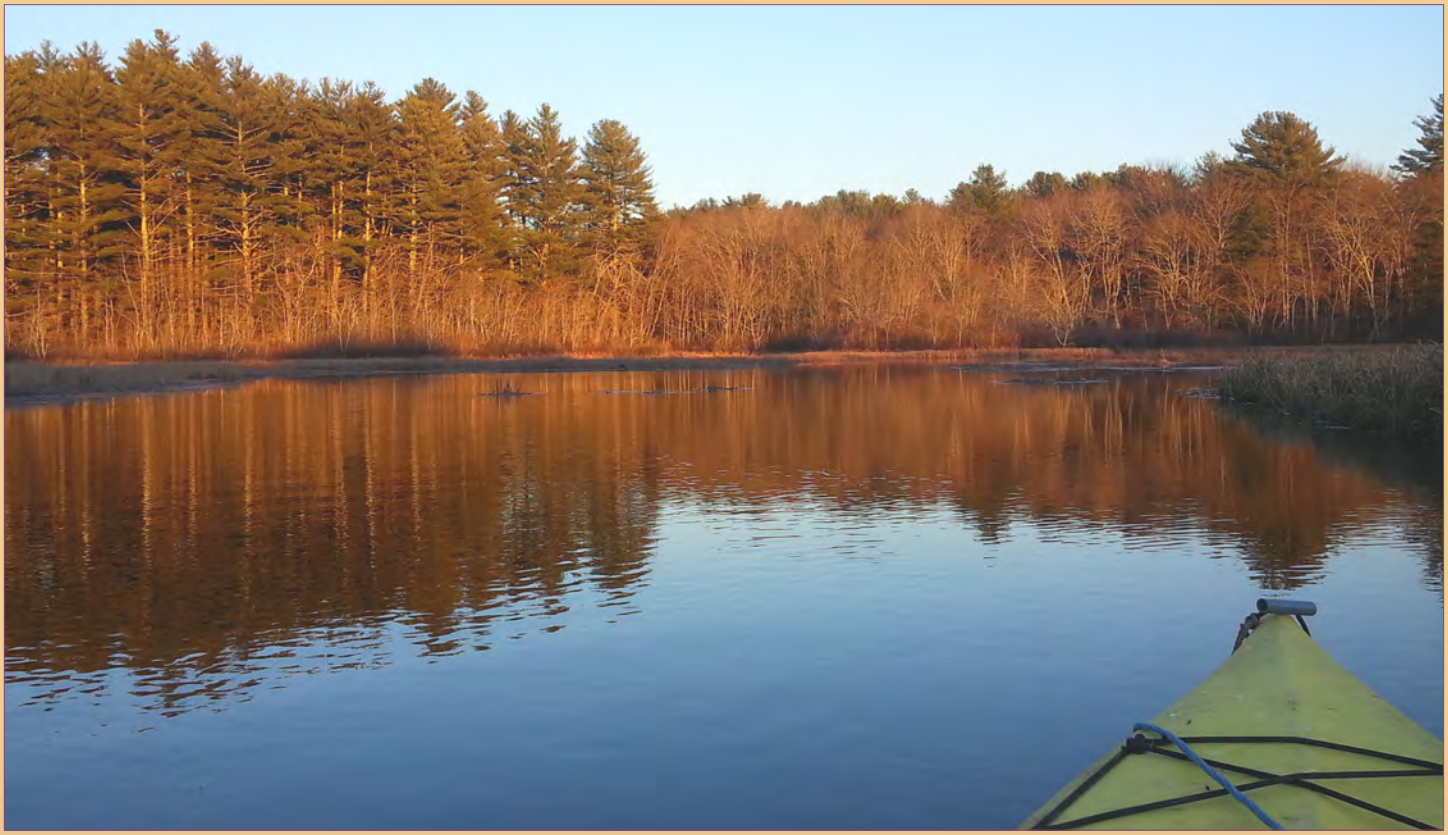

Building Capacity to Adapt to Climate Change Through Local Conservation Efforts

A SOUTH KINGSTOWN LAND TRUST PILOT PROJECT

Rhode Island Sea Grant & URI Coastal Resources Center • 2013

BUILDING CAPACITY TO ADAPT TO CLIMATE CHANGE THROUGH LOCAL CONSERVATION EFFORTS

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ACKNOWLEDGEMENTS

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We greatly appreciate the efforts of organizations and individuals that developed statewide assessments in Massachusetts and Connecticut related to conservation and climate change. We relied upon their efforts throughout our report as the ecosystems, habitats, climate trends and management options are similar.

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ACRONYMS

ALPC	Agricultural Land Preservation Commission
BMP	Best Management Practice
CRMC	Coastal Resources Management Council
ELU	Ecological Land Unit
LiDAR	Light Detection and Radar
LTA	Land Trust Alliance
RIDEM	Rhode Island Department of Environmental Management
RIGIS	Rhode Island Geographical Information System
SKLT	South Kingstown Land Trust
SLAMM	Sea Level Affecting Marshes Model
TNC	The Nature Conservancy
URI-CRC	University of Rhode Island Coastal Resources Center
URI-EDC	University of Rhode Island Environmental Data Center
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

INTRODUCTION: SETTING THE CONTEXT: OUTLINING THE SCOPE AND PURPOSE OF THE PROJECT

Since 2010 Rhode Island has experienced three major storm events causing widespread power outages, major coastal and inland flooding, and significant damage to homes, property, and infrastructure. These increasingly frequent major storms are indicative of changing variability in climactic patterns effecting Rhode Island, and it is important to recognize that the impacts of climate change have a profound effect on the state's valuable ecosystems and habitats as well as buildings and infrastructure. One of the major impacts of climate change is alteration in the timing of seasonal activities, such as flowering of plant species and hatching of insects. These shifts, known as "phenological" changes, affect some species more than others, leading to increased incursion of previously southern species as their ranges shift northward and cause changes in species diversity. Changes in air and water temperatures, shifting rainfall patterns, and rising sea levels will affect the distribution and abundance of plants and animals and the health of ecosystems and the services they provide. There is already evidence of encroachment of species previously considered pests (such as kudzu) in the southern US into southern New England as well as changing breeding ranges in northern bird species (SUNY College of Environmental Science and Forestry, 2009). A study of plants in Concord, Massachusetts found that 27% of the plants originally documented by Thoreau are now extinct in the area and 36% are so sparsely distributed that extinction is likely in the near future (Willis et al., 2008). Invasive plant species such as Norway maple, garlic mustard and mile-a-minute vine are becoming established or expanding their previous habitat ranges (Rhode Island Climate Change Commission, 2011). All of these factors must be taken into consideration by conservation organizations as they plan for habitat and ecosystem preservation in a climate-changing world.

Rhode Island has one of the highest population densities in the United States, yet the state's landscapes remain relatively intact with nearly sixty percent of its land area classified as forest (Rhode Island Division of Planning, 2006). Strong conservation policies and the ongoing commitment from public, private and non-profit institutions have been critical to enhancing conservation of natural habitats, open space, agricultural lands and other key elements in preserving ecosystem services and associated quality of life.

Rhode Island's current planning efforts related to climate change and natural resources have been primarily at the state level. Such efforts include the establishment of the Rhode Island Climate Change Commission with its three working groups (including the Natural Resources and Habitats group), modeling of wetland migration with sea level rise, and updating of the state's Comprehensive Wildlife Conservation Strategy to include a climate change

perspective in management strategies. Municipal-level efforts have begun to address climate change, complementing local comprehensive plans and multi-hazard mitigation planning. These hazard mitigation plans require communities to evaluate their exposure to different hazard events and identify actions to enhance human safety and reduce damage to the built environment. The updated Comprehensive Planning and Land Use Act (adopted in 2011) requires cities and towns to include, as part of their comprehensive plans, an identification of areas that could be vulnerable to the effects of sea level rise, flooding, storm damage, drought, and other natural hazards. Additionally, municipalities must identify goals, policies, and implementation techniques that help to avoid or minimize the effects that natural hazards on lives, infrastructure, and property.

While this vital work is being performed at the governmental level, it is also important for local conservation organizations, such as land trusts and watershed associations, to consider the reality of a changing climate. This report outlines a five-step approach for assessing vulnerability and monitoring both adaptation actions and habitat changes. These changes create a new set of challenges and opportunities that have the potential to greatly affect the conservation strategies of these organizations. For example, preserved forest areas should be relatively large to function effectively as resilient reserves and some larger organizations or partnerships of various groups are capable of assembling such acquisitions. Critical habitats –areas in which targeted species can persist and/or relocate over time– may provide a refuge from climate change impacts and become high-priority candidates for acquisition and enhanced conservation efforts. Land trusts involved with agricultural operations can promote innovative pest management, monitoring, irrigation methods, and other farming practices designed to address climate change. Research can be conducted to identify structurally diverse and species-rich habitats as well as important movement corridors. Monitoring for new invasive plants, insects and other pests may be implemented. Cool water streams and cold water fish habitat can be incorporated into a land trust's or watershed association's buffer strategy in order to conserve connected water bodies and protect vegetative canopies over streams to help reduce impacts of warming temperatures. Local conservation groups have the ability and knowledge to take the lead in habitat and buffer restoration utilizing diverse native species, thereby increasing the resiliency of habitats to the stresses of climate change and shifting environmental conditions.

BUILDING CAPACITY TO ADAPT TO CLIMATE CHANGE THROUGH LAND TRUSTS AND LOCAL CONSERVATION EFFORTS

The pilot project developed in 2010-2012 and presented in this report is a contribution towards fostering climate change adaptation at the community level. The report's emphasis is on the role and perspective of local land trusts, acknowledging recent guidance on the need to incorporate a climate lens into local conservation planning (such as the Land Trust Alliance's Climate Change Toolkit). Both the experience of engaging in this process and the resulting analyses, maps and recommendations offer lessons and materials that we believe are relevant for other land trusts and conservation groups as well as for municipal conservation and planning commissions.

As a part of a larger program of climate change adaptation activities the University of Rhode Island Coastal Resources Center (URI-CRC) working with the Rhode Island Coastal Resources Management Council (CRMC), and various stakeholder groups in the state, we undertook an initiative to accomplish three primary goals:

- Initiate a discussion of climate change with local land trusts and their partners;
- Build the capacity of local land trusts to understand the implications of climate change for Rhode Island's coastal land and water habitats;

- Identify ways to implement adaptation strategies through conservation, management and investment.

This initiative features the work of the South Kingstown Land Trust (SKLT) and other partners including The Nature Conservancy (TNC) and the University of Rhode Island's Environmental Data Center (URI-EDC), creating a collaborative approach that includes information gathering, tool development, identifying adaptation strategies, and capacity building. Over the past few years Connecticut and Massachusetts agencies have engaged panels of recognized experts to address vulnerability assessments and adaptation strategies focusing on a broad range of natural resources. This pilot project drew upon the above expert-driven processes and results to address the vulnerabilities of Rhode Island's shared resources and similar ecosystem types.

Given the significant conservation and stewardship role of local conservation organizations, this project creates an opportunity to evaluate how such organizations could begin incorporating climate change with the tools used for acquisition and management in order to help ensure that their efforts are effective during these changing times. It is hoped that as a result of identifying vulnerable resources, management strategies can be adapted for existing properties and vulnerabilities of potential land acquisitions to changing climate, sea level rise, and flooding can be assessed.

The potential capacity of local communities to adapt to climate change is enhanced by a high degree of collaboration that is often present among the private and public partners involved in land conservation. The assets under the stewardship of land trusts are commonly part of a larger community conservation and management context; large areas of its land and seascape areas categorized as highly valuable, with significant biodiversity often go beyond municipal borders to a regional level as well.

FOCUS ON THE SOUTH KINGSTOWN LAND TRUST AS A PILOT

The approach outlined in this report was applied to the South Kingstown Land Trust as an example and case study. SKLT has actively engaged in this project by assessing the vulnerability of its holdings and priority areas of interest and identifying options for incorporating adaptation within their conservation and management policies and programs (often referred to as mainstreaming climate change adaptation).

Benefits of Climate Change Planning for Land Trusts

Increased awareness about climate change, its trends and potential implications for land conservation and larger community issues.

Understanding that climate change is an additional stressor for land and water conservation, adding to existing concerns such as invasive species and encroaching development.

Climate threats (such as those of rising temperatures to cold water species) can be revealed and incorporated into management strategies.

Additional considerations for prioritizing acquisitions can be discovered in the vulnerability assessment process.

GIS-based maps for climate-related habitat sensitivity and ecological land units can be combined with other tools being utilized.

Increased awareness of habitat sensitivity, climate change impacts, and adaptation actions will add a new dimension to management plans and conservation easements.

Leverage funding to support adaptation and/or mitigation actions.

This project has provided SKLT with new options to prioritize its land stewardship and tap into expertise which it otherwise might have not been considered. Although the emphasis of the project has been on SKLT, many of the data sets, maps and background information created can be applied to communities throughout Rhode Island.

OUTLINE OF THE REPORT

This report provides information and tools, as well as a process for local conservation groups to better understand climate change and begin to take action by incorporating actions into existing conservation and management programs. Section 1 summarizes a five-step approach to integrating climate change adaptation into local conservation strategies. Section 2 shares an in-depth look at how the South Kingstown Land Trust followed this approach to identify potential adaptation strategies. Section 3 provides a compilation of relevant options for management, protection and outreach for the SKLT and others to consider. The remaining appendices, listed below and found in a companion document, contain important information that will assist local conservation groups in their adaptation planning. Keep in mind however, that this is a new and rapidly expanding field of knowledge. Since information, resources and tools are emerging rapidly in Rhode Island and beyond, users of this document are encouraged to complement the information presented here with other materials as they become available.

Section 1: "Integrating Climate Change Adaptation into a Local Conservation Organization's Portfolio: A Five-Step Approach" introduces a vulnerability assessment and adaptation methodology adjusted to focus on landscape conservation and habitat protection.

Section 2: "The South Kingstown Land Trust Case Study" presents the summary analysis of habitat vulnerability for each of the main focus areas where the SKLT concentrates its conservation and stewardship effort including key findings and opportunities for action in a climate-changing context.

Section 3: "Options for Management, Protection and Outreach" summarizes information and opportunities for land trusts and local conservation groups to consider as complements to their existing tools used for conservation and protection.

A Companion Document:

Appendix 1: "Summary of Climate Change Impacts and Non-Climate Stressors" summarizes the trends in Rhode Island, the projections' high and low emissions scenarios for the Northeastern United States and their likely impacts on Rhode Island. Non-climate stressors already being seen in Rhode Island are also summarized.

Appendix 2: "Habitats and other Assets in a Vulnerability Assessment" examines the climate change sensitivity of the five primary landscape/habitat types in Rhode Island

Appendix 3: "Ecological Land Units (ELUs) – A New Strategy for Achieving Conservation Goals" introduces a new type of landscape analysis that classifies and assesses the importance and distribution of the different underlying geological and land form characteristics.

Appendix 4: "Sea Level Rise Mapping in Rhode Island" provides an overview of resources and current work being done around the state to create maps that may be used for sea level rise modeling projections and risk management assessments for built and natural environments.

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SECTION 1: INTEGRATING CLIMATE CHANGE ADAPTATION INTO A LOCAL CONSERVATION ORGANIZATION'S PORTFOLIO: A FIVE-STEP APPROACH

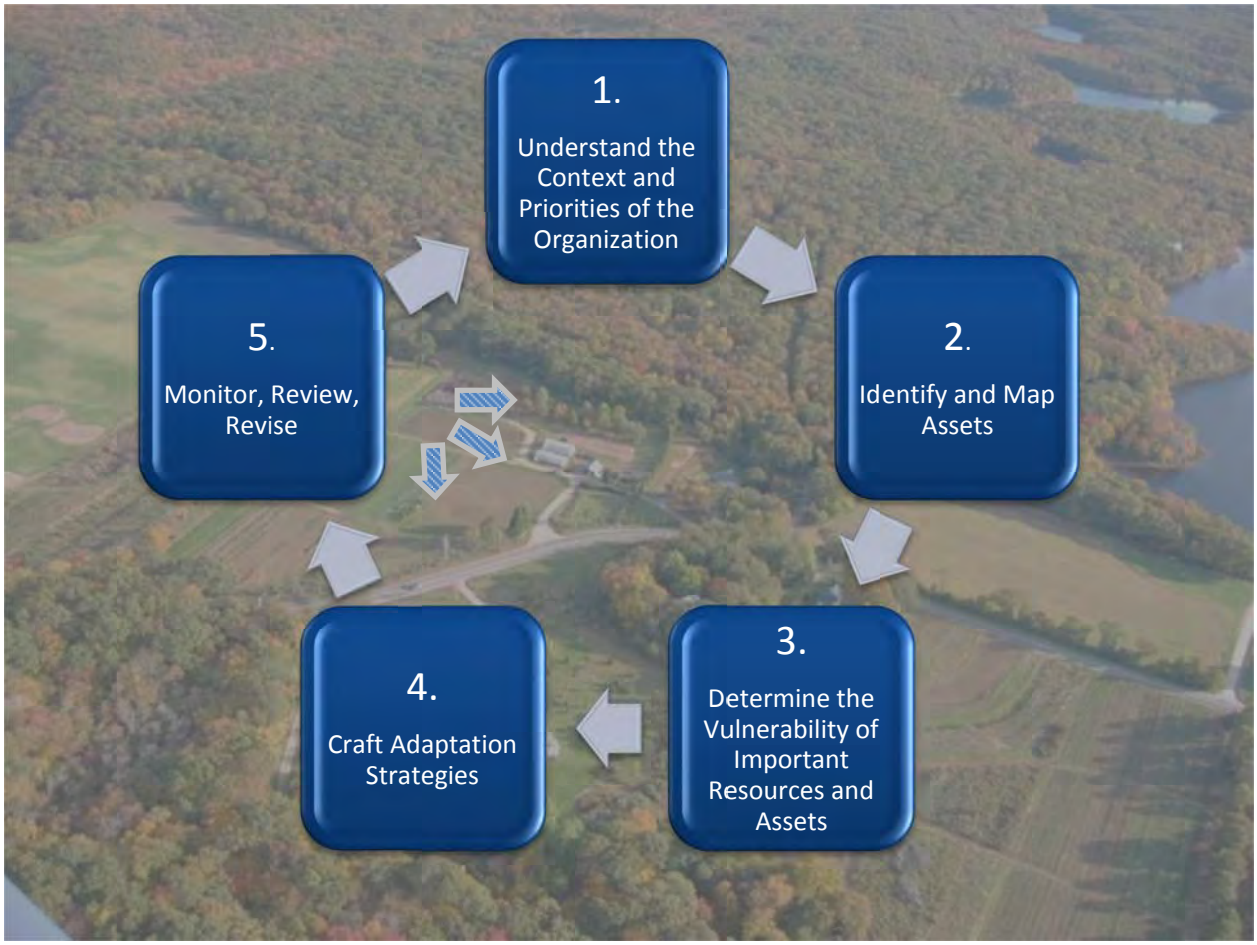

Figure 1. The Five-Step Approach for Adaptation is an Iterative Process.

There is an abundance of general guidance for organizations on planning for climate change and adjusting program strategies in response to future impacts on the resources they value. Most of this guidance has been designed for governmental and non-governmental organizations at the state and regional levels. Advice and information concerning climate change planning on a local level is less common, especially pertaining to adoption of conservation strategies. This is the case in Rhode Island as well as many other states, where local conservation groups contribute substantially to land and water conservation successes.

This project examines climate change impacts from the view of a local conservation organization while recognizing the larger-scale perspectives at the municipal, state and regional levels and the complexity of decision-making regarding local acquisition and management priorities. We have created a simplified, practical series of steps that may be adjusted to fit within the capacity and mission of a land trust or other local conservation group. Many of the resources and tools used in these steps build on those developed by the Land Trust Alliance (LTA). The LTA has developed a partnership to share guidance (such as examples of "adaptable" conservation easements) to adapt

basic conservation methods to encompass climate as well as non-climate stressors on natural resources and ecosystems.

The approach outlined here is based on the process used by the SKLT, which chose to organize its assessment by geographic focus areas incorporating existing holdings within the context of larger landscape and habitats of interest. A municipality could take a similar approach or include all of the land areas within its borders, while a land trust or watershed association may concentrate its efforts on a single drainage basin or sub-basin. We hope that the approach presented in the following sections will encourage other land trusts, conservation groups and municipalities engage in similar efforts and share their experiences through the network of organizations in Rhode Island and beyond.

For each step, a general description is given followed by a series of guiding questions. Each step also contains an example from the SKLT case study described in detail in Section 2. Key resources are listed at the end of each section and appendix to further assist the adaptation planning process.

UNDERSTANDING THE TERMS

Adaptation: Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Adaptive Capacity: The ability of a system (natural or social) to adapt to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Exposure: The degree of climate stress upon a particular natural habitat, species, or function caused by changes in climate conditions or by changes in climate variability over a period of years or decades.

Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.

Sensitivity: The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct or indirect.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

For more information see the Intergovernmental Panel on Climate Change or the Land Trust Alliance's Climate Change Glossary.

STEP ONE: UNDERSTAND THE CONTEXT AND PRIORITIES OF THE ORGANIZATION

In order to effectively evaluate the vulnerability of land trust assets to climate change it is important to first review and understand the mission of the organization, its approach to conservation, and its available resources; this will inform all other steps of the process.

SKLT'S STEP ONE

The town of South Kingstown contains important coastal and upland landscapes and valuable ecosystems. The town's unique location and the presence of important and rare habitats has resulted in major conservation efforts within the town, leading to the protection of approximately one-third of the municipality by various conservation organizations including SKLT.

SKLT's primary goals are habitat and species conservation, sustaining agricultural uses of the town's landscape, groundwater protection, maintaining open space for passive recreation and community attractiveness, and historic asset preservation. This land trust primarily pursues acquisition of properties based on its main objectives and goals; however, opportunistic acquisitions of properties are also made. The majority of SKLT's protected properties are forested or farmed. SKLT has been less focused on shorelines, floodplains, and riparian buffers because the high acquisition costs and the fact that other organizations pursue such lands.

SKLT protects and manages numerous properties in South Kingstown and contributes to the larger town and regional conservation strategy by partnering with the Town of South Kingstown, U.S. Fish & Wildlife Service, The Nature Conservancy, RI Department of Environmental Management and the Audubon Society of Rhode Island.

GUIDING QUESTIONS

1. **What are the goals and objectives (or mission and vision) of the organization and how do those guide land acquisition and management?**

The mission of the organization scopes both the challenges and solutions posed by climate change; it informs how assets are identified, prioritized and managed. Assets affected by climate change may be ecological (i.e. habitats, ecological services), cultural (i.e. farms, historical resources or viewscapes), social (i.e. public access, education), or economic (i.e. property, infrastructure, income generation).

Clarifying organizational priorities early on will assist in decisions about mapping (Step Two), assessing the vulnerability of assets to climate change (Step Three), formulating an adaptation strategy (Step Four) and identifying approaches to monitoring (Step Five). For example, if groundwater protection is a primary objective of the land trust then you may identify increased drought as a climate factor of concern, but if wetland conservation and riparian buffers are higher priorities then you might focus on issues related to sea level rise and storm events.

Land acquisition is typically guided by the goals and objectives of the organization. A land trust can accept all parcels or easements as they are offered, or they may pursue acquisition of strategic parcels in accordance with its

mission. If properties are acquired strategically, then the risk of taking on assets that may be beyond the organization's management abilities in the future can be minimized. For example, a coastal property acquired today may be inundated and require protection and/or lose value as a result of sea level rise in the future. On the other hand, this property may become an opportunity for future wetland migration, which could benefit the organization and the environment.

2. What resources are available to the organization?

An evaluation of the available resources also helps establish the ability of the organization to adapt its work to changing climate conditions, often referred to as *adaptive capacity*. Resources may include existing and potential partnerships, staff and volunteers, and finances.

By building upon active partnerships with other organizations, land trusts can begin to incorporate climate concerns into their conservation strategies. Going beyond institutional and geographical borders will greatly benefit conservation efforts as we move ahead, given the changes in ecosystems that are expected.

Operating budgets and an organization's ability to finance adaptive management actions must be considered. Keep in mind that additional fundraising and partnership opportunities may exist if an organization expands its portfolio to climate change assessment, adaptation, mitigation and/or monitoring change.

PARTNERSHIPS TO SUPPORT ADAPTATION PLANNING

Municipal Governments are beginning to address sea level rise and climate change impacts in their hazard mitigation plans and local comprehensive plans.

RI Department of Environmental Management is updating the Comprehensive Wildlife Conservation Strategy, which will include a climate "lens" on management strategies.

RI Coastal Resources Management Council, The Nature Conservancy, RI Sea Grant, National Estuarine Research Reserve are developing statewide models on salt marsh migration with sea level rise.

Save the Bay is evaluating impacts on wetlands and shorelines and identifying options to reduce erosion and flooding, while increasing habitat value.

Additional initiatives are listed in the Climate Change Commission's 2012 Rhode Island Climate Change Report.

STEP TWO: IDENTIFY AND MAP ASSETS

Now that the organization's priorities have been reviewed it is important to clarify the location and characteristics of the organization's assets. If a priority is protecting groundwater then it is important to identify watersheds, or if agricultural preservation is a priority then areas of prime agricultural soils must be identified. Once these priority areas are identified, potential exposure to climate and non-climate stressors can be displayed on the map

Mapping is an essential tool in any climate change vulnerability assessment and adaptation strategy. Visual representations of assets or properties are a vital aide in understanding individual assets and how they might relate to each other. Maps can show not only geographical location, but also essential information such as land use, habitat type or watershed boundaries. Mapping software also allows for quantification of property characteristics, which can assist in resource prioritization.

Maps should be created at multiple scales. Both the scale of climate impacts as well as adaptation strategies must be considered. Land trusts may choose to focus conservation efforts on different scales, including individual properties and clusters of parcels, corridors, and valued landscape components.

As an organization moves through this process there will be more opportunities for mapping, moving beyond initial identification into analysis.

SLKT'S STEP TWO

All of SKLT's protected properties have been collected into a dataset using GIS technology which allows the land trust to easily locate their parcels and maintain detailed records of information related to each property. An overview of the map of protected properties revealed that SKLT targeted different geographic areas for different objectives. These were labeled "focus areas" for the purpose of this project (see Figure 2.2). Using GIS technology to map SKLT's parcels provides a view of assets and resources targeted for conservation while simultaneously placing the organization's protection objectives within the larger landscape of regionally significant habitats and resources. Through this pilot project several new map products were developed to assist SKLT in managing their protected parcels and planning future acquisitions. In the future these maps and GIS databases can be updated and managed by staff or a member of SKLT with GIS skills.

GUIDING QUESTIONS:

1. Where are the organization's assets and how best can these be represented on a map?

Identifying parcels and their assets is a good start. However, the organization may choose to cluster parcels within a landscape, corridor, or watershed, depending on their conservation strategies. SKLT chose to analyze their assets within "focus areas" representing strategic acquisition for different habitats and geographic priorities.

2. What is the organization's mapping expertise level?

Detailed mapping and analysis requires the expertise (either in-house or contracted from outside), time and software to perform Geographic Information System (GIS) mapping. However, there are online tools that can assist organizations without those capabilities to do basic mapping (see inset).

3. What information or data is available?

If the organization has full GIS capabilities, a wide range of data can be downloaded from RIGIS. Data from the URI Environmental Data Center and the Rhode Island Sea Grant is available for either online or desktop GIS mapping. Finally, ArcGIS Online has a searchable database for use with their online service.

4. What do you want to map and how can this information be displayed in the most clear and informative way possible?

Deciding what information you want to map and display will depend largely upon your priorities identified in Step One. Try to find a way to map as many climate impacts or non-climate stressors as possible. Mapping sensitivity of habitats, sea level rise inundation projections or migrating wetlands is often helpful, while non-climate stressor data might include impervious surface cover. Avoid the temptation of mapping all the data you can find. A lot of information or data layers can be displayed on a map, but for clarity data displayed must be done so strategically. This will also depend on the type of display. Much more data can be made available if the maps are viewed in an interactive electronic format where data layers can be turned off and on by users. The amount of data or detail displayed on a static map will depend upon the size of the final map.

FREE ONLINE MAPPING TOOLS

ArcGIS Online: Use the online map viewer to create maps and view data. Data available is searchable in the map interface. Good search terms include "Rhode Island" and "URI-EDC". The Rhode Island Sea Grant sea level rise maps and URI-EDC's ELU maps use a publicly available ArcGIS Online interface.

Google Earth: Free downloadable application that allows for user-friendly geographical exploration. Good for exploring aerial imagery, including historical imagery. Some data is available to download in the Google Earth format, such as URI-EDC's MapCoast data.

Online Data Viewers: Some organizations and municipalities, including URI-EDC and the Town of South Kingstown have published data online through interactive maps. The Watershed Counts website also provides both static and interactive maps of a variety of data for the Narragansett Bay watershed.

NOAA Digital Coast: Communities can visualize potential impacts from sea level rise on land and coastal marsh.

STEP THREE: DETERMINE THE VULNERABILITY OF IMPORTANT RESOURCES AND ASSETS

There are a variety of vulnerability assessment methodologies emphasizing different starting points, strategies, and scales. All of these approaches include some combination of specifying likely climate impacts, estimating exposure to these impacts, accounting for non-climate stressors, and examining the sensitivity of priority resources or assets to these stresses. Given many uncertainties –from the amount of global warming to the impacts on species and their interactions– it is difficult to determine how habitats and ecosystems will respond. However, understanding ecological vulnerabilities provides valuable information that may be used to better inform existing decision processes and may also suggest new policies or actions to reduce future impacts.

SLKT'S STEP THREE

The vulnerabilities of SKLT's assets were determined by first mapping the habitats of each parcel and overlaying them with climate sensitivity, identified in the Connecticut Governor's Steering Committee on Climate Change report. After identifying sensitive habitats in each focus area, SKLT reviewed the non-climate stressors faced by different assets and how they contribute to the overall climate change vulnerability.

For example, Card's Pond in SKLT's Perryville focus area has a medium sensitivity to climate change according to the Connecticut report. This pond has a *phragmites* population that has resisted eradication attempts and *phragmites* is an invasive species that is less negatively affected by climate stressors. Therefore, this pond is more vulnerable to climate change than a similar pond where *phragmites* is not present even though they may have the same sensitivity.

GUIDING QUESTIONS

1. **What potential climate factors might impact your assets? Are you already seeing climate change impacts?**

Rhode Island is already experiencing precipitation changes, increased storminess, land and water temperature increases, sea level rise, and summer drought conditions. These trends are continuing and in many cases accelerating. Appendix 1 contains a list of current and predicted climate change impacts to Rhode Island. Which of these changes are already affecting your assets and which factors will impact your assets most significantly?

2. **What are the existing stressors to your assets?**

Land trusts and conservation organizations are acutely aware of the risks posed by non-climate challenges to the environments and landscapes they work to protect. Whether

PROJECTED CHANGE BY 2100

Sea level rise 3-5 feet

Leaf out 7-15 days earlier

Summers 21-44 days longer

Average air temperatures 3.5-12.5° F warmer

Precipitation increase 10% in spring and summer, 13% in fall, and 20-60% in winter

Ocean pH levels 0.3-0.4 units more acidic

Source: Coastal Resources Center & RI Sea Grant, 2012.

Habitat Type Climate Change Sensitivity Values

- Low Sensitivity Habitats

Warm Water Streams & Associated Riparian Zones

Bogs and Fens

Coastal Uplands

Early Successional Shrublands and Forests

- Medium Sensitivity Habitats

Lakes, Ponds, Impoundments & Shorelines

Upland Forest Complex

- High Sensitivity Habitats

Cold Water Streams & Associated Riparian Zones

Major Rivers & Associated Riparian Zones

Forested Swamps

Herbaceous Freshwater Wetlands

Open Water (Marine)

Intertidal Flats and Shores

Subtidal Aquatic Beds

Beaches and Dunes

Offshore Islands

Tidal Marsh

Subcommittee to the Governor's Steering Committee on Climate Change. (2010). See Appendix for more details.

it is invasive species, such as Japanese knotweed, encroaching development on wetlands, or non-point source pollution, non-climate stressors affect our critical resources and the services they provide. Non-climate stressors may reveal key factors for understanding habitat resilience as well as options for management under changing climate conditions.

