Domain Conservation: an overview of threats, management strategies, and student opportunities

Dr. Evans's Advanced Conservation Biology Class, Easter 2010

Edited: Nathan Bourne
# Introduction

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This document is a compilation of the work of Dr. Jonathan Evans's Advanced Conservation Biology class from the Easter 2010 semester. It is a conservation document. It is not a comprehensive management plan meant to tell the administration how it should operate, but rather reflects the values of biodiversity important to the students of the University of the South. This is not a final, completed document, but is an open one—a beginning to a process that will hopefully culminate in a management plan that posits the conservation of biodiversity and associated educational opportunities as its major priorities. Too often there exists a disconnect between the administrative structure of the university and the students, when in reality this university exists for the students and should always include them decisions that will affect both their own experiences and the experiences of their successors for generations to come. This document seeks to bridge that gap, to show the administration what the values and priorities of students are regarding the management of the Domain, and to address a series of pressing issues that are of conservation concern.

In the Domain we have a tremendous resource. the 13,000 acres provides great diversity and abundance of opportunities for students. These opportunities come in many different areas: recreation, independent research, and other educational opportunities. All of these activities are, however, contingent on the preservation of the diversity of habitats and the richness of biodiversity across the Domain; but this biodiversity is threatened from many different directions. As many different habitats across the world are facing widespread degradation and depletion from anthropogenic factor, so the Domain faces its own set of threats. This document's purpose is to describe some of the most pressing threats to biodiversity on the Domain and the solutions that will best address and alleviate that threat.

This document is broken up into sections by categories of threats. The overarching categories are: Habitat Loss and Fragmentation, Overpopulation of Deer, Invasive Species, and Pollution. Within each of these larger categories specific threats are described and methods of dealing with them are proposed, and contained at the end of each section is a list of general conclusions relating to that specific threat. At the end of the document is a list of educational opportunities associated with the study and management of these threats. This section assumes a
great deal of importance, as student opportunities are the top priority of the University as an academic institution.

This is not the final say on where conservation efforts on the Domain need to be focused, but is just a beginning. It is our hope that students and faculty will continue to edit it, to make additions, and to work towards a comprehensive vision of how the university can best preserve the integrity of the wealth of habitats and biodiversity present on the Domain.

Habitat Loss and Fragmentation
Introduction to Habitat Loss and Fragmentation

A habitat is the environment or niche of a particular species. Human land-use and water-use conversions cause habitat loss, which threatens populations across many taxa. Habitat fragmentation is the loss and separation of habitats into smaller isolated parts, which leads to detrimental edge effects that threaten populations of native biodiversity.

Many types of habitat loss and fragmentation are threatening biodiversity on the Domain. They include habitat loss from dams, fire suppression, and urban sprawl and development, and habitat fragmentation by roads and utility rights-of-way. Because habitat loss and fragmentation is the most immediate cause of species extinction, it is an area in which action on the domain could be instrumental in stemming the loss of biodiversity.

Chapter I: Future Development and Sprawl on the Domain
Daniel Church

Introduction

Future development on the Domain is inevitable. As an institution, it is necessary for the university to expand its academic and institutional resources to compete with other institutions and to keep up with ever changing technology. New developments are not inherently bad; however, they can potentially negatively affect the environment and biodiversity on the Domain. There are several new developments in the works which, unless constructed with proper techniques and methods in mind, will lead to environmental degradation. The projects that will cause the most problems are the construction of new parking lots to cope with the growing demand for parking and increase in cars on campus and the potential expansion of the Wiggins Creek 2 neighborhood.

Changes in Parking on Campus

The Campus Master Plan, created in 2001 and ultimately decided upon by Vice Chancellor Cunningham and the Board of Trustees and Regents, sets out a new idea for parking on campus. The large numbers of cars parked along University Avenue from Hunter Hall to Louisiana Circle and along Georgia Avenue has long been thought of as aesthetically unappealing. In order to rid the campus of this eyesore and make the campus more pedestrian friendly, the University decided to eliminate most street parking and build larger parking lots in several specific locations.

These locations include:

- New McCrady parking lot
- New Parking lot between BC and Stirling's
- New parking lot behind Tuckaway
- New parking lot behind Johnson
Expansion of Wiggins Creek

Roughly 1.75 miles from central campus, Wiggins Creek was first built in the mid to late 1990’s to fill the increasing demand for housing. Because of its relative distance from central campus and the lack of sidewalks between the two, Wiggins Creek is essentially a commuter, “suburban” community. As Sewanee tries to become more pedestrian friendly and reduce our carbon footprint, the expansion of Wiggins Creek contradicts many of the goals established by the school. But a continued increased demand for housing has caused for a planned expansion of Wiggins Creek. Wiggins Creek produces the same problems associated with urban sprawl as occurs in other regions of the country.

Threat to Biodiversity

Each new parking lot brings about its own respective environmental concerns, but all pose a potential threat to biodiversity. There are many problems caused by parking lots. Runoff is the most pressing problem. As impervious surfaces, asphalt and concrete do not allow rainwater to percolate through the soil as they naturally would but instead funnel it to one or several specific locations. A one acre parking lot produces up to sixteen times more runoff than an undeveloped meadow (Johnson and Klemens 36). Some of the planned parking lot locations are in areas which are in natural drainage areas. Building the parking lots in this area has the potential to cause significant harm to their watersheds. Besides pollution flowing into the watersheds, the parking lots will also remove important plant life and soil which is critical in filtering and slowing water movement. Parking lots and other impervious structures “increase flooding during wet years and decreases base flow during dry years” (Rushton 172). By disrupting the flow of water, species downstream which depend on the constant flow of water are put in danger.

In order to build new parking lots, the previous landscape has to be altered in some way. The new parking lots planned by the University all lie in forested areas. Some of the areas are more heavily forested than others, but the loss of these forests will cause many problems. The loss of tree cover will cause for a loss of habitat for species which reside within those trees, namely squirrels, songbirds, and other small animals. It will also speed up erosion by eliminating a natural barrier against runoff.

Another major problem caused by sprawling development is overexploitation. On the Domain, sprawl will affect animal and water resources. The close proximity of large human populations to populations of wild animals causes for increased interaction. This can, inevitably, lead to the “harvesting” of many of these species. Although the innocent removal of box turtles or other species by humans, especially children, seems insignificant, it can, over time, cause local populations to go extinct (Johnson and Klemens, 40). Water resources are perhaps the most overexploited resource caused by sprawl. With larger homes and larger lawns come more bathrooms, swimming pools, and increased lawn watering. All of these cause a dramatic increase in water usage as compared with homes in cities. Suburban homes tend to use 16 times more water than their urban counterparts (Johnson and Klemens, 41). Also, the watering of lawns causes much of the water to evaporate instead of recharge the soil. This can lead to increased aridity of a region.

Assessment of Threat

With an increasing demand for housing and parking in Sewanee, this threat will become a greater issue on the Domain. Changes in biodiversity should be studied around areas where new
parking lots are created. Areas in which parking lots would cause the least effect on biodiversity loss should be determined immediately in order to have information before the construction of future lots.

**Recommendations for Action**

If the plan for larger, outlying parking lots comes to fruition, there are several strategies which can be used to reduce the environmental problems which will arise. The first step will be to reduce the total forest cover loss. The best method would be to find areas around campus which are already void of forest cover. If no such areas exist or such areas are too small, ways should be found to incorporate important areas of habitat or trees into the parking lot’s design. Another important strategy is the parking lot’s design itself. New, minimally invasive designs have begun to be implemented across the country. The use of swales (grassy impressions in the earth) between different parking rows is one way to reduce runoff. These swales funnel runoff water into vegetated channels which both filter and slow down the water. The water then collects in a storm water retention pond. Another design being used in parking lot design is pervious parking surfaces. Pervious parking surfaces, such as gravel or other ground covers which allows water to filter through, allow for the absorption of groundwater, which also slows runoff.

In order to meet the demand for more housing, there are several steps that the University could take to reduce or eliminate sprawl. The first step would be to increase housing by building smaller, higher density housing units. One such development, Parson’s Green, is currently being built behind Shenanigans in “downtown Sewanee”. It is a 60-acre development which includes “a mix of single-family cottages and townhouses” (Sewanee – The University of the South). This development destroyed a relatively small amount of forest cover but has allowed for the construction of a large number of centrally located homes. These centrally located homes will also reduce the amount of carbon released by Sewanee residents since their homes are located within easy walking distance of the central business district. More such developments are needed to both reduce sprawl and forest cover loss. Another step the University could take would be to redevelop areas which already have housing. There are some areas of Sewanee comprised of old, low density housing which could easily be redeveloped into nicer, high density housing.

If plans for Wiggins Creek 3 are carried out, there are several policies the school could implement to reduce the new neighborhood’s effects on the Domain. The first and easiest solution is to make the Wiggins Creek neighborhoods more pedestrian friendly. The lack of a sidewalk or bike path greatly discourages pedestrian travel between the neighborhood and central campus. They also should do their best to reduce the amount of greenery which is lost in the construction of both the streets for the neighborhood and the homes themselves. Another important step the University could take would be to limit or ban the use of certain fertilizers and pesticides which might be harmful to the surrounding ecosystem and the ecosystems downstream.

Due to the shortage of water atop the Plateau that has become more apparent in recent years, it the university could place a limit on the amount of water which can be used to water lawns. This would reduce the amount of runoff and conserve on water. Another important step would be to monitor and control which herbaceous species are planted in the new neighborhood. By knowing which species are planted in the neighborhood, it will help in control invasive species which might be detrimental to native species.
Chapter II: Roads
Sam Koebly and Sierra Hayes

Introduction

Urban sprawl and societal demands for logging and clearcutting in the United States have caused one of the most radical changes to the landscape in the past century: the development and extension of road infrastructure. Ranging from paved interstate highways to dirt roads, roads affect the ecosystem and cause habitat fragmentation. When undisturbed forest habitats are fragmented by roads, it changes the landscape into a patchwork of widely dispersed sections. These sections are often isolated from one another by degraded landscape, and their edges experience an altered set of conditions. As a result of these conditions, habitat fragmentation associated with roads is now being recognized as a serious threat to biodiversity (Primack, 2006). The edge habitat created by roads is unique from natural edges. Edges created naturally over time regenerate vegetation and become less defined. Road edges however, tend to exist long-term and be disturbed more frequently.

Without roads, many forest locations would be inaccessible. In the past, roads in the Southern Appalachians were useful to land managers, extractive industries, and developers for acquiring timber. They were also used for accessing minerals and establishing towns. Now roads are more useful as routes for the general public to recreational sites, hiking grounds, towns and neighborhoods, and educational sites for research on the domain.

There are many roads on the Sewanee Domain, which are necessary to sustain the University and its community. Included among these are the firelanes that cut across undeveloped areas. These access roads have significant affects on Sewanee’s biodiversity; impacts that will only compound if road infrastructure is expanded.

Threat to Biodiversity

When roads fragment forested habitats they have both indirect and direct effects on a wide range of species and alter ecosystem dynamics (Bennett, 1991). Road construction marks the beginning of an ongoing cycle of ecological damage to abiotic and biotic conditions of any ecosystem in which it is present. Road construction alters the quality of the soil underneath and adjacent to the road, and increases soil compaction up to 200 times relative to undisturbed sites (Riley 1984). This threatens the survival of organisms that are not directly killed. Road construction also negatively affects the hydrology of the landscape. Accumulating high concentrations of sediment, minerals and other materials from road concentration can directly kill aquatic life and impair productivity (Newcombe & Jensen 1996).

Road construction displaces and kills plants and slow moving animals in its path. Once the road infrastructure is established permanently, it facilitates even more ecological damage. This damage includes animal mortality through vehicle collisions, modification of animal behavior, the spread of exotic species, and the increased contact with humans and human land use activities.
Roads directly impair organisms’ productivity by affecting the movement and causing mortality of animals ranging from amphibians to large carnivores (Forman & Alexander, 1998; Trombulak & Frissell 2000.) Vertebrates suffer more from road related mortality than hunting (Forman & Alexander 1998).

Roads have indirectly affected plants and animals by altering the abundance and richness of soil fauna. Macroinvertebrates are an important component of soil nutrient and energy processing abilities because they breakdown leaf litter and make the nutrients accessible to plants (Coleman & Crossely 1996). In addition, macroinvertebrates serve as a food source for many vertebrates, especially birds and amphibians. Changes in the abundance of soil fauna affect nutrient availability and the distribution of organisms. Traffic affects plant communities by spreading dust onto nearby plants, inhibiting photosynthesis, respiration, and transpiration (Farmer 1993).

Animal and plant populations are affected by roads which completely destroy ecosystems. For some species—particularly small animals with highly specialized habitats—the destruction of small areas of habitat can be ruinous. Roads also create edges which facilitate in the spread of exotic species. The plants and animals that utilize roads for movement are often habitat generalists, a category many invasive species fit into. These species thrive and spread in highly variable ecological conditions such as those at roadsides (Forman and Alexander 1998).

The magnitude of the effect of development varies and is dependent upon the location of the organism in relation to the road. Specific habitats that are affected are forested habitats on the Cumberland Plateau and Southern Appalachian region. Roads and road construction activities are major sources of sediment that can affect the water quality of nearby marine ecosystems (Kochendefer et al. 1997; Nowlis et al., 1997). Roads can serve as conduits for exotic edge-adapted species (Rich et al. 1994; Gates & Evans, 1998), and road traffic can be a primary source of mortality for native fauna (Drews 1995; Noss et al., 1996). Roads also reduce the depth of the leaf-litter layer. A change or decrease in soil fauna has been shown to have detrimental effects on the ability of the soil to process nutrients and energy. This, in turn, affects abundance and distribution of other organisms (Haskell et al., 2000). Roads disrupt the function of forest by fragmenting organism populations through mortality and modification of animal behavior.

As in the rest of the world, habitat fragmentation associated with roads is prevalent on the Cumberland Plateau Landscape due to the expansion of human population and human activities. Although roads provide human access to previously inaccessible locations they are major ecological threats that cause habitat fragmentation of areas within the path of the road, pollution of bodies of water with displaced sediment and construction material, and habitat loss for organisms that live at the construction site. Multiple negative outcomes may arise, from the overpopulation of a species, to its complete eradication. Habitat fragmentation associated with roads also creates edge habitat and promotes the colonization of invasive species. Research suggests that the colonization of exotics can be exacerbated by the increase in nitrogen and CO2 concentrations, components of global change. (Dukes et al., 1999).

**Assessment of Threat**

Nature organizations, researchers, and authorities conduct and analyze case studies to assess the impact of fragmentation. However, the general public assesses the impact of fragmentation by
reacting to the steadily growing number of animal casualties on roads. Impact studies in several countries have underlined the consequences for constructing transport infrastructure on biodiversity. Those consequences include: traffic mortality, habitat loss and degradation, pollution, altered microclimate, and hydrological conditions, and disturbance caused by increased human activity in adjacent areas. Other groups have delineated different categories. These categories include: measuring the physical loss of wildlife habitat due to road cover, determining the impact of species movement and probable isolation due to fragmentation (Barrier effect), utilizing road kill counts to assess the affect of traffic on wildlife, disturbance and pollution, and the ecological function of verges as a resource for wildlife. Modifying human land use projects regarding settlement and industrial development should be considered when assessing human ecological damage on undisturbed wildlife habitats.

In order for the University to successfully manage the effects of roads on biodiversity, an assessment of Domain roads in particular is necessary. There are a variety of ways to do this. Walking and driving surveys may be conducted to quantify direct mortality of species associated with vehicle collisions. This may help to identify parcels of particularly high species diversity or species activity (Langen et al., 2007). There are options for assessing the status of ecosystem functions, including the hydrogeomorphic method as used by the Corps of Engineers and the habitat evaluation process as used by the U.S. Fish and Wildlife Service. In addition, the use of GIS can be extremely helpful in identifying areas of key concern on the Domain. The Florida Department of Transportation, for example, developed an outline for ecological questions that must be addressed before any new roads are constructed (National Research Council, 2005). This would be of great value as a reference for future University decisions.

**Recommendations for Action**

The 2003 Domain Management Plan stated as one of its top priorities that the University will begin to apply timber harvesting to the Domain in an effort to provide a good, sustainable example of land management. As a component of this statement, the University has stated that no new roads will be constructed for the purpose of timber harvesting. The plan also expresses concern over the future of Breakfield Road and the potential it has to be paved.

The University’s policy regarding road construction can be monitored very simply. It would be difficult for new roads to be built without raising public awareness. The duty to prevent further construction falls upon those concerned with the biological integrity of the ecosystems threatened by such activity. It would be helpful to conduct a survey of the habitat surrounding University roads so that effective monitoring projects may be conducted.

Since ecologists study and witness first-hand the impact of transportation infrastructure on the landscape, I believe they should play a vital role in promoting public awareness and governmental concern for habitat degradation. Ecologists as well as all other scientists that conduct research on the effects of roads on the environment need to communicate with policy makers to make the most significant findings of their research accessible and comprehensible for the general public. Also road-planners and engineers need to develop adequate tools for the assessment, prevention and mitigation of the impacts of infrastructure. Since Europe has made significant progress in addressing the environmental threat of roads, it would be logical for the United States to follow their model of the Infra Eco Network Europe (IENE) and adapt future infrastructure projects, such as overpasses and underpasses, to be more suitable for wildlife. Once these structures are built, they need to be monitored to check for the effectiveness of the mechanism. This practice will save money for future
developments, for if the project is unsuccessful, road developers will avoid making the same mistake.

Chapter III: Dams
Mary Matthews

Introduction

Many dams have been created on the domain and in the region to create water reservoirs and ponds for controlling erosion, irrigating crops, watering cattle, and recreation. Dams are a threat to biodiversity because they alter stream habitats directly by changing the water flow, and indirectly through chemical leaching producing yellow boy. Dams, however, have created new habitats that allow for a diversity of different species, including beavers, fish, and aquatic plants.

Throughout the 1900s the university created many dams on the domain. The department of forestry created an earthen dam on university farm in 1953, a dam enlargement on Lake O'Donnell in 1958, a dam creating Lake Jackson in 1968, and one for Lake Dimmick in 1971 (“2003 Management Plan” 17). These lakes were created for a variety of reasons, including drinking water reservoirs, recreation, and fire suppression. The 1966 university management planned called for using lakes for recreational purposes. The most recent plan, published in 2003, proposes that the university “identify which reservoirs are worth maintaining as these earthen dams start to fail, allow for weakened dams to fail, and allow natural vegetation to reclaim sites” (“2003 Management Plan”4).

There are many values associated with this threat. Impeding naturally flowing streams results in a loss of biodiversity; however, dams create lakes, which also have biodiversity values. For example, salamanders are threatened by the impediment of streams, but beavers benefit from lakes. The university, with the goal of education, benefits from both the existence of dams and the existence of naturally flowing streams. Life support values are also important because dams are used to provide drinking water to the community. While there are biological and educational values in the presence of behaviors, they can be a menace to the smooth functioning of water provision to the community. Amenity values also play a large role in this threat. Many stakeholders are in support of lakes for their aesthetic beauty; however, the aesthetic beauty of downriver habitats is destroyed.

Threat to Biodiversity

Many species are affected by the loss of naturally flowing stream habitat. They include stream dependent species such as salamanders, mayflies, dragonflies, caddisflies (Tanuma). On the other hand, many species on the domain benefit from lakes. For example, the Bass (Micropterus dolomieni), Brim (Lepomis macrochilus), Carp (Ctenopharyngodon Idellus), Blacknose Dace (Rhinichthys atratus) inhabit Farm Pond, Running Knob Hallow Lake, Lake Torian, Lake Audubon, and Lake Cheston on the domain (Burgette et al). There are also many beavers in Lake Dimmick and a recent appearance of beavers in Lake Cheston.
Because of the yellow boy effect, dams negatively affect population sizes of chemically sensitive organisms. Free-flowing streams on the domain have a higher abundance and species richness of salamanders. Population sizes are also reduced because of water deprivation (Bergette et al). Meanwhile, beaver population increase when there is more available habitat. Habitat loss caused by dams may cut off salamander populations from each other, thereby decreasing the genetic pool and diversity within the population.

At the site of the dam, the natural habitat is transformed into a lake. In the stream itself, the flow rates, oxygen levels, temperatures and level of phytoplankton are altered. The chemical make up of the stream is affected by the water boy affect in which the “harder” water molecules laden with metals like iron, arsenic, and zinc accumulate towards the bottom of the impounded body of water.

