National Park Service
U.S. Department of the Interior

Northeast Region
Boston, Massachusetts

Management Plans For Invasive Plant Species of Acadia National Park

Natural Resources Report NPS/NER/NRR--2007/018

ON THE COVER
(Japanese Barberry (*Berberis thunbergii*, fruiting branch)
Photograph by: Jill Weber

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U.S. Department of the Interior
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Boston, Massachusetts

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Abstract

The main objective of the current work was to develop management plans for the most problematic invasive species at Acadia National Park (ACAD). Plans describe each species' abundance at ACAD; background information regarding habitat and species biology; goals of management; methods used for control, as reported in the literature or in use by other agencies; experimental treatments and recommended monitoring protocols for managed populations.

Plans were written for 22 species:

Amur maple (*Acer ginnala*)
Norway maple (*Acer platanoides*)
Garlic mustard (*Alliaria petiolata*)
Barberries (*Berberis* X *ottawensis*, *B. thunbergii*, *B. vulgaris*)
European bittercress (*Cardamine impatiens*)
Oriental bittersweet (*Celastrus orbiculata*)
Canada thistle (*Cirsium arvense*)
Burning bush (*Euonymus alatus*)
Japanese knotweed (*Fallopia japonica*)
Alder-leaved buckthorn (*Frangula alnus*)
Shrubby St. Johnswort (*Hypericum prolificum*)
Non-native honeysuckle species (*Lonicera* spp. and *L. japonica*)
Privet (*Ligustrum* spp.)
Forest woodrush (*Luzula luzuloides*)
Ninebark (*Physocarpus opulifolius*)
Black locust (*Robinia pseudoacacia*)
Multiflora rose (*Rosa multiflora*)
Bittersweet nightshade (*Solanum dulcamara*)
Coltsfoot (*Tussilago farfara*).

Eradication, prevention of spread, public education, reduction in area and/or number of individuals and prevention of seed production are goals identified in the plans. Recommended control methods are: pulling/digging; removal of flowers/fruits; mowing/cutting; applying glyphosate (cut stem or foliar); and applying triclopyr (cut stem or foliar).

The report also discusses data management and invasives management from a whole park, rather than species by species perspective. Recommendations for priority actions are included.

Executive Summary

About 5,000 non-native plant species have become established in natural systems in the US. As of 1998, approximately 700,000 ha/yr were being invaded by non-native plant species, which can outcompete native species for habitat, light or nutrients, resulting in the natives' displacement or elimination (Pimentel et al. 1999). In addition to changing species composition, invasive plants can change the ecology of an entire system. It is estimated that 35-49% of all threatened and endangered species are impacted by invasives. In addition to the ecological costs, invasives have a significant economic impact: recent calculations suggest that the costs of damage caused by and control of non-native plant and animal species amount to $138 billion/year in the US (Pimental et al. 1999).

Many introduced plant species affect public lands. It is common for non-native plant species to comprise about 25% of the total flora on an NPS unit and, in some parks, over 50% of the plant species are exotic species. Executive Order #13112 mandates that managers of public lands manage invasive species (Federal Registry 64[25]: 6183-6186). The National Park Service has developed additional policies that require eradication efforts if invasive species interfere with natural processes (NPS 1999, 2006). Response to the mandate among NPS units has been varied, ranging from parks with decades-old invasives control programs, to those where inventory of exotic plants is just beginning. In the last decade the trend has been for Parks to develop plans that follow an integrated pest management (IPM) approach, which includes identification of: priority species, best management methods, action thresholds, monitoring methods and evaluation of treatment effectiveness.

Acadia National Park (ACAD) has long supported botanical inventory work, and invasive non-native plant species occurrences were documented opportunistically for over a decade. Purple loosestrife management began in 1988 and continued through 2006. ACAD then completed a study in which a model was developed to predict the rate and pattern of invasive species spread of 15 species documented in the Park. The model resulted in *Lonicera* X *bella* and *L. morrowii* being ranked 1, or most invasive. Rank 2 species are: *Berberis thunbergii*, *Celastrus orbiculata*, *Frangula alnus*, *Lythrum salicaria* and *Rosa multiflora*. *Acer platanoides*, *Alliaria petiolata*, *Solanum dulcamara* and *Tussilago farfara* are Rank 3. Rank 4 (least likely to pose a threat) taxa are: *Bromus inermis*, *Cirsium arvense*, *Dactylis glomerata* and *Sonchus arvensis*.

In 2000, ACAD worked to better document and map the distribution and abundance of the species thought to be most invasive and widely distributed in the Park. In addition to the 15 species used in the predictive model, the distribution and abundance survey identified several other exotics likely pose a threat to the integrity of ACAD's natural communities: Amur maple, Dutchman's pipe, goat's beard, common barberry, Japanese barberry, European bittercress, burning bush, Japanese knotweed, shrubby St. Johnswort, goldenchain tree, privet, forest woodrush, wall lettuce, ninebark, black locust and cow vetch. The data from the abundance and distribution project quantified the extent of the invasive plant species problem at ACAD and provided a basis on which management decisions could be made.

The main objective of the current work was to develop management plans for the species included in the abundance and distribution project. Plans include: occurrence at ACAD;

background information regarding habitat and species biology; goals of management; methods used for control, as reported in the literature or in use by other agencies; experimental treatments; recommended monitoring protocols for managed populations and a timeline for management and monitoring.

Other goals of this report are to provide: some possible management strategies in a Parkwide context, and suggestions regarding how to manage the units where complete distribution and abundance inventories have not been conducted (Schoodic, Isle au Haut, offshore islands, St. Croix, easements). Options for prioritizing management actions and suggestions for data synthesis and management are also included.

ACAD is located in east coastal Maine and comprises units on Mount Desert Island and Schoodic Point, in Hancock County; on Isle au Haut, in Knox County; and St. Croix Island, in Washington County. The management plans included here pertain only to the 12,150 hectare (30,000 acre) Mount Desert Island unit.

Management plans were developed for 22 species: Amur maple (*Acer ginnala*), Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolata*), barberries (*Berberis* X *ottawensis*, *B. thunbergii*, *B. vulgaris*), European bittercress (*Cardamine impatiens*), oriental bittersweet (*Celastrus orbiculata*), Canada thistle (*Cirsium arvense*), burning bush (*Euonymus alatus*), Japanese knotweed (*Fallopia japonica*), alder-leaved buckthorn (*Frangula alnus*), shrubby St. Johnswort (*Hypericum prolificum*), non-native honeysuckle species (*Lonicera* X *bella*, *L. morrowii* and *L. japonica*), privet (*Ligustrum* spp.), forest woodrush (*Luzula luzuloides*), ninebark (*Physocarpus opulifolius*), black locust (*Robinia pseudoacacia*), multiflora rose (*Rosa multiflora*), bittersweet nightshade (*Solanum dulcamara*) and coltsfoot (*Tussilago farfara*). Literature reviews were conducted to collect information on each species': background, nativity and history of introduction; life history; threats posed to native habitats; distribution at ACAD; abundance at ACAD; typical habitat at and outside ACAD; management alternatives; management goals; recommended management and an action threshold that must be met before management activities are triggered.

Individual invasive species management plans included one or more of the following goals: eradication, prevention of spread, public education, reduction in area and/or number of individuals and prevention of seed production.

Plants with different life forms require different management methods, but treatments for all of those studied can be summarized by using the general categories: mechanical and chemical. Mechanical methods include pulling and digging; removal of flowers or fruits; and mowing or cutting. Various glyphosate treatments are recommended for all but two species.

Invasive plant documentation data sheets were developed. Data sheets document new occurrences, pre- and post-control monitoring of invasive plant species and management actions. Use of standardized data forms will improve ACAD's ability to implement the invasive plant management plans and track progress.

Recommendations are made regarding management goals, treatment methods, data management, management by site rather than by species, and management from a park wide perspective.

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The authors wish to acknowledge David Manski and Judy Connery, of Acadia National Park, and NPS reviewers Wayne Millington and Ron Hiebert for helpful comments on earlier drafts of this report. We also thank Linda Gregory, formerly of Acadia National Park, for her botanical expertise and for her unflagging support.

Introduction

As a result of intensive research efforts, understanding of invasive non-native plant species has increased dramatically over the last 15-20 years. Studies of exotic species have focused on their biology and their ecological and economic impacts. About 5,000 non-native plant species have become established in natural systems in the US (Morse et al 1995). As of 1998, approximately 700,000 ha/yr were being invaded by non-native plant species, which can outcompete native species for habitat, light or nutrients, resulting in the natives' displacement or elimination (Babbit 1998). In addition to changing species composition, invasive plants can change the ecology of an entire system. For example, pre-invasion natural fire frequency in the Great Basin of Idaho and Utah was every 60-110 years; following establishment of non-native European cheatgrass (*Bromus tectorum*), fires now occur every 3-5 years, which prevents the growth of native shrubs that characterize the shrub-steppe ecosystem, and affects other native plants and the wildlife species dependent upon them (Pimentel et al. 1999). Invasives may also alter ecosystems by altering soil properties (Ehrenfield et al. 2001). Rare plants are also affected by invasives: it is estimated that 35-49% of all threatened and endangered species are impacted by invasives (NPS 2004). Four rare species occur in Minute Man National Historical Park, Concord, Massachusetts, in wetland, forest and aquatic habitats and all four are affected by invasive plant infestations (Agius 2005a). In addition to the ecological costs, invasives have a significant economic impact. Pimentel et al. (2005) calculate that the costs of damage caused by and control of non-native plant and animal species amount to $138 billion/year in the US.

Many introduced plant species affect public lands. Some 400 of about 1,500, or 27%, of the vascular plant species in Great Smoky Mountains National Park are exotic; ten of these pose serious threats to native species (Hiebert and Stubbendick 1993). At ACAD, non-native species account for 25% of the 1055 species in the flora and more than 20 species have invaded undisturbed areas in the Park (Greene et al. 2004, 2005). The flora of Sagamore Hill National Historic Site comprises 48% non-native species, 30 of which are highly invasive (Werier 2006). Olympic National Park estimates that about 25% of the plant species that grow there are non-native, and of these, 17 species pose a significant threat (Olsen et al. unpublished). Executive Order #13112 mandates that managers of these public lands manage invasive species (Federal Registry 64[25]: 6183-6186). The National Park Service management policies require eradication efforts if invasive species interfere with natural processes (NPS 1999, 2006).

Response to the mandate among NPS units has been varied. Some parks have been managing invasives for decades; for example, invasive plant management has been ongoing at Yosemite since the 1930's (NPS 2005). Many units have had a piecemeal approach to invasives management, and management efforts have been undertaken to control particular species or conserve specific sites without having completed inventory work to assess distribution and abundance of problematic species or an overall, guiding invasives management plan (NPS 2005). In the last decade the trend has been for Parks to develop plans that follow an integrated pest management (IPM) approach, which includes identifying priority species, incorporating least toxic best management methods, setting

action thresholds, monitoring and evaluating treatment effectiveness (Werier 2006). Some units have completed botanical inventories and already know which invasive species occur on their lands and may have mapped them and calculated their abundance. Other units have completed plans, but have identified inventory and mapping as tasks yet to be completed (NPS 1990, 2003; Agius 2005a, b; NPS 2005; Werier 2006).

Acadia National Park (ACAD) has long supported botanical inventory work, and invasive non-native plant species occurrences have been documented opportunistically for over a decade by a variety of botanical and ecological research projects carried out in the Park (McInnes 1986; Smith 1987; McMahon 1993; Mittelhauser et al. 1996, 2004; Glanz and Connery 1999; Greene et al. 1999, 2002, 2004, 2005; Lubinski et al. 2003). During this time, research on invasive plants and their effects on the landscape yielded data showing that some exotic species have significant impacts on native plant and animal species. In addition ACAD has developed an integrated pest management program (Connery 1991). ACAD then completed a study in which a model was developed to predict the rate and pattern of invasive species spread (Reiner and McClendon 2002). The model was applied to 15 invasive plant species thought to pose the greatest threat in the Park, resulting in their ranking in one of four classes according to the predicted rate of invasion. The taxa ranked in the model were: *Lonicera* X *bella* and *L. morrowii* (ranked 1, most invasive). Rank 2 species are: *Berberis thunbergii, Celastrus orbiculata, Frangula alnus, Lythrum salicaria* and *Rosa multiflora*. *Acer platanoides, Alliaria petiolata, Solanum dulcamara* and *Tussilago farfara* are Rank 3. Rank 4 (least likely to pose a threat) taxa are: *Bromus inermis, Cirsium arvense*, *Dactylis glomerata* and *Sonchus arvensis*.

Qualitative estimates suggested that these high-ranked invasives had become more common in ACAD over the several years preceding the study, but no systematic inventory of invasive plant species distribution and abundance had been done. An initial effort to catalogue the invasives present in the Park was made in 1987 (Smith et al. 1987). Mittelhauser et al. (1996) recorded the presence of invasive species in their inventories of 10 ACAD islands. Purple loosestrife management began in 1988 and continued through 2006 (Connery, 1997). In 2000, ACAD began to document and map the distribution and abundance of the species thought to be most invasive and widely distributed in the Park. Because purple loosestrife had already been inventoried and was being actively managed, it was not included in the distribution and abundance survey, nor is it included in this work. In addition to the 15 high-ranked species, the distribution and abundance survey identified several other exotics that threaten the integrity of ACAD's natural communities (Greene et al. 2004). For example, Japanese knotweed (*Fallopia japonica*) was not included in the model, but is known to be invasive and extremely difficult to control, and its occurrence in the Park had already been documented. Some taxa, including ninebark (*Physocarpus opulifolius*), are established in limited areas of ACAD where other known invasive species occur. Abundance and distribution data for the following taxa were also collected: Amur maple (*Acer ginnala*), Dutchman's pipe (*Aristolochia serpentaria*), goat's beard (*Aruncus dioicus*), Common barberry and Ottawa barberry (*Berberis vulgaris, B.* X *ottawensis*), European bittercress (*Cardamine impatiens*), burning bush (*Euonymus alatus*), shrubby St. Johnswort (*Hypericum prolificum*), goldenchain tree (*Laburnum* X *wateri*), privet (*Ligustrum* sp.), forest woodrush (*Luzula luzuloides*), wall

lettuce (*Mycelis muralis*), black locust (*Robinia pseudoacacia*) and cow vetch (*Vicia cracca*). The data from the abundance and distribution project quantify the extent of the invasive plant species problem at ACAD and provide a basis on which management decisions can be made. However, with the exception of purple loosestrife (Connery 1997), ACAD has no management plans for controlling or monitoring these invasive plant species.

The main objective of the current work was to develop management plans for the species included in the abundance and distribution project. Plans include:

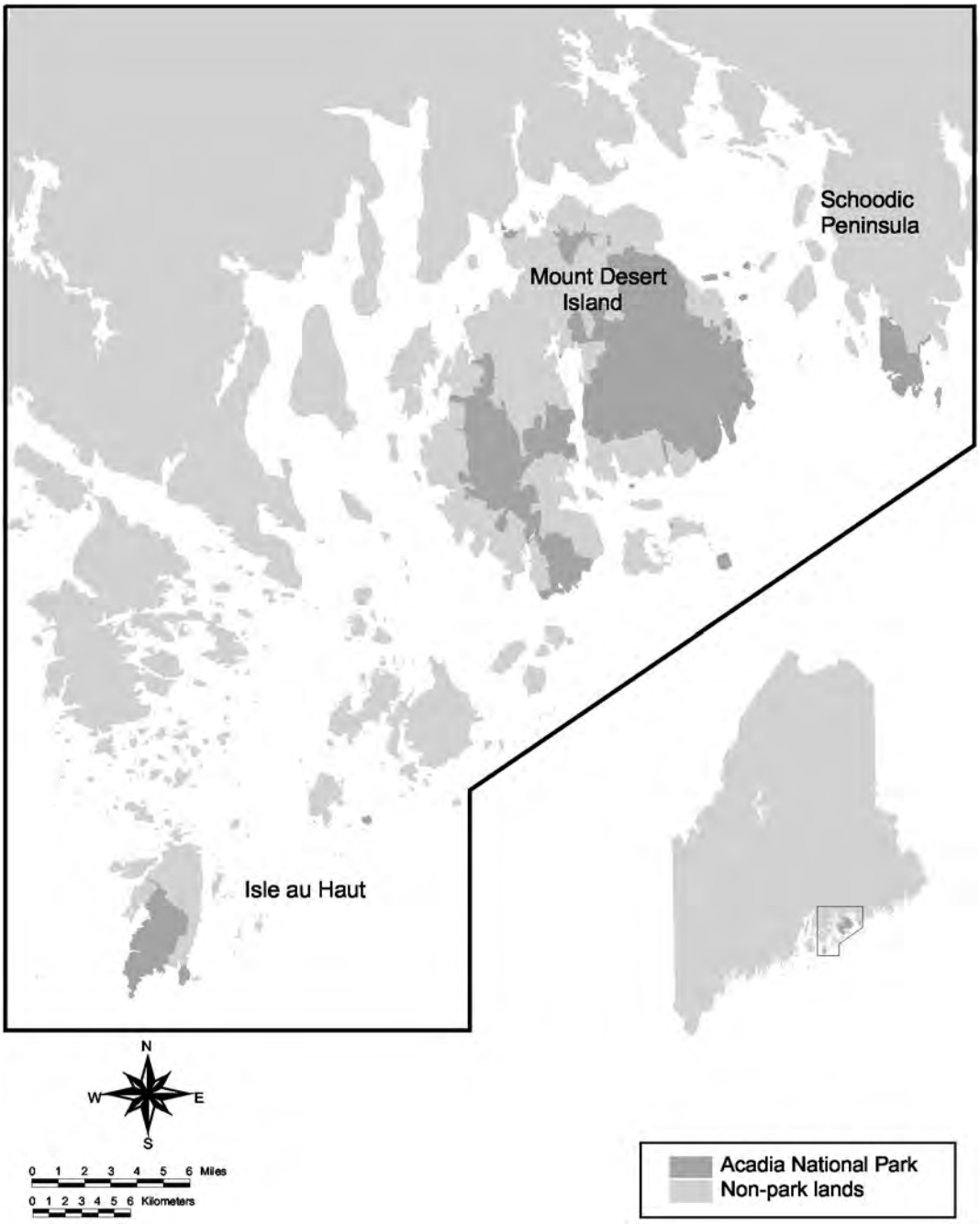
- Abundance and distribution at ACAD
- background information regarding habitat and species biology
- goals of management (eradication vs. control)
- methods used for control, as reported in the literature or in use by other agencies
- experimental treatments (e.g. combine mechanical and chemical methods on mature shrubs, mechanical only on smaller shrubs and chemical only on young or heavily browsed individuals in the same population)
- recommended monitoring protocols of managed populations
- a timeline for management and monitoring

Another goal of this report is to provide some possible management strategies in a Parkwide context. For example, multiple species occur on the same sites in the Mt. Desert Island section of ACAD. In such cases, management of a site may take precedence over the control of any one species. Another parkwide issue is how to manage in areas where distribution and abundance inventories have not been conducted (Schoodic, Isle au Haut, islands, St. Croix Island International Historic Site, easement lands). We will also discuss options for how to prioritize management actions (i.e. commit management resources to the most heavily infested areas to control populations of invasives or attempt eradication in areas with few invasives). Finally, we include suggestions for data synthesis and management.

Study Area

ACAD is located in eastern coastal Maine and comprises units on Mount Desert Island and Schoodic Point, in Hancock County, and on Isle au Haut, in Knox County (Figure 1). The park also manages several offshore islands, over 150 private properties on which the NPS holds conservation easements and St. Croix Island International Historic Site. The management plans included here pertain only to the 12,150 hectare (30,000 acre) Mount Desert Island unit because that is the portion of the park where an invasive species distribution and abundance inventory has been conducted. In addition, facilities and staffing on the Mount Desert Island portion of the Park would better support initial

Figure 1. Locator map for study area



Prepared by K. Anderson, Acadia National Park

management activities; other Park sections could be included after the efficacy of management plans is tested.

Methods

Management plans were developed for species identified by Reiner and McLendon (2002) and Greene et al. (2004) to be invasive at ACAD. These are: Amur maple (*Acer ginnala*), Norway maple (*Acer platanoides*), garlic mustard (*Alliaria petiolata*), barberries (*Berberis* X *ottawensis*, *B. thunbergii*, *B. vulgaris*), European bittercress (*Cardamine impatiens*), oriental bittersweet (*Celastrus orbiculata*), Canada thistle (*Cirsium arvense*), burning bush (*Euonymus alatus*), Japanese knotweed (*Fallopia japonica*), alder-leaved buckthorn (*Frangula alnus*), shrubby St. Johnswort (*Hypericum prolificum*), non-native honeysuckle species (*Lonicera* spp. and *L. japonica*), privet (*Ligustrum* spp.), forest woodrush (*Luzula luzuloides*), ninebark (*Physocarpus opulifolius*), black locust (*Robinia pseudoacacia*), multiflora rose (*Rosa multiflora*), bittersweet nightshade (*Solanum dulcamara*) and coltsfoot (*Tussilago farfara*). We conducted literature reviews to collect information on each species' background, nativity and history of introduction; life history; threats posed to native habitats; distribution at ACAD; abundance at ACAD; typical habitat at ACAD and elsewhere; and management alternatives. A large body of literature exists for some of the more problematic species, and for these, we cite existing literature reviews that contain exhaustive references, rather than citing all published papers; our aim was to provide references that would allow ACAD staff to consult the primary literature, if needed, to make appropriate management decisions. The plans also include management goals and a specific threshold that must be met before management activities are triggered. In addition we used ACAD data, information from our literature review and field experience at ACAD to develop a recommended management method for each species.

Results

General

Management plans for the 22 target species were developed as planned and are included as Appendix A. Our review of the literature yielded information about each species regarding its nativity and distribution, and features useful in identification. We also report aspects of species biology that confer competitive advantage, and therefore, increase the invasive potential of these plants. For example, the reproductive biology of garlic mustard enhances its persistence and rapid spread because it can self-pollinate, it produces thousands of seeds per plant and it can function as an annual, biennial or short-lived perennial. For most species, there was abundant literature regarding effective control options as well as reports of control regimes that proved ineffective. The individual plans present this information in detail; we present summary information below.

Threats to Natural Areas

The plans report ways in which the target invasive species have been demonstrated to threaten natural communities. All of the invasives included in this study have been shown to outcompete and displace native plants (Table 1) (Nuzzo 2000; Thunhorst and Swearingen 2001; Rhoades and Block 2002; Swearingen et al. 2002; Mehrhoff et al. 2003; Minnesota Dept. of Natural Resources 2004). The next most common threat is habitat alteration. Invasives may alter the habitat by changing soil properties; light, water and nutrient availability; and by releasing chemicals that inhibit the germination and growth of other plants (Thunhorst and Swearingen 2001; Rhoades and Block 2002; Rowe and Swearingen 2004). They can change wildlife habitat by forming thickets that prevent animal movement (Swearingen 2004). The presence of invasive plants can also change wildlife behavior by eliminating favored browse or by changing available nesting and sheltering areas (Nuzzo 2000). In addition to altering wildlife behavior, research shows that honeysuckles and ninebark produce fruits that are less nutritious than the native shrubs that they displace (Rehder 1960; Miller 2003). Invasive species may also cause decreased fruit set by native species (Table 1). In hardwood forests populated by native species, diverse herbaceous plants flower before canopy trees leaf out so that pollinators can access them. Norway maple leafs out much earlier than native tree species, and, where Norway maple has invaded, diversity of herbaceous species is greatly decreased, due, in part to the inability to get pollinated (Rhoades and Block 2002). Garlic mustard also displaces forest spring ephemerals and the invertebrate species dependent on their pollen (Nuzzo 2000). Research has shown that black locust, which produces showy flowers and copious nectar, is favored over native flowers, resulting in lower fruit and seed set by native species. At least five species are reported to have invaded rare species habitat (includes rare plants and animals): garlic mustard (Nuzzo 2000), Oriental bittersweet (Dreyer 1994), Canada thistle Greene at al. 2004; Japanese knotweed (Swearingen et al. 2002) and coltsfoot (Table 1). At ACAD, garlic mustard, Canada thistle and coltsfoot have been documented in or near rare plant populations (Greene et al. 2004).

Management Goals

Individual invasive species management plans included one or more of the following goals: eradication, prevention of spread, public education, reduction in area and/or number of individuals, and prevention of seed production. Eradication was set as a goal for Amur maple, hybrid barberry, common barberry, burning bush, privet, Japanese honeysuckle, black locust and multiflora rose. Partial eradication (elimination of some populations) was set as a goal for Japanese knotweed, forest woodrush and coltsfoot (Table 2). Eradication will, by definition, prevent the spread of these species within ACAD; the goal of prevention of spread was set for all species not targeted for eradication (Table 2). Public education was identified as a management goal for all species included in the study (Table 2). This includes education of visitors, who might identify and report previously unknown populations of invasives at ACAD and education of abutters, who might manage invasives on their property in order to prevent their spread

Table 1. Summary of threats posed by invasive plant species as reported in published literature.

		Threat					
Common Name	Scientific Name	Outcompetes Native Vegetation/ Decreases Diversity	Negatively Affects Native Polllinators	Invades Rare Species Habitat	Produces Less nutritious Fruits than Natives	Alters Wildlife Behavior (movement& foraging patterns)	Alters Habitat
Amur maple	*Acer ginnala*	X					
Norway maple	*Acer platanoides*	X	X				X
Garlic mustard	*Alliaria petiolata*	X	X	X			X
Japanese barberry	*Berberis thunbergii*	X					X
Common barberry	*Berberis vulgaris*	X					
European bittercress	*Cardamine impatiens*	X					
Oriental bittersweet	*Celastrus orbiculata*	X		X		X	X
Canada thistle	*Cirsium arvense*	X		X			X
Burning bush	*Euonymus alatus*	X				X	
Japanese knotweed	*Fallopia japonica*	X	X	X			X
Alder-leaved buckthorn	*Frangula alnus*	X					X
Shrubby St. Johnswort	*Hypericum prolificum*	X					
Privet	*Ligustrum* spp.	X				X	X
Japanese honeysuckle	*Lonicera japonica*	X			X	X	
Honeysuckle species	*Lonicera* spp.	X			X	X	X
Forest woodrush	*Luzula luzuloides*	X					
Ninebark	*Physocarpus opulifolius*	X			X	X	
Black locust	*Robinia pseudoacacia*	X	X				X
Multiflora rose	*Rosa multiflora*	X				X	X
Bittersweet nightshade	*Solanum dulcamara*	X					
Coltsfoot	*Tussilago farfara*	X		X			

into the Park. Some species are sufficiently pervasive or difficult to control that eradication is not possible at this time. For these species, namely: Norway maple, garlic mustard, Japanese knotweed, alder-leaved buckthorn, honeysuckle spp., forest woodrush, ninebark, bittersweet nightshade and coltsfoot, the goal is to reduce their current cover (Table 2). Preventing seed production, another goal set for several species, will help to halt the spread of some species and may even result in the decline of others. Taxa for which this goal has been set are: garlic mustard, Japanese barberry, European bittercress, Oriental bittersweet, alder-leaved buckthorn, privet, honeysuckle spp., ninebark and coltsfoot (Table 2).

Recommended Treatment Methods

The invasive species covered by this study include woody and herbaceous plants; annuals, biennials and perennials; and vines, shrubs and trees. Plants with different life forms require different management methods, but treatments for all of those we studied can be summarized by using general categories (Table 3). Mechanical methods include pulling and digging; removal of flowers or fruits; and mowing or cutting. Various glyphosate treatments are recommended for all but two species. Pulling and digging are recommended for herbaceous plants such as garlic mustard, European bittercress, bittersweet nightshade and coltsfoot, and for seedlings of many woody invasives: Amur and Norway maples; hybrid, Japanese and common barberries; burning bush; and honeysuckle (Table 3). Flower and fruit removal are recommended for garlic mustard, European bittercress, Canada thistle, privet and forest woodrush (Table 3). Mowing and cutting are components of the recommended treatments for Japanese knotweed, shrubby St. Johnswort and Japanese honeysuckle (Table 3). Application of glyphosate to the cut stems of woody plants is the treatment most often recommended for woody invasives at ACAD. In addition to pulling plants and removing fruits, control of garlic mustard, European bittercress, Canada thistle and Japanese honeysuckle is enhanced by foliar glyphosate application (Table 3). Because no data were available for forest woodrush control, we recommend trials with foliar applications of glyphosate to assess their efficacy (Table 3). Oriental bittersweet and bittersweet nightshade are difficult to control and are the only species for which use of the herbicide triclopyr is recommended: cut stem application for the former and foliar spray for the latter (Table 3). Any pesticide use at ACAD must be approved by the NPS prior to application and must adhere to NPS policies and the State laws governing pesticide application. All pesticide applications at ACAD must performed by a certified Master Pesticide Applicator.

