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- To capture and document how large-team transdisciplinary research can be orchestrated effectively
- Strategies to guide future work addressing climate change vulnerability, adaptation, and resilience

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Developing and managing transdisciplinary and transformative research on the coastal dynamics of sea level rise: Experiences and lessons learned

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Abstract There is increasing emphasis from funding agencies on transdisciplinary approaches to integrate science and end-users. However, transdisciplinary research can be laborious and costly and knowledge of effective collaborative processes in these endeavors is incomplete. More guidance grounded in actual project experiences is needed. Thus, this article describes and examines the collaborative process of the *Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico* transdisciplinary research project, including its development, implementation, and evaluation. Reflections, considerations, and lessons learned from firsthand experience are shared, supported with examples, and connected to relevant scholarly literature.

1. Introduction

The "usability gap" between what scientists and decision-makers consider useful climate change-related knowledge [*Lemos et al.*, 2012] has generated much discussion and concern among scholars, practitioners, politicians, and the public. Addressing this issue is crucial, but difficult. "As the complexity and interconnections among human–environment systems are recognized, funding agencies have been increasingly promoting and encouraging large collaborative research projects that are 'transdisciplinary', crossing disciplinary and professional boundaries to integrate multiple different kinds of knowledge" [*Allen et al.*, 2013, p. 345]. However, more understanding of effective collaboration stemming from actual project experiences is needed [*Moser and Ekstrom*, 2011; *Podesta et al.*, 2013]. Thus, this article's purpose is twofold: (1) to contribute to the research literature by describing and examining the collaborative process of an actual project and (2) to capture and document how large-team transdisciplinary research can be orchestrated effectively.

Sponsored by the US National Oceanic and Atmospheric Administration (NOAA), the *Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico* (EESLR-NGOM) is one such transdisciplinary project. This 6-year regional-scale study involved a large and diverse team of biology, civil (coastal) engineering, and social science (communication) scholars from multiple institutions working with government agency personnel and industry professionals collaborating with a group of stakeholders (coastal resource managers). EESLR-NGOM's primary focus was on detailed assessment and process-based modeling to project scenarios of climate change and sea level rise (SLR) impacts on coastal floodplains, wetland habitats, bays, and estuaries along the central northern Gulf. The project spanned the Mississippi, Alabama, and Florida Panhandle coasts, with concentration on the three National Estuarine Research Reserves (NERRs). The complex and multifaceted research questions required a genuine transdisciplinary approach. More background information about EESLR-NGOM is available on this project's website: http://coastalscience.noaa.gov/projects/detail?key=162.

Transdisciplinarity is generally considered, "an approach characterized by partnerships that cross boundaries among fields of research and modes of inquiry and between academic and non-academic actors" [*Allen et al.*, 2013, p. 344]. While definitions of transdisciplinarity are numerous and varied, there appears to be broad agreement in the literature that this approach: (1) addresses a practical real-world problem, (2) has an evolving methodology that iteratively integrates different scholarly disciplines, and (3) involves engagement and collaboration with non-academic stakeholders throughout the research process [*Wickson* *et al.*, 2006; *Walter et al.*, 2007; *Klein*, 2008; *Leavy*, 2011; *Allen et al.*, 2013]. As emphasized in the literature [e.g., *McNie*, 2007; *Walter et al.*, 2007; *Klein*, 2008; *Riley et al.*, 2011; *Matso and Becker*, 2014], efforts to generate useful scientific information to help solve complex practical problems should carefully attend to the research process as well as to the results and products produced. Discussion of these interrelated transdisciplinary characteristics in EESLR-NGOM will be elaborated henceforth, with focus on collaborative engagement.

To address the "usability gap," it was crucial to transition EESLR-NGOM's scientific findings on SLR impacts into convenient, user-friendly decision-support tools (i.e., hard and soft products that include maps, web-based delivery systems, software, and other related materials) so that they could be readily applied by key end-users (coastal resource managers) and disseminated to other stakeholders and geographic locations facing similar issues. EESLR-NGOM employed an integrated, collaborative science-management approach that started with conceptualizing program priorities, Federal Funding Opportunity (FFO) and project development, and subsequent implementation. Through this process, mechanisms for transition were identified and collaboratively developed. Thus, in addition to a dynamic combination of natural scientific and social scientific research methods executed by disciplinary scholars with technical expertise, multiple stakeholder engagement mechanisms (detailed below) were also selectively employed to improve accessibility and utility of the scientific results and products. Engagement was a priority for this project because as noted by *Jacobs et al.* [2005, p. 19], "building relationships is the key component in bridging the gap between climate science and decision-makers."

Stakeholders have been defined as, "individuals or groups with a vested interest in the outcome of a decision" [*McNie*, 2007, p. 19] or in the research project [*Phillipson et al.*, 2012]. The literature [e.g., *Jakeman et al.*, 2006; *Roux et al.*, 2006; *Liu et al.*, 2008; *Frazier et al.*, 2010; *Barron et al.*, 2012; *Phillipson et al.*, 2012; *Picketts et al.*, 2012; *Bartels et al.*, 2013; *Podesta et al.*, 2013] highlights a variety of benefits of stakeholder engagement including providing local system knowledge and verifying assumptions; improving quality and credibility of scientific information and models; fostering trust, a sense of ownership, and acceptance and effective use of results; promoting dissemination of findings; and inspiring future collaboration.

There are increasing calls for stakeholder engagement in environmental projects [*Phillipson et al.*, 2012] and a diverse array of engagement mechanisms has been documented and described [*Allen et al.*, 2013; *Bartels et al.*, 2013]. Prior relevant projects have varied in goals, scope, and stakeholder types, but typically have utilized a combination of engagement activities, finding that each technique offers particular strengths in capturing different insights [*Jacobs et al.*, 2005]. Likely due in part to the "evolving methodology" hallmark of transdisciplinarity, there does not appear to be a single prescriptive formula or a cohesive foundation of scholarly empirical studies that have systematically tested and compared the effectiveness of different types of stakeholder engagement mechanisms in environmental projects [*Phillipson et al.*, 2012]. Nonetheless, several common features of effective engagement have been identified, including involving stakeholders from the start, interacting with them frequently throughout the entire project process in a science-management collaborative learning partnership, inclusively considering various perspectives, and encouraging iterative feedback [e.g., *Jacobs et al.*, 2005; *Jakeman et al.*, 2006; *Roux et al.*, 2006; *Liu et al.*, 2008; *Phillipson et al.*, 2012; *Bartels et al.*, 2013; *Podesta et al.*, 2013; *Thompson et al.*, 2015]. Central in many of these examples of effective engagement is an emphasis on the expectation for two-way information exchange [*Jacobs et al.*, 2005] and a shift from transferring to a process of relating knowledge [*Roux et al.*, 2006].

