Strategies to improve implementation of adaptive management practices for restoration in coastal Louisiana

By

Tim J.B. Carruthers,[1] Richard C. Raynie,[2] Alyssa M. Dausman,[1] and Syed Khalil[2]

1) The Water Institute of the Gulf, Baton Rouge, LA 70802; email: tcarruthers@thewaterinstute.org

2) Coastal Protection and Restoration Authority, Baton Rouge, LA 70804; email: Richard.Raynie@LA.GOV

ABSTRACT

Natural resources of coastal Louisiana support the economies of Louisiana and the whole of the United States. However, future conditions of coastal Louisiana are highly uncertain due to the dynamic processes of the Mississippi River delta, unpredictable storm events, subsidence, sea level rise, increasing temperatures, and extensive historic management actions that have altered natural coastal processes. To address these concerns, a centralized state agency was formed to coordinate coastal protection and restoration effort, the Coastal Protection and Restoration Authority (CPRA). This promoted knowledge centralization and supported informal adaptive management for restoration efforts, at that time mostly funded through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA). Since the Deepwater Horizon (DWH) oil spill in 2010 and the subsequent settlement, the majority of restoration funding for the next 15 years will come through one of the DWH mechanisms; Natural Resource and Damage Assessment (NRDA), the RESTORE Council, or National Fish and Wildlife Foundation –Gulf Environmental Benefit Fund (NFWF-GEBF). This has greatly increased restoration effort and increased governance complexity associated with project funding, implementation, and reporting. As a result, there is enhanced impetus to formalize and unify adaptive management processes for coastal restoration in Louisiana. Through synthesis of input from local coastal managers, historical and current processes for project and programmatic implementation and adaptive management were summarized. Key gaps and needs to specifically increase implementation of adaptive management within the Louisiana coastal restoration community were identified and developed into eight tangible and specific recommendations. These were to streamline governance through increased coordination amongst implementing entities, develop a discoverable and practical lessons learned and decision database, coordinate ecosystem reporting, identify commonality of restoration goals, develop a common cross-agency adaptive management handbook for all personnel, improve communication (both in-reach and outreach), have a common repository and clearing house for numerical models used for restoration planning and assessment, and expand approaches for two-way stakeholder engagement throughout the restoration process. A common vision and maximizing synergies between entities can improve adaptive management implementation to maximize ecosystem and community benefits of restoration effort in coastal Louisiana. This work adds to current knowledge by providing specific strategies and recommendations, based upon extensive engagement with restoration practitioners from multiple state and federal agencies. Addressing these practitioner-identified gaps and needs will improve engagement in adaptive management in coastal Louisiana, a large geographic area with high restoration implementation within a complex governance framework.

KEYWORDS: Coastal Management, Deepwater Horizon (DWH), Natural Resource and Damage Assessment (NRDA), Louisiana Coastal Protection and Restoration Authority (CPRA), National Fisheries and Wildlife Foundation, (NFWF), Gulf Environment Benefit Fund (GEBF), RESTORE Council, The Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA).

Manuscript submitted 10 October 2019; revised & accepted: 10 January 2020.

The economies of Louisiana and the entire United States are supported by the natural resources of coastal Louisiana. Historically, there has been extensive human intervention to protect communities and infrastructure that has altered many natural coastal processes. As a large coastal delta of the Mississippi River, this area is highly dynamic and susceptible to storm events, subsidence, sea level rise, and increasing temperatures (Day *et al.* 2000; Scavia *et al.* 2002). Historically, the majority of coastal restoration funding in Louisiana came through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Task Force (LA $30 million to $80 million per annum) and projects implemented to achieve Coastal Protection and Restoration Authority (CPRA) goals (CWPPRA 2014). However, since the Deepwater Horizon oil spill in 2010 and the resultant settlement, three new mechanisms will fund the majority of coastal restoration in Louisiana over the next 15 years. These are the Natural Resource Damage Assessment (NRDA) through the Louisiana Trustee Implementation Group (LA TIG) (LA $5 billion) (DWH NRDA 2016), RESTORE Council (LA $553 million of Spill Impact component + LA allocation of $1.6 billion Restoration component) (GCERC 2016), and NFWF Board of Directors through the Gulfwide Environmental Benefit Fund (GEBF) (Gulfwide $2.544 billion; LA $1.272 billion over five years for barrier island and river diversion projects) (https://www.nfwf.org/gulf/Pages/home.aspx).

Adaptive management in deltaic environments needs to be flexible and integrate natural and socio-economic systems, considering risk and uncertainty to manage these complex ecosystems (Steyer *et al.* 2004; Steyer and Llewellyn 2000). It promotes solutions that are sustainable under changing, or unknown, conditions by providing a science based and structured process for making decisions and programmatic or project adjustments. Key concepts for success in deltaic systems are connecting short-term investments