When the current project was well underway, Park staff asked that a discussion of the invasiveness of lupine (*Lupinus polyphyllus*) be included in our report. Lupine, present along roadsides and in other disturbed habitats at ACAD for many years, was observed by Resource Division staff to be colonizing one of the Park's large wetland complexes. We added this species to our literature review to determine whether it had been documented as an invasive species elsewhere and, if so, what control measures were effective. Information on lupine is included as Appendix B. A summary of ACAD's purple loosestrife management activities is included as Appendix C.

Table 2. Summary of management goals for invasive species of Acadia National Park.

		Goal				
Common Name	Scientific Name	Eradication	Prevent Spread	Educate Public	Reduce Current Cover	Prevent Seed Production
Amur maple	*Acer ginnala*	X		X		
Norway maple	*Acer platanoides*		X	X	X	
Garlic mustard	*Alliaria petiolata*		X	X	X	X
Hybrid barberry	*Berberis* X *ottawensis*	X		X		
Japanese barberry	*Berberis thunbergii*		X	X		X
Common barberry	*Berberis vulgaris*	X		X		
European bittercress	*Cardamine impatiens*		X	X		X
Oriental bittersweet	*Celastrus orbiculata*		X	X		X
Canada thistle	*Cirsium arvense*		X	X		
Burning bush	*Euonymus alatus*	X		X		
Japanese knotweed	*Fallopia japonica*	6 smallest populations	X	X	3 larger populations	
Alder-leaved buckthorn	*Frangula alnus*		X	X	X	X
Shrubby St. Johnswort	*Hypericum prolificum*		X	X		
Privet	*Ligustrum* spp.	X		X		X
Japanese honeysuckle	*Lonicera japonica*	X		X		
Honeysuckle species	*Lonicera* spp.		X	X	X	X
Forest woodrush	*Luzula luzuloides*	13 smallest populations	X	X	10 larger populations	
Ninebark	*Physocarpus opulifolius*		X	X	X	X
Black locust	*Robinia pseudoacacia*	X		X		
Multiflora rose	*Rosa multiflora*	X		X		
Bittersweet nightshade	*Solanum dulcamara*			X	X	
Coltsfoot	*Tussilago farfara*	Little Harbor Bk. and Jordan Str. populations	X	X		X

Table 3. Summary of recommended treatment methods for invasive species of Acadia National Park

		Recommended Treatment Method						
Common Name	Scientific Name	Pull/Dig Plants	Remove Flowers/ Fruits	Mow/Cut	Glyphosate on Cut Stumps	Glyphosate Foliar Spray	Triclopyr on Cut Stumps	Triclopyr Foliar Spray
Amur maple	*Acer ginnala*	seedlings <2cm diam		Aug-Sept	Aug-Sept			
Norway maple	*Acer platanoides*	<1cm diam		May-June	May-June			
Garlic mustard	*Alliaria petiolata*	X	X			apply 2% glyphosate to rosettes in early spring		
Hybrid barberry	*Berberis* X *ottawensis*	seedlings		Aug-Sept	Aug-Sept			
Japanese barberry	*Berberis thunbergii*	seedlings		Aug-Sept	Aug-Sept			
Common barberry	*Berberis vulgaris*	seedlings		Aug-Sept	Aug-Sept			
European bittercress	*Cardamine impatiens*	X	X			apply 2% glyphosate to rosettes in early spring		
Oriental bittersweet	*Celastrus orbiculata*						May-June	May-June
Canada thistle	*Cirsium arvense*		X			Aug-Sept		
Burning bush	*Euonymus alatus*	<1m tall		before fruit ripens	before fruit ripens			
Japanese knotweed	*Fallopia japonica*			2-3x/y	fill hollow stems after cutting	1 month after mowing		
Alder-leaved buckthorn	*Frangula alnus*				Sept-Oct			
Shrubby St. Johnswort	*Hypericum prolificum*			X	Aug-Sept			
Privet	*Ligustrum* spp.		X	Growing season	drill holes in stumps and fill			
Japanese honeysuckle	*Lonicera japonica*			mid-summer		apply to resprouts within 2d of first killing frost		
Honeysuckle species	*Lonicera* spp.	<1cm diam		Sept-Oct	Sept-Oct			
Forest woodrush	*Luzula luzuloides*		X			early, middle and late season applications to test efficacy		
Ninebark	*Physocarpus opulifolius*			Sept-Oct	Sept-Oct			
Black locust	*Robinia pseudoacacia*			July-August	July-August			
Multiflora rose	*Rosa multiflora*			July-August	July-August			
Bittersweet nightshade	*Solanum dulcamara*	X					July-Aug	
Coltsfoot	*Tussilago farfara*	X	X					

Data Management

We developed data sheets to document invasive plant occurrences, to document pre- and post-control monitoring of invasive plant species and to document management actions. The data sheet shown in Figure 2 can be used to document a previously unknown invasive species occurrence or to update data about a known population. This form allows the location to be given by air photo number, topographic map name, descriptively (e.g. on the west side of the Park Loop Road, 50 m north of Bear Brook picnic area), or with GPS coordinates. Users also supply information about the habitat and the population size. Once the form is completed, the data can be easily transferred to an ACAD database, which can be updated as management or monitoring are undertaken. Figure 3 shows a data sheet to be used for pre- or post treatment monitoring. Workers using the monitoring form should use the same site name and description that originated on the documentation form. Control activities can be tracked using the form shown on Figure 4, and data can again be transferred to the ACAD database.

Discussion

Management Goals

The goals set in the individual management plans should be attainable if the plans are implemented. Even if ACAD does not undertake active management activities, the goal of public education can be met. Resource Management staff could begin by providing rudimentary training about invasives for people in other divisions. If Park employees who are out in the field are trained about the importance of identifying, documenting and controlling invasives in the Park they will be able to provide valuable data to resource managers and amplify what the Resource Management Division can do. It will also be useful to educate private landowners who abut Park property about invasives. ACAD should provide invasives fact sheets (available from other government entities), which explain why invasives threaten natural ecosystems and how to control them. Effective communication with abutters and support of their efforts to control invasives will result in fewer exotic plant invasions of Park lands from neighboring properties. Similarly, ACAD should make owners of easement lands aware of any invasive species on their property and encourage them to control those species. Resource Division staff should also work with the Interpretive Division to help them incorporate invasives education into their programming. Park staff worked in cooperation with University of Maine Cooperative Extension and several other entities to develop two brochures about landscaping with native plants (UMCE Bulletins 2500 and 2502). This project also funded distribution and display of the brochures at nurseries throughout Maine. It would undoubtedly be helpful to maintain communication between ACAD and the nursery industry regarding invasive plants. In addition, public education efforts will likely result in consumer requests for nurseries to discontinue sales of invasive species and for increased offerings of native species appropriate for home gardens. Finally, ACAD might want to consider partnering, or at least communicating with local towns about invasives and offering educational resources that would give more citizens an awareness of how invasive species affect the landscape and how they can be controlled.

Figure 2. Sample invasive species documentation data sheet

INVASIVE PLANT SPECIES DOCUMENTATION RECORD

Species_____
Date_____
Surveyors _____
Photograph taken (circle)? Y N _____
Location (UTM) _____N _____E
USGS Quad _____
Air Photo Number and Year (if known) _____
Landmark/General Area _____
Site Description (check one) __disturbed road edge __disturbed trail edge
__undisturbed area near road; distance from road_____ft.
__undisturbed area near trail; distance from trail____ft.
__other disturbance; describe_____
__other undisturbed site; describe_____

Associated Plant Species:

Stratum	Dominants	Cover (%)
Canopy		
Shrub/Sapling		
Herb		
Bryophyte		

Population Size:
__1-5 individuals __5-10 individuals __10-20 individuals
__20-100 individuals __>100 individuals
Area Occupied by Population: _____m^2 ___<1 acre ___>1 acre

Phenologic Stages observed: __vegetative __flowering
__fruit __seedlings

Notes:
_____
_____
_____

Figure 3. Sample invasive plant monitoring data sheet

Grid Monitoring Data Sheet

Grid #: **Date:**
Transect #:
Personnel:

Plot Number	Meter Number	# Reproductive Stems	# Non-reproductive Stems	Notes
1	**1**			
2	**3**			
3	**5**			
4	**7**			
5	**9**			
6	**11**			
7	**13**			
8	**15**			
9	**17**			
10	**19**			
11	**21**			
12	**23**			
13	**25**			
14	**27**			
15	**29**			

Figure 4. Sample invasive plant management documentation data sheet

INVASIVE PLANT SPECIES MANAGEMENT DOCUMENTATION

Species_____
Date_____ **USGS Quad** _____
Location (UTM)_____N _____E
Personnel _____
Air Photo Number and Year (if known) _____
Landmark/General Area _____
Weather conditions (complete if applying herbicides):
Air temperature: _____ Wind speed: _____
Precipitation: _____
Area Occupied by Population: _____m^2 ___<1 acre ___>1 acre
Population Size:
__1-5 individuals __5-10 individuals __10-20 individuals
__20-100 individuals __>100 individuals

Treatment:

Mechanical:

Pulling/Digging, Flower Removal, Fruit Removal:
How many/much removed (specify numbers or volume e.g. two 50 gallon bags)?
_____
_____
Disposal site: _____
Mowing/Cutting: Specify area mowed or cut _____m^2 ___<1 acre ___>1 acre

Chemical:

Herbicide Application (specify chemical, concentration, mode of application):
_____
_____
_____
Specify area controlled: _____m^2 ___<1 acre ___>1 acre
Notes:
_____
_____
_____
_____
_____

Recommended Treatment Methods

All treatment methods recommended in this report have proved to be effective elsewhere and some have already been used at ACAD. Park staff should review the plans and assess how they mesh with established integrated pest management (IPM) guidelines, modify them as needed and implement them when feasible. Pulling plants has proved efficacious to control garlic mustard and European bittercress. Population sizes have decreased dramatically over the several years during which Park staff and volunteers have worked to remove these plants at ACAD (2005). Both species are annuals in the mustard family and produce hundreds of seeds per plant. Plants have been pulled before seeds ripen, preventing dispersal of additional seeds, so most of the plants that have grown since management efforts began are the result of seed-banked seeds. Removal of immature fruits may also prove to be effective in controlling the spread of lupine in the Park (see Appendix B.). We recognize that ACAD may be unable to fully implement all plans immediately; however, we recommend that the garlic mustard and bittercress programs continue. The benefits are at least threefold: 1) the invasives are controlled, 2) because volunteers do the work, the program is essentially cost-free, and 3) volunteers see the impact of invasive species on Park lands, become educated about invasives and carry this knowledge with them to share with others. Many of the plans for woody species recommend pulling them as seedlings and small plants. This would be most appropriate in sites where control of reproductive plants has taken place, and new seedlings are the result of seed-banked seeds. There is less point in pulling young plants if fruit-bearing plants are not removed.

Mowing and cutting are recommended for several species, most often in combination with herbicide application. No methods for shrubby St. Johnswort control were available; however, field observations indicate that this species may not produce shoots from cut stems. If this is true, simple cutting would be a non-chemical control method and one that could be undertaken by volunteers. We suspect that this species could become much more widespread in the Park and recommend that ACAD do some trials to assess the effectiveness of stem cutting to control shrubby St. Johnswort. If successful, the management plan should be fully implemented before the population spreads any farther. In addition, ACAD staff should publish their identification of shrubby St. Johnswort as an invasive species and the results of control efforts. Cutting alone may also be sufficient to kill the lone Japanese honeysuckle plant at ACAD. Because this species is known to be highly invasive elsewhere and because the warming climate will likely result in increased success of Japanese honeysuckle and other plants common farther south, any stems in the documented population should be cut and removed. Mowing is an important component of a Japanese knotweed control program. Mowing two or three times a year can help to prevent the spread of knotweed and, like pulling and cutting, it offers a non-chemical means of control. A follow-up application of glyphosate is important if a decrease in population size is the goal.

Herbicide treatments are recommended for the majority of the plants studied. Glyphosate is the herbicide recommended most often, either brushed on cut stems or as a foliar spray. An advantage of cut stem treatments is that the can be restricted to the target species, whereas, foliar sprays often effect non-target species (Eckardt 1987; Dreyer 1994). Triclopyr is recommended for two species: Oriental bittersweet and bittersweet nightshade because studies have shown this to be the herbicide most effective in controlling them (Converse 1984; Dreyer 1994; Miller 2003). Evaluation of herbicides and their use on Park lands is beyond the scope of this work; we

sought to identify the best control methods as identified in the literature. If the literature showed that two herbicides were equally effective for an invasive species, we chose glyphosate because it has two potential advantages: first, it has been in use at ACAD for over ten years with no apparent negative effects on the natural systems in which it has been used, and second, its breakdown products are tightly bound to soil particles and so are not mobile in the environment (Extoxnet 1994).

Data Management

Standardized data management methods and consistency in data handling will be vital to the success of ACAD's invasive plant management program. As discussed above in Management Goals, education about invasives should be incorporated into trainings for all Park divisions with staff who go into the field. Use of the documentation form should be included in the training, so that people in other divisions know how to make Resource Management Division staff aware of new populations of exotics, and can add them to the existing database. Management plans can then be modified to include any new sites. It will be equally important to use standardized data collection methods for pre- and post-management monitoring, and to document management activities. Transfer of data from the data sheets to the Park database should be a relatively simple matter, with lack of staff time the only impediment. ACAD might consider including invasives data entry in the list of opportunities available to volunteers. Work on this task might also be appropriate for an intern from the local high school or college (Mount Desert Island High School or College of the Atlantic). The best way to facilitate data management would be to collect it electronically and eliminate the need for data entry. The current forms could easily be modified to a format compatible with hand-held data loggers. If ACAD has field data recorders, their use for invasive plant management would be appropriate.

If ACAD chooses to implement the invasive species management plans, the importance of data management cannot be underestimated. Documenting populations of invasives provides the Park with information about what species are present, where they are and the size of each population, but if those data are not added to the database and new populations scheduled for management (either monitoring or control), then populations can continue to grow and spread. Or, if management actions are taken, and pre- and post-treatment monitoring data are never collected, entered and evaluated, managers won't know if their efforts have been successful or if further management is needed.

Invasives Management by Site

Invasive species management has, thus far, been discussed on a species by species basis and that makes sense much of the time. Some very problematic plants, like Japanese barberry and honeysuckle, are distributed widely over most of the Park with scattered plants dotting the landscape. Committing to controlling these species, occurrence by occurrence, would mean spending a large amount of time using GPS to navigate to each plant, hiking there with the equipment needed to treat the invasive plant, and hiking back. Based on the Park's distribution and abundance data for invasives, we have identified four sites where several invasives co-occur, generally in high numbers (Table 4). We recommend that ACAD prioritize these sites for invasives control. If several invasive species grow in the same area, it makes sense to control

them all during the same management visit, rather than taking a species by species approach and returning to the site several times to treat one species at a time. Because the control methods for many of the species are similar, the same equipment and chemicals (if needed) could be used for several taxa, minimizing the amount of gear to be carried to and through the site.

Nine invasive species have been documented in the Great Meadow Area. Control of invasives at Great Meadow is important for two reasons. First, although the area has an extensive history of human-caused disturbance, there has been little disturbance for about a century, and it is a natural-appearing wetland complex. Second, it is near the eastern boundary of the Park and could act as a buffer between private lands and the interior of the Park. Controlling invasives here would prevent their spread into the more undisturbed parts of the Park.

Fourteen invasive species grow in the Outer Ledgelawn area. Outer Ledgelawn is also on the periphery of the Park and ridding this area of invasives would prevent these species from spreading into to the Park. We suspect that this area has been somewhat neglected because of the extensive disturbance history in this area, and its proximity to non-Park lands. About five years ago, a connector trail to allow pedestrian access to ACAD from downtown Bar Harbor was routed, in part, through the ACAD portion of Outer Ledgelawn. The trail has had fairly heavy use year round since it opened. Trail users can act as dispersers of invasive plant seeds when the seeds get stuck to shoes or clothing, move with them, and then drop off, potentially in less disturbed interior areas of the Park. Invasives that grow on Outer Ledgelawn and might be most easily spread in this way are garlic mustard and European bittercress.

Duck Brook harbors three invasive species, the most numerous of which is Japanese barberry. Scattered barberry shrubs grow along the length of the brook, from its start at Eagle Lake to its confluence with the ocean. Honeysuckles grow along the brook too, but there are fewer of them, with even fewer alder-leaved buckthorn plants. All three of these species have invaded natural areas at ACAD and the Duck Brook populations should be eliminated because they are seed sources for potential colonization of new sites. Purple loosestrife was documented and managed in the wetland east of Duck Brook and management activity in this area would enhance the likelihood of finding new purple loosestrife and controlling it before it was able to spread.

The Schooner Head/Great Head area supports eight invasive plant species. The area includes some sites of estates that were extant prior to a large wildfire in 1947; Great Head, and Sand Beach. The estate sites are located along Schooner Head Road, and the area is another example of a place near the edge of the Park that could buffer Park lands from exotic plant invasions from populations on private lands. Managing invasives in the Schooner Head Road area would decrease their spread farther into the Park. Great Head is also the site of a former estate that had extensive horticultural plantings. Honeysuckles have escaped to become the dominant shrub in some fields behind Sand Beach and Oriental bittersweet forms dense curtains immediately adjacent to the beach. Sand Beach includes the only occurrence of a beach dune community at ACAD. Oriental bittersweet is documented to have invaded dune communities farther south and is growing up to edge of the dunes now. Purple loosestrife has also been documented and managed in this area in the past. We recommend this area as another place where it makes sense to manage all invasives at a site, rather than by following the prescriptions of individual plans.

Table 4. Sites that harbor numerous invasive species at Acadia National Park.

		Site			
Common Name	Scientific Name	Great Meadow	Outer Ledgelawn	Duck Brook	Schooner Head/Great Head
Amur maple	*Acer ginnala*	X			
Norway maple	*Acer platanoides*		X		X
Garlic mustard	*Alliaria petiolata*		X		X
Hybrid barberry	*Berberis* X *ottawensis*				
Japanese barberry	*Berberis thunbergii*	X	X	X	X
Common barberry	*Berberis vulgaris*	X	X		X
European bittercress	*Cardamine impatiens*		X		
Oriental bittersweet	*Celastrus orbiculata*	X	X		X
Canada thistle	*Cirsium arvense*		X		X
Burning bush	*Euonymus alatus*				
Japanese knotweed	*Fallopia japonica*		X		
Alder-leaved buckthorn	*Frangula alnus*	X	X	X	
Shrubby St. Johnswort	*Hypericum prolificum*	X			
Privet	*Ligustrum* spp.				
Japanese honeysuckle	*Lonicera japonica*				X
Honeysuckle species	*Lonicera* spp.	X	X	X	X
Forest woodrush	*Luzula luzuloides*	X			
Ninebark	*Physocarpus opulifolius*	X	X		
Black locust	*Robinia pseudoacacia*		X		
Multiflora rose	*Rosa multiflora*		X		
Bittersweet nightshade	*Solanum dulcamara*		X		
Coltsfoot	*Tussilago farfara*				

An alternative to number of invasive species at a site as a criterion for prioritizing the site for management is site quality or value. Ecological or some other Park determined value of documented invasive occurrences could be evaluated, and those with high value could be prioritized for management. For example, of the sites listed in Table 4, Great Meadow and Duck Brook would likely still be high priority sites because spread of invasives from these areas threatens undisturbed habitats. Great Meadow and Duck Brook comprise sites where visitor use is high and habitat restoration might enhance visitor the experience. Conversely, disturbance at Outer Ledgelawn and Schooner Head/Great Head has been extensive, visitor use of these sites is lower, and ACAD might not prioritize them based on the site quality criterion.

Parkwide Perspective

Mount Desert Island is the only portion of ACAD where an inventory of invasive species distribution and abundance (with GPS location data) has been completed. Some data have been collected for Schoodic, Isle au Haut, park-owned offshore islands, St. Croix Island International Historic Site and easement lands (McInnes 1986; Smith et al. 1987; Mittelhauser et al. 1996; Gregory, Weber and Rooney ACAD files). Once inventory work has been completed on these units, the invasive species plans in this report could be appended to apply to the entirety of ACAD. Few invasives have been reported from the Schoodic unit, and it should be given low prioritiy for inventory. One invasive, common reed (*Phragmites australis*) grows at Schoodic as part of a water treatment system. One of the habitats that this species most often invades is saltmarshes, some of which occur on Schoodic. We recommend scheduling annual trips to remove flower or immature seed heads from these plants to prevent its spread, even if no management plans are developed for Schoodic or for common reed.

The best documentation of invasives on other ACAD units comes from Isle au Haut where Japanese barberry appears to be the worst problem (Smith 1987; Weber and Rooney ACAD files). It grows extensively outside the Park, is common in the Duck Harbor area of ACAD, and forms a dense thicket in at least one brookside wetland on Park land. We recommend that ACAD plan for and undertake invasives inventory work on Isle au Haut. Private landowners are aware of the problem and we believe that some control efforts have taken place on private land. Because there is already awareness of the problem, ACAD might be well situated to enlist private landowners to remove barberry from their land, thus helping to prevent new infestations in ACAD.

ACAD also has an opportunity to protect its lands from new infestations by working with private landowners whose property the NPS holds conservation easements. Many easement properties are near NPS lands and managing invasives on easements would reduce the spread of these species into the Park. The first step in this process is to search the existing database of baseline species lists for easement lands to identify those where invasives have been documented. Landowners could then be provided with information about these species and the methods recommended for their control at ACAD.

Recommendations

Management Goals

- incorporate education about invasives into staff trainings
- incorporate education about invasives into interpretive programs
- provide information about invasives and their management to easement property owners if invasives have been documented on their lands
- communicate with local towns and owners of abutting lands about invasives and their management
- continue to communicate with local nursery owners about the effects of invasives on natural communities and encourage use of native plant material
- coordinate educational efforts with State agencies working on the issue (e.g. Department of Agriculture/State Horticulturist; Maine Natural Areas Program)

Recommended Treatment Methods

- review invasive species management plans with regard to ACAD's IPM guidelines
- continue efforts to control garlic mustard and European bittercress using volunteers
- conduct trials to assess the efficacy of stem cutting for shrubby St. Johnswort control
- mow or cut mapped Japanese knotweed populations to slow its spread at ACAD
- review effectiveness of plans five years after implementation and update as needed

Data Management

- incorporate use of data forms into invasives education for ACAD staff
- establish a system for entering data from forms into electronic database and keeping database updated (possibly utilize interns or volunteers)
- move to electronic data collection using hand-held data recorders

Invasives Management by Site

- prioritize sites with multiple invasive species for management: Great Meadow, Outer Ledgelawn, Duck Brook, Schooner Head Road/Great Head/Sand Beach

Parkwide Perspective

- remove immature fruits from common reed at Schoodic water treatment facility
- do an invasives inventory on Isle au Haut unit
- work with private landowners on Isla au Haut to control Japanese barberry
- identify conservation easement parcels where invasives have been documented and educate landowners about controlling them

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Appendix A

Management Plans for Invasive Species in Study

***Acer ginnala* Maxim., Amur Maple**
Sapindaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Amur maple is native to China and Japan. Introduced to the US in the 1860's, *Acer ginnala* has since become naturalized in several states, with extensive populations in Illinois and Missouri (Dirr 1983; Hoffman and Kearns 1997; Easy Living Native Perennial Wildflowers 1999; Minnesota Department of Natural Resources 2004). It continues to be sold as an ornamental.

Life History/Biology: Amur maple is a small tree, growing as wide as tall and often multistemmed. The double-toothed leaves are opposite, longer than wide and shallowly lobed, the middle lobe much longer than the lateral lobes. Clusters of yellow-white, fragrant flowers appear in the spring. Fruits are reddish samaras, about 2-3 cm long which are retained until late fall. Prolifically produced seeds are reported to be widely wind-dispersed (Dirr 1983).

Threats to Native Habitats: *Acer ginnala* displaces native trees and shrubs in open forest settings. Once established, it tends to shade out native herbaceous vegetation (Easy Living Native Perennial Wildflowers 1999; Minnesota Department of Natural Resources 2004).

Distribution at ACAD: One site on has been documented to date. It is on the east edge of Great Meadow (Greene et al. 2004).

Abundance at ACAD: About 20 individuals comprise the population (Greene et al. 2004). A few of these are large (>10 cm dbh), reproductive individuals; the rest are smaller, vegetative plants.

Habitat: Amur maple has been observed to colonize hedgerows, open woods, forests and prairies (Minnesota Department of Natural Resources 2004).

At ACAD: The known occurrence is located in an area which burned during the 1947 fire. Gray birch (*Betula populifolia*) and red maple (*Acer rubrum*) dominate the canopy. Alder-buckthorn (*Frangula alnus*), a woody invasive, is the dominant shrub and downy goldenrod (*Solidago puberula*) and flat-topped white aster (*Doellingeria umbellata*) dominate the herb layer. Historic land uses near this site include a water works, farm and air strip. Many occurrences of invasives have been documented near this site (Greene et al. 2004).

Management Goals:

- Eradicate this species at ACAD
- Educate the public about identifying this species and preventing its spread

Action Threshold: Presence of one plant

Management Alternatives:
Mechanical:

Burning will top-kill Amur maple, but abundant stump sprouts are produced. Similarly, sprouts will be produced if trunks are cut. Seedlings and small plants can be pulled, but digging or pulling larger individuals causes excessive soil disturbance (Easy Living Native Perennial Wildflowers 1999; Minnesota Department of Natural Resources 2004).

Chemical:
Trunks should be cut and full strength glyphosate dripped or painted on the cut stump (easywildflowers.com 1999). Alternatively, full strength triclopyr can be applied to cut stumps or mixed with water (1:1) and applied as a basal bark spray (Minnesota Department of Natural Resources 2004). Repeat as necessary following resprouts or appearance of new plants.

Biological: None are available at this time.

Recommended Management Method for ACAD: Pull seedlings and plants under 2 cm stem diameter. Cut larger plants and apply full strength glyphosate to cut stumps. Herbicide treatment should take place late in the growing season (August or September) when at least two rain-free days are predicted.

Monitoring Protocol: The population comprises less than 100 m^2. Pre-treatment monitoring should comprise: a count of all stems greater than 10cm dbh and three $1m^2$ plots within which stems less than 10cm dbh are counted. The site should be visited twice during the growing season following herbicide treatment. Because the population is small, the whole treatment area can be evaluated for the presence of seedlings, stump sprouts and trees missed during treatment. Seedlings should be immediately pulled and removed from the site. Re-treatment of stump sprouts should be scheduled. Once plants are eradicated, annual monitoring should continue for the next five years; biennial checks of treated sites should follow. No data are available regarding viability of seed-banked seeds.

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***Acer platanoides* L., Norway Maple**
Sapindaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Norway maple is the most widespread European maple, and is native from Norway to Turkey and northern Iran. It was introduced to the US by John Bartram who received seedlings from London in 1756. Bartram then began offering it for sale and George Washington purchased two plants from him in 1792 for installation at Mt. Vernon. This tree is tolerant of poor conditions, has been widely planted in urban areas and is still sold in the nursery trade (Rhoades and Block 2002).

