COMMONWEALTH of VIRGINIA

Management Plan for Sweet Hall Marsh Chesapeake Bay National Estuarine Research Reserve

Prepared by:
Virginia Department of Conservation and Recreation
Division of Natural Heritage

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2008

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Management Plan for Sweet Hall Marsh
Chesapeake Bay National Estuarine Research Reserve

PLAN SUMMARY

Sweet Hall Marsh is one of the four components of the Chesapeake Bay National Estuarine Research Reserve System in Virginia (CBNERRVA). The National Estuarine Research Reserve System (NERRS) is administered nationally by the National Oceanic and Atmospheric Administration (NOAA) for the primary purpose of addressing research and management issues in coastal and estuarine environments across the United States.

CBNERRVA is administered by the Virginia Institute of Marine Science (VIMS) within the College of William and Mary. Reserve components currently comprising CBNERRVA are all within the York River watershed and include Goodwin Islands, Catlett Islands, Taskinas Creek, and Sweet Hall Marsh. Sweet Hall Marsh is privately owned and is the most upstream of the four Virginia reserves. Resource management and use of Sweet Hall Marsh is coordinated by CBNERRVA program staff and the landowners under written management agreements (Appendix A).

Sweet Hall Marsh, 443 ha (1094 ac) in area, represents an extensive tidal fresh water marsh ecosystem located in the Pamunkey River. Sweet Hall Marsh is approximately 7 km from West Point, where the Pamunkey and Mattaponi converge to form the York River. The Sweet Hall Marsh component consists of a 384 ha (949 ac) core region that encompasses emergent, fresh and low salinity marsh, seasonally flooded forested wetlands and scrub-shrub wetlands (Figure 1). A 59 ha (145 ac) buffer consists primarily of uplands forests and open agricultural fields.

Sweet Hall Marsh supports two exemplary natural communities, a population of the federally-listed plant – *Aeschenomyne virginica* (sensitive joint vetch), a population of the globally rare butterfly – *Problema australis* (rare skipper), Bald Eagle foraging habitat, and significant historic resources. Management issues at Sweet Hall Marsh include invasive species control – specifically for *Phragmites*, protection and monitoring for rare species populations, protection and monitoring of natural communities, and coordination of private recreational uses with VIMS research use. High priority management issues are *Phragmites* control and protection and monitoring of rare species populations and natural community occurrences.

The purpose of this management plan is to guide an adaptive management process that balances the research mission with the objectives of the landowner while adequately protecting natural resources. This plan has an intended timeline of approximately five years.

INTRODUCTION

Site Purpose

The core mission of CBNERRVA is to preserve a network of reserves that represent the diversity of coastal ecosystems found within the York River estuary and its principal tidal tributaries and to manage these reserves to support informed management of coastal resources through estuarine research, education, stewardship, and advisory service. In this context, the Sweet Hall Marsh Reserve was selected as a site representing low-salinity, forested wetlands surrounded by extensive marshes.

The property is privately owned and is incorporated into the CBNERRVA system through a formal management agreement. The original Management Agreement was signed on September 24, 1990 by William Reed, Preident of the Tacoma Hunting and Fishing Club and Frank Perkins, Director of the Virginia Institute of Marine Sciene of the Collge of William and Mary. On Monday, August 6th, 2007, CBNERRVA staff met with the current principal shareholders in the Tacoma Hunting and Fishing Club and owners of the property which comprises the Sweet Hall Marsh Reserve to review the 1990 Management Agreement and discuss appropriate changes and updates. Based on these dicussions, a draft copy of the new Management Agreement can be found in Appendix A. Changes included removing outdated attachments decribing the ecological condition of the Pamunkey River, updating maps and text to describe the current core and buffer area boundaries of the Sweet Hall Marsh Reserve (please see section on "Additional Protection Needs" for updates on the Tick Hill tract portion of the Reserve), updating liability forms, and identifying land stewardship as a principal Reserve activity in addition to research and education.

Management Approach and Policies

Operation and management of CBNERRVA reserve sites is the responsibility of VIMS and is directed by the CBNERRVA Program. The Virginia Department of Conservation and Recreation, Division of Natural Heritage (DCR-DNH), as well as other state and federal agencies and private organizations are available to serve in advisory roles and provide technical assistance with the management of CBNERRVA sites. Visitor use at Sweet Hall Marsh Reserve is by permission of the landowners or the CBNERRVA. Public use at this reserve component is not permitted (Appendix B).

Complete management policies for CBNERRVA are provided in Appendix C and summarized in the following statement:

> *The health and natural integrity of reserve sites will be protected and, where necessary, restored, to provide a productive, stable environment for research, education, and compatible traditional activities. Reserve programs, activities, and facilities will not augment or replace the conservation, research, education, and historical uses of the site. Reserve programs will also complement traditional uses outside reserve boundaries. Resource protection and non-manipulative research will be given the highest priorities in the management of reserve sites (VIMS 1991).*

BACKGROUND INFORMATION

Description and Location

Sweet Hall Marsh Reserve occupies approximately 1,094 acres (443 ha) in a large meander of the Pamunkey River, about 10.7 nautical miles upstream from its confluence with the Mattaponi River at the town of West Point. The Reserve is located on the north side of the Pamunkey in King William County, Virginia. Sweet Hall Marsh is one of eight major marshes and tidal swamps created by stream meanders of the Pamunkey River.

Sweet Hall Marsh is approximately 45 nautical miles from the mouth of the York River and represents a tidal freshwater/oligohaline zone (0 – 2 ppt) within the upper reaches of the York River system (Figure 1). The site occupies a broad meander of the Pamunkey River and consists of upland forests and agricultural fields, non-tidal bottomland forests, and extensive tidal freshwater marshes.

Climate

While detailed climatic data are not specifically available for Sweet Hall Marsh, data collected at nearby West Point 2 SW, VA (449025) from 1954 – 2005 show an average annual minimum temperature of 8.28° C (46.9° F) and an average annual maximum temperature of 20.94° C (69.7° F). Average total precipitation for the same period is 119.13 centimeters (45.29 inches) (Southeast Regional Climate Center 2006) with highest amounts falling in July and August. Average monthly maximum temperature for the same time period is in July (31.72 ° C; 89.1° F) and the average minimum monthly temperature occurs in January (-2.78° C; 27.0°F).

Precipitation is generally well distributed throughout the year with slightly more than average rainfall in the summer and slightly less in the autumn. Soils tend to be wettest in winter and early spring due to reduced evaporation and evapotranspiration. Snow can be expected any time from November to April. The average growing season length is approximately 197 days, and although variable, first fall frosts usually occur in late October and the last spring frosts are often in early to mid-April.

Weather events can drastically affect the Chesapeake Bay and Atlantic coastal areas. Northeasters tend to occur in the autumn, winter, and spring. Hurricanes and tropical storms are less frequent, generally more severe, and usually occur in late summer through autumn. Some northeasters may reach the strength of a tropical storm. These storm events can cause extreme high tides and produce winds capable of partial to complete canopy disturbance in forest communities, with potential for profound changes to Reserve lands and surrounding areas. Due to its relatively inland position, Sweet Hall Marsh is relatively protected from wind effects of hurricanes, tropical storms, and northeasters; however during Hurricane Isabel, there were storm surges of over 2 meters recorded in the tidal freshwater reaches of the Pamunkey River (Reay and Moore, 2005). Conseques of storm surges can include extensive flooding of low-lying areas, shoreline erosion, sediment re-suspension and increased upstream salinities (Walker, 2001). During Hurricane Isabel, salinity values wre approximately 10 ppt greater than pre-storm conditons at Sweet Hall Marsh (Reay and Moore, 2005).

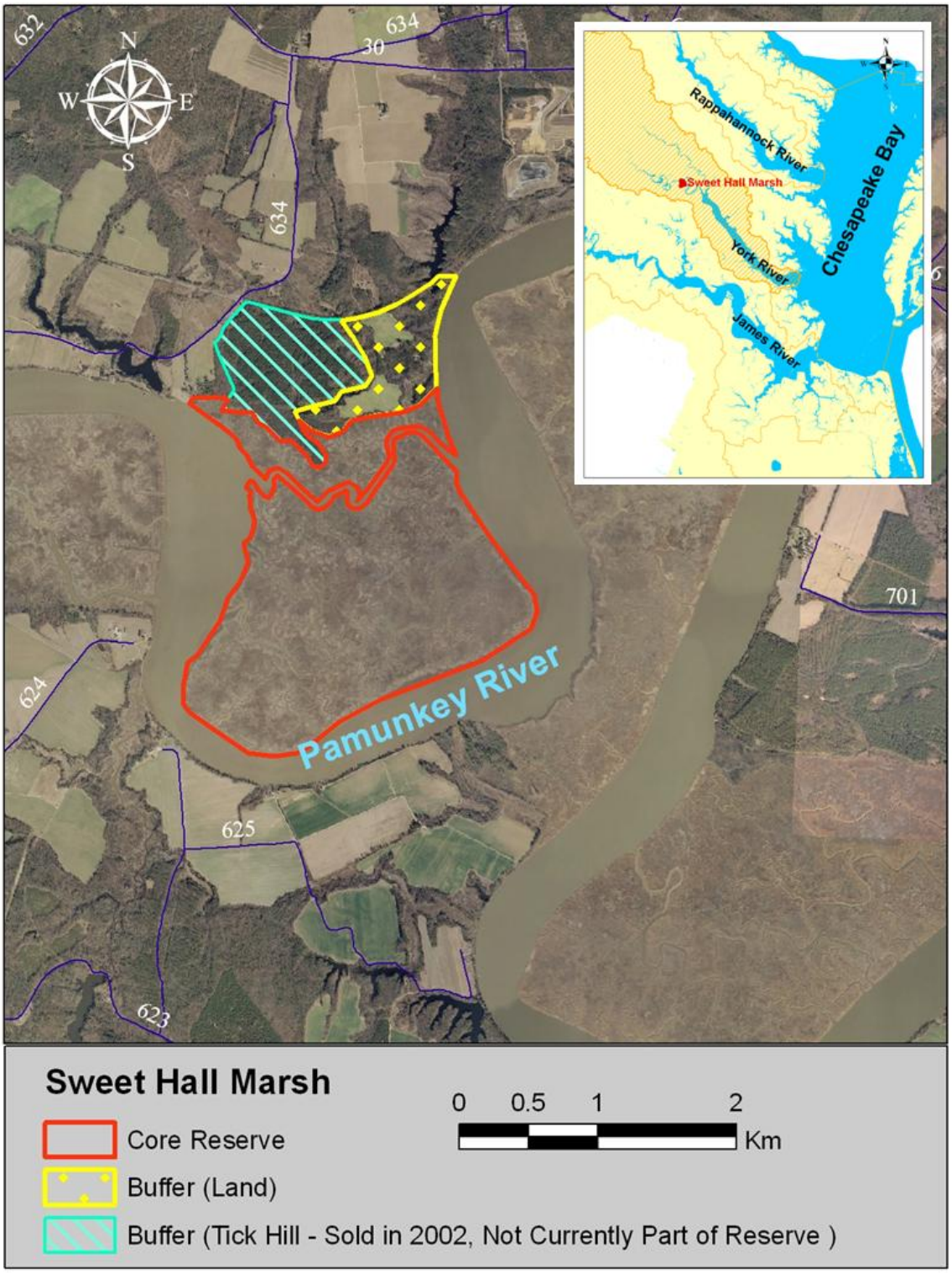

Figure 1. Boundaries and location of Sweet Hall Marsh Reserve in Virginia. Please note that the Tick Hill Tract (formerly owned by the Chesapeake Corporation) is now privately owned and not currently part of the Sweet Hall Research Reserve.

Seasonal variations in the mean sea level cycle can impact the reach of storms and flooding risks. The months of August, September, and October have the highest heights; these months correspond to the highest risk of extratropical activity along the East Coast and Chesapeake Bay. Superimposed on the storm surge and astronomical tide, long-term sea level change can significantly increase the reach of storm waters (Boon, 2003).

Understanding the role of storms as well as long-term change in sea level is an essential part of coastal planning. In particular, knowing the projected rate of change in water levels is essential for determining coastal hazards from storms and flooding risks. Current long-term rates of sea level rise within the Chesapeake Bay range from 3.1 mm yr-1 in the northern Bay region to 7.0 mm yr-1 near the Bay's mouth (Zervas 2001); historic rates over the past 6000 years were on the order of 1.4 mm yr-1 (USGS 1998). In the York River, the rate of change between 1950 and 1999 was 3.95 mm yr-1 (NOAA website 2006). When combined with locally high rates of subsidence (3 to 5 mm yr^{-1}; Holdahl & Morrison, 1974) many marshes will not be able to keep pace with rising sea-levels through the natural process of sediment deposition and root mass accumulation. Observations including increased plant stress, increased creek development, and interior pond formation are all indicators of marshes which are in various stages of degradation and could be areas of potentially high marsh loss in future decades (Kearney et al 1988).

Physical Setting

Geology and landforms. The geology of Sweet Hall Marsh is part of the fluvial depositional system of the Coastal Plain of Virginia (VIMS 1991). The marsh is divided into four general geomorphic zones – creek bank, levee, low marsh flat, and high marsh/upland edge (Frey and Basan 1986). The most dynamic and tidally influenced region is the creek bank along the edge of the marsh (Reay 1989).

Soils. Marsh soils are flooded twice daily and composed of thick, loosely consolidated deposits of Quaternary alluvium, primarily fine-textured silt and clay. These are poorly drained and almost level at an elevation just above sea level. North of the marsh, upland soils consist of well- to moderately-well drained loamy textured soils on marine terraces. Typical soil series include Kempsville fine loams and Bama loams on the highest elevations and Conetoe and State loams on upland terraces. Lower terrace soils include Tetotum fine loams (VIMS 1991).

Hydrology. Hydrology of the upper estuarine reaches of the York River system is strongly influenced by tides and surface water flow. At Sweet Hall, the Pamunkey River is microtidal, with a mean tidal range of 70 cm (neap tide) to 90 cm (spring tide). The Pamunkey River at Sweet Hall Marsh averages 1,400 ft in width and has a depth of at least 12 ft. Exposure to wind-generated waves is small due to the narrow width and meandering nature of the river. A 20-year salinity record for the Pamunkey River gives a range from 0 to 5.0 ppt with an average of 0.5 ppt at Sweet Hall Marsh (Brooks 1983). In 2005 - 2006, average salinity at Sweet Hall marsh was 1.6 ranging from 0 to 16.4 ppt (NOAA/NERRS SWMP Data, Sweet Hall Marsh, 2003-2006). These higher salnities and the increasing presence of the oligohaline species Spartina cynosuroides in the marsh may be indicative of a long-term shift from freshwater to oligohaline conditions (Perry & Hershner, 1999).

CBNERRVA also participates in the NOAA/NERRS System-Wide Monitoring Program and maintains a network of long-term, year-round continuous water quality stations within the York River system. One station located at Sweet Hall Marsh has been collecting information on water quality since 2000 and recent measurements can be found in Table 1.

Table 1: Summary of water quality measurements collected from the Sweet Hall Marsh SWMP Station over the time period from January 2003 to December 2006.

		Water Temp ©	Salinity (ppt)	DO (mg/l)
Annual	**Min**	**-0.10**	**0.00**	**2.67**
	Max	**33.83**	**16.44**	**15.24**
	Average	**17.02**	**0.92**	**8.12**
Winter (Dec-Feb)	**Min**	**-0.10**	**0.00**	**7.61**
	Max	**13.45**	**5.61**	**15.24**
	Average	**5.73**	**0.17**	**11.51**
Spring (Mar-May)	**Min**	**2.52**	**0.00**	**4.16**
	Max	**29.37**	**6.22**	**12.19**
	Average	**15.22**	**0.48**	**9.07**
Summer (Jun-Aug)	**Min**	**17.44**	**0.03**	**2.67**
	Max	**33.83**	**12.37**	**9.36**
	Average	**27.40**	**1.50**	**5.49**
Fall (Sep-Nov)	**Min**	**8.37**	**0.02**	**2.71**
	Max	**30.46**	**16.44**	**10.07**
	Average	**18.89**	**1.45**	**6.70**

Water quality (information from CBNERRVA Site Profile - Reay, 2007).
Growing populaitons along with associated land use changes are primary factors causing water quality and habitat degradation in Chesapeake Bay and its tributaries. Key water quality management issues and threats to the Bay system (and specifically the Pamunkey River) include excessive sediments, excessive nutrients, and introduction of toxic chemicals.

- Sediments: Recent sediment water quality status reports indicate continued degraded conditions in the Chesapeake Bay and York River subestuary. Based on 2005 estimates, agriculture lands contributed 62% of the sediment load to the Bay followed by forested (20%) and urban/suburban (18%) lands (CBP 4.3 Watershed model results). Long-term (1985-2006) sediment concentration trends at primary CBP River Input Monitoring Program (RIM) stations (located at gaging stations above the point of tidal influence) were adjusted to reflect changes in river flow. Data from these monitoring stations generally showed decreasing or no significant trends in flow adjusted sediment concentrations. However, an exception occurred in the Pamunkey River where

significant increased trend (reported percent change 85%; 1989 to 2006) was observed (Landland et al. 2007).

- Nutrients: As with sediments, nutrient water quality status reports indicate continued degraded conditions in the Chesapeake Bay and York River subestuary. Agricultural land uses continue to dominate nutrient load nutrient contributions to the Bay system. Based on 2005 estimates, agriculture fertilizer and manure sources contributed 34 and 45 percent of the nitrogen and phosphorus load to the Bay, respectively (CBP 4.3 Watershed model results). Atmospheric sources of nitrogen such as nitrous oxide emissions from vehicles, electric utilities and industry and ammonia contributions from livestock and fertilized soils are significant and responsible for approximately 30 percent of the nitrogen load to the Bay. Other significant contributors of nitrogen and phosphorus include municipal and industrial wastewater, responsible for approximately 20 percent of the annual loads, and fertilizer loads from urban/suburban lands. Long-term (1985-2006) nitrogen and phosphorus concentration trends at primary Bay tributary RIM stations were adjusted to reflect changes in river flow. Data from these monitoring stations generally show decreasing or no significant trends in flow adjusted nitrogen and phosphorus concentrations. Exceptions or increasing trends for nitrogen were observed in the Pamunkey River (reported change = 20%) and for phosphorus in the Pamunkey (reported change = 122%), Appomattox (a tributary of the James River) and the Choptank Rivers (Langland et al. 2007).
- Dissolved Oxygen: With respect to status and trends of bottom waters within the York River estuary, dissolved oxygen level status (2002-2004) is fair to good and there were no significant degrading or improving trends in all segments of the estuary (Dauer, 2005).
- Toxics: Chemical contaminants enter Chesapeake Bay and its tributaries from a variety of natural and anthropogenic pathways, including weathering of rock and human derived point and nonpoint sources. Priority toxic contaminants identified by the CBP include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, and mercury. While broad-scale generation of the York River Estuary due to toxicological stressors is not apparent, there are some issues with PCBs and Mercury in the Pamunkey River System (Reay, 2007).

General Vegetation Description

The vegetation at Sweet Hall Marsh consists chiefly of emergent herbaceous vegetation containing both perennial and annual species, including *Peltandra virginica* (arrow-arum), *Zizania aquatica* (Northern Wild-Rice), *Pontederia cordata* (pickerelweed), *Spartina cynosuroides* (big cordgrass), *Eleocharis palustris* (common spike-rush), *Echinochloa walteri* (common cockspur grass), *Polygonum punctatum* (dotted smartweed), *Hibiscus moscheutos* ssp. *moscheutos* (eastern rose-mallow), *Typha angustifolia* (narrow-leaved cattail), *Rumex verticillatus* (swamp dock), and *Bidens* spp. (beggars-ticks) (Silberhorn and Zacherle 1987; Davies 2004). A range of plant communities are present, all of which are in relatively pristine condition and generally free of exotic species. Scattered individuals and small clumps of *Phragmites australis* occur in the freshwater and oligohaline vegetation at Sweet Hall Marsh, some appearing to represent both the native and the aggressively invasive, exotic haplotype (Saltonstall 2002; Saltonstall et al. 2004).

The northernmost portion of the Reserve's wetlands supports deciduous woodland dominated by *Nyssa biflora* (swamp tupelo) and *Fraxinus profunda* (pumpkin ash) with a diverse understory of shrubs and ground layer of forbs and graminoids. Chronic stress and crown dieback have become salient features of this community, presumably the result of sea-level rise.

Site History

Sweet Hall Marsh was part of the original Romancoke Estate on the Pamunkey River granted in 1653 to Col. William Claiborne. More recent owners have included George Washington and Robert E. Lee, Jr. Eventually becoming known as the Tuckoman Estate during the 18th century, the property was purchased in 1898 by the Tacoma Hunting and Fishing Club. Since then, Sweet Hall Marsh has been passed down to descendants of the original club members and the marsh has been used almost exclusively for hunting and fishing for over 100 years (VIMS 1991). Today, VIMS faculty and studentsm, researchers from other academic institutions and scientists from state and federal agencies increasingly use the site for research, education, and training.

Land Uses and Natural Resources

Most of this portion of King William County remains rural and is largely in agricultural or forestry land use; however residential development is increasing as urban areas expand from both Richmond and the Hampton Roads regions into King William County and adjoining areas. Since 2000 there has been an increase in residential development, particularly along primary shorelines. This trend contributes to landscape fragmentation, an increased demand for services and infrastructure, and subsequent increases in groundwater withdrawl, surface water pollution, and runoff into local watersheds.

Sweet Hall Marsh is one of eight large wetland complexes along the Pamunkey River between West Point and White Hall. Downstream from Sweet Hall, Hill Marsh is the first of a series of oligohaline marshes. Upstream and beginning at Cousiac Marsh, there is an abrupt transition from freshwater tidal marsh to freshwater tidal forested wetlands. Above Cousiac, forested wetlands are the dominant wetland type with only an occasional marsh (VIMS 1991).

These wetland and marsh habitats support many roosting, foraging, and nesting bird species and are well known for supporting overwintering migratory waterfowl. The olighaline and tidal-freshwater portions of the Pamunkey and Mattaponi watersheds have satisfied the criteria to be designated as an Important Bird Area in Virginia (National Autobon Society, 2004). Numerous species of finfish have been documented at the Reserve which also supports a diverse array of mammalian wildlife including muskrats, marsh rabbits, raccoons, and white-tailed deer (VIMS 1991).

The Reserve property consists of extensive tidal marsh with adjacent bottomland hardwood forest and uplands in agricultural fields, a managed pine plantation, and mixed pine-hardwood forest. The landowners of Sweet Hall Marsh, Tacoma Hunting and Fishing Club, maintain a private road, boathouse, and clubhouse on the uplands above the marsh. The Club uses the property for various recreational purposes, especially waterfowl hunting (VIMS 1991). .

NATURAL HERITAGE RESOURCES

Overview

Natural heritage resources are defined in the Virginia Natural Areas Preserves Act (Section 10.1-209 through 217, Code of Virginia), as "*the habitat of rare, threatened, or endangered plant and animal species, rare or state significant natural communities or geologic sites, and similar features of scientific interest benefiting the welfare of the citizens of the Commonwealth*." Natural heritage resources are the most likely natural resources to be lost without conservation action in the near future. DCR-DNH conducts extensive inventories and maintains current lists of the natural heritage resources of the state.

A variety of rarity patterns exist based on the geographic range, habitat specificity, and local abundance of species (Rabinowitz 1981). The Natural Heritage Network ranks plants, animals, and natural communities on two scales of rarity. The global rank (G-rank) and state rank (S-rank) are based on the number of occurrences of a species at a global scale and state scale, respectively (Appendix D). G- and S-ranks help direct conservation actions to the rarest species and communities since these are usually the most vulnerable to extinction.

Ecological Communities

The inventory and classification of ecological communities constitute a "coarse-filter" approach to biological conservation that ensures protection of diverse organisms. Identification and protection of excellent examples of all natural community types facilitates protection of the majority of component native plant and animal species, including a host of taxa too cryptic, poorly known, or numerous to receive individual management strategies. At present, DCR-DNH classifies communities principally at the level of ecological community group, representing a broadly defined unit based on combinations of topographic, edaphic, physiognomic, and gross floristic similarities (Fleming et al. 2001). Nearly all of Sweet hall Marsh is covered by two broad ecological communities: Tidal Freshwater Marsh, and on the northwestern edge, Tidal Hardwood Swamp.

Significant Natural Communities

Field inventories of tidal marsh and hardwood swamp communities were conducted at Sweet Hall Marsh by DCR-DNH ecologists between September 1998 and September 1999. These surveys identified and described two significant natural communities at the Reserve – both considered to qualify as element occurrences (EOs) under natural heritage methodology. EOs are specific sites where a particular rare species or exemplary ecological community occurs. EOs are mapped and tracked by DCR-DNH in the natural heritage database, *Biotics*.

Tidal Freshwater Marsh. Much of the interior of Sweet Hall Marsh consists of tall, tidal freshwater marsh vegetation dominated by *Zizania aquatica* var. *aquatica* (wild rice) (Figure 2). Common associates include *Peltandra virginica* (arrow-arum), *Pontederia cordata* (pickerelweed), *Bidens laevis* (smooth bur-marigold), *Hibiscus moscheutos* ssp. *moscheutos* (eastern rose-mallow), *Polygonum punctatum* (dotted smartweed) and *Leersia oryzoides* (rice cutgrass). Sites supporting tidal freshwater marsh typically flood with each tidal cycle and are subject to primarily freshwater conditions (salt concentrations < 0.5 ppt). Along interior tidal channels, where lower substrate results in longer periods of inundation, shorter-statured

vegetation prevails in typically narrow bands. Although many of the same species are present, *Zizania aquatica* typically attains much lower vegetative cover. Instead communities are usually dominated by the broad-leaved, perennial forbs *Peltandra virginica* and *Pontederia cordata* or by the narrow, vertically oriented, angular-stemmed graminoids *Eleocharis quadrangulata* (squarestem spikerush) and *Schoenoplectus pungens* var. *pungens* (common threesquare). The western perimeter of Sweet Hall Marsh consists of low mudflats which are submerged during the majority of each tidal cycle and characterized by a near monoculture of *Nuphar advena* (spatterdock).

Data were collected from four 100 m^2 plots and captured three distinct community types. The *Zizania aquatica – Polygonum punctatum* community (plots PAMR017 and PAMR099) is especially well-developed on the Pamunkey and Mattaponi Rivers, but has also been documented from the Chickahominy River, Dragon Run/ Piankatank River, and a tributary of Fuhick Bay on the Potomac River. It is assigned a rank of "S4" in Virginia, reflecting the extent of individual occurrences but apparently limited distribution outside the York River drainage. A comparable community has been ranked "G4" by NatureServe and the Natural Heritage network. The *Eleocharis quadrangulata– Pontederia cordata –* (*Schoenoplectus pungens, tabernaemontani*) community (PAMR018) also occurs primarily along the Pamunkey and Mattaponi Rivers, but additional examples are known from the Potomac River. This vegetation typically forms linear patches in the low intertidal zone along primary river channels and large tidal tributaries. It is ranked "S2?" because of its locally restricted distribution; a loosely equivalent type recognized by NatureServe and the Natural Heritage network has not been assigned a global conservation rank. The *Peltandra virginica* community (PAMR101) appears to occur chiefly on the Pamunkey and Chickahominy Rivers in Virginia, although its distribution on the Mattaponi is unclear. It has not been assigned a conservation rank in Virginia. Although the example at Sweet Hall Marsh is co-dominated by *Peltandra virginica* and *Pontederia cordata*, the latter species is often absent from other known occurrences. NatureServe and the Natural Heritage network recognize a community characterized by both species with a rank of "G3G4." Mean species richness of the four vegetation sample plots was 8.

The Tidal Freshwater Marsh at Sweet Hall Marsh is part of a larger community element occurrence ranging from Cousic Marsh, immediately upstream from Sweet Hall Marsh, to Hill Marsh, immediately downstream. It occupies approximately 2965 acres (1200 ha) and is considered an "A" occurrence because of its extent. In addition to species listed above, other common constituents include *Zizaniopsis miliacea* (southern wild rice), *Asclepias incarnata* ssp. *pulchra* (swamp milkweed), *Acorus calamus* (sweetflag), *Amaranthus cannabinus* (waterhemp pigweed), *Sagittaria latifolia* (broadleaf arrowhead), and *Kosteletzkya virginica* (Virginia seashore mallow). The eastern edge of Hill Marsh has a slight berm which supports *Panicum virgatum* (switchgrass).

Figure 2. Low Tidal Freshwater Marsh community at Sweet Hall Marsh dominated by *Pontederia cordata* (pickerelweed) and *Peltandra virginica* (arrow-arum).

Tidal Hardwood Swamp. The northwestern section of Sweet Hall Marsh (primarily within the Tick Hill Tract now under private ownership and not formerly part of the Reserve) supports approximately 20 ha (50 acres) of Tidal Hardwood Swamp vegetation (Figure 3). This woodland community is characterized by a relatively low-statured, variably open canopy co-dominated by *Fraxinus profunda* (pumpkin ash) and *Nyssa biflora* (swamp tupelo). *Acer rubrum* (red maple) often constitutes a significant subcanopy component. Shrub cover and diversity are notably high; characteristic species include *Clethra alnifolia* (sweet pepper-bush), *Rhododendron viscosum* (swamp azalea), *Alnus serrulata* (smooth alder), *Myrica cerifera* var. *cerifera* (southern bayberry), *Ilex verticillata* (winterberry), *Leucothoe racemosa* (fetterbush), *Magnolia virginiana* (sweetbay), *Vaccinium fuscatum* (hairy highbush blueberry), *Cornus amomum* (silky dogwood), *Itea virginica* (Virginia-willow), and *Viburnum nudum* (possum-haw). Common woody vines include *Smilax rotundifolia* (common greenbrier) and *Toxicodendron radicans* (poison ivy). Where canopy cover is especially low, *Zizania aquatica* var. *aquatica* (wild rice) may dominate the herb layer. Other frequent herbaceous species that attain moderate to low cover are *Polygonum arifolium* (halberd-leaf tearthumb), *Polygonum punctatum* (dotted smartweed), *Osmunda cinnamomea* (cinnamon fern), *Osmunda regalis* var. *spectabilis* (royal fern), *Woodwardia areolata* (netted chain fern), *Leersia oryzoides* (rice cutgrass), *Boehmeria cylindrica* (false nettle), *Cicuta maculata* var. *maculata* (water-hemlock), *Sium suave* (water-parsnip), and *Symphyotrichum lateriflorum* (starved aster). Two 400 m^2 plots were sampled at Sweet Hall Marsh (PAMR125 and PAMR126), with an average species richness of 50.

This community type ranges from Delaware to Virginia, with the vast majority of occurrences restricted to the Chesapeake Bay drainage area. Given its restricted distribution, both across its range and within individual river systems, it is considered globally uncommon and assigned a conservation rank of "G3" by NatureServe and the Nature Heritage network. Although additional inventory is needed to determine the full range of this type in Virginia, it appears to be chiefly limited to the Pamunkey and Mattaponi Rivers, where it occupies a narrow zone in freshwater stretches of these moderately sized tidal rivers. Similar vegetation may be rare on or even absent from larger tidal rivers in the state (Potomac, Rappahannock, James), where geomorphological differences seem to have resulted in an extensive low levee system along tidal freshwater stretches, behind which back swamps may not flood daily. Development and persistence of forest vegetation appears to be limited downstream by salinity and upstream by the availability of sufficient sediment. Hence tidal hardwood swamps are associated primarily with the upper (higher salinity) end of the freshwater portion of the salinity gradient and typically occur on higher landscape positions adjacent to tidal freshwater marshes. Soil is generally organic-rich and contains a frequently deep organic horizon over silty alluvial deposits. Pronounced hummock-and-hollow microtopography is characteristic. Hollows are inundated by diurnal tides; hummocks may be only irregularly flooded, and the tops of hummocks are only rarely submerged (Rheinhardt 1992).

Figure 3. Tidal Hardwood Swamp community at the northern end of Sweet Hall Marsh. *Zizania aquatica* var. *aquatica* (wild rice) dominates the herb layer beneath a very open canopy of *Nyssa biflora* (swamp tupelo) and *Fraxinus profunda* (pumpkin ash).

A single element occurrence comprises all patches of Tidal Hardwood Swamp along the Pamunkey River, from Sweet Hall Marsh upstream to Polkwest Creek, encompassing approximately 1535 ha (3800 acres). The rank of "AB" reflects the size and extent of this occurrence and its relatively pristine condition, but also chronic disturbance and uncertain probability of persistence. Contemporary crown stress and tree mortality constitute a visible and widespread phenomenon in hardwood swamp forests that is generally attributed to the effects of sea-level rise. A continued reduction in overstory cover can be expected to accelerate conversion of tidal arboreal vegetation to open woodlands and marsh. Although such open habitats often support unusually diverse assemblages of species, they are also characteristically dominated by *Murdannia keisak* (marsh dewflower), a highly aggressive, invasive exotic with the potential to exclude native marsh species.

Other Natural Communities

Tidal Oligohaline Marsh. Although salinity throughout Sweet Hall Marsh may exceed 0.5 ppt at least during some tidal cycles or periods of the year, only the eastern portion supports vegetation with distinctly oligohaline affinities. Sweet Hall Marsh represents the transition between marsh vegetation characteristic of freshwater regimes and that characteristic of oligohaline conditions on the Pamunkey River. Although oligohaline habitats generally occur near the perimeter of Sweet Hall Marsh proximate to the main river channel, they are also distributed locally in the interior of the marsh, adjacent to tidal channels which may not flush saltwater completely with every ebb cycle.

Vegetation plots captured three tidal oligohaline community types (Figure 4). The *Spartina cynosuroides – Polygonum punctatum* type (PAMR124) occurs along the eastern perimeter of Sweet Hall Marsh. Robust *Spartina cynosuroides* (big cordgrass) dominates this community, with a substantial but much shorter component of *Leersia oryzoides* (rice cutgrass) and *Echinochloa walteri* (Walter's barnyard grass). Other associates include *Polygonum punctatum* (dotted smartweed), *Polygonum arifolium* (halberd-leaved tearthumb), *Hibiscus moscheutos* ssp. *moscheutos* (eastern rose-mallow), and *Peltandra virginica* (arrow-arum). This community has been ranked G4/S4 by NatureServe and the Natural Heritage network and by VNHP, respectively. The *Hibiscus moscheutos - Polygonum arifolium - Leersia oryzoides* - (*Carex stricta*) is a diverse (mean richness of 30 species per 100 m^2 plot) community characterized by variable dominance by species able to tolerate a wide range of salinity. Common constituents include *Hibiscus moscheutos* ssp. *moscheutos, Polygonum arifolium, Zizania aquatica* var. *aquatica* (wild rice), *Kosteletzkya virginica* (Virginia seashore mallow), *Leersia oryzoides, Polygonum punctatum, Mikania scandens* (climbing hempweed), *Murdannia keisak* (marsh dewflower), *Pluchea odorata* (saltmarsh fleabane), *Amaranthus cannabinus* (waterhemp pigweed), and *Osmunda regalis* var. *spectabilis* (royal fern). This community type, represented by plots PAMR122 and PAMR123, has been documented from Virginia, Maryland and New Jersey but has not received global or state conservation ranks. In the interior of Sweet Hall Marsh, open mudflats which may have formed by subsidence support relatively sparse vegetation containing *Eleocharis palustris* (common spikerush), *Schoenoplectus pungens* var. *pungens* (common threesquare), *Zizania aquatica* var. *aquatica*, and *Peltandra virginica*. The *Peltandra virginica – Echinochloa walteri –* (*Schoenoplectus pungens, tabernaemontani*) community type (PAMR098) has also been documented from the James River watershed and bears gross similarity in composition, physiognomy, and landscape position to the *Eleocharis*

quadrangulata – Pontederia cordata – (*Schoenoplectus pungens, tabernaemontani*) Tidal Herbaceous Vegetation, which occurs under chiefly freshwater conditions. It is only provisionally recognized at this time by VNHP and hence has not been ranked.

Perry and Hershner (1999) documented significant changes in the vegetation of Sweet Hall Marsh between 1974 and 1987. Data indicated an increase in abundance of several species characteristic of oligohaline marshes – *Carex hyalinolepis* (shore-line sedge)*, Echinochloa walteri, Amaranthus cannabinus*, *Rumex verticillatus* (swamp dock) and especially *Spartina cynosuroides* – and a decline in the salt-intolerant annual *Impatiens capensis* (spotted jewelweed). This shift in vegetation from freshwater to oligohaline is thought to have resulted from eustatic sea-level rise and a consequent upriver migration of the salinity gradient.

Llittle research has focused on the response of tidal freshwater marsh communities to sea level rise and salinity intrusion. In the York River, the rate of change due to sea level rise between 1950 and 1999 was 3.95 mm yr^{-1} (NOAA website 2006). When combined with locally high rates of subsidence (3 to 5 mm yr^{-1}; Holdahl & Morrison, 1974) due to groundwater withdrawl and post-glacial crustal rebound, relative sea level rise in the lower Pamunkey River is rising at a rate of 6.95 to 8.95 mm yr^{-1}).

Graduate research conducted by Sarah Davies at Sweet Hall Marsh found both long-term and inter-annual variation within the annual and perennial components of the plant community (Davies, 2004). A preliminary comparison of the results of this study (2003 vegetation) with previous work (conducted in 1974 and 1987) suggested this plant community was shifting towards more salt-tolerant vegetation. However, a follow-up study of the vegetation suggested that the large number of salt-tolerant species found during 2003 may have been a short-term response to a very salinity event in 2002 and not a gradual change to more salt tolerant community due to sea level rise and salinity intrusion. Data also suggested that the vegetation community at Sweet Hall marsh may be highly variable on an inter-annual scale. The study suggested that more frequent vegetation surveys are needed to separate long-term trends from inter-annual variation in these tidal freshwater marshes and has important implications for the spatial and temporal design of future NERRS biomonitoring work.

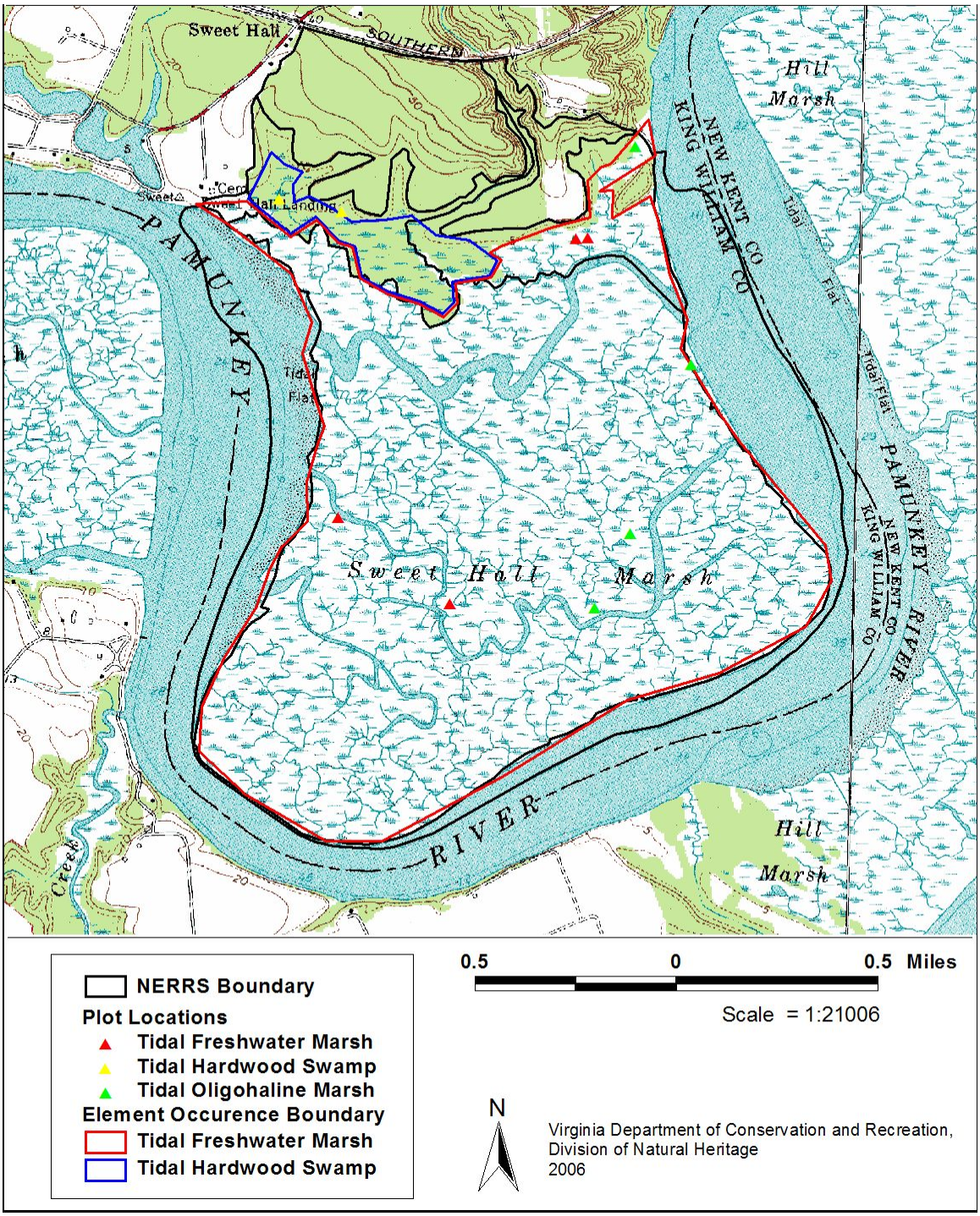

Figure 4. Map depicting locations of significant natural communities and vegetation sample plots at Sweet Hall Marsh Reserve. * Reflects Reserve Boundary as of 2000 – Before Sale of Tick Hill Tract.

