Appendix E

USFWS

Habitat restoration

Habitat Management Plan Potential Management Prescriptions

■ Upland Forests, Shrublands, and Grasslands

■ Tidal and Freshwater Wetlands

A. Upland Forests, Shrublands, and Grasslands

❖ Strategy 1. Manipulate Plant Species Composition

1.1 Silvicultural Prescriptions

1.1a Clearcutting

Clearcutting is the removal of an entire stand of trees in one cutting with reproduction obtained naturally or artificially (e.g., by planting, broadcast seeding, or direct seeding). Two common methods of clearcutting are patch or block clearcuts and strip clearcuts. This regeneration method is considered to be even-age management, although somewhat coarse multi-aged stands can be accomplished through progressive patch or progressive strip clearcut systems. Clearcut size does have an effect on regeneration. As clearcuts increase in size, they tend to favor the regeneration of shade intolerant species. As they become smaller, they tend toward encouraging intermediately tolerant and tolerant species. The size and shape of the clearcut can have an effect on bird species richness and influence herbivore use.

Patch Clearcut

Patch or block clearcuts can be many different shapes and sizes, depending on management objectives, forest type, terrain, or boundaries. Natural regeneration from the adjacent stands is not heavily relied upon, but can have varying degrees of influence depending on patch size. All stems 2” dbh and greater should be removed unless some advanced regeneration of desired species exists. Although somewhat difficult to apply, an alternate or progressive patch clearcut approach can be an option. These approaches are more often associated with the strip clearcut method. The application of these options should follow the respective strip clearcut strategy substituting the strips with patches.

Strip Clearcut

Strip clearcutting is used to promote natural regeneration and growth in the harvested strips through the adjacency of the unharvested area. In the harvest areas, all stems 2” dbh and greater should be removed unless some advanced regeneration of desired species exists. The unharvested strips act as a seed source and protection for the harvested areas. As regeneration is established in the harvested areas, the unharvested areas are progressively removed. Concerns related to wind damage are warranted when using this method of clearcutting because of the increase in amount of edge that is exposed. This can be avoided by minimizing the width of the strips being harvested (50–100 feet on stable soil and 30–50 feet on wet soil or questionable sites), ensuring at least one end of the strip is closed, and harvesting as soon as cleared strips are regenerated. Strip clearcuts are more successful when applied to healthy forests found on deep, well-drained soils. These harvests can be designed in an alternate or progressive fashion.

Alternate Strip Clearcut

Alternate strip clearcuts are accomplished in two stages. The first harvest removes vegetation in long narrow clearcuts with unharvested leave-strips in between. The second harvest removes the leave strips once regeneration is established in the first-pass harvest areas. This technique does not allow for much regenerative influence on the second-pass areas, and may require artificial means to accomplish specific regenerative objectives. This requirement can be minimized if a seed source is in reasonable proximity, or advanced regeneration is present. To minimize windthrow, the strips should be oriented at right angles to the prevailing winds. The width of the strips should be influenced by the seed dissemination ability for the preferred species and the potential for wind damage.

Progressive Strip Clearcut

Progressive strip clearcuts accomplish results similar to the alternate strip clearcuts, but in three or more passes rather than in two. Using this method instead of the alternate strip clearcut method offers a number of advantages. One is the strips can be progressively harvested into the prevailing wind, reducing the exposed edge and windthrow. Another is more area has the ability to regenerate naturally, resulting in less area requiring potential for costly artificial regenerative techniques. To some, this may also have less negative aesthetic impact.

1.1b Single Tree Selection

Single tree selection is the removal of individual trees uniformly throughout a stand. This technique is often used to promote the quality and growth of the remaining trees. It can also result in the regeneration of mostly shade tolerant species due to the small canopy openings created during the harvest. The use of this technique, on a continual harvesting cycle, is considered uneven-aged management. Actively managing a stand in uneven ages can reduce its natural ability to resist insect, disease, and other debilitating health issues. Careful extraction of the trees is necessary to help limit residual stand damage, which can create an opportunity for insects and disease to enter otherwise healthy trees. Root damage by soil compaction also needs to be considered. This technique can also be used during even-aged management and, when done so, is commonly referred to as an intermediate thinning. Single tree selection can be used to mirror a small-scale disturbance. When only large trees are selected, the large opening produced in the canopy typically will be utilized quickly by the crowns of adjacent older trees.

1.1c Group Selection

Group selection is the removal of small groups of trees to maintain an uneven-aged forest. Normally, to be considered a group selection, as opposed to a patch clearcut, the size of the harvest group should be less than or equal to twice the height of the adjacent mature trees. This method will encourage the regeneration of intermediately tolerant and tolerant species, but some intolerant species can appear toward the center of the harvest areas when the groups are at the maximum size. The likelihood of the harvest areas regenerating, combined with the ability to schedule continual harvest entries, results in this technique being a method of choice to convert even-aged stands to uneven-aged stands when desired. Actively managing a stand in uneven ages can reduce its natural ability to resist insect, disease, and other debilitating health issues. Careful extraction of the trees is necessary to help limit residual stand damage, which can create an opportunity for insects and disease to enter an otherwise healthy stand. Root damage by soil compaction also needs to be considered.

1.1d Shelterwood System

Shelterwood is a series of harvests carried out with the intent of regenerating a stand using mature trees that are removed at the end of the scheduled rotation. This technique typically is used to regenerate intermediately tolerant (mid-successional) and tolerant (late successional) species, but in certain instances can be used for intolerant (early successional) species. The use of this technique is considered even-aged management, although variations more often found in the irregular shelterwood system can result in a multi-aged stand. For a shelterwood system to be considered, a stand should be reasonably well stocked with a moderate to high component of the species desired for regeneration. A number of shelterwood system applications exist. The more commonly used is the open shelterwood system. Although less commonly used, the dense shelterwood, deferred shelterwood, irregular shelterwood, natural shelterwood, and nurse tree shelterwood systems are also useful in accomplishing specific regenerative needs and other resource management objectives.

2-Stage Open Shelterwood System

The two-stage open shelterwood system consists of an initial harvest (stage 1) used to encourage regeneration, and an overstory removal harvest (stage 2) once regeneration is established. This technique usually results in regeneration with a higher component of intermediately tolerant species. In a well-stocked stand this translates into removing 30 percent to 50 percent of the stand in the first harvest. Residual crown closure should be between 30 percent and 70 percent. The harvest should focus on undesirable species, suppressed, co-dominant, and unhealthy dominant trees. The residual should be an evenly distributed stand of large crowned, healthy, dominant and co-dominant trees. This will provide the greatest potential for seed production and resiliency to windthrow. Regeneration is considered established when it is found to be, at a minimum, >1 foot tall for softwoods and >3 feet tall for hardwoods and hemlock. A minimum of 5,000 well-distributed seedlings per acre should be established before the overstory removal (stage 2), which should be conducted in the winter, with adequate snow depth to help minimize damage to the regeneration.

3-Stage Open Shelterwood System
The three-stage open shelterwood system consists of a preparatory harvest (stage 1) to encourage tolerant regeneration, a secondary harvest (stage 2) used to encourage intermediately tolerant and tolerant regeneration, and an overstory removal harvest (stage 3) once regeneration is established. This technique usually results in regeneration with a higher component of tolerant species. In a well-stocked stand this translates into removing a maximum of 15 percent of the stand in the initial harvest (stage 1). The harvest should focus on undesirable species and suppressed stems. An additional 15 percent to 30 percent of the residual stand should be removed in the secondary harvest (stage 2). Residual crown closure should be between 30 percent and 70 percent. The harvest should focus on undesirable species, suppressed, co-dominant, and unhealthy dominant trees. The residual should be an evenly distributed stand of large-crowned, healthy, dominant and co-dominant trees. This will provide the greatest potential for seed production and resiliency to windthrow. Regeneration is considered established when it is found to be, at a minimum, >1 foot tall for softwoods and >3 feet tall for hardwoods and hemlock. A minimum of 5,000 well-distributed seedlings per acre should be established before the overstory removal (stage 2), which should be conducted in the winter to help minimize damage to the regeneration.

Dense Shelterwood System
The dense shelterwood system consists of an initial harvest used to encourage tolerant regeneration, and an overstory removal harvest once regeneration is established. This technique usually results in regeneration with a higher component of tolerant species. In a well-stocked stand this translates into removing 15-30 percent of the stand in the first harvest. Residual crown closure should be around 80 percent. The harvest should focus on undesirable species, suppressed, co-dominant, and unhealthy dominant trees. The residual should be an evenly distributed stand of large crowned, healthy dominant and co-dominant trees. This will provide the greatest potential for seed production and resiliency to windthrow. Regeneration is considered established when it is found to be, at a minimum, > 1 foot tall for softwoods and > 3 feet tall for hardwoods and hemlock. A minimum of 5,000 well-distributed seedlings per acre should be established before the overstory removal (stage 2), which should be conducted during the winter, with adequate snow depth to help minimize damage to the regeneration.

