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## Implementing adaptive management into a climate change adaptation strategy for a drowning New England salt marsh

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1 **Abstract**

2           Due to climate change and other anthropogenic stressors, future conditions and impacts  
3 facing coastal habitats are unclear to coastal resource managers. Adaptive management strategies  
4 have become an important tactic to compensate for the unknown environmental conditions that  
5 coastal managers and restoration ecologists face. Adaptive management requires extensive  
6 planning and resources, which can act as a barrier to achieve a successful project. These barriers  
7 also create challenges in incorporating adaptive management into climate change adaptation  
8 strategies. This case study describes and analyzes the Rhode Island Coastal Resource  
9 Management Council’s approach to overcome these challenges to implement a successful  
10 adaptive management project to restore a drowning salt marsh using the climate adaptation  
11 strategy, sediment enhancement, at Quonochontaug Pond in Charlestown, RI. Through effective  
12 communication and active stakeholder involvement, this project successfully incorporated  
13 interdisciplinary partner and stakeholder collaboration and developed an iterative learning  
14 strategy that highlights the adaptive management method.

15 **Keywords**

16 Adaptive management; Climate change adaptation; Sediment enhancement; Salt marsh

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## 25        **1. Introduction**

26            Much research has been conducted on climate change mitigation, but comparatively less  
27 attention has focused on implementation of adaptive management strategies to protect  
28 environments impacted by climate change (IPCC., 2014). Accelerated relative sea level rise  
29 (hereafter referred to as SLR) rates are a major effect of climate change and are a serious threat  
30 to coastal environments throughout the Northeast USA (Ashton et al., 2008; Carey et al., 2017;  
31 Weston, 2014). New England itself is facing SLR rates that are three or four times the global  
32 average (Sallenger et al., 2012). These elevated rates are likely to cause increased flooding,  
33 damage to infrastructure in low-lying and coastal areas, decreased resiliency to storms, and loss  
34 of coastal wetlands, including salt marshes (Ashton et al., 2008; Wigand et al., 2017). Climate  
35 adaptation focuses on enhancing resilience to current and future climate change impacts  
36 including SLR, which will help in managing and maintaining coastal ecosystems such as salt  
37 marshes (Stein et al., 2013; Wigand et al., 2017).

38            Climate change and other anthropogenic impacts have lowered the resiliency of  
39 Northeast coastal marshes. Salt marshes serve as a carbon sink, food source, breeding habitat,  
40 and nursery ground for birds (including the endangered salt marsh sparrow, *Ammodramus*  
41 *caudacutus*), fish, and shellfish (Bayard and Elphick, 2011; Hanson and Shriver, 2006; Raposa  
42 and Roman, 2006). These environments also provide flood abatement and help prevent coastal  
43 erosion (Barbier et al., 2011; Leonard and Luther, 1995). Historically, lateral transgression and  
44 vertical accretion of New England marshes have been able to keep pace with SLR (Raposa et al.,  
45 2017; Redfield, 1972). However due to increased coastal development, reduced sediment  
46 supplies (caused by urbanization, dam construction, and reforestation), and accelerating rates of  
47 SLR, marshes are no longer able to migrate or accrete at a rate fast enough to withstand SLR

48 impacts (Sallenger et al., 2012; Weston, 2014; Watson et al., 2017). As a result of these impacts,  
49 Northeast marshes, including those in New England, have suffered from increased dieback areas,  
50 vegetation loss, peat subsidence, waterlogged soils, and ponding (Hartig et al., 2000; Alber et al.,  
51 2008; Raposa et al., 2017). SLR has also exacerbated salt marsh erosion as a result of increased  
52 crab burrows in high marsh areas, due to waterlogged soils (Crotty et al., 2017; Raposa et al.,  
53 2018). These combined effects further decrease salt marsh resiliency in light of storms and  
54 climate change impacts, which the Northeast is particularly susceptible to (Frumhoff et al., 2007;  
55 Kirwan and Megonigal, 2013; Crotty et al., 2017).

56         Climate change adaptation is a management strategy that addresses climate-related  
57 vulnerabilities of susceptible habitats and focuses on preparing for, coping with, and responding  
58 to the impacts of current and future system changes (Stein et al., 2013; Wigand et al., 2017).  
59 Investing in climate change adaptation projects can increase coastal resiliency to environmental  
60 threats and minimize damages (monetary and environmental) from storm events (Narayan et al.,  
61 2017; Sutton-Grier et al., 2015) Climate adaptation strategies have been implemented across the  
62 U.S. (including living shorelines, green infrastructure, green roofs, flood abatement strategies,  
63 irrigation efficiency for agricultural practices, etc.) on the federal, state, local/regional, and  
64 private sectors (Bierbaum et al., 2013). One climate adaptation approach to build salt marsh  
65 resiliency is sediment enhancement (SE), also known as thin layer deposition where dredged  
66 sediment material is added to the salt marsh surface (Cahoon et al., 2019). The purpose of this  
67 technique is to raise the salt marsh platform to an elevation that can withstand future projections  
68 of SLR. Although climate adaptation strategies have been adopted nationwide, the incorporation  
69 of adaptive management within these projects is uncommon.