2. Collaborative Engagement Mechanisms

As mentioned previously, engagement was an integral part of EESLR-NGOM. Several types of interrelated collaborative mechanisms were strategically initiated by NOAA during development of the FFO and infused throughout the resultant EESLR-NGOM process. Figure 1 depicts EESLR-NGOM's collaborative engagement and evaluation components and their relationships. Pre-project mechanisms included targeted planning workshops, engagement with potential end-users, and explicit guidance for projects within the FFO that included a requirement of an Applications Principal Investigator (PI) to lead a stakeholder advisory committee. EESLR-NGOM complimented these mechanisms with a project conceptual model, annual stakeholder advisory workshops, focus groups, webinars, and product usability testing. These forms of engagement were selected as they have been reported to be successful in previous projects with similar aims; deemed

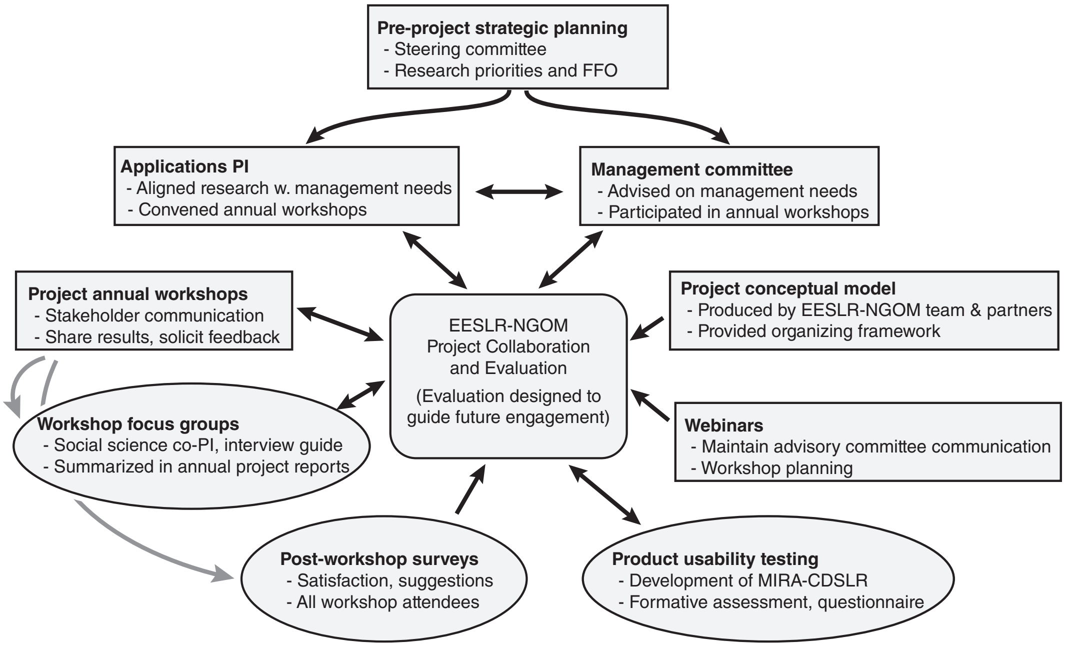

Figure 1. Diagram of the primary components of *Ecological Effects of Sea Level Rise in the Northern Gulf of Mexico* (EESLR-NGOM)'s collaboration and evaluation strategy. Rectangles indicate collaboration components and ovals indicate evaluation components. Direction of arrows indicates the primary direction of application of information and products.

appropriate for EESLR-NGOM's geographic scope, time frame, and budget; and had potential for optimal synergistic integration of activities. The strengths and strategies of each mechanism are detailed below.

2.1. Pre-Project Strategic Planning

Seeking to expand the extramural, competitive Ecological Effects of Sea Level Rise research program, NOAA National Centers for Coastal Ocean Science initiated a multi-year engagement and research prioritization process in the Gulf of Mexico. A steering committee comprised of representatives from the Gulf coastal management community, federal agencies, and out-of-region scientists was formed and they organized a planning workshop in the northern Gulf of Mexico that defined key management needs and prioritized research gaps. The resultant white paper [*Auer et al.*, 2008], which represented the consensus of workshop attendees, served as the foundation for a 2009 FFO. Based on input from the planning workshop and lessons learned from prior funding opportunities, NOAA instituted a series of novel requirements in the FFO designed to facilitate application of project results. These requirements included a funded Applications PI to coordinate project engagement activities and a plan for a stakeholder advisory committee to provide the project team with guidance throughout the project.

Thus, an Applications PI was included in the EESLR-NGOM grant proposal and project implementation to facilitate continuous two-way communication so that research interests were aligned with management needs, as well as to provide information, advice, and assistance to researchers to facilitate results that were meaningful to resource managers. As a partial evaluation measure of its success, EESLR-NGOM required translation of the project research findings into tools that could be used directly by resource managers. To this end, the Applications PI, in collaboration with the NOAA Office for Coastal Management (OCM) and the NERRs, convened a series of workshops beginning at EESLR-NGOM project initiation and recurring at key points throughout the project. These workshops, as detailed below, were conducted to identify management needs, exchange information gleaned from EESLR-NGOM's research, solicit management input into tool development, and present and train managers in tool usage.

2.2. Stakeholder Advisory Committee

The primary EESLR-NGOM collaborative mechanism was a volunteer stakeholder advisory committee, called the Management Committee (MC), that was established at the project start. The MC built on participants from the FFO development and was comprised of a diverse group of local, state, and federal coastal resource managers in the Northern Gulf of Mexico region. The MC was tasked with collaborating in the development of these research products such that they could be readily used by the managers themselves as well as various other stakeholders. MC membership was established during the first year of the project (2011) based on professional network advisement and online survey results, and evolved slightly over time following input from the MC and increasing interest in the project. The MC served in an advisory capacity throughout the entire project and was guided by a charter that defined roles, responsibilities, and expectations. One important expectation was participation in the annual MC workshops. There were a total of 84 attendees across all five workshops and an average of 17 attendees for each workshop. A core group of six MC members attended three or more of the annual MC workshops.

2.3. Project Conceptual Model

A second collaborative mechanism was a project conceptual model. As indicated in the literature [e.g., *Liu et al.*, 2008; *Kragt et al.*, 2013; *Podesta et al.*, 2013], developing and using conceptual models offers a number of interrelated benefits for transdisciplinary projects. Conceptual models can foster common understanding among research team members, stakeholders, and other audiences and can serve as practical tools for communicative purposes [*Liu et al.*, 2008]. The introductory article of this *Earth's Future* special section on "Integrated field analysis & modeling of the coastal dynamics of sea level rise in the northern Gulf of Mexico" includes a conceptual model in the form of the EESLR-NGOM Process Model (EPM) to provide a concise visual explanation of the entire project including each essential component, the relationships and dynamics among the components, and their broader societal and management interconnections [*Liu et al.*, 2008; *Kragt et al.*, 2013]. The EPM was produced collaboratively by the EESLR-NGOM team and partners at an initial stage of the project and appeared prominently and consistently in all materials (e.g., PowerPoint slides, posters, articles, etc.) and activities (e.g., annual workshops, conferences). Among the EPM's multiple purposes were clarifying the scope of work, enhancing communication and understanding about the project within and outside of the research team, providing an organizing framework, supporting team leadership in management and decision making, and assisting stakeholders (managers) in seeing their relationship to and significance in the overall integrated project.

