Climate Change Adaptation Plan

Heritage Unit (Prudence Island, RI)

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Using the Adaptation Workbook – AdaptationWorkbook.org

Abstract

NBNERR utilized the Adaption Workbook, an on-line tool and resource for land managers developed by the Northern Institute of Applied Climate Science, to generate a climate change adaptation plan for the Heritage Unit, a 290-acre forested stand. Primary habitats include central hardwood pine and lowland riparian forest; both of which have been significantly degraded by persistent forest pest species. The anticipated change in climate conditions is expected to result in further degradation, particularly in the lowland riparian forest. The adaptation workbook provides a structured format for evaluating regional climate impacts and site-specific considerations as well as potential adaptation strategies. The specific management goals identified include: (1) retain the majority component of this closed canopy forest with current habitat characteristics, (2) limit replacement of under- and over-story vegetation by non-native invasive species, and (3) support wildlife species that are dependent on these forest types. Identified objectives are evaluated based on potential challenges and opportunities, feasibility, and other considerations. A suite of adaptation tactics appropriate to meeting specific objectives are identified and assessed to determine benefits, barriers to implementation, and practicability. In addition, monitoring items to gauge effectiveness of management actions are identified. Despite numerous identified barriers and challenges, it is recommended that all identified adaptation tactics be implemented as soon as practicable to ensure the long-term persistence of these habitats.

Introduction

The recent degradation of Prudence Island's closed canopy forest as the result of prevalent and persistent forest pest and invasive species has resulted in a significant change in habitat condition. Recognized as a critical habitat in the state's wildlife action plan, this forest, owned by the State of Rhode Island and under management by the Narragansett Bay National Estuarine Research Reserve (NBNERR) will continue to be degraded in future under altered climate conditions. Significant management action will be required to ensure that some component of this forest is retained. Alternate locations on Prudence Island have suffered from a complete loss of forest with replacement cover dominated by invasive shrub and vines, a potential end state for the project area in the absence of management. No management plan or strategy has been generated for this area to date; however, this adaptation plan is intended to inform the restoration component of a revised management plan for the Reserve (currently under development) to specifically acknowledge current issues, potential climate impacts, and appropriate management strategies if and when resources become available.

Heritage Unit Site Description

Area: 290 acres

Land ownership: State of RI (managed by NBNERR)

Habitats associated with management unit:

Central hardwood-pine

These forests are found in dry to mesic conditions across a variety of sites in southern New England. Dominant species may include several oak species, especially red, white, black, or scarlet oak, and other hardwood species.

Lowland riparian forest

Diverse forested wetlands are found in depressions and low-lying areas, along waterways, and in floodplains. Dominant species may include ash, red, or silver maple, swamp white oak, sycamore, American elm, and river birch.

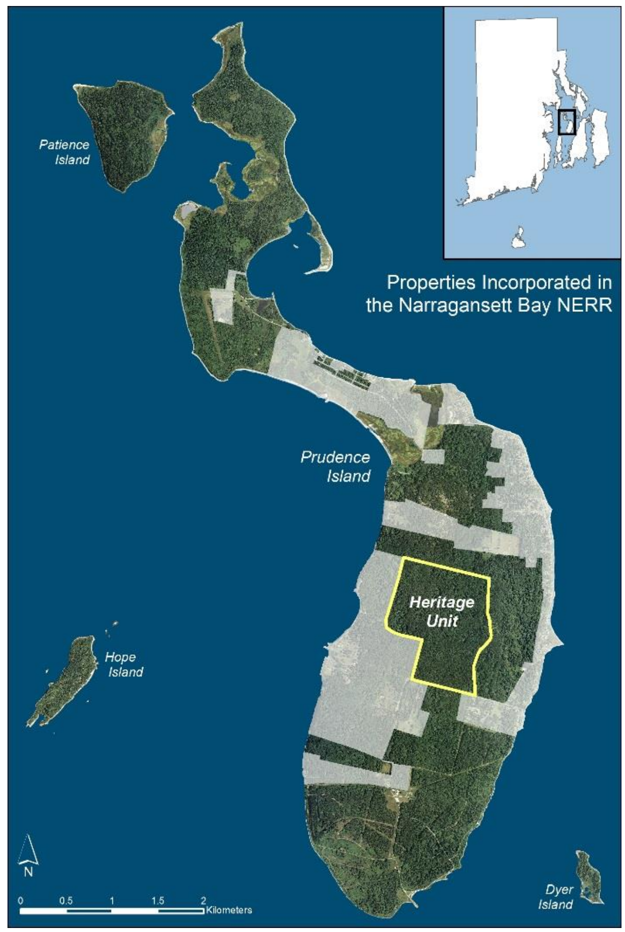

Figure 1: General location of the Heritage Unit on NBNERR managed lands.

