STATE OF MAINE
DEPARTMENT OF AGRICULTURE, CONSERVATION & FORESTRY
LAND USE PLANNING COMMISSION
22 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0022

JANET T. MILLS
GOVERNOR

AMANDA E. BEAL
COMMISSIONER

STACIE R. BEYER
EXECUTIVE DIRECTOR

Memorandum

To: LUPC Commissioners

CC: Stacie R. Beyer, Executive Director

From: Megan Leach, Senior Planner
Aeriel Oncita, Mapping and Graphic Arts Specialist
Ben Godsoe, Planning Manager

Date: April 5, 2024

Re: Potential Impacts to Island Structures from Predicted Sea Level Rise: Report of Results

---

Commission staff recently completed a report: "Potential Impacts to Island Structures from Predicted Sea Level Rise: Report of Results," and plan to present it at the Commission Meeting on April 10, 2024. This effort started with an internship project in the summer of 2023, which sought to create a structure inventory on coastal islands in the Commission's service area. Since then, the inventory has been used to analyze the potential effects of sea level rise on developed portions of those coastal islands.

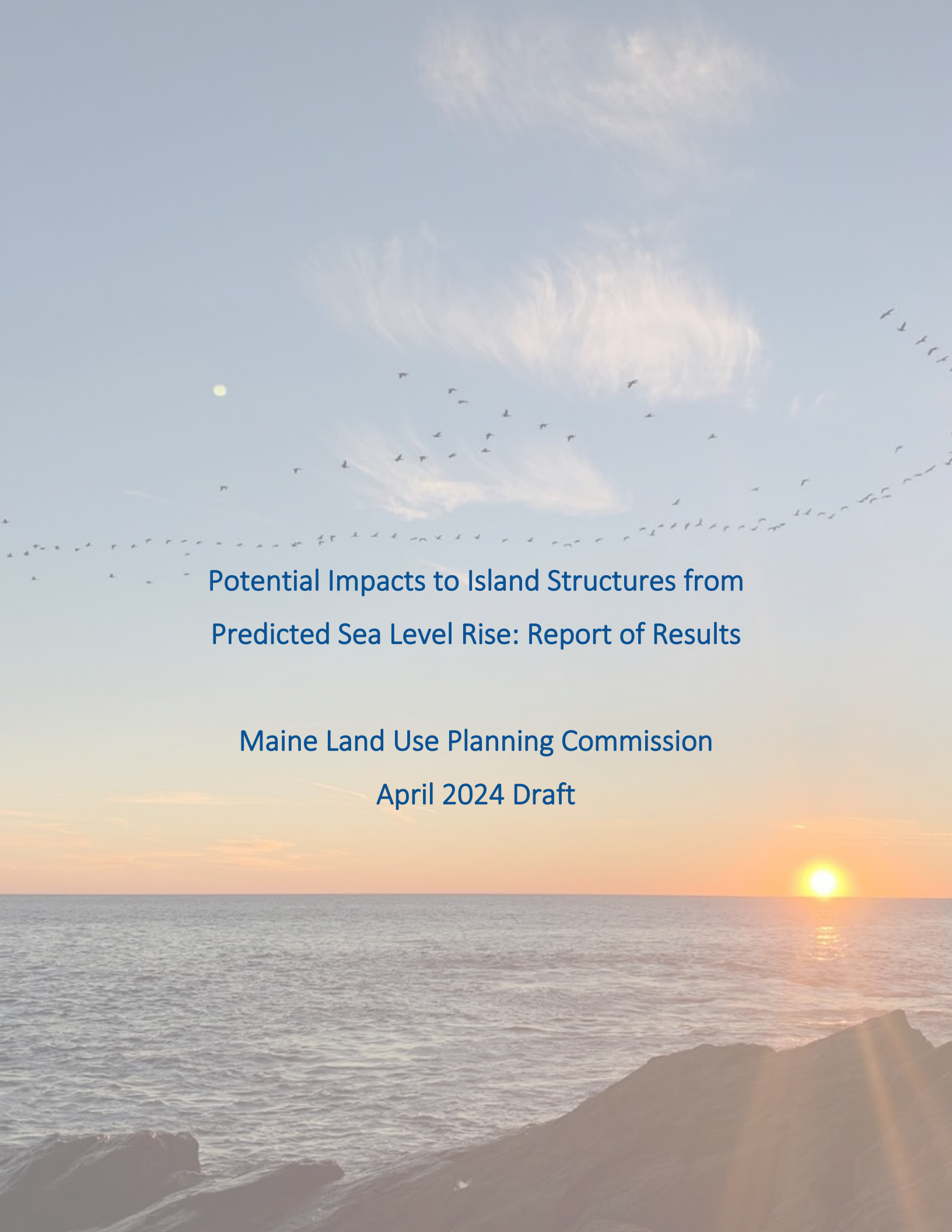
The presentation will cover information in the report (attached), as well as a brief update on the effects of recent strong winter storms. The staff seeks to discuss potential next steps with the Commission, which are also outlined in the report and could begin with targeted outreach efforts in 2024, potentially followed by additional policy work with local partners.