Life History/Biology:
Acer platanoides is a large tree (18-20 m tall, trunk diameter up to 2 m) with smooth grey bark. Its twigs are brown; the leaf scars have 3 bundle scars. Leaves are 5-7 lobed, dark, glossy green, wider than long and ooze milky sap when torn. Flowers are yellow-green in stalked clusters appearing in early spring. Fruits are samaras with widely divergent wings (Rhoades and Block 2002).

This species is a canopy hardwood that leafs out earlier than most other species in the spring and retains its leaves longer in the fall. Seedlings and saplings are extremely shade-tolerant (Rhoades and Block 2002).

Threats to Native Habitats: Norway maple invades natural areas, where it outcompetes native red and sugar maples and other deciduous trees. Its competitive ability results in a monoculture, decreasing species diversity. Because it can invade intact hardwood forests, the ecology of these sites is altered. For example, spring ephemeral species grow primarily in hardwood forests and are dependent on a period of early season high light conditions for their survival. When Norway maple invades, that high light period is eliminated or reduced because it leafs out so much earlier than native tree species, outcompeting natives for light, nutrients and moisture, and altering pollinator foraging patterns (Rhoades and Block 2002; Swearingen et al. 2002).

Distribution at ACAD: Norway maple has been documented from 17 sites on the east side of MDI and one site on the west side of the island. Most of the populations are within about two miles of downtown Bar Harbor, but this taxon also occurs on Great Head, at Blackwoods Campground, Jordan Pond, off the Stanley Brook Road and at the Seawall Picnic Area (Greene et al. 2004).

Abundance at ACAD: At nine of the documented sites, the populations comprised 10 or fewer individuals. Three of the populations had 11-20 individuals, three had 21-100, two had more than 100 and no population estimate was made for one population (Greene et al. 2004).

Habitat: Norway maple has invaded forests and other natural habitats, as well as disturbed sites like roadsides and old fields (invasive.org, no date given; Haines and Vining 1998)

At ACAD: it is most often associated with old estates and the extant populations are likely the progeny of trees used in landscape plantings (Greene et al. 2004).

Management Goals:

- Reduce abundance of Norway maple to maintenance level, which will be reached when the only occurrences are stump sprouts from managed trees and seedlings originating from seed-banked seeds.
- Prevent new invasions
- Educate the public about identifying this species and preventing its spread

Action Threshold: Presence of one plant

Management Alternatives:

Mechanical:

Pulling is feasible at seedling stage. Mowing and cutting can be done when young and saplings can be removed with power saws (brush-hog). Girdling is also effective: using an axe, cut through the bark all the way around the base of the trunk (Rhoades and Block 2002; Swearingen et al. 2002; University of Connecticut).

Chemical:

Seedlings and young trees can be controlled with a foliar spray of:
Roundup® [glyphosate (41%)]: 1.25 fl. oz./gal or FINALE® [glufosinate-ammonium (11.33%)]: 3 fl. oz./gal (University of Connecticut).

Small trees (under 10 cm dbh) will also be effectively killed by applying 2-4% Brush-B-Gone® (triclopyr) in oil to the bark within 25 cm of the root collar (Rhoades and Block, 2002). This treatment is most effective if done just before active growth begins or during the early part of the growing season.

Large trees should be cut and one of the following herbicide treatments applied to the freshly cut stump: Brush-B-Gone (triclopyr) undiluted (hort.uconn.edu, no date given; Rhoades and Block, 2002) or Roundup (glyphosate) 1:1 glyphosate:water (University of Connecticut).

Biological: None available at this time.

Recommended Management Method for ACAD:

Pull seedlings and plants small enough to be removed without causing extensive soil disturbance (plants with dbh < 1cm). All Norway maple plants that are too large to pull should be cut early in the growing season. A 1:1 Roundup:water solution should be applied to the cut stumps.

This treatment is appropriate for all sites with the possible exception of the Jordan Pond house, where trees are large and highly visible. Trees could be cut and removed in March or April, before the area is open to visitors. If management is completed while the ground is still frozen, there will be less visible impact to the area.

Monitoring Protocol:

The documented populations are small, allowing all plants to be counted at the sites where control is planned. Following initial control the total area of each site should be searched for seedlings, stump sprouts and trees missed during treatment. Each treatment site should be monitored twice during the growing season following treatment. Any seedlings found should be pulled and removed from the site. Stump sprouts and missed trees should be scheduled for removal and herbicide treatment. If seedlings and stump sprouts are no longer observed during monitoring, sites should be visited once the following year. If no more seedlings or stump sprouts have appeared, annual visits to the site where Norway maple persisted longest should be made for the next five years.

Documentation of recently established and previously overlooked populations is a vital component of monitoring. All newly documented populations small enough to be eradicated should be removed by digging or employing the methods described above for eradication. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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***Alliaria petiolata* (Bieb.) Cavara & Grande, Garlic Mustard**
Brassicaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Alliaria petiolata* is native to Europe, North Africa, Sri Lanka and India. The first US record is from 1868 on Long Island, NY. It has naturalized from Quebec to Ontario, south to North Carolina and Kentucky and west to Kansas and North Dakota (Pratt no date given; Blossey et al. 2002; Rowe and Swearingen 2004).

Life History/Biology: Garlic mustard is a biennial herb that produces vegetative rosettes with broad, kidney-shaped, round-toothed leaves during the first year of growth. Numerous white flowers, ~5 mm wide, appear early the second year. Leaves on fertile stem are alternate, triangular and more toothed than those of the rosette. When crushed, the leaves and stems give off a garlic odor. Each flower produces a fruit up to 10 cm long, and each plant can produce thousands of seeds. The flowering stems reach almost a meter in height, allowing seeds to be dispersed as far as several meters from the parent plant. Garlic mustard flowers can self-pollinate and produce viable seed from the mating, resulting in progeny which are genetically identical to the parent plant. Because only one plant is needed, this mechanism facilitates colonization of new sites (Pratt, no date given; Rowe and Swearingen, 2004). Garlic mustard populations may fluctuate: sites where it appears to have been eliminated may support dense stands a season later (Munger 2001).

Threats to Native Habitats: *Alliaria petiolata* invades forests in the northeastern US forming a monospecific understory layer. It monopolizes light, moisture, nutrients and space; eliminates native herbaceous species and degrades biodiversity. Cover of herbaceous and woody perennials is reduced following garlic mustard invasion; spring ephemerals are particularly vulnerable (Munger 2001; Blossey et al. 2002; Rowe and Swearingen 2004; Pratt, no date given). Changes in species composition diminish the wildlife value of invaded habitats; e.g., species that depend on ephemerals for pollen, nectar, fruits, seed and roots are deprived of these resources. Garlic mustard can invade intact natural areas, previously thought to be resistant to invasion by non-natives (Nuzzo 2000).

Outside Maine, garlic mustard has been demonstrated to threaten the West Virginia white butterfly, a rare taxon whose caterpillars are dependent on toothworts, a genus of spring ephemerals, as a primary food source. Invasion of garlic mustard has diminished the availability of the food source, and garlic mustard, though in the same family as toothwort, appears to contain a substance toxic to the butterflies' eggs (Rowe and Swearingen 2004). No similar situations have been reported for Maine or ACAD, but our knowledge of insect occurrence and plant-insect interactions is incomplete.

Distribution at ACAD: During a recent study garlic mustard was documented from 12 sites in ACAD: 11 on the east side of MDI and one west of Somes Sound. Nine of the eastern sites are within the extent of a 1947 wildfire, the other two are near Stanley Brook and northwest of the Brown Mountain Gatehouse (Greene et al. 2004). Subsequently, new populations have been reported from Ship Harbor (Susan Heyward, pers. com.), Park Headquarters (Geneva Langley, unpublished data) and along two boundary lines in Otter Creek (Jill Weber and Sally Rooney,

unpublished data). The Ship Harbor plants grew from seed carried to the site in trail construction fill dirt (Linda Gregory, pers. com.). Because trail maintenance and other construction projects continually occur throughout the park, garlic mustard will likely become more widely distributed.

Abundance at ACAD: Nine of the documented populations comprised more than 100 plants (often >1000 in a square meter). One population comprised 21-100 plants, one had 10 or fewer individuals and no population count was made at one site (Greene et al. 2004).

Habitat:
Garlic mustard tends to invade rich, moist, shady sites most aggressively. It has been reported from floodplains and forests, as well as disturbed habitats like roadsides and construction sites (Pratt no date given; Rowe and Swearingen 2004).

At ACAD: Establishment of this annual species appears to be dependent on the availability of bare, mineral soil. While many garlic mustard sites documented by the inventory burned in 1947, several did not. Garlic mustard was found in a variety of habitats: burned areas, a carriage road edge, beaches, an old home site and a stump dump. Plants that colonize disturbed areas, including many invasive species, were present with garlic mustard. Associated taxa are: Japanese knotweed (*Fallopia japonica*), European bittercress (*Cardamine impatiens*), wood bluegrass (*Poa nemoralis*), ox-eye daisy (*Leucanthemum vulgare*), tumble mustard (*Sisymbrium altissimum*) and yellow king-devil (*Hieracium caespitosum*) (Greene et al. 2004).

Management Goals:
- Prevent seed production in all documented garlic mustard populations at ACAD
- Reduce abundance of *Alliaria petiolata* to a level where most populations are eradicated and persistent ones (those with a large seed bank where seedlings continue to appear) are pulled or sprayed annually to eliminate them or at least prevent their further spread.
- Educate the public about this species: identification, its extreme invasiveness, management alternatives for homeowners
- Contact abutters and easement owners to establish cooperative management activities

Action Threshold:
- Primary: presence of reproductive individuals
- Secondary: presence of vegetative plants

Management Alternatives:
Mechanical
Fire has been used in some large natural areas, but it can encourage germination of stored seed and promote growth of emerging mustard seedlings. If burning is used, it must be repeated for 3-5 consecutive years (Connecticut Invasive Plants Working Group no date given; Nuzzo, 2000; Munger 2001).

Cutting flowering plants at ground level results in 99% mortality and eliminates seed production. Timing is critical: if done too early, plants will resprout; if plants are cut or pulled too late, the

seeds will disperse. All cut or pulled material should be removed from the site and disposed of with refuse; garlic mustard should NOT be composted. Motorized weed whackers, can be used for large infestations, but there can be a significant by-kill of native species. Mowing may be as effective as cutting, but it is almost impossible to remove mowed garlic mustard plant material intact. Cultivation is not recommended because it disturbs the soil (providing excellent conditions for establishment of seed-banked seed) and causes root fragmentation with subsequent resprouting. Soil should be thoroughly tamped after pulling to discourage germination of seed-banked seeds, which remain viable for at least five years (Connecticut Invasive Plants Working Group no date given; Munger 2001; Pratt no date given; Nuzzo 2000; Rowe and Swearingen 2004).

ACAD has used mechanical methods to control garlic mustard populations at the Otter Creek boat launch and at a site off Schooner Head Road. In 2003, garlic mustard plants from all life stages were removed from the boat launch site. No counts were made, but two 30 gallon bags were filled with pulled plants. The population was revisited in 2004 and all plants found were pulled. Again, no plant counts were made, but the yield was greatly reduced from 2003, with less than half of one 30 gallon bag filled with pulled plants (Weber and Rooney unpublished data). Plants were pulled at the Schooner Head Road site in 2004 and the site will be surveyed again in 2005. These data suggest that pulling may be an effective management method for small garlic mustard populations at ACAD.

Chemical:
Most authors agree that early spring herbicide treatment is best because recently germinated seedlings will be killed as well as 2nd year plants, which will be killed before they can flower and produce seed

2, 4-D:
Used alone, 2, 4-D is ineffective in controlling garlic mustard, however, 2,4-D + Dicambra killed all flowering plants (Nuzzo 2000; Munger 2001).

Acifluoren:
Acifluoren is not recommended because it killed only about 30% of garlic mustard plants present and because it is persistent in the environment and is toxic to fish (Munger 2001).

Bentazon:
Bentazon herbicide not recommended because it is water-soluble and does not bind to soil. Therefore, it poses a threat as a contaminant in run-off (Nuzzo 2000; Munger 2001).

Glyphosate:
According to some studies, glyphosate is effective in reducing garlic mustard cover, but native graminoid and forb cover are generally reduced as well if treatment occurs during the growing season. Even dormant season application damages semi-evergreen native plants including *Carex* spp. and *Avens* spp. (fs.fed.us, no date given). However, others report that foliar sprays of 1, 2 and 3% glyphosate reduce garlic mustard cover by >95% and do not affect species richness nor mean total herbaceous cover (Connecticut Invasive Plants Working Group no date given; Pratt no date given; Nuzzo 2000; Munger 2001;).

Triclopyr:
Spring foliar spray application of Garlon 3A® (61.6% triclopyr; 7oz./gallon) killed 91% of garlic mustard plants (Nuzzo 2000).

No method has yet been developed to kill seed-banked seeds without damaging those of native species.

Biological Control:
Alliaria petiolata has shown some susceptibility to fusarium root rot (*Fusarium solani*), but no control protocols utilizing this agent are available at this time (Munger 2001).

Studies have identified 69 insects and 7 fungi associated with garlic mustard in Europe (invasive.org, no date given). Within its native range, garlic mustard is attacked by weevils (*Ceutorrhynchus* spp.), leaf beetles (*Phyllotreta ochripes*), and lepidopteran caterpillars: none has been shown to be sufficiently host-specific to warrant release in the US to control garlic mustard. Trials are ongoing (Nuzzo 2000; Blossey et al. 2002).

Recommended Management Method for ACAD:
Garlic mustard can likely be controlled by pulling plants and cutting immature seed pods. *Alliaria petiolata* control should take place before July, to insure that no seed pods are allowed to ripen and disperse their seeds. If management staff discover sites with compacted soils (making pulling difficult or impossible), a 2% glyphosate foliar spray should be applied to the evergreen rosettes in the early spring, before native species have broken dormancy.

Monitoring Protocol:
All garlic mustard sites should be surveyed in May to determine whether any flowering plants are present. If not, then any plants present should be counted and pulled. If so, a revisit to the site should be made in June to cut ripening seed pods. This procedure should take place annually as long as plants are observed at any site. If no plants are observed, two rounds of biennial monitoring should be conducted. If sites remain garlic mustard-free, monitoring can be discontinued.

Identification and control of new populations will be vital to achieving the management goal for this species. The Maintenance Division should alert the park Botanist any time fill dirt is used at ACAD. Filled sites should be surveyed the following growing season for the presence of garlic mustard (and other invasive species). Any plants present should be pulled and the sites added to the list of those which are annually monitored.

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***Berberis* x *ottawensis* Schneid., Ottawa Barberry**
Berberidaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Berberis* x *ottawensis* is a hybrid between Japanese and common barberries (*Berberis thunbergii* DC. x *B. vulgaris* L.) first made in 1889 (Rehder 1960; Haines and Vining 1998).

Life History/Biology: Ottawa barberry is a many-branched woody shrub that is morphologically intermediate between its parental species. It can be distinguished from *B. vulgaris* by its reddish rather than yellow branches and by its semiumbellate rather than racemose infloresence (Rehder 1960).

Threats to Native Habitats: There are no reports of invasions by *Berberis* x *ottawensis* outside ACAD, but the *Invasive Plant Atlas of New England* suggests that it may become problematic in areas where both invasive parental species are present (Mehrhoff et al. 2003).

Distribution at ACAD: Ottawa barberry, previously undocumented on MDI, was recorded from one site in Bar Harbor near an old driveway (Greene et al. 2004).

Abundance at ACAD: One individual has been documented (Greene et al. 2004).

Habitat:
At ACAD: The organic soil layer at this site was destroyed by a wildfire in 1947, and scrubby, post-fire vegetation still dominates here. There is a sparse canopy of red oak (*Quercus rubra*) and white birch (*Betula papyrifera*), with huckleberry (*Gaylussacia baccata*), shrubby honeysuckle (*Diervilla lonicera*) and meadowsweet (*Spiraea alba*) in the shrub layer. Large-leaved aster (*Aster macrophyllus*) is the most common herbaceous species (Greene et al. 2004).

Management Goals:
- Eradicate the documented population
- Prevent reinfestation

Management Alternatives:
No control methods specifically for Ottawa barberry are available at this time because it is not a widespread invasive.

Recommended Management Method for ACAD:
Cut the stems of the documented plant near ground level and immediately paint the stumps with undiluted Roundup (41% glyphosate). Management should be done in August or September when herbicide will be most effectively translocated.

Monitoring Protocol:
There is one known site for Ottawa barberry at ACAD, comprising one or few individuals. These should be counted before treatment. Visit the treatment site twice during the growing season

following treatment. Retreat if resprouting is observed. If sprouts are not present, the site should be checked once the following year and retreatment done if sprouts are present.

Documentation of recently established and previously overlooked populations is a vital component of monitoring. All newly documented populations small enough to be eradicated should be removed by digging or employing the methods described above for eradication. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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***Berberis thunbergii*, Japanese Barberry**
Berberidaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Japanese barberry is native to Japan. It was introduced to the US in 1875, when seeds were sent from St. Petersburg Botanic Gardens, in Russia, to the Arnold Arboretum, in Boston. Plants grown from these seeds were planted at the New York Botanic Garden in 1896. This species was widely planted for use in hedgerows, dyes and jam, and was promoted as a substitute for common barberry, a host for black stem grain rust. Japanese barberry is listed as invasive in 20 states, mainly in the East and Midwest (Maine Natural Areas Program no date given; Brunelle and Lapin 1996; Mehrhoff et al., 2003; Swearingen 2004).

Life History/Biology: *Berberis thunbergii* is a much-branched, spiny, deciduous shrub about 2.5 m high with small, blue-green or red leaves. Flowers are small and pale yellow in clusters of 2-4 along the length of the stem; fruits are red berries (Rhoades and Block 2002; Mehrhoff et al. 2003; Swearingen 2004).

Japanese barberry spreads by seed (germination may be as high as 90%) and vegetatively, by layering of stems and resprouting of root fragments. Fruits are consumed by birds (especially ground-foraging species like grouse and turkey) and small mammals which disperse seeds widely (Brunelle and Lapin 1996; Rhoades and Block 2002; Mehrhoff et al. 2003; Swearingen 2004).

Threats to Native Habitats: *Berberis thunbergii* can invade undisturbed natural areas, forming dense thickets in forests, woodlands and wetlands as well as old pastures. Its presence alters the habitat by changing soil pH, nutrient levels and biological activity in the soil (Maine Natural Areas Program no date given; Rhoades and Block 2002; Mehrhoff et al. 2003).

Japanese barberry displaces native plant species, reducing native browse and forage. White-tailed deer browse preferentially on native species, thereby reducing their cover and giving barberry a competitive advantage (Swearingen 2004).

This species remains popular with gardeners and landscapers, and is offered for sale at almost every garden center. Continued planting will facilitate Japanese barberry's persistence in the landscape.

Distribution at ACAD: Japanese barberry is the most abundant and widely distributed invasive plant documented at ACAD. It occurs most frequently on the east side of MDI, near old estates and carriage roads, but it has also been documented from similar sites west of Somes Sound. Of particular note is its distribution along three water bodies: Duck Brook, Breakneck Brook and Witch Hole Pond. Its distribution pattern at these sites suggests that its seeds may have been water-dispersed (Greene et al. 2004). It is grows adjacent to the Duck Harbor campground, on Isle au Haut (Smith 1987).

Abundance at ACAD: A recent inventory recorded this taxon at 157 sites, 131 of which had ten or fewer plants present. Nine sites had 11-20 plants, five sites had 21-100 plants and three had more than 100 plants. No population data were taken at seven sites (Greene et al. 2004).

Habitat:

Japanese barberry will tolerate a variety of ecological conditions ranging from dry, open woods to wetlands. It grows best in full sun, but will flower and fruit in shade (Maine Natural Areas Program no date given; Rhoades and Block 2002; Mehrhoff et al. 2003; Swearingen 2004).

At ACAD: Japanese barberry occurs in diverse habitats. It has colonized dry, sandy and rocky sites, including carriage road edges and talus slopes. *Berberis thunbergii* also grows on deeper, richer soils near Jordan Pond and near Park housing at Harden Farm. In addition to these upland sites, there are extensive barberry populations in wetlands, most notably: the Great Meadow, Duck Brook and Breakneck Brook (Greene et al. 2004).

Management Goals:

- Prevent fruit production by mature plants
- Prevent establishment of new populations
- Educate nursery owners and the public about this species: identification, its extreme invasiveness, management alternatives for homeowners

Action Threshold:

- Primary: presence of a single reproductive individual
- Secondary: presence of a single vegetative plant

Management Alternatives:

Mechanical:

Pulling is an effective control method as long as roots are removed and soil disturbance is minimized. Small plants can be pulled by hand; shovels can be used to remove larger shrubs (<1 m tall). A Weed Wrench ® can be used effectively on very large individuals (>1 m tall). Mowing prior to seed production can prevent recruitment of new plants at a site, but cut plants produce numerous stump sprouts (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Brunelle and Lapin 1996; Rhoades and Block 2002).

Chemical:

Foliar application of glyphosate (2 fl. oz. Roundup®/gal) or triclopyr (4 fl. oz. Brush-B-Gon®/gal) with a 0.5% non-ionic surfactant are effective in controlling Japanese barberry (Connecticut Invasive Plants Working Group; Rhoades and Block 2002; Swearingen 2004). Barberry flowers and leafs out early in the spring, before most native species have broken dormancy, so damage to native species can be minimized if treatment occurs when natives are dormant (Brunelle and Lapin 1996).

Larger diameter stems can be cut and their stumps treated with a 1:1, Roundup (glyphosate 41%): water solution or Brush-B-Gon (undiluted 8% triclopyr) (Connecticut Invasive Plants Working Group; Rhoades and Block 2002; Swearingen 2004).

Biological:
None have been identified (Rhoades and Block 2002; Swearingen 2004).

Recommended Management Method for ACAD: Seedlings and plants small enough to cause minimal soil disturbance should be pulled. Larger stems should be cut and glyphosate applied to the cut stumps.

Monitoring Protocol: Annual monitoring of all Japanese barberry sites is impractical because they are so numerous and widespread. Sites which represent high and low density occurrences should be monitored each year in a rotating schedule by area, e.g. Great Meadow and carriage road occurrences in Year 1 and Breakneck Brook and west side occurrences in Year 2. Monitoring of low density sites will consist of surveying for seedlings and the presence of stump sprouts or plants missed during treatment and documenting their presence or absence. Any necessary retreatment should be done during monitoring site visits. In high density areas, a center point will be chosen. One north-south and one east-west transect will pass through the center point and extend to the outer limit of the occurrence, as identified by GPS coordinates provided by the distribution and abundance survey (Greene et al. 2004). The number of seedlings, stump sprouts and reproductive plants will be recorded. Priority for retreatment will be given to those sites where reproductive barberry plants are present. Annual monitoring will be necessary for the foreseeable future because this species is so abundant and widely dispersed at ACAD.

Additionally, new invasions via bird dispersal are anticipated and documentation of recently established and previously overlooked populations will be a vital component of monitoring. All newly documented populations small enough to be eradicated should be removed by digging or employing the methods described above for eradication. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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***Berberis vulgaris,* Common Barberry**
Berberidaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Common barberry is native to Europe. It was introduced to the US in the 17th century by colonists and used as a dye plant, for jam, and as a thorn fence. Eradication was attempted in the early 20th century after it was discovered to be an alternate host for wheat rust. Common barberry is currently reported from the northern states, south to CO, MO and NC (Rehder 1960; Haines and Vining 1998; Mehrhoff et al. 2003).

Life History/Biology: *Berberis vulgaris* is a vase-shaped, spiny shrub reaching ~3 m in height. Its leaves are 2-4 cm long and obovate-oblong in shape. Flowers are bright yellow and malodorous, in racemes of 10-20 flowers, later forming 1 cm-long bright red fruits, with 1-3 seeds/fruit (Rehder 1960; Haines and Vining 1998; Mehrhoff et al. 2003).

Threats to Native Habitats: Threats are minimal in a regionwide context, due to the success of previous eradication efforts. However, unchecked spread of remaining plants could result in the invasion of natural areas by common barberry (Mehrhoff et al. 2003).

Distribution at ACAD: Common barberry was documented throughout ACAD by a recent inventory of invasive plant species. All populations located by this inventory were near old home or building sites (Greene et al. 2004).

Abundance at ACAD: Fifteen populations were discovered during the inventory: 13 with 10 or fewer plants, one with 11-20 plants and one with 21-100 plants (Greene et al. 2004).

Habitat:
In New England, common barberry has been reported from many natural communities including: old fields, coastal grasslands, early successional forests, floodplain forests, forested wetlands, shrub wetlands and various disturbed habitats (Mehrhoff et al. 2003).

At ACAD, common barberry was found most often in post-disturbance forests comprising white birch (*Betula papyrifera*), white pine (*Pinus strobus*) and quaking aspen (*Populus tremuloides*) in the canopy. There is usually a well-developed shrub layer, often with invasive species present. Associated shrubs include: quaking aspen, alder-buckthorn (*Frangula alnus*), honeysuckles (*Lonicera* spp.), Japanese barberry (*Berberis thunbergii*) and low sweet blueberry (*Vaccinium angustifolium*). Downy goldenrod (*Solidago puberula*) and bluejoint grass (*Calamagrostis canadensis*) are present in the herb layer, with large-leaved aster (*Aster macrophyllus*), flat-topped white aster (*Doellingeria umbellata*) and lupine (*Lupinus polyphyllus*) sometimes present (Greene et al. 2004).

Management Goals:

- Eradicate current populations
- Eradicate new infestations as they are documented
- Educate the public about identifying this species and preventing its spread

Action Threshold: Presence of one individual

Management Alternatives: Common barberry is not widely considered to be an invasive species and no published information was found regarding its management. However, it is likely that methods which have proved effective for the more invasive Japanese barberry (*Berberis thunbergii*) would also control common barberry. These methods are given below.

Mechanical:
Pulling is an effective control method as long as roots are removed and soil disturbance is minimized. Small plants can be pulled by hand; shovels can be used to remove larger shrubs (<1 m tall). A Weed Wrench ® can be used effectively on very large individuals. Mowing prior to seed production can prevent recruitment of new plants at a site, but cut plants produce numerous stump sprouts (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Brunelle and Lapin 1996; Rhoades and Block 2002).

Chemical:
Foliar application of glyphosate (2 fl. oz. Roundup®/gal) or triclopyr (4 fl. oz. Brush-B-Gon®/gal) with a 0.5% non-ionic surfactant are effective in controlling Japanese barberry (Connecticut Invasive Plants Working Group no date given; Rhoades and Block 2002; Swearingen no date given). Because barberry flowers and leafs out early in the spring, before most native species have broken dormancy, damage to native species can be minimized if treatment occurs when they are dormant. (Brunelle and Lapin 1996).

Larger diameter stems can be cut and their stumps treated with a 1:1, Roundup (glyphosate 41%): water solution or Brush-B-Gon (triclopyr 8%) (Connecticut Invasive Plants Working Group no date given; Swearingen no date given; Rhoades and Block 2002).

Biological:
None have been identified (Swearingen no date given; Rhoades and Block 2002).

Recommended Management Method for ACAD: Seedlings and plants small enough to cause minimal soil disturbance should be pulled. Larger stems should be cut and glyphosate applied to the cut stumps.

Monitoring Protocol: Common barberry plants which have been documented at ACAD occur most often as isolated individuals or fairly dense clumps of individuals, allowing survey of entire sites before and after treatment. Monitoring should comprise survey of all treatment sites for the presence of seedlings, stump sprouts or plants missed during treatment. After documenting extant plants, seedlings should be pulled, bagged and disposed of off-site; sprouts and untreated plants should be retreated, if present. Because *Berberis vulgaris* is not highly invasive and

appears to be somewhat slow growing, biennial or triennial surveys of documented sites would be sufficient to keep this species controlled at ACAD.

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Cardamine impatiens L.**, European Bittercress**
Brassicaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Cardamine impatiens* is native to Europe and was introduced to North America before 1916. In the Northeast, it was known only from southern NH and eastern PA in 1950. It has since naturalized in ME, south to PA, west and north to MI (first MI collection was in 1978) (Mehrhoff et al. 2003). More recent records suggest that is becoming more common in MI (Voss 1985).