Rare Species

Rare species are defined as the rarest known species in Virginia as designated by DCR-DNH. In Virginia, rare animals include species with global ranks of G1, G2, and G3, and state ranks of S1, S2, S3, SH, SX, and SU (Appendix D). Data on species with state ranks of S1, S2 (or S2S3), SH, and SX are maintained in the Biotics system and summarized annually on a master list of Virginia's rare animals (Roble 2003). Element occurrences (EOs) are specific sites where a particular rare species or exemplary ecological community occurs. EOs are mapped and tracked by DCR-DNH in the natural heritage database, *Biotics*. DCR-DNH also maintains Vascular Plant and Animal w*atchlists* which list those plants and animals uncommon in Virginia but not rare enough to be included on the Rare Species Lists (Townsend 2006; Roble 2006).

Rare plants. Sensitive joint-vetch (*Aeschynomene virginica*) is a federally-listed (Threatened) and state-listed (Threatened) plant known to occur at Sweet Hall Marsh (Figure 5.). This species is a generally tall, annual herbaceous plant in the legume (Fabaceae) family that grows in fresh to slightly brackish tidal marshes. It has been found at the outer fringe of marshes, the levee marsh zone, and marsh interiors (Rouse 1994) (Hershner and Perry 1987) (USFWS 1995). Extant populations occur in New Jersey, Maryland, Virginia, and North Carolina. The species has been extirpated from Delaware and Pennsylvania (NatureServe 2006). The DCR-DNH *Biotics* database lists 30 occurrences in Virginia, but 10 of these are considered to be historical and the status of two more is unclear. An additional 15 occurrences are considered extant in North Carolina, Maryland and New Jersey with the majority of these in North Carolina (NatureServe 2007). The Sensitive Joint-Vetch Recovery Plan lists a wide variety of threats to this species, both from anthropogenic and natural sources including sedimentation, competition from exotic plant species, boating activities, shoreline stabilization and structural development, sea level changes, severe storm events, and herbivory, among others (USFWS 1995). Recent research has shown the negative effects of increasing water depth and high standing biomass on seedling establishment in sensitive joint-vetch (Griffith and Forseth 2002).

Figure 5. Sensitive joint-vetch (*Aeschynomene virginica*).

2006 plant survey objectives. The 2006 plant survey at Sweet Hall Marsh had the following objectives: 1) Conduct an inventory for rare plants and reassess the status of any known rare plants guided by past survey work; 2) note any *watchlist* plant species; 3) investigate the *Phragmites* occurrences at the site to determine which of the two varieties, the invasive *Phragmites australis* var. *australis* or the native *Phragmites australis* var. *berlandieri*, is present; 4) document presence of invasive plant species other than *Phragmites*. (Methods and results for these last two objectives are presented in the later section on Invasive Plants.)

A major focus of the plant survey was to determine the current status of sensitive joint-vetch at Sweet Hall Marsh both by reassessing the known occurrence in the finger of freshwater tidal marsh near the boathouse and by conducting survey work for this species in the main marshes. Other rare species are known further upstream on the Pamunkey River. Tropical water hyssop (*Bacopa innominata*) (G3G5/S2) and button-bush dodder (*Cuscuta cephalanthi)* (G5/S1?) are the upstream rarities nearest to Sweet Hall Marsh; however, they have not been documented in more downstream areas. In addition, two *watchlist* species, marsh senna (*Chamaecrista fasciculata* var. *macrosperma*) and fragrant ladies'-tresses (*Spiranthes odorata*) had previously been observed within the Sweet Hall Marsh Reserve.

Rare plant survey methods. To initiate the 2006 inventory of rare plants at Sweet Hall Marsh, existing data on element occurrences within the study area were obtained from the DCR-DNH *Biotics* database and manual files (Table 2). Information in *Biotics* is partly based on information gathered from botanical literature and from examination of collections at the following institutions: College of William and Mary, George Mason University, Longwood College, Lynchburg College, National Arboretum, Old Dominion University, University of Richmond, U.S. National Herbarium (Smithsonian Institution), University of North Carolina, Virginia Commonwealth University, and Virginia Polytechnic Institute and State University.

Table 2. Rare and *watchlist* species known from Sweet Hall Marsh prior to 2006.

Common name (*Scientific name*)	Global/State Rarity Ranks	Federal / State Legal Status	First Observed / Last Observed
Rare:			
sensitive joint-vetch (*Aeschynomene virginica*)	G2 / S2	LT / LT	1987 / 1999
Watchlist:			
Marsh senna *(Chamaecrista fasciculata* var. *macrosperma)*	G5T3 / S3	-	1987 / 1999
fragrant ladies'-tresses (*Spiranthes odorata)*	G5 / S3	-	1999 / 1999

Botanical survey of the large marsh was conducted using a jon boat on September 25, 2006 by DCR-DNH Field Botanist Nancy Van Alstine and Staff Botanist Johnny Townsend. Tide Charts for the week of September 25 had been consulted to determine the day when tide conditions would be optimal for boating into the interior of the marsh, as high tides are necessary. Sensitive joint-vetch was searched for along the main channels and up several small channels, but a complete survey was not conducted due to previous searches by DCR-DNH and VIMS (Jim Perry, VIMS, pers. comm.) at the site which found no other occurrences for this species.

A reassessment of the known sensitive joint-vetch population was conducted on foot by Field Botanist Nancy Van Alstine on September 27, 2006 within the finger of marsh that extends north from the main marsh and is cut off from a narrow fringe of marsh along the Pamunkey River to the east by a causeway. As much of the marsh as could be covered on foot, at and beyond the known population area, was searched during low tide using "mudders" to facilitate walking in the extremely mucky substrate. On this date, sections of the significant Tidal Hardwood Swamp north of the main marsh were also visited to note the presence of any invasive plant species or other current threats to the significant community. The attempts to walk into the swamp encountered soil conditions far too mucky to allow much survey by foot even with "mudders", but a metal "boardwalk" was present that extended far out into the section of the Swamp nearest the slopes and southwest of a large soybean field and this enabled some observations in the interior of the swamp to be conducted.

2006 plant survey results. No rare plant species were found during the 2006 botanical surveys. Sensitive joint-vetch was observed previously within the narrow marsh west of the causeway and near the boathouse in 1998 (five short plants) and 1999 (five plants) by DCR-DNH botanists (DCR 2007). This is an area which has received both natural and anthropogenic-related disturbances. For example, swaths of wild rice (*Zizania aquatica*) have been documented lying on the ground within this marsh, apparently as a result of a natural storm event.

Sensitive joint-vetch was first found at Sweet Hall Marsh by VIMS staff at which time up to 50 plants were observed (exact number was not recorded) (Perry 1987). This occurrence of sensitive joint-vetch is the farthest downstream occurrence known on the Pamunkey River (DCR 2007). Plants have not been seen in the original location in recent years by VIMS staff or students and searches in numerous other areas of Sweet Hall Marsh have been unsuccessful (J. Perry, pers. comm.). In addition, extensive survey work for sensitive joint-vetch performed by DCR-DNH over three days in 1999 using a jon boat to navigate up small channels at high tide to reach the interior of the marsh resulted in no sensitive joint-vetch found (DCR-DNH manual files).

Two *watchlist* plant species were noted during the 2006 plant surveys: Marsh senna (*Chamaecrista fasciculata* var. *macrosperma)* and River seedbox (*Ludwigia leptocarpa)*. Another watchlist species, Fragrant ladies-tresses (*Spiranthes odorata*) which had been observed in 1998 in the northern section of the finger of marsh near the boat house, was not seen in 2006 (Table 3).

Table 3. Plant *watchlist* species within Sweet Hall Marsh and 2006 status.

Species	Observation Year	Locations	Notes
Marsh senna *(Chamaecrisata fasciculata* var. *macrosperma)*	1999, 2006	Two locations: Along edge of causeway and bank; interior of Sweet Hall Marsh	Numbers along bank/causeway similar to 1999; fewer plants at interior marsh site than in 1999.
River seedbox (*Ludwigia leptocarpa*)	2006	Eastern shoreline of ponded tributary north of Tidal Hardwood Swamp	Three plants observed.
Fragrant ladies'-tresses (*Spiranthes odorata*)	1999	North side of narrow marsh near causeway and boat house.	Not seen in 2006.

Rare animals. To initiate inventory of rare animals at Sweet Hall Marsh, existing data on element occurrences within and near the marshes were obtained from the Tracker database and reviewed. Additional information was gathered from zoological literature and from examination of selected collections at the following institutions: U.S. Museum of Natural History, the Carnegie Museum, Lord Fairfax Community College, Eastern Mennonite College, Old Dominion University, Virginia Polytechnic Institute and State University, Virginia Commonwealth University, and the Virginia Museum of Natural History. Prior to this survey, rare animal occurrences near Sweet Hall Marsh consisted of several pairs of nesting Bald Eagles (*Haliaeetus leucocephalus*). No other rare animals were known from the site.

Aerial photographs and other map sources were consulted to determine the extent of potential rare animal habitats. Subsequently, a field plan, based on all the available preliminary information, was developed to direct investigation of potential rare species habitats for the targeted animal groups. Appropriate survey techniques were planned and the methods employed are summarized below. Inventory for targeted species required repeated visits to many sites and potential habitats at different seasons. Surveys were conducted in 2006 at Sweet Hall Marsh on July 26-27 and August 15.

Sampling methods employed included using sweep nets to collect Lepidoptera, Odonata, Coleoptera and other invertebrates found either flying or on vegetation in both marsh and upland habitats. Nocturnal lepidopterans and other invertebrates were captured using UV Light traps consisting of standard bucket traps equipped with a blacklight (= ultraviolet) powered by a 12-volt gel-cell battery. Ethyl acetate was used as a killing agent. Traps were setup to run overnight at Sweet Hall Marsh from 26-27 July 2006 (Figure 6). Other collections were made by hand and additional observations (sight or sound) were recorded.

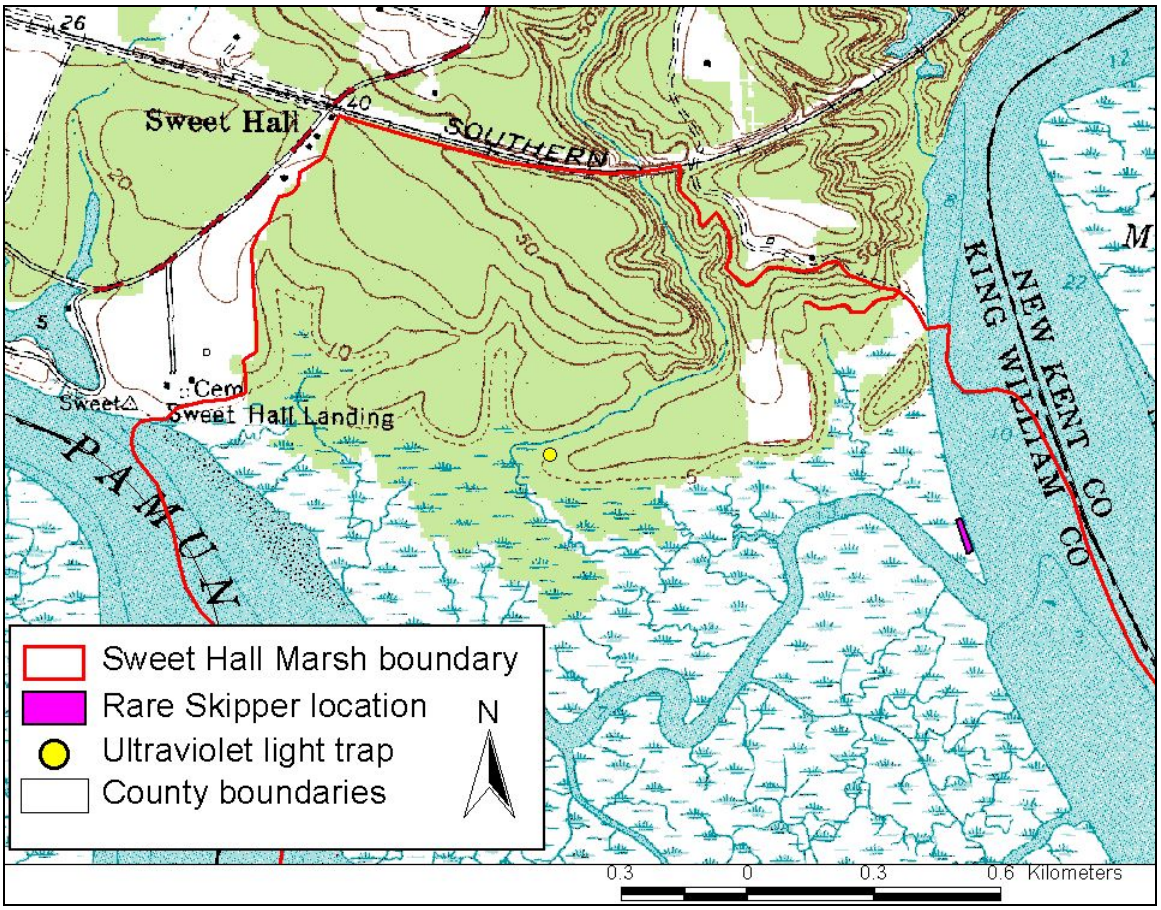

Figure 6. Locations of UV light trap and rare skipper population discovered at Sweet Hall Marsh Reserve in 2006. * Reflects Reserve Boundary as of 2000 – Before Sale of Tick Hill Tract.

All specimens collected during the study were preserved using standard methods (Martin 1977). Some specimens may be deposited in the National Museum of Natural History and the reference collection (primarily Lepidoptera and Odonata) of DCR-DNH.

Zoology Survey Results. Prior to the study, certain animals were 'targeted' as rarities that either had been known from Sweet Hall Marsh or there was a probability of being on the property. To date, most of the Odonata (dragonflies and damselflies) and Lepidoptera (butterflies and moths), and groups of Coleoptera (beetles) of interest (e.g., tiger beetles) have been identified. Some identification is still pending confirmation from experts. Surveys for other readily identifiable groups (e.g. birds, amphibians and reptiles) found no rare animals.

Rare Skipper. Two male specimens of the globally rare butterfly *Problema bulenta* (rare skipper, G2G3/S1), were captured at Sweet Hall Marsh on August 15, 2006 (Figures 6 and 7). These were observed on the eastern edge of the marsh, approximately 450m south of the boat landing (Figure 6). Both were nectaring on pickerelweed (*Pontederia cordata*). This capture is significant as it represents only the fourth known location in Virginia (Chazal and Hobson 2002), and it is the first to be found in the Pamunkey River – York River drainage.

Figure 7. Rare skipper (*Problema bulenta*) – a globally rare butterfly species now known to occur at Sweet Hall Marsh Reserve. Photo by A.C. Chazal.

With respect to the rare skipper, there are a few potential threats. The presence of the invasive non-native variety of *Phragmites* at Sweet Hall Marsh is noteworthy since it can readily become established and quickly out-compete native vegetation and form dense monotypic stands with little wildlife value (Havens et al. 1997; Rice et al. 2000). Also, any changes in salinity levels brought about by sea level rise, a potential consequence of global warming, will likely negatively affect the long-term vegetation composition at the known location of the skipper.

The rare skipper population should be monitored yearly and further surveys should be conducted to determine its full extent. Possible negative effects of boat traffic in the Pamunkey River (such as fuel spills) should be investigated to determine the extent to which they may be threats to the rare skipper. Implementing best management practices in the uplands should help assure that the hydrology and water quality of the immediate area will remain intact. Habitat alteration, such as dredging, filling, or construction may impact the habitat by compacting the soils, or allowing common reed to overrun the marsh, thus creating an unsuitable habitat for the persistence of the rare skipper. The status of *Phragmites* in this site should be closely monitored and control measures taken, if necessary, to prevent significant expansion of this invasive plant within the marsh.

Bald Eagles. Several Bald Eagles nesting locations are located near, but not within the boundaries of Sweet Hall Marsh (Figure 8 – data from VDGIF 2004). Eagles use both the water and upland resources within the Reserve boundary for fishing and resting and should be considered in management plans. Yearly surveys for bald eagle nest sites will determine if any breeding pairs move on to the Reserve (contact VDGIF and Center for Conservation Biology (CCB) for information and nesting data). The guidelines for Bald Eagle primary or secondary management zones should be adhered to where they intersect with the Sweet Hall Marsh Reserve boundary (USFWS and VDGIF 2000). Based on recent data provided by the Center for Conservation Biology, the secondary management zone of two active eagle nest(s) which were occupied by nesting pairs as of 2007 intersects with the Sweet Hall Marsh boundary (Watts and Byrd, 2007; Bart Paxton, pers. comm).

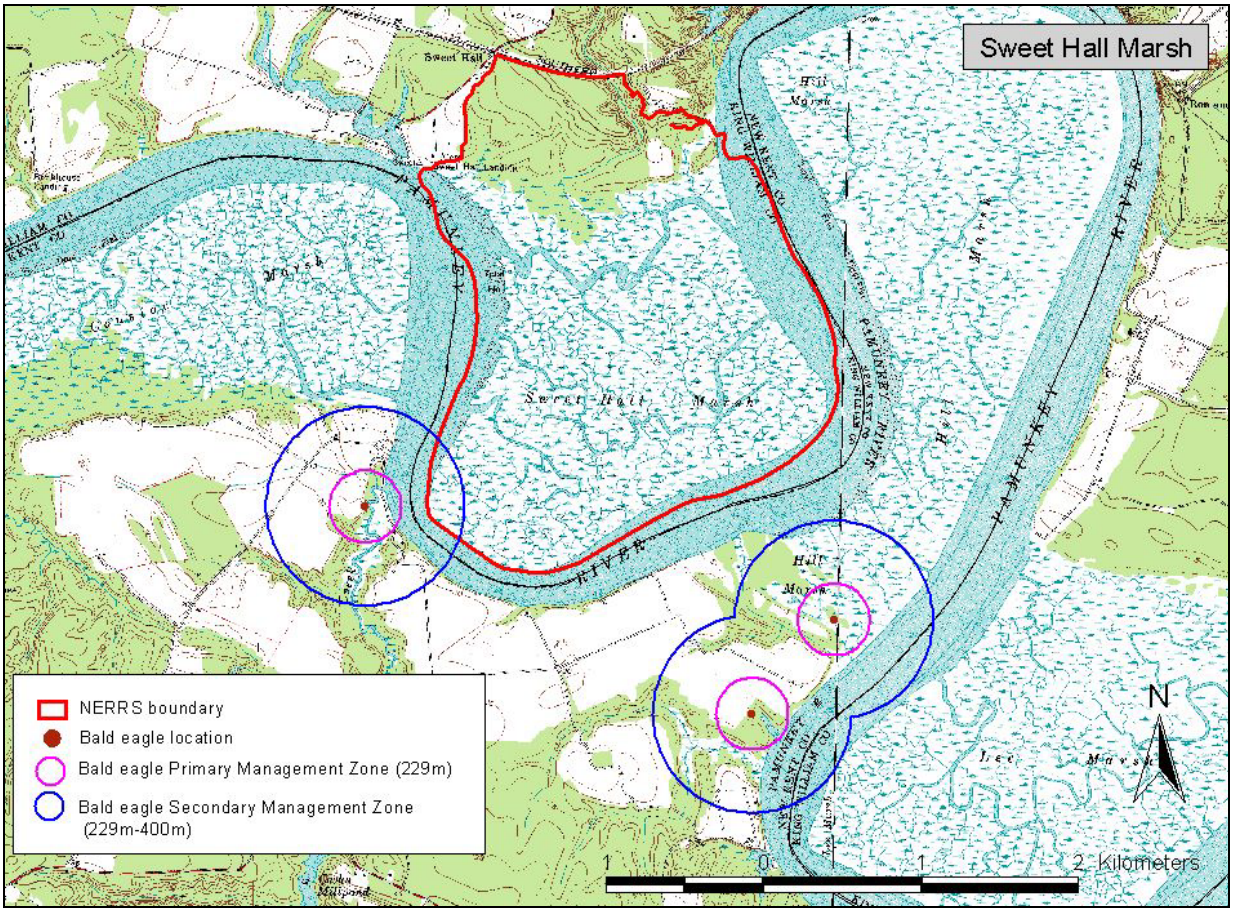

Figure 8. Bald Eagle nest locations (2004 VDGIF data) and management zones. * Reflects Reserve Boundary as of 2000 – Before Sale of Tick Hill Tract.

Potential Natural Heritage Resources

Continued site protection, management actions, the passage of time, on-going monitoring, and additional biological surveys could all result in discovery of new or regenerated occurrences of certain species and/or natural communities. Potential rare plants include two species found upriver from Sweet Hall Marsh: tropical water hyssop (*Bacopa innominata*) (G3G5/S2) and button-bush dodder (*Cuscuta cephalanthi*) (G5/S1?).

Bald Eagles use Sweet Hall Marsh extensively for roosting, loafing, and foraging. Since the habitat appears to be suitable and as nesting substrate is present, it is possible that a pair of Bald Eagles could establish a nest site here in the future. Other potential rare animal species include Swamp Sparrow (*Melospiza georgiana*) (G5/S1B/S4S5N), King Rail (*Rallus elegans*) (G4/S2B/S3N), lesser siren (*Siren intermedia*) (G5/S2), and glossy crayfish snake (*Regina rigida*) (G5/S1) (Table 4.)

Table 4. Potential rare species for Sweet Hall Marsh Reserve.

Scientific Name	Common Name	Federal / State status	Global/State Rank	Comments
Plants				
Bacopa innominata	Tropical water hyssop	- / -	G3G5 / S2	Known within 10 miles upstream
Cuscuta cephalanthi	Button-bush dodder	- / -	G5 / S1?	Known within 10 miles upstream
Animals				
Haliaeetus leucocephalus	Bald Eagle	LT(PDL) / LT	G5 / S2S3B/S3N	Three active nests nearby
Melospiza georgiana	Swamp Sparrow	- / -	G5 / S1B/S4S5N	Good potential
Rallus elegans	King Rail	- / -	G4 / S2B/S3N	Known within 10 miles of site
Siren intermedia	Lesser Siren	- / -	G5 / S2	Low potential; tributary streams
Regina rigida	Glossy Crayfish Snake	- / -	G5 / S1	Some potential

Invasive Plants

Both the native and introduced varieties of *Phragmites* are known to occur in Virginia (Saltonstall 2002). Determining which or if both varieties are present at Sweet Hall Marsh is important for developing management strategies and recommendations. As part of the 2006 rare plant surveys, three *Phragmites* stands were visited and sampled in order to collect specimens to determine whether the invasive or the native variety was present. In addition, DCR-DNH botanists collected information on the presence and location of other invasive plant species seen during the course of conducting rare species and *Phragmites* surveys and collections at the Reserve.

Methods. During the aerial survey of the marsh conducted July 12, 2006 by DCR-DNH staff (Appendix E), GPS locations representing *Phragmites* stands were collected. During the September ground surveys of the marsh, additional small *Phragmites* stands, missed by the aerial survey, were noted on a USGS quadrangle map with GPS data collected to aid in mapping these stands.

Initial aerial assessments suggested that *Phragmites* at Sweet Hall Marsh was mostly of the native variety, based on growth form. Collection of specimens were made during ground surveys in order to confirm this assessment. Collection techniques were followed as stipulated

by protocols of the Ecology and Management of Invasive Plants Program at Cornell University, who would be determining the identification (see Appendix F or the following website: http://www.invasiveplants.net/Diagnostic/instructions.htm.)

Collections were made at three *Phragmites* stands within Sweet Hall Marsh, one on the northeast corner, Boardwalk Duck Blind, one near the western side, West Creek Mouth, and one bordering a channel along a more interior section of the marsh, the *Chamaecrista* site. At a selected stand, five stems from the previous year's growing season and five green stems from the current year were cut at the base, folded, and placed in separate plastic bags with labels. Back in the office, information was entered at the website and a reference number was obtained. Fresh specimens were then shipped as soon as possible to Cornell.

Results. Dr. Bernd Blossey of Cornell University determined that the collections of *Phragmites* made at two of the 2006 collection locations, Boardwalk Duck Blind and West Creek Mouth, were native. Those specimens collected at the *Chamaecrista* site, however, proved more complicated. Senesced stems that were thought to be the previous year's growth when collected were, in fact, current year senesced stems of the native variety. Green stems collected in 2006 were the non-native variety (Figure 9). Dr. Blossey also examined seeds to further confirm his assessment. From this work, the conclusion is apparent that a recent invasion of the non-native variety is occurring into some native *Phragmites* stands at Sweet Hall Marsh (Blossey 2006a, Blossey 2006b). In addition, both native and non-native *Phragmites* stands exist at the Reserve (Figure 10).

Another invasive plant species seen in Sweet Hall Marsh was the highly invasive *Murdannia keisak* which was common just west of the boat house - the location where sensitive joint-vetch has been found in the past. Here, *Murdannia* occurs in patches sparse to locally dense. This invasive plant was present with 5-10% cover in a vegetation plot sampled by DCR-DNH in 1999. Apparently, this species has become more abundant in this section of marsh, as it was not mentioned in 1999 general survey notes (other than within the sampled plot). However, there were notable densely covered areas observed in 2006. No quantitative data is available to support this subjectively apparent increase. In the section of Tidal Hardwood Swamp that was visited in 2006, *Murdannia keisak* was sporadic to locally dense within the small portions that could be surveyed. It was listed on one of the vegetation plots sampled in 1999 as being present but with very low cover (0.1-1 %).

Japanese honeysuckle (*Lonicera japonica*) was listed on two vegetation plots sampled in the Tidal Hardwood Swamp in 1999 as having low cover [0-0.1% (trace) and 0.1-1%] and was not seen in the small area of this vegetation community surveyed in 2006. In 2006, Japanese honeysuckle was observed as common to sometimes abundant along upland slopes visited to get views of the swamp and back sections of the marsh.

Figure 9. Non-native *Phragmites* invading Sweet Hall Marsh. Note the typical blue-green color and dense growth habit.

Figure 10. Stand of (apparently) native *Phragmites* at Sweet Hall Marsh. Note the lack of blue-green color and the presence of other marsh species within the stand.

RESOURCE STEWARDSHIP

Goals and Objectives

The primary stewardship goal at Sweet Hall Marsh Reserve is to maintain a functioning ecosystem with a matrix of natural communities that will provide the research community with a long-term site for habitat-focused research opportunities. The management approach and policy direction for CBNERRVA sites is outlined in Appendix C. Reserve-level management and monitoring actions, as well as cooperative management initiatives and protection strategies are planned based on the best current information and available resources.

Management objectives for Sweet Hall Marsh include:

- Maintain and restore natural communities and habitats of rare species.
- Foster research to accomplish conservation goals and contribute to the body of knowledge on flora, fauna, and natural communities of Virginia.
- Manage habitat to benefit and provide for protection of natural resources, scenic resources, and historic resources.
- Evaluate effects of management on plants, animals, and natural communities.
- Monitoring marsh communities at Sweet Hall Marsh Reseve for long-term vegetation changes and marsh movement due to sea level rise and other climatic factors.

Management Issues at Sweet Hall Marsh Reserve

Actions must sometimes be taken in natural areas to maintain natural conditions and to return human-altered land or vegetation to a condition that supports continued existence of rare species and/or natural communities. In general threats to biodiversity include: habitat degradation and loss, invasive non-native species, pollution, overexploitation, disease, land conversion, water development, some agricultural practices, livestock grazing, off-road vehicles, pollutants, infrastructure development, disruption of fire regimes, logging, and mining activities (Wilcove et al. 1998). After habitat loss, invasive non-native species are the greatest threat to terrestrial species. For aquatic species, water pollution is the most significant threat after habitat loss (Richter et al. 1997). Because of these threats to biodiversity, active management is often needed to restore and maintain natural resources (Wilcove and Chen 1998).

- One management issue of high concern and likely to cause negative impacts to natural resources at Sweet Hall Marsh is invasive non-native plants, in particular, *Phragmites australis*.
- Additional, less locally managed issues which have been previously identified by VIMS (1991 Management Plan) and reamin current threats include localized subsidence caused by regional groundwater withdrawals for urban needs, increased residential development along the Pamunkey River, and challenges associated with sea level rise.

Invasive non-native plants. Nationwide, invasive species have been identified as the second highest threat to biological diversity, second only to loss of species and habitat from development and urban sprawl (Stein et al. 2000). Control of invasive non-native plants is expensive, resources are limited, and management efforts must be prioritized (Hiebert and Stubbendieck 1993). The goal of management is to either prevent invasive species from becoming established in high-quality natural communities or to reduce and maintain invasive

species abundance to non-damaging levels. Control efforts usually focus on reducing abundance of the most problematic invasive plants in the highest quality natural communities.

At Sweet Hall Marsh, the following invasive species have been documented: common reed (*Phragmites australis)*, Marsh dewflower (*Murdannia keilsak),* and Japanese honeysuckle (*Lonicera japonica*). The Nature Conservancy has compiled natural history, impacts/threats, management, monitoring, research, and extensive bibliographies for many invasive non-native species into "Element Stewardship Abstracts," (ESAs). ESAs for *Phragmites* and Japanese honeysuckle are provided in Appendix G. A DCR fact sheet on *Murdannia* can be found at the following website: http://www.dcr.virginia.gov/natural_heritage/documents/fsmuke.pdf

Common reed (*Phragmites australis*). The invasive wetland grass known as common reed (*Phragmites australis)* (herein referred to as *Phragmites*) is one of our most serious and problematic invasive plant species (Marks et al. 1993; Norris et al. 2002). *Phragmites* is found in every U.S. State and is well-established and increasing in coastal habitats of Virginia. This fast-spreading plant grows up to four meters tall and forms dense monotypic stands, crowding out other native marsh plants. *Phragmites* is long-lived and spreads rapidly due to its ability to reproduce both by seed and dispersed rhizome fragments, establishing readily in disturbed areas. As a result, marsh plant species diversity and habitat quality is drastically reduced for many kinds of marsh-dependant wildlife.

Phragmites is now known to exist in North America, including Virginia, in two genotypic forms. One form is native to the U.S. and appears to have been a non-dominant component of diverse mid-Atlantic and northeastern marsh communities for millennia. Recent DNA studies provide strong evidence that a distinct, non-native *Phragmites* genotype is also present in the U.S. (Saltonstall 2002). This supports an existing theory that an introduced variety of *Phragmites* has for decades been aggressively invading and dominating coastal marshes and other wetland communities, in part due to a lack of natural biological control mechanisms. The presence of an invasive non-native form of *Phragmites* would explain how and why this species has rapidly become dominant over thousands of acres of wetland communities during the last few decades in the Northeast and mid-Atlantic regions. The Virginia tributaries of the Chesapeake Bay are currently experiencing high rates of invasion by non-native *Phragmites*. Disturbances that expose mineral substrate, such as dredging and placing spoil or natural disturbances such as wildfire and hurricanes, can heighten both the risk and rate of *Phragmites* colonization and/or spread.

In 2006, an aerial GPS survey was conducted by DCR-DNH staff to document distribution and abundance of *Phragmites* at Sweet Hall Marsh (Appendix E). This survey found 18.5 acres of *Phragmites* growing in 50 patches at the Reserve. Some of the *Phragmites* appeared from the air to have growth characteristics indicative of the native variety (Figure 10). It was subsequently determined by careful laboratory inspections that both native and non-native *Phragmites* is present at Sweet Hall Marsh. In some locations, the non-native variety is apparently expanding into stands of native *Phragmites* (Blossey 2006b).

The presence of invasive non-native *Phragmites* at Sweet Hall Marsh represents a distinct threat to the continued future existence of sensitive joint-vetch. Likewise, the rare skipper butterfly is

threatened since *Phragmites* has the potential to displace the native plant species upon which this animal feeds. Continued spread of *Phragmites* has the potential to negatively impact the integrity of the two exemplary natural communities found at the Reserve, and decrease the food value of the marsh to migrating waterfowl and other resident and migratory animals.

Marsh dewflower (*Murdannia keilsak*). *Murdannia* is a member of the spiderwort family (Commelinaceae) with weak, prostrate stems 12 to 30 inches long, rooting at the lower nodes. The alternate leaves taper rapidly from the sheath to a very narrow blade. In Virginia, the three-petalled, white to bluish-purple flowers extend from the upper axils in late August to late September.

Found in freshwater marshes and along the edges of ponds and streams, *Murdannia* was probably first brought to South Carolina or Louisiana in rice imported from Asia for growth in this country. While the earliest records of existence in the U.S. date to the 1920s, circumstantial evidence suggests that it could have been associated with the early rice industry for many years before that. *Murdannia* is found in China, Japan, and Korea; in the U.S. it is found in all coastal areas from Delaware to Louisiana. In Virginia it is found in all coastal counties except the Eastern Shore. *Murdannia* seeds are a favorite food of ducks and other waterfowl, which may be an important dispersal vector for the plant.

The aggressive nature of this plant has now been clearly displayed by its ability to establish itself in freshwater wetlands and crowd out native vegetation by forming solid mats of vegetation. Even in its native regions, this species is a troublesome weed. Not only does it produce thousands of very small seeds, it can reproduce vegetatively. Mechanical removal of *Murdannia* is not recommended even when on ground that will support the equipment because remaining stem fragments will root and re-establish the plant. Only an approved wetlands herbicide can be used with some effectiveness (DCR 1999).

Japanese honeysuckle (*Lonicera japonica*). Japanese honeysuckle is a semi-evergreen vine of the Caprifoliaceae family. A serious pest throughout eastern North America, it outcompetes native vegetation for both soil nutrients and light (Nuzzo and Randall 1997). Japanese honeysuckle was the most frequently observed non-native species in a study of almost 2000 DCR-DNH ecological community classification plots located across the state of Virginia (Heffernan et al. 2001). Japanese honeysuckle was found scattered in some of the upland forested areas surveyed at Sweet Hall Marsh and is considered to be occasionally common to locally abundant.

Native problem species. Due to overabundance, certain native species of animals have become problematic – from both ecological and economic perspectives. While these species are native to Virginia, their recent population increases have resulted in negative effects on habitat. Overabundance of some species is often incompatible with a broad array of resource management objectives. For ecological and or economic reasons, natural resource managers must often control burgeoning populations of native animals.

Southern pine beetle (*Dendroctonus frontalis*). Southern pine beetle is a native insect species that attacks stressed or dying pine trees, as well as pines infested previously by other native bark

beetles (Coulson and Witter 1984). This species causes significant damage in cycles, and when outbreaks occur, the beetles can attack, colonize, and kill even vigorous healthy trees. Pine stands that are dense and/or drought stressed are most susceptible to southern pine beetle. Pine bark beetles have been reported from Sweet Hall Marsh. Additional information is available in Appendix G.

White-tailed deer (*Odocoileus virginianus*). A large body of research (Russell et al. 2001) presents evidence that dense populations of deer in many eastern U.S. ecosystems can negatively impact tree and herb regeneration, recruitment and composition (Alverson and Waller 1997, Horsley et al. 2003), alter natural community composition (Rooney and Dress 1997), eliminate certain plant species from areas (Augustine and Frelich 1998), and disrupt bird populations (deCalesta 1994; McShea and Rappole 1997). Deer also avoid browsing on the invasive non-native plants, such as Japanese stilt grass (Tu 2000) further exacerbating the nefarious effects of these weeds on native flora. Of particular concern for natural areas management are negative effects of high deer densities on herbaceous plants (Balgooyen and Waller 1995; Augustine and Frelich 1998) and rare plants (Miller et al. 1992). At the end of the 19th century, deer were over-hunted to the point of near extirpation from Virginia. Since then, implementation of strict game laws, elimination of natural predators, and the changing landscape (with more edge habitat) has given rise to a burgeoning deer population that today, in most areas of the state, exceeds estimated presettlement deer densities (Knox 1997). Monitoring programs can be designed to estimate and track deer population densities and deer impacts in order to guide management actions. Additional information on white-tailed deer monitoring and control can be found in Appendix G.

Sea level rise. Due to the combination of eustatic sea level rise and regional subsidence, the marsh at Sweet Hall Marsh is experiencing a rapid relative sea level rise of approximately 6 to 9 mm/yr (Holdahl & Morrison, 1974; NOAA website 2006**).** The effects on vegetation at the Reserve are increasingly apparent, with stunting and dieback in forested wetlands and apparent upstream movement of salt-associated vegetation types (Perry and Hershner, 1999; Davies 2004). The sensitive joint-vetch population at Sweet Hall Marsh is the most downstream location known for this species on the Pamunkey River; however, plants have not been seen since 1999. Recent research has shown the negative effects of increasing water depth and high standing biomass on seedling establishment in sensitive joint-vetch (Griffith and Forseth 2002).

Fire management. Fire management includes both prescribed fire and wildfire suppression and is an important aspect of natural areas management in Virginia. Historically, lightning-induced wildfires as well as fires started by Native Americans would have influenced Sweet Hall Marsh and shaped the natural communities and species habitats found there. It is not clear whether prescribed fire needs to be used at the Reserve to achieve either VIMS or landowner objectives. However, there is evidence that fire has occurred at the site in the not so distant past (Figure 11). Likewise, the potential effects of and contingency plans for managing wildfires at the Reserve have not been established and are not considered under this management plan. The need for a fire management plan to be developed for the site is evident, although priority is not high due to the absence of fire-maintained rare species habitats and the perceived mild consequences were a wildfire to occur.

Figure 11. Old charred stump within Sweet Hall Marsh.

Operations management. Natural area managers design and maintain infrastructure such as posted boundaries, access road gates, and informational signage to protect resources from adverse human effects. Operations management actions include boundary line monitoring and maintenance, public use monitoring, sign design and posting, and access control.

Federal and state natural resource laws. Laws and other regulations that may affect management of Sweet Hall Marsh are noted in Appendix H. The conservation emphasis of management at CBNERRVA sites means that VIMS will only rarely engage in land or water modifications subject to regulation. Decisions to permit fishing or hunting must comply with federal and state laws. At all CBNERRVA sites, efforts to control invasive species, protect rare and endangered species, and protect existing natural and historic resources will fulfill the requirements of several natural resource laws.

Visitor management. Sweet Hall Marsh is in private ownership. Any public use other than that specifically authorized through permission of VIMS and the landowner is inappropriate and unlawful (i.e., trespassing). Potential inappropriate uses include unauthorized hunting and illegal artifact collection. Such activities threaten resources and raise concern regarding visitor and researcher safety and compliance with state and federal regulations.

Appropriate uses. The Reserve is used for research, teaching, and environmental education by VIMS staff and students. Hunting and trapping at Sweet Hall Marsh are activities exercised exclusively by the landowners.

Inappropriate uses. Deterring inappropriate public uses at Sweet Hall Marsh Reserve will require some level of site operations work; e.g., boundary marking, on-site staff presence, public contact, outreach efforts, and law enforcement. Specific inappropriate uses include:

- *Non-permitted collection of plants and animals*. Any and all collection of plant and animal specimens should be for research and educational purposes only and requires a permit issued and approved by VIMS staff. Unauthorized collection of plants, animals, or minerals may negatively impact the ecological integrity of a site and can quickly decimate populations of rare plants or animals.

- *Artifact collection* degrades cultural and historic sites and disrupts substrates and vegetation. Artifacts are occasionally found on and around Sweet Hall Marsh, but illegal collecting is not known to be a problem at this time. To protect historic resources at this and other CBNERRVA sites, artifact collection is not permitted.