Deferred Shelterwood System
The deferred shelterwood system consists of an initial harvest (stage 1) to encourage regeneration, and a delayed overstory removal harvest (stage 2) once established regeneration is well advanced. This technique can be tailored to encourage a high regenerative composition of either intermediate or tolerant species by adjusting the intensity of the initial harvest. In a well-stocked stand this translates into removing 15 percent to 50 percent of the stand in the first harvest. Residual crown closure should be between 30 percent and 80 percent. The harvest should focus on undesirable species, suppressed, co-dominant, and unhealthy dominant trees. The residual should be an evenly distributed stand of large-crowned, healthy, dominant and co-dominant trees. This will provide the greatest potential for seed production and resiliency to windthrow. Regeneration is considered well advanced when it is found to be, at a minimum, >10 feet tall for softwoods and >15 feet tall for hardwoods and hemlock. A minimum of 5,000 well-distributed seedlings/saplings per acre should be established before the overstory removal (stage 2) is conducted.

Irregular Shelterwood System
The irregular shelterwood system consists of an initial harvest to encourage regeneration, optional intermediate harvests to encourage supplemental regeneration, and an overstory removal harvest once regeneration is established. This system usually results in regeneration with a higher component of intermediately tolerant or tolerant species. It differs from other shelterwood systems by introducing the concept of leaving a component of the original stand that either can be removed during subsequent harvests or can be left throughout the series of harvests and beyond. The long-term residual component can be left singly or in groups. Harvests can be applied in a variety of ways, including harvesting uniformly, in groups, or in strips. The harvest should focus on undesirable species, suppressed, co-

dominant, and unhealthy dominant trees. This will provide the greatest potential for seed production and resiliency to windthrow.

1.1e. Seed Tree System

The seed tree system is the removal of most of a stand while retaining a minority of seed-producing trees, left standing to retain some component of the desired species in the regenerating stand. Seed trees can be left singularly and/or in groups, and should be distributed as uniformly as possible throughout the stand. This system usually is prescribed when desired species are lacking as a seed source in the overstory (negating shelterwood as an option), or regeneration composition is not a primary objective. It could also be used, somewhat more unpredictably, to convert species composition to an earlier successional variety while retaining a small component of desired species (e.g. softwood to mixed wood). Desired species that are healthy, dominant, large-crowned, and well-rooted should be targeted to leave standing. The rest of the stand should be removed in its entirety (2” dbh and greater). The residual trees/groups can be removed after regeneration is established, or may be left to accomplish other stand objectives. Residual trees are subject to harsh environmental conditions with very little protection. Sudden exposure to light can stimulate epicormic sprouting in hardwoods, which should be expected and addressed. A common approach to reduce epicormic sprouting is to leave adjacent trees that will provide immediate shade to the bole of the seed tree. The more shallow-rooted softwoods have the least resilience to wind and other environmental factors, and are less likely to perpetuate until natural resilience is reestablished with the regenerating stand.

1.2 Stand Improvement

Stand improvement consists of entering an even- or uneven-aged stand at any stage of development with the intent of tending to habitat needs through thinning, weeding, cleaning, liberation, sanitation, or other improvement methods. The primary function of this system is to control species composition and reduce an overabundance of stems per acre to a more desired stocking level. Another function should be to consider other habitat needs during these stand entries, and introduce methods to help meet desired criteria. This translates into thinning young stands (pre-commercially) to control species composition, conducting intermediate thinnings in middle-aged stands to maintain accelerated growth and remove unwanted vegetation, and controlling the stocking levels of habitat features such as snag trees, cavity trees, den trees, downed wood and other features.

1.3 Herbivore Control

Selective feeding or browsing by wild herbivores can negatively affect woody plant species composition and stand structure. Deer are the most common species that causes impacts of concern to wildlife and forest managers. Methods to reduce negative impacts include deterrents, exclusion, or population reduction. Deterrents (e.g., chemical application, scare devices) and exclusion (e.g., fencing, seedling tubes) are labor-intensive and costly to employ. Chemicals can create environmental hazards, and both methods usually are not practical or satisfactory except in small-scale situations such as nurseries or small plantations. Population reduction methods include reproductive controls (e.g., chemosterilants, contraceptives) that are costly and require continual reapplication, and public hunting. Hunting is the most widely practiced tool for reducing the negative impacts of herbivory in these settings. Hunting must be regulated (e.g., hunting methods, timing of seasons, hunting pressure) and the harvests monitored to prevent negative impact on the long-term survival of target herbivore populations.

In some situations, beavers can conflict with certain refuge management objectives through the excessive felling and girdling of trees and the flooding of sensitive habitats. Beavers can also create wonderful wetland habitats. Installing anti-flooding/damming devices (e.g., “beaver bafflers”) at culverts, water control structures, or bridges can sometimes be effective in mitigating undesired flooding.

1.4 Mechanical and Herbicidal Treatments for Native Vegetation

Many treatments and numerous types of equipment are available for mechanically manipulating upland sites from one cover type to another. The selection of the type of mechanical treatment often depends on your habitat goals. Do you want to have all vegetative material left on the ground, have it removed from the site, piled in slash, broadcast spread, burned or chipped? If an area is cut from young forest, and with the intention of creating a permanent shrubland, should the stumps be removed?

Strategies and tools:

- Drum mowers for removal of small trees
- Hydro-Axe—This piece of equipment consists of an articulated tractor with a mower mounted on the front. It is generally able to cut trees up to approximately 6–8” dbh. Woody material is reduced to fine chips, often finer then those resulting from a roller mower.
- Roller Chopper Mower
- Mowing and brush hogging—Mowing is an appropriate treatment for grass, forbes and small shrubs and saplings. Vegetation >4 inches often needs a higher powered machine.
- Girdling—Girdling can be appropriate to kill single trees to create snags and open up the canopy for further development of understory. It can also cause stump sprouting.
- Chainsaws—Saw work can be appropriate to remove single trees or groups of trees and pen up the canopy for further development of understory. Stump sprouting may occur.
- Coarse Woody Debris Management—Different prescriptions will leave differing amounts of woody debris. Objectives will drive the best management technique for dealing with the debris. Often, it can be left to decay on the forest floor. However, if conversion to another habitat type (grassland or shrubland) is desired, the woody materials left must not complicate future management actions (e.g., leaving large logs in a unit may make it hard to brush hog).
    - Chipping—Materials can be chipped and broadcast onsite. Their depth should not exceed 2–3 inches.
    - Piling—Native vegetation may be piled on site and left for habitat or burned in a slash pile.
    - Removal from site—Materials can be chipped and removed from the site or removed as whole logs or shrubs
    - Spreading small slash will not make future treatments difficult, and returns nutrients to the soil.
- Herbicides for stable shrublands—In some cases where the structure of a stable shrubland is desired, selective herbicides are applied to tree species. This eventually results in the selection of a dense shrub overstory and the development of a minimal amount of trees. This can create habitat that will remain in the shrub stage longer than that of most other management techniques.

Maryland Partners in Flight Committee. 1997. *Habitat Management Guidelines for the benefit of landbirds in Maryland.* Maryland Partners in Flight.

1.5 Invasive Plant Control

Manual and Mechanical Control

The mechanical removal of plants can be effective against some herbaceous plants, shrubs and saplings, and aquatic plants, especially if they are annuals or have a taproot. Care should be taken to minimize soil disturbance to prevent creating conditions ideal for weed seed germination. Repeated cutting over a growing period is needed for effective control of many invasive plant species. Care should be taken to properly remove and dispose of any plant parts that can re-sprout. Treatments should be timed to prevent seed set and re-sprouting. The following methods are available: hand-pulling, pulling with hand tools (weed wrench, etc.), mowing, brush-hogging, weed-eating, stabbing (cutting roots while leaving in place), girdling, mulching, tilling, burning using a hand-held tool, smothering (black plastic or other means), and flooding.

The advantages of mechanical treatment are the low cost for equipment and supplies and the minimal damage to neighboring plants and the environment. The disadvantages are higher costs for labor, increased soil disturbance, and the inability to control large areas. For many invasive species, mechanical treatments alone are not effective, especially for mature or well-established plants, or those with extensive rhizomes. Mechanical treatments are most effective when combined with herbicide treatments (e.g., girdling and treating with herbicide).

Prescribed Fire

Fire can either suppress or encourage any given plant species, so great care must be taken to understand the ecosystem and the life histories of the native and invasive plants before using this tool. It is most successful when used to mimic natural fire regimes. The proper timing of prescribed burns is essential for controlling target invasive species. The most effective fires for controlling invasive plants occur just before they flower or seed set, or at the young sapling/seedling stage. Repeated burns or a combination of burning and herbicide treatments may be needed to effectively control the invasive plant and seedlings that may sprout after the burn.

This tool requires a good deal of pre-planning (including permitting) and requires a trained crew available on short notice during the burn window. Spot burning using a propane torch can be a good method of controlling small infestations of invasive plants. It can be advantageous where conditions are too wet or there is little fuel to carry a prescribed fire.

