system dynamics models) and having created trusted relationships through co-production of the COAST Card can and will catalyze positive change.

Socioecological Network Analysis

Socioecological Network Analysis of the Mississippi River Watershed. My dissertation proposal included the application of socio-ecological network analysis in the Mississippi River watershed. My objective was to investigate the relational patterns of stakeholders involved in the report card development and linked their collaboration and communication network with the scores of their basin and the values that were assessed (Figure 3). Increasing our understanding of the social networks and social dynamics within the Mississippi River watershed can help

stakeholders prioritize their actions and be used to better leverage existing relationships to generate collective action and collective impact to improve holistic management. Combining stakeholder-driven socio-ecological assessments and network analysis can be a powerful tool in studying and understanding coupled social-ecological systems.

However, because of the lack of funding and project commitment at that time, it didn't happen as expected. It was only October 2019 when this project started again. I was able to send out an evaluation survey with network questions from November 2019 through the end of December 2019. Because of time constraints, we decided not to include it in this dissertation but I am still continuing to assess the quality of my data and performing network analyses.

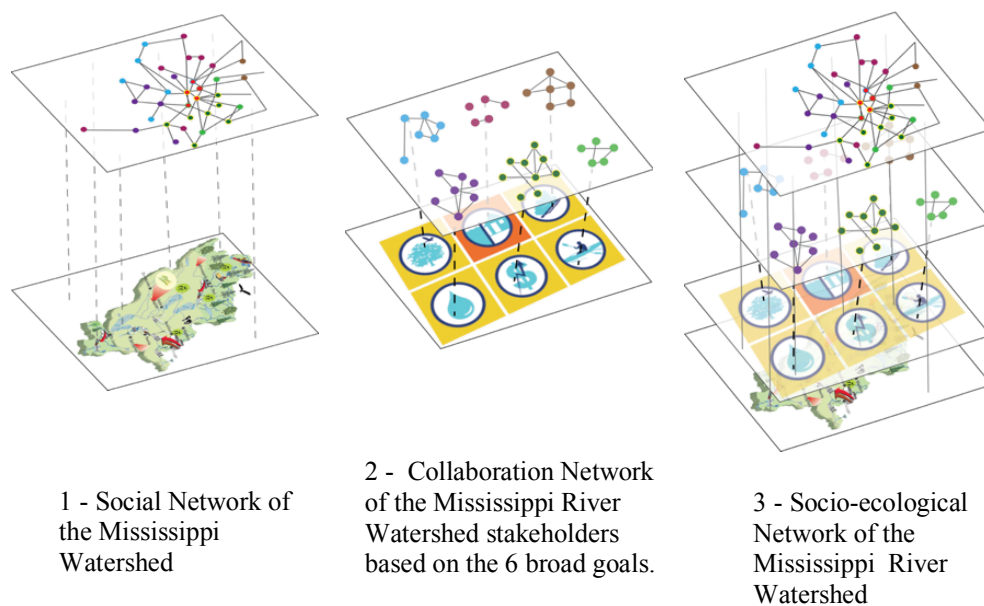


Figure 3. Framework for a Socioecological Network Analysis of the Mississippi River watershed

Resource Assessments for Management Strategies. When the initial plan for the Mississippi social network analysis did not work out, another opportunity presented in one of our projects with the National Capital Region Park Service. *Resource Assessments for Management Strategies Interface* or the RAMS interface is part of an ongoing National Capital Region National Park Service/UMCES partnership to assess and identify preservation needs for significant natural and cultural resources within the NCR parks. This interface presents the status of eight categories of natural and cultural resources based on multiple within each category. Indicators and categories are scored against target thresholds, which are based on published scientific consensus. By assessing natural and cultural resources together, this interface will, for each park, inform the integrated management of these resources.

Engaging the right people is vital to ensure the success of RAMS-informed, targeted management strategies. Social Network Analysis, part of the RAMS project, will analyze existing collaborative relationships between National Capital Region resource professionals and technicians and park stakeholders. Understanding relationships will strengthen collaborations between National Capital Region resource professionals and technicians and stakeholders and can be used to reinforce and foster novel collaborations. The next phase is Socio-Ecological Network Analysis, which combines Social Network Analysis (SNA) with ecological network data to characterize the landscape-level relationships. Including Socio-Ecological Network Analysis in the RAMS project expands the scale at which management priorities and challenges can be identified (Figure 4). Ultimately, Socio-Ecological Network Analysis will identify links among National Capital Region parks and their broader

landscape and opportunities for National Park Service management to benefit this landscape broadly. The socio-ecological network component is going to happen in the Summer or early Spring 2020.