70 Adaptive management incorporates learning-based decision making into management  
71 actions (Salafsky et al., 2001; Allen and Gunderson, 2010; Williams, 2011). This strategy is an  
72 iterative learning process that allows management actions to proceed despite uncertainty and  
73 requires changes in action to improve the management strategy as knowledge and understanding  
74 increases (Allen and Gunderson, 2010; Williams, 2011). There is a benefit to this strategy that  
75 accounts for uncertain and unexpected responses of a management action, but adaptive  
76 management involves challenges that must be overcome. Lack of resources and communication,  
77 disorganized coordination and leadership, inherent lack of flexibility within institutions,  
78 minimized stakeholder engagement, and action procrastination and avoidance can inevitably lead  
79 to adaptive management failure (Adger et al., 2009; Allen and Gunderson, 2011; Bierbaum et al.,  
80 2013; McNeeley, 2012). Since adaptive management requires a monitoring component, a larger  
81 commitment of time and resources is needed, which can pose an additional challenge. These  
82 challenges provide barriers to incorporating adaptive management into climate adaptation  
83 projects and require intensive planning to overcome.

84 The Quonochontaug (Quonnie) project located in Charlestown, RI, a state-run and  
85 federally funded initiative lead by the Coastal Resource Management Council (CRMC),  
86 incorporates the SE climate change adaptation strategy and adaptive management while  
87 integrating lessons learned from past SE projects. This paper describes the successful  
88 incorporation of adaptive management into the Quonnie SE project and highlights the use of  
89 collaboration and outreach in restoration initiatives. We analyze how adaptive management  
90 components: 1) Create a project model 2) Establish a clear and common purpose/action 3)  
91 Develop and implement a management and monitoring plan 4) Analyze results and iterate 5)  
92 Communicate results, were applied for the successful implementation of the Quonnie climate

93 change adaptation project (Salafsky et al., 2001). Through this analysis, we intend to identify  
94 best practices in planning and implementing an adaptive management strategy for a climate  
95 change adaptation project.

## 96 **2. Establishing the Climate Change Adaptation Project: Identifying Stakeholders and** 97 **Partners**

### 98 *3.1 Establishing the salt marsh climate change adaptation and adaptive management team*

99 For the Quonnie sediment enhancement adaptive management (Q-SEAM) project, the  
100 initial goal was to gather together organizations and people dedicated to salt marsh protection,  
101 including agencies experienced in assessing salt marsh vulnerability and condition and  
102 implementing restoration actions. This required the expertise of federal, state, and local agencies,  
103 as well as non-profit and non-government organizations (NGOs); all held specific roles and  
104 responsibilities (Table 1). The creation of this team occurred during the stage of initial  
105 assessment of salt marsh condition, prior to the SE implementation.

### 106 *3.2 Initial salt marsh condition assessment*

107 Rhode Island follows the Salt Marsh Monitoring and Assessment Program (SMMAP)  
108 (Raposa et al., 2016). SMAPP monitoring helped identify the degrading marsh conditions and  
109 provided the necessary data to support the SE initiative at the Quonnie Pond site and funding  
110 provided by the NOAA Resiliency Grant (Figure 1). The funding supported CRMC staff time,  
111 monitoring, construction, and materials for the project (Table 2). This monitoring involved the  
112 rapid assessment of marsh conditions with marsh site visits across the state. Monitoring showed  
113 an abundance of ponding and vegetation die-off areas and the displacement of high marsh plants  
114 by low marsh plant species within the Quonnie salt marsh (Cole Ekberg et al., 2017; Kutcher,  
115 2019). This site was also identified to have relatively low surface elevation within the tidal frame

116 and was characterized as an area of high disturbance (i.e. high density of human-made ditches,  
117 crab burrows, and edge erosion) (Kutcher, 2019).

118         The Sea Level Affecting Marshes Model (SLAMM) simulates the response of salt marsh  
119 areas to varying SLR rate scenarios (SLAMM, 2009). Results of the SLAMM model simulations  
120 help evaluate marsh migration potential and prioritize appropriate marsh adaption and restoration  
121 efforts (Cole Ekberg et al., 2017; Wigand et al., 2017). The Quonnie SLAMM results predicted  
122 significant marsh loss with 1m of SLR within the next 40-50 years and recognized limited  
123 potential for salt marsh migration  
124 ([http://www.crmc.ri.gov/maps/maps\\_slamm/20150331\\_RISLAMM\\_Summary.pdf](http://www.crmc.ri.gov/maps/maps_slamm/20150331_RISLAMM_Summary.pdf)). These  
125 results and the SMMAP monitoring helped determine the SE treatment as an appropriate climate  
126 adaptation strategy for this site.