Biological control

Biological control is the use of animals or disease organisms that feed upon or parasitize the target invasive species. Usually, the control agent is imported from the invasive species' home country, and/or artificially high numbers of the control agent are fostered and maintained. There are also "conservation" or "augmentation" biological control methods where populations of biological agents already in the environment (usually native) are maintained or enhanced to target an invasive species.

The disadvantage of biological control is the small chance that an introduced control agent can itself become an invasive species. Great care is taken in selecting appropriate biocontrol agents; they are regulated by the USDA. Control agents appropriate for all invasive species may not even exist. The advantages of this method are that it avoids the use of chemicals and can provide relatively inexpensive and permanent control over large areas. More effort is placed on using a "conservation" approach to biological control; and this has great promise as an effective, long-term control method. If biological control methods are used, ensure that all state and federal permits are in place.

Herbicides

A wide variety of chemicals are toxic to plant and animal species. They may work in different ways, and be very target-specific, or they may affect a wide range of species. Herbicides may be "pre-emergent," that is, applied before germination to prevent germination or kill the seedling, or "post-emergent," and may have various modes of action (auxin mimic, amino acid inhibitor, mitosis inhibitor, photosynthesis inhibitor, lipid biosynthesis inhibitor). Products may come in granular, pellet, dust or liquid forms. Liquid herbicides commonly are diluted to an appropriate formula and mixed with other chemicals that facilitate mixing, application or efficacy. Common application methods include foliar spray, basal bark, hack and squirt, injection, and cut stump.

The advantages are that the correct chemicals, applied correctly, can produce desired results over a large area for a reasonable cost. The disadvantages are that the chemicals may affect non-target species at the site (including the applicator) and/or contaminate surface or groundwater. Proper planning includes using the most target-specific, most effective, chemical that is least hazardous to humans and the environment.

In addition, attention to protective gear, licensing requirements and other regulations is essential. Herbicides are most effective when used in combination with the non-chemical methods described above.

1.6 Planting or Seeding

Planting or seeding areas can change the species composition. Some examples are converting fields of cool season grass to warm season grass through planting, restoring areas that have been damaged either by wildfire or by erosion, introducing native ground cover to out-compete non-native plant species, or jump-starting areas to a new habitat type by planting shrubs or trees. The use of locally adapted plant species, e.g., local genotypes, is preferable, but this locally propagated plant stock is often difficult to locate, unless you grow or salvage your own. When purchasing plant stock from a nursery it is critical to use a reputable dealer and ensure the stock you purchase is indeed a native and not derived from another source. There have been many instances where either a cultivar, or a similar species from another country, has been sold as a native plant. Care must also be taken to ensure nursery stock does not contain unwanted diseases or pests.

Tools and Equipment
The tools and equipment chosen will depend on the type of planting stock you are using. Warm season grass mixes may be broadcast seeded or a seed drill may be used. If seeds are broadcast spread, the field should be lightly disced or packed to incorporate seed. Attachments on tractors can assist with shrub or tree planting. To minimize soil disturbance, a large auger may be used to dig planting 18" holes. For bare root seedlings or whips, dibble sticks can be used manually to plant.

Site Preparation
Many native grass species are not good competitors with aggressive weedy species. The seed bed should be free of weeds and noxious plants before seeding. For native trees and shrubs, grass competition should be reduced by mowing and invasive shrubs and trees removed before planting. Minimizing soil disturbance during planting will help prevent the establishment of new nonnative plants. Follow up control of undesirable plants may be necessary.

Planting Technique

Stock
Season: Planting is best completed during times when there will be ample precipitation, either in early spring or fall. Avoid summer planting when possible as new transplants and tender seedlings are prone to drought damage.

Monitoring
Appropriate monitoring plans must be in place to measure plant survivorship and establishment of communities.

Pfaff, S. and M.A. Gonter. *Florida Native Plant Collection, Production and Direct Seeding Techniques*. 1996. US Department of Agriculture. 61 pgs.

❖ Strategy 2. Maintain or Provide Structural Components of the Woody Uplands

2.1 Retain or Provide Coarse Woody Debris

Snags or live trees that fall to the forest floor are known as coarse woody debris (CWD). CWD ranging in size from branches to bole to entire trees adds structural diversity and serves as hiding and thermal cover, den sites, foraging substrate, and winter access to subnivean (i.e., below the surface of the snow) habitats. As the wood decays, it releases essential nutrients such as sulphur, phosphorous, and nitrogen. The need for creating CWD depends on the forest type, stage of succession, and management history. Allowing snags to fall naturally, felling and leaving live trees, or leaving non-merchantable tops, limbs, and products other than logs during commercial logging can augment the levels of CWD.

2.2 Retain or Create Snags

Snags play an important ecological role for at least 149 avian, 73 mammalian, and 93 herpetile species (Thomas et al. 1979). Based on the state of decomposition, snags can be hard (sound sapwood, rotting heartwood) or soft (rotting sapwood and heartwood). Because they are considered safety hazards, the abundance of snags can be compromised in commercially managed forests. There are several ways to "create" snags, or initiate the decomposition process. Each is an effort to damage a healthy tree's integrity by creating a pathway for fungal infection. They include girdling, topping, removing branches, inoculating with fungi, and injecting herbicides. The density and size of suitable snags depends on the individual forest types and natural disturbance patterns. Snag retention must be done in appropriate places (e.g., not within felling distance of public paths).

Thomas, J. W. 1979. *Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington*. USDA, Forest Service, Agriculture Handbook No. 553.

2.3 Patch Retention

Patch retention is leaving groups within a stand with the primary purpose of satisfying structural or other non-regenerative objectives. This can be applied in combination with other silvicultural systems. Patch size can vary, and should be determined on how effectively it will meet the objective. Trees can be left singly, but should be left in conjunction with groups to form a mosaic as opposed to uniform singular use that will resemble other silvicultural systems. Patches can be removed in a variety of scheduled intervals; but, to set this method aside from variations that can be found in other silvicultural systems, longevity is vital.

2.4 Control Deer Populations

Selective feeding or browsing by deer in particular can negatively affect woody plant species composition and stand structure in Northern Forest habitats. Methods of reducing negative impacts include deterrents, exclusion, or population reduction. Deterrents (e.g., chemical application, scare devices) and exclusion (e.g., fencing, seedling tubes) are labor-intensive and costly to employ; chemicals can create environmental hazards; and both methods usually are not practical or satisfactory except in small-scale situations such as nurseries or small plantations. Population reduction methods include reproductive controls (e.g., chemosterilants, contraceptives) that are costly, require continual reapplication, and often are ineffective except within island environments, and public hunting. Hunting is the most widely practiced tool for reducing the negative impacts of herbivory in these settings. Hunting must be regulated (e.g., hunting methods, timing of seasons, hunting pressure) and the harvests monitored to prevent negative impact on the long-term survival of target herbivore populations. In general, shotgun seasons are more effective then bow seasons when the goal is to reduce deer populations. However, bow hunting is more acceptable in heavily developed areas. Doe-only harvests are effective at reducing and controlling populations. The harvest of bucks will do little to control population growth.

❖ Strategy 3. Manipulate Site Conditions

3.1 Site Preparation

See 1.6. These techniques can be applied at a smaller scale to increase structural objectives.

3.2 Prescribed Fire

Ecological Role of Fire

The Southern New England Partners in Flight physiographic area (PIF Region 9) spans parts of northern New Jersey, southern New York including Long Island, most of Connecticut, Rhode Island, eastern Massachusetts, the southeastern corner of New Hampshire, and south-coastal Maine (figure E.1). It roughly corresponds to the upper half of NABCI Bird Conservation Region 30. Urban land covers about one-third of this highly developed physiographic area; about one-quarter remains in agriculture (Dettmers and Rosenberg 2000). The fragmented forests that remain are predominantly hemlock-white pine and northern red oak-white pine vegetation alliances, although a variety of other mixed oak-hardwood forests are widely represented and distributed, especially in southern and coastal areas. Patches of sugar maple-beech-birch (i.e., northern hardwood) and red spruce transition forest grow in some highland/hill areas. Rarer, ecologically significant forests include pine-oak woodlands or "barrens" on coastal or xeric sites. Non-forest habitats include maritime dune communities and tidal marshes (Dettmers and Rosenberg 2000).

Figure E.1. Partners In Flight (PIF) physiographic area 9, covering 4,425,100 ha across NJ, NY, CT, RI, MA, NH, and ME (Dettmers and Rosenberg 2000).

