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EXOTIC SPECIES IN NATIONAL PARKS

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EXOTIC SPECIES IN U.S. NATIONAL PARKS:
Diverse Facets of an Increasingly Pervasive Problem

Guest Editor: Lloyd L. Loope

On the Cover: *Melaleuca quinquenervia,* native to Australia, is an aggressive invader of the Florida Everglades. See the article on how the Florida Exotic Pest Plant Council is developing strategies against this and other invasive plant species. Photo courtesy of Robert F. Doren.

Alien Forest Insects and Diseases in Eastern USNPS Units: Impacts and Interventions

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GREAT SMOKY MOUNTAINS NATIONAL PARK
Gatlinburg, Tennessee

Eastern North America contains one of the most extensive temperate deciduous forests on the planet, extending from southern Canada south to Florida and west to eastern Texas and Minnesota. The only other major regions to be dominated by similar vegetation in the northern hemisphere are in western and central Europe, and eastern Asia (Goode, 1974).

Botanists and biogeographers have long been intrigued by how closely related these distant floras are to one another, with many of the same genera in common and even some of the same species. While these extreme disjunctions are known for a few vascular plants at the species level, they are not at all uncommon for some non-vascular groups such as bryophytes (Allendorf, 1983).

As closely related as these forested regions appear to be, they may have been separated for approximately 10-20 million years (Matthews, 1978). The trees' associated species have probably changed, including those that form parasitic relationships.

Native forest trees in eastern North America have a number of native parasitic insects and fungal pathogens with which they have co-

evolved (Hepting, 1971). Classically, these organisms are at low population levels only, or reach levels high enough to be lethal to their hosts only when a special set of factors, including recent climate, site characteristics, and status of their own predators and parasites, are met. Most parasites from other continents that have been introduced into eastern North America have probably perished from lack of compatibility with primary host, alternate host, climate, native predators and parasites, or other factors.

Unfortunately, some forest insect and fungal species from other continents have become established all too well here, to the detriment of native forest species. These alien or exotic species pose some of the most difficult challenges to managers of natural areas in eastern North America.

Since these species are usually adapted to a closely related host, they can spread throughout a region and often throughout the entire range of their new host. The American host sometimes possesses no or only ineffective resistance mechanisms. With high populations of the pest, whole stands and ultimately all stands of the host can become infected. With no resistance to this attack, the host dies over large areas, although a common result is an overwhelming reduction in population and reproduction of the affected species, without extirpation. The impact of these losses, however, should be measured not only in *severity* but in *duration*. With only a few years or decades since these pests became widespread, the hosts' long-term survivability is unknown.

This paper examines some of the significant alien insects and fungal diseases that attack eastern U.S. forests. Specific impacts at Great Smoky Mountains National Park are noted, along with suggested management strategies.

ALIEN FOREST INSECTS AND DISEASES OF CONCERN

Table 1 (p. 4) shows ten eastern native tree species that are at risk of significant decline, the alien species responsible, and home range of the pest. It may not be a coincidence that these are all species valued for ornament, shade, timber, or other products. Society's desire to acquire trees with these same characteristics and uses has meant the importation over the years of hundreds of thousands of Asian and European tree seeds and seedlings of the same genera. Chinese chestnut blight, balsam woolly adelgid, Dutch elm disease, and others arrived in North America in this manner. Biological diversity usually yields relative stability in natural communities; interestingly, with eastern North American trees and their imported Eurasian kin, it may also mean eventual vulnerability.

Great Smoky Mountains National Park is a 209,000-hectare natural area in Tennessee and North Carolina that is renowned for its trees, both for number of species (130), and the fact that approximately 57,000 hectares of the park is old-growth forest (Tyrell, 1991). Old-growth forest is a rarity in the eastern United States, but Great Smoky Mountains has more of this uncut forest left than any other site east of the Great Plains (Davis, 1990). Table 2 (pp. 6-7) shows selected USNPS units and some native forest trees at risk of decline due to alien insects or diseases.

White pine blister rust This fungus was accidentally brought into eastern North America about 1898 by agencies involved in reforestation efforts, who had sent eastern white pine seeds to Germany to be reared into seedlings and then shipped back for reforestation (Anderson, 1990). Many alien insects and diseases were inadvertently brought in before such impacts were known,

Table 1. Selected Alien Forest Pests—Eastern North America

Native Host Species	Alien Pest	Original Range of Pest
Fraser fir *(Abies fraseri);* also *A. balsamea*	balsam woolly adelgid *(Adelges piceae)* • insect	Europe, Asia
sugar maple *(Acer saccharum);* others	pear thrips *(Taeniothrips inconsequens)* • insect	Europe
American chestnut *(Castanea dentata);* some oaks; chinquapins	Chinese chestnut blight *(Endothia parasitica)* • fungus	Asia
flowering dogwood *(Cornus florida);* other American *Cornus*	dogwood anthracnose *(Discula destructiva)* • fungus	probably East Asia
Butternut *(Juglans cinerea)* or white walnut	butternut canker *(Seriococcus claviginetijuglandacearum)* • fungus	unknown; most *Juglans* in Asia , South-Central Europe
eastern white pine *(Pinus strobus);* also some western five-needled pines	white pine blister rust *(Cronartium ribicola)* • fungus	Europe
Oaks *(Quercus* spp.*);* many other genera such as *Acer, Betula, Carya, Populus*	gypsy moth *(Lymantria dispar)* • insect	Europe, North Africa, Asia
American mountain ash *(Sorbus americana)*	European sawfly *(Pristiphora geniculata)* • insect	northern Europe
eastern or Canadian hemlock *(Tsuga canadensis);* also *Tsuga caroliniana*	hemlock woolly adelgid *(Adelges tsugae)* • insect	East Asia
American elm *(Ulmus americana);* other eastern elm species	Dutch elm disease *(Ceratocystis ulmi)* • fungus	Europe, Asia

and more careful customs inspections instituted. All North American five-needled species are susceptible to white pine blister rust (Johnson, 1990).

A massive program on federal lands in the Appalachians from the 1930s to the 1960s attempted to eradicate *Ribes* spp. shrubs within 275 meters of significant stands of eastern white pine. In Great Smoky Mountains, at least 150,000 *Ribes* spp. shrubs are known to have been pulled or treated with herbicide during that period. This is probably a conservative estimate since records from the time are incomplete. Current observations at Great Smoky Mountains indicate only minor effects to eastern white pine from blister rust.

Chinese chestnut blight The well-known story of its introduction into New York City and disastrous spread into the Appalachians will not be retold here. The American chestnut is the largest species of its genus, and it occasionally reached trunk diameters of nearly three meters in the southern Appalachians. This was one of our dominant mid-elevation trees, producing abundant mast crops reliably each year. *Not a single mature tree remains,* although specimens that were seedlings and saplings at the time of infestation in the 1920s and 1930s still resprout only to be killed at ground level again before producing nuts. This disease commonly infects scarlet oak *(Quercus coccinea),* causing basal defects of the bole, and kills Allegheny and Ozark chinquapin *(Castanea pumila and C. p. ozarkensis).*

Dutch elm disease This fungus was first found in the United States in Cleveland, Ohio, and New York City in the 1930s, where veneer logs from Europe had been imported (Anderson, 1990). The fungus is dispersed from tree to tree by both introduced (European) elm bark beetle and the native American elm bark beetle *(Hylurgopinus rufipes).* The disease moved south and west across the United States, killing millions of American and other elms native to the region. In Great Smoky Mountains, the disease was seen in the mid-1960s and began a resurgence in the late 1980s. American elms in the park are now at very low numbers, with most remaining trees infected.

Balsam woolly adelgid This small, cottony insect was introduced into Nova Scotia and Maine just after the turn of the century and spread into the southern Appalachians around 1950 (Eagar, 1984). The insect is dispersed on the wind in its first instar, which is its only mobile stage. The adelgid feeds by inserting its mouthparts into the bark, causing cell hypertrophy and thereby disrupting translocation of fluids within the tree. Mortality can occur within 2-7 years of infestation (Johnson, 1980). Although balsam fir and some Pacific northwestern *Abies* spp. are also at risk, Fraser fir appears to be the most acutely affected. European silver fir *(Abies alba),* which coevolved with the adelgid, is able to tolerate infestation by compartmentalizing wounded tissue at the feeding site (Kloft, 1957).

Fraser fir is restricted to several small mountainous areas in Virginia, North Carolina, and Tennessee. About 74% (19,717 hectares) of all spruce-fir forest in the southern United States is in Great Smoky Mountains (Dull *et al.,* 1988). Since its discovery in 1963 in Great Smoky Mountains, the adelgid has killed almost all the adult fir in the park. Only four mountain peaks in the highest elevations still have small remnants of mature fir forest, and this will succumb in the next few years. Trees do not become significantly infested until about twenty years of age, which is also about the age at which they first begin to produce seed crops. Research is underway to determine if the Fraser fir

Table 2. Some Species at Risk in Selected USNPS Units

	Juglans cinerea	*Tsuga canadensis*	*Ulmus americana*	*Cornus florida*	*Castanea dentata*	*Acer saccharum*	*Quercus* spp.
North Atlantic							
Cape Cod							•
Acadia		•	•			•	•
Saratoga		•	•		•	•	•
Morristown	•		•	•	•	•	•
Fire Island							•
Gateway		•	•	•			•
Rocky Mountain							
T. Roosevelt			•				
Wind Cave			•				
Badlands			•				
Mid-Atlantic							
Colonial			•	•			•
Shenandoah	•	•	•	•	•	•	•
Del Wat Gap	•	•	•	•	•	•	•
Valley Forge			•	•		•	
New River	•	•	•	•	•	•	•
Richmond			•	•			•
Allegheny Pg	•	•	•	•	•	•	•
Johnstown	•	•	•			•	•
Assateague I				•			•
Southeast							
Cp Hatteras			•				•
Blue Ridge	•	•	•	•	•	•	•
Grt Smoky	•	•	•	•	•	•	•
Shiloh			•	•	•	•	•
Cumb'l'd I			•				•
Congaree			•	•		•	•
Big So Fork	•	•	•	•	•	•	•
Mammoth C	•	•	•	•	•	•	•
Obed River	•	•	•	•	•	•	•
Natchez Tr	•		•	•	•	•	•
Cumb'l'd Gp	•	•	•	•	•	•	•

	Juglans cinerea	*Tsuga canadensis*	*Ulmus americana*	*Cornus florida*	*Castanea dentata*	*Acer saccharum*	*Quercus* spp.
Ft Donelson			•	•		•	•
Everglades							•
Chick-Chatt			•	•	•	•	•
Ft Caroline				•	•		•
Big Cypress							•
Cp Lookout				•			•
Horeshoe Bd	•			•			•
Midwest							
Pipestone			•				
Voyageurs			•				
Slp Bear Du	•	•	•		•	•	•
Cuyahoga V	•	•	•	•	•	•	•
Ozark River	•		•	•		•	•
Pictured Rck		•	•			•	
Effigy Mnds	•		•			•	•
Isle Royale			•			•	
Ind Dunes	•		•	•	•	•	•
Wilson's Cr			•			•	•
G W Carver			•				
Apostle Islds		•				•	•
National Capital							
Catoctin	•	•	•	•	•	•	•
Antietam			•	•		•	•
Manassas		•	•	•		•	•
Rock Creek	•		•	•	•	•	•
Pr William				•	•		•
G Wash Pky		•	•	•	•		•
Southwest							
Big Thicket			•	•		•	•
Jean Lafitte			•				
Hot Springs			•	•			•
Buffalo River			•	•		•	•
Big Bend							•

Note: *Sorbus americana* is at risk in Acadia, Shenandoah, Delaware Water Gap, Blue Ridge Parkway, Great Smoky Mountains, Voyageurs, Pictured Rocks, and Apostle Islands. Source: NPFLORA, GIS Division, USNPS, Denver, 1992.

will remain a viable part of the park ecosystem.

Gypsy moth This is currently the most publicized alien in eastern forests. The moth escaped in Medford, Massachusetts, in 1869 and has slowly spread west and south so that it now generally infests a large region from New England west to Michigan and south to North Carolina. Much has been published on this pest (USDA–Forest Service, 1981) and millions of dollars expended. About 100 old-world parasites of the gypsy moth have been released in eastern North America; several have become widely established, but effective control has been minimal. Although earlier instars of the larvae favor some tree species over others, later instars are voracious and will consume the foliage of all but a few eastern tree species, especially when high larval populations are reached (USDA–Forest Service, 1981). High populations occur in oak-dominated forest stands. Outside the generally infested zone described above, isolated outbreaks (usually one to several thousand hectares in size) are eradicated upon detection. There has been a trend in the last 10-15 years to switch from aerially applied broad-spectrum insecticides to target-specific agents. Currently a bacterium *(Bacillus thuringensis)* is the agent most commonly used to suppress or eradicate gypsy moths; it was used on 68% of the 460,000 hectares treated in 1991. Unfortunately, it is lethal to all early instar lepidopteran larvae. Much interest is now centering on developing adequate supplies of a viral product (Nucleopolyhedrosis virus, or NPV) that is specific to *Lymantriidae,* the family in which gypsy moths and tussock moths are classified.

Beginning in the 1980s, populations of gypsy moth have been discovered nearly all around Great Smoky Mountains in the southern Appalachians. All the "spot infestations" have been or are being eradicated. Approximately 38%, or 80,000 hectares, of the park may be susceptible to significant defoliation, based on work by MacKenzie (1991). About 12,000 hectares is probably old growth, perhaps the largest amount of old-growth oak left in eastern North America (as derived from Pyle, 1985).

Dogwood anthracnose This fungus was first found near Chehalis, Washington, in the mid-1970s on *Cornus nuttallii,* the Pacific dogwood. Dying flowering dogwoods were reported in the New York City area in 1978 (Pirone, 1980). Like some native fungi, dogwood anthracnose forms numerous lesions on leaves but then grows into twigs and branches. Trees die over 3-5 years, usually from the ground up. Cool, moist habitats favor the growth of the anthracnose; in such areas stands of 1,000 stems per hectare can die without a single surviving tree or seedling. By 1982 it was found in the Blue Ridge of Maryland (Mielke and Langdon, 1986), and in 1987 was found in northern Georgia and western North Carolina. In the southeastern United States it appears to be relegated to mountainous and upland regions. By 1991 dogwood anthracnose had been laboratory-verified from 126 counties in the southeastern United States. Dogwood anthracnose was not confirmed in Great Smoky Mountains until 1988. Baseline monitoring plots were established that same year across the entire park, and showed almost 60% of the plots to be without the fungus and another 27% to be lightly infected. Annual monitoring clearly shows a decline within dogwood plots; by 1991 only 15% were uninfected, while 65% were now in severe epidemic (Windham, Montgomery, and Langdon, 1992).

Butternut canker A detailed and thorough monograph on fungal

diseases of butternut in 1923 (Graves, 1923) failed to find any trace of this canker disease, which is now crippling the tree almost rangewide. The U.S. Forest Service Forest Pest Management section has found an 80% decrease in butternut in South Carolina and North Carolina in the last twenty years of its forest inventory program (Anderson, 1990). The fungus enters the trunk, branches, twigs, and even the nuts and forms a small canker up to about 10 centimeters in length. The fungus completes it life cycle in one year, but reinfects the last tree, often at wounds left by previous cankers. Mortality appears to be more the result of a chronic decline rather than acute attack. More alarming is the apparent suppression of nut crops by fungal activity within the immature nut, and subsequent abortion. At Great Smoky Mountains, seventy butternut trees have been monitored for four years, with only a small number of nuts produced in a single year; almost all were on two vigorous trees in full sun.