### 127         **3. Quonnie Sediment Enhancement Adaptive Management Project**

#### 128         *4.1 Quonnie project model*

129         Iteration is a major theme in adaptive management; Q-SEAM incorporated methods and  
130 lessons learned from a previous SE project at Ninigret Pond in Charlestown, RI. Q-SEAM  
131 adapted the same Before, After, Control, Impact (BACI) experimental design model as the  
132 Ninigret project, where the control (area where no management action took place) and impact  
133 (sediment enhancement) sites were monitored before and after treatment (Smith, 2014). The  
134 model incorporated monitoring that would occur for at least five years after sediment placement.  
135 It was hypothesized that the control would show signs of degradation (displacement of high  
136 marsh plants by low marsh plants, increase in vegetation die-off areas, loss of soil organic  
137 carbon, loss of habitat value) over time, while the impact area would gradually recolonize  
138 vegetation and nekton communities and accumulate soil organic matter over the five-year



139 monitoring period. Project targets and metrics (Table 3) were incorporated into the BACI model  
140 to guide learning. To optimize results and enhance the project, communication, construction, and  
141 monitoring techniques learned from the Ninigret project were incorporated in the Q-SEAM plans  
142 (Table 4). Results learned from the BACI monitoring and analyses would inform future decision  
143 making for Quonnie maintenance as well as future SE projects.

144 Important stakeholder communication techniques and construction and field strategies  
145 were learned and adapted for Q-SEAM to help gain project support and improve management  
146 strategies (Table 4). For example, dredging methods used at Ninigret were altered and improved  
147 for the Quonnie project (RTK mounted equipment and amphibious and low ground pressure  
148 equipment). Earlier monitoring at Ninigret taught the Q-SEAM team that intensive post-  
149 construction sediment grading (to ensure target elevations were met and establish drainage) was  
150 needed, that geese would use the area for foraging, and that excessive wind and sediment  
151 movement could impact the target elevations. By being aware of these potential issues, Q-SEAM  
152 project managers were able to incorporate actions (i.e. goose fencing; beach grass and dune  
153 fencing placement for wind protection and sediment stabilization) into the management plan,  
154 which were expected to have positive results on maintaining target elevations and subsequent  
155 plant colonization.

#### 156 *4.2 Establish a common purpose/action*

157 An important initial adaptive management step was to create a clear project mission that was  
158 discussed and agreed upon by all stakeholders. Addressing and recognizing stakeholder goals  
159 early on helped to avoid future complications, and it held the partners accountable and  
160 committed to their project responsibilities. While addressing the major goals of the project  
161 stakeholders, the mission statement was manageable and conveyed realistic expectations (Figure  
162 2). CRMC leaders ensured they were clear and forthcoming about the roles of each stakeholder,

163 the logistics of the project and their impacts on stakeholders' goals, which was an important  
164 component of their management technique and helped to manage stakeholder expectations.

165 CRMC and the monitoring partners had a pre-existing relationship due to similar past  
166 projects that involved the same partners as Q-SEAM. Due to these pre-existing relationships,  
167 group trust and working dynamics had already been established, which aided in the effective  
168 communication and coordination of agreed upon actions that occurred for Q-SEAM. The  
169 substantial funding provided by NOAA along with matching funds from Town of Charlestown  
170 and Salt Ponds Coalition supported these relationships as well as alleviated financial and  
171 resource stressors that could have impacted these collaborations. Compromises needed to be  
172 made between CRMC and the Town of Charlestown to achieve an agreed upon action. CRMC  
173 went through a negotiation process with the Town of Charlestown and the Salt Ponds Coalitions  
174 before agreeing on the amount of sediment to be dredged. Although concessions and  
175 compromises were made (Town of Charlestown provided more funds to dredge additional  
176 sediment and determined the dredging areas), CRMC ensured that the stakeholders' needs were  
177 heard and considered, which further helped to establish trust and commitment amongst the  
178 stakeholders and partners.

#### 179 *4.3 Development and implementation of a management and monitoring plan*

180 CRMC and the monitoring partners collaborated to create the Quonnie Quality Assurance  
181 Project Plan (QAPP), which included a flexible management and monitoring plan that allowed  
182 for learning and monitoring plan adjustments, highlighting the adaptive management approach.  
183 The QAPP included project targets and metrics such as elevation, vegetation community, and  
184 wildlife community (Table 3) and methods to assess these targets. Monitoring these targets was

185 essential to evaluate marsh function and restoration progress as well as for the learning needed to  
186 support future decision-making and management plan adjustments.