Life History/Biology: European bittercress is a weedy annual or biennial upright herb 15-20 cm tall. The stem is branched or simple with many pinnately compound, membranaceous leaves. Flower petals are absent or white, <0.5 cm long. Each seed pod produces 15-20 seeds and the pods are explosive, dispersing seeds away from the parent plant (Fernald 1950; Voss 1985; Haines and Vining 1998).

Threats to Native Habitats: *Cardamine impatiens* forms dense stands in mesic forests, outcompeting and eliminating native species. Bittercress invasion results in lower species diversity (Mehrhoff et al. 2003; Greene et al. 2004).

Distribution at ACAD: A distribution and abundance inventory documented only three European bittercress sites on MDI, all of which are in the town of Bar Harbor (Greene et al. 2004).

Another Bar Harbor population was documented in 2004 along a park boundary line (Jill Weber and Sally Rooney unpublished data).

Abundance at ACAD: Two of the populations comprised thousands of plants when first documented. However, control has been initiated and numbers have been greatly reduced (Weber and Rooney unpublished data). Control is also ongoing at the Wild Gardens of Acadia where *Cardamine impatiens* was documented and management began at least a decade ago. However the population is persisting in small numbers (Greene et al. 2004).

Habitat: European bittercress grows in early successional forests, floodplain forests, herbaceous wetlands, disturbed sites and river banks. It is shade tolerant (Fernald 1950; Voss 1985; Haines and Vining 1998; Mehrhoff et al. 2003).

At ACAD: All of the ACAD populations of European bittercress occur in disturbed areas. As mentioned above, this plant grows in the Wild Gardens of Acadia. The population is located in an area managed to mimic a beach environment. Another population is located east of Duck Brook Road. This site appears to have been part of a farm or dwelling and was probably also disturbed when the Park Loop Road was constructed. The population is limited to a seepy area dominated by cinnamon, interrupted and sensitive ferns (*Osmunda cinnamomea*, *O. claytoniana* and *Onoclea sensibilis*, respectively) under a canopy of quaking aspen (*Populus tremuloides*) and white birch (*Betula papyrifera*). The third site is located downslope of the Bar Harbor Transfer Station, along an old road bed that is highly disturbed and harbors what may be the

most diverse collection of invasive species in the Park (Greene et al. 2004). The newly discovered population is located on a boundary line, adjacent to a commercial greenhouse under a canopy of green ash (*Fraxinus pennsylvanica*) and Norway maple (*Acer platanoides*) (Jill Weber and Sally Rooney unpublished data).

Management Goals:

- Prevent reproduction of *Cardamine impatiens* at ACAD
- Prevent new infestations
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners
- Contact abutters and easement owners to establish cooperative management activities

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Action Threshold: Presence of one plant

Management Alternatives: European bittercress is not widely considered to be an invasive species and no published information was found regarding its management. However, it is likely that methods which have proved effective for the highly invasive garlic mustard (*Alliaria petiolata*) would also control *Cardamine impatiens* because they are both herbaceous species in the mustard family. This plan is based on management techniques found to be effective against garlic mustard.

Mechanical

Fire has been used in some large natural areas, but it can encourage germination of stored seed and promote growth of emerging mustard seedlings. If burning is used, it must be repeated for 3-5 consecutive years (Connecticut Invasive Plants Working Group no date given; Nuzzo 2000; Munger 2001).

Cutting flowering plants at ground level results in 99% mortality and eliminates seed production. Timing is critical: if done too early, plants will resprout; if plants are cut or pulled too late, the seeds will disperse. All cut or pulled material should be removed from the site and disposed of with refuse; garlic mustard should NOT be composted. Motorized weed whackers, can be used for large infestations, but there can be a significant by-kill of native species. Mowing may be as effective as cutting, but it is almost impossible to remove garlic mustard plant material intact. Soil should be thoroughly tamped after pulling to discourage germination of seed-banked seeds, which remain viable for at least five years (Connecticut Invasive Plants Working Group no date given; Pratt no date given; Nuzzo 2000; Munger 2001; Rowe and Swearingen 2004).

ACAD has used mechanical methods to control garlic mustard populations at the Otter Creek boat launch and at a site off Schooner Head Road. Results of these efforts suggest that pulling may be an effective control method for small garlic mustard populations at ACAD.

Additionally, efforts to control one of the *Cardamine impatiens* populations were undertaken in 2002. All plants observed at the site (977 individuals in an area ~ 20 m X 10 m in extent) were pulled and disposed of offsite. When the site was checked in 2003, 235 plants were found and removed and in 2004, 45 reproductive plants and about 5000 seedlings were removed (Jill Weber and Sally Rooney unpublished data; Weber and Rooney 2005). The high seedling number in

2004 is likely a result of germination of seed-banked seeds. Despite the 2004 figure, pulling is likely an effective control method for this species.

Chemical:
Most authors agree that early spring herbicide treatment is best because recently germinated seedlings will be killed as well as 2nd year plants, which will be killed before they can flower and produce seed

2,4-D:
Used alone, 2,4-D is ineffective in controlling garlic mustard, however, 2,4-D + Dicambra killed all flowering plants (Nuzzo 2000; Munger 2001).

Acifluoren:
Acifluoren is not recommended because it killed only about 30% of garlic mustard plants present and because it is persistent in the environment and is toxic to fish (Munger 2001).

Bentazon:
Bentazon herbicide is not recommended because it is water-soluble and does not bind to soil. Therefore, it poses a threat as a contaminant in run-off (Nuzzo 2000; Munger 2001).

Glyphosate:
According to some studies, glyphosate is effective in reducing garlic mustard cover, but native graminoid and forb cover are generally reduced as well if treatment occurs during the growing season. Even dormant season application damages semi-evergreen native plants including *Carex* spp. and *Avens* spp. (Munger 2001). However, others report that foliar sprays of 1, 2 and 3% glyphosate reduce garlic mustard cover by >95% and do not affect species richness nor mean total herbaceous cover (Connecticut Invasive Plants Working Group no date given; Pratt, no date given; EasyLiving Native Perennial Wildflowers 1999; Munger 2001; Nuzzo 2000).

Triclopyr:
Spring foliar spray application of Garlon 3A® (61.6% triclopyr) killed 91% of garlic mustard plants (Nuzzo 2000).

No method has yet been developed to kill seed-banked seeds without damaging those of native species.

Biological Control:
No biological control methods have been developed.

Recommended Management Method for ACAD:
European bittercress can likely be controlled by pulling plants and cutting immature seed pods. *Cardamine impatiens* control should take place before July, to insure that no seed pods are allowed to ripen and disperse their seeds. If management staff discover sites with compacted soils (making pulling difficult or impossible), a 2% glyphosate foliar spray should be applied to the evergreen rosettes in the early spring, before native species have broken dormancy.

Monitoring Protocol:

All European bittercress sites should be surveyed in May to determine whether any flowering plants are present. If not, then any plants present should be pulled. If so, a revisit to the site should be made in June to cut ripening seed pods. This procedure should take place annually as long as plants are observed at any site. If no plants are observed, two rounds of biennial monitoring should be conducted. If sites remain bittercress-free, monitoring can be discontinued.

Documentation of recently established and previously overlooked populations is a vital component of monitoring. All newly documented populations small enough to be eradicated should be removed by pulling. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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***Celastrus orbiculata* Thunb., Oriental Bittersweet**
Celastraceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Oriental bittersweet is native to Japan, Korea and China. It was introduced to the US by the 19th century (apparently before 1879) and has naturalized from ME to GA and west to MN (Bergmann and Swearingen, no date given; Connecticut Invasive Plants Working Group no date given; Dreyer 1994). Patterson (1974) says it has naturalized in 21 of the 33 states in which it is cultivated. *Celastrus orbiculata* is known to be particularly invasive in CT, NY and the southern Appalachians. It remains a desirable ornamental which is still sold by the nursery trade (Dreyer 1994).

Life History/Biology: *Celastrus orbiculata* is a deciduous, woody vine that can climb to the forest canopy and reach a stem diameter of 10 cm. It produces clusters of small, yellow-green flowers in May which are bee- and wind-pollinated. In the fall the green fruits turn red in yellow capsules. This species can be confused with the native *Celastrus scandens*, which produces only terminal flower clusters; *C. orbiculata* produces axillary flower clusters (Bergmann and Swearingen, no date given; Dreyer 1994; Miller 2003).

Oriental bittersweet produces abundant seeds and germination rates are very high (30-95%) compared to *C. scandens* (20%). In addition, *C. orbiculata* seeds can germinate in the low light conditions found in forested habitats (Patterson, 1974; Dreyer et al. 1987; Clement et al. 1991).

Oriental bittersweet produces abundant seeds, which are widely dispersed by birds and small mammals (Bergmann and Swearingen no date given; Connecticut Invasive Plants Working Group no date given; Miller 2003). The lipid and sugar content of the fruits is comparable to that of native shrubs, but birds don't consume them in fall; they tend to eat them in winter. Dispersal by humans has also been important in the spread of this fruitiferous species (Wheeler 1987; Dreyer 1994). *Celastrus orbiculata* readily reproduces vegetatively via suckers (Bergmann and Swearingen no date given). It has been widely planted by gardeners on good sites with little competition, allowing good growth and heavy fruiting. It has also been used by highway departments and recommended by Federal agencies for wildlife and conservation plantings. *Celastrus orbiculata* is often mislabelled as *C. scandens* by nurseries.

Oriental bittersweet can hybridize with *C. scandens*. *C. scandens* is relatively rare and the combination of invasiveness of Asiatic bittersweet and the presence of a possibly vigorous hybrid may threaten the native species (Haines and Vining 1998; Mehrhoff et al. 2003).

Threats to Natural Habitats: *Celastrus orbiculata* poses a serious threat to natural communities due to its high reproductive rate, long-range dispersal, ability to rootsucker, and rapid growth rate (Connecticut Invasive Plants Working Group). Many rare species are dependent on some disturbance and, because disturbance is controlled in managed areas, some rarities are now restricted to human-disturbed sites. These habitats tend to be the ones most likely to be colonized by invasives (Dreyer 1994). Oriental bittersweet can kill trees and shrubs by constricting, and thereby girdling, the stems. Girdled trees are more susceptible to damage by wind, snow and ice storms (Maine Natural Areas Program no date given; Siccama, et al.; 1976; Langdon 1993). It

also blocks light, reducing the competitive ability of native species (Bergmann and Swearingen no date given).

Bittersweet has invaded beach habitats in Connecticut, where it is thought to have changed the dynamics of dune formation and erosion, thereby changing the beach and dune habitat (Dreyer 1994). At ACAD, *C orbiculata* grows adjacent to Sand Beach, the Park's only example of a sand beach and dune system.

Distribution at ACAD: Oriental bittersweet occurs throughout ACAD. The majority of populations documented by a recent invasive plant inventory are located on the east side of Mount Desert Island (Greene et al. 2004).

Abundance at ACAD: Oriental bittersweet has been documented from 42 sites. Sixteen populations have 10 or fewer individuals, six have 11-20, eight have 21-100, 8 have more than 100 and no population data were recorded from four populations (Greene et al. 2004).

Habitat:
In its native range Oriental bittersweet occurs on lowland slopes and in thickets (Dreyer 1994).

In the US *Celastrus orbiculata* is documented to have invaded undisturbed and successional forests, alluvial woods, rocky slopes, dunes, beaches and shrub communities. It can also become established on disturbed sites including roadsides and fencerows (Bergmann and Swearingen, no date given; Dreyer 1994; Miller 2003).

At ACAD: Most populations appear to have persisted from horticultural plantings. Oriental bittersweet populations occur near disturbed areas, including: carriage road bridge abutments, the Jordan Pond House, an old farmstead and the Eagle Lake pump house. This species was also found in several locations along Jordan Stream, which drains from Jordan Pond. Fruits may have floated downstream from the horticultural plantings and become established on the stream banks and gravel bars (Greene et al. 2004).

Associated tree species include: red oak (*Quercus rubra*), green ash (*Fraxinus pennsylvanica*), white birch (*Betula papyrifera*), yellow birch (*Betula alleghaniensis*) and sugar maple (*Acer saccharum*). Shrub species are: red maple (*Acer rubrum*), huckleberry (*Gaylussacia baccata*), meadowsweet (*Spiraea alba*) and red spruce (*Picea rubens*). Dominant species in the herb layer include: large-leaved aster (*Aster macrophyllus*), wood bluegrass (*Poa nemoralis*), downy goldenrod (*Solidago puberula*) and bracken fern (*Pteridium aquilinum*).

Management Goals:

- Prevent fruit production on the extant plants
- Prevent new invasions
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

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Action Threshold: Presence of reproductive plants

Management Alternatives:

Mechanical:

Weekly mowing or cutting controls the spread of bittersweet by halting fruit production and prevents further damage to native vegetation by eliminating vines that strangle and shade out native vegetation (Connecticut Invasive Plants Working Group no date given; Dreyer 1994). Vines should be cut as close to the root collar as possible. If cutting is the only method to be used, it should be repeated at 2 week intervals throughout the growing season, otherwise, it will stimulate abundant root sprouts and bittersweet cover will increase (Dreyer 1994).

It may be possible to remove small bittersweet infestations by digging out and removing all plant parts. However, the resulting soil disturbance may expose buried seeds to conditions that will promote their germination. Management sites should be monitored for signs of regrowth and new seedlings (Connecticut Invasive Plants Working Group no date given).

Chemical:

Amitrole:

Amitrole (Amitrol®, Weedazol®) is ineffective against *Celastrus orbiculata* (Dreyer 1988).

Glyphosate:

Glyphosate (Roundup®, Rodeo®) did not rootkill bittersweet in studies conducted by Dreyer (1988), but has been reported to be effective as a cut stump treatment (Bergmann and Swearingen no date given; Miller 2003).

Triclopyr:

Use of triclopyr, which targets dicots, should be considered as a control agent, especially if damage to monocots is a concern. Dreyer (1988) developed the following protocol which resulted in 100% mortality of *Celastrus*: All bittersweet was cut to ground level early in the growing season. The plants then resprouted and were allowed to grow for about four weeks. A 2% solution of triclopyr (Garlon 3® and Garlon 3A® were each used separately) was applied as a foliar spray. No damage to other species was reported after four years of trials. Miller (2003) recommends spraying foliage with a 2% solution (in water with a surfactant) of Garlon 4® or 3A® (8 oz. herbicide/3 gal. mixture). This treatment should be done during the growing season.

Triclopyr was also effective when applied undiluted to the cut stumps of woody bittersweet stems (Bergmann and Swearingen no date given; EasyLiving Native Perennial Wildflowers no date given; Dreyer 1994;). Miller (2003) reports that a 25% solution of Garlon 4® (32 oz./gal. mixture) as a cut stump treatment is sufficient to cause rootkill. Undiluted Brush-B-Gon® (triclopyr 8%) can also be applied as a cut stump treatment (EasyLiving Native Perennial Wildflowers no date given).

Biological:

No biological controls are known at this time (Bergmann and Swearingen no date given; Dreyer 1994; Miller 2003).

Recommended Management Method for ACAD:
Most of the Oriental bittersweet cover at ACAD comprises tall, woody stems that would be best controlled by being cut early in the growing season. A cut stump treatment using triclopyr (undiluted Garlon® or Brush-B-Gon®) should be applied when vines are cut. The Eagle Lake pump house site supports a lush growth of low-growing bittersweet which would best be controlled by a foliar spray of triclopyr.

Monitoring Protocol:
All treatment sites should be surveyed during the same growing season that management takes place. The presence of any actively growing shoots should be documented, cut and removed from the site. Sites should be surveyed twice annually. If no shoot regrowth occurs, annual monitoring to prevent flowering will be sufficient to meet the management goal. If there is abundant shoot growth, foliar spraying should be considered.

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***Cirsium arvense* (L.) Scop., Canada Thistle**
Asteraceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Canada thistle is native to Europe, North Africa and Asia. It was introduced to North America in the 17th century, probably as a contaminant of crop seed (Cardina et al. no date given). Vermont drafted legislation for its control in 1795 and, by 1953 *Cirsium arvense* had been declared a noxious weed in 43 states because of its extensive damage to agricultural areas.

It is most frequent east of the Rockies, but naturalized populations are found across the US from CA to ME and south to VA (Hutchison 1990). Canada thistle's range is determined by rainfall, temperature and daylength. Its northern limit corresponds with the -18° C isotherm; the southern limit is thought to be determined by high summer temperatures (Nuzzo 1997; Thunhorst and Swearingen 2001).

Life History/Biology:
Canada thistle is a 0.5-1.5 m tall forb with deep, spreading, horizontal roots. Stems are grooved and slender, branching only at the top. Leaves are sessile, oblong and deeply divided, with prickly margins (Cardina et al. no date given Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen, 2001). Thistle plants are dioecious (male and female flowers on separate plants); flowers are rose-purple to white, numerous and <2 cm in diameter. Seeds are small (~0.5 cm), light brown with a tuft of tan hair at the base. On a good site, female plants can produce 29 flowering shoots/m^2, each with an average of 41 flower heads per shoot and 59 seeds/flower head. Honeybees are the primary pollinators but wind pollination is also effective (Cardina et al. no date given; Hutchison 1990; Nuzzo,1997; Thunhorst and Swearingen, 2001).

Cirsium arvense can be confused with two native species: bull thistle (*Cirsium vulgare*), which has spiny wings on the leaves, and spine-tipped involucral bracts, both of which are absent in Canada thistle. It can also be confused with musk thistles (*Carduus* spp.), which also have spiny wings, but, unlike Canada thistle, does not have branched pappus hairs (Cardina et al. no date given; Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen, 2001). The identity of suspected Canada thistle plants should be confirmed before management activities are initiated.

Dispersal of *Cirsium arvense* most often occurs via windborn seeds but seeds float and may be water dispersed. Fresh seeds germinate best in high light conditions; older seeds in lower light, with seed viability lasting up to 20 years (Nuzzo 1997).

Although establishment occurs by seed, Canada thistle spreads primarily via rhizomes and root segments. Roots can penetrate 1 m and spread laterally up to 2 m per growing season. Subsoil studies in Washington state have documented shoot growth is initiated in January, with growth of up to 7.5 cm during February. Shoots emerge from the ground when mean weekly temperatures reach 5° C (Nuzzo 1997).

Threats to Natural Areas: As Canada thistle colonizes an area, overall plant diversity decreases. It crowds out and eliminates native forbs and grasses (Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen 2001). There is evidence that both roots and leaves may be allelopathic, which would further discourage growth of native species (Thunhorst and Swearingen 2001).

One of the sites documented at ACAD also harbors the State-endangered New England northern reed grass (*Calamagrostis stricta* ssp. *inexpansa*) (Greene et al. 2004). Establishment of Canada thistle at rare plant sites would degrade habitat quality and potentially threaten the rare taxa.

Distribution at ACAD: The majority of documented Canada thistle sites are on the east side of Mount Desert Island, with only one site west of Somes Sound. Undoubtedly, this taxon is distributed more widely than a recent inventory suggests. It probably grows in every open field on Mount Desert Island (inside and outside the Park) and on many beaches (Greene et al. 2004).

Abundance at ACAD: Twelve populations have been documented: two with 10 or fewer plants, 3 with 11-20 plants, 5 with 21-100 plants, one with more than 100 plants and one for which no population data were collected (Greene et al., 2004). In their assesment of exotic plant species at ACAD, Reiner and McLendon (2002) listed this taxon as low priority for management.

Habitat: *Cirsium arvense* colonizes diverse habitats. It establishes most easily in disturbed areas and on wet sites with fluctuating water levels. Sedge meadows adjacent to disturbed areas have been invaded by Canada thistle. This species is salt tolerant and may become established on beaches (Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen 2001).

At ACAD: Canada thistle is most commonly associated with human disturbance (e.g. old fields, carriage road edges), but it has also colonized sites disturbed by beaver activity. In fact, the largest populations are on gravel bars and beaver meadows along Little Harbor Brook. Trees recorded at the thistle populations include red maple (*Acer rubrum*) and gray birch (*Betula populifolia*). The most frequently associated shrub species are white pine (*Pinus strobus*), meadowsweet (*Spiraea alba*), Morrow's honeysuckle (*Lonicera morrowii*) and English hawthorn (*Crataegus monogyna*) (Greene et al. 2004).

Management Goals:

- Prevent the spread of extant Canada thistle populations
- Prevent new infestations
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

Management Alternatives:

Mechanical:

Mowing slows the dispersal of Canada thistle by preventing seed production and reduces above-ground biomass, but it will not kill *Cirsium arvense* unless it is done every 1-4 weeks for four years. Canada thistle plants should be mowed at a height that allows at least 9 stem leaves to

remain. This prevents stimulation of lateral buds. Mowing at 21 day intervals may prevent flowering (Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen 2001).

Mulching with hay promotes growth of thistle shoots. Mulching with boards, sheet metal and tar paper will control *Cirsium* as long as the area covered exceeds the population size by several meters in all directions. If only existing stems are covered, the thistles will produce lateral shoots which will emerge outside the covered area. A disadvantage of this treatment is that all mulched vegetation, including native species, will be killed, leaving bare soil for colonization by Canada thistle or other invasives (Nuzzo 1997).

Tilling is not a practical control method. First, it is inappropriate for most natural areas (Hutchison 1990; Nuzzo 1997). Second, the root system of Canada thistle is below the level of most mechanical tillers (roots have been found growing up to 1.8 m deep), so tilling wouldn't affect them (Nadeau and Vanden Born 1989; Thunhorst and Swearingen 2001).

Fire: Fire may be the least damaging management tool in terms of site restoration because fire promotes growth of native species, and native seeds and rootstocks remain on the site post-treatment, eliminating the need for replanting. Also there is no residual herbicide effect. A dormant season burn may result in the production of 50% fewer Canada thistle flowerheads and stimulation of growth by native species, enabling them to compete more effectively with Canada thistle (Hutchison 1990; Nuzzo 1997; Thunhorst and Swearingen 2001). However, a burn conducted during the growing season will increase thistle shoot and seedling production and reduce growth by native plant species (Nuzzo 1997). Three consecutive annual burns are recommended (Hutchison 1990).

Chemical: Herbicide effectiveness on *Cirsium arvense* is dependent upon growth stage, environment, ecotype and genotype. Herbicide effectiveness will likely vary with ecotype, with some types tolerant to one herbicide but not to another. If herbicides are used, at least two different chemicals should be applied in succession, each with a different mode of action (Nuzzo 1997).

Glyphosate:
Glyphosate (Roundup®, Rodeo®), a systemic herbicide, controls Canada thistle by reducing the number of root buds and secondary shoots produced (Thunhorst and Swearingen 2001). Late season application is best. Glyphosate should be applied while temperatures are still warm and when there is ample soil moisture for best translocation. A 2.5% solution has been shown to be more effective than 5, 10, and 30% solutions. Lower concentrations kill leaves slowly, allowing more translocation to occur. The 2.5% solution reduced shoot growth by 76%. Minimal surfactant should be used. Four consecutive annual applications of glyphosate resulted in >98% reduction in shoot density. Wick applicators are difficult to use because thistle rosettes are hidden by other vegetation. The best application tool is a backpack sprayer with stream (not mist). Agricultural dyes can be helpful in identifying treated plants (Nuzzo 1997). Hutchison (1990) recommends individual plants be treated with a 1-2% solution of Roundup® applied in early spring using a wick applicator. Thistle plants should be 15-25 cm tall. The most effective method described to date incorporates mowing and herbicide application: Thistles are mowed in July and a 2.5% solution of glyphosate is applied 4 weeks later (Nuzzo 1997). If herbicide alone

is used, treatment should occur just before anthesis because root reserves are low and root mortality will be greater.

Clopyralid:
Clopyralid and Clopyralid plus 2,4-D (brandname Curtail®) are effective in controlling *Cirsium arvense* but are broad spectrum and will kill native forbs and shrubs. However, Curtail® breaks down quickly and there is little soil residual. These herbicides are formulated to target species in the Asteraceae, Polygonaceae and Fabaceae. Thistle mortality is highest when shoots 5-15 cm tall are treated. (Nuzzo 1997).

Herbicides Not Recommended for Canada Thistle Control:
Clorsulfuron:
Chlorsulfuron is a post-emergent herbicide that proved ineffective in suppressing shoot growth of Canada thistle (Nuzzo 1997).

Picloram:
Picloram (sold as Tordon®) is effective in eliminating *Cirsium arvense*. However, this herbicide must be applied only by licensed applicators, it kills all vegetation, it persists in the soil for up to three years and its solubility allows it to percolate through the soil to groundwater, and to be moved through the environment via rainwater runoff (Nuzzo 1997).

Dicamba:
Diacamba is relatively ineffective in controlling Canada thistle, in part because of widely varying responses to it by different thistle genotypes. Additionally, it persists in the soil for a long time, which makes its use in appropriate for natural areas (Nuzzo 1997).
Metasulfuron:
Tests proved metasulfuron to be ineffective at controlling *Cirsium arvense* (Nuzzo 1997).

2,4-D:
This herbicide is ineffective in controlling Canada thistle. In addition, over 3% of the herbicide applied, is extruded into the soil from the roots, where it can be taken up by non-target species (Nuzzo 1997).

Bentazon:
Bentazon can control Canada thistle, but non-target species are extremely susceptible to damage by this herbicide (Nuzzo 1997).

Biological: Extensive surveys for biological control agents have been carried out since 1959. Research has been carried out in Canada, US, Japan, Iran, Pakistan and China (invasive.org, no date given).

The following insects have been released in the US over the last several years: a weevil, *Ceutorhynchus litura*; a stem- and petiole-galling fly *Urophora cardui*; seed-feeding weevil *Larinus planus*, the leaf-feeding beetle *Altica carduorum* and the leaf-feeding tortoise beetle, *Cassida rubiginosa*. Of these, *Altica carduorum*, *Cassida rubiginosa* and *Ceutorhynchus litura* appear to have the greatest potential as biological control agents (Swearingen et al. 2002).

In addition, the rust, *Puccinia punctiformis*, and the fungus, *Sclerotinia sclerotiorum*, have been tested as possible control agents. The biology of control appears to be very complex, with neither insects nor pathogens providing sufficient control alone, but pathogen-infected plants more are likely to be attacked by insects than non-pathogen-infected plants. Research suggests that a combination of at least three control agents may be necessary for control, and the choice of agents is dependent on environmental conditions (i.e. drought year vs. wet year) (Swearingen et al. 2002).

Biocontrol agents tested thus far are not synchronized with thistle life cycle in North America. While over 130 species (diseases, birds and insects) attack Canada thistle, only an average of 4.5 species attack the thistle in its native range, and this predation seldom, if ever results in plant death. In North America, larvae of the painted lady butterfly (*Vanessa cardui*) feeds on and occasionally defoliates Canada thistle, but effects vary greatly from year to year (Nuzzo 1997).

At present, biological agents are not a viable means of controlling *Cirsium arvense* (Nuzzo 1997; Swearingen et al. 2002).

Recommended Management Method for ACAD:
Prioritize Little Harbor Brook *Cirsium* population for management. Cut stems before flowers open and remove from site. Leave at least nine leaves on stems to prevent stimulation axillary and root bud growth. Other populations should be managed opportunistically. Canada thistles growing in areas targeted for herbicide treatment of invasive plants (e.g. Great Meadow) should be treated with 2.5% Roundup® late in the season, as described above.

Populations not within targeted areas but encountered by resources staff during unrelated tasks should be managed as time permits via the cut stem method as described above.

Another important management component for this species will be documentation and eradication of newly established populations. Individual plants in small, new infestations should be treated with a 2.5% solution of Roundup® as soon as they are discovered and documented.

Monitoring Protocol: Monitoring must include protocols which track extant, managed populations and protocols to search for and document unknown and newly established populations.

<u>Managed Populations</u>
Plant number and population area should be estimated before management occurs. One transect through each of the Little Harbor Brook population centers should be established before treatment by recording the GPS coordinates of the starting and ending points. All *Cirsium arvense* plants within 0.5 m on either side of the transect tape (1 m wide belt transect) should be tallied. The Little Harbor Brook populations should be monitored annually by repeating the transect counts. Pre-management estimates of plant numbers and population area should be recorded for opportunistically managed populations. Post-management data could be recorded in the same way: if staff go through the site to monitor a high priority species or site, follow-up data

could be recorded. Otherwise, post-management monitoring of opportunistically managed occurrences is desirable, but not essential.