2.4. Annual Workshops

A third collaborative mechanism for EESLR-NGOM was annual workshops. Various workshop types and formats, used alone or in combination with other participatory techniques, have been reported and discussed in the literature [e.g., *Halofsky et al.*, 2011; *Schroth et al.*, 2011; *Picketts et al.*, 2012; *Thompson et al.*, 2015]. Workshops served as the central collaborative mechanism of stakeholder engagement for EESLR-NGOM to help align the project's scientific research results and products with operational needs. The workshops provided a consistent and comfortable venue for sharing project-related information, identifying needs and resources, and building relationships (especially trust and rapport) among project participants, including the scientists and engineers who conducted the research, the program manager, and importantly, the MC stakeholder group of regional coastal resource managers.

Careful preparation and skilled facilitation are necessary for workshop success [*Halofsky et al.*, 2011]. Workshop planning and implementation was coordinated by the EESLR-NGOM Applications PI with assistance of professional workshop facilitators and the NERR Coastal Training Program Coordinators and involvement of the project team communication specialists, Science PI, and program manager from NOAA. Appropriate potential attendees were identified by the Applications PI in consultation with the project team and invited to participate in the workshop. The majority of workshop attendees were members of the EESLR-NGOM MC. As mentioned above, some attendees participated in more than one of the annual workshops.

Six total annual MC workshops were conducted (two in each of the partnering NERRs in the study area). The first workshop was held on May 18–19, 2011 at the Apalachicola NERR facility in Eastpoint, Florida; the second on June 14, 2012 at the Grand Bay NERR in Moss Point, Mississippi; the third on June 21, 2013 at the Weeks Bay NERR in Fairhope, Alabama; the fourth returned to the Apalachicola NERR on July 17, 2014; the fifth returned to the Grand Bay NERR on July 28, 2015, and the sixth will return to the Weeks Bay NERR in 2016. The primary objectives of all workshops were to: review EESLR-NGOM's progress over the past year and future directions; learn about noted and expected ecological changes and concerns related to SLR, erosion, and hurricane storm surge; gather stakeholder needs related to product development; share reactions to the project's emerging data and tools; understand implications of EESLR-NGOM's SLR science on the project-area communities; identify possible applications and outreach strategies for EESLR-NGOM information and tools; gain insight on potential connection with on-going SLR research and extension efforts in the region (e.g., restoration planning); and design strategies for team interaction with the MC, colleagues, and partners.

All workshops followed a similar structure consisting of a welcome session for introductions, communication of the workshop objectives, clarification of the function and purpose of the MC, and review of the agenda; an overview session about EESLR-NGOM and progress to date; several scientific research presentations that provided updates on the field work and computer modeling being conducted, with time for questions and answers; several facilitated panel discussions on noted ecological changes, SLR-related planning issues and needs (e.g., preferences for and questions about SLR scenarios and time frames for the modeling), reactions to the scientific presentations, and identification of product user groups; concurrent breakout sessions including a project planning meeting for the scientists and a focus group activity (described below) for the resource managers; and a concluding wrap-up session that involved reviewing the next steps in the project, making closing remarks, and administering an in-person survey to evaluate the workshop. During the workshops, the professional facilitators led discussions while simultaneously capturing detailed notes for attendees to review and consider. The workshops were evaluated and these general procedures are described in Section 3 of this article. More detailed information including the workshop findings is available in a summary report of each annual workshop written by the social science co-PI with review and input from all project team members, the MC, and the program manager.

2.5. Focus Groups

A fourth collaborative mechanism for EESLR-NGOM was focus group interviews. As the term “focus group” is often used loosely and inaccurately to refer to an assortment of activities that may not be methodologically sound, we emphasize that the EESLR-NGOM focus group interviews were legitimate scholarly inquiry that followed the formal social scientific approach and techniques for this type of qualitative research method [e.g., *Stewart and Shamdasani*, 2015]. A typical focus group session involves a predetermined set of topics addressed as open-ended questions asked by a trained moderator to guide discussion among a small group of generally 6–12 purposefully selected participants [*Eisenhauer and Nicholson*, 2005]. Through group dynamics, this qualitative social science interviewing approach offers strengths in capturing candid, spontaneous comments and detailed firsthand descriptions in the words of participants [*Morgan*, 1997; *Krueger and Casey*, 2000; *Berg and Lune*, 2012; *Stewart and Shamdasani*, 2015]. Further, the focus group interviewing method is a flexible data collection tool with broad applicability across disciplines and contexts and has been used in other environmental stakeholder engagement efforts, including those pertaining to climate change-related policy and decision making [*Frazier et al.*, 2010; *Picketts et al.*, 2012] and environmental communication [*Eisenhauer and Nicholson*, 2005]. As discussed in the literature, focus group research, “provides a deeper, more nuanced, and more contextualized understanding” [*Frazier et al.*, 2010, p. 508] and can also have partnership-building benefits [*Eisenhauer and Nicholson*, 2005]. However, this method requires careful planning and procedures for optimal outcomes [*Morgan*, 1997; *Krueger and Casey*, 2000; *Berg and Lune*, 2012; *Stewart and Shamdasani*, 2015].

An innovative component of EESLR-NGOM and important because of the diversity of perspectives and biases of the scientists and engineers toward their own research, focus groups were conducted with coastal resource managers as part of the annual workshops. Six total 90-min audio-recorded focus groups of between 8 and 13 participants each were conducted for EESLR-NGOM during the annual workshops. The objectives for all focus groups corresponded with those of the overall workshop, but this qualitative social science research method involved a specialized protocol, trained questioning, and greater interaction on the topics in a smaller group setting whereby participants exchanged, discovered, and explored in depth their various views and experiences regarding SLR impact preparation behaviors and needs and the EESLR-NGOM tools, outreach ideas, and project process.

As described in Section 2.4, the EESLR-NGOM social science co-PI briefly explained the purpose and role of the focus group to all workshop attendees and then, a subset of attendees (the coastal resource managers) participated voluntarily in the focus group while the remaining attendees (the scientific researchers) convened in a separate room for a project planning meeting. For all focus groups, implementation was the same. Each began with introductions and an explanation of the focus group objectives and procedures. The moderator then asked a series of open-ended questions to the group using an interview guide instrument that served as a flexible framework for discussion. There was minimal moderator involvement. The moderator encouraged participant interaction, listened carefully, and remained nonjudgmental. Each focus group was audio-recorded with permission, lasted approximately 90 min, and had present a research assistant who took notes, monitored time, and managed logistics.

Construction of the interview guide involved consultation with others on the EESLR-NGOM team, the professional workshop facilitators, and the relevant scholarly literature. The content of the guide remained relatively consistent each year, with refinements in some question wording for clarity. The instrument consisted of open-ended questions about participants' SLR, coastal erosion, and hurricane storm surge impact preparation experiences and desired actions; input on EESLR-NGOM's scientific research products; and recommendations for related outreach and communication activities. Open-ended questions were used predominantly because they enabled participants to respond from their points of view and in their own words. The interview guide was pretested to ensure optimal data collection.

