Estuaries and Coasts (2018) 41 (Suppl 1):S223–S234
DOI 10.1007/s12237-017-0261-y

Integrating Regional Management Needs into a Mid-Atlantic Shorelines Research Project

Elizabeth Turner[1] **· Thomas Jordan**[2]

Received: 20 September 2016 / Revised: 1 May 2017 / Accepted: 7 May 2017 / Published online: 12 June 2017

Abstract We provide an example of how one estuarine research project engaged regional managers to help guide the research towards the needs of managers and policymakers dealing with shoreline management in the Mid-Atlantic region of the USA. Elements of the approach that contributed to success included a well-targeted initial request for proposals, a review process that included management input both as a review criterion and on the review panel, a careful process in choosing advisory members at the appropriate level in the agencies, regular opportunities for interactions between the management advisory group and the science team, and active involvement of a program manager as liaison throughout the life of the project. Engagement of a management advisory group changed some of the scientific approaches, helped to communicate results, and formed a foundation for incorporation into regional management and initiatives.

Keywords Estuarine management · Shoreline hardening · Stakeholder input · Science to management

Communicated by Cathleen Wigand

Electronic supplementary material The online version of this article (doi:10.1007/s12237-017-0261-y) contains supplementary material, which is available to authorized users.

✉ Elizabeth Turner
Elizabeth.turner@noaa.gov

Thomas Jordan
jordanth@si.edu

[1] National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Room 146 Gregg Hall, 35 Colovos Road, Durham, NH 03824, USA

[2] Smithsonian Environmental Research Center, 647 Contees Wharf Road, Edgewater, MD 21037, USA

Introduction

Estuaries and coastal ecosystems are highly dynamic and productive systems that provide a variety of ecosystem services. Management of these systems requires knowledge of resource population dynamics and ecological processes, but in many cases, estuarine science is not fully or effectively incorporated into coastal management (CSO 2005; ORRAP 2007; Nursey-Bray et al. 2014; Cvitanovic et al. 2015; Coffey and O'Toole 2016). Impediments to integration were identified in a 1995 report by the Ocean Studies Board and include cultural differences between science and management communities, overcoming institutional boundaries, governance issues, and differing time frames for producing scientific results vs. management cycles. These are inherent between the different disciplines of science practitioners and resource managers, and have not changed substantially in more than two decades since that report (Leschine et al. 2003; CSO 2005; McNie 2007; ORRAP 2007).

Several recommendations from various groups have sought to improve interactions between science and management in the coastal zone. These have emphasized the importance of collaboration between scientists and managers or policymakers at every step, from setting research priorities and defining problems to oversight and guidance of ongoing research and ultimately in applications to coastal management (CSO 2005; ORRAP 2007; McNie 2007; Dilling and Lemos 2011). Many also call for specific facilitation of these relationships by boundary spanning organizations in different phases of the process (ORRAP 2007; Matso 2012) or agency personnel themselves (CSO 2005).

Adaptive management (Walters and Hilborn 1978; Holling 1978; Walters and Holling 1990; Walters 1997; Zedler 2017) is a process whereby management is flexible and responsive to scientific advances and stakeholder input. It allows for experimentation with policy approaches with a continual feedback loop between management and scientific analysis of the results from that management. Adaptive management recognizes that a system is dynamic, so a goal is to develop an optimal management capacity, not necessarily an optimal environmental state (Johnson 1999). Scientific questions are usually based on determining how well management approaches are working and science results help to guide future management options. It can require substantial investment and institutional commitment in a complex process that includes a wide variety of stakeholders (Williams and Brown 2014).

The process we describe is less comprehensive in scope than a full adaptive management approach. Instead of engaging a full spectrum of all potentially affected stakeholders, it focused on a smaller objective of linking managers and scientists during the implementation of a research program. It also functioned in the opposite direction—instead of management adapting to scientific results, an ecological research project sought to learn from managers and adapt their science to management needs. Relatively few concrete examples exist of this type of integration where management advice can steer ongoing coastal ecosystem science projects (but see examples in Leschine et al. 2003; Carney et al. 2009; Saarman et al. 2013; Matso and Becker 2014; De Lorme et al. 2016). This paper will provide one example of a program that attempted to create a mechanism to engage regional managers in a scientific study of the effects of shoreline hardening on Mid-Atlantic coastal ecosystems. It is not intended to be an exhaustive review on the subject of linking science to policy and management but complements the other papers in this issue by providing management context for the science results.

Our goal is to provide an example that other estuarine science programs can use to structure their own processes for engaging managers and drive their own research towards outcomes that are useful in the management context. De Lorme et al. (2016) called out for more examples of collaboration between scientists and managers, and we offer this as one case study. We describe how management needs drove the development of the science program's request for proposals (RFP), outline the formation of a Management Transition Advisory Group (MTAG) for a specific project and its responsibilities, discuss how the functions of the MTAG differed in different phases of the project, and provide some results of the interactions between the MTAG and science personnel.

Methods

Formulation of Research Issues and Proposal Review

Engagement of management needs into this science program occurred before the start date of the individual project funded and continued after the end date of the project (Fig. 1). The first stage of engaging regional managers began prior to the request for proposals issued by the National Oceanic and Atmospheric Administration (NOAA). National reports (Ocean Studies Board 2007) recommended research to understand the ecological impacts of hardened shorelines. A regional workshop that included both managers and scientists (STAC 2006) highlighted the primacy of this issue in the Mid-Atlantic region. Both reports highlighted a need for knowledge of sheltered shoreline processes and ecological services and the cumulative effect of many individual small-scale shoreline erosion control measures.

To respond to these stated research needs, the NOAA National Centers for Coastal Ocean Science issued a request for proposals (see electronic supplement for RFP: NOS-NCCOS-2008-2001064) entitled "Cumulative Impacts of Stressors at the Land-Water Interface in the Mid-Atlantic". The announcement requested proposals "for a regional-scale ecosystem research study investigating the cumulative impacts of multiple stressors at the land-water interface of estuaries and bays on recreationally, economically, or ecologically important living resource populations and communities." Proposers were required to identify management issue(s) addressed by the research and to specify how results could "address the needs expressed by managers for information that could allow them to manage the problem of protecting and/or restoring these fringing ecosystems, and the living resources that depend upon their integrity, in a regional framework." The RFP defined management tools widely, including research syntheses and models. The proposal had to identify the end user group explicitly and include participation of co-investigators from both scientific and management entities.