Attachment: Potential Impacts to Island Structures from Predicted Sea Level Rise: Report of Results

HARLOW BUILDING, 4TH FLOOR
WWW.MAINE.GOV/DACF/LUPC

PHONE: 207-287-2631
FAX: 207-287-7439

Attachments to 4/5/2024 Commission Memorandum



Potential Impacts to Island Structures from Predicted Sea Level Rise: Report of Results

Maine Land Use Planning Commission

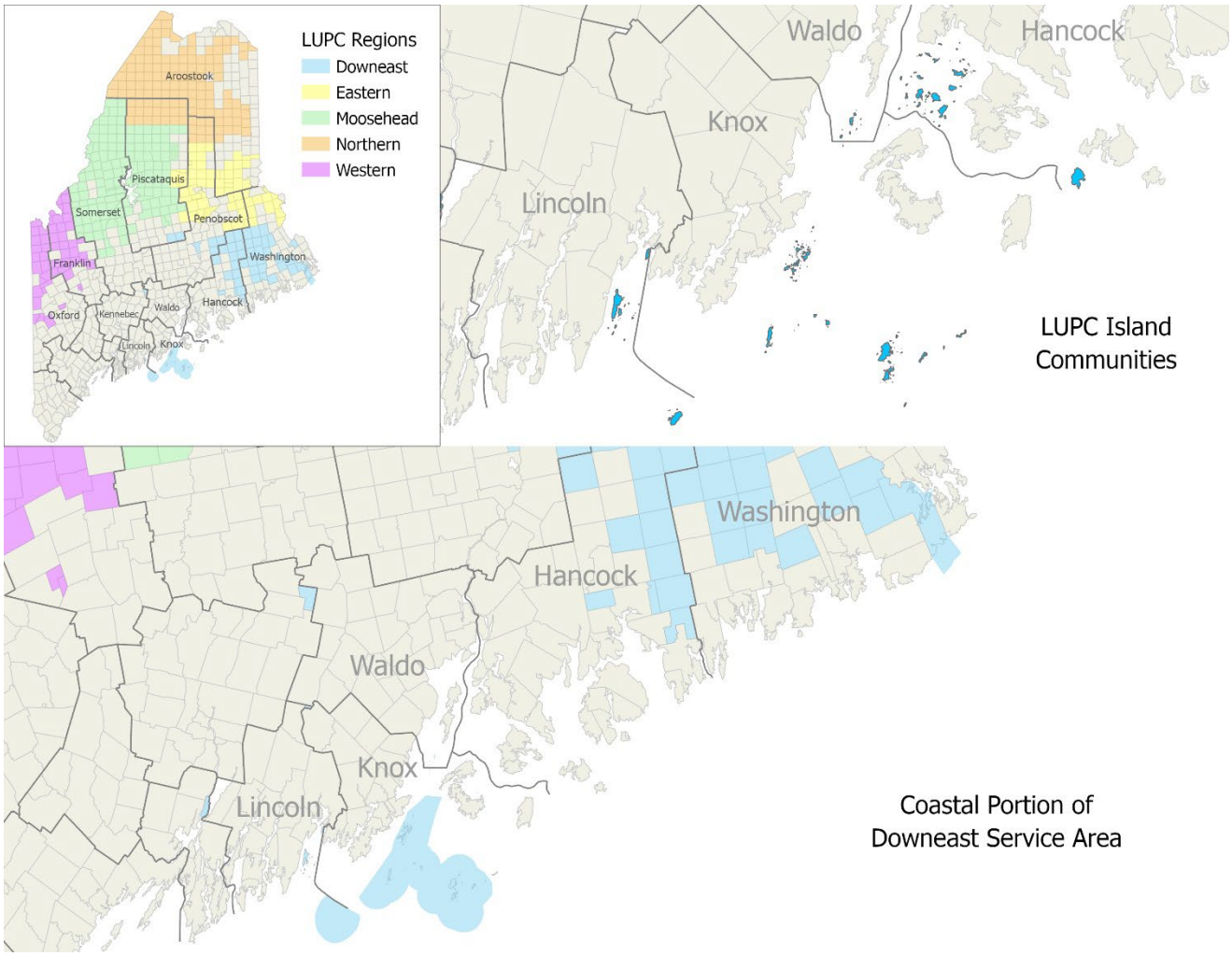
April 2024 Draft

Table of Contents

Introduction

Sea level rise affects coastal communities and offshore islands in the Maine Land Use Planning Commission's (LUPC or the Commission) service area. To better understand these effects, LUPC staff completed an inventory of structures on coastal islands, and then compared this inventory with maps illustrating sea level rise. This report presents the results of a desktop spatial analysis, which Commission staff hope to use for outreach and discussions with residents and property owners, with the idea of identifying strategies to mitigate impacts along with any potential regulatory barriers that may exist in the Commission's rules.

The Maine Land Use Planning Commission is part of the Bureau of Resource Information and Land Use Planning within the Department of Agriculture, Conservation and Forestry.[1] The LUPC is responsible for planning, zoning, permitting, and code enforcement for unorganized and deorganized areas of the state. The LUPC serves over half of the state, encompassing approximately 10.5 million acres, including numerous coastal islands. Planning for such a large area is challenging and even more difficult when



[1] Maine Land Use Planning Commission: www.maine.gov/dacf/lupc/

considering the effects of climate change.

Background

Understanding the Development Patterns and Potential Impacts

In the summer and fall of 2023, the Commission, in partnership with the Margaret Chase Smith Policy Center at the University of Maine, hosted an internship to create a structure and infrastructure inventory (the inventory) for coastal islands in the LUPC service area. Commission staff sought to understand better which islands have structural development and how that development might be impacted by projected sea level rise. The resulting maps include approximate structure locations on all coastal islands in the LUPC service area and depict which structures will experience some level of inundation based on sea level rise projections. Commission staff hope to use this information to help prioritize outreach and collaborative projects with local partners.

NOAA's Projected Sea Level Rise

The National Oceanic and Atmospheric Administration (NOAA) is a federal agency providing data, tools, and services that support work to protect environments and increase community resilience. NOAA studies and provides resources for sea level rise attributed to climate change and has developed predictions based on current and increased greenhouse gas emissions. [2] Under current emission levels, sea level is predicted to rise an average of ten to fourteen inches by 2050 and two feet by 2100. If emissions continue to climb, sea level rise may be as high as three to seven feet by 2100.[3]

Climate Change and Sea Level Rise Work in Maine

Due to the significant impacts that climate change is projected to have on communities and the environment, the Maine Climate Council (the Council) was created in 2019 by Governor Janet Mills and the Maine Legislature. The Council, made up of scientists, industry leaders, bipartisan state and local officials, and citizens, produced a report describing the impacts of climate change and providing strategies and plans for building community resilience. The Council recommends that the state commit to managing for 1.5 feet of relative sea level rise by 2050 and 3.9 feet by 2100 but also suggests that sea level rise could be as high as 3.0 feet by 2050 and 8.8 feet by 2100.[4]