Unknown and Newly Established Populations

A standard invasive plant data sheet should be completed for any newly discovered Canada thistle populations. Those that are well established should be evaluated for management. After documentation, those that comprise few individuals should be treated with a 2.5% solution of Roundup® as described above. At least a subset of these should be monitored post-treatment and plant number and extent rechecked.

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***Euonymus alatus* (Thunb.) Siebold, Burning Bush**
Celastraceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Euonymus alatus* is native to northeastern Asia west to central China. It was introduced to the US in the mid-19th century, becoming a popular ornamental because of its bright red fall foliage and interesting twig texture. Burning bush has also been widely used as a highway planting. Since its introduction, *E. alatus* has become naturalized from New England to northern FL and the Gulf Coast (Martin 2002; Rhoades and Block 2002; Miller 2003). The earliest documented invasions were in PA in the 1960's (Rhoades and Block 2002). Invasions have now been documented in CT, VA, PA and IL (Martin 2002).

Life History/Biology: *Euonymus alatus* is a spreading deciduous shrub, reaching 2-5 m in height and width. Its branches and twigs have distinctive, corky wings. The elliptic leaves are opposite and finely toothed. Flowers are inconspicuous and bloom in the early spring, followed by small (~1 cm), purplish fruits which usually contain four seeds. There is often a dense layer of seedlings below mature bushes as a result of fruits that drop. Birds consume the abundant fruits and, because the seed remains viable after passing through avian digestive tracts, they disperse the seeds to new locations when they defecate (Martin 2002; Rhoades and Block 2002; Miller 2003). Burning bush also colonizes via root suckering (Miller 2003).

Threats to Native Habitats: *Euonymus alatus* is a threat to natural communities, including woodlands, forests and coastal scrubland (Martin, 2002). It can outcompete native species, resulting in lower plant and animal species diversity. Burning bush forms dense thickets which can shade and crowd native plants and alter animal movement through and use of natural communities. Because it is shade tolerant, it is capable of invading intact forests (Martin 2002; Rhoades and Block 2002; Miller 2003). New invasions of this species are very likely because it continues to be widely planted as an ornamental and because no pests which control its spread have been identified (Rhoades and Block 2002).

Distribution at ACAD: Burning bush has been documented at two sites in the town of Bar Harbor: a former estate and an abandoned nursery (Greene et al. 2004).

Abundance at ACAD: One site documented by a recent inventory supported 10 or fewer plants and the other had 21-100 plants (Greene et al. 2004).

Habitat: *Euonymus alatus* grows well in sun or shade where it tolerates a variety of soil types and pH levels. It grows best on mesic sites, but it has also been observed growing in dry situations (EasyLiving Native Perennial Wildflowers 1999; Rhoades and Block 2002; Miller 2003). Populations have been found in several natural communities: woodlands, mature oak forests, ravines and prairies. Burning bush can also colonize disturbed areas, including abandoned pastures (Martin 2002; Rhoades and Block 2002).

At ACAD: Winged euonymus grows under a closed canopy comprising: white birch (*Betula papyrifera*), Norway maple (*Acer platanoides*) and quaking aspen (*Populus tremuloides*). Green ash (*Fraxinus pennsylvanica*), Oriental bittersweet (*Celastrus orbiculatus*), privet (*Ligustrum*

spp.) and Morrow's honeysuckle (*Lonicera morrowii*) occur in the shrub layer and large-leaved aster (*Aster macrophyllus*), wood bluegrass (*Poa nemoralis*) and flat-topped white aster (*Doellingeria umbellata*) dominate the herb layer (Greene et al. 2004).

Management Goals:

- Eradicate extant populations
- Prevent establishment of new populations
- Educate the public and local nursery owners about this species: identification, its invasiveness and management recommendations for homeowners

Action Threshold: Presence of one plant

Management Alternatives:

Mechanical:

Burning bush plants less than ~0.5 m tall can be easily pulled, bagged and disposed of off-site. Larger plants should be dug out with a fork or pulled with a Weed Wrench®. Digging and pulling of larger plants may expose seed-banked seeds to suitable germination conditions, necessitating revisits to monitor for the presence of new seedlings (Martin 2002; Rhoades and Block 2002; Miller 2003).

Chemical:

Glyphosate:

A 1:1 dilution of Roundup® (41% glyophosate):water can be applied to the cut stumps of larger individuals to prevent resprouting. Glyphosate can also be applied as a foliar spray at the rate of 2 oz. Roundup® (41% glyophosate)/ gallon solution to control infestations too large to employ more time-intensive method of cutting and stump painting (Connecticut Invasive Plants Working Group no date given; Martin 2002; Rhoades and Block 2002; Miller 2003).

Imazapyr:

Arsenal AC® (53.1% Imazapyr) can be applied to foliage during the growing season as a 1% solution in water (4 oz. Arsenal AC®/3 gallons solution) with surfactant. Although residual effects are minimal, this herbicide is broad-spectrum and non-target plants will be damaged if there is spray drift (Miller 2003).

A 10% solution of Arsenal AC® with surfactant can also be applied to stumps immediately after cutting (Miller 2003).

3,6-Dichloro-o-anisic acid:

Vanquish® (56.8% 3,6-dichloro-o-anisic acid) can be applied to foliage during the growing season as a 1% solution in water (4 oz. Vanquish®/3 gallons solution) with surfactant. Although residual effects are minimal, this herbicide is broad-spectrum and non-target plants will be damaged if there is spray drift (Miller 2003).

Triclopyr:

Brush-B-Gon® (8% triclopyr) can be applied as a foliar spray (4 oz./gallon with water). Undiluted Brush-B-Gon® (8% triclopyr) can also be applied to cut stumps of burning bush to

prevent repsrouting. To control large individuals, Garlon 4® (61.6% triclopyr) can be mixed with basal oil (20% garlon:80% oil) and sprayed on the bark at the base of the shrub (Connecticut Invasive Plants Working Group no date given; Miller 2003).

Biological: No biological control agents are available at this time (Rhoades and Block 2002).

Ineffective Management Alternatives:
Mowing small plants followed 1 month later by triclopyr salt, triclopyr ester or 2, 4-D application (Martin, 2002).

Recommended Management Method for ACAD: Eradicate the two known populations by pulling plants less than 0.5 m tall. Cut larger individuals near the base of the trunk and treat stumps with a 1:1 solution of Roundup®:water. Remove all plant material from site for incineration. Management should take place during the growing season, but before fruits ripen so that no viable fruits will drop during cutting and removal.

Any newly discovered populations should be documented and eradicated before they become established. If any well established burning bush occurrences are discovered at ACAD, they should be documented and an appropriate management technique chosen for their control.

Monitoring Protocol: Count all plants at managed sites before treatment. Monitor treated sites annually for regrowth and new germinants. Because the two known *Euonymus alatus* populations are small, no plots or transects are necessary to monitor them. Rather, a site visit to verify eradication would be effective.

In addition, information about this species should be included in educational materials distributed to Park staff so that any new populations can be documented and managed as quickly as possible.

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***Fallopia japonica* Sieb. & Zucc., Japanese Knotweed**
Polygonaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Japanese knotweed is native to eastern Asia where it grows on hills and mountains and is a pioneer species on volcanic slopes. It was introduced to Europe in 1825 and the US in the late 19th century (EasyLiving Native Perennial Wildflowers no date given; Maine Natural Areas Program, no date given; Seiger 1991; Shaw and Seiger 2002). *Fallopia japonica* has become naturalized in the eastern and northern US and southern CA; it has been documented from 36 of the lower 48 states and Alaska (which has few other exotic invasives) (Maine Natural Areas Program no date given; Remaley no date given; Seiger 1991; Shaw and Seiger 2002; Swearingen 2002). Japanese knotweed has been planted as an ornamental and as a soil stabilizer (Swearingen et al. 2002).

Life History/Biology: *Fallopia japonica* is a herbaceous, clone-forming perennial. It is 1-3 m tall with simple, unbranched stems which are hollow and glabrous. The large leaves (up to 15 X 12 cm) are ovate, with a truncate to cuneate base. Plants are dioecious. Their greenish white, bee-pollinated flowers bloom from August to September in dense, axillary panicles (Maine Natural Areas Program no date given; Remaley no date given; Seiger 1991; Shaw and Seiger 2002). Although reproduction via seed has been demonstrated in Japan, seedling establishment has not been observed in Europe or North America. Apparently, all infestations in the UK are part of the same female clone; no fertile male plants have been documented there; the only viable pollen comes from a hybrid between *Fallopia japonica* and *F. sachalinense* (Seiger 1991). No data regarding fertility of North American clones are available.

Reproduction and spread occur through rhizomes which can reach 15-20 m in length (Remaley no date given; Seiger 1991; Shaw and Seiger 2002). Rhizome fragments can be dispersed naturally through ice scour and erosion along rivers, or anthropogenically. In addition to reproduction via rhizome fragments, small masses of internode tissue have been shown to produce plants. Rhizome fragments buried 1 m below a 5 cm cap of asphalt are capable of regeneration and emergence (CABI-Bioscience no date given; Shaw and Seiger 2002).

Japanese knotweed breaks dormancy early in the spring, and because of the abundant reserves stored in its rhizomes, it can attain a height of almost 1 m before other vegetation has started growing. Early season growth can be up to 8 cm per day (Seiger 1991; Shaw and Seiger 2002).

Threats to Native Habitats: *Fallopia japonica* is extremely fast-growing and quickly forms dense thickets which crowd and shade out native species. The biomass remaining after the growing season mulches the soil surface, preventing the establishment of native species. Its early spring emergence provides a further competitive advantage over natives, which tend to break dormancy later (Maine Natural Areas Program, no date given; Remaley no date given; Seiger 1991; EasyLiving Native Perennial Wildflowers 1999; Shaw and Seiger 2002). This plant most frequently invades riverine habitats, which are already under threat by various types of disturbance. Japanese knotweed has little or no wildlife value (EasyLiving Native Perennial Wildflowers no date given; Maine Natural Areas Program no date given; Shaw and Seiger 2002; Swearingen 2002).

The costs of invasion in the UK are estimated to be in the tens of millions of dollars per year, the primary cost being control efforts estimated to be $\$1.60/m^2$/year (Shaw and Seiger 2002). The high cost of control poses a threat to habitats because few land managers have the financial resources to mount that kind of effort. However, without control a species as aggressive as knotweed can quickly degrade natural areas where it becomes established.

Distribution at ACAD: All sites documented for Japanese knotweed are located on the east side of Mont Desert Island, with the exception of one site on the southwest part of the island. Human disturbance is apparent at all occurrences (Greene et al. 2004).

Abundance at ACAD: Nine populations of Japanese knotweed were recorded in ACAD during an invasive species distribution and abundance inventory. Two have ten or fewer plants, one has 11-20 plants, three have 21-100 plants and three have more than 100 plants (Greene et al. 2004).

Habitat: Japanese knotweed frequently colonizes wetlands (especially alluvial areas), waste places, roadways and old fields. It tends not to invade undisturbed or shaded sites (Maine Natural Areas Program no date given; Seiger 1991; Shaw and Seiger 2002; Swearingen 2002).

Fallopia japonica is tolerant of a wide range of growing conditions (pH 4.0-7.4), soil types (silt, loam, sand) and high salinity. While it is more common on mesic sites, Japanese knotweed has also been documented on xeric ones. Low light appears to be the limiting factor to its spread (Remaley no date given; Seiger 1991; Shaw and Seiger 2002; Swearingen 2002). In Maine, many infestations are the relicts of historical plantings (Maine Natural Areas Program no date given).

At ACAD: Habitats for this taxon range from a highly disturbed stump dump to a relatively natural streambank. When a canopy is present, it comprises red maple (*Acer rubrum*), heart-leaved birch (*Betula cordifolia*), white pine (*Pinus strobus*), Norway maple (*Acer platanoides*) and quaking aspen (*Populus tremuloides*). Honeysuckles (*Lonicera* spp.) and roses (*Rosa* spp.) occur in the shrub layer. Associated herbaceous species include wood bluegrass (*Poa nemoralis*), large-leaved aster (*Aster macrophyllus*) and spreading dogbane (*Apocynum adrosaemifolium*) Greene et al. 2004).

Management Goals:

- Eradicate the 6 smaller populations and prevent further spread of the three larger ones.
- Prevent establishment of new populations
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

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Action Threshold: Presence of one plant

Management Alternatives: Small, recently established Japanese knotweed infestations are easiest to control or eliminate. However, the best management tool is to prevent this plant's establishment (Maine Natural Areas Program no date given; Seiger 1991).

Mechanical:
Digging: In general, removal of plants by digging is not recommended to control Japanese knotweed because it tends to spread root fragments and the soil disturbance digging causes promotes regrowth and/or coloniztion by other invasives (Maine Natural Areas Program no date given; Seiger 1991). Digging is only appropriate for very small infestations from which all portions of the extant plants can be successfully be removed (Connecticut Invasive Plants Working Group no date given; Remaley no date given).

Cutting: Cutting may be an effective means of controlling *Fallopia japonica*, but it must be done at least 3 times per growing season for several consecutive years (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given). Like digging, cutting is probably only appropriate to control very small populations and those which occur in environmentally sensitive areas where herbicide use is not recommended (Seiger 1991).

Mulching: A study by Pridham and Bing (1975) suggested that covering *Fallopia japonica* with several layers of black plastic weighted with asphalt or stones may provide control, but not cause mortality. Because knotweed can penetrate asphalt, stems should either be cut to ground level before covering, or the shade material should be placed at the full height of the knotweed (Seiger 1991).

Fire: No data reported.

Chemical:
Dicamba: Diacamba, a nonselective and persistent herbicide has been shown to be effective against knotweed, but is not recommended for conservation lands (Seiger 1991).

Glyphosate: Herbicides are most effective when combined with cutting. Two or three cuttings followed by a late season (August or September) application of glyphosate (25% solution) appears to be the most effective control regime (fall is the time of greatest herbicide translocation to rhizomes, so greatest rhizome mortality would occur then) (CABI-Bioscience no date given; Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Remaley no date given; Seiger 1991; Swearingen 2002). Because glyphosate is nonselective, care should be taken to avoid damage to non-target species; application with a weed wiper or herbicide glove is recommended. Another cutting plus herbicide treatment that has proven effective on National Park lands is the following: allow knotweed stems to grow until they are about 1 m tall, cut them near ground level and allow them to regrow for 6-8 weeks. When they are about thigh-high, treat with a foliar spray of: 5% Glypro® (glyphosate formulation), 0.5% Arsenal® (imazapyr), 1% Clean Cut® surfactant, and 0.5% agricultural dye in water. Alternatively, cut plants above the fist node and squirt 10 ml of a 1:1 solution of Glypro®: water into the hollow stem using a standard laboratory wash bottle (Brian McDonnell, NPS, pers. com.).

Picloram: The herbicide picloram has also been used with some success. This is a selective herbicide, but unlike glyphosate, it persists in the soil and its use in natural areas should be avoided (Seiger 1991).

Triclopyr: Triclopyr is effective in killing top growth, but there is no residual effect to prevent resprouting. Subsequent applications are necessary to kill knotweed (Connecticut Invasive Plants Working Group no date given; Remaley no date given).

Biological:
Japanese scientists have compiled lists of herbivorous insects and plant pathogens associated with *Fallopia japonica* in its native range, but no biological control agents are available at this time (Seiger 1991). Recent research has suggested that a leaf beetle and a fungus are highly specific to Fallopia japonica and may be good control agents (Seiger 1991).

Some researchers suggest revegetation with competitive native species as a possible adjunct to other control methods (Connecticut Invasive Plants Working Group no date given).

Recommended Management Method for ACAD:
Eradication of six smaller populations: Follow the method described above which has proven effective at other parks (two cuttings with herbicide applied to hollow stems). Repeat annually as necessary.

Control of three larger populations: Cut all stems near ground level 2-3 times per season. If time and personnel are limited, control could also be achieved by doing a cutting in July, followed by a foliar spray of 25% glyphosate in August. Repeat annually, as necessary.

Monitoring Protocol:
Populations to be eradicated: The year after initial treatment, make a site visit to cut persistent stems in anticipation of an August herbicide treatment. If no stems are present, make annual site visits during July for the next three years; repeat treatment if plants are present. If plants persist after three years of treatment, reassess the recommended control method.

Populations to be controlled: Measure the perimeter of the population at the time of initial cutting. Remeasure at each cutting. If there is no increase, the population is under control. If there is an increase, add herbicide application to the control regime, as described above.

Documentation of recently established and previously overlooked populations is a vital component of monitoring. All newly documented populations should be managed by employing the methods described above for eradication. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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***Frangula alnus* P. Mill., Glossy Buckthorn, Alder-buckthorn**
Rhamnaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Frangula alnus* is native to North Africa and Eurasia. It was introduced to the US during or slightly before the 19th century for use as a hedge, and later to enhance wildlife habitat (Converse 1984; Ohio Department of Natural Resources 2001; Rhoades and Block 2002; Wieseler 2003). Glossy buckthorn has naturalized from Nova Scotia to TN and throughout the Midwest (Maine Natural Areas Program no date given; Wieseler 2003). This species has not been sold by nursery trade since the 1930's (Jeanette 2000).

Life History/Biology:
Glossy buckthorn is a shrub or small tree with lenticular and slightly pubescent twigs. Its alternate, finely-toothed or entire leaves are obovate and glossy. Care should be taken to confirm the identification of this plant because the native species, alder-leaved buckthorn (*Rhamnus alnifolia*), also occurs in some Maine wetlands. These dioecious plants reach reproductive age quickly and flowering occurs from May through September (flowers and mature fruits are often found on the same branch). Five-parted flowers are yellow-green and occur in sessile umbels. The fruit is a black drupe containing 2-3 seeds. *Frangula alnus* reproduces sexually via abundant fruits; there is little evidence of asexual reproduction in this species (Converse 1984; Maine Natural Areas Program no date given; Ohio Department of Natural Resources 2001; Rhoades and Block 2002; Wieseler 2003).

Although *Frangula alnus* fruits contain emodin, rendering them poisonous or at least unpalatable to many species, dispersal by starlings, blackbirds, wood ducks, cedar waxwings, robins, bluejays and mice has been documented (Connecticut Invasive Plants Working Group no date given; Natural Areas Program no date given; Converse 1984; White et al. 1993; Jeanette 2000; Maine Rhoades and Block 2002; Wieseler 2003). Water may be an important dispersal mechanism in seasonally flooded habitats: in laboratory studies, fresh fruits floated for 19 days and dry seeds floated for a week (Converse 1984). Germination is best in full light conditions on sites where soil is disturbed and there is little competing vegetation (Converse, 1984). Seedling density in or near seed shadows can be as high as 54 seedlings/0.1 m^2 (Wieseler 2003).

Traits that make *Frangula alnus* a good invader are: fast growth rate, early leaf-out, ability to form prolific stump sprouts and late season leaf retention (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984; Ohio Department of Natural Resources 2001). Following early season trunk removal, glossy buckthorn can produce stump sprouts up to 2 m tall during the growing season and one cut trunk can produce up to 50 sprouts (Converse 1984).

Threats to Native Habitats: Glossy buckthorn displaces native shrub species soon after invasion and, once it forms a continuous canopy, shades out native herbaceous species (Maine Natural Areas Program no date given; Converse 1984; White et al. 1993; Ohio Department of Natural Resources 2001). This species forms dense, even-aged thickets, decreasing plant species diversity at invaded sites and preventing native tree and shrub regeneration (Converse 1984;

Rhoades and Block 2002; Wieseler 2003). Lack of vegetation under continuous buckthorn canopies suppresses fire in fire-dependent natural communities (Wieseler 2003).

Distribution at ACAD: Documented sites for alder-buckthorn are limited to the town of Bar Harbor, on the east side of MDI (Greene et al. 2004).

Abundance at ACAD: A recent distribution and abundance survey recorded alder-leaved buckthorn at 76 locations. There were 10 or fewer plants at 35 of them, 11-20 plants at nine of them, 21-100 plants at 11 of them and 100 or more plants at 13 of them. No abundance data were collected from eight locations (Greene et al. 2004).

Habitat: *Frangula alnus* occurs most often in mesic to hydric habitats, including: alder thickets, bogs, marshes, riverbanks and fens. It tends to occupy drier sites within wetlands and is comparable in its water tolerance to sedge meadow communities. Glossy buckthorn has also been found in heath-oak, pine and spruce forests, all of which are upland communities (Maine Natural Areas Program, no date given; Converse 1984; Jeanette 2000; Ohio Department of Natural Resources 2001; Rhoades and Block 2002; Wieseler 2003). However, glossy buckthorn can also colonize disturbed sites like old fields, roadsides and hedgerows (Maine Natural Areas Program no date given; Wieseler 2003).

Frangula alnus is tolerant of many soil types but establishes best on sites with ample light and bare soil (Maine Natural Areas Program no date given; Converse 1984; Wieseler 2003).

At ACAD: All alder-buckthorn sites are within the area burned during the 1947 fire. In some places, the fire was hot enough to have destroyed all vegetation and the organic matter in the soil. This allowed much of the remaining soil to erode, leaving expanses of bare soil in full sun: ideal conditions for buckthorn germination and establishment.

Alder-buckthorn has been documented on fire-damaged soils east of Great Meadow and between Schooner Head and the Park Loop Road. Quaking aspen (*Populus tremuloides*), white birch (*Betula papyrifera*) and red oak (*(Quercus rubra*) are the dominant trees on drier sites. Shadbushes (*Amelanchier* spp.) and quaking aspen are common shrubs and wood bluegrass (*Poa nemoralis*) and flat-topped white aster (*Doellingeria umbellata*) are common herbs. Alder-buckthorn populations are largest in the vicinity of Great Meadow, a basin where soils are deep and wet. Gray birch (*Betual populifolia*), white birch and quaking aspen comprise the often sparse canopy. Red maple (*Acer rubrum*), ninebark (*Physocarpus opulifolius*), green ash (*Fraxinus pennsylvanica*) and wild-raisin (*Viburnum nudum* v. *cassinoides*) make up the shrub layer, with flat-topped white aster and bluejoint grass (*Calamagrostis canadensis*) the most frequently found herbs (Greene et al. 2004).

Management Goals:

- Eliminate fruit production by glossy buckthorn in Great Meadow
- Reduce cover of glossy buckthorn in Great Meadow so that it is limited to stump sprouts on managed plants and seedlings arising from the seedbank
- Document and eradicate any small, newly established populations found by Park staff

- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

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Action Threshold: Presence of one reproductive plant

Management Alternatives:

Mechanical:

Digging/Pulling: Digging and pulling are only effective in controlling very small glossy buckthorn infestations populated by young plants. Excavation of larger plants causes soil disturbance that may expose seed-banked seeds to conditions appropriate for germination as well as disturbing the roots of non-target species (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984; Jeanette 2000; Ohio Department of Natural Resources 2001; Rhoades and Block 2002; Wieseler 2003).

Cutting and Mowing: Cutting must be done several times per season; plants will not be killed, just controlled. Stems cut twice a year for two years had shorter and fewer stems than a control (Converse 1984; Maine Natural Areas Program, no date given; Rhoades and Block, 2002). Buckthorn shrubs and seedlings can be cut and left on-site to create fuel for future burns (Wieseler, 2003).

Girdling: Removal of a 2-3 cm wide strip of bark exposes the phloem and kills glossy buckthorn trees and no resprouting should occur (Converse, 1984; hort.uconn.edu, no date given; Maine Natural Areas Program, no date given).

Fire: Prescribed burning resulted in higher growth rates and stem densities in *Frangula alnus* populations. This is likely due to the cool, slow-spreading fires that result from the low fuel loads under the dense buckthorn thickets; buckthorn shrubs were only top-killed (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984; White et al 2003; Wieseler 2003).

Five or six annual burns kill plants, but create good germination conditions for seed-banked seeds. Burns to control buckthorn should be conducted in the early spring, as soon as any litter has dried and while carbohydrate reserves are low (Wieseler 2003).

Underplanting: Planting native shrubs in disturbed areas that could potentially be invaded by buckthorn can be effective in preventing its establishment (Converse 1984).

Chemical:

2, 4-D:

An early season application of 2,4-D in diesel fuel (2-4% herbicide:96-98% oil) painted on the basal bark of stems 10 cm or less in diameter resulted in 100% mortality (Converse 1984).

Glyphosate:

Glyphosate provides good control if applied as a foliar spray (2% glyphosate in water) in the spring. Because buckthorn retains its leaves longer than most native species, a late season foliar spray can be done after native species have dropped their leaves. This is effective and minimizes

damage to non-target species (Connecticut Invasive Plants Working Group no date given;). Stems can also be cut late in the growing season and the stumps treated with 20-50% aqueous solution of glyphosate (Connecticut Invasive Plants Working Group no date given; Converse 1984; Jeanette 2000; Rhoades and Block 2002). In one study, glyphosate applied to cut stumps late in the growing season (at the rate of 1:5, herbicide:water) yielded 85% buckthorn mortality (Wieseler 2003).

Picloram:
Frill application of ready to use picloram during growing season resulted in 100% buckthorn mortality, but there was damage to non-target species (Converse 1984).

Triclopyr:
Brush-B-Gon® (8% triclpyr) can be applied as a foliar spray (4 oz./gallon) or, undiluted as a cut stump treatment (Connecticut Invasive Plants Working Group no date given). A 1:4, herbicide:water with dye solution applied to cut stumps during the growing season provides excellent buckthorn control (Wieseler 2003). A 1:7, triclopyr:oil mixture applied to cut stumps controls buckthorn, as does a 1:16, triclopyr oil mixture sprayed or brushed on the bark, just above the root collar (Wieseler 2003). Cut stump treatments with Garlon 4® (61.6% triclopyr) is also effective for buckthorn control (Rhoades and Block, 2002).

Biological:
No biocontrol agents available at this time. No insect agents have been identified, but several pathogens appear to have potential, including: *Fusarium*, *Nectria* and *Trocothecum roseum* fungi (Converse, 1984; Ohio Department of Natural Resources 2001; Rhoades and Block 2002).

Recommended Management Method for ACAD: Stem cutting and removal followed by application of glyphosate to the cut stumps is recommended for control of glossy buckthorn at ACAD. Several treatments are effective in controlling *Frangula alnus*, but the one recommended is attractive for several reasons: 1) it is effective, 2) there is no soil disturbance, 3) glyphosate formulations are safe to use in natural areas and 4) it meets the goal of preventing buckthorn spread, but will likely have the added benefit of killing the majority of buckthorn plants.

Management should occur late in the season (September or October). Stems should be cut close to ground level and glyphosate should then be painted on the cut stumps. Dye added to the herbicide allows applicators to visually assess which stems have and have not been treated, facilitating 100% coverage. Retreatment may be necessary.

Monitoring Protocol: Because buckthorn is frequent and widespread within the Great Meadow basin, transects through the area would be the best way to estimate treatment effects. A series of 100 m transects should be established before treatment. Coordinates of their starting and ending points should be recorded using GPS units. To adequately cover the population, the transects should be located in the following areas of buckthorn concentration: 1) east of the Park Loop Road, north of Sieur de Monts Spring, 2) west of the Park Loop Road, north of Sieur de Monts Spring, 3) southwest of the Loop Road near its intersection with Hardin Farm Road. Transects should be traversed before treatment and the number of stems within a 1 m band (0.5 m on either side of the tape) should be recorded.

Treated sites should be monitored in July of the year following treatment. The same transects should be run, again recording the number of stems within 0.5 m on either side of the tape. Pre- and post-treatment numbers can then be recorded to assess treatment effectiveness.

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***Hypericum prolificum* L., Shrubby St. Johnswort**
Clusiaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Shrubby St. Johnswort is native in the US from NY south to GA, west to LA, north to MN and Ontario (Haines and Vining 1998). *Hypericum prolificum* is listed as State-endangered in NJ and as State-threatened in NY (USDA 2007). A recent study at ACAD identified it as invasive in the Park (Greene et al. 2004).