In contrast to its role in northern forests (i.e. PIF Regions 27 and 28), fire historically played a major role in shaping the ecosystems of coastal and southern New England, particularly the oak-dominated forests in the south and in barrens coastal marsh habitats. Several natural historians have concluded that wildfires and fires set frequently by native peoples were important ecological factors in New England, especially in oak forests and pine plains (Bromley 1935, Day 1953, Motzkin et al. 1996). In reconstructing pre-European North American fire frequencies[1], Frost (1998) estimated that pre-settlement fire frequency regimes in PIF Region 9 were approximately 7–12 years in the more fire-prone habitats of the coastal plain, while on plains with hills or low mountains farther inland, fire-prone areas burned approximately every 13–25 years. Fire-prone areas in New England usually coincide with soils derived from glacial outwash sands and gravels, fractured or loose rock, or shallow soils over bedrock (DeGraaf et al. 2005). Davis (1996) reports that fire was the major historic disturbance that shaped the vegetation of coastal MA, CT, RI and NY.

Restoration of Fire-Dependent Ecosystems

- *Natural Fire Regimes*

Because fire was an historic, significant ecological factor in southern and coastal New England and coastal New York, restoring natural fire regimes is a logical approach to help restore and maintain biological integrity, diversity and ecosystem health on refuges in this region, especially in habitats that normally would have burned frequently, such as oak-hickory forests, pine-oak barrens, maritime heathlands/grasslands, and coastal salt marshes. Each of the following sections contains background fire ecology information and summary fire regime data that may be used to derive fire prescriptions for habitat management units that include those fire-dependent ecosystems. Summary tables contain (1) estimates of the proportions of the historic landscape that were in specific successional stages for each ecosystem (Vegetation Type and Structure Classes), and (2) hypothesized natural fire regimes for those successional stages. This information comes from draft reference conditions models being developed by the interagency Fire Regime Condition Class (FRCC) Program by the USFWS, USDOI, TNC, and Systems for Environmental Management. Models are available for downloading at the FRCC website: http://frcc.gov/index.html). The Rachel Carson refuge lies at the northernmost boundary of this area, and supports habitats common to both PIF Area 9/BCR 30 and PIF Area 27/BCR 14. The overall historical fire frequency is assumed to have been somewhat lower in some of our plant communities is southern Maine than in the habitats to our south discussed below.

[1] Frost (2000) used a synthesis of physiographic factors (land surface form and topography), fire compartment size, vegetation records, fire-frequency indicator species, lightning ignition data, composite fire scar chronologies, remnant natural vegetation communities, and published fire history studies.

- *Oak-Hickory Forests*

Oaks have been an important component of eastern deciduous forests since the end of the last glaciation. The recognition is growing that oaks are "highly fire adapted, and fire played an important role in the ecology of oak forests…particularly in promoting the dominance of oak in regeneration layers" (Sutherland and Hutchinson 2002). According to Abrams (1998), "Presettlement oak forests of southern New England…must have burned at some intermediate frequency (e.g., 50- to 100-year intervals) that promoted the dominance and stability of oak." Forest ecologists now recognize that fire suppression activities in the last half of the 20th century have had significant impacts on the natural processes and vegetation composition of forests with oak-hickory components (Dodge 1997, Abrams 1998, Hutchinson et al. 2005).

Oaks have adapted to fairly frequent fire occurrence through mechanisms such as thick bark, rot resistance, deep roots, prolific sprouting ability, and increased post-fire germination. Oaks have also adapted to the dry and "high light" conditions that exist post-fire: thick leaves, rapid hydration, increased photosynthesis, high stomate level, and low wilting point. In contrast, thin-barked hardwood competitor species such as red maple, or softwoods such as white pine, are more susceptible to fire damage and post-fire mortality due to drought and disease.

Recent surveys by the USFS in the eastern United States indicate that in many eastern oak-hickory forests, less disturbance-dependent, competitor species (e.g., red maple, sugar maple, and yellow poplar) are growing faster than oaks and, as a proportion, oaks are decreasing (Moser 2005). Forests shift to dominance by competitor species (Abrams 1998) as shade-tolerant trees and shrubs invade the understory, oak recruitment fails under conditions of decreased light, and overstory disturbance (e.g., disease, wind-throw) leads to displacement by competitors (Hutchinson et al. 2006).

Forestry experts hypothesize that prescribed fire and, in some cases, selective cutting may be necessary to regenerate oaks in areas previously dominated by oaks and hickories. Recommended treatments generally involve (1) thinning to reduce stand density (especially non-oak species in the midstory) and increase light conditions on the forest floor, coupled with (2) applying prescribed fire *in the understory* to reduce non-oak seedlings and favor oak resprouting and seedling establishment (Brose et al. 1999, Hutchinson 2006).

If habitat management goals and objectives call for restoring historic oak-dominated conditions and stimulating oak regeneration in stands showing signs of shifting dominance, restoring a natural fire regime, possibly in combination with selective cutting, may be necessary. Those tools may give a competitive edge to oak and hickory seedlings and saplings by increasing light, decreasing available moisture, and directly impacting competitor species with fire. As a guide for re-establishing a prescribed fire regime in oak forests, see table E.1 for estimates of the proportions of the historic landscape that were in specific seral stages and hypothesized estimates of natural fire regimes for eastern oak-hickory forests.

- *Oak-Pine Barrens*

Barrens are areas of restricted tree growth, often, but not always found on coarse-textured, droughty soils in the eastern United States and usually maintained by fire (Anderson et al. 1999). In the northeast, these rare communities often are characterized by significant cover of Pitch pine (*Pinus rigida*), scrub oak (*Quercus ilicifolia*), and other oak species. Healthy oak-pine barrens communities generally have at least a partially open canopy, little to no mid-story, and a fairly diverse understory of short, ericaceous (heath) shrubs (e.g., huckleberry [*Gaylussacia spp.*], blueberry [*Vaccinium spp.*]), and drought-tolerant grasses (e.g., hairgrass [*Deschampsia spp.*], little bluestem [*Schizachrium scoparium*]) (Raleigh et al. 2003). An example of an oak-pine barrens community classified at the NVCS Alliance level is "Pitch Pine Woodland." Barrens communities are globally rare, and often contain state-listed plants and animals (Raleigh et al. 2003). Important federally listed barrens species include sandplain gerardia (*Agalinis acuta*) and Karner blue butterfly (*Lycaeides melissa samuelis*).

Table E.1. Estimates of the proportions of the historic landscape that were in specific successional stages for eastern oak-hickory forests and estimates of natural fire regimes (FRCC 2004[a]).

Vegetation Type and Structure

Class*	Percent of Landscape	Description
A: early seral - prairie	2	Grassland prairie maintained by frequently recurring fire (1-2 yrs) age class-0-1 years
B: early seral - grubs	6	Early tree regeneration (root and stump sprouts) phase; fire frequency about 3-9 yrs. Age class – 2-9 years
C: mid-seral open – savanna & woodland	34	Oak-hickory savannas and woodlands. Fire return interval of 5-15 yrs. Age class- 10-299+ years
D: late- seral – oak forest	54	Oak-hickory forests. Fire-return interval of 15 to 30 yrs. Open understories of oak seedlings exist. Age class – 60+ years
E: late- seral – maple forest	5	Mixed (maple) forests develop during the absence of fire. Dense understories of shade-tolerant species develop. Age class – 150+ years
Total	100	

*Formal codes for classes A-E are: AESP, BMSC, CMSO, DLSO, and ELSC, respectively.

Fire Frequency and Severity

Fire Severity	Fire Frequency (yrs)	Probability	Percent, All Fires	Description
Replacement Fire	50	.02	22	Occurs primarily in A and B
Non-Replacement Fire	14	.07	78	Maintains C and D
All Fire Frequency*	12.5	.09	100	

*All Fire Probability = sum of replacement fire and non-replacement fire probabilities. All Fire Frequency = inverse of all fire probability (previous calculation).

Because these rare habitats historically occurred near the coast in southern New England and New York (figure E.2), a large proportion has been lost to urban development. Fire suppression has caused further degradation, including colonization by invasive or exotic plants, conversion to unnaturally dense stands of close-canopied pitch pine or scrub oak thickets and, subsequently, suppression or extirpation of populations of rare, disturbance-dependent, barrens plants and animals. Fire suppression also increases the likelihood of severe crown fires in these habitats as fuels accumulate and the density of fire-prone overstory vegetation increases (Patterson and Crary 2006).

Figure E.2. Select northeastern United States barrens habitats (Raleigh et al. 2003).

Over the past few decades, ecologists and restorationists have constructed models of vegetation dynamics for northeastern oak-pine barrens habitats. Various fire regimes and soil types and moisture regimes have emerged as the most important factors driving barrens ecosystem changes (figure E.3). Barrens specialists generally agree that prescribed fire, possibly in combination with mechanical treatments to simulate fire effects, is crucial in maintaining healthy barren ecosystems, including a range of successional types and a diversity of rare species (Raleigh et al. 2003). See table E.2 for estimates of the proportions of the historic dry soil landscape that were in specific successional stages for oak-pine barrens, and hypothesized natural fire regimes estimates that may assist in developing fire prescriptions for this vegetation type.

