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

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Abstract

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

Keywords

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

1. Introduction

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

Climate change and other anthropogenic impacts have lowered the resiliency of Northeast coastal marshes. Salt marshes serve as a carbon sink, food source, breeding habitat, and nursery ground for birds (including the endangered salt marsh sparrow, *Ammodramus caudacutus*), fish, and shellfish (Bayard and Elphick, 2011; Hanson and Shriver, 2006; Raposa and Roman, 2006). These environments also provide flood abatement and help prevent coastal erosion (Barbier et al., 2011; Leonard and Luther, 1995). Historically, lateral transgression and vertical accretion of New England marshes have been able to keep pace with SLR (Raposa et al., 2017; Redfield, 1972). However due to increased coastal development, reduced sediment supplies (caused by urbanization, dam construction, and reforestation), and accelerating rates of SLR, marshes are no longer able to migrate or accrete at a rate fast enough to withstand SLR impacts (Sallenger et al., 2012; Weston, 2014; Watson et al., 2017). As a result of these impacts, Northeast marshes, including those in New England, have suffered from increased dieback areas, vegetation loss, peat subsidence, waterlogged soils, and ponding (Hartig et al., 2000; Alber et al., 2008; Raposa et al., 2017). SLR has also exacerbated salt marsh erosion as a result of increased crab burrows in high marsh areas, due to waterlogged soils (Crotty et al., 2017; Raposa et al., 2018). These combined effects further decrease salt marsh resiliency in light of storms and climate change impacts, which the Northeast is particularly susceptible to (Frumhoff et al., 2007; Kirwan and Megonigal, 2013; Crotty et al., 2017).

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

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

The Quonochontaug (Quonnie) project located in Charlestown, RI, a state-run and federally funded initiative lead by the Coastal Resource Management Council (CRMC), incorporates the SE climate change adaptation strategy and adaptive management while integrating lessons learned from past SE projects. This paper describes the successful incorporation of adaptive management into the Quonnie SE project and highlights the use of collaboration and outreach in restoration initiatives. We analyze how adaptive management components: 1) Create a project model 2) Establish a clear and common purpose/action 3) Develop and implement a management and monitoring plan 4) Analyze results and iterate 5) Communicate results, were applied for the successful implementation of the Quonnie climate change adaptation project (Salafsky et al., 2001). Through this analysis, we intend to identify best practices in planning and implementing an adaptive management strategy for a climate change adaptation project.

2. Establishing the Climate Change Adaptation Project: Identifying Stakeholders and Partners

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

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

3.2 Initial salt marsh condition assessment

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

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

3. Quonnie Sediment Enhancement Adaptive Management Project

4.1 Quonnie project model

Iteration is a major theme in adaptive management; Q-SEAM incorporated methods and lessons learned from a previous SE project at Ninigret Pond in Charlestown, RI. Q-SEAM adapted the same Before, After, Control, Impact (BACI) experimental design model as the Ninigret project, where the control (area where no management action took place) and impact (sediment enhancement) sites were monitored before and after treatment (Smith, 2014). The model incorporated monitoring that would occur for at least five years after sediment placement. It was hypothesized that the control would show signs of degradation (displacement of high marsh plants by low marsh plants, increase in vegetation die-off areas, loss of soil organic carbon, loss of habitat value) over time, while the impact area would gradually recolonize vegetation and nekton communities and accumulate soil organic matter over the five-year monitoring period. Project targets and metrics (Table 3) were incorporated into the BACI model to guide learning. To optimize results and enhance the project, communication, construction, and monitoring techniques learned from the Ninigret project were incorporated in the Q-SEAM plans (Table 4). Results learned from the BACI monitoring and analyses would inform future decision making for Quonnie maintenance as well as future SE projects.

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

4.2 Establish a common purpose/action

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

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

4.3 Development and implementation of a management and monitoring plan

CRMC and the monitoring partners collaborated to create the Quonnie Quality Assurance Project Plan (QAPP), which included a flexible management and monitoring plan that allowed for learning and monitoring plan adjustments, highlighting the adaptive management approach. The QAPP included project targets and metrics such as elevation, vegetation community, and wildlife community (Table 3) and methods to assess these targets. Monitoring these targets was essential to evaluate marsh function and restoration progress as well as for the learning needed to support future decision-making and management plan adjustments.

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

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

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

4.4 Analyze results and iterate

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

4.5 Communicate results

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

4. Community Outreach and Engagement

Throughout the Quonnie project, outreach and community engagement was a continuous priority. During the early stages of the project, Charlestown members were brought in for site visits, and CRMC presented SE plans at town council meetings to help gain support for the project and improve understanding of the project's purpose. A Quonnie planting event, organized and facilitated by Save the Bay, was one of the largest outreach initiatives that occurred after sediment placement in the early spring of 2019. This event brought together school groups, Save the Bay volunteers as well as volunteers from various town organizations, project stakeholders and partners, and Charlestown citizens. Planting events allowed citizen volunteers to make a physical contribution and connection to the project (Figure 3c &d). CRMC sponsored short promotional videos to highlight the restoration that occurred in the state (http://www.crmc.ri.gov/). The Salt Ponds Coalition published an article about the project in its newsletter, Tidal Page, as well as produced videos focused on the SE projects within the state. CRMC and monitoring partners continue to present at local, regional and national meetings to share their experiences and results with the SE technique.

5. Conclusions

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

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

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

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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
Monitoring Partners		
Save The Bay (Narragansett Bay)	Non-profit, NGO	Construction oversite, 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
Approximate total	$2,384,428

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 (*Spartina patens*, *Juncus gerardii*, *Distichlis spicata)* community elevation range	0.23-0.46m (0.75-1.5ft NAVD88)
Iva frutescens 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