- *Camping* causes long-term concentrated impacts on soils and vegetation from trampling and fire rings (Marion and Cole 1996), and is an inappropriate use of this CBNERRVA Reserve. Nearby private facilities and state parks offer a wide array of camping opportunities.

Data Gaps and Research Needs

A variety of data gaps and research needs exist in regard to management issues at Sweet Hall Marsh. Further monitoring, research, and inventory will be required to address these questions, which include:

- What can be done to control the spread of invasive, exotic species that threaten the native communities of Sweet Hall Marsh?
  - What is the most effective ways to manage non-native Phragmites and other invasive species?
- What aquatic communities are present at the Reserve?
  - Are there any trends of native finfish populations which might be of concern?
  - Are there management concerns for these communities/species?
- What is the breeding bird use and capacity at Sweet Hall Marsh?
  - Are waterfowl or marsh bird species composition shifting with changes in vegetation?
- What are the impacts (if any) of any permitted uses of Sweet Hall Marsh (including hunting and trapping).
  - Are there any management options which might need to be implemented?
- What is the status of mercury pollution in the Pamunkey River?
  - What are long-term implications for terrestrial and aquatic populations?
- What are the effects of sea level rise and marsh subsidence on Sweet Hall Marsh and what are the implications for long-term resource management?
  - Is the marsh vegetation composition changing?

        - What are long-term implications of such change on Reserve resources?
    - What is the long-term outlook for the marsh?
        - Will it subside to the extent that vegetation is greatly altered or eliminated (low tide mud flat communities), or will accretion offset erosion and accretion leave it in essentially the same condition as today?
- Does increased recreational boating activity pose a threat to the newly discovered population of rare skipper at the preserve due to increased shoreline erosion from boat wakes and potential fuel spills?
    - More generally speaking, are channel-facing marshes at Sweet Hall Marsh significantly affected by wakes of passing boats?
- What is the historical/archaeological significance of artifacts on the preserve?
    - Where do these artifacts occur and how should they be managed?

Monitoring.

General Overiew: A wide variety of monitoring techniques are used to assess change in natural community composition and rare species population status. Monitoring can determine if natural processes essential to natural heritage resources health are occurring and whether or not management actions have been effective. Monitoring is also needed to document effects of human visitation and public use patterns on natural heritage resources and other natural features protected within natural areas. The term "monitoring" describes several different types of data collection related to resource management and includes inventory, natural history study, research, implementation monitoring, trend measurement, baseline measurement, and long-term ecological studies. Monitoring in a strict sense is "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress towards meeting a management objective." (Elzinga et al. 1998). This strictly defined mode of monitoring is most useful for rigorously measuring change.

NERRS System-Wide Monitoring Program (SWMP): The goal of the NERR System Wide Monitoring Program is to "Identify and track short-term variability and long-term changes in the integrity and biodiversity of representative estuarine ecosystem and coastal watersheds for the purpose of contributing to effective national, regional, and site-specific coastal zone management". Three broad categories have been identified for monitoring under SWMP:

- Phase I: Abiotic parameters (water quality, weather, nutrients)
- Phase II: Biological parameters (communities and habitats)
- Phase III. Watershed parameters (land use and land cover changes)

Current and Future Monitoring at Sweet Hall Marsh Reserve: Since 2000, CBNERRVA has fully participated in the NOAA/NERRS System-Wide Monitoring Program at the Sweet Hall Marsh Reserve. CBNERRVA currently maintains long-term, year-round continuous water quality (2000 to present) and meteorological stations (2003-present) as well as collecting monthly nutrient (nitrate, nitrite, ammonium, phosphate) samples from the waters near the water quality station (2002-present).

CBNERRVA will also be examining the overall spatial distribution (Tier 1 Analysis) and patterns of inter-annual and long-term variability within selected areas of emergent vegetation (Tier II Analysis) within the Sweet Hall Marsh Reserve as funds become available. At the Sweet

Hall Marsh Reserve, CBNERRVA has started work on the Tier II monitoring through internal operation funds establish long-term vegetation transects to build off of the work done by Perry and Hershner (1999) and Davies (2004). Starting in the spring of 2008, CBNERRVA will be monitoring vegetation, establishing groundwater wells, establishing sediment elevation tables, and implementing vertical control (through geodetic and water level datum reference systems) at the Sweet Hall Marsh Reserve to accurately describe reference conditions and better understand habitat change. This work is also related to and will become part of the NERR SWMP Phase III effort of tracking and evaluating changes in estuarine habitats and ecological conditions as related to anthropogenic influences from the watershed and environmental stressors from climate change.

At Sweet Hall Marsh Reserve, other specific monitoring needs include:

- Annual monitoring of the rare skipper population. Further surveys should also be conducted to determine the population's full extent.
- Amount of boat traffic in the Pamunkey River to correlate possible effects of wakes on shoreline erosion.
- Every two years, the status of both native and non-native *Phragmites* at the Reserve should be evaluated to assess expansion and recolonization in areas where control measures have been applied.
- Yearly surveys for bald eagle nest sites will determine if any breeding pairs move into the NERRS tracts (contact VDGIF for information and nesting data).

Research. Research to improve understanding of natural history, biology, and population dynamics of rare species and ecosystem functions is needed for sound and defensible management planning. Numerous data gaps, listed above, need to be addressed and information collected upon which to base improved management strategies. Scientific studies conducted by VIMS or sponsored through funding support will answer basic natural history questions and inform management decisions and actions.

Studies conducted on all CBNERRVA components require submission of an application, which must be reviewed and subsequently approved by VIMS staff. An annotated bibliography of prior research conducted within the Reserves boundaries including Sweet Hall Marsh can be found at: http://www.vims.edu/cbnerr/research/26February2006_research_biblio.PDF

Management Recommendations

Rare species. To assure that the habitat for rare skipper butterflies remains intact, controlling *Phragmites*, monitoring salinity and boating effects, and implementing best management practices in the uplands are key management actions. Losses of native vegetation and/or substrate disturbance in the marsh could allow *Phragmites* to overrun the marsh, thus creating an unsuitable habitat for the persistence of the rare skipper.

Bald Eagle nest protection. Bald eagles nest at three known locations near Sweet Hall Marsh and also use both the water and upland areas for fishing and resting. Guidelines for bald eagle primary or secondary management zones should be adhered to where they intersect with the Reserve boundaries (USFWS and VDGIF 2000). Based on recent data provided by the Center for Conservation Biology (CCB), the secondary management zone of two active eagle nests

(which were occupied by nesting pairs as recently as 2006/2007) intersect with the Sweet Hall Marsh boundary (Watts and Byrd, 2007; Bart Paxton, pers. comm). It is recommended that the existing Bald Eagle nest within YRSP be monitored at least annually, and that signs warning against disturbance and harassment be posted. Additional management assistance may be available from staff at the CCB or VDGIF – Wildlife Diversity Division.

***Phragmites* control.** At Sweet Hall Marsh, a high priority management action is *Phragmites* control. *Phragmites* covers at least 18.5 acres at the Reserve, as determined by aerial survey methods during summer 2006 (Appendix E). Due to its current limited distribution, control actions for *Phragmites* have a high likelihood of success at relatively low cost. Delayed action will result in increased expansion of existing patches, possible development of new patches, and increased control costs.

Until recently*, Phragmites* was treated exclusively with glyphosate-based herbicides (Norris et al. 2002). Use of these products has been shown to require carefully timed and successive-year repeat treatments to give good control. However, an alternative product became available for treating *Phragmites* in wetland situations in 2003. Containing the active ingredient imazapyr, the herbicide Habitat™ has been shown to provide good control often with only one treatment, followed by minor "mop-up" treatments to control areas that may have been missed the first time. The effective application window for imazapyr is wider than for glyphosate. Therefore, managers have more leeway in planning and executing management. Glyphosate treatment requires late growing season application, which coincides with higher occurrence of tropical storm activity. Imazapyr can be applied throughout the growing season, although later applications (as with glyphosate) have the advantage of selectively controlling target vegetation due to the late senescence habit of non-native *Phragmites*.

Additional notes on imazapyr. Imazapyr is a non-selective herbicide used to control grasses, broadleaved and woody species. It inhibits the synthesis of broad-chained amino acids which are only found in plants. Animals obtain this group of amino acid by eating plants. Imazapyr is degraded in soils by microbial breakdown, where its half-life in soils range from one to five months. When exposed to sunlight in a water column, the half-life may be as low as one to two days. Testing of imazapyr has shown it is not toxic to birds or mammals, but it can cause severe eye damage. Although imazapyr has been shown to have no toxic effects on bobwhite quail and mallard ducks, it has not been tested specifically on shorebirds (Entrix, Inc. 2003). It does not affect algae or submersed vegetation, and has a low toxicity to fish (Tu et al. 2001).

The goal of *Phragmites* management at Sweet Hall Marsh is to reduce its abundance and encourage recolonization of the infested areas by native vegetation. Anticipated cost for aerial Habitat™ application in 2007 is $250/acre, including both chemical and applicator fees. This cost estimate assumes aerial spraying at Sweet Hall Marsh in conjunction with aerial spraying at other nearby properties, since economies of scale will greatly affect aerial application cost rates. Costs for ground-based and boat-based herbicide control of *Phragmites* are highly variable and dependent on many factors. Estimated (2007) costs of boat-based spraying using Habitat™ are $300-$500/acre; estimated costs of boat-based spraying using generic glyphosate products are $200-$350/acre; and estimated costs of backpack-based ground control are $100-$320/acre. The lower estimates are for "in-house" staff (trained and certified), while the higher end of the range assumes use of contractor services.

Control recommendations.

- Set goal of controlling *Phragmites* by reducing cover at least 90% through herbicide treatment.
- Achieve control of *Phragmites* through aerial and ground-based application of imazapyr herbicide.
- Mop-up small remnant patches with imazapyr herbicide applied using backpack or boat-based portable sprayer. A portable sprayer has a treatment range limited by hose length, which may be 50 to 300 feet. A two-person crew can treat approximately one to two acres per day. Timing of treatment may be anytime during the growing season.
- Monitor the *Phragmites* infestation response to herbicide treatment. Monitoring efforts can be scaled to available resources. Comparison of pre- and post-treatment plot data indicates to what degree *Phragmites* cover has changed. At a minimum, low intensity qualitative monitoring using permanent photomonitoring plots is recommended. A monitoring protocol frequently used by DCR-DNH measures live *Phragmites* stems, average stem height, and visual estimate of cover of *Phragmites* and other vegetation in a set of permanent 0.25 m x 2 m quadrats. Quadrats are established along transect(s) within a *Phragmites* patch. The number of transects/ quadrats depends on the desired level of monitoring intensity.
- Conduct monitoring surveys annually for three to five years to assess quality of *Phragmites* control and to track re-vegetation patterns in controlled areas. As needed, seek guidance from other natural resource managers if desired results are not achieved.

Table 5. Recommended *Phragmites* management timeline.

Year one	Year two	Year three & beyond
1. Install *Phragmites* monitoring plots during the early growing season (May through July) before first herbicide application. 2. Treat with herbicide using aerial or ground (boat) application methods (August into October) and with imazapyr herbicide.	1. Conduct post-treatment monitoring. 2. Assess need for further herbicide treatment of remnant *Phragmites* patches. 3. If treatment is needed, use ground crew and backpack sprayers or boat-based herbicide sprayers and imazapyr herbicide.	1. Continue post-treatment monitoring at least one year following the last herbicide treatment. 2. Assess need for further herbicide treatments. 3. As necessary, treat remnant or new *Phragmites* patches to maintain low abundance.

Finally, it is recommend that VIMS and/or the landowners contract with DCR-DNH or some other capable service provider to complete a full aerial survey of Sweet Hall Marsh Reserve as part of an intensive effort to map all *Phragmites* completely and to distinguish native and non-native patches. The results of this work would inform efforts to treat the non-ative and mixed patches. Such control measures should be done as soon as is practical.

Murdannia. It is recommended that annual monitoring of the extent of *Murdannia* invasion at Sweet Hall Marsh be conducted. Control measures should be considered and undertaken only if clear conflicts with landowner objectives become apparent. This is not an easily controlled species and prospects for effective treatment are uncertain.

Japanese honeysuckle. Japanese honeysuckle was found in some forest communities visited at Sweet Hall Marsh in 2006. No management actions for this ubiquitous species are recommended at the Reserve for this species at this time. Japanese honeysuckle is well established throughout Virginia and should only be controlled with herbicides when clear problems arise and its presence conflicts with management objectives. At this time, no natural heritage resources (rare plant habitats or natural community occurrences) are known to be threatened by this species. On-going periodic monitoring surveys for this and other potential invasive plants are recommended.

White-tailed deer. It is recommended that the landowners maintain a continuing harvest of deer, guided by recommendations from VDGIF wildlife biologists. Harvesting an adequate number of does, in combination with a targeted number and size and quality of harvested bucks, is an accepted and proven way to keep overall herd numbers at acceptable levels while improving the quality and abundance of trophy class animals. Participation in the state Deer Management Assistance Program (DMAP) is a good way for private landowners to achieve their deer management goals.

Agriculture and forestry. All farming or forestry activities at the Reserve should comply with provisions set forth in the Chesapeake Bay Act in order to protect surface and groundwater quality. Residents and landowners living or managing property within the Chesapeake Bay Preservation Area should comply with agriculture and forestry BMPs designed to reduce sedimentation and run-off.

Spill contingency plan. It is recommended that VIMS work closely with the U.S. Coast Guard, the Virginia Department of Environmental Quality (DEQ), and other appropriate agencies and organizations with expertise in petroleum or toxic materials spills to develop a contingency and response plan to protect Sweet Hall Marsh resources in the event of an incident in the Pamunkey River.

Unauthorized artifact collection. It is recommended that VIMS staff work with DHR and the College of William and Mary - Center for Archaelogical Research to determine more information about the type and extent of historical sites and artifacts found at Sweet Hall Marsh Reserve and to determine protection needs and focus conservation efforts. DHR and land managers with experience in protecting cultural resources can assist with developing and locating signs to discourage trespass and subsequent illegal artifact collection. DHR may also provide assistance with developing effective outreach programs.

Fire management plan. To explore the possible need for and benefits of prescribed burning, and to provide guidance in the event of a wildfire in the future, a fire management plan should be developed for Sweet Hall Marsh. Such a plan would establish the past role of fire on the Reserve, state the potential benefits and disadvantages of fire under current landowner and management perspectives, state landowner management objectives, provide guidance should a wildfire occur, and make recommendations regarding the need and approach to using prescribed fire. A fire management plan could be developed by VIMS staff in consultation with agencies and organizations that frequently deal with fire management issues, including the Virginia

Department of Forestry (DOF), DCR, and The Nature Conservancy. Implementing this plan would require close coordination with DOF as well as local volunteer fire departments.

ADDITIONAL PROTECTION NEEDS

At the time of designation in 1991, the Tick Hill tract of the Reserve's Sweet Hall Marsh component was owned and managed by Chesapeake Corporation. The Tick Hill tract was 76 ha (189 acres) in area and primarily consisted of upland and forested wetlands. Comprising the majority of the tract and serving as a buffer to the core region, the upland portion of the tract was managed by Chesapeake Corporation for pulpwood production and scheduled for harvest in 2004. In the years following Reserve designation, Chesapeake Corporation embarked on new business strategies that resulted in the sale of the West Point mill in 1997 followed by additional divestitures including the sale of significant land holdings. The Tick Hill tract was sold to a private citizen in 2000. A Memorandum of Understanding between VIMS/W&M and the new owner does not currently exist. Because of this sale, the Reserve has had to modify its boundaries as to only reflect the property holdings of the Tacoma Hunting and Fishing Club (see Figure 1 for an aerial photo of Sweet Hall Marsh Reserve component delineating new core/buffer areas and land ownership). This tract is deemed important to Reserve operations and attempts will be made to establish working relations with the new property owners that will hopefully lead to the development of a new management agreement.

To adequately protect and conserve the larger landscape ecosystem of Sweet Hall Marsh, additional adjacent lands may require further conservation and/or open space easements. Habitat fragmentation will increasingly threaten nearby lands, and to mitigate some of these impacts, VIMS may consider pursuit of conservation and open-space easements and management agreements on key tracts near the Reserve.

Areas designated as high priority are those undeveloped marsh/upland/agricultural tracts located adjacent to Sweet Hall Marsh and are a high priority for addition to the Reserve for several reasons. These areas likely serve as foraging, nesting, and loafing habitat for bird species using Sweet Hall Marsh including Bald Eagles, Osprey, Northern Harriers, Great Blue Herons, and numerous other marsh birds. Adding these lands to the Reserve, or protecting them through conservation easements or formal management agreements, would complement the current site with additional or like habitat for mobile species.

Agricultural and forest lands included in these adjacent lands could be protected with open space and conservation easements and management agreements. Such protection measures could allow most existing uses to continue while still offering increased protection to the Reserve from future development. Community outreach and education in these areas might help landowners and residents understand the importance of protecting soils, surface and ground water, as well as promoting use of agriculture and forestry BMPs. Community or neighborhood meetings provide citizens with opportunities to ask questions, allow for information exchange, and help develop a sense of protection and conservation for specific sites such as Sweet Hall Marsh.

SUMMARY

Management to protect and maintain natural resources and biological diversity at Sweet Hall Marsh Reserve will require ongoing actions and assessments to ensure that resources are conserved. The complexity of ecosystems and a shortfall of staff time and funds usually precludes a full understanding of the effects of ongoing biological change and a sufficiency of management actions to direct and monitor that change. By taking an active and adaptive management approach at Sweet Hall Marsh, by using and building on an existing baseline of inventory data, and by monitoring trends in natural communities and/or species populations following management actions it is likely that successful stewardship of natural resources will be attained.

Future Improvements to Sweet Hall Marsh Natural Resource Plan (in 2013)

1) Updating Information on Hydrologic and Water Quality Conditions
   - Continue to update hydrologic and water quality conditions in the York River subestuary through data collected by CBNERRVA SWMP Monitoring and the U.S. EPA Chesapeake Bay Shallow Water Monitoring Program, currently administered by CBNERRVA. This should include compiling (and when possible collecting) information related to toxicity in the lower Pamunkey River (through mercury and/or PCBs).
   - This program combines the use of high resolution surface water quality mapping (Dataflow) with continuous, fixed water quality stations to provide accurate measurements of the temporal and spatial variability in water quality constituents as well as assessing water quality criteria within the York River subestuary.
   - This water quality information is compiled thorugh the Virginia Estuarine and Coastal Observing Sytem website: http://www2.vims.edu/vecos/

2) Updating Informaiton on Potential Impacts to Water Quality at Sweet Hall Marsh Reserve
   - Documenting Land Use/Land Cover Changes in Sweet Hall Marsh Watershed.
     - The Coastal Change Analysis Program (C-CAP) is a nationally standardized database of land cover and land change information, developed using remotely sensed imagery, for the coastal regions of the U.S. C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring these habitats by updating the land cover maps every five years. Data for Virginia exists for 1996, 2001, and 2005.
       - http://www.csc.noaa.gov/crs/lca/ccap.html
   - GIS Based Tools or Products to Assess Water Quality Impacts Related to Anthropogenic Activities in the Watershed.
     - N-SPECT is a complex yet user-friendly geographic information system (GIS) extension that helps coastal managers and local decision makers predict potential water-quality impacts from nonpoint source pollution and erosion. Users enter information about their area (land cover, elevation, precipitation, and soil characteristics) to create the baseline information. Users then add different land cover change scenarios (such as a development) to get information about potential changes in surface water runoff, nonpoint source pollution, and erosion
       - http://www.csc.noaa.gov/crs/cwq/nspect.html

3) Update on Current and Future Biomonitoring and Habitat Change Studies
   - As the NERRS monitor environmental parameters in a coordinated and consistent manner, reserves are valuable sites for developing an in-depth understanding of the past, present, and future status in the extent and quality of coastal habitat.
     - Use historical aerial photography and other remotely sensed products to calculate erosion rates and habitat conversion/loss over long-term temporal scales and/or resulting from episodic events (i.e. large storms, hurricanes).
     - Document the current spatial distribution and future changes (through Reserve-level mapping) of estuarine habitats within the Sweet Hall Marsh Reserve (and possibly other nearby oligohaline/tidal freshwater marshes which are part of the

marsh complex of the lower Pamunkey River) according to the NERRS classification system.
    - Document patterns of inter-annual and long-term variability within selected areas of emergent vegetation as they relate to anthropogenic (i.e. watershed development, changing water uses, groundwater withdrawl) and environmental (i.e. storms, sea level rise, severe droughts) factors.
        - This includes developing a network of sediment elevation tables (SETs), sediment tiles and feldspar marker horizons at Sweet Hall Marsh Reserve to measure marsh vertical accretion, marsh-surface elevation change (at micro-topographic acales), and shallow and deep soil subsidence on shorter-term time scales in response to sea level rise and storm impacts.
        - This also includes building up previous work on sedimentation and accretion at Sweet Hall Marsh Reserve conducted by Friedrichs & Perry (2000) and Neubauer et al. (2002).

4) Update on Establishing Vertical Control at Sweet Hall Marsh Reserve (NERRS HMC Plan)
    - Specific objectives are to establish a vertical control reference system at Sweet Hall Marsh Creek Reserve of high level accuracy elevation (cm/mm).
    - Make an assessment of gaps in vertical control points at Sweet Hall Marsh Reserve and identify the infrastructure or steps to fill in those gaps.
    - Install and tie geodetic benchmarks to the current tidal datum.

5) Updating Information on Avian Populations in Sweet Hall Marsh Reserve
    - Work with the Center for Conservation Biology (CCB) to target avian species which have the potential to occur within our reserve sites based on their geographic locations and habitat types. http://www.ccb.wm.edu/
        - Especially those species of "conservation concern" identified by CCB or VaDGIF through their Wildlife Action Plan.
    - Especially important because the Sweet Hall Marsh Reserve falls within an Important Bird Areas (IBAs's) in Virginia.
        - http://iba.audubon.org/iba/viewSiteProfile.do?siteId=3043&navSite=state
        - The IBA program is a science-based initiative designed to identify, conserve, and monitor sites that provide essential habitat for bird populations. Under this initiative, sites that are critical for the long-term survival of bird populations have been identified across the globe using internationally agreed upon criteria.
        - The CCB joined forces with the IBA program with funds from the Coastal Program to provide the information resources and expertise needed to identify and establish a network of conservation sites in coastal Virginia.

6) Incorporation of Wildlife Action Plan Information (Virgina DGIF)
    - The Virginia Wildlife Action Plan provides a blueprint and vision for effective and efficient wildlife conservation in the Commonwealth.
        - http://bewildvirginia.org/wildlifeplan/
    - The Virginia Wildlife Action Plan identifies 925 species of greatest conservation need, 60% of which are aquatic and 70% of which are invertebrates.

  - The species are grouped into four tiers of relative conservation need: critical, very high, high, and moderate which allow for prioritization of conservation actions.
  - In making this assessment, Virginia DGIF focused on species that demonstrated some level of rarity or risk of imperilment (e.g. subject to habitat loss, impacted by pollutioin, currently at low population levels).
- Using information in this document and the Map Wild! Website (a GIS applicaton under development allowing users to query information from the Wildlife Action Plan), CBNERRVA may identify additional species (known to exist within the habitats at the Sweet Hall Marsh Reserve) for future monitoring or management actions.
  - *This information will supplement those species already identified by the Natural Heritage Division of DCR within this Natural Resource Plan.*

7) <u>Update Information on Finfish Populations and Introduced Species in Pamunkey River:</u>
   - Build upon the research by former CBNERRVA staff member, Eric Wooden, within the tidal creeks of Sweet Hall Marsh and information from VIMS Trawl Survey within the areas of the Pamunkey River adjacent to the Sweet Hall Marsh.
     - By using online databases, historical studies, and possibly limited field-based monitoring, determine if there are any trends in the finfish populations in this area of the Pamunkey River relate these trends to natural and anthropogenic factors.
   - CBNERRVA should also consider monitoring introduced finfish species (for example blue catfish) within the lower Pamunkey River.
   - The goal of the monitoring should be to control the species in the Dragon Run; however, there is some question as to whether this is technically feasible
     - A more comprehensive monitoring program for introduced species will likely exceed the limitations of current CBNERRVA staff; however, some of this work may be accomplished through partnerships with other state agencies and academic institutions.

8) <u>Update Changes to Reserve Boundaries at Sweet Hall Marsh Reserve</u>
   - Since the approval of the 1991 CBNERRVA Management Plan, two land tracts (Harrison tract and SE Catlett Island tract) within the York River basin have been acquired by CBNERRVA and deeded to entities of the Commonwealth and one tract (Tick Hill component of Sweet Hall Marsh) has been sold to another private party.
   - The sale of the Tick Hill component of Sweet Hall Marsh and expiration of the associated management agreement will require additional negotiations with the current landowners and potential changes in Reserve boundaries.
   - Changes in Reserve Boundaries will affect information in all sections of this Natural Resource Plan, especially within the “Natural Resources” and “Resource Stewardship” areas, and the next Natural Resource Plan for Sweet Hall Marsh will reflect these changes.

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LIST OF APPENDICES

Appendix A

Management Agreement: Sweet Hall Marsh National Estuarine Research Reserve in Virginia

THIS MANAGEMENT AGREEMENT, made this ____ day of _____, 2007 by and between Tacoma Hunting and Fishing Club, hereinafter called the Grantor, and The College of William and Mary in Virginia, hereinafter called the Grantee. This Management Agreement supercedes the original Management Agreement for the Sweet Hall Marsh component of the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA) dated September 24, 1990.

WITNESSETH

WHEREAS, the Grantor is owner in fee simple of certain real property (hereinafter described and referred to as "Sweet Hall Marsh"), situated in the County of King William, Commonwealth of Virginia, being more particularly delineated as "freshwater tidal wetlands extending from mean low tide on the Pamunkey River to the wetland/upland border landward of the Pamunkey River" as shown in Exhibit A, attached hereto and incorporated by reference herein; and

WHEREAS, Sweet Hall Marsh has substantial wetland resources and significant natural, ecological, research, educational, and aesthetic values, which this management agreement will help to preserve, maintain, and protect water quality and important aquatic resources and habitats of the Pamunkey River; and

WHEREAS, this Management Agreement is being made with the intention and understanding of both the Grantor and Grantee that the subject property will remain designated as a component of the CBNERRVA; and

> WHEREAS, the Grantor desires and intends that the natural, ecological, research, educational, and aesthetic values of Sweet Hall Marsh shall be preserved and maintained by restricting and limiting the use of the land and contiguous water areas of the property, on the terms and conditions and for the purpose hereinafter set forth, and the Grantee is willing to accept responsibility for managing the property for the purpose of conducting basic scientific and applied research and providing timely and accurate information to the Grantor and the citizens of the Commonwealth regarding the quality and conservation of the resources, both living and non-living, of Sweet Hall Marsh, on the terms and conditions and for the purposed hereinafter set forth; and

NOW THEREFORE, as an absolute gift of no monetary consideration ($0.00) but in consideration of the mutual covenants, terms, conditions, and restrictions hereinafter set forth, the Grantor hereby conveys to the Grantee, its successors, and assigns for a period of five (5)

years a Management Agreement for the purpose of research, observation, and education and to the extent hereinafter set forth with respect to Sweet Hall Marsh.

To achieve these objectives, the following conditions and restrictions are set forth:

ARTICLE I. GENERAL PURPOSE AND DURATION

1. General Purpose – The purpose of this Management Agreement is to preserve and protect the environment of Sweet Hall Marsh and to maintain its natural and cultural values and its dominant scenic, rural, woodland, and wetland character so that the property remains suitable for long-term research on natural and human processes occurring within the Pamunkey River Tributary of the Chesapeake Bay.

2. Duration – This Management Agreement shall be valid for a 5 year period, and the terms, conditions, restrictions and purposes imposed with this Management Agreement shall not only be binding on the Grantor but also the Grantor's agents, personal representatives, heirs, assigns and all other successors to the Grantor's interests for the duration of the Management Agreement, subject to the agreed upon termination provisions. This Management Agreement may be renegotiated at the end of the 5 year period at the discretion of both parties.

ARTICLE II. MANAGEMENT OBJECTIVES

3. Management Plan Preparation and Implementation – There shall be an updated Management Plan prepared to provide the framework to direct and track progress of the CBNERRVA. In addition to the CBNERRVA Management Plan, there shall be a Natural Resource Management Plan developed specifically for Sweet Hall Marsh to guide the management process that balances the research and education mission of the Grantee with the objectives of the Grantor while adequately protecting natural resources.

> Both the CBNERRVA Management Plan and the Sweet Hall Marsh Natural Resources Management Plan shall be prepared by the Virginia Institute of Marine Science (VIMS), in consultation with other resource management agencies of the Commonwealth, and shall be submitted to the Grantor for their review and approval. The Grantor and Grantee shall meet at least annually, and more frequently at the request of the either party, to review the Management Plans and research, education and stewardship results and, where appropriate, to develop more specific recommendations for carrying out certain aspects of the Plans. The CBNERRVA Management Plan and Sweet Hall Marsh Natural Resources Management Plan shall be updated at least every five years.

4. On-Site Management. VIMS is the agency designated by the Grantee and the Governor of the Commonwealth of Virginia to manage the CBNERRVA. In this capacity, VIMS shall serve as on-site manager for research on Sweet Hall Marsh and shall be responsible for seeing that research, education and stewardship activities conducted on the property is conducted in a manner consistent with the goals of the CBNERRVA, the objectives of the CBNERRVA Management Plan and Sweet Hall Marsh Natural Resources Management Plan, and the wishes of the Grantor and Grantee. The on-site manager will be the Grantee's primary representative for the purpose of monitoring uses of the property for consistency with this Management Agreement.

5. Natural Area Preservation – Sweet Hall Marsh shall be maintained as open space, wildlife and waterfowl habitat, and a natural field laboratory for research and education,

consistent with the resource protection policies of the Grantor. Any industrial commercial activities shall be prohibited on Sweet Hall Marsh. The protection and conservation of the marsh and bottomlands subject to this Management Agreement is consistent with the goals and policies of the CBNERRVA.

6. Research, Education and Stewardship – Sweet Hall Marsh shall be used for research, education and stewardship activities associated with the CBNERRVA. Research and education uses of Sweet Hall Marsh shall be in accordance with the principles, objectives, and performance standards set forth in the CBNERRVA Management Plan developed by VIMS and approved by the Grantor and Grantee, it being understood that the proposed research, education and stewardship activities will not involve large groups of people or continuous or frequent visits to the site by other than the few regularly designated personnel of VIMS. The CBNERRVA will provide review and approval of proposals for research, education and stewardship activities at Sweet Hall Marsh. Proposals and activities shall be approved by the Grantor and Grantee. Such approval shall not be unreasonably withheld.

7. Information Exchange – Research, education and stewardship activities conducted at Sweet Hall Marsh shall be used to enhance awareness, understanding, and wise use of estuarine environments. VIMS shall provide the Grantor and Grantee with an annual report on research, education and stewardship activities conducted at Sweet Hall Marsh and shall disseminate timely and accurate information to the Governor, General Assembly, State and local agencies, industry, an the citizens of the Commonwealth regarding the living and non-living resources of Sweet Hall Marsh and their relationship to the Chesapeake Bay system and the coastal waters of the Commonwealth of Virginia.

ARTICLE III: CONTROLLED ACTIVITIES

8. Wetland and Forest Maintenance – Wetlands shall be protected and maintained in accordance with the CBNERRVA Management Plan, Sweet Hall Marsh Natural Resources Management Plan and the Wetlands Guidelines developed pursuant to Chapter 2.1 of Title 62.1 of the Code of Virginia. Forest management activities shall be conducted in accordance with Best Management Practices promulgated by the Commonwealth of Virginia, Division of Forestry and recommended by the U.S. Department of Agriculture, Forest Service and Soil Conservation Service. There shall be no other destruction or alteration of wetlands on Sweet Hall Marsh, except as needed to eradicate noxious plant species, enhance native wetland communities, and as approved by the Grantor and Grantee. Management activities shall not materially impair the scenic quality of Sweet Hall Marsh.

9. Waterfowl and Wildlife Maintenance. Waterfowl and wildlife maintenance activities shall be conducted in accordance with the CBNERRVA Management Plan. In general, such activities shall be limited to maintenance of existing habitat and minor improvements, where necessary (such as tree thinning to improve understory vegetation, opening of small areas to provide a great diversity of habitats, raising and releasing of geese and ducks), and as approved by the Grantor and Grantee. Any waterfowl and wildlife management activities shall be carried out under the guidance of the Commonwealth of Virginia, Department of Game and Inland Fisheries and the U.S. Department of the Interior, Fish and Wildlife Service. Any plant and

insect management activities that may affect species of plants or insects protected under the Virginia Endangered Plan and Insect Species Act shall be carried out under the guidance of the Virginia Department of Agriculture and Consumer Service.

10. Hunting and Fishing – The Grantor may pursue such hunting and fishing activities as it may elect as long as such activities are in compliance with applicable state or federal law.

11. Water Quality – There shall be no human activities on or uses of Sweet Hall Marsh that are detrimental or adverse to the maintenance and conservation of surface and subsurface water quality. There shall be no manipulation or alteration of natural water courses, shorelines, marshes or other water bodies, nor shall there be activities conducted on or around Sweet Hall Marsh or the Pamunkey River that could alter natural water level flow, salinity, or turbidity of Sweet Hall Marsh or the Pamunkey River, or both.

12. Structures, Roads, Trails and Plantings – There shall be no restrictions on the Grantor's right to construct hunting blinds, nesting boxes or other structures, and plantings throughout the marsh. All Roads and significant trails will be restricted to the buffer region of Sweet Hall Marsh. All structures, roads, trails and plantings should be constructed in a manner to minimize damage to the natural resources of Sweet Hall Marsh. Structures constructed and utilized by the Grantee must be for research, education, stewardship and naturalistic purposes and approved by the Grantor. Similarly, the Grantor must approve removal of existing research, education, stewardship and naturalistic structures.

13. Signs and Billboards – Display of billboards, signs, or other advertisements is not permitted on or over Sweet Hall Marsh except to state the name and/or address of the owner, to provide notice of the designation as a component of CBNERRVA, to post the property as a No Wake Zone, and/or to post the property against the trespass.

14. Subdivision – Sweet Hall Marsh shall not be partitioned or subdivided during the life of this management agreement.

15. Excavation, Dredging, and Mining – Excavation, dredging, mining and removal of loam, gravel, soil, rock, sand, coal, petroleum, and other materials or alteration of the topography of the land is prohibited on the Sweet Hall Marsh except as related to the collection of geological data. Such activities shall be planned for in the CBNERRVA Management Plan and approved by the Grantor and Grantee.

16. Industrial and Commercial Activities – No industrial or commercial activities shall be conducted at Sweet Hall Marsh

17. Trash, Rubbish, and Waste – Neither the Grantor or the Grantee shall authorize dumping of soil, trash, ashes, garbage, waste, or offensive materials on Sweet Hall Marsh or filling in of any wetland, pond, or waterway and such dumping shall be absolutely prohibited. Neither the Grantor or the Grantee shall not be responsible for unauthorized dumping.

18. Off Road Vehicles – Neither the Grantor or the Grantee shall authorize operation of motor vehicles, trail bikes or all-terrain vehicles within the core area of Sweet Hall Marsh (see Exhibit A for delineation of core and buffer regions).

ARTICLE IV. ENFORCEMENT AND REMEDIES

19. Injunctive Relief and Restoration – Upon any breach of the terms of this management agreement by the Grantor, its successors and assigns or the Grantee, its successors and assigns, the breaching party may be subject to suit to (1) enjoin any breach or enforce any covenant by temporary restraining order, preliminary and/or permanent injunction; (2) require that the property be restored promptly to the condition required by the management agreement; or (3) seek any other remedy available, in law or equity, to assure compliance with the terms of this management agreement.

20. Perpetual Right of Enforcement – Failure on the part of the Grantee to enforce any covenant or provision hereof shall not discharge or invalidate such covenant, or any other covenant, condition, or provision of a subsequent breach or default.

ARTICLE V. GRANTOR'S RIGHTS

21. Grantor's Rights – The Grantor expressly reserves to itself, its personal representatives, heirs, successors and assigns the right to:

a) Continue the naturalistic uses of Sweet Hall Marsh under the terms and conditions set forth herein;

b) Continue to hunt, fish, or trap on Sweet Hall Marsh and raise and release ducks and geese subject to applicable laws;

c) Improve, repair, restore, alter, remove, remodel, or replace permitted structures and planting; and

d) Continue the use of Sweet Hall Marsh for all purposes consistent with this Management Agreement.

ARTICLE VI. RIGHT OF GRANTEE

22. Rights of Grantee – To accomplish the purpose of this Management Agreement the following rights are conveyed to the Grantee by the Management Agreement:

a) To preserve and protect the conservation values of the Sweet Hall Marsh.

b) To enter upon the Sweet Hall Marsh at reasonable times in order to conduct approved research, education and stewardship activities and to monitor Grantor's compliance with and otherwise enforce the terms of this Management Agreement' provided that such entry shall be upon prior reasonable notice to Grantor, such entry shall be by water, and shall not unreasonably interfere with Grantor's use

and quite enjoyment of the Sweet Hall Marsh; and further provided that any such entry during a period commencing two weeks prior to the migratory waterfowl seasons in the Commonwealth of Virginia shall be made only with prior notice to and consent fro the Grantor, which consent may be withheld in the grantor's sole discretion.

c) To give permission to appropriate persons to conduct research, education and stewardship activities approved for the Sweet Hall Marsh component of CBNERRVA, provided that permittees carry and display an official permit issued by the Grantee and approved by the Grantor.

d) To prevent any activities or use of the Sweet Hall Marsh that is inconsistent with the purposes of this Management Agreement and to require the restoration of such areas or features or the Sweet Hall Marsh that may be damaged by any inconsistent activity or use.

ARTICLE VII. GRANTOR'S AND GRANTEE'S LIABILITY

23. Upkeep by Grantor – The Grantor, its successors, and assigns further agrees that it shall be responsible for upkeep of Sweet Hall Marsh and shall hold the Grantee, its successors and assigns harmless from charges or liens arising out of upkeep or taxes.

24. Taxes – The Grantor agrees to pay any and all real property taxes and assessments levied by competent authority on the property.

25. Grantor's Liability – The Grantor, its successors, and assigns shall not be held responsible for injury to persons or damages to property arising out of any research or educational activity being conducted on Sweet Hall Marsh pursuant to the CBNERRVA Management Plan and this management agreement except those arising out of the negligence of the Grantor, its successors, and assigns. All persons participating in research, education or stewardship activities at Sweet Hall Marsh must sign a liability release form indemnifying and holding harmless the Grantor, its officers, directors, agents, and guests, from any and all liability, claims, or expenses for injury, death, or damages to self or property, including without limitation attorney's fees, resulting from or arising out of or in anyway relating to the activities of the Grantee, any of its representatives, agents or guests, or resulting from, or occurring in the course of transit to or from Sweet Hall Marsh. A copy of the release form appears as Exhibit B.

The Grantee has inspected Sweet Hall Marsh and accepts its condition "as is". Any existing conditions or future conditions relating to permitted uses of Sweet Hall Marsh by the Grantor, including without limitation any hunting and fishing activities, shall not constitute conditions giving rise to a claim of negligence on the part of the Grantor or to any potential liability for damage to property or injury to person. The Grantor's liability for all other activities on Sweet Hall Marsh shall remain in effect.

26. Grantors' Liability – The Commonwealth of Virginia and all its agencies and institutions are covered by a self-insurance program as authorized by Section 2.1-526.8 of the Code of Virginia which is based upon a comprehensive general liability manuscript policy form as shown in Exhibit C. All persons who are not employees of the Commonwealth must receive approval from the Grantor and furnish evidence of liability coverage in the amount of $100,000/$300,000/$100,000 before participating in research, education and stewardship activities at Sweet Hall Marsh. All persons, whether employees of the Commonwealth or not, shall sign a liability release form reference in paragraph 25 and appearing in Exhibit B.

ARTICLE VIII. PUBLIC ACCESS

27. Public Access – The granting of this Management Agreement does not grant to the public any right to enter the property. The Grantor reserves the right to place a gate or chain with a lock across any and all roads leading into Sweet Hall Marsh. If a lock is employed, a key will be made available to the Grantee to use for authorized purposes by authorized personnel only in accordance with the Management Plan and the terms of this agreement. The Grantee's right of entry permits use of the Grantor's pier for water quality sampling and other activities approved by the Grantor, but does not include access to the interior of buildings or structures. All other protection against trespass by the public shall remain in effect.