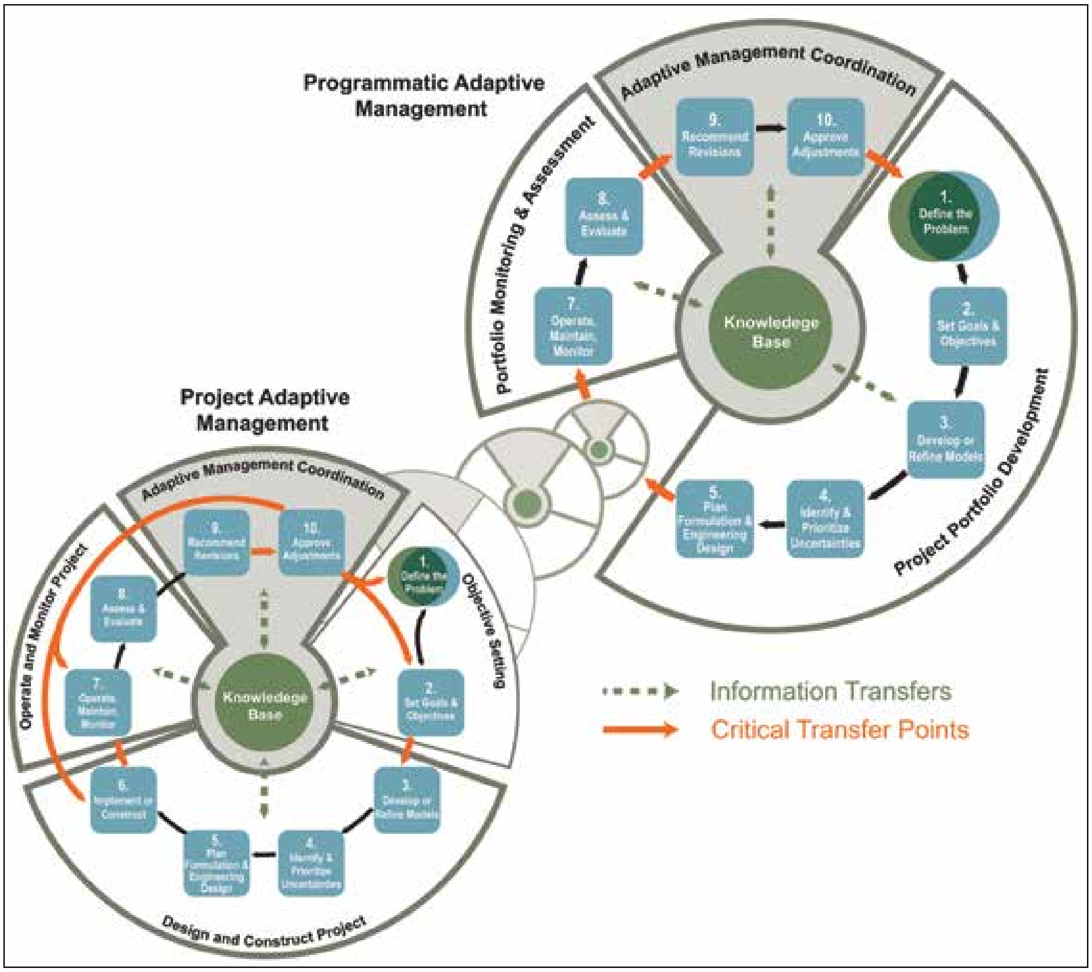

Figure 1. The 10 steps for adaptive management to implement project and programmatic coastal restoration in Louisiana.

with long-term changes and the selection of actions that allow for maximum flexibility (Delta Alliance 2014). Historically, as human developments increased in the Mississippi delta, decisions were made that resulted in long-term consequences, including the location of New Orleans and constructing Mississippi River training levees (Khalil and Raynie 2015). Learning from these past decisions and understanding resultant limitations can maximize future flexibility through development of adaptation pathways (Delta Alliance 2014; Haasnoot 2013). Successful adaptive management is iterative, allowing for incorporation of new knowledge at every step of the process (The Water Institute of the Gulf 2013).

Environmental systems are inherently complex and non-linear, making predictions of restoration success highly challenging (National Research Council and Academy of Sciences 1992). Therefore, decision making to increase sustainability relies on knowledge about the state of the ecosystem and the prognosis for development, which both have a degree of uncertainty (Thom 2000). Adaptive management relies on the accumulation of evidence to support decisions that demand action (Walters and Holling 1990). For adaptive management to be successful, it is critical to have a defined framework and specified management actions. Adaptive management is a passive or active process to capture and communicate institutional knowledge. It can improve understanding of the system and assist management actions to best achieve restoration goals. All phases of restoration management must be coordinated and share information, not only to maximize the benefits on a project-by-project basis, but also to carry the information learned from past projects into the development of future project and programmatic success (Raynie and Visser 2002). A high level of institutional commitment is needed to successfully incorporate adaptive management into ongoing programmatic coastal ecosystem restoration efforts.

The definition of adaptive management for coastal restoration in Louisiana was developed and adopted by 49 coastal restoration practitioners from five state and federal agencies. Adaptive management was defined as a systematic process to incorporate new and existing knowledge into management decisions (The Water Institute of the Gulf 2020; Williams *et al.* 2009). It is a learning-based, iterative process to improve management decisions, based on increasing understanding and feedback between learning and subsequent decisions (Williams 2011). Finally, it includes a science-based approach to identify explicit goals and objectives, performance measures and decision triggers, management action planning and implementation, assessment of ecosystem response to actions, and decision-making.

CURRENT ADAPTIVE MANAGEMENT PRACTICE IN LOUISIANA

The iterative nature of adaptive management involves a process of design, management, and monitoring to facilitate learning. The number and structure of steps has been proposed in multiple formats of varying complexity (Murphy and Weiland 2014). Adaptive management has been limited in improving management outcomes and to be successful requires careful planning and well formulated frameworks for decision making (Murphy

Table 1.
Description of adaptive management activities.