All focus group audio-recordings were reviewed at least twice and transcribed in entirety by the moderator and research assistant. The transcripts were then read carefully multiple times and analyzed using qualitative content analytic techniques to uncover patterns in the data and assess for relationships and themes [*Berg and Lune*, 2012]. These findings were distributed to the entire MC in the annual workshop summary reports and used to help evaluate the project process.

2.6. Webinars

A fifth collaborative mechanism for EESLR-NGOM was webinars, which were conference calls and virtual presentations used to augment the annual workshops. Virtual meetings can support collaborative projects by enabling synchronous communication and building trust among participants, though they are more effective for teams that have additional opportunities for face-to-face collaboration [*Hossain and Wigand*, 2004]. While webinars and other virtual collaboration technologies do not replace in-person meetings that afford more opportunities for interpersonal interaction and trust-building, they may be used to enhance information transmission and consensus-building [*Hossain and Wigand*, 2004] or prepare team members for in-person meetings [*Ernst and van Riemsdijk*, 2013].

The EESLR-NGOM webinars were designed to provide additional opportunities for dissemination of scientific results and discussion of project direction and concerns among the science team and MC between the annual workshops. A total of six webinars were held (one in each of 2011, 2012, 2014, and 2015, with two in 2013). The structure of the webinars was similar throughout the project, with the MC lead or NOAA program manager opening the webinar, setting the agenda, and updating the participants on project activities since the last meeting; a member of the science team delivering a virtual presentation on research activity progress, addressing questions, and soliciting feedback from the other participants; and a member of the MC closing the webinar after a reminder and question-and-answer period about upcoming MC activities, such as an upcoming annual workshop. Reaction to the webinars by both the MC and science team indicates they were effective for sharing and deliberating about project developments between the annual meetings.

2.7. Product Usability Testing

A sixth type of collaborative engagement centered on the development of the Mapping Interface for Research Applications-Coastal Dynamics of SLR (MIRA-CDSLR) visualization tool, a key project product (see http://champs.cecs.ucf.edu/CDSLR/index.html). This engagement mechanism consisted of a formative task-based usability assessment and a questionnaire designed to elicit user perceptions of the tool, its place in EESLR-NGOM, and its potential future uses. Participants consisted of members of the MC and other target users (e.g., coastal managers) from the region. Formative usability evaluation of interactive visualization tools is recommended to identify technical issues at an early stage [*Freitas et al.*, 2014] and enable tool developers to better tailor products toward the application needs of their audiences [*Mirel*, 1998] by enhancing interaction and collaboration between developers and end-users. This is particularly important for the products of transdisciplinary research, which are often designed for multiple audiences with differing topical and technical skills.

3. Evaluation

According to the transdisciplinarity and environmental science literature, evaluation of transdisciplinary research projects is imperative but challenging. There are a number of reasons for these evaluative challenges such as the complexity, diversity, and contextualized nature of transdisciplinary research, lack of an established transdisciplinary peer community, potential conflicts of interest, and difficulties in assessing causation [*Stokols et al.*, 2003; *Wickson et al.*, 2006; *Klein*, 2008; *Trochim et al.*, 2008; *Riley et al.*, 2011; *Schroth et al.*, 2011; *Brandt et al.*, 2013; *Podesta et al.*, 2013; *Krellenberg and Barth*, 2014]. The subject of evaluation has been receiving increasing attention among scholars and practitioners and concerted efforts have been made toward identifying, developing, and applying new types of evaluation strategies and broadly applicable, critically robust criteria and procedures [*Stokols et al.*, 2003; *Jakeman et al.*, 2006; *Wickson et al.*, 2006; *Walter et al.*, 2007; *Hall et al.*, 2008; *Klein*, 2008; *Trochim et al.*, 2008; *Feng et al.*, 2010; *Moser and Boykoff*, 2013; *Podesta et al.*, 2013]. Various conceptual frameworks stemming from literature reviews and empirical studies of large-scale projects at different phases (e.g., Team Science in the field of biomedical research) have specified different metrics and criteria for evaluating transdisciplinary project antecedents, processes, and outcomes [e.g., *Stokols et al.*, 2003; *Wickson et al.*, 2006; *Walter et al.*, 2007; *Hall et al.*, 2008; *Klein*, 2008; *Trochim et al.*, 2008; *Feng et al.*, 2010]

For example, *Klein* [2008] proposed a framework of seven "generic principles" to consider with respect to evaluation based on themes found in her literature review of international interdisciplinary and transdisciplinary research. These principles include: variability of goals; variability of criteria and indicators; leveraging of integration; interaction of social and cognitive factors in collaboration; management, leadership, and coaching; iteration in a comprehensive and transparent system; and effectiveness and impact [*Klein*, 2008]. *Hall et al.* [2008] developed and applied a conceptual model and new tools (e.g., survey instruments) for assessing the effectiveness of transdisciplinary collaboration in the National Cancer Institute's Transdisciplinary Research on Energetics and Cancer (TREC) initiative. The three basic components of the model include collaborative readiness (i.e., "circumstances that facilitate or constrain effective teamwork"), collaborative capacity, and collaborative products with results demonstrating evidence of collaborative readiness among the participants during the initiative's first year [*Hall et al.*, 2008]. In other Team Science work, *Trochim et al.* [2008] conducted a pilot evaluation of the National Cancer Institute's Transdisciplinary Tobacco Use Research Center (TTURC) using the Evaluation of Large Initiatives (ELI) approach. The pilot evaluation was guided by a framework in the form of a collaboratively produced outcome logic model [*Trochim et al.*, 2008]. The model addresses evaluation questions pertaining to short-term outcomes (training, collaboration, transdisciplinary integration), intermediate outcomes (methods, science and models, recognition, publications, communications, improved interventions), and long-term outcomes (effects on policy, practice, and health outcomes) [*Trochim et al.*, 2008]. Based on their pilot results, *Trochim et al.* [2008] offer the following guidance: develop a comprehensive conceptual model, use participatory and collaborative evaluation approaches, incorporate integrative mixed-methods, integrate evaluation with existing reporting systems, adapt the evaluation to the initiative's stage of development, develop standardized cross-initiative evaluation systems, utilize peer review approaches, address issues of causation and control, improve funding and organizational capacity for evaluation, and address management issues in large initiative evaluation.

In earlier work, *Wickson et al.* [2006] from the fields of environmental (biological) sciences, technology, and education, adapted the Carnegie Foundation schema for evaluating the quality of scholarship in an effort to make it more relevant to transdisciplinary research. The six adapted criteria they propose include: responsive goals (project goals are defined through on-going consultation with stakeholders and problem context), broad preparation (reviewing and integrating theory and literature across an array of disciplines and engaging with the problem in its larger context), evolving methodology (a research approach that is integrative and flexible to adjust to a changing research context), significant outcome (the project results contribute to the solution of a problem that satisfies multiple agendas), effective communication (there is initiation and maintenance of two-way communication with stakeholders throughout the entire project process), and communal reflection (collective reflection as well as individual reflection such that multiple disciplinary and stakeholder perspectives are informed and transformed throughout the entire project process) [*Wickson et al.*, 2006]. However, *Wickson et al.* [2006] stress that they are not suggesting that all criteria must be satisfied equally in order to produce quality transdisciplinary work.

