Century Bog, Massachusetts

Climate Change Adaptation Plan

Manomet Center for Conservation Sciences

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May 2013

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Contents

Tables

Figures

Suggested citation: Galbraith, Hector. 2013. Climate Change Adaptation Plan for Century Bog, Plymouth, MA. Manomet Center for Conservation Sciences, Plymouth, MA.

Support for this project was provided by The Kresge Foundation.

This report is available for download at: http://www.manomet.org/climate_solutions/Century_Bog.pdf


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Executive Summary

The restoration of Century Bog presents engineering and biological challenges that, while unique to this site, also raise far-reaching questions about conservation choices in the face of human-created climate change. In a climate-altered world of uncertain ecological outcomes and limited resources, Century Bog provides an opportunity to explore how priorities can best be established for action, at what scale and cost, and with what results. These are difficult but vital issues to confront for any adaptation response, and relevant to how success is expected and measured at Century Bog and beyond.

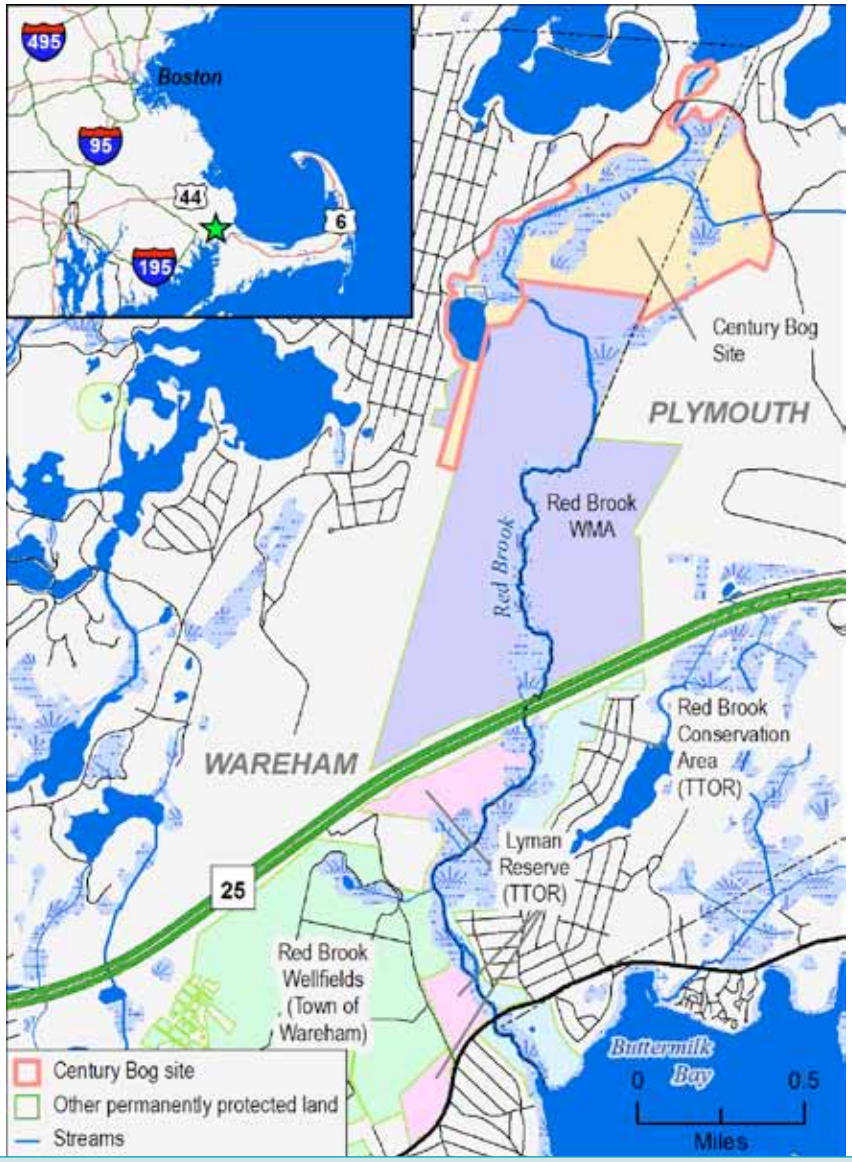


Figure 1. Location map and upper reaches of Red Brook

Project site and protected lands downstream in Wareham and Plymouth, Massachusetts. Wetland and watercourse data obtained from the NHD and MassGIS DEP Wetlands (1:12,000); roads and permanently protected lands from MassGIS.