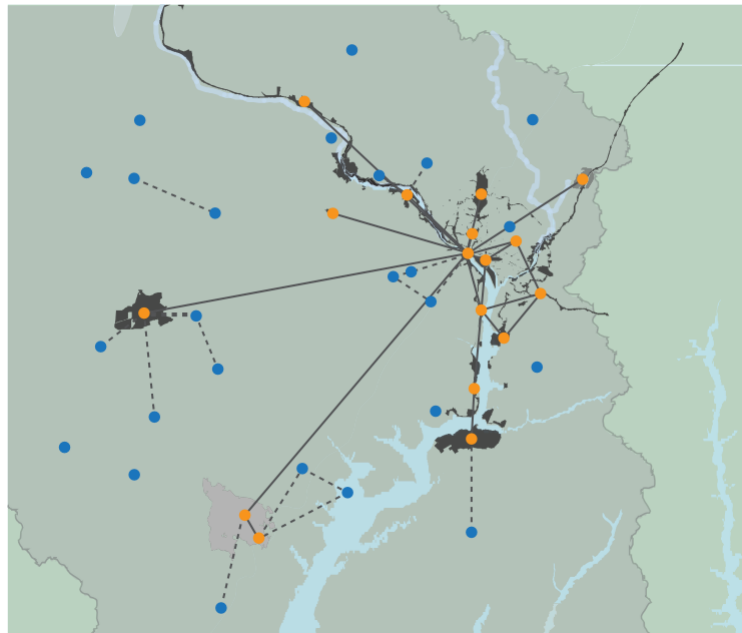


Figure 4. Socio-Ecological Network Analysis for NCR Parks

Synthesis and recommendations

In my dissertation, I present the process of developing socio-environmental report cards as an effective strategy in addressing sustainability challenges by simultaneously advancing transdisciplinary research needs and promoting social learning towards sustainable actions. Beyond its role in science communication, I showed that the process of co-developing report cards facilitates transdisciplinary collaboration and enhances adaptive governance of socio-environmental systems.

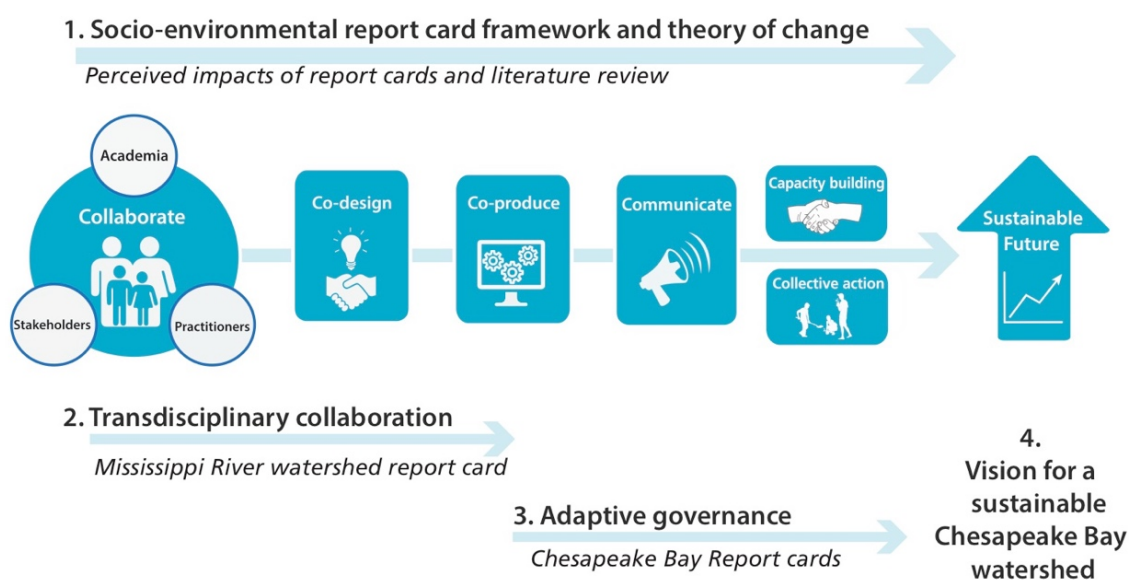


Figure 1. Research summary from Introduction

Below are my contributions to the use of socio-environmental report cards in the science and practice of transdisciplinary research and socio-environmental systems, and related complex-based approaches:

1. Developed a systematic three-phases framework for developing socio-environmental report cards (Figure 2):

- a. Using a system's approach and collaborative learning in Phase 1 Planning. Conceptualizing existing knowledge, culture, and values and identifying stakeholders and various governance networks is an essential first step. Learning from Team Science literature in developing a management plan, communication plan, stakeholder engagement plan, and evaluation plan.
- b. Using transdisciplinary collaboration in Phase 2, emphasizing the co-design and co-production in indicator selection, determining the threshold, calculating scores, and developing products such as newsletters, diagrams, and the report card itself.
- c. Using the social sciences and socio-environmental systems modeling to inform Phase 3, Raise the grade. Understanding what affects behavior change - the capabilities, motivation, and opportunities of people, and address them is essential (Langer et al., 2016). Developing targeted communication strategies and building capacity can contribute to collective action. The socio-environmental systems modeling is an emerging field and can be used for scenario planning.
- d. Social science tools such as social network analysis and cultural analysis can be used in all three phases of the process. These tools can be used to identify stakeholders and conceptualize relationships in Phase 1. Network structures can be used as indicators in Phase 2. Cultural models can be used to identify indicators and quantitative methods such as Cultural Consensus Analysis can be used as indicators as well. Both social network analysis and cultural analysis can be used in developing Phase 3 Raise the Grade strategies and can

be used in evaluating the process. Understanding both stakeholder relationships and cultural models can lead to a productive collaboration that can lead to affirmative action, that go beyond the usual and mostly symbolic call to action.

