Management in Coastal Louisiana Restoration

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1. Overview

Louisiana has lost over 4800 km^2 of coastal land since 1932, and a large-scale effort to restore coastal Louisiana is underway, guided by *Louisiana's Comprehensive Master Plan for a Sustainable Coast*. This entry reviews science-based planning processes to address uncertainties in management decisions, and determine the most effective combination of restoration and flood risk reduction projects to reduce land loss, maintain and restore coastal environments, and sustain communities. The large-scale effort to restore coastal Louisiana is made more challenging by uncertainties in sediment in the Mississippi River, rising sea levels, subsidence, storms, oil and gas activities, flood-control levees, and navigation infrastructure. To inform decision making, CPRA uses structured approaches to incorporate science at all stages of restoration project planning and implementation to: (1) identify alternative management actions, (2) select the management action based on the best available science, and (3) assess performance of the implemented management decisions. Applied science and synthesis initiatives are critical for solving scientific and technical uncertainties in the successive stages of program and project management, from planning, implementation, operations, to monitoring and assessment. The processes developed and lessons learned from planning and implementing restoration in coastal Louisiana are relevant to other vulnerable coastal regions around the globe.

2. Background

River deltas are some of the most ecologically and economically productive and highly populated environments in the world, and also some of the most vulnerable [1][2]. Low-lying landscapes built at river mouths, the architecture of a delta is the product of both a river system and its sediments, as well as the physical processes of the receiving basin [3]. The world's deltas formed during the last 6500–8500 years as sea level rise stabilized after the last glacial maximum ~18,000 years ago [4][5]. Changes in environmental conditions both in the drainage basin and the receiving basin can profoundly transform the delta plain, and lead to advancement or retreat of the delta, aggradation, or delta switching. Subsidence from both natural compaction processes and anthropogenic factors. such as fluid withdrawal, increases the relative sea level rise of these coastal landscapes. Reductions in sediment supply due to upstream levees and dams lessen mitigation of subsidence [6], with an estimated 25 million people living on sediment-starved deltas [7]. Although 11,000 deltas globally have experienced net land gain over the past 30 years from increases in river fluvial sediment content from deforestation, as well as redistribution of sediments on deltas transitioning toward increasingly tide-dominated, these gains are not expected to be sustained under rising sea level conditions [8][9][10][11] and projected declines in fluvial sediment delivery [12]. Many of the world's deltas are also population centers, with the majority of megacities located on deltas [13]. These deltas are impacted by human habitation and urbanization, and by increased subsidence from large-scale engineering projects and resource extraction [14]. Flooding of these highly populated delta surface areas is estimated to increase by 50% in the twenty-first century [9].

Coastal Louisiana, largely built by the Mississippi and Atchafalaya Rivers over the last ~7000–8000 years, lost an estimated 4833 km^2 of its land area from the early 1930s to 2016 [15]. The Mississippi River Delta is one of the most ecologically important habitats in North America [16], providing habitat for millions of migratory waterfowl [17] and supporting highly productive fisheries [18] and tourism. The top port (by tonnage) in the United States is the Port of South Louisiana, positioned in the Mississippi River Delta [19], and Louisiana is a major supplier of oil and natural gas [20]. A diverse landscape of freshwater, brackish, and saline wetlands, barrier islands, coastal bays, low-relief uplands, and ridges, coastal Louisiana is home to over two million people, including unique coastal cultures. Projections of future coastal Louisiana land loss, in the absence of sediment input, range from 10,000 km^2 to 13,500 km^2 by 2100 [21] to 3126 km^2 to 10,679 km^2 in 50 years [22]. Building on the current trajectories, undertaking no additional restoration action is projected to lead to both ecological and socio-economic catastrophe in coastal Louisiana's deltaic plain.