The species composition of these habitats is greatly affected by dam building. Fish and beavers now live where native fauna used to exist and is no longer supported. In the streams, the diversity of species decreases where water is dammed. The structure and function of these habitats is greatly altered by dams. Aquatic habitats can no longer function as free-flowing streams. The man-made reservoirs will not function in the same way as the natural landscape nor as a natural lake. The composition, structure and function of terrestrial habitats downstream are also affected by a dumping of sediment that erodes from stream banks that were once covered in water (Tanuma).

The Effect of Beavers

The presence of beavers on the domain is a major consequence of dams. Although they may have once inhabited the domain to some degree, man-made dams have created a habitat in which beavers can expand their abundance. Like other species, such as the red spotted newt, which existed on the domain in other habitats, their population sizes have increased due to disturbances imposed by human activity.

Beavers, as ecological engineers, can have a large effect on their habitat. They kill living trees to for dams, creating ponds which can modify the nutrient cycle, degrade the riparian habitat of a stream, and affect the abundance and composition of species. The extent to which beavers will transform a habitat, however, depends on the population’s size and distribution (Lawton 372).

If the university considers eliminating beavers from the domain, it would be important to study the effect of such an action. Because beavers are a keystone species, their removal can have a cascading effect on the entire ecosystem. Although beavers are not the only engineers of the aquatic habitats in which they live on the domain (the lakes are man-made), this could apply especially in areas on the plateau where beavers have populated streams. (Lawton 373).

Invasive Aquatic Plants
Another consequence of dams is the intrusion of exotic plant species on the domain. The only natural bodies of water on the Domain are vernal pools, in which aquatic plants and many other organisms are unable to survive year round. If only these ephemeral ponds existed, many invasive plant species on the domain would not have been able to establish populations. However, in light of approximately 16 manmade lakes that exist on the domain, invasive aquatic plant species have a habitat in which they can thrive. Four plant species have been classified as potentially harmful established populations on the domain: *Myriophyllum aquaticum* (Parrot feather), *Myriophyllum spicatum* (Eurasian water-milfoil), *Polygonum caespitosum* (Oriental lady’s thumb), and *Brasenia schereberi* (watershield). While invasive species can potentially harm native aquatic plant populations on the domain, they provide research opportunity for students and would not exist without manmade dams (Kate Cummings “Invasive Aquatic Plants”).

**Assessment of Threat**

There are both benefits and disadvantages to the presence of dams on the domain. On the one hand, dams impede the flow of streams on the domain that support biologically valuable populations such as salamanders. On the other hand, dams allow for the existence of reservoirs, necessary to support the drinking water intake of the community, recreation, and educationally valuable habitat and species interactions important for student study and research. The presence of dams creates a habitat for beavers, which themselves have both disadvantages and advantages. They threaten the effectiveness of reservoirs for drinking water, but they are also an interesting species to be studied.

**Recommendations for Action**

Outside of the domain, many ways for deconstructing dams while minimizing ecological impact have been studied. Dealing with sedimentation and temporary diversion of water are two factors that should be well planned before deconstruction. Like the 2003 Management Plan recommends, the university should allow for failing dams to deconstruct and allow the natural vegetation to reclaim the land. This will allow for the restoration of some natural watersheds on the domain and species dependent on them.

However dams that are still well functioning should be kept intact, and the university should expect future upkeep and maintenance on dams that provide critical drinking water and a high frequency of recreational use (such as Lake Dimmick for crew practice and SOP activities, and Lake Cheston because of its proximity to central campus).

The current plan to only allow dams that fail on their own to be deconstructed is not necessarily the best. Although it is a good starting point, it would be best to evaluate the benefits and disadvantages of each dam on the domain, and look at all the dams on a broader scale to decide how many provide a viable number for research opportunity and needs for drinking water and recreation.

**Beavers**

The current policy of the domain is to shoot beavers when they are seen on Lake Dimmick or Lake Cheston. Although it is important to keep the beaver population low enough that it will not overwhelm the functioning capacity of our drinking reservoirs, the university should acknowledge their educational value. If they are not causing excessive problems, they provide an interesting sight for anyone in the community to see. Also, they can be studied for biological research projects.
Although beavers are not natural to the local environment, they are spreading across Middle
Tennessee. By allowing a limited population to remain on the domain, beavers could take
unforeseen action, which in some cases can be good. For example, on Crow Creek between
Sewanee and Sherwood, beaver dams are restoring the stream after the effects of channelization in
the 1960s (Smith).

Conserving beavers can often lead to problems of conflict with man and destruction of
natural habitats. In response, the Netherlands Institute of Ecology suggests that ideal conservation
would involve restoring natural riparian wood habitat and natural aquatic environments (Nolet and
Rosell 165). Although this is not necessarily a concern of the domain, it is important to note that if
beaver populations became too large, there would be more conflict with people on the domain.
Therefore, it is important to establish a desired population size at which to maintain beavers on the
domain. I recommend that the University draw up a plan for conflict resolution before beavers
become such a problem.

Chapter IV: Powerline Corridors and Biodiversity

Nathan Bourne

Introduction

When added to a landscape, powerline cuts create cleared, linear corridors
in what would otherwise be contiguous forest. These long linear cuts serve to
fragment habitat in a uniform way, creating large amounts of edge habitat
and unnatural clearings. These power lines require the ground below to be
devoid of tall vegetation, leading to the
regular and repeated clearing using
either herbicides or mowing. The edge
habitat and cleared land within these
areas, both on the Domain and
elsewhere, serve to enhance as well as
threaten biodiversity. Different sets of
organisms with different responses to
varied habitats and corridors respond
differently to these habitat alterations.
A number of groups of native species
thrive in these anthropogenic habitats,
whereas populations of other native
species are inhibited by the
fragmentation of the landscape. Many exotic species respond well to corridors and artificial edge habitats.

As the domain is a location for houses and buildings with all the modern amenities, power-line cuts have been necessary to supply the community with electricity. The major power-line cuts extend from the bottom of the plateau up to the top, where they meet up with urban areas and branch off into smaller cuts. The corridors as well as the lines are managed by the TVA, the Sewanee utility district, and the Duck River Electric Corporation. The TVA and Duck River are in control of the major lines reaching up to the plateau, and the utility district maintains the smaller ones. Management strategies by the corporations have evolved over time, moving from indiscriminate mowing and cutting along with inordinate herbicide use to more sustainable practices. As have many utility companies across the country, both the Duck River and the TVA have adopted policies of Integrated Vegetation Management (IVM), a policy that advocates the use of integrated mowing, cutting, and herbicide policies in maintaining rights-of-way (TVA 2003; Brush Back 9). These IVM programs do, however, make herbicides their primary method of management, a fact that many on the domain are opposed to. There have been objections raised from groups on the plateau against the use of herbicides to maintain utility corridors. What the IVM policies of the two organizations advocate is not the indiscriminate use of herbicide to kill all vegetation, but to treat individual trees or problem areas maintained, or if that is not possible then to turn to mowing or hand-cutting. Whether this is the case merely in policy and not practice should be one of the university’s focuses in analyzing the threat. The TVA has also expressed its commitment to the use of its rights-of-way for wildlife food and cover, emphasizing quail, turkey, deer, and other members of local fauna (Aspen Grove- Westhaven Transmission Lines VII). According to TVA documents, “TVA has been working with universities (such as Mississippi State University, University of Tennessee, Purdue University, and others), chemical companies, other utilities, and personnel of the U.S. Department of Transportation, U.S. Fish and Wildlife Service, and U.S. Forest Service to explore other means of dealing with problem vegetation” (TVA 2003) The TVA has consulted with these institutions on management strategies, and there is possibility for the University of the South to be included among these ranks.

While these corridors are on the Domain, the University’s control over them is limited by the fact that they are part of utility right-of-ways and are directly under the jurisdiction of the utility companies. The University has a limited control over these areas under the current system. Ultimately, the decisions made in regard to these edge-creating structures are always in the hands of the utility companies. The issues faced on the domain are the same one faced wherever power-lines bisect an ecosystem. Habitats are fragmented by these linear cuts, and management strategies are limited by the necessity of maintaining the clearings. The University is limited in its ability to directly manage these areas, but through positive interaction with the utility companies and initiative on the part of the University, agreements may be reached and opportunities may arise that protect the interests of all involved in the matter.

The utility companies are trying to find the most cost-effective way to place and manage their utilities in the form of the power-lines; the homeowners and others who need power have a specific set of demands for electricity and are removed from concerns of biodiversity; and there are the people for whom the preservation of biodiversity is the ultimate concern, outweighing matters of cost-efficiency and inconvenience. The dialogue on the Domain concerning this issue has often assumed these values to be exclusive. Those concerned with biodiversity have fought against the
utility companies’ use of pesticides which they have seen as a product of the companies’
preoccupation with cost-efficiency.

Threat to Biodiversity

These power-line corridors affect different groups of organisms both negatively and positively. Groups that are negatively affected are birds, reptiles, and some plants. A study performed by Anderson and Burgin (2002) showed a significant drop in the abundance of certain skink species within these edge habitats created by the powerline cuts. Another study performed on nesting bird species along corridors in East Tennessee (Kroodsma 1987) found that bird nesting site density significantly decreases along these edge habitats, and found no species to be dependent upon the presence of these artificial edges. Also regarding birds, it has been found that these distinct edges do not so much provide nesting sites and transitional zones, but represent a boundary in the ranges of individuals (Chasko and Gates 1982). These edge zones have also been attributed to lowering bird fledgling success (ibid.). Groups positively affected include many species of plants, butterflies, some reptiles and certain bird species. There have been studies performed on many different taxa in regarding their use of early successional corridors, a category into which most powerline clearings fit. It has been shown that many species of butterfly will move over much greater distances within these corridors than in the surrounding core forest (Haddad 1999). These types of findings are significant in revealing the positive implications that these corridors can have on habitat restricted species. The aforementioned study on skink populations (Anderson and Burgin 2002) also found that, while certain skink species experience a drop in abundance near powerline rights-of-way, other species within the same genus significantly increase in abundance in these habitats, a fact that elucidates the paradox of the powerlines. For every species that is negatively impacted by this disturbance, it seems that another is able to flourish because of it. On the domain, a number of plant species have been found only in these corridors.

For some populations, the corridor provides an area for easier movement across greater distances, allowing for increased breeding and an increase to population density. Pollinators of many plant species have been shown to move along these corridors more than in undisturbed forest (Townsend and Levy 2005). These corridors also often lead to increased success of populations of shade-intolerant, early successional plants, which include many opportunistic invasive species. While the corridors serve to facilitate movement of some species, for others they serve to divide populations, and deter movement. Many bird species are far less likely to cross gaps or clearings, and when they do, some are often killed by high voltage power lines (Bevanger 1995). This serves to divide populations of birds within the forest, as well as reduce numbers of individuals.

The fragmentation of habitat can divide populations and fragment gene flows, having an effect on the genetic diversity of a population. This fragmentation serves to benefit certain species while causing detriment to others depending on the species’ specific habitat needs. Many of the species positively affected by the fragmentation are exotic or invasive species, such as the red imported fire ant, which can have deleterious effects on native biodiversity by outcompeting other species (Stiles and Jones 1998). The species benefited also include a number of native species, such as a number of shade intolerant plants including black locust (Robinia pseudacacia) and white ash (Fraxinus Americana) (Luken et. al 1992).

While they can have impact on the population level, the majority of the impact of the power-line cuts comes at the community level. These cuts are linear, and are often made without discrimination
toward habitat type, and so many different terrestrial habitats are affected. While these cuts degrade the natural habitats, they create new habitats of their own. These habitats offer a drastically different set of conditions to the surrounding forest, which leads to unique floral communities. The communities that occupy these created habitats are often representative of early successional habitats that contrast sharply with the later successional surrounding forest. These habitats allow for predation, parasitism, and competition to threaten the flora and fauna of the interior forest, as well as allowing for the proliferation of damaging invasive species (Public Service Commission of Wisconsin 2009). Whenever extreme disturbance becomes part of a community, the competitive advantage naturally possessed by native species is often eliminated, which leads to a higher likelihood of invasive species becoming established within the community (Byers 2002). At the same time, however, within these areas unique habitat is created that allows for the growth of species which would be limited by light and nutrient constraints within an interior forest. It provides an artificial form of disturbance where natural forms such as fire once abounded.

These areas can give rise to invasive species which are often able to out-compete native species occupying a similar niche, moving the composition away from a predominantly native habitat to one dominated by invasive species. The habitats within the corridors, while containing many of the same species as the surrounding forest, are cut and maintained in a way that allows for unique communities more suited to open, high light environments to become established. The communities that develop in these cuts can become structurally monotonous depending on management techniques, allowing only for the success of early successional plants that are never allowed to grow high and the subsequent fauna that occupies these areas. The ecological function of these communities ends up being to either hinder or promote movement and dispersion of many different species. The communities created by these cuts more closely resemble other disturbance areas. Disturbance has been a long-standing element in forests such as those found on the Domain, especially on the plateau. Traditionally, these disturbances came in the form of fire, but as time has progressed and fire has been suppressed, these openings have come in differing forms, one of which is currently powerline rights-of-way.

These corridors are widespread in the areas they affect. Anywhere that has urban areas near forest has a forest habitat susceptible to being bisected by power-line cuts. These cuts result in the fragmentation and break in continuity of landscapes. An otherwise continuous forest can be divided by these cuts which not only affect the area directly beneath the lines, but also affect the structure of the surrounding forest through the creation of edges that would not be found naturally. These corridors allow for easy colonization of many invasive plants. If power-line cuts are treated with chemicals and herbicides, pollution can be a major issue if care is not taken in the application of these chemicals.

**Assessment of Threat**

The threat of power-line cuts is difficult to assess. As long as these corridors are maintained through sustainable methods, they can have both positive and negative effects on biodiversity. With this, it becomes necessary to evaluate the threat on a case by case basis, weighing the benefits versus the negative effects, and figuring out how those negative effects can be minimized. With effective management strategies, the negative consequences of these created habitats can be reduced and the positive effects such as the creation of new habitat with different abiotic and biotic features can be emphasized, providing new opportunities for biodiversity.
Recommendations for Action

The University is currently working with the TVA to try and ensure positive practices of management of right-of-way areas. This is essential to the maintenance of these areas in a way that will preserve the different values associated with the issue. Strong proactive cooperation between the different entities in actively managing these areas in an informed way is essential in attempting to provide the maximal benefit to biodiversity in these areas.

New Policies

Continue to work with the TVA and other utility companies to ensure that the maintenance of power-line cuts is performed in a way that has minimal impact on biotic communities. As these corridors are on the University’s property and have affects on the flora and the fauna of the Domain, the University must play a more active role in managing these sites. The University should not merely react to independent TVA decisions, but should work with the utility companies in a proactive way, establishing the means by which these areas are to be managed and clearly outlining what goals they are to be managed for.

One of the most important strategies for approaching this threat to biodiversity is the analysis of how the IVM strategies of maintaining corridors are being implemented, if they are at all. While both utility companies make claims and have policies demanding ecosystem management within these areas that preserves habitat for native flora and fauna, this claim needs to be tested, and the actual implementation of the strategies need to be analyzed. Part of IVM is to respond to the specific needs of each right-of-way, best ensuring the compliance of the corridors with laws regarding the power lines as well as preserving valuable habitat. Whether or not this is the case on the domain will need to be researched, and then suggestions should be made accordingly. Methods of management that could bolster the methods already being implemented by both companies could also be explored. The threat of these corridors is something very real, but is also a threat easily minimized. It will just take some oversight and pressure from the part of the university to get the utility companies to manage the right-of-way properties in such a way that the most benefit is to be had for a variety of species.

The University needs to explicitly lay out its goals in the management of these areas while respecting the needs of the Utility companies. The University is an educational institution, and so learning opportunities should be the foremost objective. Coming after this is the role of the Domain as a preserve for biodiversity. Taking these two sets of values in mind, the objective of the University in the maintenance of these areas needs to be the maximization of benefit to biodiversity within these areas rather than paying attention to specific species. These corridors present a unique habitat, and should be treated as such. It is inevitable that these clearings will exist and will have a composition drastically different than that of the surrounding forest, and so they should be maintained as such and utilized in terms of this uniqueness. Some of the specific goals which the university should be managing for include:

- Promote a unique floral habitat paralleling that found previously in naturally disturbed areas
- Protect habitats necessary for the movement, distribution, and reproduction of animals
- Minimize edge effects
• Control invasive species  
• Utilize the habitat for unique education opportunities

The TVA has shown a willingness to involve universities and other institutions in creating new, innovative ways to manage these rights-of-way regarding specific environmental needs (TVA 2003), which means that it will be the University of the South’s job to create a specific management plan to proactively work towards the maintenance and management of these areas. Duck River Electric has also demonstrated a commitment to management strategies that support biodiversity, which should translate into a willingness to work with the university in an attempt to achieve these ends (Brush Back 2008).

Active Management

While much of what needs to be done in regard to controlling this threat on the Domain demands preliminary assessment and information regarding each of the specific habitats created by each of the major powerline cuts, the removal of invasive species provides a necessary management goal to work towards. The removal of these invasive species from these zones will provide an opportunity for a diverse set of native plants to occupy these zones, and has the potential to tip the balance of the effects of the rights-of-way towards the positive. Invasive species stifle the diverse plant communities which could spring up in these clearings by tying up sunlight and nutrients (Public Service Commission of Wisconsin 2009). While it is tedious and difficult to eradicate invasives entirely, it will provide an opportunity to witness the development of a flora distinct from that of the surrounding forest and to study succession within a natural ecosystem. The issue of invasive species is one that will require the cooperation of the university and the utility companies, as it is the utility companies who have the resources to execute the removal of the invasive species, though it may not make as much economic sense for them to do so.

One of the major goals regarding this threat needs to be the creation of a comprehensive management plan. The University needs to explicitly lay out how it would like powerlines on the domain managed in relation to the values it finds to be most important. The model that has been proposed by various utility companies regarding their Integrated Vegetation Management Plan could potentially provide a firm basis for this analysis. As it has been laid out by these other organizations (FortisBC 2005) the steps for developing a successful IVM are:

• Gathering information on a tree and shrub inventory  
• Deciding how often active management will take place and what methods would be used  
• The development of long and short-term plans  
• The preparation of cost and budget estimates  
• Directing and controlling fieldwork  
• Evaluating the overall process

The university could play a valuable role in assisting the TVA in all of these steps, ensuring that each step caters to needs unique to the university. This approach also affords great education opportunities for students who might have interest in ecosystem management, as well as allows for a comprehensive management plan to be generated and to guide decisions in the future.
It will be necessary for continued and sustained monitoring of these locations over time in order to evaluate how management strategies are serving the goals established by the university. To monitor for success, it will be necessary to ascertain a better understanding of what species occupy these zones, which demands inventories to be taken of the flora and the fauna and changes over time to be tracked. The monitoring for success will provide repeated study opportunities for students interested in changes in such a habitat.

Chapter V: Past Pine Plantations on the Domain
Rikki Crowder

Introduction

Many of the native hardwood forests of the Cumberland Plateau have been converted to pine plantations. Huge, homogeneous tracts of fast-growing Loblolly pine were planted to be logged and sold to timber companies. The native Oak-Hickory plateau forest matrix traditionally dominates the communities of the plateaus, and the replacement of them has serious consequences for species ecologically dependent upon these habitats.

There is a long history of logging and timber plantations in the Southeastern United States. There has been a relatively recent adoption of the method of making large-scale intensively managed pine plantations (largely Loblolly). In 2000, 26,592 hectares of native forest cover had been lost. 74% of this was for Loblolly pine plantations (McGrath et al. 2004). The government’s assessments consider these types of plantations to be “forest”. However, they don’t have nearly the same biodiversity value as hardwood forests. Even partially-forested areas that are human-inhabited have higher biodiversity values. (Haskell et al. 2006)

There have been pine plantations and logging on the Domain in the past. It has largely been abandoned in recent years. However, there are still many nearly uniform (in tree age, composition, structure, etc.) stands of pines in various areas of the domain. There are also no actual sanctions against future plantations on university lands.

For many years, privately owned land on the Cumberland Plateau was being converted at an alarming rate from native hardwood to pine plantations. (McGrath et al. 2004) However, in 2004 a group of Sewanee professors had their report “Mapping Land-Use Change and Monitoring the Impacts of Hardwood-to-Pine Conversion on the Southern Cumberland Plateau in Tennessee” published. This report tracked the effects and distribution of pine conversion on the plateau, and served to alert the region of the detrimental effects of the practice. Today, many logging companies have pulled out of the region and there has been a slow regeneration of native hardwood habitat.