2. Established the use of a socio-environmental report card versus ecosystem health report card for socio-environmental assessments. Depending on the resources and expertise available, a socio-environmental report card might not be possible, but even in the development of ecosystem health or environmental report card in the traditional sense, the framing of a socio-environmental system should be used to move discourse towards this direction.

3. Developed a theory of change for socio-environmental report cards that can guide the process and be used for evaluation. This framework can also be used in other transdisciplinary approaches. I demonstrated the value of socio-environmental report cards in addressing sustainability challenges:

- a. Co-design and co-production of new knowledge and boundary objects for stakeholder engagement
- b. facilitates social learning, transdisciplinary collaboration, collaborative learning
- c. promotes behavior change and collective action
- d. enhances adaptive governance

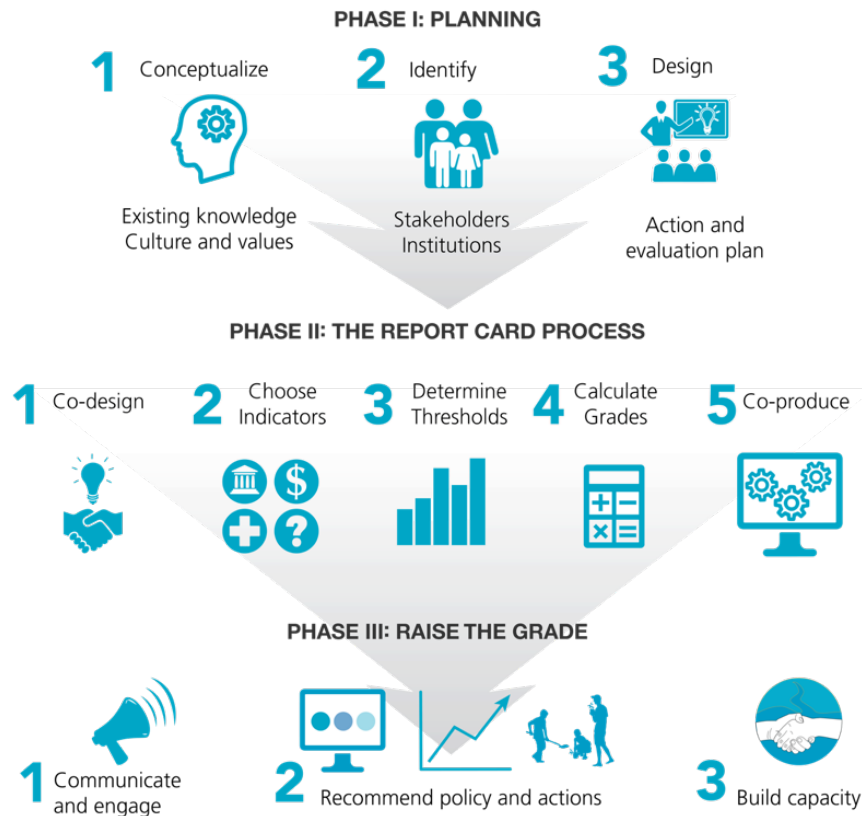


Figure 2. Three-phase framework for socioenvironmental report card development from Chapter 1

In my first chapter, I showed that report cards, although initially intended to communicate and raise awareness of environmental status, can promote behavior change and that adding socio-economic components can further increase its social impact. The report card is a useful tool to synthesize information and make it relevant to stakeholders. But we need to ensure that the issues that are important to stakeholders are represented in the report card. It is not always a simple simplification/summary of the data. Most interview participants had expressed that if the synthesized message fails to appeal to the key stakeholders - then it could be

detrimental in producing appropriate behavior change. There is also a clear need for the report card to be presented to a broader audience for better understanding, discussion, and "call to action." Most report card initiatives also lack a clear connection between management initiatives and report card grades. As it is currently used, it is a great tool to initiate change, but the message has to be passed on to multiple stakeholders to be able to move forward toward solutions. Because report cards assess present conditions, current indicators that are commonly used are not appropriate in complicated and "futuristic" issues such as climate change, resilience, and sustainability.

Based on my results and literature review, I developed a theory of change for the report card process. I also developed a new three-phase framework for developing socio-environmental report cards that build on IAN's original 5-step process, with particular emphasis on collaboration, co-design, and co-production. My results highlighted the evolution of report cards from a product created to increase awareness and education about environmental issues, to a process that engages stakeholders. Report cards that can lead to a sustainable future should include both social and environmental values, and the process has to be more stakeholder-driven and action-oriented.

In Chapter 2, I showed that the report card co-development process is a practical solution for achieving stakeholder engagement, providing opportunities for collective action in complex systems using the Mississippi River watershed report card as a case-study. The co-development of report cards as boundary objects is

critical in sustaining stakeholder engagement by enabling participants to develop a shared understanding, fostering trust in the collaboration process. This process can be used in any system. It can provide the foundation for collaborative solutions by creating a holistic assessment that incorporates multiple perspectives from multi-sectoral actors using the Mississippi River watershed as a case study.