Life History/Biology: *Hypericum prolificum* is a small deciduous shrub with flattened, two-edged twigs, which grows about 1 m tall and equally wide. Its leaves are opposite, entire and narrow. Flowers are bright yellow, about 1" wide. The fruit is a three-valved capsule containing many seeds (Connecticut Invasive Plants Working Group no date given; U.S. Department of Agriculture no date given; Haines and Vining 1998).

Threats to Native Habitats: The only documentation of this species as invasive is at ACAD, where it has invaded a successional forest adjacent to a large wetland. It is the dominant species in the shrub layer and likely has reduced the density of native shrub species (Greene et al. 2004). The *Invasive Plant Atlas of New England* describes *Hypericum prolificum* as potentially invasive, due in part to its ability to produce numerous progeny (Mehrhoff et al. 2003).

Distribution at ACAD: Shrubby St. Johnswort is known only from the area immediately east of Great Meadow and at the north end of the Tarn, in Bar Harbor (Greene et al. 2004).

Abundance at ACAD: This taxon is unique, in that it had been documented by only one or two herbarium specimens prior to a recent study of invasive plant species at ACAD. It had never been reported as invasive in Maine, yet the extant population near Great Meadow comprises thousands of individuals (Greene et al., 2004). Data from transects across the population show a density of slightly over one shrubby St. Johnswort plant per square meter (Weber and Rooney, unpublished data).

Habitat: In its native range, *Hypericum prolificum* occurs in swamps, damp thickets and pastures (U.S. Department of Agriculture no date given). It thrives on dry, rocky soils and can tolerate a variety of soil pH levels (Mehrhoff et al. 2003).

At ACAD: Gray birch (*Betula populaifolia*), white birch (*B. papyrifera*) and quaking aspen (*Populus tremuloides*) comprise the often sparse canopy. Red maple (*Acer rubrum*), common and Japanese barberry (*Berberis vulgaris* and *B. thunbergii*, respectively), ninebark (*Physocarpus opulifolius*) and wild-raisin (*Viburnum nudum* v. *cassinoides*) make up the shrub layer, with flat-topped white aster (*Doellingeria umbellata*) and bluejoint grass (*Calamagrostis canadensis*) the most frequently found herbs (Greene et al. 2004).

Management Goals:

- Prevent the spread of shrubby St. Johnswort beyond the Great Meadow area.
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

Action Threshold: Presence of reproductive plants

Management Alternatives:
Because there are no records of this taxon as an invasive outside ACAD, there is no literature regarding its control. Management methods that have been found to be effective for other shrubs would likely be effective in controlling shrubby St. Johnswort (see Management Plans for Japanese barberry, alder-buckthorn, honeysuckle species and privet species, also included in this report).

Recommended Mangement Method for ACAD:
Initial treatment efforts should be concentrated on the periphery of the population to insure that shrubby St. Johnswort does not spread beyond its current distribution. No information was found regarding the effectiveness of simply cutting stems near ground level as a management tool for this species. Trials employing this method and with methods used for other shrubs are recommended. *Hypericum prolificum* is limited to the Great Meadow area, where management of several other shrubby species is planned. The recommended management method for most of them is a cut stump treatment with glyphosate. Because shrubby St. Johnswort stem diameters are small, a foliar spray might prove more effective than a cut stump treatment. Both herbicide treatments should be tested.

Monitoring Protocol: A series of 100 m transects should be established through the Great Meadow population before treatment. Coordinates of their starting and ending points should be recorded using GPS units. Transect should be located in the most dense part of the population, between the Park Loop Road and the edge of the wetland). Estimates of shrubby St. Johnswort cover should be recorded from meter square plots located every other meter on alternating sides of the transect line. Sampling should occur before treatment.

Managed sites should be monitored in July of the year following treatment. The transects should be run, again recording cover estimates of shrubby St. Johnswort in the same square meter plots sampled pre-treatment . Pre- and post-treatment numbers can then be compareded to assess treatment effectiveness.

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***Ligustrum* spp., Privet**
Oleaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Privets are shrubs or small trees native to Europe, North Africa and Asia. They were introduced to North America as early as the 18th century for use as garden hedges and have become naturalized in many eastern and south-central states (Batcher 2000; Miller 2003; Cuyahoga Valley National Park 2007). Two privet species have been documented in Maine: *Ligustrum amurense* L. (Amur privet) and *L. vulgare* L. (common privet).

Life History/Biology: While most privets remain shrubby, some can grow to be trees with trunk diameters of up to 25 cm. Amur privet is semi-evergreen; common privet is deciduous. Both species have smooth, grey bark; twigs are fine and four-angled at the nodes. Leaves are elliptic and opposite (Batcher 2000; Cuyahoga Valley National Park 2007). Privets are afforded some protection from insect damage due to the phenolic compounds found in their leaves (Miller 2003). Flowers are small, white and bell-shaped. Fruits are ovoid drupes, each containing 1-4 seeds. Mature plants fruit heavily and fruits are eaten and dispersed by birds. *Ligustrum* grows readily from seed and from root and stump sprouts (Batcher 2000; Cuyahoga Valley National Park 2007).

Threats to Native Habitats: Privets form dense thickets which displace native vegetation and reduce plant species diversity (Batcher 2000; Miller 2003). Invasion of disturbed and regenerating sites results in dominance of privet and exclusion of native species. *Ligustrum* spp. often invade disturbed areas first (roadsides and hedgerows), then expand into undisturbed habitats (Batcher 2000). Dominance of privets in a community alters wildlife habitat and behavior. Because *Ligustrum* spp. contain phenolic compounds that make them unpalatable to herbivores, their displacement of native species eliminates sources of browse for mammals and food and host plants for insects (Batcher 2000).

Distribution at ACAD: Privet is likely more widely distributed than a recent invasives inventory reflects. Because it was not ranked as an invasive during a preliminary study, documentation of its occurrence did not begin at the start of the inventory. Two sites were recorded in Bar Harbor (Greene et al. 2004.

Abundance at ACAD: One documented occurrence comprises 21-100 plants and there are over 100 plants at the other site (Greene et al. 2004).

Habitat:
Privet invades natural areas, including floodplain forests, hardwood forests, woodlands, bogs and calcareous barrens (Batcher 2000). It also colonizes roadsides, old fields and other disturbed habitats. *Ligustrum vulgare* grows in sun and shade and can tolerate high and low nutrient levels and dry or moist soils.

At ACAD: During an invasive plant inventory, privet was documented from two sites: a former nursery and a former estate. Both sites have a history of anthropogenic disturbance, both burned during a 1947 wildfire and each harbors many invasive plant species. The forest canopy at the nursery site is dominated by quaking aspen (*Populus tremuloides*) and red oak (*Quercus rubra*). Alder-buckthorn (*Frangula alnus*) and non-native honeysuckles (*Lonicera* spp.) are the major shrubs and flat-topped white aster (*Doellingeria umbellata*) and wood bluegrass (*Poa* nemoralis) are the most common herbaceous species. Red maple (*Acer rubrum*), white birch (*Betula papyrifera*) and Oriental bittersweet (*Celastrus orbiculata*) comprise the canopy at the former estate (Greene et al. 2004).

Management Goals:

- Prevent fruit production by privet, thereby preventing its further spread
- Eradicate privet from the ACAD flora (low priority, treat opportunistically)
- Educate the public about identifying this species and preventing its spread

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Action Threshold: Presence of reproductive plants

Management Alternatives:

Mechanical:

Repeated mowing (at least twice per growing season) will control the spread of privet, but will not eradicate it (Batcher 2000). Seedlings can be pulled and larger plants can be pulled with a Weed Wrench®, but such excavation disturbs the soil and provides germination conditions for seed-banked seeds (Batcher 2000; Miller 2003). Any remaining root fragments can resprout.

Chemical:

Foliar sprays can be used for large infestations. If this method is used, herbicide application should be in the early spring or late fall to minimize effects on non-target species. Glyphosate and triclopyr (2% solution of either) with surfactant have proven effective (Batcher, 2000; Miller 2003; Cuyahoga Valley National Park 2007).

Application of herbicides to cut stumps poses the least risk to non-target vegetation and is highly effective. Apply a 25% solution of either glyphosate or triclopyr to freshly cut stumps (invasive.org, no date given). Effectiveness increases if herbicide reservoir holes are made in the stumps (Batcher 2000).

Biological:

Both *Ligustrum amurense* and *L. vulgare* are susceptible to several fungal pathogens (*Cecrospora adusta*, *C. lilacis* and *Pseudocercrospora lugustri*), but no biological control agents are available at this time (Batcher 2000).

Fire:

Fire will kill privets, but successive burns are necessary. Also, burning is only effective on dry sites (Batcher 2000).

Recommended Management Method for ACAD: Remove immature fruits from privets at documented sites. If resources are available, cut stems near ground level, drill holes in the stumps and fill the holes with a 25% solution of glyphosate.

Monitoring Protocol: Establish transects through the populations before treatment and perform stem counts within 1m of the transect line every other meter. Make annual surveys of treated populations to check for the presence of fruits and sprouts from cut stumps.

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***Lonicera japonica*, Japanese Honeysuckle**
Caprifoliaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Lonicera japonica* is native to East Asia (Nuzzo 1997). It was introduced to Long Island, NY in 1806 and by 1912 its range extended from CT to FL. It has naturalized from MA to FL, TX, MO and IL, 26 states in all (Bravo no date given; Maine Natural Areas Program, no date given; Nuzzo, 1997; EasyLiving Native Perennial Wildflowers. 1999; Miller 2003). The northern limit of its range is determined by a minimum winter temperature of -25°C. Japanese honeysuckle is considered by some workers in the southeastern US to be the most commonly occurring invasive plant species.

Life History/Biology: *Lonicera japonica* is a perennial vine. The semi-evergreen leaves are opposite, ovate and entire. Leaf retention allows photosynthesis to occur when natives species are dormant, gives Japanese honeysuckle a competitive advantage over them. Young stems are reddish brown and older stems have shredding, exfoliating bark and hollow pith. The tubular flowers are paired, axillary, fragrant and white (fading to yellow). Flowers are 3-5cm long and pubescent on the outside. The fruits are black and each contains 2-3 dark brown seeds (Maine Natural Areas Program no date given; Miller 2003; Cuyahoga National Park 2007). Seed dispersal by robins, turkeys, bluebirds and goldfinches has been documented. Japanese honeysuckle spreads readily via seed, but it also spreads vegetatively from underground buds and roots, and from stem fragments (Connecticut Invasive Plants Working Group no date given; Nuzzo 1997; Cuyahoga National Park 2007).

Care should be taken in the identification of this exotic species because three native honeysuckle vines have been documented in Maine. The terminal one or two pairs of leaves are separate in *Lonicera japonica* and it has black fruits. In the native species, the terminal leaves are connate and the fruits are yellow-orange (Maine Natural Areas Program no date given; Nuzzo, 1997; Miller 2003; Cuyahoga National Park 2007).

Threats to Native Habitats: Japanese honeysuckle outcompetes native vegetation for light, water and nutrients (Nuzzo 1997). Its long, twining stems cover and shade out native species and the vines often girdle and kill other woody species; the shear weight of a honeysuckle clone can cause the supporting vegetation to collapse (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; EasyLiving Native Perennial Wildflowers 1999; Cuyahoga National Park 2007). Semi-evergreen leaves allow *Lonicera japonica* a prolonged growing season, increasing its competitive ability (Bravo no date given; Nuzzo 1997). Ability to seedbank also increases the threat of this species: seeds can accumulate in the soil and cause an immediate and severe infestation if site conditions change.

Honeysuckle invasions result in structural changes within the community, including lower species diversity and significant reductions in herbaceous and shrub layer cover (Nuzzo 1997).

Winter temperatures north of New York inhibit flower production and, therefore, fruit production, making it less of a threat in northern areas. However, if average and minimum winter

temperatures increase by 3°C (as predicted due to increases atmospheric CO_2), the range of Japanese honeysuckle would extend north ~400 km (Nuzzo 1997).

Distribution at ACAD: Japanese honeysuckle is known from one location where it is growing on the edge of a former estate near Schooner Head Road (Greene et al. 2004).

Abundance at ACAD: One clone comprises the solitary documented occurrence of this taxon (Greene et al. 2004).

Habitat:
Japanese honeysuckle invades disturbed areas, old fields, roadsides and forest edges as well as floodplain forests (Bravo no date given; Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Nuzzo 1997; Cuyahoga National Park 2007). It has also been documented as able to colonize forest openings. It grows best in full sun and mesic soils, but has adapted to diverse habitats (Miller 2003). This species may persist in unsuitable habitat, then expand rapidly following a disturbance that improves the habitat (e.g. one persistent clone in full shade at ACAD; canopy tree mortality would provide abundant sun for improved growth).

At ACAD: ACAD's only documented plant of Japanese honeysuckle is growing under a partially closed canopy of red maple and green ash. There are many Morrow's honeysuckle (*Lonicera morrowii*) and Japanese barberry (*Berberis thunbergii*) shrubs nearby. Interrupted ferns (*Osmunda claytoniana*), large-leaved aster (*Aster macrophyllus*) and yellow king-devil (*Hieracium caespitosum*) provide almost continuous herbaceous cover (Greene et al. 2004).

Management Goals:
- Eradicate Japanese honeysuckle from ACAD
- Educate the public about identifying this species and preventing its spread

Action Threshold: Presence of one plant

Management Alternatives:
Mechanical: Cutting and pulling are ineffective and often result in increased shoot growth in large populations. Pulling may be an effective way to manage small infestations (Bravo no date given; Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program, no date given; Nuzzo, 1997; Cuyahoga National Park 2007).

Chemical: Herbicides afford the best control of Japanese honeysuckle to date. The semi-evergreen nature of this species allows herbicide application when native species are dormant, reducing damage to non-target species. Herbicides should be applied after the first killing frost, but before a hard freeze.

Glyphosate
The highest honeysuckle mortality resulted from a foliar application of 0.75% glyphosate within two days following the first killing frost; applications made after the 2 day window resulted in lower mortality, even at higher glyophosate concentrations (Nuzzo 1997). Glyphosate (25%

solution) is also effective when applied to cut stems any time that the ground is not frozen. Resprouting may occur and repeat applications are usually necessary (Bravo no date given; Maine Natural Areas Program no date given; Miller 2003).

Dichloroprop + 2, 4-D
Dichloroprop (1.5%) mixed with 3.6g 2, 4-D/liter resulted in 94% *L. japonica* mortality if applied within 2 days of the first killing frost (Nuzzo 1997).

Triclopyr
Triclopyr (25% solution) is effective when applied to cut stems any time that the ground is not frozen. Resprouting may occur and repeat applications are usually necessary (Bravo no date given; Maine Natural Areas Program no date given; Miller 2003). Triclopyr can also be applied as a foliar spray (8% triclopyr) during the growing season (Connecticut Invasive Plants Working Group no date given).

Biological: No biocontrol agents are available at this time (Nuzzo 1997).

Fire: Fire top-kills Japanese honeysuckle, but results in increases shoot production (Nuzzo 1997). Fire may be effective if used in combination with herbicides: a dormant season burn would reduce Japanese honeysuckle biomass, which would facilitate herbicide treatment (foliar glyphosate application) of post-fire sprouts (Nuzzo 1997; Miller 2003).

Recommended Treatment Method for ACAD: Cut all stems near ground level in mid-summer. Within two days following the first killing frost, apply a foliar spray of 0.75% glyphosate to any shoots that have appeared since cutting.

Monitoring Protocol: Survey the managed site annually for the presence of shoots that have regrown since treatment. Re-treat as necessary.

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Lonicera spp., Honeysuckles
Caprifoliaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Several honeysuckle species, hybrids and cultivars have become invasive in the US. Many taxa within this group are difficult to separate without reproductive material and are grouped here as *Lonicera* spp. because they behave similarly on the landscape. *Lonicera morrowii* is native to Japan, was introduced in the US in the late 19th century and has become naturalized throughout the northeastern, mid-Atlantic and some midwestern states and southeastern Canada (30 states and provinces in all) (Batcher 2000; Maine Natural Areas Program no date given). *L. tatarica* is native to western and central Russia and was introduced to the US as early as 1752 (Williams no date given; Batcher 2000). It shares a naturalized distribution similar to Morrow's honeysuckle, but extends farther west. *L.* X *bella* is their hybrid and occurs where both parents grow (Miller 2003). Shrub honeysuckles have long been and continue to be used in ornamental plantings. They have also been promoted by government agencies as wildlife and shelterwood plantings (Maine Natural Areas Program no date given; Williams no date given; Batcher 2000; Miller 2003).

Care should be taken in the identification of these species because ACAD supports the native shrub honeysuckles *L. canadensis* and *L. villosa*. Native species have glabrous styles, actinomorphic flowers and a solid pith; non-natives have pubescent ovaries, zygomorphic styles and hollow pith (Maine Natural Areas Program no date given; Williams no date given; Cuyahoga National Park 2007).

Life History/Biology: *Lonicera morrowii*, *L. tatartica* and *L.* X *bella* are multistemmed deciduous shrubs that grow 2-6 m tall (Batcher 2000). *L. morrowii*'s leaves are opposite, entire, grey-green and pubescent. Paired tubular flowers and peduncles of *Lonicera* spp. are pubescent; they are white, fading to yellow with red fruits. *L. tatarica* has glabrous leaves, peduncles and flowers, the flowers white fading to pink; fruits red or yellow. *L.* X *bella* exhibits intermediate leaf and flower characters; fruits are red or yellow (Maine Natural Areas Program no date given; Williams no date given; Batcher 2000; Miller 2003).

Reproduction in these taxa is almost exclusively through seed, which is produced abundantly and consistently exhibits high germination rates (Connecticut Invasive Plants Working Group no date given; Batcher 2000; Miller 2003). Seeds are dispersed by birds and small mammals; honeysuckle fruit dispersal has been documented in over 20 avian species (Williams no date given; Cuyahoga National Park 2007).

Non-native bush honeysuckles have been found to leaf out earlier than native trees and shrubs and they retain their leaves longer in the fall, allowing them a longer growing season than their native competitors (Maine Natural Areas Program no date given; Batcher 2000; Miller 2003). *Lonicera* X *bella* can tolerate a wide variety of light conditions, which allows it to invade sites inaccessible to less tolerant species (Connecticut Invasive Plants Working Group no date given; Batcher 2000).

Threats to Native Habitats: *L. morrowi* and *L.* X *bella* form dense thickets and reduce native plant species diversity. They alter habitats by deceasing light availability and by depleting soil moisture and nutrients (Maine Natural Areas Program no date given; Williams, no date given; Miller 2003). They may also exhibit allelopathic characteristics (Williams no date given). Their greatest impact may be in their effectiveness at reducing tree regeneration by outcompeting tree seedlings (Batcher 2000). Annual herbaceous species are also reduced or eliminated (Batcher 2000).

Non-native shrubs may also attract pollinators more effectively than natives, resulting in lower fruit-set by native species.

Native frugivores feed heavily on bush honeysuckle fruits. However, because of their lower fat content, fruits of non-natives provide a low quality food source (Miller 2003). Some workers have suggested that the dominance of non-native shrubs in the landscape is contributing to high mortality rates recently suffered by migrating neotropical migrants (Williams no date given). Increased predation of robin and wood thrush nests has been shown to occur when nests are built in shrub honeysuckles instead of native shrubs (Batcher 2000).

Distribution at ACAD: Most of the honeysuckle populations documented by a recent inventory of invasive species are in Bar Harbor. There are a few occurrences south of Bar Harbor and east of Somes Sound and even fewer west of Somes Sound (Greene, et al. 2004).

Abundance at ACAD: Of 94 documented honeysuckle sites, there are ten or fewer plants at 56 of them, 11-20 plants at seven of them, 21-100 plants at seven of them and more than 100 plants at 9 of them. No population data are available for 13 honeysuckle sites (Greene, et al. 2004).

Habitat: In their native ranges**,** Morrow's honeysuckle occupies mesic sites and Tatarian honeysuckle grows in dry cool conditions (Batcher 2000). Both species and their hybrid are found on disturbed sites, including forest edges and old fields, but will also invade intact forests and riparian areas (Maine Natural Areas Program no date given). Morrow's and Bell's honeysuckles are know to have invaded bogs, fen, lakeshore and sand plains (Williams no date given; Miller 2003).

At ACAD: Non-native honeysuckle occurs in a variety of habitats at ACAD: along old roads, on a pondshore, in a streambed and associated with old habitations. These shrubs are found most often in dry, open areas or where there is a sparse canopy of red oak (*Quercus rubra*), red maple (*Acer rubrum*) or big-toothed aspen (*Populus grandidentata*). Regenerating canopy species and huckleberries (*Gayussacia baccata*) are usually present in the shrub layer and wood bluegrass (*Poa nemoralis*), large-leaved aster (*Aster macrophyllus*), sarsaparilla (*Aralia nudicaulis*) and pale sedge (*Carex lucorum*) comprise the herb layer.

Honeysuckles also occur as a linear population that extends from the outlet of Eagle Lake and intermittently along Duck Brook, to the ocean. The shrubs grow on gravel bars in the stream bed which emerge after the spring run-off and in the brook's floodplain (Greene, et al. 2004).

Management Goals:

- Eliminate fruit production by shrub honeysuckles
- Reduce cover of shrub honeysuckles so that they are limited to stump sprouts on managed plants and seedlings arising from the seedbank
- Document and eradicate any small, newly established populations found by Park staff
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

Action Threshold: Presence of one reproductive plant

Management Alternatives:

Mechanical: Pulling is only practical in very small infestations with small plants and requires a monitoring commitment of at least five years (Williams no date given; Batcher 2000). Pulling of many plants or larger individuals causes soil disturbance which, in turn, creates optimal germination conditions for seed-banked seeds (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Batcher 2000). Cutting larger plants results in numerous sprouts, which must then be clipped at least twice a year to insure control (Williams no date given). Winter pruning encourages vigorous resprouting and should be avoided (Connecticut Invasive Plants Working Group no date given; Batcher 2000).

Chemical: Herbicide application appears to be the best control method for shrub honeysuckles because herbicides effectively kill them, there is no soil disturbance and the time and labor required are lower than for other methods.

A 20-25% solution of glyphosate can be applied to cut stumps, as can triclopyr. Foliar sprays of either 2% glyphosate or triclopyr are effective. Glyphosate is non-selective and will kill non-target grasses and broad-leaved plants. Triclopyr kills only broad-leaved plants. Cut stump treatments should be carried out from mid-summer through dormancy; foliar spray should be applied late in the growing season (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Williams no date given; Batcher 2000; Miller 2003). Late season application minimizes damage to native species which become dormant before the *Lonicera* species.

Biological: There are no known biological controls for *L. morrowii, L. tatarica* or *L.* X *bella* at this time (Williams no date given; Batcher 2000; Miller 2003).

Fire: Burning topkills honeysuckles, but because of resprouting in these species, burns must be repeated annually for several years to control them (Batcher 2000).

Recommended Treatment Method for ACAD: Cut all stems larger than 1cm diameter to near ground level and apply a 25% solution of glyphosate. Conduct management as late in the fall as possible to minimize damage to non-target plants. Pull all plants smaller than 1 cm diameter and dispose of them off-site.

Monitoring Protocol: Record the GPS coordinates of all managed sites. Record the treatment used and the number of stems pulled or cut. Revisit managed sites annually and repeat treatments as necessary.

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***Luzula luzuloides* (Lam.) Dandy and Wilmott,**
Forest Woodrush
Juncaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Forest woodrush is native to central Europe. The earliest New England records of *Luzula luzuloides* are from MA in 1910 and ME in 1912 (Mehrhoff et al. 2003). It is unclear whether its introduction was intentional or accidental (Howard 1978). It is reported to have medicinal or culinary uses (Randall 2004). Naturalized populations have been documented in CT, MA, ME, MN, NJ, NY, PA, VT and WI (Haines and Vining 1998).

Life History/Biology: *Luzula luzuloides* is a perennial woodrush that grows in dense tufts with leaves that are up to 30 long and 7 mm wide, with abundant hairs along the margins. Clusters of 2-8 pink-white flowers appear in spring and summer in loosely branched inflorescences. Fruits are oval, reddish capsules containing many small (1 mm diameter), shiny, dark brown seeds (Haines and Vining 1998, Mehrhoff et al. 2003). Forest woodrush also spreads vegetatively by means of stolons.

Threats to Native Habitats: Although this plant has not spread widely during the century since its introduction, it has the ability to grow in forested habitats, making it a threat to intact natural areas (Mehrhoff et al. 2003). At ACAD, it occurs in dense and extensive patches to the exclusion of native species (Greene et al. 2004). This species' wide ecological amplitude (see **Habitat** section, below) constitutes a threat because there are no ecological barriers to its establishment or spread.

Distribution at ACAD: The current known distribution of forest woodrush is limited to the towns of Bar Harbor and Mount Desert (Greene et al. 2004, Weber and Rooney unpublished). Two main areas of concentration were documented during an inventory of invasive species: near Sieur de Monts Spring and near the intersection of West St. Extension and Duck Brook Road (Greene et al. 2004).

Abundance at ACAD: Twenty-four sites were documented for forest woodrush during an inventory of invasive plant species at ACAD. Population sizes were recorded as follows: 10 or fewer plants at two sites; 11-20 plants at six sites; 21-100 plants at five sites and over 100 plants at 10 sites. There was one additional site at which no plant count was made (Greene et al. 2004).

Habitat: At ACAD, forest woodrush occurs under a closed canopy with red oak (*Quercus rubra*), white pine (*Pinus strobus*), big-toothed aspen (*Populus grandidentata*), white birch (*Betula papyrifera*), red maple (*Acer rubrum*), American beech (*Fagus grandifolia*) and hemlock (*Tsuga canadensis*) as components. Regenerating canopy species comprise the shrub stratum; striped maple (*Acer pensylvanicum*) and balsam fir (*Abies balsamea*) are present at some sites. Wood bluegrass (*Poa nemoralis*), large-leaved aster (*Aster macrophyllus*) and bracken fern (*Pteridium* aquilinum) are herbaceous species often associated with forest woodrush (Greene et al. 2004).

Elsewhere in New England, *Luzula luzuloides* has been documented in abandoned fields, early successional forests, floodplain forests, disturbed open areas, river and stream banks, and lawns (Mehrhoff et al. 2003).

Management Goals:

- Eradicate the thirteen smallest populations at ACAD
- Reduce the extent of the largest 10 populations by at least 50% (thereby decreasing the spread of woodrush into adjacent undisturbed sites)
- Prevent establishment of new populations
- Educate the public about identifying this species and preventing its spread

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Action Threshold: Action should be taken immediately. Additional management should be undertaken if goals are not met after initial treatment.

Management Methods: To our knowledge, no management methods have been reported for this species. Methodologies below are adapted from those used for other grass-like plants.

Mechanical: Pulling is not recommended because of the soil disturbance it causes. Soil disturbance tends to promote germination of seed-banked seeds, of which each woodrush plant produces hundreds every year.

Removal of flowering culms or immature seed heads would slow the spread of this species by preventing dispersal of new propagules.

Chemical: A late season foliar spray of 2% glyphosate should be effective in killing this plant (Tu et al. 2001).

Biological: None known at this time.

Recommended Treatment Method for ACAD: Remove flower heads or immature fruiting heads from plants and dispose with incinerated trash.

Because there are no published management protocols for this species, control tests should be undertaken in a single population to assess treatment effectiveness. Early, middle and late season applications of a foliar spray of 2% glyphosate should be made within a large population and their effectiveness compared via cover estimates. The most effective treatment should be used on other priority populations the following year.

Monitoring Protocol: Establish three transects through a large woodrush population when spring growth begins. Estimate forest woodrush cover in a series of 1 square meter plots along the one transect followed by an early season herbicide application. Re-sample plots 1 month after application. Repeat pre- and post-treatment assessments for the other two transects in July and September.