Activity	Description
Knowledge base components	
Information management	Organizing, managing, and making relevant data and information discoverable in a format to inform management decisions.
Applied synthesis and research	Research to resolve specific uncertainties at project, regional, or coastwide scales. Synthesis and assessment documents summarize studies and compare/contrast research findings to inform programmatic implementation.
Stakeholder engagement	Dialogue, deliberation, and two-way communication with residents and stakeholders with diverse perspectives helps remove barriers to program and project success.
Communication	One-way communication to disseminate knowledge and information to multiple audiences, both in-reach (within agency) and outreach (outside of agency).
Steps of adaptive management in practice in Louisiana	
1. Define the problem	A clearly defined problem statement articulates the underlying reason why action is needed and establishes a foundation for restoration implementation.
2. Set goals and objectives	Identifying (or reassessing) goals and objectives that specifically address the problem is critical to successful restoration implementation and assessment.
3. Develop or refine models	Models may be necessary to understand the relationship between the problem, goals, objectives, and proposed restoration actions. Models also help identify critical uncertainties that need to be monitored to evaluate success.
4. Identify and prioritize uncertainties	Quantifying uncertainty is critical to understand modeling limitations, identify confidence in planning processes, and target future monitoring and research needs.
5. Plan formulation and engineering design	Plans should be designed in a manner that is robust and targeted to the problems identified and the specific goals/objectives. However, they need to remain sufficiently flexible to address any identified uncertainties.
6. Implement or construct	Programmatically implementing a formulated plan to efficiently address a specific problem, related goals and objectives. At the project level, this includes the construction activities specific to the project. Implementation of the plan and construction of projects must also remain flexible to ecosystem changes and document actions related to changes during implementation.
7. Operate, maintain, and monitor	Operation and maintenance are critical to ensure that the project (or project portfolio) is functioning as expected. Operations refer to the daily running of a project in response to external decision drivers (for example, weir opening in response to river stage). Maintenance is any action to repair or update the project to ensure continued performance. Monitoring is a means both to track performance against expectations and to advance scientific understanding. Monitoring data provide feedback between decision-making and ecosystem response relative to goals and objectives. This data also supports other aspects of adaptive management, such as problem identification, model development, and plan formulation.
8. Assess and evaluate	Assessment of restoration performance can resolve uncertainties to increase understanding and predictive capability and identify the need to change course. This is also where problem statement and goals and objectives are reassessed.
9. Recommend revisions	Utilize findings of assessment and evaluation to recommend programmatic or project modifications or refinements (both structural and operational) to improve overall performance.
10.Approve adjustments	Take technical recommendations through appropriate approval processes or seek funding (if needed) to implement adjustments.

and Weiland 2014). Therefore, the steps and structure for adaptive management need to engage local governance structures to be effective. For this reason, 10 steps were identified to summarize current and historic practice of adaptive management for Louisiana to ensure engagement of adaptive management needs and processes into historical and current planning and prioritization for coastal restoration (Table 1). The clarification of step three, Develop or Refine Models, reflects a particularly strong focus on using numerical modeling at an ecosystem scale within Louisiana for large-scale restoration planning, including within the Louisiana Coastal Master Plan process (CPRA 2017). The local management practitioners also agreed that it was helpful to differentiate the process of recommending revisions from approving adjustments as these processes often include different governance processes and this part of the adaptive management cycle is the most challenging to successfully implement (Table 1). To ensure effective communication to highest level decision-makers and the public, the steps of the adaptive management cycle for projects were summarized into four phases, and programmatically into three phases (Figure 1). The linkages and commonalities between programmatic and project adaptive management are discussed below.

CURRENT LINKAGES BETWEEN PROJECT AND PROGRAMMATIC ADAPTIVE MANAGEMENT

Adaptive management is applied both programmatically (i.e. portfolios of projects) and within individual projects (Figure 1). Programmatic adaptive management is a structured process for learning, based on the relative success of implemented projects and portfolios of projects. It enables adjustments in design, management, and selection of projects as new information becomes available. Project specific adaptive management occurs for the life of that project and maximizes the success of the project by accessing knowledge from previous projects of relevant type or geographic location. Uncertainty around project performance and success will be greater in the absence of knowledge from previous projects. In addition, adaptive management supports a structured process for quantified assessments of project performance to manage project operation, refine project monitoring, or develop and implement project redesign. Programmatic restoration efforts often implement a portfolio of projects that have been identified and prioritized together, providing potential for strong linkages between project and programmatic adaptive management (Figure 1).

Programmatically, the lessons learned from the implementation and assessment of the portfolio of projects is currently used, informally or passively, to inform selection and implementation of subsequent portfolios of projects to achieve overarching programmatic goals (step nine, Figure 1). Recommendations of mechanisms or tools to support decisions on project portfolios can be made by any implementing personnel (e.g. planners, engineers, construction personnel). Revisions are primarily recommended by project specific staff (project managers, project engineers, and topic scientists). Within the context of DWH NRDA restoration, this phase in the adaptive management cycle includes implementing corrective actions, when necessary, to projects that are not trending toward established performance criteria or having crossed identified action triggers or thresholds. It may also involve adjustments over time to projects that require ongoing decision-making (e.g. water flow structures), reducing decision uncertainty. Understanding and documenting causes of reduced project performance, including unanticipated events, can adaptively inform development of corrective actions.