FIG. 1

Site Description and History

Located in the towns of Wareham and Plymouth, southeastern Massachusetts (Figure1), the 250 acres of Century Bog comprise a working cranberry bog bordered by upland pitch pine and scrub oak forest, lakes and ponds, and residential areas. Red Brook flows through the Bog from its source at White Island Pond to its confluence with the sea.

Previously owned by the A.D. Makepeace Company (ADM), Century Bog was transferred to the State of Massachusetts Department of Fish and Game (DFG) in January 2010. This transaction was the result of a long and productive conservation collaboration between DFG and ADM. The state's acquisition of this site is an important capstone in its long-term strategy for land conservation in southeast Massachusetts. Together with the adjacent Red Brook Wildlife Management Area, also owned and managed by the DFG, and the Theodore Lyman Reserve, owned and managed by The Trustees of Reservations (TTOR), the total protected area now comprises almost 900 acres of the Red Brook watershed. The site and neighboring state-protected lands comprise an extensive and important archipelago of protected lands across southeastern Massachusetts – an area within which important habitats have been lost as a result of residential and commercial development.

The history and human use of Century Bog dates back to before colonial times. Archaeological evidence discovered close to the site indicates that Native Americans were using it seasonally to harvest fish, shellfish and other wildlife as early as 1200 AD. Up until and after the first contact with European colonists the Wampanoags continued to move through, camp on, and use the site, harvesting the seasonally abundant fish. Use of the Century Bog and its environs by the colonial settlers probably began soon after the colonization but the first real evidence of this dates to 1666 when the Selectmen of the Town of Plymouth bought 8,000 acres of the watershed from the

"Upper reaches of Red Brook flowing through cranberry bogs. Upland pitch pine and scrub oak woodland in background."

Wampanoags (TTOR, 2005). Between then and the mid-1800s, there is evidence that the land around Century Bog and Red Brook was used by colonists for three main activities: harvesting timber; harvesting the seasonably abundant alewives, trout and herring; and the extraction of iron ore for the production of nails and other metal goods. In the 1860s, the first efforts to cultivate cranberries on a large scale began to be made in the vicinity of Red Brook and Century Bog.

After the purchase of the watershed land by the Town of Plymouth, it was sold off beginning in the 1670s and 1680s to private owners. Beginning in the 1860s, many of these holdings began to be acquired by Theodore Lyman, a wealthy Bostonian who valued the land for the natural landscape and for the hunting and the fishing opportunities that it provided. By the 1870s, much of the watershed was owned by the Lyman family. In 2001 the Lymans transferred almost 640 acres to the Massachusetts Land Trust Coalition (MLTC), who then conveyed 428 of these acres to the Massachusetts Division of Fish and Wildlife. This land became the Red Brook Wildlife Management Area. Two years later the MLTC conveyed 210 acres of the land that they had received from the Lyman Family to TTOR as the Theodore Lyman Reserve. Beginning at this time, Trout Unlimited (TU) and TTOR collaborated in important fish habitat restoration work in the lower part of Red Brook, preparing the way for the restoration activities that are currently being planned and implemented. In 2010, A.D. Makepeace sold 245 acres of their working cranberry bog (Century Bog) and surrounding pine and scrub oak forest to the DFW. This brought the total holdings by conservation organizations within the watershed to 885 acres. The DFW and the TTOR continue to manage these sites for nature conservation.