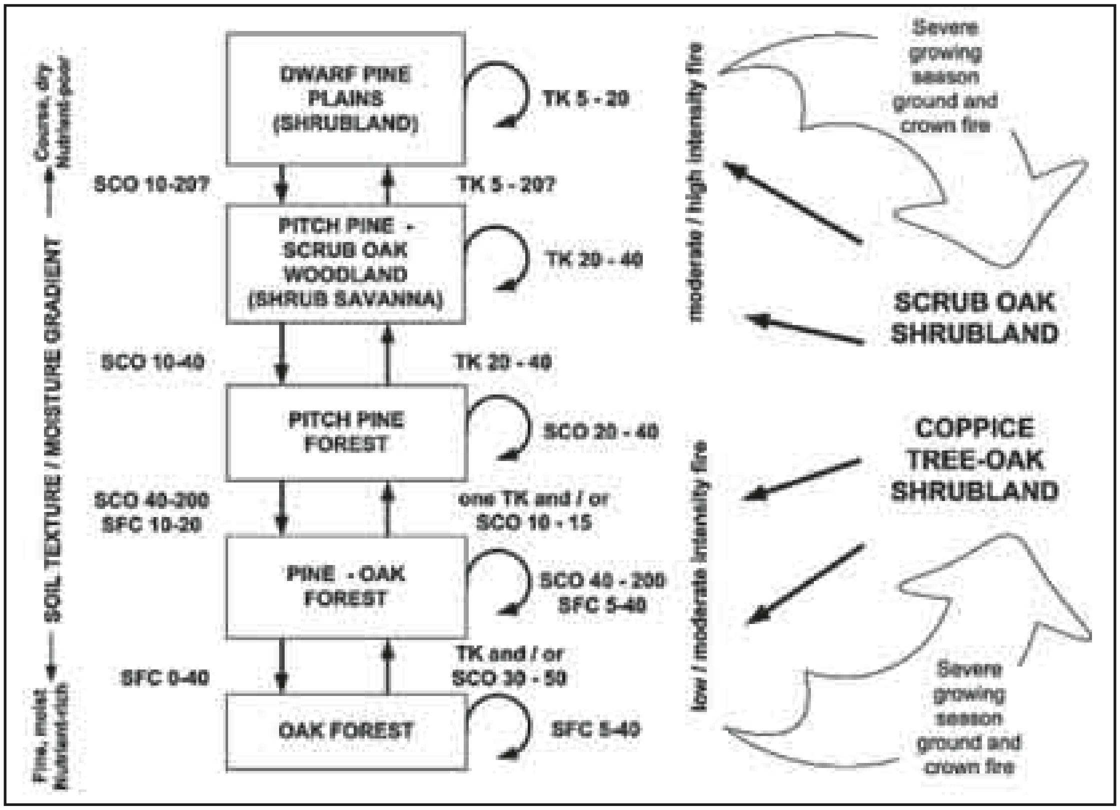


Figure E.3. Conceptual model for pine barrens ecological community types. This model depicts fire regimes that maintain vegetation types, or that result in transitions from one type or another. TK is a top-killing, high intensity (temperatures) surface or crown fire, sometimes with an associated ground fire. SCO is a scorching, moderate intensity surface fire that may heat-kill small–medium size trees. SFC is a surface fire, typically low intensity in the dormant season, that top-kills only the smallest woody stems, and burns only surface fuels above the duff layer. Ground fire burns the forest floor duff layer (From Jordan et al. 2003).

- *Maritime heathlands/grasslands*

In the northeastern United States, sand barrens are a subset of barrens ecosystems occurring in dry sandy areas such as outwash plains. These areas often are classified as maritime heathlands or grasslands, and are found on coarse-textured, outwash soils along the Atlantic coasts of New England/New York (Raleigh et al. 2003). An example of a maritime heathland community classified at the NVCS Alliance level is “Woolly Beach-heather/Coastal Panicgrass Dwarf-shrubland.” Those are non-forested, coastal communities, characterized by short, ericaceous (heath) shrubs (e.g., short blueberry species, pine barren golden heather [*Hudsonia ericoides*]), and drought-tolerant grasses (e.g., hairgrass, little bluestem). These heathlands and grasslands are highly dependent upon frequent disturbance, and would succeed rapidly to less diverse shrub-scrub cover in the absence of frequent fire, grazing, or salt spray (Vickery and Dunwiddie 1997, Raleigh et al. 2003). Like oak-pine barrens, maritime heathlands and grasslands are also geographically rare, have been decimated by development, and often contain federal- or state-listed taxa.

Open habitat specialists agree that prescribed fire, also possibly in combination with mechanical treatments to simulate fire effects, is critical in maintaining maritime heathlands/grasslands, suppressing aggressive shrubs, and in some cases, helping to suppress invasive exotic plants (Vickery and Dunwiddie 1997, Raleigh et al. 2003). The reader should refer to the early successional stage “post-replacement” in table E.2 of the previous section on oak-pine barrens for estimates of the proportions of the historic New England landscape on sandy soils that were in heath or grass cover. According to the FRCC barrens model in table E.2, heath or grass cover was historically an ephemeral stage in barrens habitats, occurring for only a short duration immediately after severe, stand-replacing fires, approximately every 20 years. However, in a conceptual model for

Table E.2. Estimates of the proportions of the historic landscape that were in specific successional stages for oak-pine barrens and estimates of natural fire regimes (FRCC 2004 [b]).

Vegetation Type and Structure

Class*	Percent of Landscape	Description
A: post replacement	5	Grass and/or shrubland, can include *Carex* and *Panicum* spp., mixed oak or pine/oak seeding mixture, heaths or dwarf pine plains
B: mid-seral closed (open?)	25	Pitch pine dominant with scrub oak dominant in the understory (*Quercus ilicifolia, Quercus prinoides, Quercus stellata*)
C: mid-seral open	30	Pure pitch pine forest; heaths may or may not be present, depending on fire history
D: late-seral open	30	Pitch pine – oak codominant; canopy oak species include *Quercus velutina, Quercus coccinea, Quercus alba, Quercus stellata*
E: late-seral closed	10	Oak–hickory forest – *Carya* spp., *Quercus velutina, Quercus rubra, Quercus alba*; some heath and scrub oak present
Total	100	

Fire Frequency and Severity

Fire Severity	Fire Frequency (yrs)	Probability	Percent, All Fires	Description
Replacement Fire	50	0.02	17	Primarily in A (20-year replacement fire) and B (20-year replacement fire)
Non-Replacement Fire	10	0.1	83	Maintains B (30-year surface fire), C (5-year surface fire), D (5-year surface fire and 100-year mosaic fire, which returns D to B) and E (100-year mosaic fire maintaining E)
All Fire Frequency*	8.3	0.12	100	

*All Fire Probability = sum of replacement fire and non-replacement fire probabilities. All Fire Frequency = inverse of all fire probability (previous calculation).

Model assumptions

Class A represents a number of possibilities at this point – anything from pine plains to shrublands to mixtures of oak and pine or just mixed oak. Needs clarification.

In the absence of a pitch pine seed source, class B will automatically progress to class E.

Class D represents the climatic climax community with fire. Should no fire occur in class D for 200 years (3 cumulative fire cycles? ~65 years for each cycle if adding all fire probabilities), it will climax at E, an oak–hickory forest.

Long Island barrens communities, Jordan et al. (2003) hypothesize that frequent (every 1–5 years) ground fires in the growing season may maintain herbaceous cover or cover by low shrubs in barrens on outwash soils (figure E.4).

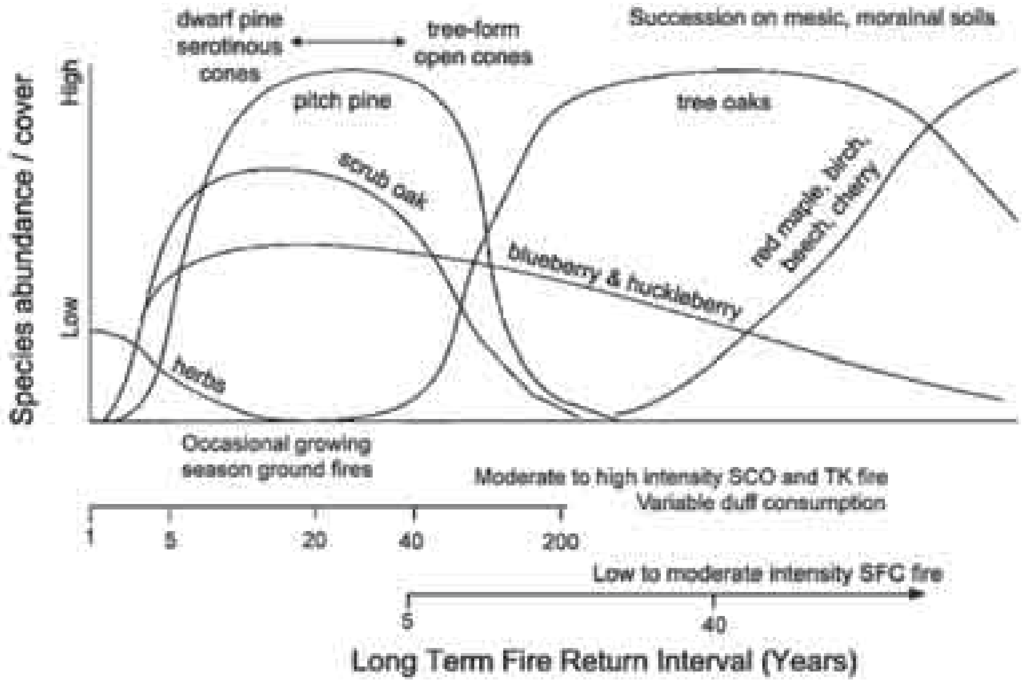
- *Coastal marshes*

Fire ecologists estimate that the pre-colonial fire return intervals on tidal marshes from the mid-Atlantic northward to the Maine coast were short (Frost 1998, FRCC 2004[c]). In the FRCC BpS model, Dr. Cecil Frost describes the hypothetical, natural fire regime for this ecosystem as follows:

> Fire regime type II, frequent replacement[2], mostly 2–10 years, occurred where marshes were contiguous with uplands burned by Native Americans…. Fires are moderate in intensity, consuming the above-ground herbaceous vegetation and top-killing most woody plants when present. This model represents an average of widely varying fire regimes, because ignition probability is affected strongly by the presence of open water channels…connection to uplands, and the natural fire regime of adjacent upland vegetation.

[2] Stand-replacement fire regime means that fires kill aboveground parts of the dominant vegetation, changing the aboveground structure substantially.

Figure E.4. Conceptual model of species response to fire regime in pine barrens habitats. Note that growing season ground fires, from 1-5 year return intervals, maintain herbaceous cover or cover by low shrubs (Jordan et al. 2003).



An example of a coastal tidal marsh community classified at the NVCS Alliance level is "Saltmarsh Cordgrass Tidal Herbaceous."

In the pre-settlement landscape, marsh plant species diversity increased as fire frequency increased, but decreased as salinity increased (Frost 1995). Salt marshes had little woody cover, because woody species cannot tolerate the multiple stresses of frequent flooding, frequent fire, and high salinity. In the salinity mid-range, brackish marshes resisted woody invasion; in the absence of fire, those with salinity less than 10 parts per thousand may have succeeded over time to nearly closed shrub cover with species such as wax myrtle (*Myrica cerifera*), silverling (*Baccharis halimifolia*), sea elder (*Iva frutescens*) and small red cedar (*Juniperus virginiana*), while the margins may have developed canopies of red cedar, loblolly pine, pitch pine and red maple. In the freshwater to oligohaline range, marshes contained, at least on their margins, mildly salt-tolerant shrubs and tree saplings whose cover may have increased dramatically in the absence of fire (Frost 1995, FRCC 2004[c]).

In general, coastal tidal marshes have undergone succession to woody vegetation and, possibly, a loss of vegetation diversity following the termination of Native American burning activities. Many lands managers now apply prescribed fires in marshes for the purposes of reducing woody plant cover, re-mineralizing litter, and increasing marsh productivity and plant community diversity. From the standpoint of restoring historic conditions, prescribed burning is probably more advisable in areas that normally would have burned frequently, i.e., large marsh areas that are not sheltered from the wind. See table E.3 for estimates of the proportions of the historic tidal marsh landscape that were in specific successional stages for northeastern tidal marshes and the hypothesized natural fire regime estimate for this vegetation type.

Note that prescribed fire should be applied carefully, using an experimental approach (e.g., exhaustively measure resource response to management actions), in salt marshes, especially because those habitats harbor endemic salt-marsh vertebrates (e.g., salt-marsh sharp-tailed sparrow (*Ammodramus cauducutus*), seaside sparrow (*A. maritimus*)) and other resources of concern (e.g., black rail (*Laterallus jamaicensis*)), who may be sensitive to particular fire regimes (Mitchell et al., in press). Fire should also be applied cautiously because Phragmites australis has invaded many oligohaline marshes, greatly increasing the risk of intense, dormant season wildfires; burns also may exacerbate Phragmites australis invasion by causing nutrient pulses (S. Adamowicz, Rachel Carson refuge, pers. comm.).

Table E.3. Estimates of the proportions of the historic landscape that were in specific successional stages for tidal marshes and estimates of natural fire regimes (FRCC 2004 [c]).

Fire Frequency and Severity

Fire Severity	Fire Frequency (yrs)	Probability	Percent, All Fires	Description
Replacement Fire	7 years	0.15	83	Light to moderate surface fires
Non-replacement fire	Never except in stage C: 35 yrs	0.03	17	Light to moderate surface fires
All Fire Frequency*	5.6	0.18	100	

*All Fire Probability = sum of replacement fire and nonreplacement fire probabilities. All Fire Frequency = inverse of all fire probability (previous calculation).

Vegetation Type and Structure

Class*	Percent of Landscape	Description
A: early seral	34	Recently burned marshes (0-4 years). More diverse herb layer when burned frequently and with lower salinity. Flammable litter sufficient to carry fire accumulates after only 1 or 2 years depending upon the dominant species.
B: mid-seral	47	4-15 years since fire. Dense herb layer dominated by medium and tall species, with heavy litter buildup except where removed by storms. Invading shrubs and trees where salinity less than 1%
C: late-seral	19	15 years + since fire. Herb layer dominated by tall species, with deep, loose litter buildup with dense shrubs and young trees where salinity permits. Age and structure of woody vegetation depends more upon irregular salinization events during storm surge rather than fire.
Total	100	

<u>*Strategies*</u>

Hazardous fuel reduction

Prescribed fire may be used to reduce scattered concentrations of dead-down woody materials, which pose a significant wildfire hazard to natural resources of concern (e.g., habitats for endangered species) or cultural resources of concern (e.g., historic buildings or archaeological sites), public resources (such as refuge administrative buildings or facilities), or adjacent private lands. Heavy fuel loads may be caused by natural events, such as ice storms, blow-downs, or insect outbreaks, yet may pose significant threats to these important and often irreplaceable resources.

Fire is used to reduce hazardous fuel threats by focusing burns in significantly altered habitats, such along the wildland urban interface (the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels) along roads, or along existing or constructed fuel breaks. Controlled burns in such areas may reduce the Crowning Index (the wind speed at which active crown fire is possible) and fire intensity, and facilitate vehicular access for suppression actions, when unplanned ignitions occur.

Prescribed fire is used generally in conjunction with other forestry treatments to reduce hazardous fuels. For example, projects to reduce the threat to housing communities in Massachusetts of wildland crown fire in pitch pine forests involve first thinning mature mixed pine/hardwood stands, reducing original stocking densities from 100–170 ft^2 basal area/acres to 25–30 ft^2 basal area/acre (fuel objectives), increasing the crowning index from 30 to 60 mph. Heavy equipment is used to grind or pile slash after thinning; then, prescribed fire is used to consume slash and dramatically reduce wildfire behavior. Fire generally is reapplied on a short-term rotation (~5 years), to maintain low canopy density, well-spaced understory woody shrubs and saplings, and low downed fuel loads (Patterson and Crary 2004).

- *Even-aged stand management*

  Prescribed fire may augment even-aged silvicultural prescriptions: for example, to create or maintain stands with trees representing one age class or a narrow range of age classes. Most northern hardwood forests were dominated by old-growth forest in pre settlement times, with young forest habitat (up to 15 years old) occupying <1% to 13% of the landscape (Lorimer 2001). Therefore, even-aged stand management, through a combination of cutting and fire, is likely to be applied in small patches, simulating the scale of natural disturbances that historically shaped the Northern Forest: the deaths of single-trees (gaps) and blowdowns (larger gaps). The intended composition of these forests is thick, young, woody growth in full sunlight dominated by shade-intolerant trees (e.g., jack pine, red pine, aspen) and shrubs (e.g., willow and cherry, *Prunus* spp). Management for temporary shrubby openings and young forests, on the order of 1–2 ha, creates ephemeral habitats important for early successional forest species such as woodcock, eastern towhee, and yellow-breasted chat (Ehrlich et al. 1988, Dessecker and McAuley 2001, NatureServ 2005).

In this context, prescribed fire is used mainly in post-cutting treatments, once small patches of softwoods (red/white/black spruce, balsam fir, hemlock, northern white cedar, eastern tamarack, eastern white and red pines) or hardwoods (aspen species, paper birch, gray birch, red maple, silver maple, sugar maple, red/white oak, ash, and beech as principal species or associates) have been harvested through clearcut, shelterwood, or seed-tree methods (Dessecker and McAuley 2001, USFWS 2001). Timber harvest treatments remove sufficient canopy to promote dense sapling and shrub growth, while follow-up prescribed fire may be used to remove logging residue and slash. After a few years, most clearcuts become too thick for early successional forest birds. At that point, a prescribed burn may be used to thin out the understory vegetation but leave enough patchiness for species such as woodcock (Krementz and Jackson 1998). Fire should be applied at regular return intervals (approximately 10 years), to provide a disturbance to maintain low residual basal areas, on the order of <4.9 m2 (Dessecker and McAuley 2001).