There are definite economic incentives for pine plantations. Landowners are given tax benefits to convert their land to agricultural or timber use. This is meant to encourage them to not develop or sell their land to large corporations. Furthermore, in 2000 only 43% of the land in this region was owned by individuals giving local addresses. There is also the considerable economic
benefit of selling timber (McGrath et al. 2004). In contrast to slow-growing native hardwood forests, pine plantations mature quickly, offering a fast and profitable turnaround.

**Threat to Biodiversity**

Nearly every type of organism that dwells in forested habitats is affected by pine conversion (McGrath et al. 2004; Haskell et al. 2006; Estades et al. 1999; Drooz 1985; Wolters 1973; Paritsis et al. 2008). Additionally, these plantations facilitate massive habitat destruction by the Southern pine bark beetle. This is a native insect that lays its eggs in mature, stressed Loblolly, Shortleaf, Virginia, and Pitch pines. Ordinarily, this insect wouldn’t cause such catastrophic changes. However, these pine plantations are ideal breeding ground for them. These fast-breeding insects will quickly disperse into areas with native pines, destroying the adult individuals and devastating the natural habitats (Drooz 1985).

Stream macroinvertebrates are more abundant in areas that have been logged, but these streams had a lower Normalized Difference Benthic Index value. Disturbance, such as intensive logging, results in increased sediment in streams. This increased sediment made these streams an ideal habitat for a small minority of organisms to detriment of many others (McGrath et al. 2004).

During intensive site preparation for plantations, organic material is removed from the forest floor. This leads to increased nitrate pools and discrepancies in nitrogen distribution. It also results in leaching, denitrification, and increased erosion (Vitousek et al. 1985). Large calcium losses have been found in first-rotation pine plantations. The lack of calcium combined with a naturally nutrient poor plateau soil limits the regrowth of native hardwoods or second-rotation pines (McGrath et al. 2004). Furthermore, the amount of herbaceous ground cover decreases as a function of increasing pine basal area in a stand. In other words, pine density and herb density are negatively correlated (Wolters 1973).

Invertebrates that are less mobile than other taxa are negatively affected by a poor composition of habitat. It is much harder for them to find food in an area that is largely made up of plant species they can’t utilize (Paritsis 2008).

The native Oak-Hickory forests are critical neotropical migratory bird habitat. The acorn mast they provide is an important food resource for many plateau mammals such as squirrels and deer. These plateau forests also have one of the highest herpetofaunal diversities in the world (McGrath et al. 2004). Because of this, pine plantations don’t support the same biological diversity as native hardwoods or even human-populated areas (Haskell et al. 2006). The homogeneity of age structure in plantations excludes stratification and prevents openings from forming by the death of older trees. This results in fewer cavities for cavity-nesting birds. There is also extremely simplified vertical and horizontal structure from removal of understory and planting of one age of one species of tree. Since the structural diversity of native forests provides many more ecological niches, they can support a much higher diversity of organisms (Haskell et al. 2006).

The uniformity of these stands leaves them very vulnerable to invasive species. In the case of the Southern pine bark beetle, a native species became destructive due to a fundamental change in the structure and composition of the forest (Drooz 1985). It is very likely that a similar event could occur with an exotic pest.
Assessment of Threat

These plantations are biologically less diverse than native hardwoods. This is causing decreased food availability for animals and a habitat structure which is significantly less useful for cover, mating, child-rearing, foraging, and other behaviors.

Recommendations for Action

There haven’t been any new pine plantations being planted in recent years, but there is no formal restriction on them. This report recommends a formal ban on creating new pine plantations for the purpose of preserving native hardwood forests.

A possible option could be to log the remaining plantations and then restore them to native hardwood forests via planting, selective removal, etc. The soil in these areas is likely depleted, so the native plants may not grow properly. It would be very difficult to regain the complexity of the original forest through replanting. It would also be very time consuming and expensive; however, it would be a valuable educational tool to show restoration processes and succession, as well as illustrating the impossibility of perfectly replicating a natural system. Future studies could be done comparing the plantation sites for species diversity, richness, etc. before restoration and at a later time when the forest has had time to regenerate.

Chapter VI: Fire Suppression

Ben Pursell

Introduction

Wildland fires are an important natural process that have maintained and sustained many different ecosystems. This disturbance, while beneficial to many species, has slowly been eradicated from much of the United States in response to its conflict with anthropogenic values. The National Parks Service, Bureau of Land Management, and the US Forest Service have created techniques used to reduce the amount of acres burned, but this policy is based upon the belief fire is not safe and it is not necessary (Pyne 1995). This is simply not the
Fire is capable of cleansing an infertile system while enriching soil with nutrients. Suppressing natural fires has resulted in reduction of biodiversity on the Cumberland Plateau.

The Domain and surrounding region has undergone a series of fire management practices. About 5,000 years ago the forest of the Southeastern United States naturally transitioned from Spruce and Fir tree species to Oak and Pine. Around this same time Native Americans used low intensity but high frequency fires to control the land. When Europeans arrived in the area during the 1820s, there was evidence of fire impacted areas. The fact that oak savannahs and grassy glades were present showed fires had occurred, but the native natural fire regime was unclear and few estimates of how often fires burned in the area exists. During the 1930s and 1940s valley cattle grazers came to the top of the plateau for a source of vegetation and would light fires ensuring quality grazing the following season. By the 1950s roughly five percent of the domain burned each year due to arson or accidental lighting. The primary culprit for accidental lighting was embers from the Goat Track Railroad which ran near the domain. In response to the fear of serious fires, fire lanes were built in order for individuals to be able to escape. In the 1960s Sewanee and the US Forest Service planted pine and began managing areas for hardwoods such as oak. Active fire suppression was instrumental in the plan to protect these tree populations. Recently the practice of fire suppression has been lifted and control burns are taking place on two separate plots on the domain (Smith 2010).

**Threat to Biodiversity**

Fire suppression has led to disturbance resistance species to be overtaken by non-disturbance resistance species. Much of the Cumberland Plateau is composed of *Acer rubrum* (red maple), *Oxydendrum arboreum* (sourwood), and *Nyssa sylvatica* (blackgum) in the understory, and *Quercus* (oak) and *Carya* (hickory) species comprising the canopy. Fire suppression on the Cumberland Plateau and on the domain has led to *Quercus* species being replaced by *Acer* species. In this area, red oak species have declined at a more rapid rate than white oak species partially resulting from fire suppression on the Cumberland Plateau. Also, this has resulted in *Q. prinus* (Chestnut Oak) replacing *Q. coccinea* (Scarlet Oak) as the most abundant upland canopy species (Reid 2008). The goal of prescribed burning is to restore mixed hardwood and more fire resistant pine species along with native grasses to forest communities and ecosystems. Fire suppression has lead to denser canopy coverage which reduces light availability to the understory and also is associated with alteration of soil composition. Trees such as Short Leaf Pines and Virginia Pines as well as blueberry shrubs thrive in areas where burns have occurred. The removal of tree species allows for numerous grass species to grow in the disturbed areas (Smith 2010). Eastern White Pine (*Pinus strobus*) and loblolly pine (*Pinus taeda*), species that have spread rapidly across the domain, are late-successional fire sensitive species and their concentrations are greatly reduced with the implementation of prescribed burns. These burns are favorable for more fire tolerant pine species such as the *Pinus echinata* (Shortleaf Pine) and will hopefully lead to their reestablishment (Elliot and Vose 2005). Fire increases the ability of *Quercus* species to regenerate by limiting competition with other species and creating microsites (Reid 2008). Furthermore, *Quercus* and *Carya* species get too old and fall rather than burning resulting in non-oak hardwood species such as red maples, sassafras, sourwood, black gum trees establishing themselves. Certain areas on the domain which are considered to be fire needy have been taken over by non-oak hardwoods in the last sixty years. These areas are found on the western and southern edges of the Plateau portion of the domain. These areas are considered to be fire needy because they are typically drier. The reintroduction of fire on the domain primarily
effects soil composition by allowing nutrients to move back into the soil permitting greater plant
growth and the associated increase in biodiversity (Smith 2010).

It is very difficult to determine the effect of fire suppression on wildlife. Prescribed burning
in the early spring on the Cumberland Plateau has minimal impact on the community impact or
abundance of arthropods in the short term (Greenberg and Waldrop 2010). Also, prescribed burning
increases the amount of deer browse available in the years following the burn. So it is important to
note prescribed burns on the plateau could potentially lead to even greater deer populations on the
domain (Dills 1970). Bird species can be greatly reduced for at least two years following high
intensity burns, as there is a high correlation between the reduction of bird species and shrub height
(Fontaine 2008). Far more research on prescribed fires is based on plant biodiversity rather than
animal. The fact that animals are far more mobile makes studying them more difficult, and allows
them to more effectively resist immediate impacts of fire.

Assessment of Threat

Many species are dependent upon fires in order for reproduction and are also reliant upon
the nitrogen level increases in the soils associated with burns (Baker 1992). From earlier studies on
the Upper Cumberland Plateau, it is evident forest dynamics of the area are driven by availability of
resources in the soil (Reid 2008). It remains debatable whether reintroduction of fire on the domain
and Cumberland Plateau will result favorably in the success of creating a hardwood/savanna
ecosystem or if it would positively benefit biodiversity of the area. This anthropogenic stochastic
alteration of the land will result in changing the ecosystem in an unpredictable manner.

There remains a great deal of difficulty determining the natural balance since nature retains a
non-equilibrium dynamic. The debate over introduction of fire presents both ethical and scientific
challenges. But there does remain a great opportunity for documenting the rate of change resulting
from the disturbances. A comparison of biodiversity alterations over long periods of time between
prescribed burned areas and fire suppressed areas of similar biological makeup will provide critical
data. This information could be used understand managed disturbances and create quality predictive
models aiding future conservation efforts (Reid 2008). Before burning, we must be confident the
benefits of burning on certain sites outweigh the cost of further imposing man’s impact on the land.

Fires could have negative effects on humans. Large quantities of smoke and strong odors are
associated with burns and could upset members of the community. Even controlled burns have
detrimental effects on surrounding air quality. Making the community aware and maintaining
community participation will be beneficial for the project.

Recommendations for Action

Recently fire suppression has been lifted and controlled fires have been ignited. The two
sites of burning are Lake O'Donnell and Armfield Bluff. Just south of Lake O'Donnell an area exists
that has previously been selectively harvested and much of the white pine population has been
removed. Burning will only occur where selected trees have already been removed and the natural
landscape has recently been disrupted. The focus of the Lake O’Donnell site, which is a six acre
plot, is to encourage oak and hardwood regeneration. The primary objective for the Armfield Bluff
site, a 30 acre plot, is to create an oak, shortleaf pine, and savannah ecosystem similar to what might
have existed if fires were naturally allowed to burn in this area. This site was formerly a pine plantation dominated by the *Pinus taeda* species. Nearly all of these trees have been removed (Smith 2010).

Burning on low wind days at time when ground moisture is not too low is key to successful burns. Dr. Ken Smith believes many of the problems associated with uncontrolled burns can be avoided by using proper techniques and burning on days with winds around five miles per hour and on days where rain has fallen in the previous 48 hours (Smith 2010).

Much debate surrounds the subject of what frequency of burning is most practical for achieving the goals of increasing biodiversity and allowing for teaching opportunities for students. A study by Elliot and Vose reports low intensity fires performed infrequently, roughly 1 to 2 fires over a period of a decade, resulted in relatively small changes in tree regeneration patterns and minimal changes to forest understory. Conversely, annual burning led to suppression of understory brush and sapling growth along with reduction in over-story density allowing for a productive herbaceous layer (Elliot and Vose 2005). However, grass species seem to respond especially well to burning, which can increase grass diversity in an area (Tester 1989). The intensity of the fires also dictates the amount of change caused by fire. More intense burns or lower intensity burns coupled with forest thinning have been shown to have a greater effect on soil nutrient enrichment and composition of the landscape (Elliot and Vose 2005). Since the areas that will be burned on the domain have recently undergone selective harvesting, they have effectively already been thinned. This means lower intensity fires which are executed on an annual basis should suffice for reintroducing fire to the domain. Also, planting seedlings of desired tree species such as *Quercus* species and *Pinus enchinata* would aid in creating the desired hardwood/savanna ecosystem.

Dr. Ken Smith stated low intensity burns on both the Armfield Bluff site and the Lake O’Donnell site will occur every 1 1/2 to 2 years during spring over an indefinite period of time, but also said adjustments will be made depending on the response of the land. On certain sections of these burned sites Dr. Smith plans to plant native grass species including purple top grass, Indian grass, and blue stem grass. On some sections of the burned sites roughly 200 short leaf pines will also be planted. Oaks will not be planted, but instead will be allowed to naturally return to the area by seed dispersal. The burned site has been divided into certain sections and one plot of land will remain unplanted after the burn acting as the control for the site (Smith 2010).

The recommendation of this study is to continue the burning recently started by the Forestry and Biology Departments. It is essential to complete species and abundance inventories for all sites prior to burning. A goal for the project must be set forth prior to the initial burn as well. It is not sufficient to simply say the goal is a certain type of landscape but instead an ideal percentage of each species composing the landscape. This would allow for measurement of success. In order to obtain this objective, this study suggests we follow the model used in the Elliot and Vose study of prescribed fires in pine-hardwood forest. This study established a plot of land and found the initial percentage of each species of the plot and calculated the density and basal area for certain plots. This study also set aside certain areas for a control. After the burn and the years following the scientists then measured the same plots of land and counted the species of each tree, comparing the treated areas to controlled areas. This way the true effects on biodiversity in the area can be recognized (Elliot and Vose 2005). In any prescribed burn situation it is essential to reduce the additional disturbance on the plot of land. For this reason burning in the spring when growth will occur
relatively rapidly which would reduce erosion is favorable. Also in order to increase the effectiveness of the study minimal soil disturbance is coveted (Smith 2010). Burning on all sites should occur at least once every five years and would ideally follow the 1 ½ to 2 year plan set forth by Dr. Ken Smith since numerous studies have reveled high frequency burns are essential in order to alter the site’s ecological composition.

After discussing the fire management scheme on the domain, it became evident there are numerous other areas that would benefit from the introduction of fire on the domain. There are certain sites off of Brakefield Road which were previously pine plantations and are now dominated by invasive species and would benefit from the implementation of prescribed burning (Evans 2010). This study also suggests the extension of burning to these areas pending the outcome of the two trial burn sites on the domain.
Conclusions Regarding Habitat Loss and Fragmentation

**Future Development and Sprawl**

- Choose areas that will reduce the total forest cover loss
- Reduce runoff with use of swales
- Use pervious parking surfaces
- Build smaller high-density centrally located housing units
- Limit water-use for lawns in Wiggins Creek
- Rules regarding fertilizers, pesticides, insecticides
- Make Wiggins creek more accessible to pedestrians and cyclists

**Roads**

- Limit future road construction on the domain
- Conduct a survey of the habitat surrounding University roads

**Dams**

- Allow natural deterioration of unneeded lakes
- Manage beaver population at number that will not overwhelm functioning capacity of dams
- Creation of a conflict resolution plan
- Creation of database, documenting characteristics of lakes on domain

**Powerline Corridors**

- Open and regular communication between TVA and University
- Removal of invasive species
- Experimentation with various methods
- Promoting a unique floral habitat paralleling that found previously in naturally disturbed areas
- Protecting habitats necessary for the movement, distribution, and reproduction of animals
- Minimizing edge effects
- Controlling invasive species
- Utilization of habitat for unique education opportunities

**Past Pine Plantations**

- A formal ban on creating pine plantations
- Could attempt to restore pine plantations to native hardwood forests

**Fire Suppression**

- Reintroduced fire to the domain this spring
- Lake O’Donnell and Armfield Bluff sites
- Stated goals are to create an oak and shortleaf pine savannah ecosystem and encourage oak and hardwood regeneration
- Recommend to continue low intensity burning on a 1 to 2 year basis in order to create desired ecosystem.
- Also should only burn on previously disturbed tracts of land.
- Creates learning opportunities for students and creates a more diverse landscape on the domain.
Deer Overpopulation
Chapter I: Deer Overpopulation
Dorsey Clarke, Bethany Moats, and Anneka Wisker

Introduction

Overexploitation of predator species has led to an increase in deer populations in many forests across the United States (Waller and Alverson 2004). Rising deer populations disrupt natural ecosystem functioning by placing a strain on resource availability throughout forests. Deer alter the landscape of the forest and interfere with the functioning of the ecosystem on a broad scale. Deer are herbivores; they consume the leaves, stems, seeds, and flowers of plants. When consumption rates become excessive due to extraordinary population increases of deer, ecological processes begin to malfunction (Maryland State Wildlife Website; Cote et al. 2004; Anderson 2001).

The overconsumption of seedlings, saplings, and flowering plants directly affects nutrient and carbon cycles and plant diversity of the forest’s understory. Over time, the diversity and abundance of trees in the overstory is reduced as well. These changes on the forest floor, intermediate canopy, and overstory have an effect on the small mammals, insects, and birds that reside in particular niches of the forest (Cote et al. 2004, Waller and Alverson 2004).

Land use decisions made by humans are the underlying cause of deer overpopulation on the Domain of the University of the South. In the mid-1900’s, deer numbers were artificially augmented in order to improve hunting conditions for local hunters (The University of the South 1966). At the same time, mountain lion populations that existed on the domain became completely eradicated due to development, overhunting, and fewer populations to prey upon (Evans and Moye 2006).

As a result of introduced deer populations and removal of their predators, deer began to thrive on the Domain. With this, land managers adjusted the natural environment to make it more suitable for hunting deer (The University of the South 1966). They constructed ponds, planted food on abandoned fields, and trapped any mountain lions that remained (Burckle and Smith 2003).

Over time, human populations living on the Domain grew as the University of the South increased enrollment. Safety became a priority over hunting, and so a hunting ban was enacted in the late 1900’s. The Domain then became a refuge for the deer, as areas surrounding the Domain continued to allow hunting (Mobley 1999). Later, when recreational uses of the forest began to outweigh hunting uses, a ban was placed on hunting in order to keep trails safe for hikers and horseback riders (Pate 2009, Burckle and Smith 2003).

With the acknowledgement that deer populations had reached excessive levels and were negatively impacting forest health, Domain managers implemented a deer cull in 2000. The hunt is controlled, consisting of bowhunting only, and occurs for roughly one month each winter. The goal of the cull is to reduce deer populations to a healthy level that will balance, instead of disrupt, the ecosystem (Burckle and Smith 2003). The cull has been minimally effective in reducing deer numbers, however, safety is the priority on campus and allowing bow hunting in the forests during the school year would endanger humans (Pate 2009).

Many values weigh into the equation when deciding how to manage deer populations. It is important to address whether proper management should be implemented to lower deer numbers or whether the deer
numbers may decrease over time due to malnourished populations. Many people value the lives of animals regardless of their effect on the environment. These people who disagree with hunting would be against killing individual deer, even if it meant betterment of the entire environment. Safety is also a concern. Hunting could endanger the lives of students, faculty, staff, or community members enjoying a hike in the forest.

**Threat to Biodiversity**

As these harvested areas obtain canopy closure, little browse material is produced and browsing pressure increases until deer seriously interfere with forest regeneration (Ford 1994). Today deer browse remains a serious issue, leading to a lack of cover, food, and structural diversity within forest communities. Deer browsing is more intense in woodlands in early spring than in summer, having a greater effect on plants that maximize their biomass production in the spring as opposed to later in the growing season (Anderson 2001). Additionally, deer browsing is significantly higher in clearcut and clearcut edge plots (Ford 1994). Browsing has been shown to cause a shift in plant species’ abundances and competitive abilities (Anderson 2001). Deer are dietary generalists; they affect a large variety of taxa, as they produce a tannin-binding protein in their saliva, which helps them adapt to many different food sources—especially in black walnut twigs and red oak acorns. Since deer often continue to browse the remaining vegetation after the most preferred items are eliminated from a site, it is possible for ecosystems to be seriously impacted and for many species to be lost before the deer population actually begins to show signs of malnutrition or reduction in herd size (Anderson 2001).

Studies have shown that deer cause changes in stem morphology and reductions in plant growth rates. In some community types, deer negatively affect the growth rate of tree seedlings and saplings, prevent adult recruitment into tree populations, and alter species composition (Russell 2001). Conclusive evidence for the negative effects on plant growth exists only for certain taxa and certain communities. Communities studied include mature and post timber harvest white pine-hemlock-northern hardwood forests and old fields. For these communities, results have been consistent in stating that deer do have a general negative effect on plant and tree growth. In one of two fields studied in Pennsylvania, it was found that deer significantly reduced proportional rates of increase in height of *Quercus rubra* and *Pinus strobus* seedlings.