Management Goals

The Bog supports a number of species and habitats that are listed as being of special concern to the state. The three main habitat types that the acquisition of the Century Bog helps protect are the pitch-pine scrub oak forest of the upland parts of the site, cold water fish habitat of Red Brook, and a coastal plain pond – Bartlett's Pond. The major goal of the Massachusetts Department of Fish and Game is to protect and restore Century Bog's important ecological attributes and services, particularly the cold water fishery.

The Bog's restoration will be carried out by the state's Divisions of Fish and Wildlife (DFW) and Ecological Restoration (DER). The goals of the restoration are to:

1. protect and enhance the current cold water fish habitat in Red Brook;
2. return much of the existing cranberry bog to natural habitat (primarily riparian or swamp woodland and wetlands);
3. protect the coastal plain pond habitat;
4. ensure the health of the existing pitch-pine and scrub oak forest; and
5. continue to ensure public access to the recreational opportunities provided by the site.

To ensure a successful restoration, the state agencies created a steering committee with partner agencies and organizations. The role of the steering committee is to evaluate and establish goals, explore potential strategies and likely outcomes, choose from a suite of conservation alternatives, and preside over the funding and implementation of the restoration work, This collective impact partnership includes the Commonwealth of Massachusetts, Trout Unlimited, The Trustees of Reservations, Manomet Center for Conservation Sciences and A.D. Makepeace Company (who will continue to support the restoration project by providing assistance in restoration activities).

The steering committee's goals are:

> ensuring a complex of linked habitats, including a healthy and flourishing cold water fish community where anadromous species like the brook trout and river herring continue to find spawning and rearing habitat, adjacent to and associated with native wetlands, a coastal plain pond community, and upland pitch pine scrub oak habitat together with the full complement of the species supported by these habitats.

Ecosystem Service Vulnerabilities

The ecosystems and associated services provided by Century Bog are agricultural production (the cranberry bog), the cold water aquatic habitat of Red Brook, the habitats found in bordering uplands forested with pitch-pine and scrub oak, and the habitat of the coastal plain pond (Bartlett's Pond).

Table 1 summarizes the overall ecosystem goods and services associated with the Bog.

Table 1. Ecosystem services provided by Century Bog.

ECOSYSTEM SERVICE	EXPLANATION
Water purification	Groundwater discharge, recharge and purification are provided by wetlands, such as Century Bog.
Flood regulation	By slowing runoff during heavy rain events, the wetlands of Century Bog mitigate potentially dangerous floods.
Biodiversity maintenance	Providing habitat for a variety of rare and common plant and animal species (such as anadromous brook trout, herring, etc.), Century Bog makes an important contribution to the overall biodiversity of the southeastern region and to the entire state (see below).
Aesthetic/recreational activities	Century Bog provides a place for local residents to pursue valued recreational activities including fishing, hunting, nature viewing, walking, etc.

Specific habitat types at Century Bog

Pitch-pine scrub oak forests are limited in New England mainly to the southeastern part of Massachusetts. They are currently threatened there by a variety of factors, including loss and fragmentation for residential and commercial development, and fire suppression. This vegetation community is especially important in Massachusetts because it supports invertebrates, particularly Lepidoptera (moths and butterflies), which depend on it for their existence in the state. It is identified as a Priority Natural Community by the Massachusetts Natural Heritage and Endangered Species Program, with a rank of S2. This ranking is applied to habitats that have typically fewer than 6 to 20 occurrences in the Commonwealth and/or are vulnerable to extirpation.

Coastal plain pond is also a threatened and rare habitat in Massachusetts, with an S2 ranking. It is confined to southeastern Massachusetts and Cape Cod. Coastal plain pondshore plant and animal communities develop around ponds that have no inlets or outlets but are fed by underground aquifers. The water levels in coastal plain ponds rise and fall seasonally, leaving varying amounts of pondshore exposed for colonization by vegetation. The fall in water levels during the summer growing season is the dominant factor in providing habitat for the unique pondshore plant communities that characterize this habitat type (Swain and Kearsley, 2007). The periodic inundations during high groundwater periods helps prevent colonization by shrubs and upland plants. Many of the plants characteristic of this community type are rare in Massachusetts and confined to coastal plain ponds.