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***Physocarpus opulifolius*, (L.) Maxim., Ninebark**
Rosaceae
Invasive Plant Species Management Plan

Background/History: The nativity of *Physocarpus opulifolius* is problematic for Maine. Most manuals give its range as including Quebec to Hudson's Bay, south to VA, TN and MI (Haines and Vining 1998). However it is not considered native to Maine and it was unknown in the ACAD region as late as 1894, when a flora of the region was published (Rand and Redfield 1894). Additionally, several sources quote 1687 as the year of its introduction (Dirr 1983; Rehder 1960). Ninebark is considered potentially invasive where it is not native (Mehrhoff et al. 2003).

Life History/Biology: Ninebark is a woody shrub that grows up to about 3 m tall and equally wide. Young twigs and branches are red; bark on older stems exfoliates in papery shreds. The leaves are alternate, simple, toothed and three- to five-lobed. Flowers are white-pink, each about 0.5 cm wide and borne in corymbs of many blossoms (Dirr 1983; Haines and Vining 1998; Rehder 1960). Fruits are reddish, inflated follicles. Abundant sprouts are formed if stems are browsed or cut and it can spread by underground suckers.

Threats to Native Habitats: At ACAD, *Physocarpus opuifolius* has formed dense, almost impenetrable thickets to the exclusion of native trees and shrubs. Individual plants are capable of producing many seedlings and suckers and can colonize suitable habitats (Greene et al. 2004). In areas where ninebark has become dominant, native shrub cover is reduced or absent, resulting in habitat alteration and a decrease in fleshy fruits important to wildlife.

Distribution at ACAD: The occurrences of ninebark at ACAD are concentrated in the Great Meadow/Tarn area. This plant is also spreading in and around Blackwoods campground Greene et al. 2004).

Abundance at ACAD: Thirty-six ninebark sites were documented during an inventory of invasive plant species at ACAD. Fourteen sites had ten or fewer plants, two had 11-20 plants, eight had 21-100 plants and eleven had more than 100 plants (Greene et al. 2004)

Habitat: *Physocarpus opulifolius* can withstand a wide range of environmental conditions: high and low pH, sun or shade and dry to moist soils. It is considered by horticulturists as a plant to be used where other shrubs would not survive (Dirr 1983; Rehder 1960).

At ACAD, ninebark is concentrated in area that had been used agriculturally and commercially before burning during the 1947 fire. Many non-native species have colonized the site under a partial canopy of red maple (*Acer rubrum*) and quaking aspen (*Populus tremuloides*). Alder-bucktorn (*Frangula alnus*) is the dominant shrub, but red maple, shadbush (*Amelanchier* sp.) and blackberry (*Rubus allegheniensis*) are also present. Alder-buckthorn is an important component of the herb layer, with wood bluegrass (*Poa nemoralis*), flat-topped white aster (*Doellingeria umbellata*) and bluejoint grass (*Calamagrostis canadensis*) as co-dominant species (Greene et al. 2004).

Management Goals:

- Prevent the spread of ninebark into new areas
- Eliminate ninebark fruit production in Great Meadow
- Reduce ninebark cover in Great Meadow so that it is limited to stump sprouts on managed plants and seedlings arising from the pre-management seedbank
- Document and eradicate any small, newly established populations found by Park staff
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

Action Threshold: Presence of one reproductive plant

Management Methods: To our knowledge, no management methods have been reported for this species. Methodologies below are adapted from those used for other invasive shrubs.

Mechanical: *Digging/Pulling*: Digging and pulling are only effective in controlling very small infestations populated by young plants. Excavation of larger plants causes soil disturbance that may expose seed-banked seeds to conditions appropriate for germination as well as disturbing the roots of non-target species (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984; Jeanette 2000; Ohio Department of Natural Resources 2001; Rhoades and Block 2002; Wieseler 2003).

Cutting and Mowing: Cutting must be done several times per season; plants will not be killed, just controlled. Stems of glossy buckthorn (*Frangula alnus*), another woody invasive, cut twice a year for two years had shorter and fewer stems than a control (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984; Ohio Department of Natural Resources 2001; Rhoades and Block, 2002).

Girdling: Removal of a 2-3 cm wide cut strip of bark exposes the phloem and kills glossy buckthorn tree, a method that may be effective in controlling ninebark (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given; Converse 1984).

Fire: Prescribed burning resulted in higher growth rates and stem densities in *Frangula alnus* populations. This is likely due to the cool, slow-spreading fires that result from the low fuel loads under the dense buckthorn thickets; buckthorn shrubs were only top-killed (Converse 1984; White 1993; Ohio Department of Natural Resources 2001; Wieseler 2003). Burning topkills honeysuckles (a suite of invasive shrubs), but because of resprouting in these species, burns must be repeated annually for several years to control them (Batcher 2000). Five or six annual burns kill glossy buckthorn plants, but create good germination conditions for seed-banked seeds. Burns to control buckthorn should be conducted in the early spring, as soon as any litter has dried and while carbohydrate reserves are low (Wieseler 2003).

There are no reports of experiments with prescribed burns to control ninebark. However, burning should top-kill ninebark, but abundant stump sprouts would likely be produced.

Chemical:
There are no published reports on chemical control of ninebark. The following information on chemical control summarizes what is effective for other woody invasive species that also grow in ACAD.

2,4-D:
An early season application of 2,4-D in diesel fuel (2-4% herbicide:96-98% oil) painted on the basal bark of stems 10 cm or less in diameter resulted in 100% mortality (Converse 1984).

Glyphosate:
Glyphosate provides good control if applied as a foliar spray (2% glyphosate in water) in the spring. Because buckthorn retains its leaves longer than most native species, a late season foliar spray can be done after native species have dropped their leaves. This is effective and minimizes damage to non-target species (hort.uconn.edu, no date given). Stems can also be cut late in the growing season and the stumps treated with 20-50% aqueous solution of glyphosate (Connecticut Invasive Plants Working Group no date given; Converse, 1984; Jeanette, 2000; Rhoades and Block, 2002). In one study, glyphosate applied to cut stumps late in the growing season (at the rate of 1:5, herbicide:water) yielded 85% buckthorn mortality (Wieseler 2003).

Picloram:
Frill application of ready to use picloram during growing season resulted in 100% buckthorn mortality, but there was damage to non-target species (Converse 1984).

Triclopyr:
Brush-B-Gon® (8% triclpyr) can be applied as a foliar spray (4 oz./gallon) or, undiluted as a cut stump treatment (hort.uconn.edu, no date given). A 1:4, herbicide:water with dye solution applied to cut stumps during the growing season provides excellent buckthorn control (Wieseler, 2003). A 1:7, triclopyr:oil mixture applied to cut stumps controls buckthorn, as does a 1:16, triclopyr oil mixture sprayed or brushed on the bark, just above the root collar (Wieseler, 2003). Cut stump treatments with Garlon 4® (61.6% triclopyr) is also effective for buckthorn control (Ohio Department of Natural Resources 2001; Rhoades and Block 2002).

Biological: None known at this time.

Recommended Management Method for ACAD: Stem cutting and removal, followed by application of glyphosate to the cut stumps is recommended for control of ninebark at ACAD. Several different methods would probably be effective in controlling *Physocarpus opulifolius*, but the one recommended is attractive for several reasons: 1) it should be effective, 2) there is no soil disturbance, 3) glyphosate formulations are safe to use in natural areas, 4) it meets the goal of preventing ninebark spread, but will likely have the added benefit of killing the majority of existing ninebark plants.

Management should occur late in the season (September or October). Stems should be cut close to ground level and removed from the site for incineration. Glyphosate should then be painted on the cut stumps. Dye added to the herbicide allows applicators to visually assess which stems have and have not been treated, facilitating 100% coverage. Retreatment may be necessary.

Monitoring Protocol: Because ninebark is frequent and widespread in the southeastern portion of the Great Meadow basin, transects through the area would be the best way to estimate treatment effects. A series of 100 m transects should be established before treatment. Coordinates of their starting and ending points should be recorded using GPS units. To adequately cover the population, the transects should be located in the following areas of buckthorn concentration: 1) east of the Park Loop Road, north of Sieur de Monts Spring, 2) west of the Park Loop Road, north of Sieur de Monts Spring, 3) southwest of the Loop Road near its intersection with Hardin Farm Road. Transects should be traversed before treatment and ninebark cover in a series of square meter plots along each transect be estimated.

Treated sites should be monitored in July of the year following treatment. The same transects should be run, again recording cover in the square meter plots along each transect. Pre- and post-treatment numbers could then be used to assess treatment effectiveness.

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***Robinia pseudoacacia* L., Black Locust**
Fabaceae
Invasive Plant Species Management Plan

Background/History: *Robina pseudoacacia* is native from PA to GA, west to IA, MO and OK (Haines and Vining 1998; Mehrhoff et al. 2003; Wieseler 2006). It was introduced as a utilitarian plant in 1635 and has naturalized in all New England states (Rehder 1960). It is still widely planted horticulturally and as a timber species because of the extremely durable wood it produces.

Life History/Biology: Black locust is a deciduous tree with deeply furrowed bark and narrow, brittle branches. Young plants are armed with thorns. The alternate, pinnately compound leaves have 7-21 small, mucronate, ovoid leaflets. White flowers are born on pendant racemes. Fruits are glabrous pods, 5-10 cm long and containing 4-9 seeds; heavy seed crops are produced in alternate years (Rehder 1960; Dirr 1983; Haines and Vining 1998). Although most trees produce ample seed, germination rates are low because the seed coats are impermeable (Converse 1984). Most reproduction in black locusts is asexual by means of root suckers and stump sprouts (Mehrhoff et al. 2003; Wieseler 2006).

Robinia pseudoacacia is a poor competitor and will not thrive where there is competing herbaceous or woody vegetation (Wieseler 2006). However, without competition and given a moderately well-drained and fertile soil, this species is capable of growing over 0.5 m per year for at least 10 years (Converse 1984; Mehrhoff 2003). Like other members of the Fabaceae, black locust is capable of fixing atmospheric nitrogen (Connecticut Invasive Plants Working Group no date given).

Threats to Native Habitats: Black locust aggressively invades open, disturbed areas where it shades out native vegetation and forms tall, dense, montypic stands (Connecticut Invasive Plants Working Group no date given; Mehrhoff et al. 2003). Its showy flowers produce abundant nectar and may lure more pollinators than native species, resulting in lower fruit-set for the natives (Mehrhoff et al. 2003; Wieseler 2006). Because black locust is nitrogen-fixing, it can colonize very poor sites, which it then enriches, potentially allowing colonization by other invasives (Connecticut Invasive Plants Working Group no date given; Peloquin and Hiebert 1999; Mehrhoff et al. 2003). Planting for erosion control, reclamation and plantations has aided its spread into natural areas (Wieseler 2006).

Distribution at ACAD: Most of the black locust sites documented by an invasives inventory are in the Bar Harbor area. This species has also been recorded at the south end of Bubble Pond, in Mt. Desert, and on the Seal Cove Road, in Tremont (Greene et al. 2004).

Abundance at ACAD: Documented black locust populations include: three with 10 or fewer plants, one with 11-20 plants, four with 21-100 plants and one with more than 100 plants. No population data were recorded at three sites (Greene et al. 2004).

Habitat: This species is not shade tolerant and most often colonizes disturbed areas, including old fields, forest edges and rights-of-way (Converse 1984; Mehrhoff et al. 2003; Wieseler 2006).

At ACAD: Black locust is a tree species that has colonized open, disturbed areas. At ACAD, it occurs most often within the limits of the 1947 fire and usually at sites where other types of disturbance have occurred (e.g. farming, road-building). This taxon often forms a monospecific, partially open canopy. Red maple (*Acer rubrum*), quaking aspen (*Populus tremuloides*), Norway maple (*Acer platanoides*), green ash (*Fraxinus pennsylvanica*) and white spruce (*Picea glauca*) were associated canopy species in or adjacent to black locust stands. These species also occur in the shrub layer, with Morrow's honeysuckle (*Lonicera morrowii*), shadbush (*Amelanchier* sp.) and meadowsweet (*Spiraea alba* v. *latifolia*). Wood bluegrass (*Poa nemoralis*), bluejoint grass (*Calamagrostis canadensis*), flat-topped white aster (*Doellingeria umbellata*) and bracken fern (*Pteridium aquilinum*) commonly comprise the herbaceous stratum.

Management Goals:

- Eradicate known ACAD populations
- Document and eradicate new populations to prevent invasion of high quality habitats
- Educate the public about identifying this species and preventing its spread

Action Threshold: Presence of one reproductive individual.

Management Alternatives:

Mechanical: Cutting and burning stimulate the growth of numerous suckers and sprouts and is not recommended (Connecticut Invasive Plants Working Group no date given; Converse 1984).

Chemical: Summer stem removal with immediate application of a 6.25% solution of glyphosate is an effective control (Wieseler 2006). Foliar application of triclopyr (4 lbs./100 gal) during midsummer is also effective, but there are greater risks to associated vegetation (Converse 1984). Triclopyr (25% solution in basal oil, 3:1, oil:Triclopyr can also be applied to cut stumps (and the bark below the cut, down to the root collar) with good results (Wieseler 2006).

Biological: None known at this time.

Recommended Treatment Method for ACAD: Glyphosate cut stump treatment, as described above.

Monitoring Protocol: Count stems before treatment. Apply herbicide mid-summer. Check sites for resprouts late season; retreat as necessary. Recheck sites annually for five years from date of last appearance of resprouts.

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***Rosa multiflora* Thunb., Multiflora or Rambler Rose**
Rosaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: *Rosa multiflora* is native to Japan and Korea. It was introduced to the US in 1886 as a rootstock for ornamental rose grafts and has naturalized throughout the US, with the exception of the Rocky Mountain states, the southeast, NV and CA (Eckardt 1987; Bergmann 2001; Miller 2003). It is especially widespread in the northeast and midwest (Miller 2003).

Multiflora rose was also promoted by government conservation agencies for use as a soil stabilizer, a wildlife food, a "living fence" for livestock and it has been widely planted by highway departments as a crash barrier and to diffuse headlight glare (Maine Natural Areas Program no date given; Eckardt 1987; Bergmann 2001; Miller 2003).

Life History/Biology: Rambler rose is a robust shrub with broadly arching or climbing armed branches. Its alternate, pinnately compound leaves comprise 9 pairs of ovate, serrate leaflets. Fragrant, white flowers (~2 cm wide) are produced in clusters in June or early July. Fruits are small hips (Rehder 1960; Haines and Vining 1998; Bergmann 2001; Miller 2003).

Rosa multiflora reproduces sexually by seeds and asexually by rooting at the tips of its stems. The small hips are a preferred wildlife food particularly sought by cedar waxwings and American robins, who are major dispersers of multiflora rose seeds. Studies show that seeds that have passed through avian digestive tracts germinate better than those which have not. The seeds retain their viability for 10-20 years (www.hort.uconn.edu, no date given). Once seedlings, rooted tips or suckers become established, they can grow over 0.5 m per week (Connecticut Invasive Plants Working Group no date given; Bergmann 2001).

Threats to Native Habitats: *Rosa multiflora* creates dense, impenetrable thickets which crowd out native vegetation (Eckardt 1987; Bergmann 2001). It can become established in light gaps in intact forest communities (Connecticut Invasive Plants Working Group no date given; Maine Natural Areas Program no date given).

Distribution at ACAD: Multiflora rose is more common outside ACAD than it is in the Park. However, two sites have been recorded within the Park's boundaries (Greene et al. 2004).

Abundance at ACAD: Ten or fewer plants make up one population and the other has 21-100 plants (Greene et al. 2004).

Habitat: Like most species, *Rosa multiflora* grows best on fertile, mesic sites, but it can grow in a wide range of conditions. It usually invades pastures, hedgerows, roadsides and forest edges (Maine Natural Areas Program, no date given; Eckardt 1987; Bergmann 2001).

At ACAD: Multiflora rose grows on open sites or sites where canopy closure is fairly complete. The ACAD populations are growing under a partial canopy of black locust (*Robinia*

pseudoacacia). The shrub stratum is well-developed and includes: speckled alder (*Alnus incana* ssp. *rugosa*), red maple (*Acer rubrum*), ninebark (*Physocarpus opulifolius*), privet (*Ligustrum* spp.) and Morrow's honeysuckle (*Lonicera morrowii*). Oriental bittersweet (*Celastrus orbiculata*), large-leaved aster (*Aster macrophyllus*), green ash (*Fraxinus pennsylvanica*), wood bluegrass (*Poa nemoralis*) and flat-topped white aster (*Doellingeria umbellata*) comprise the herb layer (Greene et al. 2004).

Management Goals:

- Eradicate existing plants and control subsequent offspring in those populations
- Document new invasion sites and manage to prevent spread
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

Action Threshold: Presence of a single plant

Management Alternatives:

Mechanical: Repeated mowing (3-6 times per season) will control, but not eradicate, multiflora rose (Maine Natural Areas Program no date given; Connecticut Invasive Plants Working Group no date given; Eckardt 1987; Bergmann 2001). Mowing is not feasible if mature bushes are present due to their large size (3 m tall X 7 m wide), or in uneven terrain.

Excavation is possible but not recommended because plants will resprout and because the resulting soil disturbance provides a seed bed for the abundant seed-banked seeds (Maine Natural Areas Program no date given).

If multiflora rose were to become established in an environmentally sensitive area where herbicide use would be inappropriate (e.g. within a rare plant population), mowing and/or cutting might be the preferred control method (Connecticut Invasive Plants Working Group no date given).

There are no reports testing prescribed burning as a control method for multiflora rose. Studies of other non-native roses have shown that fire top-kills the roses, but that resprouting is vigorous and immediate (Eckardt 1987).

Chemical: The plant growth regulators chlorflurenol, maleic hydrazine and MBR-18337 have been used to control *R. multiflora* by preventing fruitset. This halts the spread of the species, but has no effect on existing plants (Hipkins et al. 1980).

A 1-2% glyphosate solution applied to foliage in spring or fall provides effective control (Lynn et al. 1979). The effectiveness of the spring treatment was not fully apparent until the spring of the following growing season. Similarly, effects of the fall treatment were not observed until the following spring.

Foliar sprays of dicamba, triclopyr, fosamine, picloram and picloram with 2,4-D have also proved to be effective in controlling multiflora rose. Fosamine is specific to woody plants and its

use is advantageous in sensitive habitats or in the presence of rare herbaceous species (Reed and Fitzgerald 1970; Sherrick and Holt 1979).

Cut stump treatments of Roundup® [glyphosate (41%)] diluted 1:1 with water or undiluted Brush-B-Gon® [triclopyr (8%)] are also effective (www.hort.uconn.edu no date given). Both foliar and cut stump treatments are more effective if applied when temperatures are at least 18°C (Maine Natural Areas Program no date given). Miller (2003) suggests application of Garlon 4® as a 20% solution in basal oil, diesel oil or kerosene (2.5 quarts per 3 gallon mix) to young bark as a basal spray (January-February or May to October).

Biological: The European rose chalicid, *Megastigmus aculeatus*, has been suggested as a possible biocontrol agent for multiflora rose. This wasp lays its eggs in immature rose seeds, the larvae consume the seeds, overwinter in the now empty hip and emerge as adults the following spring. They are extremely weak fliers and will not disperse from their natal rose bush. Because so many of the *Rosa multiflora* intentionally planted in the US derived from cuttings, the wasp was not dispersed with the rose, allowing unchecked spread of this invasive plant (Eckardt 1987; Bergmann 2001). Currently, *M. aculeatus* is not available as a biocontrol agent.

Another potential biocontrol agent for multiflora rose is rose rosette disease, which causes abnormal floral development and alters pigmentation of leaves and shoots. It was first reported on *R. multiflora* in Nebraska and appears to be moving east. Because it is lethal to all roses, it appears unlikely that it will be developed as a biocontrol agent (Eckardt 1987).

Recommended Treatment Method for ACAD: Apply herbicide to cut stumps. Test efficacy of recommended cut stump treatments with glyphosate and triclopyr.

Monitoring Protocol: *Rosa multiflora* occurs at only two sites in ACAD. These sites should be visited annually for five years following initial treatment or until neither seedlings nor resprouts are observed. Site inspections should then be biennial. Plants should be retreated if resprouting occurs and any seedlings should be pulled, removed from the site and disposed of with refuse that is not composted and returned to the landscape.

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***Solanum dulcamara* L., Bittersweet Nightshade**
Solanaceae
Acadia National Park Invasive Plant Species Management Plan

Background/History: Bittersweet nightshade is native to Europe, North Africa and eastern Asia. Historically, this plant was used as a medicinal and its introduction to North America was probably intentional. It has since naturalized throughout most of the US, with the exception of the deep South (Haines and Vining 1998; Mehrhoff et al. 2003) and has occurred in the ACAD region since at least 1894 (Rand and Redfield 1894).

Life History/Biology: *Solanum dulcamara* is a perennial vine that exhibits either a prostrate or climbing habit. The stems are hollow, the older ones becoming woody. Its leaves are alternate and ovate or three-lobed and have a disagreeable odor when brushed or torn. Clusters of 10-25 small, purple flowers (~1 cm wide) form opposite the leaves, followed by fruits which turn bright red when ripe. Each fruit may contain 40 seeds (Francis no date given; Haines and Vining 1998; Mehrhoff et al., 2003). **Note:** The fruits are toxic to children and livestock.

Bittersweet nightshade reproduces sexually, by seeds, and asexually, by rooting along the stem. Its fruits are eaten and the seeds dispersed by birds, however, seed longevity is only one year (Reiner and McClendon 2002).

Threats to Native Habitats: This species was identified as invasive in ACAD by Reiner and McLendon (2002), who suggest that it poses a moderate threat in the park, in part because it is widespread and is present even in remote, seemingly undisturbed areas. Bittersweet nightshade can become established in intact natural areas because its seedlings are shade tolerant (Mehrhoff et al. 2003). It can form large, sprawling clones that outcompete native vegetation.

Distribution at ACAD: Bittersweet nightshade is distributed over all of Mount Desert Island and is likely much more common than ACAD's recent invasive plant inventory reflects. Beaches and headlands were largely excluded from the inventory because previous work had shown that few invasives colonize them. These communities do, however, provide suitable habitat for bittersweet nightshade and, if time had been spent searching them, its distribution would likely have been shown to be much wider (Greene et al. 2004).

Abundance at ACAD: As discussed above, if a large time commitment had been made to search for bittersweet nightshade, the resulting abundance estimate would doubtless have been higher. Twenty-three sites were documented for bittersweet nightshade by the invasives inventory. Thirteen of the sites had ten or fewer plants, two had 11-20 plants and three had 11-21 plants. No plant counts were made at five of the sites (Greene et al. 2004).

Habitat: *Solanum dulcamara* has been documented in thickets, clearings, open woods, banks of streams, coastal dunes, ditches and a variety of disturbed sites (Reiner and McLendon 2002; Mehrhoff et al. 2003). Francis (no date given) reports that this species grows best on sites with continuous soil moisture, including river banks, seashores and edges of bogs, lakes and fens.

At ACAD: Bittersweet nightshade can grow in full sun, but the populations documented by ACAD's invasives inventory usually had at least a partial canopy of green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*) or northern white cedar (*Thuja occidentalis*). Speckled alder (*Alnus incana* ssp. *rugosa*) and winterberry (*Ilex verticillata*) grew in the shrub layer and wood bluegrass (*Poa nemoralis*), sensitive fern (*Onoclea sensibilis*), fowl mannagrass (*Glyceria striata*) and nodding and sallow sedges (*Carex gynandra, C. lurida*) occupied the herbaceous layer (Greene et al. 2004).

Management Goals:

- Reduce cover of bittersweet nightshade at ACAD by controlling opportunistically
- Educate the public about this species: identification, its invasiveness and management recommendations for homeowners

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Action Threshold: Presence of *Solanum dulcamara* plants in sensitive areas (e.g. rare plant sites)

Management Alternatives: Because *Solanum dulcamara* is not considered to be highly invasive, there is little information available regarding its control.

Mechanical: Young plants can be pulled and removed from the site.

Chemical: Francis (no date given) recommends "spot spraying" with broadleaf or broad-spectrum herbicides. Glyphosate is reported to be effective in controlling other nightshade species. Application must be done when plants are actively growing (King County Department of Natural Resources 2000).

Biological: None known at this time.

Recommended Treatment Method for ACAD: Pull plants as encountered. Bittersweet nightshade plants observed in sensitive areas (e.g. rare plant occurrences) should be prioritized for management.

Monitoring Protocol: Although *Solanum dulcamara* is widespread in ACAD, no large infestations were documented during a recent invasives distribution and abundance survey. Opportunistic control and monitoring of this species are recommended. Sites where control efforts have neeb made need only be monitored if they are near control/monitoring sites for more invasive, higher priority species. A simple presence /absence determination would suffice for this taxon.

Newly documented sites should be visited by park botanists and the need for management determined (i.e. only control nightshade at ecologically sensitive areas or sites of rare plant populations).

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Tussilago farfara L., Coltsfoot

Asteraceae

Acadia National Park Invasive Plant Species Management Plan

Background/History: *Tussilago farfara* is native to Europe. It was used medicinally and in teas, candy and as a smoking material, thus, its introduction to North America was probably intentional (Haines and Vining 1998; Mehrhoff 2003). It has been documented in the US from ME to NC and west to MN. This species is not considered to be highly invasive.

Life History/Biology: Coltsfoot is an herbaceous perennial. Its large leaves (up to 20 cm) are heart-shaped to round, with a smooth upper surface and underside covered with white, woolly hairs. The yellow flowers, ~3 cm diameter, emerge in early spring, before the leaves and are held on scaly scapes. After flowering, the long-haired seeds develop into heads similar to those of dandelions. *Tussilago farfara* reproduces sexually, by seeds and asexually by means of extensive rhizomes. Wind-dispersed, the seeds have been reported to travel eight miles from the parent plant and 1,000-8,000 seeds are produced by each plant (Haines and Vining 1998; Reiner and McLendon 2002; Mehrhoff 2003).

Threats to Native Habitats: *Tussilago farfara* is an early successional species that colonizes disturbed sites. Its large leaves may shade out native species, preventing their establishment (Mehrhoff 2003). In addition, it often forms large matlike colonies that may outcompete and displace or eliminate native species (Greene et al. 2004).

Distribution at ACAD: Coltsfoot occurs primarily on carriage road edges on the east side of MDI. It has also been recorded from two streambeds (Greene et al. 2004).

Abundance at ACAD: Five coltsfoot populations were documented by a recent invasive plant inventory at ACAD. One population comprises ten or fewer plants, one has 11-20 plants, two have 21-100 plants and one has over 100 plants (Greene et al. 2004).

Habitat: *Tussilago farfara* is most common on roadsides and streambanks, usually in at least partial shade (Mehrhoff 2003; Southeast Exotic Pest Plant Control Council 2003).

At ACAD: Coltsfoot grows in disturbed, sandy and gravely areas, either along carriage roads or on gravel bars in streambeds. There is often a fairly dense canopy comprising red spruce (*Picea rubens*), yellow birch (*Betula alleghaniensis*), balsam fir (*Abies balsamea*) and white pine (*Pinus strobus*). Shrub cover is minimal. Blackberry (*Rubus allegheniensis*), nodding sedge (*Carex gynandra*), goldenrods (*Solidago* spp.), calico aster (*Symphyotrichum lateriflorum*), sweet vernal grass (*Anthoxanthum odoratum*) and common woodrush (*Luzula multiflora*) occur in the herb layer (Greene et al. 2004).

Management Goals:

- Eradicate populations on Jordan Stream and Little Harbor Brook
- Prevent further spread of coltsfoot by removing flower or immature seed heads

- Document and eradicate any newly discovered populations to prevent establishment and spread

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Action Threshold:

- Presence of any coltsfoot plants at rare plant occurrences (e.g. Little Harbor Brook *Calamagrostis stricta* ssp. *inexpansa* population)
- Presence of reproductive plants elsewhere in the Park.

Management Alternatives:

Mechanical: Clip immature seed heads and remove from site. Pulling can be effective if soil is not compacted.

Chemical: Coltsfoot is resistant to 2,4-D; sodium chlorate is effective (Reiner and McLendon 2002).

Biological: None available at this time.