The proposal review process in 2008 included resource managers as well as scientific experts. The final review panel comprised two scientists from Federal agencies involved in applied coastal research, two state agency representatives who manage coastal wetlands and shorelines and one academic researcher with expertise in coastal and marsh ecology. In addition, each proposal was evaluated by mail prior to the panel meeting, with at least one, and sometimes two of three outside reviewers being a resource manager. Review criteria for both mail reviews and the panel included a factor that evaluated evidence of managers being involved in the formulation of the scientific questions and projected outcomes (ORRAP 2007; Matso 2012). The project that was ultimately funded was entitled "*Predicting Impacts of Stressors at the Land-Water Interface*" and was active from 2009 to 2016. It was a collaborative proposal among the Smithsonian Environmental Research Center, University of Maryland, University of Delaware, Virginia Institute of Marine Science, Pennsylvania State University, US Geological Survey, US Army Corps of Engineers, and Maryland Department of Marine Resources. In addition to high scientific merit, the collaborative team demonstrated evidence of the involvement

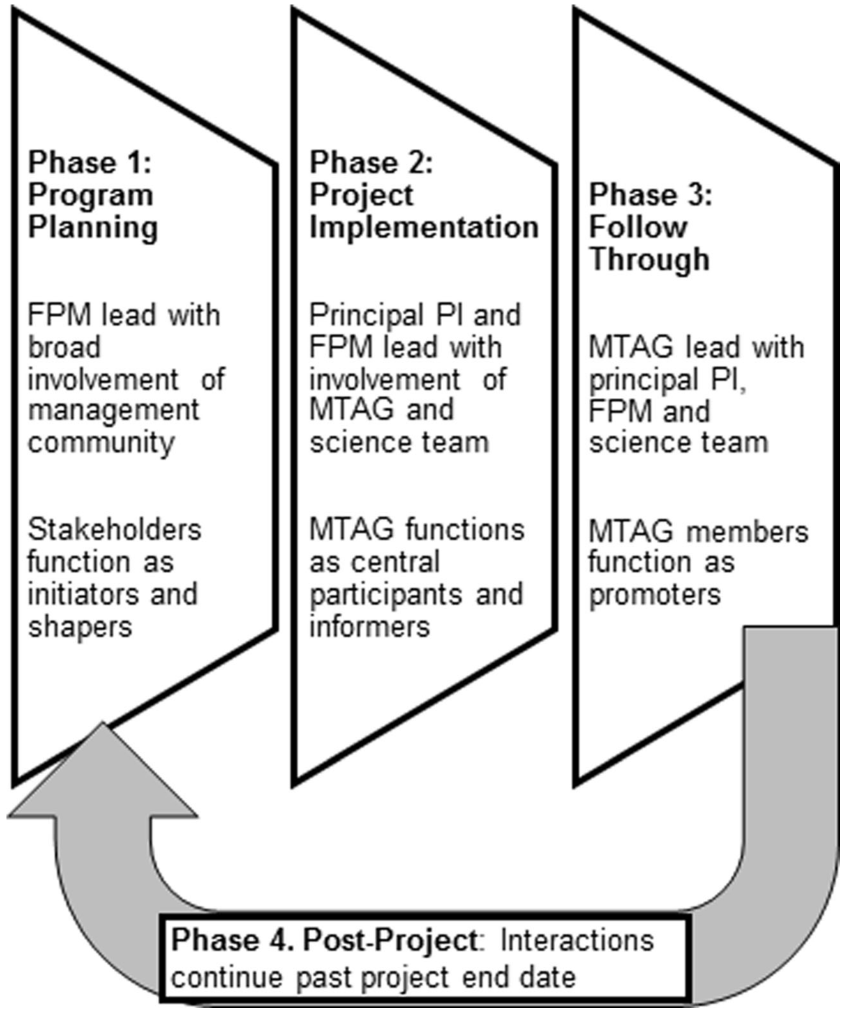

Fig. 1 Management engagement strategy. FPM = Federal Program Manager, PI = Principal Investigator, MTAG = Management Transition Advisory Group. In phase 1, the FPM led program planning that included science synthesis and workshops, RFP development and inclusion of proposal reviewers and review criteria stressing management needs. In phase 2, the lead PI was in charge of project implementation with the FPM and recruited appropriate MTAG members with regular opportunities for feedback and time for informal trust-building. In phase 3, the MTAG led follow through to make opportunities available for communication of results and incorporation of results into management actions. In phase 4, all actors continued to communicate to use results in setting future priorities for action and generating new science ideas

of managers in formulating the research questions, with letters of support from the Chesapeake Bay Program, Chesapeake Bay Foundation, Maryland Department of Natural Resources, and the Virginia Marine Resources Commission. The proposal included a plan to form a management and technical advisory committee to meet annually.

The overall goal of the shorelines project was to increase knowledge of the combined effects of shoreline hardening, watershed land-use, water clarity, diel hypoxia, and *Phragmites* invasion of tidal wetlands on habitat quality for submerged aquatic vegetation (SAV) and estuarine fauna (Prosser et al. 2017). To address this array of subjects, the project was divided into four working groups with these foci: water quality, wetlands, SAV, and macrofauna (including: benthic invertebrates, gelatinous zooplankton, fish, crustaceans, and waterbirds). All the working groups interacted and all, except water quality, included researchers from more than one institution.

The research compared a number of sub-estuaries of the Chesapeake Bay and coastal bays along the Mid-Atlantic coast (Prosser et al. 2017). Each sub-estuary (an embayment at the mouth of a tributary stream) has its own local watershed. Sub-estuaries differ widely in their watershed land uses and occur across the full range of salinity, making them convenient, replicated study units for comparing systems dominated by different land uses and salinity regimes (e.g., Li et al. 2007; Patrick et al. 2014). The comparisons spanned a range of spatial scales. At the broadest scale, there were comparisons of more than 100 Chesapeake Bay sub-estuaries and Delmarva coastal bay systems to relate SAV distribution to shoreline type, sediment characteristics, geomorphology, wave energy, watershed land-use, and other factors (e.g., Patrick et al. 2017). Field studies compared selected sub-estuary and bay systems with watersheds dominated by forest, agriculture, or developed land. Comparisons at the sub-estuary scale provided insights into system-wide responses to whole system characteristics, such as watershed land use (e.g., Jordan et al. 2017) and shoreline composition. At finer spatial scales, comparisons of habitats and fauna adjacent to different shoreline types contrasted riprap, bulkhead, shallow beach, and tidal wetlands with or without invasive *Phragmites* (e.g., Landry and Golden 2017; McCormick et al. 2017, Hazelton et al. 2017).