Coldwater stream habitat in Massachusetts supports coldwater invertebrates such as the larvae of stoneflies and caddis flies, and coldwater-adapted fish, including sculpins and brook trout. It is mainly limited to the higher elevations and western part of the state, however, a few rare examples also occur on the southeastern coastal plain in streams that are fed by coldwater aquifers. At Century Bog, the Red Brook headwaters are fed by a coldwater aquifer and the resulting cool water temperatures provide spawning and rearing habitat for a fish community that was once widespread in New England, but is now rare (due to stressors such as dams, riparian vegetation destruction, the positioning of impermeable surfaces, pollution, etc.). Century Bog provides habitat for three important fish species: anadromous brook trout (which spawn and breed in the headwaters but migrate to the sea for much of their growth), river herring (which are marine for much of their existence but spawn in Red Brook); and anadromous alewives, which also use Red Brook to reach their spawning areas.

The climate change ecological vulnerability assessments that have been carried out in New England (e.g., Manomet and DFG, 2010; Jacobson et al., 2009) have shown that the most vulnerable species and services are likely to be those that are:

- Dependent on habitats restricted to cool or cold climatic conditions
- Sensitive to extreme weather events
- Drought intolerant

When the Century Bog ecological resources and ecosystem services are compared against these characteristics, it becomes obvious that many of them are or may be vulnerable to the anticipated changes in climate (Table 2).

Table 2. Vulnerabilities of Ecosystems and Ecosystem Services to Climate Change

ECOSYSTEMS AND ECOSYSTEM SERVICES	VULNERABLE TO CLIMATE CHANGE?	RATIONALE
Pitch-pine scrub oak habitat	Probably not	The distribution and ecology of this habitat indicate that it likely is resilient to climate change.
Cold water fish habitat	Yes	Changes in ambient temperatures and drought regimes could eliminate or degrade this habitat.
Coastal plain pond habitat	Yes	Changes in ambient temperatures, precipitation patterns, drought regimes, and groundwater dynamics could adversely impact this habitat.
Listed species	Yes	Loss of cold water and coastal plain pond habitats could adversely impact species.
Water purification	Perhaps	Disruption of wetland function by changes in drought regimes and precipitation patterns could adversely impact capability of site to continue this service.
Flood regulation	Perhaps	More severe, frequent, and prolonged precipitation events and storms could overwhelm site's ability to mitigate floods.
Biodiversity maintenance	Yes	Loss of climate-dependent habitats could entail loss of sensitive species and their contribution to biodiversity.
Aesthetic/recreational activities	Perhaps	Loss of cold water-dependent species such as brook trout could reduce recreational angling value of site.

Thus, almost all of the resources and services for which Century Bog is valued, and for which it was acquired by the state, are likely to be vulnerable to climatic changes over the remainder of this century. Consequently, future management and restoration strategies must take climate change into account.

Recommended Adaptation Actions at Century Bog

Current and future climate change could jeopardize the existence of some of the most valued Century Bog habitats, particularly the cold water fish habitat and the coastal plain pond. Thus, it is imperative that the restoration and management prescriptions for the site are climate-smart, that is that they increase the resiliencies and adaptive capacities of these habitats to the changing climate and thereby enhance their sustainability.

The Identification and Selection of Climate-smart Restoration Options: There were two main considerations and/or information sources that informed the identification and selection of restoration options by the steering committee:

Hydrological and Soils Information. Soil borings were collected at the site in 2011 to generate information about soils and the hydrology of the site that could be useful to the restoration. The main conclusions of this sampling effort were that:

- The dominant soil types at the site are poorly graded sand, sappric soils and mucks and peat.
- Sand layer thickness ranged up to three feet. Sand is not original to the site, and it was applied during the years of active cranberry management.
- Depth to water table was generally within one foot of the bog surface.