ARTICLE IX. MISCELLANNEOUS

28. Transfer and Reversion – The Grantor agrees to send in writing to the Grantee the names and addresses of any party to who Sweet Hall Marsh is to be transferred at the time said transfer is executed. The Grantee agrees to hold this Management Agreement exclusively for conservation purposes, and that it will not transfer the management agreement in exchange for money, other property, or services. This provision shall not preclude the Grantee from using the monetary value of any donations or gifts from the Grantor as match for money, other property, or services that will contribute to fulfilling the objectives of the management Plan or the terms of this agreement.

The Grantee may assign its rights under this Management Agreement to VIMS in such manner as to achieve the purposes and conditions herein. If any such assignee shall cease to exist or abandon this Management Agreement or the rights and duties of enforcement herein set force, or if proceedings are instituted for condemnation of this Management Agreement, the Management Agreement and rights of enforcement shall revert to the Grantee. If the Grantee shall be dissolved and if the terms of the dissolution fail to provide a successor, then the court shall appoint an appropriate successor as Grantee.

29. Termination – In the event that circumstances arise that cause Sweet Hall Marsh to be withdrawn from the CBNERRVA, cause the CBNERRVA to cease to exist, or cause the Grantee to not have sufficient funds to conduct activities under the CBNERRVA, this management agreement shall be terminated by the Grantee by providing 90 days written notice to the Grantor. If either party breaches the terms and conditions of this management agreement, the other party may terminate this management agreement with 90 days written notice.

30. Notification – The Grantor agrees to notify the Grantee, in writing, before exercising any reserved right the exercise of which may have an adverse impact on the conservation interests associated with Sweet Hall Marsh. Any notices by the Grantor to the Grantee pursuant to any provision hereof shall be sent by registered or certified mail, return receipt requested, addressed to Coleman Wortham, III, Davenport & Company, LLC, 901 East Cary Street, Richmond, Virginia 23219, with copies to F. Scott Reed, Dominion Environmental Services, 5000 Dominion Blvd.,Glen Allen, VA 23060 and Philip W. Reed, Virginia Outdoor Foundation, James Monroe Building, 101 N. 14th St., 17th Floor, Richmond, VA 23219.

IN WITNESS WHEREOF, the Grantor and Grantee have hereunto set their hands and seals the day and year above written.

Grantor:

_____ (SEAL)

_____ (SEAL)

ACCEPTED BY
AS GRANTEE

_____ (SEAL)

_____ (SEAL)

APPROVED AS TO FORM:

_____
Assistant Attorney General for the
Attorney General of Virginia

RECOMMEND:

_____
Director
Division of Engineering and Buildings

RECOMMEND

_____
Director
Department of General Services

APPROVED FOR THE GOVERNOR:

Pursuant to the provisions of Section 2.1-504.2, Code of Virginia (1950), as amended, and by authority of Executive Order 78 (89), dated December 21, 1989, I hereby approve the acquisition of the demised premises pursuant to this management agreement and the execution of this instrument for, on behalf of, and in the stead of the Governor of Virginia.

_____
Secretary of Administration

_____
Date

Exhibit A. Map of property highlighting boundary of agreement.

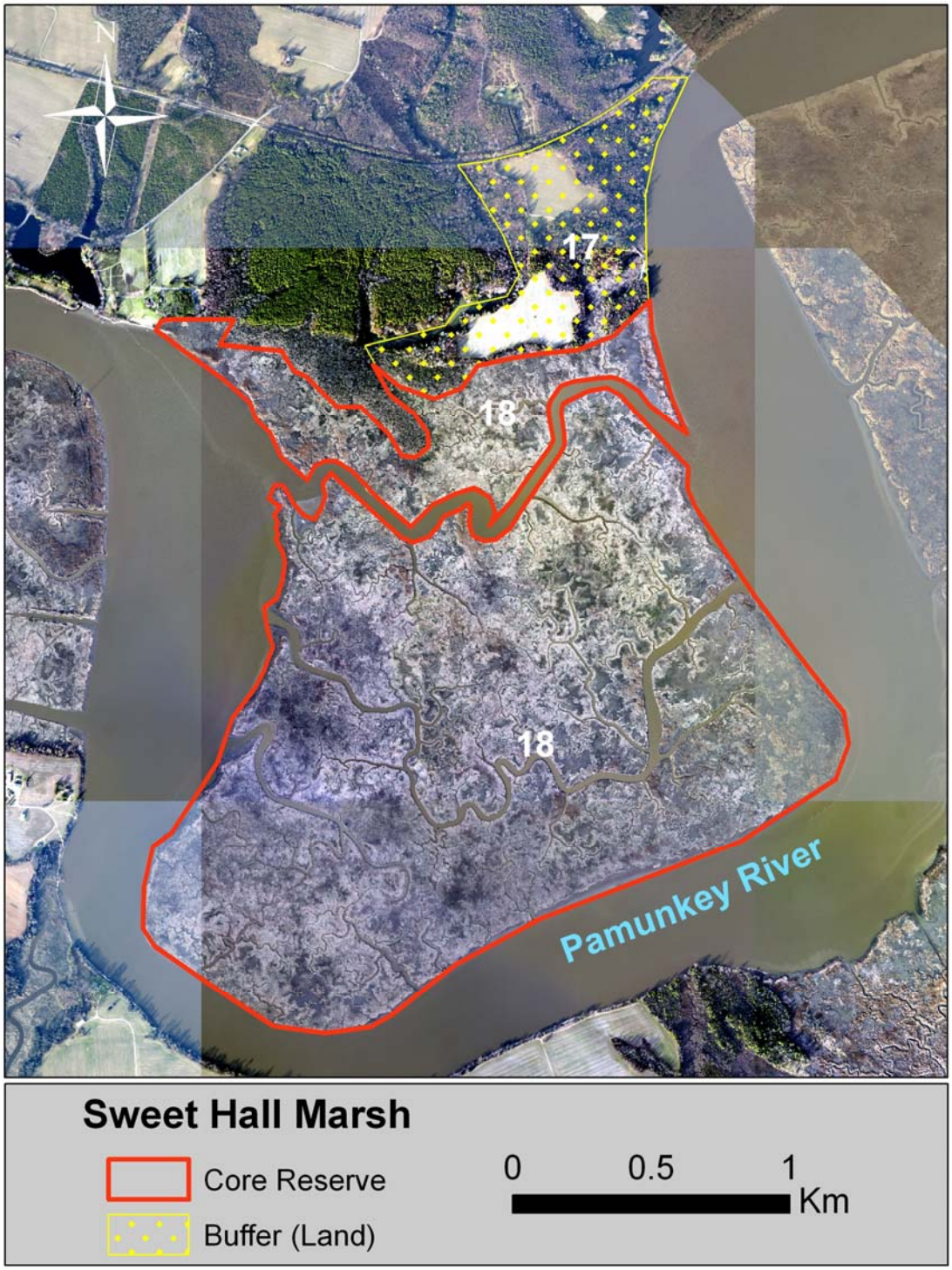

Exhibit B. Liability release and waiver of claims form.

LIABILITY RELEASE AND WAIVER OF CLAIMS
(For Agents of the Commonwealth, Paid Consultants and Volunteers)

The undersigned, in consideration of being allowed to participate in research, education or stewardship activities at the Sweet Hall Marsh component of the Chesapeake Bay National Estuarine Research Reserve System in Virginia, owned by Tacoma Hunting and Fishing Club and managed by the Virginia Institute of Marine Science (VIMS) of the College of William and Mary, which research, education or stewardship activities will begin on the ____ day of _____ 20____ and continue for a period of approximately ____ days does hereby release the said landowner and VIMS from any and all liability, claims or expenses for injury, death or damages to self ad property, including without limitation attorney's fees, resulting from or arising out of or in anyway relating to participation in research, education or stewardship activities, or resulting from, or occurring in the course of transit to and from the Sweet Hall Marsh component of the Chesapeake Bay National Estuarine Research Reserve System in Virginia, except to the extent that such injury, death or damages is caused solely by the negligence of VIMS, its agents, or employees, or is caused solely by the negligence of the landowner, its heirs, successors, or assigns.

The undersigned who is a paid consultant or volunteer must furnish evidence of liability coverage in the amount of $100,000/$300,000/$100,000.

The undersigned who is a volunteer for the Sweet Hall Marsh component of the Chesapeake Bay National Estuarine Research Reserve System in Virginia further understands and declares that participation in said research, education and stewardship activities is voluntary, and that there will be no compensation for them, nor will they create eligibility for, without limitation, such benefits as salary wages, or workers' compensation during or as a result of participation in those activities.

The undersigned further understands and declares that this agreement extends only to the length of participation in the above-mentioned activities, and is binding on the heirs, successors, and assigns of the undersigned.

I acknowledge my right to seek counsel prior to signing this release, and have voluntarily affixed my signature this ____ day of _____ 20____.

_____
Signature

_____
Printed Name

Exhibit C. Certificate of Insurance.

WILLIAM & MARY
VIMS
Virginia Institute of Marine Science
School of Marine Science

CERTIFICATE OF COVERAGE

ISSUED TO: **Tacoma Hunting and Fishing Club**

INSURER: COMMONWEALTH OF VIRGINIA

AUTHORIZATION: Risk Management Plan and the **Code of Virginia**, §2.2-1837 and §2.2-1840

COVERAGE PERIOD: Period of contract

PURPOSE: Verification of insurance coverage for activities of its employees and authorized agents.

COVERAGES: Tort Liability, including Medical Malpractice and Automobile. This covers liability and physical damage for use of rental/leased vehicles used on official business.

LIMITS: $2,000,000 - Tort claims against persons $100,000 - Tort claims against the Commonwealth $1,650,000 - Medical Incident per occurrence – Effective 7/1/02 $1,600,000 - Medical Incident per occurrence Effective 7/1/01 ACV - Non owned (hired, rented/leased) vehicles

ADMINISTRATOR: Division of Risk Management
P.O. Box 1879 Richmond, VA 23218-1879

This is for information only. It does not alter any provisions of the Risk Management Plan nor the **Code of Virginia**.

VERIFIED BY:

State Official's Name: Jane A. Lopez
Title: Director, Sponsored Programs
Date: 8/14/07

Appendix B.
General Public Access Plan for Chesapeake Bay National Estuarine Research Reserve Sites
(*Last Modified: September 12, 2004)*

A. Mission and Goals

CBNERRVA is responsible for the long-term management of its reserve components in order to protect the ecological integrity of the natural system and provide a stable environment to support research, monitoring and education missions. In some cases, the reserve component can be managed to meet this objective while still supporting some level of public use.

B. General Policy

Public access to the four CBNERRVA components is regulated on a site-specific basis. The objectives of regulated access are to maintain each site's integrity for research and education while permitting traditional uses which do not conflict with reserve goals or agreements with private landowners. CBNERRVA and site property owners reserve the right to impose additional restrictions to curtail any activity threatening to disturb natural conditions or ongoing research and education activities. It should be noted that specific public uses are not compatible, for example bird and wildlife watching is not compatible with concurrent waterfowl hunting. In such cases, CBNERRVA will strive to minimize conflicts through spatial and temporal separation strategies. If negative impacts are observed, the causative public use(s) will be determined and re-evaluated. When warranted, the assistance of local and state law enforcement agencies may be called upon to enforce access regulations. Prosecution of violators will serve as a deterrent against vandalism, littering and arson.

C. Public Access Rules and Schedules

Goodwin Islands
The College of William and Mary maintains a limited-use public access policy for the Goodwin Islands. In accordance with that policy, Goodwin Islands are managed exclusively for research and education. Goodwin Islands are only accessible by shallow draft boats. There are no docking facilities or designated trails on Goodwin Islands. The following access rules apply to Goodwin Islands:

- Public access is limited from dawn to dusk and therefore overnight camping is prohibited.
- Beach areas can be used for picnicking, beachcombing and other non-destructive activities if visitors do not willingly or negligently disturb the environment or scientific experiments/equipment.
- Bicycles, off-road vehicles, and horses are prohibited.
- Building of any type of fire is prohibited.
- Waterfowl hunting from floating blinds is allowed, however, a reserve issued permit is required. No stationary blinds are allowed. Upland and wetland hunting activities are not permitted.
- Fishing, crabbing and collection of shellfish is allowed if in accordance with applicable state laws and regulations.

- Collection of plants, animals (other than that allowed by applicable state laws and regulations), minerals, or artifacts is prohibited.
- Dogs or other domestic animals accompanying visitors must be kept on a leash at all times.

Catlett Islands
With the exception of a single tract acquired by VIMS, the Catlett Islands are privately owned. Visitation is controlled by the property owner(s) and general public access is not permitted on the Catlett Islands. The islands are posted against trespass. Hunting, trapping and oyster gathering are the exclusive rights of the property owners and their assigns. In waters around Catlett Islands, commercial and recreational harvest of fish and crabs is allowed if in accordance with applicable state laws and regulations.

Taskinas Creek
Taskinas Creek reserve is within the boundaries of York River State Park. Access is controlled by park regulations. The park is open year-round from 8am to dusk. The eastern portion of Taskinas Creek within park boundaries is used for passive recreation and nature study. This region contains the park's Visitor Center and outdoor amphitheater, which are open seasonally (closed in the winter) to provide opportunities to learn about coastal environments and local history. Visitors are encouraged to use more than 25 miles of self-guided hiking, biking and equestrian trails. The park and/or park concessionaire charges a nominal park entrance fee and rental fee for picnic shelters, canoes and other recreational items. Picnic tables are available throughout the park on a first-come, first-served basis. Playground equipment, horseshoe pits and volleyball courts are also available. Many of the facilities and trails are ADA compliant.

Croaker Landing, which provides access to the York River, includes a parking area, a boat launch and dock on the York River, and restrooms, is open twenty-four hours a day for boating and has a 10 p.m. closing time posted for non-boating activities. Overnight facilities, in terms of limited primitive group tent camping, are available. Fishing and boating opportunities exist within an upland freshwater pond, Taskinas Creek and the York River proper. Boat (pond only) and canoe rentals are available seasonally. Croaker Landing provides access to the York River and includes a newly constructed fishing pier, a parking area, a boat launch and dock, and restrooms; parking and launch fees are required at all times. Hunting is only allowed in season (November/December) during special controlled hunts. During the hunts, the park is closed to all other visitors. Access to the western portion of Taskinas Creek, which incorporates the reserve, is generally not encouraged.

Sweet Hall Marsh
Sweet Hall Marsh is privately owned. Visitation is controlled by the property owner(s) and general public access is not permitted. Hunting and trapping are the exclusive rights of the property owners and their assigns. In waters around Sweet Hall Marsh, commercial and recreational harvest of fish and crabs is allowed if in accordance with applicable state laws and regulations.

Appendix C.
Management Policies for Chesapeake Bay National Estuarine Research Reserve Sites from 1991 CBNERRVA Management Plan

APPENDIX B
MANAGEMENT POLICIES FOR YORK RIVER SITES

Designated Research Reserves shall be managed to maintain its aesthetic, topographical, and biological integrity. The Reserve shall be maintained as open space, fish and wildlife habitat, and natural field laboratory for nonmanipulative research. The following policies will apply.

Geology

Surface and subsurface features possessing unique geological characteristics shall be maintained and protected so as to preserve those characteristics from unwarranted disturbance and/or destruction. Visitor access to these features will be limited to insure protection of the features and the safety of the visitor. VIMS will work with the Department of Mines, Minerals and Energy to have a geological survey conducted at each reserve site. Surveys must be conducted by a qualified geologist, recognized in the areas of field investigation.

Pertinent statutes, regulations and guidelines
Virginia Cave Protection Act
Coastal Primary Sand Dune Protection Act

Soils

Excavation, mining, or removal of loam, gravel, rock, sand, coal, petroleum, or minerals or alteration of topography shall not be permitted except as related to the collection of geological and geophysical data. Areas devoted to agricultural use or areas subject to user impact, such as trails, should be developed and/or maintained to minimize damage to and loss of existing soils. Soil maps and soil suitabilities shall be obtained or developed for each research reserve.

Pertinent statutes, regulations and guidelines
Virginia Erosion and Sediment Control Law
Agriculture—Best Management Practices
Guidelines on Construction and Maintenance of Trails (to be developed)

Shorelines

Shorelines shall be preserved in their natural state and existing condition. Restoration of severely eroding shorelines by planting native vegetation may be allowed with approval on an individual basis as an applied research. Opposition to existing and/or proposed off-site activities will be considered if such activities may adversely affect existing shoreline and/or water resources along or within reserve boundaries.

Pertinent statutes, regulations and guidelines
Virginia Erosion and Sediment Control Law
Hydrologic Modifications—Best Management Practices
Subaqueous Guidelines
Coastal Primary Sand Dune Protection Act
Federal Clean Water Act, Section 401
Federal Coastal Zone Management Act

Stream Beds and Channels

Stream beds and channels shall be preserved in their natural state and existing condition. There shall be no manipulation or alteration of natural water courses, channels, or other water bodies, nor shall there be conducted activities on or around the reserve site that could alter natural water level, flow, or both except in conjunction with applied research projects where the impact will be temporary and nondestructive. Opposition to existing and/or proposed off-site activities will be considered if such activities may adversely affect natural water courses, channels, levels, flow, or other resources within the reserve boundaries.

Pertinent statutes, regulations and guidelines
Hydrologic Modifications—Best Management Practices
Watercourses Generally
Minimum Instream Flow Generally
Subaqueous Guidelines
Federal Clean Water Act, Section 401

Water Quality

There shall be no human activities or uses of the reserve site that are detrimental or

adverse to the maintenance, improvement or conservation of existing surface and ground water supplies and quality. All activities within a reserve must be conducted so as to avoid violation of established State Water Control Board Water Quality Standards.

Pertinent statutes, regulations and guidelines

Waters of the State, Ports and Harbors
Federal Clean Water Act
Standards of Water Quality (established by State Water Control Board)
Minimum Instream Flow Generally
Sources Affecting Ground Water—Best Management Practices
Hazardous Waste Management Reglations

Air Quality

No activities shall be permitted in the reserve that have the potential to cause air pollution which exceeds acceptable air quality standards. Air quality will be monitored at appropriate sites.

Pertinent statutes, regulations and guidelines

Federal Clean Air Act
Virginia Air Pollution Control Law
Regulations for the Control and Abatement of Air Pollution

Wetlands

All tidal and nontidal wetlands located within or along reserve boundaries shall be protected in a natural condition. Wetlands include bogs, swamps, freshwater and tidal vegetated marshes, and unvegetated flats.

Pertinent statutes, regulations and guidelines

Virginia Wetlands Act
Federal Clean Water Act, Section 404 and Section 401

Forests

Timber management within the core area of reserve lands should be directed toward the development and preservation of significant old growth stands, except where selective harvesting of mature trees is a traditional use of the property. Disease, insect, or exotic plant control, facility development, and/or stand improvement considerations in the buffer zones shall be the controlling or motivating factors behind decisions to harvest or treat timber. Any harvesting of timber will be conducted in accordance with guidelines established by VDOF. The research reserve program shall work with the Virginia Department of Forestry to develop an inventory and evaluation of standing timber at each site. VIMS will work with the Virginia Department of Agriculture and Consumer Affairs to survey timber stands for forest pests, disease, and exotic and rare/endangered plant species and to develop appropriate pest/disease management procedures.

Pertinent statutes, regulations and guidelines

Forestry—Best Management Practices
Gypsy Moth Control Guidelines (to be developed)

Fish and Wildlife

Game and nongame species shall be managed to preserve the overall health of the various populations within the reserve and to maintain fish and wildlife habitat. Traditional hunting, fishing, oystering, and trapping will be allowed, consistent with applicable laws. VIMS will work cooperatively with the Virginia Department of Game and Inland Fisheries to establish reserve-specific wildlife management plans.

Pertinent statutes, regulations and guidelines

Forestry—Best Management Practices
Agriculture—Best Management Practices
Game and Inland Fisheries Hunting Regulation
Virginia Marine Resources Commission Fishing Regulations

Rare, Threatened or Endangered Species

Areas identified as possessing rare, threatened or endangered species shall be managed, according to recommended regulations and guidelines, to preserve and protect the

species. The presence of an endangered or threatened species shall not necessarily preclude continued or proposed uses of an area. The flora and fauna on research reserves will be surveyed, identified and classified with the assistance of the Virginia Natural Heritage Program and Department of Game and Inland Fisheries.

Pertinent statutes, regulations and guidelines

Federal and State Endangered Species Act
Virginia Endangered Plan and Insect Species Act

Traditional Uses

Traditional hunting, trapping, oystering, and fishing activities will be allowed in accordance with applicable laws. Private landowners may place noncommercial blinds on the reserve for personal use or use by assigns. Agricultural and silvicultural activities within the buffer areas of research lands will be conducted in accordance with environmentally sound practices (BMPs).

Pertinent statutes, regulations and guidelines

Game and Inland Fisheries Hunting Regulations
Virginia Marine Resources Commission Fishing Regulations
Virginia Erosion and Sediment Control Law
Virginia Pesticide Law
Agriculture—Best Management Practices

Structures, Roads and Trails

No new buildings, facilities, structures, piers, roads or trails shall be constructed on the reserve site, except those designed, constructed, utilized in, and accessary to research, education, hunting and naturalistic uses of the reserve site. Such construction shall only be permissable only after the environmental impact of any such construction is fully assessed and approved. Similarly, removal of existing structures shall be assessed for potential environmental impact. There shall be no compulsion to remove existing structures.

Signs and Billboards

Display of signs, billboards, or other advertisements shall not be permitted on or over the reserve sites, except to state the name and/or address of the owner, to provide notice of the designation as a Chesapeake Bay National Estuarine Research Reserve, and/or to post the property against trespass or littering.

Fire

A proactive fire plan to consider wildland fire prevention and supression will be developed in cooperation with the Department of Forestry. A two-phased approach to the prevention, management, and suppression of fire will be encouraged. The plan will take into consideration that fire is a natural process in forest ecology and will not seek to control all fires. However, proactive plans to protect structures, and other significant resources which are sensitive to fire damage and to protect human safety will also be developed. Any prescribed burns to be used for resource management purposes will be conducted only under the supervision of a qualified master burner.

Pertinent statutes, regulations and guidelines

Forest Wardens and Fires

Trash, Rubbish and Waste

No soil, trash, ashes, garbage, hazardous waste, or offensive materials shall be dumped or deposited on the research reserve site. No wetland, pond, or waterway shall be filled.

Off-Road Vehicles

No motor vehicles, trail bikes, or all-terrain vehicles shall be operated at the reserve site, except in designated buffer areas and/or for official reserve management operations.

Archaeological and Historical Sites and Objects

Reserve sites shall be inventoried to locate sites and objects possessing prehistoric and/

or historic significance and plans to protect such sites and objects shall be prepared. Activities which may in some way affect significant sites or objects shall require review and/or permitting by the Division of Historic Landmarks and approved by reserve manager.

Pertinent statutes, regulations and guidelines
Virginia Antiquities Act
Virginia Cave Protection Act
1986 Appropriations Act
National Historic Preservation Act

Historic Buildings, Structures and Objects

Historic structures shall be protected and preserved and the history of such structures shall be incorporated in the reserve's interpretive offerings where appropriate. Eligible structures shall be surveyed and evaluated for nomination to the Virginia Landmarks Register and the National Register of Historic Places. Buildings and structures possessing historic significance shall be protected by established statutes and regulations. Plans for the alteration, remodeling, or redecoration of historic structures on the Virginia Landmarks Register must be submitted to the Division of Historic Landmarks for review and comment to insure that the historic and/or architectural integrity of these properties is maintained.

Pertinent statutes, regulations and guidelines
1986 Appropriations Act
Division of Engineering and Buildings Directive No. 1
National Historic Preservation Act

Collection of Natural, Historical or Cultural Resources

All collecting of plant, animal, mineral, or fossil specimens shall require the prior issuance of a collecting permit by VIMS and the Division of State Parks, where appropriate. The collection of historic or archaeological artifacts will be allowed only with collecting permits approved by the Division of Historic Landmarks. Use of metal detectors by public visitors is prohibited.

Pertinent statutes, regulations and guidelines
Division of Parks and Recreation Regulation No. 5
Virginia Antiquities Act
Virginia Cave Protection Act

Manipulative Research

In order to protect the natural integrity of the research reserve, no manipulative research activities with a significant or long-term adverse impact on reserve resources shall be allowed. Habitat manipulation for resource management purpose shall not be allowed, except as allowed under policies for shorelines, timber, fish, wildlife, and fire management. If waivers of certain policies or portions of policies are determined to benefit the overall management of the research reserve system, they could be considered on an individual basis.

Industrial and Commercial Activities

No industrial or commercial activities shall be conducted in the research reserve core area, with the exception of commercial fishing.

RELEVANT STATE STATUTES AND REGULATIONS AFFECTING PROPOSED RESERVE SITES

Endangered Plant and Insect Species Act

The Endangered Plant and Insect Species Act (Va. Code Ann. Sec. 3.1-1020 et seq.) makes it unlawful for any person to dig, take, cut, process, or otherwise collect, remove, transport, possess, sell, offer for sale, or give away any species native to or occuring in the wild in Virginia that are listed as threatened or endangered.

A license is required to cut or collect any threatened species and records of purchases must be kept. Any person who violates the

provisions will be found guilty of a Class 4 misdemeanor.

Erosion and Sediment Control Law

The Erosion and Sediment Control Law (Va. Code Ann. Sec. 10.1-560 et seq.) states that the Board of Agriculture and Consumer Services shall create regulations for the effective control of soil erosion, sediment deposition and nonagricultural runoff to prevent unreasonable degradation of properties, stream channels, waters and other natural resources.

Land-disturbing activities are regulated by the Act as well. No person may engage in any land-disturbing activity until an erosion and sediment control plan for the land-disturbing activity has been reviewed and approved. Violations or noncompliance will result in the stopping of all or part of the land-disturbing activities. Penalties, injunctions, and other legal actions are outlined in the Act for those found in noncompliance or violation.

Stormwater Management

The Erosion and Sediment Control Law also provides for the establishment of stormwater management programs. The Department of Agriculture and Consumer Services is authorized to promulgate regulations which specify minimum criteria and administrative procedures for stormwater management programs in Virginia. A local government which has adopted a stormwater management program must grant written approval of a plan, the conditions for approval, etc. within a specified time period. Any person who violates any provision of a local ordinance or program shall be guilty of a misdemeanor.

Air Pollution Control Board

The State Air Pollution Control Board is created by this chapter (Va. Code Ann. Sec. 10.1-1300 et seq.) and shall be composed of five members appointed by the Governor for four-year terms. The Board has the power to promulgate regulations, including emergency regulations, abating, controlling and prohibiting air pollution. The Board may create local air pollution control districts to assist the Department in its air monitoring programs, to initiate and make studies relating to air pollution and make recommendations to the Board. Any owner violating this law shall be guilty of a misdemeanor and shall be subject to a fine of not more than $1000 for each violation within the discretion of the court. Each day of continued violation after conviction shall constitute a separate offense.

Virginia Waste Management Act

The Virginia Waste Management Act (Va. Code Ann. Sec. 10.1-1400 et seq.) allows for the creation of the Virginia Waste Management Board which shall consist of seven Virginia residents appointed by the Governor. The Department of Waste Management is continued and also has the power to administer the policies and regulations established by the Board. The Act provides for the requirement of a permit to operate a sanitary landfill or other facility for the disposal, treatment or storage of nonhazardous solid waste. Open dumps are prohibited. Revocation of permits is outlined and the Board is given the power to promulgate regulations. Any person may submit to the Board a notice of intent to file an application for a certification of site approval. The applicant shall submit to the Board a draft impact analysis for the proposed facility within ninety days after the initial briefing meeting. Any person who violates any provision of this Act or regulation shall be assessed a civil penalty of not more than $10,000 for each day of such violation.

Historic Resources Act

The Department of Historic Resources is created in the Act (Va. Code Ann. Sec. 10.1-2200 et seq.) and shall be headed by a Director. The Virginia Historic Landmarks Board is continued as the Board of Historic Resources with seven members appointed by the Governor. The Board may promulgate regulations necessary to carry out the provisions of the Act. Underwater historic property shall be preserved and protected and shall be the exclusive property of the Commonwealth. Any

person violating the provisions of this section shall be guilty of a Class 1 misdemeanor and, in addition, shall forfeit to the Commonwealth any objects recovered.

Endangered Species Act

In this section the General Assembly declares that certain species of fish or wildlife are threatened with extinction and are entitled to preservation and protection as a matter of general state concern (Va. Code Ann. Sec. 29-230 et seq.). The Commission of Game and Inland Fisheries is authorized to issue regulations to implement the provisions of this section. Any person who violates the provisions of this section shall be punished by a fine of not more than $1000, or imprisonment not to exceed six months, or both. The Commission may permit the taking, exportation, transportation or possession of any fish or wildlife which is listed by the provisions of this chapter for zoological, educational, or scientific purposes, wherever such activities are permitted under federal law, regulation, or permit.

Watercourses and Subaqueous Beds

In Section 62.1-1 of the Annotated Virginia Code and its associated sections, all the beds of the bays, rivers, creeks and the shores of the sea within the jurisdiction of the Commonwealth not conveyed by special grant or compact will continue to remain the property of the Commonwealth of Virginia. The Marine Resources Commission is given the authority to issue permits for all other reasonable uses of state-owned bottomlands. A fee of $25 shall be paid for issuing each permit, but if the cost of the project or facility is more than $10,000, the fee paid shall be $100. A fee of $25 shall be paid for recovery of underwater historic property. All royalties or funds that are collected from such agreements or contracts shall be paid into the state treasury to the credit of the Special Public Oyster Rocks Replenishment Fund.

Tidal Wetlands Act

Standards apply for the use and development of wetlands and shall be considered in the determination of whether applications required by this chapter should be granted or denied. The provisions of the guidelines promulgated by the Commissioner of Marine Resources shall be considered in applying the foregoing standards. No person may conduct any activity which would require a permit under a wetlands zoning ordinance unless he has such permit. The person must apply directly to the Marine Resources Commission for a permit. Any person who knowingly, intentionally, negligently or continually violates any order, rule or regulation will be guilty of a misdemeanor. Following conviction, every day the violation continues shall be deemed a separate offense.

Coastal Primary Sand Dune Act

In order to implement the policy in this chapter, the Commission promulgates guidelines which set forth the consequences of the use of these dunes. No person shall conduct any activity which would require a permit under a coastal primary sand dune ordinance unless he has such permit. In the Coastal Primary Sand Dune Protection Act or an ordinance adopted pursuant to it, all the duties and responsibilities and procedures specified in the Wetlands Act will be followed.

Fish, Oysters, Shellfish, etc.

In Section 28.1-1 et seq. of the Annotated Virginia Code, the Marine Resources Commission jurisdiction extends to the fall line of all tidal rivers and streams and the Commission shall have the jurisdiction over all commercial fishing and all marine fish, marine shellfish, and marine organisms below the fall line on all tidal waters of the Commonwealth. It is unlawful for any person to remove from the waters of this state under the jurisdiction of the Commission any marine fish, marine shellfish, or marine organisms without having first a collection permit. The Commission shall have the power to establish a license commensurate with other

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licenses in the amount not to exceed $100 for any device used for the taking and catching of seafood in the waters of the Commonwealth. The Commission, after ten days' notice to any person having a license issued to it may revoke such license for violations of any provisions of this title.

Groundwater Act of 1973

The administration and enforcement of the provisions of this chapter lie with the State Water Control Board and The Department of Health jointly (Va. Code Ann. Sec. 62.1-44.83). No certificate of groundwater right, permit or registration statement authorized by this chapter will be required for any water withdrawal of less than 300,000 gallons a month for groundwater withdrawn for agricultural and livestock purposes. The Board may require persons who withdraw more than 300,000 gallons of water per month in a groundwater management area for the same purposes to report the amount of withdrawal. Whenever, after a public hearing, the Board finds that the permit holder is wilfully violating any provision of a permit the Board may cancel or suspend such certificate or impose conditions on the use therof in order to prevent future violations. Any person adjudged to have violated provisions of this chapter shall be guilty of a misdemeanor.

Scenic Rivers Act

In the Scenic Rivers Act (Va. Code Ann. Sec. 10.1-400 et seq.) the Director of the Department of Conservation and Recreation is empowered to identify rivers or sections of rivers that should be considered for designation because of their scenic, recreational and historic attributes. The agency designated by the General Assembly shall administer the scenic river or section to preserve and protect its use and enjoyment, periodically survey the scenic river and its immediate environs and monitor all existing and proposed uses.

Chesapeake Bay Preservation Act

The Act (Va. Code Ann. Sec. 10-313 et seq.) establishes the Chesapeake Bay Local Assistance Board. The Board is authorized to provide land use and development and water quality protection information. The Board shall also promulgate regulations which establish criteria for use by local governments to determine the ecological and geographic extent of Chesapeake Bay Preservation Areas. Local governments will employ the criteria to ensure that the use and development of land in Chesapeake Bay Preservation Areas shall be accomplished in a manner that protects the quality of the state's waters. The Board adopted regulations on September 20, 1989. These regulations give Tidewater local governments until September 20, 1990 to designate Chesapeake Bay Preservation Areas and employ performance criteria within them.

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Appendix D.
Natural Heritage Rarity Ranks and Status Explanation

Natural Heritage Rarity Ranks and Status Explanation

Each of the significant natural features (species, community type, etc.) monitored by DCR-DNH is considered an element of natural diversity, or simply an element. Each element is assigned a rank that indicates its relative rarity on a five-point scale (1 = extremely rare; 5 = abundant; Table 1). The primary criterion for ranking elements is the number of occurrences, i.e., the number of known distinct localities or populations. Also of great importance is the number of individuals at each locality or, for highly mobile organisms, the total number of individuals. Other considerations include the condition of the occurrences, the number of protected occurrences, and threats. However, the emphasis remains on the number of occurrences, so that ranks essentially are an index of known biological rarity. These ranks are assigned in terms of the element's rarity within Virginia (its State or S-rank), the element's rarity within a Nation (its National or N-rank), and the element's rarity across its entire range (its Global or G-rank). Subspecies and varieties are assigned a Taxonomic (T-) rank in addition to their G-rank. A Q indicates taxonomic uncertainty. Taken together, these ranks give an instant picture of an element's rarity. For example, a designated rank of G5S1 indicates an element which is abundant and secure range-wide, but rare in Virginia. In some cases, ranks are provisional or lacking, due to ongoing efforts by the Natural Heritage network to classify community syntaxa and cryptic plants or animals. Rarity ranks used by DCR-DNH are not legal designations, and they are continuously updated to reflect new information.

Table D-1. Definition of Natural Heritage state rarity ranks. Global ranks are similar to state ranks, but refer to a species' range-wide status. Note that GA and GN are not used and GX means extinct. GM and GW are ranks used only for communities, and refer to highly modified (GM) and ruderal (GW) vegetation respectively. National ranks are similar as well, and refer to a species' rarity within a nation, such as the United States or Canada. Sometimes ranks are combined (e.g., S1S2) to indicate intermediate or somewhat unclear status. Elements with uncertain taxonomic validity are denoted by the letter Q, after the global rank. These ranks should not be interpreted as legal designations.

S1	Extremely rare; usually 5 or fewer occurrences in the state, or in the case of communities, covering less than 50 hectares in aggregate; or may have a few remaining individuals; often especially vulnerable to extirpation.
S2	Very rare; usually between 5 and 20 occurrences, or in the case of communities, covering less than 250 hectares in aggregate; or few occurrences with many individuals; often susceptible to becoming endangered.
S3	Rare to uncommon; usually between 20 and 100 occurrences; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances.
S4	Common; usually more than 100 occurrences, but may be fewer with many large populations; may be restricted to only a portion of the state; usually not susceptible to immediate threats.
S5	Very common; demonstrably secure under present conditions.
SA	Accidental in the state.
SH	Historically known from the state, but not verified for an extended period, usually more than 15 years; this rank is used primarily when inventory has been attempted recently.

SM Applied to vegetation extensively modified by disturbance but considered recoverable by management, time, or restoration of ecological processes.

SN Regularly occurring migrants or transient species which are non-breeding, seasonal residents. (Note that congregation and staging areas are monitored separately).

SU Status uncertain, often because of low search effort or cryptic nature of the element.

SW Applied to vegetation dominated by ruderal or exotic species.

SX Apparently extirpated from the state.

The spot on the landscape that supports a natural heritage resource is an element occurrence. DCR-DNH has mapped over 7,500 element occurrences in Virginia. Information on the location and quality of these element occurrences is computerized within the Division's BCD system, and additional information is recorded on maps and in manual files.

In addition to ranking each element's rarity, each element occurrence is ranked to differentiate large, outstanding occurrences from small, vulnerable ones. In this way, protection efforts can be aimed not only at the rarest elements, but at the best examples of each. Species occurrences are ranked in terms of quality (size, vigor, etc.) of the population; the condition (pristine to disturbed) of the habitat; the viability of the population; and the defensibility (ease or difficulty of protecting) of the occurrence. Community occurrences are ranked according to their size and overall natural condition. These element occurrence ranks range from A (excellent) to D (poor). Sometimes these ranks are combined to indicate intermediate or somewhat unclear status, (e.g., AB or CD). In a few cases, especially those involving cryptic animal elements, field data may not be sufficient to reliably rank an occurrence. In such cases a rank of E (extant) may be given. A rank of H (historical) is used to indicate an historical occurrence that could not be relocated by recent survey. Element occurrence ranks reflect the current condition of the species' population or community. A poorly-ranked element occurrence can, with time, become highly-ranked as a result of successful management or restoration.

Element ranks and element occurrence ranks form the basis for ranking the overall significance of sites. Site biodiversity ranks (B-ranks) are used to prioritize protection efforts, and are defined in Table D-2.

Table D-2. Biodiversity ranks used to indicate site significance.

B1 Outstanding Significance: only site known for an element; an excellent occurrence of a G1 species; or the world's best example of a community type.

B2 Very High Significance: excellent example of a rare community type; good occurrence of a G1 species; or excellent occurrence of a G2 or G3 species.

B3 High Significance: excellent example of any community type; good occurrence of a G3 species.

B4 Moderate Significance: good example of a community type; excellent or good occurrence of state-rare species.

B5 General Biodiversity Significance: good or marginal occurrence of a community type or state-rare species.

The U.S. Fish and Wildlife Service (USFWS) is responsible for the listing of endangered and threatened species under the Endangered Species Act of 1973, as amended. Federally listed species (including subspecific taxa) are afforded a degree of legal protection under the Act, and therefore sites supporting these species need to be highlighted. USFWS also maintains a review listing of potential endangered and threatened taxa known as candidate species. Table D-3 illustrates the various status categories used by USFWS and followed in this report. The status category of candidate species is based largely on the Service's current knowledge about the biological vulnerability and threats to a species.

As of February 27, 1996, species formerly referred to as Category 2 (C2) candidates for listing as threatened or endangered are no longer considered "candidates" under the Endangered Species Act. The USFWS no longer maintains a formal, comprehensive list of such species. However, the Virginia Field Office of the USFWS intends to maintain an informal list of these and other "Species of Concern" that may warrant future consideration as candidates. These "Species of Concern" can be regarded as species for which the Service has insufficient scientific information to support a listing proposal. Former Category 1 (C1) species are now considered "candidates" (C) for listing. "Candidate" species are species for which the USFWS has enough scientific information to warrant a proposal for listing. The designation of Category 3 species (3A, 3B, 3C) has been discontinued. However, the USFWS will continue to maintain its files on these species in case new information indicates a need for reevaluation.

Table D-3. U.S. Fish and Wildlife Service species status codes, with abbreviated definitions

LE	Listed endangered
LT	Listed threatened
PE	Proposed to be listed as endangered
PT	Proposed to the listed as threatened
C	Candidate: status data supports listing of taxon as endangered or threatened
SOC	Species of Concern: no official status, evidence of vulnerability, but insufficient data exists.

In Virginia, two acts have authorized the creation of official state endangered and threatened species lists. One act (Code of Virginia ' 29.1-563 through 570), administered by the Virginia Department of Game and Inland Fisheries (DGIF), authorizes listing of fish and wildlife species, not including insects. The other act (Code of Virginia ' 3.1-1020 through 1030), administered by the Virginia Department of Agriculture and Consumer Services (VDACS), allows for listing of plant and insect species. In general, these acts prohibit or regulate taking, possessing, buying, selling, transporting, exporting, or shipping of any endangered or threatened species appearing on the official lists. Species protected by these acts are indicated as either listed endangered (LE) or listed threatened (LT). Species under consideration for listing are indicated as candidates (C).