Formation and Utilization of the Advisory Group

Once the NOAA shorelines project began in fall 2009, the lead Principal Investigator (PI) arranged an initial meeting of stakeholders in the spring of 2010. This included more than 30 representatives of the states of Delaware, Maryland and Virginia; Federal agencies (US Army Corps of Engineers, US Fish and Wildlife Service, NOAA Chesapeake Bay Office) and non-governmental organizations (The Nature Conservancy, RiverKeepers) along with project scientists and the NOAA program manager. The meeting provided an overview of the project's objectives and had breakout groups structured along the main areas of interest (SAV, macrofauna, wetlands, water quality). The breakout groups were charged with compiling needs of the management organizations that could be met by the project, and defining what the most useful research products might be. The managers in attendance were most interested in prioritizing habitats for restoration and demonstrating the importance of (unhardened) shallow habitats to the entire bay system, compared to altered shorelines. Useful research products included projections of habitat changes due to shoreline hardening and decision trees to help in deciding when to allow hardened structures for erosion control vs. when to build living shorelines. Annual meetings were recommended to update managers on research projects. This initial meeting with broad stakeholder participation was a one-time event but helped to identify interested parties and good candidates for an ongoing management advisory group that could help to guide the project and be involved in outreach to more local planning boards and individual landowners.

The project's lead PI and the Federal program manager used input from the stakeholder meeting to develop a Management Transition Advisory Group (MTAG). The MTAG would advise the program scientists on management priorities and information needs, and how to direct and package research results for optimal utility (see examples in results section). This group was not directly involved in the research itself but had evolving responsibilities during different phases of the research project. Overall, the MTAG had four goals (Fig. 2):

1. Offer suggestions on research questions and approaches,
2. Be engaged throughout the life of the project,
3. Provide feedback from management on interim science results, and
4. Assist in translation and transmission of scientific findings to management agencies.

The formation of a MTAG involved a deliberate process led by the NOAA program manager (PM) with input from the project's lead PI. The findings from the project were intended to provide a basis for environmental management decisions by state resource management agencies, Federal agencies, and organizations involved in coastal and estuarine management. A main management decision point related to the project is the permitting of shoreline structures, especially hard structures such as bulkhead and riprap. Therefore, the PM looked to recruit MTAG members from Maryland, Delaware, and Virginia state agencies involved in shoreline permitting decisions. To span the geographic range of the research, MTAG members were sought from the Delaware Inland Bays and Maryland Coastal Bays programs as well as from programs related to Chesapeake Bay waters. The MTAG was not designed to have individual representatives from every stakeholder group with an interest in altered shorelines. Representing all stakeholders in a workable advisory group would be extremely difficult and would risk unfocused input. However, MTAG members did have communication lines set up with their own stakeholder groups and local communities and could provide input from them.

Several attributes were considered desirable in prospective MTAG members. First, in connecting science to management, it is important to engage people at the appropriate level in management organizations (Jacobs et al. 2005). For the shorelines project, this was judged to be a middle level in the management structure—if the candidates were at a high management level in the organization, they were thought to be less available and less able to be engaged; if they were too low or new in the organization, their involvement might not be impactful. It was also important for MTAG members to have experience working at the interface of science and policy and to be available through the entire project duration. Finally, it was important that the candidates have sociable personalities and be good communicators so they would be able to reach out to other managers outside of the MTAG. The MTAG needed to be small enough to function effectively while still reaching enough people to provide varied input from a wide range of potential users.

The process of recruiting MTAG members took nearly one full year from the initiation of the project. It involved several phone meetings between the lead PI and the PM to determine the desired size, scope, and breadth of the MTAG; and numerous phone calls with prospective MTAG members to describe their level of commitment. MTAG members needed time to get permission from their supervisors, given the time commitment to MTAG and the lack of financial support from the shorelines project, except for travel funding.

The final MTAG included seven members with representatives from the Delaware Department of Natural Resources and Environmental Control, the Maryland Department of Natural Resources and the Maryland Critical Areas Commission, the Virginia Marine Resources Commission, The US Fish and Wildlife

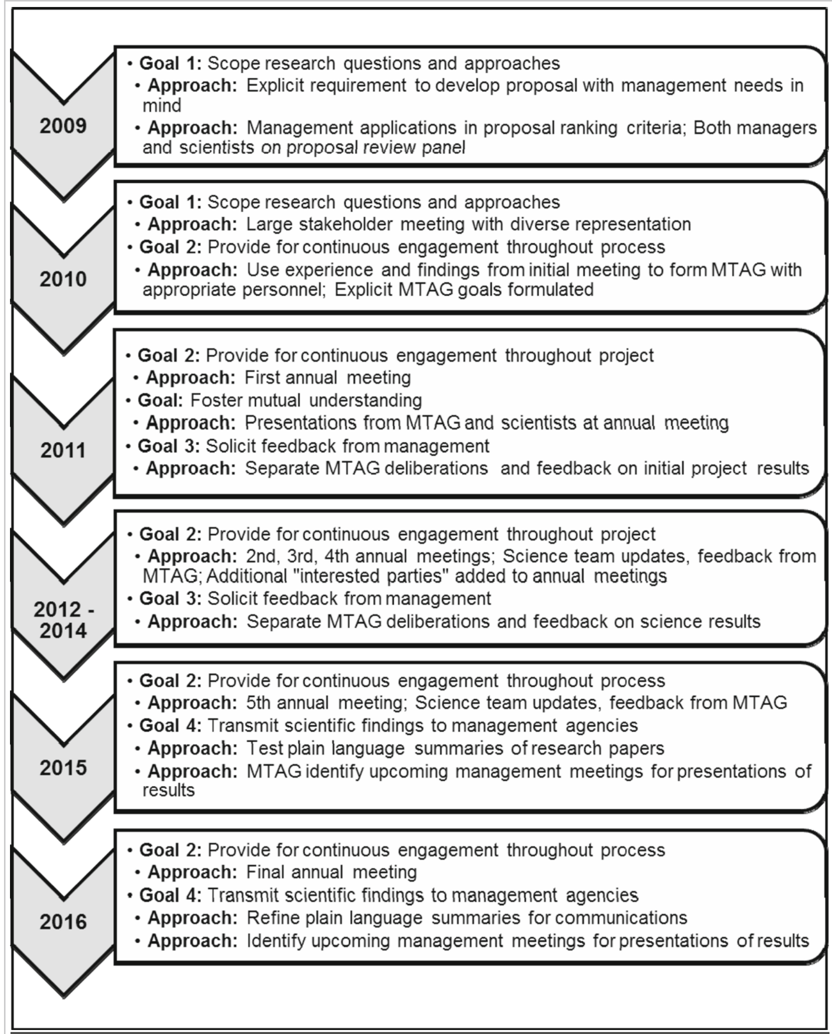

Fig. 2 Evolution of the management transition advisory group (MTAG) during the project implementation phase. The MTAG addressed different goals at different stages in the course of the project. Goal 1 was addressed in the early years (2009–2010), goal 2 carried through all years (2009–2016), goal 3 was addressed in the middle years (2011–2014), and goal 4 was addressed in the final years (2015–2016)

Service, and the Delaware Inland Bays Program and Maryland Coastal Bays Program. In addition, representatives from the NOAA Chesapeake Bay Office, the US Army Corps of Engineers, the US Geological Survey, and the regional multi-state Chesapeake Bay Program were invited to annual project meetings and participated in some MTAG discussions.