187 CRMC sought partner and stakeholder feedback and input throughout the development of  
188 the adaptive management plan via meetings and public presentations to municipal commissions.  
189 This allowed for stakeholders to voice concerns and identify issues early, and for the project  
190 team to address them in a manner that aligned with the project's goals and targets. CRMC  
191 maintained open and frequent communication with the project stakeholders, and shared project  
192 designs and plans as they were developed. This transparency aspect of the CRMC management  
193 technique built trust within the stakeholders, and also allowed CRMC to address concerns early  
194 and rectify issues to prevent future conflict.

195 Having a clear management and construction plan to convey to the dredging company, J.  
196 F. Brennan Company, Inc. (hereafter J. F. Brennan), helped with communication and  
197 collaboration. CRMC ensured that the construction plans for J. F. Brennan were detailed enough  
198 for design implementation, but were flexible enough to incorporate contractor expertise and  
199 methodologies. CRMC and J. F. Brennan went through an iterative process throughout  
200 construction, where adjustments to the construction plan and design were made as necessary and  
201 as the project progressed. J. F. Brennan appreciated having their inputs valued. One of the lead  
202 constructors in an interview said, "They [CRMC] look to us for ideas and value our opinion...the  
203 process is made easier because they are open and upfront." Establishing two-way communication  
204 between hired contractors, where contractors' ideas and expertise were respected, considered,  
205 and incorporated, enhanced the outcome of Q-SEAM and highlights the learning/adaptive  
206 component of adaptive management.

207           The monitoring plan was helpful in establishing goals and parameters as well as the  
208 responsibilities of each partner, which in turn kept the partners accountable. Monitoring occurred  
209 during the peak growing season, between mid-August and mid-September before sediment  
210 placement and the first season after placement and was intended to continue for four additional  
211 growing seasons thereafter. Monitoring partner meetings were held before each salt marsh  
212 growing season to discuss the parameters that would be measured, monitoring methods, and  
213 timelines as well as a meeting after the growing season to discuss monitoring results and  
214 adjustments for the next season. Meetings were then scheduled as needed throughout the  
215 growing season to address unexpected issues and adjustments to the original  
216 monitoring/management plans. Outside of these meetings, the monitoring partners were in open  
217 and continuous communication to address questions as they arose.

#### 218 *4.4 Analyze results and iterate*

219           As data was interpreted and field conditions became clearer, CRMC and partners had to  
220 adapt and learn from unexpected challenges, which sometimes called for adjustments to the  
221 QAPP and data collection methods. For example, the Quonnie site was more accessible than  
222 previous SE sites and civilians used the area as a recreational space. In response to this, signage  
223 and fencing were placed on the borders of the site and a separate area was designated as a  
224 recreational location (Figure 3a &b). Monitoring changes were needed as well, which included  
225 adjusted pH and soil salinity sampling methods due to the low moisture content of the dredge  
226 material. During construction, the Q-SEAM team learned that the use of one dredge versus two  
227 dredges would make the handling/distribution of dredge material more manageable and prevent  
228 sediment buildup. As adaptive management calls for, management and monitoring plans were  
229 adjusted accordingly as this new information arose. The flexibility of each monitoring partner

230 and efficient communication allowed for quick responses to these unexpected outcomes and  
231 adjustments to original methods.

#### 232 *4.5 Communicate results*

233 The Q-SEAM monitoring data were made available throughout the monitoring process to  
234 provide transparency, cultivate public engagement, and provide project updates, via the CRMC  
235 ArcGIS Online Quonochontaug Data Gallery  
236 ([https://crmcgis.maps.arcgis.com/apps/MinimalGallery/index.html?appid=bfda4d36733c43fa938](https://crmcgis.maps.arcgis.com/apps/MinimalGallery/index.html?appid=bfda4d36733c43fa93874e09414457e4)  
237 [74e09414457e4](https://crmcgis.maps.arcgis.com/apps/MinimalGallery/index.html?appid=bfda4d36733c43fa93874e09414457e4)). The CRMC communicated SE project results through regional conference  
238 presentations and site visits with the community and regional agencies, and is currently  
239 developing supplemental material such as restoration guidance and lessons learned documents.  
240 Making information readily available helped maintain public involvement and interest in the  
241 project as well as educated other agencies that were interested in learning more about the SE  
242 restoration technique. Agencies including NBNERR and EPA Atlantic Coastal Environmental  
243 Sciences Division, communicate with other NERRs and EPA facilities across the country to help  
244 to further develop SE best practices and apply them to other sites.