Deer prefer feeding in disturbed and early successional forest communities (Russell 2001), causing a decrease in regeneration in these communities. It has also been proven that deer flourish in presence of habitat fragmentation (Anderson 2001). Deer populations respond simply and directly to the increased forage resulting from reduction in deer numbers and increased timber harvest, especially clearcutting. Clearcutting exposes the site to increased temperatures and reduces moisture—greatly encouraging regrowth (Ford 1994).

The abrupt increase in sunlight and surge of sprout growth following clearcutting greatly increases the production of browse important to deer during the growing season. Within clearcuts, deer affect highly preferred browse species such as yellow poplar and blackgum which are the most nutritious during the growing season. Newly regenerated timber harvest areas such as clearcuts provide herbaceous forage and highly preferred browse of shade intolerant woody species which are not available to deer in significant amounts in closed canopy forests. A reduction in the acreage of clearcuts will only result in available browse being more dispersed, which will further disperse the deer population (Ford 1994).
On the Domain there has been evidence of forest change due to deer browsing, including declines in the number of oaks. Because deer feed selectively, deer can affect the species diversity and species composition in both herbaceous and canopy layers in forest communities. Through both direct effects on juvenile trees and indirect effects of changes in the species composition of the herb layer, deer can slow the rate and alter the direction of succession in forests. Both experimental and comparative descriptive studies have shown that deer density is frequently and significantly correlated with the magnitude of deer effects on vegetation (Russell 2001).

If deer population density is high, the impact of browsing on woody species can be a major factor in diminishing tree and shrub recruitment of palatable species (Anderson 2001). Forest composition will not revert to its original stable state even if the deer are removed. In many cases it may be impossible to re-establish the original tree and plant community. Furthermore, wherever deer alter species composition of a plant community, a corresponding effect upon ecosystem properties and processes, such as size of nutrient pools in the soil, rate of nutrient cycling, or primary productivity may occur (Russell 2001). As deer browsing increases, there is an increase in abundance of understory species that are least browsed. This abundance can become a problem as some of these understory species can become invasive (Anderson 2001).

During the growing season, the leaves of woody plants dominate the deer diet. This consumption of plant matter negatively affects species richness of regenerating woody species (Russell 2001). Both herbaceous and woody plants may be able to partially or fully regrow tissue consumed by herbivores. Such compensatory growth may cause a reduction in both aboveground and belowground growth, ultimately compromising the individuals’ survival. It has been found that frequency of browsing is more important than its intensity in determining stem density, for tree death occurs most often as a result of cumulative effects of deer browsing. In addition to frequency, timing of deer browse is another important factor. Several studies suggest that the magnitude of deer effects on the rate of recruitment of adult trees can vary greatly on a landscape scale and that deer only prevent adult recruitment in sites with high deer densities, including deer yards and thinned or clear-cut patches in forests. Another common effect of deer on woody plant morphology is a “browse line” below which deer have removed stems and twigs of trees (Russell 2001); the average preferred browsing level by deer is below 1.5 m (Hughes 1991). Deer can cause up to a 75% reduction in the number of stems below the browse line (Russell 2001).

The most commonly reported effect of deer upon individual plants is a change in plant morphology following removal of the terminal meristem. There are also indications that deer can reduce growth rates of tree seedlings and saplings. The under-representation of saplings in some tree populations in communities where deer are abundant may reflect reductions in seedling survival as well as growth. In sites with high deer densities, deer can affect size distributions of populations of preferred browse species by preventing recruitment to sapling and small adult size classes. Many studies have documented fewer saplings and small adult trees outside exclosures than inside them. It is hard to differentiate whether observed changes are caused by reduced survival or growth and at which life-stage negative effects occur (Russell 2001). During a tree’s seedling and sapling life stages its entire aboveground biomass can be browsed, which is why research on effects of deer on tree survival has focused on these life stages. A study in southern Minnesota showed that the survival rate of *Quercus rubra* seedlings over two years was 3.2% for seedlings exposed to deer herbivory and 34.6% for seedlings protected from deer by tree shelters. In fact, under-representation of sapling size classes outside deer exclosures has been described for many forest tree species, including *Liriodendron tulipifera* and *Fagus grandifolia* in clear cuts in southern Appalachian cove forests. Exclosure experiments have demonstrated that deer can decrease tree regeneration; alter the dominant tree species in
the sapling layer leading to a change in the species composition of the canopy; and decrease species richness of tree seedlings, herbs and shrubs. In old growth hemlock-beech and hemlock forest in northwestern Pennsylvania, an increase in deer densities from near zero in the early 20th century to 7-19 deer/km² is correlated with 80.4% and 59% decreases in the number of understory herb and shrub species in hemlock-beech and hemlock forests, respectively (Russell 2001).

In a study done on the Domain quantifying deer browse levels on woody species in Dick Cove (Pendleton 1999), it was found that a higher level of deer browse is found within cove disturbance gaps than on the plateau. The plateau around Dick Cove consists of upland mixed hardwood forest inhabiting dry, shallow, sandy soils with less nutrient ability than found in lower slopes. The lower slopes and cove sites in Dick Cove consist of mixed mesophytic forest and are more productive and diverse because of a higher potential for storage of water and the increased nutrient availability found in the deeper, richer soils (Puckette 1996). Deer are large consumers of deciduous woody plant species (Ford 1994); and it has been found that seedlings of woody species are more abundant in gaps than in closed canopy forests (Rebertus 1997). Correspondingly, deer browse levels increase within clear cuts because there is a more concentrated source of forage as a result of new succulent growth (Johnson 1994). Furthermore, species associated with clear cuts generally have heavier twigs with higher protein and soluble carbohydrates for deer foraging potential (Hughes 1991). Gaps are more commonly found on the plateau, though when a gap is created in an old growth forest in the cove, the size of the gap is larger than on the plateau. This is because the plateau forests have a relative high frequency of disturbances. Higher light levels are found in larger gaps, the cove has deeper soils that are rich in clays therefore the soil has a higher concentration of nutrients and better water availability. This soil quality and water availability leads to the presence of more diverse species which deer prefer.

Deer browse, in addition to affecting woody plant communities, has been shown to have extremely negative effects on understory herbaceous communities (Anderson 1994, Knight 2004, Webster et al. 2005). These understory herbaceous species are characterized as species lacking woody stem, with leaves and stems that die down at the end of every growing season. These deleterious effects are typified by species such as white trillium (Trillium grandiflorum) and ginseng (Panax quinquefolius), which are often used as indicator species (Anderson 1994). While deer diet primarily consists of woody plants during the winter, the growth of spring flora coincides with a shift in diet such that the spring diet of deer is upwards of 75% herbaceous species (Webster et al. 2005).

White trillium shows an especially unique relationship to deer browse (Knight 2004) such that its density and morphological characteristics can be used as an indicator for deer browsing intensity in ecosystems (Anderson 1994). Studies of trilliums have shown that increased browsing results in shorter stem height as the larger individuals are consumed preferentially by deer. Also, trilliums are also affected by defoliation from browsing, as individuals may not reproduce for a season or more after the defoliation (Webster et al. 2005).

This intense browsing of the herbaceous plant species has serious genetic repercussions. The preferential browsing of larger, sexually mature plants (Webster et al. 2005) as well as the predation on fruit and seeds (Furedi et al. 2004) leads to a loss of genetic diversity. The loss of sexually mature plants in a population leads to severely impacted reproduction rates, as well as decreasing population genetic diversity (Ruhren et al. 2003); even in cases in which deer browse does not kill the individuals, the population may become dominated by small, nonreproductive plants.
The predation of fruits and seeds negatively impacts the ability of herbaceous species to contribute to their in-ground seed bank, as well as the population growth through reduced recruitment rates (Furedi et al. 2004). Although rarely seen in actual cases, several studies have been undertaken to discover the role of deer as seed dispersers. Even though they are more likely to be seed predators, researchers have found that they show a very limited ability to disperse seed by way of feces (Furedi et al. 2004, Vellend et al. 2003).

Deer browsing pressure changes the composition of understory species. Browsing pressure selects for species with defensive traits such as bitterness, thorns, and other browse-tolerant traits which allow species to recover quickly. These traits include hidden meristems, storing resources underground, or the ability to regrow quickly (Côté et al. 2004). Species with these traits increase in percent composition under browse pressures. Browse intolerant species, particularly those with long life cycles that are shade-tolerant and slow-growing, are particularly vulnerable to predation by deer and show a corresponding decrease in percent composition (Côté et al. 2004). These browse-intolerant plant species, in addition to experiencing decrease while under browse-pressure, have been shown to have a limited ability to recover once the browse-pressure has been lifted due to the unavailability of remaining individuals to recolonize the habitat (Webster et al. 2005). This indicates that the removal of browse pressure will result in the recovery of browse-tolerant species, and that recovery of browse-intolerant species may require active restoration efforts.

The overconsumption of plants by deer in a given land area negatively impacts vertebrate and invertebrate communities. Deer trigger a series of cascading effects by excessively consuming forest flowers, tree seedlings and saplings, and acorns to meet their high energy demands and sustain their large population sizes (Cote et al. 2004). Such an interaction occurs at multiple trophic levels, affecting a variety of species and altering regulatory ecosystem processes. These systems enable nutrients and energy to cycle through food webs and are imperative for species survival. When such functions are disrupted, interactions within an ecosystem begin to break down (McShea 2000).

Many scientific studies have been done across the United States to record and assess the damaging effects that deer overpopulation has on nearby animal communities. The effect deer have on the rest of the animal community is two-fold. Deer either directly compete with other animals for resources and habitat or they modify the forest in such a way that other animals living within the forest can no longer sustain themselves. Both effects result in a deer-dominated forest, which ultimately harms the remaining animal community.

When deer are in abundance, they modify forests in such a way that many insect communities can no longer function in their usual manner. By overconsuming flowering plants in the understory of the forest, deer demolish insect habitat and food sources. As a consequence of the effect of deer on canopy composition, less habitat and fewer resources are available to birds for nesting and foraging.

When deer overconsume flowering plants in the forest, they disrupt the interactions between plants and their insect pollinators (Cote et al. 2004). Key insect pollinators affected by deer are bees, butterflies, hummingbirds, moths, and wasps (Waller and Alverson 2004). Insect pollinators are necessary components of the pollination process, which enables plants to grow. The pollinators consume the pollen on one flower, and then transport it to another flower, which inadvertently instigates fertilization. It is important to note that pollination occurs as a byproduct of the insect pollinator acquiring its food source.
As deer consume all of the available food sources for the insect, which in this case would be all of the flowers on the forest floor, the insects leave the particular area because there is no pollen for them to feed on. With fewer pollinators, the rate of pollination drops and with that the forest floor is depleted of flowers. With fewer flowers on the forest floor, deer turn to another area with flowers to feed upon, potentially stripping an entire forest of flowering plants and insect pollinators (Cote et al. 2004).

Excessive rates of herbivory reduce spider web-site availability within a forest. A study was conducted in order to document the effect high consumption of plants by deer had on spider numbers, comparing forests with and without deer. The study showed that spider numbers and potential web-sites were lower in the forests where deer were present. The sites offer less available habitat for the spiders and consequentially make the area less livable (Miyashita 2004).

Being both foragers and nesters, songbirds are greatly affected by deer-induced habitat modification. When deer overgraze the landscape, they consume saplings and seedlings, which eventually causes a decrease of tree growth in the forest. When fewer trees make up the landscape of the forest, habitat options for songbirds lower along with that tree decline.

An investigation of the interrelatedness of dwindling songbird numbers and deer overabundance was completed by studying the effects of four different deer densities on the number of songbirds. After ten years of browse-pressure, songbird numbers were counted in the four different enclosures. When compared, the ground and upper canopy of the sites did not experience change; however, the intermediate canopy showed a progressive decline of songbirds throughout the four environments from lowest to highest deer densities (deCalesta 1994).

William McShea studied interactions between deer, squirrels, and mice when acorn availability was both high and low within the forests of Virginia using exclosure plots. The experiment compared high acorn mast years with low acorn mast years and the resulting impact each scenario had on deer, mice, and squirrels (McShea 2000). The study showed that squirrel and mice populations heavily concentrated within the exclosures during low mast years, demonstrating that they rely heavily on acorn resources. High mast years were different, however, and the exclosures contained low numbers of squirrels and mice when acorns could be found elsewhere in the forest (Cote et al. 2004).

The cascading effects of low acorn availability and declining populations of mice and squirrels have been studied and well documented by a number of researchers across the country. A study discussing competition for acorns on the forest floor concluded that fewer White Oak acorns are likely to become embedded into the soil and eventually grow into trees. Consequently, white oak tree regeneration rate will decrease (Anderson 2001), leading to lower acorn production in the future for consumption. With this decrease in acorn availability, competition for the crop will intensify.

Subsequently, lowering acorn availability within a forest affects bird numbers. Squirrels feed on acorns throughout the year, whether they have stowed them up for winter or immediately eat the acorns when they are found. Regardless, when there are no acorns available for squirrels to eat, squirrels must search for other resources within the forest. As acorn availability decreases, bird nest predation increases as squirrels turn to bird eggs as a food source (McShea 2000).
As previously stated, the decrease in acorn numbers could lead to a decline in mice populations (Waller and Alverson 2004). A study in Virginia shows that declining mice populations directly affected gypsy moth populations, which in turn influenced pine and hemlock productivity. Mice prey upon gypsy moths in eastern deciduous forests, regulating gypsy moth numbers. When mice populations decline, gypsy moth populations increase as a consequence. The increasing number of gypsy moths requires higher amounts of foliage on hemlock and pine trees for sustenance. Gypsy moth predation of hemlock and pine tree foliage leads to the decline of both tree species (McShea 2000).

Deer compete directly with each other for food resources across a landscape. When high densities of deer are concentrated in an area where only a limited amount of resources are available for consumption, deer suffer from both starvation and malnutrition. Since deer can be considered a keystone species in eastern deciduous forests across the eastern US (Waller and Alverson 2004), this off balance can serve as a warning sign that the entire ecosystem is suffering. Deer starving due to lack of food resources indicates that the forest floor is nearly barren of browseable plant life.

To further degrade already weak populations of deer, deer ticks carrying Lyme disease target weak populations of highly-concentrated deer (McShea 2000, Anderson 2001). As Lyme disease spreads across the deer community, the deer move away from one another and extend their range across the forest. With this sprawl, there is a greater chance for both humans and mammals to contract Lyme disease (McShea 2000).

Assessment of Threat

In terms of assessing the overall threat of deer to biodiversity on the Domain, there are a number of strategies. First and foremost, we must obtain a more accurate idea of how many deer actually exist on the Domain. One effective method would be to conduct aerial surveys, during the winter, utilizing infrared to locate the deer (NRC Inc 2007). Using the Domain data found regarding the current deer density, a deer density goal should be determined and serve as the basis for removal goals. Based on trillium height studies, the ideal sustainable deer density should be between 4 and 6 deer per square kilometer (Anderson 1994).

After assessing the deer population, we must find out exactly how they are affecting the biodiversity on the Domain. In terms of deer impact on plants and trees, the relationships between timber harvest and deer in terms of quantity, spatial distribution, and species composition of forages should be evaluated. Determining specific understory impact on the Domain can be accomplished through setting up paired exclosures and control plots, 4m x 4m x 2m is an example size, although the exact dimensions are flexible (Ruhren and Handel 2003, Webster et al. 2005).

Overall, proper assessment of the threat will include time, research, and money. Research to determine and quantify discrete variation in deer numbers on the Domain will be a vital part of the assessment process. This variation should be taken into account and can help determine proper management strategies. Further research will also require long term monitoring of plant communities to quantify effects on vegetation as accurately as possible. Once this research has been carried out through the various methods listed above, an accurate assessment can be made and management systems can be implemented.

While further research is undoubtedly needed, it is undeniable that there is a “deer problem” on the domain. Processes of assessment should not exclude management. Immediate action is needed alongside research.
Recommendations for Action

Current Actions – Not Recommended

The current Sewanee deer cull was initiated in 2000, consisting of light archery deer culling preceded by a pre-cull archery hunt (SMM 2008, SMM 2009). This method is not recommended as there is no evidence that archery hunting can successfully reduce deer populations to a sustainable level. Archery hunting, while often practiced by very skilled hunters, is inherently less efficient than firearm hunting, requiring the hunter to be closer to the deer in order to make a kill, while the extended reload time in relation to firearms reduces the ability to make more than one kill when presented with a group of deer. Not only are individual deer less vulnerable to archery hunting, but herds and populations of deer are more likely to learn to avoid hunters. This taught avoidance will make their removal by successive days of the deer cull more difficult, expensive, and time consuming (NRC Inc 2007).

Mitigation Techniques – Not Recommended

Mitigation techniques included supplemental feeding and fencing. These techniques do not manage the problem, but rather attempt to lessen the impact. Neither of these techniques reduces the deer population, in fact supplemental feeding promotes population growth beyond the carrying capacity of the ecosystem, while fencing relocates the population to an exterior location where they will increase the existing population. Neither of these options reproduces a natural occurrence, and both have the potential to negatively impact the ecosystem (NRC Inc 2007). Supplemental feeding, through grain or hay addition, has the possibility of introducing an invasive species. In addition to this risk, studies have shown that food supplementation does not decrease the browse effect on the habitat. Fencing has the potential to impede the migration of other species, which could affect the species composition of the Domain (NRC Inc 2007). Neither of these techniques is consistent with the University’s management goal of managing for education.

Trapping – Not Recommended

Trapping can be used for two different end consequences. The first method is trapping and euthanizing. A single deer is baited into a trap where it is then euthanized by a gunshot to the brain. The second method is trapping and transferring. Large numbers of deer are trapped and relocated to either commercial deer feedlots or to a facility where deer are kept for recreational “hunting”. These methods are considered inhumane, as deer are traumatized by trapping, and in both cases the time of their death is merely delayed. Trapping and euthanizing may delay their death for a few hours, and deer transferred to a holding facility have been shown to have an average life expectancy of only a year (NRC Inc 2007).

A study of deer management in Columbus, Ohio which looked at both relocation and culling, estimated mortality rates between 19% and 79% for trapping. As well, they calculated a minimum of $133 per deer for trapping equipment only, not including costs of independent contractors.

Reintroduction of Predators – Recommended, Likely Unfeasible
The overpopulation of deer, being directly related to the extirpation of predators from the region, could be remedied by the reintroduction of predators, such as mountain lions, wolves, and bears. The reintroduction of native, extirpated predators poses very little ecological risk. This method of deer population management is likely unfeasible, however, because of the current legal extirpated status of the predators. In addition, while the reintroduction of predators poses very little ecological risk, the real or perceived risk to humans and human interests will create public resistance to their reintroduction. The availability of sufficient intact habitat is another possible consideration which may be a limiting factor of sustainable predator densities (NRC Inc 2007).

Contraception – Research Recommended

Two types of contraception in wildlife have been studied; the first consists of administering synthetic steroids designed to prevent ovulation similar to a birth control pill; the second is an immunocontraception vaccine meant to develop antibodies that attach to the deer’s reproductive cells and block fertility (NRC Inc 2007). The most commonly researched wildlife-applicable contraceptive is the immunocontraceptive vaccine Porcine Zona Pellucida (PZP) (McShea et al. 1997, Miller et al. 2001). Contraceptives are not recommended to reduce the current deer population, as it does not reduce a population but rather limits the recruitment of the population by limiting reproductive success, but it shows potential for controlling the reproductive rate of a sustainable density population (NRC Inc 2007). Studies have shown that a minimum of two doses of PZP, delivered by dart gun, are required for immunocontraceptive effectiveness as well as a booster every year additional. The two doses of PZP can be given as a series during a single year, or annually with effectiveness beginning after the second year of treatment (McShea et al. 1997).

Contraception as a method of deer population control includes both negative and positive aspects. Negative aspects to consider include an unnatural method of population control, an increase in energy requirements in deer populations during the mating season, a labor intensive delivery method, and a lack of information of the successfulness of contraceptives on wild populations. Positive aspects to consider include a decrease in energy requirements during the winter leading to an increase in doe weight gain, and reversible effects (NRC Inc 2007, McShea et al. 1997, Miller et al., 2001).