Annual meetings held during the course of the project allowed periodic updates (Fig. 2). Meetings were typically 1.5 days long and included a social event during the evening of the first day. Not only did this provide advice throughout the life of the project but it fostered an ongoing growth of trust between the MTAG and the scientific team. Science groups updated the MTAG on their plans, and then the MTAG met separately to consider how they might help to advise the project going forward. The NOAA program manager served as a facilitator for MTAG discussions. While the MTAG met separately, the science team met to discuss more logistical aspects of sampling and field plans, with the project principal investigator serving as facilitator. After the separate groups met, they reconvened and the NOAA program manager served as a liaison to report MTAG recommendations to the science team. During the field studies in 2012–2014 the MTAG received updates from the science teams and reacted to the science findings in a separate group, then reported back to the science team. By the end of the project, it was felt that there was no need to have separate meetings of the science team and MTAG.

As the project progressed, other "interested parties" from management agencies were invited to the annual meetings, such as representatives from the US Geological Survey, a representative from a terrapin conservation group, and additional personnel from the NOAA Chesapeake Bay Office and the NOAA lab in Oxford, MD. These additional management representatives were not considered part of the ongoing MTAG but offered their input in a more ad hoc way through verbal comments captured in meeting minutes.

Results

Incorporation of MTAG Input to Science Project

The MTAG met with the project scientists to identify promising avenues of research with the most potential for management applications, and potential study sites that would be of most management interest. The MTAG also identified the timing of particular management decisions and how pertinent research results could fit into that timeline. As the project advanced, the MTAG tracked the progress of the research and offered suggestions on how to focus research activities to best meet management needs. Throughout the project, but especially during the synthesis phase, the MTAG provided insights on communication and transition of the research results.

The first meeting of the MTAG occurred in 2011, just after most of the field studies had started. The MTAG developed and approved terms of reference that explicitly identified the purpose and responsibilities for the MTAG. The MTAG was able to provide advice on site selection and coordination of sampling among the project's science groups. For instance, the MTAG recommended the addition of field sites that included sills and expanding the number of living shoreline sites. They also recommended common designations for sampling locations and watershed land uses for all the research subgroups, to facilitate site comparisons across subgroups. The science group incorporated these recommendations into future field work. Some recommendations were harder for the science group to incorporate, such as including sea level rise scenarios into the project. Since sea level rise was not one of the stressors in the original proposal, there was little capacity in the science group to include it, even though it was of interest to the MTAG.

The initial meeting also included presentations from MTAG members to describe to the science team what issues they address, the management decisions they make, and the timescales of those decisions. For instance, the MD Critical Areas Commission deals with habitat protection for significant plants and wildlife and evaluates buffer management plans for shoreline permits. The MD Coastal Bays program focuses on restoration activities and spends time with local landowners describing the ecological benefits of natural vs. armored shorelines. While both groups have interests in shoreline hardening, their specific usage of the research results vary. The development of mutual understanding between science personnel and management advisors was crucial to the rest of the project's success (see also Hartley and Robertson 2006).

As the project scientists began their analysis of data, the MTAG was able to recommend different ways of looking at the data that would be useful for their purposes. For example, understanding that the MTAG was interested in community level indices rather than individual species responses was helpful in defining metrics for analysis. The MTAG also endorsed the project's approach to regional analyses based on sub-estuary comparisons, as they felt that management actions were taken on the sub-estuary scale, but management goals were set for Chesapeake Bay as a whole. Understanding sub-estuaries in a regional context was of key interest to the MTAG.

For communication purposes, the MTAG recommended the use of conceptual models for outreach to the management community rather than a long and detailed written synthesis (Liu et al. 2008; Kragt et al. 2013; De Lorme et al. 2016). MTAG members felt that managers busy with day-to-day activities would not read a long synthesis of the research results, or even a series of shorter scientific syntheses, no matter how interested they might be. An example is provided in Fig. 10 in Kornis et al. 2017a that includes shoreline hardening and land use (developed and cropland) and traces positive or negative relationships between these drivers and water clarity, primary production and SAV, and ultimately to groups of affected macrofauna. By representing these relationships on one diagram with simple positive and negative arrows, it conveys a great deal of information in one drawing.

The scientific team members were committed to preparing scientific publications from their research (this volume is a good example). However, these would not be suitable for management outreach, as the MTAG considered that managers would not have the time to delve deeply into scientific publications. Instead, they recommended "plain-language" summaries of publications or short statements of major findings that managers could assimilate easily. Managers were the main audience identified for these, although stakeholders at large might also be interested. At the final meeting in 2015, the project team developed a list of publications and plain-language summaries of each publication's main findings. For instance, a 15-page publication (Patrick et al. 2014) on the effects of shoreline alteration on SAV (SAV) was summarized in a few lines:

"We related the abundance of SAV in sub-estuaries to the prevalence of shoreline hardening and to watershed land cover, shoreline land use, and other potential stressors. Major findings include:

1. SAV abundance in a sub-estuary is negatively related to agriculture and development in its watershed and to armoring of wetlands along its shoreline.
2. Wetlands and forest in the watershed and forested shoreline were all positively related to SAV abundance in a sub-estuary.
3. Since 1984, SAV abundance has continued to increase in sub-estuaries with less than 5.4% riprap but not in sub-estuaries with more riprap.
4. SAV responses to stressors differed among salinity zones, probably because the zones are dominated by different SAV species."

Applications of Scientific Results from the Project

A major outlet for findings from the NOAA shorelines project is the Chesapeake Bay Scientific and Technical Advisory Committee (STAC). This is a body that advises the Chesapeake Bay Program (CBP), a multi-state and Federal partnership that leads and directs Chesapeake Bay restoration and protection. In addition to the STAC, the CBP has six topical Goal Implementation Teams (GITs), which focus on Sustainable Fisheries, Habitat, Water Quality, Watersheds, Stewardship and Partnering. At the end of the project's term, the MTAG began to get more explicit about what meetings to target in order to communicate research results to the STAC and the GITs, especially the Sustainable Fisheries GIT, the Habitat GIT and the Water Quality GIT. The MTAG identified upcoming meetings of these groups for project scientists to present their results. Because members of the MTAG sat on or were connected to these management groups, they were able to facilitate scientific presentations at their meetings.