Refer to Appendix 1 for a brief summary of non-climate stressors of habitats and landscapes. For an in depth analysis of the non-climate stressors faced by Rhode Island wildlife, see the Rhode Island 2005 Comprehensive Wildlife Conservation Strategy.

3. What is the sensitivity of valued environmental and economic assets to climate change?

Some habitats are more susceptible to the effects of climate change. For instance, cold water stream habitats are more likely to be impacted by rising temperatures than warm water streams. Appendix 2 contains a description of Rhode Island's habitats and their sensitivities to climate change. These analyses were interpolated from expert-driven work sessions in Connecticut and Massachusetts, which share many similar habitats with Rhode Island. Sensitivities are rated as low, medium or high based on both the likelihood and severity of impacts.

Acknowledging the sensitivities of different habitats can help organizations understand how ecosystems are likely to respond, thereby informing their management strategies for the short and long term.

4. Can you use ELU's to determine the resilience of your habitats?

Conservation ecologists have coined the term Ecological Land Unit (ELU) to describe and map the physical properties of landscapes. The Nature Conservancy and the URI-EDC have mapped ELUs for the entire state and identified which ELUs are well protected and which are most important for ensuring future biodiversity. These areas are likely to be more resilient, or less vulnerable, to climate change (Ruddock et al, 2013).

Each ELU is defined by its unique combination of soils, geology, landform, and elevation. ELUs are often associated with specific plant communities and the diversity of ELUs may be used to estimate habitat diversity and resilience. Key landscape characteristics such as soil type, slope, and drainage are related to the number and type of species the area can support. Thus,

habitats with great diversity of ELU types are also likely to support more diverse plant communities, positively impacting the overall resilience of the habitat. Presumably, a conservation area with many different types of ELUs will have many different types of plant communities, thus high biodiversity. The project team tested this hypothesis by counting the different kinds of ELUs on 24 Audubon Society of Rhode Island refuges, finding a positive relationship between the number of ELUs on a refuge and species diversity. This is consistent with results observed in other studies, thus, we are confident that areas with a variety of ELUs will typically support large numbers of plant and animal species.

See Appendix 3 for a more detailed description of ELUs or refer to the resources listed at the end of this section.

5. What other issues and opportunities are revealed through mapping?

The habitats listed above and described in Appendix 2 were linked to various categories within the map data available on the Rhode Island GIS website, so that these sensitivities could be overlain on the parcels. In this way an organization can visualize the potential implications and begin to identify strategies relevant for management at the organization and/or community scale. Another planning resource available to Rhode Island coastal communities is an interactive web-based map of sea level rise scenarios. Areas prone to sea level rise, erosion or storm damage may present opportunities for acquisition if protection could reduce hazard risk and increase ecological resilience. Conversely, an organization may choose to shift focus from these areas, whose conservation may be beyond the capabilities of the organization.

Another tool that is being developed for Rhode Island's coastal communities addresses the future of salt marshes. Preparation is underway to map Rhode Island shorelines with the Sea Level Affecting Marsh Migration (SLAMM) model to be finalized early in 2014. This analysis was carried out separately for the municipality of North Kingstown and is being used to evaluate conservation and management opportunities for the longer term when marshes will try to move upland as sea level rises.

STEP FOUR: CRAFT ADAPTATION STRATEGIES

Once vulnerability factors of the valued assets such as habitats and landscapes have been determined and mapped, a strategy for increasing their resilience to climate change must be created. When considering adaptation strategies, two things are key: building upon the organization's existing 'tool box' and collaborating with organizations within the broader community engaged in conservation and management.

Land trusts and conservation groups have existing tools (i.e. maps or acquisition criteria) which can incorporate adaptation considerations to support and enhance their conservation successes in response to climate change. At the same time it is important to acknowledge that there are many other organizations addressing adaptation through land use policies, research, outreach and extension, protection of landscape corridors and changes to other policies related to water resources management, water extraction and coastal management. Reaching out to other groups, whether for collaborative purposes or simply for consultation on topics outside of the organization's specialty, is vital to crafting a successful climate change adaption strategy.

SLKT'S STEP FOUR

SKLT's first step in identifying adaptation strategies for management was to examine their current management plans and actions through a climate change lens. Following this examination several current management actions were identified that could support climate adaptation goals such as preserving healthy riparian areas bordering cold water streams and regularly monitoring for invasive species. These current management strategies may be expanded to accommodate adaptation actions (i.e. by modifying language within conservation easements to be more adaptable for climate variability and change).

SKLT also identified several new adaptation actions that are consistent with the organization's mission, priorities, and role that may be incorporated into management plans and actions. These "no regrets" actions –establishing good management practices to reduce drought impacts on agricultural lands and focusing acquisition on contiguous parcels in an effort to create large connected habitat areas– provide benefits today and in a climate changing future.

The SKLT Case Study targets potential adaptation and management actions pertinent to the goals of their focus areas and more specifically to different assets within these focus areas.

GUIDING QUESTIONS

1. What opportunities are there to include climate change considerations into conservation efforts?

There are several ways that climate change can be incorporated into conservation efforts, as outlined below. It is useful to take stock in the land trust's existing initiatives, where actions may be formally incorporated in management plans, outlined in grant proposals, or implemented on an ad hoc basis as the need (or opportunity) arises. (Refer to Section 3 for a summary of potential adaptation actions related to management, protection and outreach.).

Management. Incorporate adaptation practices within individual parcel or corridor management plans using tools such as good management practices or conservation easements that can integrate climate change concerns.

Protection. Prioritize protection of resilient areas with high biodiversity that are likely to provide a refuge for plant and animal species in a future climate change-impacted environment.

Acquisition. Evaluate acquisition priorities and strategies using additional map overlays with information such as habitat sensitivity or ecological land units. Concentrate on specific corridors and landscapes, leveraging needed resources through strategic partnerships.

Outreach. Work with landowners, the community, state and federal organizations to build interest and capacity to implement additional adaptation measures that support the organization's mission. Engage with organizations, such as the Rhode Island Land Trust Council or the Rhode Island Rivers Council, who help connect, coordinate and support organizations to advance land and water conservation and management statewide.

2. How can climate change resilience be increased through no-regrets actions?

Implementing no regrets actions –with multiple benefits today and in the future, with or without climate change– can reduce vulnerabilities and increase the resilience of ecosystems to cope with current environmental pressures and climate variability; A number of the potential actions are extensions of the work already performed by land trusts including acquisition of new sites within a priority corridor, property management to deal with non-point source pollution or control of invasive plant species. Reducing non-climate stressors can increase the intrinsic resilience of ecosystems, providing greater resistance to future climate change impacts.

3. How does the organization prioritize management strategies?

Given the number of adaptation options that might be appropriate for a habitat, site or organization, it is important to prioritize actions. Conservation organizations already use criteria (formally or informally) to prioritize acquisitions or management approaches. It is important to remember to incorporate the information gathered during the vulnerability assessment in Step 3 in this analysis. For example, SKLT sees some options to use ELU variety as well as the presence of underrepresented ELUs to help prioritize habitats for protection while the Richmond Land Trust uses ELU as one of their criteria to inform land acquisitions.

One framework that has been traditionally used by communities to select hazard mitigation actions is currently being applied for adaptation planning. The "STAPLEE" method, developed by the Federal Emergency Management Agency, incorporates social, technical, administrative, political, legal, economic and environmental considerations. Each potential action is scored as a way to help organizations determine which action would be most appropriate.

4. How can partner organizations help in climate change adaptation efforts?

Municipal Government. Efforts undertaken by local land trusts such as SKLT could be greatly enhanced by actions that the municipality is best positioned to undertake, such as flood plain management, land use plans and decisions protecting animal migration corridors, or zoning that favors local food production and nursery crops. Municipal goals and policies (outlined in the Local Comprehensive Plan) can play an important role in fostering the adoption of low impact land development policies, site development practices and promoting ways to insure that plans, zoning, subdivision and building practices reduces some climate and non-climate stressors affecting habitat and ecosystem resilience.

Statewide Programs by Agencies or Coalitions. The State of Rhode Island is one of the main land holders of and stewards of conservation areas, forests, lakes, ponds, wetland areas and beaches. State-sponsored work by the Department of Environmental Management, the Coastal Resources Management Council and others on low impact development practices, invasive species control, watershed and stream protection and habitat restoration encompass key areas of policy and regulation with beneficial effects on reducing landscape vulnerability. Statewide programs can provide a framework and leadership in initiatives supported by land trusts and other groups, such as promoting small-scale farming for local food production or ecosystem monitoring (i.e. the Watershed Counts that summarizes the condition of Narragansett Bay Watershed) program). As an interagency commission, the Rhode Island Bays, Rivers, and Watersheds Coordination Team provides a forum for discussion and some strategic investment supporting efforts to promote a vital and sustainable environment and economy for Rhode Island in the face of changing conditions.

The Rhode Island Climate Commission's Natural Resource Working Group can provide a forum for discussion and leadership for prioritizing actions that may be relevant to local conservation organizations. Ideally, future programs would promote new criteria supporting climate adaptation in its grant programs and strategies to aid in

wildlife corridor connectivity, water abstraction policies, or wetlands protection as marshes migrate landward with sea level rise.

Research, Extension and Advisory Services. The university community, in conjunction with various state and federal agencies can help Rhode Island's conservation efforts related to climate change and stewardship. Programs of the Narragansett Bay National Estuary Program and the National Estuarine Research Reserve, the Natural Resources Conservation Service, the Rhode Island Natural History Survey, URI's Cooperative Extension, and Rhode Island Sea Grant among others will be increasingly relevant given our climate change challenges include pest management, crop selection and farming practices, environmental monitoring systems, sectoral best practices, and habitat restoration techniques given. The research and NGO community can assist in refinement and expanded use of predictive models for sea level rise, erosion and flooding; improved data and analysis regarding changes in land cover, habitats and ecosystems; understanding coastal wetlands impacts and options for management; and the identification of climate refugia (areas unaltered by climate change that can serve as haven for flora a fauna adversely affected by the changing climate).

Stewardship and Conservation. Rhode Island has many organizations currently engaged in activities where climate change issues are relevant, some of which are highlighted here. The Environment Council of Rhode Island actively supports and advocates efforts related to climate change adaptation and mitigation, including the preparation of a 2012 report on resilience for urban under-served communities. Projects of the Land and Water Partnership enhance collaboration and learning among grassroots conservation organizations and has incorporated climate change panels into its prominent Land and Water Summit for several years. They have also compiled an extensive resource library. The Rhode Island Land Council provides leadership on critical aspects related to sustainable land conservation for the state and its land trust partners. Save the Bay has engaged in research, restoration, outreach and advocacy on issues related to climate change, with a focus on wetlands and the impacts of both climate and non-climate stressors. The Nature Conservancy is also working to protect Rhode Island's land and water resources and the ecosystem services they provide, incorporating the latest research and tools that address climate vulnerability and adaptation actions.

STEP FIVE: MONITOR, REVIEW, AND REVISE

There are two types of monitoring that are useful when addressing climate change issues. The first is the monitoring of the outcomes of adaptation actions to ensure that they are meeting expectations of the land trust and supporting their conservation goals. This is a step that can often be overlooked, especially in an organization with limited resources. However, given that uncertainties exist in climate change projections, it is vital for management practices to be adaptive and organizations must be agile to respond to changing conditions. The process of reflecting on and adjusting the course of action based on evaluation results, new information, and changing conditions is referred to as adaptive management. The Land Trust Alliance and others are considering ways to incorporate this information into management planning.

The second type of monitoring is done to track changes in species, habitat diversity and phenology as the climate changes. This type of monitoring is commonly done in coordination with partner organizations, as the changes are seen at larger scales.

SLKT'S STEP FIVE

SKLT organizes annual volunteer monitoring with the goal of tracking changes on their protected properties, whether it is invasive species or manmade impacts from people accessing the land. The current monitoring program is not highly structured; however, the program could provide a foundation for future work in tracking invasive species encroachment or species phenology changes.

SKLT has recently joined with the URI Master Gardeners, the American Chestnut Foundation and the South County Garden Club to propagate and monitor American Chestnuts on one of the land trust's parcels. SKLT can work with volunteers and staff of URI's Watershed Watch, increasing their knowledge and capacity to include water quality monitoring results in their management plans as appropriate.

GUIDING QUESTIONS

1. Are your management practices achieving their objectives?

Formulate a monitoring protocol to incorporate into the management plan, making the link between monitoring and management objectives. This protocol is a plan that explains how data will be collected, managed, analyzed and used. Even something relatively simple to monitor, like stream temperature, must have a protocol to clarify so that measurements are made at a consistent time of day, at the same spot of the stream. This will help to insure that changes identified are those in nature, not by poor execution. Monitoring data does little good if it is not compiled and analyzed. This could be as simple as creating, updating, and periodically reviewing a spreadsheet. The data can be made into a simple graph that can assist in spotting trends. Explore what others are monitoring (such as those indicators evaluated by the Narragansett Bay Watershed Counts Coalition) or discuss with researchers the most appropriate options for assessing management success.

2. Have there been unanticipated changes and what do those changes mean for the management plan?

For example, if a cold water stream under active management continues to increase in temperature faster than expected then maybe there is something the management plan is not addressing. Could there have been changes in non-climate stressors, such as increased development that has resulted in changes in runoff or riparian buffers that necessitate adapting management strategies? On the other hand, climate change trends may show faster or rates, which will require reassessment of vulnerability and subsequent adaptive management.

3. Are there larger monitoring initiatives to which your organization can contribute to better understand local changes?

While extremely beneficial, a commitment to effective monitoring is extensive and requires significant time and resources. For this reason, it may be more feasible to link to other initiatives where staff and/or volunteers have an opportunity to participate. For example, a land trust could host and organize a Christmas Bird Count in conjunction with the National Audubon Society or engage volunteers and the data they collect through Rhode Island's Watershed Watch citizen water quality monitoring program.

Another successful national and regional monitoring program is run by The National Phenology Network which is dedicated to compiling data from individuals and organizations to track climate change over time. This network of citizen volunteers, scientists, educators and others monitor "nature's calendar," or the schedule of phenological events like flowering and bird migrations that are sensitive to climate change. Animal and plant species are monitored and changes in migration, arrival dates, and blooming dates are recorded. Long-term monitoring of indicator species, such as lilacs, shows that they bloom several days earlier at present than in 1965. Land trusts, local conservation groups, and individual citizens can select target species and sites and contribute monitoring information to the growing database, and benefit from the collective knowledge accumulated over time.

Partnering with other more local organizations, such as Save the Bay's program on wetlands monitoring and restoration, or University research programs can also provide added benefit to your organization and mission, while advancing science and/or application of new techniques for adaptation.

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SECTION 2: THE SOUTH KINGSTOWN LAND TRUST CASE STUDY

South Kingstown, like many of Rhode Island's coastal communities, is fortunate to have a land trust that is active in land protection and management and actively works with a variety of partners to pursue its conservation goals. The primary goals of the South Kingstown Land Trust (SKLT) include conserving critical habitat and species, sustaining agricultural uses of the town's landscape, protecting groundwater, maintaining open space for recreation and community attractiveness, and preserving historical character. SKLT has a strong interest in finding practical tools and ready-to-use data on the impacts of climate change on their properties and the ecosystem services they provide. Although the emphasis of this project has been on SKLT, many of the data sets, maps, and background information created through the pilot program apply to the entire state.

This project addresses habitat conservation at a local level using the five-step planning process outlined in Section 1. The issues addressed and potential solutions are of interest to land trusts as well as to municipal and state level policy makers. This case study also draws upon and offers innovative uses of the same information base available to municipal and state agencies throughout the state, thus providing practical insights and suggestions that can be of value as other levels of governance take up the challenge.

The general approach for preparing the vulnerability assessment and adaptation strategy is described in Section 1. SKLT decided to organize the information according to its focus areas of interest, mapping assets, assessing vulnerability, and addressing management actions within each specific focus area.

UNDERSTANDING THE CONTEXT AND PRIORITIES OF THE SOUTH KINGSTOWN LAND TRUST

South Kingstown's historical land development pattern is based on the emergence of villages during the 18th and 19th centuries and the town remains committed through its Comprehensive Plan to reinforcing a village-oriented pattern of land use. The South Kingstown Land Trust incorporates the village concept of a more developed center with less developed areas on the periphery in its land acquisition and management decisions.

South Kingstown is located on part of the southern Rhode Island terminal moraine with extremely well drained soils. Forested habitat is primarily upland in nature, comprised of a mixed pine-oak overstory with a huckleberry-blueberry understory. Large parcels used as cropland and pasture are also present, along with a trout hatchery and recreational areas including hiking trails.

SKLT owns and manages properties throughout the Town of South Kingstown and contributes to a larger town and regional conservation strategy. Over a decade ago the South Kingstown land conservation partnership was established, which includes SKLT, Town of South Kingstown, U.S. Fish and Wildlife Service, The Nature Conservancy, Rhode Island Department of Environmental Management, and the Audubon Society of Rhode Island.

SKLT utilizes multiple criteria in setting priorities for land acquisition and management. These criteria are reflected in their main objectives, which include:

- **Protection of groundwater resources** including aquifer recharge and wellhead protection areas, which are especially important since the community of South Kingstown is exclusively dependent on use of groundwater.
- **Protection of biodiversity and ecosystem resources** including suitable habitat for rare or unique species, wetlands, large areas of undeveloped forest, ponds, riparian buffers and barrier beaches.
- **Protection of aesthetic, cultural and recreational resources** including farmland, scenic vistas, and lands with unique recreational, cultural or neighborhood values. Preserving the community's ability to provide their own food and protecting the town's sense of place are also important goals.
- **Opportunistic acquisitions** including large lots (greater than 5 acres) or those intended for resale.

In broad terms, SKLT preserves land to:

- Support the north-south landscape corridor along the western edge of the town, which ties together coastal lands near Trustom, Cards, and Potter Ponds and extending inland towards the Great Swamp, Worden Pond and Yawgoo Pond in the northwestern corner.
- Protect open space and scenic vistas in actively farmed land, including along scenic roadways such as Ministerial Road and Route 1 along the South Shore.
- Protect lands in Perryville in the geologically unique terminal moraine, an accumulation of soil and rock left by retreating glaciers that marks the maximum advance of the glaciers.
- Conserve important surface water and aquifer areas in Matunuck Hills and the Mink Brook Aquifer.
- Contribute to conservation of the Queen's River and Beaver River watershed, which is part of the western corridor, including lands adjacent to Yawgoo Pond and Barber Pond.
- Pursue opportunities in the Saugatucket River watershed as they arise, including farmland and lands adjacent to Indian Lake.
- Improve forest health and productivity.

THE SOUTH KINGSTOWN LAND TRUST STRATEGY FOR CLIMATE CHANGE ADAPTATION

SKLT's protected lands are clustered in distinct areas of interest with unique characteristics. Discussions with staff lead to the realization that the land trust views different areas of town with different overarching priorities. They determined that there are five *focus areas,* which are discussed in the proceeding section in the following order:

Focus Area 1: West Kingston
Focus Area 2: Mink Brook Aquifer
Focus Area 3: Matunuck Hills
Focus Area 4: Perryville
Focus Area 5: South Shore/Coastal Plain

Two other areas, Green Hill and Kingston, are also of interest but are not primary targets for SKLT.

According to the five-step approach outlined in Section 1, SKLT first reviewed their organizational priorities (Step One). For each focus the project team mapped their assets (Step Two), assessed their sensitivity and vulnerability (Step Three), identified adaptation options (Step Four), and discussed approaches for monitoring (Step Five). Climate change adaptations at the parcel level and in the focus areas can contribute to efforts at the landscape and regional level where SKLT and partners can collaborate to enhance resilience to climate change.

The South Kingstown Land Trust has identified a number of actions that can to be taken to incorporate climate awareness into its mission to protect groundwater resources, protect biodiversity and ecosystem resources (including suitable habitat for rare or unique species and the Northeast Flyway for bird migration), and protect important aesthetic, cultural and recreational resources (including farmland, scenic vistas, and lands with unique recreational, cultural or neighborhood values).

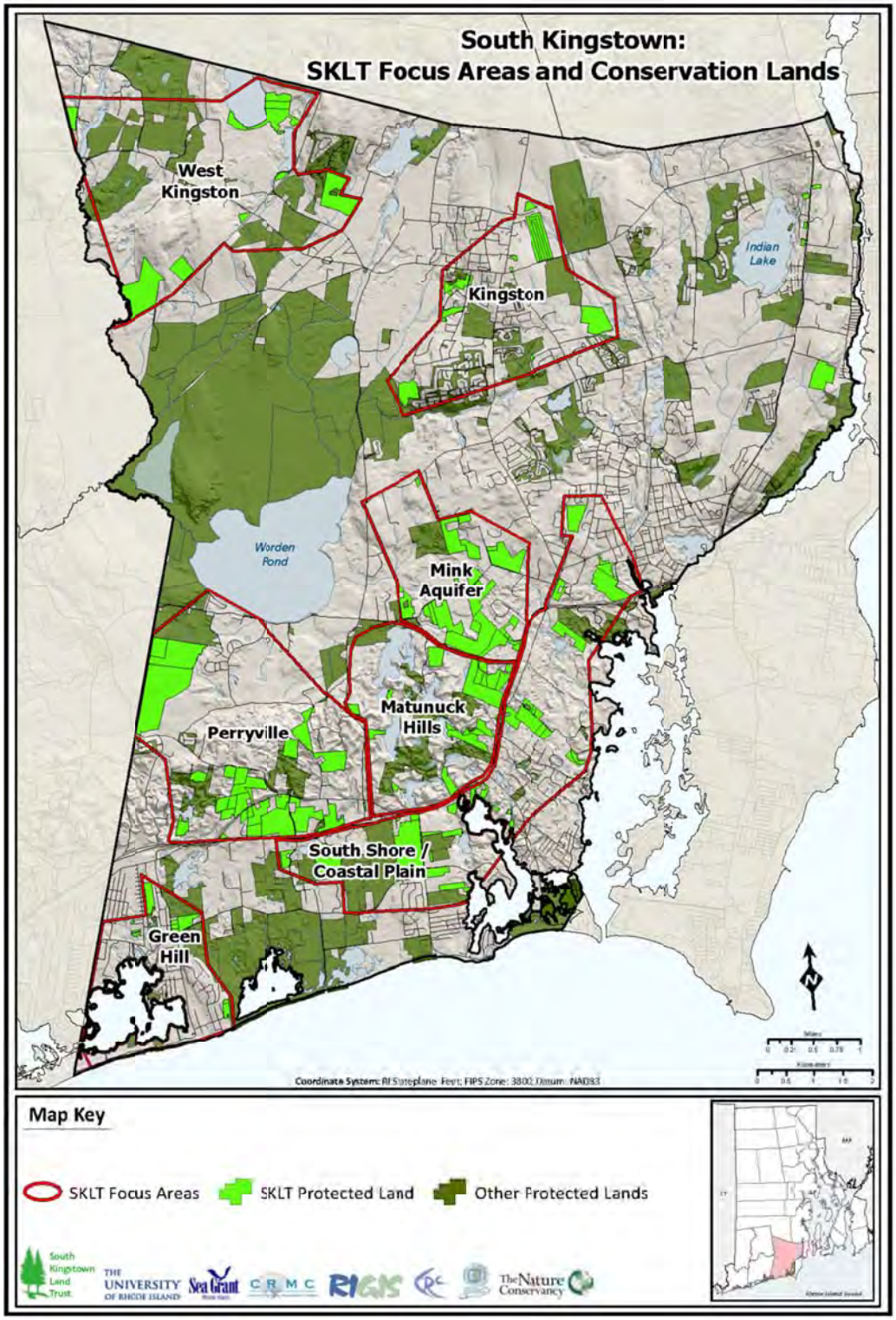

Figure 2. SKLT Focus Areas selected by the SKLT

OVERVIEW OF PROPOSED ADAPTATION STRATEGIES FOR SOUTH KINGSTOWN LAND TRUST

There is a high degree of vigilance and cooperation among local, state, and federal groups throughout South Kingstown that will make it possible to adopt and implement some adaptation options, which fall into the following categories:

Agriculture and farmland. Protecting and maintaining riparian buffers near agricultural lands will help protect streams from the impacts of erosion, flooding, and water contamination from both fertilizer and pesticide use. Increasing efforts to monitor the use and occurrence of pesticides in the environment will address non-climate stressors. Over the medium term, promoting the concept of "buy local" increases the consumption of locally grown products, supporting the viability of farming, reducing the negative effects of shipping agricultural produce, and supports local agriculture. An additional important action is sourcing native plants for restoration that are propagated from locally sourced seed and cut stem material, thus expanding the spread of local varieties and resulting in greater genetic diversity. SKLT is also involved in research on crop adaptation and diversity in conjunction with the university community and other partners. A recent joint project involves propagation American Chestnuts on one of the Land Trust's parcels and monitoring the saplings' growth and health. In addition to research and advocating "eat local" concepts, SKLT can encourage farmers to use Best Management Practices (BMPs) for irrigating their parcels, contributing to water conservation efforts and protection of groundwater resources.

Bogs, fens, forested swamps and herbaceous wetlands. As Rhode Island develops its adaptation strategies for watersheds and habitats it will become even more essential to preserve remaining undeveloped areas that are not impacted by human/man-made stressors. Forested watersheds, for example, warrant protection, and the land trust is a good mechanism for contributing to this. The land trust is already engaged in efforts to control invasive species and increase the connectivity among landscape patches. A number of important wetland areas remain to be protected along with maintaining the quality of wetland areas already under SKLT stewardship.

Terrestrial uplands. SKLT is aware of the need to reduce over-browsing by deer, control non-native plants, and monitor for the outbreaks of pests in its terrestrial upland holdings. SKLT acquisition strategies include buffering high-quality habitats already under protection, contributing to conservation of large blocks of upland, and improving habitat connectivity. SKLT also allows deer hunting by members with permits on selected properties to help manage their deer populations.

Upland forests and shrubs. Successional habitats are relatively rare in Rhode Island. SKLT is committed to protecting areas that have been disturbed by natural or human-related events in order to allow the regeneration of native habitats, which involves managing invasive species and tracking pests as well as securing or contributing to the conservation of additional unfragmented blocks of this landscape and habitat type. SKLT also actively manages their upland forest parcels to promote successional habitats through selective thinning and timber harvesting, creating a more diverse habitat with greater resilience and species diversity.

FOCUS AREA 1: WEST KINGSTON

CONTEXT AND PRIORITIES

West Kingston is a working village with a mix of land uses including industrial development, small businesses, agriculture, forest land and increasing numbers of suburban neighborhoods. The area is dependent upon the quality of its aquifers and its prime farmland. Despite the presence of high intensity uses (an Amtrak station and Route 138), West Kingston retains the feel of a small rural village.

SKLT's priorities for acquisition and management in West Kingston include:

- Continued protection of prime farmland soils and existing farms
- Protection of groundwater resources
- Connection of existing open space areas held by SKLT and other groups

KEY ASSETS IN THIS FOCUS AREA

The West Kingston focus area encompasses about 3,000 acres with large sections of upland forest (approximately 1,812 acres) and forested swamp (about 535 acres). Lakes, ponds, and cold water streams are also very important asset types in this area. SKLT currently protects 425 acres in this focus area, including upland forest (212 acres), forested swamp (80 acres), and cold water stream habitat (31 acres).

Groundwater Reservoirs and the Sole Source Aquifer. Over 80% of the West Kingston focus area overlies a groundwater recharge area, which includes parts of two groundwater aquifers: the Chipuxet and the Usquepaugh/Queen. These aquifers are accessed by individual landowners, private businesses (both agricultural and non-agricultural) and by non-community wells, but they represent a significant potential for future drinking water supplies on a larger scale as well. A sole source aquifer designation means that the area obtains more than 51 percent of its drinking water from an aquifer and that there is no reasonable alternate source of potable water. In West Kingston, all drinking water is sourced from these groundwater aquifers.

Lakes and Ponds. Yawgoo Pond is a coastal plain pond similar to the ponds in Matunuck Hills that provide favorable conditions for many rare plants. It is fed by warm water streams and has a depth of approximately 30-34 feet according to the Pond Watcher information. SKLT owns about 40% of the shoreline of Yawgoo Pond. Barber's Pond is stocked for trout in spring and fall. Rhode Island DEM maps indicate that the pond is 18 feet at its deepest point. Pressure from commercial development along Route 2 and Route 138 may be a threat to these ponds in the future, especially Yawgoo. Public access for fishing also presents its own set of impacts due to problems with transportation of aquatic invasive species for those areas where boats can be launched. Barber's Pond has already been infested with several species of aquatic invasives and faces threats from further introduction of invasives. There have been serious effects from industrial runoff to Yawgoo Pond, which has experienced severe algal blooms due to upstream disposal of clamshell waste in an on-site landfill.

Coldwater Streams. The Queens River runs through the Eppley Preserve (Audubon Society of Rhode Island) and along the border of the Marchant Farm, protected in a conservation easement by SKLT. A cold water stream connects Yawgoo and Barbers Ponds. Typical cold water streams are characterized as fast flowing streams bounded by native vegetation with a maximum summer water temperature usually no higher than 68° F and often 60° F or less.

Forested Swamps. There are several protected shrub swamps in this focus area. Audubon's Eppley property is mostly forested swamp with a small pond. SKLT protects shrub swamps on parts of properties along Route 2, including Atlantic white cedar swamps. There are other unprotected shrub swamps in West Kingston that are considered to be high priority areas for SKLT.

Agriculture. West Kingston mostly consists of outwash soils, which are suitable for supporting agriculture. Most of the active farmland in West Kingston is protected by conservation easements, which helps to maintain West Kingston's rural character. Some of the farmland in West Kingston is in turf, which is a water intensive use but is a better option than development from the Land Trust perspective. However, the heavy use of chemicals in turf production is an important issue that may impact the water quality in West Kingston if not managed properly.