A natural population management strategy involves reproducing the effect of predators by removing individuals, particularly sexually mature individuals, from the population, while this strategy instead reduces the reproductive success of the population. By decreasing the reproductive success of the population, contraceptives promote an increase in mating activity, increasing the energy requirements of the population (McShea et al. 1997); however they do not promote an elongated mating season. In contrast to the increased energy requirements, studies have shown that does gain and retain more weight than their reproductive counterparts as they do not experience the increase energy requirements of pregnancy and lactation (Miller et al. 2001). The labor intensive delivery method, requiring a minimum of two sequential doses to be effective, makes it less likely that all targeted does will be affected. The difficulty in assuring the annual vaccination of does also poses potential limitations on the effectiveness due to ability to administer the vaccine. Very few studies have been conducted on wild, uncontrolled populations; most studies included paired deer enclosures with a control group and a vaccinated group, leading to limited information regarding the actual effectiveness of vaccination (McShea et al. 1997, Miller et al. 2001). The estimated of cost-per-deer is $1,100 per deer (Peck and Stahl 1997) not including personnel costs.
This report does, however, recommend that the University conduct research into the applicability of contraceptives for the Domain, particularly as a method to control population growth after successful reduction of population size through another method. While studies have shown drawbacks in the theoretical applicability of contraceptive, there has been little research showing the actual applicability. Contraceptives do not bioaccumulate, the delivery method poses little threat of affecting other species, and the effects are reversible simply by ceasing to dose the deer with contraceptive.

**Culling – Recommended**

The recommendation is primarily an improvement of the University’s current policy. Methods recommended for use include utilizing sharpshooters, a nocturnal setting with a spotlight, and bait (NRC Inc 2007, Frost *et al.* 1997). Hunters may be either hired sharpshooter or state certified hunters. Hired sharpshooters increase the effectiveness of the cull, while utilizing local hunters decreases the cost. A baiting period of three week allows deer to pattern on the bait location. This patterning ensures that deer will be at the site at the time of the cull, as well as allow the University to predetermine sites for deer removal away from residential or academic locations, to maximize hunting safety. Bait should be bagged shell corn and the amount used should be determined by observation of use and sites should be replenished every other day (NRC Inc 2007). For both diurnal and nocturnal hunts, hunters should be positioned so that they are above the bait site, in a tree stand or in the back of a vehicle so that all shots are fired downward. Night shoots should include an appropriate earthen backdrop; during these shoots, both the shooter and the spotlighter must agree that a shot is safe before taking a shot (Frost *et al.* 1997).

Culling reproduces the effects of natural predators, making it the most natural deer management option. While it is the most natural solution, it should be noted that deer culling will create significant temporary disturbances of other habitats through the presence of nutritional resources in the form of bait as well as disturbances causes by the presence of people, tree stands, and gunshots.

Deer culling is not a permanent solution to the problem of deer overpopulation. Annual repetition is required to keep up with the population growth, although if contraceptives were ever shown to be effective in controlling reproduction, this could perhaps be reconsidered. The ability of each cull to successfully reduce the deer density is dependent on the element of surprise in each season’s hunt, requiring that the deer be unaware or unconcerned regarding the hunt. This dependence on deer ignorance makes it crucial that archery hunting be limited until after a sharpshoot cull to allow for the success of the cull in reducing deer density (NRC Inc 2007).

Once the deer population has been culled to a sustainable level, cullings will not need to be as heavy. In a study of deer management in Gettysburg National Park (Frost *et al.* 1997), researchers found that in a 2,862-ha study area with an initial deer population density of 136 deer per square kilometer required three years of intensive culling to reach their deer population goal, 10 deer per square kilometer. 500 deer were culled the first year, 350 the second year, and 85 the third year. After they reached their density goal, they projected that they would be able to maintain the deer population with cullings of less that 40 deer per year after that.

Cost-per-deer of culling varies greatly by the hunt. Studies show cost-per-deer figures which range from $88-$207, with an average cost-per-deer of $133. The exact cost of culling is primarily
processing costs, with the additional costs of hired sharpshooters. A lack of public support has been shown to drastically increase the cost-per-deer by requiring additional management of protesters (Frost et al. 1997, Kilpatrick et al. 1997, Peck and Stahl 1997).

**Public Education – Recommended**

Public education consists of both instructing hunters on Quality Deer Management (QDM) techniques, but also in educating the public on the methods the University is taking towards deer management. QDM is a theory of deer management in which hunters preferentially shoot does instead of bucks, this method most naturally reproduces the effect of predators. While QDM is not a substitute for culling in the Domain's deer management plan, instructing archers for a post-cull archery hunt or recreational hunters from the surrounding area in the practice of QDM would increase the effectiveness of these forms of hunting on controlling deer densities. The participants in QDM have been shown to have a greater satisfaction with their hunts, particularly in using QDM to select for larger trophy bucks (Woods et al. 1996).

Public education on the management practices of the University is crucial for the success of those management practices, particularly culling (Green et al. 1997, Kilpatrick et al. 1997, Peck and Stahl 1997). An uneducated public often misconstrues the reasons for culling activity, leading to protests and vandalism (Kilpatrick et al. 1997). Studies have shown that education of the public regarding the needs for deer management, and the goals associated with it can serve to support sound deer management (Green et al. 1997). Following these examples, studies have also shown that a previously unsupportive public can alter its opinion after proper explanation of the management practices has occurred (Peck and Stahl 1997).

We recommend that the University create a Deer Management Council, similar to one in effect at Swarthmore College, comprised of students, faculty, and members of the public, through which all deer management techniques and practices should be reviewed. This council would also serve to make recommendations to the University regarding changes in procedure which might arise as deer density goals are met (NRC Inc 2007). Adaptive management is crucial to the success of any management strategy, while a deer council would also serve as an educational tool to garner public support for deer management on the Domain.

Cullings can also be made more cost-effective by donating meat to charities. Organizations such as the Tennessee Wildlife Federation’s chapter of Hunters for the Hungry (TWF 2010), or simply the local needy could be recipients of deer meat garnered by the culls. Several deer management programs have found that donating deer meat reduces the cost-per-deer of cullings as well as promotes a more positive public image (Frost et al. 1997, Peck and Stahl 1997, Kilpatrick et al. 1997).

**Conclusions**

Deer are a valid and present threat to the biodiversity of the Domain. Their threat is a vast one, affecting individuals, populations, communities, and entire ecosystems. In order to effectively manage the threat of deer overpopulation on the Domain, the University must first assess the exact effects deer are having on the ecosystems of the Domain, and then determine the exact extent of the threat by determining the current deer-density. Once these assessment goals have been achieved,
deer can be successfully managed through a long-term adaptive culling strategy. Public support and education is crucial to the success of a Domain deer management plan, thus we highly recommend the creation of a deer management council composed of students, faculty, and local community members.
Invasive Species
**Introduction**

Invasive species pose a significant threat to biodiversity all over the world. An invasive species is defined as a species that has been introduced by humans into an area where it is not native and has had an effect on the biodiversity of that area. Each year, invasive species lead to the extinction of many native species either by preying upon them or outcompeting them for resources. Species that are invasive typically share several characteristics. They are usually generalists, meaning that they do not have specific requirements for food or habitat. Typically, they thrive in habitat that has been disturbed by humans and push out native species in such areas. Invasive species are also characterized by high reproductive rates and are able to disperse themselves quite easily. With this knowledge in mind, we will now look at the invasive species that are present on the Domain, their effects on biodiversity, and how we can control them.

**Chapter I: Tree of Heaven (*Ailanthus altissima*)**

Daven Hassell

*Introduction*  

*Ailanthus altissima*, also known as the Tree of Heaven or Chinese sumac is a tree species native to China. It was first introduced into North America in 1784 because of its hardiness, and was commonly used in gardens and for urban decoration. Because of its high tolerance to air pollution and its potential to sequester pollutants, it was planted particularly in cities (Ding et al., 2006). In the late 1800s, *A. altissima* became naturalized in Tennessee (TNEPPC).

Currently no decisions have been made on the Domain with regard to *A. altissima*, but Professors Jon Evans and Deborah McGrath of the Sewanee Biology Department have both studied this tree on campus and monitored its spread (Dr. Evans). Outside the domain, the threat has been recognized by state governments; Connecticut, Vermont, New Hampshire, and Massachusetts have placed the tree on a ban list, prohibiting its import and sale (NRCS, 1999).

*Threat to Biodiversity*

*A. altissima* has a relatively rapid growth rate, between 1.96 and 3.70 mm of radial growth per year, which allows it to easily colonize and outcompete native species in gaps (Knapp, 2000). Adamik and Braun (1959) found that seedlings can grow 1-2 meters in the first year, and sprouts can grow 3-4 meters in the first year.

Areas with disturbance, both natural and otherwise, are at greatest risk, due to *Ailanthus*’ aggressive invasive tactics. Knapp and Canham (2000) found that *Ailanthus* outcompeted such native species as Eastern Hemlock (*Tsuga canadensis*), White Oak (*Quercus alba*), Scarlet Oak (*Quercus rubra*), Sugar Maple (*Acer saccharum*), and Tulip Poplar (*Liriodendron tulipifera*).
A. altissima produces ailanthone, an allelopathic chemical. Merger (1959) found that 11 hardwood and 34 conifer species were negatively affected by this chemical. Even at low doses, the germination of other species is delayed which gives the already rapidly growing A. altissima even more of an advantage over them (Heisey, 1996).

Because A. altissima can tolerate a wide range of conditions, it poses a threat to most places in the United States, as can be recognized by its colonization in forty-two of the fifty states. Specifically, the places most at risk are those that have disturbance of some kind; A. altissima saplings are shade intolerant. According to the Virginia Department of Conservation and Recreation, A. altissima is the fifth most prevalent invasive in the state of Virginia. Because of the heavy disturbance associated with them, it is likely to succeed near roads or in areas where logging or burning has occurred. Stipes (1995) found that 30 percent of the mileage along highways in southwestern Virginia was infested with Ailanthus (Stipes 1995 as cited in Burch 2003). It can affect both the composition and structure of native forests because, when left to spread, it forms thick pure stands that shade out other growth and affect the native diversity (Burch 2003).

Assessment of Threat

Currently the threat posed by Ailanthus on the domain is a very manageable one. There are a few definable affected areas that could be cleared by various methods, if that were found to be the most suitable solution. With more disturbance, however, the tree will have more opportunities to expand its local range. Disturbance on the plateau includes residential development, road building, logging, and burning. A study by Hart et al. (2008) in Fentress County on the Cumberland Plateau found that out of 30 plots, Ailanthus was the only invasive tree species and had a relative dominance of five percent. This means that as an invasive it will not only outcompete native species, but it also has no competition from other invasives. Although the plant is present, it is manageable.

In order to accurately assess the threat, the distribution and abundance of A. altissima should be investigated on the Domain. In order to do this effectively, the Domain should be divided up into plots and the number of trees per plot counted. In this manner, we could evaluate how vulnerable the entire area is and determine the most vulnerable habitats.

Recommendations for Action

There is currently nothing being done to control the spread of A. altissima or to remove it on the Domain. Its presence is well known and documented here, but there is not a defined removal or management plan. There are many methods available to remove A. altissima. These include cutting, girdling, hand pulling, foliar spray, cut stump method, basal bark method and herbicides. Other methods being researched are biocontrol methods with the use of fungi or mychoherbicides. One study compared eight herbicidal treatments and one manual hand pulling treatment. The herbicide methods consisted of manual removal to a height of three to six inches above the ground, then spraying with treatment until the bark was wet, but not to the point of runoff. Herbicides studied include: pure Garlon 4, pure Stalker, various ratios of a Garlon 4 and Stalker mixture, Stalker and Tordon K, and Garlon 4 and Tordon K. The most effective herbicides are those that contain any combination of Garlon 4 and Tordon K, eliciting nearly 100% fatality to trees. These herbicides were most effective because they not only killed the above ground plant but were also transferred to the roots, which stopped suckers from growing. The study also found that the A. altissima was often replaced by native species without requiring reseeding (Burch 2003).
Most manual treatments of control are ineffectual due to the ability of *A. altissima* to produce root suckers and to sprout from stumps. This method of control would be very costly and time consuming. The best way to remove *A. altissima*, based on what I have found would be an herbicide composed of Garlon 4 and Tordon K. I think that the best approach would be removal in some areas where it is especially dominant, like the lot behind the SUT, and doing research in other areas where the benefits of studying it outweigh the negative ecosystem effects.

Brauns and Adamik (1957) showed that *A. altissima* has high cellulose content and low lignin content. This coupled with the fast growth rate that they observed make this tree effective in the production of pulp for paper, especially if it is going to be removed. This would return some of the cost for removal. However, the process and chemicals used to manufacture paper are very tree specific, and currently the paper industry is set up to deal with primarily pine (Dr. Evans). In addition, Ailanthone and other chemicals taken from the tree may also be used as insecticides and natural herbicides. Because it is known to sprout from stumps and succeed through root suckers, it would be necessary to monitor the success of removal of *A. altissima*. The easiest way to do this would be to mark the location and density of the areas that are managed and monitor them at specified time intervals.

**Chapter II: Invasive Aquatic Plants**

Kate Cummings

*Introduction*

Natural water systems on the Domain include streams, ephemeral ponds, man-made reservoirs, and possibly some beaver-made bodies. The primary focus of this report will be on the artificial lakes, including approximately sixteen large lakes owned and operated by the University. As the lakes and reservoirs themselves are non-natural habitats the issue of invasive aquatic macrophytes is in a unique position. Aquatic macrophytes, or aquatic photosynthetic organisms that can be seen by the naked eye, are classified as submerged, floating, or emerged, and include 33 orders and 88 families in the vascular macrophytes (Chambers, 2008). Worldwide, there are fewer aquatic plants than terrestrial, but they represent some of the most severe invasions. They have disastrous effects on aquatic systems as well as the surrounding terrestrial lands when they alter ecosystems, hydrology patterns, and nutrient cycles. If they go unnoticed or unchecked irreversible damage could be done to native ecological communities; the economical consequences of managing the invasive could be great as well (Les, 1999).

Table 1. List of aquatic plants found on the Domain and classified by the United States Department of Agriculture as being ‘exotic’, or both invasive and potentially or known to be threatening to native populations (Non-indigenous Aquatic Species, USDA, 2010).
The four species listed in bold have become established on the Domain and have either posed a problem in the past, like *Brasenia scherberi*, commonly known as watershield, or need to be closely monitored, such as *Myriophyllum spicatum*, and *Myriophyllum aquaticum*. Watershield has been sprayed with chemicals in the past in Bratton Lake on Carruthers Road (Gottfried, 2010). The decision to partially remove Watershield was made because the plant was decreasing light availability to other plants and out-competing for space, nutrients, and dissolved oxygen. *M. aquaticum*, which is established in the lakes by Trez and Courts and potentially in Lake Cheston, is a significant threat or one that needs to be watched closely. *M. spicatum* is a severe threat, it can potentially displace other species. *P. caespitosum* has large established populations near Roark’s Cove, Shakerag Hollow, and the old railroad, and is a species that needs to be studied and watched further (“Tennessee Invasive Exotic Pest Plants”; Gottfried, 2010).

### Threat to Biodiversity

As alien plant species create the ecosystem within the lakes, removal of aquatic invasive species would mean the removal of all plant life and the organisms dependent on them. This decision would affect the nitrogen, carbon, and oxygen systems in the lake that aquatic plants use and contribute to nutrient availability and organic matter. Plants provide habitat for micro and macro invertebrates, which are then food for fish and other wildlife species like waterfowl and small rodents. Aquatic plants provide detritus when they die and decompose, or food for bacteria, fungi, and aquatic invertebrates. The edge ecosystems between the water and woods are maintained by some of these plants (Les, 1999).

There are few studies on the interactions between aquatic plants and the water systems on the Domain. Some of the invasive plants, like the bolded species in the above table (watershield in particular), can spread and fill a pond. In doing so, they out-compete other plants for light, space,
nutrients, spreading quickly and disrupting the oxygen balance. The plants can cause erosion issues or completely shift the type of ecosystem in an area. Invasive aquatic plants can seriously alter the hydrology of streams and lakes, and affect the oxygen and acidity levels of the drinking water. Algae blooms from fertilizer run-off as well as decaying invasive plants that produce a large amount of biomass, like watershield, could decrease the amount of nutrients, oxygen, light, and space for native populations or interfere with water systems (NISC). It could clog up filtering systems in the reservoirs that provide drinking water for the University.

If eutrophication of the water system occurs, then the aquatic species could suffocate and populations might lose their drinking source. Eutrophication from run-off or a large invasive population could have negative effects. The plants could be deadly to other plants and animals, particularly the poison hemlock found on the domain that is well-known for its toxicity to humans. Some humans or animals could be allergic or sensitive to exotic plants, putting them at risk.

Nitrogen and phosphorus are often the nutrients that limit plant growth in an aquatic system, or which, in excess, can cause an increase in plant growth to artificial levels and cause eutrophication. As nitrate is highly water-soluble, it leaches into water systems easily from sewage effluent or fertilizer run-off; phosphorus binds to clay particles and occurs in high concentration in sediment. Wetland systems with low nutrient levels are increasingly rare, as are the nutrient-poor flora and invertebrate fauna associated with them. Water systems that are fed by groundwater or springs that are nutrient poor, acidic, or calcium-rich are especially damaging as they can dramatically and rapidly change the nutrient cycles and levels (Auden, 2007).

**Assessment of Threat**

The first step to assessing the threat of invasive aquatic macrophytes on the Domain is to initiate research on the effects of the plants on water reservoirs, lakes, ephemeral ponds, and streams. The priorities and purposes of the water systems on the Domain need to be listed and ranked, including recreation, drinking water, education and research, and biodiversity, in order to assess how the invasive aquatics need to be addressed. Following the strategies of the National Invasive Species Council, the University should aim to prevent the establishment or spread of harmful invasive aquatics, initiate an early detection and rapid response plan, monitor control and management of the current invasive aquatics, and organize collaboration among affiliated groups (NISC, 2008). Currently, only the Biology Department, the Sewanee Herbarium, and Physical Plant Services are watching the major bodies of water and stepping in when invasive plants get out of control, like in the case of the watershed in Bratton Lake.

**Recommendations for Action**

Policies stipulating immediate action should be partnered with raising public awareness of harmful species to control the introduction of new, potentially harmful or widespread exotic invasives. These policies should include:

(1) There should be no dumping of aquarium plants in ponds, streams, or ditches.

(2) There should be no planting of exotic aquatic species on private property, in backyard ponds or streams.
Monitoring run-off from pesticides, fertilizers, and other chemicals from University activities and private property.

The University should measure water quality, which is usually done a minimum of six times a year as nutrients can vary with different water flow rates, nearby human activity, and seasonal plant growth. Maintaining water quality should include managing the pH and nutrient levels, as well as monitoring the potential run-off from pesticide, fertilizers, and other chemicals. Protecting lakes and ephemeral ponds found on the Domain can be achieved by ensuring sewage effluent does not have high levels of phosphate, reducing fertilizers from lawns and golf courses, and using buffer zones or vegetation filter strips, which need to be a minimum of 30 meters around the water. These buffer zones also provide valuable wildlife habitat, as would reedbed treatment systems that can trap excess nutrients and sediment from obvious run-off or problem areas. If the lakes have high levels of algae and cyanobacteria, one author suggests adding barley straw twice a year, 10-50 g of straw per square meter of surface water (Ausden, 2007).

A priority of the University could focus on increasing biodiversity in and around the water bodies, particularly the large lakes that attract a lot of visitors, student groups, and academic research and classes. Adding fish species to Lake Dimmick, for example, would increase opportunities for fishing and monitoring of fish population, as well as provide food for nesting waterbirds. Shallow water systems can allow open marginal or mud habitat for many water bird species, plants, and invertebrates that offer opportunities for studies.

There have been studies done on the potential use of an Asian leaf beetle, Galeruella birmanica, as a biocontrol agent for the plant watershield. Even though watershield is a native to North America, the beetle has found to reduce watershield colonies without developing overwhelming populations that threaten native beetles, though the studies indicated more research needs to done. If the University so chooses, the introduction of this beetle, provided it is approved for experimentation in North America, could be an alternative control method to using chemical pesticides (Ding et al., 2007). The use of pyralid moth (Acentria ephemerella), chironomid midge (Cricotopus myriophylli), and an indigenous weevil (Euhrychiopsis lecontei) have been explored in Minnesota and Wisconsin for the control of the submersed water milfoil, or P. spicatum, which is harder to eradicate than floating and emergent aquatic macrophytes. The use of biological control agents can be unpredictable at times and must be considered with caution, as the introduction of exotic species can have devastating effects if not experimented thoroughly (Newman, 2008).