To date, the project has provided input to the Sustainable Fisheries GIT, and project results have implications for Habitat, Water Quality and Watersheds (see other papers in this issue). One of the MTAG members worked directly with Mid-Atlantic Fisheries Management Council (MAFMC) staff to highlight the project and its importance for understanding habitat effects on fisheries. MAFMC is developing a guidance document on Ecosystem Approaches to Fisheries Management. Project results have contributed to the Habitat Section of the document, which should help to broaden the impact of this project beyond the Chesapeake.

In addition to regional management through the Chesapeake Bay Program and the MAFMC, project scientists have integrated a subset of their findings into a NOAA Habitat Focus Area (HFA) in the Choptank River. This program centers on native oyster restoration in three of the Choptank's major tributaries, the Little Choptank River, the Tred Avon River, and the Harris Creek. The NOAA shorelines project had sampling sites in the Choptank before the selection of the Choptank as a target HFA. Data on these sites from the shorelines project are being incorporated into activities and outreach under the HFA, including a detailed assessment of ecosystem conditions and threats. The HFA is also engaging in a common visioning process for the protection and restoration of the Choptank watershed, and the "plain-language" summaries and conceptual models are useful for this type of outreach, as they provide a more accessible version of results that can be synthesized for communication purposes. Finally, the NOAA shoreline project's annual meetings provided opportunities for representatives from the Choptank HFA to hear the project's latest findings and for project scientists to be updated on the HFA initiative as it developed and consider how their results could be used in the context of the Choptank oyster restoration efforts.

Discussion

Management—Science Interaction Context

This project exemplifies scientific research with targeted outreach rather than co-production of knowledge (Harris and Lyon 2014; Schuttenberg and Guth 2015; Puente-Rodríguez et al. 2016). Pohl (2007) recognized two types of interactions between the academic sector and other societal sectors: one (like the shorelines project) that *reorganizes knowledge* aimed at policy decisions, synthesizing academic information for use by community representatives; and one that is a *co-production of knowledge*, where the interaction among all stakeholders is an integral part of research informing a particular public policy decision. Our project aimed to provide scientific syntheses and knowledge in a form useful to managers but did not fully involve all stakeholders in knowledge production. Thus, our project is an example of "reconciling supply and demand for science" (Sarewitz and Pilkey 2007), where project PIs function as "science arbiters" (Pielke 2007). In a full co-production of knowledge, scientific information is used as part of a public decision-making process, and an aim is to have input from a wide range of stakeholders (Harris and Lyon 2014).

In the Mid-Atlantic shorelines project, it was not feasible to include a wide swath of public participation. The goal was not to completely examine all policy issues surrounding shoreline management but to provide information to managers on the ecological impacts of shoreline modification in the context of other stressors. Both this approach and the co-production of knowledge have utility, and the different approaches are useful in different situations (Runhaar et al. 2016). Because the Mid-Atlantic shorelines project had more focused goals than a full societal assessment and goal-setting exercise concerning shoreline hardening, a strategy targeted more specifically towards management applications seemed appropriate. This is why the advisory group was named the Management Transition Advisory Group instead of a Stakeholder Advisory Group. The intent was to inform shoreline management practices with the science results, not to completely include all stakeholder interactions around the issue.

The NOAA shorelines project was conceived to provide information to support decisions about shoreline and watershed management in the Mid-Atlantic region. Scientific results could be applied in evaluating individual permit applications, setting overall limits for the total amount of shoreline that might be permitted in a particular sub-estuary, and/or communicating with landowners about impacts of their individual projects. In this objective, it was more broadly focused than projects attempting to bridge science and management by producing a discrete tool for managers with specific application (De Lorme et al. 2016) or incorporating science advice into a management context in a highly structured decision process (Saarman et al. 2013). The MTAG did not recommend a web-based modeling tool. The shorelines project was not identifying specific areas for management actions (e.g., using a GIS-based tool such as those produced by NOAA's Digital Coast (https://coast.noaa.gov/digitalcoast/)) nor was it examining a range of future scenarios (e.g., using a dashboard-type tool such as http://tippingpointplanner.org/). The MTAG did discuss developing a decision tree but several of the decision points were far beyond the scope of this project. Many other factors go into decisions around shoreline management including permitting issues, landowner perceptions, education of contracting firms, differential costs of materials and labor, etc., and it was felt that what was really needed was a synthesis of information from this project in modes that were accessible to management. In this respect, the shorelines project was more concerned with conceptual effects than instrumental effects (sensu Rudd et al. 2011). Instrumental effects contribute to specific policy or management decisions in the short term, whereas conceptual effects develop knowledge and understanding that informs decision making over a longer time frame.

Many examples of science-management collaboration are designed not only to get scientific results, but also to build consensus and trust among various groups around an issue (Hartley and Robertson 2006; Berkes 2009; Dilling and Lemos 2011; Trimble and Berkes 2013). In the case of the NOAA shorelines project, the scientific group had a history of working productively with regional management and there was a mutual level of trust already established. This was evaluated as part of the review criteria for the initial request for proposals and was a key factor in the success of the research proposal through the initial review process. Those connections were only strengthened and extended through the work of this project.

Phased Approach to Management Input

Scientific results from the shorelines project are being used in multiple applications rather than one project-wide application. This requires a multi-pronged approach to management engagement, which was facilitated by different agents during different phases of the process (Fig. 1). Carney et al. (2009) identify several ways that stakeholders can interact with science projects (in their case, climate change research). As discussed below, the shorelines project included many of these roles at different times in the process.

In the program, planning phase (phase 1, Fig. 1), the purpose of engaging management was to identify and prioritize science questions and ensure that management needs were included in the proposal review process. The main stakeholder role was as "initators" and "shapers" (sensu Carney et al. 2009). The funding program and federal program manager (FPM) led efforts to incorporate management input into the resulting RFP. Research priorities were identified through workshops and national reports with a broad reach to the management community. These broad needs were refined with a regional workshop and report (STAC 2006) targeted towards the Mid-Atlantic. While the science and management communities both had input to this process, it was important to keep specific planning within the funding program, as conflicts of interest could result from having research priorities set by those who would ultimately be applying for the research funding.

During development of the RFP, the FPM and funding program included not only the science priorities identified by managers but also the requirement to involve managers in the proposed work (see RFP in electronic supplement). This was clear in the review criteria (Matso and Becker 2014), where 30% of the review score depended on proposers to identify the specific research results that would apply to needs expressed by managers. An additional 10% of the score related to a demonstration of "clear connections to management entities that will use the results of the proposed work and define the specific products, outcomes and timing of the proposed work that will be used in achieving this goal." The remaining score was based on scientific merit (30%), qualification of applicants (20%), and project costs (10%). Management input was also included in the review process for proposals by soliciting external reviewers and panelists from coastal management agencies at the Federal and state level, as noted in the methods section above.