Based upon multiple projects previously implemented by CPRA, revisions may result in changes to operations, monitoring, maintenance, or design. In those cases, the field engineer and monitoring manager, with input from topic scientists and the study manager, will develop and ultimately approve recommendations for revisions or changes (Figure 1). If recommended revisions necessitate changes to programmatic goals or will have major design considerations for other projects, the decision-making process to approve revisions may be administratively elevated. At the other extreme, some projects have no opportunity for revision (due to funding or small scale of project) and so any lessons learned need to be captured programmatically for future projects. For DWH NRDA projects, modifications to a project or the project monitoring and adaptive management (MAM) plan are by the Implementing Trustee (s) in coordination with the Trustee Implementation Group (TIG). Public notification is required if the corrective actions require additional environmental review (e.g. modification to regulatory permits) or material changes to the project (https://www.doi.gov/deepwaterhorizon/adminrecord).

Although recommendations and approvals of revisions currently occur informally in Louisiana, incorporation of lessons learned has been limited by a lack of a formalized process to identify personnel, incentives, support mechanisms, and funding to drive systematic progress in adaptive management. Additionally, the current increase in project implementation has increased the individual and collective knowledge of restoration, in terms of generated knowledge and need to access current knowledge. Recommending revisions and approving adjustments in the adaptive management process would be improved by formally documenting decisions and lessons learned and making the knowledge discoverable and searchable.

During Adaptive Management Coordination (Figure 1), development of recommendations relies on input from information management, including results and lessons learned from constructed projects. Additionally, supporting information can come from scientific data and syntheses from Applied Synthesis and Research and compiled data and information available from Information Management (Figure 2). Stakeholder Engagement and Communication also provide key feedback from restoration implementation personnel and external stakeholders on lessons learned from current efforts and considerations for future efforts (Figure 2). Basing recommendations on best available science, lessons learned, and input from stakeholders maximizes the potential for improved future planning and decision-making. While this currently occurs in Louisiana during restoration implementation, formal processes and clarified governance interactions would enhance the benefits of these feedback mechanisms.

DEFINING THE KNOWLEDGE BASE — THE "CURRENCY" OF ADAPTIVE MANAGEMENT

Developing discoverable institutional knowledge is essential to improve understanding of ecosystem functioning and reduce uncertainties. Actively maintaining this knowledge, data, and information ensures continued institutional knowledge growth, rather than just individual knowledge growth, to improve restoration outcomes. The knowledge base is defined here as the accumulated institutional knowledge, data, lessons learned, and discussions that inform adaptive management coordination and implementation (Figure 2). Many of the elements described have been historically, or are currently, part of ongoing restoration practice in Louisiana, however this definition provides a synthesis and framework of how these information elements interact and highlights gaps and knowledge needs. The knowledge base includes four components: Information Management, Applied Synthesis and Research, Stakeholder Engagement, and Communication (Figure 2). Current status of each is described below and gaps or needs identified.

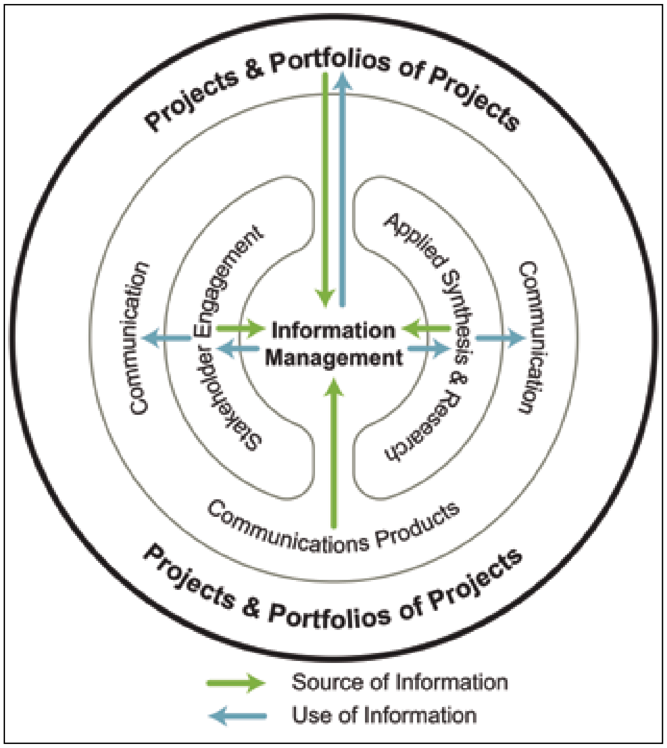

Figure 2. The knowledge base is the essential mechanism for information and knowledge capture and transfer for effective adaptive management and is composed of Information Management, Stakeholder Engagement, Applied Synthesis and Research, and Communication.

Applied synthesis and research consists of efforts to resolve scientific or technical uncertainties (e.g. performance of marsh creation projects with different sediment types), related to individual projects or larger regional uncertainties (e.g. subsidence in Louisiana) (Figure 2). It also includes efforts to improve and refine numerical models (e.g. Coastal Master Plan models), resolve uncertainties of model calibration and validation, and direct research to improve prediction accuracy. Active efforts to synthesize this newly accumulated knowledge have been developed for some geographic basins in Louisiana, however data and knowledge synthesis is not currently regular or systematic. Project-level monitoring also identifies site or project knowledge gaps to prioritize as research needs. Resolving these uncertainties may require applied research including feasibility studies, additional modeling, or experiments. These corrections have historically, and are currently, informal and ad-hoc or else within a very specific process such as revising the numerical models of the Coastal Master Plan. Formalized and documented processes with high compliance would greatly increase the utility and application of applied synthesis and research.