I also showed that report cards could enhance adaptive governance in the Chesapeake Bay. In the following chapter, I applied ethnography to develop a framework for a socio-environmental report card for the Chesapeake Bay by investigating stakeholder values and perception of what a restored Chesapeake Bay is. Developing socio-environmental report cards require a transdisciplinary and system's approaches, and conceptualizing existing knowledge, culture, and values is an essential first step. It is also important to understand what affects behavior change - the capabilities, motivation, and opportunities of people and addresses them (Langer et al.,2016). In the Chesapeake Bay watershed, stakeholders share a similar vision for a future sustainable watershed, but priorities may differ. More research on the social component and how it relates to the Bay is needed.

In the first three chapters of my dissertation, I have given evidence on the validity of my proposed socio-environmental report card theory of change (Figure 3). Transdisciplinary collaboration during the report card process leads to the development of a shared vision and understanding among stakeholders. The co-production of the report card and the communication of results can lead to

environmental literacy, behavior and social change, and collective action towards sustainability and adaptive governance.

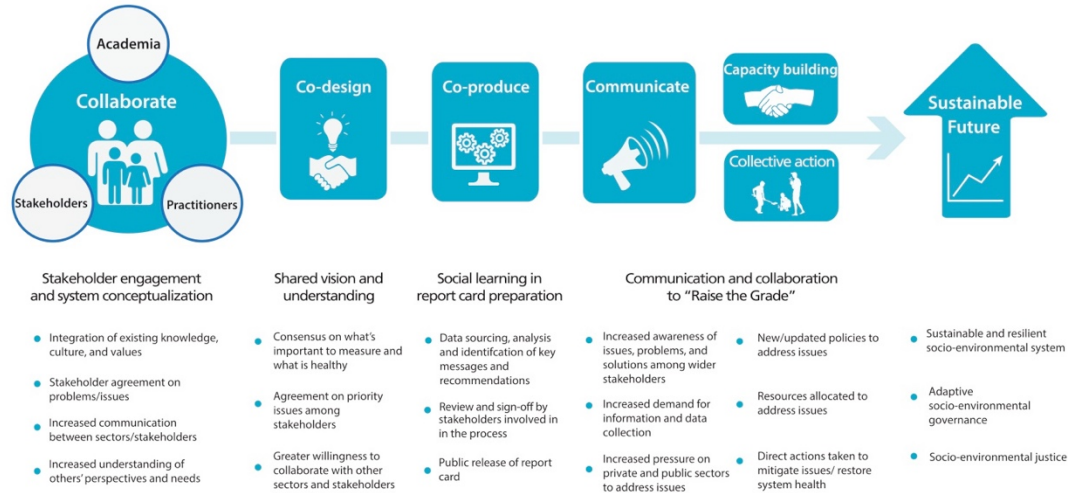


Figure 3. Socio-environmental report card Theory of Change from Chapter 1

Developing socio-environmental report cards has a lot of challenges, but it is important to emphasize that the process is more important than the physical product. First, report cards as a final product can frame and create environmental knowledge in such a way that what is not in the report card can be perceived as not important and left out in the environmental discourse. Phase I, conceptualizing different knowledge types, then becomes critical in making sure that these different cultural models are taken into consideration in the report card process. Often values that are found important do not have the corresponding or appropriate indicator/thresholds once in Phase 2, so they could be left out of the report card product. But one of the values of the process is in the identification of these knowledge gaps, and so it is important in

Phase 3 that appropriate measures are taken to ensure that these gaps are addressed in future iterations of in the communication and dissemination strategy.

Second, developing socio-environmental report cards might not be the most appropriate tool, or a situation exists where boundary objects and third places are not sufficient to bridge differences in cultural models and social networks. Again, going through Phase 1 can help identify early on if such a situation exists, and appropriate alternative scenarios could be planned. It could very well be that a traditional report card with grades will not be developed, but an alternative assessment or report or model will be co-design and co-production in Phase 2. Developing socio-environmental report cards as outlined in my dissertation can also be resource-intensive, so identifying the tradeoffs, the appropriate tools to use, and design appropriate strategies in the first phase can save time, money, and build goodwill to follow through the end of the process.

Third, incorporating ecological, social, economic, and cultural values is difficult. Unlike ecological and physical values, there have not been many studies on how to define and measure social and cultural values. Often, stakeholders that are present during the report card development process are managers and natural scientists that might not have the necessary knowledge to address these questions. Information that is included in the report card, such as the type of indicators, data that would be used, and perspective is dependent on who is in that room at that particular time. It is possible that at a different time with a slightly different group, you might get different indicators, outcomes, even values, things that people care about.

Therefore, stakeholder analysis and social network analysis in Phase I becomes critical in making sure that natural and social scientists and different stakeholders are consulted in the process is needed. Local or experiential knowledge of some critical stakeholders should also be appropriately taken into consideration.

Fourth, the quality of data and expertise in the room can significantly affect the discourse around the report card. Typically, empirical knowledge in setting thresholds and employ traditional (parametric) statistical analysis in calculating scores is used. This approach can pose a problem, especially when there is not enough available data, and when uncertainty is a significant concern. Combining different indicators, be it traditional ecological indicators or the socio-economic indicators from various sources with varying degrees of uncertainty, can pose a challenge. Conventional statistical models are limited in their capacity to integrate these different data types and thus represent limitations in the ability of socio-environmental report cards to include all these goals.