European mountain ash sawfly It is known to occur in Europe and Asia as well as North America, where it was first recorded in 1926 at Haines Falls, New York. By 1964 the sawfly had been observed throughout New England and southern Canada, west to Michigan, and south to Pennsylvania (Forbes and Daviault, 1964). Isolated but severe defoliations of American mountain ash were found in the southern Appalachians in the 1980s. The larvae feed gregariously and exclusively on American mountain ash and can completely strip a tree of foliage by the time feeding peaks in August. The resulting reduction in tree vigor is particularly critical in the habitat of mountain ash where growing seasons are short (i.e., high elevations and northern geographical areas).

Mountain ash has been declining in recent years in Great Smoky Mountains. Throughout most of its high-elevation habitat, trees are dying back from the crown and many have died completely. Decline syndromes are often a combination of such stress factors as repeated defoliation, poor air quality, adverse weather, and habitat degradation. (In the case of the mountain ash, the loss of the Fraser fir component is probably a factor.) While the exact cause of death is unknown, a four-year study of plots in the spruce-fir forests showed 45% mortality of mountain ash (Durr, pers. comm., 1991).

Hemlock woolly adelgid This adelgid is in the same genus as the balsam woolly adelgid *(Adelges)* and is believed to be an East Asian insect. First found on *Tsuga* spp. on the Pacific coast of North America, it caused little damage to natural areas. An introduction into the mid-Atlantic states, however, is causing widespread injury and loss (McClure, 1987), and it has recently entered Connecticut and Massachusetts. The insect is spread by wind, arboreal foraging birds, and many other means. In Shenandoah National Park in Virginia, work on conifers did not reveal any hemlock woolly adelgids in 1980, nor were these insects found during searches for it in 1985 at Catoctin Mountain Park in Maryland. By 1992, hemlock in both parks were infested. At Shenandoah, 88% of hemlock stands have the adelgid (Keith Watson, pers. comm., 1992). In early 1991 it was located as far south on the Blue Ridge Parkway as Floyd County, Virginia, near the North Carolina border (USNPS, 1992). The insects exhibit mass feeding behavior at the base of hemlock needles, which generally weakens the tree, although trees can die in one year (McClure, 1987). On the Blue Ridge Parkway in Virginia, this pest has also been found attacking the Appalachian endemic Carolina hemlock *(Tsuga caroliniana).* Great Smoky Moun-

tains probably does not have the hemlock woolly adelgid at this time, but the park is thought to contain some of the largest old-growth Canadian hemlock stands remaining anywhere, and an inventory is in progress.

Pear thrips This small winged insect was first found on pears in California in the 1920s and on sugar maples in New England in 1979. It is also known to feed on other trees, including the following genera: *Betula, Fraxinus, Pinus,* and *Fagus* (USDA–Forest Service, 1989). It feeds on buds in late winter and early spring, but its effects are not noticed until later. Feeding by pear thrips damages a maple's foliage as well as the next year's buds, reducing the tree's ability to manufacture food and causing branches to die back. This has created great concern in the New England sugaring industry. In 1988 it damaged 189,000 hectares of sugar maple in Vermont (Vermont Agency of Natural Resources, 1988). The thrips are now in the mid-Atlantic states, but varying populations make it difficult to detect and track. This pest is not currently known from the southern Appalachians, but abundant hosts (including old-growth stands) and favorable climatic conditions make its spread here likely.

SPECIAL PROBLEMS IN THE MANAGEMENT OF ALIEN FOREST INSECTS AND DISEASES

Native or alien? Some of the pests discussed above are not *absolutely* known to be introduced. This is not as remarkable as it may first appear, given that most in this category are fungi, which are not as well known as insects. In their home range these fungi may be very inconspicuous and during early expansion in North America may have initially resembled the irruption of native fungal diseases. An assessment of all available information, however, usually presents a pattern of first-time colonization. Historical reports of outbreaks—or the lack of them—and monographs of tree diseases by U.S. Department of Agriculture workers early in this century are invaluable, yet 100% confidence in assigning non-native status may not be possible. Delaying all actions until the origin is known is not necessary nor in the best interest of threatened resources. Use of legal standards of action prove useful. Detection and monitoring should be started after consultation with a forest pathologist establishes that there is a "reasonable suspicion" that a disease may be a recent introduction. No suppression actions should be undertaken unless evidence accumulates beyond reasonable scientific doubt.

Detection Not all forest insect and disease infestations are apparent on the landscape, even when the host is undergoing rapid loss and decline. The insidious character of these infestations is usually related to the abundance and habitat type of the host, and also to the speed at which decline of individual trees occurs.

Most insects and diseases require initial identification or at least verification of identification by specialists. Fungi will sometimes have to be cultured in a laboratory before taxonomic classification is certain. Newly discovered diseases must undergo a pathological verification process known as Koch's Postulates (Anderson, 1989). Dogwood anthracnose, known since the 1970s, was not scientifically described as a new species, *Discula destructiva,* until 1991 (Redlin, 1991). This was especially confusing since a number of varieties were being described. The U.S. Forest Service's Forest Pest Management (FPM) offices and state universities, which may be reached through local cooperative extension service offices, are the best sources of assistance in detection and verification.

Monitoring If the decision to begin monitoring a tree species has been made, consultation with the regional FPM office is essential. Most insect and fungal diseases have already had standardized monitoring methodologies established. Those that have not should be patterned after monitoring protocols for similar pests, again in consultation with FPM.

At a minimum, monitoring should be designed to detect loss of, and, if possible, decline in, the host species. Sensitivity to detecting host decline is critical when dealing with pathogenic fungi, since quantification of their populations is extremely difficult. Insect populations can be sampled during the most apparent life stage, i.e., egg masses, larvae, pupae, or adult, and a number of techniques have been published for some species (Doane and McManus, 1981). Multiple sampling methods can be used, but when the pest has more than one generation per year (e.g., balsam woolly adelgid), proper timing is critical for reliable data. If possible, reproduction in the host, site changes, and alteration of ecological processes should also be considered when scoping out potential issues for inclusion in monitoring.

The numbers of some host trees have been so decimated from their natural levels that associated native species, especially taxa obligate on the host, are much reduced or presumed extinct. Such is the case with the American chestnut. Several insects known to be closely associated with the tree have not been found in recent decades (USFWS, 1984). In another example, eight species of nationally rare bryophytes are threatened with extirpation at Great Smoky Mountains due to the loss of their obligate substrate, mature Fraser fir (Smith, MacFarland, and Davison, 1991). If possible, an inventory of obligate species should be undertaken, and those taxa prioritized for monitoring. The Natural Heritage Office in each state capital should be able to provide guidance on rarity ranking and prioritizations.

Interventions Before making the decision to intervene in a natural area to protect resources, USNPS Integrated Pest Management policy requires that we identify both the level of intolerable injury to the host, and the point in pest levels where action needs to be taken to prevent significant injury from occurring. Direct suppression, changes in habitat, or both may also be incorporated into pest management, but the most target-specific, effective actions should always be chosen. The U.S. Forest Service FPM offices have been given the coordination and funding role for emergency suppression of forest insect and disease pests on all federal lands. Their role is to help agencies meet the particular land management objectives of the affected park, forest, refuge, or military installation. Funding is received by a benefitting agency only after it has submitted a prioritized list of projects and the local FPM office has completed a biological assessment of each project. These monies can be used for actual suppression and for pre- and post-treatment monitoring of pest and host. They *cannot* be used for research, environmental assessments, or other purposes, as per interdepartmental agreement.

Conventional use of biocides, especially target-specific agents, are useful for delaying the loss of threatened hosts when other production techniques are on the horizon, or when the need for a biocide is strongly cyclical. Undertaking a long-term protection program based solely on the application of biocides is usually defensible only in special situations involving resources of extreme value or the establishment of "micro refuges" of the host (see the "Special Ecological

Areas" concept in USNPS Guideline NPS-77).

Use of biological control agents has been successful against many alien insects, but not against many fungi. Classical biocontrol reunites an alien pest with its natural predators and parasites from which it was released by being imported into the new continent without them, or by their having been lost during the initial colonization. It is not a panacea, but should be applied to more forest pests. The process is expensive and takes years to develop before organisms are ready to be released with confidence that the introduction will not be detrimental to non-targets. Much coordination is required between federal and state agencies. The U.S. Department of Agriculture's Agricultural Research Service is one of the coordinating agencies.

Increasingly, effecting genetic changes in hosts is being attempted as a long-term intervention to protect native forest trees from being lost to disease. Usually this has been an effort to develop a superior breed of tree for commercial use. Often the result is a general-purpose cultivar that has undergone a significant reduction of genetic material from its natural state.

Searching for resistant host individuals is a worthwhile endeavor and should be done in areas with the heaviest infection. "Resistant" trees get infected but survive, although in varying degrees of vigor, while "immune" trees (those individuals that *cannot* get infected) are almost never encountered. Putatively resistant trees should have scions taken from them and grafted or rooted, in a horticultural setting, to facilitate screening verification of resistance. If resistant, propagation should be strongly considered, both to disseminate the resistant stock through the wild population and for further breeding work. Putatively resistant flowering dogwoods found at Catoctin Mountain Park, and butternut from throughout its range, are currently undergoing screening (M. Windham, pers. comm., 1991; Minnesota Department of Natural Resources, 1990).

Using Old World trees of the same genera as the threatened tree to bring in resistance in a hybrid was tried unsuccessfully with American and Oriental chestnuts species early in the century. Some workers believe these efforts used strategies that doomed them to fail, and a new breeding strategy (Hosier, Burnham, and Read, 1985) has been developed that is being pursued by the American Chestnut Foundation in Minnesota and Virginia. This strategy starts with an initial cross of American and Chinese chestnuts, but their progeny get "back-crossed" to other American chestnuts for three generations, being inoculated and evaluated for resistance at each generation. Finally they are interbred as a group and screened for resistance once more. The result is a *population* of chestnuts that are about 95% American, yet contain the resistance of the Oriental parent. The Foundation has second back-crossed progeny under cultivation at this writing, and most physical characters expressed, even at this stage, are American.

Managers of natural areas need to be aware that native tree species that have undergone hybridization in the above manner may still not be suitable for re-introduction into natural zones. It is to be hoped that embryonic screening for resistance can speed up the current generational time for each screening (approximately five years), so that additional back-crossed generations can remove all significant traits of the exotic parent. Some major universities and non-governmental organizations such as the American Chestnut Foundation offer excellent opportunities to cooperatively develop resistance for park

species at risk—but currently about twenty years is required to produce the resistant group.

Beyond intervention If the alien forest insect or disease problem is so acute that most or all of the host will be lost in spite of intervention alternatives, *ex situ* preservation should be considered. This is being accomplished now for Fraser fir. The U.S. Forest Service also is planning to collect flowering dogwood seed from southeastern National Forests at risk for dogwood anthracnose for germination and protection at a site where the fungus will not thrive or be controlled chemically (R.L. Anderson, pers. comm.).

Another last-ditch step is to quickly and comprehensively document the life history and role of the host before it is diminished. Such studies should include a quantified characterization of primary and marginal habitats, distribution, phenology, and breeding systems. Long-term monitoring of plots containing the host will eventually elucidate the taxa that replace it at formerly dominated sites. At Great Smoky Mountains, studies of Fraser fir, American chestnut, flowering dogwood, American mountain ash, and butternut either have been completed, are underway, or are planned.

By helping understand the role of missing pieces, this information may contribute to successful future re-introduction programs and studies of natural systems.

SUMMARY

Alien forest insects and diseases have had and are having a major impact on natural zones in many eastern USNPS units. Despite devastation of some species, some pest problems are not easily recognized and certainly not easily managed. A process exists for receiving funding for suppression, in cooperation with the U.S. Forest Service, but biocontrol and breeding of resistance into native species has not been undertaken in earnest, although many federal, state, and non-governmental organizations are interested in the same general aims of such projects.

Unfortunately, park efforts may only be able to focus on characterizing the ecological role of a soon-to-be-diminished native tree species. One can only hope that development of advanced technologies in upcoming decades will allow mitigation and re-introduction actions.

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The Exotic Pest Plant Council

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While restorationists in most areas now face problems with exotic plant species, these problems are especially serious in southern Florida, and have reached critical proportions. During the past twenty years they have begun to threaten the survival of ecosystems such as the Everglades. The Exotic Pest Plant Council (EPPC) was formed in 1984 to help cope with this increasingly severe problem. It has proved remarkably successful both in drawing attention to exotic plant problems in natural areas and in coordinating efforts to deal with them. EPPC efforts have improved cooperation among numerous agencies sharing responsibility for the restoration and management of Florida's natural areas, and have played a key role in local and state coordination and management plans and acquiring funds for carrying them out.

The purpose of this paper is to describe the EPPC and its formation and goals, and to provide a brief overview of its accomplishments and current efforts.

Though the first exotic plants were introduced to southern Florida around 1900, major problems with the invasion of the state's natural areas are much more recent, and became really serious and widespread only during the past few decades. This was partly because many of our most serious pests were not introduced until comparatively recently, and also because disturbances in and near the state's natural areas have increased dramatically during this period, creating numerous opportunities for expansion of populations of these weedy species. Interestingly, most of southern Florida's exotic

pest plants were brought here deliberately, ostensibly to improve the environment. Many were brought to help "reclaim" the wetlands, drying up the "swamp," and to allow people to live in and farm these otherwise "useless" places. People like John Gifford, an early plant explorer and supporter of managed forests for development, were instrumental in introducing many of these pest plants for "reclamation" purposes. In any event, a host of exotics were brought in during the early part of this century. Most have had little ecological impact, but some have invaded certain of Florida's unique ecosystems with devastating effect.

While exotics now pose threats to the integrity of various natural ecosystems, these invasions first attracted widespread attention when they began to interfere with popular public activities such as fishing or boating on canals or lakes, where dense growths of exotic aquatic weeds began to appear about 1950. Eventually more subtle environmental problems became evident as species such as *Melaleuca quinquenervia* and *Schinus terebinthifolius* began to alter the composition of the plant and animal communities in our natural preserves. Many people responded to these problems, but usually individually. Often a single state or county park, one agency, or even one person in an agency reacted, but without participation or communication with anyone else. Occasionally individuals within an agency shared information, but there was no coordinated, interagency program for management of exotic pest plants in the region.

Florida's first organized effort was for the control of aquatic weeds, and resulted in the development of the Bureau of Aquatic Weeds under the Florida Department of Natural Resources. This provided a model for the EPPC to follow. However, until the formation of the EPPC, very little was being done to coordinate any work on the woody exotics invading our upland and wetland areas. Earlier organized efforts, such as the *Melaleuca* Symposium in 1980, were ad hoc efforts. As a result, many managers were unfamiliar with exotic weeds as pests (because many of the woody weeds created environmental problems, not people problems) and there was a serious lack of funding for pest control and related research (which is still the case). Meanwhile, since the problem had grown enormously without respect for political boundaries, the whole issue of exotic pest plants, especially woody species, posed a problem that demanded a concerted, coordinated effort.

The foundation of the EPPC started when those of us in the land management profession began contacting one another regarding this issue. These contacts soon led to informal meetings of people involved in exotics management, control, and research, which soon led to more formal get-togethers such as the *Melaleuca* Symposium in 1980 (the proceedings of the symposium, edited by R. K. Geiger, were published in 1981 by the Florida Department of Agriculture, Division of Forestry, Tallahassee). Eventually the interest became so strong that a more formal structure was needed. Responding to this, we management professionals organized EPPC as a registered nonprofit corporation.