In December 2011 soil and sediment sampling and chemical analyses were conducted at the site. Dieldrin, a highly persistent organophosphate insecticide banned from agricultural use in 1974, was detected at some sampling sites at concentrations that could pose risks to human health. As Dieldrin is a highly bioaccumulable contaminant, it may also pose a risk to food chains, as well as to some recreational uses of the site.

Century Bog Design Guidance Investigations. Funded by the State of Massachusetts, Princeton Hydro LLC submitted to the steering committee in January 2012 a report identifying restoration design features intended to guide the climate-smart restoration of the site and meet the primary ecological restoration goals already determined by the committee (protection of cold water fish habitat, restoration of native wetlands). The resulting plans are shown in Figure 2. This menu of restoration options focused on two alternatives – a basic and less ambitious option shown as the uppermost map, and a more ambitious option shown as the lower map. The various design features of the so-called “Advanced Concept” were intended to be considered a-la-carte in that most of the treatments could be pursued or ignored, for whatever reason, without peril to the ultimate goals of the project.

Following an in-depth review by the steering committee, the resulting proposed restoration actions with the steering committee’s rationales where appropriate are presented below

Table 3. Adaptation of Ecosystems and Ecosystem Services to Future Climate Change

ECOSYSTEMS AND ECOSYSTEM SERVICES	ADAPTATION AND MANAGEMENT MEASURES	RATIONALE
Cold water fish habitat	Relocate Red Brook stream channel	Minimize warming of water and maximize longevity of cold water fish habitat
Wetland habitat	Include design features to minimize movement of warm surface waters to Red Brook	Minimize warming of water and maximize longevity of cold water fish habitat
Upland forest	Expand upland forest on restoration site	Maximize value of those areas of site not restored to wetlands

1. Relocate Red Brook. Currently, the upper reach of Red Brook from its source at White Island Pond almost to the western perimeter of the Century Bog is channeled through the middle of the cranberry growing area (Figure 2, upper). This exposes the stream to solar radiation (since there is little or no shade) and promotes a slow flow that efficiently warms when exposed to the sun. The result is thermal habitat that is inimical to brook trout. In the basic plan the stream is left in situ but is shaded from solar radiation by the construction of flanking berms on which riparian shrubs and trees will be planted. The Steering committee believes that this may not be adequate to ensure the existence of cold water fish habitat in Red Brook under a warming climate. They believe that the stream has to be relocated to the south as shown in Figure 2, lower. This relocation will have three major benefits: first, it will move Red Brook into an area that is already well-shaded by the pitch pine forest. Second, it brings the stream into closer proximity with the main discharge areas of the cold water aquifer (at the interface of the forested uplands and the bog itself). Thus, the stream will not only be better shaded than it currently is but it will be better positioned to receive more cold water discharge. Last, it separates the stream from the projected wetland area. If Red Book is retained in its current position it would have to be isolated from the projected wetlands where water will warm since the wetlands will be exposed to the sun. The only way to do this would be to build protective berms running along either bank of the stream, not a natural or aesthetically pleasing solution.

2. Wetland restoration in the cranberry bog. With Red Brook relocated to the southern perimeter of the site, this leaves the entire area that is currently used for cranberry cultivation (approximately 60% of the site) available for conversion to wetlands. This would entail restoration of the historic natural condition of the site which, prior to conversion to agriculture, was probably either red maple or Atlantic white cedar wetlands. (Figure 2, lower). In practice it will be unlikely that this entire area can be restored to wetlands because the costs would be prohibitive. Instead, one approach that the committee is exploring would be to confine wetland restoration to an area extending south from the approximate mid-line of the current cranberry bog to the relocated Red Brook. The restored wetland surface will be vegetated with species typical of southeastern Massachusetts' wetlands. Since the site was likely to be historically vegetated with Atlantic white cedar swamp and/or red maple, this is the wetland type that the restoration will aim for.