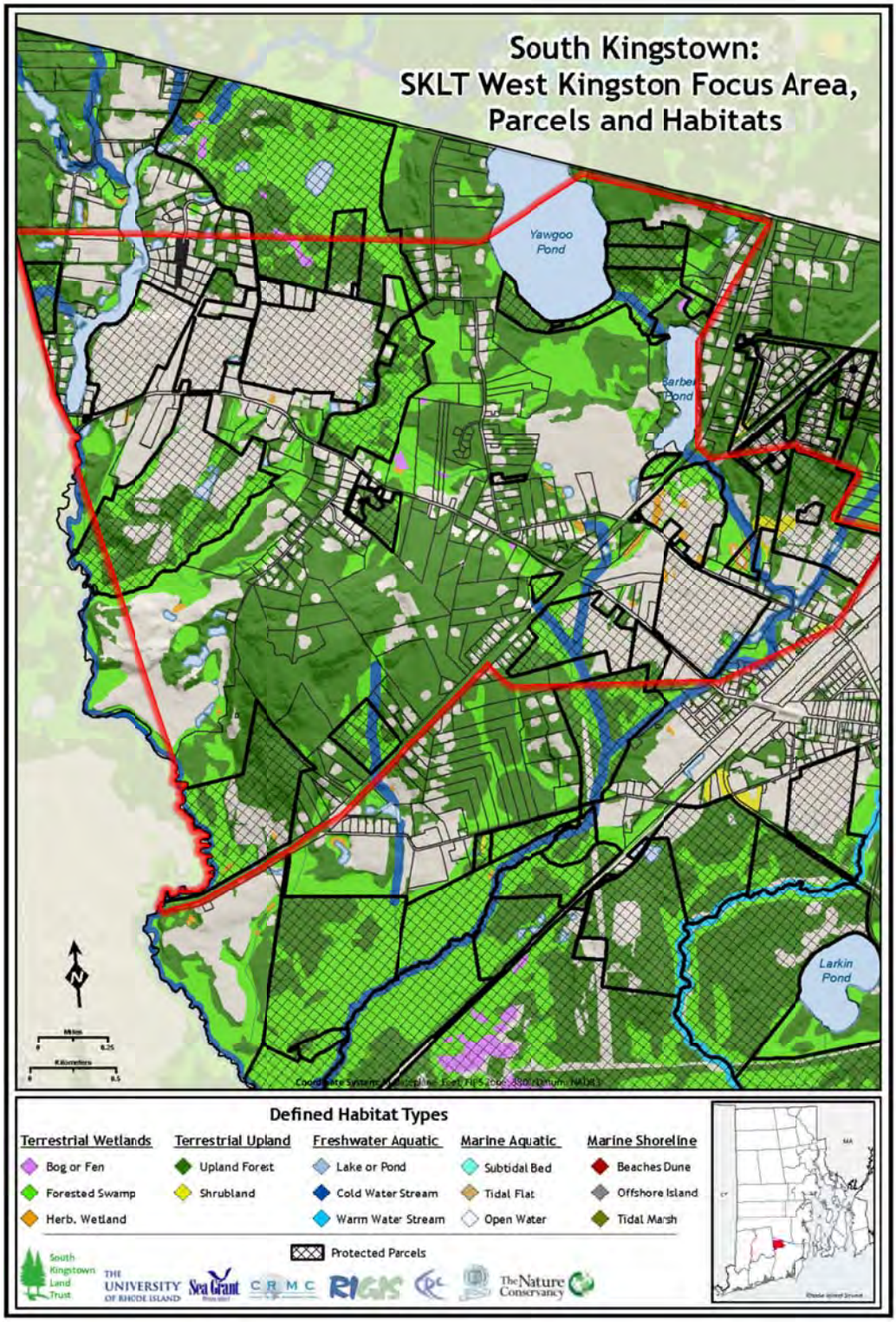

Figure 3. West Kingston Focus Area, Parcels and Habitats

VULNERABILITY OF KEY ASSETS

What are the existing and projected stressors and trends?

Possible increases in commercial and/or residential growth along Route 2 and Route 138 pose a significant issue for West Kingston and its vitally important groundwater reservoirs and aquifer. Future increases in water demand from extensive residential or commercial development may reduce existing water resources, leaving West Kingston with limited sources of clean drinking water. Reduction of water resources may also severely impact the area's natural habitats and species, resulting in habitat degradation and increasing stress on native plant and animal species. In addition to increasing future water demands, residential and commercial development may contribute to pollution of West Kingston's streams and ponds through onsite wastewater systems or storm water runoff from impervious surfaces. In order to protect West Kingston's important groundwater resources and vulnerable habitats future growth and development must be carefully managed and planned.

Increased development pressure may also result in the conversion of West Kingston's unprotected prime farmland to residential housing lots. In order to maintain the town's rural agricultural character, residential development should be concentrated in high-density areas, thus preserving large open spaces for farming and habitat preservation.

Existing stressors such as storm water runoff pollution and habitat loss caused by encroaching development must be addressed and taken into consideration when making future growth and development plans. West Kingston's valuable and important groundwater reservoirs and aquifer must be protected from depletion or contamination in order to provide future drinking water for the town and surrounding areas.

What is the sensitivity of West Kingston's assets to climate change?

The climate change scenarios for Rhode Island anticipate earlier spring weather, increased temperatures and precipitation, but also drought and an extended fall. While precipitation trends are increasing, the majority of that increase in the future will likely be during the fall and winter, thus leading to droughts during the spring and summer growing season. Changes in precipitation and increased regional demand for water may cause farms to switch to irrigation to address intermittent drought, which could be feasible given current abundance of groundwater resources. This would present a possible solution to inadequate consistent precipitation during the growing season, although such water use would need to be effectively managed and would require an evaluation prior to beginning more intensive irrigation to insure that forested wetlands and streams are not impacted.

In the future, cold water streams may survive in locations with higher elevations as air and water temperatures increase faster at lower elevations. Ensuring tree canopy shading of cold water streams can help prolong their existence at lower elevations such as in West Kingston. Shrub swamps and Atlantic white cedar swamps are also vulnerable habitats, although they are primarily threatened by red maple succession due to lack of controlled fires rather than the effects of climate change.

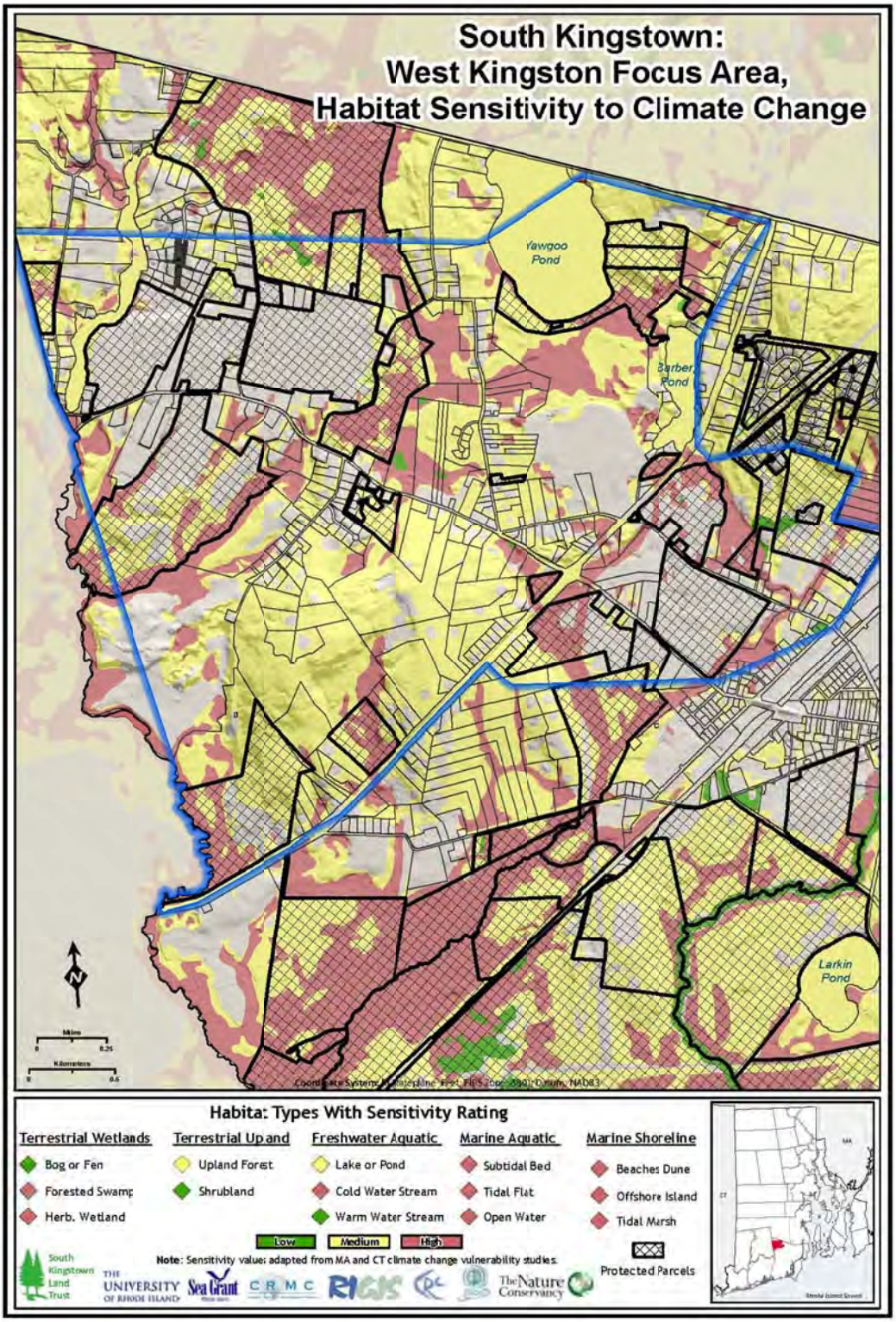

Figure 4. West Kingston Focus Area, Habitat Sensitivity to Climate Change

How vulnerable is the West Kingston focus area to climate change?

Given current development patterns are maintained this area will likely be relatively resilient to climate change due to its low population, abundant groundwater supply, and current active water management practices. This could change with increased development pressures that could stress the quality and quantity of groundwater resources. Large areas of land have already been protected in this area, which contributes to ecosystem and habitat resilience. However, continued efforts to preserve cold water streams are necessary to extend the protection of temperature-sensitive species until habitat conditions become unviable for species survival or species adapt.

MANAGEMENT OPPORTUNITIES WITH A CLIMATE CHANGE VIEW

What are the current management actions taken in this area?

In the early 1980s, the state's Agricultural Land Preservation Commission (ALPC) began to conserve farmland in this area and SKLT continues to add to the current agricultural land preservation when possible. SKLT, ALPC and

The aquifer is not currently being pumped or managed by a water company and there is a need to protect the land above the aquifer in order to maintain good water quality. The Town of South Kingstown's Comprehensive Plan policy 5.1 states that the Queens River Corridor (Hundred Acre Pond - Thirty Acre Pond - Great Swamp - Worden Pond) area shall be preserved as a greenway which follows natural geologic or geographic features (Town of South Kingstown, 2005). Policy 5.2 looks to continue protection from adverse effects through various land use and conservation actions. West Kingston is also part of a designated aquifer recharge area; hence the Town of South Kingstown implements policies regarding water quality and conservation.

Commercial, industrial and residential development along Routes 138 and 2 is a looming threat to the groundwater quality and rural nature of the area. Large developments, especially commercial ones such as a hotel and retail complex, have been proposed for the area. If these plans go forward, it is likely that adjacent landowners would sell off their land as land values rise. Increased development levels would negatively impact groundwater resources due to increased demand for fresh water as well as higher pollution levels from increased storm water runoff.

There is a large water draw by URI and Kingston Water District from the nearby Chipuxet River but not from the aquifer to the west. The Kingston Water District is committed to an active water conservation program and has been a partner in land preservation efforts with SKLT.

SKLT and farm operations have taken advantage of USDA incentive programs to protect water quality in this focus area through Environmental Quality Incentives Program and Conservation Stewardship Program grants. Farmers have received funding to build and operate manure treatment and pollution control for cattle operations and SKLT has adopted wetland and riparian buffer management practices around Yawgoo Pond.

What opportunities are there for improved management of current properties?

Management practices must be linked to the type of ecosystem or habitat represented in specific properties and must focus on building resilience to both climate and non-climate stressors. In West Kingston, SKLT owns 33 acres of freshwater aquatic habitat. In these areas SKLT and its partners could implement management actions focusing on ensuring that water temperatures stay cool in streams and ponds. The first step is to identify cold water streams and water bodies on SKLT properties so that more focused actions may be taken. One effective method of

protecting cold water streams and ponds is preserving riparian buffer zones and restoring damaged areas by planting native trees and bushes to shade streams. Identifying and removing in-stream barriers (such as non-functioning dams or obstructions) helps reconnect aquatic habitats and maintain or reestablish natural water flow.

SKLT also protects several parcels of open agricultural land which could be managed with goals of increasing organic matter in the soil in order to reduce erosion, flooding, and water contamination and protecting or maintaining riparian buffers between farmed lands and streams. Pest monitoring efforts could also be implemented in order to keep track of changing invasive pests while promoting the use of non-pesticide control methods where possible. Irrigation methods that minimize excess water usage could be investigated so that farmers can irrigate their fields in the most water-efficient way possible, thus conserving groundwater supplies.

What opportunities are there for future acquisitions and landscape preservation?

In West Kingston particular attention should be paid to protecting important groundwater supplies, cold water streams, Yawgoo and Barber's Pond, shrub swamps, and preserving open land from the encroachment of development. Given the area's rural nature, there are still numerous large parcels of land available for acquisition and preservation through purchase or easement.

Although there are already several protected areas in West Kingston, there are numerous properties adjacent to protected lands that could be acquired in order to create larger blocks of contiguous preserved habitats. Given the Land Trust's priority of creating large sections of protected lands, acquiring new properties that abut preserved areas should be a significant consideration when evaluating which properties to focus on. In the northeast and eastern section of the West Kingston focus area there are several properties that meet this requirement as well as several large properties in the western and southwestern area.

When evaluating potential properties for acquisition it is also important to take into consideration the sensitivity and vulnerability of habitats represented on a particular parcel. If preservation of highly climate-sensitive habitats is an acquisition priority, the properties discussed above include a range of highly and moderately sensitive habitats and thus provide realistic and valuable acquisition opportunities. If small changes in climate will damage a habitat beyond survival then depending on the organization's priorities and time frames, acquisition focus may be better spent on sensitive habitats with the potential to remain resilient to climate change given adequate protection and effective management.

FOCUS AREA 2: MINK BROOK AQUIFER

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CONTEXT AND PRIORITIES

The Mink Brook Aquifer focus area lies to the east of Worden Pond and Ministerial Road and stretches east to the border of the Wakefield-Peace Dale town centers. This area is characterized by low-density residential development, agricultural land, and a quarry.

Aside from being an aquifer recharge area supplying water to South Kingstown and Narragansett, this focus area also contains valuable habitat assets, including numerous streams, ponds, and wetlands. United Water draws water from areas adjacent to these habitats, making them valuable for groundwater purification and conservation.

The primary goals for SKLT in the Mink Brook Aquifer focus area include:

- Acquiring land for the protection of groundwater resources and valuable habitat
- Encouraging and supporting the preservation and sustainable use of agricultural lands

KEY ASSETS IN THIS FOCUS AREA

Forested swamps and terrestrial uplands are the dominant habitats within the focus area. SKLT's land holdings in this area mostly preserve terrestrial upland habitat and farmlands that are held under fee simple ownership and agricultural easements. Some of these properties overlay the Mink Brook Aquifer.

There are other notable habitats within this focus area but they are less widespread. Browns Brook is a cold water stream that originates to the west of South Road; it enters Mill Pond then flows into Point Judith Pond. A branch of White Horn Brook, a warm water stream, flows into the Mink Brook Aquifer focus area from the north, crossing Curtis Corner Road and ends in the middle of the focus area. SKLT has a few properties that intersect this stream.

Several bogs (consisting primarily of mosses) are found within this focus area, some of which are protected by SKLT and others that are currently unprotected. There are also a few small patches of wetlands that primarily lie on private lands.

VULNERABILITY OF KEY ASSETS

What are the existing and projected stressors and trends?

Southern Rhode Island's areas continue to attract residential and commercial development. Suburban growth can impact both the quantity and quality of critical drinking water supplies. Not only do suburban households consume large quantities of water (approximately 75 gallons a day per person), suburban development patterns also reduce critical groundwater replenishment from rainfall, further limiting source water supply. Additionally, impervious surfaces such as driveways, rooftops, and sidewalks divert rainwater flow, often as polluted runoff, into nearby streams and rivers (South Kingstown Source Water Assessment, 2003).

Taking into account these trends, the Rhode Island Department of Health has recently conducted an assessment of the impacts of climate change on water supply. This is a significant challenge given that Rhode Island has a decentralized water management strategy with approximately 30 major public water suppliers, hundreds of small suppliers as well as a multitude of private and commercial wells, which limits an overall assessment of future water supply for the state. With increasing populations and warmer summers likely in the future, water supply needs to be carefully managed. Rhode Island policies need to consider the future impacts of climate change as they evaluate their system of water supply management.

Current and future residential development and local population increases threaten the quality of habitats. Fortunately, much of this area is zoned for low intensity development because of its location within a groundwater protection overlay district. However, wellhead overdevelopment could threaten groundwater supply.

The Chipuxet-Mink Brook Aquifer was cited in a 2006 report by the Coalition of Water Security as an example of a water supply source that is close to or beyond environmentally sustainable yields. United Water states that their wells in South Kingstown can produce up to 7 million gallons of water per day; however, they have already experienced water shortage issues with this aquifer. The water supply for approximately 19,000 people in the towns of Narragansett and South Kingstown is drawn from the Mink Brook Aquifer, which has created an out-of-watershed transfer issue. In a Statewide Planning Report published in 1981, it was stated that the Mink Brook Aquifer should not be pumped at more than 2.4 million gallons per day or the groundwater supply would be seriously depleted.

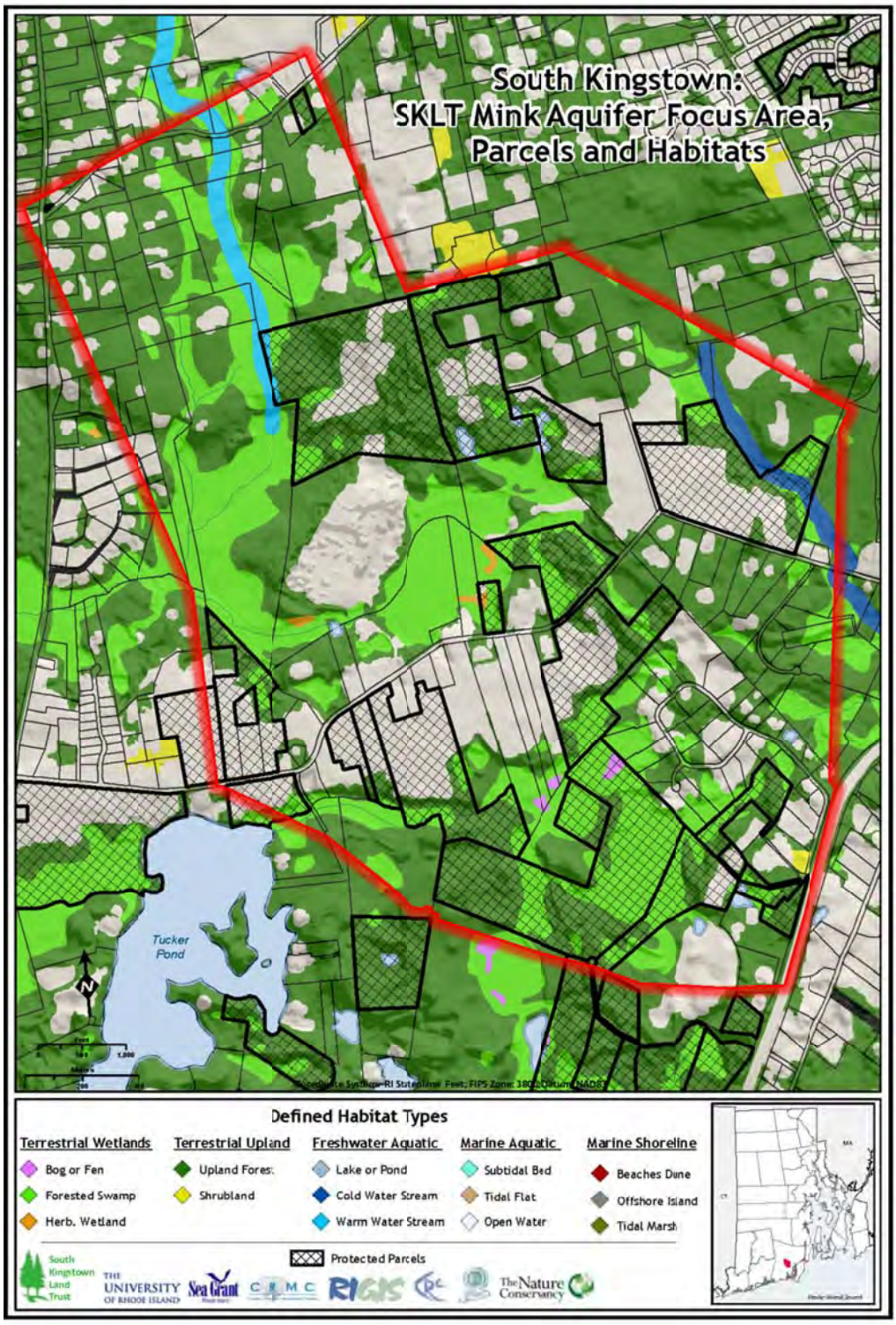

Figure 5. Mink Brook Aquifer Focus Area, Parcels and Habitats

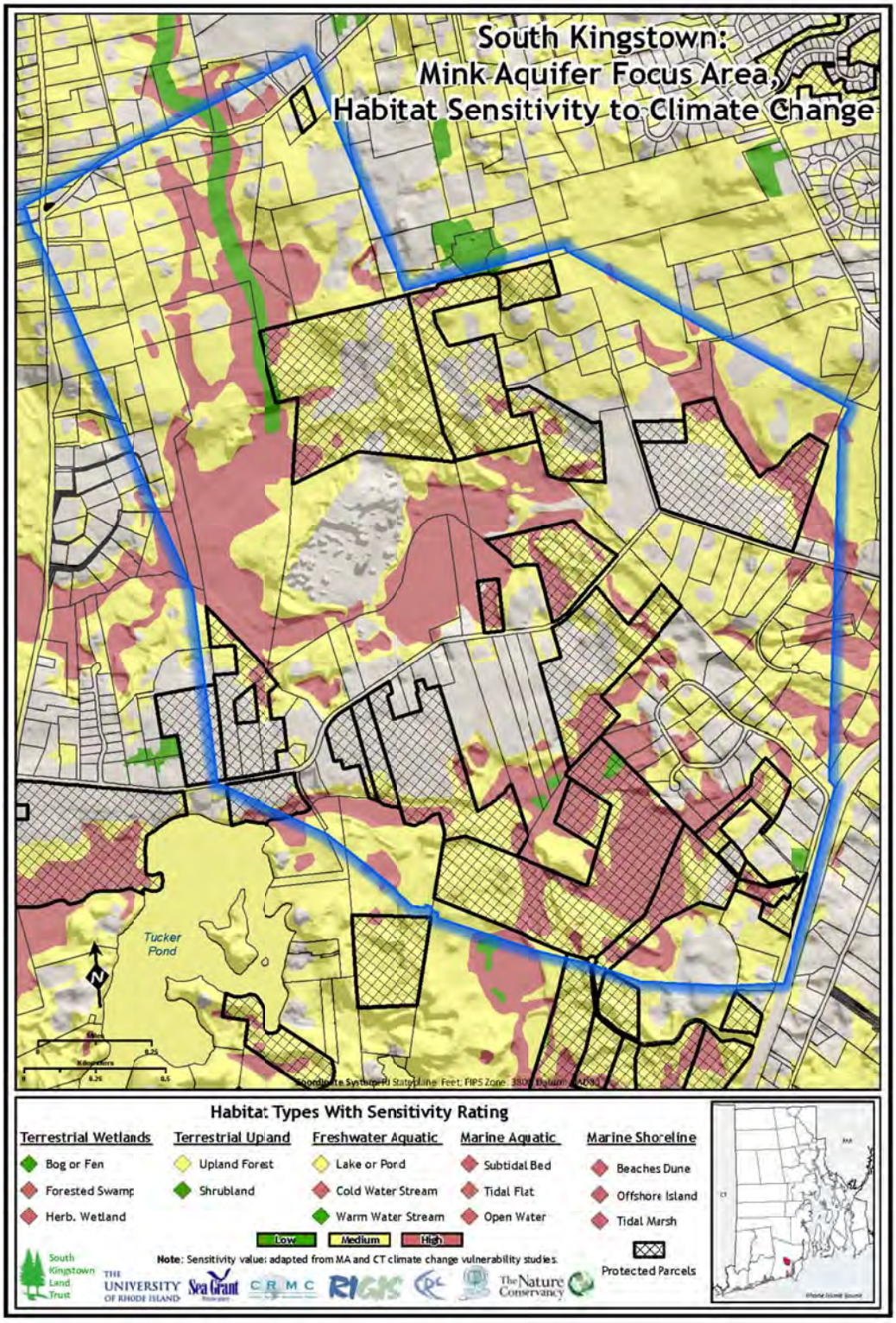

Figure 6. Mink Brook Aquifer Focus Area, Habitat Sensitivity to Climate Change

The Town of Narragansett Comprehensive Plan states that with the combined population of Narragansett and South Kingstown growing significantly in the next two decades, there is a concern for the environmental consequences of additional water withdrawal from the Mink Brook Aquifer in South Kingstown (Town of Narragansett, 2005-2008). This aquifer is currently pumped at near its capacity.

What is the sensitivity of Mink Brook Aquifer's assets to climate change?

Mink Brook Aquifer contains several different habitat types that have varying vulnerabilities to climate change. Forested swamps, cold water streams, and herbaceous wetlands are all moderately to highly vulnerable habitats and changes in temperature and precipitation will have a significant impact on them. The Mink Brook Aquifer area contains approximately 365 acres of forested swamp, of which 97 acres is already protected in some form by the SKLT. This area's cold water streams and herbaceous wetlands (accounting for 20 acres) must be carefully managed and preserved in order to protect them from climate change-related impacts.

How vulnerable is the Mink Brook Aquifer focus area to climate change?

With the anticipated increase in temperature and greater variability of precipitation, the potential occurrence of summer droughts may further strain the public water supply and the yields of agricultural crops may decline. Forested swamps are very sensitive to potential water shortages that may occur due to climatic shifts and changes in precipitation patterns. These forested swamp areas are also near where the United Water pumps are located, thus increased extraction of water due to higher human demand may also impact this habitat area.

MANAGEMENT OPPORTUNITIES WITH A CLIMATE CHANGE VIEW

What are the current management actions taken in this area?

A considerable amount of land has been purchased for conservation with funds allocated by United Water from a 1% fee on water usage by the state. Additionally, SKLT maintains agricultural easements that involve the cultivation of turf, vegetables, and a nursery. SKLT has accessed Farmland Protection Funds in this area as well. Other SKLT properties within the Mink Brook Aquifer focus area have been purchased or acquired through donations.

While SKLT is not responsible for the sustainable management of the Mink Brook Aquifer, there have been issues with overuse indicating that proper management practices need to be implemented, likely beginning with managed summer water use restrictions.

What opportunities are there for management of current properties?

Management of currently protected properties in the Mink Brook Aquifer focus area should be centered on preserving vulnerable forested swamp areas, maintaining upland forest habitats, protecting riparian zones along cold water streams, and insuring continued viability of agricultural operations. Control of invasive species is very important in forested swamps in order for native species to maintain their role in the ecosystem. Improving the quality of wetland habitats also improves their resilience to climate change, so preserving hydrological connectivity is an important measure in forested swamp and cold and warm water stream habitats. Protecting riparian zones and maintaining a canopy cover over cold water streams will help keep these vulnerable habitats cool in warming temperatures.

Increasing summer drought is a likely outcome of climate change in Rhode Island and lack of sufficient water will have a significant impact on water-dependent habitats. SKLT can coordinate with the town and others to help insure that the aquifer is managed appropriately to accommodate future trends in water usage and climate change.

In order to promote water conservation SKLT can encourage the use of drip irrigation for vegetable crops on their own agricultural lands and other farmed lands throughout South Kingstown. Turf growth may be limited if the land cannot be irrigated in the future (and/or if demand for turn continues in decline). Alfalfa can be grown here and is a high water use crop, like turf, but it is also relatively resilient to drought due to its deep root system and can survive long periods between irrigation in low water conditions. Thus, areas that are currently used for turf growth may benefit by switching to other crops in the future.

Upland forest habitats tend to be relatively less vulnerable to climate change, however invasive species still pose a threat to native species and ecosystems. If drought conditions become more frequent and temperatures increase some species may come under increasing stress and become more vulnerable to encroachment from invasive species. Management strategies that include invasive species removal should be considered while ecological monitoring programs designed to keep track of invasives are established. Deer population management should also be a component of SKLT's land management strategy across all habitat types in order to enhance the health and resilience of forested areas by protecting them from over-browsing and the destruction of understory plant species and for regeneration.

What opportunities are there for future acquisitions and preservation?

There are several locations in the Mink Brook Aquifer focus area where SKLT could acquire highly vulnerable habitat areas whose preservation will have multiple benefits. These parcels contain habitats that are highly sensitive to the impacts of climate change and many of them are adjacent to currently protected parcels. The acquisition of these areas would fit within SKLT's goal of preserving large areas of land to protect habitat connectivity while focusing on groundwater protection of highly sensitive areas.

FOCUS AREA 3: MATUNUCK HILLS

CONTEXT AND PRIORITIES

Matunuck Hills, located north of Route 1, is a sparsely settled area of dense woods and kettle ponds that provides habitat for many rare plant species. The Matunuck Hills focus area, comprising about 1656 acres, is primarily covered by forest (1238 acres, 74.8 percent), while about 6.1 percent is residential, 2.4 percent is in agricultural use, 0.3 percent is wetlands, and 0.2 percent is open land. A large segment of this focus area is already protected by various conservation organizations and the state. SKLT is involved in managing about 232 acres of this area.

The deeper kettle ponds in this focus area intersect with the groundwater table, allowing fresh water to flow into the kettle ponds. This focus area is one of only a few good sites in the Northeast United States to find kettle pond shore habitats.

SKLT's primary goals in this area include:

- Protection of rare kettle pond shore habitats and the species particular to these areas
- Preservation of the wet habitats in this area, including forested swamps and kettle ponds

KEY ASSETS IN THIS FOCUS AREA

The Matunuck Hills focus area includes approximately 1,200 acres that are geologically part of the Charlestown moraine. The area's 10 kettle ponds and adjacent wetlands provide habitat for at least 17 different state-listed rare plant species and this site is ranked fourth out of the 140 sites in the state for biological diversity significance. Matunuck Hills is one of a few locations in the region that has rare kettle pond-shore habitat. The shorelines of the ponds provide habitats for unique plant and insect species because of their hydrological separation from other water bodies and the periodic water level changes the ponds experience. Damselfly and dragonfly habitat and several rare plant species are also found adjacent to Peddler's Pond.

Kettle ponds are one of the primary habitat types in this focus area. Most of the ten ponds in this area are 20-40 feet deep. Round, White, Hothouse and Wash Ponds are all cool water habitats.

There are very few bogs in South Kingstown. The peat bog in Matunuck Hills is already owned and preserved by The Nature Conservancy. There are a few other bogs near Peddler's Pond that are not currently protected. Bogs are a very rare and unique habitat type and not many bog areas are currently protected, thus bogs should be a high protection priority.

The majority of the forest habitat in Matunuck Hills is made up of scarlet and black oaks and to a lesser extent white oak and pitch pine. The trees are generally larger than those in the Perryville focus area and there are more water-loving plants, including swamp azalea along pond shores. There is also a dense understory of mountain laurel and rose bay rhododendron.

VULNERABILITY OF KEY ASSETS

What are the existing and projected stressors and trends?

The Matunuck Hills focus area is a highly desirable area for development and may experience population growth in the coming decades if some of the larger lots are sold. Increased development accompanied by population growth will add anthropogenic stressing factors (i.e. increased groundwater usage and nutrient inputs to ponds) to climate change-related stressors, putting even greater pressure on native species and ecosystems.

Invasive plant species such as bittersweet and Japanese knotweed are already becoming more apparent in wet areas along Route 1, providing a view into the likely invasive species problem facing this area.

What is the sensitivity of Matunuck Hills' assets to climate change?

The numerous kettle ponds in the Matunuck Hills focus area are extremely sensitive to the impacts of climate change. Projected increases in temperature will result in general warming of the ponds, shrinking the smaller shallower ponds during the hot summer months and impacting plant and animal species adapted to a cool water environment.

Changes in water level will also affect the appearance and prevalence of plant, amphibian, and animal species accustomed to specific water levels. Several ponds in this area are already getting smaller and shallower in the summer and one pond often goes dry in the summer. Some of these ponds are quite deep and have low primary productivity as a result of low nutrient content.

As native species experience increased stress due to warmer temperatures, invasive species may become increasingly dominant in some areas, pushing native species out and causing shifts in ecosystems and habitats.

How vulnerable is the Matunuck Hills focus area to climate change?