The purposes of the EPPC are to facilitate communication and education, provide a forum for discussion, and provide advice on funding and research on the management and control of exotic pest plants.

After seven years, EPPC now has over 200 members representing more than forty different agencies and corporations, and has become a major force for the management of exotic pest plants. We are now in the process of becoming a national or-

ganization and have taken the first steps toward establishing a chapter in California under the leadership of one of our former board members who has since moved to California. Some of our major projects include:

• A *symposium* in November 1988 on exotic pest plants that brought over 300 scientists and managers from all over the world to discuss problems related to the management of exotic pest plants. (Proceedings of this symposium are now available from Donna O'Leary, Editor, U.S. National Park Service, Denver Service Center, Air Quality Division, P.O. Box 25287, Denver, Colorado 80225.)

• *Legislation.* The EPPC, using an existing ordinance from Dade County, Florida [where part of Everglades National Park is located], developed a "model" county ordinance as a guide for local governments to use in writing exotic pest plant control legislation. This has since led to the enactment of numerous county ordinances restricting the sale, transportation, or cultivation of many exotic pest plants by twelve different county and city governments. Many of these regulations require the removal of certain noxious species, notably *Melaleuca quinquenervia.* More recently, the State of Florida enacted legislation that prohibits the transportation, sale, or use of *M. quinquenervia, Schinus terebinthifolius, Casuarina* spp., and *Mimosa pigra* within the state.

• *Melaleuca research.* Because management of *M. quinquenervia* is considered critical, and because of its rapid invasion of Florida in recent years (Figure 1), EPPC's Biocontrol Committee (BIOCOM) petitioned the U.S. Department of Agriculture (USDA) to begin research to determine the potential for using biological agents in the control of this

Figure 1. *Melaleuca* invading a prairie.

species. An interagency agreement was developed for biological control. Since 1986, by working closely with the offices of U.S. Representative E. Clay Shaw and U.S. Senator Bob Graham, and through private industry and a number of federal, state, and local units of government, we have procured more than $3 million to fund a biological control program, including support for a new quarantine facility at Fort Lauderdale. So far, USDA entomologists directing the project have found more than 300 insects that feed on *Melaleuca,* approximately twenty of which are considered excellent biocontrol candidates. The first insect will be brought into U.S. quarantine for further evaluation in 1992.

• *"Rogue's Gallery" video.* EPPC members worked with a local film company to produce a thirteen-minute video on the environmental problems associated with Australian cajeput in Florida. The video has been used extensively for educational purposes and has provided an excellent, professional documentation of the serious environmental problems exotics can pose. This film has been presented on local public networks, and at numerous meetings and symposia throughout the country. It is available from: Artful Rhetoric Film and Video, Inc., 2421 Lake Pancoast Drive #4H, Miami Beach, Florida 33140. EPPC members have also worked with the television programs "Good Morning America" and "CBS Sunday Morning" to produce nationally televised segments for these shows about the environmental problems exotic pest plants pose.

• Congress's Office of Technology Assessment (OTA) recently contacted EPPC regarding a review of the exotic pest problems in the United States. EPPC worked with OTA to assist them in developing and reviewing the issues regarding plant pests, and provided them with resources and national and international contacts for their assessment. The EPPC's current Chairperson, Don Schmitz, has been placed on the OTA board for this assessment, and has testified before Congress regarding the seriousness of exotic pest plants.

• EPPC's Publications Committee has produced a *handbook* that summarizes treatment techniques used by land managers for four widespread exotic pest plants: *M. quinquenervia, Casuarina* spp., *S. terebinthifolius,* and *Colubrina asiatica.* The handbook discusses the various methods of control of exotic pest plants, including detailed discussion of the use of herbicides. The handbook was published by the University of Florida's Institute of Food and Agricultural Sciences in December 1990 and is available from local extension offices and EPPC.

• The Publications Committee is also developing an *exotic plant identification manual and species list for Florida.* The manual will include *Melaleuca, Casuarina* spp., and *Schinus,* the species that are now regarded as the most widespread, disruptive pest plants in Florida; an additional twenty exotics considered most likely to pose a serious threat to our natural areas; literature describing the introduction and spread of these species in tropical and subtropical areas similar to Florida; and the experience of managers and scientists within EPPC.

• The Publications Committee has also prepared a complete *list of the exotic pest plants found throughout Florida,* and ranked them by their threat to natural areas and their overall level of invasion in native communities. The manual and list will be published by the South Florida Water Management District in 1992.

• *Everglades National Park.* In 1985, EPPC developed a plan to establish a "buffer zone" to protect Everglades National Park from invasion by *Melaleuca quinquenervia* and

other exotic pest plants now present east of the park in the area known as the East Everglades. This plan, and the relationships developed within EPPC, have recently resulted in joint funding by the State of Florida, the Dade County Department of Environmental Resource Management, and Everglades National Park of a project to control exotic plants in the East Everglades. Thus far, the project has resulted in the treatment of all *Melaleuca* found within a three-mile (4.8-km) strip east of the park, and treatment of all *Casuarina* species found within a one-mile (1.6-km) strip east of the park. Many of these areas have been re-treated for resprouts and seedlings that have appeared in the years since the initial treatment. Funding for the project has already totaled approximately $500,000, and funding commitments for the fiscal years 1991, 1992, and 1993 total an additional $1,152,000.

• In 1988, EPPC collaborated with Everglades National Park, Dade County Department of Environmental Resource Management, Florida Department of Community Affairs, Florida Department of Environmental Regulation, and U.S. Army Corps of Engineers to create a mitigation study site in former agricultural lands within the park, known as the Hole-in-the-Donut. Through the lines of communication formed by EPPC, the members of EPPC working with mitigation issues were able to develop the foundation for approval and implementation of this project. The project involved removal of disturbed farming substrate on a 60-acre study site, and two years of follow-up monitoring of the site. The cost of the test ($650,000) was borne completely by mitigation funds and the process has proved to be very successful. As a result of these lines of communication provided by EPPC, the test was completed and now the park is working with the same agencies to extend the project to the entire 4,000 acres within the Donut. The total cost is being funded through a county mitigation initiative and is expected to provide over $100 million during the next ten to fifteen years of project implementation.

In summary, the EPPC's responses to some especially severe exotic pest plant problems provides a forum for restorationists struggling with alien species—and a model for interagency cooperation.

(Further information about EPPC activities and membership may be obtained by writing to: The Exotic Pest Plant Council; Attn: Mike Bodle, Secretary; South Florida Water Management District; 3301 Gun Club Road; P.O. Box 24680; West Palm Beach, Florida 33416, or by telephoning (407) 689-6132.)

Preventing Establishment of New Alien Species in Haleakala National Park and the Island of Maui, Hawaii

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The future of Haleakala National Park and other protected natural areas as reservoirs of native biological diversity in the Hawaiian Islands may depend more than anything else on the success of efforts to stop new alien plant and animal species from becoming established. Flora and fauna of oceanic islands in general and the Hawaiian Islands in particular are well-known to be highly susceptible to displacement by invasions of non-native species (Elton 1958; Williamson 1981; Brockie *et al.* 1988; Diamond 1989), and much damage has already been done (Cuddihy and Stone 1990). Alien species could ultimately overwhelm Haleakala National Park. Many species causing serious problems are already established (Smith 1985, Stone and Loope 1987, Loope *et al.* in press). There are clearly many aggressive alien plant and animal species not yet present or established on Maui which can exploit and modify habitats not threatened by any alien species already established. Unless combatted with ingenuity and commitment, the insidious threat of alien species can be expected to proliferate and inundate all but the most resistant native ecosystems of Haleakala National Park and the larger

conservation unit (with an adjacent State Natural Area Reserve, State Forest Reserves, and a Nature Conservancy Preserve) of which it forms the core.

The U.S. National Park Service has led the way in Hawaii in the 1970s at Hawaii Volcanoes National Park and in the 1980s at both Haleakala and Hawaii Volcanoes in dealing with those alien threats already present, demonstrating that native Hawaiian biota, previously written off as hopelessly lost, can be protected through active management (e.g., Stone and Loope 1987). Although current efforts are less than adequate, recent interagency efforts are in place to more adequately address the problems (Hawaii Department of Land and Natural Resources *et al.* 1991). The primary threats to Hawaii's natural areas can be categorized as (1) threats from alien species already present; (2) threats from new alien species yet to be introduced; and (3) disruptions caused by global climate change which may tip the balance further in favor of alien species.

Diamond (1989) included the impact of introduced species among his "evil quartet" of primary causes of recent extinctions and further predicted that "it may well be that the worst is yet to come." In view of the difficulty and expense of controlling invasive species once they are permanently established, efforts to prevent establishment of new introductions may be highly cost-effective. Haleakala National Park (111 km^2 in area), an international Biosphere Reserve, while located on an 1864-km^2 oceanic island, is not in itself an island. The park's survival as a viable conservation unit depends on implementation of Biosphere Reserve-like regional management. Maui, as well as other Hawaiian islands, needs to develop and refine interagency cooperation to avoid the absurd, but probably common, situation in which aggressive species become established because no agency feels that it has the mandate or responsibility to stop them.

LARGE-SCALE AND GRASSROOTS EFFORTS TO DEAL WITH THE ALIEN SPECIES PROBLEM

Efforts are in progress at the national level (by the Office of Technology Assessment) and in Hawaii (led by The Nature Conservancy and Natural Resources Defense Council) to identify gaps in the legal and quarantine systems within Hawaii and to work at top governmental levels to close the gaps. The inherent complexity of perfecting quarantine systems to stop innumerable potential invaders coming in through diverse routes is compounded by the large number of agencies having responsibilities in this field. A meeting to address the issue, called by The Nature Conservancy and the Natural Resources Defense Council in October 1991, was attended by the following agencies and organizations: Hawaii Department of Agriculture (HDOA), Plant Quarantine Branch; HDOA, Plant Pest Control Branch; HDOA Animal Industry Division, Inspection and Quarantine Branch; the Hawaii Department of Land and Natural Resources (HDLNR), Division of Forestry and Wildlife; HDLNR, Division of Aquatic Resources; the Hawaii Department of Health, Environmental Services Division, Vector Control Branch; the U.S. Customs Service; the U.S. Army, Pacific Command; the U.S. Postal Service; the U..S Forest Service; the U.S. Fish and Wildlife Service, Enforcement Division; the U.S. National Park Service; the U.S. Department of Agriculture Animal and Plant Health Inspection Service (APHIS); and the Hawaii Sugar Planters Association. The need for coordination and cooperation among such a diverse array of players is obvious.

At Haleakala National Park, we have from necessity initiated a grassroots effort, fully complementary to, but not duplicative of, federal and state-wide efforts. State and federal interagency cooperation within Hawaii is currently at an all-time high. What is already clear is that no program will succeed without grassroots understanding and support. Experience gained by Haleakala National Park during emergency efforts to stop establishment of rabbits and several plant species suggests that the public is receptive to a campaign to really do something to stop the proliferation of alien species.

Rapid growth of the local population on Maui and ever-increasing commerce between Maui and other islands and continents are causing accelerated introduction of potential invaders. Between one and two dozen new species get established in the Hawaiian Islands every year (The Nature Conservancy of Hawaii and the Natural Resources Defense Council 1991). Fortunately, not all of them will adversely affect surviving native biota and relatively few will threaten the pristine, high-elevation native ecosystems. Which ones will adversely affect Haleakala National Park? The best source of information about potential invaders potentially comes from other areas where these species have proved to be invasive. IUCN has a project based in England nearing completion which aims at cataloguing invasive species on the islands of the world. Even before that study becomes available, we are able to make reasonable predictions of the likely invasiveness of species based simply on information on their invasiveness in other areas with comparable habitat.

PAST INADEQUATE RESPONSE: THE EXAMPLE OF BANANA POKA

There is an abundance of examples in Hawaii of how devastatingly aggressive alien species became established through regrettable neglect. One example on Maui is that of the banana poka vine *(Passiflora mollissima).* The species was introduced to the Hawaiian Islands as an ornamental in the early 1900s. It is uncommon in its native habitat in the Andes where it is attacked by numerous species of coevolved insects. Lacking natural herbivores in Hawaii, it has become established in over 500 km^2 of native forest on the islands of Hawaii and Kauai. In some areas, it has become so dense that the vines drape from tree to tree, smothering large tracts of native forest. It occupies elevations of 610–1,525 m and thrives where mean annual precipitation is between 500 and 5,000 mm. Feral pigs are its primary dispersal agent, but alien birds spread it as well. Widely recognized as one of the worst weeds in Hawaii, it is now the focus of a cooperative effort by federal and state agencies to screen organisms from *P. mollissima's* native habitat in South America for introduction as biocontrol agents to Hawaii (Markin *et al.* in press). The cost of this biocontrol project is already around $500,000 with no visible results for actually reducing the invasiveness of the weed. However, several promising organisms have been tested and released, so that there is still optimism that the program will eventually prove effective. Haleakala National Park fully supports the biocontrol efforts against banana poka since this species is a tremendous threat to park ecosystems in the long run.

Banana poka has been known to be an aggressive weed since the 1960s, and its establishment on Maui could have been readily prevented with a coordinated effort to stop it. In 1971 a group of three mature banana poka plants were reported from a farm lot in Kula, Maui. In the period since then, State Department of Agricul-

ture personnel on Maui have intermittantly been involved in control efforts in that area, but the control effort was low on the priority list since the threat was not perceived as imminent and the threat to agriculture (the primary mandate for the Hawaii noxious weed program) was regarded as negligible. Access to infested private lands was a chronic problem. The problem was considered manageable until November 1984 when State Forestry crews combatting a persistent fire in the Kula Forest Reserve noted the unsuspected spread of this weedy vine throughout several hundred hectares of dense black wattle *(Acacia mearnsii,* alien) forest in upper Kula (1,070–1,220 m elevation). Prospects for control of this infestation are complicated by its occurrence on private lands. A well-organized education and eradication campaign was mounted, however, by Lorna Harrison of Makawao, Maui, beginning in 1988. This effort led directly to funding ($60,000) by the State Legislature for banana poka mechanical control on Maui through the Hawaii Department of Land and Natural Resources in 1989-90, and hopes were high that success could be achieved. However, that amount proved inadequate to do the job and no additional funding has been allotted. The only hope now seems to be biocontrol; two moth species were released on Maui for this purpose in early 1991. The plant poses a threat to Haleakala's Kipahulu Valley koa *(Acacia koa)* forests as well as many other natural areas on Maui.

CASE STUDIES OF RECENT EFFORTS BY THE USNPS TO STOP ALIEN SPECIES ON MAUI

Many other examples of alien species establishment on Maui are horror stories in the making. Haleakala National Park, through cooperative efforts between its Research and Resource Management divisions, has been integrally involved in trying to prevent such invasions from materializing over the past few years. Some of these stories are detailed below.

European rabbit ***(Oryctolagus cuniculus)*** Rabbits have been liberated on at least 700 islands throughout the world, and devastation resulting from their establishment has been well-documented in several areas (Atkinson 1989). Although the Hawaiian Islands are well-known to be highly vulnerable to biological invasions, the domestic European rabbit *(Oryctolagus cuniculus)* had come to be disregarded as a potential invader after more than a century without invasion on a major island. Haleakala National Park initiated rabbit removal and monitoring in July 1990 following discovery of a reproducing rabbit population covering 25 ha in high-elevation (2,075–2,135 m) native shrubland. Because of the threat of feral rabbits to native biota, rabbit eradication was placed as the highest park priority. The population is believed to have originated from as few as six unwanted cage-reared rabbits released by a pet owner in October 1989. A total of 93 rabbits were removed from the 25-ha area of the infestation during August 1990–March 1991, through snaring, shooting, and trapping. Four more rabbits were removed upslope (elevation 2,135–2,440 m), at distances of 0.6-2.4 km from the main area of infestation, the last one on May 6, 1991. Monitoring of transects (assessment of rabbit pellet presence or absence, age, and abundance), combined with scouting and follow-up of reports of rabbit sightings by visitors and other park employees, concurrently with control, allowed accurate assessment of numbers and location of remaining rabbits.