In addition to NOAA and the Council, many public and private organizations provide support to communities in understanding and planning for the rise of sea level. Some examples include the Federal Emergency Management Agency (FEMA), Maine Island Coalition, the Island Institute, The Nature Conservancy, Regional Planning Organizations, the Maine Department of Environmental Protection, the Maine Municipal Assistance Program, and the Maine Geological Survey (see Appendix One for a more comprehensive list). The Maine Emergency Management Agency, and individual counties have also developed hazard mitigation plans to help communities plan for and deal with hazards such as sea level

[2] NOAA Sea Level Rise Portal: https://oceanservice.noaa.gov/hazards/sealevelrise/
[3] NOAA Sea Level Rise Technical Report: https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html
[4] The Maine Climate Council and Maine Won't Wait Four Year Plan: www.maine.gov/future/climate/council

rise. [5] The LUPC can contribute to managing projected sea level rise by engaging with Maine people and communities about climate impacts and opportunities.

2023 Winter Storms

In 2023, storms along the entire coast of Maine resulted in high winds, high tides, and stormwater runoff. The resulting flooding and other effects were enormously destructive to public and private property, businesses, homes, and infrastructure like roads, utilities, or marine infrastructure (wharves, breakwaters, etc.) and necessitated a federal disaster area declaration.

Efforts to recover from these storms and repair vital infrastructure are ongoing. Commission staff are working with officials from Monhegan Island Plantation and Matinicus Island Plantation to provide assistance where they think it would be helpful. Appendix Three includes pictures gathered by the Monhegan Volunteer Fire Department that show some of the damage on Monhegan.

Island Structure Analysis

Methods

Commission staff, with assistance from the Margret Chase Smith intern, performed a desktop analysis using ArcGIS Pro to develop maps displaying the effects of sea level rise on coastal islands in the LUPC service area. Data were obtained from NOAA's Digital Coast: Data Access Viewer, United States Geological Survey's (USGS) LiDAR Explorer Map, Microsoft's Bing Maps Building Footprints, and the USDA's National Agriculture Imagery Program (NAIP). See Appendix Four for more detailed information on analysis methods.

Island Structure Inventory

First, LiDAR data were used to generate detailed maps of island terrain to visualize structures, roads, and other development. A point feature class was created based on available information in the generated terrain layers to identify all island structures. This layer was then refined manually based on a review of aerial imagery. Ultimately, the inventory identified:

1. Islands in the LUPC service area with structures;
2. The number and location of structures on each island;
3. The elevation of each structure; and
4. Each structure's proximity (or nearest straight-line distance) to the coastline.

Historically, the Commission has not maintained an up-to-date and comprehensive inventory of structures and infrastructure in its service area. However, the Commission's permitting data, some additional data collected as part of past planning projects, and other information available through sources such as the Maine Office of GIS (MEGIS) helped inform the inventory. For example, E911 addresses were not available everywhere, only accounted for dwellings or primary structures, and typically only showed approximate locations (e.g., the point was located at the end of a driveway), but

[5] State Hazard Mitigation Plan: www.maine.gov/mema/hazards/natural-hazard-mitigation; e.g., Knox County Hazard Mitigation Plan: www.knoxcountymaine.gov/county_departments/emergency_management_agency/hazard_mitigation_plan_page.php

still proved to be a helpful cross-reference in some situations. The most valuable information available for completing the inventory was aerial imagery.

Potential Impact of Sea Level Rise

The inventory was used for analysis with NOAA sea level rise maps. The sea level rise maps show how far inland sea level is projected to rise above the mean high-water mark along coastlines. Maps are available for zero to ten feet of sea level rise, with each map increasing by one foot. [6]

On islands with significant amounts of development, or significant overlap between the inventory and NOAA's projections, the staff created a more detailed map using polygons in addition to the point feature class. To make this layer, the Staff began with an incomplete state-wide building footprint layer and then modified it to include additional known structure locations. Building footprints allow for more accurate analysis because a polygon occupies more space than a point on the map and, therefore, may overlap with a SLR scenario before a point. (See Appendix Four for more information.)

Results

Island Structure Inventory

There are 319 coastal islands in the LUPC's service area. The inventory identified 854 structures on 42 of these islands. Islands and island groups with the highest number of structures are Monhegan Island Plantation (271) and Matinicus Isle Plantation (260). Islands and island groups with less than 100 structures include the Hancock County group of islands (79), Lincoln County group of islands (84), Muscle Ridge Township (70), Ragged Island (57), and the Knox County group of islands (28).

Potential Impact of Sea Level Rise

Of the 854 structures mapped on coastal islands, 156 structures will experience some level of inundation between 1 and 10 feet of sea level rise (Table 1). Twenty-three coastal islands contain structures that will potentially experience inundation, and eighteen coastal islands contain structures that are not projected to experience inundation at any projected sea level rise (Tables 1 through 4).

Islands with the largest number of affected structures include Matinicus Island (35), Ragged Island (28), and Monhegan (22) (see detailed structure maps in Appendix Two). Several of the structures on each of these islands will be affected by lower levels of sea level rise. On Ragged Island, for example, three structures will be affected by a sea level increase of one to 2 feet, and nine structures will be affected by a sea level increase of three to four feet. A larger proportion of structures will experience inundation with higher sea level rise (five to ten feet). On Matinicus Island, for example, 27 of the 31 structures will experience some level of inundation between five and ten feet. On Monhegan and Ragged, this number is 19 out of 22 and 13 out of 23, respectively.

[6] NOAA Digital Coast Sea Level Rise Viewer Frequently Asked Questions: https://coast.noaa.gov/data/digitalcoast/pdf/slr-faq.pdf

Table 1. Summary of islands with structures that will potentially be affected by current sea level rise projections.