Regarding scientific products, *Jakeman et al.* [2006, p. 604] state that models produced from a transdisciplinary approach that are intended to influence management should be assessed not only based on the standard criteria of "good model practice" (i.e., clear objectives, clear statements of model assumptions and implications, and reporting of results, including validation) but also on, "fitness for purpose, flexibility to respond to changing management needs, and transparency so that stakeholders can see how the results were derived."

Though EESLR-NGOM did not follow a particular framework from this emerging literature stream, evaluation was, nonetheless, considered a vital and integral component of EESLR-NGOM. Evaluative components were designed to both feed back into project development and assess summative results. It was important to determine if (how, and to what extent) the collaborative processes were effective, the project produced the required results, and the results could be generalized and applied to other situations and contexts [*Deconchat et al.*, 2007; *Voinov and Bousquet*, 2010; *Moser and Ekstrom*, 2011]. Evaluation was iterative such that methods and measures were continually revisited, refined, and applied according to results. Team and stakeholder input and feedback were collected regularly and integrated into subsequent project planning and decision making as appropriate based on careful consideration and discussion. For EESLR-NGOM, numerical counts of activities (e.g., meetings, teleconferences, etc.), products (e.g., publications, presentations, posters, reports, decision-support tools, websites, project-related publicity), and student achievements (theses, dissertations, employment) were documented by the PI, along with results from annual MC workshop surveys and other evidence of quality (e.g., awards; scholarly citations; MIRA-CDSLR usability testing results, feedback, adoption and use; informed management decisions).

On-going stakeholder interaction and formal and informal feedback via the Applications PI and collaborative engagement mechanisms (MC, annual workshops, EPM, focus groups, webinars, product usability testing) resulted in year-by-year refinements of EESLR-NGOM implementation and scientific product development, while also increasing confidence of project participants in the research and results. Collaboration with coastal resource managers throughout all project phases enabled effective communication and tailoring of the scientific products so they were most appropriate and beneficial in helping to determine the viability of future management actions relative to predicted conditions. Engagement also placed these managers in a more knowledgeable position to inform policy makers as to the likely consequences of their decisions.

3.1. Focus Groups

One of the objectives of the focus groups was to serve as a year-by-year and cumulative qualitative evaluation method for the project process. Overall, the focus groups were productive in capturing and synthesizing the stakeholders' wide-ranging opinions and perspectives about SLR-impacts preparation in the region, identifying their needs and preferences for the development of useful decision support tools, and gauging their reactions to EESLR-NGOM's approach. The insights and nuances gained from the focus groups helped the team in better understanding the everyday context of resource managers' local SLR impact planning and decision making, which highlighted the importance of considering the interplay of ecological and socioeconomic factors that may be associated with challenges and opportunities for using EELSR-NGOM's research and products. It also aided in pinpointing areas in need of clarification about the project objectives, plans, scope, and procedures. Specific results of the EESLR-NGOM focus group interviews are available in the annual project reports.

3.2. Post-Workshop Surveys

Surveys are a standard, efficient, and effective social science research method for evaluation in a variety of contexts, including workshops [*Moser and Ekstrom*, 2011; *Thompson et al.*, 2015]. Thus, one of the important forms of evaluation for EESLR-NGOM was surveys of attendees at the conclusion of each annual MC workshop. The project team, NERR coastal training coordinators, and outreach specialists collaborated in constructing, administering, and analyzing the surveys. At the end of each annual workshop, attendees completed the survey voluntarily on their own with informed consent. The two-page survey took approximately 5 min to complete. The survey instrument (questionnaire) structure remained similar from year to year and consisted of closed-ended and open-ended questions that measured satisfaction with the workshop's content (e.g., scientific presentations), format, networking opportunities, and usefulness, and gathered suggestions for the future. To ensure optimal data collection, the questionnaire was pretested. All workshop survey data were compiled, tabulated, and analyzed by the NERR coastal training coordinators using software to produce descriptive statistics [*Thompson et al.*, 2015]. Specific results of the EESLR-NGOM workshop surveys are available in the annual project reports.

Overall, the evaluation surveys across all of the annual workshops indicated that attendees were very satisfied with the workshop experience. In sum, they found the presentations, content, and format informative and useful and felt they had opportunities to communicate their resource management needs and to provide input on EESLR-NGOM's research and products. Attendees found different aspects of the workshops valuable (e.g., the focus group discussions, science updates, and opportunity to interact with science team members), suggesting that incorporating multiple types and formats of activities was valuable.

One particular benefit of the workshops that attendees commented on was a sense of feeling like an integral part of the project. Weaving the workshops into the fabric of the project design and research process helped ensure regular two-way communication and coordination with stakeholders and was instrumental in shaping scientific objectives and the development of products (SLR impact decision support tools) that attain optimal utilization by resource managers and effective dissemination to other audiences. Although, as noted by *Moser and Ekstrom* [2011, p. 67], "evaluating the effectiveness of stakeholder engagement in any assessment, planning, or decision-making process is challenging and inherently subjective," the survey results together with observations, team debriefing meetings, and critical reflection provided multiple data sources and insights into the success of the collaborative mechanisms in achieving the intended objectives and areas for improvement. For example, the project PIs focused on SLR scenarios and the projections of impacts to the coast. However, the MC recognized that perhaps the best way to look to the future was to first assess the past. That suggestion led to the development of a hypothesis: The historical changes in sea level, coastal morphology, land use and land cover, and infrastructure have a nonlinear effect on hurricane storm surge flooding. Tests of that hypothesis resulted in a seminal publication [*Bilskie et al.*, 2014] and fostered a paradigm shift away from bathtub assessments (e.g., simply raising the sea level, inundating present day topography and then, assessing the impact to the built and natural environment) to an approach that involves process-based assessments of the impacts of the coastal dynamics of SLR (i.e., recognizing that as the sea level rises the coastal land margin, land cover, land use, and natural system all respond interactively and that the human population and footprint continues to grow).

3.3. Product Usability Testing

The results of the usability testing engagement mechanism informed the development of one specific aspect of the project, the MIRA-CDSLR, and are summarized in *Stephens et al.* [2015]. Participant responses also helped identify larger communication issues among the science team and the MC, and thereby fed back into the overall objectives of EESLR-NGOM. There were four key implications for project collaboration and success of the MIRA-CDSLR. First, usability testing was crucial in allowing the project team to collaborate directly with users to clearly identify the ultimate context in which the MIRA-CDSLR would be used. Second, testing helped us to identify key design features that were applicable to this specific type of product. Third, testing provided the opportunity to clarify underlying assumptions, such as the distinction between the computer model used to simulate impacts from SLR scenarios and the resulting data that was displayed in the MIRA-CDSLR. Fourth, feedback from testing helped us to better understand how to communicate risks in the MIRA-CDSLR so that this product could assist broader (i.e., non-specialist) audiences in better understanding them. In sum, these results lead us to recommend that evaluation of specific communication tools in transdisciplinary projects should be viewed as both a mechanism for tailoring the tools to the needs of the target audience as well as for further refining the collaborative relationship among project participants.