The numerous kettle ponds and forested swamp areas in the Matunuck Hills focus area are extremely vulnerable to climate change-related impacts. Changes in the timing and quantity of precipitation will have direct impacts on plant, amphibian, and animal species that depend on current water levels and temperatures. Shifts in precipitation patterns and warmer weather may result in water shortages, putting pressure on native species and giving invasive species an advantage. The value of the Matunuck Hills area as a site for development and population growth may add anthropogenic stressors to the pressure exerted by climate change, further stressing native species and delicate habitats.

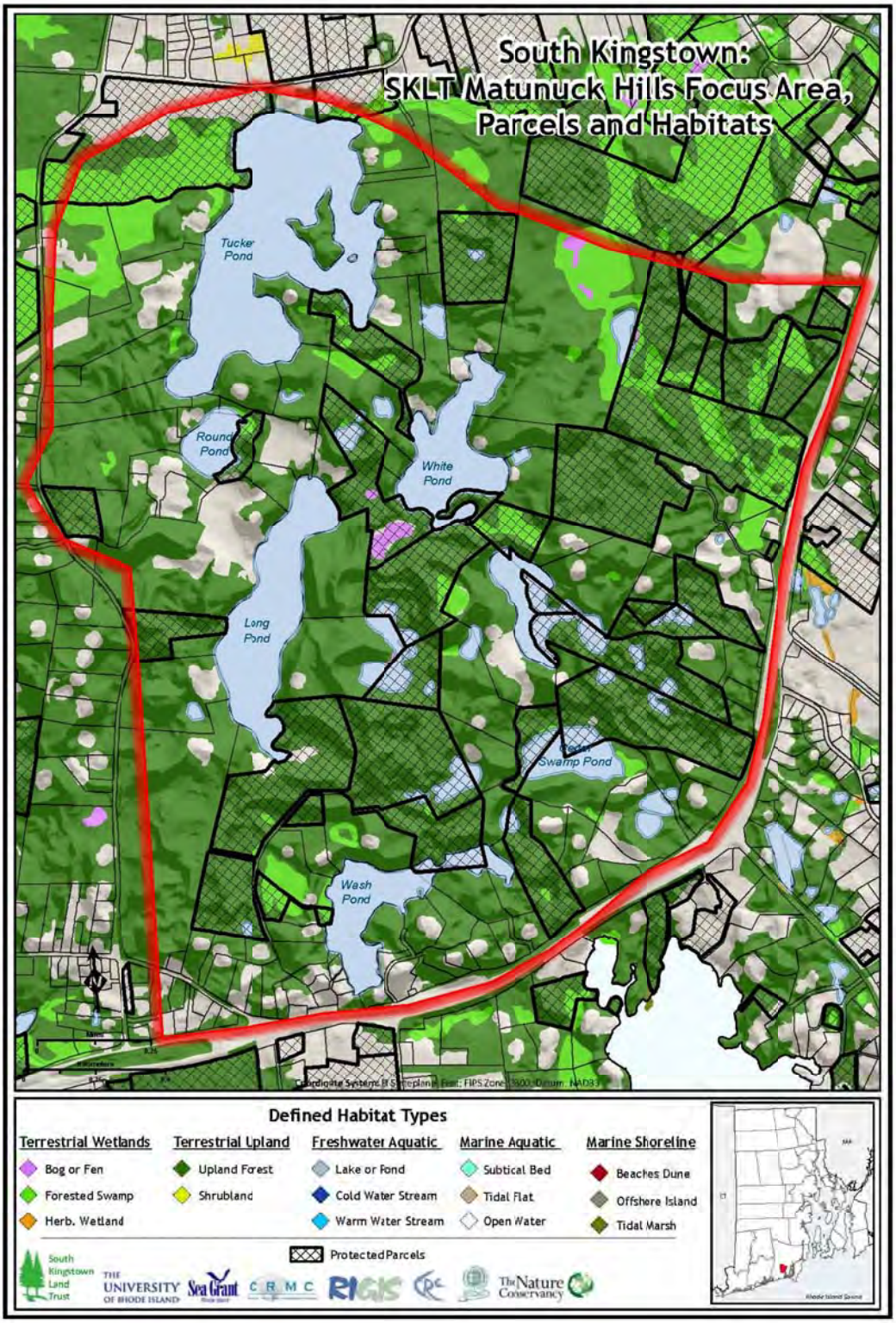

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Figure 7. Matunuck Hills Focus Area, Parcels and Habitats

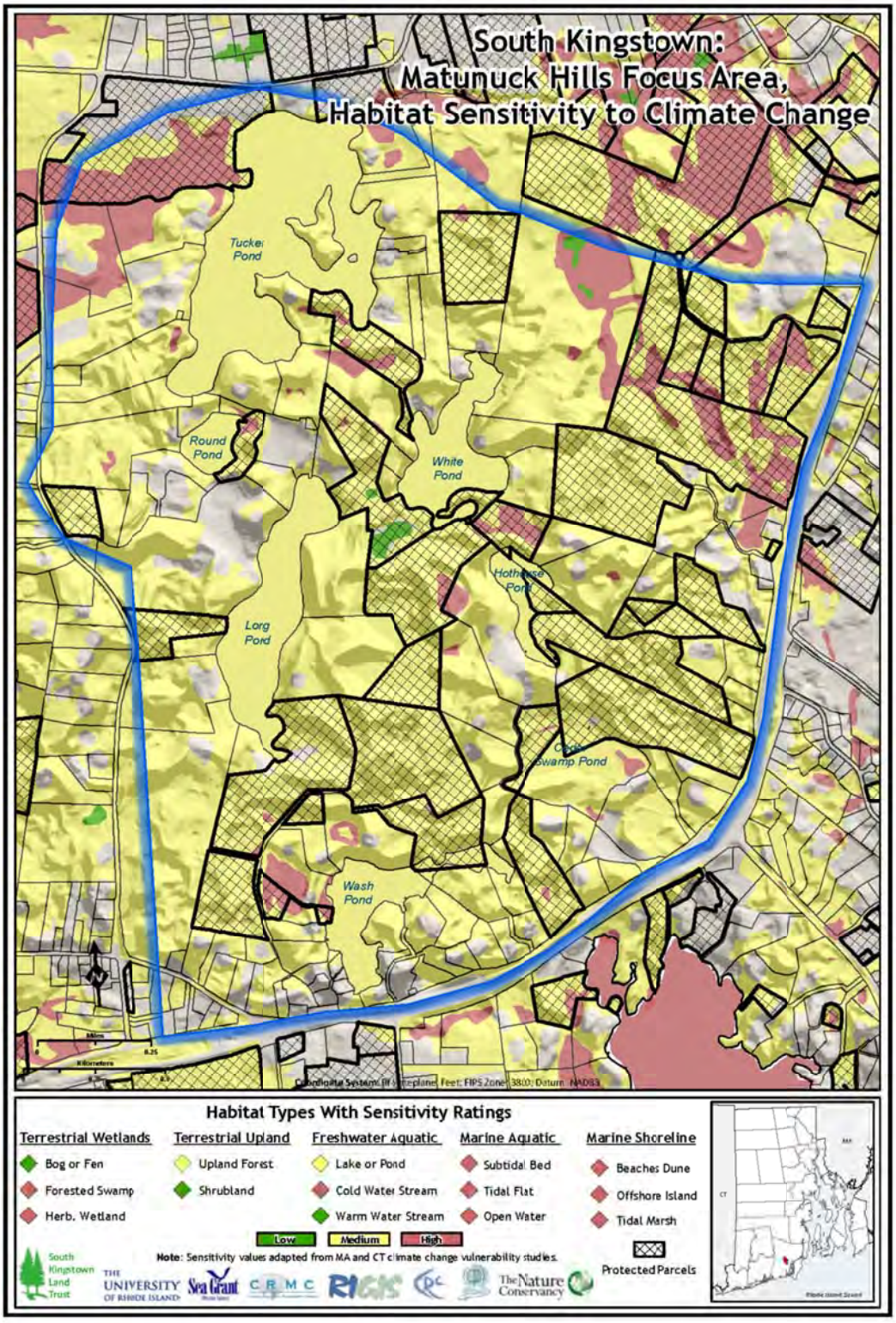

Figure 8. Matunuck Hills Focus Area, Sensitivity to Climate Change

MANAGEMENT OPPORTUNITIES WITH A CLIMATE CHANGE VIEW

What are the current management actions taken in this area?

South Kingstown's Comprehensive Plan Policy 5.1 states that the Matunuck Hills kettle pond and moraine area shall be preserved as a greenway which follows natural geologic or geographic features. Policy 5.2 looks to continue protection from adverse effects through various land use and conservation actions. Consistent with these policies, The Nature Conservancy and SKLT work in coordination to preserve land in this area. SKLT currently has several holdings in this focus area totaling 234 acres and plans to remain involved in preservation of important habitats in this area. The majority of the land is held by a few families in large lots, which also helps keep the area protected from development.

What opportunities are there for management of current properties?

The majority of SKLT's current holdings in the Matunuck Hills area are in upland forest, forested swamp, or freshwater aquatic (pond) habitats. Management efforts in upland forest habitats will focus on managing invasive species, including removal of non-native species and planting of native species in disturbed areas as well as practicing active deer population management. Protection of forest regrowth should also be a management priority because healthy regeneration helps maintain forest ecosystem functions. Maintaining cool water temperatures in streams and kettle ponds is a primary management action in freshwater aquatic habitats in this focus area and efforts to preserve or restore riparian zones providing cover to ponds or streams are a high priority.

In forested swamps prevention and control of invasive species is an important management action, just as in upland forest habitats. Maintaining and improving wetland habitats will assist in increasing wetland quality and habitat resilience. In order to help manage aquatic invasive species conservation organizations and land trusts should encourage landowners to limit boat use to boats which do not travel to other water bodies in the state, or if this is not possible to wash their boats thoroughly when traveling between water bodies. Other water bodies may have invasive vegetation or invertebrates that can easily hitch a ride to another area on the hull of a boat. This effort to increase awareness could be quite effective when combined with increased education on aquatic invasive species.

Finally, there is currently a lack of information concerning the degree of water level fluctuation in kettle ponds on a year-to-year basis, indicating a need for more monitoring and research.

What opportunities are there for future acquisitions and preservation?

SKLT should continue its preservation actions in this area in cooperation with TNC, focusing future acquisitions on vulnerable streams, kettle ponds, and forested swamp areas. There are several large parcels adjacent to currently protected areas that remain unprotected, so SKLT's acquisition efforts can focus on acquiring easements to these properties. There are also several highly sensitive areas that are not yet protected by easement or purchase, providing the possibility to protect them and create large blocks of protected land.

FOCUS AREA 4: PERRYVILLE

CONTEXT AND PRIORITIES

The Perryville focus area is located on the hilly Charlestown Moraine, which was created by the retreat of the Late Wisconsinan Laurentide ice sheet about 14,000 years ago. Perryville remains a small hamlet with a distinct village feel. Winding rural roads, active agricultural areas, high quality water resources, public recreation, and critical habitats on large tracts of undeveloped natural spaces and low-density development mark this portion of town (Town of South Kingstown, 2005).

The Perryville focus area includes approximately 3,000 acres and is comprised largely of a terminal moraine. This area is primarily covered by forest (81.7%) with some residential use (10.6%), agricultural use (3.4%), wetlands (1.5%), and open land (1.3%). SKLT has made important contributions to resource protection and public access in this area through the acquisition of large forested parcels and farmland. It is involved in managing about 700 acres in this area.

Perryville is strategically located between the Great Swamp and Worden Pond, and the coastal salt on the south shore. This location comprises a major north-south habitat and conservation corridor in South Kingstown. Perryville exemplifies the SKLT approach of combining ecosystem protection and conservation objectives with its goals to improve recreational access to natural areas, as well as preserve open space related to pasture and cultivated lands and to aid in sustaining agriculture.

Trails that link SKLT managed lands and other protected parcels together, including the DuVal Hiking Trail and the Browning Woods Farm Trail, are an important unifying feature.

SKLT's priorities for acquisition and management in Perryville include:

- Developing trails that provide access to protected parcels and contribute to a protected corridor in the region
- Protecting biodiversity and ecosystem resources
- Consolidating holdings to enhance the connectivity among habitat and landscape patches protected by SKLT and other groups

KEY ASSETS IN THIS FOCUS AREA

The largely intact wooded parcels in this area are part of a coastal drainage sub-basin that sends surface and groundwater toward the coastal ponds. It is somewhat resilient to drought conditions and protects the kettle ponds and underlying aquifer as well as the associated salt ponds. Insect infestations, invasive plants and wild fires are critical threats, which the SKLT addresses in its management approach and plans. Wildfires (although useful for managing certain habitats) caused extensive damage in the 1940s and again in the 1960s.

The landscape conditions and absence of infrastructure as well as zoning policies make use of this area less attractive for large scale residential development and favors use as pasture and farmland. Expansion of cropland and pasture would involve clear-cutting adjacent woodlands but could also expand the amount of fields and edges, which benefit some wildlife species.

The majority of this focus area is composed of upland forest consisting of pitch pine, scrub oak, and central hardwoods with an understory of mountain laurel, sheep laurel, inkberry, and blueberry. Pitch pine and scrub oak barrens comprise a large area that lies south-southeast of Worden Pond. Further to the west, along the moraine backside ridge, there is a large amount of pitch pine. This upland forest is ranked sixth out of 140 areas in the state in terms of biological significance, and it provides habitat for over a dozen species of state-listed plants and animals. Pitch pine and scrub oak forests are steadily changing into central hardwood forests, such as oak mixed with white pine, because the soils are still coarse and well drained. Pitch pine habitats are visible on the tops of small hills and in locations that had previously been burned. The pine barren habitat consists of dry, sandy soils and supports several rare and endangered species. Soil conditions are a limiting factor for the expansion of the pine barren habitat. Dry upland forests contain many white, black, and scarlet oak trees with a deciduous understory of high and low bush blueberry and huckleberry shrubs.

Red maple forested swamps are common in this focus area along the northern edge near Worden Pond. The wetlands in this area were predominantly white cedar in the mid-1900s but are now dominated by red maple. There are also shrub swamps around and within the Great Swamp. This habitat is found along pond edges, so it will migrate down gradient if the pond or shoreline gets smaller (i.e. dries up); if water levels rise, they will migrate upland. In areas along the Chipuxet River the SKLT has holdings containing this habitat. South of Worden Pond the Browning Woods parcel has some wetlands where sweet pepper bush, swamp azalea, and witch hazel grow.

SKLT protects two small areas of shrublands located behind the Village at Worden's Pond (previously known as Tuckertown Village) and along Healy Brook. Healy Brook is currently undeveloped but has been disturbed by its use as a quarry and dump ground.

Herbaceous wetlands composed of sedges and grasses are mostly found along the edges of Worden Pond, south of Worden Pond and along the Chipuxet River. Also, there is a small emergent marsh south of the pond on The Nature Conservancy property. Another small marsh, north of Bullhead Pond, is adjacent to a small pond. Additionally there is bog on the Browning Property south of Worden's Pond Road. The Perryville focus area also contains two small kettle ponds in the southern part of the focus area with much of the perimeter in conservation lands.

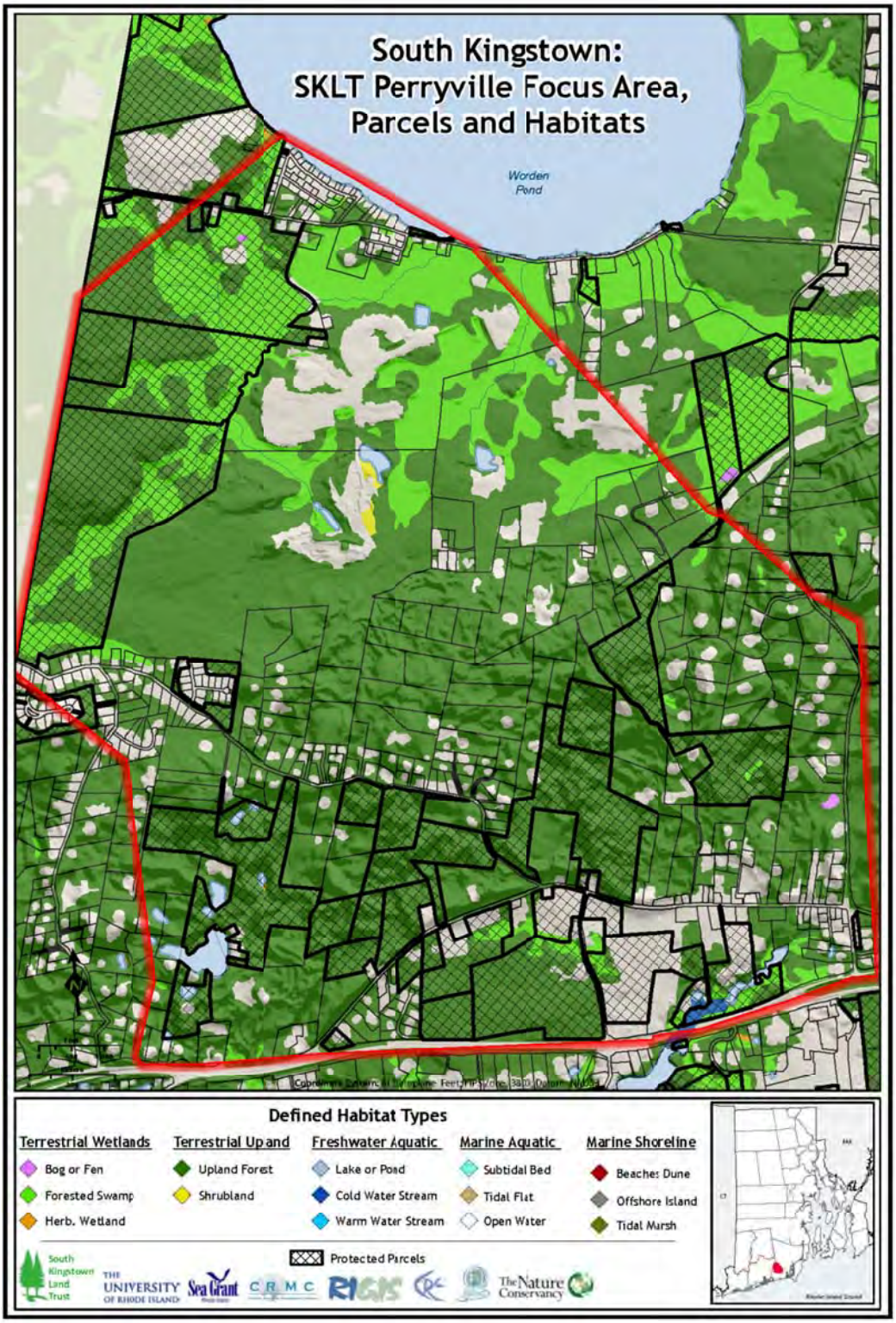

Figure 9. Perryville Focus Area, Parcels and Habitat

Phragmites and purple loosestrife have replaced cattail in the Perryville wetlands. Invasive species, such as loosestrife, are more tolerant of seasonal drying out and drought, gaining a competitive advantage. Over the last twenty years *phragmites*, a species introduced from Europe, has been out competing native species.

This focus area's moraine geology means that there are many kettle holes in the area that are not filled with water. The moraine in Perryville is made up of dry soils that are relatively unfertile. Although analysis of Ecological Land Unit (ELU) maps of this area indicates that there is comparatively low diversity in this landscape, the SKLT believes that the unique presence of the moraine needs to be protected for its own sake, especially when one things about the larger regional significance.

VULNERABILITY OF KEY ASSETS

What are the existing and projected stressors and trends?

The wildlife habitat quality in the forests and wetlands of Perryville is threatened by invasive species and development. Fortunately, there are few invasive species present in the upland forest since the presence of dense root mats of blueberries and other native species in the understory prevent invasive species from gaining a foothold. However, invasive species such as loosestrife and *phragmites* are a concern in herbaceous wetlands. In nearby areas Japanese knotweed is common along roadsides and disturbed areas. Japanese barberry also presents a threat in the wetland systems on the Browning Woods property south of Worden Pond Road.

Development and population growth continues to be a concern and may exert increased pressures on natural systems and habitats. Because of Rhode Island's dense human population pitch pine and scrub oak management techniques employing fire cannot be used on a wide scale, so these forest patches are threatened and will eventually convert to other land cover and habitat types without fire management. However, drier summers and increased temperatures may increase the incidence of unplanned forest fires.

What is the sensitivity of Perryville's assets to climate change?

The climate change scenarios for Rhode Island anticipate earlier springs, increased temperatures and precipitation but also drought, and an extended fall. The change in temperature and growing season will affect the understory of wild blueberry bushes found throughout this area as well as the cultivation of blueberry, raspberry, and apples as agricultural crops. Changes in precipitation and increased regional demand for water may limit the ability of farms to switch to irrigation to address shortfalls in rain and snow precipitation.

SKLT depends in part on revenues from leasing pasture and farmland for agricultural activity. Increased temperature together with more variable summer precipitation may lead to periodic drought conditions that could impact existing crops and farming operations and may result in less water availability for irrigation.

Within the forested areas, red maples will likely not be impacted significantly by higher temperatures as their range currently extends through Virginia. However, because red maples require a certain level of moisture, their habitat may narrow and be replaced by oaks as soils become drier during the summer season. Overall, red maple is more susceptible to change into upland forest.

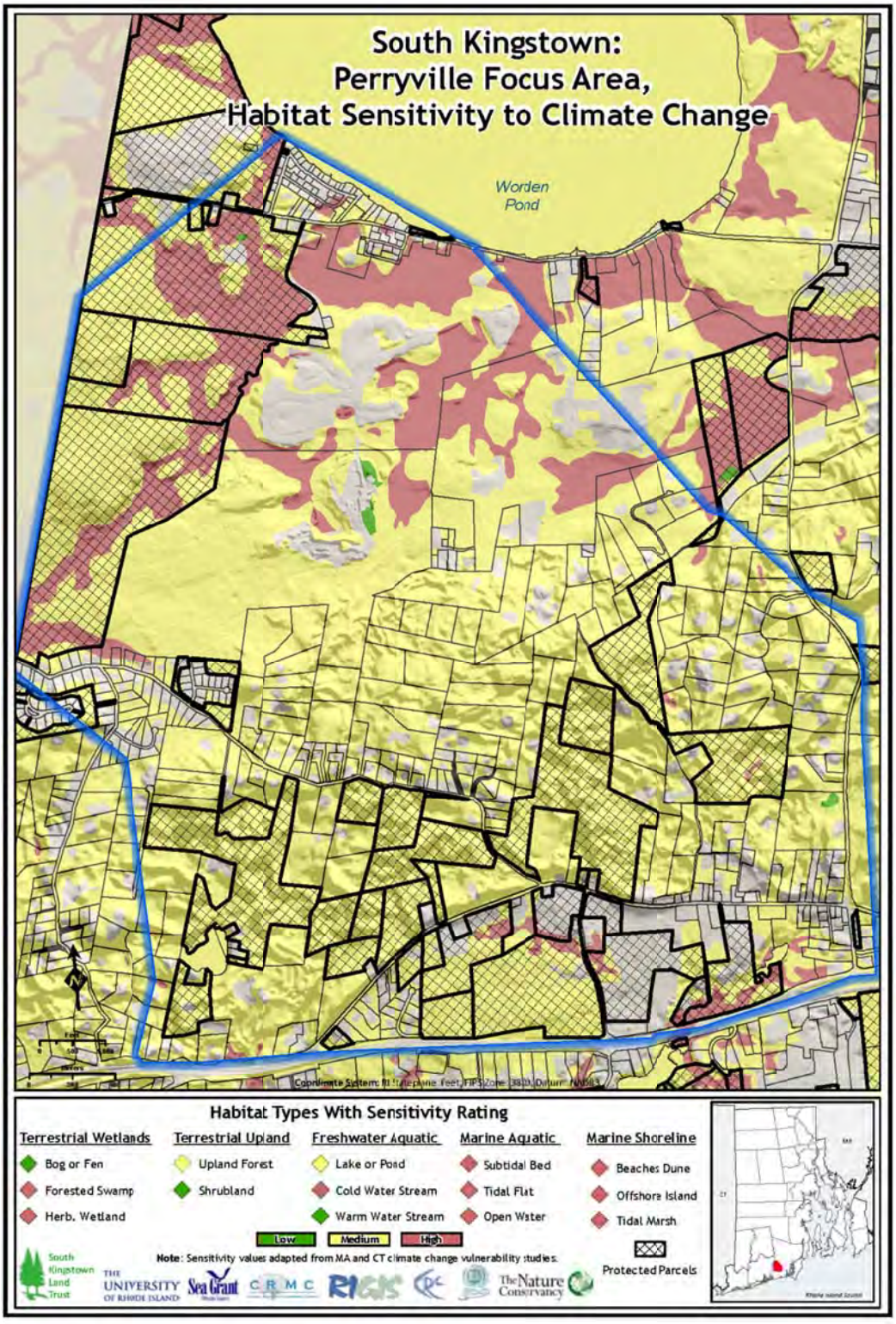

Figure 10. Perryville Focus Area, Habitat Sensitivity to Climate Change

Herbaceous wetlands are highly vulnerable due to predictions of increasing temperatures and altered precipitation patterns associated with climate change. These habitats are also highly vulnerable to invasive species like *phragmites* and purple loosestrife.

How vulnerable is the Perryville focus area to climate change?

Scrub oak forests will likely remain intact with predicted climate changes, but without periodic fire the forest type is likely to change. Fires are an essential part of the scrub oak habitat and with frequent fires the canopy consists of individual pitch pines with an understory of scrub oak and occasional patches of bare sand and islands of low vegetation. Without fire, pitch pine may form an almost closed canopy with a tall scrub understory and little ground cover, significantly decreasing habitat diversity. Fire suppression could also lead to an expansion of hemlock stands. However, as average temperatures increase, the hemlock woolly adelgid (a highly destructive pest introduced from East Asia) is expanding its range to the north and destroying many stands of Eastern Hemlock.

Additionally, the regeneration of oaks in scrub oak forests could be in decline due to the pressure from over-browsing by deer, thus active deer population management must be practiced.

MANAGEMENT OPPORTUNITIES WITH A CLIMATE CHANGE VIEW

What are the current management actions taken in this area?

To preserve the unique moraine environment, SKLT seeks to increase the size of its open space holding. SKLT's current holdings have generally been acquired through opportunistic means; many donations have been made by a founding member of the SKLT.

There is considerable cooperation with others to protect this area. The Nature Conservancy, RIDEM and the Town of South Kingstown have partnered for land purchases. The DuVal Trail is a popular recreation trail for hiking, biking, horse riding, and cross-country skiing, which crosses numerous parcels protected by SKLT and RIDEM.

Perryville has also been a focus for a North-South trail, which would tie the town together from the Hundred Acre Pond near URI to Trustom National Wildlife Refuge. The Town's Comprehensive Plan Policy 5.3 calls for expansion of the DuVal trail in the state Greenway Plan. A big challenge in advancing this trail project is determining how to safely cross Route 1.

What opportunities are there for management of current properties?

There are currently few invasive species present in Perryville's upland forests, thus serious effort does not currently need to focus on invasive eradication. However, a program of invasive species monitoring in the uplands should be implemented. Active management of deer populations is also important because heavy browsing by white-tailed deer can damage sensitive habitats and inhibit forest regeneration.

In Perryville's wetlands, the invasive species *phragmites* in wetlands is proving very difficult to manage currently, and management will only become more difficult as *phragmites* is less affected by climate stressors than native vegetation and can take advantage of increased nutrient loading in water bodies. The USFWS has worked on eradicate *phragmites* in Cards Pond, but it has proven resistant to measures attempted so far. Given the level of interest in eradicating invasives, other approaches such as biomass harvesting should be researched.

The projected climate trends could shift Rhode Island's climate to become more like Virginia or South Carolina in terms of temperature, which could favor hay production on land trust parcels and other actively farmed

properties. This in turn would have the benefit of increasing the habitat value of the properties kept in active agricultural use. Although large scale controlled burns are not an actively practiced management technique in Rhode Island's communities, opportunities to work with USFWS to do small scale controlled burns could be explored for sites including Browning Woods, which has pine barrens and white pine.

What opportunities are there for future acquisitions and preservation?

Several parcels of land south of Worden's Pond are currently unprotected with two large forested parcels adjacent to already protected properties. Some of these parcels contain sensitive habitats that may be a high protection priority. Other parcels containing freshwater aquatic or forested swamp habitats should also be considered for future acquisitions as these habitats generally contain high biodiversity and are highly vulnerable to the impacts of climate change. Acquisition or protection by easement of large undeveloped parcels can also slow down the rate of development, minimizing impacts associated with increased population in this area.

FOCUS AREA 5: SOUTH SHORE/COASTAL PLAINS

CONTEXT AND PRIORITIES

South Kingstown's South Shore/Coastal Plain focus area is a swath of land bordered by Route 1 to the north, Moonstone Beach Road on the south, and Point Judith Pond to the east. It is highly developed in some areas due to its location near the ocean and two large coastal lagoons, Potter Pond and Point Judith Pond. The focus area for SKLT does not include the shoreline of Block Island Sound.

Much of the critical land in this focus area has already been protected (by the federal and state government), so SKLT's primary objectives in this area are to make connections between protected parcels and protect and manage large parcels of undeveloped land. The US Fish and Wildlife Service (USFWS) owns a lot of land in this area and is actively engaged in management, thus SKLT's preservation and management objectives would benefit through cooperation and coordination with USFWS's work in this area.

SKLT's priorities for acquisition and management in the South Shore/Coastal Plain focus area include:

- Protecting biodiversity and ecosystem resources particularly around the ponds
- Protecting aesthetic, cultural, recreational and agricultural resources valued by the community

KEY ASSETS IN THIS FOCUS AREA

Although this focus area has experienced a lot of development there continue to be many important habitats and agricultural assets represented here.

Upland forest is the most abundant habitat type in this area. There are two small areas of shrublands in the southern region of the focus area. Shrublands are an underrepresented habitat in Rhode Island and many of these patches in South Kingstown have already been developed for housing or converted to agricultural lands.

The South Shore/Coastal Plain region is characterized by a series of coastal lagoons: Point Judith, Potter, Cards, and Trustom Ponds. Biologically, they provide nursery areas for fish that spend the remainder of their life cycles at sea or in fresh waters. Potter Pond has two coves, Fresh Pond and Perch Cove in Matunuck, which are now brackish as a result of the installation of permanent canals. SKLT has an easement property that contains a small portion of the

Fresh Pond coastline and a number of other properties that preserve small portions of the Potter Pond and Perch Cove coastlines. There are several areas of forested swamp on the northwestern edge of Pont Judith Pond. One focus of SKLT is to expand the conservation of the forested swamps found in this area.

There are two cold water streams within this focus area. Brown's Brook flows south from Mill Pond into Trustom Pond; the second brook runs through Mill Pond and into Point Judith Pond. There are also intertidal flats and subaquatic beds to the south of the focus area on the shores and bottom of Point Judith and Potter Ponds.

Agricultural land composes a large part of SKLT's holdings in this area and they are generally made up of many contiguous parcels. SKLT owns Bliss and Weeden Farms and maintain easements on Perkins, Osman and Gammell Farms. Some farms are owned and rented for income, while others are open fields and pastures. SKLT properties do not currently have wells for irrigation but neighboring farms do.

There are also cultural and historic landscapes of note in the South Shore/Coastal Plain region. This area is a key location of open space and scenic corridors, whose maintenance is a conservation goal in the South Kingstown Comprehensive Plan. SKLT has cooperated with other organizations to preserve places like the Grist Mill, old stone walls, and the scenic views across Weeden Farm and from the DuVal Trail to the coast. The coastal ponds are important centers of residential, recreational, and commercial use supporting tourism, recreational boating and fishing industry. Given the route along the bird migration corridor, birding is also a popular recreational activity at Trustom Pond National Wildlife Refuge to the west, and along the coast.

VULNERABILITY OF KEY ASSETS

What are the existing and projected stressors and trends?