Regional Climate Change Impacts & Property-Level Considerations

The following climate change impacts (shown in bold text) are regional expectations drawn from published resources. Under each regional climate change impact statement, property-level considerations describe how the general trend might be meaningful at the scale of this management unit. Specific site characteristics that affect whether the management unit is more or less vulnerable include species and structural composition, soils, topography, past management, forest health issues, and the surrounding landscape.

General

The winter season will be shorter and milder across New England and northern New York, with less precipitation falling as snow and reduced snow cover and depth.

Precipitation as rain in winter months may hinder groundwater recharge and availability during the growing season.

Precipitation patterns will be altered, with projected increases in annual precipitation and potential for reduced growing season precipitation in New England and northern New York.

In most years the groundwater aquifer reaches storage capacity during winter and spring months. An increase in precipitation during these seasons, and modest reductions in summer and fall precipitation would cause reduced groundwater and soil moisture levels during the growing season, resulting in increased tree stress.

Warmer temperatures and altered precipitation in New England and northern New York will interact to change soil moisture patterns throughout the year with the potential for both wetter and drier conditions depending on the location and season.

There is currently no potential for water retention from intense precipitation events. The project area is expected to experience drier conditions, particularly during summer and fall.

Forest vegetation in New England and northern New York may face increased risk of moisture deficit and drought during the growing season.

Local anecdotal and empirical evidence suggests that there has already been an increased occurrence of moisture deficit and seasonal drought during the past half century.

Certain insect pests and pathogens will increase in occurrence or become more damaging in New England and northern New York.

Forest impacts associated with prevalent and persistent forest pests are already evident. The possible range expansion or prolonged effect of additional pests or pathogens may negate current management capacity (if any) to mitigate existing damage.

Many invasive plants will increase in extent or abundance in New England and northern New York.

Even in the absence of expanded populations of additional invasive species, the widespread distribution of numerous current invasive plant species throughout adjacent lands will, if they are likely to become more competitive, present significant challenges for forest persistence in the project area; particularly as opportunities currently exist for increased encroachment potential due to the establishment of numerous gaps in the forest canopy.

Habitat will become more suitable in New England and northern New York for some southern species.

Although tree species are not anticipated to shift drastically, the possibility of additional biological stressors in an area that is already impacted by forest pests and invasive species may tip the balance as to whether adaptive management practices are effective or practical.

Forest composition will change across the landscape in New England and northern New York.

The widespread encroachment of red maple into Rhode Island's forests that occurred over the past century may be reversed over time; leading to a greater proportion of oak species in mixed hardwood forests.

Low-diversity systems are at greater risk from climate change.

As an example of central hardwood-pine forest, the project area is relatively low in species diversity due to the historic removal of select, high-profit species (e.g. chestnut, ash, white pine).

Species in fragmented landscapes will have less opportunity to migrate in response to climate change.

Situated on an island, species migration into and out of the project area is unlikely to occur within the generally accepted timeframe without assistance.

Systems that are more tolerant of disturbance have less risk of declining on the landscape.

The pervasiveness of invasive plant species will likely alter the potential for this forest to recover from gap-phase disturbances.

Habitat Specific

Central hardwood-pine (CHP)

Central hardwood-pine forests are widely distributed across a variety of sites, increasing adaptive capacity.

Any projected increase in adaptive capacity is anticipated to be minimal at this location. The site is at lower elevations and is generally assumed to be warmer and drier than the majority of this forest's range.

Changes in herbivore populations may also have substantial effects on forest growth and composition.