Ecosystem sustainability is often constrained in highly-engineered deltaic systems worldwide [23]. Anthropogenic interventions such as levees, dams, and channel deepening for navigation control the development of many deltas currently, moving the morphology away from a natural state [10], and increasing the importance of understanding delta instabilities such as bank failure and avulsion [24][25]. Restoration of deltaic systems can be complicated by sediment and nutrient loads that are often affected by actions thousands of kilometers upstream [26]. Although the scientific knowledge of deltaic systems is advanced, knowledge about restoration processes in these complex systems is comparatively nascent. Integrating science into environmental decision making can be difficult, and the time between detecting a problem and political action can be lengthy [27][28][29][30]. This presents additional challenges as environmental changes are occurring at accelerated rates due to human impacts. There is a growing need for adaptation planning, and for chronicling and evaluating planning processes, which are not well known among practitioners and the scientific community [31].

The transdisciplinary application of science and engineering necessary to restore and protect coastal Louisiana is pioneering. This paper reviews, describes, and evaluates the processes Louisiana's Coastal Protection and Restoration Authority (CPRA) has developed and uses to make science-based management decisions in uncertain conditions, with input from stakeholders, to restore a low-lying coastal ecosystem. This information has previously mostly only been available in governmental reports, which were reviewed and synthesized in combination with institutional knowledge for this paper. Successful management requires integrating science into decision making to support the strategic implementation of restoration programs and projects. Addressing and reducing uncertainties in management decisions and finding solutions to ecosystem restoration and human community resilience that are sustainable in the face of continued subsidence, rising sea levels and repeated storm impacts driven by human activities, including climate change, are critical to the continued environmental and economic productivity of Louisiana and the Gulf of Mexico region, and other vulnerable coastal deltaic ecosystems worldwide.

3. Discussion

Louisiana's coastal natural environments are critical to the ecology of the Gulf of Mexico, the identity of the State's human communities and the nation's economy. CPRA's restoration approach integrates science into long-term coastal restoration planning to reduce and address uncertainties in determining restoration action need and the implementation of effective projects. Applied science and synthesis is incorporated at each step of the program and project development and implementation process, and includes expert input and review. Nowhere else has a restoration program of this scale been developed or implemented, and the program's success relies on using the most advanced technical information and decision support tools, and a keen understanding of the complex interactions and trade-offs that are inherent in a program of this magnitude.

Restoration in coastal Louisiana is a complex endeavor requiring the use of natural processes in a system experiencing the results of many anthropomorphic changes, including dams, levees, and changes to nutrient and sediment dynamics in the Mississippi and Atchafalaya Rivers which are being impacted upstream. The Coastal Master Plan process integrates principles such as sediment limitation, natural processes, and climate change uncertainties in a scenario approach underpinning the model projection. Riverine sediment resources can supply a portion of the needed sediment for restoration projects. However, the current riverine sediment load is insufficient for restoring the Louisiana coast to its former extent, given reduced sediment supply and changing environmental conditions such as rising sea levels [32]. Indeed, Blum and Roberts [32] concluded that without sediment addition, "significant drowning of the delta is inevitable." Both the Future Without Action and Future With Action models run substantial coastal wetland loss over the 50-year period of analysis. When compared against each other, though, the Future With Action projections estimate that potential wetland loss can be offset by as much as 3000 square kilometers, in the case of the most severe environmental scenario [22].

Louisiana's large-scale ecosystem restoration program is guided by a science-based Coastal Master Plan, and needs and opportunities for science to address technical uncertainties occur throughout the planning and project implementation process. This paper reviews how CPRA's processes incorporate science to resolve scientific and technical information needs and uncertainties at project and program scales to inform management decisions. A tremendous amount of knowledge is generated through CPRA's restoration efforts that increases understanding of the coast it is charged with protecting and restoring. Institutional knowledge gained by Louisiana from the planning and implementation of various restoration plans over the last few decades is also directly relevant to the risk reduction and restoration of resources in other states around the Gulf and to other coastal regions around the globe.

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