3.4. Programmatic Evaluation

At a programmatic level, NOAA evaluation of EESLR-NGOM transdisciplinary success was based on achievement of outcomes that included demonstrated improvements in management knowledge (e.g., paradigm shift SLR modeling), changes in management behavior (e.g., use of tools or data), and improved environmental conditions (e.g., habitat restoration). Though difficult to measure, these outcomes focus on assessing the value and overall impact of project products and outputs to coastal managers and communities. As discussed in Section 5 and the associated literature in this special section of *Earth's Future* [e.g., *Passeri et al.*, 2015], that EESLR-NGOM has achieved two of these outcome types is indicative of a highly collaborative, transdisciplinary project.

In addition to outcome-based evaluation, an additional measure of EESLR-NGOM success includes the facilitation of complimentary and/or leveraged external efforts. For example, the collaborative network established by EESLR-NGOM provided the foundation for the NOAA-led, interagency Gulf of Mexico Sentinel Site Cooperative (http://oceanservice.noaa.gov/sentinelsites/). The Cooperative focuses on enhancing the science-to-application continuum of SLR activities through coordination, leadership, and focusing resources. In addition, a separate collaborative activity among a subset of the EESLR-NGOM team, MC, NERR Coastal Training Program Coordinators, and the Alabama Coastal Foundation was developed, in part, in response to concerns and ideas about broader engagement raised during the EESLR-NGOM focus groups and in general discussions among project participants. It was intended to leverage lessons learned and relationships built during EESLR-NGOM to engage and inform citizens in the region about SLR decision-support tools so that they can better understand and prepare for the local effects of rising seas. The findings were used to guide the development of stakeholder workshops and outreach materials to inform about SLR and three SLR decision-support tools (the MIRA-CDSLR, the Nature Conservancy's *Coastal Resilience*, and NOAA's *Sea Level Rise and Coastal Flooding Impacts Viewer*).

4. Reflections and Considerations: Lessons Learned and Recommendations

While a transdisciplinary approach offers many opportunities for addressing the complexities of climate change-related issues, various challenges are recognized for such endeavors [e.g., *Liu et al.*, 2008; *Podesta et al.*, 2013; *Krellenberg and Barth*, 2014]. Common concerns include those stemming from different disciplinary research traditions, values, methods, language, and levels of technical sophistication among project participants [e.g., *Liu et al.*, 2008; *Podesta et al.*, 2013]; a necessary significant investment in time and resources [*Liu et al.*, 2008; *Krellenberg and Barth*, 2014; *Matso and Becker*, 2014]; and challenges in evaluating success, as mentioned previously [*Stokols et al.*, 2003; *Wickson et al.*, 2006; *Klein*, 2008; *Trochim et al.*, 2008; *Riley et al.*, 2011; *Schroth et al.*, 2011; *Moser and Boykoff*, 2013; *Podesta et al.*, 2013; *Krellenberg and Barth*, 2014]. The literature on interdisciplinarity and transdisciplinarity is vast, and much has been written from a philosophical perspective. While direct relation to much of this material is beyond the scope of the present manuscript, several examples of large-scale transdisciplinary initiatives that offer valuable insights can be found in the Team Science literature in biomedical sciences [e.g., *Stokols et al.*, 2003; *Hall et al.*, 2008; *Klein*, 2008; *Trochim et al.*, 2008]. What is clear is that more examples of collaborative endeavors in different contexts are needed for comparative purposes and to advance understanding and application. Following are selected reflections and practical recommendations stemming from the EESLR-NGOM experience which center on three major interrelated areas important to consider for effective collaboration (project management, team dynamics, and communication).

4.1. Project Management

For effective collaboration in transdisciplinary projects, proactive management is crucial [*Lyall et al.*, 2013; *Krellenberg and Barth*, 2014; *Matso and Becker*, 2014]. EESLR-NGOM was driven by complimentary oversight consisting of two PIs (a Science PI and an Applications PI) and experienced grant program managers who remained actively involved in a facilitation and advisory capacity. These contextual conditions and leadership characteristics are types of "collaborative-readiness" factors according to the Team Science transdisciplinary research literature [*Hall et al.*, 2008]. For EESLR-NGOM, area of expertise was a primary factor in constructing the research team, but prior established working relationships among some of the members were also influential and helpful in building team trust and rapport relatively quickly [*Podesta et al.*, 2013]. This interpersonal dimension of team members' histories of collaboration on earlier projects is another type of "collaborative-readiness" factor deserving consideration in transdisciplinary research according to Team Science [*Hall et al.*, 2008]. Regarding stakeholders, while it was clear that stakeholders were essential for EESLR-NGOM, identifying and prioritizing exactly who those stakeholders were and determining who would be most appropriate and likely willing to make a voluntary commitment to serve on the MC over this long-term project was a laborious task. Further, EESLR-NGOM stakeholders, though all natural resource managers, were also diverse in that they represented a variety of federal, state, and local agencies and organizations and had different perspectives, concerns, and management goals. This diversity was associated with a wide range of knowledge, opinions and behaviors regarding SLR-related impacts, which was beneficial for the project in some respects (e.g., gaining a holistic view of the region's situation) but limiting in others (e.g., depth of knowledge about the unique characteristics of different types of coastal resource management perspective and actions). Future research that examines and compares different types of coastal resource managers in different geographic regions is encouraged. However, as with any research, tradeoffs are necessary for decisions about study design given goals and resources.

Through proactive management and with skilled and committed assistance, EESLR-NGOM was well-organized and activities were planned thoroughly and scheduled carefully. For example, a substantial amount of planning and organizing went into the annual MC workshops. Each workshop was planned months in advance with assistance of professional workshop facilitators from the NOAA OCM and training coordinators at the local NERRs and involved numerous teleconferences and emails. Though time-consuming, these efforts were imperative for confidence, comfort, and efficient and effective execution of events. Involving professional workshop facilitators who have the necessary experience, skills, and attention to details in these manners without losing sight of the overall project picture is highly recommended. In addition, identifying optimal project partners is also strongly advised. For instance, the local NERRs were strong supporting partners in this project, and provided motivated personnel to coordinate the workshops and assist with scientific and local knowledge of the ecological and social situations of their particular geographic areas. As established and familiar organizations in their respective communities, the three NERRs and regional NOAA OCM staff also infused EESLR-NGOM with local credibility and helped the team connect to existing grassroots networks to help disseminate this project's information and results. The NERRs also provided tangible resources in the form of facilities to host the annual MC workshops.