Chapter III: Feral Cats
Amory Walker

Introduction

Four thousand years ago the African Wildcat (Felis silvestris lybica) was domesticated. Since then, cats have been introduced globally as people colonize around the world and bring cats along as pets (Nogales et al., 2004). In the majority of cases, cats are introduced to control rodent and rabbit populations. Cats are able to live in inhospitable habitats because they are opportunistic predators that will eat almost anything including mammals, birds, reptiles, amphibians, and invertebrates (Nogales et al., 2004).
House cats and feral cats (*Felis catus*) are supplied food and habitat by humans (Johnson *et al.*, 2005). Although cared for by humans, both house cats and feral cats cannot avoid their instinct to kill natural prey. Prey abundance varies with habitat and since cats are opportunistic, they will go after the most abundant prey (Nogales, 2004). The native birds they prey on are of high concern because their populations are already weakened by urban sprawl which increases habitat loss and fragmentation. The important implications of these bird populations becoming very small is that the genetic variability amongst populations will result in genetic drift which can result in the extinction of the species. It is estimated that hundreds of millions of birds are killed by cats annually (Johnson *et al.*, 2005).

**Threat to Biodiversity**

Studies have been conducted throughout the world to determine the effect that cats have in different ecosystems. Cats hunt the most abundant prey; once a prey population decreases, they will move to the next. Unlike most predators, their populations do not decline once their prey population declines because they can move on to different prey species and are also subsidized by humans who both directly and indirectly feed feral cats (Johnson *et al.*, 2005).

For cats, mammals are the highest consumed prey (69%) while birds were found 21% of the time in scat and gut contents. This is contributed to the finding that mammals are hunted at night while song birds are hunted during the day (Fitzgerald *et al.*, 1988). Feral cats are known to be out primarily at night, which would account for a higher number of mammal prey when compared to bird prey.

Diego, a cat that lives on Sewanee’s domain provides anecdotal evidence regarding cat predation on local prey. It serves as a point from which to begin understanding that cats are affecting the domain. After talking to Diego’s owner, it was reported that in the past week he has killed a total of 6 animals: 1 frog, 2 voles, 1 bat, and 2 rabbits (Vierling, 2010). In this one week the sample represents the wide range of prey that cats are known to kill.

Diseases carried by feral cats can be introduced to wild populations of animals through direct contact with the infected cat or by contact with the infected animal’s feces. The diseases that they carry may cause a decrease in other animals’ immune systems also contributing to their decline in abundance (Johnson *et al.*, 2005).

**Assessment of Threat**

Currently on the domain there are no regulations on controlling cats. The number of cats on the domain has not been determined but the numbers are thought to be quite high. Habitats affected by feral cats are those that are on the edges of forest near urbanization. Feral cats are reported to not survive well in forested areas. Many of the Domain's forests are fragmented by urbanization and the edge environments created by the fragments. These are the habitats cats predominantly inhabit and thrive (Haskell *et al.*, 2001).

As a result of the high number of feral cats present on the domain, nest predation is reported to be a large issue. Haskell *et al.* (2001) found that with an increase in housing density there was an increase in nest predation largely due to cats. As with most other invasive species, the university has no policy for dealing with feral cats.
Recommendations for Action

Since little is currently being done about feral cats on the Cumberland Plateau and no policy is currently in place for the Domain, the possible options need to be explored.

Before action is taken, research needs to be conducted to assess abundance of feral cats on the Domain, their ecological impact, and the actual role they play in the decline of bird, mammal, reptile, and amphibian species.

A policy that could be implemented is giving tax benefits or other incentives to veterinary clinics in the surrounding area that devote some of their resources into programs to manage feral cats. Programs used in other places include TNR or spayvac. This is the best option of directly controlling feral cat population numbers because the killing feral cats is often looked down upon. In addition, there should be education to the general public explaining the project and encouraging cat owners not to contribute further to the problem. A monitoring plan must also be implemented that will monitor the success of the actions taken and determine what needs to be added or taken away from the plan.

Chapter IV: Brown-headed Cowbird (*Molothrus ater*)
Cate Vierling

Introduction

The Brown-headed Cowbird (*Molothrus ater*) is an obligate brood parasite occurring year-round throughout the southeastern United States. They lay their eggs in the nests of other birds (hosts) and do not take part in rearing their own young. Over 140 host species of the Brown-headed Cowbird have been described. The most common hosts include Yellow Warblers, Song and Chipping Sparrows, Red-eyed Vireos, Eastern Towhees, and Red-winged Blackbirds, all of which occur on the Sewanee Domain. Mayfield (1965) reports that before the early to mid 1800s the Cowbird was generally confined to the Great Plains. Clearing of forests for agriculture and development as a result of industrialization enabled the bird to spread to the Eastern United States, causing it to be labeled an invasive species. Now, the Brown-headed Cowbird occurs across all of North America, Mexico and parts of Canada.

Threat to Biodiversity

The degree to which cowbird populations affect biodiversity is debatable and differs from place to place. Brown-headed cowbirds have the potential to affect host offspring sex ratios. Zanette et al. (2005) studied the offspring sex ratios of song sparrow hatchlings in nests that had been parasitized and compared them to unparasitized songbird nests to see what kind of affect the cowbird chick had on the sparrows. They found that the proportion of female sparrows in parasitized nests was half that compared to unparasitized nests. The reason for this is that the female sparrows are generally smaller and have less of a competitive edge in the nest. When a cowbird is thrown into the mix, they cannot compete with both the cowbird and the male sparrows. The parents end up provisioning more food to the chicks with the largest mouth gape during feeding.
time. This skewed sex ratio could eventually cause declines in host populations, like the song sparrow.

The threat of parasitism by Brown-headed Cowbirds interacts most heavily with the threat of increasing edges brought about by habitat destruction and fragmentation. As previously mentioned, cowbird populations did not thrive until agricultural development created a more fragmented landscape allowing them to inhabit areas they normally would not have. Chalfoun et al. (2002) examined the relative abundance and species richness of songbird nest predators and Brown-headed cowbirds in forest edge and interior within a fragmented agricultural landscape in Missouri. They found that the occurrence of nest predators, like snakes was often twice as high in edge habitats as they were in interior forest habitats. Also, they found that cowbird densities were higher along edges adjacent to pastures because cowbirds prefer this type of habitat. This has implications for the Domain because increased edges could bring decreased songbird richness and evenness as cowbirds tend to occur at higher densities along these edges.

Assessment of Threat

The Eastern Bluebird is a target of the brown-headed cowbird that inhabits the Domain. Dr. Haskell, along with his ornithology classes, has built special nest boxes for this species so that they have an option that prevents nest parasitism by the cowbird as well as competition for nesting space by the introduced and invasive European Starling. The nest boxes have helped immensely in most locations as the Eastern Bluebird can be seen most days. At this point, no action has been taken to examine the effects of nest parasitism by Brown-headed Cowbirds on the Domain. With this paper, I propose that we take steps to complete comprehensive bi-annual bird surveys during the spring months to get a solid idea of which species constitute local bird populations. I then suggest studying the effects of cowbirds on these local or migratory bird populations. I also suggest the possible implementation of a cowbird removal program and preservation of large contiguous tracts of land as a way to combat the problem.

Recommendations for Action

Concerning the management of this problem within the Domain, I propose monitoring and obtaining regular bird surveys to examine which species are here and when. Over time, we can establish which populations are increasing or decreasing and perhaps why. Monitoring of the nests of “suitable hosts” for cowbird eggs would be helpful in determining parasitism rates by cowbirds. An appropriate method for this study might be to implement an experimental cowbird removal program and compare the effects of parasitized versus unparasitized nests. This will test the effects of cowbirds and the effects a removal program might have. If nest parasitism becomes a problem for any bird on the Domain, a cowbird removal program may be implemented, but as we learned from the studies presented, they are not always sufficient and they are costly. While bird surveys may be done as a class or individual student project, cowbird removal might not be feasible without funding from some outside sources, such as the Audubon Society or the government. Conservation planning that focuses on maintaining contiguous tracts of forest should be the focus, as most studies agree that edge effects coupled with habitat loss/fragmentation due to agricultural development is the main culprit of the problem.
Chapter V: Insects
Stephanie Loria

Introduction

The South American fire ant (Solenopsis sp.) is a well-known invader. Its presence was first documented in North America in Mobile, Alabama in the early 1900s. Two species have been introduced in the United States including the red fire ant (Solenopsis invicta), which is commonly found in southeastern North America and the black fire ant (Solenopsis richteri), which lives at higher latitudes. A hybrid fire species, Solenopsis invicta x richteri, also exists and primarily inhabits regions that are intermediate of the ranges of S. invicta and S. richteri (Gibbons and Simberloff, 2005). An ant survey on the Southern Cumberland Plateau in Sewanee, Tennessee, discovered S. invicta x richteri to be the only invasive fire ant species present in this area (Davis, 2010).

The North American invasion of the gypsy moth (Lymantria dispar) attests to the powerful impact that exotic species can have on ecosystems. Populations of this European insect were brought to Massachusetts in the early nineteenth century (Abrahamson and Klass, 1976; Davidson et al., 1999; Liebhold et al., 1997; Myers, 2000; www.invasives.org; Sharov and Liebhold, 1998; The Gypsy Moth, 1970). Since its arrival, the gypsy moth has moved to the states of New York, Pennsylvania, Wisconsin, Michigan, Ohio, West Virginia, Virginia, North Carolina, Maryland, and New Jersey (Abrahamson and Klass, 1976; Bersiford et al., 1994; The Gypsy Moth, 1970; Slow the Spread; Stalter and Serrao, 1983; www.invasives.org). No gypsy moth populations have been documented in Sewanee, Tennessee.

Threats to Biodiversity

Fire ants, as stated previously, have the ability to outcompete native ant species (Davis, 2010; Gibbons and Simberloff, 2005; Jacobsen, 2009; O’Donnell, 1994). Gibbons and Simberloff (2005) discovered that S. invicta x richteri reached food resources more quickly than native ant species and dominated these resources. They suggested that domination by Solenopsis occurred via pheromones since little to no aggressive behavior between ants was observed during their study. Domination by Solenopsis was also feasible since this species often outnumbers native ant colonies by the thousands. Furthermore, a report by the U.S. Fish and Wildlife Service (O’Donnell, 1994) assessing threats to endangered Texan cave fauna noted fire ants attacking native arthropod species. Besides having impacts on native fauna, fire ants are also ecological engineers. Their large mounds aerate the soil disrupting natural processes (Oliver 2009).

It is worthwhile to note that although fire ant mounds are located in a variety of habitat types, these invasive insects seem to thrive in disturbed areas. A survey conducted by Davis (2010) on the Southern Cumberland Plateau found fire ants only in areas that had undergone some previous human disturbance. Even the Gibbons and Simberloff study (2005) noted a significantly large number of fire ants in regularly disturbed pasture areas. Thus it seems that habitat disturbance is beneficial to these invasives in some way. Quite frankly, the most interesting outcome of the introduction of the Solenopsis species has been the birth of the hybrid fire ant, S. invicta x richteri. Here, a species unknown to exist in the native habitat of its two parent species has been created in a foreign land (Gibbons and Simberloff, 2005). Unfortunately, research has found that the ecological impacts of S. invicata x richteri appear to be the same as that of other invasive fire ants (Gibbons and Simberloff, 2005).
The ecological effects of invasive gypsy moths are more visible than those of fire ants. This insect has caused defoliation in seventy-five million acres of forest in North America (Slow the Spread). Trees that are primarily affected include oak, sweet gum, basswood, as well as several others (Keating et al., 1998; Krasny and Digregorio, 2001; invasives.org; Liebhold et al., 1997; Sharov and Liebhold, 1998; Slow the Spread; Stalter and Serraro, 1983). After a tree has been defoliated by gypsy moths, it produces new leaves, but these will be smaller since there is not enough stored energy in plant tissue (Davidson et al., 1999; Jones, 1998; Schultz and Baldwin, 1982; Wargo, 1978). Studies also have found that small leaves are rich in fiber, and this causes decomposition to happen at a faster rate. It is possible that increasing the decomposition rate will shift energy cycles in ecosystems (Hutchens and Benfield, 1999). Other studies on the ecological impacts of gypsy moths have focused on change in forest composition. According to a USDA pamphlet (The Gypsy Moth, 1970), most trees do not survive more than two gypsy moth attacks. Trees that are killed are typically large and old (Davidson et al., 1999; 1983). Thus, if such a tree dies, a gap in the canopy is created and this increases light availability on the forest floor and lowers the moisture content of soils (Kransy and Digregorio, 2001). The probability of tree mortality increases if parasites, such as the fungus Armillaria, are present (Abrahamson and Klass, 1976; Krasny and Digregorio, 2001; Stalter and Serrao, 1983; Wargo, 1978). From this data, we can see that gypsy moths have had a major impact on the deciduous forests of North America.

Assessment of Threat

With an understanding of the impacts that fire ants and gypsy moths have on ecosystems all over North America, we can now focus our attention on the threats that these insects pose specifically to biodiversity on the Southern Cumberland Plateau. The Southern Cumberland Plateau, located in eastern Tennessee and northern Alabama, provides habitat for a diverse array of species. Its forests are classified as being mixed mesophytic. In Sewanee, hybrid fire ants have already been sighted. Davis collected over five hundred of these ants at former Sewanee pine plantations. Pine plantations are disturbed areas and thus provide habitat for invasive species. Furthermore, he discovered that more than half of all native ant species collected in his study shared habitat with the invasive hybrid (Davis, 2010). Thus, contrary to previous research, fire ants did not appear to have a negative impact on native ant species, they actually seemed to provide them with benefits. The results of Davis’ study call for more research on the ecological effects of fire ants in Sewanee, TN before any management practices are undertaken.

Gypsy moths, on the other hand, have not reached the Southern Cumberland Plateau; but they are on the verge of arriving. Gypsy moth populations in North Carolina and Kentucky exist immediately outside the Tennessee border (Slow the Spread). It is only a matter of time before they reach Sewanee. Once these invasives enter Sewanee, their effects on native ecosystems will be detrimental. As discussed previously, gypsy moth larvae thrive on oak trees, and oak trees are very abundant in the forests of the Southern Cumberland Plateau. A gypsy moth invasion on the Southern Cumberland Plateau will probably result in entire forests being destroyed as trees are completely defoliated. This will create gaps in the canopy and affect the survivorship of many other species. It is essential that gypsy moth monitoring programs start now so that we can alleviate the effects of their arrival.

Recommendations for Action
We will now evaluate potential methods to protect biodiversity on the Domain from gypsy moth and fire ant invasions. We already know that fire ants are indeed present in Sewanee forests. Whether we should take any action to reduce their population numbers has yet to be determined. As we have seen, recent research has shown that fire ants in Sewanee do not have the same negative impacts on native ant species as they do in other locations. The university should be hesitant towards applying any sort of pesticide to ant mound. We need to determine if the costs of a pesticide would outweigh the benefits in such a situation. It also might be futile to pour boiling water over mounds. A better treatment method would be to continue to make sure that native forest is protected since fire ants thrive in disturbed habitat. Also, more research needs to be done to truly evaluate the effects that fire ants have on the native flora and fauna.

As far as gypsy moth management is concerned, the best method right now is prevention, since these moths have not yet reached the Southern Cumberland Plateau. There are several ways to do this. First and foremost, restrictions should be made on what types of wood products are allowed to enter Sewanee. Products should not be imported unless they have been deemed “safe” by Slow the Spread guidelines. This is the most essential strategy for gypsy moth prevention. Secondly, gypsy moth populations need to be monitored by placing pheromone traps throughout the forests in Sewanee. These traps will need to be checked regularly to see if any moths appear. If gypsy moth populations do arrive, early detection will help keep their populations low. Finally, managing the forests can also reduce gypsy moth impacts. By removing trees that could be attacked, the forests in Sewanee will have more vigor. When gypsy moths reach Sewanee, the bacteria Bacillus thuringensis (Bt) should be sprayed immediately over a large area of land. Application of this pesticide should wipe out all individuals before they have a chance to reproduce. It is possible that this treatment method might lead to controversy, since its application will kill many other Lepidopteran species. However, in this situation, the benefits outweigh the costs. Killing all gypsy moths before they have a chance to defoliate the entire forest is more essential than losing one or two generations of moths. If this method fails, then other “ecologically friendly” methods should be applied thereafter. One such example is use of the GMNPV virus. This virus kills gypsy moths, without harming other species (Abrhamson and Klass, 1976; Keating et al., 1998; Myers, 2000).

Chapter VI: Multiflora Rose (**Rosa multiflora**)
Matt Valentine

**Introduction**

Multiflora Rose (**Rosa multiflora**) is an invasive species that is present here on the Domain in places such as Shakerag Hollow, Lake Cheston, Lake Dimmick, and in clearings caused by forest disturbances such as power lines. It was introduced in America in the early 1800’s from Asia. Multiflora rose is a thorny, perennial deciduous shrub with small white or pinkish-white flowers, which bloom in April and May. It produces millions of seeds every year and has the ability to outcompete other plants for space (USDA, 2010). During the month from September to May, Multiflora Rose bears fruit, which provides food, mostly for birds, which are the main method of seed dispersal (Rosene, 1950).
Threats to Biodiversity

Multiflora Rose can affect the ecology of an area. It does this by outcompeting native species. This invasive usually grows in old fields, pastures, prairies, along roads, and open woods (USDA, 2010). Though it is mostly found in areas of forest disturbance, it is significantly more likely to be found in highly forested areas than other invasive plants (Huebner, 2003). Multiflora Rose reproduces by seeds and through the formation of new plants that root from arching tips that are in contact with the ground (USDA, 2010). This creates large, dense thickets of the plant, which crowds out native species. The largest threat of Multiflora Rose is that fact that it crowds out native species. However, positive uses have been found for Multiflora Rose as well. Recently, it has been planted in highway medians to serve as a crash barrier and reduce headlight glare from cars. It also provides wildlife cover for native wildlife such as pheasant, bobwhite quail, and cottontail rabbit (NPS, 2010). The fruit produced has become a good source of food for many animals in the area, specifically birds. While this is beneficial for both the bird and the plant, germination is enhanced through the digestive process and only aids the spread of Multiflora Rose.

Assessment of Threat

Multiflora Rose is present on the Domain in areas such as Lake Dimmick, power-line corridors, and even Shakerag Hollow. The only harm it causes is competition for resources and crowding out of other species. Control techniques, not matter what the method, have all proven to be costly and not 100% effective.

Recommendations for Action

Considering that Shakerag Hollow is known for its native old growth forest and natural beauty, it should be an area of focus for removal of Multiflora Rose. However, larger areas such as Lake Dimmick or along streams on the Domain may be better off being left alone. The money that would be spent in an attempt to control Multiflora Rose could be better spent elsewhere. Classes could also study the spread of invasive species such as Multiflora Rose by observing the nature of the plant over time. As said before, Multiflora Rose also provides food and habitat for other species in the area. Removing this species would in turn remove the habitat of several species, affecting more biodiversity than just the plant itself.

Chapter VII: Nepal Grass (*Microstegium viminieum*)
Mitzi Harrington

Introduction

*Microstegium viminieum* is known by many common names including Nepalese browntop, Japanese stiltgrass, Nepal grass and Chinese packing grass. This grass is native to Asia but is an invasive species in the United States. It was brought to the United States in the early 1900s when it was used as packing material for the transportation of fragile objects (Tu, 2000). Since then, it has spread rapidly in the eastern U.S. where it grows aggressively because it has few predators (Fig. 1). Like many successful nonnative invasive plants, its predators that are found in its native range are not here in the U.S. to keep it in balance within its ecosystem (CISEH, 2009). Thus, this plant
grows far more rampantly here than many native species. There is an abundant amount of research that proves that this species threatens many ecosystems throughout the eastern U.S. in various ways. There is high potential for the ecosystems of the Domain to be threatened by this species as well, especially since *M. vimineum* infestations have already been documented in several locations on the Domain (Evans, 2010).

**Threats to Biodiversity**

The Tennessee Exotic Pest Plant Council (TNEPPC) ranks *Microstegium vimineum* as a “severe threat” in the state of Tennessee. “Severe threat” is the highest rank of invasiveness and is assigned to those invasive plants that “spread easily in native plant communities and displace native vegetation”. *M. vimineum* grows aggressively and becomes a particular problem when it grows into dense mats in the understory. This creates monotypic stands that push out native plants that compete with it for resources, thus lowering the biodiversity within the ecosystem (TNEPPC; Tu, 2000). The native species that are most affected are those that are found in similar habitats as *M. vimineum* and include mostly herbaceous vegetation (Tu, 2000). The grass can also have an indirect impact on other organisms that depend on those native plants, thus throwing the entire ecosystems off balance.

A study in southwestern Tennessee showed that *M. vimineum* in the understory can outcompete woody seedlings for nutrients, water and sunlight and a dense mat of the grass may block the seeds that fall from the canopy from reaching the soil and germinating (Oswalt et al., 2007).