Given the large increase in summer population, demand for services, and increased temperatures water shortage and summer droughts are common issues for this area. The town usually implements water use restrictions in the South Shore region during the summer when water demand peaks. Fortunately, population density is relatively low in comparison to Green Hill, so water scarcity is less of a pressing issue here. Year-round residents are more common than decades in the past, as small cottages are being replaced by larger homes. These trends will likely continue. Low lying shorefront lots and roads along Point Judith and Potters Pond are experiencing wetter conditions during spring tides consistent with rising sea levels. Various saltmarsh areas throughout the state are already experiencing the stress of drowning in place as tides have increased.

What is the sensitivity of South Shore/Coastal Plain's assets to climate change?

This area is located near the coast and is exposed to hurricanes, thus the area is likely to experience increasingly frequent storms and the wind and flood damage associated with them. The Rhode Island Sound coast is an eroding shoreline with long term rates averaging upwards of 3 feet per year, with increasing risk to private property and public infrastructure. The pond shorelines are more stable, however, still experience flooding during storms and extreme tides.

This area is also sensitive to sea level rise. Wetlands, sensitive to tidal flow and elevations, will naturally migrate inland with rising seas. If the non-climate stressors of development and hard shorelines are present landward of the wetlands, this habitat will be prevented from migrating and will shrink or even disappear. Wetlands growth may not be able to keep up with sea level rise, and soils may be altered, causing some saltmarsh to drown in place.

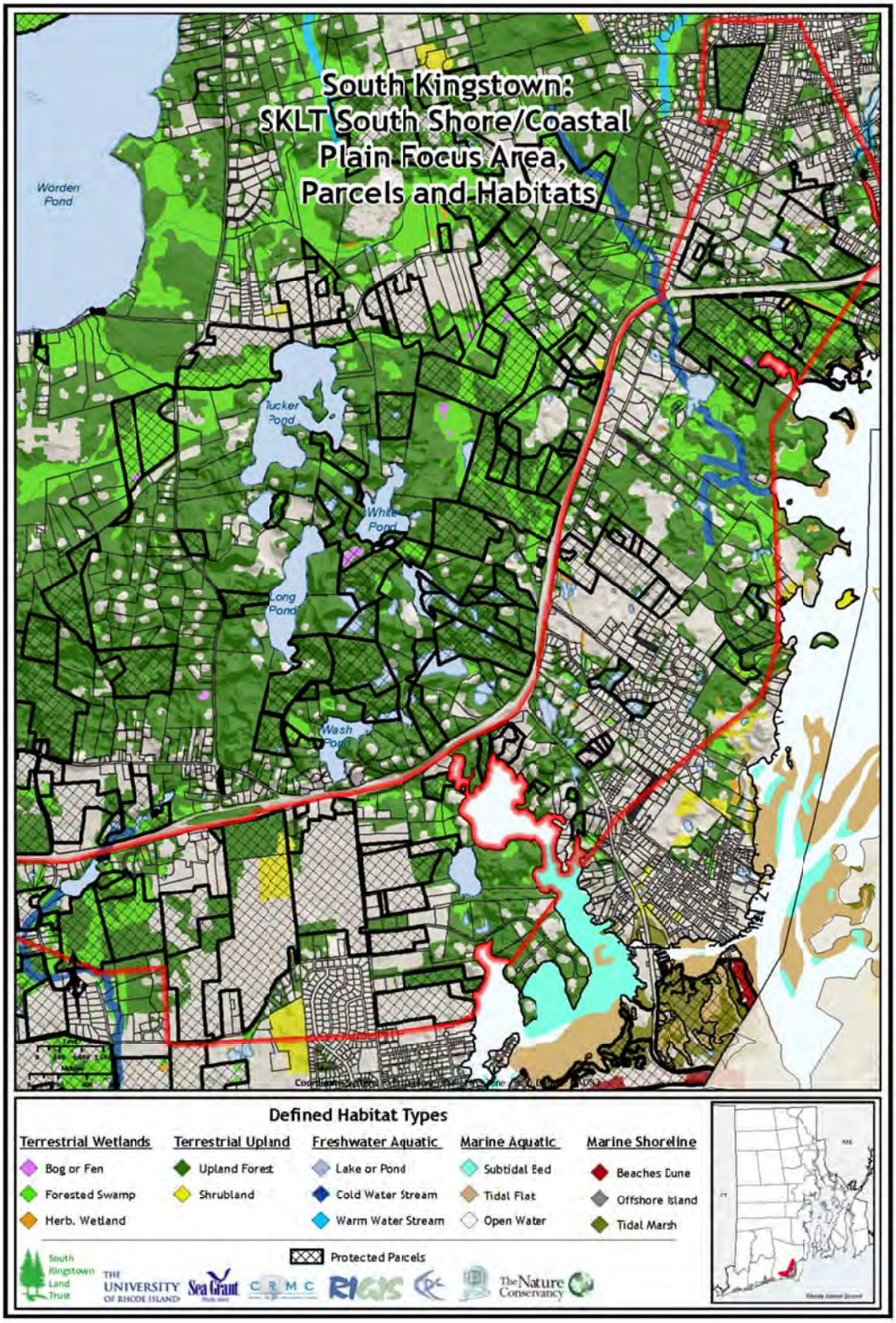

Figure 11. South Shore/Coastal Plain Focus Area, Parcels and Habitats

Another potential issue is that of saltwater intrusion in wells due to the changing coastline, increasing seas, changes to groundwater levels along with increased demand for water pumping. Currently, farmers are using deep wells (70 foot depth to groundwater), but during drier summer months wells close to the coast may be at risk of saltwater intrusion.

The cold water streams in this area are also at risk from the effects of climate change. They rely on thorough shading from bordering plants to maintain a temperature cool enough for cold-water species like trout to survive.

How vulnerable is the South Shore/Coastal Plain focus area to climate change?

As discussed above, the vulnerability of the agriculture parcels may need attention with increased variability of rainfall, increasing temperatures, more frequent drought and continued high groundwater demand from residential properties. This could affect the quality and quantity of groundwater for crops.

Effects of climate change in Rhode Island may lead to seasonal drying of wetland soils, impacting the forested swamps in this focus area, which are of interest for conservation.

Most of the SKLT protected parcels in this focus area do not abut the shore and therefore are not as vulnerable to sea level rise and increased flooding. However, low-lying areas around the coastal ponds are more vulnerable with scenarios of 3 and 5 feet of sea level rise later in the century. Coastal erosion will continue to be a high risk to those along the open shore, such as those properties located in Matunuck and at Roy Carpenters beach. Efforts to understand sea level rise and its effects on wetland ecosystems are underway for the entire state, which will help inform management of protected parcels as well as guide both future acquisition and shoreline development.

MANAGEMENT OPPORTUNITIES WITH A CLIMATE CHANGE VIEW

What are the current management actions in this area?

This area has a contiguous protected corridor consisting mostly of farms and forested swamps. There is a mix of forms of farmland ownership and easements. Some farms, like Weeden Farm, are owned by SKLT and others are preserved through conservation easements. Trustom and Cards Ponds to the west are managed and protected by USFWS. The Federal government also owns much of the land surrounding Trustom Pond and their holdings continue towards East Matunuck.

What opportunities are there for management of current properties?

SKLT parcels in this focus area contain some upland forest (241 acres) and forested swamp (33 acres) habitat; however the majority of SKLT holdings in this area are agricultural lands (about 320 acres). Management actions for agricultural lands should focus on increasing the organic matter content of soils in order to improve soil fertility and reduce erosion, flooding and water contamination. Alternative irrigation practices should also be investigated

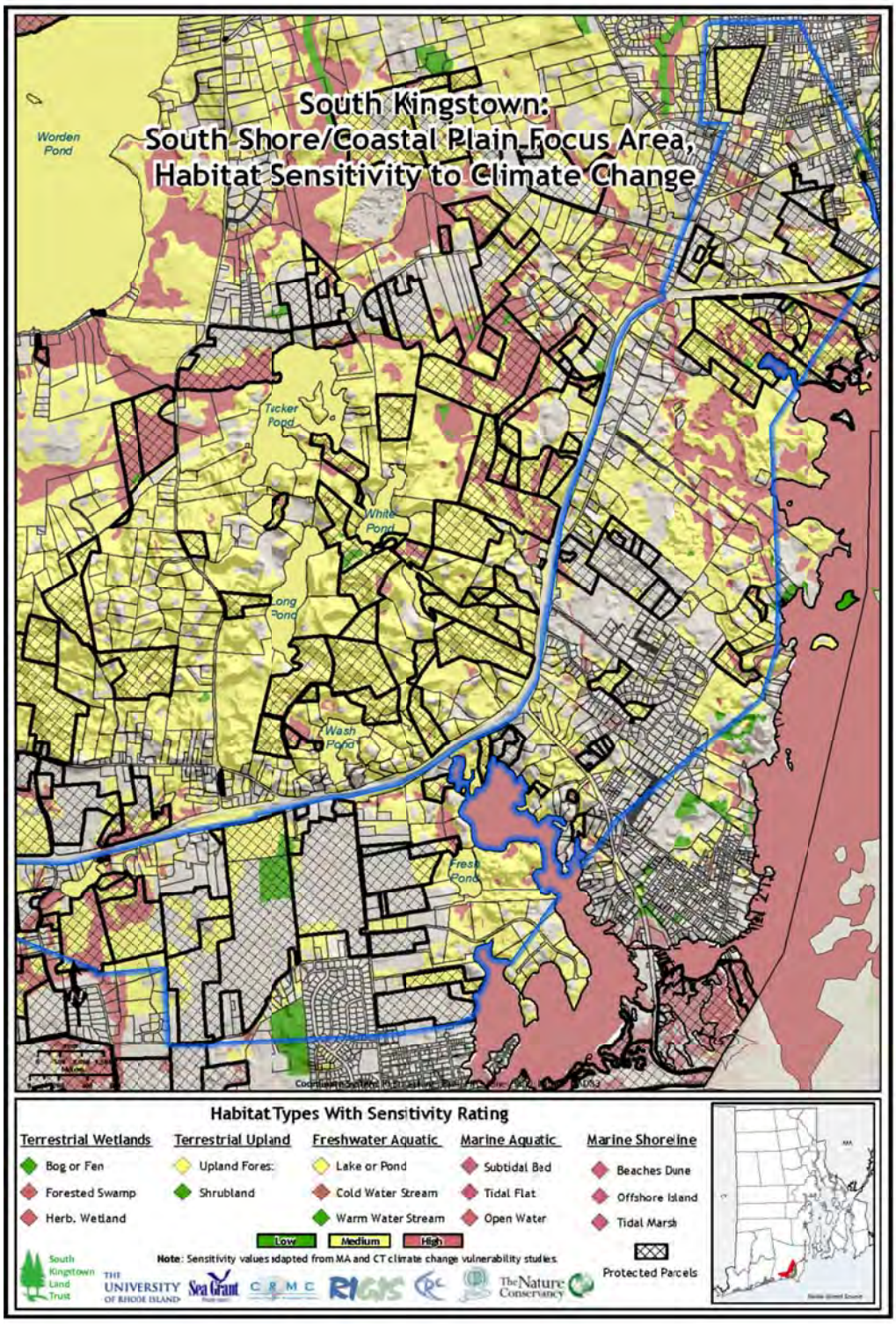

Figure 12. South Shore/Coastal Plain Focus Area, Habitat Sensitivity to Climate Change

as a means of reducing water consumption. Pest monitoring efforts could be organized and implemented in order to keep track of potential invasive pests. It is also important to create and/or maintain riparian buffer zones next to agricultural lands in order to reduce erosion and protect water quality.

Properties that contain the cold water streams of Brown's Brook and an unnamed stream that runs through Mill Pond into Point Judith Pond could be managed to maintain an appropriate riparian buffer in order to shade the water and filter pollutants from runoff.

On SKLT's shorefront properties, shoreline monitoring should be performed regularly to track erosion and rising tide levels and explore what type of remedial measures should be taken.

What opportunities are there for future acquisitions and preservation?

Conservation in this area began in the 1970s with the establishment of Trustom Pond National Wildlife Refuge. Due to the effective protection efforts of federal and state agencies and SKLT, there are few undeveloped areas that are not currently protected. There are a few remaining unprotected parcels that are moderately to highly sensitive in the northeast section of the focus area that could present acquisition possibilities. As parcels become available SKLT could consider purchasing them or protecting them under easement.

To the west of this focus area, federal and state agencies, in partnership with SKLT, have worked effectively to protect coastal ponds. SKLT is also interested in acquiring land for conservation adjacent to or near Trustom and Cards Pond, which lie to the southwest of this focus area.

In evaluating potential acquisition sites and opportunities, SKLT and other organizations should begin to consider sea level rise projections and the location of current salt marshes. As sea levels increase, salt marshes will be threatened by marsh drowning unless there are protected inland areas for marsh migration. Although SKLT does not currently manage many coastal parcels, coastal areas adjacent to current salt marshes should be a high preservation priority in order to protect undeveloped areas for marsh migration. Within and around the South Shore/Coastal Plain focus area there are several parcels close to Fresh Pond, Cards Pond, and Trustom Pond that may provide inland areas for salt marshes to migrate towards if they are protected from development.

OTHER AREAS OF CONSIDERATION: GREEN HILL AREA

The Green Hill area is primarily a residential community bordered by Green Hill Pond to the west and southwest and Trustom Pond National Wildlife Refuge to the east. SKLT currently manages approximately 85 acres in this area with most of their parcels consisting of upland forest (32 acres) and forested swamp (25 acres) habitats. This area is not a high priority focus area for SKLT because there are few large undeveloped parcels available for protection through purchase or easement. The majority of unprotected parcels are small residential-sized plots. Land prices in this area are also higher than SKLT's financial capacity can accommodate, thus limiting SKLT's ability to preserve land in this area.

Although SKLT does not own many parcels in this area, there are several important habitats that are of high protection value. As sea levels rise and inundation becomes a major issue, low-lying areas will be significantly impacted. Many areas surrounding Green Hill Pond will be flooded, including vulnerable intertidal flats, tidal marshes, beaches and dunes. This area contains valuable resources of intertidal flats (6 acres), tidal marshes (30 acres), and beaches and dunes (33 acres); however, SKLT only protects a small portion of beaches and dunes (0.1 acres) and tidal marsh (0.3 acres). Intertidal flats, tidal marshes, beaches and dunes are highly vulnerable to sea level rise and storm surge and without adequate protection these habitats may disappear. Gently sloping undeveloped areas adjacent and upland to current tidal salt marshes are a high protection priority in order to ensure that marshes will have room to migrate inland as sea levels rise. Wetlands and adjacent areas around Green Hill Pond may provide future marsh migration sites and should be protected from development.

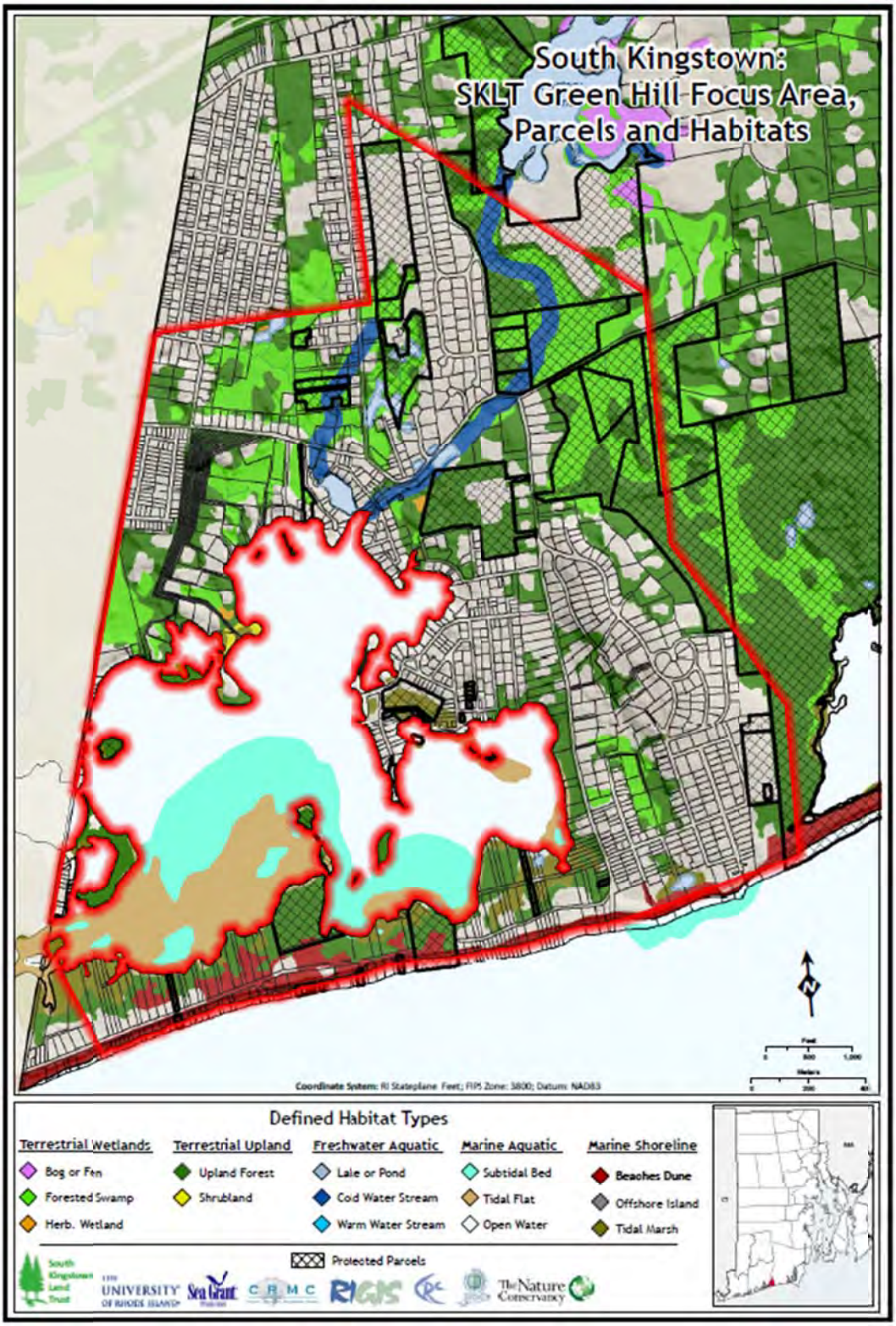

Figure 13. Green Hill Focus Area, Parcels and Habitats

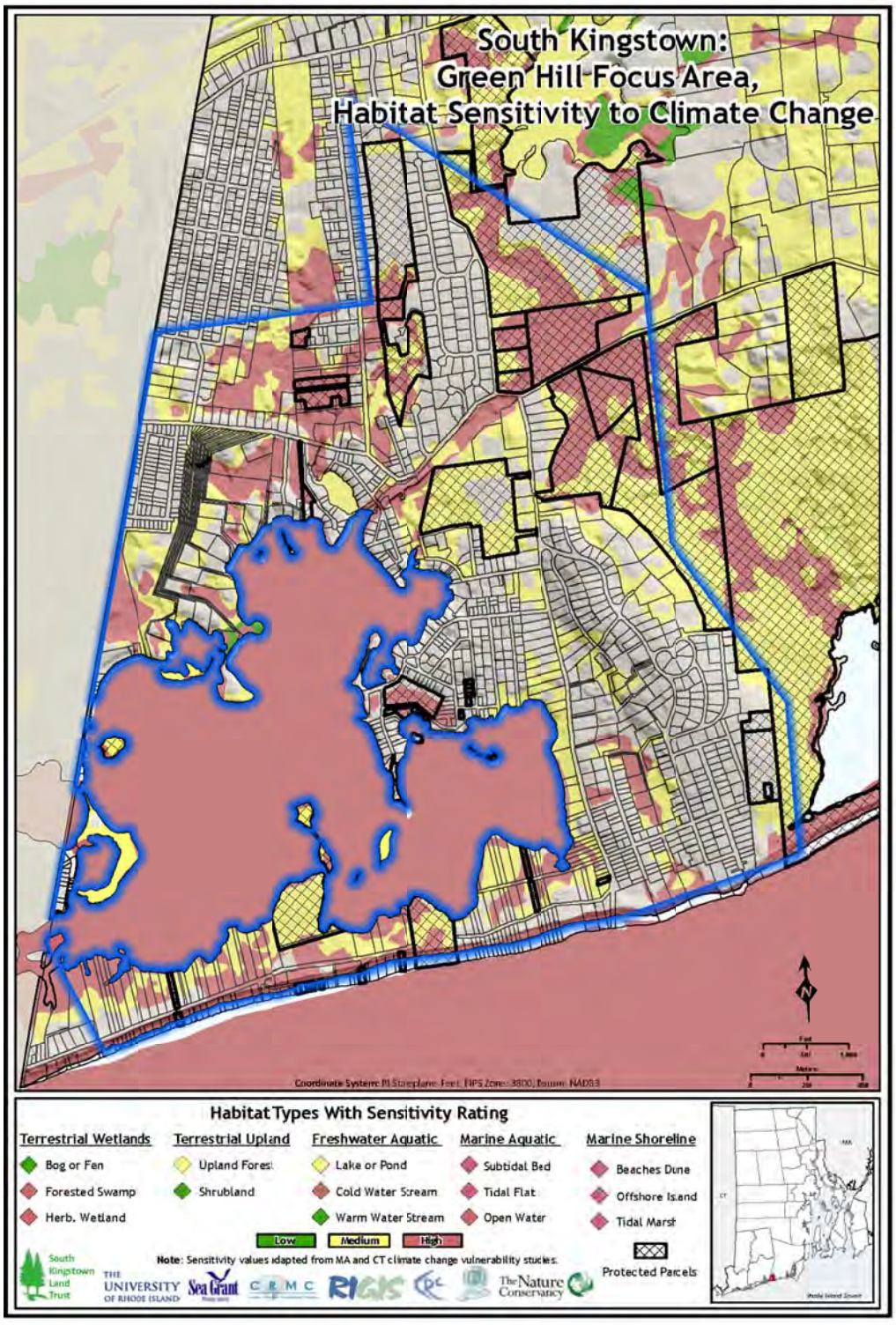

Figure 14.Green Hill Focus Area, Habitat Sensitivity to Climate Change

OTHER AREAS OF CONSIDERATION: KINGSTON

The Kingston area is largely developed as a residential and college community and includes the historic Kingston town center and the University of Rhode Island campus. SKLT protects several parcels however the residential nature of the area does not permit protection of large conservation areas.

SKLT currently protects a total of approximately 223 acres in Kingston, including 160 acres of upland forest, 38 acres of forested swamp, and 11 acres of warm water stream habitats. One of the primary focuses of management on these properties is control of invasive species including garlic mustard and Japanese stilt grass which is becoming more prevalent in the Biscuit City area, indicating a need for more monitoring efforts.

Several other parcels are already protected which leaves primarily small residential plots as the only unprotected lands in this area. There are a few medium sized parcels adjacent to currently protected areas that may be worth considering for expanding preservation here, but SKLT feels that this area is primarily too developed for SKLT to focus their resources on acquisition of small segmented parcels.

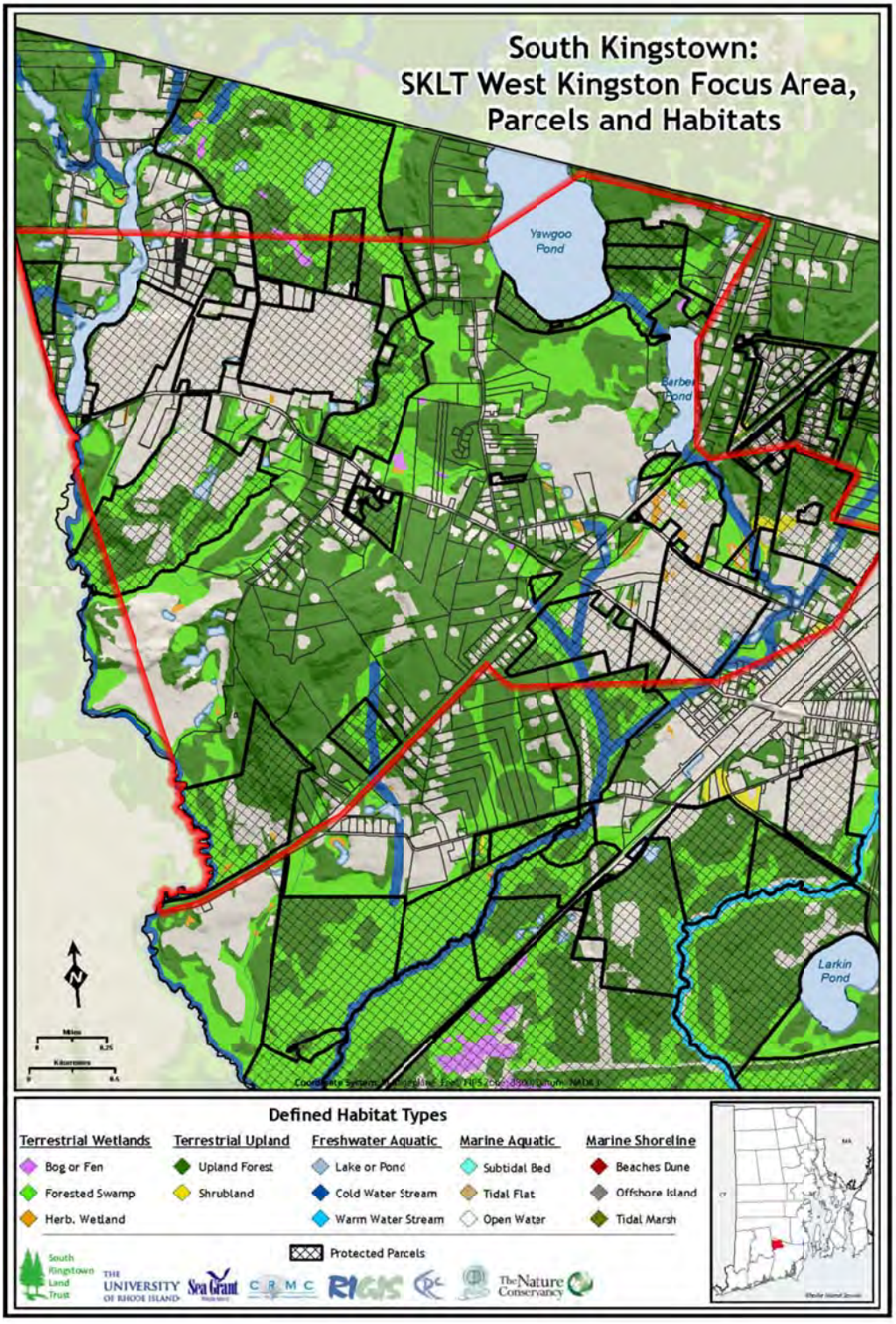

Figure 15. Kingston Area, Parcels and Habitats

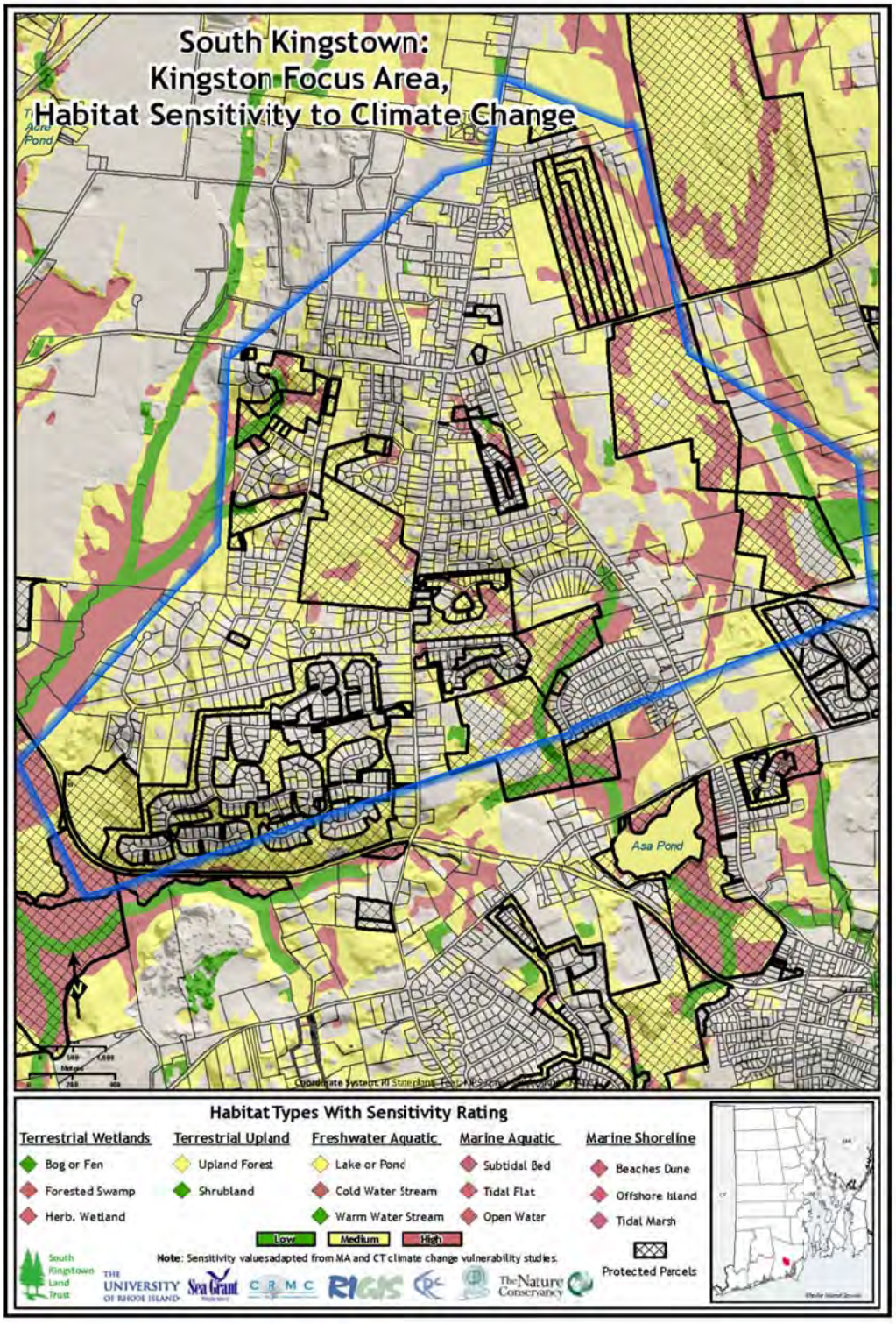

Figure 16. Kingston Area, Habitat Sensitivity to Climate Change

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SECTION 3: OPTIONS FOR MANAGEMENT, PROTECTION AND OUTREACH[1]

The SKLT Case Study identified numerous management, protection, and outreach actions that may be incorporated into the Land Trust's management strategies. The following list of management goals, principles, and actions complement existing practices and may be expanded upon to address climate change adaptation and habitat resilience goals.

GENERAL MANAGEMENT ACTIONS

Actively manage deer populations. Active management of deer populations is an important management action because high levels of browsing of native vegetation by white-tailed deer adversely affect the structure, composition, and functioning of forested ecosystems, thereby reducing their diversity and resilience to climate stressors. Overgrazing also opens the way for increased rates of infestation by invasive non-native plants. Control measures such as hunting or fencing where feasible may be considered on conserved properties. Regulated hunting allows managers to reduce or maintain deer populations and protect important vegetated ecosystems.

Monitor invasive non-native species. Invasive non-native species pose a threat to the health and diversity of ecosystems and the resilience of healthy habitats to withstand climate change. Efforts must be made to establish effective monitoring and response plans to detect and track infestations and outbreaks in their early stages and then take decisive actions to eliminate problem species before they get out of control. Regular monitoring by volunteers or staff can be an effective approach to help preserve native species diversity and ecosystem resilience.