Information management in Louisiana is currently multiple information centralization and delivery systems, including databases, project management mechanisms, commonly accessible drives and website portals (Figure 2). An essential element of information management to support effective adaptive management is some centralized, discoverable, and searchable mechanism for capturing and storing lessons learned, as well as documenting approaches and information used to support decision-making. The location or platform is less important than high functionality, so this mechanism or tool must be broadly accessible, easy to use, searchable, and adaptable so that it can evolve with changing funding sources, needs and technologies over time. This is not currently available in Louisiana, although two web-based databases, CIMS and DIVER, meet the fundamental reporting needs of current restoration implementing entities, such as NRDA. Primary input to information management is from implementation of projects and portfolios of projects. This includes programmatic vision statements, planning documents, background resources and information, project design, completion and monitoring reports, and outputs from modeling efforts to support project design and operations. These primary documents are used to inform stakeholder engagement; to provide source documents for synthesis (e.g. by geography or restoration type); and to identify and prioritize applied research needs (Figure 2). However, these documents, information, data, and knowledge are not currently centralized across implementing entities.

Stakeholder engagement is an essential component of coastal restoration adaptive management (especially for large-scale or contentious projects) (Figure 2). Involving stakeholders in planning ensures transparency and facilitates inclusion of stakeholder interests, values, ideas, experiences, and expectations. It also builds trust, thereby increasing the likelihood of support for the restoration process through a common vision of success. Shared understanding with stakeholders can also limit costly delays, legal actions, and increase support for policy alterations. Stakeholder Engagement is a critical piece of CPRA's adaptive management program and facilitates the inclusion of knowledge from a variety of perspectives from communities and families who live and work along Louisiana's coast and have first-hand experience with coastal issues. Advisory boards are currently one key mechanism for stakeholder engagement at CPRA. Formal public hearings are also commonly implemented and enable large numbers of people to have their say, provide opportunity to explain processes, share information, and gain feedback. While formal public hearings within the permitting process allow stakeholders three minutes to speak, agency personnel are not allowed to directly respond so this format may not help to advance public understanding, even when the recorded public comments are specifically and individually responded to in written project documents.

Communication is critical to maintain connectivity with multiple audiences and differs from stakeholder engagement in that it is more limited to delivering information (one way) whereas stakeholder engagement represents a two-way flow of information (Figure 2). In-reach occurs as communication within key agencies or decision-making authorities, to ensure agency staff are fully informed and can make more informed decisions. A desire for increased in-reach was consistently raised by representatives from the five federal and state agencies closely engaged with this work. Opportunities to implement lessons learned across projects are more likely with increased in-reach communication. Outreach includes actions to keep other agencies and the public informed, such as emails, press releases, internet messaging, briefings, meetings, and presentations. These communications have been the most developed and formalized for coastal restoration in Louisiana, in-reach processes are less well developed and largely informal.

Informed restoration decisions (effective adaptive management) rely on easily available and discoverable data and information for managers and decision-makers (Information Management, Figure 2). Programmatically, it is important to maintain consistency in formats, quality standards, and availability of data and documents, ensuring accommodation of specific requirements of all funding sources. This consistency helps facilitate the aggregation of data and information to make decisions that are larger in scale than individual projects.

CURRENT PROJECT ADAPTIVE MANAGEMENT PROCESSES — THE FUNDAMENTAL BASIS

Even a perfect programmatic plan of action will have no influence on ecosystem condition without effective and successful project implementation. Therefore, a greater understanding of processes for project implementation is fundamental to understand capacity limitations and knowledge gaps to improve both project and programmatic adaptive management.

The adaptive management actions, personnel involved, processes for capturing lessons learned, data, and need for knowledge input vary during the steps of project implementation (Figure 3). Each phase engages a diversity of personnel including accountants, administrative specialists, attorneys, data managers, engineers, executive administrators, land rights specialists, monitoring managers, permitting specialists, planners, project managers, and social and natural resource scientists. Within coastal Louisiana, restoration projects are primarily implemented through the state Coastal Protection and Restoration Authority (CPRA). Therefore, a summary of current project implementation staff is presented as an example of detailing which personnel need to be engaged with adaptive management at each step of the project adaptive management cycle (Figure 3). Two examples, both with great potential for collective learning, highlight the utility of this synthesis for adaptive management planning and implementation. Firstly, identification of critical project transfer and linkage meetings, and secondly, times during a project cycle where projects may be halted or abandoned, "project off-ramps" (Figure 3).

At the end of the project objective setting phase there is a critical knowledge transfer to the Design and Construct Project phase, which begins with a project kickoff meeting. This meeting provides an opportunity to discuss the problem being addressed, to clarify the project-specific objectives, and to maximize information and knowledge transfer to the new set of responsible personnel (Figure 3). It also provides opportunities to more formally capture decisions and lessons learned, for example in an adaptive management lessons learned and decision database. Another critical transfer point is the hand off meeting from the Design and Construct Project phase, with potential for enhanced knowledge and data transfer to improve adaptive management (Figure 3). Particular attention on developing processes and procedures to capture knowledge and information at these critical transfer points can enhance adaptive management within a project and, over time, for project types, within geographic areas, and programmatically (Figure 1).