The lead PI from the project and the FPM shared responsibilities for management engagement once the implementation phase began (phase 2, Fig. 1). This phase emphasized the engagement of managers for the science team to learn about specific needs associated with shoreline management decisions and for the MTAG to provide feedback on science approaches. It involved the initial workshop, recruitment of individuals to serve on the MTAG, clarifying roles and responsibilities for the MTAG, scheduling regular interactions with opportunities for informal trust building, and facilitating discussions between the science team and the MTAG. Participants in the initial workshop could be considered "informers" (Carney et al. 2009). They provided input and advice in the initial stage of the project that helped to clarify project approaches and set a tone for eventual information products.

Once the MTAG was initiated, this process became more of a group interaction among the PI, FPM, MTAG, and project scientists. During this phase, the MTAG gave feedback on project approaches and findings, offered suggestions for further study and helped to create main messages from the science results that would resonate with managers. Therefore, the MTAG served Carney et al.'s (2009) "central" role as shapers of the science approach, reviewers of the information being produced, recipients of findings, and reflectors on the scientific approach and ideas for further study.

The application phase (phase 3, Fig. 1) emphasizes outreach and utilization of the results by MTAG members and extends past the end date of the project. It depends on the continued involvement of the MTAG with the FPM and the science PIs. MTAG members identify venues for the science results to be presented to management bodies and use scientific results in their deliberations and policymaking. This is very difficult to quantify, as MTAG members may be influenced in many ways by the science and there is rarely a direct path from a science result to a specific management decision. This type of interaction was not specifically identified by Carney et al. (2009) but could be characterized as "promoter" or "ambassador", since they actively promoted the dissemination of research results in their own management orbits.

An additional post-project phase (phase 4, Fig. 1) is not often highlighted in reports of science-management connections, but it serves crucial functions. It allows the science results to have impacts far beyond the end date of the project. In most cases, the scientists and managers will continue to interact in other venues, and knowledge gained from a specific project can be propagated beyond the original intent of the proposal. New scientific ideas can be generated through the connections fostered during the course of the project, which then feed back into the program planning phase for a subsequent project.

Challenges Encountered

One challenge in integrating science and management for this project was that the management landscape evolved during the project through different state administrations. As state administrations turned over after elections, they had differing approaches to environmental policy and installed different personnel in their coastal management agencies. Sustained involvement of MTAG members could have been a challenge. Because the membership was targeted towards middle-management rather than agency heads, most of the MTAG representatives remained consistent throughout the project, although their agencies changed direction somewhat based on gubernatorial election results. This emphasis on middle-level managers allowed the MTAG to provide advice grounded in their day-to-day interactions with both their upper-level management and the wider stakeholder community for their agency.

Another challenge for this project was applying results towards local actions, mostly at the county level where much of the permitting and on-the-ground shoreline alteration occurs. The involvement of local permitters could have been more robust, with targeted information products specific to their needs. However, the project was designed to work on the regional level. Finding one or two county representatives that could articulate needs for the entire Mid-Atlantic region would be a problem, and expanding the size of the MTAG to incorporate representatives from every locality was not feasible. Furthermore, the project would not have been able to produce individualized science products for every locality, as the strongest relationships were uncovered by analyzing data that looked across the whole bay, rather than a single sub-estuary (Jordan et al. 2017, Hannam et al. 2017, Kornis et al. 2017b, Landry and Golden 2017, Prosser 2017). One of the initial recommendations from the MTAG was support for the project's focus on the sub-estuary scale, which was thought to be the most fruitful spatial scale for investigation of multiple stresses in a regional context. These regional-scale analyses are more useful to wider-scale management efforts under the Chesapeake Bay Program.

A significant challenge in applying science from the Mid-Atlantic shorelines project to management is the time lag between management adoption and research findings (OSB 1995; Kates et al. 2001; CSO 2005; Cash et al. 2006; McNie 2007; ORRAP 2007). Scientists genuinely want their results to be used to inform management and policy decisions, but policy changes do not happen on the same time frames as scientific progress nor is a scientific result the sole driver for policy change. In the case of shoreline management, the project was able to provide evidence of interactions between watershed development, shoreline type, and ecological impacts (see other papers in this issue). Results from this project will be influential in providing information and will be impactful beyond the end date of this individual project, but immediate changes to policy were not possible during the time frame of the project. However, there is an opposite timing challenge as well, in that some scientists were reluctant to bring their research results to managers before thorough analysis was completed.

Continued involvement with the Chesapeake Bay Program STAC and other information outlets will be needed to fully capitalize on the research. Future communications are made easier by the history of collaboration by the science team, and new connections were made through the MTAG.

The challenges above involve the application of science in a management context, with the flow of information going from science results to management applications. However, the MTAG did not have a specific goal of implementing new management based on the science findings (see the four MTAG goals above and in Fig. 2) but to influence the science program as it was ongoing. Therefore, an important flow of information was going in the other direction, from management advisors to scientists. The MTAG members listened to research presentations and were informed by them. Then, the MTAG informed the science team about which findings were most relevant to management and suggested what directions would be most fruitful to pursue.

The MTAG was quite successful in providing advice to guide the science program (see examples given in results section). However, some challenges still remained. In particular, the proposal goals were set and the research team was in place to address those goals before the MTAG was initiated. It was difficult to modify these goals once the project was in progress. For instance, the MTAG was interested in diamondback terrapins, which are classified as a "species of greatest conservation need" in Maryland. While the field teams did manage to collect some presence/absence data on terrapins, the original proposal did not include terrapins as target species and the science team had little expertise (or extra resources) to apply to terrapins. A comment from one of the project participants expresses this dilemma: "The questions and approaches were already defined in the successful proposal and award. Many MTAG suggestions for changes or additions couldn't be implemented because of data or resource limitations". And, "It would have been helpful to have their involvement at the PROPOSAL phase, though I'm not sure how possible that would be. Assembling such a team prior to submitting a proposal would be a huge time investment, with little assurance of a return".

Conclusions

Notwithstanding these challenges, the project was able to address several needs articulated by the MTAG. The project's regional approach with a focus on sub-estuary comparisons aligned with MTAG interests. The science team was able to make modifications to their sampling and analyses based on MTAG recommendations. Perhaps most importantly, the MTAG was able to suggest venues and formats for the science to be communicated to regional management bodies, and the results are being incorporated into the Chesapeake Bay Goal Implementation Teams, planning for NOAA HFAs, and state management efforts. Without a MTAG for this project, it is unlikely that these outcomes would be as plentiful or as impactful.