#### 245 **4. Community Outreach and Engagement**

246 Throughout the Quonnie project, outreach and community engagement was a continuous  
247 priority. During the early stages of the project, Charlestown members were brought in for site  
248 visits, and CRMC presented SE plans at town council meetings to help gain support for the  
249 project and improve understanding of the project's purpose. A Quonnie planting event, organized  
250 and facilitated by Save the Bay, was one of the largest outreach initiatives that occurred after  
251 sediment placement in the early spring of 2019. This event brought together school groups, Save

252 the Bay volunteers as well as volunteers from various town organizations, project stakeholders  
253 and partners, and Charlestown citizens. Planting events allowed citizen volunteers to make a  
254 physical contribution and connection to the project (Figure 3c &d). CRMC sponsored short  
255 promotional videos to highlight the restoration that occurred in the state  
256 (<http://www.crmc.ri.gov/>). The Salt Ponds Coalition published an article about the project in its  
257 newsletter, Tidal Page, as well as produced videos focused on the SE projects within the state.  
258 CRMC and monitoring partners continue to present at local, regional and national meetings to  
259 share their experiences and results with the SE technique.

## 260 **5. Conclusions**

261 The Q-SEAM project demonstrated that effective collaboration, efficient communication,  
262 community involvement, and outreach were necessary to overcome adaptive management  
263 challenges and achieve success. Collaboration was an integral part of the adaptive management  
264 approach as the Quonnie project required the expertise of multiple disciplines. Partnership and  
265 collaboration came with benefits including resource and cost sharing, division of responsibilities,  
266 development of management plans, and implementation of monitoring. However, challenges  
267 were associated with collaboration, which CRMC was able to overcome with compromise,  
268 frequent and open communication with partners, and guided, productive monitoring and project  
269 meetings. The partners established and held similar goals, which led to accountability,  
270 commitment, and timely follow through with actions. Due to the nature of the small state of RI,  
271 CRMC has the capacity to work closely and develop strong ongoing relationships with key  
272 scientists and coastal managers within the state. In cases where this type of involvement is not  
273 feasible, the use of third-party cross-boundary management agencies can help to oversee these  
274 types of adaptive management initiatives as well as other interdisciplinary projects.

275 Community involvement and outreach were instrumental components of the Q-SEAM  
276 project. Therefore, establishing trust and actively involving the community in the adaptive  
277 management approach was essential for the success of the project. CRMC operated under full  
278 transparency with the Town of Charlestown and other stakeholders, addressing their concerns  
279 early on and managing expectations. Establishing trust early with the stakeholders, through site  
280 visits, town and project planning meetings, was essential to gain stakeholder support and  
281 assistance. Involving the community throughout the project grants the public an invested  
282 interested in its success.

283 Rhode Island's use of an adaptive management strategy to implement the SE climate  
284 change adaptation project is expected to influence future decision-making on coastal marsh  
285 restoration in the Northeast USA and beyond. Adaptive management worked well for the Q-  
286 SEAM project due to the relatively new application of the sediment enhancement method in New  
287 England and its flexible nature that accounts for unexpected results and adjustable management  
288 and monitoring plans to account for outcome uncertainty. Incorporating adaptive management  
289 strategies within climate change adaptation and resiliency projects becomes increasingly  
290 important as climate change progresses and future conditions are more uncertain.