Herbivore impact has varied widely in the past decade. Deer management was instituted in the 1970's as the direct result of overabundance and clear environmental impact but still reached island-wide population densities of 125 deer per sq. mi. in the past decade. More recent control efforts have reduced the herd to approximately 35 deer per sq. mi. and significant understory vegetation recovery has occurred. However, consistent population control remains a challenge due to reduced hunter effort and restricted access.

High levels of diversity may increase the ability of forests to adapt to climate change.

Land use history at this location, with wide-spread abandonment of agriculture occurring over a relatively short time frame (in the mid-to late 1800's), resulted in reduced levels of diversity; particularly in the higher, drier portions of this site.

Insect pests and forest diseases could become more problematic in central hardwood-pine forests under a warmer climate.

The effect of forest pest species (e.g. oak crypt gall wasp, winter moth, gypsy moth) has already been significant. The relatively shallow (i.e. 0-50 feet) glacial till overlying fractured bedrock exacerbates stress associated with warmer and seasonally drier conditions.

Invasive species such as buckthorn, honeysuckle, and garlic mustard are expected to become more problematic under climate change.

Invasive plants are widespread in the surrounding area but had been limited in the understory due to shade intolerance in this particular forest stand. With the increase in sunlight reaching the forest floor, the incursion of invasive plants is likely. In particular, seedling oriental bittersweet which is widespread and will persist for years, is taking advantage of the opportunity presented by the compromised canopy to become established.

Figure 2: Gaps in the canopy reduce shading in the understory; allowing invasive plant incursion.

Previous human influences, including fragmentation and fire suppression, may have reduced the adaptive capacity of some central hardwood-pine forests.

Shade tolerant species, such as red maple, are already a common component of this mixed hardwood forest. With the potential for warmer and drier conditions it is hoped that regeneration of oak and hickory species will increase (assuming additional challenges associated with herbivory and invasive species establishment can be overcome).

Many of the dominant tree species in central hardwood-pine forests are projected to have similar or increased habitat, including black, chestnut, scarlet, and white oak and pignut and shagbark hickory.

Assuming effective management of invasive species to prevent wide-spread establishment is possible, the regeneration of many existing component species in this forest is likely and may result in greater diversity across the landscape.

Vulnerability assessment for Central hardwood-pine component

Potential Impact of Climate Change on Health and Function of System:	*Mixed-Neutral*
Adaptive Capacity of System to Climate Change Impacts or Disturbances:	*Moderate*
Vulnerability Determination:	*Moderate*

Lowland riparian forest (LRF)

Lowland and riparian forests may have limited tolerance to changes in precipitation and water tables.

An increase in winter and spring precipitation will not have a buffering effect during summer months as groundwater capture and storage capacity is limited. Local data demonstrate that groundwater levels consistently drop throughout the growing season and do not recover until leaf fall in late autumn.

Invasive species such as Japanese stiltgrass and buckthorn are expected to become more problematic under climate change.

Already significantly disturbed, this forest is likely to see a greater incursion of invasive species, particularly if soil moisture levels drop in most years as anticipated.

Insect pests and forest diseases could become more problematic in these forests under a warmer climate.

Prevalent and persistent forest pest species have already caused significant impact. It is anticipated that continued tree stress associated with short-term drought and moderate winter temperatures that favor pest species will result in continued canopy damage.

Vulnerability assessment for Lowland riparian forest component

Potential Impact of Climate Change on Health and Function of System:	*Disruptive*
Adaptive Capacity of System to Climate Change Impacts or Disturbances:	*Low-Moderate*
Vulnerability Determination:	*High*

Management Goals and Objectives

Three management goals and multiple associated objectives were identified for the Heritage Unit in order to promote the long-term persistence of its component habitats. Adopted specifically for this management unit, it is likely that the goals and many of the listed objectives would be equally applicable to comparable management units located elsewhere on Reserve managed lands.

Management Goal 1: Retain the majority component of this closed canopy forest with current habitat characteristics.

Management Objectives:

(Central hardwood-pine)

1.1 The extent of upper elevation dry to mesic oak-dominated forest is not less than 75% of the geographic area covered in 2016.
1.2 The risk of catastrophic/stand replacement wildfire associated with heavy fuel loading is reduced.

(Lowland riparian forest)

1.3 The extent of lower elevation red maple dominated forested wetland is not less than 90% of the geographic area covered in 2016.
1.4 Seasonal groundwater levels in the fractured bedrock aquifer of Prudence Island are maintained at historic levels.