The MTAG was an important component of the NOAA shorelines project. Elements of the approach that contributed to success included:

- a well-targeted initial request for proposals that required a management advisory group,
- a review process that included management input both as a review criterion and on the review panel,
- a careful process in choosing MTAG members at the appropriate level in the agencies,
- regular opportunities for interactions between the MTAG and the science team, and active involvement of the NOAA program manager as liaison throughout the life of the project.

More projects are adopting ways of integrating managers and policymakers with scientists, and every situation will require approaches tailored to their geographies, issues, governance structures, and personnel. Not every science program can implement a full adaptive management approach, or involve managers in all phases of the initial planning of the science proposal in a joint fact-finding enterprise. This case study provides an example of targeted engagement that influenced a science program to help make its results applicable to managers. Similar efforts should be encouraged to enhance the utility of coastal science and provide information to sustain coastal ecosystems for future generations.

Acknowledgements This project was supported under a grant from the National Oceanic and Atmospheric Administration (NA09NOS4780214). This is publication number 17-015 of theNOAA/CSCOR Mid-Atlantic Shorelines project. The opinions provided are those of the authors, not an official position of the National Oceanic and Atmospheric Administration. The authors thank Alan Lewitus, Diann Prosser, and three reviewers for extremely helpful and constructive comments.

References

Berkes, Fikret. 2009. Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management* 90 (5): 1692–1702.

Carney, Sebastian, Lorraine Whitmarsh, Sophie A. Nicholson-Cole and Simon Shackley. 2009. A dynamic typology of stakeholder engagement within climate change research. Tyndall centre for climate change research working paper 128. http://www.tyndall.ac.uk/sites/default/files/wp128.pdf. Accessed 1 Feb 2017.

Cash, David W., W. Neil Adger, Fikret Berkes, Po Garden, Louis Lebel, Per Olsson, Lowell Pritchard, and Oran Young. 2006. Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecology and Society* 11 (2): 8 URL: http://www.ecologyandsociety.org/vol11/iss2/art8/.

Coffey, Brian, and Kevin O'Toole. 2016. Exploring the role of science in coastal and ocean management: a review. In *Chapter 3 in. Science, information, and policy Interface for effective coastal and ocean management*, ed. Bertrum H. MacDonald, Suzette S. Soomai, Elizabeth M. DeSanto, and Peter G. Wells, 47–74. Boca Raton: CRC Press.

CSO (Coastal States Organization). 2005. Translating science into management: challenges and opportunities for the coastal community.

http://www.calwater.ca.gov/CALFED_LMS/lms/Content/calfed/library/Translating_Science_Into_Managment_Coastal%20State%20Org.pdf. Accessed July 2016.

Cvitanovic, Christopher, Alistair J. Hobday, Lorrae van Kerkhoff, Shaun K. Wilson, Kirstin Dobbs, and N.A. Marshall. 2015. Improving knowledge exchange among scientists and decisionmakers to facilitate the adaptive governance of marine resources: a review of knowledge and research needs. *Ocean & Coastal Management* 112 (2015): 25–35.

De Lorme, Denise E., David Kidwell, Scott C. Hagen, and Sonia H. Stephens. 2016. Developing and managing transdisciplinary and transformative research on the coastal dynamics of sea level rise: experiences and lessons learned. *AGU Earth's Future.* doi:10.1002/2015EF000346.

Dilling, Lisa, and Maria Carmen Lemos. 2011. Creating useable science, opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change* 21 (2): 680.

Hannam, Michael et al. 2017. Submerged Aquatic Vegetation Depth Distribution Varies with Watershed Land Use in the Chesapeake Bay. Estuaries and Coasts in revision

Harris, Frances and Fergus Lyon. 2014. Transdisciplinary environmental research: a review of approaches to knowledge co-production. Nexus Network Think Piece Series, Paper 002. http://www.thenexusnetwork.org/wp-content/uploads/2014/08/Harris-and-Lyon_pg.pdf. Accessed 30 Jan 2017.

Hartley, Troy, and Robert A. Robertson. 2006. Emergence of multi-stakeholder-driven cooperative research in the Northwest Atlantic: the case of the Northeast Consortium. *Marine Policy* 30 (5): 580–592. doi:10.1016/j.marpol.2005.09.006.

Hazelton, Eric J., et al. 2017. Seedbank composition in native and Phragmites-invaded Chesapeake Bay marshes: potential for passive revegetation following herbicide treatment. Estuaries and Coasts in revision

Holling, C.S., ed. 1978. *Adaptive environmental assessment and management*. Chichester: Wiley.

Jacobs, Katherine, Gregg Garfin, and Melanie Lenart. 2005. More than just talk: connecting science and decisionmaking. *Environment* 47 (9): 6–21.

Johnson, Barry L. 1999. The role of adaptive management as an operational approach for resource management agencies. *Conservation Ecology* 3 (2): 8 [online] URL: http://www.consecol.org/vol3/iss2/art8/. Accessed 30 Jan 2017.

Jordan, Thomas E., Donald E. Weller, Patrick J. Neale, and Carey E. Pelc. 2017. Effects of local watershed land use on water quality in mid-Atlantic coastal bays and subestuaries of the Chesapeake Bay. *Estuaries and Coasts* in revision

Kates, R.W., William C. Clark, Corell Robert, J. Michael Hall, Carlo C. Jaeger, Ian Lowe, James J. McCarthy, Hans Joachim Schellnhuber, Bert Bolin, Nancy M. Dickson, Sylvie Faucheux, Gilberto C. Gallopin, Arnulf Gruebler, Brian Huntley, Jill Jäger, Narpat S. Jodha, Roger E. Kasperson, Akin Mabogunje, Pamela Matson, Harold Mooney, I.I.I. Berrien Moore, Timothy O'Riordan, and Uno Svedin. 2001. Sustainability science. *Science* 292: 641–642.

Kornis, Matthew S., Denise Breitburg, Richard Balouskus, Donna M. Bilkovic, Lori A. Davias, Steve Giordano, Keira Heggie, et al. 2017a. Linking the abundance of estuarine fish and crustaceans in nearshore waters to shoreline hardening and land cover. *Estuaries and Coasts*. doi:10.1007/s12237-017-0213-6.

Kornis, MS, Bilkovic, DM, Davias, LA, Giordano, S, and Breitburg, DL. 2017b. Shoreline hardening affects nekton biomass, size structure, and taxonomic diversity in nearshore waters, with responses mediated by functional species groups. *Estuaries and Coasts*, online early edition. doi 10.1007/s12237-017-0214-5.

Kragt, Marit E., Barbara J. Robson, and Christopher J. A. Macleod. 2013. Modellers' roles in structuring integrative research projects. *Environmental Modeling and Software* 39: 322–330. 10.1016/j.envsoft.2012.06.015.