The park is still faced with the likelihood that release or escape of pet rabbits will pose a recurring problem. A snowfall on January 15, 1992, brought large numbers of local people to the park. One car brought

a pet rabbit which was running loose for a short time at park headquarters until park rangers intervened. We recently learned that during the summer of 1991, a landowner in Kahakuloa, West Maui, became concerned about a rabbit population on the edge of his land, because he was afraid that his horses would break their legs in the holes ("tunnels") the rabbits were digging. His dogs were killing the baby rabbits, but the adults could escape because of cliffs. The landowner told me that he shot about fifteen rabbits over a period of a few weeks until the population was eradicated.

It is clear that free-running dogs have served as a major factor preventing rabbit establishment up to now. There are many localities in Hawaii without free-running dogs or other significant predation pressure on adult rabbits, however. For example, a single male rabbit survived for about three years just adjacent to the Haleakala Highway at elevation 5500 ft in lands belonging to Haleakala Ranch. In our opinion, rabbit establishment on one or more of the Hawaiian Islands is just a time bomb waiting to go off.

It seems that new state legislation is needed to strengthen the law regulating rabbits and a clear mandate and responsibility needs to be given to some agency to prevent rabbits from becoming established in the Hawaiian Islands. As far as Haleakala National Park is concerned, we are just trying to maintain awareness of the problem and document any new cases of incipient rabbit establishment.

Miconia calvescens *Miconia calvescens,* "the plague of French Polynesia," is a tree, up to 18 m tall, whose large, dark-green leaves have maroon undersides. It is native from southern Mexico south to northern Argentina and Chile, where it grows at elevations of 300–1830 m and is apparently an understory species and an invader of small light gaps. A former Harvard University physics professor, Harrison Smith, introduced *M. calvescens* to a garden at Papeari, in the south of Tahiti, in 1937. In the same year, it was also planted on the Plateau of Taravao. During the decades following the introduction of *Miconia* to Tahiti, *M. calvescens* spread but was not recognized as a problem. The first published record of its apparent invasiveness was in 1976 (Birnbaum 1991). (However, F.R. Fosberg (pers. comm. 1991) of the Smithsonian Institution saw it on the Taravao Plateau in 1971 and concluded that "this is a plant that could destroy Hawaiian forests.") Interpretation of aerial photographs from 1978 found that *Miconia* in the forest canopy was mappable only in an area of 100–200 ha on the Taravao Plateau. However, by 1989 *Miconia* dominated the canopy over a large part of the island and was present over 75% of the island (Birnbaum 1991).

Miconia apparently attained canopy dominance over such a wide expanse of Tahiti following severe forest disturbance by two hurricanes in March and April of 1983. The two hurricanes devastated Tahiti's native forests by breaking the tops of trees and detonated a demographic explosion of *Miconia.* Birds had spread seedlings of the species widely, and with the opening of the forest canopy, *Miconia* seedlings grew more quickly than anything else to reach the canopy.

Because of its perceived attractiveness as an ornamental, *M. calvescens* was introduced in the 1970s through the horticultural industry to at least three Hawaiian islands–Hawaii, Oahu, and Maui. Whereas it is said to show little evidence of invasive tendencies on Oahu, it may be locally beyond control in the vicinity of Hilo on Hawaii. The situation on Maui is such that control appears feasible if prompt and concerted action is taken. Tiny, bird-dispersed seeds

are produced after about 4-5 years of vegetative growth; each tree has the capacity to produce tens of thousands of seeds annually. It thrives best in partial shade and can establish seedlings in moderately dense shade.

Haleakala National Park learned about the threat of *Miconia* when one of the park's employees (Betsy Gagne, who was in Tahiti in 1988, and thus attuned to the threat from this plant) noticed a single tree growing in a botanical garden near Hana, on the northeast coast of Maui. Following an inquiry to the owner of the botanical garden (Alii Gardens) in January 1991, our knowledge of its status on Maui has advanced rapidly. It probably first arrived on Maui with a horticultural shipment to Helani Gardens, near Hana, in the late 1970s. Founding individuals have grown to nearly a foot in diameter and over 10 m tall and produced abundant seedlings locally.

M. calvescens appears to merit special concern on East Maui since few other plant species are highly invasive in forest situations above 1200 m elevation. Haleakala National Park is concerned that *Miconia* will not only alter landscapes in coastal areas, but will quickly spread to upland areas and disrupt natural plant succession in otherwise pristine native forests in such locations as the Park's Kipahulu Valley, State Forest Reserves, and The Nature Conservancy's Waikamoi Preserve. It can become established in such dense stands that it can change the landscape and cause massive loss of biological diversity.

It is becoming increasingly obvious that there is no effective mechanism operating in Hawaii to keep aggressive alien species such as *M. calvescens* from being brought in. Our approach has been to attempt, at least on a small scale, to publicize this problem, as we have done with rabbits, and to raise community consciousness and concern.

Beginning in April 1991 we distributed home-made "wanted" posters illustrating *Miconia* around windward East Maui and now feel that we have a fairly good knowledge of the extent of this plant, although there are undoubtedly populations that we don't know about, since it is clear that plants have been distributed from Helani Gardens. We now know of eight populations.

Publicity in local newspapers assisted in informing the public and giving credibility to our efforts. Following a presentation in an alien-species symposium at the XVII Pacific Science Congress in May 1991, a front-page story appeared in the *Honolulu Star-Bulletin.* A concerned legislator wrote a letter to the governor complaining that although *M. calvescens* had been known as an aggressive weed for years as a result of contacts with botanists from Tahiti, the plant has still not been declared a noxious weed and is brought into the state legally. By December 1991, the Conservation Council of Hawaii, in collaboration with the Hawaii Department of Land and Natural Resources and other organizations, had printed up thousands of "wanted" posters warning of the threat to native ecosystems from *Miconia.* Still, no revision of the state noxious weed list was forthcoming, but this was promised for the coming months.

In June 1991, the park began an exploratory effort to obtain permission from landowners to eradicate *M. calvescens* from Maui. All landowners contacted to date have been highly cooperative. A major preliminary effort to eradicate *Miconia* from Maui was undertaken in Helani Gardens during four days in June and July by Haleakala National Park staff and volunteers. Helani Gardens owner Howard Cooper gave full support to the effort, and Keola Hana Maui Company gave

permission to remove *Miconia* plants on their land adjacent to Helani. A total of 9,200 *Miconia* plants were removed in the following size classes: 0-5 cm diameter–97.5%; 5-10 cm diameter–1.8%; 10-20 cm diameter–0.4%; > 20 cm diameter–0.3%. It is estimated that 95% of the *Miconia* plants in the garden (and more than 50% of the plants on Maui) were removed. Follow-up has since been implemented, with a volunteer assigned two days a week to *Miconia* during December 1991–April 1992. One negative finding is that the seed bank lasts for at least one year and probably for at least several years. Periodic follow-up for an unknown length of time will be necessary to remove seedlings from the seed bank.

Pampas grass *(Cortaderia jubata)* Two very similar South American species of pampas grass, *Cortaderia selloana* (Schult.) Asch. & Graebn. and *Cortaderia jubata* (Lem.) Stapf, have been widely planted as ornamentals, although until now only the former *(C. selloana)* has been recognized in botanical literature as occurring in Hawaii. The latter *(C. jubata)* has proved to be an aggressive weed in California and elsewhere, and would clearly be an undesirable introduction to the Hawaiian Islands. We have recently become aware that there are at least two kinds of pampas grass present in upcountry Maui and that one of them is escaping from cultivation. It turns out that there are two species–*C. selloana* and *C. jubata,* based on confirmation by Paul Peterson of the U.S. National Herbarium in Washington, D.C. (Loope and Medeiros 1991). Both species are perennial bunch grasses with coarse saw-edged leaves well over 1.5 m in length and silvery, plume-like inflorescences on stalks 2 m or more in length.

Beginning in 1987-88, seedlings of pampas grass, easily recognized by their large size and sharp-edged leaves, became apparent along Haleakala Highway at 1,220–1,839 m elevation. In October 1989, for the first time several of these plants developed flowering stalks, which were removed. In late October 1989, a large individual of *Cortaderia* with flowering stalks over 3 m tall was sighted from a helicopter by park personnel just inside the park boundary at 2,010 m elevation on the wall of Haleakala crater in Koolau Gap. Flowering stalks were destroyed by park personnel in 1989. In July 1990, just prior to flowering, the entire plant was destroyed. The plant appeared large enough to have flowered in at least one year before 1989. In early 1991, seven seedlings were found and destroyed in the area.

Based on literature on the species in California, *C. jubata* is most likely to thrive in Hawaii in mesic, middle-elevation sites not occupied by closed vegetation. As of yet, the ability of *C. jubata* to withstand hard freezes commonly encountered during winter months above 2,000 m on East Maui remains unknown. If it can tolerate the diurnally frozen soil and harsh climate in Haleakala Crater, it could become a major invader of that area.

In January 1991, we began contacting landowners and eliminating seed sources of *C. jubata.*

Mullein *(Verbascum thapsus)* Mullein is a highly invasive weed on the Big Island of Hawaii; it grows all over Mauna Kea, up to 3,350 m elevation, in habitat very similar to that occupied by Haleakala silversword (Juvik and Juvik in press). Few other plants are known which can invade Haleakala silversword habitat. Haleakala National Park personnel found and destroyed two mullein plants growing on park roadsides in 1986 and continue to be on the alert for additional plants.

In July 1990 Haleakala National Park researcher Art Medeiros was purchasing herbs at Maui Gar-

den and Hardware in the town of Pukalani, about 20 km from the park, when he noticed mullein plants for sale. After the supplier (a small nursery named Haleakala Herbs) was tracked down, a front-page story appeared (with the endorsement of the nursery owner) in *The Maui News* publicizing the potential damage this plant could do to the national park and asking that mullein purchasers destroy their plants. The article was widely noted and may have been effective in encouraging people to destroy any mullein plants. However, a year later when park superintendent Don Reeser purchased a house in Olinda, a mullein plant was still growing in the yard. The seller apologized to Reeser, admitting that she had seen the article, but she "just didn't have the heart" to destroy her mullein plant. (She did nothing illegal; mullein is not on any prohibited list.)

Australian tree fern *(Cyathea cooperi)* *Cyathea* tree ferns have been in cultivation in the Hawaiian Islands at least since the 1960s as ornamentals at homes and botanical gardens. The widely cultivated species, *Cyathea cooperi,* is native to Queensland and New South Wales in eastern Australia. It is widely planted in Hawaii since it is a hardy, attractive species and is faster-growing than native Hawaiian tree ferns *(Cibotium* spp.).

It has been recently discovered that populations of *C. cooperi* are invasive in ohia *(Metrosideros polymorpha)* and koa *(Acacia koa)* rain forests in Kipahulu Valley of Haleakala National Park (Medeiros *et al.* in press). There are four known populations comprising over 1,000 individuals at 610–1,040 m elevation. Even in nursery and houselot situations, *C. cooperi* has a tendency to escape, often becoming established several hundred meters from the parent populations, especially in wet areas. This species is planted and locally naturalized at several tropical botanical nurseries near Hana, approximately 12 km from the Kipahulu Valley populations. The species is also escaping from cultivation on Kauai.

The greatest threat that *C. cooperi* poses to Hawaiian forests is its displacement of native species where the fern has achieved high densities and local dominance of communities. Unlike native *Cibotium* tree ferns, *Cyathea* does not support the dense colonies of epiphytic native species that often colonize the trunks of tree ferns (Medeiros *et al.* submitted). Where *Cyathea* forms dense stands in Kipahulu, the understory is conspicuously open and lacking many characteristic native species normally found there. This is apparently due to exclusion of other species by the thick layering of fibrous roots that forms at the soil surface surrounding a growing tree fern. On large tree ferns of this species, this dense layer of near-surface roots may extend out over a diameter of 10-15 feet, effectively excluding most other vegetation (Medeiros *et al.* in press).

Within Haleakala National Park, an attempt is being made to control this alien species before it becomes too extensively established. The known populations of *C. cooperi* are being removed, cutting the taller ferns with chainsaws and removing the growing tips. Investigation of the current stand structure and monitoring of fixed relocatable plots in the areas where *C. cooperi* is removed will allow evaluation of the feasibility of long-term control. Reconnaissance in Kipahulu Valley and surrounding forest areas will be conducted to attempt to locate additional populations of *C. cooperi,* both within and outside Haleakala National Park.

The relationship of this "wild" population of *C. cooperi* to cultivated plants on Maui remains unclear. This aspect urgently needs

investigation, as a possible prelude to efforts at stopping its continued cultivation. Bezona (1991) has recently published an article promoting the cultivation of *C. cooperi* as a substitute for the common practice of removal of native *Cibotium* tree ferns from wildland forests. Several nurseries on the island of Hawaii are already devoted primarily to growing *C. cooperi.* Although our recommendation (Medeiros *et al.* in press) is that "*Cyathea cooperi* be designated a noxious weed by the Hawaii Department of Agriculture and its horticultural trade be discontinued," we realize that this issue is a complex one that will not be easily solved.

Fountain grass *(Pennisetum setaceum)* This large bunchgrass from northern Africa has spread aggressively throughout leeward Hawaii Island during the past two decades, becoming uncontrollable in part of Hawaii Volcanoes National Park. Fountain grass creates an exceptionally large standing fuel source and promotes the spread of fires more than any other grass yet introduced to the Hawaiian Islands (with the possible exception of *Melinis minutiflora*). Fountain grass is present on Maui only in a small area of the sand hills of southeastern Wailuku. However, it poses a serious threat to rangelands of southern East Maui with young volcanic substrate as well as to the relatively intact ecosystems of upper Haleakala. Based on its occurrence as high as 2,740 m on Mauna Kea (J. Jacobi, pers. comm.), it must be regarded as a potential invader of most of Haleakala Crater. Indeed, it is one of the invasive plant species which the park must fear most.

Persistent control efforts by the Maui weed control office of the Hawaii Department of Agriculture (HDOA) since about 1976 have confined Maui's fountain grass population to a single site near a former dump, a favorable habitat on sandy soil. In May 1986, when Haleakala National Park personnel first visited the site with the HDOA, it was pointed out that populations are controlled by hand pulling of seedlings and mature plants at 1-2 month intervals, with bagging of seeding inflorescences for disposal at a nearby landfill. An average of about 2,000 plants per year were removed in 1983-85. In 1986, population numbers were low and apparently decreasing due to a declining seed bank after several years of concerted effort at control of young plants before seed was set.

In early 1991, Richard Mack from Washington State University, who is studying fountain grass at Hawaii Volcanoes National Park and elsewhere on the Big Island, wanted to sample from the Maui population. I assured Mack that it would likely be impossible to obtain seeds of fountain grass from Maui because of an effective control program. However, when we visited the site in March 1991, Mack was able to obtain abundant seed and the population seemed to be spreading in one direction. Most of the area occupied by fountain grass burned on June 30, 1991. Fountain grass is known to thrive following fire, mobilizing released nutrients, producing abundant seed, and undergoing rapid growth in the years immediately following fire. It was clear by July that the HDOA had done no control during the past year, and was apparently putting fountain grass on the back burner since it seemed contained. In a conversation with the Maui coordinator of the noxious weed control program for HDOA, it was confirmed that fountain grass was regarded as virtually controlled and not a high priority for further effort.