Management Goal 2: Limit replacement of under- and over-story vegetation by non-native invasive species.

Management Objectives:

(Central hardwood-pine)

2.1 Control forest pest species (i.e. winter moth) to prevent further canopy degradation and opportunities for invasive plant incursion.
2.2 Control known invasive species (i.e. oriental bittersweet, Japanese barberry, autumn olive) within the project area and on adjacent preserved lands.

(Lowland riparian forest)

2.3 Native species regeneration is ensured and species diversity is enhanced.

Management Goal 3: Support wildlife species that are dependent on this forest type.

Management Objectives:

(Central hardwood-pine)

3.1 Species and structural diversity is maintained or enhanced.

(Lowland riparian forest)

3.2 Stream temperatures and flow levels are sufficient to support native (naturalized) brook trout.
3.3 Evaporative loss associated with a recent decline in tree cover is offset to preserve habitat requirements of species of concern (e.g. eastern box turtle).

Evaluation of Climate Change Impacts on Goals and Objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting both challenges and opportunities. For each objective, this section also includes a simple rating and description for the feasibility of meeting management objectives under current management and other considerations such as the level of available resources. This analysis is a critical step to evaluate whether identified management objectives are robust in light of anticipated changing climate conditions.

Table 1: Considerations when assessing potential for achieving individual identified objectives.

Challenges	**Opportunities**	**Feasibility**	**Other Considerations**
Management Goal 1 Retain the majority component of this closed canopy forest with current habitat characteristics.			
Objective 1.1 (Central hardwood-pine; Target end date: 2025) The extent of upper elevation dry to mesic oak-dominated forest is not less than 75% of the geographic area covered in 2016.			
Recent occurrences of short term drought during the growing season and presumed	This forest type is widely distributed across a variety of sites (and occurs in	**Low** In the short-term, efforts to mitigate the impacts of forest	Limited resources are available for habitat management

tree stress as well as the extended survivorship of forest pest species has created significant damage. A continuation of drought conditions and the potential for forest pests to become yet more problematic with warming will only exacerbate the problem.	adjacent preserved lands locally) and there may actually be a competitive advantage for component oak and hickory species. These species would become more prevalent, replacing red maple that has increased in dominance over the past century, potentially leading to greater diversity and resilience in the future.	pest species (i.e. greater number and extent of canopy gaps) on the understory community may lead to greater regeneration of tree species. If no management actions occur in the near term to reduce incursion by non-native species, it is likely that a tipping point will be reached whereby forest stand recovery is not possible.	activities. However, the Reserves' state-agency partner has indicated that the retention of large, intact (e.g. unfragmented), closed canopy forests on state land is a high priority. Island residents and hunters also recognize the value and unique local character of this forest so support for intensive management activity is likely.
Objective 1.2 (Central hardwood-pine; Target end date: 2025) The risk of catastrophic/stand replacement wildfire associated with heavy fuel loading is reduced.			
Anticipated drier and warmer conditions coupled with standing dead trees and increased fuel loading associated with forest pest damage creates progressively more suitable conditions for the occurrence and greater intensity of wildfire.	<None identified>	**Medium** Efforts to reduce the risk of, or prevent, catastrophic wildfire are made more challenging by the concurrent desire to retain the unfragmented condition of this forest stand. If feasible, the application of prescribed fire in concert with boundary breaks may reduce risk if undertaken in the near term. In the absence of management actions, site conditions conducive to intense wildfire will simply intensify.	Forest degradation is evident to even the most casual observer and the current development of a Community Wildfire Protection Plan (which includes public outreach/ information meetings) and the implementation of a Firewise Education program should serve to garner support for activities that reduce wildfire risk.
Objective 1.3 (Lowland riparian forest; Target end date: 2050) The extent of lower elevation red maple dominated forested wetland is not less than 90% of the geographic area covered in 2016.			
The anticipated increase in temperature and shift	<None identified>	**Low**	State-wide lowland/riparian