(November 2000)

Appendix E.
2006 *Phragmites* Aerial Survey Report for Sweet Hall Marsh Reserve

Introduction
The objective of this project component was to conduct an aerial census of *Phragmites* patch occurrences at Sweet Hall Marsh Creek Reserve. Effective strategies for managing large scale invasive species problems require reliable information for prioritizing and choosing control targets. Thus, it was evident that a need existed for a current data on *Phragmites* distribution and abundance in order to guide long term conservation planning and management actions. Previous experience by DCR-DNH staff with GPS ground mapping of *Phragmites* made it clear that such methods would not be cost effective or even possible given time and funding constraints for estimating *Phragmites* at Sweet Hall Marsh. Thus, the aerial method was used.

Methods
Aircraft. The aerial survey was conducted using a Schweitzer 300 CBi two-seat helicopter (Figure E-1). Small, stable in flight, and highly fuel-efficient, the Schweitzer allowed the pilot and one passenger (the observer) up to three hours of flight time between fueling stops. The cockpit provided an excellent view as most construction material is clear Plexiglas. Most flights were conducted with the door removed on the passenger side, further enhancing the view for the observer.

Figure E-1. Schweitzer 300 CBi helicopter used in the 2004 *Phragmites* aerial census.

The survey flight for Sweet Hall Marsh was conducted on July 12, 2006. A flight log was kept with the following information recorded:

Flight date	Fuel stops
Time in	Flight area
Time out	GPS files
Total flight time	Notes

GPS equipment. The observer carried and operated a handheld GPS receiver (Trimble GeoExplorer 3) for collecting position data. A data dictionary was developed to support the census goals and provide some flexibility to meet a variety of field conditions. The following GPS rover unit settings were used during all census flights:

PDOP mask	4.0	Minimum satellites	4
SNR mask	6.0	Recording interval	1 second
Elevation mask	15 degrees		

Identification of vegetation. *Phragmites* was easily identified from the air during the survey period (Figures E-2 and E-3). The following characteristic features of *Phragmites* contributed to a highly distinct search image: tall stature, bluish green leaves, leaf shape and arrangement on stem, purple-red inflorescence, and dense stand formation. Native *Phragmites* exhibits slightly greener color, less cover density, and sparser florescence. However, the native form is still distinguishable from *Spartina cynosauroides* and other tall native marsh species.

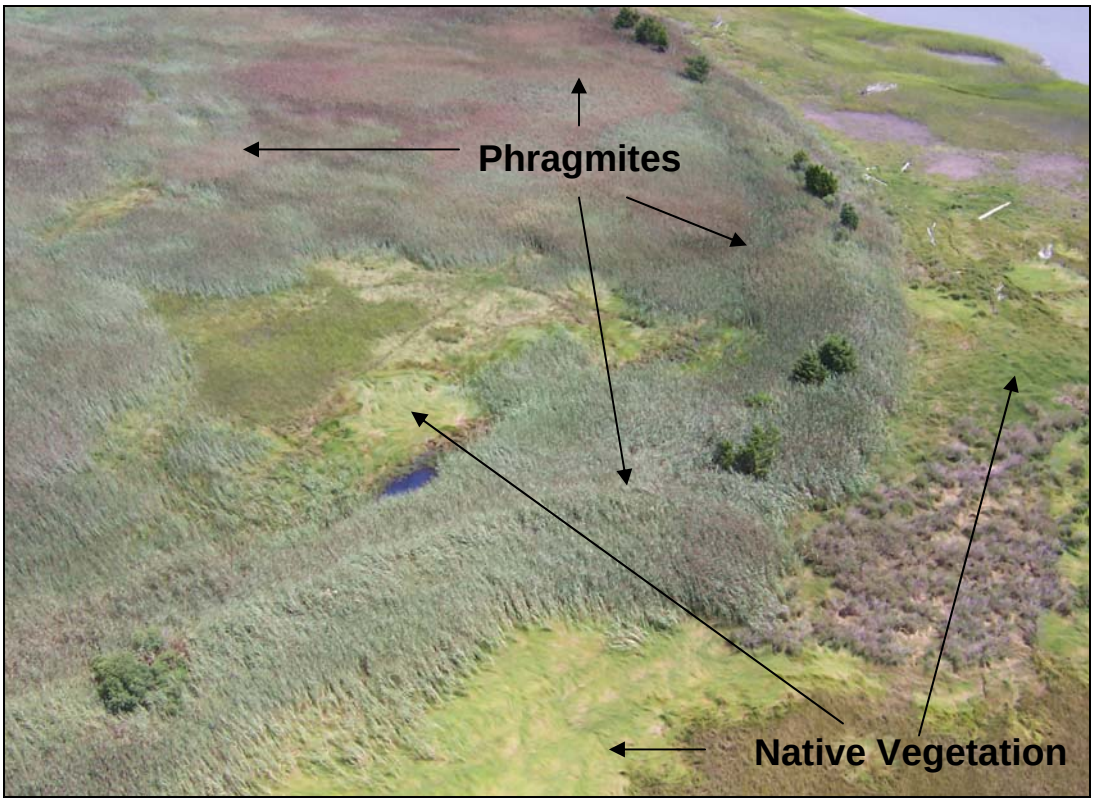

Figure E-2. *Phragmites* patch as viewed from helicopter. Color, stature, and dense growth habit identify this as the invasive non-native variety of *Phragmites*.

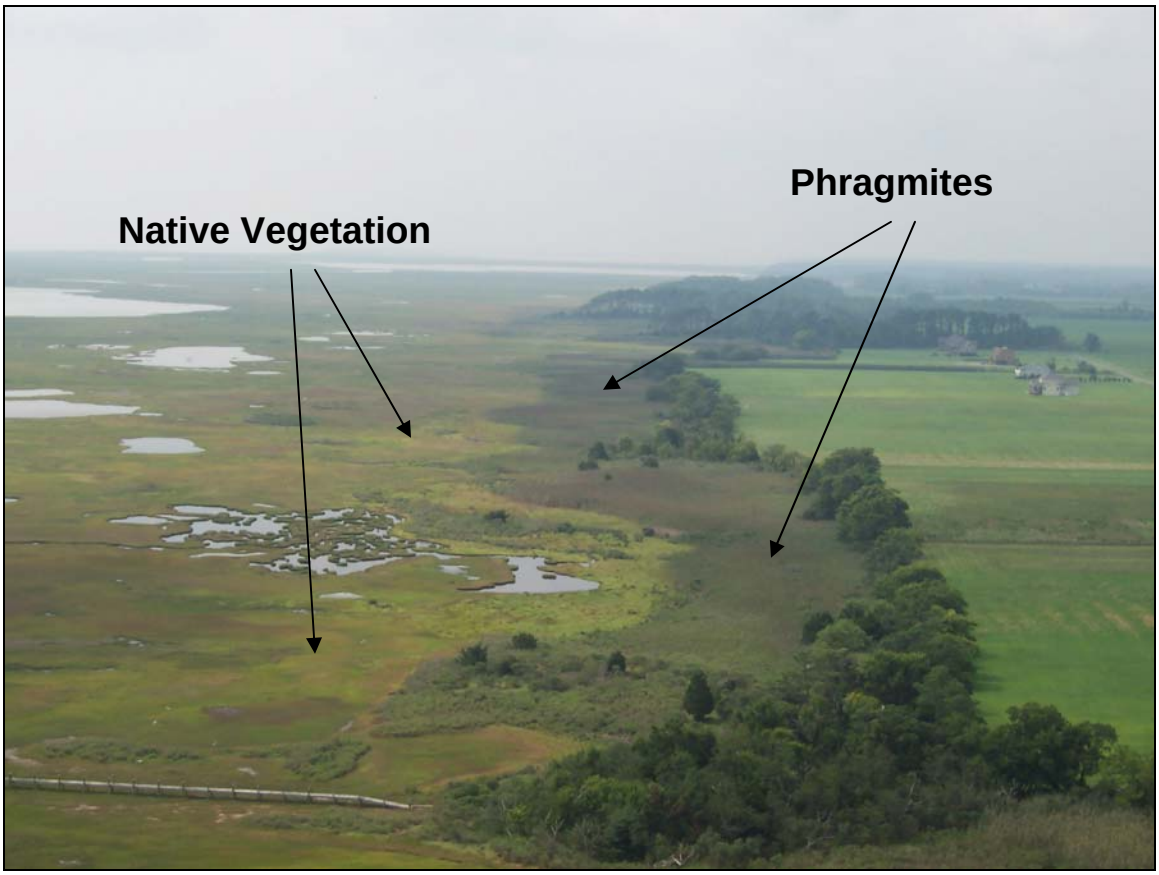

Figure E-3. Long linear patch of *Phragmites* bounded on the upland edge (to the right) by a treeline and by *Spartina patens* (to left) along the marsh edge. Photo was taken on the Eastern Shore of Virginia.

Large *Phragmites* patches were mapped as polygons. Point features were collected for patches of 0.125 acre or less and for patches greater than 0.125 to 0.25 acres in size, based on visual estimates.

All *Phragmites* patches were assigned a visual estimate of cover. Estimates were made by the observer from the helicopter while collecting GPS data on a given patch. Cover classes used were: < 25% cover, 26-50%, 51-75%, and 76-100%. Most patches occurring in open marsh had cover of 76-100% (Figure E-4).

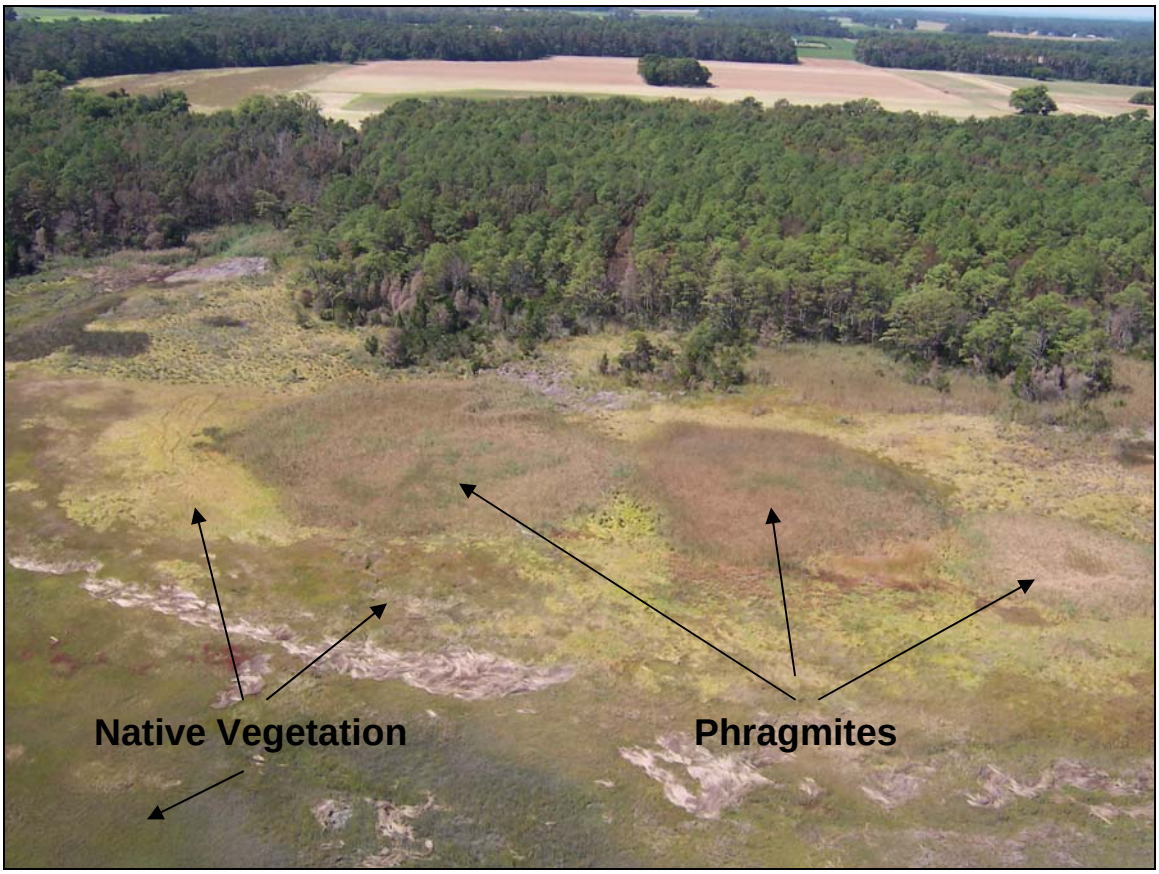

Figure E-4. Expanding *Phragmites* patches (cover class = 76-100%) still surrounded by native marsh vegetation. Photo was taken on the Eastern Shore of Virginia.

Summary of Procedures

Flight altitude during GPS collection varied from patch to patch and sometimes within a given patch, ranging from 15 feet to 80 feet above the surface. Altitude while searching for patches ranged from 50 feet to 200 feet above the surface. After the flight, GPS data files were downloaded and backed up as soon as possible. All GPS data was converted to ArcView shapefiles and projected over the Virginia Base Map data layer comprised of geo-referenced digital aerial photographs. For this report, USGS topographic layer was used to create the final map layout.

Summary of Findings

Not all of the Phragmites at Sweet Hall Marsh was mapped due to shortage of resources: time allotted for mapping ran out before all patches were mapped. Approximately 50-75% of the patches were mapped. At Sweet Hall, a total of 50 *Phragmites* patches were mapped. Twelve patches ranging in size from just over 0.28 acre to 3.2 acres. Total polygon area is 12.8 acres. Thirty-eight patches were mapped as points. Of these, seven patches were estimated to be between 0.125 acre and 0.25 acre and 31 smaller than 0.125 acre, for a maximum of 5.7 acres. The gives a grant total for the maximum area currently mapped as 18.5 acres.

Appendix F.
Collecting Instructions for Native vs. Non-Native Phragmites Determininations at Cornell University

IMPORTANT: Please first read or print out the below instructions.

This webpage offers you the opportunity to become a registered user for **multiple submissions**. This becomes particularly important if you plan to submit more than a single sample. By registering your information (name, affiliation, email) will be automatically retrieved and pasted into the appropriate form fields if you submit a new sample.

Register for multiple submissions -- Details Below

INSTRUCTIONS -- Printable Format

CHECKLIST:

BEFORE YOU GO INTO THE FIELD PLEASE MAKE SURE TO TAKE THE FOLLOWING:

1. GPS unit or topographic map
2. Clippers to cut Phragmites stems
3. Zip-lock or plastic bags to store samples
4. Paper to record site information. Use printout of form from web
5. Pencil or pen (no ink please)
6. Camera

INSTRUCTIONS FOR FIELD COLLECTION

1. Use the checklist to assemble the necessary tools and materials.

2. Once you arrive at the sampling location please take a picture of the stand (or several)

3. Fill out all pertinent information on the form sheet. Use data form provided on the web (**Printable Form**)

4. Record GPS (Lat/Long) coordinates.

5. Walk to the stand and cut 5 stems from last years growing season. Cut stems at base of shoot as far down as possible. Fold each stem individually and place into plastic bag. During the growing season when green stems from the current year are available, please also cut 5 green stems. Follow procedures as outlined above for older stems. Please place green stems into a separate plastic bag. If you continue to another sampling location, please make sure your samples are clearly marked with site name, GPS location etc. Ideally a piece of paper with this information should be kept in each plastic bag secured to the stems.

6. Once you return from the field, please enter all information via our website. Each sampling location will receive a unique reference number assigned by our website. You will receive this reference number once you submit and approve the information you entered. Please make a printout of this information for your own records and place a copy into the plastic bag with the old stems and another copy into the bag with the green stems. We will receive many samples and this system allows us to keep track of the samples and reduce mix-ups.

7. During the growing season when green stems are shipped, please send material ASAP after field collection. Please avoid sending samples that are wet since they will get moldy quickly. Otherwise, samples will last in plastic bags for a few days. Ideally they should arrive in Ithaca within 2-3 days after collection. This is less urgent for samples collected during the dormant season but avoid moist samples as well.

8. Place clearly labeled samples into shipment box or envelope and mail to:

Bernd Blossey
Department of Natural Resources
Fernow Hall, Cornell University
Ithaca, NY 14853

EXPLANATION ON HOW TO SUBMIT THE INFORMATION VIA THE WEB

This webpage offers you the opportunity to become a registered user for **multiple submissions**. This becomes particularly important if you plan to submit more than a single sample. By registering your information (name, affiliation, email) will be automatically retrieved and pasted into the appropriate form fields if you submit a new sample. This will save significant time typing.

If you are planning to submit several samples from various locations (now or in the future), please first chose "Register for Multiple Submissions". After filling out the form you will receive an ID-number which you can use to logon the site. If at anytime you forget your ID-number or password please contact Raj Smith at jps21@cornell.edu.

If you need to make changes because your affiliation, phone or email has changed, please click on "Update".

HOW TO FILL OUT THE FORM -- Printable Form

Fields 1-9: These fields are self explanatory

Field 10: Name of collection site. Please be specific, we have allowed sufficient space for you to enter this information. For example if your collection site is a National Wildlife refuge, enter

more than the NWR name. For example : West side of brown pond along feeder ditch. You may want to give a short name and then a more elaborate description. All submitted sample will automatically receive a unique identification number. This number will appear on the confirmation screen you will see once you submit the information. All samples will be tracked and referenced by this number.

Field 11: Please enter the day the samples were collected. The morphological characters change throughout the growing season and over the winter. It is important to keep track of the actual collection date. Please submit samples that contain green stems ASAP after collections.

Fields 12-14: Longitude/Latitude. We will create a North American distribution map of native and introduced Phragmites using your samples. This requires accurate location information. If you are unable to provide GPS location information, use UTM coordinates and transform into Lat/Long. If neither is available to you use a topographic map to interpolate GPS coordinates. Please check the appropriate box in Field 14 so we know how the information was derived. If you are unable to provide this information, please submit a photocopy of a road atlas with the location clearly indicated. Please use a separate map for each sample you are submitting or clearly label sampling sites.

Field 15. Habitat. Please check one of the provided categories. If none of the provided ones fit, please provide a new category and a description of the site.

Field 16. Growing conditions. There is some indication that native Phragmites may not be able to tolerate continuous flooding while introduced Phragmites thrives under these circumstances. You information about the growing conditions will be extremely useful. We recognize that this can be only a "snapshot" but we consider it worthwhile.

Field 17. Size of population. Please estimate the extent of your Phragmites patch. Chose one of our broad categories.

Field 18. Appearance of stand. Native Phragmites appears often less dense but not always. Mostly because old stems appear to decompose faster. We need additional information to assess whether this is a general patterns across NA.

Field 19. Coming Soon -- Digital photo. We would like to create a photo library of growing locations across North America. We have already begun this collection and your photos would be a great addition. We will give appropriate credit for all photos we opt to use. If you have only prints or slides, we welcome these as well and will create digital images if you send us copies. When submitting images, please clearly label them with the unique identification number you will receive when submitting information for each sample. In those cases where the person submitting the information is not the photographer, please provide this info as well so we can give credit accordingly.

Appendix G.
Invasive Non-native Species and Problem Native Species Information

Element Stewardship Abstract – *Phragmites australis*

Element Stewardship Abstract – *Lonicera japonica*

Chemical Ecology of the Southern Pine Beetle – Donald M. Grosman, Texas Forest Service

White-tailed deer and Virginia Natural Area Preserves – Mike Leahy, former Mountain Regional Steward, Department of Conservation and Recreation, Division of Natural Heritage, Roanoke, VA

Impacts and Economic Costs of Deer in Suburban Landscapes – Paul D. Curtis, Extension Wildlife Specialist, Department of Natural Resources, Cornell University, Ithaca, NY.

ELEMENT STEWARDSHIP ABSTRACT
for

Phragmites australis

Common Reed

To the User:

Element Stewardship Abstracts (ESAs) are prepared to provide The Nature Conservancy's Stewardship staff and other land managers with current management-related information on those species and communities that are most important to protect, or most important to control. The abstracts organize and summarize data from numerous sources including literature and researchers and managers actively working with the species or community.

We hope, by providing this abstract free of charge, to encourage users to contribute their information to the abstract. This sharing of information will benefit all land managers by ensuring the availability of an abstract that contains up-to-date information on management techniques and knowledgeable contacts. Contributors of information will be acknowledged within the abstract and receive updated editions. To contribute information, contact the editor whose address is listed at the end of the document.

For ease of update and retrievability, the abstracts are stored on computer at the national office of The Nature Conservancy. This abstract is a compilation of available information and is not an endorsement of particular practices or products.

Please do not remove this cover statement from the attached abstract.

Authors of this Abstract:
Marianne Marks (original version), Beth Lapin & John Randall

The Nature Conservancy
Element Stewardship Abstract
For *Phragmites australis*

I. IDENTIFIERS

Common Name: COMMON REED Global Rank: G5

General Description:
Phragmites australis is a large perennial rhizomatous grass, or reed. The name Phragmites is derived from the Greek word for fence, phragma, in reference to its fence-like growth along streams.

Diagnostic Characteristics:
Members of the genus Phragmites are superficially similar to Arundo. Sterile specimens of P. australis are sometimes misidentified as Arundo donax, a grass introduced to North America from Asia and now troublesome in natural areas, especially in California. The genera can be distinguished when in flower because the glumes of Phragmites are glabrous while those of Arundo are covered with soft, whitish hairs 6-8 mm long. In addition, the glumes are much shorter than the lemmas in Phragmites.

II. STEWARDSHIP SUMMARY

Communities that have stable Phragmites populations present but have been exposed to disturbance should be closely monitored. Management is necessary when evidence indicates that Phragmites has spread, or is spreading and threatening the integrity of rare communities, invading the habitat of rare plants or animals or interfering with the wildlife support function of refuges. Cutting, burning, application of herbicides (in particular Rodeo), or water management schemes are possible control measures. The measure(s) used will depend on a number of factors including the size and location of the infestation, the presence of sensitive rare species and the work-force available.

III. NATURAL HISTORY

Range:
Phragmites australis is found on every continent except Antarctica and may have the widest distribution of any flowering plant (Tucker 1990). It is common in and near freshwater, brackish and alkaline wetlands in the temperate zones world-wide. It may also be found in some tropical wetlands but is absent from the Amazon Basin and central Africa. It is widespread in the United states, typically growing in marshes, swamps, fens, and prairie potholes, usually inhabiting the marsh-upland interface where it may form continuous belts (Roman et al. 1984).

Because Phragmites has invaded and formed near-monotypic stands in some North American wetlands only in recent decades there has been some debate as to whether it is indigenous to this continent or not. Convincing evidence that it was here long before European contact is now available from at least two sources. Niering and Warren (1977) found remains of Phragmites in cores of 3000 year old peat from tidal marshes in Connecticut. Identifiable Phragmites remains dating from 600 to 900 A.D. and constituting parts of a twined mat and other woven objects were found during archaeological investigations of Anasazi sites in southwestern Colorado (Kane & Gross 1986; Breternitz et al. 1986).

There is some suspicion that although the species itself is indigenous to North America, new, more invasive genotype(s) were introduced from the Old World (Metzler and Rosza 1987). Hauber et al. (1991) found that invasive Phragmites populations in the Mississippi River Delta differed genetically from a more stable population near New Orleans. They also examined populations elsewhere on the Gulf coast,

from extreme southern Texas to the Florida panhandle, and found no genetic differences between those populations and the one near New Orleans (Hauber, pers. comm. 1992). This increased their suspicion that the invasive biotypes were introduced to the Delta from somewhere outside the Gulf relatively recently.

Phragmites is frequently regarded as an aggressive, unwanted invader in the East and Upper Midwest. It has also earned this reputation in the Mississippi River Delta of southern Louisiana, where over the last 50 years, it has displaced species that provided valuable forage for wildlife, particularly migratory waterfowl (Hauber 1991). In other parts of coastal Louisiana, however, it is feared that Phragmites is declining as a result of increasing saltwater intrusion in the brackish marshes it occupies. Phragmites is apparently decreasing in Texas as well due to invasion of its habitat by the alien grass ARUNDO DONAX (Poole, pers. comm. 1985). Similarly, Phragmites is present in the Pacific states but is not regarded as a problem there. In fact, throughout the western U.S. there is some concern over decreases in the species habitat and losses of populations.

Habitat:
Phragmites is especially common in alkaline and brackish (slightly saline) environments (Haslam 1972, 1971b), and can also thrive in highly acidic wetlands (Rawinski, pers. comm. 1985). However, Phragmites does not require, nor even prefer these habitats to freshwater areas. Its growth is greater in fresh water but it may be outcompeted in these areas by other species that cannot tolerate brackish, alkaline or acidic waters. It is often found in association with other wetland plants including species from the following genera: SPARTINA, CAREX, NYMPHAEA, TYPHA, GLYCERIA, JUNCUS, MYRICA, TRIGLOCHIN, CALAMAGROSTIS, GALIUM, and PHALARIS (Howard et al. 1978).

Phragmites occurs in disturbed areas as well as pristine sites. It is especially common along railroad tracks, roadside ditches, and piles of dredge spoil, wherever even slight depressions hold water (Ricciuti 1983). Penko (pers. comm. 1993) has observed stunted Phragmites growing on acidic tailings (Ph 2.9) from an abandoned copper mine in Vermont. Various types of human manipulation and/or disturbance are thought to promote Phragmites (Roman et al. 1984). For example, restriction of the tidal inundation of a marsh may result in a lowering of the water table, which may in turn favor Phragmites. Likewise, sedimentation may promote the spread of Phragmites by elevating a marsh's substrate surface and effectively reducing the frequency of tidal inundation (Klockner, pers. comm. 1985).

A number of explanations have been proposed to account for the recent dramatic increases in Phragmites populations in the northeastern and Great Lakes States. As noted above, habitat manipulations and disturbances caused by humans are thought to have a role. In some areas Phragmites may also have been promoted by the increases in soil salinity which result when de- icing salt washes off roads and into nearby ditches and wetlands (McNabb and Batterson 1991). On the other hand, bare patches of road sand washed into ditches and wetlands may be of greater importance. Phragmites seeds are shed from November through January and so may be among the first propagules to reach these sites. If the seeds germinate and become established the young plants will usually persist for at least two years in a small, rather inconspicuous stage, resembling many other grasses. Later, perhaps after the input of nutrients, they may take off and assume the tall growth form that makes the species easily identifiable . Increases in soil nutrient concentrations, may come from runoff from farms and urban areas. It has also been suggested increases in nutrient concentrations, especially nitrates, are primarily responsible for increases in Phragmites populations. Ironically, eutrophication and increases in nitrate levels are sometimes blamed for the decline of Phragmites populations in Europe (Den Hartog et al. 1989).

Ecology:
Salinity and depth to the water table are among the factors which control the distribution and performance of Phragmites. Maximum salinity tolerances vary from population to population; reported maxima range

from 12 ppt (1.2%) in Britain to 29 ppt in New York state to 40 ppt on the Red Sea coast (Hocking et al. 1983). Dense stands normally lose more water through evapotranspiration than is supplied by rain (Haslam 1970). However, rhizomes can reach down almost 2 meters below ground, their roots penetrating even deeper, allowing the plant to reach low lying ground water (Haslam 1970). Killing frosts may knock the plants back temporarily but can ultimately increase stand densities by stimulating bud development (Haslam 1968).

Phragmites has a low tolerance for wave and current action which can break its culms (vertical stems) and impede bud formation in the rhizomes (Haslam 1970). It can survive, and in fact thrive, in stagnant waters where the sediments are poorly aerated at best (Haslam 1970). Air spaces in the above-ground stems and in the rhizomes themselves assure the underground parts of the plant with a relatively fresh supply of air. This characteristic and the species' salinity tolerance allow it to grow where few others can survive (Haslam 1970). In addition the build up of litter from the aerial shoots within stands prevents or discourages other species from germinating and becoming established (Haslam 1971a). The rhizomes and adventitious roots themselves form dense mats that further discourage competitors. These characteristics are what enable Phragmites to spread, push other species out and form monotypic stands.

Such stands may alter the wetlands they colonize, eliminating habitat for valued animal species. On the other hand, the abundant cover of litter in Phragmites stands may provide habitat for some small mammals, insects and reptiles. The aerial stems provide nesting sites for several species of birds, and Song Sparrows have been seen eating Phragmites' seeds (Klockner, pers. comm. 1985). Muskrats (ONDATRA ZIBETHICUS) use Phragmites for emergency cover when low lying marshes are swept by storm tides and for food when better habitats are overpopulated (Lynch et al. 1947).

Studies conducted in Europe indicate that gall-forming and stem- boring insects may significantly reduce growth of Phragmites (Durska 1970; Pokorny 1971). Skuhravy (1978) estimated that roughly one-third of the stems in a stand may be damaged reducing stand productivity by 10-20%. Mook and van der Toorn (1982) found yields were reduced by 25 to 60% in stands heavily infested with lepidopteran stem- or rhizome-borers. Hayden (1947) suggested that aphids (HYALOPTERUS PRUNI) heavily damaged a Phragmites stand in Iowa. On the other hand work in Europe by Pintera (1971) indicated that although high densities of aphids may bring about reductions in Phragmites shoot height and leaf area they had little effect on shoot weight. Like other emergent macrophytes, Phragmites has tough leaves and appears to suffer little grazing by leaf-chewing insects (Penko 1985).

As mentioned above, there is great concern about recent declines in Phragmites in Europe where the species is still used for thatch. In fact, the journal Aquatic Botany devoted an entire issue (volume 35 no.1, September 1989) to this subject. Factors believed responsible for the declines include habitat destruction and manipulation of hydrologic regimes by humans, grazing, sedimentation and decreased water quality (eutrophication) (Ostendorp 1989).

Detailed reviews of the ecology and physiological ecology of Phragmites are provided by Haslam (1972; 1973) and Hocking et al. (1983) and an extensive bibliography is provided by van der Merff et al. (1987).

Reproduction:
Phragmites is typically the dominant species on areas that it occupies. It is capable of vigorous vegetative reproduction and often forms dense, virtually monospecific stands. Hara et al. (1993) classify sparse stands as those with densities of less than 100 culms m-2 and dense stands as those with densities of up to about 200 culms m-2 in wet areas or up to 300 culms m-2 in dry areas. Mammalian and avian numbers and diversity in the dense stands are typically low (Jones and Lehman 1987). Newly opened sites may be colonized by seed or by rhizome fragments carried to the area by humans in soils and on machinery during construction or naturally in floodwaters.

The plants generally flower and set seed between July and September and may produce great quantities of seed. In the northeast, seeds are dispersed between November and January. However, in some cases, most or all of the seed produced is not viable (Tucker 1990). The seeds are normally dispersed by wind but may be transported by birds such as red-winged blackbirds that nest among the reeds (Haslam 1972). Following seed set, nutrients are translocated down into the rhizomes and the above- ground portions of the plant die back for the season (Haslam 1968).

Temperature, salinity and water levels affect seed germination. Water depths of more than 5 cm and salinities above 20 ppt (2%) prevent germination (Kim et al. 1985; Tucker 1990). Germination is not affected by salinities below 10 ppt (1%) but declines at higher salinities. Percentage germination increases with increasing temperature from 16 to 25 oC while the time required to germinate decreases from 25 to 10 days over the same temperature range. Barry Truitt (pers. comm. 1992) has observed that areas covered by thick mats of wrack washed up during storms and high water events are frequently colonized by Phragmites on the Virginia Coast Reserve. It is not clear whether it establishes from rhizome pieces washed in with the wrack or from seed that blows in later.

Once a new stand of Phragmites takes hold it spreads, predominantly through vegetative reproduction. Individual rhizomes live for 3 to 6 years and buds develop at the base of the vertical type late in the summer each year. These buds mature and typically grow about 1 meter (up to 10 m in newly colonized, nutrient-rich areas) horizontally before terminating in an upward apex and going dormant until spring. The apex then grows upward into a vertical rhizome which in turn produces buds that will form more vertical rhizomes. Vertical rhizomes also produce horizontal rhizome buds, completing the vegetative cycle. These rhizomes provide the plant with a large absorbent surface that brings the plant nutrients from the aquatic medium (Chuchova and Arbuzoba 1970). The aerial shoots arise from the rhizomes. They are most vigorous at the periphery of a stand where they arise from horizontal rhizomes, as opposed to old verticals (Haslam 1972).

IV. CONDITION

Threats:

IMPACTS (THREATS POSED BY THIS SPECIES)
Phragmites can be regarded as a stable, natural component of a wetland community if the habitat is pristine and the population does not appear to be expanding. Many native populations of Phragmites are "benign" and pose little or no threat to other species and should be left intact. Examples of areas with stable, native populations include sea-level fens in Delaware and Virginia and along Mattagota Stream in Maine (Rawinski 1985, pers. comm. 1992). In Europe, a healthy reed belt is defined as a "homogeneous, dense or sparse stand with no gaps in its inner parts, with an evenly formed lakeside borderline without aisles, shaping a uniform fringe or large lobes, stalk length decreasing gradually at the lakeside border, but all stalks of one stand of similar height; at the landside edge the reeds are replaced by sedge or woodland communities or by unfertilized grasslands" (Ostendorp 1989).

Stable populations may be difficult to distinguish from invasive populations, but one should examine such factors as site disturbance and the earliest collection dates of the species to arrive at a determination. If available, old and recent aerial photos can be compared to determine whether stands in a given area are expanding or not (Klockner, pers. comm. 1985).

Phragmites is a problem when and where stands appear to be spreading while other species typical the of the community are diminishing. Disturbances or stresses such as pollution, alteration of the natural hydrologic regime, dredging, and increased sedimentation favor invasion and continued spread of

Phragmites (Roman et al. 1984). Other factors that may have favored recent invasion and spread of Phragmites include increases in soil salinity (from fresh to brackish) and/or nutrient concentrations, especially nitrate, and the introduction of a more invasive genotype(s) from the Old World (McNabb and Batterson 1991; Metzler and Rosza 1987, see GLOBAL RANGE section for further discussion).

Michael Lefor asserts that one reason for the general spread of Phragmites has been the destabilization of the landscape (pers. comm. 1993). In urban landscapes water is apt to collect in larger volumes and pass through more quickly (flashily) than formerly. This tends to destabilize substrates leaving bare soil open for colonization. Watersheds throughout eastern North America are flashier due to the proliferation of paved surfaces, lawns and roofs and the fact that upstream wetlands are largely filled with post-settlement/post agricultural sediments from initial land-clearing operations.

Many Atlantic coast wetland systems have been invaded by Phragmites as a result of tidal restrictions imposed by roads, water impoundments, dikes and tide gates. Tide gates have been installed in order to drain marshes to harvest salt hay, to control mosquito breeding and, most recently, to protect coastal development from flooding during storms. This alteration of marsh systems may favor Phragmites invasion by reducing tidal action and soil water salinity and lowering water tables.

Phragmites invasions may threaten wildlife because they alter the structure and function (wildlife support) of relatively diverse Spartina marshes (Roman et al. 1984). This is a problem on many of the eastern coastal National Fish and Wildlife Refuges including: Brigantine in NJ; Prime Hook and Bombay Hook in DE; Tinicum in PA; Chincoteague in VA; and Trustom Pond in RI.

Plant species and communities threatened by Phragmites are listed in the Monitoring section. Some of these instances are described below:

1. Massachusetts, a brackish pondlet near Horseneck Beach supports the state rare plant MYRIOPHYLLUM PINNATUM (Walter) BSP, which Phragmites is threatening by reducing the available open water and shading aquatic vegetation (Sorrie, pers. comm. 1985).

2. Maryland, at Nassawango Creek, a rare coastal plain peatland community is threatened by Phragmites (Klockner, pers. comm. 1985).

3. Ohio, at the Arcola Creek wetland, Phragmites is threatening the state endangered plant CAREX AQUATILIS Wahlenb. (Young, pers. comm. 1985).

Phragmites invasions also increase the potential for marsh fires during the winter when the above ground portions of the plant die and dry out (Reimer 1973). Dense congregations of redwing blackbirds, which nest in Phragmites stands preferentially, increase chances of airplane accidents nearby. The monitoring and control of mosquito breeding is nearly impossible in dense Phragmites stands (Hellings and Gallagher 1992). In addition, Phragmites invasions can also have adverse aesthetic impacts. In Boston's Back Bay Fens, dense stands have obscured vistas intended by the park's designer, Frederick Law Olmstead (Penko, pers. comm. 1993).

As noted above Phragmites is not considered a threat in the West or most areas in the Gulf states.

Restoration Potential:
Areas that have been invaded by Phragmites have excellent potential for recovery. Management programs have proven that Phragmites can be controlled, and natural vegetation will return. However, monitoring is imperative because Phragmites tends to reinvade and control techniques may need to be applied several times or, perhaps, in perpetuity. It is also important to note that some areas have been so heavily

manipulated and degraded that it may be impossible to eliminate Phragmites from them. For example, it may be especially difficult to control Phragmites in freshwater impoundments that were previously salt marshes.

V. MANAGEMENT/MONITORING

Management Requirements:
Invasive populations of Phragmites must be managed in order to protect rare plants that it might outcompete, valued animals whose habitat it might dominate and degrade, and healthy ecosystems that it might greatly alter.

Management Programs:
Cultural, mechanical and/or chemical methods can be used to control Phragmites. The factors that are believed responsible for the alarming decreases of Phragmites beds in Europe and Texas include habitat destruction, increased soil nitrate levels, and eutrophication (Boar, Crook and Moss 1989, Ostendorp 1989, Sukopp and Markstein 1989) are not appropriate as management tools in natural areas.

BIOLOGICAL CONTROL: Biological control does not appear to be an option at this time. No organisms which significantly damage Phragmites australis but do not feed on other plant species have been identified. Naturally occurring parasites have not proven to be successful controls (Tscharntke 1988, Mook and van der Toorn 1982, van der Toorn and Mook 1982). In addition, some of the arthropods that feed on Phragmites are killed by winter fires and thus would likely be eliminated from the systems where prescribed fires are used. Coots, nutria, and muskrats may feed on Phragmites but appear to have limited impacts on its populations (Cross and Fleming 1989).

BURNING: Prescribed burning does not reduce the growing ability of Phragmites unless root burn occurs. Root burn seldom occurs, however, because the rhizomes are usually covered by a layer of soil, mud and/or water. Fires in Phragmites stands are dangerous because this species can cause spot-fires over 100 feet away (Beall 1984). Burning does remove accumulated Phragmites leaf litter, giving the seeds of other species area to germinate. Prescribed burning has been used with success after chemical treatment for this purpose at The Brigantine National Wildlife Refuge, NJ (Beall 1984) and in Delaware (Lehman, pers. comm. 1992). Occasional burning has been used in Delaware in conjunction with intensive spraying and water level management. This helps remove old canes and allows other vegetation to grow (Daly, pers. comm. 1991)

At Wallops Island, Virginia, a small (100' x 400') brackish to saline to dry wetland was burned November 1990 to control Phragmites (M. Ailes, pers. comm. 1992). A variety of other species appeared in the year following the burn but they appeared leggy while the Phragmites remained vigorous. A second winter burn is planned and monitoring of transects will continue (there are no pre-treatment data).

At Wertheim National Wildlife Refuge in New York, a 20-30 acre freshwater impoundment was drained in the fall of 1989, burned the following winter and then reflooded (Parris, pers. comm. 1991). Phragmites was eliminated from the half of the marsh that was treated and the area remained free of the grass through 1992.

According to Cross and Fleming (1989), late summer burns may be effective, but winter and spring burning may in fact increase the densities of spring crops. Thompson and Shay (1985) performed experimental burn treatments on Delta Marsh, Manitoba. They found that spring, summer and fall burns resulted in higher total shoot densities and lower mean shoot weights than on controls primarily as a result of greater densities of shorter, thinner vegetative shoots. Shoot biomass was greater in spring-burned and fall-burned plots than in control areas but less on summer- burned plots. They also found that below-

ground production increased following spring and fall burns but not following summer burns. The increase in light availability following burns generally appears to benefit Phragmites. A variety of understory responses to these burns was noted. For example, summer burns increased species diversity, richness, and evenness, although certain species declined (Thompson and Shay 1985).

In Connecticut late spring burns followed by manual flooding with salt water was successful in reducing Phragmites height and density (Steinke, pers. comm. 1992). After three years, the fuel load was exhausted; the process was very expensive and self- regulating tide gates were installed instead (see MANIPULATION OF WATER LEVEL AND SALINITY).