Island	Jurisdiction	County	Total Structures	Number of Structures Affected at Sea Level Rise					Total Affected
				1-2 ft.	3-4 ft.	5-6 ft.	7-8 ft.	9-10 ft.	
Ragged Island	Criehaven Twp	Knox	57	4	11	8	2	3	28
Bear Island	Hancock County Island	Hancock	9	1		1	1		3
Eagle Island	Hancock County Island	Hancock	40	1	1	2		1	5
Great Spruce Head Island	Hancock County Island	Hancock	20			1	1		2
Pumpkin Island	Hancock County Island	Hancock	4			1			1
Scott Island	Hancock County Island	Hancock	2			1			1
Scrag Island	Hancock County Island	Hancock	4		1	1	2		4
Lasells Island	Knox County Island	Knox	10		1		1	1	3
Metinic Island	Knox County Island	Knox	18			1	5	1	7
Indian Island	Lincoln County Island	Lincoln	1				1		1
Louds Island	Lincoln County Island	Lincoln	73		1	3	1	1	6
Marsh Island	Lincoln County Island	Lincoln	10			1	1	2	4
Matinicus	Matinicus Isle Plt	Knox	260	2	4	9	10	10	35
Wheaton Island	Matinicus Isle Plt	Knox	5				1	1	2
Monhegan	Monhegan Island Plt	Lincoln	271	1	2	4	10	5	22
Andrews Island	Muscle Ridge Twp	Knox	10	1	1	1	4	2	9
Dix Island	Muscle Ridge Twp	Knox	10			1		2	3
Flag Island	Muscle Ridge Twp	Knox	1				1		1
Great Pond Island	Muscle Ridge Twp	Knox	3				1	2	3
Hewett Island	Muscle Ridge Twp	Knox	22			3	1	2	6
Little Green Island	Muscle Ridge Twp	Knox	1					1	1
Mink Island	Muscle Ridge Twp	Knox	4					2	2
The Neck	Muscle Ridge Twp	Knox	7				1	3	4
Pleasant Island	Muscle Ridge Twp	Knox	12				1	2	3

Table 2. Summary of islands with 100 percent inundation with up to 10-foot sea level rise.

Island	Jurisdiction	County	Total Structures	Number of Structures Affected at Sea Level Rise					Total Affected
				1-2 ft.	3-4 ft.	5-6 ft.	7-8 ft.	9-10 ft.	
Scrag Island	Hancock County Island	Hancock	4		1	1	2		4
Indian Island	Lincoln County Island	Lincoln	1				1		1
Flag Island	Muscle Ridge Twp	Knox	1				1		1
Great Pond Island	Muscle Ridge Twp	Knox	3				1	2	3
Little Green Island	Muscle Ridge Twp	Knox	1					1	1

Table 3. Summary of islands that experience structure inundation with low levels of projected sea level rise.

Island	Jurisdiction	County	Total Structures	Number of Structures Affected at Sea Level Rise					Total Affected
				1-2 ft.	3-4 ft.	5-6 ft.	7-8 ft.	9-10 ft.	
Ragged Island	Criehaven Twp	Knox	57	4	11	8	2	3	28
Bear Island	Hancock County Island	Hancock	9	1		1	1		3
Eagle Island	Hancock County Island	Hancock	40	1	1	2		1	5
Lasells Island	Knox County Island	Knox	10		1		1	1	3
Louds Island	Lincoln County Island	Lincoln	73		1	3	1	1	6
Matinicus	Matinicus Isle Plt	Knox	260	2	4	9	10	10	35
Monhegan	Monhegan Island Plt	Lincoln	271	1	2	4	10	5	22
Andrews Island	Muscle Ridge Twp	Knox	10	1	1	1	4	2	9

Table 4. Summary of islands with structures unaffected by projected sea level rise.

Island	Jurisdiction	County	Total Structures
Bar Island	Hancock County Island	Hancock	2
Barred Island	Hancock County Island	Hancock	2
Beach Island	Hancock County Island	Hancock	7
Birch Island	Hancock County Island	Hancock	1
Butter Island	Hancock County Island	Hancock	6
Eaton Island	Hancock County Island	Hancock	1
Hog Island	Hancock County Island	Hancock	4
Horse Head Island	Hancock County Island	Hancock	1
Little Spruce Head Island	Hancock County Island	Hancock	5
Large Green Island	Knox County Island	Knox	15
Little Green Island 2	Knox County Island	Knox	1
Matinicus Rock	Matinicus Isle Plt	Knox	4
Manana Island	Monhegan Island Plt	Lincoln	2
Fisherman's Island	Muscle Ridge Twp	Knox	1
Graffam Island	Muscle Ridge Twp	Knox	1
Otter Island	Muscle Ridge Twp	Knox	3
Two Bush Island	Muscle Ridge Twp	Knox	2
Swan Island	Perkins Twp Swan Island	Sagadahoc	10

Discussion And Next Steps

Implications

The Coastal Islands Structure Inventory identifies islands with structural development. It can also be used to determine approximately where and when structures on islands may experience impacts from sea level rise. For example, Ragged Island, Bear Island, Eagle Island, Matinicus Island, and Monhegan all have at least one structure that will be affected by sea level rise of 1-2 feet, which is predicted by 2050 (26 years) with current emission levels (Table 3). If sea level rises to the higher prediction of 3 feet by 2050, additional structures will be affected (see Table 1). In creating the inventory, the staff also noted other types of infrastructure that may be at risk, such as airstrips, breakwaters, wharves, or vulnerable road segments.

Commission staff will use the information in this report to help prioritize outreach and assistance to people who live and work on these coastal islands as they continue to upgrade infrastructure and take actions to mitigate the effects of sea level rise. The staff intends the report to be useful to local partners in seeking recovery assistance from federal and state government sources.