Assess vulnerability of habitats. Each Land Trust parcel's climate vulnerability is determined by its exposure to climate stressors, the sensitivity of the habitat and its capacity to adapt. In order to develop effective climate change adaptation actions consider vulnerabilities of target parcels, habitats and corridors and identify actions for management, protection and advocacy that complement the goals of the land trust for that area.

Address climate and non-climate stressors in management strategies. In addition to creating management strategies addressing non-climate stressors (i.e. non-point source pollution and deer over-population), climate change adaptation must also be included in management planning.

Employ adaptive management approaches. The organization should reevaluate the effectiveness of monitoring and management actions at regular intervals (every 1, 2, or 3 years) and revise or make improvements as necessary. This will help address changing conditions as well as ensure management effectiveness over the longer term.

Collaborate with others. Land trusts and local conservation organizations can develop and foster collaborative partnerships with other organizations as well as state agencies (such as the RI Department of Environmental Management) and national non-profits (like the Audubon Society and the Nature Conservancy) to expand their capacity and resources enabling acquisition of sensitive habitats and management of vulnerable areas.

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[1] The management and protection actions described in this chapter have been compiled from various documents including "Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams" , "Climate Change and Massachusetts Fish and Wildlife", and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health"

Use Low Impact Development Best Management Practices to promote resilience. Low impact development (LID) management actions can play an important role in climate adaptation by increasing resilience of habitats, ecosystems and watersheds. Thus, support of LID principles may be included in conservation organizations' best management practices. Land trusts can incorporate LID principles on parcels that they own or manage. Conservation easements can incorporate LID practices as well. Finally, land trusts can work with municipal officials to integrate appropriate practices into local ordinances and plans. Refer to the Rhode Island LID Site Planning and Design Guidance Manual for more information and view examples of LID in Rhode Island at the RI Stormwater Solutions website.

MANAGEMENT ACTIONS

Asset 1: Lakes, ponds, cold water streams, and warm water streams

- Identify ways to maintain cool water temperatures in streams and ponds so that species adapted to cool temperatures are able to survive.
- Evaluate options for dam removal or fish ladders so that anadromous fish such as salmon can reach cooler water to spawn, aiding in restoration efforts. Local species of interest for restoration include shad, alewife, smelt, sea run brook trout, sturgeon, and white perch.
- Identify and protect remaining critical cold water fish habitat areas and seek to reconnect high quality habitats by removing in-stream barriers and re-establishing in-stream flows.
- Maintain and expand riparian vegetated buffer areas so runoff from impervious surfaces has the opportunity to cool down and have some pollutants removed before entering cold water streams and ponds.
- Encourage application of geotextiles and bioengineering techniques for erosion control and stream stability, such as placing geotextiles in or next to streams.
- Control aquatic invasive species through more active monitoring efforts, aggressive elimination and control activities, boater education and boat inspections in infested areas.
- Control and seek to minimize non-climate stressor impacts including pollution from non-point sources and impervious surface runoff.

Asset 2: Bogs, fens, forested swamps, and herbaceous wetlands

- Maintain or improve habitat quality and, correspondingly, the resilience of wetland habitats to changing conditions.
- Promote riparian zone and floodplain management, restoration and preservation by removing restrictions between rivers and floodplains, removing dams, and integrating brownfields remediation projects with floodplain restoration; riparian buffers and dam removal can also benefit down-stream water bodies. Climate change projections predict an increase in more intense storms resulting in more floods, thus actions focused on flood reduction and floodplain management may be a high priority.

Asset 3: Beaches, dunes, offshore islands, and tidal marshes

- Explore mechanisms that proactively address migrating salt marshes (caused by sea level rise); consider utilizing rolling easements that facilitate marsh and/or beach migration inland as sea level rises. Prioritize protection of suitable upland habitats for future salt marsh locations.
- Identify, assess, and remove existing impediments (i.e. seawalls) to future inland migration of coastal salt marshes.

- Establish policy and procedures for post-storm restoration that minimizes sand removal from barriers where sand overwash should be allowed to be maintained for landward barrier migration.

Asset 4: Terrestrial uplands, including upland forest and shrublands

- Reduce over-browsing by white-tailed deer by controlling deer populations in order to protect regeneration of habitats; delays in regeneration reduce the ability of the forest ecosystem to function consistently over time.
- Manage invasive species; launch an initiative to remove invasives from large unfragmented forest blocks on protected (private, state, federal) land in collaboration with partners.
- Track and eliminate invasives and pests; where feasible transplant preferred native species to restore areas with invasives.
- Manage resilience across a maturing forest landscape by identifying structurally diverse and species-rich areas of mature forest for retention and regenerating more homogeneous areas of second-growth trees to young forest habitat through timber sales.
- Identify forest types likely to be most vulnerable to climate change and prioritize practices that may reduce impacts on ecosystem value and functions.
- Promote forest reserve management practices that allow natural processes to determine the long-term structure, composition, function, and dynamics of the forest to the maximum extent possible.
- Manage ecosystem change by selective cutting, introductions of preferred climate-resilient species, and control of non-climate stressors such as invasive species.
- Explore opportunities to enhance carbon sequestration in forests.
- Consider restoring habitats with plant species that are more resilient to future conditions of change.

Asset 5: Agriculture and farmland

- Increase efforts to monitor the use of pesticides in the environment as extensive use of pesticides degrades water quality and wetland habitats.
- Increase organic matter on farms in order to reduce erosion, flooding, and water contamination resulting from more intense storms.
- Review crop planting to accommodate extended growing seasons as feasible; potential increases in temperature and summer drought conditions should also be taken into consideration when selecting resilient crops.
- Seek implementation of alternative irrigation practices and install water conservation practices to reduce vulnerability to water supply fluctuations.
- Encourage adoption of best management practices to control runoff of pesticides, nutrients, or fertilizers, and soil, which contribute to poor water quality, degrading wetland and aquatic habitats and decreasing these habitats' resilience to climate change.
- Escalate pest monitoring efforts in order to most effectively manage invasive pests.
- Investigate use of pest controls for changing climate conditions; use integrated pest management.
- Shift to alternative varieties or products that are more tolerant of our changing climate.

PROTECTION ACTIONS

Asset 1: Lakes, ponds, cold water streams, and warm water streams

- Identify and protect climate refugia, areas and systems that are more resilient to climate change or which allow habitats such as wetlands to migrate as sea level rises or flood plains are modified.
- Protect naturally connected waters in order to maintain natural flow patterns.
- Target land acquisition and conservation restrictions to protection of vulnerable intermittent headwater streams and their buffer areas; acquisition could be supplemented by stream easements in order to preserve riparian zones and ensure adequate shading of cold water streams.

Asset 2: Bogs, fens, forested swamps, and herbaceous wetlands

- It is essential to preserve areas and buffers that are not yet impacted by human development. As impacts of climate change increase species may depend on large undeveloped areas for survival.
- Identify and protect resilient wetland ecosystems; focus land protection on large areas with high ecological integrity and functionally healthy wetland complexes that have higher resiliency over time.
- Identify and prioritize protection of migration corridors between wetland areas and between wetlands and associated upland habitats including large resilient parcels connected by migration corridors. Larger parcels of habitat will be more resilient to impacts from climate change and thus may provide a refuge for plant and animal species when they are pressured by climate-related stressors.
- Use LiDAR and other data to identify important wetland areas and ensure that a variety of wetland types are represented in land protection planning in order to make habitats more resilient to climate change.
- Protect inland wetlands for floodwater storage. Continued protection of floodplains and stream buffers is also an important feature of a comprehensive Low Impact Development (LID) strategy to protect the environment and property under current and future conditions.
- Maintain floodplains as undeveloped areas, especially preventing high-risk development that may experience more flooding with increased storminess.

Asset 3: Beaches, dunes, offshore islands, and tidal marshes

- Identify and protect undeveloped areas and/or freshwater wetlands that are up-gradient from saltmarsh wetlands to allow wetland migration and buffer intact ecosystems.
- Using high-resolution elevation models (based on LiDAR data), identify and prioritize protection of areas that may become wetlands in the future as sea levels rise.
- Protect undeveloped barrier systems (dunes, beach, and marsh) and allow their natural move landward with storm processes, for example overwash and erosion.

Asset 4: Terrestrial uplands, including upland forest and shrublands

- Improve buffering to safeguard core, high-quality habitats so that they may provide a refuge for plant and animal species experiencing pressure from climate and non-climate stressors.
- Identify and preserve habitat movement corridors and improve habitat connectivity to facilitate movement of organisms displaced by human development or climate change-related stressors.
- Protect large unfragmented forest blocks of habitat to provide refuges for displaced plant and animal species.
- Maintain ecological function over long periods by managing forest reserves that are large, minimally fragmented, and representative of varied ecological settings that include forest biodiversity.

Asset 5: Agriculture and farmland

- Protect and maintain riparian buffers near agricultural lands.
- Target properties with good soils for agricultural uses for protective acquisition.

ADVOCACY AND OUTREACH ACTIONS

Asset 1: Lakes, ponds, cold water streams, and warm water streams

- Increase vegetative buffers; restrict building of impervious surfaces close to cold water streams and rivers.
- Promote education on the transportation of aquatic invasive species by boats to different water bodies.

Asset 2: Bogs, fens, forested swamps, and herbaceous wetlands

- Encourage the passage of state regulations (with supporting local level zoning and planning ordinances) and use of other tools to strengthen protection of isolated vegetated wetlands that are most vulnerable to climate change.
- Promote restoration of floodplains and wetlands for floodwater storage with expansion, where feasible, for larger floods in the future.
- Promote the increase of vegetated buffers to reduce non-climate stressors such as non-point source pollution and runoff from impervious surfaces.

Asset 3: Beaches, dunes, offshore islands, and tidal marshes

- Work with town, state and federal partners to identify priority properties for acquisition after a damaging hurricane or storm. Develop a dedicated fund and process for accessing funds for post-disaster acquisition of destroyed waterfront and coastal properties.
- Identify upland areas adjacent to salt marsh for future protection that may be feasible migration corridors

Asset 4: Terrestrial uplands, including upland forest and shrublands

- Provide foresters with information and support services concerning how climate change may disturb forests and impact strategies for keeping forests viable.
- Conduct outreach and education on water and land conservation practices and the changes expected to come with a warming world.
- Add state tax incentives to keep forests as forests, such as a state tax credit for the cost of professionally prepared forest management plans.

Asset 5: Agriculture and farmland

- Promote the concept of “buy local”.
- Facilitate research on crop adaptation and diversity for future climates.
- Evaluate the benefits of modifying development and zoning priorities to increase access to places to purchase fresh food and engage in healthy living activities.
- Promote and provide technical and financial support for small-scale farming; work with farmers to buy development rights to continue farming, or lease farmers land for relatively little.
- Consider providing personnel and/or funding to monitor for new insects or weeds that are likely to expand their range into Rhode Island.
- Promote urban/community gardening efforts within the community and/or on Land Trust parcels.

SUMMARY OF LOW IMPACT DEVELOPMENT BEST MANAGEMENT PRACTICES

Avoid Impacts

Protect as much undisturbed open space as possible to maintain pre-development hydrology and allow precipitation to naturally infiltrate into the ground.

Maximize the protection of natural drainage areas, streams, surface waters, wetlands, and wetland buffers.

Minimize land disturbance, including clearing and grading; avoid areas susceptible to erosion and sediment loss.

Minimize soil compaction; restore soils that were compacted due to construction activities or prior development.

Reduce Impacts

Provide low-maintenance, native vegetation that encourages water retention and minimizes the use of lawns, fertilizers, and pesticides.

Minimize impervious surfaces.

Match or increase time of concentration from pre-construction to post-construction, where "time of concentration" means the time it takes for runoff to travel from the hydraulically most distant point of the drainage area to the point of interest within a watershed.

Manage Impacts from Runoff at the Source

Infiltrate precipitation as close as possible to the point it reaches the ground using vegetated conveyance and treatment systems.

Break up or disconnect the flow of runoff over impervious surfaces.

Provide source controls to prevent or minimize the use or exposure of pollutants into storm water runoff at the site in order to prevent or minimize the release of those pollutants into storm water runoff.

Conservation Developments

Advocate for conservation development planning, concentrating residential development in smaller area leaving larger undeveloped areas for green space.

Conservation designs minimize the amount of impervious surfaces, reducing flooding and runoff pollution.

Conservation development promotes preservation of large blocks of undeveloped land, important for preserving contiguous habitat blocks; promotes protection of riparian buffer zones around streams, rivers, and wetlands.

Promote the preservation of vegetated riparian buffers of a minimum of 100 feet; for protection of cold-water streams a "no-touch" buffer of 150 feet is a minimum.

Riparian Buffers

Communities can use their own land-use regulatory power to require protection of more comprehensive wetland/aquatic buffer zones which will enhance ecosystem functions.

A minimum buffer width of 100 feet is widely recommended for protection of most buffer functions in developed areas where large areas of impervious surfaces result in increased temperatures of runoff, wider buffer zones are necessary in order to preserve cold-water stream habitats.

Replanting and restoring disturbed buffer areas with native species can help restore and improve buffer functions.

Excerpted from "Rhode Island Low Impact Development Site Planning and Design Guidance Manual, February 2011." LID techniques can be viewed online at the LID Inventory at the Rhode Island Stormwater Solutions.

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APPENDIX

BUILDING CAPACITY TO ADAPT TO CLIMATE CHANGE THROUGH LOCAL CONSERVATION EFFORTS

A SOUTH KINGSTOWN LAND TRUST PILOT PROJECT

APPENDICES

Appendix 1: Summary of Climate Change Impacts and Non-Climate Stressors

Appendix 2: Habitats and Assets in a Vulnerability Assessment

Appendix 3: Ecological Land Units (ELUs) – A New Strategy for Achieving Conservation Goals

Appendix 4: Sea Level Rise Mapping in Rhode Island

APPENDIX 1: SUMMARY OF CLIMATE CHANGE IMPACTS & NON-CLIMATE STRESSORS

CURRENT TRENDS AND FUTURE CLIMATE CHANGE IMPACTS IN RHODE ISLAND AND NEW ENGLAND

This section summarizes existing climate trends and potential future impacts related to high and low emissions scenarios for the Northeastern United States and their likely impacts on Rhode Island. High emission scenarios project the impacts of climate change if humans continue adding large quantities of carbon dioxide into the atmosphere while low emission scenarios provide a best-case projection based on severely reduced levels of emissions.[2]

Key Resources

Climate Change & Rhode Island's Coasts

Land Trust Alliance Summary of Impacts of Climate Change

Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions

Northeast Impacts and Adaptation, EPA

Average air temperatures in Rhode Island have risen by about 1.7° F from 1905 to 2006. Winters have been warming the fastest, at 1.3° F per decade since 1970. By 2100 annual temperatures in New England are projected to increase 3.5 to 6.5°F under a low emissions scenario and 6.5 to 12.5°F under the higher-emissions scenario. Narragansett Bay's average mean temperature has increased 2° F, while the average mean winter sea surface temperature has increased 4° F over the last 30 years.

Rhode Island's climate is becoming increasingly warm and more like the climate of states farther south. By the end of the century, summer in Rhode Island could feel like a typical summer in Virginia or coastal South Carolina depending on the extent of warming (see Figure 1). Seasonal changes affect our environment and our economic interests. The recent changes in the USDA Plant Hardiness Zone Maps may reflect a warming climate.

Figure 17. Changes in Rhode Island's average summer heat index under low and high emission scenarios (Union of Concerned Scientists, 2007).

[2] Note that the climate trends described here are based on the 2007 Northeast Climate Impacts Assessment from the Union of Concerned Scientists, which provides downscaled projections for Rhode Island. While the overall trend is not likely to reverse, the exact projections of the magnitude of changes are likely to be revised. Given this, readers are advised to stay abreast of climate predictions from reputable sources such as the US Global Change Research Program.

Table 1. Observed Trends and Projected Climate Change Impacts for Rhode Island (RICRMC, 2010; Union of Concerned Scientists, 2007; Heffner et al., 2012)

Climate Change Stressors/ Phenomena	Observed Trends in Rhode Island	Projections for the year 2100 (Low and High Emission Scenarios)	Potential Impacts and Consequences
Sea Level Rise	In Newport, sea level has risen 8.7 inches since 1930. Over the past 50 years, sea level in the northeast has been increasing 3-4 times faster than the global rate.	LOW: 4 - 24 inches HIGH: 36 - 60 inches	**Inundation of shore areas, accelerated erosion, changes in shoreline** **Loss of salt marshes due to decreasing space between high tide and landward development or topography** **Increase in severity of damaging storm surges and coastal flooding along the coast**
Air Temperature	Average annual temperature rose 1.7° F from 1905 to 2006	1.**LOW**: 3.5° - 6.5° F; more than 30 days over 90 °F 1st leaf and bloom: 7 days earlier Summer onset/end: 9 days earlier/12 days later HIGH: **6.5° - 12.5° F; more than 60 days over 90° F** 1st leaf and bloom: 15 days earlier Summer onset/end: 21 days earlier/23 days later Frost free days: more than 6 weeks	• **Important plant and animal lifecycles that are directly linked may no longer align. For example, bird species that time their nesting to coincide with insect hatches may miss a vital source of food if insect hatches occur earlier.** • **Winter chilling requirements for blueberries, cranberries, raspberries and some apple varieties not are met across most of state.** • **Longer growing season for warm-weather crops**
Bay Temperature	In Narragansett Bay winter sea-surface temperatures have risen 4°F since the 1960s	LOW: 4 - 5° F HIGH: 6 - 8° F	• **Lack of sufficient oxygen in the Bay due to large algae blooms resulting from warmer water temperatures may cause massive die offs of fish and other species.** • **Important plant and animal lifecycles that are directly linked may no longer align. Decline and/or collapse of lobster populations**
Storm intensity	In the U.S. Northeast, the severity of future tropical cyclones in the North Atlantic may increase	10 - 20 % increase in intensity	• **Increase in severity of damaging storm surges and coastal flooding along the coast** • **Increase in intensity of storms will stress new and aging infrastructure**

Climate Change Stressors/ Phenomena	Observed Trends in Rhode Island	Projections for the year 2100 (Low and High Emission Scenarios)	Potential Impacts and Consequences
			• **Storm surges from hurricanes and tropical storms will be bigger, causing more coastal flooding**
Changing precipitation patterns	Over the past 100 years, Rhode Island precipitation (rain and snow) has increased by 0.12 inches per year Annual mean wind speed at T.F. Green Airport has significantly declined since at least the 1960s.	**LOW**: increase by 5 inches **HIGH:** increase by 9 - 14 inches Precipitation increase by 2100 of 10% in spring and summer, 13% in fall, and 20-60% in winter	• **Summer precipitation is likely to be in the form of infrequent but heavy rain, resulting in periods of drought interspersed with potential flooding from heavy rain events** • **Increased demand for irrigation due to lack of regular precipitation**
Ocean Acidification	**Globally: current pH in the surface ocean is 0.1 units lower than pre-industrial levels**	**The most recent IPCC report projects that by late century, globally, pH will drop 0.3 to 0.4 units from current levels, resulting in increasingly high levels of ocean acidity.**	• **Decline/collapse of many marine species, particularly shellfish**

INCREASING RESILIENCE OF HABITATS AND LANDSCAPES THROUGH MANAGEMENT OF NON-CLIMATE STRESSORS

Land trusts and their local, state and federal partners currently address issues that affect ecosystem change and habitat degradation, such as poorly-sited development encroaching on habitats, non-point source pollution and invasive species. Reducing these **non-climate stressors** offers opportunities to increase the intrinsic resilience of ecosystems, in turn providing a greater resistance to future climate change impacts. For example, controlling habitat loss and fragmentation to conserve wildlife travel corridors and connect larger habitats could be an adaptive response reducing the future impacts of climate change on forested habitats. It is important to identify and prioritize where efforts can be enhanced today to reduce the following stressors[3]:

Changes in ecosystem structure and function caused by **invasive species** (both aquatic and terrestrial), excessive animal predation, and incidental take by humans.

Habitat fragmentation and degradation caused by chemical contaminants, disease, and human disturbances (i.e. encroaching development, impervious surfaces).

[3] For a more extensive list of stressors, please refer to the 2005 Rhode Island Comprehensive Wildlife Strategy.

Habitat loss due to lack of large contiguous protected areas, impairment of aquatic contiguity by habitat fragmentation, and disrupted plant succession.

Ineffective management and habitat restoration plans or actions resulting in **loss of critical habitat**, such as areas vital for plant succession or breeding habitat for amphibians.

Habitat degradation due to **impairment of water quality** in many habitats, particularly terrestrial wetlands, freshwater aquatic areas, marine shorelines, tidal zones, and agricultural lands.

Coastal and freshwater **water quality impairment** from erosion, sedimentation, agricultural run-off, industrial discharge, and heavy metals as well as nutrient-loading from sewage pollution (from treatment plants or individual lots).

Loss of shoreline habitat in buffer and riparian areas from development, construction of bulkheads, and hardening of the shoreline; impact of sedimentation and associated light reduction in the water column.

Table 2. Non Climate Stressors Currently Affecting Vulnerable Habitats. Source: Manomet Center for Conservation Sciences and Massachusetts Division of Fisheries and Wildlife, 2010b.

Habitat	Non-climate Stressors
Spruce-Fir Forest	• Invasive species • Pest outbreaks • Fragmentation • Periodic fire
Boreal Swamp	• Pest outbreaks • Periodic fire • Invasive species incursion
Northern Hardwood Forest	• Pest outbreaks • Invasive species • Fragmentation of habitat • White-tailed deer browsing • Periodic fire
Riparian Forest	• Water management/withdrawals • Non-point source contaminants • Invasive species • Dams
Coldwater Lakes and Ponds	• Non-point source contaminants • Invasive species • Dams and culverts
Coldwater Rivers	• Water withdrawals • Elimination of shade vegetation • Invasive species • Impervious surfaces
River Mainstems	• Water management/withdrawals • Non-point source contaminants • Invasive species
Kettle Ponds	• Change in water levels • Adverse management practices • Invasive species
Intertidal Wetlands	• Habitat loss and fragmentation • Invasive species

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APPENDIX 2: HABITATS AND ASSETS IN A VULNERABILITY ASSESSMENT

INTRODUCTION

Ecosystems and the services they provide are vital for our communities. Some habitats and ecosystem functions are more sensitive to temperature, while others are more sensitive to shifts in precipitation. However, it is important to evaluate and assess the vulnerability of each habitat type to impacts from climate change as well as non-climate stressors such as human-related habitat degradation, invasive species encroachment, and continued development.

Key Resources

The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources and Public Health

Climate Change and Massachusetts Fish and Wildlife

The land trust's overarching mission for habitat conservation forms the foundation for understanding potential climate change impacts on high-priority natural resource assets. When assessing the South Kingstown Land Trust's (SKLT) parcels and habitats (summarized in Chapter 2), the project team utilized the Massachusetts and Connecticut climate change impact reports as primary sources. Since Rhode Island shares borders, habitats and common ecosystems with both states, the SKLT case study interpolated relevant information provided by expert panels convened by Massachusetts and Connecticut. These panels included scientific and industry experts gathered to develop information on how landscapes, marine resources and economic activities might be affected by climate change scenarios. Connecticut examined its natural resource-based industries such as farming, mariculture, forestry and tourism and evaluated its landscapes from an ecological and habitat perspective. The report includes an examination of habitat climate sensitivity risks and primary climate drivers. Massachusetts conducted in-depth examinations of climate change impacts on fish and wildlife habitats, identified habitat and species vulnerability, and reviewed habitat management considerations.

This chapter provides highlights of these extensive reports which have been summarized for the habitat types found in Rhode Island. Agriculture and farmland, while not a habitat, was also included here, given its importance as an asset within the town and the land trust's mission. In addition to the potential impacts of climate change, there are suggested options for management, protection and advocacy that can be considered to help insure habitat resilience. The following assets are reviewed:

Asset 1: Lakes, ponds, cold water streams, and warm water streams
Asset 2: Bogs, fens, forested swamps, and herbaceous wetlands
Asset 3: Beaches, dunes, offshore islands, and tidal marshes
Asset 4: Terrestrial uplands, including upland forest and shrubland
Asset 5: Agriculture and farmland

ASSET 1: LAKES, PONDS, COLD WATER STREAMS, AND WARM WATER STREAMS[4]

Freshwater aquatic ecosystems include major rivers, riparian areas, cold water and warm water streams, lakes, ponds, kettle ponds and vernal pools. These important assets provide diverse habitats supporting numerous plant and animal species and providing vital ecosystem functions.

Climate Sensitivity Summary of Freshwater Aquatic Habitat

Summary of Climate Sensitivity

Freshwater aquatic ecosystems and habitats are highly vulnerable to changing temperatures and precipitation related to climate change and shifting weather patterns. Increased temperatures threaten cold water habitats such as cold water streams, ponds, lakes and their associated riparian buffers that species, such as the brook trout, depend on for survival. Shifting precipitation patterns may affect the timing of vernal pool appearance and disappearance, impacting the reproduction cycle of species such as the wood frog that rely on seasonal hydrology changes.

IMPACTS OF CLIMATE CHANGE

Cold-adapted habitats that predominantly occur in northern New England are close to the southern edge of their range in Rhode Island and are at risk from increased temperatures related to climate change and shifting global weather patterns. Climate change is likely to result in a reduction in the overall extent of cold water habitats since streams at lower elevations will be more vulnerable to temperature increases, however higher elevations can better maintain cold water habitats. Thus, these habitats are likely to shrink in size and extent rather than disappearing entirely. Protecting vulnerable cold water ecosystems is important in order to preserve habitat for sensitive cold-adapted species such as brook trout (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b).

Habitat	Sensitivity Risk (likelihood x severity)	Climate Driver
Cold Water Streams & Associated Riparian Zones	High	Temperature
Lakes, Ponds, Impoundments & Shorelines	Medium	Temperature
Major Rivers & Associated Riparian Zones	High	Precipitation
Warm Water Streams & Associated Riparian Zones	Low	Precipitation

Source: Natural Resources Workgroup, 2010

[4] The information in this section has been summarized from several documents and contextualized to Rhode Island. "Climate Change and Massachusetts Fish and Wildlife" and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health"

Aquatic systems are susceptible to impacts from flooding, including erosion of stream banks, water quality degradation and damage to aquatic habitats potentially making them unsuitable for certain species. Freshwater aquatic habitats are also highly vulnerable to drought, which is anticipated to increase in frequency and intensity during summer months under projected climate change scenarios. That being said, the Northeast trends of the past decades show dry years occurring less frequently. While low water years are critical to the preservation of the rare and endemic shore vegetation, drought conditions can cause vernal pools and kettle ponds to dry out more rapidly, negatively impacting the reproductive cycles of numerous amphibian species. More intense rain events, one of the potential impacts of climate change, are likely to cause more erosion and sedimentation along stream banks, impacting water clarity and spawning sites for native fish species. One potential result of increased precipitation and more intense rainfall events is that vernal pools may increase in size and retain water for several years in a row, enabling the introduction of fish populations that feed on amphibians, further threatening vulnerable amphibian species. Another serious risk posed to aquatic freshwater habitats is the conversion of rare habitat types, such as the transformation of cold water to warm water streams and tidal marshes to submerged lands (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b). The continued reduction in suitable freshwater aquatic habitat for climate change-threatened species will likely impact the use of public and private lands and the revenue derived from recreation such as fishing.

The effects of climate change on water supplies in Rhode Island are likely to exacerbate the threats to freshwater aquatic resources already stressed by summer low flow conditions. The Rhode Island Department of Health completed a study in the spring of 2013 that reviews these specific issues in depth. Increased societal demand for water during periods of extended warming and drought will intensify the negative impacts of climate change on freshwater aquatic ecosystems, resulting in even greater vulnerability of threatened species and habitats. However, increased absorption and retention of precipitation from storm events during the spring and summer by large intact forest and wetland systems in Rhode Island could help reduce downstream flooding impacts and minimize cost of infrastructure repair as well as contributing to replenishment of aquifer and groundwater supplies.

NON-CLIMATE STRESSORS

In addition to climate change related environmental stressors, it is important to remember that non-climate stressors also play a significant role in ecosystem changes in this habitat.

Development impacting riparian buffers.

Community shifts caused by aquatic invasive species, excessive animal predation, and human development are important non-climate related stressors.

Decreased water quality due to point and non-point source pollution can significantly degrade aquatic habitats.

Sedimentation from erosion and human disturbance because of development and road construction can make lakes and ponds shallower, which in turn affects water temperatures.

Habitat fragmentation and degradation caused by chemical contaminants, diseases, and human disturbances such as development, road construction, and runoff.

MANAGEMENT AND PROTECTION ACTIONS RELATED TO FRESHWATER AQUATIC HABITATS

The particular vulnerabilities of each habitat or ecosystem type must be taken into consideration when designing effective management and protection action plans. Preserving riparian buffers, habitat connectivity, and cold water streams are primary management goals in freshwater aquatic ecosystems.

MANAGEMENT

- Identify ways to maintain cool water temperatures in streams and ponds so that species adapted to cool temperatures are able to survive.
- Evaluate options for dam removal or fish ladders so that anadromous fish such as salmon can reach cooler water to spawn, aiding in restoration efforts. Local species of interest for restoration include shad, alewife, smelt, sea run brook trout, sturgeon, and white perch.
- Identify and protect remaining critical cold water fish habitat areas and seek to reconnect high quality habitats by removing in-stream barriers and re-establishing in-stream flows.
- Maintain and expand riparian vegetated buffer areas so runoff from impervious surfaces has the opportunity to cool down and have some pollutants removed before entering cold water streams and ponds.
- Encourage application of geotextiles and bioengineering techniques for erosion control and stream stability, such as placing geotextiles in or next to streams.
- Control aquatic invasive species through more active monitoring efforts, aggressive elimination and control activities, boater education and boat inspections in infested areas.
- Control and seek to minimize non-climate stressor impacts including pollution from non-point sources and impervious surface runoff.

PROTECTION

1. Identify and protect climate refugia, areas and systems that are more resilient to climate change or which allow habitats such as wetlands to migrate as sea level rises or flood plains are modified.
2. Protect naturally connected waters in order to maintain natural flow patterns.
3. Target land acquisition and conservation restrictions to protection of vulnerable intermittent headwater streams and their buffer areas; acquisition could be supplemented by stream easements in order to preserve riparian zones and ensure adequate shading of cold water streams.

ADVOCACY AND OUTREACH

1. Increase vegetative buffers and prohibit building of impervious surfaces close to cold water streams and rivers.
2. Promote education on the transportation of aquatic invasive species by boats to different water bodies.

ASSET 2: BOGS, FENS, FORESTED SWAMPS, AND HERBACEOUS WETLANDS[5]

Freshwater wetlands include a wide variety of aquatic habitats such as bogs, fens, forested swamps, and herbaceous wetlands. These areas require a natural supply of water from ponds, streams or rivers, connections with groundwater, or rainfall. At the boundary between land and water they provide vital ecosystem services including water purification with the trapping sediments and excess nutrients, flood protection by holding excess runoff, and fish and wildlife habitat for breeding and foraging of local and migratory species.

Summary of Climate Sensitivity

The greatest climate change-related threats to bogs, fens, forested swamps, and herbaceous wetlands come from potential changes in precipitation patterns, increasing vulnerability to invasive species, and habitat shifts due to both. Although wetland communities and systems will persist under future climate change-affected conditions, the species composition of these habitats is likely to vary under a changed future climate.

Forested wetlands in Rhode Island include: (1) deciduous forested wetlands, the majority of which are red maple swamps; (2) coniferous forested wetlands, dominated by Atlantic white cedar, white pine, or hemlock; and (3) mixed forested wetlands of deciduous and coniferous trees.