In view of the importance of keeping fountain grass out of Haleakala National Park, what action should be taken? Rather than creating a major political issue, my response was to visit the site periodi-

cally, removing whatever plants I could find about once a month. After removing 135 plants, I am unable to find additional plants, but will return periodically to check for germinants from the seed bank. There is apparently another population which must be checked also.

CONCLUSIONS: COALITION BUILDING IN PREVENTING ALIEN SPECIES ESTABLISHMENT

The above case studies provide concrete examples of the types of problems with incipient alien species establishment which we have encountered at Haleakala National Park. The importance of building coalitions at all levels should be clear. The USNPS can not act legally on its own outside of its area of exclusive jurisdiction and lacks the resources to do so extensively even if it possessed the legal authority. Long-term success in such endeavors will depend on creation of an enlightened public through education, and cooperation with any agency willing to help. Significant facets of a developing coalition to this point in time are enumerated below:

• We have provided input at several points toward a study underway (1991-92) by the congressional Office of Technology Assessment on U.S. policy toward exotic species. Results of this study may provide major impetus toward federal action to tighten the system for quarantine and control in Hawaii and elsewhere.

• A study by The Nature Conservancy of Hawaii and the Natural Resources Defense Council addresses remedies for problems with alien pest invasion in Hawaii. Results of this study may provide major impetus toward federal and state action to tighten the system for quarantine and control within Hawaii.

• An educational effort by the National Audubon Society (Alien Species Awareness Program) is reaching Hawaii citizens through various media.

• The Hawaii Department of Agriculture is in the process of soliciting public and agency review of a revised noxious weed proposal.

• An East Maui Watershed Cooperation was recently formed. An agreement was signed in November 1991 by major landowners on windward East Maui—Hawaii Department of Land and Natural Resources, Haleakala National Park, The Nature Conservancy of Hawaii, East Maui Irrigation Company, Haleakala Ranch Company, and Keola Hana Maui Company. The purpose is to work together to maintain the quality of the East Maui watershed and to preserve its biological diversity, through cooperative efforts and feral ungulate and weed control.

• A "Melastome Committee" was initiated in August 1991 by the local Soil Conservation Service and Maui Land and Pineapple Company. This committee has the goal of working through political channels to ban further importation of any plant in the Melastomataceae and to control existing problem species (especially *Miconia calvescens, Clidemia hirta,* and *Tibouchina herbacea).*

• The park program has had major interaction with local newspapers, almost entirely positive. This has been our major means of public education to date.

• Our program has had day-to-day interaction with employees of other local land management agencies.

• We have had interaction with the nursery industry through articles in *Hawaii Landscape Industry News* (Loope 1991, Loope and Medeiros 1991) and through informational letters and personal contacts.

• We have had interaction with the pet industry and the humane society through personal contacts.

• We have interacted with the Maui County Council through our testimony in opposition to internationalization of Maui's airport because of park concerns over alien species introduction.

• We have negotiated with the U.S. Air Force over safeguards needed (including surveillance for alien species) in the installation at Haleakala volcano's summit (outside the park) of the world's tenth largest telescope.

• We are involved in an interagency survey of the status of Maui forest birds and their habitat. This will result in a comprehensive survey of alien plant distribution on East Maui.

• We have made use of volunteers from Sierra Club and The Nature Conservancy in alien plant control.

• We have kept in touch with local legislators. Local state representative David Morihara visited the park during the height of our rabbit invasion and attended the first meeting of the Hawaii Environmental Education Association at which we presented posters on rabbits and *Miconia.*

• This work has involved close cooperation among the Superintendent and the Research and Resource Management divisions of Haleakala National Park. The Interpretation division has helped educate the public and has provided numerous "leads" on alien species through conversations with visitors. The Visitor Protection division called the rabbit problem to our attention and assisted with emergency control efforts. The Maintenance division provided crucial information which helped lead to snaring the last rabbit.

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Humane Natural Area Management in Hawai`i

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Animal welfare and animals rights have long been human concerns. Animal *welfare* relates to the care of animals, often in laboratory situations, in terms of adequate food, water, space, etc., for the species of interest; prevention of "suffering" is an important goal. Animal *rights* more often address the status of the animal *vis á vis* human interests and demands. Anthropocentric interests are often judged *no more* important than the rights of non-humans to existence by animal rightists, who avoid and sometimes criticize consumption of meat, wearing of fur coats, sport hunting and fishing, and so forth. Not all animal rights advocates believe *all* non-human life is of equal value with human life.

Most people would probably agree that the life force is to be respected, but that *some* non-human lives are more valuable than others. Killing a disease organism doesn't seem nearly as serious as killing a bald eagle. Society seems to support this idea by actively encouraging disease cures and penalizing heavily those who do kill endangered species. That a range of choices exists whenever humans and other species conflict, is axiomatic. The problem is making reasonable choices in different situations and trying to justify choices to a wide variety of individuals. The cumulative effects of choices on societal values must also be considered. Piecemeal fragmentation of natural areas through approval of one individual development project

after another over time is an example of this. Eventually the pieces may be so small as to have little or no value as natural areas.

In Hawai`i, as elsewhere, ignorance, apathy, and greed have resulted in the loss of tremendous numbers of native species found nowhere else, and in loss or degradation of most of the "natural areas" in the state. A large part of what is left is threatened by introduced, or *alien*, species, many of them feral barnyard animals found around the world. From the standpoint of human responsibility or concern for non-human species, arguments for favoring native *species* over introduced species when conflicts arise in natural areas are: (1) more options for future human use are preserved; (2) native species are unique, aliens are not; (3) more people "use" native species than aliens over time; (4) benefits from tourism to see unique species should eventually exceed those derived from consumptive use of game species; (5) consumptive use of introduced species can be accomplished in areas of Hawai`i that are not designated for natural area production; (6) extinction of native species is unacceptable when caused by human actions or inactions.

From the standpoint of saving *individual* non-human lives in natural areas, it can be argued that native species are more important than those of introduced species because removal of proportionately *few* individuals of a *few* alien species allows *many* individuals of *numerous* native species to flourish (birds, invertebrates, and plants, especially) over time in natural areas. The lives lost by alien species are few in comparison, especially if aliens are eliminated from an area or continually managed for very low numbers. Society apparently values the lives of birds, invertebrates, and plants more highly than in the past, with increasing concerns about biodiversity, ecological problems, and so forth. The lives of non-human mammals are no longer the only lives of concern.

If one accepts the general argument that some non-human lives are more important than others, and the particular arguments that mammals are no more important than birds, invertebrates, and at least some plants, and that aliens *in natural areas* are less important than natives, the next question relates to *humane* removal of aliens where conflicts between alien and native exist. In addressing the question of humane removal, one might first ask the awkward question, "How would *you* like to die?" Americans don't like to think about this sort of thing, but if the question of "humaneness" is raised, the question is unavoidable because, to most people, to be humane seems to mean to treat as humans wish to be treated. Choices of death could include strangulation, asphyxiation, internal bleeding, exposure, poisons that affect the nervous system, poisons that stop cell oxygen exchange, electrocution, and shock. To more fully answer the question, you might want to know, "Which is the most painful?" And "Which is the quickest?" Humans can and do have different ideas and feelings about the easiest death, as seen in their choices of suicide methods and in experiences they relate about near-death events.

But the question of humane death becomes more complicated when applied to non-humans because they cannot tell us either their preferences nor their experiences as they die. What should humans measure for non-humans to provide an index to pain, suffering, and, by inference, humaneness? Stress hormones, nervousness, tremors, perceived discomfort, gasping responses, contorted features, and other measures have been proposed. Brain scans would perhaps be most conclusive, but this is difficult in non-laboratory situations, and we

know surprisingly little about pain even under controlled conditions. Again, judgments of humans about these indicators are various, and a general definition of humaneness is difficult. An animal that goes into shock or becomes lethargic or extremely weak from loss of blood, exposure, or heat stress over time may actually feel much less pain than an animal that is shot, stabbed, electrocuted, clubbed, or poisoned. Suffering is also probably a function of how treatments are *applied* to and *received* by the animal.

Unfortunately, distaste to humans is not really a workable criterion of humaneness, particularly when many humans expressing distaste have neither killed nor witnessed the deaths of wild animals. Although human emotions are very much a part of the issue, secondhand emotions can be misleading. In contrast, people who have to kill animals can become hardened to the task to a varying degree. Some animal welfare and animal rights people would say that *anything* causing "apparent discomfort" or even "boredom" in animals is inhumane. But this seems akin to stating that anything that causes cancer should be banned from use when nearly everything is a carcinogen. The problems in question cannot be realistically addressed by all-or-nothing statements. Other values are at stake. In Hawai`i, few would abandon the protection of natural areas from invading animals by applying a discomfort criterion to animal control methods.

What of native animals that suffer introduced diseases, parasitism, competition, and predation of introduced species? Obviously, ethical considerations of immediate *humaneness* are not involved here, but, ultimately, humans have caused the problem. Ethical considerations of human-caused *extinction*–another kind of human ethical responsibility–are also involved. Which is the more important responsibility? Many would say that allowing the extinction of populations, subspecies, species, genera, and even families of plants and animals is a far more serious problem for the human race (let alone for the non-human species affected) than the humane treatment of individual animals. The welfare of groups is often more important than the welfare of individuals. We humans make such difficult decisions about our own species in times of war and in countless other situations that call for protection of society from individual humans.

One reason for reducing extinctions and the homogenization of the animal and plant landscapes around the world is to keep future human options open–economic, æsthetic, humane (to other humans through medicine and crop development), and ecological (various services performed for us by the natural world including cleansing water and air, encouraging soil stability, decomposing wastes). Devaluation of native species and natural areas little affected by humans places an immense faith in technology, probably further exacerbating the problem of environmental degradation. Although human benefits realized from increased technology are many, human mismanagement of technology is of serious concern today: witness global warming, ozone depletion, and other problems. Devaluation of natural areas also results in loss of biological and other baseline data that enable us to clearly evaluate effects of our actions elsewhere.

All life is precious and should be highly valued by natural area managers. However, *choices* must be made in the real world. Future generations will certainly ask whether natural area managers and administrators did all they could to reduce species loss and preserve biodiversity and natural areas, as we now ask that question about past de-

cision-makers. Educating the public about the choices that must be made between alien species and the native life of the land is a vital part of the job. Managers who work hard to preserve native ecosystems with tools that are as "humane" as possible will continue to be considered good conservationists by most knowledgeable persons. Responsible media coverage will get the story straight. The search for more animal control tools and more humane methods to control alien species is important, but this does not necessitate public criticism of tools that now work well to protect natural areas and, by inference, those who are "insensitive" enough to use them in protecting native species. Looking for new tools evidences the desire for improvement. But panaceas are no more likely with new methods of control than with old. And control of aliens in designated natural areas should not be further delayed by research and development in search of one final solution, much less by administrative indecision and political arguments. "Humaneness" will always be a *relative* issue and is not likely to be accomplished to the satisfaction of all. Like abortion, it is one ethical consideration sometimes in conflict with others faced by humans.

Perceptions that hunters or "the public" or animal rights activists will be upset enough about "humane" treatment of introduced species to cause severe problems in management of natural areas should be countered with factual information about the problems of native species losses and alien invasions, the overriding reasons for control programs, and an active *defense* of effective methods used as humanely as possible. Humane treatment of animals cannot be totally decided by emotional reactions in a factual void. The human animal must reason well in the context of real-world conflicts. Concerns about humaneness should be documented by administrators and weighed carefully prior to letting what might be a small minority concerned about a difficult-to-define issue affect the dwindling biological heritage of Hawai`i. Other motives of groups and individuals opposed to responsible control programs in natural areas should also be weighed carefully. Natural area managers should be supported by their organizations in the difficult and important work that they do, especially that involving alien species control. Public criticisms and doubts from within the conservation community are counterproductive unless they are based on fact. *Leadership, encouragement,* and *adequate program support* to accomplish the best possible management for the benefit of Hawai`i's unique biota and ecosystems will enable those involved in fulfilling mandates for designated natural areas to succeed. Hawai`i's future biological diversity depends upon action programs that effectively counter alien species invasions now.

The Effects of Alien Species on Archeology in Hawai`i

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Much has been written about the impacts of alien species on native Hawaiian vegetation (*cf.* Cuddihy and Stone 1990; Smith 1985; Wagner, Herbst, and Sohmer 1990). What has not received as much attention is the impacts of those same alien species on the cultural resources in Hawai`i. To discuss all the alien species that are adversely impacting cultural resources throughout Hawai`i would be a monumental task and is beyond the scope of this paper. Instead this paper will illustrate the problem by discussing a limited number of species and the impacts they are having on the cultural resources in some of the national park areas in Hawai`i.

The species included here are christmasberry *(Schinus terebinthifolius),* lantana *(Lantana camara),* kiawe *(Prosopis pallida),* American or red mangrove *(Rhizophora mangle),* Java plum *(Eugenia cuminii),* koa haole *(Leucaena leucocephala),* and false kamani *(Terminalia catappa).* These species should be well-known to anyone working in the field in Hawai`i, whether they are botanists or archeologists.

Christmasberry *(Schinus terebinthifolius)* was introduced as an ornamental before 1911, but its beauty ends with its red berries. Its seeds are easily bird-borne and in Hawai`i it is now a serious weed in many places. By 1962 it had invaded 42,000 ha (103,740 ac) in Hawai`i. It dominates many abandoned agricultural sites and pasturelands and is an aggressive invader of

most mesic-to-wet lowland environments (Neal 1965:525; Smith 1985:202; Cuddihy and Stone 1990:86; Wagner, Herbst and Sohmer 1990:83, 197). Lantana *(Lantana camara)* was originally brought to Hawai`i for gardens. It was apparently introduced in 1858 and was well-naturalized prior to 1871. It has become an extremely serious weed of the mesic forest, diverse mesic forest, dry shrubland, and other low-elevation, dry, disturbed habitats. It is a thorny shrub that can form impenetrable thickets (Neal 1965:722; Smith 1985:192; Wagner, Herbst, and Sohmer 1990:1320).

Kiawe *(Prosopis pallida)* was first planted in Honolulu in 1828. Although Neal (1965:413) has described kiawe as "the commonest and most valuable tree introduced to Hawaii," few, if any, archeologists would agree with the "most valuable" label. It is a dominant component of the vegetation in low-elevation, dry, disturbed sites. Where there are subterranean water courses in dry areas, dense populations of the tree are found (Smith 1985:200; Wagner, Herbst, and Sohmer 1990:693).

American or red mangrove (*Rhizophora mangle*) was introduced to Hawai`i in 1902. It can dominate coastal marshes and streams and often forms impenetrable thickets excluding all other species. It has significantly altered brackish water ecosystems and fish ponds (Neal 1965:625; Smith 1985:200; Wagner, Herbst, and Sohmer 1990:1099).

Java plum (*Eugenia cuminii)* was cultivated in Hawaii prior to 1871. It has become naturalized in mesic valleys to disturbed mesic forest and forms dense cover, excluding all other species. One area with a heavy infestation is Kalaupapa peninsula (Smith 1985:189; Wagner, Herbst, and Sohmer 1990:975).

Koa haole *(Leucaena leucocephala)* was introduced before 1837 and is one of the most widespread alien shrubs or small trees in the arid lowlands. It often forms dense thickets, excluding all other plants. It grows in dry-to-mesic habitats up to 700 m (2300 ft) in elevation and was deliberately broadcast over lowland habitats in the middle of this century (Neal 1965:411; Smith 1985:193; Cuddihy and Stone 1990:85).