in seasonal precipitation (with greater instances of growing season drought) will cause soil moisture deficit and additional tree stress. This will likely promote continued forest pest impacts and the resulting gaps in the forest canopy will exacerbate the effects of a changing climate and could, in time, lead to generally drier conditions that do not support forest wetland species.		The impact of forest pest species is already significant; if not addressed in the near future the project area may be degraded to such an extent that mitigation efforts are not feasible and the habitat characteristics of this lowland/riparian forest will be lost.	forest may actually fair better than this particular site given the capacity for most locations to store groundwater, thereby buffering the effects of short term drought. At this location, retaining an intact canopy is the best mechanism for ensuring that soil moisture deficits and resulting tree stress do not lead to a change in habitat type.
Objective 1.4 (Lowland riparian forest; Target end date: 2050) Seasonal groundwater levels in the fractured bedrock aquifer of Prudence Island are maintained at historic levels.			
Available groundwater levels may be further compromised by altered temperature and seasonal precipitation patterns which cause greater tree stress or mortality and reduced recharge capacity in future. In the extreme case, reducing groundwater levels could lead to salt water intrusion into the aquifer along bedrock fractures.	The threat of saltwater intrusion may make a more compelling argument for addressing freshwater retention needs in the near future.	**Low** Management efforts need to be undertaken before the aquifer becomes compromised; later recovery efforts would likely be more challenging or wholly ineffective.	Groundwater is a shared resource; the northern reaches of the watershed in which the island's community wells are located is within the project area. The continued degradation and potential loss of this lowland forest also puts the drinking water supply at risk.
Management Goal 2 Limit replacement of under- and over-story vegetation by non-native invasive species.			
Objective 2.1 (Central hardwood-pine; Target end date: 2020) Control forest pest species (i.e. winter moth) to prevent further canopy degradation and opportunities for invasive plant incursion.			
The potential for more persistent and pervasive forest pests under warmer conditions suggests a greater distribution and suite of forest pests across all state managed lands; making it even less likely that state-agency partner support will be available for addressing concerns on Reserve managed lands.	The recent outbreaks of forest pests throughout the state as the presumed result of milder winters has motivated the state to take action against select pest species, most notably winter moth. As this effort has proven effective where applied, the	**Medium** If not applied in the near-term, any effectiveness of treatment will not compensate for the extreme damage done as non-native species will complicate (at best) or prevent (at worst) forest recovery and regeneration.	Limited resources are available for habitat management activities. Pursuing this course of action is necessary to prevent additional damage, provide an opportunity for forest recovery, and meet state-partner agency priorities for

	state may be more inclined to take preventative or active control measures in a more timely fashion in future as forest pest species become more problematic.		retaining intact forest on state lands.
Objective 2.2 (Central hardwood-pine; Target end date: 2025) Control known invasive species (i.e. oriental bittersweet, Japanese barberry, autumn olive) within the project area and on adjacent preserved lands.			
Best management practices apply only to current conditions and may not, in fact, be applicable under future conditions given the projected change in temperature, precipitation, and increasingly problematic invasive species.	<None identified>	**Low** Any effort to reduce the spread and dominance of invasive plants in the near term would make forest recovery more likely; later attempts would require significantly more effort to implement if the seed bank is more established and widespread.	Limited resources are available for habitat management activities. Access into the site is logistically (and physically) challenging.
Objective 2.3 (Lowland riparian forest; Target end date: 2025) Native species regeneration is ensured and species diversity is enhanced.			
The anticipated loss of tree cover as result of warmer temperatures, altered precipitation patterns, and more prevalent forest pests will exacerbate soil moisture deficit conditions and enhance competition by invasive species, making the displacement of native species more likely.	<None identified>	**Medium** If addressed in the near term, soil moisture conditions should remain most suitable for native plants adapted to the hydric conditions associated with the lowland forest. Efforts to ensure the regeneration of native plants will provide the greatest resilience for this site into the future.	Limited resources are available for habitat management activities. Access into the site for management activities is logistically (and physically) challenging.
Management Goal 3 Support wildlife species that are dependent on this forest type.			
Objective 3.1 (Central hardwood-pine; Target end date: 2025) Species and structural diversity is maintained or enhanced.			
An increase in the occurrence and extent of canopy gaps is anticipated as the result of warmer temperature, drought, and increased prevalence of forest pest species. As invasive species are anticipated to become more problematic as well,	An increase in distribution of this habitat is predicted under challenging climate conditions which suggests greater potential for regeneration of dominant species such as black chestnut,	**Low** Any effort to promote native species regeneration must be undertaken in the near term before invasive plants become established. Native greenbrier (Smilax	Limited resources are available for habitat management activities. Access throughout the project area for management activities is very challenging and may