Herbaceous wetlands are dominated by non-persistent grasses, sedges, rushes, and other grass-like plants with minimal representation by woody trees or shrubs. In Rhode Island, shallow and deep marshes typically occur along the margins of pond basins primarily near the coast, and range inland along the floodplains of major river systems. Herbaceous wetland types are typically distinguished by the wetland's substrate. Marshes and pond shores generally occur on mineral soil or bedrock, whereas bogs and fens develop on peat-based substrates (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b). Emergent wetlands include some of the more unique wetland communities in the state but most are very small (less than 25 acres). As such, emergent wetlands tend to be widespread but account for only 3% of the state's freshwater wetlands.

Both **bogs and fens** have a variably thick layer of sphagnum peat that supports a vascular plant community dominated by herbaceous species. Bogs receive water primarily from direct rainfall, with little or no influence of groundwater or runoff. Peat mosses can form a nearly continuous carpet across the bog surface, which in deeper basins results in the characteristic "quaking bog" condition. Fens also receive and accumulate rainfall but are principally fed by groundwater or surface drainage. Consequently, there is a slow but constant influx of water and nutrients into the system, thus supporting a richer plant community (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b).

IMPACTS OF CLIMATE CHANGE

Modeling of regional climate change suggests precipitation levels in the Northeast will increase, mostly as rain in the winter months. Models also indicate that the summer months may be characterized by rising temperatures, greater evaporation and evapotranspiration, and little or no increase in precipitation. This could lead to seasonal

[5] The information in this section has been summarized from several documents and contextualized to Rhode Island. "Climate Change and Massachusetts Fish and Wildlife" and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health"

drying of wetland soils. Potential increases in the frequency and severity of summer droughts could have adverse impacts on wetland habitat types, at least at lower elevations, as the soils dry out and the water table is lowered. This could result in greater vulnerability to invasion by vegetation better adapted to drier habitats (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b).

Vulnerable habitats include shrub swamps, hardwood swamps, and riparian forests. The distributions of each of these habitats may be impacted by changes in precipitation patterns and temperatures. Warmer winter temperatures may also negatively impact the growth of blueberries, which are an important component of shrub swamp and bog habitats, thus a shift in species composition in these habitats may occur (Natural Resources Workgroup of the Adaptation Subcommittee, 2010).

Predicting the fate of herbaceous and forested wetland habitats under climate change is beset with uncertainties for several reasons.

Our ability to confidently project changes in precipitation and soil moisture regimes using general circulation models is far less certain than predicting temperature changes.

Human actions and non-climate stressors have the potential to modify the likely outcomes under climate change conditions. One of the effects associated with increasing human population density and sprawling settlement patterns could be a greater need for fresh water, the concomitant depletion of aquifers and increased water diversions as well as continued changing drainage patterns from roads and paved areas. Such non-climate stressors could result in the drying out of existing swamp areas and adversely impact this habitat type.

While all habitats are vulnerable to climate and non-climate stressors to varying degrees, terrestrial wetlands are particularly sensitive to changes in hydrology. In addition to the changes brought through climate shifts, population growth patterns and development practices also have a significant impact on hydrological flows, impacting these habitats to a great extent and making them less resilient.

Climate Sensitivity Summary of Terrestrial Wetlands

Habitat	Sensitivity Risk (likelihood x severity)	Climate Driver
Bogs and Fens	Low	Precipitation
Forested Swamps	High	Precipitation/ Temperature
Herbaceous Freshwater Wetlands	High	Precipitation

Source: Natural Resources Workgroup, 2010

The most important climate change factors that might affect the distribution of forested swamps would be shifts in precipitation patterns and rising temperatures. As with other forested habitats, the rising temperatures could be accompanied by an increased risk of fire and insect attack (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b). Vulnerability also exists to blowdown during increasingly frequent and severe windstorms as this is a shallow-rooted community. Warmer temperatures may also enhance

the survival of insect pests resulting in more outbreaks over extended areas. Colonization by invasive plants facilitated by increased temperatures could also have adverse impacts on the extent and distribution of this habitat type.

Although this habitat is vulnerable to blowdown from severe windstorms, this may not necessarily be a negative impact for forested wetlands. Herbaceous wetlands have declined leading to a decrease in habitat for Rhode Island's rare orchid species, such as the Dragon's Mouth, the Northern Coral-root, and the Showy Orchis orchid. Disturbances from blowdowns may have a positive impact by opening up pockets in the forest canopy and allowing for the growth of herbaceous species leading to an increase in vegetation diversity.

White cedar swamps need saturated peat soils and standing water to survive. The ability of cedar swamps to exist in areas with markedly warmer temperature regimes (i.e. Florida and the Gulf Coast) makes it unlikely that increased temperatures will adversely affect the distribution of this habitat type in Rhode Island. It is possible that rising temperatures could actually benefit this habitat. The most important climatic factors that might affect the distribution of white cedar swamps will be those that have adverse impacts on hydrology. It is likely that most Atlantic white cedar habitat will respond to climate change by retreating inward to areas in the centers of swamps with higher water tables, rather than by disappearing entirely. Some swamps in more marginal hydrologic circumstances may be eliminated; however, these are likely to be in the minority.

Atlantic white cedar swamp is a disturbance-adapted community (particularly to fire), and it is possible that its future status and distribution may be a result of human responses to climate change rather than to temperature or precipitation change. As fire suppression efforts increase, the vulnerability scores assigned to this habitat type will be higher. Without fire, red maples may become established in white cedar habitat, changing the soil acidity and therefore making it vulnerable to changes that may lead to the establishment of a hardwood swamp (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b). A key threat to white cedar swamps may be red maple infiltration rather than the effects of climate change, however one management strategy under climate change may be to ensure that suitable fire regimes are maintained where allowed.

The main risk to shrub swamp wetlands is likely to be due to changes in hydrology from climate and non-climate factors. These changes could result in alterations in the extent of this habitat. In some areas there could be a net loss of habitat; in others the effect could be that the shrub swamp will retreat inward toward more saturated soils and areas where the water table is closer to the soil surface. If the shrub swamps surround open water habitat or emergent swamps they could move inward, replacing those habitats as the overall wetland dries. In such cases there may be relatively little shrub swamp habitat loss. Indeed, it is possible that there could be a net habitat gain. Local topography and hydrology will be of paramount importance and generalizing impacts to this habitat is difficult.

The main risk posed by climate change to **herbaceous wetland** communities is likely to be due to changes in hydrology. These changes may result in loss of wetland habitat as the upper areas of marshes dry out during the summer months and the vegetation is eventually replaced by wetland tree species (i.e. red maple) or upland species. The effect of this could be that the marshes will retreat inward toward deeper or more reliable water sources. Smaller, less well-watered marshes may be entirely replaced by upland vegetation while larger marshes could become fragmented and reduced in area. Further establishment of invasive plant species is likely to be another climate change-related impact on emergent marshes. Three invasive species that are currently having the greatest adverse effects on freshwater marshes, purple loosestrife, *phragmites*, and Japanese knotweed, are highly tolerant of seasonal soil drying and drought – more so than most native species. Seasonal drying of marsh soils and drought is likely to increase the competitive advantage of these species over native vegetation and result in further loss of native habitat.

NON-CLIMATE STRESSORS

Terrestrial wetlands are particularly vulnerable to numerous stressors including flooding of Atlantic white cedar stands by beaver activity, hydrologic changes, loss of breeding habitat for amphibians, and disruption of water way continuity caused by human development.

MANAGEMENT AND PROTECTION ACTIONS RELATED TO BOGS, FENS, FORESTED SWAMPS, AND HERBACEOUS WETLANDS

MANAGEMENT

3. Maintain or improve habitat quality and, correspondingly, the resilience of wetland habitats to changing conditions.
4. Promote riparian zone and floodplain management, restoration and preservation by removing restrictions between rivers and floodplains, removing dams, and integrating brownfields remediation projects with floodplain restoration; riparian buffers and dam removal can also benefit down-stream water bodies. Climate change projections predict an increase in more intense storms resulting in more floods, thus actions focused on flood reduction and floodplain management may be a high priority.

PROTECTION

1. It is essential to preserve areas and buffers that are not yet impacted by human development. As impacts of climate change increase species may depend on large undeveloped areas for survival.
2. Identify and protect resilient wetland ecosystems; focus land protection on large areas with high ecological integrity and functionally healthy wetland complexes that have higher resiliency over time.
1. Identify and prioritize protection of migration corridors between wetland areas and between wetlands and associated upland habitats including large resilient parcels connected by migration corridors. Larger parcels of habitat will be more resilient to impacts from climate change and thus may provide a refuge for plant and animal species when they are pressured by climate-related stressors.
2. Use LiDAR and other data to identify important wetland areas and ensure that a variety of wetland types are represented in land protection planning in order to make habitats more resilient to climate change.
3. Protect inland wetlands for floodwater storage. Continued protection of floodplains and stream buffers is also an important feature of a comprehensive Low Impact Development (LID) strategy to protect the environment and property under current and future conditions.
4. Maintain floodplains as undeveloped areas, especially preventing high-risk development that may experience more flooding with increased storminess.

ADVOCACY AND OUTREACH

1. Encourage the passage of state regulations (with supporting local level zoning and planning ordinances) and use of other tools to strengthen protection of isolated vegetated wetlands that are most vulnerable to climate change.
2. Promote restoration of floodplains and wetlands for floodwater storage with expansion, where feasible, for larger floods in the future.
3. Promote the increase of vegetated buffers to reduce non-climate stressors such as non-point source pollution and runoff from impervious surfaces.

ASSET 3: BEACHES, DUNES, OFFSHORE ISLANDS, AND TIDAL MARSHES[6]

Beaches, dunes, islands and marshes line Rhode Island's 400 mile shoreline. From urban marshes to undeveloped beaches, the shoreline is subject to changes, both natural and human-caused. These coastal features provide numerous benefits to the Ocean State, including tourism, recreation, fish and wildlife habitat, and storm buffers.

Summary of Climate Sensitivity

Beaches, dunes, offshore islands, and tidal marshes are very sensitive to the impacts of sea level rise, inundation and erosion. As sea level increases, certain habitats may convert to adjacent forms (intertidal flats become sub-tidal, freshwater marsh becomes brackish or salt marsh). Tidal marshes will come under increasing stress with sea level rise; if the upland areas are developed or unsuitable for marshes to migrate then marshes will be lost. If the rate of sea level rise is too rapid or sediment sources are cut off, accretion on the marsh may not be able to keep up with the change. Beaches and dunes are vulnerable to storm surge inundation and erosion associated with increased storm intensity, causing changes in profile that may impact their role as natural protection for the back shore area.

HABITAT VULNERABILITY: IMPACTS OF CLIMATE CHANGE

Tidal marshes, beaches and dunes are already under great stress from human development and activity. Climate change is an added stressor with potential for greater impacts. **Intertidal habitats** appear to be highly sensitive to even relatively modest sea level rise scenarios. The long-term effects of sea level rise may result in the conversion of habitat types. These changes are projected to increase in magnitude under higher sea level rise scenarios, where Rhode Island may experience 3-5 feet of sea level rise by 2100. Different habitat types are projected to have varying rates of change with some expanding in extent and others shrinking. It is likely that in the absence of human intervention, land that is currently intertidal will become sub-tidal as sea levels rises, resulting in an increase in open water and loss of tidal flats. Salt marshes could move inland replacing brackish marshes as inundation and salinity gradients shift landward. There are also indications that sea level rise could result in a conversion of salt marsh to open water where rising sea level rapidly alters marsh drainage patterns and the rate of sea level rise outpaces marsh accretion rates (Manomet Center for Conservation Sciences & Massachusetts Division of Fisheries and Wildlife, 2010b).

Beaches and dunes on coastal barriers naturally move landward (if unimpeded by development) as sea level rise and storms cause overwash of sediments. These areas are highly susceptible to erosion and may be more significantly impacted as the frequency and intensity of storms increase. This would further impact a number of State and Federally threatened plant, bird and turtle species in Rhode Island, as well as the economic and recreational value of the state's beaches. Beachfront development will be more susceptible to damage as erosion increases.

Salt marsh migration landward may occur if development does not impede it. A statewide assessment using the Sea Level Affecting Marsh Migration (SLAMM) Model is underway and will highlight areas of opportunity and conflict for salt marsh migration.

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[6]The information in this section has been summarized from several documents and contextualized to Rhode Island. "Climate Change and Massachusetts Fish and Wildlife" and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health"

Climate Sensitivity Summary of Marine Aquatic Habitats		
Habitat	**Sensitivity Risk (likelihood x severity)**	**Climate Driver**
Open Water Marine	High	Temperature
Intertidal Flats and Shores	High	Sea Level Rise
Subtidal Aquatic Beds	High	Sea Level Rise
Beaches and Dunes	High	Sea Level Rise
Offshore Islands	High	Sea Level Rise
Tidal Marsh	High	Sea Level Rise

Source: Natural Resources Workgroup, 2010.

NON-CLIMATE STRESSORS

While beaches, dunes and marshes receive a high degree of protection in Rhode Island through state and local regulation, much of the shoreline is highly developed with residential and commercial uses abutting the natural features. Human activities such as construction of shoreline protection structures, impervious surfaces, and critical infrastructure often affect natural processes needed for healthy ecosystems, such as salt marsh growth, erosion for longshore beach health, or landward migration of coastal barriers.

MANAGEMENT AND PROTECTION ACTIONS RELATED TO MARINE AQUATIC HABITATS

MANAGEMENT

1. Explore mechanisms that proactively address migrating salt marshes (caused by sea level rise); consider utilizing rolling easements that facilitate marsh and/or beach migration inland as sea level rises. Prioritize protection of suitable upland habitats for future salt marsh locations.
2. Identify, assess, and remove existing impediments (i.e. seawalls) to future inland migration of coastal salt marshes.
3. Establish policy and procedures for post-storm restoration that minimizes sand removal from barriers where sand overwash should be allowed to be maintained for landward barrier migration.

PROTECTION

1. Identify and protect undeveloped areas and/or freshwater wetlands that are up-gradient from saltmarsh wetlands to allow wetland migration and buffer intact ecosystems.
2. Using high-resolution elevation models (based on LiDAR data), identify and prioritize protection of areas that may become wetlands in the future as sea levels rise.
3. Protect undeveloped barrier systems (dunes, beach, and marsh) and allow their natural move landward with storm processes, for example overwash and erosion.

ADVOCACY AND OUTREACH

1. Work with town, state and federal partners to identify priority properties for acquisition after a damaging hurricane or storm. Develop a dedicated fund and process for accessing funds for post-disaster acquisition of destroyed waterfront and coastal properties.

ASSET 4: TERRESTRIAL UPLANDS, INCLUDING UPLAND FOREST AND SHRUBLANDS[7]

Given its high population density, Rhode Island's quality of life depends on healthy forests which support critical wildlife habitats, clean water supplies, recreational opportunities and other services for people, plants, and animals. While **upland forests** covered approximately 46% of Rhode Island's land in 2010, there has been a steady decline over the past half century as development pressures have led to habitat fragmentation and loss of forest land.

Summary of Climate Sensitivity

Some cold-adapted species and the communities they support may not be able to survive higher temperatures associated with climate change, resulting in species shifts and habitat changes. Variable patterns of precipitation will also affect terrestrial uplands, impacting habitats vital for the survival of numerous plant and animal species. Temperature increases favor invasive pests such as the wooly adelgid which have a large impact on hemlocks. Changing climate conditions may also increase incidences of non-native fungal pathogens, further endangering native tree species.

IMPACTS OF CLIMATE CHANGE

While not extensive, cold-adapted habitats that are predominantly located in northern and western parts of the state and are close to the southern edge of their ranges may experience large-scale habitat contractions. In the next few decades, maple syrup production should be able to hold its own, particularly as the demand for locally produced food becomes more fully established. However, over the longer term as regeneration of sugar maples begins to fail due to climatic changes, the resource upon which this industry is based will begin to decline. There is evidence that indicates maple syrup production in this region will be one of the agricultural features impacted. It is possible that maple syrup production in Rhode Island and Connecticut may even be impossible by 2080, particularly at lower elevations, due to predicted increases in temperature (Natural Resources Working Group of the Adaptation Subcommittee to the Governor, 2010). These temperature changes are expected to increase particularly in late winter and early spring, which would erase the dichotomy of warm days and freezing nights that are necessary to induce sap flow.

Habitats that are less sensitive to potential climate change impacts include pitch pine-scrub oak communities and oak-hickory forests, the major types of forest in Rhode Island (RIDEM Division of Fish & Wildlife, 2005). The distribution of each of these habitats extends further south than Rhode Island and they are thus not likely to be as limited by the expected temperature changes.

Climate Sensitivity Summary of Terrestrial Uplands

Habitat	Sensitivity Risk (likelihood x severity)	Climate Driver
Coastal Uplands	Low	Temperature
Early Successional Shrub lands /Forests	Low	Precipitation
Upland Forest Complex	Medium	Temperature

[7] The information in this section has been summarized from several documents and contextualized to Rhode Island. "Climate Change and Massachusetts Fish and Wildlife" and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health"

Source: Natural Resources Workgroup, 2010.

Pitch pine-scrub oak forests occur in significantly warmer climates such as New Jersey and Maryland. If the only determinant of this habitat's distribution were climate, it is likely that its distribution would extend under a warming climate. However, non-climatic factors, mainly the distribution of sandy, nutrient-poor soils, fire frequency, and development are also important factors. These are likely to be the primary limiting factors in any future spread of pitch pine barrens, not climate change.

Central-southern hardwoods habitat including species such as oak, hickory, tulip trees, and ash might be expected to extend its range further northward and to higher elevations as the climate changes, replacing the northern hardwoods forest. Uncertainties exist regarding how this community type might be affected by climate-related and non-climate factors. If more frequent or more intense fires are a consequence of warming temperature, droughts, and desiccation of soils, then the potential spread of this habitat could be limited. Its range is also currently limited by soil type as it is found mainly on coarse, well-drained soils. This could limit its spread into areas with finer soils or higher rainfall.

Discussions concerning the impact of climate change on upland forests do not necessarily predict how it will affect the forest products industry – it is only possible to predict what trees might be available in the future for the timber industry to use (Natural Resources Working Group of the Adaptation Subcommittee to the Governor's Steering Committee on Climate Change, 2010). With a warming climate the competitive advantage is likely to shift to the more southerly oak-hickory mix, necessitating a shift in Rhode Island's timber industry which is currently composed of predominantly white pine and mixed oak. At the same time, storms and other weather extremes may cause increased tree mortality. A consequence of these disturbances will be an accelerated transition of the forest to new species and conditions. Increased wood volume and storm-damaged trees (as salvage after past storms has shown) will provide market opportunities for those who harvest timber (Natural Resources Working Group of the Adaptation Subcommittee to the Governor, 2010).

NON-CLIMATE STRESSORS

Upland forests are affected by suburbanization, the forest products industry, invasive species, forest patch fragmentation and loss of habitat connectivity as well as the process of plant succession. Increased browsing by white-tailed deer also negatively impacts forest regeneration and understory and herbaceous cover, thus creating niches for colonization by invasive plant species. In order to address this issue, careful management of deer populations is an important facet of forest management. Forests in Rhode Island also face increasing threats from invasive pest species such as the emerald ash borer and the Asian long-horn beetle which can cause extensive damage to native tree species. Although neither of these species is currently present in Rhode Island, they can be found in both Massachusetts and Connecticut.

MANAGEMENT AND PROTECTION ACTIONS RELATED TO TERRESTRIAL UPLAND HABITAT

MANAGEMENT

1. Reduce over-browsing by white-tailed deer by controlling deer populations in order to protect regeneration of habitats; delays in regeneration reduce the ability of the forest ecosystem to function consistently over time.
2. Manage invasive species; launch an initiative to remove invasives from large unfragmented forest blocks on protected (private, state, federal) land in collaboration with partners.

3. Track and eliminate invasives and pests; where feasible transplant preferred native species to restore areas with invasives.
4. Manage resilience across a maturing forest landscape by identifying structurally diverse and species-rich areas of mature forest for retention and regenerating more homogeneous areas of second-growth trees to young forest habitat through timber sales.
5. Identify forest types likely to be most vulnerable to climate change and prioritize practices that may reduce impacts on ecosystem value and functions.

Promote forest reserve management practices that allow natural processes to determine the long-term structure, composition, function, and dynamics of the forest to the maximum extent possible.

Manage ecosystem change by selective cutting, introductions of preferred climate-resilient species, and control of non-climate stressors such as invasive species.

Explore opportunities to enhance carbon sequestration in forests.

Consider restoring habitats with plant species that are more resilient to future conditions of change.

PROTECTION

1. Improve buffering to safeguard core, high-quality habitats so that they may provide a refuge for plant and animal species experiencing pressure from climate and non-climate stressors.
2. Identify and preserve habitat movement corridors and improve habitat connectivity to facilitate movement of organisms displaced by human development or climate change-related stressors.
3. Protect large unfragmented forest blocks of habitat to provide refuges for displaced plant and animal species.
4. Maintain ecological function over long periods by managing forest reserves that are large, minimally fragmented, and representative of varied ecological settings that include forest biodiversity.

ADVOCACY AND OUTREACH

1. Provide foresters with information and support services concerning how climate change may disturb forests and impact strategies for keeping forests viable.
2. Conduct outreach and education on water and land conservation practices and the changes expected to come with a warming world.
3. Add state tax incentives to keep forests as forests, such as a state tax credit for the cost of professionally prepared forest management plans.

ASSET 5: AGRICULTURE AND FARMLAND[8]

Agricultural grasslands provide a unique habitat type that supports a distinct assemblage of field-nesting birds and a diverse invertebrate community. Although the origin and history of this habitat type in southern New England before European settlement is conjectural, the conversion of most of Rhode Island to agriculture by 1850 created significant acreages of grassland habitat, and consequently increased the prevalence of grassland-adapted species (RIDEM Division of Fish & Wildlife, 2005). However, unlike the natural prairies and grasslands found elsewhere in the Northeast, most of the habitats in Rhode Island used by grassland species are artificial (Askins, 1997). Preserving and increasing the amount of agricultural and farmland is a high priority in Rhode Island that has various benefits, including protection of open space green corridors for species movement and as part of a growing economic industry and the local food movement.

Summary of Climate Sensitivity

Agricultural grasslands and farmlands are sensitive to impacts of climate change, especially changing patterns of precipitation combined with increase in temperature. Although warmer temperatures may have some benefits for agriculture, predictions indicate that the negative impacts (including drought during growing season) will far outweigh the positive aspects of climate change. In addition to impacting the cropland itself, climate change-related effects will have a significant impact on the economic aspect of agriculture in Rhode Island.

IMPACTS OF CLIMATE CHANGE

Although agriculture is not a mainstay of Rhode Island's economy, it is still an important and growing sector that will experience increased pressure from the impacts of a changing climate and is a focus of land trust preservation activities in many communities. Shifting climactic patterns resulting in warmer overall temperatures and potentially varying precipitation patterns will affect the growing season, resulting in positive impacts for some agricultural products and the decrease or demise of others. Crops and products that depend on cooler weather and cold winters, such as maple syrup and dairy production, will have difficulty adapting to the warmer temperatures and may be unable to survive Rhode Island's new climate. Individuals and organizations focused on preserving agriculture and farmland must take into consideration the impacts of climate change on local agricultural products.

Cropland near shorelines is in danger of direct loss due to erosion and coastal flooding. There is also the possibility of decreased cropland and freshwater quality due to saltwater intrusion and rising groundwater levels. Although higher carbon dioxide concentrations will increase photosynthesis in plants up to a certain peak temperature (±85 degrees Fahrenheit) resulting in higher production from some plants, it will also lead to greater growth of invasive plants and weeds. For example, higher carbon dioxide levels will also result in increased poison ivy growth with more concentrated toxins.

[8] The information in this section has been summarized from several documents and contextualized to Rhode Island. "Climate Change and Massachusetts Fish and Wildlife" and "The Impacts of Climate Change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health".

Rhode Island's **nurseries** are also likely to experience both negative and positive impacts from climate change. Greenhouse production will be mostly unaffected by climate change. However, hotter summers with less precipitation could negatively affect irrigation if periods of drought lead to water shortages. Conversely, warmer winter temperatures could decrease winter heating costs while increased carbon dioxide levels could increase plant growth. Outside production of trees, shrubs, and herbaceous plants will be impacted to a greater degree by climate change than greenhouse production. Changes in precipitation pose the greatest risks to outside production. Predicted increases in winter precipitation could positively impact production, however many nursery plants do not grow well in saturated soils so too much rain in short periods of time can damage or kill plants. Increases in the number of extreme weather events such as hail, strong winds, and heavy rainfalls could also damage plants and leave them more vulnerable to pests and diseases (Natural Resources Working Group of the Adaptation Subcommittee to the Governor's Steering Committee on Climate Change, 2010).

There is the potential that a longer growing season, warmer winters, and a relative abundance of precipitation may enhance Rhode Island's value as an agricultural area in spite of the increased threat from pests, pathogens and disease. Although future predictions indicate increased precipitation, it is possible that rain will fall less frequently in larger quantities leading to periodic droughts interspersed with flooding, resulting in erosion of valuable topsoil and destruction of crops. Increased precipitation could also result in delayed planting and harvesting and diminished yields or crop failure due to root rot. Such changes in precipitation may also cause changes in the type and number of pests, pathogens, and diseases, leading to increased need for pesticides and herbicides that can runoff and leach into the soil and groundwater, polluting the ecosystem. Increased run-off of nutrients from fertilizer would also diminish the quality of shellfish beds due to pollution from nitrogen loading.

Drought is another potential impact of climate change that would have a tremendous impact on agriculture in Rhode Island. Decreased or infrequent precipitation during summer months will increase water needs for animals, crops, and greenhouse irrigation, leading to increased costs for farms. Existing agricultural infrastructure would need to be altered to meet greater irrigation demands, leading to competition for water resources with other users.

Changes in the timing and intensity of storms will also increase the risk to farmers, leading to more dependence on crop insurance. Heavy rains resulting in flooding would lead to immediate crop loss while hurricanes would cause damage from high winds and flooding, resulting in crop loss, damage to fruit trees, and destruction of infrastructure. Damaged crops are more susceptible to fungal and bacterial infections as well as diseases and pests, potentially leading to even greater crop loss.

Warmer winters may result in new and increased numbers of pests, pathogens and diseases that are currently unable to survive the cold winters typical in Rhode Island. Likewise, the longer growing season would necessitate the use of more pesticides and herbicides to control increased levels of pests and weeds. However, there are also potential opportunities for production expansion, including biofuel crops and crops adapted to warmer climates.

Climate change may also have a significant negative impact on the **dairy industry** in Rhode Island. The primary climate driver for dairy is temperature; more frequent higher daytime temperatures and the absence of nighttime cooling will cause more stress to dairy cows, causing depression of appetite, reduced lactation and decreased calving resulting from reproductive issues. The stress of increased temperature will lead to long-term poor animal health and reduced herd size and income potential. Higher temperatures will also increase energy demands from fans and water-cooling required keeping dairy cows cool during hotter summer temperatures. Decreased precipitation during the hottest summer months will further stress dairy cows and dairy farming operations. Feed production for dairy cows will be affected by projected changes in precipitation. Increased rain could decrease the

quality and quantity of production, especially for hay, by impacting harvest timing while land in corn silage may be subject to increased erosion and pest and irrigation issues (Natural Resources Working Group of the Adaptation Subcommittee to the Governor's Steering Committee on Climate Change, 2010).

Rhode Island agricultural grasslands are widely scattered throughout the state, although most are concentrated in coastal communities. Impacts to agriculture (from climate and non-climate stressors) result in an accompanying decline in habitat quality for grassland-dependent species, several of which are listed as State Endangered and Threatened (northern harrier, barn owl, upland sandpiper, and grasshopper sparrow) which are most prevalent on Block Island (RIDEM Division of Fish & Wildlife, 2005).

NON-CLIMATE STRESSORS

Agricultural land and habitat is affected by suburbanization as it is often the easiest land to develop. These lands are also subject to plant succession as nature tries to reclaim the once-forested landscape.

MANAGEMENT AND PROTECTION ACTIONS RELATED TO AGRICULTURAL LANDS

MANAGEMENT

1. Increase efforts to monitor the use of pesticides in the environment as extensive use of pesticides degrades water quality and wetland habitats.
2. Increase organic matter on farms in order to reduce erosion, flooding, and water contamination resulting from more intense storms.
3. Review crop planting to accommodate extended growing seasons as feasible; potential increases in temperature and summer drought conditions should also be taken into consideration when selecting resilient crops.
4. Seek implementation of alternative irrigation practices and install water conservation practices to reduce vulnerability to water supply fluctuations.
5. Encourage adoption of best management practices to control runoff of pesticides, nutrients, or fertilizers, and soil, which contribute to poor water quality, degrading wetland and aquatic habitats and decreasing these habitats' resilience to climate change.
6. Escalate pest monitoring efforts in order to most effectively manage invasive pests.
7. Investigate use of pest controls for changing climate conditions; use integrated pest management.
8. Shift to alternative varieties or products that are more tolerant of our changing climate.

PROTECTION

1. Protect and maintain riparian buffers near agricultural lands.
2. Target properties with good soils for agricultural uses for protective acquisition.

ADVOCACY AND OUTREACH

1. Promote the concept of "buy local".
2. Facilitate research on crop adaptation and diversity for future climates.
3. Evaluate the benefits of modifying development and zoning priorities to increase access to places to purchase fresh food and engage in healthy living activities.
4. Promote and provide technical and financial support for small-scale farming; work with farmers to buy development rights to continue farming, or lease farmers land for relatively little.

5. Consider providing personnel and/or funding to monitor for new insects or weeds that are likely to expand their range into Rhode Island.
6. Promote urban/community gardening efforts within the community and/or on Land Trust parcels.

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APPENDIX 3: ECOLOGICAL LAND UNITS (ELUS) – A NEW STRATEGY FOR ACHIEVING CONSERVATION GOALS

Protection of native flora and fauna is one of the central goals of most conservation organizations, and land trusts play an important role in accomplishing this goal at the local level. This includes acquisition and conservation of sites that contain rare and endangered species and protection of habitats or landscapes that are known to be important for plants and animals. Over the long term, ecosystems change due to both natural and human-caused phenomena and stresses. Natural causes of change include disturbances such as fire, flood, drought, wind, diseases, pathogens and changes brought about by the arrival of new species or the loss of keystone species. Land clearing and development, watershed and hydrology modifications, transportation and energy corridors, increased impervious surfaces and introduction of invasive plant species are among the direct stresses on ecosystems caused by human activity.

This poses a challenge for conservationists: how can they protect habitats for plants and animals when the composition of the ecological communities will be rapidly changing over the next century? The identification and protection of *ecological land units* (ELUs) can help the conservation community assess the potential value of "the stage" to ensure that we will be able to maintain rich communities of native plants and animals as climate change effects manifest themselves (Anderson et al., 2010). Landscapes with a large variety of species tend to be more resilient to disturbances and are able to continue delivering important ecosystem services.

Protecting "The Stage"

Mark Anderson, regional scientist for The Nature Conservancy, argues that it is difficult to protect the specific "actors" (i.e., the plants and animals) because we do not know who they will be as climate change effects occur, but we can protect the "stage" (i.e., the physical habitat) on which they will thrive. Find out more at the URI-EDC website: http://www.edc.uri.edu/elu/.

Other criteria also inform conservation decisions such as the size and connectedness of protected lands and the mission and goals of individual land trusts and conservation organizations. The number and diversity of ELUs which can be found in a candidate site is one of many important factors to consider.

ECOLOGICAL LAND UNITS DEFINED

Ecological Land Units (ELUs), a concept developed by The Nature Conservancy, are areas on the landscape with unique physical properties based on soil characteristics and topography. ELUs provide an ecological setting for plant communities. Areas with many different ELUs often have diverse plant and animal communities and show high levels of biodiversity. Therefore, ELUs help identify landscapes that will support high future biodiversity as plant communities shift in response to climate change.