Ultimately, various adaptation and mitigation strategies may be needed, depending on the location and circumstances. Some examples of adaptation strategies that could occur on coastal islands include:

- Natural or green infrastructure projects[7] (such as establishing or re-establishing dunes and wetlands);
- Shoreline stabilization or living shoreline projects;
- Upgrading transportation infrastructure (culverts, bridges, wharves, breakwaters, roads, airstrips, etc.);
- Elevating structures; and
- The managed retreat of structures to higher ground.

Structures Inventory Data Limitations

The inventory and accompanying maps showing SLR scenarios are useful in identifying where structures are located on coastal islands in the LUPC service area and in understanding which structures may become inundated under certain scenarios. However, the inventory is limited in these ways:

- Unique data points indicating marine structures such as breakwaters or wharves have not yet been included in the structure inventory unless captured because a structure also existed in the same location. The staff have noted where it seems there are real implications for this kind of infrastructure but will ultimately rely on local knowledge and expertise to characterize the risk from SLR, especially when identifying necessary upgrades.
- SLR scenario mapping is approximate and based on averaged projections. Maps do not accurately predict when areas will flood. Events such as storm surges, king-tides, and stormwater runoff from weather events can have combined effects similar to a more advanced SLR scenario than the inventory maps may project. The effects of sea level rise are felt by island communities today during significant storms such as those that occurred in winter 2023.
- A point feature class was generated from the analysis. Points do not accurately reflect the footprint of various structures or infrastructure. Consequently, when a particular SLR scenario implicates a structure is dependent on when the scenario layer overlaps with the data point, not the footprint of an actual building. In a few example locations (e.g., islands like Monhegan or Matinicus, where there is significant existing development), building footprint maps were generated to improve the accuracy of the results.
- Interpolation of aerial imagery for this purpose can be imprecise because it is dependent on what can be seen from above and because results have not been verified on the ground. For example, vegetation or image imperfections can “hide” a structure and prevent it from being counted. There are likely structures that were obscured in this way. Conversely, some activities, such as the storage of fishing gear, can resemble a structure when seen in aerial imagery. Finally, aerial imagery only captures conditions when the photo was taken.
- It is impossible to determine the land use of a particular structure based on its appearance from above. Therefore, the inventory only shows where structures are located and does not capture their use.

[7] NOAA’s description of natural infrastructure: https://coast.noaa.gov/data/nationalfacts/pdf/hand-out-natural-infrastructure.pdf.

Next Steps: Outreach

The staff will use the results of this report to guide outreach over the next year to property owners, residents, and regional organizations providing assistance on coastal islands. Outreach efforts may include sharing the information in this report, and perhaps further analysis where helpful, but would primarily focus on learning from local and regional partners what strategies they hope to pursue to mitigate the effects of sea level rise and associated flooding, storms, etc.

Questions staff have for property owners or local leaders on inhabited coastal islands:

1. What are people most concerned with regarding SLR in your community? (e.g., intensifying storms, flooding, erosion, power outages, etc.)
2. Which structures or infrastructure are most at risk, in your opinion?
3. Where should the community focus its resources?
4. How best can LUPC provide assistance?

The answers to these questions will help identify if there are potential regulatory barriers or other considerations for a particular approach. For example, some communities have indicated already that they intend to work on raising the height of common marine infrastructure such as wharves or breakwaters. Because this may be a common issue for multiple islands, the Commission staff are developing materials covering permitting procedures, best practices, etc.

The staff seeks to focus outreach efforts on Ragged Island (because of the scale of potential effects) and Matinicus and Monhegan due to the large number of structures potentially affected. Matinicus and Monhegan are also plantations, which provide a mechanism for engaging with residents and property owners. Ragged and other islands do not have local government officials, so working with property owners may be more difficult. Other islands may also be candidates for this work, but similarly, they do not have local government and may not have other organizations that can serve as points of contact. Bear, Eagle, Scrag, and Louds islands all have structures that will experience some level of inundation with a sea level rise of up to four feet, most likely to occur within just 20 years.

Structures represent one aspect of community infrastructure that should be considered for potential impacts from sea level rise. Also of concern is the potential effect on transportation infrastructure (roads, bridges, airstrips, wharves), community water supplies, and natural resources that protect communities from flooding (wetlands, sand dunes). This work is only the first step in understanding potential impacts and engaging island communities in planning for sea level rise.

Due to limited time and resources, coastal island communities were the focus of this report, but the Commission staff plan to conduct similar analyses for other coastal communities using the methods developed by this report.

Appendices

Appendix One: Community Resources for Sea Level Rise

Gulf of Maine Research Institute

Helping Coastal Maine Communities Adapt

Knox County

Hazard Mitigation Plan

Lincoln County

Hazard Mitigation Plan

Maine Coastal Program

Tidal Restriction Areas

Maine Department of Environmental Protection

Maine Climate Hub
Maine Adaptation Toolkit

Maine Geological Survey

Sea Level Rise Viewer
Property Owners Guide to Erosion, Flooding, and other Coastal Hazards