In Europe, experimental removal of litter in winter resulted in doubling the above-ground biomass (Graneli 1989). Increased light availability at the soil surface and aeration of the soil around the rhizomes may have been responsible for this increase. Burning in the winter in an experimental field caused little damage, while burning during the emergence period led to the death of the majority of Phragmites shoots (van der Toorn and Mook 1982).

CHEMICAL: RodeoTM, a water solution of the isopropylamine salt of glyphosate is commonly used for Phragmites control. This herbicide is not, however, selective and will kill grasses and broadleaved plants alike. Toxicity tests indicate that it is virtually non-toxic to all aquatic animals tested. It should be noted that many of these tests were performed by or for Monsanto, the company which manufactures Rodeo. Bioconcentration values for glyphosate in fish tissues were insignificant. Glyphosate biodegrades quickly and completely in the environment into natural products including carbon dioxide, nitrogen, phosphate and water. Finally, since glyphosate does not volatilize, it will not vaporize from a treated site and move to a non-target area (Brandt 1983; Comes, Bruns and Kelly 1976; Folmar, Sanders and Julin 1979; Monsanto 1985).

Rodeo must be mixed with water and a surfactant which allows it to stick to and subsequently be absorbed by the plant (Beall 1984). Instructions for application, amounts needed per acre, the approved surfactants and ratios for mixing, are on the Rodeo label. Glyphosate must be mixed with clean or, if possible, distilled water because it binds tightly to sediments and is thus rendered non-toxic to plants (Lefor, pers. Comm. 1992). This limits its effectiveness but also may help prevent it from acting on plants that were not originally targeted. Rodeo should not by applied in windy conditions, as the spray will drift (I. Ailes, pers. comm. 1985). It also should not be applied if rain is forecast within 12 hours because it will wash away before it has a chance to act (Daly 1984). Application rates may vary but, as one example, effective control of Phragmites in a Delaware marsh was achieved with 4 pints/acre of concentrate (Lehman, pers. comm. 1992).

Application of Rodeo must take place after the tasseling stage when the plant is supplying nutrients to the rhizome. At this time, when Rodeo is sprayed onto the foliage of aquatic weeds, it translocates into the roots. Rodeo interferes with essential plant growth processes, causing gradual wilting, yellowing, browning and deterioration of the plant. Studies on tasseling at the Augustine Tidal area, in Port Penn Delaware, indicated that tasseling in a stand is never 100% but that it is possible to spray when 94% of the plants are tasseling. In dense stands, subdominant plants are protected by the thick canopy and thus may not receive adequate herbicide. For these reasons, touch up work will be necessary (Lehman 1984).

At Brigantine National Wildlife Refuge, Rodeo was applied aerially after the plants tasseled in late August. The application resulted in a 90% success. The following February, a fast moving prescribed burn was carried out to remove litter, exposing the seed bed for re-establishment of marsh vegetation. However funding was not available for several years and Phragmites has returned to 90% of the previously treated areas (Beall, pers. comm. 1991). Treatment was resumed in fall 1991.

In September, 1983, at the Prime Hook Wildlife Refuge in Delaware, 500 acres of freshwater impoundments were sprayed with Rodeo from a helicopter for Phragmites control. The plants yellowed within 10 days. The following May aerial and ground evaluations of the sprayed area revealed a 98% kill of Phragmites (Daly 1984). In addition to applying herbicide, Prime Hook manipulates water levels with a stop log to stress Phragmites; winter water levels are held at an elevation of 2.8' msl until June, when water would otherwise be held at 2.2 msl. The combined spraying and water management approach was successful and many aquatic plants returned. A regime of spraying in August-September for two years followed by flooding has been used through 1991 (Daly, pers. comm. 1991). Annual costs of Phragmites control are $20K annual at Prime Hook (1,000 acres) and $3K at Bombay Hook (20-60 acres); monitoring costs, which include reading vegetation transects for species presence and density each September are not included in the cost.

Aerial spraying has been used since 1983 in many Delaware state wildlife refuges (Lehman, pers. comm. 1992). Using Rodeo, the state sprays freshwater and brackish impoundments, brackish marshes, and salt marshes from early September to early October; this is combined with winter burns between the first and second year of spraying. Areas will be spot-treated whenever needed after that. The herbicide treatments consist of 4 pints/acre the first year and 2 pints/acre the second, with an average cost of $65/acre. The state is involved with cost-sharing programs with private landowners where the state pays half the spraying cost with a willing owner. Desirable native vegetation usually returns after spraying; no revegetation is done. Occasionally become open mud flats that are eventually repopulated by Phragmites.

At Chincoteague National Wildlife refuge, an aerial spraying program initiated in 1986 in an 18-mile long freshwater impoundment was terminated due to budget cuts. Phragmites quickly reclaimed the area, estimated to be 100-150 acres total in small scattered stands (I. Ailes, pers. comm. 1991). In September 1991, spraying with Rodeo began again; it is expected that the entire area will be sprayed again in 1992, and that small areas of re-growth will be sprayed in 1993. Because the area is impounded, the water level usually is lower in the spring, which helps prevent Phragmites regrowth.

Herbicides are used at Tinicum Environmental Center, because other control options are limited. Unplanned burns do occur, but prescribed burns are not allowed due to the proximity to the highway and airport. Tinicum was recently granted $2M to restore a 18-acre site. Here they will be altering the elevation of the marsh, seeding with native plants, and monitoring the results (Nugent, pers. comm. 1991).

At Parker National Wildlife Refuge, an aerial spraying program (annual budget $5K) for 50 acres of a 100-acre freshwater impoundment began in mid-August 1991. A winter burn is anticipated and a second year of spraying planned. Results will be monitored by using aerial photos to delineate the boundaries of the Phragmites clones. A nearby tower also provides a suitable viewing point to observe progress (Healey, pers. comm. 1992).

In more fragile situations where Phragmites is threatening a rare plant or community, aerial spray techniques are inappropriate because such large-scale application could kill the community that the entire operation was designed to protect. Glyphosate can be applied to specific plants and areas by hand with a backpack sprayer. Wayne Klockner of The Nature Conservancy's Maryland Field Office has been successful in eliminating most Phragmites at the Nassawango preserve by applying glyphosate by hand with a backpack sprayer (Klockner, pers. comm. 1985). The control program there began in 1983; actual spraying is conducted along the power line ROW by Delmarva Power (Droege, pers. comm. 1991). Delmarva Power generally sprays with trucks, backpacks or helicopter, depending on the accessibility of the area and presence of rare plants nearby (Johnstone, pers. comm. 1991). They use Rodeo in tidal areas, and AccordTM (another glyphosate product) in non-tidal areas from mid-August to mid-October, when the plants are going to seed. They spray intensively the first year, and conduct touch-up spraying the

second year which eliminates 90-95% of the plants. They then return every three years to eliminate any new plants. They do not spray if the plants are not tasselling and are short.

Rodeo was used at Cape May Meadows in 1989, 1990, and 1991. It was applied with a 30 gallon gas-powered tank with spray nozzle mounted on a truck, Indian pump sprayers, 2.5 gallon hand-held sprayers, and wick applicators (Johnson, pers. comm. 1991). This appeared to kill most, if not all, of the treated Phragmites in this 20-acre area; plants found in the area following treatment were shorter and the stand was less dense (determined visually). However the dead stalks remained and blocked views from the trail.

In Connecticut a 5m x 23 m patch of Phragmites has been treated with a hand-held spray of Rodeo (1988 and 1989) and Roundup (1990 and 1991) for four years in late August-early September. The Phragmites is shorter and less dense at the site but it is still present (Lapin pers. obs.). Actions to supplement and enhance herbicide applications including the removal of tassels (1991) and removal of dead stalks (planned 1992), have been and will be taken.

Other chemicals have been used on Phragmites and are described in Cross and Fleming (1989).

Also see CUTTING at Constitution Marsh for another method of application.

CUTTING: Cutting has been used successfully to control Phragmites. Since it is a grass, cutting several times during a season, at the wrong times, may increase stand density (Osterbrock 1984). However, if cut just before the end of July, most of the food reserves produced that season are removed with the aerial portion of the plant, reducing the plant's vigor. This regime may eliminate a colony if carried out annually for several years. Care must be taken to remove cut shoots to prevent their sprouting and forming stolons (Osterbrock 1984). In the Arcola Creek Preserve in Ohio, cutting reduced the vigor of the Phragmites colony. Also in Ohio, at Morgan Swamp, cutting began in mid to end of July (before tassel set) in 1989 around a gas well in a freshwater wetland (Seidel, pers. comm. 1991). The preferred tool was an old-fashioned hedge trimmer with an 8" flat blade with serrations manufactured by Union Fork and Hoe. The trimmers worked better than loppers and were safer than sickles; a circular blade on a weed whacker was also used and proved to be faster and good for staff but it was more dangerous for volunteers and detracted from the atmosphere of the work-day (Huffman, pers. comm. 1992).

Small patches (10' x 50') in a New York freshwater system were cut at the end of July or the beginning of August for two successive years with positive results (Schneider, pers. comm. 1990). The hand-cut material was removed from the site and thrown on a brush pile (unfortunately it was located too close to the water and returned to the system).
Massachusetts Audubon staff have cut the perimeter around a 0.25 acre Phragmites patch at the end of July since 1986 in a freshwater wetland at Daniel Webster Preserve in Marshfield, Massachussetts (Anderson, pers. comm. 1992). They have monitored their success in keeping it from spreading by using a map and hand compass.

Stands of Phragmites of less than 1 acre in extent that block views in Everglades National Park are cut just before the onset of the rainy season. The rise in water elevation from the rains that follow stresses the roots of the plant. This works to a degree but Phragmites returns (Dowlen, pers. comm. 1985).

In Quincy, Mass., the town used small Bobcats with lawnmower clippers mounted on the buckets with a flexible cable to cut an area with 75% cover of Phragmites and 20-25' of muck (Wheelwright, pers. comm. 1991; Dobberteen pers. comm. 1991). Cutting this 10-acre plot three times during the summer (April, June, August) cost $150K. The cut material was stockpiled nearby where it was to be burned in the winter when it was washed away in a severe storm. In winter 1992, the town plans to open the tide gate and allow flushing to prevent further return of Phragmites. Results are not yet known.

Cutting culms to 6" followed by addition of rock salt on a 10' x 10' patch appeared to have reduced the height and density of Phragmites in a salt marsh in Greenwich, CT (Jontos and Allan 1984). Continued observations indicated that this trend appeared to continue (Jontos, pers. comm. 1992).

Cutting an area 25' x 25' to waist height with a hedge clippers and the applying one drop of Roundup with a syringe with a large needle (horse size) into the top of the plant in a brackish- freshwater marsh was begun in Constitution Marsh in New York in 1991 (Keene, pers. comm. 1991). Initial results indicate 90% eradication.

In Connecticut, cutting below the first leaf at the end of July in 1986, 1989, 1990, 1991, and 1992 in a freshwater tidal wetland around the perimeter of a one-acre patch has prevented subsequent expansion of the patch. Monitoring using aerial photos taken at five-year intervals indicated the control success. Cutting was done with hand-held cutters and gas-powered hedge trimmers, which were very efficient. Cut material was removed from the site and allowed to decompose on upland areas. In a second area, similar efforts in a calcareous wetland 1990-1992 were monitored by placing red survey wires around the perimeter of the patch. Preliminary observations indicate a cessation of Phragmites expansion.

In Europe, Weisner and Graneli (1989) found that oxygen transport was reduced by cutting the culms above and below the water surface;cutting below the water in June almost totally inhibited regrowth of shoots the following summer, while cutting above water reduced regrowth of shoots. Cutting in August did not reduce growth the following summer. Cutting in sandy substrates was minimally effective, while cutting on calcareous muds caused decreases in oxygen levels.

Also see MANIPULATION OF WATER LEVEL AND SALINITY.

GRAZING, DREDGING, AND DRAINING: Grazing, dredging, and draining are other methods that have often been used to reduce stand vigor (Howard, Rhodes and Simmers 1978). However, draining and dredging are not appropriate for use on most preserves (Osterbrock, 1984).

Grazing may trample the rhizomes and reduce vigor but the results are limited (Cross and Fleming 1989). Van Deursen and Drost (1990) found that cattle consumed 67-98% of above-ground biomass; in a four year study, they found that reed populations may reach new equilibria under grazing regimes.

MANIPULATION OF WATER LEVEL AND SALINITY: A self-regulating tide gate which reintroduced saltwater tidal action was used to help restore a diked marsh in Fairfield, Connecticut (Thomas Steinke pers. comm. 1992; Bongiorno et al. 1984). A 1-3 foot reduction in stem height resulted over each of three years . In addition to reduced height, plant density declined dramatically from 11.3 plants m-2 in 1980 to 3.3 plants/ m-2 the following year. In following years, Phragmites continued to decline, although less dramatically. In addition to the decreased height and density of the Phragmites stands, typical marsh flora including SALICORNIA, DISTICHILIS, SPARTINA ALTERNIFLORA Loisel. and S. PATENS (Aiton) Muhl. returned. Depending on topography and elevation, Phragmites was eliminated in large areas and continues to remain short and sparse in other areas through 1992. Hence, reintroduced tidal action and salinity can reduce Phragmites vigor and restore the community's integrity. This has been implemented successfully in other degraded former salt marshes in Connecticut (Rozsa, pers. comm. 1992).

Flooding can be used to control Phragmites when 3 feet of water covers the rhizome for an extended period during the growing season, usually four months (Beall 1984). However, many areas can not be flooded to such depths. Furthermore, flooding could destroy the communities or plants targeted for protection.

Open Marsh Water Management (OMWM) has been used as a method to control Phragmites. Plugging of ditches and addition of culverts to raise the soil salinities appears to have caused Phragmites die-back over the last four growing seasons at Fireplace Neck, New York (Niniviaggi, pers. comm. 1991; Rozsa, pers. comm. 1992).

Hellings and Gallagher (1992) found that Phragmites was negatively impacted by increasing salinity and increased flooding. They also found that cutting and subsequent flooding also reduced growth and survival in outdoor experiments. They suggest that Phragmites may be controlled by increasing flooding and salinity levels. Matoh, Matsushita and Takahashi (1988) also found reduction in vigor with increased salinity. However death apparently occurred only when cutting was combined with brackish flooding (Hellings and Gallagher 1992).

In Europe, episodic freshwater flooding occurring early in the growing season has been suggested as one of the reasons for reed population declines (Ostendorp 1991). McKee et al. (1989) investigated root metabolic changes due to freshwater flooding and labelled Phragmites as a flood-tolerant species.

Also see Chincoteague NWR under CHEMICALS, Wertheim NWR under BURNING, and Town of Quincy under CUTTING for additional references.

MOWING, DISKING, AND PULLING: Beall (1984) discourages mowing and disking. Mowing only affects the above ground portion of the plant, so mowing would have to occur annually. To remove the rhizome, disking could be employed. However, discing could potentially result in an increase of Phragmites since pieces of the rhizome can produce new plants. Cross and Fleming (1989) describe successful mowing regimes of several year duration during the summer (August and September) and discing in summer or fall.

In Cape May Meadows, New Jersey, a brackish to freshwater non- tidal sandy area, an attempt was made to remove rhizomes by pulling to a depth of three feet (Johnson, pers. comm. 1991). This resulted in a very sparse Phragmites stand the following year. However it was very labor-intensive (using 130 people-hours to cover a 50 ft2 patch) and could be applied best to sandy soils.

In a private yard, Phragmites was mowed and a thin layer of soil and grass seed were added. This was mowed weekly over the course of the summer. In the second summer shoots of Phragmites occurred around the edges. The rhizomes were decomposing after this treatment (M. Ailes, pers. comm. 1992).

PLASTIC: Clear plastic six-mil thick, 12 x 17 m, weighing 51.8 kg, was carried into a North Carolina marsh by air and held in place by sandbags (Boone et al. 1987, 1988). Plants were initially cut to 6-8" with a hand-pushed bush hog (Boone, pers. comm. 1991) or a weedeater with blade, with an area of 20 x 20 m taking several days to cut. The cut material was left and the plastic put over the area. The high temperatures under the plastic caused die-off of Phragmites in 3-4 days. After 8-10 weeks, the plastic deteriorated. The rhizomes appeared to have died back, but the project was of short duration and the results were not monitored the following year (Boone, pers. comm. 1991). Turner (pers. comm. 1992) noted that follow-ups in subsequent years indicated Phragmites returned but not as densely. Plastic management in each 12 x 12 m plot took an average of 53 hours, compared with 17 hours to cut and three hours to burn (Boone et al. 1987).

Clear plastic in two narrow swaths (70 m x 20 m) was placed along the edge of a tidal brackish pond after hand-cutting the Phragmites at the end of July 1991 (Anderson, pers. comm. 1992). One plot, in total sun, had a complete kill of Phragmites in 10 days, while the plot in partial shade had a partial kill. It is unknown how the plastic was kept in place or what was done with the cut material.

Clear and black plastic were used on 50' circular areas at Constitution Marsh in New York in 1990 and 1991 (Keene, pers. comm. 1991). Although there was difficulty due to tidal influence, the plastic was weighted down with rocks and appeared to kill what is under it. Runners along the edge were treated with a syringe application of Roundup in August. In November 1991, a hole cut in the middle of the black plastic provided the opportunity for cattail shoots to germinate. After the first year there was viable Phragmites in the areas covered. It appeared that the black plastic was more effective, due to the higher heat levels attained (Rod, pers. comm. 1992).

Monitoring Requirements:
Phragmites populations require close monitoring in order to determine whether they are increasing in area or not. Populations that are growing may quickly threaten or even eliminate rare elements. Monitoring provides the data needed in order to decide if control measures are necessary. If and when a control program is begun it is important to monitor targeted populations so that the program's effectiveness can be determined. If it is possible to leave untreated control areas without jeopardizing the success of the control program these should be monitored as well for comparison. It is imperative to continue monitoring even if a control program succeeds initially because Phragmites may reinvade and the sooner this is detected the easier it will be to combat.

To assess if a Phragmites colony is spreading, quantitative measurements should be made of percentage of aerial cover, stem density and culm height, especially at the periphery of the stand. Annual data should be compared to detect if the colony is expanding and the stand gaining vigor. Inventories of the vegetation in and near the colony should also be carried out in order to determine whether declines in species diversity are occurring.

In Europe, reed declines have been documented by comparing areas covered by Phragmites colonies on up-to-date maps or aerial photographs with older sources, monitoring permanent quadrats within or at the border of the reed belt and mapping the stubble fields left after die-back (Ostendorp 1989). In lakes (Stark and Dienst 1989), wooden poles 5 m apart were connected with string and the numbers of reed stalks directly below the strings were counted each year in the spring.

Monitoring Programs:
The programs listed below used various methods to control Phragmites populations and are monitoring the success of these actions including the degree of recovery of native species and the longevity of the control.

CONNECTICUT Monitoring Phragmites reduction and replacement vegetation after reintroducing tidal flow, using transects and line intercept. Contact: Charles T. Roman, William Niering, Scott Warren Dept of Botany Connecticut College New London, CT 06320

Monitoring Phragmites reaction to reintroduction of tidal flow and salinity. Contact: Tom Steinke Fairfield Conservation Commission, Independence Hall 725 Old Post Road Fairfield, CT 06430 203-256-3071

Addition of rock salt and casual observation of reduction of Phragmites height and density; also potential impact of inadvertent spill of used fryerlator oil. Contact: Robert Jontos, Jr. Land-Tech Consultants, Inc. Playhouse Corner Suite 205 Southbury, CT 06488 203-264-8300

Reintroduction of salt water into degraded former salt marshes, removal of dredge material and restoration of tidal creek in several sites in CT with transect and line intercept monitoring of results.

Contact: Ron Rozsa Long Island Sound Program Department of Environmental Protection 165 Capitol Avenue Hartford, Ct 06106 203-566-7404

Annual cutting of perimeter of one-acre stand and monitoring with aerial photos on five-year basis; herbicide application on small patch at edge of salt marsh. Contact: Beth Lapin The Nature Conservancy 55 High Street Middletown, CT 06457 203-344-0716

DELAWARE Aerial spraying of RodeoTM (glyphosate) and water management plan using stoplogs and vegetation analyses (using transects that measure density and species of plants) of replacement species. Contact: Paul Daly Bombay Hook National Wildlife Refuge RD #1 Box 147 Smyrna, DE 19977 302-653-9345

Monitoring the ecological factors (water table level, PH, salinity) governing the growth of Phragmites in 4 habitats; 1) open high salt marsh, 2) open low salt marsh, 3) brackish water impoundment, 4) freshwater impoundment. Investigating Phragmites control with glyphosate. Contact: Wayne Lehman and Bill Jones Delaware Division of Fish and Wildlife P.O. Box 1401 Dover, DE 19903 302-653-2079

LOUISIANA See RESEARCH PROGRAMS section below.

MASSACHUSETTS Cutting three times in one season, followed by opening of tidal flood gate to restore natural water regime, with initial 1 m random quadrats to measure stem density and plant height Contact: Mike Wheelwright Department of Public Works Town of Quincy Quincy, MA 02169 617-773-1380 x210 Contact: Ross Dobberteen Lelito Environmental Consultants 2 Bourbon St. #102 Peabody, MA 01960 508-535-7861

Aerial spray of RodeoTM (glyphosate) two years in a row, with winter burning; aerial photos to determine decrease in affected boundaries. Contact: Joann Healey Parker National Wildlife Refuge Northern Blvd. Plum Island Newburyport, MA 01950 508-465-5753

Clear plastic over cut bands along edge of tidal pond and cutting around perimeter of 0.25 acre stand. Contact: Jeanne Anderson Massachusetts Audubon Society South Great Road Lincoln, MA 01773 617-259-9500

Plastic mulch experiments Contact: Edward Stashko Brookline Massachusetts Conservation Commission 617-730-2088

Restoration of saltmarshes now dominated by Phragmites Contact: Larry Oliver U.S. Army Corps of Engineers New England Division 424 Trapelo Road Waltham, MA 02254 617-647-8347

MARYLAND Nassawango Creek, A Nature Conservancy Preserve RodeoTM (glyphosate) applied with backpack sprayer. Monitoring site to determine both reaction of natural plant community and evidence of Phragmites re-invasion. Contact: Wayne Klockner The Nature Conservancy Chevy Chase Center Office Building 35 Wisconsin Circle, Suite 304 Chevy Chase Maryland 20815 301-656-8073

Spraying with RodeoTM (glyphosate), burning; monitoring vegetation and invertebrates, annual expansion of Phragmites in untreated areas. Contact: Steve Ailstock Environmental Center Anne Arundel Community College Arnold, MD

NEW JERSEY Aerial spraying with RodeoTM (glyphosate), prescribed burn to remove litter, evaluating success. Contact: David Beall Edwin B. Forsythe National Wildlife Refuge Brigantine Division PO Box 72, Great Creek RD Oceanville, NJ 08231 609-652-1665

Pulling rhizomes, chemical spray; visual monitoring of presence/absence, sense of height and density. Contact: Liz Johnson The Nature Conservancy 17 Fairmont Road Pottersville, NJ 07979 908-439-3007

NEW YORK Cutting (herbicide use would require a permit), using visual assessment for success. Contact: Kathy Schneider Department of Environmental Conservation 700 Troy-Schenectady Road Lathan, NY 12110-2400 518-783-3932

Cutting and covering with plastic (black and clear); dripping herbicide in cut stems with syringe at Constitution Marsh, New York. Contact: Chuck Keene Museum of Hudson Highlands The Boulevard P.O. Box 181 Cornwall-on-Hudson, NY 12520 914-534-7781 Contact: Jim Rod National Audubon Society RFD 2, Route 9D Garrison, NY 10524 914-265-2601

Open Marsh Water Management with GIS infrared aerial photos and black and white photos (1986 & 1990) to monitor success Contact: Dominick Niniviaggi New York DEC Building 40 SUNY Stony Brook, NY 11790-2356 516-751-7900 x379 516-751-2719

Using water level manipulation and burning and visual monitoring Contact: Bob Parris Wertheim NWR P.O. Box 21 Smith Road Shirley, NY 11967 516-286-0485

PENNSYLVANIA Tinicum National Environmental Center Chemical application, 18 acre restoration with seeding Contact: Dick Nugent Tinicum Environmental Center Scott Plaza 2 Philadelphia, PA 19113 215-521-0663

OHIO Arcola Creek Wetland, Morgan Marsh Controlling Phragmites by cutting when reserves are in the aerial portion of the plant (before nutrients are translocated into the rhizomes); using aerial photos to map extent of areas, small (1 x 1 m plots) to measure stem density. Contact: Terry Seidel The Nature Conservancy Ohio Field Office 1504 West 1st Ave. Columbus, Ohio 43212 614-486-6789

VIRGINIA RodeoTM (glyphosate) application and monitoring program, with transects (mainly used for changes in vegetation and not in Phragmites) and vegetation maps on "topo" scale. Contact: Irvin Ailes Chincoteague National Wildlife Refuge Chincoteague, VA 23336 804-336-6122

Winter burns, checking progress in summer with six 400 m transects perpendicular to the shore that measure % cover and list species in 0.1 m2 plots every ten meters; success marginal. Contact: Marilyn Ailes Public Works Office Building Q29 Aegis Combat System Center Wallops Island, VA 23337 804-824-2082

VI. RESEARCH

Management Research Programs:
LOUISIANA Aerial photographs of the Mississippi River Delta indicated that different stands of Phragmites had different infrared signatures. Isozyme analyses were performed on samples from these stands in order to determine whether they differed genetically and constituted different clones. Two distinct clones were found and both differed from stands elsewhere on the Gulf coast. Additional isozymal work is planned on populations from elsewhere on the Gulf coast and, if time allows, from populations in the eastern and Great Lakes states as well

For research on population biology and control methods refer to BIOLOGICAL MONITORING PROGRAMS section.

Research Needs (General):
What are the genetics of natural populations and how do stable and invasive populations differ?

Management Research Needs:
Research on the following facets of Phragmites invasions and basic biology are needed: 1. what types and levels of disturbance and stress induce Phragmites to invade and/or dominate an area?; 2. how effective are various control programs and what conditions promote or allow Phragmites to reinvade areas from which it has been removed?; 3. if Phragmites does reinvade how long does this process take?; 4. are there ways to alleviate or mitigate for the stresses that induce the spread of Phragmites?; 5. can the use of competitive plantings of TYPHA or other desirable species be used to control Phragmites.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

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ELEMENT STEWARDSHIP ABSTRACT
for
Lonicera japonica

Japanese Honeysuckle

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The Nature Conservancy

Element Stewardship Abstract

For *Lonicera japonica*

SCIENTIFIC NAME (GNAME)
Lonicera japonica Thunb.

The common name "Japanese honeysuckle" refers to the species *Lonicera japonica* Thunb. including the more aggressive cultivar *Lonicera japonica* var. halliana, also known as Hall's honeysuckle and the less common *Lonicera japonica* var. chinensis (P.W. Wats.) Baker. The original Latin name of the species was *Nintooa japonica* (Gleason and Cronquist 1963), but the species has been referred to as *Lonicera japonica* since at least 1889 (Wood and Willis 1889).

The genus name *Lonicera* refers to German naturalist Adam Lonitzer (1528-1586), the species epithet *japonica* to Japan, and the variety name *halliana* to Dr. George Hall, who introduced the variety to the United States in 1862 (Coombes 1991).

COMMON NAME

JAPANESE HONEYSUCKLE is the name most commonly used to refer to *Lonicera japonica* and its varieties, *L. japonica* var. halliana (Hall's Japanese honeysuckle) and *L. japonica* var chinensis. Hall's Japanese Honeysuckle is more common and aggressive than the species. In old floras *Lonicera japonica* was occasionally referred to as "woodbine" (Lounsbury 1899) and "Chinese honeysuckle" (Wood and Willis 1889; probably *L. japonica* var. chinensis).

DESCRIPTION (DIAGNOSTIC CHARACTERISTICS)

Lonicera japonica is a perennial trailing or climbing woody vine of the honeysuckle family (Caprifoliaceae) that spreads by seeds, underground rhizomes, and aboveground runners (USDA 1971). It has opposite leaves that are ovate, entire (young leaves often lobed), 4-8 cm long, with a short petiole, and variable pubescence. In the southern part of the range the leaves are evergreen, while in more northern locales the leaves are semi-evergreen and fall off in midwinter (Fernald 1970). Young stems are reddish brown to light brown, usually pubescent, and about 3 mm in diameter. Older stems are glabrous, hollow, with brownish bark that peels in long strips. The woody stems are usually 2-3 m long, (less often to 10 m). *Lonicera japonica* creates dense tangled thickets by a combination of stem branching, nodal rooting, and vegetative spread from rhizomes.

Lonicera japonica (including the varieties) is easily distinguished from native honeysuckle vines by its upper leaves and by its berries. The uppermost pairs of leaves of *Lonicera japonica* are distinctly separate, while those of native honeysuckle vines are connate, or fused to form a single leaf through which the stem grows. *Lonicera japonica* has black berries, in contrast to the red to orange berries of native honeysuckle vines. The fruits are produced September through November. Each contains 2-3 ovate to oblong seeds that are 2-3 mm long, dark-brown to black, ridged on one side and flat to concave on the other.

The fragrant white (fading to yellow) flowers of *Lonicera japonica* are borne in pairs on solitary, axillary peduncles 5-10 mm long, supported by leaflike bracts. The species has white flowers tinged with pink and purple. Individual flowers are tubular, with a fused two-lipped corolla 3-4(-5) cm long, pubescent on the outside. Flowers are produced late April through July, and sometimes through October. *Lonicera japonica* var. halliana may be distinguished from the species by its pure white flowers (fading to yellow; Dirr 1983) and more vigorous growth. *Lonicera japonica* var. *chinensis* has purple, essentially glabrous leaves, red flowers, and a more limited range than the species, occurring north to New Jersey and Pennsylvania (Fernald 1970), with an outlier in southern Illinois (Mohlenbrock 1986).

This description was derived from Gleason and Cronquist (1991) and Fernald (1970). Excellent illustrations of *Lonicera japonica* are contained in USDA (1971).

STEWARDSHIP SUMMARY

Lonicera japonica invades fields, forest edges and openings, disturbed woods, and floodplains, in eastern North America, where it spreads rapidly and outcompetes native vegetation by vigorous above- and below-ground competition. Once established, the vine may literally engulf small trees and shrubs, which collapse under the weight, and few plants survive beneath the dense canopy. It has also escaped cultivation at scattered locations in California and in Hawaii where it has the potential to become a severe pest in mesic and wet forest areas.

Lonicera japonica has few natural enemies in North America and is difficult to control once established. Thus, the best and most effective control method is to prevent its establishment by surveying a site for its presence regularly and immediately destroying every plant located. Unfortunately *Lonicera japonica* is difficult to locate when small and without careful attention may go unnoticed until it is well established.

Because Japanese honeysuckle is so difficult to control once established, an appropriate control program goal is 100% kill of all plants in the target area. Removing above-ground stems by cutting pulling or burning will temporarily weaken, but not kill, *Lonicera japonica* as it will resprout from subterranean buds and roots, and from cut branchlets.

In northern states, *Lonicera japonica* retains some leaves through all or most of the winter (semi-evergreen or evergreen), when most native plants have dropped their leaves. This provides a windows of opportunity from mid-autumn through early spring when it is easier to spot and treat with herbicides, fire or other methods without damaging native species. The most effective treatment is a foliar application of glyphosate herbicide (trade names Roundup, Rodeo or Accord; 1.5 v/v), applied after native vegetation is dormant and when temperatures are near and preferably above freezing. Applications within 2 days of the first killing frost are more effective than applications later in the winter. *Lonicera japonica* is less susceptible to herbicides after the first hard frost (-4^{o}C). Combining fire and herbicides may prove to be more effective than either method by itself if late autumn or winter burns are used to reduce Japanese honeysuckle biomass and all resprouts are then treated with a foliar application of glyphosate about a month after they emerge. Prescribed burns may also be used to help prevent spread of Japanese honeysuckle because seedlings and young plants are most susceptible to fires. Soil disturbance should be avoided in infested areas to minimize germination of seed in the seedbank.

IMPACTS (THREATS POSED BY THIS SPECIES)

Lonicera japonica damages natural communities it invades by outcompeting native vegetation for both light (shoot competition [Thomas 1980, Bruner 1967]) and below-ground resources (root competition [Dillenburg et al. 1993a, 1993b, Whigham 1984]), and by changing forest structure (Sasek and Strain 1990, 1991). *Lonicera japonica* grows very rapidly, sending out numerous runners that give rise to still more runners. The vines overtop adjacent vegetation by twining about, and completely covering, small trees and shrubs. Dense Japanese honeysuckle growth can topple trees and shrubs due to its weight alone (Williams 1994, McLemore 1981). As Lonicera japonica becomes established in forest openings it forms a dense blanket that excludes most shrubs and herbs (Oosting 1956). Few tree seedlings can penetrate the mat and those that do are often quickly overgrown and bent down by the vine, and consequently die (Slezak 1976, Thomas 1980). Forests invaded by *Lonicera japonica* gradually lose their natural structure as canopy openings are invaded, and understory herbs shrubs and replacement trees suppressed and killed by thick mats of honeysuckle. This results in a simplified, increasingly open understory. *Lonicera*

japonica, in turn, becomes even more vigorous with the increased light (Thomas 1980). These openings also promote further invasion by other non-native species including aggressive vines like kudzu (*Pueraria lobata*) and English ivy (*Hedera helix*) (Miller 1985; Thomas 1980).

Shading under the extensive and rapid aerial growth of *Lonicera japonica* poses the most obvious threat to native species. However, Dillenburg et al. (1993a, 1993b) demonstrated that in the early stages of invasion, below-ground competition by *Lonicera japonica* reduced tree growth, particularly leaf size and expansion rate, significantly and more than above-ground competition. After two growing seasons, *Lonicera japonica* root competition significantly reduced growth of young sweetgum trees (*Liquidambar styraciflua*) and greatly exceeded root competition from the native vine *Parthenocissus quinquefolia* (Dillenburg et al. 1993b). The combined effects of above- and below-ground competition can suppress growth or result in direct mortality of trees and seedlings (Whigham 1984). Bruner (1967) documented that after five years of co-occurrence, 33% of yellow-poplar seedlings were dead, 22% were overwhelmed, and 45% were heavily draped with *Lonicera japonica* that germinated from seed in the first year.

Lonicera japonica has an additional competitive edge as it grows during part or all of the winter, when many native species are dormant (Carter and Teramura 1988a). This evergreen or semi-evergreen character allows *Lonicera japonica* to photosynthesize at winter temperatures and light levels. The shade it casts during early spring may inhibit ephemeral herbs that complete their life cycle in the six weeks prior to deciduous tree leaf-out.

Alteration of forest understory and overstory structure by *Lonicera japonica* may lead to a decline or alteration in songbird populations (Nyboer 1990). However, no studies have been conducted on interactions between *Lonicera japonica* and native animals, with the exception of white-tailed deer (*Odocoileus virginianus*) which favors *Lonicera japonica* leaves as food (Handley 1945, Harlow and Hooper 1971). In fact, wildlife managers in some states actively promoted growth of this aggressive vine to provide winter forage for deer (Dyess et al. 1994; Segelquist and Rogers 1975, Stransky 1984). Japanese honeysuckle foliage is most digestible and nutritious in spring, but it is still relatively high in nutritional value in winter (Blair et al 1983) when other food sources are less available to deer (Dyess et al. 1994). Seeds and leaves are eaten by cottontail rabbits, as well as birds (Dyess et al. 1994), and the tangled thickets provide cover for birds and small mammals.

Lonicera japonica is a severe threat in the southeastern and eastern states (Florida to Texas, north to Kansas, Missouri, central Illinois and New York), and a severe potential threat in northern states outside the current (1995) range. On the northern edge of the range, *Lonicera japonica* flower production is inhibited by winter temperatures (Swink and Wilhelm 1994), and the vine is thus a moderate threat. For example, in Illinois, *Lonicera japonica* is not a serious pest in the colder, northern third of the state, but is increasingly common in the central part of the state (Nyboer 1990). *Lonicera japonica* continues to spread gradually northward (Wagner 1986), possibly due to increasing cold tolerance, or to warm winters, or to other factors.

As of 1995 *Lonicera japonica* northern range was limited by winter temperatures, and its western range by drought-induced stress at the seedling stage (Sasek and Strain 1990). If atmospheric CO_2 concentrations increase as predicted, resulting in a 3^{o}C increase in average and minimum winter temperatures, the northern range of *Lonicera japonica* is predicted to shift up to 400 km north (Sasek and Strain 1990). Further westward expansion may be limited by decreased summer precipitation, although *Lonicera japonica* has improved water use efficiency and increased drought tolerance at higher CO_2 levels (Sasek and Strain 1990). *Lonicera japonica* is also predicted to become a more serious competitor

of native trees at higher CO_2 levels, as it experiences much greater growth rates at higher CO_2 levels than do native woody erect species (Sasek and Strain 1991).

Virginia and Illinois have produced honeysuckle control circulars (Williams 1994, Nyboer 1990). Minnesota ranks the species as a severe potential threat (MN DNR 1991).

GLOBAL RANGE

Lonicera japonica is native to east Asia, including Japan and Korea (Gleason and Cronquist 1991, Lee et al. 1990). From this native range it has spread to Hong Kong (Thrower 1976), England (Clapham et al. 1962), Wales (Martin 1982), Portugal (De Baceler et al. 1987), Corsica (Jeanmonod and Burdet 1992), Hawaii (Wagner et al. 1989), Brazil, (Bove 1993), Argentina (Bonaventura et al. 1991), possibly the Ukraine (Panova 1986), and the continental United States, primarily by way of horticultural introductions.

The species was introduced into the U.S. in 1806 on Long Island, NY (Leatherman 1955), and the similar but more aggressive variety halliana was introduced to the country in 1862 in Flushing, N.Y. As with many invasive species, Japanese honeysuckle initially had a very gradual rate of spread, primarily to the south and east. *Lonicera japonica* was not included in Chapman's Flora of the Southern States (1884; in Hardt 1986) but in 1889 Wood and Willis included the variety *chinensis* in their flora of the eastern United States and a decade later Britton and Brown (1898) reported that the species ranged from New York and Pennsylvania to North Carolina and West Virginia. In 1899 *Lonicera japonica* was described in a wildflower book as the most widely planted of the honeysuckles (Lounsbury 1899). *Lonicera japonica* was reported from Florida in 1903, and from Texas in 1918 (Hardt 1986). By 1912, it had "escaped from cultivation", and ranged from Connecticut to Florida (Atkinson 1912), and within a few years was identified as an invasive problem species from the Gulf of Mexico to Massachusetts, creating "a network of tangled cords that covers the ground wherever this ruthless invader gets a foot hold" (Andrews 1919).

Lonicera japonica now occurs throughout the eastern half of the United States, south of a line extending from Massachusetts west to Lake Michigan, Illinois, and Missouri, and then southwest through Texas to Mexico, an area encompassing 26 states (USDA 1971, Leatherman 1955). The northern range limit coincides with maximum 30-year winter temperatures of -25^{o}C (Sasek and Strain 1990). The area of greatest infestation is in the center of this range, where annual precipitation averages 100-120 cm, and 30 year low temperatures are -8^{o}C to -15^{o}C (Sasek and Strain 1990). *Lonicera japonica*'s range is limited to the north by severe winter temperatures, and to the west by insufficient precipitation and prolonged droughts which limit seedling establishment (Sasek and Strain 1990). At the northern edge of the range, plants have reduced growth due to a shorter growing season, and produce few or no flowers (Swink and Wilhelm 1994). *Lonicera japonica* continues to spread northward, however, possibly due to increasing cold tolerance or warmer winters (Wagner 1986). It may spread up to 400 km north if global temperature increases 3^{o}C (Sasek and Strain 1990).

Japanese honeysuckle sporadically escapes from cultivation in California where it is present in scattered locations, primarily below 1000 m elevation (Hickman 1993). It has also escaped cultivation in scattered locations in the Hawaiian islands, particularly in mesic to wet forest in Kokee State Park on Kauai and near Volcano on the island of Hawaii (Wagner et al. 1990). It apparently does not produce seed at most locations in Hawaii and will likely become a much more serious pest there if fertile strains develop. Unfortunately, most plants in an escaped population in Manoa Valley on Oahu reportedly set seed (Wagner et al. 1990). A recent report from Kauai also indicates the Japanese honeysuckle population there may be spreading and has potential to become a severe pest in the Kokee area (Flynn, personal communication).