In mixing qualitative and quantitative data, methods such as the one employed by Pascoe et al. (2016) in developing a social, cultural, and economic report card for Gladstone Harbour can be emulated. Following Pascoe et al. (2016), Bayesian Belief Networks can be used to incorporate community survey results and expert opinions with quantitative data. Sequences of conditional probabilities can be used to assess management goals and different types of data (community surveys and expert opinions), and prior information can be collected and combined by a series of conditioning. Therefore, there is a need to consider other methods of analysis to make

the use of report cards more robust. For a review of the different analytical frameworks in indicator selection, weighing, etc. currently used for ecosystem health report card development, see Logan et al. (2020).

Fifth, complex theory-based principles such as transdisciplinary science and socio-environmental systems research are emerging fields, and thus its application in practice can be challenging and could require specialization that might not be widely available. Some of these tools that can be adapted in the report card process, aside from Bayesian Belief Networks, include Geographic Information Systems (GIS), Remote Sensing, System Dynamics Modeling, Social Network Analysis, and Cultural Analysis, Socio-Ecological Network Analysis and Agent-based Modeling (ABM). These tools have the potential to integrate different data types and show the linkage between the natural and social systems. The use of system dynamics modelling has been explored in public health (Marshall et al., 2015), impact management (Ricciardi et al., 2020), and sustainability (Nabavi et al., 2017). The system dynamics modelling and social network analysis will be used in the COAST Project while socio-ecological network analysis will be used in the Mississippi River watershed report card and the RAMS project, and will be discussed in the section “Next Steps.”

Network Analysis can also potentially show the interconnection between ecological, socio-cultural, economic, health, and governance indicators in one assessment. Also, specific characteristics of social networks can also be used as indicators that can be used in report cards. Potential indicators are network density and fragmentation, centrality measures, and the type of network structure formed.

SNA can also be used to design targeted communication strategies to have broader reach and behavior change impacts. SNA can identify the flow of information in the system, identify who the public turns to for information, and the different belief and value system that exists within the network, among others. Change in network structure during the process can also be used in the evaluation.

Agent-based Modeling (ABM) is a computer simulation that explicitly represents individual heterogeneity and interactions (Hammond 2015). An agent is an autonomous, adaptive decision-making entity that interacts with its environment and other agents through prescribed behavioral rules to produce emergent system-level patterns (Marshall et al., 2015). A wide range of phenomena has been modeled with ABMs, including disease modeling, migration, population dynamics, community resource management, and many others. Agent-based models are used to design intervention and explore future scenarios; it is not used to make a prediction or empirical validation.

ABM would be useful in making recommendations in Phase 3, especially in conjunction with social networks and system dynamics. Decisions and actions of multiple actors and potentially multiple spatial relationships are generally absent from System Dynamics models. However, these things are inherent features of ABMs as they can incorporate social/ecological processes and structure, social norms, and institutional factors. Thus, combining these two can be promising (Martin and Schluter 2015). Especially promising is the use of Participatory ABM (Rose et al 2015), which involves stakeholders in an iterative process of describing contexts,

soliciting decisions, running the ABM, and envisioning scenarios arising from the corresponding decisions. Co-developing and accessing intervention strategies can potentially foster social learning, developing a shared understanding that can lead to action.

Finally, evaluation is one of the biggest challenges in transdisciplinary research and sustainability science (Brandt et al., 2013), and socio-environmental report card development is not an exception. The proposed theory of change can be a useful guide, but it should be an on-going research effort on how best to assess the quality and impact of a transdisciplinary approach. I have used existing theories to inform my theory of change and framework and what is needed moving forward is to validate these theories in practice using mixed methods approaches. By using surveys, social network analysis and other ethnographic approaches, for example, we can determine whether the report card process follows the diffusion of innovation model. Cultural analysis and ethnography can also be used to develop a report card cultural model using data from different countries and different cultures.

Report Cards have evolved from a document created to increase awareness and education about environmental issues, to a process that engages stakeholders in developing conceptualizations of systems, assessment frameworks for analysis, and the design of communication products. This evolution presents increased opportunities for socio-environmental report cards to influence positive environmental and social change towards sustainability. By incorporating conceptual frameworks and research tools from the natural and social sciences, my research will

help advance the field of use-inspired and action-oriented science and assist in analyzing the complex relationships between effective governance, ecological resilience, and sustainable development. Socio-environmental report cards can be used in any system. They can provide a foundation for collaborative solutions by creating a holistic assessment that balances environmental, economic, and social concerns and incorporates multiple perspectives from multi-sectoral stakeholders.