False kamani *(Terminalia catappa)* was cultivated in Hawai`i prior to 1871 and thrives near sandy shores. It is confined to mesic and wet coastal habitats and shades out all other species (Neal 1965:627; Smith 1985:203; Wagner, Herbst, and Sohmer 1990:548).

Locating, identifying, studying and managing the archeological resources in the national park units in Hawaii presents us with many interesting challenges. The challenge that has received the most attention is that of lava flows inundating areas where archeological resources are present (Ladefoged, Somers, and Lane-Hamasaki 1987; Carter and Somers 1990; Masse, Carter, and Somers 1991; Somers 1991). The effects of other natural phenomena, such as earthquakes and tsunamis, have also been discussed (Somers 1991). This paper provides a welcome forum to discuss one of the other great challenges, i.e., alien plants.

Alien plants affect archeological resources by: (1) making it difficult to find and record the resources; (2) causing damage to stone structures; and (3) making it difficult to understand what the vegetation was like before historic introductions became established. This paper will address these issues one at a time.

Obviously, before we can manage the archeological resources in the parks we must know where and what the resources are. Just finding and recording the archeological resources can be a major chal-

lenge because of the alien plants that have overgrown portions of the parks. The worst alien plants in this regard are christmasberry, lantana, kiawe, and koa haole. Anyone doing much archeology in Hawai`i will rapidly come to hate these plants, especially christmasberry.

A park that illustrates this point especially well is Kalaupapa National Historical Park on the island of Moloka`i. From October 1983 to May 1984 the U.S. National Park Service undertook an intensive archeological survey of 142 ha (350 ac) of the park along a corridor from Waihanau Valley to and through Kalaupapa Settlement (Figure 1) (Somers 1985). The purpose of the survey was to locate, identify, and record archeological sites so that a waterline could be routed within the corridor in such a way so as to affect the fewest number of sites. The predominant vegetation within that portion of the peninsula consists of christmasberry, lantana, and koa haole. Smith's (1985:192, 202) descriptions of christmasberry as an aggressive invader, of lantana's capability of forming impenetrable thickets, and of koa haole's ability to form dense thickets apply to Kalaupapa exceptionally well.

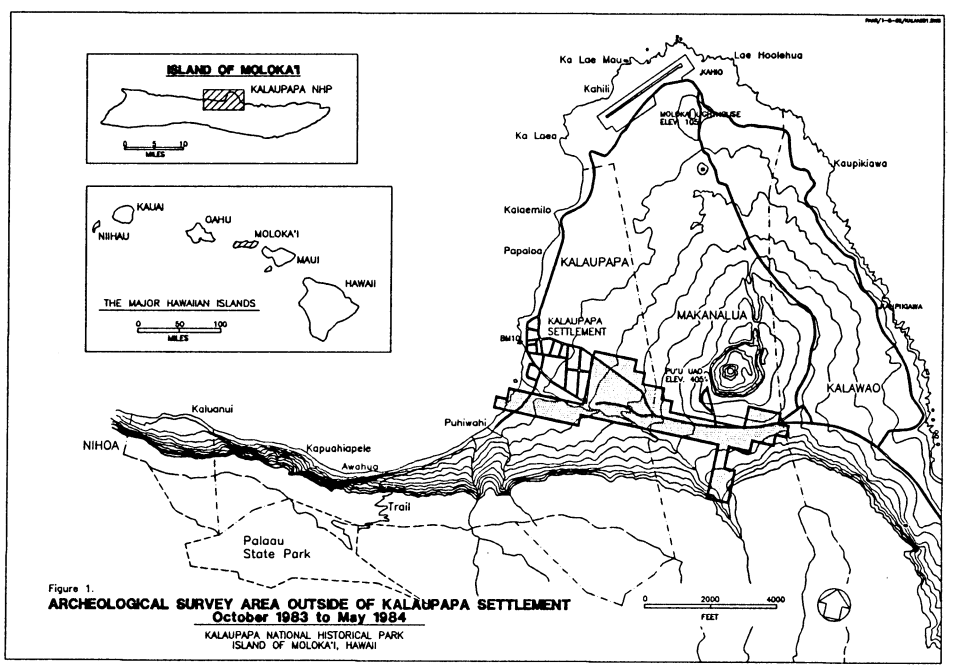

Figure 1.
ARCHEOLOGICAL SURVEY AREA OUTSIDE OF KALAUPAPA SETTLEMENT
October 1983 to May 1984
KALAUPAPA NATIONAL HISTORICAL PARK
ISLAND OF MOLOKA'I, HAWAII

The vegetation was so thick in the project area, the only way to get through it and be able to see and record the archeological sites hidden beneath was to cut lines using chain saws, machetes, and sickles (Figures 2 and 3). Grid units that were 100 m (328 ft) on a side were established using a transit to align them to the four cardinal directions. After the primary hectare-sized grid unit was established, intermediate grids every 25 m (82 ft) were aligned using tapes and compasses, and then cut. These grid lines were necessary to allow access to the areas that had to be examined, and also provided reference lines from which the identified features could be mapped. Without the lines you could not have penetrated the vegetation effectively and even if you found a site you would not have been able to determine where you were.

Figure 2. Aerial view of grid lines cut to facilitate archeological survey, Kalaupapa National Historical Park.

Figure 3. Ground view of grid line cut to facilitate archeological survey, Kalaupapa National Historical Park.

A similar approach was used to conduct archeological surveys through dense vegetation at Hawai`i Volcanoes National Park on the island of Hawai`i (Ladefoged, Somers, and Lane-Hamasaki 1987) and at Haleakala National Park on the island of Maui (Rosendahl 1976). Although this method is quite effective, it is also very labor-intensive and time-consuming. At Kalaupapa, in the area outside the settlement, the survey took an average of about 10 person-days per hectare (4 person-days per acre) (Somers 1985:37). At Haleakala, in the Kipahulu District, a similar survey took an average of about 6.5 person-days per hectare (2.6 person-days per acre) (Rosendahl 1976:5, 10). The existing records are not good enough to determine what the person-day-per-hectare rate was at Hawai`i Volcanoes, but it was probably similar to the Haleakala rate.

The best way to put these figures into perspective is to compare them to average survey rates

that are used in the arid southwestern United States where vegetation is usually not a problem. According to George Teague (pers. comm. 1992), an archeologist at the Western Archeological and Conservation Center in Tucson, Arizona, the average figure they use for estimating the rate of coverage for surveys is 25–40 acres per person-day (10–16 hectares per person-day). If the above rates for Hawai`i are converted to acres per person-day, instead of person-day per acre, they would be 0.25–0.38 acres per person-day (0.1–0.15 hectares per person-day). In other words, the average archeological surveyor in the desert Southwest could cover 100 times as much area in a day as the average surveyor could in the Hawaiian parks discussed above. Although the density of archeological sites is a factor in the different rates of coverage, the primary reason for the difference is the density of the alien plants in the Hawaiian parks.

At Kaloko-Honokohau National Historical Park on the island of Hawai`i, the major problems around the fish ponds are red mangrove and kiawe. Wagner, Herbst, and Sohmer's comment that red mangrove "often forms impenetrable thickets" (1990:1099) is borne out at Kaloko fish pond. Within the last 15 to 20 years red mangrove became established at Kaloko fish pond and completely took over the edges of the fish pond and the seawall and cross-walls associated with it (Figure 4). The U.S. National Park Service

Figure 4. Kaloko fish pond showing dense stand of red mangrove, Kaloko-Honokohau National Historical Park.

has been manually removing the mangrove since 1988 and still has about 25% of it left to go. Before its removal, the mangrove completely obscured the archeological features associated with the fish pond, and its impenetrable nature made it impossible to get to the features from the water side of the pond. It was also difficult to get to the features from the land side of the pond because immediately inland from the mangrove was a dense stand of kiawe. An even denser stand of kiawe and pockets of dense mangrove also are present around Aimakapa fish pond.

Two other alien plants, Java plum and false kamani, are also widespread, especially at Kalaupapa, and they are both a blessing and a curse. Unlike the other species discussed so far, these two trees form a dense cover, or overstory, which shades out other species. The landscape under them tends to be open and easy to walk through. On the other hand, however, their roots are widespread and cause considerable damage to archeological resources.

In Hawai`i the archeological resources are predominantly stacked stone structures built without any mortar. Consequently, they are particularly vulnerable to damage by root action. The stones in walls and platforms are spread apart and shifted by roots and are dislodged when tree limbs or entire trees fall on them. A particularly vicious cycle, which has been repeated in Hawai`i more than once, occurs when one-time money is received to clear the vegetation from a site, but there is no money to maintain it in that condition and the vegetation is allowed to grow back. When the vegetation is removed, the stones often settle in upon themselves. Then when the plants are allowed to grow back, the roots spread the rocks apart again, further weakening the wall or platform.

Although walls and platforms can be rebuilt, thus restoring their original appearance, there is an irretrievable loss of archeological data whenever a wall or platform is broken apart and falls down. The structure itself, whether a wall or platform, can be thought of as a large artifact. Two characteristics that should be noted when recording such an artifact are how it was constructed and what are its dimensions. When a wall or platform has been reduced to rubble, it is often no longer possible to record those characteristics. In those cases, what could have been originally recorded has been seriously compromised by the collapse; in terms of recording, fact has been replaced by supposition or speculation.

Finally, if you are able to get through the vegetation and find the sites, and they have not been reduced to rubble by roots and other factors, then you are still faced with the problem of trying to determine what the vegetation was like when the sites were occupied. What is present today usually has little or no relationship to what was present when the Hawaiians were occupying and using the sites. Obviously, cultivated plants that require tending will not survive long after a site has been abandoned and is no longer used. Unfortunately, because of the historically introduced species, the cultivated species were rarely replaced by native or even Polynesian-introduced species. Instead plants that are considered noxious weeds tend to dominate the disturbed landscape. The descriptions of the plants at the beginning of this paper illustrate this point.

Christmasberry dominates many abandoned agricultural sites; lantana is a serious weed in low-elevation, dry, disturbed habitats; kiawe is a dominant component of vegetation in low-elevation, dry, disturbed sites; Java plum is naturalized in disturbed mesic forest; and koa haole thrives in all of the above environments. This often applies not only

to the archeological sites themselves, but to the landscape surrounding them. Since the Hawaiians lived and farmed predominantly between sea level and 2,000 feet (and this is the area in Hawai`i where historically introduced species are most prevalent), we are not often even able to study remnant pockets of relevant vegetation. Instead we must rely on sketchy early written accounts of the vegetation, tree molds, pollen, and wood remains to try to reconstruct a completely altered landscape.

The profession of archeology is often very challenging and in that regard conducting archeological studies in Hawai`i is no different from anywhere else. What the archeologist in Hawai`i does face, however, are challenges that are somewhat different from many other places. On the island of Hawai`i, for example, historic lava flows have buried hundreds, and probably thousands, of archeological sites. In addition, landscapes and the archeological sites present on them have changed due to earthquakes, landslides, and tsunamis. How these actions have skewed the archeological record is something that must be addressed by archeologists working in Hawai`i (Somers 1991). There are other challenges, such as the lack of effective temporal dating techniques, to add to that presented by alien plant species.

Sites can be difficult to find, record, and interpret because they are obscured and damaged by alien plants. (Although native plants can do the same thing to archeological sites, they are not nearly the problem alien species are.) Although some of the problem species have been established in Hawai`i for over 100 years, two of the more noxious and rapidly expanding species, christmasberry and red mangrove, have only become established since 1900. As the archeological professional struggles to identify, record, and understand the remains of the prehistoric Hawaiian culture, these species are expanding and making the task even more difficult. Because of the dominance of alien species in the areas where most of the archeological sites in Hawai`i are found, archeologists working in Hawai`i not only need to know how to use a transit, compass, and other standard archeological equipment, but a chain saw, machete, and sickle. The ability to crawl on your hands and knees and sometimes on your belly is also a very useful skill.

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Cooperative Research Efforts to Develop the Use of a Nematode for Russian Knapweed Biocontrol

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THE PROBLEM

Russian knapweed, *Acroptilon (Centaurea) repens* (L.) DC. is a noxious herbacious weed in the family Compositae. This weed has invaded millions of acres of native rangeland and farmland throughout the western and north-central United States and western prairies of Canada. Russian knapweed is an exotic weed which was imported to the Pacific Northwest

about 1900. The species *Centaurea rothrockii* and *Centaurea americana* are the only two native American species of the closely allied genus *Centaurea* (Reed and Hughes, 1970). Russian knapweed is an extremely aggressive and pernicious invader. It has an extensive, creeping horizontal root system which can penetrate soil to a depth of over eight feet, and is a prolific shoot producer.

Russian knapweed is considered a severe weed pest for several reasons besides its invasiveness. Russian knapweed may be allelopathic (Fletcher and Renney, 1963) because it produces a variety of compounds such as polyacetylenes and sesquiterpene lactones (isolated from roots and shoots, respectively) which are phytotoxic to several important economic crops and native species (Kelsey and Bedunah, 1989). In addition, these toxic compounds inhibit seed germination of many grasses, thereby decreasing forage quality of rangeland. Besides its noxious effect on other plants, Russian knapweed is also toxic to livestock. Sheep, cattle, and horses are sensitive to poisoning, which can occur from grazing or by ingesting contaminated hay (Young *et al.*, 1970). Russian knapweed has invaded several USNPS areas in the western United States. It is especially effective in establishing new populations in disturbed areas. However, the aggressive nature and resistance to control of this species makes it a serious threat even to relatively undisturbed areas such as those found in many western USNPS units.

THE NEMATODE

The endoparasitic nematode *Subanguina* (Paranguina) *picridis* (Brzeski, 1981) forms galls (plant cancers) on Russian knapweed stems, leaves, and root collars. These galls considerably stunt and weaken infected plants. Scientists in the Soviet Union (Kirjanova and Ivanova, 1969) and Canada (Watson, 1986) have shown that *S. picridis* overwinters in galls in plant residue. In early spring, infective nematodes are released from disintegrating galls and penetrate young knapweed shoots as they sprout through wet soil. Watson (1986) has investigated the host range of the knapweed nematode using a large variety of *Centaurea* species and other families containing economically important plants. Russian knapweed is the best host for *S. picridis*, while flax, lettuce, sunflower, onion, kohlrabi, potato, wheat, safflower, carrot, Jerusalem artichoke, and globe artichoke were unaffected by the nematode (Watson and Harris, 1984). In the United States, the host range was again tested by Rosenthal (1989) of the USDA-Agricultural Research Service (ARS) at the request of the USDA-Animal and Plant Health Inspection Service Technical Advisory Group (APHIS-TAG). Her research essentially confirmed the previous results and thus allowed the nematode to be cleared for release in the United States in 1989.

USING THE NEMATODE AS RUSSIAN KNAPWEED BIOCONTROL AGENT

Management strategies to control Russian knapweed have met with little success before the recognition of the biological control potential of *S. picridis*. Several USNPS areas have had marginal success in treating even very small knapweed populations with herbicide where no large-scale invasion has occurred. More often, the proliferation of Russian knapweed in agricultural or rangeland areas contiguous to USNPS units make such treatments futile. In Russia, acres of knapweed are planted as nurseries to propagate the nematode. Crushed gall material is distributed in knapweed fields each spring to initiate infections. The nematode has been introduced

into Canada by Agriculture Canada for knapweed biocontrol, but the use of the nematode for commercial purposes has not been explored. Therefore, no techniques for mass production (and resultant availability in more than experimental quantities) have been developed in the United States or Canada.