HABITAT

Lonicera japonica is native to east Asia. In Korea, *Lonicera japonica* is part of the understory in later successional forests dominated *Carpinus cordata, Fraxinus rhynchophylla* and *Cornus controversa* (Lee et al. 1990).

In North America, *Lonicera japonica* primarily occurs in disturbed habitat, including successional fields, roadsides, forest edges, and fencerows (Williams 1994). It is common in dry-mesic to wet-mesic upland forest, floodplain forest, and southern pine stands, and particularly common in forest openings created by disturbance, such as treefall, logging, or disease. *Lonicera japonica* continues to be planted for landscape purposes in gardens and along highways.

Lonicera japonica grows most vigorously in full sun and on rich soil, but is shade and drought tolerant and therefore able to grow in a wide variety of habitats (Leatherman 1955). It develops high frequency and cover in young forests while densely shaded, mature forests support fewer, and smaller, colonies (Robertson et al. 1994). *Lonicera japonica* usually invades disturbed communities and rarely colonizes deeply shaded, mature forests unless canopy openings are created by human disturbances or natural processes (disease, wind throw, drought, etc.) (Slezak 1976; Thomas 1980). In Virginia *Lonicera japonica* quickly invaded a former forest site destroyed by avalanche (Hull and Scott 1982), and it grew vigorously in a forest opening in Arkansas (McLemore 1981). This species can persist in low numbers in relatively undisturbed forest and then "break out" following disturbances that open the canopy, e.g.; windthrow, ice storm, disease, scouring flood, or drought. Once established, *Lonicera japonica*'s dense canopy inhibits establishment of later successional species (Myster and Pickett 1992). *Lonicera japonica* rarely invades deeply shaded, mature forests unless the canopy is somehow opened (Robertson et al. 1994).

In Pennsylvania, *Lonicera japonica* is a major component of the third stage of succession in old fields, increasing after fields have been abandoned for four years (Keever 1989). In New Jersey *Lonicera japonica* invaded an oldfield 13 years after abandonment, and was present for at least 18 years (Myster and Pickett 1992). In Virginia *Lonicera japonica*, is most abundant in the piedmont and coastal plant forests (Williams 1994). In Illinois *Lonicera japonica* grows where overstory canopy provides filtered light, especially oak forests, cedar glades, and barrens, and along the banks of streams where the natural break in canopy creates a light opening (Nyboer 1990). Plants then spread into adjacent shaded forest. *Lonicera japonica* has been found on Michigan sand dunes (Wagner 1986), and persists near abandoned homesites in the Chicago region (Swink and Wilhelm 1994). In Indiana, *Lonicera japonica* is abundant in urban forest preserves, but is absent from woodlots isolated by agricultural fields and distant from urban areas (Brothers and Springarn 1992).

BIOLOGY-ECOLOGY

Lonicera japonica is a strong competitor due to wide seed dispersal, rapid growth rate, extended growing season, ability to capture resources both above- and below-ground, wide habitat adaptability, and lack of natural enemies. Some of these factors have received considerable study, while others have been given little or no attention.

Lonicera japonica blooms most prolifically in full sun (Leatherman 1955), and decreases flowering activity as light decreases; in 8% of full light no flowers are produced (Blair 1982, Robertson et al. 1994). The blooming period extends from April to December in Georgia (Andrews 1919), late May to October in Kentucky (Sather, personal communication), May to June in Illinois (Mohlenbrock 1986), and June in Michigan. Flowers open a few hours before sunset, and remain open for approximately three days

(Roberts 1979). In Wales, the majority of flowers are pollinated the day after opening by bumblebees (*Bombus lucorum* and *B. pascuorum*). Other bee species may be potential pollinators, as nectar is available to species with tongues ≥ 4 mm long (Roberts 1979). Flowers remain open at night, indicating the possibility for moth pollination (Roberts 1979). In the United States *Lonicera japonica* is probably pollinated by a variety of insects, due to its extended blooming season and wide geographical range.

Relatively few studies have documented seed production, seed viability, germination requirements, or seedling establishment.

The inconspicuous black berries contain 2-3 seeds (USDA 1971). Fruit production is much higher in full sun than in shade (average 222 vs. 11 g seeds per plant, respectively) in Texas (Halls 1977). Fruit production decreases as soil nitrogen increases (Segelquist and Rogers 1975). Seed viability is highly variable. Leatherman (1955) determined that 85% of seed were viable, and obtained 63% germination. Haywood (1994) attempted to study long-term seed viability, but seed was unsound when collected. This variation is typical of the *Lonicera* genus, which is characterized by having variable seedcoat dormancy, embryo dormancy, and/or no dormancy both within and among species (Hartmann and Kester 1968). Bruner (1967) reported rapid growth from seed in South Carolina, and Carter and Teramura (1988b) stated that *Lonicera japonica* reproduces abundantly from seed. Berries are consumed by a number of birds including robin, turkey, quail, bluebird, and goldfinch (Martin et al. 1951, Jackson and Cooper 1974), which then disseminate the seeds (Nyboer 1990).

Rate of growth from the seedling stage is not known; most researchers and nurseries propagate *Lonicera japonica* from stem cuttings, particularly the var. halliana, which forms roots "wherever the canes touch moist ground" (Hartmann and Kester 1968). Leatherman (1955) suggested that seedlings likely photosynthesize shortly after germination, due to the low food reserves in each seed. Seedlings are known to establish in shaded understories, which implies that light may not be necessary for seed germination. Seedling growth is apparently slow for the first two years (Little and Somes 1967). *Lonicera japonica* is drought sensitive, particularly at the seedling stage (Sasek and Strain 1990). Biomass appears to decline with summer drought (Faulkner et al. 1989).

Once established, *Lonicera japonica* is capable of extremely vigorous growth. In a moist bottomland forest vines overtopped a 4.5 m tree in one year (Bruner 1967), although growth rates of 1.5 m/year may be more typical (Leatherman 1955). Bell et al. (1988) recorded a maximum shoot elongation of 4.6 mm/day in Maryland. This rapid growth rate allows *Lonicera japonica* to outcompete native trees; In one year, *Lonicera japonica* overtopped three-year old sweetgum (*Liquidambar styraciflua*) trees (Dillenburg et al. 1993a). *Lonicera japonica* vines spread both vertically and horizontally (Williams 1994).

Individual vines have numerous long vegetative runners; the combined length of lateral and sublateral runners from one sprout in one year exceeded 15 m (Little 1961). Vines in high light have been recorded with ≥ 7 runners, each over 60 cm long (Slezak 1976). The runners develop roots at nodes in contact with soil, and thus form dense mats. If the above ground parts are severed, each new root system develops into a separate, but genetically identical, plant. The root system has been recorded at up to 3 m across and 1 m deep (Leatherman 1955). Roots are highly competitive with native species (Carter and Teramura 1988a, 1988b).

Lonicera japonica's climbing architecture is adapted to early successional forest (Carter and Teramura 1988a), which typically has small diameter trees and a dense understory. The vines twine about vegetation in closely spaced spirals, thus creating a strong support structure that permits them to remain upright after the host tree is killed. Individual shoots may be very long, but due to the numerous spirals, a vine's height above the ground may not be great. Japanese honeysuckle vines typically climb stems <15

cm diameter (Andrews 1919). Larger stems are rarely used as hosts, as *Lonicera japonica* cannot climb wide boles unless small branches or other vines are present to provide support (Andrews 1919).

Longevity of individual plants has not been measured. As *Lonicera japonica* reproduces vegetatively, life span of individual stems or roots is not a measure of genet longevity.

Lonicera japonica is adapted to growing in 25-100% of full light, and grows vigorously in full sun. Stem density is greatest in full light, and decreases with increasing shade: In Pennsylvania, Robertson et al. (1994) recorded mean stem densities of 25.4/m^2 in an oldfield, 15/m^2 in a thicket, 13.6/m^2 in a woodland, and 8.6/m^2 and 8.1/m^2 in riparian forest and upland mature forest, respectively. Stem density was similarly high in both oak and maple associations (Robertson et al. 1994). In Washington D.C. *Lonicera japonica* produced good growth at 47% of full sun (Thomas 1980). In this location winter light measurements in closed forest range from 49% to 86% of full light. *Lonicera japonica* is able to persist in deciduous forest at low summer light intensities, and put on growth in winter, or when canopy gaps occur.

Lonicera japonica tolerates low light conditions, and may spread vegetatively, but rarely produces flowers or fruits under low light (25% of full light; Robertson et al. 1994). Honeysuckle plants are severely stressed in low light, and lose substantial amounts of aboveground biomass after long periods of low light: Blair (1982) reported that leaf biomass declined 94% after two years at very low light (8% of full sunlight), and plants suffered stem dieback and leaf loss, but did not die. Leatherman (1955) similarly reported that half of her experimental cuttings survived at 10% of full light, and the majority survived at 25% of full light. Once established, *Lonicera japonica* can persist at low light levels with little or even negative growth, and respond to winter sun and canopy openings with more vigorous growth (Carter and Teramura 1988a). Interestingly, as a twining vine *Lonicera japonica* is less physiologically adapted to low light levels than native tendril climbing vines, such as *Parthenocissus quinquefolia* (Carter and Teramura 1988a), which can rapidly climb up supporting trees to reach higher light levels.

Lonicera japonica has a long photosynthetic season due to its evergreen nature and its ability to grow in cold temperatures. *Lonicera japonica* shoots grow until the first frost, apparently because they are able to lignify rapidly, which gives them greater cold-hardiness than more tender species (Panova 1986). In southern locales *Lonicera japonica* retains its old leaves over winter (Schierenbeck and Marshall 1993) permitting year-round photosynthesis. In these areas, *Lonicera japonica* leaves are physiologically active during the winter and can grow when minimum predawn air temperatures are at or above -3^{o}C. At these temperatures, net photosynthetic rates on warm winter days are comparable to those in summer (Carter and Teramura 1988b). The presence of old leaves during the period of new-leaf formation (January - March), combined with the higher photosynthetic rates in new leaves, increases total carbon gain and thereby growth rate and invasiveness (Schierenbeck and Marshall 1993). Shoots produce an early burst of growth in spring, before native species leaf out (Dillenburg et al. 1993a).

In the northern states *Lonicera japonica* retains its leaves until late December or January (semi-evergreen), while native trees lose their leaves in October. The vines continue to photosynthesize for several months after overstory trees have dropped their leaves, which allows them to maintain presence in low light communities (Robertson et al. 1994, Carter and Teramura 1988a). In Maryland, *Lonicera japonica* is physiologically active for 9 weeks after native deciduous vines have gone dormant (*Parthenocissus quinquefolia* and *Vitis vulpina*) (Bell et al. 1988). In spring *Lonicera japonica* begins growth some two months earlier than native species, from the period when temperatures are above freezing, until deciduous trees produce new leaves (Hardt 1986). Thomas (1980) calculated that in the Washington D.C. area there are an average of 52 days/year between first and last frost when temperature and light conditions in closed canopy forests are adequate for *Lonicera japonica* photosynthesis.

Lonicera japonica leaves are unaffected by minimum temperatures of -0.6°C, and continue to function, at lower efficiency, until temperatures drop below -3.0°C (Carter and Teramura 1988b). The relatively high rate of leaf gas exchange in autumn, winter, and spring indicates that carbon gain during this period may contribute substantially to *Lonicera japonica*'s rapid growth rate. Although *Lonicera japonica* leaves photosynthesize in winter, the lowered activity reduces effectiveness of foliar herbicides applied after the first frost (Regehr and Frey 1988). In Tennessee, defoliation occurred at -26°C, but plants were not apparently killed (Faulkner et al. 1989).

Lonicera japonica is spread primarily by birds, which consume the fruits and pass the seeds, carrying them from landscape plantings to natural areas and disseminating them in forest openings and disturbance zones. Once established, *Lonicera japonica* can develop a large seedbank that germinates when the soil is disturbed. This attribute led to a dramatic increase in southern states in the 1950's, when timber companies promoted intensive site preparations (discing, burning, bush-hogging) to facilitate tree regeneration after clearcutting (Prine and Starr 1971). Honeysuckle grew so rapidly from both seedbank and top-killed plants that tree seedlings were outcompeted (Prine and Starr 1971). Consequently, forest companies have conducted much of the research to identify herbicides that control *Lonicera japonica* (Edwards and Gonzalez 1986, McLemore 1981).

Originally introduced as a landscape plant, *Lonicera japonica* is still considered a desirable species by some landscapers, highway designers, and wildlife managers. Wildlife managers promote increased growth of *Lonicera japonica* to provide winter forage, particularly for deer (Dyess et al. 1994). Landscape architects plant *Lonicera japonica* for its fragrant flowers and rapid growth (Georges et al. 1993, Nam and Kwack 1992, Bradshaw 1991), and highway designers use the plant for erosion control and bank stabilization (Stadtherr 1982, Hardt 1986).

In China *Lonicera japonica* is a valued medicinal herb that contains anti-complementary polysaccharides (Shin et al. 1992). Polyphenolic compounds isolated from *Lonicera japonica* inhibit human platelet activation and provide protection from cellular injury, and thus help maintain human vascular homeostasis (Chang and Hsu 1992). Aden I, a mixture of *Lonicera japonica* flower buds and parts of other plants, has both antibiotic and antiviral effects, comparable to results produced by standard antibiotics (Houghton et al. 1993). Leaves and flowers are used in the therapy of chicken pox (Luo 1989), and may be used as a food additive to increase productivity of broiler chickens in Korea (Cho 1992).

CONTROL

Prevention/Legislation

In Illinois, the sale and distribution of *Lonicera japonica* is prohibited under the Illinois Exotic Weed Act (1988).

Biological control

The only technique that could control *Lonicera japonica* on a regional scale is biological control, but as of 1997 no formal program had been established. Interestingly, in China, a biocontrol program using *Sclerodermus* spp. was established to protect *Lonicera japonica* from the cerambycid *Xylotrechus grayi* (Tian et al. 1986). *Lonicera japonica* is utilized by some insects in its native habitat and the U.S. In Sichuan, China, *Lonicera japonica* growing near cottonfields is an early spring host for aphids that feed on crops later in the growing season (Li and Wen 1988). In North Carolina, the two-spotted spider mite (*Tetranychus urticae*), an agricultural pest in corn and peanut fields, overwinters on *Lonicera japonica* growing on field margins (Margolies and Kennedy 1985). *Lonicera japonica* is also a suitable host for the

cicadellid cotton pest (*Empoasca biguttula*) in Hunan, China (Chen et al. 1987), and may be a host for tobacco leaf curl virus, which was detected in the horticultural variety *Lonicera japonica* var. aureo-reticulata (Macintosh et al. 1992). The vine is susceptible to honeysuckle latent virus (Brunt et al. 1980), and to tobacco leaf curl bigeminivirus (TLCV) transmitted by whiteflies (MacIntosh et al. 1992).

Burning

Fire removes above-ground vegetation, and reduces new growth, but does not kill most *Lonicera japonica* roots, and surviving roots produce new sprouts that return to pre-burn levels of cover within a few years (Oosting and Livingstone 1964). A single spring fire reduced Japanese honeysuckle cover 50% in Illinois (Nyboer 1990). Two sequential fires topkilled *Lonicera japonica*, reducing crown volume (m^3/ha) by 80%, but new growth from root sprouts maintained *Lonicera japonica* as a dominant groundcover species in North Carolina (Barden and Matthews 1980). In Virginia burning is used to reduce abundance of *Lonicera japonica*, and inhibit spread for 1-2 growing seasons (Williams 1994). Prescribed burning significantly reduced *Lonicera japonica* biomass in Tennessee, by 93% when burned in October, and by 59% when burned January - March (Faulkner et al. 1989). Top-killed honeysuckle resprouted in spring (March - April), apparently from roots or runners just below the unburned litter layer. In this situation, follow-up application of 2% glyphosate in spring, 2 - 6 months after burning, appeared to control honeysuckle better on unburned than burned plots, possibly because tall herbaceous vegetation that grew up after the fire on the burned plots intercepted the herbicide before it could reach the shorter honeysuckle resprouts (Faulkner et al. 1989). In Texas, burning in February removed all above ground foliage, but did not kill plants (Stransky 1984). However, burned plants produced fewer and shorter runners than unburned plants, and fire therefore reduced total vegetative growth (Stransky 1984).

Combining fire and herbicides may prove to be more effective than either method by itself if late autumn or winter burns are used to reduce Japanese honeysuckle biomass when most native species are dormant and all resprouts are then treated with a foliar application of glyphosate about a month after they emerge (Johnson, personal communication). Prescribed burns may also be used to help prevent spread of Japanese honeysuckle because seedlings and young plants are most susceptible to fires (Richter, personal communication) .

Chemical

The evergreen and semi-evergreen nature of *Lonicera japonica* allows application of herbicides when many native species are dormant. Timing of application is critical to effectiveness; in general, applying herbicide shortly after the first killing frost, and before the first hard frost (ca. -4.0^{o}C) is most effective. Herbicide effectiveness can be reduced in areas where large stones or fallen logs protect root crowns from soil-active herbicides (Miller 1985) or where overtopping vegetation intercepts foliar herbicides (Faulkner et al. 1989). Many herbicides produce a short-term reduction in foliar coverage, but do not kill the plant and buds left undamaged by the herbicide can produce new growth that often exceeds growth from untreated plants within a year (Prine and Starr 1971). A foliar application of 1.5% glyphosate shortly after the first frost appears to be the most effective treatment. Treated plants should be re-examined at the end of the second growing season, as plants can recover from herbicide application (McLemore 1981).

GLYPHOSATE (brand names include: Roundup, Rodeo, Accord)

• October applications of 0.75% and 1.5% v/v glyphosate killed 99% of treated *Lonicera japonica* within six months in Delaware, and few plants resprouted within 30 months of treatment (Regehr and Frey 1988). The two application rates were equally effective. The same experiment conducted in December resulted in 68% mortality at the lower concentration, and 86% mortality at the higher concentration, and

regrowth from buds was much greater than in plants treated in October. The authors concluded that timing of application was critical; applying glyphosate within 2 days of the first frost resulted in very high mortality. After the first frost, higher concentrations of glyphosate were needed to achieve somewhat lower mortality. Defoliation after glyphosate treatment was very slow; only 5-15% of leaves were gone one month after treatment, although 78-90% of stems were dead.

• A mid-August application of 2.2 kg/ha glyphosate controlled 83% of actively growing *Lonicera japonica* in North Carolina; control was reduced under drought conditions (Younce and Skroch 1989). Glyphosate (2 lb active ingredient/gal) at 1 to 1.5 gallons/acre controlled "most" *Lonicera japonica* in Alabama (Miller 1985).

• In Arkansas, a 6.72 kg active ingredient/ha application resulted in 85% control after one growing season, and 80% control after two growing seasons (McLemore 1981). Lower application rates were less effective two years after treatment.

• Effectiveness of glyphosate increased linearly with increasing herbicide concentration (0.48-4.8% w/w), but no concentration gave complete control with one application; repeated treatment with 4.8% glyphosate produced complete shoot necrosis in only 50% of plants (Ahrens and Pill 1985).

• Efficacy of glyphosate was not increased by addition of surfactants (Younce and Skroch 1989, Regehr and Frey 1988).

DICHLORPROP + 2,4-D

• Dichlorprop mixed with 2,4-D at 3.6 grams active ingredient/liter (1.5% v/v) resulted in 94% mortality when applied within two days of the first frost in October, but only 46% mortality when applied in December. Thirty months after treatment, 14% of stems sprayed in October resprouted, and 75% of stems sprayed in December produced new growth (Regehr and Frey 1988).

2,4-D + PICLORAM (brand names include: Tordon)

• Picloram is a restricted use soil-active herbicide that is prohibited in California, as it is relatively persistent and subject to leaching.

• Tordon 101 (4:1 2,4-D amine + picloram, at 1 to 2 gal/acre) "reduced existing honeysuckle to a few surviving crowns" (Miller 1985). Tordon 10K at 50 lb/acre had similar effectiveness (Miller 1985).

• Tordon 101 at 10 gal acre reduced foliage by 72.5% one year after treatment; a second application of Tordon 101 reduced foliage by a total of 90% one year after re-treatment (Prine and Starr 1971)

• A foliar spray of Tordon 101 at 2.8-8.4 kg/ha gave 84-94% control in a pine stand (McLemore 1982), similar to control provided by amitrole at 2.24 and 4.48 kg/ha. (McLemore 1982).

TEBUTHIURON (brand names include: Spike)

• Spike 80W (80% tebuthiuron) and Spike 20p (20% tebuthiuron) provided very effective control when applied at 4-5 lbs active ingredient/acre, "resulting in essentially bare plots with yellowing sprigs of vegetation" (Miller 1985).

DICAMBA (brand names include: Banvel, Brushkiller)

• Banvel 720 (2 lb 2,4-D and 1 lb dicamba) was very effective when applied at 4 gal/acre, but had only partial effectiveness at 3 gallons/acre (Miller 1985).

• Lower rates of Dicamba, as in Brushkiller 4-41 and 10-51, resulted in limited or no mortality (Miller 1985). In fact, *Lonicera japonica* growth was stimulated by application of Brushkiller 10-51 (Miller 1985).

SULFOMETURON (brand names include: Oust)

• A February application of sulfometuron methyl in South Carolina at .25 lb/acre active ingredient, applied when vegetation is less than 30-45 cm high, is recommended for control of *Lonicera japonica* in loblolly pine stands (Michael 1985).

• In Georgia, *Lonicera japonica* was not controlled by a late application of Sulfometuron applied at 3 oz/acre (Withrow et al. 1983)

• *Lonicera japonica* was almost completely killed (99% mortality) by a May application of 2 oz metsulfuron-methyl + 0.25% surfactant in central Georgia (Edwards and Gonzalez 1986)

INEFFECTIVE

• In Illinois, herbicides that are not used by the Department of Conservation due to ineffectiveness or environmental persistence are: picloram; amitrole; aminotriazolel atrazine; dicamba; dicamba + 2,4-D; 2,4-D; DPX 5648; fenac; fenuron; simazine; and triclopyr (brand names for triclopyr include Garlon 3A, Garlon 4 and Brush-B-Gone) (Nyboer 1990).

• Hexazinone at 2.24 and 6.72 kg Active ingredient/ha was ineffective (McLemore 1981), as was application at 1 or 2 lb active ingredient/acre (Michael 1985). Hexazinone pellets at 8 lb active ingredient/acre reduced *Lonicera japonica* cover from 100% to 25% cover after three years, while a 2 lb/acre rate resulted in a decrease in cover from 100% to 52% over the same time period (Michael 1984).

• Oryzalin is apparently ineffective, as it is recommended for use in controlling weeds that threaten *Lonicera japonica* planted as a groundcover (Bowman 1983)

• Brushkiller 10-51 at 1.5 gal/acre "encouraged" growth of *Lonicera japonica* (Miller 1985). Brushkiller 170 resulted in a 45% decrease in foliar cover one year after June treatment (Prine and Starr 1971).

• June application of 2,4-D (4 lb active ingredient/acre at 10 gal/acre) increased foliar growth of *Lonicera japonica* by 48% one year after treatment (control plants increased by 0.9%) (Prine and Starr 1971).

• June application of Banvel resulted in increased foliar growth one year after treatment (Prine and Starr 1971).

• Triclopyr in both ester and salt formulations (3 and 4lb/gal, respectively) and as an ester combined with 2,4-D (1 and 2lb/gal respectively) failed to control *Lonicera japonica* one year after treatment (Dreyer 1988). However, in Illinois the latter formulation is reputedly effective (Nyboer 1990).

Mowing, Discing and Pulling

Removing the above-ground portion of *Lonicera japonica* reduces current-year growth but does not kill the plant, and generally stimulates dense regrowth. Cut material can take root and should therefore be removed from the site (not practical with most infestations).

Mowing is an ineffective control method, stimulating growth and encouraging formation of dense, albeit shorter, mats. Plants mowed in February formed a dense, 20 cm tall mat within two months, growing from cut stems and rooting from severed runners; by the following November (21 months later) mowed plants were 60 cm high (Stransky 1984). Twice-yearly mowing in Virginia slowed vegetative spread but increased stem density (Williams 1994).

Bush-hogging is an ineffective control, as *Lonicera japonica* re-invades within one growing season (McLemore 1985).

Discing is apparently an effective control method: McLemore (1985) reported that "control of the honeysuckle was still effective after two years". Discing depth was not indicated. Discing is a highly destructive procedure that destroys native groundlayer species, and may stimulate *Lonicera japonica* seed bank germination.

Hand-pulling is a time-consuming procedure with limited effectiveness, as the entire plant (roots and shoots) must be removed. Pulling may be a practical method to remove small patches of seedlings.

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Chemical Ecology of the Southern Pine Beetle *Dendroctonus frontalis* Zimmermann (Coleoptera:Scolytidae)

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Introduction

The southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann (Coleoptera: Scolytidae), is considered to be the most important cause of damage and mortality to pine trees in the southeastern United States (Drooz 1985). Over the last several decades, entomologists have striven to unlock the secrets that allow this native beetle to rise up in epidemic proportions that lead to such vast tree mortality. It is now well known that bark beetles possess elaborate semiochemical communication systems which they use to orientate to host material to feed, mate, and reproduce. Many detailed reviews have been provided in this area (Birch 1978, 1984; Borden 1974, 1977, 1982, 1984, 1985, 1989; Brand et al. 1979; Byers 1989; Geizler and Gara 1978; Geizler et al. 1980; Renwick and Vité 1970, 1980; Rudinsky and Ryker 1977; Ryker 1984; Smith et al. 1993; Vité and Francke 1976; Wood 1970, 1973, 1982; Wood and Bedard 1977). The chemical ecology of SPB involves a complex host of beetle- and host-produced compounds. Scientists are continually revealing the once hidden nature of these compounds and their role in insect ecology, but far more important, their significance in manipulating insect behavior. The broader aspects of SPB chemical ecology and implications for bark beetle management are addressed.

Semiochemical Communication System

Semiochemicals are natural compounds produced and released by individuals of a species which elicit a behavioral response in members of the same or different species (Nordlund 1981). Semiochemicals which are used in intraspecific communication are referred to as pheromones. Behavioral responses to pheromones include searching for mates by one sex (e.g., sex pheromones), aggregation of both sexes at a host plant (e.g., attractant or aggregation pheromones), and dispersal of both sexes away from a specific area (e.g., inhibitor or antiaggregation pheromones). Semiochemicals used in interspecific communication are referred to as kairomones when the species receiving the chemical message benefits and allomones when the emitter of the chemical message benefits at the expense of the receiver. There is considerable overlap with regards to the functions of a compound, i.e., the same compound may serve both intra- and interspecific functions. For example, frontalin serves as an pheromone to SPB and a kairomone to its natural enemy, *Thanasimus dubius* (Fabricius) (Vité and Williamson 1970).
A series of studies conducted at the Boyce Thompson Institute for Plant Research provided the foundation by which the semiochemical system of SPB was first described (Coster 1970; Coster

and Gara 1968; Gara 1967; Gara and Coster 1968; Renwick 1970; Renwick and Vité 1969, 1970; Vité and Crozier 1968; Vité and Renwick 1968) and later revised (Vité and Francke 1976). Recently, Smith et al. (1993) presented an extensive historical review of research on the semiochemical communication system of SPB and other members of the southern pine bark beetle guild. Although several host- and beetle-associated chemicals have been found to be produced and/or utilized by SPB as part of its communication system, behavioral responses of this beetle have only been determined for a few of these compounds.

Chemical Structure, Blends and Concentration in Species Specificity

The activity of a semiochemical is dependent on many factors including its size, shape, functional groups, degree of saturation and chirality (Tumlinson and Teal 1987). Small molecules are used when a fast response is required (e.g., alarm pheromones), while large compounds, which tend to be less volatile, are used when long, extended exposure is required (e.g., sex, aggregation, and antiaggregation pheromones). Although the structure of pheromones differs greatly between insect orders and families, generally compounds are of similar structural types within genera as seen with terpene pheromones of *Ips* and *Dendroctonus* bark beetles. The position, number, and geometry of double bonds and functional groups are also important with regard to the activity of compounds. Payne et al. (1988), evaluating the antennal olfactory and behavioral response of SPB to different frontalin analogs, showed that response to frontalin was significantly greater than to any of the analogs. Chirality, in turn, imparts a greater degree of specificity to a species' pheromone system. Silverstein (1979) described nine possible categories of behavioral response to enantiomers or diastereomers. At least two of these categories have evolved as part of the SPB semiochemical-based system. For example, SPB produce both enantiomers of frontalin, but is significantly more attracted to ()-frontalin than to the (+)-antipode (Payne et al. 1982). On the other hand, Vité et al. (1985) showed that (+)-*endo*-brevicomin significantly enhanced attraction of SPB to frontalure, whereas ()-*endo*-brevicomin inhibited response. Thus, one enantiomer may be active and the other inactive or each enantiomer may elicit different responses. Seybold (1993) provided an extensive review on the roles of chirality in olfactory-directed behavior.

Just after the discovery of the first pheromone, bombykol, from the silkworm moth, *Bombyx mori* (L.)., it was generally thought that each insect species produced and responded to a single pheromone (Karlson and Butenandt 1959). However, *Ips paraconfusus* was later found to produce and respond to a blend of three pheromones (e.g., (S)-()-ipsenol, (S)-(+)-ipsdienol, and (S)-()-cis-verbenol) (Silverstein et al. 1966). It has since been discovered that most insects produce multicomponent blends of pheromones and that the single component system is the exception rather than the rule. The blend of pheromones is important because some or all components may act as synergists; individually they elicit little or no attractiveness, but together they are highly attractive. The pheromone blend of *I. paraconfusus* is one example. Another example is the SPB attractant blend of frontalin, *trans*-verbenol, turpentine (containing α-Pinene and other monoterpenes), verbenone, and (+)-*endo*-brevicomin. Individual components of a blend may also function in concert to maximize steps in a behavioral sequence as has been found in several Lepidoptera species (Baker and Carde 1979, Linn et al. 1984, Teal et al. 1986). Blends and component ratios within blends play important roles in maintaining or increasing reproductive isolation of closely related species or reducing competition in sympatric species. A species may release a component which is inactive to conspecifics, but inhibitory to related species (Tumlinson and Teal 1987). On the other hand, a component, essential to reproductive

behavior in the releasing species, may also be inhibitory to members of related species. Finally, two species may produce different component ratios of the same chemicals.

Mechanism of Host Tree Colonization by SPB

A summary of known or speculated biosynthetic pathways and responses to some of the most studied semiochemicals are discussed below in relation to their respective roles within an actively expanding infestation.

Initial Attack

Upon landing on a tree, "pioneer" females bite into the bark. If the host is found to be suitable, the females begin releasing the primary aggregation pheromone, frontalin, and the synergist *trans*-verbenol (Fig. 1). At the same time, females release small quantities of Verbenone and *endo*-Brevicomin, both serving as synergists to enhance the attractiveness of frontalin. These compounds, in combination with host volatiles, primarily α-Pinene, stimulate mass aggregation of conspecifics (predominantly males) to the host (Renwick and Vité 1969, Rudinsky 1973) and are described in greater detail below.

α-Pinene - As the pioneer beetles begin to invade the host, conductive phloem tissues are cut and copious amounts of oleoresin exude from these wounds. The monoterpine α-pinene is the major component in the resin of most *Pinus spp*. (Mirov 1961) and serves as one of the more important host-tree odors in the behavioral chemical complex of SPB (Renwick and Vité 1969). Although, α-Pinene alone has not been shown to be attractive to field populations (Payne et al. 1978), it does synergize the attractiveness of frontalin (Kinzer et al. 1969). In combination with frontalin, α-Pinene appears to function as a kairomone arrestant; whereby, the pheromone draws beetles to the tree and the kairomone arrests their flight so they land (Renwick and Vité 1970; Payne 1980). In laboratory studies, α-Pinene also causes arrestment of walking beetles (McCarty et al. 1980, Payne 1979).

Frontalin - Found in the hindguts of newly emerged SPB females (Coster and Vité 1972), is a primary aggregation pheromone produced by several *Dendroctonus* species including SPB. It is most likelyreleased by flatulation or in frass when females land on a tree and have determined it to be a suitable host. Frontalin likely plays a dual role, as sex pheromone to males (McCarty et al. 1980) and aggregation pheromone to both sexes, functioning in close-range communication, to bring individual beetles together in sufficient numbers to overcome host tree defenses (Johnson and Coster 1978, Payne et al. 1978). The natural enemy, *Thanasimus dubius*, responds to frontalin as a kairomone, thereby allowing the predator to find its prey (Vité and Williamson 1970).

trans-Verbenol - The production of this compound results from the oxidation of □-Pinene upon consumption of phloem material or exposure to vapors while in the host (Hughes 1973, 1975; Renwick et al. 1973), and is found in the hindgut of newly emerged female SPB (Renwick 1967). *trans*-Verbenol is also produced outside the beetle by the autoxidation of α-Pinene upon exposure to air (Hughes 1975, Hunt et al. 1989, Moore et al. 1956). This may explain why *trans*-verbenol can substitute for α-Pinene as a synergist for the pheromone frontalin (Kinzer et al. 1969; Payne et al. 1978; Renwick and Vité 1969, 1970). *trans*-Verbenol is also reported to be metabolized from α-Pinene internally by bacteria in the beetle's gut (Brand et al. 1975) and

externally by other microbial activity (Prema and Bhattacharyya 1962). As with α-Pinene, *trans*-verbenol alone is unattractive to walking and flying beetles (Vité and Crozier 1968).

Verbenone - During initial attack, verbenone is released by females in small quantities and acts as a synergist to enhance the attractiveness of frontalin. A multifunctional pheromone, verbenone is produced predominantly by male SPB (Renwick 1967) and other scolytid species (Borden 1985). The SPB derives verbenone from α-Pinene upon the oxidation of *trans*-verbenol (Hughes, 1973, 1975). This compound is also produced outside the beetle in two ways. One is by the autoxidation of *trans*-verbenol in the presence of air (Hunt et al. 1989, Moore et al. 1956). A second external source of verbenone is the symbiotic fungi introduced into the host tree by SPB (Brand et al. 1976). Verbenone is understood to be a multi-functional population regulator (Renwick and Vité 1980, Rudinsky 1973).

Mass Attack

During mass attack, arriving males land on the host, locate the entrance hole of single females and begin to release frontalin, *endo*-brevicomin, and verbenone in low concentrations (Fig. 2). The resulting aggregation, along with the introduction of symbiotic fungi, enables SPB to successfully attack a host tree and produce brood which emerge to attack other trees.

Frontalin - Females continue to produce large amounts of frontalin. Males have also been found to produce frontalin (Rudinsky et al. 1974), where it is used in short range communication, frontalin acts to reduce rivalry fighting and competition with other males.

endo-Brevicomin - Synthesized by male SPB in very small quantities. (+)-*endo*-brevicomin is released by males during mass attack in low concentrations which functions to enhance the attractiveness of frontalin and host volatiles.

Verbenone - During mass attack verbenone is released primarily by males in low concentrations where it acts to balance the sex ratio of beetles attracted to the host by enhancing the attractiveness of aggregation pheromones to females (Billings 1985, Rudinsky et al. 1974).
trans-Verbenol - As mentioned previously, females produce large amounts of *trans*-Verbenol during initial attack. After 48 hours of feeding, the level of *trans*-verbenol declines significantly(Coster and Vité1972).

α-Pinene - As attacks increase over the bole of the tree the primary host attractant α-Pinene is still being produced in large quantities.

Switching of Attack

As the population of attacking beetles increases, the concentration of verbenone and *endo*-brevicomin released by males also increases. At some unknown threshold, these compounds begin to inhibit beetle response to the aggregation pheromones and cause arriving beetles to switch their attack to neighboring trees (Payne et al. 1978, Rudinsky 1973, Rudinsky et al. 1974, Vité and Renwick 1971) (Fig. 3). It has been suggested that the switching of mass attack from one host tree to a neighboring tree may be the result of both the cessation of release of attractive compounds (frontalin and α-Pinene) and the increased concentration of inhibitor pheromones

(verbenone and *endo*-brevicomin) released from the tree as was found for *Ips typographus* (L.) (Schlyter et al. 1987, 1989).

Verbenone - At the height of mass attack (3 to 5 days after initial attack) large numbers of males release high concentrations of verbenone which inhibit the response of both sexes to frontalin and causes a significant drop in the number of arriving beetles (McCarty et al. 1980, Payne et al. 1978, Renwick and Vité 1969). Ryker and Yandell (1983) determined for *D. ponderosae* that verbenone must exceed the level of *trans*-verbenol (the primary aggregation pheromone of this species) by approximately 15 percent before it would exert its antiaggregative properties. It is unknown if such a verbenone threshold level is required to inhibit SPB response to frontalin.

endo-Brevicomin - Vité et al. (1985) demonstrated that (-) *endo*-brevicomin significantly reduced beetle response and was more inhibitory than racemic (equal proportions of + and -) *endo*-brevicomin. Racemic *endo*-brevicomin was previously demonstrated to inhibit the aggregation of both male and female SPB to attractive trees and thus switch the mass attack to new host trees (Payne et al. 1978, Vité and Renwick 1971).

Behavioral Chemicals and the Management of Bark Beetles

The history of methods used to manipulate or control SPB are varied and imaginative (Billings 1980). Some of the earliest tactics included rapid conversion of infested material into lumber (e.g., salvage) and burning the slabs (Hopkins 1909, 1911); immersing unbarked logs in water; and exposing unsalvageable infested trees to solar heating (e.g. cut-and-leave) (St. George and Beal 1929). Some of these methods, i.e. salvage and cut-and-leave, are still used today. Other treatments, more recently evaluated, include the use of pesticides, the application of mechanical and silvicultural controls, and the use of behavioral chemicals. The use of behavioral chemicals is summarized below.

There is extensive literature regarding the use of semiochemicals in the management of insect pests (Beroza 1970, 1976; Birch 1974; Borden 1989, 1993; Mitchell 1981; Wood 1982,). Borden (1989) described five principal means by which semiochemicals can influence the population dynamics of bark beetles: mediation of aggregation and mass attack on new hosts; cessation of aggregation and shifting of attack to an unexploited region of the host or to new hosts; induction of aggregation by species that compete for the same host resource; inhibition of aggregation and attack by species that compete for the same resource; and mediation of host finding by commensal and entomophagous insects. The author listed six fundamental strategies for potential pest management of scolytids, including:

1. Prevention of Aggregation Pheromone Production - For the SPB, examples of Strategy 1 have involved removing sources of attraction (e.g. cut-and-leave or salvage) to disrupt aggregation (Swain and Remion 1981), or cause the tree to become toxic to the beetle (e.g., pesticides) (Berisford et al. 1981).

2. Disruption of Olfactory Perception - Although, Strategy 2 has not been tested in the field, electrophysiological evidence (Payne and Dickens 1976) and behavioral data (Borden 1967) indicate that sensory adaptation or habituation occurs in pheromone-saturated environments.

3. Exploitation of Semiochemical-based Secondary Attraction (Monitoring) - Examples of Strategy 3 tested to monitor or control SPB include: use of frontalin and turpentine-baited traps to determine predator : prey (*Thanasimus dubius* : SPB) ratios for predicting regional SPB population trends (Billings 1988); the trap tree method (Vité 1970); and deployment of elution devices containing frontalure (1:2 mixture of frontalin and α-Pinene) on all non-host and host brood trees within an SPB infestation in order to draw beetles away from the active head (Richerson et al. 1980).

4. Exploitation of Repellent Allomones - A promising example of Strategy 4 involves the recent discovery that 4-allylanisole, a host-produced compound, repelled several bark beetle species from the allomone source in laboratory bioassays and significantly reduced capture of both sexes of SPB in attractant-baited traps in the field (Hayes et al. 1994). In addition, SPB may be repelled by a unknown compound released by I. grandicollis (Birch et al. 1980, Svihra et al. 1980), however this phenomena is in need of further study.

5. Exploitation of the Kairomonal Response by Entomophagous Insects - In the case of Strategy 5, several natural enemies of SPB have demonstrated response to kairomones emitted from the beetles or associated fungi, including: the clerid, *Thanasimus dubius,* to the aggregating beetle pheromone, frontalin (Vité and Williamson 1970); the predatory fly, *Medetera bistriata*, to the semiochemicals released from of the associated bark beetle (e.g., SPB and I. grandicollis) infested logs (Williamson 1971); the parasitoid, *Dinotiscus dendroctoni* to a blend of compounds collected from beetle-infested trees (Salom et al. 1991); and numerous species whose arrival coincide with various stages of beetle attack and brood development (Camors and Payne 1973, Dixon and Payne 1980).