Appendices

Appendix 1. Published Chapter 2

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Environmental Management



Using Socioenvironmental Report Cards as a Tool for Transdisciplinary Collaboration

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ABSTRACT

The process of developing a socioenvironmental report card through transdisciplinary collaboration can be used in any system and can provide the foundation for collaborative solutions for sustainable resource management by creating a holistic assessment that balances environmental, economic, and social concerns that incorporates multiple perspectives from multisectoral actors. We demonstrated this in the Mississippi River watershed, USA with the ultimate goal of promoting holistic management of the region's natural resources. But working at the scale of the Mississippi River watershed presents the challenge of working across geographical, organizational, and disciplinary boundaries. The development of a socioenvironmental report card served as the focus for efforts to foster a shared vision among diverse stakeholders in the watershed and to promote transdisciplinary collaboration. The process engaged more than 700 participants from environment, flood control, transportation, water supply, economy, and recreation sectors, from more than 400 organizations representing local, state, and federal government agencies, businesses and trade associations, and private, nonprofit, and academic institutions. This broad engagement in the selection of important themes, indicators, measures, and assessment methods as part of the cocreation of boundary objects aimed to foster social and mutual learning and to develop common understanding and shared visioning among stakeholders with differing perspectives. The process was facilitated by boundary-spanning organizations, creating an atmosphere of trust by utilizing “third places” for knowledge exchange and integration. This transdisciplinary process also led to collective action through collaboration and selection of restoration and management activities that could improve conditions for multiple sectors simultaneously and/or recognize potential tradeoffs for informed decision making. *Integr Environ Assess Manag* 2020;00:1–14. © 2020 The Authors. *Integrated Environmental Assessment and Management* published by Wiley Periodicals, Inc. on behalf of Society of Environmental Toxicology & Chemistry (SETAC)

Keywords: Mississippi River Socioenvironmental Report card Transdisciplinary collaboration Integrated management

INTRODUCTION

Transdisciplinary collaboration in the context of integrated management (Allen et al. 2011) allows for multisectoral stakeholders to reconcile a diversity of perspectives and act together more effectively to pursue shared objectives (Putnam 1995), leading to collective action (Vanni 2014) and collective impact (Kania and Kramer 2011). Transdisciplinarity promotes social learning or mutual

learning through the use of “third places” and the co-development of “boundary objects” (Jahn et al. 2012; Vilsmaier et al. 2015; Roux et al. 2017). Third places are learning spaces where diverse stakeholders meet and share experiences with an equal voice (Roux et al. 2017) allowing for knowledge exchange, integration, and production to occur. Examples of boundary objects include models, indicators, and maps that allow for different groups to share meaning and incorporate individual perspectives while still maintaining an identity that is recognized by all (Star and Griesemer 1989; Fox 2011; Jahn et al. 2012; Roux et al. 2017). Ideally, transdisciplinary processes are facilitated by boundary-spanning organizations that help increase the legitimacy of science by fostering trust and sustaining interaction and engagement among the participants

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Appendix 2. Consent to Participate

Project Title	Developing a Holistic Report Card for the Chesapeake Bay
Purpose of the Study	This research is being conducted by Vanessa Vargas Nguyen at the University of Maryland, College Park. I am inviting you to participate in this research project because you are a representative of a stakeholder group within the Chesapeake Bay watershed that are either involve in the report card development for the Bay or any of its tributaries or directly affected by information presented in any of the Chesapeake Bay related report cards. The purpose of this research project is to lay the foundation for a holistic Chesapeake Bay report card that consider both the accuracy of scientific information and the diversity of cultural values and experiential knowledge held by the various stakeholder groups within the Chesapeake Bay.
Procedures	The procedure involves an hour long semi-structured interview that will be recorded. The recorded interview will be transcribed but you will be assigned a pseudonym to protect your identity. The interview will include 12 semi-structured questions to identify how you value the Bay, the issues most interesting to you and where/who you get information from. It will also include questions aim to understand your perception on the management impacts and limitations of report cards and it potential in role in helping improve the bay.
Potential Risks and Discomforts	There are no known and foreseeable risks to participating in this study.
Potential Benefits	There are no direct benefits from participating in this research. However, overall benefits to be gained include new knowledge and understanding on how stakeholders value the Chesapeake Bay and improvement in communication and stakeholder engagement practices. Results of this study will also help in the development of a holistic report card that has the potential to positively influence individual decision-making to improve Chesapeake Bay health.
Confidentiality	Any potential loss of confidentiality will be minimized by storing data in a locked file cabinet and/or saved in a password protected computer. If I write a report or article about this research project, your identity will be protected to the maximum extent possible. Only I and my faculty advisors for this project, Dr. William Dennison and Dr. Michael Paolisso, will have access to the raw data. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.

Right to Withdraw and Questions	<p>Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.</p> <p>If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report an injury related to the research, please contact the investigator:</p> <p style="text-align: center;">Vanessa Vargas Nguyen 429 4th St. Annapolis, MD, 21401 vvargas@umces.edu; 201-4065904</p>	
Participant Rights	<p>If you have questions about your rights as a research participant or wish to report a research-related injury, please contact:</p> <p style="text-align: center;">University of Maryland College Park Institutional Review Board Office 1204 Marie Mount Hall College Park, Maryland, 20742 E-mail: irb@umd.edu Telephone: 301-405-0678</p> <p>This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.</p>	
Statement of Consent	<p>Your signature indicates that you are at least 18 years of age; you have read this consent form or have had it read to you; your questions have been answered to your satisfaction and you voluntarily agree to participate in this research study. You will receive a copy of this signed consent form.</p> <p style="text-align: center;">If you agree to participate, please sign your name below.</p>	
Signature and Date	NAME OF PARTICIPANT [Please Print]	
	SIGNATURE OF PARTICIPANT	
	DATE	

Appendix 3. Interview Instrument

Interviewee Name: _____

Interviewee Code: _____

Interviewer: _____

Date: _____

Describe how you work/interact/experience the Chesapeake Bay?