McGrath and Binkley (2009) found that *M. vimineum* infestations change the chemistry and microarthropod communities of soils on the Cumberland Plateau. Growth of dense *M. vimineum* infestations results in soils with a high pH, compared to surrounding soils beneath the oak-hickory canopy, due to rhizosphere production of organic acids. High pH results in increased bioavailability of phosphorus and the base cations Mg$^{2+}$ and Ca$^{2+}$. The phosphorus content in the soil is further boosted by phosphorus-rich leaf litter that slowly decomposes. The higher Ca$^{2+}$ and phosphorus content of the soil, in addition to the higher moisture beneath the dense mat of *M. vimineum*, encourages the dominance of mites, resulting in a loss in microarthropod diversity. Such a change in microarthropod communities can affect the soil food-web dynamics. How these changes to the soil may affect the plants that grow on them has not yet to be studied. McGrath and Binkley (2009) suggest further research to investigate whether the change in soil conditions encourage colonization of more invasive plants.

In a 2003 study conducted by students, Wallace and Williamson showed that the 2002 harvesting of several loblolly pine (*Pinus taeda*) stands on the Domain due to southern pine beetle infestations facilitated the invasion of *M. vimineum* onto the cut sites. The removal of these pines provided a soil disturbance that encouraged the invasion of the grass which then spread into the forests adjacent to the sites. The students found that the infestation into these forests decreased with distance from the harvest edge (Wallace and Williamson, 2003).

**Assessment of Threat**

In the United States, *Microstegium vimineum* was first seen in 1919 growing near Knoxville, TN. Since then it has spread throughout the eastern US. It is not surprising, then, that it has reached the Domain. Infestations are scattered around the Domain. For example, there is a large
infestation under the white pine stands near the Equestrian center, according to Dr. Jonathan Evans (2010). Evans also stated that *M. vimineum* is a growing problem on the Domain though it is not the most problematic invasive here because our intact forests limit its spread. The dense mat of roots under the forest floor prevents the plant from growing there.

*M. vimineum* on the Domain is most often found along trails, roads, and stream banks which provide a level of disturbance with bare mineral soil and plenty of light. In addition, the high traffic of hikers, bikers, horses, and cars along trails and roads provide transport of *M. vimineum* seeds to new locations along these corridors. It has been suggested that horses in particular play a large role in the transportation of the seeds along trails (Evans, 2010; Wallace and Williamson, 2003). Once deposited along edges, *M. vimineum* will spread into the forest understory on the Domain.

The study conducted by McGrath and Binkley (2009) described in the section above, found that *M. vimineum* stands change the soil pH and nutrient availability in the soil which results in lower microarthropod diversity. The field sites of this study were located on the Cumberland Plateau, not far from the Domain. The Domain, which is also located on the Cumberland Plateau, has similar oak-hickory forests and sandy, upland soils as the field sites. Thus it is likely that *M. vimineum* has the same impact on soils where it grows on the Domain.

It would be beneficial to study the impact that *M. vimineum* is having on the Domain. If it is interfering greatly with natural ecological processes as it is in other places in the U.S., the sooner its impact is realized, the sooner the problem can be addressed and the less harm it will have. In order to determine its impact on the Domain, inventory of *M. vimineum* distribution should be collected. A systematic sampling method should be created that involves taking GPS points where *M. vimineum* occurs. Sampling sites should include those with high potential for infestation, such as along trails and other entry paths, and those with ecological value. From the data collected, the distribution of *M. vimineum* in similar sites elsewhere on the Domain can be inferred. A map should be created using GIS software that displays its distribution on the Domain along with other invasive plants. The degree of threat that the grass poses on the Domain should be based on the frequency of its occurrence, the density of infestations and the visible evidence of the displacement of native vegetation.

**Recommendations for Action**

The results of the assessment of the threat of *M. vimineum* on the Domain will ultimately determine the extent of control that is necessary or beneficial. There are some costs to controlling the invasive plant that will need to be considered when determining the level of control. These include the financial costs of herbicides, equipment, replacement plants and paid labor; the time and labor spent in controlling the plant and the environmental impacts that control, in particular chemicals control, can have. In addition, eradication of the plant would result in the loss of an invasive that has educational worth. However, it seems impractical to envision completely eliminating this species.

Due to the possible extent of infestation of *M. vimineum* on the Domain and its negative ecological impact, a level of control of *M. vimineum* on the Domain is recommended at this time, especially because the mesophytic forests of the Domain contain some of the highest biodiversity in the temperate zone. Some action will be necessary to protect ecosystems threatened by the grass, ecologically valuable ecosystems, such as Shakerag hollow. A management plan should be created that determines the level of control that is desirable and practical. It will have to prioritize control
which will involve selecting which locations must be controlled first. This should be based upon ecological value/level of biodiversity, and degree of infestation. Interviews with personnel in the Office of Domain Management about any past efforts of control could indicate which treatments and strategies have or have not been successful.

It might be useful to restrict horses from the trails and require walkers to clean their shoes after a hike in the forest so that they don’t carry any *M. vimineum* seeds to their next hiking destination. Sections of the trail that are infested with *M. vimineum* could be closed off until the plant is removed and the seeds are no longer viable, however, this may be very difficult to implement because the seeds can be viable for up to five years.

Control methods will need to be considered. Control methods fall into two broad categories: chemical and mechanical. Each method has its own set of pros and cons. Methods of control are listed below:

Mechanical control is the removal of plants with hands or tools and without the use of chemicals. It can be very labor and time intensive and typically control must be administered multiple times in order to be effective. Mechanical control options for *M. vimineum* are mowing or pulling *M. vimineum* before it flowers in September (Miller, 2004; TNEPPC; PCA, 2009). Pulling will turn up fresh soil, creating conditions that are easily colonized by the same or other invasive plants (Tu et al., 2001).

Chemical control is more effective and less labor and time intensive. In addition, using an herbicide leaves the plants and soil in place, thus minimizing the recolonization of invasive plants (PCA, 2009). However, the cost of equipment and chemicals, and the environmental impacts are greater than with mechanical control. If chemicals drift, they may harm or kill desirable native plants or animals. A dye may be added to the solution to track any drift of herbicides. Selective application of chemicals avoids harming desirable natives by applying chemicals to specific plants. Miller (2004) suggests applying a solution of glyphosate, water and a non-ionic surfactant (which reduces the surface tension of the liquid, making it easier to spread) to the leaves of *M. vimineum* in late summer. Applying Vantage instead will reduce potential damage to nearby plants (Miller, 2004). Another option is to apply a solution of sethoxydin, water and nonphytotoxic vegetable-based oil as foliar spray (TNEPPC). Pre-emergent herbicide imazapic has also been found to be effective control for the grass because it causes less harm to native plants than other chemicals (PCA, 2009; Tu, 2000).

There are many chemical options for controlling *M. vimineum* and a helpful study was conducted at Indiana University by Luke Flory (2008) to compare the different methods and find which was the most effective. Flory compared hand weeding (HW), postemergent grass-specific herbicide (POST) and the postemergent herbicide plus a preemergent herbicide (POST + PRE). He was interested in which method was best at removing the plant without significantly damaging the native plant community or creating conditions that welcome reinvasion. His research revealed that the POST treatment was the most preferable for controlling *M. vimineum* because it effectively controlled invasions, promoted the recovery of native plants, and prevented reinvasion of treated sites. The POST herbicide solution contained active ingredient fluazifop-P-butyl and a nonionic adjuvant surfactant.

Specific control methods should be selected on a case-to-case basis. Mechanical control methods should be used when labor and time permits it. Mechanical control should always be used
near riparian areas. For large infestations, chemicals may need to be used. Careful application will reduce the potential for harmful herbicide contamination. Whichever control method is used, treatment will need to be repeated for several years because the seeds of *M. vimineum* in the soil will remain viable for up to five years (Miller, 2004). In order assess the success of control efforts, inventory of *M. vimineum* distribution on the Domain should be collected every two to five years and GIS maps should be created.

### Chapter VIII: Princess Tree (*Paulownia tomentosa*)

**William King**

**Introduction**

Princess tree (*Paulownia tomentosa*), henceforth known a *P. tomentosa*, is an invasive exotic tree species. *P. tomentosa* is native to eastern Asia, predominantly in China (Remaley, 2009). It was first introduced to the United States in 1844 as an ornamental tree because of its large lavender flowers (University of Connecticut, 2009). Since then it has naturalized and spread to become invasive in 25 states, mostly in the east, centered around the Appalachian Mountains (Remaley, 2009). It is a threat to local flora because it grows rapidly and can spread quickly.

There are currently 13 recognized invasive exotic plant species on the Domain, including *P. tomentosa*. This species has been recognized already as a problem on the Domain by the 2003 Domain Management Plan. According to the Tennessee Exotic Plant Council, *P. tomentosa* is listed as a severe threat to native plants and ecosystems (Burckle, 2003). The Office of Domain Management seeks to control this species of tree (Smith, 2003). They also encourage leaseholders to remove *P. tomentosa* from their properties. Forestry Professor Karen Kuers advocates the control of *P. tomentosa* and teaches students how to identify it and how to girdle it to prevent its spread (Kuers, 2008).

**Threats to Biodiversity**

The species that are impacted by *P. tomentosa* are mostly early-successional species that follow disturbance as well as xeric site species. This is because *P. tomentosa* has adaptations that make it an ideal early-successional species and exhibits strong invasive characteristics. These adaptations include: production of profuse amounts a small seeds which are easily carried by wind, rapid growth of seedlings, production of seeds at an early age, and the ability to sprout (Innes, 2009). A single seed pod can hold up to 2,000 seeds and a single tree can produce 20 million seeds (The University of Georgia, 2008). The seeds are small and winged so they can travel long distances by wind or water. A study by Professor Dane Kuppinger found *P. tomentosa* seeds 3.746 kilometers from the nearest parent source (Kuppinger, 2006), though he admitted most seeds wound up within 50 meters of the source. *P. tomentosa* seeds can persist in the soil seedbank for 2-3 years so they can respond to growth opportunities after a disturbance. *P. tomentosa* seedling can grow very quickly; up to 7 feet in one year, but the average height is 2 feet. This is significant because *P. tomentosa* is shade intolerant, so it requires a lot of sun. If it is able to grow higher than other plant species. At a height of 5 feet *P. tomentosa* can produce enough foliage to completely shade out plants below its canopy (Innes, 2009). *P. tomentosa* can produce seeds within 8-10 years. They can also sprout from stumps
and grow up to 15 feet in one year (Remaley, 2009). All of these factors allow *P. tomentosa* to outcompete native species. Plant species that rely on disturbance are especially vulnerable because *P. tomentosa* is adapted to thrive in these habitats. It is commonly found along roads, trails, streams, and edges, but it can also live on rocky cliffs with little soil, especially on south facing slopes (Innes, 2009). Because *P. tomentosa* has adventitious buds it can continue to prosper through forest fires, cutting, and being bulldozed by sprouting (Remaley, 2009). *P. tomentosa* is dependent on disturbance and high amounts of sunlight; if native plants can get above it, this invasive cannot survive. *P. tomentosa* dominates many primary succession and native pioneer species and a study of this on the Domain could prove fruitful. It is certain that *P. tomentosa* outcompetes and choke out native vegetation.

Due to *Paulownia*’s competitive advantage after disturbance they often dominate the composition of disturbed sites. They depend on these disturbances and are eventually choked out themselves but not before they have changed the composition of the forest. If *P. tomentosa* integrates into the canopy they slow succession by shading out native trees until they are eventually surpassed. *P. tomentosa* also thrives in xeric sites with poor, dry and can severely damage them (Innes, 2009). Plant communities are changed, which impacts the overall ecosystem function. This causes problems for not only plants but animals and water quality as well. Due to *P. tomentosa*’s inability to tolerate shade it becomes a, “transient invader” moving from disturbance to disturbance (Innes, 2009). This invasive is most common along areas disturbed by humans like roadways and trail.

**Assessment of Threat**

As mentioned in the introduction, *P. tomentosa* is present on the Domain. There is a high abundance of this plant on Roark’s Cove Road. There is not at this time good data available on the pervasiveness of *P. tomentosa* on the Domain. Collecting this data and monitoring the presence of this species is something that needs to be done. The extent of the impact on local flora and fauna also needs to be determined. On the Domain the problem of *P. tomentosa* is also compounded by the presence of the Tree of Heaven (*Ailanthus altissima*). *Ailanthus*, an invasive from China, has many of the same adaptations as *P. tomentosa* but additionally spreads through sprouting from root suckers (Pannill, 2009). These two trees have greatly changed the landscape at disturbed sites on the Domain. *P. tomentosa* has been characterized as the 5th most successful invasive trees species in the Southeastern United States so its prevalence is substantiated (Innes, 2009).

**Recommendations for Action**

There are multiple ways to control *P. tomentosa* depending on age and size. Young saplings can be hand removed by pulling them from the ground; it is important to do this when the ground is soft to be sure to get all of the roots so they do not resprout. Another way to kill *P. tomentosa* is by girdling them near their bases, about 6 inches off of the ground, but it is necessary to cut deeply through the bark and through the vascular cambium into the xylem. This inhibits the stems ability to uptake water and nutrients so that the stems die. You can also simply cut down the tree but sprouts are very common and you will have to cut again (Remaley, 2009). While these mechanical methods are most effective, the most ensured way to prevent spraying is through chemical means. Chemical treatment should be looked into.

Though control is possible it will be labor intensive because most of the treatment has to be done on a tree-by-tree basis. In addition to the cost of labor there is also the cost of the actual chemicals. There is a risk to other plants from using the chemicals. The difficult part is even if you
do remove the individuals, each one has potentially released 20 million seed and the likelihood of *P. tomentosa* returning is good. Any removal will probably be temporary but it will still give native vegetation a chance. In order for a treatment to be effective the manager must be persistent and keep checking and retreating each site every year. Active control may not be necessary in areas where disturbance is uncommon, such as interior forests, because *P. tomentosa* is shade intolerant and only has a limited number of years before it is over taken by other plant species. The most crucial sites to control *P. tomentosa* are xeric sites and sites where natives will not be able to take over, such as the sides of roads and trails (Innes, 2009).

Chapter IX: Privet (*Ligustrum*)
Katie Moses

*Introduction*

Privet (*Ligustrum*) was brought to the United States from China in 1852 for ornamental planting. This species fragments the landscape and is invasive in Southern Tennessee. On the Domain, privet out-competes the native flora and fauna by blanketing the landscape. The plant reproduces rapidly through the use of its small white flowers and the copious amount of berries it produces. This flowering plant is known for its ability to penetrate and proliferate in areas of natural and human-induced disturbance. The plant prefers recently disturbed areas, giving it a competitive advantage over the native flora (Kartesz, 1999). Privet thrives in abundant sunlight and has a high tolerance for a wide variation of soil types and moisture levels (Mikowski and Stein, 2004). This invasive has been shown to out-compete other species due to its ability to capture light.

On the Domain, students have found privet most abundant at the edges of fragmented forests and around fragmented areas, including streams. They concluded this prevalence around streams is due to its being dispersed by water and areas of habitat disturbance that invite invasives such as privet to become abundant (Taylor and Harris, 2004).

The rise of privet in the area, caused by the increasing number of disturbed areas, will change the composition of the forest, and as of now, privet is increasing on the Domain (Evans, 2010). Both Chinese Privet and Common privet are categorized as severe threats by the Tennessee Exotic Pest Plant Council (TN-EPPC, 2007).

*Threats to Biodiversity*

Privet effects native plants in its ability to produce entire invasive communities. It out competes other species. In contrast, privet provides a positive aspect of being a major bird and rabbit habitat (Grimes, 2007).

Privet is predominately found along roadsides or other levels of disturbed soil at elevations less than 3000 feet (Taylor, 2004). The privet shrub acts as a competitor for loblolly pine and shortleaf pine, two of the pine trees commonly found in pine plantations on top of the Cumberland Plateau. This again shows privets ability to thrive in disturbed areas. It also outcompetes plants that
grow on the forest floor (Merriam, 2002). Privet also interacts with sunflowers and honeysuckle to crowd out native species, which causes alteration forest composition and limits hardwood regeneration as well (Mikowski and Stein, 2004).

Chinese privet is shade tolerant and can establish in shaded woodland environments, but when disturbance occurs (such as logging, tree removal, or road construction), it can take over the site and impede the restoration by desirable native plants (Randall, 1996). USDA Forest Service research indicates that Chinese privet infests five percent of all forestland from Virginia to Florida, and the infestation has doubled in the past two decades.

Once privet has dominated an area, natural regeneration of more desirable hardwood species such as oaks, hickory, and blackgum will become stressed by privet competition, and the forest will likely never recover a mature overstory condition (Urbatsch, 2000). Privet infestations are extremely detrimental to the ecological and recreational values of a property.

**Assessment of Threat**

The shrub must be identified as colonized or dispersed before an adequate action plan can be deciphered. To survey privet one would make a grid of the area based on certain habitats within the area. Once the grids are established, a survey would take place by counting the number of privet stems per unit area. It would be difficult, however, to systematically assess privet once it has colonized, such as the area around the creek behind Woods Lab on Sewanee’s campus.

Privet is a known threat, and so a survey could be done to see how much fragmentation, disturbance of habitat, and the presence of water effects the density of privet growth which could be determined by a grid and counting system (Taylor and Harris, 2004). The USDA Forest Service research indicates that Chinese privet infests five percent of all forestland from Virginia to Florida, and the infestation has doubled in the past two decades.

**Recommendations for Action**

The main way to prevent the prevalence of privet is to educate the public. It is effective and low cost. Extensive passive monitoring through public vigilance is key to keep the species from spreading (USDA Plants). People need to know not to plant this invasive in their yards. They also must be educated on the harmful effects of habitat degradation. On the domain, in forest fragments with only minimal disturbance, little to no privet was found, both in the interior as well as the exterior of the fragment (Taylor and Harris, 2004).

In a working forest environment, such as southern pine plantation management, Chinese privet can be controlled by regular forest management activities, such as chemical site preparation and release treatments with tank mixes. Once privet becomes the dominant plant in streamline areas, as seen in Sewanee, any future disturbance in the overstory will enhance privet spread and cover (Urbatsch, 2000). If an exotic plant infestation is spotted or already occurs, then proper and aggressive eradication measures should be undertaken or spread is inevitable. Continued treatment and re-treatments will be necessary to be successful. Effective herbicide applications offer the best means of containment or eradication, because herbicides can kill roots and do so without baring soil for reinvasion or erosion. The best approach is to use selective applications of herbicides to target exotic plants while avoiding or minimizing application to desirable plants.
Pesticide Use

There are three types of herbicidal controls: foliar spray method, cut stump method, and basal bark method. The foliar spray method should be considered for large thickets where the risk to non-target species is minimal (TN-EPPC, 2007). Glyphosate would be used, but it is a nonselective systemic herbicide that may kill non-target partially-sprayed plants. Cut stump method should be considered when treating individual bushes and also involves glyphosate. The stems would first be cut horizontally and then the herbicide would be applied. Basal Bark Method is effective throughout the year as long as the ground is not frozen and is applied to the basal parts of the shrub. The cost in this is that wetting is necessary for good control and the herbicide must be sprayed until the run-off is noticeable on the ground, which increases the chance of the herbicide contacting a non-target plant (Tennessee, 2010). In a study done at Auburn University, four pesticides were tested for their efficacious control of privet. Their results showed that Privet control exceeded 90 percent with glyphosate and imazapyr when applied in August or September (Miller, 1998).

It is difficult to control the effects on non-target species in regards to pesticide use. Herbicides should be used in a healthy way as to not cause detriment to the environment. The most effective herbicide used against privet is gyophosate (Miller, 1998). The uses of herbicide and management procedures are costly and in regards to the domain, herbicides will not prove beneficial to riding the domain of privet because it is colonial. Yet, privet should be monitored every one to five years because its seed grows quickly.

A study was done to analyze the foliar sprays of glyphosate and triclopyr. These experiments included wide ranges of application rate, timing, and formulation to refine methods of controlling privet (Harrington and Miller, 2005). Privet was not affected by application timings, yet overall they concluded that low rates of glyphosate (1.7 kg ae/ha or lower) will effectively control privet when applied in the spring (April) or fall (October and December). Therefore, the timing is not an issue, but whether or not the treatment will be effective for a completely privet-dominated area remains a point of concern.

Where removal is not practical, such as in the case with some areas in Sewanee, privet can be treated and left standing. This method can also help to prevent erosion but will only be suitable if the dead tree does not become a hazard. To do this, holes must be drilled all the way around the tree trunk and filled with herbicide.