- *Forest Restoration*

Prescribed fire may be used to prepare degraded sites (e.g., heavily logged areas, former forest roads, or mined sites), for natural and artificial tree regeneration. In general, burned-over surfaces and mineral soil are excellent sites for seed germination. In contrast, unburned organic layers on the forest floor, depending on their moisture content, provide less favorable sites for seed germination and, depending on their composition, can impede the planting and development of artificial regeneration. Undisturbed organic materials often favor the establishment of heavy-seeded plants (with seeds that can penetrate the heavy organic layers) and advance regeneration. Conifers and deciduous tree species have differential responses to forest floor disturbance, as do shrub and forb species. Some species become established primarily from seed (e.g., jack pine, pitch pine), whereas others regenerate from sprouts (aspen). Prescribed fires that remove organic layers from the forest floor can be used to influence the composition and quantity of regenerating trees, favoring early-successional species such as pines (Graham et al. 1998).

- *Early successional habitats*

Fire historically has been used on refuges in BCR 30 to maintain grassland openings such as abandoned pastures, old fields, and blueberry barrens for grassland birds and woodcock. Prescribed fire may be used to increase grass biomass (e.g., by eliminating woody shade plants, extending the growing season by removing litter, and buffering soil chemistry); selectively control tall forbs or fire-sensitive woody plants (by topkilling or causing mortality); mineralize litter; and, increase community diversity (by altering the composition of early-flowering or late-flowering plants). Prescribed fire also may used to maintain an interspersion of shrub- and grass-dominated communities attractive to shrubland passerines, by topkilling shrubs in old fields and allowing them to resprout into thickets. And finally, fire may be used to help eradicate exotic, invasive plants from open habitats, in some cases precluding the need for chemical herbicides.

When using prescribed fire to alter woody plant cover in early successional habitats, it is important to consider that many woody plants, especially shrubs, are adapted to disturbance, regenerating new shoots prolifically. Fire can increase or decrease shrub stem density in a habitat. Thus, fire can either help eliminate (through direct mortality) or maintain shrub-scrub habitat structure (by pruning tall woody plants back, killing less fire-adapted trees, encouraging shrub sprouts). The key to predicting fire effects on woody plants is fire regime (the frequency, seasonal timing, severity, and geographic size of fire). The fire regime will affect differential shrub and sapling mortality (which species dies, which doesn't); mortality vs. top-kill effects; and, post-fire vegetative regeneration.

Several principles should be considered in using prescribed fire to control woody plants in early successional habitats:

1. Plant mortality is strongly tied to the death of "growth points" (i.e. meristems/buds), which are more sensitive to heat damage when actively growing and tissue moisture is high (Miller 2000).

Therefore, applying fire in the spring, when target woody plants are mobilizing water and nutrients and breaking the dormancy of leaf or flower buds, or during fall cold-acclimation periods, is more likely to kill growth points than prescription fire during dormant periods.

2. Total plant mortality is often the result of injury to **several different** parts of the plant, (e.g., crown damage coupled with stem tissue mortality). Many prescribed fires, often executed in the dormant season, "top-kill" shrubs, but fail to kill the entire plant, which re-sprouts from dormant buds. New shoots can originate from dormant buds located both above the ground surface (e.g., epicormic sprouts, root collar sprouts), and from various levels within the litter, duff, and mineral soil layers (e.g., rhizomes, root crowns). The severity of fires (depth of fire and ground char) directly affects shrubs' re-sprouting ability from those buds. Moderate-severity fires (moderate ground char, consumes litter layer, partially consumes duff layer) frequently cause the greatest increase in stem numbers from root sprouters, such as rhizomatous shrubs, by pruning rhizomes below the surface, causing several new shoots develop per rhizome. High-severity fires (deep ground char, removes duff layer and large woody debris) are more likely to eliminate species with regenerative structures in duff layer or at the duff-soil interface. In such fires, resprouting is eliminated from shallowly buried tissues, often delayed from deep rhizomes or roots (Miller 2000).

Therefore, if the goal is to increase the density of shrub stems, a moderate-severity, dormant-season fire is probably preferred. If the goal is to decrease shrub stems, a high-severity, growing-season fire is probably best. If a management unit contains shrubs to be controlled as well as shrubs to be maintained, no single burn prescription is going to accomplish that, and selective treatments will be necessary.

3. Concentrations of metabolic compounds, e.g., sugars, salts, and lignins, vary seasonally, and have been shown to relate to seasonal effects on shrubs. Consequently, the timing of the treatments may be more important than the type (cutting versus burning) in controlling shrubs. To maximally reduce woody stems, fires should be applied during periods of low below-ground carbohydrate storage (i.e., immediately after spring flushing and growth), and should be followed with a second growing-season treatment (such as mowing, herbicide, or more prescribed fire) before total non-structural carbohydrate (TNC) levels are replenished. Repeated burning in several consecutive years during the low point of a plant's TNC cycle can amplify the negative effects of the treatment (Richburg and Patterson 2003, 2004).

4. Fire reduces the cover and thickness of organic soil layers; this can increase light and, seasonally, temperatures at the soil surface, causing an increase in sprouting from woody rhizomes (Miller 2000). Thus, to control shrubs, a follow-up treatment (herbicide, mowing) is almost always required post-fire (Patterson 2003).

5. Invasive plants are well-adapted to disturbance, often surviving fire and spreading rapidly through a disturbed landscape. Studies in northeastern successional habitats have shown generally that fire alone *will not* remove invasive shrubs. Additional herbicide and/or cutting treatments are necessary (Patterson 2003).

6. In general, drought conditions (either normal lows in precipitation in summer/fall, or abnormal winter/spring droughts) dry large fuels and duff, increasing the potential for duff consumption, subsurface heating, and mortality for buried shrub regenerative structures (Miller 2000). Burning when litter layers, duff, and upper soil layers are saturated (winter and early spring) is not likely to suppress shrub stems.

7. Prolonged heating, as in a slow, backing fire versus a fast-moving head-fire, causes greater burn severity and plant tissue death. In general, slow, backing fires cause more woody tissue damage than rapid head-fires (Miller 2000). However, the warmer the Wx conditions, the shorter the heating duration necessary to cause shrub tissue death, and the greater the likelihood of suppressing shrub stems.

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❖ Strategy 4. Allow Natural Succession and Processes

Natural disturbances such as wind throw, herbivory, beaver activities, native disease and insect outbreaks, major wind or ice storms, succession and flooding may provide the desired structure for many upland habitats. Natural processes like succession and wind throw may result in the development of micro-habitats, while other natural processes such as outbreaks of native insects and hurricanes may result in stand-replacing events. Often, those can assist managers reach their desired habitat type. However, monitoring those habitats is important to ensure that those hands-off approaches result in high-value habitats for wildlife.

For many habitats freshwater marshes, shrublands and grasslands, natural processes may drive them toward more mature stages. Site capacity, soil types, aspect ratio, climate, and prior management will influence their stability. Some may require infrequent management (vegetation occurring on sandy or stressed soils like pine barrens and native shrublands), while other types, such as old field thickets, may progress rapidly. The monitoring and adaptive management of habitats where natural processes are the primary management tool is critical.

B. Tidal and Freshwater Wetlands

❖ Strategy 1. Restore tidal hydrology to salt marshes

Restricted tidal flow can result in severe tidal marsh degradation, as demonstrated by expansion or domination by invasive *Phragmites australis*, surface subsidence, conversion to open water, or conversion to brackish or freshwater plants (Roman et al. 1984). Such degradation can result in the loss of habitat for salt marsh fish species, particularly *Fundulus heteroclitus*, and decreased use by shorebirds and wading birds. The restoration of tidal hydrology must proceed cautiously, accounting for changes in marsh elevation (subsidence) that developed since the occurrence of restricted flow; the immediate restoration of full tidal volumes could result in creating mud flats or permanent open water. Full tidal restoration could also result in negative impacts, such as flooding human structures built on low-lying elevations during the time of tidal restriction, and flooding sharp-tailed sparrow and seaside sparrow nests (DiQuinzio et al. 2002). The installation of self-regulating tide gates has been used to address the potential flooding of human structures (Roman et al. 1995). The benefits of tidal restoration include restoring salt marsh habitat, controlling invasive *Phragmites*, increasing the number and abundance of nekton species, and increasing the use by shorebirds, wading birds, and sharp-tailed sparrows. Techniques used to achieve restoration of tidal flow include replacing undersized culverts with properly sized ones set at an appropriate elevation or replacing culverts with bridges and removing fill. Water control structures, such as flap gates, self-regulating tides gates and the like, should be employed with extreme caution; they generally do not represent landscape equilibrium conditions, require monitoring and, necessarily, need maintenance.