1. Why is the Chesapeake Bay important to you? What are the threats to the Chesapeake Bay?
2. In what ways have you noticed the Chesapeake Bay has change, and how have these changes affected you? *Do you think that's true with others that you work with?*
3. What issues are you most interested to know about the Chesapeake Bay? And who/where do you go to get this information?
4. Are you familiar with the different report cards developed for the Chesapeake Bay and what do you think about them *(If not, I will explain and show examples)?*
5. What do you think are the benefits of these report card you know of? And what do you see the limitation?
6. How do you think the report card should be use?
7. What other criteria should be included in the report cards? What other human and environmental criteria should be included in the report card?
8. Where/Who do you go to get information about the different criteria of the Chesapeake Bay you mentioned previously?
9. How can the report card generate more support from your community (i.e. other anthropologist? Watermen? Other modelers etc.). *Is it a tool for information? Generate more support for fund raising? For assessment?*
10. What does an improved/restored Chesapeake Bay look like? How should we measure and monitor this improve bay? *Can you see a report card playing a role in doing this?*
11. What have we not talked about in this topic of report cards?

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Education

- Spring 2015 – Spring 2020 **Marine, Estuarine, Environmental Science – Environment and Society.** University of Maryland College Park
PhD Dissertation: The role of socio-environmental report cards in transdisciplinary collaboration and adaptive governance for a sustainable future
- Fall 2010 – Fall 2013 **MSc Marine, Estuarine, Environmental Science – Environmental Biotechnology.** 2013. Institute of Marine and Environmental Technology, University of Maryland College Park
MSc Thesis: *Proteus mirabilis* surface sensing pathway
- Fall 2009-Summer 2010 *Biomedical Science Graduate Program (PhD Program), Medical University of South Carolina*
- May 2010 **MSc Marine Science.** 2010. The Marine Science Institute, University of the Philippines, Diliman
MSc Thesis: Isolation and characterization of algicidal bacteria against *Pyrodinium bahamense* var *compressum*
- May 2004 **BSc Molecular Biology and Biotechnology.** 2004. National Institute of Molecular Biology and Biotechnology, University of the Philippines, Diliman
BSc Thesis: Phylogenetic and molecular characterization of putative strains of *Vibrio harveyi* and *Vibrio campbellii* shrimp pathogens

Fellowships and Awards

- **SESYNC Graduate Research Fellow.** Social-Ecological Network Structures of Lake Erie Water Quality Management, **National Socio-Environmental Synthesis Center (SESYNC)**, University of Maryland, October 2017 – May 2019
- 2019 CERF Biennial Conference Student Travel Award
- Jacob K. Goldhaber Travel Grant, University of Maryland Graduate School, March 2019
- 2018 American Geophysical Union Fall Meeting Travel Awards
- Jacob K. Goldhaber Travel Grant, University of Maryland Graduate School, May 2018
- International Conference Student Support Award, University of Maryland, May 2018

- **Dean of Computer, Mathematical and Natural Sciences (CMNS) Fellowship award**, University of Maryland College Park, 2017
- **Dean's Scholarship in Biomedical Sciences**, Medical University of South Carolina, AY 2009-2010

Work Experience

- **Science Communication Assistant**, Integration and Application Network, UMCES, **2014-2015**
- **Senior Research Associate**, Marine Science Institute, University of the Philippines, **2008-2009**
- **University Research Associate**, Marine Science Institute, University of the Philippines, **2005-2008**
- **Research Associate**, Department of Food Science and Nutrition, UP, **2004-2005**

Peer-reviewed Publications:

- **Vargas-Nguyen, V.**, Kelsey, R. H., Jordahl, H., Nuttle, W., Somerville, C., Thomas, J., & Dennison, W. C. 2020. Using socio-environmental report cards as a tool for transdisciplinary collaboration. *Integrated Environmental Assessment and Management*.
- Laumann, K.M., Nastase, E.A., **Vargas-Nguyen, V.**, Kelsey, R.H., Carew, A., Donovan, E.C., Fries, A.S., Spitzer, S.E. and Dennison, W.C., 2019. Moving beyond the ecosystem in ecosystem health report cards. *Environmental Practice*, 21(4), pp.216-229.
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- Azanza, RV., **VMD Vargas**, K. Fukami, K. Shashank, DF. Onda, and MPV Azanza. 2013. Culturable algalytic bacteria isolated from seaweeds in the Philippines and Japan. *Journal of Environmental Science and Management* 1-10 (Special Issue 1-2013)
- Azanza, M.P.V., R.V. Azanza, **V.M.D. Vargas**, C.T. Hedreyda. 2006. Bacterial endosymbionts of *Pyrodinium bahamense* var. *compressum*. *Microbial Ecology*. Vol. 52, Number 4, November 2006.