Maine Municipal Planning Assistance Program

Planning for Climate Variability
Municipal Climate Adaptation Guidance Series

Maine Natural Areas Program

Potential Tidal Marsh Migration Map

Maine Sea Grant

Coastal Community Resilience

NOAA

Sea Level Rise and Coastal Flooding Risk

The Island Institute

Sea Level Rise Resources

State of Maine Governor's Office of Policy and Innovation

Community Resilience Partnership
Grant Opportunities
Maine Climate Council

The Nature Conservancy

Coastal Resilience Tool

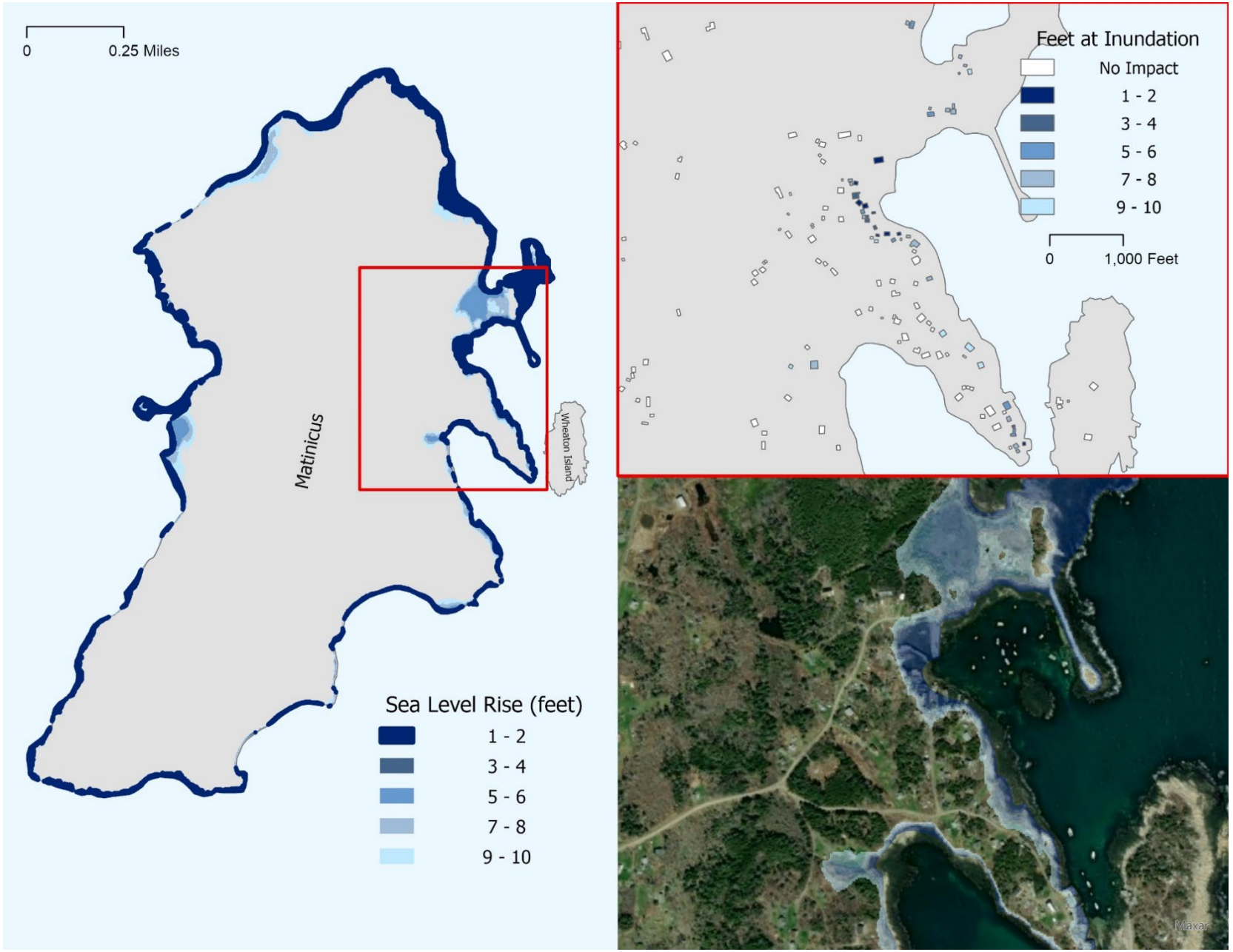
United States Federal Government

U.S. Climate Resilience Toolkit

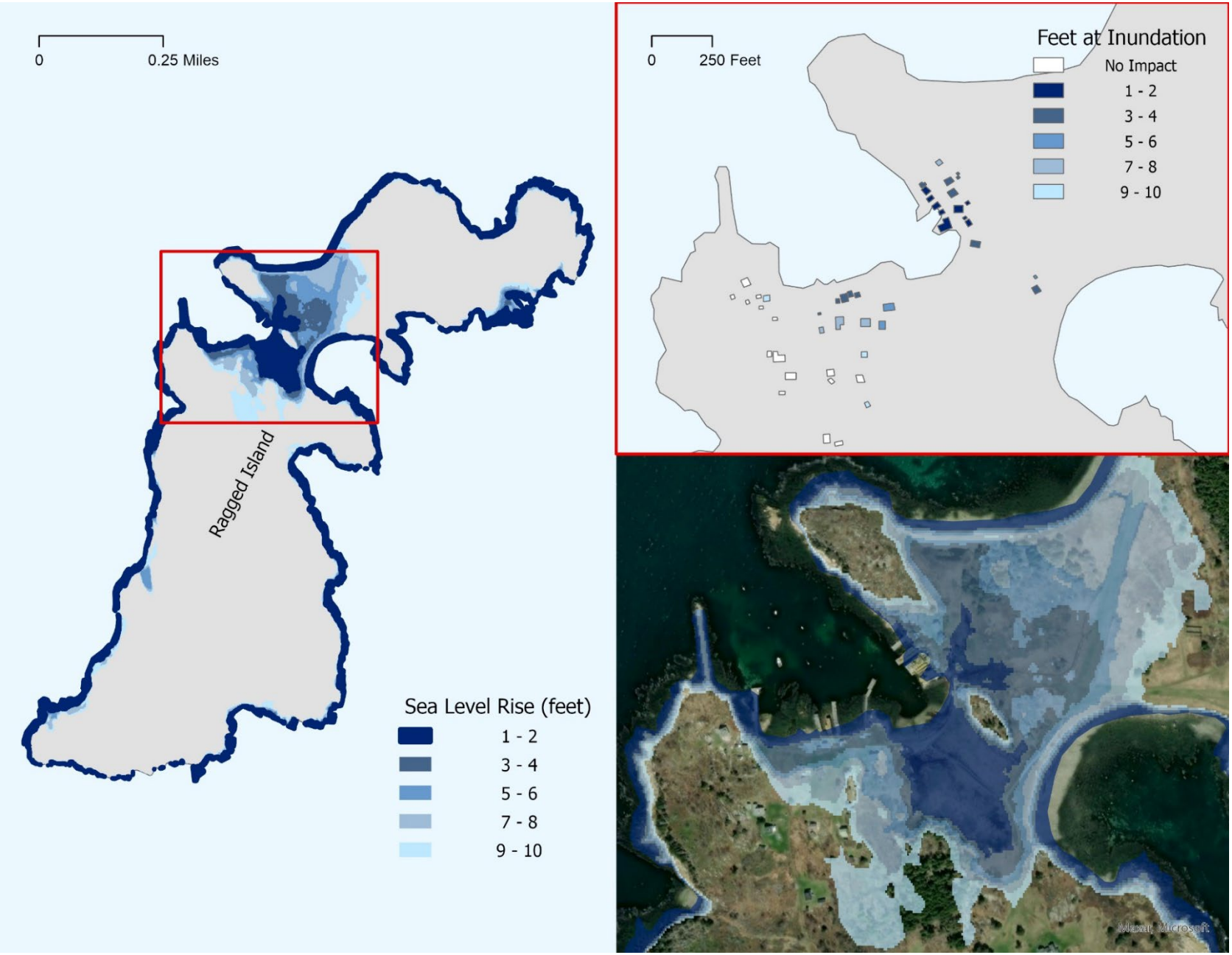
University of Maine Cooperative Extension