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❖ Strategy 2. Control native aquatic vegetation community composition

- Altering Salinities - Freshwater species such as cattail can be controlled by allowing salt water into an area or an impoundment to increase its salinity levels. That can set back vegetation either temporarily, in the case of impoundment management, or permanently, in the case of tidal restoration. Changes in salinity can result in fish kills and, if done during the summer months, can cause botulism. Changes in salinity likely will impact all freshwater biota, and should be undertaken with caution. The Rachel Carson refuge does not manage impoundments, and is unlikely to alter salinities in freshwater environments.

- Setting back succession -

  - Prescribed burns, herbicides or mechanized equipment may be used to set succession back in areas where vegetation is too rank for wildlife use. This approach may be appropriate in cattail marshes that are so dense they are reverting to upland vegetation types. Mechanized equipment for use in wetlands is specially adapted with a low ground pressure so that habitats are not damaged.

❖ Strategy 3. Restoring natural hydrology in the salt marsh

The natural hydrology of the salt marshes has been altered since colonial times through ditching and diking. Over 90 percent of all eastern marshes have been ditched by 1938, although that percentage is somewhat lower in Maine. Ditches have been constructed for salt haying, mosquito control and other purposes. Ditches drain surface water and groundwater from this tidally flooded habitat, and have also been found to impound water on salt marshes by forming peat spoil levees and clogging ditches with debris and slumped peat blocks.

Natural, unditched salt marshes are characterized by large, highly sinuous creek and runnel systems. Those drainage features remove surface water from a marsh without draining natural pools. Although the restoration of tidal flow *to* a marsh is often restricted to one small area (such as a culvert), restoring natural hydrology *within* a marsh is complicated by the direct (surface water drainage) and indirect (impoundment, peat drainage) effects of ditching as well as their physical size and number.

Although techniques historically employed to “restore” ditched marshes, such as filling and plugging, have increased surface water habitat, they have not restored pre-ditching hydrology. Ditch plugging also has led to the saturation of peat up to 15 m perpendicularly away from a ditch, resulting in the conversion of high marsh vegetation to low marsh vegetation. Although that outcome may be desirable in some circumstances, it does highlight the need to develop new techniques to restore ditched marshes. Public health officials in the late 1930s noted that ditching replaced one form of marsh hydrology (creeks) with another (ditches). In order to *restore* salt marshes, we must consider the need to restore natural creek hydrology, i.e., remove ditches and return panne and pool habitat. In addition, restoration to date has highlighted the unique nature of each marsh site. Extensive site investigations and measurements must be part of the *planning* process to increase the likelihood of the project’s success and move the science of restoration forward.

Small impoundments, whether constructed incidentally as part of the ditching process or purposefully through diking for agriculture or other ends, also represents an alteration of natural hydrology within the marsh. The restoration of impounded or diked areas must proceed with the same cautions noted in strategy 1.

Pools are common features on unditched marshes, but not on ditched sites. They occur throughout New England and the mid-Atlantic coastal marshes. Ditching has led to their filling, drainage or loss. The restoration of pool habitats is a significant concern, since they provide important habitat for fish, invertebrates, mammals and birds. Creating pools by excavation does increase surface water habitat on marshes. Careful consideration must be given, however, to the correct dimension of each pool, particularly its size, sidewall slope, and depth. Most natural pools contain less than 30 cm of water, and have soft organic sediment bottoms. When creating pools, it is imperative not to excavate through the peat to underlying sediments; otherwise, the pools will not retain water. Furthermore, natural pools exist in a variety of depths—though few over 100 cm. The construction of sumps in man-made pools may be desirable, but should be executed judiciously. Because the excavation of peat results in acute redox conditions deleterious to nekton, naturally formed pools should be left intact.

Adamowicz, S.C. and C.T. Roman. 2005. *New England salt marsh pools: A quantitative analysis of geomorphic and geographic features*. Wetlands: 25:279-288

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❖ Strategy 4. Restore freshwater or salt water wetland native vegetation

4.1 Planting or seeding

The successful restoration of native marshes in New England depends on hydrology, salinity regime (for estuarine environments), and the relative competitive strengths of native versus invasive plants. Planting or seeding a salt marsh restoration area is more expensive than allowing natural reseeding to occur, but has several advantages. Planting or seeding provides a competitive advantage to native vegetation by occupying a space first. That is particularly important if a natural native seed source is at some distance. Purchased plant and seed stock should be carefully selected to ensure correct province, temperature tolerances, and other local genetic features. Plant material should be installed at the beginning of the growing season to allow the plants sufficient time to establish before winter. One drawback of planted material is that it is often attractive to grazers such as snow geese and Canada geese.

4.2 Fill Removal

Salt marshes often have been used as dumping grounds for dredge, sanitary landfill, and toxic materials. The removal of that material can range from simple and straightforward to highly regulated and complex. As in restoring tidal flow, establishing the correct elevations for tidal input and restored marsh surfaces is imperative. Because of the disturbed nature of many of these sites, hydrology and elevation are critical in controlling the invasion of nearby *Phragmites*. The benefits of removing fill material can be significant: the conversion of a disturbed fill area to high quality salt marsh habitat. Because fill areas often occur in urbanized locations, restored areas substantially increase available salt marsh habitat by a large percentage.

Niedowski, N.L. 2000. *New York State salt marsh restoration and monitoring guidelines*. New York State Department of State, Division of Coastal Resources and New York State Department of Environmental Conservation, Division of Fish, Wildlife and Marine Resources. 172 pp.

Thunhorst, G., and D. R. Biggs. 1993. *Wetland planting guide for the Northeastern United States*. Environmental Concern, Inc. 179 pp.

4.3 Control invasive plants

Most of the techniques for controlling invasive plants in uplands are appropriate for wetlands, with the caveat that required wetland permits are in place, and chemical control methods are labeled for wetland use.

❖ Strategy 5. Manage tidal marsh dieback

The occurrence of tidal marsh dieback appears to be a new phenomenon in the Northeast. Dieback can occur gradually over the course of decades, as in Jamaica Bay, NY, or rapidly, over the course of one growing season, as in several locations in Connecticut, Massachusetts and Maine (Adamowicz and Wagner 2005). Successful strategies to manage dieback depend on identifying the causal agent(s) in each case. No specific causes have yet been identified in the Northeast. Decontaminating all footwear, gear and machinery after visiting a dieback site has been recommended as a minimum precaution until causal agents and remedies have been determined (Adamowicz and Wagner 2005). For additional information see *www.brownmarsh.net* and *www.NEERS.org*.

Adamowicz, S. C. and L. Wagner. 2005. *Northeast sudden wetland dieback workshop proceedings*. U.S. Fish and Wildlife Service. 69 pp.

❖ Strategy 6. Manage contaminants

In addition to toxic materials (organic chemicals, heavy metals), salt marsh contaminants include nutrient and freshwater runoff (introducing reduced salinity regimes). Nutrient additions commonly occur through both atmospheric deposition and stormwater runoff. Successful strategies for controlling stormwater runoff include offsite treatment; correct location of discharge point; and maintenance of an adequately wide, naturally vegetated upland buffer (Bertness et al. 2004). Freshwater marshes also can have contaminant issues based on their location or prior uses.

Bertness, M., B. R. Silliman, and R. Jefferies. 2004. *Salt marshes under siege*. American Scientist 92: 54-61.

Schueler, T.R. 1987. *Controlling urban runoff: a practical manual for planning and designing urban BMPs*. Metropolitan Washington Council of Governments, Washington, DC.

Schueler, T.R., P.A. Kumble, and M.A. Heraty. 1992. *A current assessment of urban best management practices - techniques for reducing non-point source pollution in the coastal zone*. Metropolitan Washington Council of Governments, Department of Environmental Programs, Anacostia Restoration Team, Washington, DC.

❖ Strategy 7. Allow Natural Succession and Processes

Many natural wetland types are relatively stable and are driven by natural processes, tides, soil type, surface water runoff, ground water and precipitation collecting in depressions or slopes. Seasonal changes in hydrology, or changes through the tidal cycle, create a fluctuating water table, resulting in wetland vegetation development. When these systems are functioning naturally, are devoid of invasive plants, and are not heavily impacted by human development, they often are not actively managed.

Tiner, R.W. 1994. *Maine Wetlands and Their Boundaries*. Institute for Wetland and Environmental, Education and Research. Sherborn, Massachusetts.

❖ Strategy 8. Mimicking Natural Freshwater Wetland Processes in Impoundments

The Rachel Carson refuge has one 1-acre impoundment, a former fire pond, which currently is not managed as a moist soil unit. Due to management constraints, the size of the impoundment, and invasive plants, the refuge will not manage this unit for moist soil vegetation at this time. If conditions or management constraints are alleviated, we may consider managing the impoundment for fall migration by lowering water levels in the spring and slowly bringing them up after moist soil vegetation grows. The construction of new impoundments at the refuge is not likely.