the challenge will be to promote regeneration of a diverse community of over- and under-story vegetation in light of that enhanced degree of competition.	scarlet oak, and hickory that are currently not well represented across the landscape.	rotund folia) also tends to occupy forest openings although this may function as a 'placeholder' and help to restrict invasive species encroachment.	prevent control efforts and plantings within interior sections of this forest.
Objective 3.2 (Lowland riparian forest; Target end date: 2050) Stream temperatures and flow levels are sufficient to support native (naturalized) brook trout.			
Tree stress and mortality will likely become a more frequent occurrence under warmer and seasonally drier conditions. As gaps in the canopy occur and potentially become occupied by non-native species, regeneration of native tree species will be compromised. The loss of forest cover will impact groundwater recharge capacity and lead to lower stream flows and warmer stream temperatures as shading is reduced.	<None identified>	**Low** If no action is taken it is unlikely that stream flow rates and temperatures will continue to support this brook trout population in the future. The moderate drought in 2016 resulted in a complete loss of flow in an extended portion of the primary creek in this drainage basin with trout taking refuge in a modest number of available pools.	Although brook trout are not listed as a species of concern in the state, significant effort has been made within the region to support this species through the restoration of habitat. Where habitat currently occurs, attempts should be made to ensure its persistence.
Objective 3.3 (Lowland riparian forest; Target end date: 2020) Evaporative loss associated with a recent decline in tree cover is offset to preserve habitat requirements of species of concern (e.g. eastern box turtle).			
Tree stress and mortality will likely become a more frequent occurrence under warmer and seasonally drier conditions. As gaps in the canopy occur and potentially become occupied by non-native species, regeneration of native tree species will be compromised, and wetland plants will be replaced by those more characteristic of mesic and dry sites.	<None identified>	**Low** The compromised canopy creates microclimates which are potentially unsuitable for species dependent on this habitat for food and cover. To ensure continued persistence of these dependent species, efforts should be made in the near future to prevent further degradation of this habitat.	As canopy gaps expand in extent, population levels of these species will likely decline as they become restricted geographically into fragmented populations across the landscape. Species such as the eastern box turtle are considered vulnerable across their range and should be afforded greater protection whenever feasible.

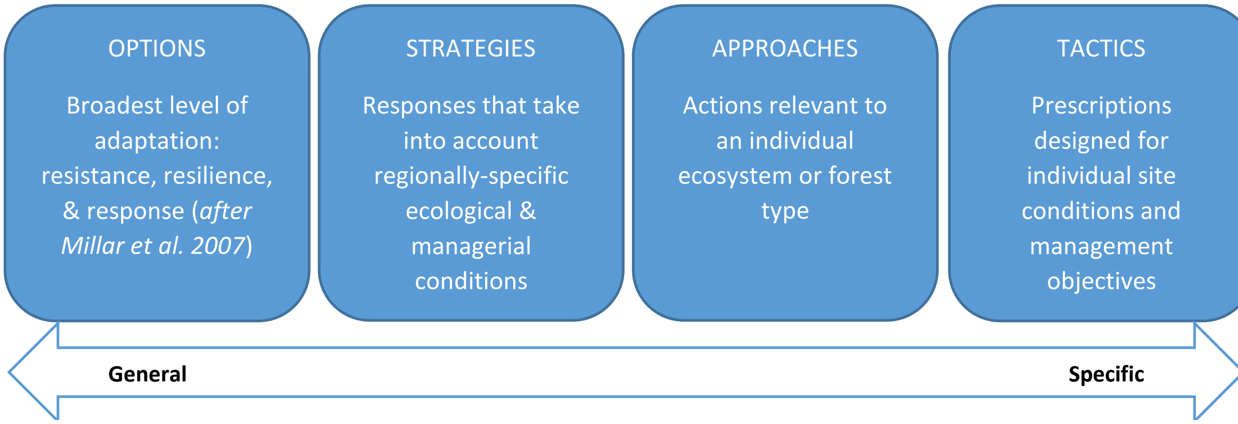

Figure 3: Continuum of potential adaptation actions. (Reproduced from Janowiak et al. 2007).