In addition to the workshops, cumulative time and effort required for effective project communication and engagement were significantly higher than anticipated during project development. Project PIs and NOAA staff routinely attended regional science and coastal management meetings to discuss progress, results, and solicit input from additional stakeholders. Members of the team contributed to relevant coordination efforts (e.g., NOAA Sentinel Site Cooperative) and frequently integrated aspects of EESLR-NGOM into their activities. Consideration of available resources is one of the contextual-environmental conditions of "collaborative-readiness" in the Team Science transdisciplinary literature [*Hall et al.*, 2008]. An additional consideration for interdisciplinary team projects is long-term data management. EESLR-NGOM annual workshop reports are archived at the NOAA office for future accessibility. Other data are currently available via the project website, and post-project ownership, including Geographical Information System (GIS) data, is currently under discussion.

Despite much careful planning and organizing, it was still necessary for EESLR-NGOM management to adapt to unanticipated circumstances. For instance, there were a number of unexpected changes in personnel, research team members, stakeholders, and partners over the duration of this long-term project because of various outside factors. These changes had a range of implications for the project process and outcomes. For example, turnover in the Applications PI, both in terms of personnel and expertise, likely limited the ability to maximize MC capabilities. While unavoidable, turnover in this position resulted in a lack of consistent engagement at times and limited the ability of the Applications PI to adapt and learn throughout the project. Expertise of the Applications PI ranged from having coastal management responsibilities to a focus on engagement and outreach. Each type of expertise brought differing, but unique perspectives and strengths. Future transdisciplinary projects could gain from having funded representation with both sets of expertise. It might also be useful to consider the Applications PI as a type of an extension (boundary) agent, an individual whose role is to help stabilize and foster continuous information transfer between researchers and practitioners [*Lemos et al.*, 2014]. This concept derives from the literature on "boundary organizations" which are defined as organizations with the purpose of protecting the science-policy interface and brokering knowledge between scientists and decision-makers [*Lemos et al.*, 2014].

4.2. Team Dynamics

A necessary consideration for successful large-team transdisciplinary collaboration is team dynamics. Effective team dynamics hinges on trust. Trust was developed in EESLR-NGOM through a combination of existing professional relationships; regular face-to-face interaction; clear and open two-way communication using a variety of technologies and venues; patience and respect; and on-going reflection about the project process, emerging outcomes, and potential influences and consequences. This approach is in line with the literature that emphasizes frequent and on-going dialogue between scientists and stakeholders [*Roux et al.*, 2006; *Olsson and Andersson*, 2007]. Some of the feedback obtained from participants in the focus groups demonstrated that while some of the MC members were initially skeptical about how well their needs would be met by the project's products, most gained confidence in the process over time through sustained and consistent interaction among science team and MC members.

There were challenges and opportunities associated with EESLR-NGOM project team dynamics in general. One challenge is based in early education that results in esoteric science approaches across and within engineering, biological, and social science disciplines. These seemingly innate approaches could have been a barrier to achieving transdisciplinary success. However, the sometimes perceived dichotomy was used as an opportunity to educate across disciplines. The MC workshop focus groups required development of an interview guide instrument. Team members from across the disciplines, including both graduate students and co-PIs, were involved in developing and pre-testing the interview guide. This collaborative activity resulted in identification of acronyms and definitions that were germane to a particular discipline, but may not have been obvious to another and needed further clarification. The elucidations engendered respect between various disciplines by making them all aware of the need to communicate more clearly. Direct results of multidisciplinary involvement in development of a robust interview guide proved to be an effective team building exercise and served as enlightenment to all.

It was, at times, challenging for individual researchers on the science team to educate others within and outside of the team about their subject matter specializations and methodological expertise. The annual workshops provided an important venue for the researchers to present their aspects of the project to the MC, and the project stakeholders to voice their questions and concerns about the science to the scientists. This interaction was not always without miscommunication, but was overall successful in helping individuals understand different perspectives and social contexts. Within the science team, pre-annual meeting conference calls, in-person visits, and practice presentations helped the practitioners of different disciplines explain their work to one another and prepare for public presentations. Also beneficial for productive collaboration was including a senior natural scientist on the team whose prior research activities required him to work across disciplines.

One of the greatest opportunities with EESLR-NGOM was the collaboration of graduate students during fieldwork. Because the field data collection and experiments were labor intensive and the number of faculty and students involved in the project was limited, biologists and engineers were often required to work together. The necessity of collaboration resulted in, for example, exchange of information on approaches to data collection and experimental analysis (by the biologists) and how the data would be used in the numerical modeling (by the engineers). The result was enhancement of both data collection and analysis, and the computational model development and simulations. Further, the structure of devising a field trip was enhanced from considerations of safety and productivity by involving both disciplines and sharing alternative approaches. More broadly, participation of students in the annual workshops gave them legitimate real-world experience with interacting with and presenting the results of their research to non-academic stakeholders. The development of cross-disciplinary communication and translation has been identified as a key transdisciplinary education objective [*Borrego and Newswander*, 2010].

4.3. Communication

There is relatively little research literature offering specific, empirically grounded guidance on best practices in transdisciplinary communication for projects focused on regional-scale climate change adaptation preparation and model development [*Halofsky et al.*, 2011; *Olabisi et al.*, 2014]. However, vigilance in close attention to communication content, delivery (e.g., channels, frequency), and outcomes throughout the life of a project for potential improvements or refinements is advised [e.g., *Hall et al.*, 2008; *Klein*, 2008]. Experiences from EESLR-NGOM underscore the value of effective communication. Communication is multifaceted in its functions and permeates all aspects and phases of projects, internally to the team as well as externally to stakeholders and various audiences. Regular and effective communication is vital for productive transdisciplinary work, perhaps especially for projects of EESLR-NGOM's size and duration.

To generate mutual understanding and trust in such projects, face-to-face interaction is very necessary because it requires team members to be active listeners and translators, yet, these activities can also be time-consuming [*Podesta et al.*, 2013; *Krellenberg and Barth*, 2014]. The EESLR-NGOM annual workshops, for example, were reduced in duration from 2 days to 1 day, in part because of the demands of coordinating the schedules and travel commitments of all participants. For effective collaboration, digital or distributed technologies should be considered to supplement face-to-face interaction if at all possible, but not replace it [*Hossain and Wigand*, 2004]. In this project, webinars were used to present and discuss specific science developments and results between annual meetings, which were beneficial in maintaining contact among the geographically dispersed project partners.

It can be challenging to observe and consider the influences, processes, and effects of communication in its myriad forms while simultaneously being immersed in face-to-face interactions. Thus, in the early stages and throughout the entire EESLR-NGOM project, the team worked intensively with professional workshop facilitators and communication specialists, which helped alleviate many communication-related issues. That these individuals also had scientific backgrounds and solid understanding of SLR and related technical topics enhanced their integrator roles and effectiveness. The decision to include communication experts on this project was highly worthwhile and supports the literature stressing the importance of communication researchers for transdisciplinarity and advocating for their greater participation in such endeavors [*Nicholson et al.*, 2002; *Liu et al.*, 2008; *Halofsky et al.*, 2011; *Lindenfeld et al.*, 2012; *Kragt et al.*, 2013; *Krellenberg and Barth*, 2014; *Olabisi et al.*, 2014].