Landry, Brooke and Rebecca Golden. 2017. In-situ effects of shoreline type and watershed land use on submerged aquatic vegetation in the Chesapeake and coastal bays of Maryland and Virginia. 2017. Estuaries and Coasts in revision

Leschine, Thomas, Bridget E. Ferres, Kathleen P. Bell, Krista K. Bartz, Sarah MacWilliams, Michlle Pico, and Andrew K. Bennett. 2003. Challenges and strategies for better use of scientific information in the management of coastal estuaries. *Estuaries* 26 (4B): 1189–1204.

Li, Xuyong, Donald E. Weller, Charles L. Gallegos, Thomas E. Jordan, Hae-Cheol, Kim. 2007 Effects of watershed and estuarine characteristics on the abundance of submerged aquatic vegetation in Chesapeake Bay subestuaries. *Estuaries and Coasts* 30(5):840–854.

Liu, Yuqiong, Hoshin Gupta, Everett Springer, Thorsten Wagener. 2008. Linking science with environmental decision making: Experiences from an integrated modeling approach to supporting sustainable water resources management. *Environmental Modelling & Software* 23:846–858.

Matso, Kalle. 2012. Challenge of integrating natural and social sciences to better inform decisions, a novel proposal review process. In *Restoring lands-coordinating science, politics and action: complexities of climate and governance*, ed. H.A. Karl et al. Dordrecht: Springer Science+Business Media B.V Chapter 7.

Matso, Kalle E., and Mimi L. Becker. 2014. What can funders do to better link science with decisions? Case studies of coastal communities and climate change. *Environmental Management* 54 (6): 1356–1371.

McCormick, Melissa K., Dennis F. Whigham, Jared R. Stapp, Eric L.G. Hazelton, Eliza K. McFarland, and Karin M. Kettering. 2017. Shoreline modification affects recruitment of invasive Phragmites australis. Estuaries and Coasts in revision

McNie, Elizabeth C. 2007. Reconciling the supply of scientific information with user demands, an analysis of the problem and review of the literature. *Environmental Science and Policy* 10: 17–38.

Nursey-Bray, Melissa J., Joanna Vince, Michael Scott, Marcus Haward, Kevin O'Toole, Tim Smith, Nick Harvey, and Beverley Clarke. 2014. Science into policy? Discourse, coastal management and knowledge. *Environmental Science & Policy* 38: 107–119.

Ocean Studies Board. 1995. *Science policy and the coast, improving decisionmaking*. Washington: National Academy Press URL: https://www.nap.edu/catalog/4968/science-policy-and-the-coast-improving-decisionmaking.

Ocean Studies Board. 2007. *Mitigating shore erosion along sheltered coasts*. National Academy Press. Washington URL: https://www.nap.edu/catalog/11764/mitigating-shore-erosion-along-sheltered-coasts.

ORRAP (Ocean Research and Resources Advisory Panel). 2007. Best practices for increasing the impact of research investments: a report by the research to applications task force of the ocean research and resources advisory panel.

Patrick, Christopher J., Donald E. Weller, Meghan N. Williams, Robert J. Orth, David J. Wilcox, and Michael P. Hannam. 2017. Land use and salinity drive changes in SAV abundance and community composition. Estuaries and Coasts in revision

Patrick, Christopher J., Donald E. Weller, Xuyong Li, and Micah Ryder. 2014. Effects of shoreline alteration and other stressors on submerged aquatic vegetation in subestuaries of Chesapeake Bay and the mid-Atlantic coastal bays. *Estuaries and Coasts* 37: 1516–1531. doi:10.1007/s12237-014-9768-7.

Pielke, Roger A. Jr. 2007. *The honest broker: making sense of science in policy and politics*. New York: Cambridge University Press.

Pohl, Christian. 2007. From science to policy through trans-disciplinary research. *Environmental Science and Policy* 1 (1): 46–53.
Prosser, Diann J., Thomas E. Jordan, Rochelle D. Seitz, Donald E. Weller, Dennis F. Whigham, and Jessica L. Nagel. 2017. Impacts of coastal land use and shoreline armoring on estuarine ecosystems: an introduction to a special issue. *Estuaries and Coasts* in revision
Puente-Rodríguez, Daniel, Erik van Slobbe, Iris A.C. Al, and Danny E. Lindenbergh. 2016. Knowledge co-production in practice: enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea. *Environmental Science & Policy Volume* 55 (3): 456–466.
Rudd, M.A., et al. 2011. Generation of priority research questions to inform conservation policy and management at a national level. *Conservation Biology* 25: 476–484. doi:10.1111/j.1523-1739.2010.01625.x.
Runhaar, Hens A.C., Henny J. van der Windt, and Jan P.M. van Tatenhove. 2016. Productive science–policy interactions for sustainable coastal management: conclusions from the Wadden Sea area. *Environmental Science & Policy Volume* 55 (3): 467–471.
Saarman, Emily Mary Gleason, John Ugoretz, Satie Airamé, Mark Carr, Evan Fox, Adam Frimodig, Tom Mason, and Jason Vasques. 2013. The role of science in supporting marine protected area network planning and design in California. *Ocean & Coastal Management* 74 (2013): 45–56.
Sarewitz, Daniel, and Roger K. Pilkey. 2007. The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science & Policy* 10: 5–16.
Schuttenberg, H.Z., and Heidi K. Guth. 2015. Seeking our shared wisdom, a framework for understanding knowledge coproduction and coproductive capacities. *Ecology and Society* 20 (1): 15.
STAC (Scientific and Technical Advisory Committee for the Chesapeake Bay Program). 2006. Assessing cumulative impacts of shoreline modification workshop report: Chesapeake Bay STAC proactive workshop. STAC Publication 07-003. Edgewater, MD. http://www.chesapeake.org/pubs/239_.pdf. Accessed July 2016.
Trimble, Michaela, and Fikret Berkes. 2013. Participatory research towards co-management: lessons from artisanal fisheries in coastal Uruguay. *Journal of Environmental Management* 128: 768–778.
Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology [online]* 1 (2): 1 URL: http://www.consecol.org/vol1/iss2/art1/.
Walters, Carl J., and R. Hilborn. 1978. Ecological optimization and adaptive management. *Annual Review of Ecological Systems* 9: 157–188.
Walters, Carl J., and C.S. Holling. 1990. Large-scale management experiments and learning by doing. *Ecology* 71 (6): 2060–2068.
Williams, B.K., and E.D. Brown. 2014. Adaptive management: from more talk to real action. *Environmental Management* 53: 465. doi:10.1007/s00267-013-0205-7.
Zedler, J.B. 2017. What's new in adaptive management and restoration of coasts and estuaries? *Estuaries and Coasts* 40: 1. doi:10.1007/s12237-016-0162-5.