Responding to Climate Change Impacts

The following adaptation actions (tactics) were identified to help meet objectives and prepare for identified climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches (Table 2). [Note: A complete list and descriptive text of all possible Adaptation Strategies and Approaches is available in the Adaptation Workbook.]

Adaptation Tactics

Tactic 1: Create firebreaks as necessary (e.g. identified in the Prudence Island Community Wildfire Protection Plan) at the stand boundary and use prescribed fire to reduce fuels.

Tactic 2: Apply pesticide or biological control methods to manage pest populations (e.g. winter moth).

Tactic 3: Use volunteers to remove non-native species in forest gaps to allow for natural regeneration of tree species and/or plant trees as necessary.

Tactic 4: Conduct a companion study at a fully degraded site to determine best management practices for the control of known invasive species (e.g. oriental bittersweet, Japanese barberry, autumn olive) and for the natural regeneration of desired species.

Tactic 5: Install culvert and a berm downstream on Mill Creek to retain freshwater associated with normal peak flows and extreme precipitation events.

As described in Janowiak et al. 2011 and Swanston & Janowiak 2016, strategies, approaches and tactics are part of a continuum of adaptation actions ranging from broad, conceptual application to practical implementation (Fig. 3). Given the anticipated challenges associated with tactic implementation as the result of limited resource availability, a modest number of tactics were identified that are believed to incorporate one or more broader level strategies and/or approaches as well as simultaneously addressing multiple objectives in an effort to improve management action efficiency.

All five adaptation tactics identified in this document are recommended for implementation on this management unit despite low to high practicability (defined as being both effective and feasible). The consequences of inaction are simply too significant for continued inaction and every effort should be made to implement these tactics and improve adaptation potential in this management unit.

Table 2: Additional considerations for tactic application.

Strategy	Approach	Tactic	Time Frame	Benefits	Drawbacks and Barriers	Practi-cability of Tactic	Applies to Object.
Sustain fundamental ecological functions	Restore or maintain fire in fire-adapted ecosystems	**1** Create firebreaks as necessary	5-10 years	Promotes fire-adapted species and may reduce invasive species.	●The unfragmented nature of this stand provides challenges for access and the safety of a fire crew. ●The creation of firebreaks may not meet state-wide management goals for retaining contiguous tracts of forest. ●No current fire crew is available to implement prescribed burns in the state so external funding would be required to contract this work.	Low	1.1, 1.2, 2.2, 3.1
Reduce the risk and long-term impacts of severe disturbances	Alter forest structure or composition to reduce risk or severity of wildfire						
	Establish fuelbreaks to slow the spread of catastrophic fire						
Reduce the impact of biological stressors	Maintain or improve the ability of forests to resist pests and pathogens	**2** Apply pesticide or biological control methods	< 2 years	May reduce further degradation of the forest canopy, allowing for regeneration of native over- and under-story vegetation. Enhanced species diversity may lead to greater resilience.	Although known to be effective, the cost associated with pesticide and biological control treatments is very high. No resources are available for habitat management activities.	Medium	1.1, 1.3, 2.1, 3.1
Reduce the impact of biological stressors	Prevent the introduction and establishment of invasive plant species and remove existing invasive species	**3** Use volunteers to remove non-native species	1-5 years	Prevent encroachment and establishment of non-native species, improve resilience through added diversity and species richness, and recover degraded components of the landscape to improve connectivity and enhance wildlife use.	No funds are available for implementing habitat management activities. Organized volunteer activities are logistically challenging due to limited access to the island, transport on island, etc. Accessing work sites within the project area is also difficult given the lack of roads, limited trails, and thick understory vegetation.	Medium	2.2, 2.3, 3.1, 3.2
Maintain and enhance	Maintain and restore						