There are at least five points during the project adaptive management cycle that can result in a project exiting the cycle temporarily or permanently; these points are identified as "project off-ramps" (Figure 3). Projects that are not pursued have an important set of lessons learned, including the information and knowledge that was used to arrive at the decisions for not proceeding. While not currently a formal practice, this information is beneficial to document in a mechanism to associate lessons learned and decisions from individual projects. During the Design and Construct Project phase, the project can exit and potentially be removed from further consideration due to issues of land rights; because the project is found to be unfeasible; or due to unforeseen site changes, such as a major storm, that greatly increase the cost or scope of a project, thus making a previously feasible project unfeasible. During the Operate and Monitor Project phase, monitoring may show that the project is performing poorly, possibly in comparison to project costs, and if conditions do not allow for project adjustments or improvements, the project may be discontinued. Another project off ramp occurs when a project reaches the end of its intended life span or operational period. In all these cases (Figure 3), the project exits the project adaptive management cycle. Project off ramps provide an important, currently under-documented, opportunity to capture lessons learned (i.e. successes and challenges) and documenting the decision-making process can improve future project implementation.

A VISION TO IMPROVE SYNERGIES IN RESTORATION GOVERNANCE IN LOUISIANA

To identify common programmatic goals and priorities as well as to maximize restoration effectiveness across the expanded governance structures in Louisiana, synergistic mechanisms between CPRA, LA TIG and Trustees, RESTORE Council, and NFWF will be needed. For the most part, the goals and requirements of RESTORE Council are captured within those of LA TIG (NRDA) and those for NFWF are largely encompassed by the goals of CPRA (Figure 4). The desired basis for adaptive management is to identify synergies in programmatic goals to increase efficiency across all implementing entities (Figure 4). Historically, land area has been the primary goal for restoration in coastal Louisiana, with the assumption that this will sustain fundamental ecosystems and ecosystem functions. Considering a broader ecosystem or landscape context for implemented restoration projects can provide a framework for emphasizing commonality of restoration goals, across implementing entities. Such a framework can support multiple benefits of restoration being quantified, including prioritized natural resources, to support assessment of proj-

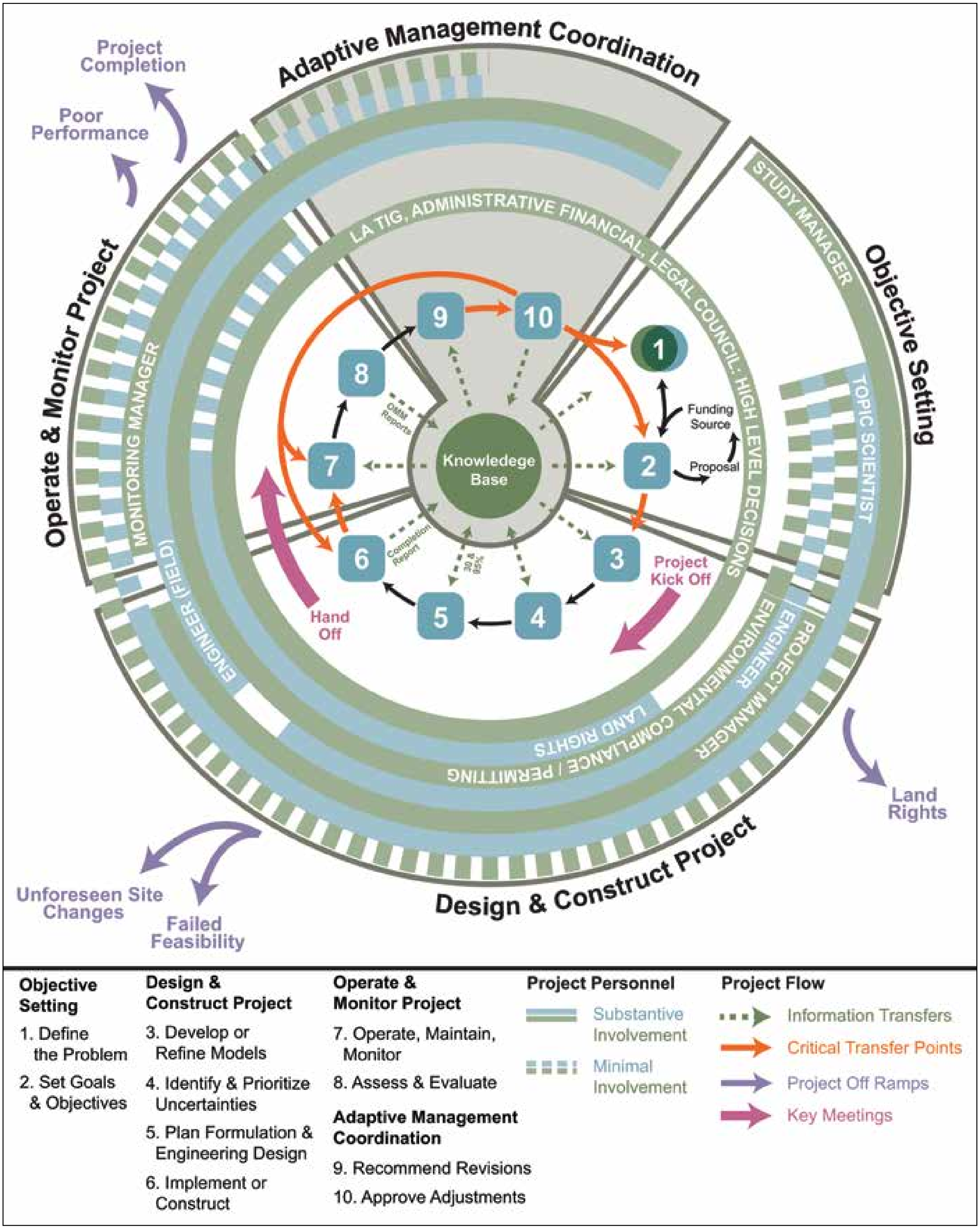

Figure 3. Detailed adaptive management cycle for habitat restoration projects, identifying key personnel functions, reporting points, meeting points, and project off ramps. Responsibilities are represented in both green and blue.