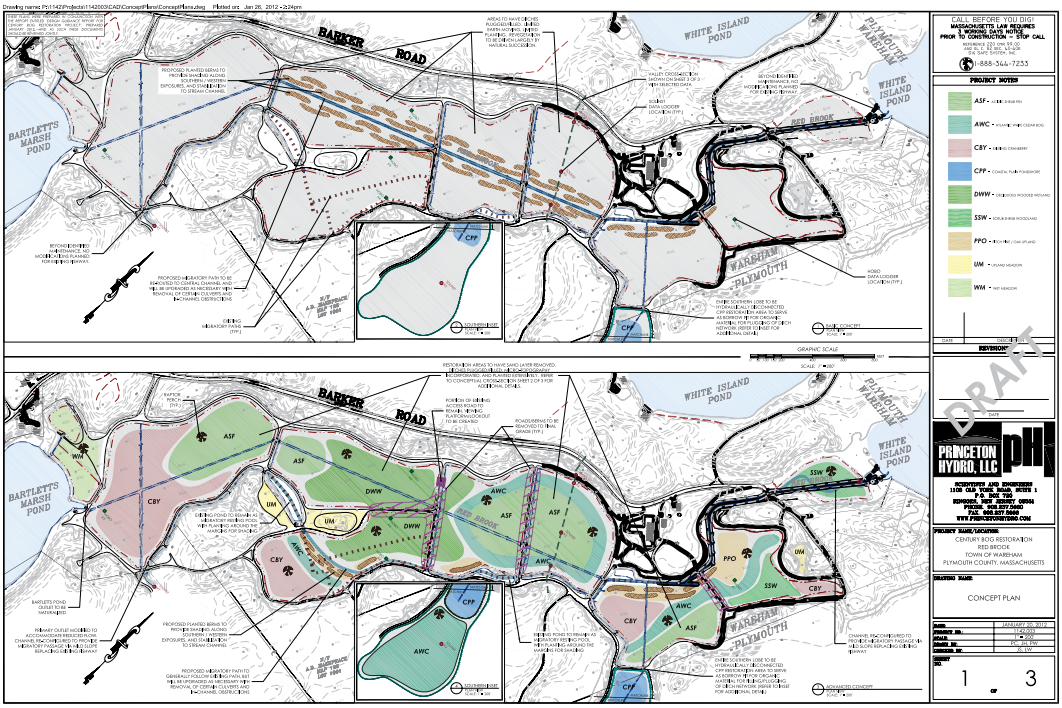
3. Separation of Red Brook from the restored wetlands. As already noted there is a risk that surface water that has been warmed in the planned wetland area could flow into Red Brook, raising the water temperature to a level that could be harmful to cold water fish. Therefore, it will be necessary to ensure in the channel design and adjacent grading that there isn't a significant flow from the wetlands to the stream. Currently, the section of Red Brook that flows along the southern perimeter of the site, is separated from the cranberry bog by a high berm which prevents flow from the wetland into the stream. It may be necessary to extend this berm along the northern bank of the relocated section of Red Brook, if the entire stream is to be protected from warmed water.

4. Extension of upland forested habitat. The area of the site that is currently under cranberry cultivation and that extends north from the bog mid line (Figure 2, upper) may not be restored to wetlands if the costs to do so would be prohibitive. Instead, portions of it may be used as areas where sands excavated from the bog will be disposed of. This will have the result of further raising the land surface, making it even more suitable for colonization by upland habitat, specifically pitch pine and scrub oak forest.