Recommended Treatment Method for ACAD: Follow spring phenology of the easily accessible coltsfoot site on the carriage road below park headquarters (begin as soon as winter snow recedes). When flowering begins, go to less accessible sites, including Little Harbor Brook population, clip immature seed heads and remove from site.

Monitoring Protocol: Visit known coltsfoot occurrences annually in early spring. If plants are present, conduct management. If no plants are observed at a previously documented site for three years, discontinue annual monitoring.

Documentation of recently established and previously overlooked populations is a component of monitoring. All newly documented populations small enough to be eradicated should be removed by digging or employing the methods described above for eradication. If large populations are documented, Park staff should assess them and assign a management goal (eradication or control).

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Appendix B

Invasive Potential of Lupine (*Lupinus polyphyllus*)

at

Acadia National Park

Problem Statement

Resource Management staff, who monitor vegetation throughout the Park, made anecdotal reports of lupine populations expanding from disturbed areas into natural areas. In the spring of 2005 Resource Management staff initiated control efforts at a site adjacent to Great Meadow, where lupine was apparently moving into unmanaged areas of the wetland. Although control efforts in 2005 consisted only of cutting and removal of flowering stems to prevent seed production, Park visitors were vociferous in their opposition to lupine control and demanded a science-based rationale for further management. This paper presents the results of a literature search on lupine's invasive potential and gives recommendations regarding the need and methods for its management in the Park.

Background

Lupine (*Lupinus polyphyllus)* is commonly considered to be one of Maine's most beloved wildflowers. Countless stores statewide sell lupine "wildflower" seeds; reputable publications, including DownEast Magazine, have published articles on lupine as a favorite "wildflower"; and Barbara Cooney's book, *Miss Rumphius,* continues to popularize the notion that the spread of lupine on the landscape is a good thing. However, lupine does not occur naturally in Maine. Its native range is western North America, specifically, California, British Columbia, Idaho and Nevada (Fernald 1950; Sholars 1993). The first collection of lupine at ACAD was made in 1927 (Greene, et al. 2005) and the specimens at the University of Maine Herbarium date from 1937 and later. So, although lupine is generally accepted to be a traditional part of Maine's landscape, its arrival here is relatively recent.

Over the last decade efforts have been made to determine which plant species are or could be invasive in Maine and in ACAD. On the statewide level, the Maine Natural Areas Program convened an ad hoc group to discuss invasive plant species and develop a list of those known to be problematic here. Within ACAD, Reiner and McLendon (2002) undertook an assessment of the invasiveness of 45 non-native species and Greene et al. (2004) completed a study of the distribution and abundance of 24 of the Park's invasives. Greene et al. and Reiner and McLendon concluded that bigleaf lupine seemed to be limited in its distribution to disturbed sites (e.g. roadsides and old fields), and, therefore, posed a minimal threat as an invasive species.

Literature Review

Contrary to our previous assessment of lupine's invasiveness at ACAD, there is evidence of its unwanted spread elsewhere. New Zealand was apparently the first place to document *Lupinus polyphyllus* as an invasive plant. It is most problematic on the gravel bars of braided rivers, dynamic habitats, subject to erosion if unaltered by the presence of lupine. When lupine becomes established on these sites, it forms extensive root mats which are not easily eroded. Instead, the river edges erode, forming steep banks and eliminating the gravel bars upon which several species of endangered bird species depend (NZ Dept. of Conservation 2003; World Wildlife Fund no date given). Work in New Zealand has also documented water dispersal of lupine seeds, allowing them to spread incalculably farther than they would if the seeds just dropped from their fruits around the parent plant. Because of the demonstrated threat, New Zealand has been

successful in enlisting public support and involvement in lupine control efforts (Weedbusters Newsletter 2004). Previous to its expansion into the Great Meadow wetland, lupine was only known to grow on roadsides and other human-disturbed sites and has been considered to have short distance dispersal, with seeds often dropping around the base of the parent plant. Documentation of water dispersal by lupine confers the ability for longer distance dispersal and necessitates the way in which we think about its invasive potential. In addition, the work in New Zealand documents lupine's potential to colonize unexpected habitats. Although ACAD has no extensive river systems like those described above, Jordan Stream and Little Harbor Brook have gravel bar habitats that might be suitable. Also, ACAD does not support avian species dependent on the gravel bar habitat, but it does support the State endangered grass New England northern reed grass (*Calamagrostis stricta* ssp. *inexpansa*), which occurs on some of ACAD's gravel bar habitats, and which could be impacted if lupine were to expand into that habitat.

In the US, lupine is invasive in Alaska, Wisconsin, Michigan and Minnesota (Alaska Natural Heritage Program 2006; Anonymous 2003; McKee 2005). Extensive work has been done to assess lupine's invasive potential in Alaska, especially on National Park lands. This research shows that lupine may become established in disturbed areas, but it can also persist there for at least 15 years. The presence of lupine on disturbed sites prevents or delays the establishment of native species. Additionally, lupine is documented to have invaded intact natural areas, including river terraces (Alaska Natural Heritage Program 2006). Alaska has ranked the invasive threat of over 50 exotic plant species based on 18 parameters. Lupine scored 55, with 0 representing no threat and 100 representing the greatest threat. In terms of ecological impact, lupine scored high due to its ability to alter ecosystems, including increasing sedimentation rates along streams and reducing open water required by waterfowl. Lupine also affects plant community structure by reducing diversity, interferes with native pollinators, and is invasive in wetland communities. Because it has been shown to be highly invasive in areas with habitats and climate similar to Alaska's (particularly northern European countries), lupine is thought to pose a considerable threat to Alaska's natural areas. Lupine is listed on the Working List of the Invasive Plants of Wisconsin and is ranked as being moderately capable of invading natural areas, highly competitive and somewhat difficult to control (Anonymous, 2003). Elsewhere in the Midwest, it considered an invader of upland habitats only, although it is a species of "moist areas to bogs" in its native range (Garske 2006). It is well established and spreading rapidly in the Lake Superior region of Minnesota, Wisconsin and Michigan, a region with vegetation similar to ACAD's. Its rapid spread in this lake and river-rich area, may be due to lupine's documented ability to disperse in water.

The climate of Northern Europe is also like ACAD's and *Lupinus polyphyllus* is invasive in several countries there, including Norway, Sweden, Finland, Germany, Switzerland and Lithuania. It is also listed by the 47 member-country European and Mediterranean Plant Protection Organization (EPPO) as a species "identified to pose an important threat to the environment and biodiversity in the EPPO region" (EPPO 2005). Lupine is thought to have arrived in Scandanavia in the 17th century as an ornamental and a green manure crop. From the time of its introduction until about 1930, it stayed where it was planted and little or no spread on the landscape was observed. Since about 1930, its escape from cultivation has been almost "explosive" (Fremstad and Elven 2002). It is it has expanded rapidly in areas close to the coast

and less so in inland areas. Results from research in Norway show that lupine rarely becomes established in forested stands, but is able to colonize habitat where natural or anthropogenic disturbances occur. Unlike most ruderal species which disappear with the emergence of more competitive species, lupine persists indefinitely once it becomes established on a site. Lupine has successfully invaded natural habitats in Finland. *Lupinus polyphyllus* appears on Switzerland's Watch List of invasive plant species, which lists species that should be controlled because they have the potential to cause damage or have caused ecological damage in neighboring countries (Gigon and Weber 2005). Reinhardt et al. (2003) report that lupine is widely distributed in Germany and has invaded undisturbed shrub and alpine communities. Lupine has displaced *Arnica montana*, an endangered plant species, in the alpine meadows it has invaded, and established lupine populations cause long lasting changes in soil characteristics that may prevent re-establishment of *Arnica* at these sites. ACAD has no alpine areas, but lupine's demonstrated displacement of the endangered *Arnica* and its ability to alter the invaded habitat is suggestive of the need to study the ecological amplitude of lupine at ACAD.

In summary, *Lupinus polyphyllus* is listed as invasive in parts of the US, New Zealand and Europe. Although its current distribution is relatively wide, lupine's invasiveness seems to be greatest in areas where the climate is similar to that of ACAD: Alaska, Wisconsin, Michigan and Minnesota, Scandinavia and Germany; it is not reported as invasive elsewhere in New England and it is not Federally listed as a noxious weed. Once established, lupine is persistent in the landscape, is capable of invading natural communities and has been shown to change the habitats it occupies enough to displace native species, including endangered birds and plants.

Lupine in ACAD

Data regarding lupine in ACAD is incomplete. Reiner and McLendon (2002) did not identify it as a priority species. Consequently, it was not included in ACAD's invasive plant distribution and abundance survey (Greene et al. 2004). After Resource Management staff noted invasion of Great Meadow by lupine and questions arose regarding lupine management, an effort was made to record lupine locations at ACAD (Figure 1). However, the locations currently documented are not the result of a systematic study, rather they are simply populations encountered during revegetation projects; lupine is likely more frequent in the Park than the current GIS map indicates. In addition, we have little knowledge of its distribution on easement lands or those that abut the Park. Lupine populations located near ACAD's boundaries could colonize Park land.

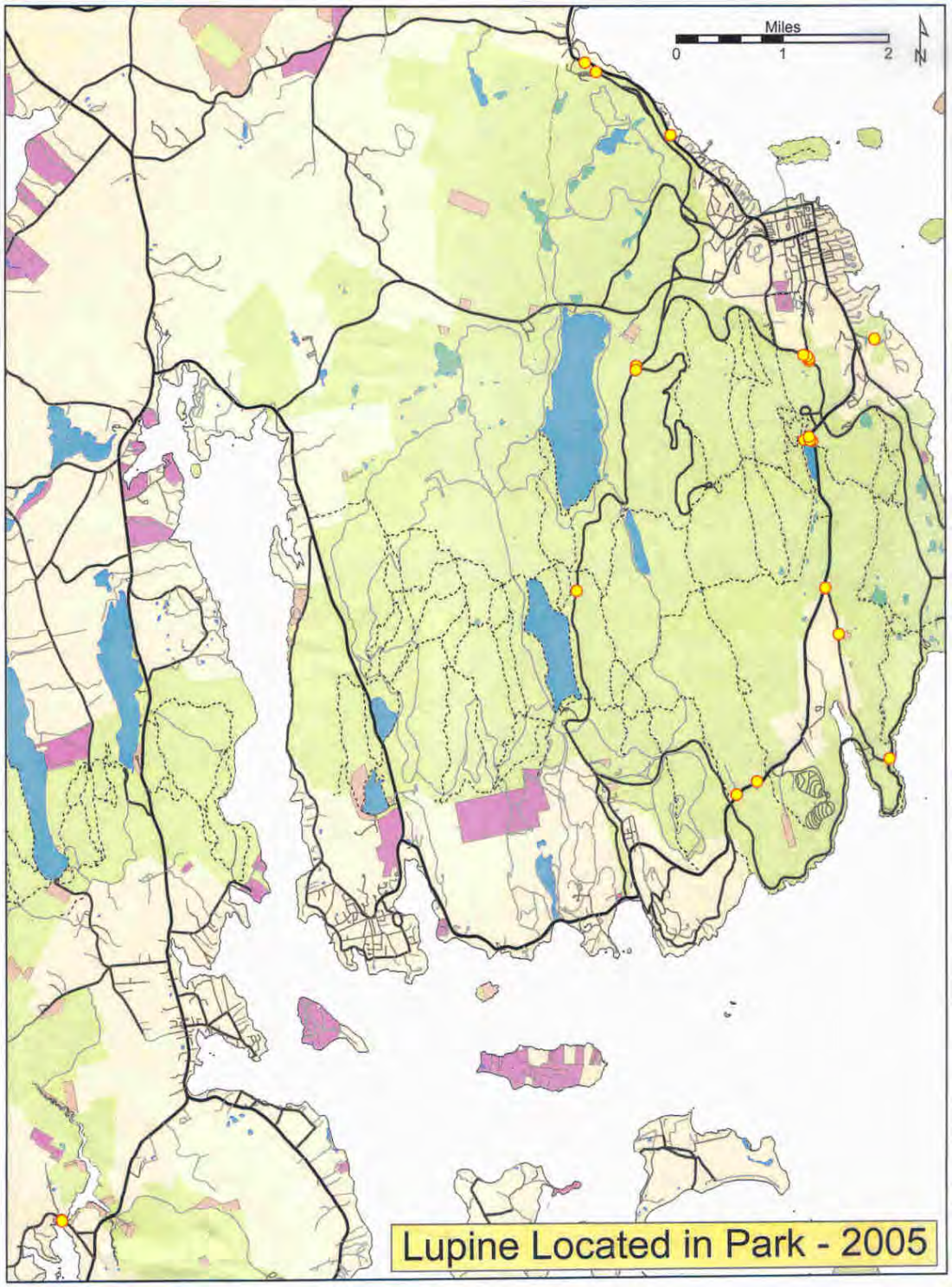
Lupine in Great Meadow

Lupine was first noted on a roadside slightly east of Great Meadow about a decade ago, following road work at the intersection of Ledgelawn Avenue and the Park Loop Road. It has been suggested that lupine seed was brought to the site with fill used in the construction. Lupine was documented on the edge of Great Meadow (west of the original construction site) in 2000, when less than half a dozen plants were observed near the wetland/upland boundary (Weber and Rooney unpublished). Woody species were thinned here in 2003 as part of a Park program to maintain vistas originally in ACAD's landscape design (ACAD files). We revisited the site in 2005 as part of another project, and observed that the lupine had spread extensively from its original roadside location. It was still present on the upland edge, where we had seen it in 2000,

but it had spread into the wetland and south along the wetland edge. Great Meadow has a long history of disturbance which includes its use for agricultural and commercial enterprises. Beaver activity in the wetland also causes fluctuations in the water level, which affects the degree to which woody vegetation can become established in the wetland and along its periphery. Most recently, woody vegetation on the east side of Great Meadow (in the area where the lupine population has expanded) was thinned as part of a program that maintains vistas that were part of the Park's original landscape plan. Vista clearing work decreased the canopy closure and removed significant shrub cover, both of which allowed more light into the area and created suitable habitat for lupine's establishment. Human disturbance within the wetland has been absent for about a century, but natural beaver disturbance continues. This is the first documented wetland invasion by lupine at ACAD. The lupine had spread from the single, small patch observed in 2000, into an area more than two acres in extent.

All life stages of lupine were observed during the 2005 survey. Seedlings were numerous and had successfully germinated and become established in the dense sedge-dominated vegetation of the mostly undisturbed wetland as well as on the more typical habitat on the upland edge. First year rosettes were also present in both habitats, as were mature plants that had lowered and produced seed (Figure 2).

Figure 1. Lupine distribution at Acadia National Park



Prepared by K. Anderson, Acadia National Park

Figure 2. Lupine in Great Meadow

Lupine seedling at base of dense gramonids.

Lupine seed heads in dense sedge growth in wetland.

Lupine seed heads in dense graminoid growth in Great Meadow wetland.

Published Lupine Control Methods

A review of the literature, and observations by Park staff and contractors present strong evidence that *Lupinus polyphyllus* is invasive outside Maine and that an ACAD population has expanded into a relatively undisturbed wetland. The evidence presented here regarding the invasive potential of lupine suggests that lupine management at ACAD would be appropriate.
It is always easier to control small, recently established populations of exotics than large ones with abundant seed banks.

Little information has been published on the management of invasive lupine populations, but work done in the Great Lakes Region of the US may be useful for lupine management at ACAD. Recommendations given by Garske (2006) are given below.

Manual Control

Small lupine populations can be controlled by cutting, mowing and digging. Repeated mowing will prevent seed production and may result in elimination of lupine plants, but it is not a practical approach for controlling populations in most natural areas. A multi-year commitment is required because lupine seed remains viable for more than one year, and germination of seed-banked seeds is likely. Digging, while effective, is impractical because it is time-consuming, causes soil disturbance (promoting germination of seed-banked seeds), and is difficult because lupine has a deep tap root.

Chemical Control

Recommendations for chemical control of lupine are based on methods developed for crown vetch control. Vetch is closely related to lupine and methods for its control are assumed to be effective for lupine. Glyphosate (1-2% active ingredient formulation) is effective but non-selective. Clopyralid targets legumes and members of the aster family, minimizing damage to non-target species. 2, 4-D and triclopyr target dicots only, leaving graminoid species unharmed.

Cultural Control

Too little is known about lupine's response to fire to recommend it as a control method. Some workers have suggested that herbicide treatment of tender, post-fire lupine growth might be effective. There is some suggestion that if lupine invades a disturbed area which will eventually be reforested, then lupine will eventually disappear due to shading. This may be true, but has little relevance to the site of interest at ACAD. It is possible that the canopy thinning that was part of the vista clearing project provided a "travel corridor" for lupine to colonize a new area, and eventually become established in the wetland. However, the area where lupine plants are currently most numerous is outside the site impacted by the vista clearing; the canopy may close again in the cleared area and lupine may disappear from the understory, but the area now occupied by lupine does not have nor is it expected to develop a woody canopy.

Seed head removal is the least invasive cultural control method. Lupine plants would be allowed to flower and immature fruits would be cut off and removed from the site for disposal. If no new seed is produced at the site, or arrives via water dispersal, then the lupine population will decline and eventually disappear.

Recommended Control Methods for ACAD

While several lupine populations have been documented at ACAD, the population at Great Meadow is the most problematic because lupine is rapidly spreading into relatively undisturbed habitat there. So far, the population isn't so large as to be unmanageable and it is confined to fairly easily accessible areas. We recommend that an integrated pest management (IPM) approach be employed to manage this population. At a minimum, flower and seed heads should be cut and removed from all plants in the population in late June. Another site visit should be made in late July to remove any seed heads missed in June. Careful documentation of the population's extent using GPS should be done during June seed head removal so that the total population area can be compared to that measured the following year. Monitoring is an important component of IPM in general and invasive plant management in particular. To monitor this lupine population, transects should be established to assess population size before and after treatment. A transect running north and south about 10m east of the edge of the population should be established via GPS coordinates. A series of transects 10 meters apart should be established using this north-south line as the starting point and running west toward the wetland and extending 10m beyond the current limit of the population. Coordinates of transect starting and ending points should be recorded using GPS units. Transects should be traversed before and after treatment. Lupine plants within $1m^2$ plots should be counted and designated as vegetative or reproductive. The $1m^2$ plots should be placed every other meter on alternate sides of the transect.

Park staff should continue to document lupine occurrences at ACAD and look for signs that lupine is spreading into unmanaged areas. Any sites where spread is suspected should receive greater scrutiny to determine the extent and degree of lupine spread, after which further management could take place as needed.

Education could be an important part of the lupine picture at ACAD. Lupine is iconic for many Park visitors, and the idea that it should be controlled runs counter to their thinking. Perhaps the lupine issue could be covered in trainings for interpretive staff so that interpreters can explain the difference between a disturbed roadside and a natural community and how non-native plants can affect wildlife species as well as plant species composition.

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Appendix C

Purple Loosestrife Action Plan

PURPLE LOOSESTRIFE ACTION PLAN

(Excerpted from Acadia National Park Integrated Pest Management Plan [Connery 1991])

SPECIES: Purple loosestrife (Lythrum salicaria)

IDENTIFICATION:

A showy non-native perennial introduced from Europe, with striking rose or magenta colored floral spikelets which bloom from mid-July through the end of August. Flowers are 1/2 - 3/4" wide, with 5 or 6 petals. The lance-shaped leaves clasp the stem, and grow in pairs or sometimes in whorls of 3. Found in swamps or wet meadows, ditches, beaver ponds. Similar native plants which may be easily confused with purple loosestrife, especially in immature form, include swamp candles (Lysimachia terrestris) and many species of goldenrods (Solidago sp).

DESCRIPTION OF PEST AND POTENTIAL FOR DAMAGE:

A highly invasive alien plant which colonizes disturbed wet environments, purple loosestrife displaces indigenous wetland vegetation, including rare species and species which are of great value to wildlife. In other parts of the Northeast, it has virtually wiped out native wetland communities by establishing mono-specific stands. Once established, it is extremely difficult to eliminate. If loosestrife becomes well established in the Park and many years of seed production have occurred, the opportunity to attempt local eradication has probably been lost (Thompson, 1987), and the native community may well be irretrievable. Lythrum salicaria was noted on a list of plants of Mount Desert Island in 1928 (Wherry, 1928). However, populations remained at relatively low levels in a handful of wetlands since that time, perhaps due to a lack of disturbance coupled with heavy competition from native vegetation. Mechanical removal of beaver dams and lodges in the Bear Brook watershed in the late 1970's and early 1980's seems to have resulted in proliferation of purple loosestrife there.

PROBLEM AREAS IN THE PARK:

The most significant populations of purple loosestrife include:

A. Park Loop Road, Beaver Dam Pond, Bear Brook - Scattered individual plants growing around the perimeter of pond. The most extensive population of loosestrife found in the Park is on the north of road in and around numerous beaver ponds and canals.

B. Hulls Cove House Wetland - Sparsely distributed individual plants in the main section of the wetland. A large, previously hidden stand was discovered among alders on the southern margin of this wetland in 1990.

C. Compass Harbor Trail - There is a scattered population of about 30 plants adjacent to the shore.

D. The Tarn - Scattered plants on the south end of the pond. Due to the extensive wetlands downstream, this population is especially dangerous.

Very small populations have been reported in other Park areas. More detailed descriptions of infested sites and treatments are available in the Purple Loosestrife Control Annual Reports (Willey, 1988; Hazen, 1990).

MONITORING AND ACTION LEVELS:

Known locations of loosestrife plants will be inspected early in July when flowers first break into bloom. When blooms become obvious, other Park wetlands will be inspected visually for purple loosestrife invasion. Because staffing limitations restrict the number of wetlands which can be monitored each year, a priority system will be established based on the following criteria:

1. previously infected areas or wetlands in proximity to other infected wetlands
2. proximity to roads or other sources of infection such as Lythrum used ornamentally in gardens
3. areas which have not been previously inspected
4. areas which have been inspected previously and were not infected

Care must be given to prevent seed transfer on boots or clothing by monitors who go from wetlands harboring loosestrife to unaffected areas. Footwear must be cleaned of all mud or debris and inspected before moving from one area to another. Areas which are monitored and treated will be mapped on a USGS topographic map "Acadia National Park and Vicinity" each year. The Park should strive to incorporate purple loosestrife control information into the Geographic Information System (GIS) as quickly as possible.

In addition to visual surveys, treatment success will be monitored using permanent grids of one square meter quadrats established in wetlands where loosestrife was present in 1989. Methodology, detailed in the 1989-90 purple loosestrife annual report, must remain consistent from year to year. Total stem counts of plants over 3 inches in height for each quadrat will be tabulated, and the results analyzed statistically.

Loosestrife is very difficult to eliminate once it becomes established, therefore, every effort will be made to eradicate it whenever populations are identified. The presence of even one loosestrife plant will be the threshold where eradication efforts are initiated.

PREVENTATIVE TECHNIQUES:

Purple loosestrife does not successfully invade natural plant communities, but responds to disturbance. Clearly, the most successful management method is to prevent the initial invasion of loosestrife by maintaining the integrity of natural wetlands. Any form of disturbance or stress to the native plant community should be avoided. This includes mechanical disturbance, such as the removal of beaver dams for managing beaver damage by the use of heavy equipment. Purple loosestrife has the ability to regenerate from adventitious buds growing from crushed stems whereas many of its native associates do not (Thompson, 1987). Water drawdowns should not occur after April or before August.

TREATMENT ALTERNATIVES:

A. No treatment - The no treatment alternative would result in continued spread of this alien species, with associated displacement of native vegetation and loss of the wetland ecosystem. Adoption of this alternative would result in the Congressional mandate to preserve naturally functioning native systems not to be met.

B. Mechanical - Plants may be partially managed by cutting or pulling.

Pulling - Small plants can be pulled using great care to remove the entire root system. It is much more difficult to pull large, mature plants because the root system is often very extensive.

Cutting - Cutting the flowering heads is most effective when done in the late summer (Malecki & Rawinski, 1985). A 54% reduction in shoots was reported when cutting was performed in late August, compared to 34% when cut in early August.

Cut or pulled plants must be removed from the site and destroyed, because they will form adventitious shoots if left lying on moist, unvegetated soil. However, it should be noted that cutting is not a permanent solution for elimination of loosestrife (Malecki & Rawinski, 1985). Cutting and pulling did not result in lower populations of plants at Acadia in 1987. In fact, some populations receiving this treatment actually increased in size (Willey, 1988).

C. Biological - Efforts are currently underway by the Department of Agriculture to test three promising European insect control agents. Host specificity will be included as an important aspect of their study (personal communication with G. Johnston, WASO). Currently, there are no known natural predators with control potential in the United States. Biological control alternatives appear to be at least several years away.

D. Chemical - Herbicide treatment studies using glyphosate have been very successful, though careful attention should be given to growth stage and timing. Although varying rates of application does not result in significantly different control, time of application does (Malecki and Rawinski, 1985). Previous studies (Monsanto Company 1975; Kline and Selleck, 1978) indicated that treatment in the later stages of development is most effective and that timing affects the extent of loosestrife reinfestation. Glyphosate is biodegradable and quickly inactivated upon exposure to moist soils (Sprankle, 1975; Sprankle et al. 1975). It is considered to be a low hazard to fish and wildlife (Batt et al., 1980). Despite the promise of early investigations of the use of glyphosate, Rawinski(1982) cautioned against its widespread use without adequate knowledge of the effects of this relatively new chemical on marsh ecosystems. See-2,4-D@ is currently being used for purple loosestrife control at Voyageurs National Park in Minnesota (Benedict & Grim 1989). While this herbicide is more selective, it has not been extensively tested in the East as has glyphosate. Should purple loosestrife populations at Acadia become resistant to Rodeo@, it would be beneficial to switch to See-2,4-D@ or another broadleaf herbicide approved for aquatic sites.

PREFERRED TREATMENT STRATEGIES:

Due to the highly detrimental nature of this invasive plant, every effort should be made to assure complete and continuous suppression of all identified populations as soon as possible. A chemical control program is the only effective method of protecting native wetlands at this time. Current populations must be held in check until more effective chemicals or biological control agents have been adequately tested and are approved for use.

However, chemical suppression alone will not maintain native wetland systems free of purple loosestrife. Chemical suppression must be integrated with:

- public education to inform visitors, neighbors and employees of the impacts of uncontrolled purple loosestrife invasion and the Park's management program
- cooperation with local nursery owners to reduce or eliminate the use of Lythrum ornamentally
- cooperation with state officials and other land management agencies (The Nature Conservancy Audubon, etc.) to share information on loosestrife suppression and work toward noxious plant legislation
- education, and where appropriate, cooperative control agreements with local landowners to reduce or eliminate the risk of invasion from adjacent lands
- continued literature review of scientific information on the ecology, biology, and management of Lythrum salicaria
- support of scientific research on purple loosestrife or the possible effects of herbicide contamination on soils, native plants, or water by private and public organizations and agencies.

Park field staff within all divisions will be alerted to look for purple loosestrife during their daily activities and will be given a guide to assist in Lythrum identification. Quantitative monitoring in permanent plots will be completed as necessary to monitor population levels and treatment effectiveness.

Prior to herbicide treatment, approval must be obtained from the Department of Agriculture, National Park Service, and the Maine Board of Pesticide Control. Newly infested wetlands which have not been previously checked will be inspected for the presence of rare and endangered plants before chemical treatment begins. Staff of visitor contact stations will be notified when management actions begin, so that they may answer visitor questions and educate the public about the park's purple loosestrife suppression program. In order to implement chemical management techniques at least one and preferably two staff members in the Division of Natural Resources and Science will maintain pesticide applicator certification in the aquatic category. In addition, safety briefings will be held before treatment is initiated each summer for all personnel involved in purple loosestrife management. Treatment actions, including amounts of herbicide application, and level of success will be documented in writing and yearly use logs will be submitted to the North Atlantic Regional Office and the Maine Board of Pesticide Control.

Herbicide will be applied by hand sprayer and care will be taken to minimize application to non-target plants. Treatment will be made only when ground wind speeds are low enough to prevent pesticide drift to non-target plants. Treated areas will be checked to assess treatment success and detect reinfestations. Other wetlands will be monitored visually to detect new populations so that they may be treated as soon as possible.

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