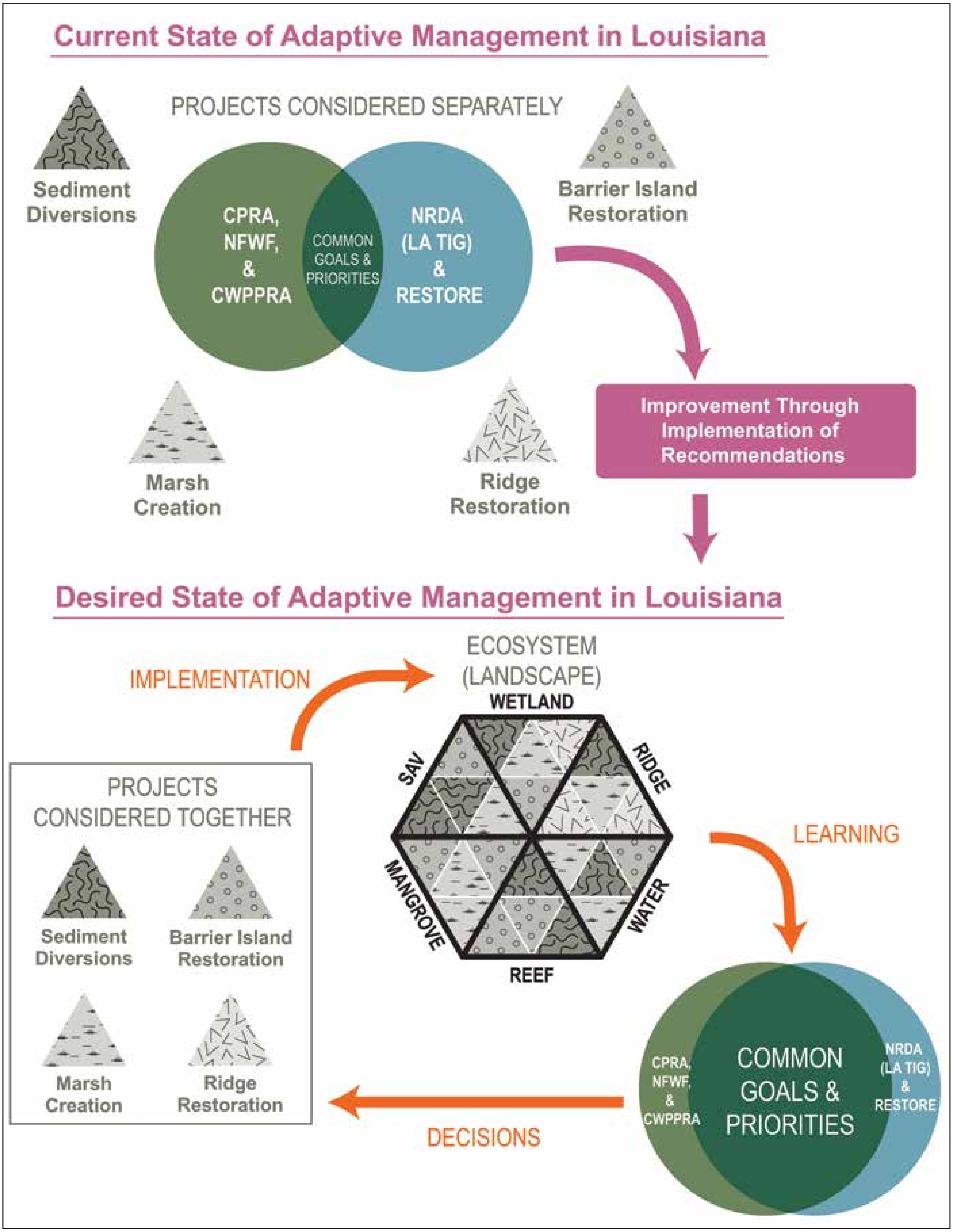

Figure 4. A vision for adaptive management implementation in coastal Louisiana.

ect and programmatic restoration efforts in coastal Louisiana (Figure 4).

CONCLUSIONS

The following eight strategic actions are recommended to fill identified governance and capacity gaps and improve adaptive management practice in coastal Louisiana (The Water Institute of the Gulf 2020). Improved adaptive management can increase the success of restoration effort in coastal Louisiana.

1. Coordination: Fund and establish dedicated additional adaptive management capacity, including but not limited to, funding a Louisiana adaptive management coordinator.

2. Data management: Develop a 'lessons learned database' in addition to interoperability of the Coastal Information Management System (CIMS-CPRA) and Data Integration Visualization Exploration and Reporting (DIVER-NOAA-NRDA) to facilitate transfer and synergies, while minimizing duplication of data access and utilization for restoration management, planning, and decision-making.

3. Ecosystem reporting: Implement cross disciplinary coastal ecosystem condition reporting (physical, ecological, social) for example an integrated ecosystem report card.

4. Restoration goals: Identify commonalities of restoration goals and objectives across implementing entities to maximize co-benefits of restoration and synergies in restoration governance.

5. Common processes: Operationalize an electronic step-by-step practical handbook for implementation of adaptive management in Louisiana for personnel involved in restoration from all implementing entities.

6. Communication: Develop science communication approaches that increase effectiveness of information dissemination to communities (outreach) and within agencies (in-reach).