However, communication in EELSR-NGOM was certainly not challenge-free. For example, findings from the first annual MC workshop focus group and facilitated panel discussions of attendees showed some confusion and concerns about the project goals and expectations for the MC. This feedback, especially at such early stages, was highly beneficial as it prompted the creation and distribution of a charter document explicitly stating the project goals and expectations for the MC. Findings from a later focus group indicated a need for clarification about the outreach implementation plans for the present project and scope of dissemination. This issue was addressed in subsequent interactions.

In sum, communication-related recommendations emerging from the EELSR-NGOM experience are to understand your audience and be an active listener; ask questions for clarification; keep messages straightforward, distinct, and consistent; create a unique project brand identity; harness the power of visuals; and reflect on potential disciplinary influences such as assumptions, scientific jargon and acronyms in communication styles during team and stakeholder interactions and adjust accordingly. For example, in EESLR-NGOM, various generic labels were used to refer to the "products" that were developed from the scientific results including "models," "maps," "decision-support tools," and "products." It may have been beneficial from a communication standpoint to name these materials more precisely and as early in the project process as possible for consistency in use and to raise awareness and enhance understanding. For example, feedback from the MIRA-CDSLR evaluation suggested the need to clarify some of the fundamental functions and purposes of this project product, such as the difference between the computer model used to develop SLR scenarios and the model output that was displayed in the visualization tool [*Stephens et al.*, 2015].

5. Conclusion

A transdisciplinary research project has the potential to be transformative. EESLR-NGOM's transdisciplinary approach became transformative when it facilitated a paradigm shift away from bathtub models to process-based models of the coastal dynamics of SLR. By involving an interactive collaborative and reflective process (as evident in this article) of integrating various forms of geographically specific scientific knowledge and local viewpoints and concerns, EESLR-NGOM is transformative. The transformative nature is demonstrated through EESLR-NGOM's production of innovative conceptual frameworks and research results and products that contribute unique and meaningful solutions to the complex and pressing real-world problems of regional-scale preparations for SLR impacts [*Frazier et al.*, 2010]. By embracing various perspectives through an effective collaborative process, this transdisciplinary research project uncovered additional new questions that may have been overlooked. For example, most of the numerical modeling work was completed by engineers. However, incorporating the insight of biologists who explained fundamental concepts behind marsh accretion enabled the engineers to conceptualize a mechanistic description that could be numerically modeled. Likewise, incorporation of hindcasting of SLR, shorelines, and storm surge at the recommendation of the MC provided enhanced abilities to test and validate modeling approaches.

Though specifics on the science are beyond the scope of the present article, EESLR-NGOM's products and outcomes stemmed from a synthesis of disciplinary strengths, yielding new interpretations of data, alternative explanations of findings, and innovative products (decision-support tools). The MIRA-CDSLR, the project's key product, can be classified as a transformative model [*Allen et al.*, 2013]. Further, EESLR-NGOM successfully addressed the science "usability gap" concern [*Lemos et al.*, 2012] by incorporating a combination of on-going interactive stakeholder engagement mechanisms that fostered production of products (decision-support tools) that correspond with coastal resource managers' SLR impact preparation needs and are readily accessible for use and distribution to other audiences in the region. The generation of contextualized knowledge advanced understanding and produced dynamic applications and innovative solutions to SLR impact issues that are more robust, comprehensive, and sustainable. The synergistic benefits also spawned numerous viable outreach recommendations with potential to reach, resonate with, and influence various target audiences.

In addition to transformative outcomes, and arguably more importantly, the EESLR-NGOM process itself has been transformative. That is, besides subject matter-related benefits, the participants involved (scholars, stakeholders, and students) have learned and grown individually and together through the process of combining intellectual and technical expertise and navigating new intellectual and communication challenges. For example, the engineering team gained valuable perspective on biological processes and challenges by participating in field-based assessments and bioassays. From these experiences, they developed or cultivated existing professional relationships; discovered new career paths and advancement opportunities; and found further related research partners and pursuits. For instance, some team members identified common research interests and secured additional grants for other projects (e.g., the *Connecting Scientists to Citizens Regarding Sea Level Rise* project mentioned previously). This appreciation of process as well as product has been recognized among scholars involved in related endeavors [e.g., *Voinov and Bousquet*, 2010]. Besides transformative outcomes, high-quantity products also resulted from EESLR-NGOM. Merged literature searches, pooled empirical datasets, strategic team coordination, and leveraged resources across multiple fields produced a prolific number of academic and applied products, publications, and presentations.

EESLR-NGOM, like all research, has limitations that are important to acknowledge. The primary limitations pertain to risk and uncertainty, and to some degree, generalizability. Thus far, success of the EESLR-NGOM collaborative process can be viewed in terms of three primary categories of outcomes. The first is a distinct change in management knowledge with respect to a paradigm shift in the science and assessment of impacts of SLR, and the resultant management applications. This paradigm shift from bathtub assessments to a coastally dynamic approach distinguishes multidisciplinary from transdisciplinary research. Bathtub assessments are often performed individually, with one scientist assessing extent of inundation because of SLR and providing their results to another scientist who determines the impact to a natural or social system. Alternatively, transdisciplinary research results when science-based, stakeholder-informed, coastal dynamic assessment of SLR is translated to management actions. Next, there has been considerable progress made toward changes in management actions. These changes are exemplified in follow-up projects by scientists and engineers throughout the United States that are documented by the scholarly literature stream [*Passeri et al.*, 2015] in general and in this special section of *Earth's Future*. The dedicated students who contributed greatly to EESLR-NGOM will incorporate their knowledge and experience throughout their careers. The final metric of success is any change in societal or environmental conditions. However, assessment of that outcome will likely take years to complete and will be difficult to demonstrate causation.

The next steps and avenues for future research and application include distinguishing and prioritizing subsets of EESLR-NGOM stakeholders more specifically and solidifying an outreach plan and distribution strategy for the MIRA-CDSLR. As "unfortunately, in far too many cases the projects die with the end of the funding" [*Voinov and Bousquet*, 2010, p. 1278], it is also this team's intent to apply for funding for further investigation of and refinement of the MIRA-CDSLR, again using a transdisciplinary approach. Training and mentoring emerging researchers to acquire the knowledge, skills, and experience for productive transdisciplinary work is at the forefront of intended proposals for related follow-up activity. As there is a need for further development and testing of standardized yet flexible evaluative tools for collaborative processes of transdisciplinary projects in different contexts (e.g., biomedical science projects compared to environmental sciences projects), more systematic and empirical study focused on evaluation is on this team's agenda as well. Particularly warranted is a post-project evaluation survey of all individuals associated with EESLR-NGOM, with instrument construction and administration procedures informed and guided by frameworks and metrics in the transdisciplinary research literature, especially those of Team Science. Finally, it is hoped that the robust science–management alliance that was established in this project will continue as, "the development of long-term partnerships between modelers and model end-users is fundamental to promoting on-going adaptive management" [*Voinov and Bousquet*, 2010, p. 1278].

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