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## References

- Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Naess, L.O., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? *Clim. Change*. <https://doi.org/10.1007/s10584-008-9520-z>
- Alber, M., Swenson, E.M., Adamowicz, S.C., Mendelssohn, I.A., 2008. Salt Marsh Dieback: An overview of recent events in the US. *Estuar. Coast. Shelf Sci.* 80, 1–11. <https://doi.org/10.1016/j.ecss.2008.08.009>
- Allen, C.R., Gunderson, L.H., 2011. Pathology and failure in the design and implementation of adaptive management. *J. Environ. Manage.* <https://doi.org/10.1016/j.jenvman.2010.10.063>
- Ashton, A.D., Donnelly, J.P., Evans, R.L., 2008. A discussion of the potential impacts of climate change on the shorelines of the Northeastern USA. *Mitig. Adapt. Strateg. Glob. Chang.* <https://doi.org/10.1007/s11027-007-9124-3>
- Barbier, E.B., Hacker, S.D., Kennedy, C., Kock, E.W., Stier, A.C., Sillman, B.R., 2011. The value of estuarine and coastal ecosystem services. *Ecol. Monogr.* 81, 169–193. <https://doi.org/10.1890/10-1510.1>
- Bayard, T.S., Elphick, C.S., 2011. Planning for Sea-level Rise: Quantifying Patterns of Saltmarsh Sparrow ( *Ammodramus Caudacutus* ) Nest Flooding Under Current Sea-level Conditions . *Auk* 128, 393–403. <https://doi.org/10.1525/auk.2011.10178>
- Bierbaum, R., Smith, J.B., Lee, A., Blair, M., Carter, L., Chapin, F.S., Fleming, P., Ruffo, S., Stults, M., McNeeley, S., Wasley, E., Verduzco, L., 2013. A comprehensive review of climate adaptation in the United States: More than before, but less than needed. *Mitig. Adapt. Strateg. Glob. Chang.* <https://doi.org/10.1007/s11027-012-9423-1>
- Cahoon, D.R., Lynch, J.C., Roman, C.T., Schmit, J.P., Skidde, D.E., 2019. Evaluating the Relationship Among Wetland Vertical Development, Elevation Capital, Sea-Level Rise, and Tidal Marsh Sustainability. *Estuaries and Coasts*. <https://doi.org/10.1007/s12237-018-0448-x>
- Carey, J.C., Moran, S.B., Kelly, R.P., Kolker, A.S., Fulweiler, R.W., 2017. The Declining Role of Organic Matter in New England Salt Marshes. *Estuaries and Coasts* 40, 626–639. <https://doi.org/10.1007/s12237-015-9971-1>
- Cole Ekberg, M.L., Raposa, K.B., Ferguson, W.S., Ruddock, K., Watson, E.B., 2017. Development and Application of a Method to Identify Salt Marsh Vulnerability to Sea Level Rise. *Estuaries and Coasts*. <https://doi.org/10.1007/s12237-017-0219-0>
- Crotty, S.M., Angelini, C., Bertness, M.D., 2017. Multiple stressors and the potential for synergistic loss of New England salt marshes. *PLoS One*. <https://doi.org/10.1371/journal.pone.0183058>
- Frumhoff, P.C., McCarthy, J.J., Melillo, J.M., Moser, S.C., Wuebbles, D.J., 2007. Confronting Climate Change in the US Northeast: Science, Impacts and Solutions. *Synth. Rep. Northeast Clim. Impacts Assess.*
- Hanson, A.R., Shriver, W.G., 2006. Hanson, A.R., Shriver, W.G., 2006. Breeding birds of

- northeast salt marshes: Habitat use and conservation. *Stud. in Avian Biol. Conserv.* 32, 141–154.
- Hartig, E.K., Kolker, A.S., Gornit, V.C., 2000. Climate change impacts on saltmarsh morphology in Jamaica Bay, New York City. 11th Int. Peat Congr.
- IPCC., 2014. Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the IPCC Fifth Assessment Report. Annex 1 1–85.  
<https://doi.org/10.1017/CBO9781107415324.Summary>
- Kirwan, M.L., Megonigal, J.P., 2013. Tidal wetland stability in the face of human impacts and sea-level rise. *Nature*. <https://doi.org/10.1038/nature12856>
- Kutcher, T., 2019. Salt marsh rapid assessment methods, MarshRAM: Analysis and Application. Technical report prepared for the Rhode Island Department of Environmental Management and the Rhode Island Coastal Resources Management Council
- Leonard, L.A., Luther, M.E., 1995. Flow hydrodynamics in tidal marsh canopies. *Limnol. Oceanogr.* 40, 1474–1484. <https://doi.org/10.4319/lo.1995.40.8.1474>
- McNeeley, S.M., 2012. Examining barriers and opportunities for sustainable adaptation to climate change in Interior Alaska. *Clim. Change*. <https://doi.org/10.1007/s10584-011-0158-x>
- Narayan, S., Beck, M.W., Wilson, P., Thomas, C.J., Guerrero, A., Shepard, C.C., Reguero, B.G., Franco, G., Ingram, J.C., Trespalacios, D., 2017. The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA. *Sci. Rep.* <https://doi.org/10.1038/s41598-017-09269-z>
- Raposa, K.B., Kutcher, T., Ferguson, W., Cole Ekberg, M., Weber, R.L.J., Chaffee, C., 2016. A strategy for developing a salt marsh monitoring and assessment program for the state of Rhode Island. Prepared by Narragansett Bay National Estuarine Research Reserve and Save the Bay
- Raposa, K.B., McKinney, R.A., Wigand, C., Hollister, J.W., Lovall, C., Szura, K., Gurak, J.A., McNamee, J., Raithel, C., Watson, E.B., 2018. Top-down and bottom-up controls on southern New England salt marsh crab populations. *PeerJ*.  
<https://doi.org/10.7717/peerj.4876>
- Raposa, K.B., Roman, C.T., 2006. Seasonal habitat-use patterns of nekton in a tide-restricted and unrestricted New England salt marsh. *Wetlands* 21, 451–461. [https://doi.org/10.1672/0277-5212\(2001\)021\[0451:shupon\]2.0.co;2](https://doi.org/10.1672/0277-5212(2001)021[0451:shupon]2.0.co;2)
- Raposa, K.B., Weber, R.L.J., Ekberg, M.C., Ferguson, W., 2017. Vegetation Dynamics in Rhode Island Salt Marshes During a Period of Accelerating Sea Level Rise and Extreme Sea Level Events. *Estuaries and Coasts* 40, 640–650. <https://doi.org/10.1007/s12237-015-0018-4>
- Redfield, A.C., 1972. Development of a New England Salt Marsh. *Ecol. Monogr.* 42, 201–237. <https://doi.org/10.2307/1942263>
- Salafsky, N., Margoluis, R., Redford, K., 2001. Adaptive Management: A tool for conservation practitioners. Washington, D.C.: Biodiversity Support Program. Adaptive Management:

- Sallenger, A.H., Doran, K.S., Howd, P.A., 2012. Hotspot of accelerated sea-level rise on the Atlantic coast of North America. *Nat. Clim. Chang.* 2, 884–888. <https://doi.org/10.1038/nclimate1597>
- SLAMM, version 6. 2009. Sea level affecting marshes model. Warren Pinnacle Consulting, Inc. P.O. Box 315, Waitsfield, VT, 05673.
- Smith, E.P., 2014. BACI Design, in: *Wiley StatsRef: Statistics Reference Online*. <https://doi.org/10.1002/9781118445112.stat07659>
- Stein, B.A., Staudt, A., Cross, M.S., Dubois, N.S., Enquist, C., Griffis, R., Hansen, L.J., Hellmann, J.J., Lawler, J.J., Nelson, E.J., Pairis, A., 2013. Preparing for and managing change: Climate adaptation for biodiversity and ecosystems. *Front. Ecol. Environ.* <https://doi.org/10.1890/120277>
- Sutton-Grier, A.E., Wowk, K., Bamford, H., 2015. Future of our coasts: The potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. *Environ. Sci. Policy.* <https://doi.org/10.1016/j.envsci.2015.04.006>
- Watson, E.B., Wigand, C., Davey, E.W., Andrews, H.M., Bishop, J., Raposa, K.B., 2017. Wetland Loss Patterns and Inundation-Productivity Relationships Prognosticate Widespread Salt Marsh Loss for Southern New England. *Estuaries and Coasts*. <https://doi.org/10.1007/s12237-016-0069-1>
- Weston, N.B., 2014. Declining Sediments and Rising Seas: An Unfortunate Convergence for Tidal Wetlands. *Estuaries and Coasts* 37, 1–23. <https://doi.org/10.1007/s12237-013-9654-8>
- Wigand, C., Ardito, T., Chaffee, C., Ferguson, W., Paton, S., Raposa, K., Vandemoer, C., Watson, E., 2017. A Climate Change Adaptation Strategy for Management of Coastal Marsh Systems. *Estuaries and Coasts* 40, 682–693. <https://doi.org/10.1007/s12237-015-0003-y>
- Williams, B.K., 2011. Adaptive management of natural resources-framework and issues. *J Environ Manage.* 92, 1346-1353

## **Figure and Table Legend**

**Figure 1:** Describes agencies' roles in the initial assessment and proposal development of the Q-SEAM project

**Figure 2.** Describes the main goals of the project stakeholders and the derived overall project mission

**Figure 3.** a. Signage placed at Quonnie restoration site b. Save the Bay designated recreational area for civilians at the Quonnie restoration site. c & d. Quonnie salt marsh planting community event organized by Save the Bay

**Table 1.** Partners, stakeholders, and decision-makers and their roles for the Quonnie sediment enhancement project

Stakeholders	Agency Type	Role of Partners
Coastal Resource Management Council (CRMC)	State	Lead and supervisory organization; Responsible for planning and implementation of the project; Performed dredge sediment testing for hazardous material; Applied for funding, permitting; Legal responsibility; Organizer of stakeholder meetings; Executed and managed contracts for construction, planting, adaptive management and monitoring
RI Department of Environmental Management	State	Property owner, manager of public fishing and boating access, permitting entity, provided equipment for post-construction excavation (Office of Mosquito Abatement).
Town of Charlestown	State	Dredge permit applicant, provided non-federal match funding, some technical and conceptual design assistance, coordination with Harbor Master and Police Department re: public safety during construction
National Oceanic and Atmospheric Administration (NOAA)	Federal	Lead funder from NOAA Coastal Resilience Grants (FFO #: NOAA-NOS-NRPO-2017-2005159)
National Fish and Wildlife Foundation	Federal	Funder; Award from Hurricane Sandy Coastal Resiliency Program (leveraged federal construction funding)
Salt Ponds Coalition	Non-Governmental Watershed	Provided non-federal matching funds, public outreach and education, letters of support for funding application