Over the past several years, several agencies (including the USNPS) in Wyoming and Montana have carried out separate, uncoordinated, and relatively ineffective efforts to control the spread of Russian knapweed. In an attempt to approach this problem in a more programmatic and effective manner, a coalition of agencies formed an action group consisting of members from several federal, state, and county agencies, e.g., U.S. Department of the Interior (USNPS, Bureau of Land Management, Bureau of Reclamation, Bureau of Indian Affairs), U.S. Department of Agriculture (Forest Service, ARS), Wyoming Game and Fish Department, University of Wyoming, Wyoming State Lands Department, and several county weed and pest supervisors from Wyoming and Montana. This group is actively supporting development of the nematode as a biocontrol agent by funding a project to develop and improve mass rearing techniques for the nematode, and to develop formulations to aid in its long-term preservation and storage. The ARS has been designated as the lead agency to initiate this project. With funding provided by the USNPS and other cooperators, the ARS Rangeland Weed Laboratory has developed a specific cooperative agreement with W.E. Dyer of the Plant and Soil Science Department at Montana State University in Bozeman. Dyer has employed T.C. Ceasar as a visiting assistant professor to conduct this research (now underway) in cooperation with S.S. Rosenthal and P.C. Quimby of the ARS Rangeland Weed Laboratory. Collaboration with a nematologist at the ARS laboratory in Beltsville, Maryland, and scientific exchanges with Canadian experts have been very valuable in the progress of the project.

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Exotic Weed Management on National Historic Sites and Monuments in the Pacific Northwest of the United States

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The U.S. National Park Service initiated a study in 1985 to address vegetation management issues on a number of small, arid parks in the Pacific Northwest. The objective of the study was to develop demonstration and research projects that would aid in the management of exotic weed species and the restoration of historic park vegetation. The purpose of this paper is to provide a discussion of the need for ecological data in management programs that deal with exotic weeds.

HISTORICAL PERSPECTIVE

Exotic weed encroachment is not a new phenomenon in the Pacific Northwest. Most exotic weeds found within historic sites and national monuments were introduced into this region in the late 1800s and early 1900s. These species include the knapweed complex *(Centaurea* spp. L.), cheatgrass *(Bromus tectorum* L.), medusahead wildrye *(Taeniatherum caput-medusae* L.), and numerous others. Most weed introductions began as

contaminants in crop seed, livestock feed, or shipping ballast that was being transported along the waterway and railway routes of the region. These initial introductions expanded as land use patterns developed within the region. Today, most rangelands, forestlands, and croplands support exotic weed species in varying amounts (1, 8).

The encroachment of exotic weeds onto park lands is associated with past and present land use. To illustrate this point, consider the land-use history of Whitman Mission National Historic Site, Fort Spokane National Historic Monument, Nez Perce National Historical Park, and John Day Fossil Beds National Monument. All these parks have a rich history of settlement, domestic livestock grazing, farming, and commodity transportation. Their landscapes reflect the cumulative influence of over 100 years of white settlement. Furthermore, many of the cultural activities that affected their landscapes were continued after these areas were incorporated into the U.S. National Park System, and some of these activities are continued today to maintain historic settings.

This historical perspective illustrates that the history of park lands and exotic weeds are not independent. Indeed, the very land uses that justified the creation of historic sites are in many cases the same attributes that aided the spread of exotic weed species. Furthermore, the process of weed encroachment will continue in the future because most historic sites and national monuments are surrounded by land use patterns that maintain exotic weed populations.

ECOLOGICAL PERSPECTIVE

Weed encroachment is a complex problem and successful solutions need to be based upon ecological principles. Land managers need to incorporate life-strategy information, and an understanding of the role of disturbance within plant communities, into exotic-weed management programs.

Plant communities are dynamic systems in which vegetation change and disturbance are constantly occurring. Successful plant introductions, whether exotic or native, occur because sufficient quantities of light, water, nutrients, temperature, and space are available within the plant community for new introductions to complete their life cycles. In other words, the composition of a plant community is the product of the allocation of limited resources (light, water, nutrients, temperature, and space) among potential plant species. Each new generation of an introduced species adjusts the process of resource allocation until a balance is achieved among the competing life strategies.

The encroachment of exotic weed species onto park lands is an example of an evolving ecological balance among competing life strategies. Unfortunately, weed encroachment is occurring on both deteriorated as well as undisturbed park lands. Weed encroachment is most obvious on deteriorated park lands, where it can disrupt successional processes and displace native plant species. In contrast, weed encroachment into undisturbed plant communities tends to be much more subtle. In this situation, weeds enter the community as scattered individuals, followed by the domination of localized areas of community disturbance. These two scenarios illustrate the breadth of the problem faced by park managers and the difficulty associated with the development of management strategies against the encroachment of weeds.

AN EXAMPLE OF THE PROBLEM

The ecological complexity of weed encroachment can best be illustrated by describing life-strategy attributes that result in encroach-

ment success. The species selected for this illustration is yellow starthistle (*Centaurea solstitialis* L.).

Yellow starthistle is an annual member of the knapweed complex and depends solely upon seed reproduction for its maintenance within plant communities. It is a Eurasian native that was introduced into the western United States at the turn of the century and currently infests millions of acres of range- and cropland (5, 6). Much of the success of yellow starthistle can be attributed to a high level of seed production and an ability to preempt resource utilization by other species.

The seed dispersal pattern of starthistle maximizes the likelihood of mature seed landing in an environment favorable to germination. This is accomplished through the production of two seed types and the utilization of two time periods in which seeds are released. Plumed seeds are produced in the outer portion of the seed head and are dispersed, through wind action during the summer and fall, away from the parent plant. Plumeless seeds are produced in the center of the seed head, are not released until winter, and then drop in the immediate vicinity of the parent plant (9).

Yellow starthistle seed germinates and initiates root growth over a wide range of conditions. Starthistle seeds have germination rates of 80-90% and can germinate during the fall, winter, or spring. Seed germination occurs rapidly, often within 24-48 hours, under a range of soil moisture conditions (0.5-0.0 -Mpa). Initial root growth by the germinated seed is tolerant to saline seedbed conditions (maximum electrical conductivity tested 12 ds/m) and root elongation is relatively unaffected by moderate (1.0 -Mpa) amounts of moisture stress (2).

The seed dispersal and germination characteristics of starthistle are well suited for the climate of the Pacific Northwest. Starthistle seeds germinate during the fall, winter, or spring depending upon yearly climatic conditions; the conditions for germination do not need to be maintained for extended time periods due to the rapid germination response. These two attributes result in a distinct advantage over many species that germinate only in the spring, and starthistle will tend to be the first species to occupy available sites within a newly disturbed community.

Starthistle seedlings become established as a tap-rooted rosette. This growth form is adapted to the cool growing conditions that prevail during late winter and early spring in the Pacific Northwest. The rosette growth form places the leaves of starthistle near the soil surface where the warmest temperatures for survival and photosynthesis are found. During this stage of growth, starthistle seedlings allocate much of their chemical energy toward the development of a tap root that is capable of extracting moisture from sources deeper in the soil profile (10). The importance of this attribute to starthistle success becomes apparent as community resources become limited during the summer months, which are often dry.

Localized ecosystem perturbation also tends to favor starthistle establishment. Increases in soil nutrient availability or soil-surface disturbance typically result in increased starthistle populations (3). These attributes suggest that starthistle exploits newly available resources more quickly than plants with which it competes.

The life-strategy attributes described so far illustrate growth form and germination characteristics that make starthistle a formidable competitor to other plant seedlings. Data are accumulating that indicate that specific plant communities can restrict starthistle (4). These communities contain dominant plants

whose resource utilization patterns overlap those of the starthistle. In addition, biological controls such as *Bangasternus orientalis* show promise of being a partial solution for starthistle control in the future (7). However, biological controls do not address the fundamental process of weed encroachment and should not be viewed as a "magic bullet" that will eliminate an alien weed population.

CONCLUSION

The ability to predict the response of desirable and undesirable species in a given management situation is a critical element in successful vegetation management. Predictive capability in these situations can only be achieved through the development of knowledge that includes the life strategies of the species being managed. This is true whether a land manager is faced with exotic weed encroachment in a population of threatened or endangered plants or if exotic weeds are threatening the re-establishment of a native plant community. In either case, access by land managers to information on life-history strategies is the first step toward the selection of the proper course of action.

It is unrealistic to manage for exotic weed exclusion on park lands. Public access, land management, and the surrounding networks of land use ensure that a supply of weed propagules will continue to enter park lands. Once there, the natural process of vegetation change and disturbance will ensure opportunities for the establishment and spread of the weeds. With these facts in mind, programs aimed at limiting the opportunity for exotic weed encroachment would appear to be the most prudent course of action in areas that are relatively free of exotic weeds. In situations where established populations of exotic weeds exist, techniques oriented toward the disruption of their life cycle are crucial to successful vegetation management. We believe that the development of acceptable solutions to the problem of weed encroachment depends upon the ability to incorporate sound ecological principles into restoration and long-term management programs.

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WE Are Kudzu

Comforted by anthropogenic science
held blindly at arms length
we castigate the uninvited
here on Turtle Island.
Ushered in unknowingly by ourselves
dogbane, gypsy moth, cheatgrass
lay waste to their respective biomes
following disturbance of our destruction.
Monographs issue forth from land grant universities
outlining expensive methodologies
for taming these apocalyptic interlopers –
restoring the natives
while grass carp, cowbird, loosestrife
quietly expand their range.
Myopically we set ourselves apart
from those who displace native sons and daughters –
Turtle Island's indigenous flora, fauna,
indeed – social systems too have fallen
in the wake of starling, sparrow, zebra mussel.
In my mind's own eye though, we anglos
travel in the company of lamprey, russian thistle, nutria.
Where is the plan to control *our* numbers?
When will we point the finger in guilt
back on ourselves, who, generations ago
displaced "the people" of Turtle Island –
we, who blindly overlook the fact that *we* too, are kudzu?

– Gregg L. Bruff

New National Parks and Other Protected Areas in Norway

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A systematic conservation program for different types of natural habitats, based on regional inventories, was initiated in Norway at the beginning of the 1970s. Its aims are to protect both representative and rare areas and ecosystems, thus maintaining biodiversity and the species *in situ.*

In recent years, 50-100 new protected areas have been established each year, and the total number of protected areas in Norway at the end of 1991 was 1,395, including 18 national parks. The remaining plans for wetlands, mires, bogs, seabird colonies, and rich deciduous forests should be approved by 1995. A plan for establishing a network of coniferous forests has a high priority in the Government's action plan for follow-up to the recommendations of the Brundtland Commission report [i.e., the U.N. Commission on Environment and Development's *Our Common Future,* 1987].

Based on the same concept, Norway got a master plan for national parks in 1986, proposing additions of 26 national parks, 14 landscape protection areas, and 3 large nature reserves. The proposal is based upon national inventories trying to find representative areas in every physical geographical region in Norway.

NORWAY'S NATIONAL AIMS FOR NATURE MANAGEMENT

In 1989, the Government followed up the Brundtland Commission with a report to the Storting (the Norwegian Parliament) on *Environment and Development.* In it, the Government formulated the following national aims:

- To ensure ecologically sound exploitation of resources, so that natural productivity and species diversity can be preserved for future generations; and
- To safeguard a representative section of Norwegian nature by protection as national parks, nature reserves, etc.

Protective measures in accordance with the Nature Conservation Act have the following basic aims:

- To secure a selection of natural areas which together constitute a representative sample of the diversity of Norwegian nature;
- To protect areas which have an ecological key function for wildlife; and
- To maintain biological diversity through protection of habitats upon which endangered species depend.

FACTS ABOUT NORWAY

Norway is a part of the Fenno-Scandian Mountain Range, and 50% of the country is bedrock. About 3% of the land area is cultivated soil, 5% is lakes, 20% is productive forest, while less than 1% is populated. The remaining part is mountains or other unproductive ground. Although Norway is the country with the second-lowest population density in Europe, it is the fifth-largest in terms of area (Table 1).

There is a substantial climatic variation in Norway due to the geographical conditions. The prevailing westerly winds reach further north in Norway than anywhere else in Europe. The temperature varies little from north to south, but there is a significant contrast between inland and coastal regions. The average yearly temperature is 8°C along the west coast, and -2°C in Finnmark in the northeastern part of the country. The annual precipitation is 1,960 mm in Bergen and 740 mm in Oslo.

The flora of Norway is richer than might be expected, with some 2,000 species. The most common trees in Norwegian forests are spruce *(Picea abies)* and pine *(Pinus sylvestris).* However, there are also several birches *(Betula* spp.) and other deciduous trees, even in the mountainous districts.

From these data you may think that there are plenty of wilderness areas in Norway. Between 1900 and 1980, however, wilderness was reduced from 40% of the land area in the southern part of the country

Table 1. Main statistical data of Norway

Total area, mainland	323,800 km^2
Svalbard	62,700 km^2
Freshwater	17,070 km^2
Coastline, mainland	21,350 km
Islands	35,650 km
Population	4,200,000

to 13%. This was due to road building, hydroelectric power production, cultivation, and other forms of technical encroachments. In 1980, wilderness areas covered about 23% of the total area of Norway (excluding Svalbard); they are still decreasing rapidly.

PHYSICAL GEOGRAPHICAL REGIONS

Any landscape may be regarded as being composed of different components—land forms, vegetation types, land use, buildings, etc. Different vegetation types are especially important as indicators of different ecosystems with a variety of biological and socioeconomic functions.

A report published by the Nordic Council of Ministers in 1983 proposed a division of the Nordic countries into 76 physical geographical regions. The delineations of each region is based upon parameters and variables that have long been used in evaluating nature conservation planning and use of natural resources. The fundamental criterion for drawing the line between physical geographical regions has been the large vegetation zones. The limits are then adjusted in relation to the geology and dominating land forms. The climatic conditions have only been used to a limited extent because they normally coincide with the vegetation zones. In most cases, there are also subregions within these main regions which have particular characteristics with regard to individual vegetation types, land forms, or climatic conditions.

Subdivisions of physical geographical regions have been used as a basis for selecting areas representing typical habitat types in different parts of the country. This has increased our knowledge of the landscape components within each region. Furthermore, these areas can be used as reference areas when evaluating nature conservation interests in connection with planning of different forms of land use.

Of the 76 relatively homogeneous regions and landscapes described for the Nordic countries, 29 (with 73 subregions) occur in Norway, e.g., Southern Mountain Area (in the Alpine zone), Heath Area of western Norway (boreal), and the Oak Region of Sørlandet .

MASTER PLAN FOR NATIONAL PARKS

After a debate in the Storting in 1981, the Ministry of the Environment asked the State Council for Nature Conservation to make a master plan for new national parks and other large protected areas (larger than 5,000 ha) based on physical geographical regions. By using these regions as a basis it is possible to select areas representing all main habitat types in Norway in a scientific way. In its report the Council has considered all remaining natural areas in Norway. The main criteria for the Council in selecting new areas have been *natural quality* and *biodiversity.*

In its report the Council shows that, at present, we have national parks or other protected areas larger than 5,000 ha in only 13 of the 29 physical geographical regions. The existing 18 national parks are found in the central mountain areas in southern Norway, and in the border areas of the North (see Table 2).

A long-term policy will be to get larger protected areas in every subregion. Only in this way will it be possible to protect representative areas of all main habitat types in our country. Norway has an international responsibility to protect northern alpine areas, coastal and fjord systems, and oceanic coniferous forests. These habitat types are rare or do not occur at all in other parts of the world.