Maine Community Resilience Workbook

Appendix Two: Maps of Selected Island Communities

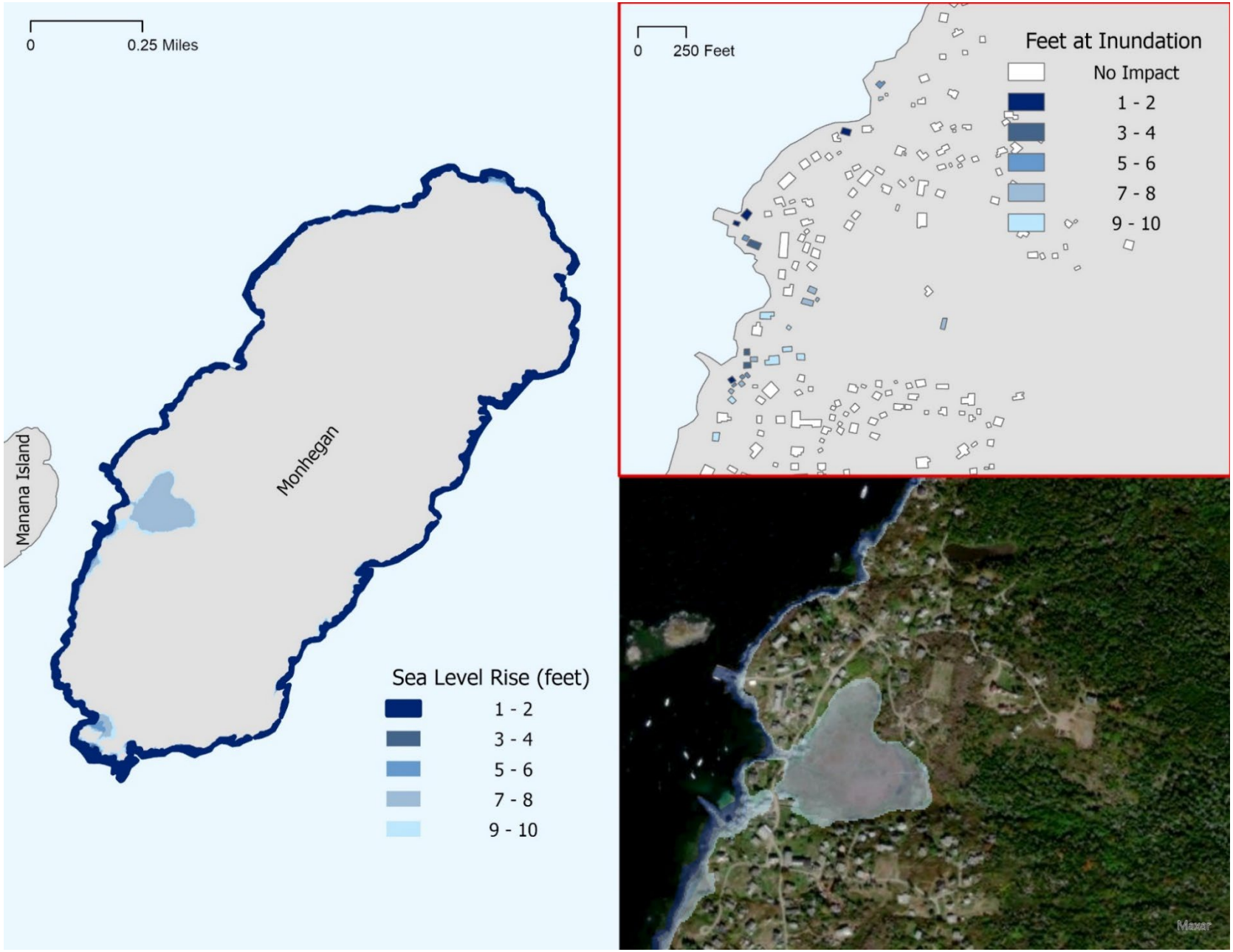


Map 1: Matinicus Island



Map 2: Ragged Island

Map 3:
Monhegan



Appendix Three: Images of Storm Damage Due to Coastal Flooding[8]

Fish Beach, Monhegan Island

Harbor Breakwater and Damaged Building, Monhegan Island

[8] Photos courtesy of the Island Institute and Jes Stevens (Monhegan Volunteer Fire Department)