	Organization (NGO)	
J. F. Brennan Company, Inc.	Contractor	Contractor for dredging and placement of material
<b>Monitoring Partners</b>		
Save The Bay (Narragansett Bay)	Non-profit, NGO	Construction oversight, Vegetation monitoring; Habitat restoration expertise; Volunteer coordination; Planting; Adaptive management in coordination with RIDEM
Rhode Island Natural History Survey	NGO	Initial MarshRAM site assessment of salt marsh condition (pre-dredge placement); Monitoring of vegetation community recovery and rare plant species
Environmental Protection Agency, Atlantic Ecology Division	Federal	Soils monitoring; Technical support on salt marsh monitoring and assessment; Consulted through US Army Core of Engineers permit process.
University of Connecticut's Saltmarsh Habitat and Avian Research Program	Educational Institution	Avian monitoring
University of Rhode Island Environmental Data Center	Educational Institution	Elevation monitoring; Hydrology monitoring; Acquisition of Unmanned Aerial Systems (drone) imagery; Development of ArcGIS online-based project data portal

**Table 2.** Approximate costs for Quonnie sediment enhancement project

Expenditures	Approximate Granted Funds
Lead Organization Staff Time	\$89,200.00
Contractual	\$2,091,000
Engineering and design services	\$116,328
Monitoring Services	\$85,200
Supplies and Equipment	\$2,700.00
<b><i>Approximate total</i></b>	<b>\$2,384,428</b>

**Table 3.** Monitoring targets for Quonnie sediment enhancement project

Monitoring Metric	Target/ Monitoring Goals
Saltmarsh habitat restored	30 acres
Eelgrass habitat restored	3 acres
Low marsh plant community elevation range	0.15-0.23m (0.5-0.75ft NAVD88)
High marsh plant ( <i>Spartina patens</i> , <i>Juncus gerardii</i> , <i>Distichlis spicata</i> ) community elevation range	0.23-0.46m (0.75-1.5ft NAVD88)
<i>Iva frutescens</i> community elevation range	0.38-0.53m (1.25-1.75ft NAVD88)
Nekton species	Summer flounder, winter flounder, striped bass, river herring, menhaden, tautog, American eel, bluefish, and scup



**Table 4.** Communication tips for working with the town, public, and other stakeholders

1. Make clear how the project's goals align with their goals
2. Avoid the use of jargon and use terms they are familiar with
3. Explain how the project will benefit them. Relate the project to issues they care about.
4. When speaking with legislature, highlight how the project will address public health and safety
5. Listen to and address concerns. Make their voices and needs heard, which helps to establish trust.
6. Engage the community throughout the process with site visits, updates, and town meetings.
7. Communicate often with stakeholders and partners with meetings and updates

**Table 5.** Permits needed for the 30-acre Quonnie sediment enhancement dredge project

Agency Issued	Permit
US Army Corps of Engineers	Section 404 Category II General Permit
RI Department of Environmental Management	Dredging Permit (includes Section 401 Water Quality Certification)
Coastal Resource Management Council	Dredging Permit / Coastal Assent
NOAA served as lead federal agency	National Environmental Policy Act (NEPA) Compliance (includes sign-off from State and Tribal Historic Preservation Officers)

**Table 6.** Quonnie and Ninigret timeline of major events and project progression.

**August 2011- Salt marsh condition assessment by Save The Bay**

**September 2012- Meeting with National Park Service about Jamaica Bay Thin Layer Deposition Project (Big Egg)**

**2013- Meetings with town, Salt Ponds Coalition and partners; Ninigret funding proposal development**

**May 2013- Funding proposal submitted for Ninigret construction, Quonnie design**

**July 2013- Site visit to Ninigret and Quonochontaug (Quonnie) with partners**

**January 2014- Regional thin layer deposition meeting on Long Island**

**October 2014- Ninigret award accepted**

**August 2015- Ninigret pre-restoration monitoring**

**September 2015- Ninigret consultant contracted for permitting and design**

**December 2016- Ninigret project designed, permitted and implemented**

**2017- Quonnie designs developed; Project team meetings for design review; Quonnie permit applications developed**

**July 2017- Applied for NOAA funding for Quonnie construction**

**November 2017- NOAA funding awarded**

**2018- Quonnie permits received**

**June 2018- Request for Proposal (RFP) issued for Quonnie construction work**

**August 2018- Quonnie pre-restoration monitoring**

**October 2018- Quonnie contractor hired, contract executed**

**November 2018- Mobilization of dredging equipment at Quonnie**

**December 2018- Quonnie dredging and placement**

**January 2019- Demobilization of dredging equipment at Quonnie; Quonnie As-built surveys**

**March 2019- Post-construction adaptive management (excavation to ensure target elevations; drainage establishment)**

**May 2019- Quonnie planting event**

**August 2019- Quonnie post-restoration monitoring**

**Monitoring Activity**

**Outreach and Coordination Activity**

**Project Implementation Activity**