6. Exploitation of Antiaggregation Pheromones - Recently, Strategy 6, i.e., exploitation of inhibitor or antiaggregation pheromones, has demonstrated the greatest potential for use in the control of the SPB. Both *endo*-brevicomin and verbenone each have been shown to significantly reduce capture of SPB in attractant-baited traps; however, combining the two compounds did not significantly reduce SPB capture over the reduction obtained with either inhibitor alone (Payne et al. 1978, Salom et al. 1992). Field tests of a 1:1 mixture of brevicomin isomers and verbenone caused reductions of 84% in beetle landing and 92% in galleries on treated trees (Payne and Richerson 1979, Richerson and Payne 1979). However, the treatment did not prevent the trees from succumbing to beetle attack even though mass attack by SPB did not occur. *Ips avulsus*, a sympatric species, was found to be capable of competitively replacing SPB (Payne and Richerson 1985). Ultimately, the treatment was considered successful, because the less aggressive *Ips* species could not sustain the growth of an infestation in the absence of SPB stressed trees. The apparent equality of response of SPB to verbenone and *endo*-brevicomin alone or combined and the cost of pheromones led to the sole evaluation of verbenone in the suppression of SPB infestation growth (T.L. Payne, personal communication). The treatment of freshly attacked trees and uninfested trees at the active head of SPB infestations with verbenone-only has shown considerable success in slowing or halting the growth of small to moderate-sized infestations (Billings et al. 1995; Payne and Billings 1988, 1989; Payne et al. 1992,). In large infestations, the verbenone-only treatment was less successful, but better success has been obtained when the verbenone treatment (treating a buffer strip only) is combined with the cut-

and-leave tactic (felling freshly attacked trees only or felling all infested trees) (Billings et al. 1995).

Significance

Bark beetles of the genera *Dendroctonus*, *Ips*, and *Scolytus* are the most destructive pests of forests in the Northern Hemisphere. Damage from these insects causes losses of billions of cubic feet of timber valued at millions of dollars each year (Drooz 1985; Furniss and Carolin 1977). Tactics currently used to control bark beetles, such as salvage, cut-and-leave, or chemical control are not always successful and/or are of environmental concern.

The use of semiochemicals as management tools show considerable promise in reducing damage and mortality by bark beetles. Some of these compounds have already been successfully used to monitor population trends or as a mass trapping and/or disruption tactic (Borden 1993). The exploitation of semiochemicals as management tools requires a thorough understanding of the mechanisms involved in the production and release of and response to these chemicals by the target species. In addition, it is important to have an understanding of the effects of semiochemicals applied on the target species and associated organisms. Lanier et al. (1972) was one of the first to suggest that the indiscriminate use of semiochemicals could theoretically lead to resistance. Such a phenomenon has been studied with regards to use of pheromones in mating disruption of the pink bollworm moth, Pectinophora gossypilla (Saunders) (Haynes et al. 1984, Haynes and Baker 1988). Just as there is the potential for the development of semiochemical resistance in the target insect, there is also the potential for the development of response "resistance" in natural enemies as many of these insects use host pheromones as kairomones.

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White-tailed Deer and Virginia Natural Area Preserves: a Discussion

Mike Leahy (July 2003)

Background

A large body of research (Russell et al. 2001) presents evidence that dense populations of white-tailed deer (*Odocoileus virginianus*) in many eastern U.S. ecosystems can negatively impact tree regeneration, recruitment and composition (Alverson and Waller 1997, Horsley et al. 2003), alter natural community composition (Rooney and Dress 1997), eliminate certain plant species from areas (Augustine and Frelich 1998), and disrupt bird populations (McShea and Rappole 1997). Deer also avoid browsing on the invasive, exotic plants stilt grass (*Microstegium vimineum*; Tu 2000) and garlic mustard (*Alliaria petiolata*; Nuzzo 1991), further exacerbating the nefarious effects of these weeds on our native flora. Of particular concern for natural areas management are the negative effects of high deer densities on herbaceous plants (Anderson 1994, Balgooyen and Waller 1995, Augustine and Frelich 1998) and rare plants (Miller et al. 1992).

It is estimated that the presettlement deer density of the eastern U.S. was around 8-11 deer/mi^2 (McCabe and McCabe 1997). At the end of the 19th century deer were over hunted to the point of near extirpation from Virginia. Since then the implementation of strict game laws, the elimination of natural predators and the changing landscape of the state with more edge habitats has given rise to a burgeoning deer population today that in most areas of the state exceeds the estimated presettlement deer densities (Knox 1997). A number of studies have demonstrated that deer densities >20 deer/mi^2 can have negative impacts on tree regeneration, recruitment and composition (Tilghman 1989, Healy 1997, Horsley et al. 2003). Deer densities of 8-15 deer/mi^2 have well-stocked and diverse woody understories (Healy 1997) and abundant and flowering herbaceous populations of such deer sensitive species as *Trillium grandiflorum* (Anderson 1994) and *Laportea canadensis* (Augustine et al. 1998). It should be noted that the effects of deer on forest ecosystems depends on the landscape context in which they occur (Horsley et al. 2003). Forest stands in landscapes with a significant amount of agricultural row-crop land are less impacted by the same density of deer than a forest stand in a primarily forested landscape.

Deer on NAPs

The results of field observations from DNH biologists coupled with deer density data from DGIF (Table 1) in light of cited research above indicates that there are currently too many deer on many of our NAPs if the goal of managing the preserves is to sustain and restore natural communities and rare plants.

Detailed and replicated, labor-intensive exclosure studies are not practical for DNH at this time to prove that deer are a problem on NAPs. I recommend that small exclosures on the scale of 5-10m^2 plots could be used that are easily constructed and monitored. Research studies have effectively used plots of this size (Alverson and Waller 1997, Healy 1997). The goal would be to monitor trends in vegetation that should track trends in deer densities. Preserves in counties or landscapes where deer densities exceed > 20 deer/mi^2 are likely negatively influenced by deer herbivory.

Deer are a problem for many of our NAPs and a deer management program via regulated hunting needs to be enacted to reduce the local herd to a density that does not negatively impact the ecological communities on a preserve. Deer hunting is the most practical method of deer control currently available (DGIF 1999). Utilizing deer birth control, trapping and moving; or erecting a deer-proof fence around a preserve would be extremely costly. DNH needs to work with wildlife biologists from the Virginia Department of Game and Inland Fisheries through the deer management assistance program (DMAP) and or the deer damage control assistance program (DCAP) to develop a deer management plan for either each preserve and or a state-wide deer hunting plan for NAPs. These DGIF programs consist of:

- DMAP is a site-specific deer management program that increases a landowner's or hunt club's management options by allowing a more liberal harvest of antlerless deer than could be obtained

under the current system of county regulations. DMAP tags can only be used to harvest antlerless deer (does and male fawns) and are not valid for antlered bucks. The primary goal of DMAP is to allow landowners and hunt clubs to work together on a local level to manage their deer herds. Secondary objectives are to increase the Department's biological database and to improve communication between deer hunters, landowners, and the Department.

- Like DMAP, DCAP was started in 1988. DCAP is a site-specific deer damage management program that increases a landowner's management options by allowing a more liberal harvest of antlerless deer than could be obtained under the existing system of county regulations. DCAP permit tags can only be used to harvest antlerless deer (does and male fawns) and are not valid for antlered bucks. The primary objective of DCAP is to provide site-specific assistance in the control of crop depredation by deer or other property damage. Secondary objectives are to maximize hunter participation in the control effort and to shift closed-season kill permit deer harvest(s) into the open deer season.

More harvest of female deer (does) will undoubtedly be a needed step towards reducing the herds using the preserves. Hunting efforts should concentrate on thinning the herd in those ecological communities most negatively impacted by excessive deer herbivory. One solution to deer overpopulation on NAPs would be to open preserves in counties with deer densities greater than a certain threshold to hunting of antler-less deer only (mainly does). In addition to obtaining the ecological benefits of a reduced deer herd on the preserves, we will be allowing greater public use of the NAPs during a time of year (fall, winter) when human impacts on the biota will be minimized.

Depending on the state other state programs vary in their approach to hunting on state natural areas. Natural areas in Missouri and Wisconsin are generally open to hunting while other programs such as Minnesota, Michigan, Illinois, Indiana and Ohio have a mix of open and closed to hunting natural areas.

Deer population pressures can be measured in terms of deer densities and or deer impacts (Horsley et al. 2003). Deer density can be assessed via a number of techniques including deer harvest data (DGIF 1999), counts at dusk (Storm et al. 1992), the drive method (deCalesta 1994), pellet counts (Neff 1968, White 1992, Alverson and Waller 1997), winter aerial surveys (Augustine and Frelich 1998) and line-transect sampling (Burnham et al. 1980, Healy and Welsh 1992). Population data on sensitive or "indicator" herbaceous plants have been used as a relatively crude but quick method of gauging the impact of deer populations on natural communities (Anderson 1994, Balgooyen and Waller 1995, Augustine and Frelich 1998, Augustine et al. 1998, Webster and Parker 2000). It is recommended that a monitoring program to track deer population densities and deer impact be utilized to assess the success of a deer management (hunting) program. Monitoring trends of deer impact on exclosure plots and measurements of sensitive herbaceous ground flora plants is recommended.

Recommendations

- Establish simple exclosure plots in NAPs with evidence of excessive deer herbivory to track trends in ground flora and the understory.
- Work with DGIF to establish some efficient system of hunting on NAPs that effectively reduces the deer impacts to preserves.
- NAPs in counties with deer population densities > 20 deer/mi^2 need to incorporate a deer management plan into the overall resource management plan.

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Impacts and Economic Costs of Deer In Suburban Landscapes

by Paul D. Curtis

The past quarter-century has witnessed a period of major growth and spread of people, automobiles, suburban living, and ownership of nonfarm rural lands. At the same time, white-tailed deer (*Odocoileus virginianus*) numbers have increased to unprecedented levels, and populations have expanded into areas with suburban development (Flyger et al. 1983). Deer in suburban landscapes cause significant economic losses to residential landowners, present safety hazards to motorists, and are perceived as agents in the transmission of Lyme disease (Connelly et al. 1987, Decker and Gavin 1987). The purpose of this paper is to provide an overview of the economic impacts caused by deer in suburban landscapes. Much of the information was obtained from several studies conducted in New York State by the Human Dimensions Research Unit at Cornell University. However, trends in other northeastern states with growing deer populations and rapid urbanization are similar. The major economic losses caused by deer are divided into three sections: deer-related vehicle accidents, Lyme disease, and plant damage.

DEER-RELATED VEHICLE ACCIDENTS

Most states keep records of deer-related vehicle accidents (DRVAs) and/or dead deer found along state highways. Romin (1994) reported that 538,000 deer collided with vehicles during 1991 in 35 states. Conover et al. (1995) estimated that the total number of reported DRVAs nationwide would be approximately 726,000 if all states were included. These estimates exclude deer that die away from the highway, and unreported DRVAs (Romin 1994). The reported number of DRVAs ranges from approximately 20 percent (Decker and Loconti 1989, Decker et al. 1990) to 50 percent (Romin 1994) of the actual number of collisions. Consequently, a conservative estimate of the total number of DRVAs nationwide would be 1.5 million annually.

Vehicle repair bills following a DRVA (in 1993 dollars) ranged from $1,200 to $2,200 in several states, with an average value of $1,577 (Conover et al. 1995). Accounting for just the 726,000 reported accidents, total annual cost for DRVAs in the United States would be about $1.1 billion. Current estimates for the cost of DRVAs in New York State alone are $50 to $70 million each year (J.R. Palmateer, New York State Department of Environment Conservation, Delmar, unpublished report).

Stout et al. (1993) examined the relationship between the perceived risk of being involved in a DRVA and public preference for local deer densities. Managing deer with consideration of public perceptions of risk from DRVAs differs from managing deer based on the actual incidence of DRVAs. Lowering the actual number of DRVAs can be accomplished with barrier fencing or reducing the size of the deer herd. However, this approach ignores the many positive recreational, aesthetic, and economic benefits people derive from higher deer densities. Risk perception is a complex process that involves more than assessing the number of DRVAs, and provides wildlife managers with an understanding of how the public balances the benefits and costs in the preference of a specific density for a local deer herd.

Respondents to a mail survey ($\underline{n}$ = 397, 66 percent response rate) indicated their most frequent deer-related concerns were DRVAs (83 percent) and Lyme disease (57 percent) (Stout et al. 1993). Most residents (88 percent) in Tompkins County, New York, were aware of at least one DRVA in the county, usually by first-hand experience of witnessing DRVAs involving other people (22 percent), or seeing car-killed deer along the highway (76 percent). Also, many respondents (69 percent) knew someone who had been involved in a DRVA in the county. However, most people (63 percent) still believed their chances of being personally involved in a deer-car accident during the next 12 months was low. A relationship

existed between perceptions of higher risk and preferences for a decrease in herd size. In addition, perceptions of social benefits from deer, probability of DRVA occurrence, tolerance of other deer-related problems, and personal involvement with a DRVA, also influenced respondents' attitude towards decreasing the size of the deer herd.

LYME DISEASE

Lyme disease was first recognized in the United States in 1975, after an unusual outbreak of arthritis near Lyme, Connecticut. Lyme disease is spread by ticks in the genus *Ixodes* that are infected with the bacterial spirochete *Borrelia burgdorferi*. *Ixodes* ticks may also spread the disease human babesiosis (*Babesia microti*), which is caused by a malaria-like parasite (Spielman et al. 1985). A public information guide from the Center for Disease Control indicated that between 12,000 and 14,000 cases of Lyme disease have been reported annually in the United States since 1994.

Larval and nymphal black-legged ticks (*I. scapularis*) commonly feed on white-footed mice (*Peromyscus leucopus*) and white-tailed deer in the northeast, but can be found on many other mammals and birds. Adult ticks, however, feed primarily upon deer (Watson and Anderson 1976, Piesman et al. 1979, Anderson and Magnarelli 1980). Although adult ticks are occasionally found on medium-sized mammals, deer densities may be a primary factor determining tick abundance (Wilson et al. 1985). *I. scapularis* is not found in regions where deer are absent, and tick abundance is greatest in areas where deer exhibit their highest densities (Piesman and Spielman 1979).

For 13 islands off the coast of Massachusetts, the abundance of larval ticks on white-footed mice was associated with deer density (Wilson et al. 1985). However, this relationship was not apparent for nymphal ticks, and it was speculated that transport of nymphs by birds confounded the relationship. On Long Island, New York, the frequency of deer use of 0.25-ha quadrats in fall was positively correlated with immature tick numbers found on white-footed mice the following summer (Wilson et al. 1990). Consequently, it has been suggested that the risk of contracting tick-borne diseases may be decreased by reducing local deer densities (Wilson et al. 1990). This may be difficult to achieve given the lack of support for hunting in many suburban landscapes.

Control of ticks on deer has been attempted mostly by deer exclusion or population reductions (Wilson and Deblinger 1993). Both methods have reduced populations of *I. scapularis* from selected experimental areas (Wilson et al. 1988, Daniels et al. 1993, Deblinger et al. 1993, Stafford 1993). However, these techniques are expensive, may be incompatible with recreational uses, and may result in opposition from animal-welfare activists.

Consequently, self-treatment of deer with acaricides is being investigated. Food-baited tubes have successfully delivered acaricides to mice and voles (Sonenshine and Haines 1985). "Damminix" tubes containing cotton have been used to treat mice with acaricides (Mather et al. 1987, Spielman 1988). A self-medicating applicator for killing ticks on deer and goats (*Capra hircus*) has been field tested in Virginia and North Carolina (Sonenshine et al. 1996). A 1 percent permethrin solution was used on a ceramic column to treat deer feeding from a circular polyethylene bin (Norval et al. 1994). Both penned and free-ranging deer readily used the applicators. Hunter-killed deer from a treated site were infested with fewer black-legged ticks (= 3.4) than those from a control site (= 10.8). Chromatographic analyses of hair samples revealed traces of permethrin on 3 of 4 deer tested. Additional large-scale field studies with similar self-application devices are currently under way.

PLANT DAMAGE

Deer damage to ornamental plants is widespread in the Northeast, but is not evenly distributed across the landscape. Impacts are often most intense near the suburban-rural fringes of large metropolitan areas (Curtis and Richmond 1992). Conover (1997a) surveyed a random sample of 100 homeowners in 10 of the 100 largest metropolitan areas in the United States, and determined that most respondents (61 percent) had experienced wildlife-related problems during the previous year. When results were extrapolated to the 60 million households in these metropolitan areas, wildlife damage was estimated to cost $3.8 billion annually. Only 4 percent of respondents reported problems with deer (2.4 million households), indicating that deer damage may cost homeowners approximately $251 million each year (Conover 1997b).

More detailed mail surveys of nursery producers and homeowners in suburban areas of southeastern New York State indicated higher levels of deer damage to landscape plants. Approximately two-thirds of producers and one-third of homeowners reported deer browsing. Nursery producers ($\underline{n} = 24$) reported total losses of $519,000 in a 5-county area during 1988, with a median loss per producer of $3,000 (Sayre et al. 1992). However, 3 producers reported more than $150,000 in deer damage, and the average loss for all growers exceeded $20,000.

Homeowners with deer impacts ($\underline{n} = 26$) reported a median loss of $200 per household in southeastern New York, and about three-fourths of these respondents classified the damage as light to moderate. The average replacement costs for trees and shrubs was nearly $500 for households with deer damage, so losses were not evenly distributed across the landscape (Sayre and Decker 1990).

Results from a self-administered mail survey of 1,002 households (70 percent response rate) in Westchester County, New York, indicated 95 percent of residents had seen a deer in the past 5 years, and 49 percent perceived an increasing trend in deer numbers (Connelly et al. 1987). More than 40 percent of respondents reported plant damage caused by deer. Average cost of plant replacement for households with deer damage averaged $94 for vegetables, $102 for flowers, $156 for fruit trees, and $635 for shrubbery. Estimated total plant replacement costs for northern Westchester County ranged from $6.4 to $9.5 million in 1987.

Despite significant plant damage in southeastern New York, two-thirds of all respondents believed that prevention of deer-car collisions should be the most important consideration of deer managers (Sayre and Decker 1990). Also, three-fourths of homeowners supported regulated hunting as a tool to manage deer populations. Even in highly suburban Westchester County, 72 percent of respondents recognized the need for deer management, and 44 percent supported the use of firearms during a regulated hunting season (Connelly et al. 1987). Two to three times more respondents expressed concerns about DRVAs and Lyme disease than about plant damage in Westchester County. It is obvious that human health and safety concerns related to deer should be the highest priority for wildlife managers.

FUTURE TRENDS

Overabundant deer populations currently cause substantial economic losses in many parts of the United States. The problems are particularly severe in the northeastern states, where expanding metropolitan areas continue to encroach on high-quality agricultural and forest lands. The forage and cover available near exclusive wooded home sites, and protection from hunting in many residential areas, have provided an ideal situation for deer populations to rapidly expand. Deer numbers in local parks and suburban landscapes may continue to double every two to three years, as long as forage is available, unless some form of mortality or fertility control is implemented. Densities in some parks now exceed 100 deer per square mile, a level that would have been beyond the belief of most wildlife managers two decades ago.

I expect the situation will get worse in the near future. Deer numbers continue to grow at the fringes of several metropolitan areas in the northeast, and elected officials are receiving more calls concerning damage to ornamentals, deer-car collisions, and Lyme disease. The greatest difficulty will be managing the social or human-dimensions aspects of these problems, as a proposal to reduce deer numbers can become a very controversial issue for a community. People hold a wide range of attitudes and beliefs concerning human-wildlife relationships, and a variety of stakeholders groups now demand a voice in wildlife management decisions. Although many different stakeholders will agree that high deer densities in suburban areas can pose significant human health and safety risks, it can be difficult to achieve consensus on an appropriate deer density for a local area, and acceptable methods for removing deer. Wildlife managers with traditional biology training may be poorly equipped to facilitate meetings and handle the competing demands of these different interest groups.

The specialized management required for suburban deer herds may be quite different from traditional programs. Although hunting will continue to be a valuable management tool for many herds, experimental methods to reduce deer fertility will continue to be tested and refined. Several recent surveys have indicated strong public support for non-lethal control of problem wildlife species. However, these high-technology approaches are very expensive, and it is unclear how many communities will be willing to pay the long-term costs for developing alternative deer management techniques. Many policy and regulatory hurdles also need to be resolved before fertility control methods will become widely available for deer managers.

In summary, suburban deer herds will continue to pose a tremendous challenge for wildlife managers. There is no quick-fix or simple solution that will resolve deer-human conflicts. Deer will utilize the habitat created by residential development, and exhibit sustained high reproductive output. Rapid population growth will continue as long as communities limit mortality factors (i.e., hunting and/or predation), and suitable forage is available. If people choose not to take action early in the process as problems start to develop, then communities often must remove many more deer at much greater expense at some point in the future.

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Appendix H.
Federal and State Natural Resource Laws

LEGISLATION	CITATION	RESPONSIBLE AGENCY
Presidential Order on Introduction of Exotic Species	Executive Order # 11987	Office of the President
U.S. Noxious Weed Law	7 USC 2802-2814	U.S. Department of Agriculture (USDA)
U.S. Clean Water Act	33 USC 1344	U.S. Army Corps of Engineers (ACOE), U.S. Environmental Protection Agency (EPA)
U.S. Anadromous Fish Conservation Act	16 USC 757a-757g	National Marine Fisheries Service (NMFS)
U.S. Clean Air Act	42 USC 7401-7671q	EPA
National Environmental Policy Act	42 USC 4321-4307d	all Federal agencies
Lacey Act (exotics)	18 USC 42	U.S. Department of Interior (DOI)
U.S. Endangered Species Act	16 USC 1531-1544	U.S. Fish & Wildlife Service (FWS), NMFS
U.S. Fish & Wildlife Coordination Act	16 USC 661-668s	many
U.S. Migratory Bird Treaty Act	16 USC 701-712	FWS
U.S. Aquatic Nuisance Prevention & Control Act	16 USC 4701-4751	FWS, NMFS
VA Commercial Fishing Law / Recreational Fishing Law	VA Code 28.2-100 – 1001	VA Marine Resources Comm. (VMRC)
VA Wetlands Act	VA Code 28.2-1300 – 1320	VMRC
VA Historic Resources Law	VA Code 10.1-2200 – 2216	VA Department of Historic Resources (VDHR)
VA Antiquities Act	VA C ode 10.1-2300 – 2306	VDHR
VA Endangered Species Act	VA Code 29.1-563 – 570	VA Department of Game & Inland Fisheries (VDGIF)
VA Fish & Wildlife Law	VA Code 29.1-100 et seq.	VDGIF
VA Endangered Plant & Insect Species Act	VA Code 3.1-1020 – 1030	VA Department of Agriculture and Consumer Services (VDACS)
VA Noxious Weed Law	VA Code 3.1-296.11 - 296.21	VDACS

Federal and State Natural Resource Laws (continued)

LEGISLATION	CITATION	RESPONSIBLE AGENCY
VA Chesapeake Bay Preservation Act	VA Code 10.1-2100 - 2115	Chesapeake Bay Local Assistance Dept. (CBLAD)
VA Water Quality Improvement Act of 1997	VA Code 10.1-2118 – 2128.B.	VDCR
VA Water Control Law	VA Code 62.1-44.2 - 44.34	VA Department of Environmental Quality (VDEQ)
VA Ground-water Management Act	VA Code 62.1-44.84 - 44.104	VDEQ
VA Environmental Quality Act	VA Code 10.1-1200 - 1221	VDEQ
VA Waste Management Act	VA Code 10.1-1400 - 1457	VDEQ
VA Open Space Land Act	VA Code 10.1-1700 - 1705	VA Outdoors Foundation (VOF)
VA Erosion & Sediment Act	VA Code 10.1-560 - 571	VDCR
VA Natural Area Preserves Act	VA Code 10.1-202 - 217	VDCR
VA Conservation Easement Act	VA Code 10.1-1009 - 1016	VDCR

Appendix I.
Glossary Of Technical Terms And Abbreviations

ac – acre(s).

acidic – having a pH value < 7.0, often indicating moderate or low fertility.

alluvial – of or pertaining to deposition of sediment by a stream.

alluvium – unconsolidated sand, silt, clay, or gravel deposited by running water.

asl – above sea level

aspect – the direction a slope faces (e.g., a north aspect).

basal area – the cross-sectional area of a tree at breast height; extrapolated to a larger area, basal area is an estimated measure of how much of a site is occupied by trees.

basic – as applied to soils, having high levels of base cation (e.g., calcium and magnesium) saturation, typically indicating high fertility; as applied to rocks, having high concentrations of iron, magnesium, and calcium.

biological resource management – those components of natural areas stewardship pertaining to or impinging on vegetation, natural communities, or habitat for rare species. Examples of biological resource management include invasive species control, habitat restoration, and monitoring of species population status.

biomass – the total weight of all living organisms in a biological community; in vegetation science, usually the total weight of all above-ground plant parts.

bryophyte – a non-vascular green plant; includes mosses, hornworts, and liverworts

colluvial – of or pertaining to colluvium.

colluvium – unconsolidated earth materials deposited on steep slopes by direct gravitational action and local unconcentrated run-off.

community – as applied to plants, any unit of vegetation regardless of rank or development; an aggregation of plants on the landscape; in broader terms, any assemblage of organisms that co-occur and interact.

cover – the percentage of the ground covered by the vertical projection of above-ground plant parts.

DCR – Virginia Department of Conservation and Recreation.

dbh – diameter at breast height (4.6 ft above the ground); the standard position at which woody stems are measured in forestry procedures.

dedication – dedication of a natural area is the strongest form of protection that can be afforded a natural area in Virginia and involves recording a legally binding Deed of Dedication with the property deed. The Deed of Dedication states the preservation purpose of the property, designates the property as Open-Space Land, restricts land uses which are incompatible, and formally places the site in Virginia's Natural Area Preserve System. Dedication is perpetual, and although ownership of the property can be transferred, the dedication will remain in effect.

density – the number of plants per unit area; used more specifically in this study as a measure of the number of woody stems ≥ 1in in diameter at breast height per hectare.

DGIF – Virginia Department of Game & Inland Fisheries.

dip slope – a side slope determined by and approximately aligned with the angle of the underlying bedrock plane.

DNH –Virginia Department of Conservation & Recreation, Division of Natural Heritage.

DOF – Virginia Department of Forestry.

dominant – of or pertaining to an organism or taxon that by its size, abundance, or coverage exerts considerable influence on a community's biotic and abiotic conditions.

dry-mesic – intermediate between dry and moist but well drained; submesic to subxeric.

duff – the matted, partly decomposed organic surface layer of forest soils.

EO – element occurrence. A site that supports a population of a rare plant or animal or an exemplary stand of an ecological community. EOs are sites tracked in the natural heritage database by the Division of Natural Heritage.

EO rank – the viability of a particular EO, graded from A to D.

ecological community - an assemblage of co-existing, interacting species, considered together with the physical environment and associated ecological processes, that usually recurs on the landscape.

ecological community group – a level in the hierarchical ecological community classification used by DNH (Fleming et al. 2001). An ecological community group consists of ecological communities with similar topographic, edaphic, physiognomic, and gross floristic traits. This level is comparable to the level at which many natural community classifications define their basic units, *e.g.*, Basic Oak-Hickory Forests. Ecological community groups are not defined at a single, standard scale. Because community groups differ in their extent on the landscape, some are very broadly defined and have large geographic coverage (*e.g.*, Chestnut Oak Forests), while

others are very narrow in concept and distribution (*e.g.*, Granitic Flatrocks). Ecological community types are nested within an ecological community group.

ecological community type – an abstract unit of vegetation representing concrete plant communities sharing a similar structure and floristic composition, and occurring under similar environmental conditions; more or less equivalent to the "association" used in traditional vegetation studies and the U.S. National Vegetation Classification. Ecological community types are the next finest level in the community classification hierarchy after ecological community groups.

ecotone – a transitional area where characteristics of adjacent communities or environments intermingle or intergrade.

ecosystem – a complete interacting system of organisms and their environment, applicable at any spatial scale.

edaphic – of or pertaining to the influence of soils on living organisms, particularly plants.

endemic – geographically restricted; a species or taxonomic group restricted to a particular geographic region.

environmental gradient - a spatially varying aspect of the environment (*e.g.*, elevation, slope position, soil pH) that is expected to be related to species composition.

ericaceous – of the Heath Family (*Ericaceae*).

ericad – a plant of the Heath Family (*Ericaceae*); for example, blueberries (*Vaccinium* spp.), rhododendrons (*Rhododendron* spp.), and mountain-laurel (*Kalmia latifolia*).

exotic – an introduced, non-native species.

fire management – all activities associated with the management of fire-prone land, including the use of fire to meet land management goals and objectives - a unique and distinct component of natural areas stewardship combining elements of both biological and operations management. Fire management activities include both prescribed fire implementation and wildfire management.

fire management plan – statement, for a specific area, of fire policy, objectives, and prescribed action.

flora – all the vascular plants that make up the vegetation of a specified area.

floristic – of or pertaining to the flora of an area and the geographic patterns of distribution represented by its taxa.

floristics – the study of a flora and the geographic distributions of its taxa.

floodplain – a nearly level alluvial plain that borders a stream and is subject to inundation (non-tidal) under flood-stage conditions.

foliose lichen - a lichen typically lying flush to its substrate, but removable such that the lower surface is visible; foliose lichens are often attached to rocks and other substrates by numerous fine structures called rhizines.

forb – a broad-leaved herbaceous plant.

forest – an ecosystem dominated by trees (≥ 20ft tall) producing a more or less closed canopy, typically with 60-100% cover; some forests may temporarily have < 60% canopy cover following disturbances such as windthrow, disease, etc.

fruticose lichen – a lichen that grows erect or pendent, with thalli that have no clearly distinguishable upper and lower surfaces; includes species that are branched and shrubby, as well as those that form unbranched stalks.

ft – foot (feet).

geomorphic – of or pertaining to processes that change the form of the earth (e.g., volcanic activity, running waters, glaciers).

graminoid – grasses and grass-like plants (e.g., sedges and rushes).

groundwater – water occurring below the earth's surface in bedrock and soil.

heath - a plant of the Heath Family (*Ericaceae*); an Ericad; for example, blueberries (*Vaccinium* spp.), rhododendrons (*Rhododendron* spp.), and mountain-laurel (*Kalmia latifolia*).

herb – a vascular plant lacking woody tissue at or above ground level.

herbivory – the consumption of plants by animals.

hibernacula – over-wintering den sites used by animals such as bats, snakes, and insects.

humus – decomposed organic matter that has lost all trace of the structure and composition of the vegetable or animal matter from which it was derived.

hydric –wet and poorly drained.

hydrology – the science that deals with the circulation, distribution, movement, and chemistry of the waters of the earth.

in – inch(es).

invasive species – any species of plant, animal, or other organism (e.g. microbes) that is both non-native (exotic) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

integrated pest management – is the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventative, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable. The methods used in pest management must be ecologically based, involve a combination of tactics from insecticides to "doing nothing" appropriate to the situation and the biota and be a part of an overall management plan for the ecosystem being considered.

interstice – an intervening space or crevice.

interstitial – of or pertaining to interstices.

Jurassic – the second period of the Mesozoic era (following the Triassic), from approximately 190 to 135 million years ago.

liana – a woody vine.

lichen – a symbiotic association between a fungus and one or more species of algae and/or blue-green algae; although not based on genetic relationships, lichen species, for the aid of identification, are divided into foliose, fruticose, crustose, and umbilicate groups based on their growth strategies.

lithologic – of or pertaining to the physical characteristics of a rock.

lithology – the description of rocks on the basis of physical characteristics such as color, mineralogical composition, and grain size.

liverwort - a nonvascular, chlorophyll-containing plant closely related to mosses and hornworts, but differing in reproductive structures; liverworts have two dominant growth forms, one which resembles moss with overlapping leaves, the other forming prostrate leafless bodies.

m – meter(s).

macroinvertebrate – an animal lacking a backbone (invertebrate) and visible without the aid of magnification.

mafic – geologically, containing large amounts of dark-colored silicate minerals rich in magnesium and iron, e.g., pyroxene, amphibole, and biotite mica; examples include igneous and metamorphic rocks such as amphibolite, basalt, diabase, gabbro, and greenstone; also applied to soils with high levels of magnesium and iron that are derived from these formations.

mesic – of intermediate moisture conditions (i.e., moist and well-drained).

mesophyte – a plant characteristic of mesic environments.

mesophytic – of or pertaining to plants or vegetation adapted to environments of moist, well-drained sites.

Mesozoic – an Era of geologic time, from the end of the Paleozoic to the beginning of the Cenozoic, or about 225 to 65 million years ago; includes the Triassic, Jurassic, and Cretaceous periods.

metabasalt – metamorphosed basalt, a fine-grained igneous rock composed largely of plagioclase feldspar, pyroxene, and volcanic glass.

metamorphic – altered in mineral composition, chemical composition, and structure by heat, pressure, and hot fluids at some depth below the earth's surface; applied to rocks of igneous and sedimentary origin.

metasedimentary – consisting of sedimentary rock that shows evidence of having been subject to metamorphism; examples include quartzite (= metasandstone) and metasiltstone.

mi – mile(s).

microclimate – the local climate of a small site; this may vary from the climate of the larger, surrounding area due to aspect, tree cover, elevation, wind exposure, and other local factors.

microhabitat – within a habitat, a subdivision or precise location that has distinctive environmental characteristics; e.g., a tree-base hummock in a flooded swamp.

microtopography – the fine-scale variation in topography within a habitat; e.g., the pattern of vertical rock faces, shelves, and crevices on a cliff.

monospecific – consisting wholly or largely of a single species.

moss - a nonvascular chlorophyll-containing plant closely related to liverworts and hornworts, but differing in reproductive structures.

muscovite – a mineral of the mica group that is common in gneisses and schists; also known as "white mica."

natural community - those ecological communities which have experienced only minimal human alteration or have recovered from anthropogenic disturbance under mostly natural regimes of species interaction and disturbance. No portion of Virginia's landscape, however, has altogether escaped modern human impacts – direct or indirect – and only a few small, isolated habitats support communities essentially unchanged from their condition before European settlement.

natural heritage resources – as defined in the Virginia Natural Area Preserves Act these are "…the habitat of rare, threatened, or endangered plant and animal species, rare or state significant natural communities or geologic sites, and similar features of scientific interest." (Code of Virginia, section 10.1-209, et seq.).

non-vascular – lacking a structural system of tissue (xylem and phloem) that conducts water and soluble nutrients; non-vascular plants include mosses, lichens, and liverworts.

oligotrophic – infertile; nutrient-poor.

operations management – those components of natural areas stewardship pertaining to or impinging on non-biological features of natural area preserves. Examples of operations management activities include public access facilities development and maintenance, boundary line marking, sign installation, law and regulation enforcement, and ensuring visitor safety.

overstory – the uppermost layer of trees forming the canopy of a forest or woodland.

Paleozoic – the era of geologic time from 600 to 230 million years ago.

patch-dominant – a species that exerts dominance by forming dense but spatially discrete colonies; such a species typically varies from abundant to completely absent within a given habitat.

pathogen – an organism that causes disease in another organism.

pH – a value on the scale 0 to 14 that gives a measure of the acidity or alkalinity of a medium.

physiognomic – of or pertaining to vegetative form and structure.

physiognomy – the form and structure of vegetation.

phytogeography – the study of the geographic distribution of plants and vegetation , with an emphasis on environmental determinants of distribution.

Pleistocene – the first Epoch of the Quaternary Period of geologic time, from approximately two million to ten thousand years ago.

prescribed burn plan – a written statement defining the objectives to be attained as well as the conditions of temperature, humidity, wind direction and speed, fuel moisture, and soil moisture, under which a fire will be allowed to burn. A prescription is generally expressed as acceptable ranges of the prescription elements, and the limit of the geographic area to be covered.

prescribed fire – a management ignited wildland fire that burns under specified conditions where the fire is confined to a predetermined area and produces the fire behavior and fire characteristics required to attain planned fire treatment and resource management objectives.

pyrophytic – of or pertaining to plants or vegetation adapted to environments in which fire is an important ecological process.

quartzite –metamorphosed sandstone.

rare species – species believed to be sufficiently rare or threatened in Virginia to merit an inventory of their status and locations by DNH.

recruitment – generally, the trees involved in natural supplementation of a forest stand; more specifically, trees that have entered a particular category (age or size class) during a given period.

refugia – sites where plants or vegetation that formerly had much wider distributions have survived locally through periods of unfavorable conditions in a region.

regolith – all unconsolidated earth materials above solid bedrock.

rhizomatous – having a horizontal, creeping, perennial rootstock that produces smaller roots and vegetative shoots.

riparian – of the area beside a stream, especially a river.

rill – a small streamlet or rivulet.

ruderal vegetation – vegetation resulting from succession following anthropogenic disturbance of an area; generally characterized by unnatural combinations of species (primarily native though including small to substantial numbers of exotics) and relatively short persistence in the absence of additional disturbance.

sandstone – a medium-grained sedimentary rock composed of rounded sand grains cemented together by silica, iron oxide, or calcium carbonate.

saturated – wet for extended periods during the growing season, but never or rarely flooded by surface water; usually applied to wetlands maintained by seepage inputs or perched water tables.

schist – a metamorphic rock containing abundant, visible platy minerals (*e.g*., mica), giving it a pronounced foliation and cleavage.

sedimentary – formed from the deposition and compression of mineral and rock particles, and sometimes material of organic origin; examples of sedimentary rocks include sandstone, shale, and limestone.

seep – a small area of groundwater discharge, either non-forested or shaded by trees rooted in adjacent, upland habitats; seeps generally support characteristic herbaceous wetland species but are too small or narrow to support hydrophytic woody vegetation.

seepage swamp – a large area of groundwater discharge supporting wetland forest or shrubland vegetation.

seral – of or pertaining to an intermediate or transitional stage in plant succession.

serotinous cone – the cone of a pine that remains closed for a period of time, sometimes years, following maturation; the opening of such cones are often triggered by the heat of fires; a reproductive adaptation that ensures seed dispersal under optimal conditions.

site operations – in the context of natural areas management, those activities that deal with boundaries, facilities, access, signage, public safety, and other human use issues.

smoke management – application of fire intensities and meteorological processes to minimize degradation of air quality during prescribed fires.

snag – a standing dead tree.

sp. – a species.

spp. - species (plural).

spring ephemeral – a plant that completes its reproductive cycle early in the growing season, typically before or during the period in which trees leaf out; such species usually die back and become dormant during unfavorable summer months when habitats are characterized by high temperatures and deep shade.

ssp. – subspecies, a taxonomic rank below species.

stewardship – in the context of natural areas management, the combination of three primary components – biological resource management, site operations, and fire management – with the objective of perpetuating occurrences of natural heritage resources and preserving inherent biological diversity.

stratigraphy – the arrangement of bedrock strata, particularly their geographic position and chronological order of sequence.

stratum – a distinct vertical layer of vegetation defined by relative height (e.g., overstory, understory) and/or by a specific range of heights.

sub-canopy – the understory tree layer immediately below the overstory.

submesic – somewhat moist but well drained, or intermediate between dry and moist; dry-mesic.

subxeric – somewhat dry and drought-prone; intermediate between submesic and xeric.

succession – natural change in the composition and structure of a plant community over time in the absence of disturbance.

successional – of or pertaining to the process of succession.

surface substrate – a collective term for the abiotic materials (e.g., leaf litter, rocks, dead wood) that constitute the ground cover of a site.

terrestrial – of or pertaining to upland (non-wetland) environments.

Triassic – the earliest period of the Mesozoic Era, from approximately 225 million to 190 million years ago.

umbilicate lichen - a leaf-like lichen attached to rocks by a single cord; umbilicate lichens, especially those of the genus *Umbilicaria*, are often referred to as "rock tripes."

understory – collective term for the small trees and shrubs growing beneath the canopy in a forest or woodland.

var. – variety, a taxonomic rank below species.

vascular – having a structural system of tissue (xylem and phloem) that conducts water and soluble nutrients; vascular plants include ferns and flowering plants.

vegetation – the plant life of an area, including its floristic composition, structure, biomass, and phenology.

watch-list species – species of uncommon or uncertain status in Virginia. More information is needed on these species, which may or may not be of high conservation concern at this time; these species are monitored for general population trends.

woodland – vegetation dominated by trees (≥ 20 ft tall) producing an open canopy, typically with 5-60% cover; such vegetation with canopy cover from 5 to 25% is referred to as a sparse woodland; some woodlands may have > 60% canopy cover following elimination or reduction of natural disturbances (e.g., fire).