In 1986 the Nature Conservation Council presented a master

plan for establishment of 26 new national parks, 14 landscape protection areas, and 3 large nature reserves. Enlarging of 7 existing national parks was also proposed. The Council was not able to find any areas larger than 5,000 ha left in 7 of the regions (encompassing 21 subregions) in the southern and southeastern part of the country, and along the coastline in western Norway. These are the most densely populated areas and, because of that, the most exploited part. The plan is now being prepared for discussions to take place in the Storting. The intention is to present a White Paper in June 1992. The Paper will probably propose up to 45 new large protected areas (including enlarging of 9 existing national parks) covering up to 20,000 km^2.

Table 2. Number and extent of protected areas in Norway

	Number		Area (km^2)		% of Norway's Total Area	
National parks	18	(21)	13,535	(23,035)	4.17	(5.97)
Nature reserves	951	(953)	1,474	(26,884)	0.45	(6.96)
Landscape protection areas	74		4,648		1.44	
Natural monuments	280		1		0.00	
Other areas	72		99		0.03	
TOTAL	**1,395**	**(1,400)**	**19,757**	**(54,667)**	**6.09**	**(14.40)**

Note: Figures in parentheses include Svalbard. Data current as of 31 December 1991.

COUNTY CONSERVATION PLANS

Adoption of the National Park Plan will secure important larger areas. There will, however, still be a number of smaller areas, e.g., highly productive sites in the lowland and smaller "islands" in a fragmented cultural landscape, which are insufficiently secured. Such areas are very important for maintenance of Norwegian biodiversity.

A systematic conservation program for different types of natural habitats, based on regional inventories, was initiated at the beginning of the 1970s. Regional conservation plans for each of the 18 counties in Norway for wetlands (especially those important for waterfowl), mires and bogs (primarily selected on botanical and hydrological criteria), rich deciduous forests (selected mainly on botanical criteria), and important seabird colonies were given priority. In 1985, inventories were started to identify coniferous forests for protection. Elaboration of conservation plans for coniferous forests has been given

high priority since 1988, when the recommendations from a national task force on protection of coniferous forests were presented.

Preparation of a county conservation plan is a long process (Eldoy 1991), starting with systematic inventories and evaluation of sites based on scientific criteria.

Though the county borders are administrative and not biological borders, we have found that the county conservation plan system is a practical working method for establishing a network of protected areas. When selecting areas in the counties, both biological and physical geographical criteria are used, and therefore all the county plans will together give a national network of protected areas based on scientific criteria.

In recent years an average of approximately 50-100 new nature reserves have been established every year through the county conservation plans.

Completing the county conservation plans for the habitats mentioned above is given high priority. In the long-term plans for the Ministry of Environment and the Directorate for Nature Management, it is a stated aim that all of the remaining county conservation plans should be approved by 1995.

WATER RESOURCES

Protection plan for river systems Norway has an estimated potential of approximately 172 TWh/year of commercially exploitable hydroelectric power. So far, watercourses corresponding to 111 TWh/year (65% of total potential) have been or are being developed.

An extensive national plan for protection of national river systems was adopted by the Storting in successive steps (Protection Plans I-III) in 1973, 1980, and 1986. A total of 192 river systems have been included in the plans. These represent a total energy resource of 12% of Norway's commercial hydroelectric potential (21 TWh/year). The plans are concerned solely with hydropower exploitation by banning licensing for any such development within the protected river systems. However, the Ministry of the Environment is preparing the legal basis for protecting the watercourses against other kinds of human encroachments.

A suggested Protection Plan IV has been proposed by an expert committee. This plan deals with 207 river systems with a power potential of 20 TWh/year. The plan is expected to be considered by the Storting during 1992.

Master plan for water resources In 1985 a national Master Plan for Water Resources was presented to the Storting. The aim of the plan was to identify those remaining watercourses where both (1) conflicts between future hydropower development and other interests, including environmental and natural conservation ones, are as small as possible; and (2) hydropower development is economically feasible. It states which projects should be considered first for a license when hydropower development is necessary. It also specifies which watercourses should be reserved for uses other than hydropower development, such as conservation purposes. The Master Plan, which covers 310 watercourses all over the country, was adopted by the Storting in 1986.

CONCLUSION

The system of new national parks, based on physical geographical regions, and the county conservation plans for special habitats, will provide Norway with a high-quality network of protected areas, in which a selection of both the representative and the more special sites are covered. If all proposed conservation areas are approved, Norway will have about 12% of the total land area protected under the Nature

Conservation Act (19% if protected areas in Svalbard are included).

The methodology used by Norway (and the other Nordic countries)—dividing the country into physical geographical regions as a basis for selecting new protected areas—can be recommended for other countries as well, provided that the criteria for identifying regions are adapted to local conditions. This method can be an efficient tool in fulfilling the aims of IUCN for a global system of protected areas, as well as the goal of the Bali Action Plan [emanating from the 3rd World Congress on National Parks, held in 1982] of a worldwide system of protected areas covering 10% of the land surface of the globe.

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Table 3. Some national parks in Norway

	Year Est'd	Size (km2)	Description
Ånderdalen	1970	669	On island of Senja. Surrounded by mountains rising straight from sea. Mountain birch forest & bogs dominate.
Børgefjell	1963	1,107	High peaks, glaciers, and deep ravines give way to gentle slopes with numerous rivers, lakes & tarns.
Dovrefjell	1974	256	Mountains crowned by Snøhetta (summit 2,286 m). Wild reindeer & musk-oxen. Northern Europe's richest mountain flora.
Femundsmarka	1971	390	Gently rolling glacial landscape. Park adjoins two large Nature Reserves and a National Park on Swedish side of border.
Gressåmoen	1970	182	Barren fells occupy much of the park. Spruce forest shows few signs of exploitation. Trout & burbot thrive in lakes.

Gutulia	1968	19	Upland area of virgin coniferous forest. Some spruce over 250 years old; some pines over 350.
Hardangervidda	1981	3,422	Northern Europe's largest mountain plateau. Europe's largest herd of wild reindeer. Famous for abundant fish as well.
Jotunheimen	1980	1,145	Galdhøpiggen, Norway's highest peak (2,469 m), is within the park.
Ormtjernkampen	1968	9	Virgin remnant of eastern Norway's coniferous forests.
Øvre Anarjåkka	1975	1,399	Host to many summer migrants, the park borders on Finland's Lemmenjoki National Park. Gently undulating tundra plateau.
Øvre Dividal	1971	743	Landscape typical of inland northern Norway. Country's four largest predators—lynx, wolverine, wolf, and bear—are found.
Øvre Pasvik	1970	67	In extreme northeastern Norway, on western fringe of the Siberian taiga. Labrador tea *(Ledum palustre)* and other eastern plant species grow.
Rago	1971	167	Wilderness of peaks, clefts, and boulder fields. Accessible only on foot. Three adjacent National Parks in Sweden cover a total of 5,700 km^2.
Reisa	1986	803	Canyon with many waterfalls, including Mollisfossen (fall of 269 m). Flora and fauna among northern Norway's richest.
Rodane	1962	580	Sparsely vegetated area characterized by sweeping mountainsides, bedrock, and narrow gorges.
Saltfjellet-Svartisen	1989	1,840	Together with four adjacent protected landscapes, protected area stretches from the fjords to the mountains on the Swedish border. Includes largest glacier in Scandinavia (Svartisen).
Stabbursdalen	1970	98	World's northernmost pine forest (70° 10′ N); some trees 500 years old. Extensive glacial deposits.

Society News, Notes & Mail

Smart Joins GWS Board

At its March meeting, the Society's Board of Directors appointed Elizabeth Bertillion Smart of the California Department of Parks and Recreation to a three-year term on the Board. She has been the Department's Curator of Statewide Collections for the last fifteen years, and as such provides review of a museum collection containing 7 million objects. She is a museum consultant, lecturer, map evaluator, and author of the Department's *Museum Collections Management Handbook* and the *California State Parks Museum Directory.*

Betty is the first state-level park professional to serve on the GWS Board. Her career with the Department, which began in 1972, includes several other firsts. She developed the Department's first academic internship program, its first statewide museum training program, and its first docent program. She was also the first female park ranger in the Sacramento District.

She received her education at California State University-Sacramento and the University of California at Berkeley. She serves on several other Boards, including those of the California Association of Museums, the California Historical Society, the Western Museums Conference, and the American Association of Museums.

Lawrence Rakestraw, 1912–1992

Lawrence Rakestraw, a long-time member of the Society, died on March 25, 1992, at the age of 80. Before his retirement to Oregon in 1982, he was a professor of history and lecturer in forestry at Michigan Technological University. He joined the university's faculty in 1957. Rakestraw authored many articles on the history of conservation and forestry.

He was born on January 9, 1912, in Carson, Washington. He earned B.A. and M.A. degrees from the University of Wisconsin and a Ph.D. from the University of Washington.

He is survived by his wife, Mary; a son, James, of Springfield, Virginia; a daughter, Society member Nora Foster of Fairbanks, Alaska; a sister, Claribel, of Portland, Oregon; and four grandchildren.

Society Seeks Nominees for Awards

As the August 31 deadline for nominations approaches, members are reminded to submit their recommendations for persons to receive the following awards, which will be presented at the Society's Seventh Conference on Research and Resource Management in Parks and on Public Lands in November. Recognition for all awards will include travel expenses and registration fees to the Seventh Conference, a framed certificate, and a year's free membership.

The George Wright Society Natural Resource Award, given in recognition of excellence and achievement in managing the natural re-

sources of parks and similar preserves (given in memory of Francis Jacot).

The George Wright Society Cultural Resource Award, given in recognition of excellence and achievement in managing the cultural resources of parks and similar preserves.

The George Wright Society Communication Award, given in recognition of excellence in communication, interpretation, or related areas pertaining to the purposes of the Society.

The George Wright Society New Scholar Award, given in recognition of excellence in published research in the natural, cultural, or social sciences applicable to furtherance of the purposes of the Society. It will be given to recipients early in their professional career (age is *not* a criterion).

Members may also suggest recipients for the Society's highest award, **The George Melendez Wright Award for Excellence.** This award is given by the Society in recognition of senior-level contributions on behalf of the Society or in furtherance of its purposes.

Nominees don't have to be members of the Society; however, only members in good standing are eligible to make recommendations. They should include the name, address, and telephone and fax numbers of the candidate, as well as those of the member making the recommendation, and a one- or two-page recommendation that contains a summary of the candidate's specific accomplishments as appropriate to the award being sought. Recommendations for the New Scholar Award must include three copies of the published work for which the nominee is being considered, and a one-page recommendation as above. Recommendations should be sent to The George Wright Society, Attention: Awards Committee, P.O. Box 65, Hancock, Michigan 49930, USA.

Conferences Slated on Eco-tourism, Historic Landscape Maintenance

The 1992 World Congress on Adventure Travel and Eco-tourism will be held September 20-23, 1992. The site is Whistler, British Columbia, seventy-five miles north of Vancouver. The Congress is organized by the Adventure Travel Society and co-hosted by the British Columbia Ministries of Tourism and Culture, the Canadian Parks Service, and the U.N. Environment Programme.

Issues to be discussed include the profitability of eco-tourism, cooperation and coordination, responsible marketing, environmental sustainability, information needs, technical and financial assistance, and indigenous people. For more information, contact the Adventure Travel Society, 6551 S. Revere Parkway, Suite 160, Englewood, Colorado 80111 USA; phone (303) 649-9016; fax (303) 649-9017.

The USNPS and the Garden Center of Greater Cleveland are cosponsoring a Historic Landscape Maintenance Workshop at the Garden Center August 19-21, 1992. The workshop is aimed at landscape managers and maintenance personnel, who play a vital role in the daily decisions that affect the preservation of historic landscapes. Field trips and on-site demonstrations will visit nearby historic properties.

Space is limited, and on-site registration is not available. For more information, contact the Garden Center of Greater Cleveland, 11030 East Blvd., Cleveland, Ohio 44106 USA; phone: (216) 721-1600; fax (216) 721-2056.

About the GWS . . .

The George Wright Society was founded in 1980 to serve as a professional association for people who work in protected areas and on public lands. Unlike other organizations, the GWS is not limited to a single discipline or one type of protected area. Our integrative approach cuts across academic fields, agency jurisdictions, and political boundaries.

The GWS organizes and co-sponsors a major U.S. conference on research and management of protected areas, held every two years. We offer the Forum, a quarterly publication, as a venue for discussion of timely issues related to protected areas, including think-pieces that have a hard time finding a home in subject-oriented, peer-reviewed journals. The GWS also helps sponsor outside symposia and takes part in international initiatives, such as the Global Biodiversity Conservation Strategy.

Who was George Wright?

George Melendez Wright (1904-1936) was one of the first protected area professionals to argue for a holistic approach to solving research and management problems. In 1929 he founded (and funded out of his own pocket) the Wildlife Division of the U.S. National Park Service—the precursor to today's science and resource management programs in the agency. Although just a young man, he quickly became associated with the conservation luminaries of the day and, along with them, influenced planning for public parks and recreation areas nationwide. Even then, Wright realized that protected areas cannot be managed as if they are untouched by events outside their boundaries.

Please Join Us!

Following the spirit of George Wright, members of the GWS come from all kinds of professional backgrounds. Our ranks include terrestrial and marine scientists, historians, archaeologists, sociologists, geographers, natural and cultural resource managers, planners, data analysts, and more. Some work in agencies, some for private groups, some in academia. And some are simply supporters of better research and management in protected areas.

Won't you help us as we work toward this goal? Membership for individuals is US$25 per calendar year (US$35 beginning 1 October 1992), and includes subscriptions to both the Forum and the GWS newsletter, discounts on GWS publications, and reduced registration fees for the GWS conference. *New* members who join between 1 October and 31 December are enrolled for the balance of the year and all of the next. A sign-up form is on the next page. Other membership options are available; please call or write to get a brochure with full details.

GWS Membership

You may use this form to sign up for membership or to renew. Or, pass it along to a colleague or friend who might be interested in the GWS. Annual membership dues are US$25. Please send a check or money order to the address below. Thank you for supporting the George Wright Society!

Name

Affiliation

Address

Zip/Postal Code

Phone (work)

Phone (home)

Fax

Occupation & expertise (optional)

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Submitting Materials to the FORUM

The editorial board welcomes articles that bear importantly on the objectives of the Society–promoting the application of knowledge, understanding, and wisdom to policy making, planning, management, and interpretation of the resources of protected areas and public lands around the world. The FORUM is now distributed internationally; submissions should minimize provincialism, avoid academic or agency jargon and acronyms, and aim to broaden international aspects and applications. We actively seek manuscripts which represent a variety of protected-area perspectives, and welcome submissions from authors working outside of the U.S.A.

Language of Submission Current readership is primarily English-speaking, but submissions in other languages will be considered; in such cases an English summary should be prepared.

Form of Submission *We strongly urge authors to submit articles on computer disk.* This eliminates troublesome re-keying. Almost any Apple Macintosh disk can be read in its original format (please indicate the version of the software). Otherwise, send an ASCII-file disk; both 3.5" and 5.25" double-density formats are acceptable. (No high-density disks, please.) A double-spaced manuscript must accompany all submissions in case there are compatibility problems.

Citations The FORUM contains articles in varied fields, e.g., history, geology, archeology, botany, zoology, management, etc. Please follow your field's conventions for citations and bibliographies. These usually will be retained in our pages.

Editorial Matters Generally, manuscripts are edited only for clarity, grammar, and so on. We contact authors before publishing if major revisions to content are needed. The FORUM is copyrighted by the Society; written permission for additional publication is required but freely given as long as the article is attributed as having been first published here.

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