Overview of Future Century Bog Landscape

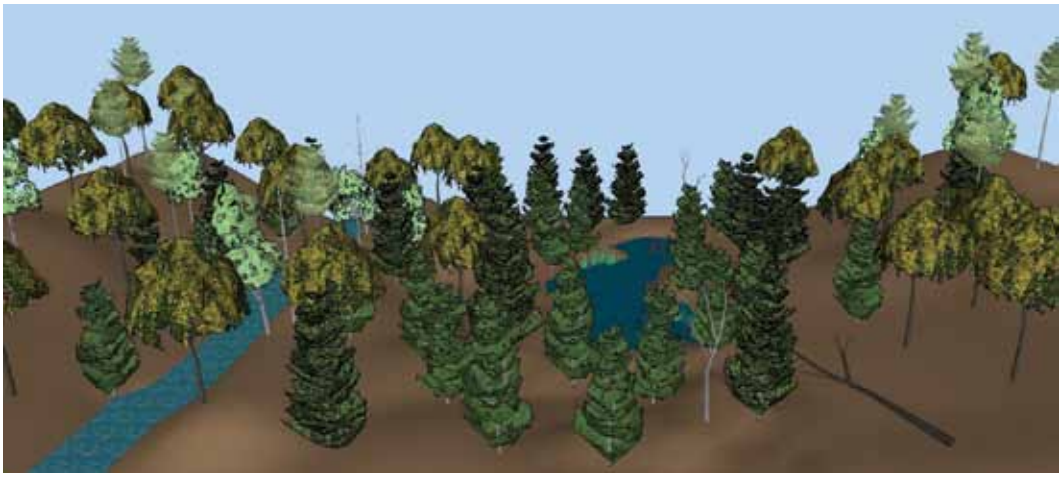
When the restoration at Century Bog is complete, an observer viewing the site would see a diverse and complex mix of wetland, riparian, upland forested, riverine, and lacustrine habitats. If this observer were to traverse the site from north to south (Figure 3), he/she would initially pass down a gentle slope through an upland area dominated by pitch pine and scrub oak habitat. After about 100 yards the ground would level out, become wetter, and would be dominated by wetland plants until, by a point halfway across the site on this transect, the observer would have left the upland forest and be in a wetland/swamp dominated by Atlantic white cedar and other hydrophytic species (e.g., red maple). Interspersed among this tree dominated landscape would be pools of standing water or marshy and graminoid dominated habitat. After wading through these wetlands, the observer would encounter a low berm vegetated with upland plant species, on the other side of which Red Brook, with its cold water habitat for fish, runs to the west and into TTOR's Lyman Reserve.

Figure 2. Design Plan for Century Bog Restoration



The observer would pass through a changing ecological landscape with a diversity of wildlife. Furthermore, while he/she would be observing essential landscape elements that are potentially vulnerable to the changing climate, they will be configured in such a way as to maximize their future survival prospects.

Figure 3. Cross-sectional View of Restoration Site



Implementation of Restoration

The next stage in the Century Bog adaptation process is for the steering committee to select a qualified firm to lead the restoration design and to estimate and secure the necessary funding.

It is anticipated that the restoration described in this report will cost approximately $1-2 million to implement, which is unlikely to come from one funder. Rather, the steering committee will solicit funding from a number of foundations and governmental sources. Also, under their sale agreement to the Commonwealth, ADM has offered to provide the resources (e.g., personnel, machines, and time) to carry out at least the initial earth-moving and engineering activities; this will have a major benefit on lowering costs and provide an attractive match for potential federal or other grant funds. Given the large scale of the proposed restoration at Century Bog, the entire project is anticipated to take 2 to 4 years to complete.

Lessons Taught by Century Bog

Biologists and climate scientists have been communicating through conferences, workshops, and publications about the need for climate-smart restoration and management activities at sites. But such restoration and management activities have remained largely theoretical. The restoration of Century Bog provides an opportunity to test these theories against the practical realities of field experience, providing real lessons to apply in future climate adaptation actions. In this context, the importance of the Century Bog project is that it takes that next step. The lessons being learned through the Century Bog restoration will be relevant to restorationists and managers facing similar climate change dilemmas elsewhere.

Six major lessons have emerged thus far from the project:

1. **The importance of a climate change vulnerability assessment.** Without performing an analysis of how vulnerable valued site attributes are to climate change and how they may be affected it may be difficult to identify which resources at a site are at risk. Such an analysis was previously performed for all of the relevant wildlife habitats in the Commonwealth of Massachusetts by Manomet and the State (2010). Vulnerability analyses aid in the identification of sensitive and threatened resources (and, also, more robust ones). If performed well, the vulnerability analysis also provides information on why the resources are at risk and, thereby, helps identify adaptation options and even whether a particular adaptation action makes sense.