7. Numerical modeling: Develop a common repository and clearinghouse for coastal Louisiana restoration related numerical models to ensure tracking, maximize continued learning, and minimize duplication of effort.

8. **Stakeholder engagement:** Establish standard operating procedures for stakeholder engagement, specifically including active and two-way mechanisms to ensure feedback and engagement in restoration planning, implementation, and operation.

This work adds to current knowledge by providing specific guidance and recommendations, based upon extensive engagement with dozens of restoration practitioners from multiple state and federal agencies. Addressing these, practitioner identified, gaps and needs will improve use of adaptive management in coastal Louisiana, a large geographic area with high restoration implementation within a complex governance framework.

ACKNOWLEDGEMENTS

The work presented here synthesizes outcomes of discussions with more than 49 coastal managers from CPRA, DOI, NOAA, EPA, USDA, LSU, and The Water Institute. This included a workshop in May 2018 and more than 100 calls. We thank Carin Bisland, Nick Aumen, Heida Diefenderfer, and Chad Smith for comment and review. Colleen McHugh assisted with graphics. This work was developed for the Coastal Protection and Restoration Authority (CPRA) and The Louisiana Technical Implementation Group (LA TIG) and funded by the LA TIG through CPRA Task Order 50.2, Contract No. 2503-12-58.

REFERENCES

CPRA, 2017. *Louisiana's Comprehensive Master Plan for a Sustainable Coast: Committed to Our Coast*. Coastal Protection and Restoration Authority.

CWPPRA, 2014. "Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) Standard Operating Procedures." Revision 24.

Day, J.W., L.D. Britsch, S.R. Hawes, G.P. Shaffer, D.J. Reed, and D. Cahoon, 2000. "Pattern and process of land loss in the Mississippi Delta: A spatial and temporal analysis of wetland habitat change." *Estuaries* 23(4), 425.

Delta Alliance, 2014. "Towards a comprehensive framework for adaptive delta management." P. 39 in *M. Marchand (Deltares) and F. Ludwig (Wageningen UR-Alerra) (Eds.), Version 2.2.*

DWH NRDA, 2016. "Deepwater Horizon Oil Spill Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement." Deepwater Horizon Natural Resource Damage Assessment Trustees.

GCERC, 2016. "Gulf Coast Ecosystem Restoration Council Comprehensive Plan Update 2016: Restoring the Gulf Coast's Ecosystem and Economy." Update. Gulf Coast Ecosystem Restoration Council.

Haasnoot, M., 2013. *Anticipating Change: Sustainable Water Policy Pathways for an Uncertain Future*. Ph.D. Dissertation, University of Twente, Enschede, the Netherlands.

Khalil, S. and R. Raynie, 2015. "An integrated system-based approach to restoration of Louisiana's barrier islands." P. 14 in *Proceedings of the Coastal Sediments 2015*. Baton Rouge, LA.

Murphy, D.D., and P.S. Weiland, 2014. "Science and structured decision making: fulfilling the promise of adaptive management for imperiled species." J. *Environmental Studies and Sciences* 4(3), 200-207.

National Research Council and Academy of Sciences, 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy.* Washington, DC: National Academy Press.

Raynie, R.C., and J.M. Visser, 2002. *CWPPRA Adaptive Management Review. Final Report.* Prepared for the CWPPRA Planning and Evaluation Subcommittee, Technical Committee, and Task Force.

Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, and J.G. Titus, 2002. "Climate change impacts on U. S. coastal and marine ecosystems." *Estuaries* 25(2), 149–164.

Steyer, G.D., and D.W. Llewellyn, 2000. "Coastal Wetlands Planning, Protection, and Restoration Act: A programmatic application of adaptive management." *Ecological Engineering* 15(3-4), 385-395.

Steyer, G.D., J.M. Visser, B. Good, J.M. Nestler, W. Nuttle, D.J. Reed, V. Rivera-Monroy, K. A. Rose, and R.R. Twilley, 2004. "Adaptive environmental assessment and management: a draft framework, Chapter 22." in *Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Volume II: Tasks 9-15. Vol. 2*, edited by R. R. Twilley. Baton Rouge, LA: Final Report to Department of Natural Resources, Coastal Restoration Division.

The Water Institute of the Gulf, 2013. *Adaptive Management Framework for Coastal Louisiana.* Produced for and funded by the Coastal Protection and Restoration Authority under Task Order 9, Contract No. 2503-12-58. Baton Rouge, LA.

The Water Institute of the Gulf. 2020, *Louisiana Adaptive Management Status and Improvement Report: Vision and Recommendations.* Prepared for the Coastal Protection and Restoration Authority (CPRA) and the Louisiana Trustee Implementation Group (LA TIG), funded by the LA TIG. Task Order 50.2, Contract No. 2503-12-58. Baton Rouge, Louisiana.

Thom, R.M., 2000. "Adaptive management of coastal ecosystem restoration projects." *Ecological Engineering* 15(3-4), 365-372.

Walters, C.J., and C.S. Holling, 1990. "Large-scale management experiments and learning by doing." *Ecology* 71(6), 2060-2068.

Williams, B.K., 2011. "Adaptive management of natural resources—framework and issues." *Journal of Environmental Management* 92(5), 1346-1353.

Williams, B., R. Szaro, and C. Shapiro, 2009. *Adaptive Management: The U.S. Department of the Interior Technical Guide*. Washington, DC: Adaptive Management Working Group. U.S. Department of the Interior.