Many factors determine which species of plants and animals live in an area. For animals, the variety and species of plants in an area are important components of "habitat." For plants, the physical properties of a site frequently determine the suitability of the area for supporting specific species. Critical physical properties are elevation, slope, aspect, geology, soils, and hydrology, information that is already available to conservationists and the general public through the Rhode Island Geographic Information System (RIGIS) website. For example, some species of plants such as pitch pines (*Pinus rigida*) thrive in gravelly, well-drained soils, in dry landscapes whereas other species, such as red maple (*Acer rubrum*), prefer moist, highly organic soils in poorly-drained locations. The

land use and disturbance history of a site are also very important and can, in some cases, be the most important factors in determining the richness of biodiversity. This is particularly true when land use destroys habitat, alters hydrology, or replaces natural vegetation with impervious surfaces.

Research by many scientists confirms that there is a strong positive relationship between the diversity of physical characteristics on the landscape and the variety of plants that may be found in a particular location. This relationship occurs at site-level scales (5 acre study plots) and larger landscape scales that may contain tens and hundreds of acres and even whole states.

The relationship between physical diversity and ecological diversity has important relevance to the conservation community – protected lands that are highly variable with respect to physical properties will likely support diverse communities of plants and animals as the climate changes. Therefore, the identification of areas on the landscape that are physically diverse may be important targets for conservationists because they are likely to support high biodiversity in the future as climactic conditions change.

The information below summarizes how the ELUs are defined and identified, using examples from the municipality of South Kingstown. More detailed information can be found on the ELU website hosted by the Environmental Data Center at the University of Rhode Island. This interactive web site contains maps, data, and on-line mapping tools for using ELUs in conservation planning.

COMPONENTS OF ELUS AND THEIR REPRESENTATION ON MAPS

ELUs are derived from soil and elevation data using GIS. Identification of Rhode Island's ELUs was kept as simple as possible and performed using only readily available data. After consulting the published literature and conferring with expert soil scientists and plant ecologists, the EDC and TNC focused on two aspects of soils: soil drainage class and soil texture. Soil drainage class is very good at distinguishing wet versus dry habitats. Soil texture (sandy, silty, loamy, etc.) is an important habitat component for plants. Using soils information from the US Department of Agriculture it is possible to prepare electronic maps of different soil drainage and soil texture classes.

Landform represents where a location is with respect to elevation, slope, and aspect (direction a hillside is facing). Landform distinguishes hilltops, hill sides, valley bottoms, etc. Elevation data and GIS modeling were used to measure and map landform. The electronic maps of landform, soil drainage, and soil texture were combined to create ELU maps.

The ELU planning class is calculated by counting how many ELUs are located within a circle with a radius of 1500 feet. The classes vary from "above average" to "best" with the "best" planning classes having the most ELU diversity. The ELUs are not confined to a particular part of the town, and include the coastal zone, flood plains, streams and uplands. The map in Figure 2 shows how many of the highest priority ELU classes are already protected by SKLT.

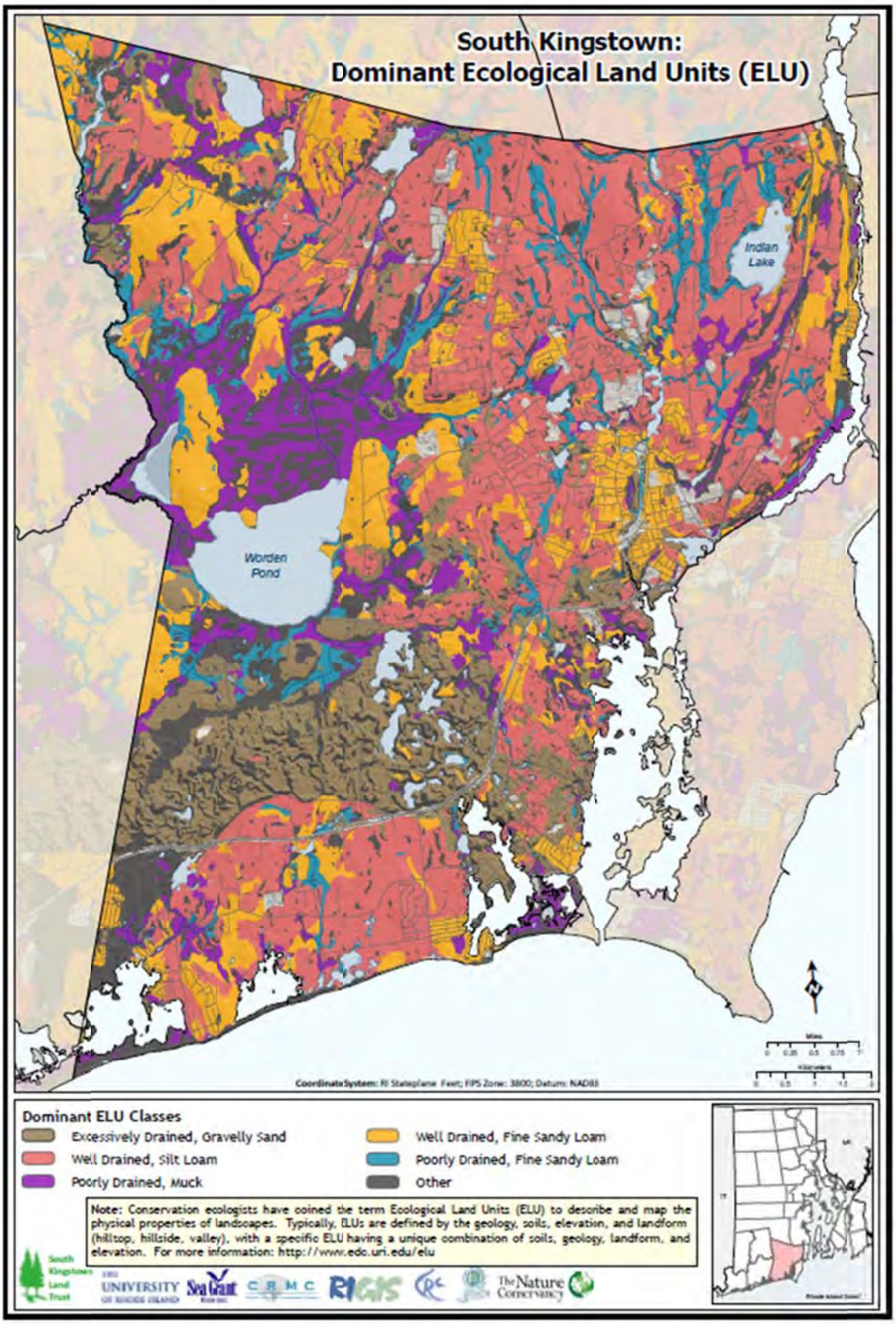

Figure 18. South Kingstown Dominant Ecological Land Units

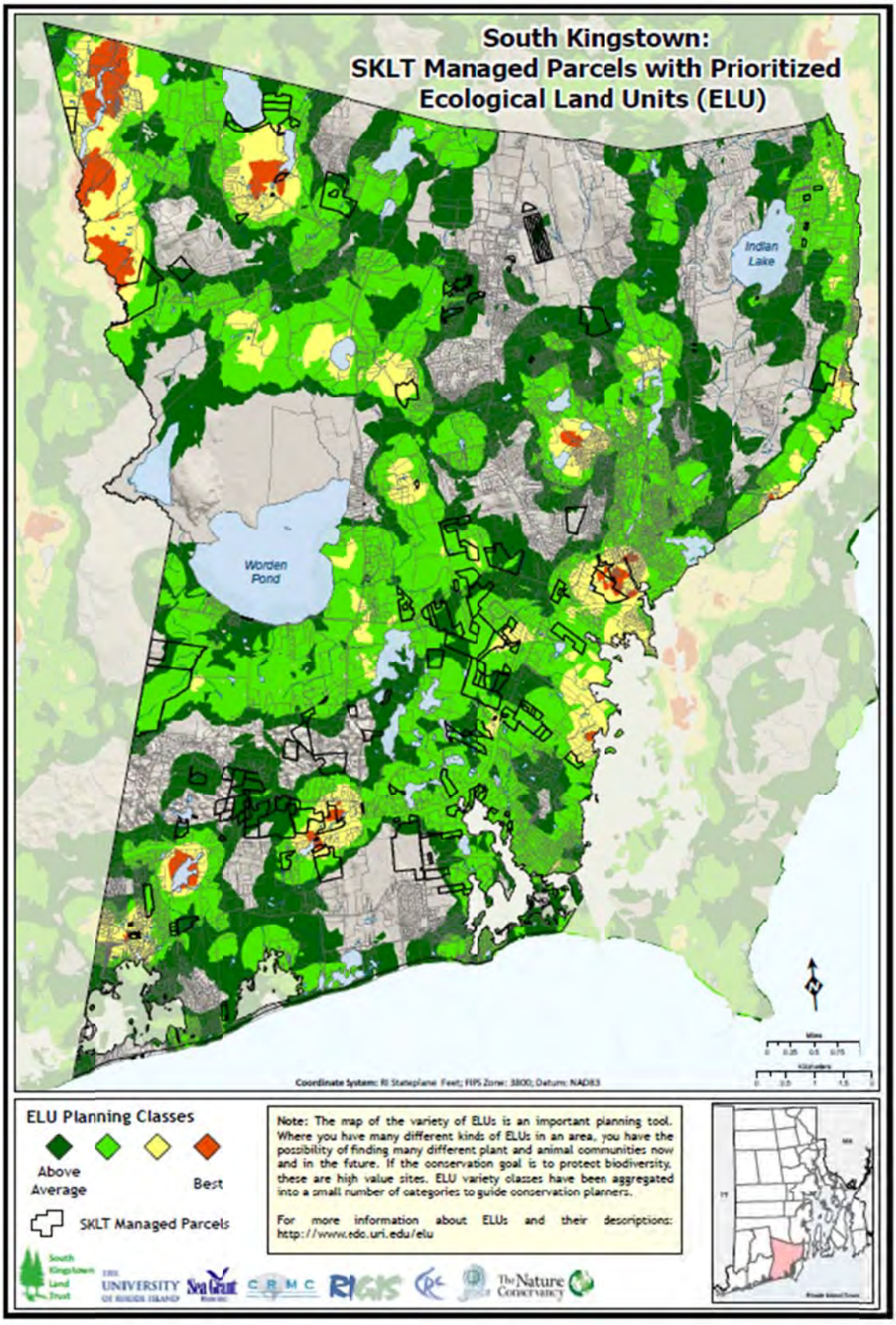

Figure 19. ELU planning classes are a measure of ELU variety and may be used to prioritize areas for protection.

ELUS ASSIST CONSERVATION PLANNERS

ELUs are a tool to help resource managers and conservationists achieve important goals for land protection. They help preserve diversity and protect representative assemblages of plants and animals. Using ELUs to inform conservation decisions is relatively simple; using GIS, ELUs can be overlaid on maps of property boundaries and existing conservation lands (see Figure 3). Candidate properties can be evaluated relative to ELU variety. All things being equal, a property with exceptional ELU variety will likely support greater biodiversity now and into the future than a property that has low ELU variety. It is important to note that ELUs are merely one of many factors conservationists should consider in choosing properties to protect. Aesthetic and cultural values, water resource protection, rare species, preserve size and connectedness, public access, etc. are all criteria that might be considered along with ELUs.

IDENTIFYING UNPROTECTED ELUS

Protecting plants and animals that are representative of the region is another important conservation goal. ELUs can provide insight into these conservation targets too. The total proportion of land occupied by each of the 20 dominant ELUs in Rhode Island was calculated by URI-EDC. The variety of ELUs in lands that have been protected by the towns, the state, federal agencies, NGO's such as TNC and the Audubon Society, and local land trusts were also calculated. By comparing the extent of one ELU across the state with how much of the same ELU is already protected, we can identify ELU classes that are not well-represented in the portfolio of protected lands. Areas that contain these underrepresented ELUs might be good targets for future land acquisitions. The map of underrepresented ELUs is a helpful guide if the conservation goal is to make sure that Rhode Island's most common ecosystems are adequately protected.

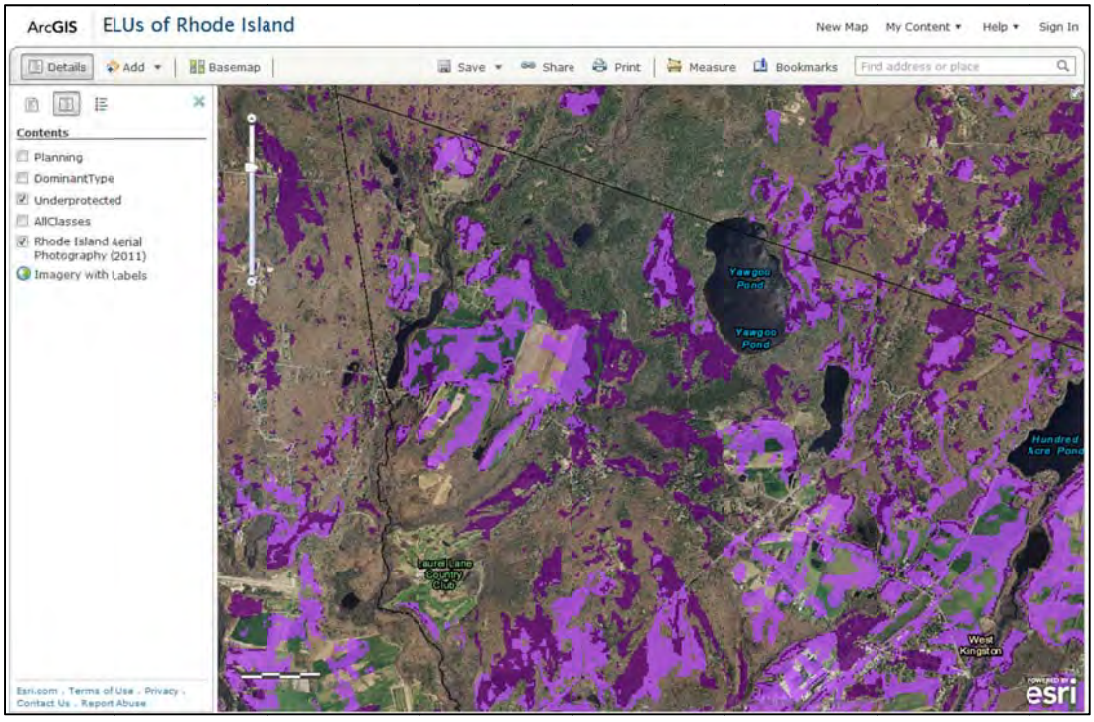

Figure 20. Underrepresented ELU's in the West Kingston area. Using the URI-EDC's interactive mapping ArcGIS Online interface, organizations can view different aspects of ELU, including planning classes, underrepresented ELU's and dominant types

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APPENDIX 4: SEA LEVEL RISE MAPPING IN RHODE ISLAND

One of the primary threats facing Rhode Island's coastal lands and communities is sea level rise. **S**ea levels have been rising over the last century on both global and local scales. This increase is a result of two major factors. First, the increase in water temperatures in recent decades has led to higher sea levels because warmer water takes up more space than cooler water (called "thermal expansion"). Second, warmer air and water temperatures have increased melt rates for the Greenland and Antarctic ice sheets and mountain glaciers, adding more water to the ocean.

At the local level, the trends are showing accelerating rates of sea level rise:

Key Resources

Sea Level Rise in Rhode Island: Trends and Impacts

CRMC Sea Level Rise Policy

Sea Level Trends for Rhode Island

Salt Marsh Migration Maps

NOAA Sea Level Rise Viewer

Since 1930, sea level in Rhode Island has increased by an average of 1 inch per decade.

Over the past half century, sea levels in the Northeast have been increasing 3 to 4 times faster than the global average rate, resulting in a 6-inch rise between 1970 and 2012.

With accelerating rates, sea level is projected to increase by 3 to 6 feet above 1990 levels in Rhode Island by 2100, with a potential of 1 foot of sea level rise by 2050.

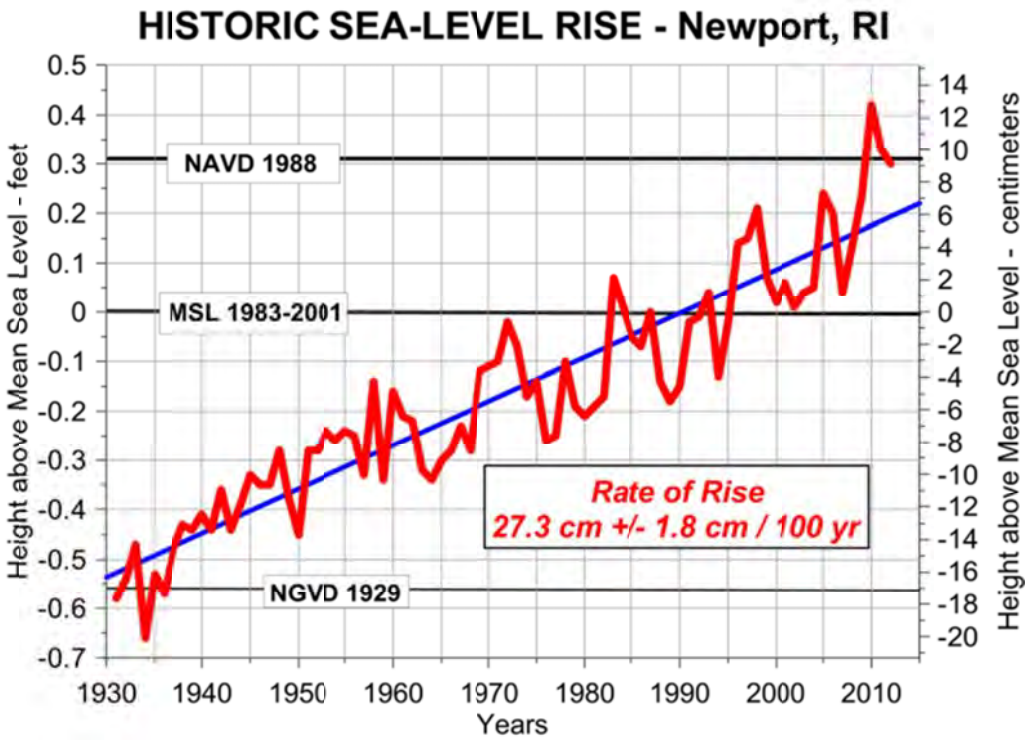


Figure 21. Observed change in average sea level at Newport, Rhode Island tide gauge from 1983 to 2012. The blue trend line shows a 10.6 inch (26.8cm) increase in sea level per century. Data from: http://tidesandcurrents.noaa.gov/gmap3/ Graph courtesy of Jon Boothroyd, 2013

VISUALIZING INUNDATED SHORELINES

Expected impacts of sea level rise on Rhode Island's communities will affect natural resources and the built environment as well as public health and safety. Coastal roads and low-lying properties are likely to experience inundation on a more regular basis (i.e. spring tides will extend further inland) as well as increased likelihood of damage to properties and/or buildings during storms, which are also projected to increase in intensity. Beaches and wetlands that naturally migrate landward may be affected if they are impeded by development, walls, or roads.

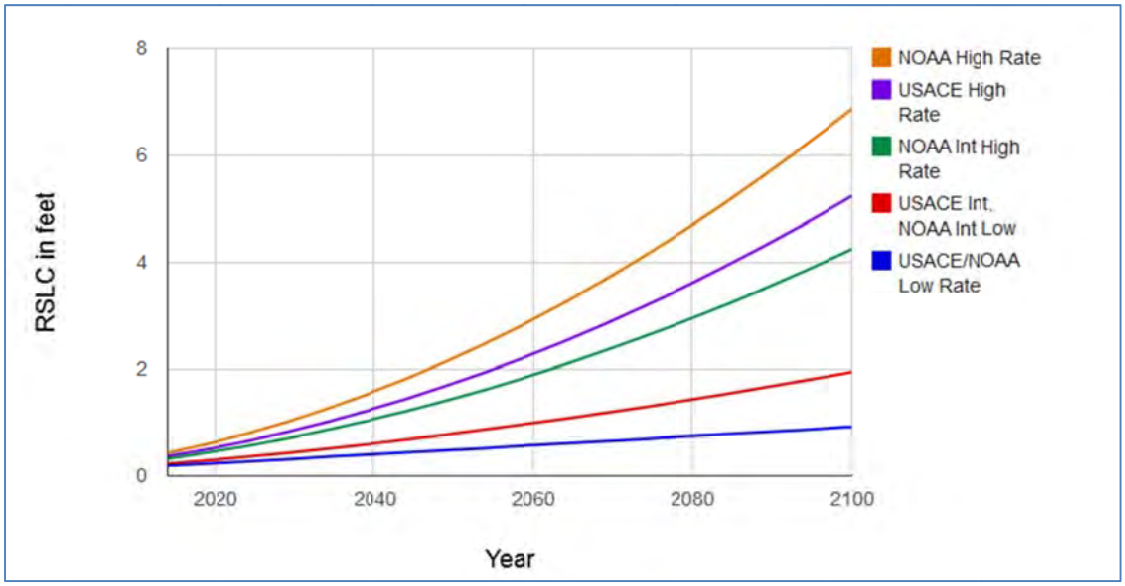


Figure 22. Projected increases in sea level at the Newport, RI tide gauge. Data are provided by the US Army Corps of Engineers and NOAA. http://www.corpsclimate.us/ccaceslcurves.cfm

Mapping different sea level rise inundation scenarios can help municipalities and property owners plan ahead to develop adaptation strategies in order to minimize risks of property loss and damage. The 2011 inundation mapping pilot project conducted in North Kingstown provides valuable information to municipal officials that can be considered in the town's Local Comprehensive Plan, Hazard Mitigation Plan, and Capital Improvement Programs. Inundation scenarios, based on the "bathtub model" [9], are available for Rhode Island coastal communities. As stated in the project methodology, these map overlays are not based on a detailed and dynamic model and should be used for planning purposes only. These overlays depicting 1, 3, and 5-foot sea level rise and the 1938 inundation level from the Newport tidal gauge datum are available for *planning purposes* at the Rhode Island Sea Grant website and from the National Oceanic and Atmospheric Administration.

[9] The "bathtub model" only takes into account a static rise in sea level throughout the state, and does not accommodate local changes in waves, erosion and other coastal dynamics.

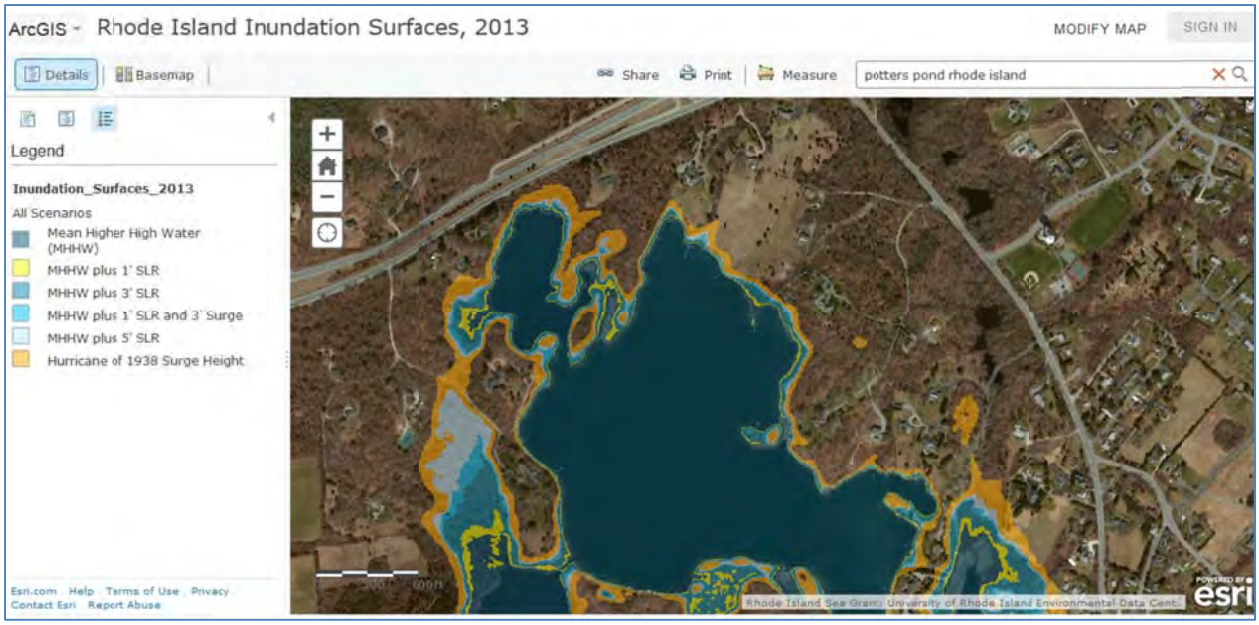


Figure 23. Simulated Inundation Areas around Potter's Pond in South Kingstown. Using Rhode Island's interactive mapping ArcGIS Online interface, maps can be viewed for planning purposes. http://seagrant.gso.uri.edu/climate/

IMPACTS TO COASTAL WETLANDS

Rising sea levels also threaten Rhode Island's vulnerable and vitally important coastal wetlands and salt marshes. These marshes support a wide variety of plant and animal species as well as serving as nurseries for juvenile fish of several different economically-important species. As sea levels increase coastal marshes and wetlands are in danger of drowning if water levels rise more quickly than sediments can accumulate. Today, we can already see marshes subsiding and retreating landward in some parts of the state as a result of sea level rise. Efforts are underway to monitor these impacts by organizations including Save the Bay, USFWS, and the National Estuarine Research Reserve, and to develop techniques to restore habitats.

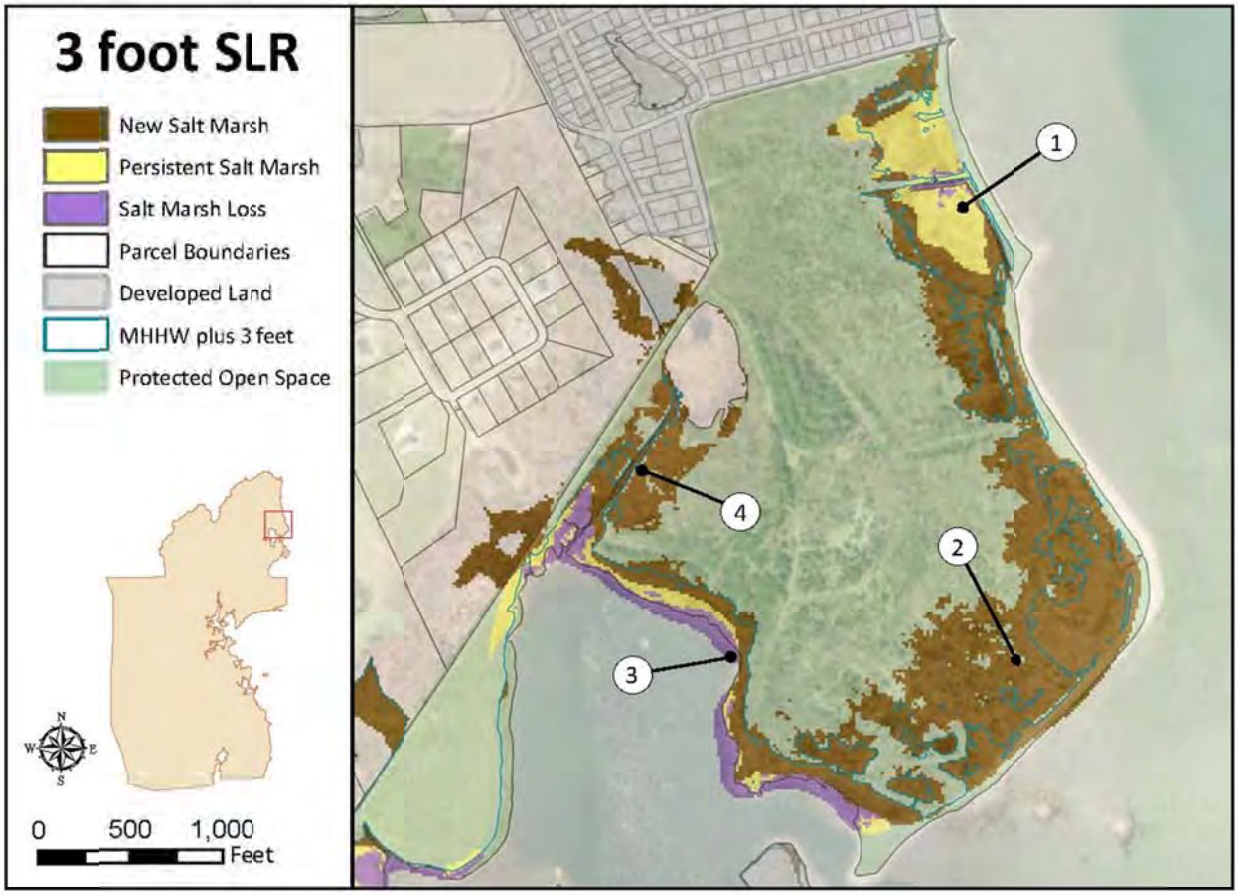
If tidal marshes cannot keep up with the accelerated rate of sea level rise, or are not able to migrate landward to higher elevations, a significant percentage of Rhode Island's coastal wetlands may be permanently lost by the end of this century. However, in order for marshes to move upward there must be suitable undeveloped areas in which to establish new salt marshes. Man-made structures, such as sea walls and developments, may limit inland movement by marshes, squeezing this vulnerable habitat between rising tides and solid structures.

To minimize marsh loss, it is necessary to identify and conserve adjacent uplands for marsh migration in response to sea level rise. There is also the need to develop and implement strategies and policies for the protection of these upland areas abutting salt marshes.

The Sea Level Affecting Marshes Model (SLAMM) is a tool developed for decision makers and resource managers to use in planning the best way to use and protect marshes under future climate change conditions. Using SLAMM maps, decision makers and other key stakeholders can locate vulnerable marshes and identify adjacent undeveloped areas for protection as possible future marsh habitats. A pilot project in North Kingstown developed SLAMM maps that were share with municipal officials, the conservation commission and the land trust as a first

step to evaluate the vulnerability of the town's coastal marshes and develop preservation and adaptation plans for this valuable habitat.

The SLAMM project has being expanded to assess all Rhode Island coastal communities to develop tools and strategies for coastal wetlands with active participation among state and local community stakeholders. Maps will be finalized in early 2014 that simulate coastal wetland migration under various sea level rise scenarios. These can be used to facilitate development and implementation of adaptive climate change strategies to protect and restore coastal wetlands. Recommended policies and guidelines will be developed to help promote long term resilience and sustainability of these valuable habitats.



Calf Pasture Point Beach and Nature Preserve is a town owned property with existing salt marsh and quality beaches. This property is projected to have some of the best opportunity for future marsh migration in the town. Since it is already owned by the town and is presumably managed for recreation and habitat, sea level rise mitigation efforts could focus on the management and stewardship of this property.

(1) This existing patch of salt marsh is projected to suffer minimal loss due to inundation, which is more than offset by gains. It has a good opportunity to migrate landward and model projections show an increase in future marsh habitat. A cursory review of aerial photography shows some type of drainage ditches running parallel to the beach and into the existing marsh. Future management activities could have significant impact to this site. Ideally, a management and monitoring plan could be implemented to help maintain the recreational beach and habitat.

(2) Due to the gently sloping nature of this area model projections show the opportunity for significant new salt marsh. These results should be taken with at least a touch of skepticism as there is not currently salt marsh close to this scale present. These do however point to a large potential that should be reviewed further, perhaps some on the ground study is needed.

(3) At three feet of sea level rise this fringe of salt marsh shows a pretty straight forward landward migration without much change in the area of coverage. At five feet sea level rise the model predicts the loss of the fringe.

(4) Though the marsh fringe at site 3 is lost at five feet of sea level rise there is new opportunity for marsh migration through this inlet to the cove and land areas behind.

Figure 24. SLAMM map showing potential wetland changes, issues and opportunities with a 3- foot sea level rise scenario at Calf Pasture Point in North Kingstown. http://seagrant.gso.uri.edu/climate/

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