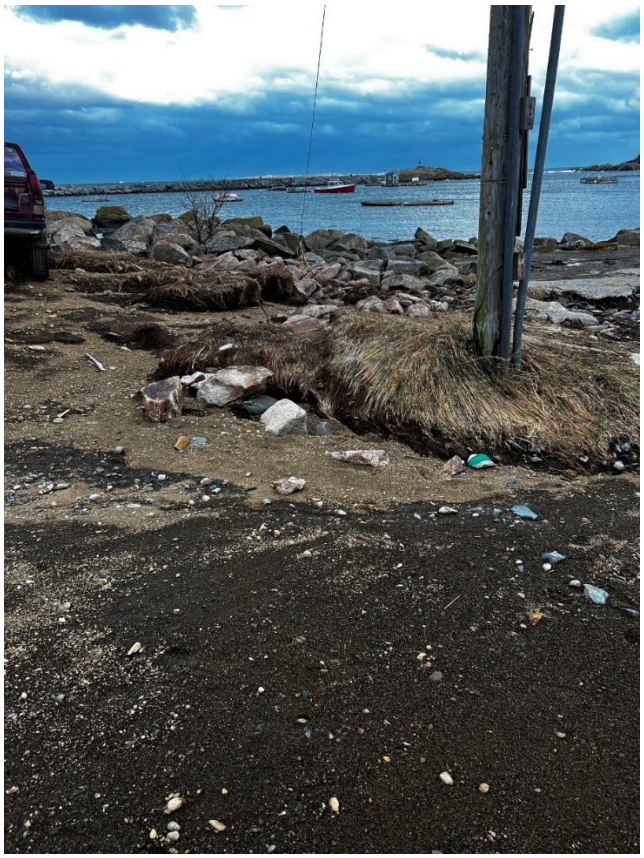
Public Wharf and Freight Shed, Monhegan Island

Public Wharf and Freight Shed, Monhegan Island

Airstrip Erosion, Matinicus Island

Shoreland Erosion, Matinicus Island

Shoreland Erosion, Matinicus Island



Shoreland Erosion (with Utility Pole), Matinicus Island

Appendix Four: Detailed Methods

Understanding Island Topography

Light Detection and Ranging (LiDAR) data is helpful in visualizing topography and land cover. This point cloud data contains the information necessary to create a three-dimensional representation of objects and surfaces. The analysis in the report utilized USGS's 2020 LiDAR data in LAS format. This high-density data contains billions of LAS points that were filtered into different LAS datasets and then classified into their respective land cover types based on return values.

This LiDAR analysis allowed for creating a Digital Elevation Model (DEM) referencing ground points and a Digital Surface Model (DSM) referencing first return points. Creating these models required converting the LAS dataset to a raster layer, creating a mosaic image, which allowed for faster data geoprocessing. The interpolation of the two LAS datasets resulted in two separate layers representing the bare-earth elevation (DEM) and the elevation of both natural and man-made features on the islands (DSM).

Identifying Island Communities and Creating a Structure Inventory

Given the large number of coastal islands under the jurisdiction of LUPC, the staff decided to focus more intensive spatial analysis on islands affected by SLR, and that also have numerous structures. Information from the 2021 NAIP imagery and 2024 Google satellite imagery were used in combination with the DSM layer to identify the locations of structures. All island structures are represented in a point feature class containing the following information:

1. The number of structure-containing islands;
2. The number of structures on each island and their situation;
3. The elevation of each structure; and
4. The nearest straight-line distance from each structure to the coast ("proximity").

This Structure Inventory point layer provided adequate information to help staff understand the extent of structures vulnerable to sea level rise; however, the model lacked accuracy in capturing the area each structure occupies on the island.

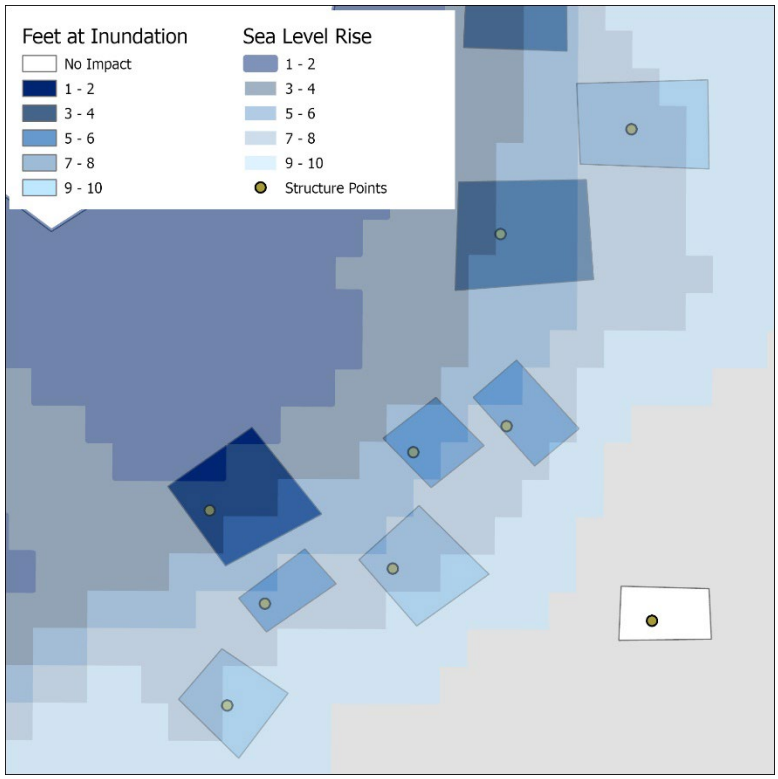


Figure 4.1. Depiction of point and polygon structure layers and point of intersection with sea level rise layers.

To address this issue, staff extracted Maine's building footprint data from Microsoft and modified it to create a new, more accurate polygon layer.

Applying Sea Level Rise Scenarios

The final step of the analysis involves overlaying NOAA's Sea level rise data on the map. The sea level rise projections span from 1 to 10 feet, displaying levels of inundation based on ground elevation. For this analysis, staff chose to map sea level rise projection using consecutive paired measurements of the data (i.e., 1-2 feet, 3-4 feet, etc.) and applying a monochromatic color scheme to display each scenario. As a result, staff can identify inundated areas and structures by filtering layers and analyzing areas where sea level rise intersects with building footprints.