Research Experience

- Graduate Research Assistant, Integration and Application Network, UMCES, **2015-2020**
- Graduate Research Assistant, Institute of Marine and Environmental Technology, UMBC, **2010-13**
- Graduate Student, Hollings Marine Laboratory and Medical University of South Carolina, **2009-10**

- Graduate Student, Marine Science Institute, University of the Philippines, **2005-2009**
- Undergraduate Student, Molecular Microbiology Laboratory, UP Diliman, **2003-2004**

Teaching Experience:

- **Course Coordinator.** Developing an ecosystem health report card, Online Course, Integration and Application Network, UMCES, 2019
- **Teaching Assistant,** Marine, Estuarine, Environmental Science Graduate Courses, University of Maryland. Science for Environmental Management (Spring 2015), Science Visualization (Spring 2016, 2018), Coupled Earth and Natural Systems (Spring 2017)
- **Instructor,** Science communication short courses, Integration and Application Network, UMCES, 2016-present

Specialized Courses

- **GEO-SD660 Natural Resource Management,** *distance-learning course, System Dynamics Group, University of Bergen, Fall 2019*
- **Summer Institute on Cyberinfrastructure,** *National Socio-Environmental Synthesis Center, July 22 – 26 2019*
- **Spatial Agent Based Modelling,** *National Socio-Environmental Synthesis Center, June 11 – 15 2018*
- **Introduction to Social Network Analysis,** *National Socio-Environmental Synthesis Center, June 5-9 2017*
- **Science Communication,** *Integration and Application Network, University of Maryland Center for Environmental Science, May 12-14, 2014*

Select Science Communication Products

- Understanding Responses to Global Change (2019). IAN Press, Cambridge, MD, 8pp (Belmont Forum Newsletter)
- Belmont Forum booklet (2017) IAN Press, Cambridge, MD, 12pp (Brochure)
- **Practitioner's Guide to Developing River Basin Report Cards.** 2017. Costanzo, S.D., Blancard, C., Davidson, S., Dennison, W.C., Escurra, J., Freeman, S., Fries, A., Kelsey, R.H., Krchnak, K., Sherman, J., Thieme, M. Vargas-Nguyen, V. (IAN Press E-book)
- Researchers and stakeholders address coastal vulnerability and freshwater security (2017). IAN Press, Cambridge, MD, 8pp (Belmont Forum Newsletter)
- Report cards and system dynamics modelling. 2017. IAN Press, Cambridge, MD, 4pp (Newsletter)

- **Laguna De Bay 2013 Ecosystem Health Report Card. 2016.** IAN Press, Cambridge, MD, 8pp (Report card)

Selected most recent presentations and workshop facilitation (2015-present):

- ***Oral Presentation.*** What's a “restored” Chesapeake Bay? Towards an integrated assessment of Chesapeake Bay and its watershed”. 2019 CERF Biennial Conference, November 3-7 2019, **Mobile, Alabama.**
- ***Facilitation.*** Ecosystem-based management and application of ecosystem values in two river basins in the Philippines Project: Get the Grade Game. June 28, 2019. **Quezon City, Philippines.**
- ***Oral Presentation.*** Using transdisciplinary report cards in solving socio-environmental problems. 79th Annual Meeting of the Society for Applied Anthropology, March 19-23, 2019, **Portland, Oregon**
- ***Facilitation and Science Communication,*** Belmont Forum Synthesis Workshop, Dec 8-10, 2018, **Washington DC**
- ***E-Lighting presentation.*** Ecosystem health report cards as science communication tools: stakeholder perspectives and impacts. 2018 American Geophysical Union Meeting, Dec 10-14, 2018, **Washington DC, USA**
- ***Oral Presentation.*** Ecosystem Health Report Cards in the Chesapeake Bay and its tributaries: management impacts and limitations, stakeholder perspectives and future direction. International Conference on the Environmental Management of the Enclosed Coastal Seas, Nov 4-8, 2018, **Thailand**
- ***Oral Presentation.*** From Random to Resilient: Social-Ecological Network Structures of Lake Erie Water Quality Management. 38th International Sunbelt Social Network Conference, June 26-July 1, 2018, **Netherlands**
- ***Oral Presentation.*** Ecosystem health report cards can be used as tools for ecosystem based management. 2017. Coastal & Estuarine Research Federation 24th Biennial Conference, November 5-9, 2017, **Rhode Island, USA**
- ***Session organizer,*** “Collaboration in practice: Tools for engagement”. 12th Chesapeake Watershed Forum, Nov 3-4, 2017, **Shepherdstown, West Virginia**
- ***Oral Presentation.*** Ecosystem health report cards are science communication tools that can raise stakeholder awareness and influence behavior. 2nd International Marine Science Communication Conference, Dec 6-7 2016, **Bruges, Belgium**
- ***Facilitation and Science Communication,*** Belmont Forum Synthesis Workshop, Dec 9-12, 2016, **San Francisco, USA**
- ***Oral Presentation.*** Presentation for the Upper Potomac Headwaters Report Card 2015. UMCES Watershed Moments Community Learning Series, December 2015, **Frostburg, MD, USA**
- ***Facilitation and Science Communication,*** Laguna de Bay Report Card Workshop, June 2-3, 2015, **Subic, Philippines**

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