species and structural diversity	diversity of native species						
Promote landscape connectivity	Reduce landscape fragmentation						
Realign ecosystems after disturbance	Allow for areas of natural regeneration to test for future-adapted species	**4** Conduct a companion study	by 2025	Improved effectiveness of invasive species control and promotion of species that are best adapted to a change in climate conditions across similar areas within Reserve properties. Investigation should result in a more resilient vegetation community at the study site.	No resources are available for habitat management activities so external funds would need to be secured for this companion study. Investigations of this scope would also require significant time and effort to implement; resources for monitoring and follow up treatments (as necessary) would be required across multiple years.	Medium	2.2, 2.3, 3.1
	Realign significantly disrupted ecosystems to meet expected future conditions						
Sustain fundamental ecological functions	Maintain or restore hydrology	**5** Install culvert and a berm downstream on Mill Creek	2-3 years	In addition to improving hydrologic conditions to reduce temperature/drought stress and increase productivity, the capture of freshwater flows during extreme precipitation events may improve recharge capacity and provide backpressure in surface flows and bedrock fractures, thereby reducing the potential for saltwater intrusion. This tactic could be implemented as part of a larger planned coastal resilience project at the outflow of Mill Creek which is designed to restore a modest, salt marsh and establish living shoreline components to mitigate storm effects, while also providing improved accessibility to a portion of the island community.	Costs to engineer, acquire permitting, and implement this tactic are high and require external funding support.	High	1.3, 1.4, 3.2, 3.3

Monitoring Adaptation Actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring items were identified as appropriate mechanisms for determining the effectiveness of the particular management objectives and adaptation tactics identified in this document.

Monitoring Items:

1. Vegetation cover maps *(CHP & LRF)*
2. Extent and frequency of canopy gaps *(CHP & LRF)*
3. Native tree and shrub species establishment *(CHP & LRF)*
4. Wetland indicator and dependent species *(CHP & LRF)*
5. Groundwater level and stream flow *(LRF)*

For the same reason that few adaptation tactics were identified (i.e. to minimize resource needs), few monitoring items were also selected. Although monitoring is recognized as a critical component of effective management, there are simply too few staff available to conduct multiple or elaborate monitoring programs. These five monitoring items were selected because they take advantage of low cost equipment or available data to support future management decisions.

Table 3: Specific threshold/criteria and implementation strategies for monitoring items.

Monitoring Item	Threshold / Criteria for evaluation	Implementation (frequency, time of year, etc.)
1	Change in extent of central hardwood-pine and lowland/riparian forest	Maps are generated for each time period that coincides with the collection of state-wide image acquisition (generally at 5 year intervals)
2	Number of impacted/dead trees is less than 10% greater than the previous year	Photo point collection at defined locations annually
3	Shift in relative abundance of native and non-native species does not exceed 5% in successive years; and, where applicable, percent survivorship of planted seedlings	Periodic (e.g. 2-5 year) surveys of species occurring in forest gaps and as a component of the understory on established transects (using line-point intercept method)
4	Species richness and abundance is not less than baseline year	Conducting periodic (e.g. 2-5 year) spring surveys for presence/abundance at established survey plot locations
5	The frequency of reduced groundwater levels in monitoring wells sufficient to trigger water conservation stages is not greater than the 10 year average; timing of seasonal flow (e.g. spring peak flow, no flow periods) is not shifted by more than a month	Monthly monitoring (on-going since 2006)

Conclusions

The Heritage Unit is already significantly degraded and the anticipated effects associated with changing climate conditions may lead to a complete loss of the two primary habitat types present if adaptation actions are not undertaken soon to improve resiliency. A change in the timing of seasonal precipitation, with greater precipitation occurring in the winter months and reduced amounts available during the growing season, is perhaps the greatest challenge anticipated. Greater tree stress and the increased likelihood of forest pest persistence under warmer conditions, will no doubt result in a continued degradation of the forest canopy. Because of the subsequent reduction in shading, non-native species are likely to encroach and prevent future regeneration of native species which would result in the demise of these habitats.

In addition to the challenges presented by changing climate conditions, other challenges, such as limited available resources (e.g. staff, equipment, funding) and access issues, may have a greater impact on the feasibility and timely implementation of management actions to promote greater resilience. Fortunately, at least one tactic (Tactic 5) is expected to be implemented within the next year or two as part of a larger coastal resiliency project for which funding has been secured. If this tactic performs as anticipated, and effectively limits the occurrence of drought stress, it may moderate the anticipated tree stress, pest damage, invasive plant response sequence expected and provide a longer timeframe in which to secure resources for implementing additional identified tactics.

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