2. **Managing versus resisting climate change impacts.** The goals at restoration and management sites under a changing climate are likely to be focused on either: (a) managing and facilitating changes that are brought about by the different conditions; or (b) trying to prevent such change by maintaining the existence of sensitive resources. At Century Bog, climate change is being managed in the overall restoration effort. However, the adaptation plan goes further, by attempting to prevent some of the changes that we expect to occur (e.g., to conserve a vulnerable fish community). A clear understanding of which goals should be pursued at a site is important for feasibility, long-term sustainability, and cost. In general, managing change may be technically more feasible (since we are working with nature, rather than against it), less costly and resource-intensive, and more sustainable in the long-term than the goal of preventing change. It should also be realized that the costs of preventing change are likely to increase through time, as the climate continues to alter.

3. **Expect complications due to non-climate stressors.** The Century Bog soils contain residues of Dieldrin that may pose risks to humans and biota. Consequently, the soils may need to be remediated either before or during the restoration. This could have important impacts on how the restoration is to be carried out, its timeline, costs, and the trajectory of the restoration. This is a good example of how non-climate stressors at a site may affect options for climate-smart restoration or management.

4. **Be flexible about defining "success".** There is no guarantee that the actions undertaken at a site will successfully preserve climate-sensitive resources. Climate change, or some unforeseen factor, might overwhelm the best intentions and actions and these habitats will lose some of the characteristics that define their value to conservationists. This risk poses important questions – most importantly, how to define success in the face of a changing climate. More specifically for Century Bog, is the existence of the cold water fish habitat the only measure of success, or are there other important success metrics? Focusing entirely on the preservation of a vulnerable (in some cases a highly vulnerable) ecosystem attribute and having no alternate acceptable outcomes ultimately may reduce the chances of achieving "success."

5. **The importance of long-term monitoring.** Given the limitations of current knowledge (particularly about the future specifics of climate change, or the adaptive capacities or sensitivities of species and systems) we cannot be certain about the fates of habitats and species. Therefore, it is important that adaptation measures selected are informed by climate projections, and can also be modified based on real-time data showing how species and ecological systems are actually responding to climate change. This requires long-term monitoring. The targets of monitoring should be carefully selected to minimize ambiguity about what is actually causing change.

6. **Costs and trade-offs need to be recognized and evaluated.** Previous work in Massachusetts and elsewhere indicates that for some sites climate-smart restoration might simply be an extension of restoration/management measures that are already routinely taken. In such cases, climate-smart restoration/management might incur relatively low additional costs.

This is not always the case. At Century Bog, a restoration strategy that did not address climate-vulnerable species might simply focus on restoring the cranberry bogs to a mix of functioning wetland, where the water table is close to the surface, and drier habitats elsewhere. The cold water fish habitat and the coastal plain pond would be allowed to be adversely affected by the changing climate. This would be a comparatively inexpensive exercise, costing less than one million dollars. However, implementing the plan shown in the lower map in Figure 2, where climate change-sensitive resources are protected is a much more demanding exercise costing perhaps 2 to 3 times that figure. It is likely that restoration goals focused on preventing change, rather than facilitating it (see above) will incur greater costs.

Conservation resources are not unlimited and a cost-effective allocation of resources will continue to be an essential in conservation planning and management. The benefits of restoring/managing for climate change-sensitive species need to be weighed against the restoration costs, opportunity costs, and the trade-offs. Specifically, we need to address the question for any adaptation action: do the goals - as measured against the realities of continuing climate change - justify the costs, or would the funding be better directed elsewhere? At Century Bog the conservation value of the fish habitat, associated wetlands, and other habitats is high enough to justify the actions proposed. The important point is that such judgments need to be based, as at Century Bog on realistic cost-benefit analyses.

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