For the management of privet, one must cut down, not just cut back all the privet once a year. The plant has a fast seeding rate of once a year, making it more complicated to eradicate (Urbatsch, 2000). The cutting down will allow the privet on the domain to be contained but not completely gone (PCA). Furthermore, ecosystem management is crucial and should focus heavily on the prevention of privet from spreading into “new” forest fragments, where the edges have been recently created and no privet is yet established in the fragment (Taylor and Harris, 2004). Also helping with the recovery of privet is the recent notation in the recovery plan for the Schweintz sunflower species that is listed as endangered in the Carolinas. This is one of the first times privet is officially being managed with enforcement (Urbatsch, 2000). Furthermore in South Carolina, landowners have been receiving management planning for Chinese privet control through the NRCS conservation programs and US Fish and Wildlife Service Partners Program.
Biological control

Biological control might offer the best method of achieving control of privet, particularly as the species has no close relatives among the indigenous flora. The identification of an effective control organism will be assisted by knowledge of the exact genetic history of the introduced material; specifically, from what geographical source it was introduced and whether it contains genetic material from more than one population or species (Abbott and Milen, 2004). This information has yet to be determined by scientists in regards to privet.

Privet should be a priority species to control because the plans on the Domain do not have high potential effectiveness of control and restoration. However, the dispersed privet should be handpicked, but the large thickets of it should not be sprayed because it will harm other species especially plots on the stream banks. Yet, if the privet remains completely unmanaged then spread will continue due to seed dispersion. Privet has built up such large numbers and is so widely dispersed that eliminating the species may be extremely difficult and expensive, plus in some areas the plant has become thoroughly integrated into the ecosystem (Primick, 2006). Nevertheless, pesticide use and handpicking are both proven successful under the right circumstances so privet can be diminished in some areas, but in other areas it is too dense and unruly to completely and permanently eradicate.
Chapter X: White Nose Bat Syndrome
Baker Mann

Introduction

White-nose syndrome pertains to the conservation of the Cumberland Plateau’s biodiversity, because it is an unknown fungus that can attribute to loss of bat populations in caves and mines. The genetic variation and success of future generations become endangered when entire populations are wiped out. Sewanee is also home to two endangered species of bats, the gray bat and Indiana bat. Little is known about white-nose syndrome, but it may be an invasive species. The fungus was first discovered in two caves around Albany, New York in February 2007, eventually killing nearly a million bats in New York, Connecticut, Massachusetts, and Vermont (Cohn, 2008). The University has been, and should continue to be, concerned because white-nose syndrome has been spreading south rapidly. No bats on Sewanee’s domain have been affected by white-nose syndrome, but the first case in Tennessee was documented in 2010.

Threats to Biodiversity

White-nose syndrome is quite unique because it affects hibernating bats. Jeffrey Cohn notes that “the bats apparently deplete their fat reserves too early, rouse themselves from their torpor, and hunt for food” in winter months when there is little or no food available (2008). Subsequently, the bats starve and die. Bats prey on night-flying insects like moths, flies, and beetles. There could be an insect problem and pesticides may have to be used more often in order to fill the ecosystem services provided by bats. With no bats to control the insect populations, “the number of moths that damage our forests could increase” (2009). This evidence shows that the white-nose syndrome is affecting both cave and forest habitats across the eastern United States. Some unaffected caves may actually benefit because of the lack of human activity.

One of the theories behind white-nose syndrome says that it is an invasive fungus that was brought over from Europe, which would make it even more problematic (Biodiversity 10.2). Something is terribly wrong when an invasive fungus may be wiping out whole populations of bats, and some species are endangered. According to the Biodiversity article, measures are being taken to see if there is any link between fungi found on European bats and fungi on U.S. bats. These actions seem necessary, as the source of white-nose syndrome is still unknown.

Assessing the Threat

On April 15, 2009, John Benson, director of Sewanee University’s Student Outing Program, notified the community that all caving trips would be cancelled through the end of the academic year. This decision was made in compliance with requests by the United States Fish and Wildlife Service (USFWS) in March of 2009 for “a voluntary moratorium, effective immediately, on all caving activity in states known to have hibernacula affected by white-nose syndrome, and all adjoining states, unless conducted as part of an agency-sanctioned research or monitoring project” (USFWS Advisory 2009). Another USFWS article states, “in addition, people may inadvertently contribute to the spread since some caves used by people have white-nose syndrome affected bats, while other, nearby caves not used by people do not seem to be affected” (2009). Therefore, the advisory also asks cavers to not wear clothing that has been in affected areas in unaffected caves, and to thoroughly clean all clothing and equipment to prevent further spread of the fungus. Also,
any scientific research conducted in affected caves would have to be evaluated to determine if they may spread white-nose syndrome (USWFS, 2009). Caving activities have cautiously resumed, and cavers are expected to act in accordance with the requests made by the USFWS.

**Recommendations for Action**

Very little is known about white-nose syndrome and researchers have yet to determine a cure. Without a way to slow the spread of white-nose syndrome, species may be lost, altering habitats and ecosystems in unknown and likely detrimental ways. It is important for Sewanee to continue taking extreme precautions in order to conserve the bat species that are found locally, and the ecosystem functions they provide by continuing restrictions on caves and follow federal recommendations.
Conclusions Regarding Invasive Species:
The follow is a summary of recommendations for action for each invasive species:

Tree of Hevean (*Ailanthus altissima*)
- Herbicidal treatment
- monitor density

Invasive Aquatic Plants
- public education on invasive species
- restrictions on planting exotic garden plants
- monitoring pesticide and fertilizer runoff
- checks on water water quality
- no dumping of aquarium plants in aquatic ecosystems
- biological control

Feral Cats
- monitor feral cat populations
- research effects feral cats have on native species
- educate the public about the problems feral cats cause to native biodiversity
- monitor the success of management practices

Brown-headed Cowbird (*Molothrus ater*)
- bird surveys
- monitor nests of native species
- experimental cowbird removal program
- conservation of native forest habitat

Invasive Insects
- protect native forests
- research on fire ants
- prevent gypsy moth introduction by placing restrictions on imported products and using pheromone boxes

Multiflora Rose (*Rosa multiflora*)
- research
- removal in Shakerag Hollow
Nepal Grass (*Microstegium vimineum*)
- research
- restrict horse use of trails
- mechanical control
- chemical control
- monitor presence of species

Princess Tree (*Paulownia tomentosa*)
- mechanical and chemical control in disturbed habitats

Privent (*Ligustrum*)
- educate the public
- herbicidal treatment
- biological treatment

White Nose Bat Syndrome
- restrict cave use
- research

**General Conclusions**

It is quite clear that invasive species pose a threat to biodiversity here on the Domain. In this report, we have named some of the key invasive species that inhabit Sewanee, their affects on native species, and possible control methods. Based on these reports, it seems that as an academic institution we need to promote student research on these species and manage their control. Only then, we will be able to protect our native flora and fauna.
Assessing and Managing Pollution in Sewanee, TN
Introduction to Pollution

In a developing world, urbanization continues to increase and disperse the amount of pollution. Pollution includes the contamination of air, water, soil, and natural light, as it “releases synthetic substances from industrial or transportation sources” (Johnson et al. 2005, 36). Other sources of pollution can include natural, nontoxic materials such as added nutrients into terrestrial or aquatic ecosystems. However, all pollutants pose a threat to biodiversity from individual to ecosystem levels. As pollution is one of the more visible threats to the environment, control and maintenance has been administered and proved effective. The Clean Air of 1990 and the Clean Water Act of 1977 are such examples of regulation that have been installed to control sources of pollutants. However, assessing the degree of threat on more local levels is needed. In Sewanee, the University can begin to assess the degree of threat of air, light and fertilizer pollution to better determine future management goals and practices.

Chapter I: Air Pollution
Hank Gerrity

Introduction

Pollution directly and negatively impacts biodiversity. Advances in technology over the last century have resulted in mass amounts of pollution, which can be broken up into sub-categories. This report focuses on air pollution, a direct result of anthropogenic activity. It comes in many forms, such as gaseous, liquid, and particulate.

Air pollution enters the biosphere through deposition and absorption into terrestrial and aquatic systems. It can be both toxic and non-toxic, point and non-point, making it the most pervasive type of pollution. Its effects on biodiversity include decreases in species richness and abundance, weakening of organisms and even death to individuals. While it possesses such a variety of deleterious abilities, it can be controlled through awareness and action, making it more manageable than the other types of pollution.

The six most common air pollutants are ozone, particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, and lead. Changes in pollutant concentrations are of concern if, singly or in combination, the chemicals affect processes in the atmosphere or biosphere, which includes human health and the environment (Taylor et al. 1994). Those that affect the environment in a direct, indirect and sometimes observable manner are ozone, nitrogen and sulfur oxides, and toxic metals such as lead. The indirect effects have a far greater impact on vegetation in unmanaged natural ecosystems than direct effects (Taylor et al. 1994). These pollutants are grouped into three major types of air pollution: acid rain, ozone production/nitrogen deposition, and toxic metals. As these sources of pollution are present in the air encompassing Sewanee, the degree of threat needs to be assessed for future management.
Acid rain occurs from nitrogen and sulfur oxides produced from industries such as smelting operations and coal- and oil-fired power plants. The oxides combine with moisture, oxygen and other chemicals in the atmosphere, resulting in mild solutions of nitric and sulfuric acids (U.S. EPA 2009). This lowers the pH of rainwater, in turn lowering the pH of soil moisture and water bodies, which can increase the concentration of toxic metals like aluminum. In the U.S. about forty million metric tons of compounds from industrial activities are released into the air (Lynch et al. 2000). Lower pH in water bodies causes many species of freshwater fish to either fail to spawn or die outright, and it decreases egg development and increases mortality in young amphibians (Stuart et al. 2004). Higher levels of acidity inhibit the microbial process of decomposition, lowering the rate of mineral recycling and ecosystem productivity (U.S. EPA 2009).

Chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in sunlight produce ozone and other secondary chemicals, collectively termed photochemical smog (U.S. EPA 2009). The major sources of NOx and VOC are industrial facilities, electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents (Bormann 1982). However, the main sources are motor vehicles (56% of NOx and 45% of VOC) and industrial/chemical processes (17% NOx and 50% of VOC) (U.S. EPA 2009). High concentrations of ozone at ground level damage plant tissues and make them brittle and ultimately more vulnerable to harmful externalities like disease and insects (Pitelka 1994). Combinations of nitrogen deposition and acid rain are responsible for a decline in the density of soil fungi that have biotic relationships with trees (Pitelka 1994). These sources effectively harm biological communities by reducing plant productivity, which translates to lower commercial yield in agricultural and forest harvests (Adams et al. 1986).

Toxic metals are released from leaded gasoline, mining and smelting operations, coal burned for heat and power, and other industrial activities. Some of these metals include lead, zinc, and mercury. They occur naturally in the environment on small levels, but when metals from pollution enter the atmosphere, they accumulate in higher concentrations in soils and sediments through deposition (Almqvist 1974). Lead presents a large problem to biodiversity as it has neurological effects on vertebrates, which can result in paralysis or death (Pitelka 1994). The metals are directly poisonous to animals and plants in the areas surrounding sources, like highways and industrial waste pipes, but can also affect biodiversity miles away (Pitelka 1994).

Airborne pollutants collect in terrestrial and aquatic landscapes via wet (rainfall and cloud water) and dry (particle and gas) deposition and their amount ranges seasonally (Taylor et al. 1994). Wet deposition occurs more rapidly during the humid seasons, spring and summer, while dry deposition is observable in drier seasons, fall and winter. Landscapes across which deposition occurs vary depending not only on climate, but also geology, land-use and human interaction (Pratsini 1999). Pollutants can remain in ecosystems for long periods of time, or travel through a system quickly, causing various ranges and types of damage, like reducing species richness. Ecosystems with a lower diversity of species will be less able to adapt to altered weather conditions, associated with rising CO2 levels and global climate change (Pitelka 1994).
Assessment of Threat

One way to calculate the severity of air pollution is to observe and record changes in bio-indicators. Bio-indicators are species, predominantly plants, which exhibit changes according to varying concentrations of air pollution. Some of the best bio-indicators for air pollution are lichens, which absorb large amounts of chemicals and airborne pollution (Jovan and McCune 2005). Lichens, which are symbiotic organisms composed of fungi and algae that can survive in some of the harshest natural environments, have distinct levels of tolerance to air pollution (Tarhanan et al. 2000). Biological parameters used to assess pollution damage to lichens include respiration, photosynthesis, chlorophyll degradation and fluorescence, and ATP concentration (Kardish et al. 1987). ATP content is more sensitive to pollution than the other parameters, and can be used to show intermediate levels of pollution (Kardish et al. 1987). Chlorophyll content in lichen, because of its high correlation with the other physiological parameters, might represent the overall status of the metabolism of each species of lichen (von Arb et al. 1990). Nitrogen and sulfur oxides are known to be deleterious to lichens (Sigal and Nash 1983), and high levels of other toxic materials can kill lichens, so distribution and abundance of lichen can identify areas of contamination around sources of air pollution (Tarhanen et al. 2000). Most pollutants in forests occur after long-range atmospheric transport, allowing for determination of air pollution ‘hot spots’ (Taylor 1994).

Recommendations for Action

Controlling air pollution lies in low-emission motor vehicles, increases in mass transit systems, improved scrubbing of smokestacks, reductions in energy use and other specific applications. However, the greatest defense against air pollution is awareness. Education is key to advancing these ideas and practices individually and legislatively. There has been a rapid evolution of air pollution studies in ecology shifting away from the agricultural paradigm of single-factor experiments to new methods that are rooted in ecology and are interdisciplinary (Taylor et al. 1994). There are three broad types of methodologies for observing forest damage from pollution: (1) productivity at the level of an individual tree, forest stand, and community, (2) biogeochemistry studies at the stand level, and (3) modeling of individual trees, stands and regional forests (Taylor et al. 1994). This means (1) visual inspections of tree health and measurements of pollutant levels within the tree, (2) examining nutrient cycling in forest ecosystems through soil and water acidification and nutrient presence, and (3) somehow growing trees, stands and regional forest types in controlled environments. This is process-level modeling, which integrates tree physiology and forest ecology, watershed chemistry, and atmosphere-forest canopy meteorology to develop models of tree physiology and growth to equate these investigations to the levels of forest stands and landscapes (Taylor et al. 1994). Studies need to focus not only on the acute effects of pollution, but integrate air pollution, chronically, with the range of environmental stresses resulting natural and anthropogenic causes (Taylor et al. 1994).
Chapter II: Noise Pollution
Sarah-Louise Phillips

Introduction

Ecological light pollution is a relatively new term, which includes “direct glare, chronic illumination, and temporary, unexpected fluctuations in lighting” (Horváth et al. 2009, 317). This degree of light pollution can alter terrestrial and aquatic ecosystems as well as degradation of human health. Ecological light pollution can be anything from lighted buildings and towers to streetlights to flashing security lights to lights on vehicles. On the Domain, ecological light pollution sources include streetlights, lighted building and dorms, and the Cross. Polarized light pollution includes the high and horizontal polarized light sources that are reflected from artificial sources (Horváth et al. 2009). These sources of light pollution include man-made products such as asphalt roads, oil spills, automobile paint, and even gravestones (Horváth et al. 2009). These pollutants around the Domain include the paved roads and highways, painted automobiles, and windows that reflect polarized light.

Threat to Biodiversity

As diurnal species, humans depend on artificial light to compete and thrive throughout the night. However, many other species are nocturnal and depend on the natural nighttime light for migrating, foraging, and mating. This addition of artificial light to the natural environment has had severe impacts on the biodiversity from individual levels to population levels. In general, species that use natural, celestial light to orient themselves for need of migration have been greatly affected. Many nocturnal migratory species including most birds and insects can become “trapped” by light. Moths are attracted to high-pressure sodium lights associated with unshielded lighted signs and buildings, which generally reflect light out and up (Longcore et al. 2004). Also, when birds fly lower because of inclement weather they may enter a lighted range, become disoriented and suddenly blinded, and possibly collide with lighted building structures. For example, Gehring et al. (2009) studied avian collisions into communication towers depending on the source of light. They found that the majority of fatalities were associated with non-flashing red lights as opposed to flashing white, red, or incandescent lights. Because the adaptations of night vision are not advanced, some species cannot adapt to quick increases in light causing most to become blind for minutes to hours (Longcore et al. 2004). Disorientation can affect individuals including habitat selection and reproduction.

Polarized light pollution has severe implications on habitat selection. The attractive nature of reflected light causes many individuals to explore these sources. Other reproductive implications can be seen, as some bird species, in particular the black-tailed gadwits, have chosen nesting sites near artificial light sources including light poles beside roadways (Longcore et al. 2004). Artificial light has also affected the timing of mating. The female Physalaemus pustulosus frogs become less selective and mate quickly in fear of predation due to increased visibility (Longcore et al. 2004). Breeding cycles, if interfered with, can cause a species to delay or quicken reproduction, which can create unnatural competition and predation. Additionally, exposure to melatonin, a component in light, can greatly reduce fertility in species (Horváth et al. 2009). Although many individual species experience biological implications, population dynamics such as competition, predation, and communication can be altered.
In populations, many species forage at different times as examples of resource partitioning. These species prefer varying degrees of light for foraging of prey. Therefore, with the addition of artificial light sources throughout the night many species that originally preferred a certain degree of light begin to forage during different times. This change can increase competition for resources that would not normally exist among species. This pressure can lead one species to thrive, as one species declines. Some species that are naturally diurnal have been recorded to move into nocturnal foraging cycles (Horváth et al. 2009). Competition caused by changes in light sources can also lead to changes in predator-prey relationships. Some species have become more effective in foraging, which decreases the natural survival rate of their food source. Many bat species are drawn to light sources in which insects are entrapped. Thus, the bat species have an unfair advantage due to the increased light sources. The increased illumination can alter foraging of predators that directly impacts the behavior of prey. Some predators such as the short-eared owl can increase their efficiency of foraging with increased light. However, the deer mice they usually prey upon have adapted to this alteration and have decreased their activity levels during increased periods of illumination to avoid predation (Navara et al. 2007).

Communication is another population dynamic that is altered by light pollution. In particular, Miller (2006) studied the effects of artificial light on American Robins (Turdus migratorius). Robins among other bird species communicate through song at dawn. Miller predicted that these birds would sing earlier in areas with high concentrations of artificial light. He indeed provided data that examined the correlation of early song behavior with these congested areas of light pollution during twilight and nighttime hours.

**Assessment of Threat**

As of present, the effects of light pollution in Sewanee are unknown. Although the Sewanee community takes part in the emission of light pollution with the lighting of buildings, vehicle lights, and other polarized light sources, the total accumulation of all light pollutants is minimal. Under the Leadership in Energy and Environmental Design (LEED) assessment, Sewanee would be characterized as LZ2, which includes areas that are “primarily residential zones, neighborhood business districts, light industrial areas with limited nighttime use and residential mixed-use areas” (U.S. Green Building Council). This assessment determines that Sewanee is of least concern. However, with any increasing population, threats to biodiversity can increase. Thus, by researching and evaluating the current threat in this community, one can estimate future implications caused by changes in land use.

**Recommendations for Action**

In Sewanee we can begin to curb light pollution by reassessing all of the light sources’ output. For the lights around campus we can switch to compact fluorescent light bulbs. This can reduce the stress put on species that are impacted by the high-intensity discharge (HID) lights. Also, the streetlights can be replaced with solid-state lighting that emit light vertically to the ground. This shielded lighting will prevent light emission that disrupts organisms’ nighttime vision (Beatty 2010). These light sources can also be censored, as to detect movement, which will keep areas of non-use dark. Motion-activated lights will also promote energy efficiency around campus.

For student involvement, the University could provide community service opportunities to educate the general public in the Sewanee community on the potential threats on the environment.
Students can work individually with Sewanee Elementary by providing incentive for being responsible in turning off unnecessary use of light or by creating their own lights out program. The University could sponsor an event in which all lights around campus be turned off for a dark night. One event could include turning off the Cross in order to preserve the natural environment neighboring this area. By inviting students and the public to be interactive in this conservation process, Sewanee can continue promoting a green living environment.

Also, as a goal for the University, student research is critical for future management decisions. In Sewanee, students could study the installed light sources around campus. The light source and watt values could be measured in correlation to number of species that visit these sources. Also, the students could study the effects of different wavelengths on organisms in different natural and developed areas on the Domain to better understand the effects of artificial light.

Chapter III: Fertilizer Pollution as a Result of Golf Course Maintenance
Erica Teasley

Introduction

Golf is a very popular sport in the United States with about 19,000 courses in existence, including one located in Sewanee, TN. This sport is watched and enjoyed by people from all social classes. While golf is a very popular pastime, golf courses can be very destructive to the environment. Loss of trees and sedimentation runoff resulting from the construction of the course can cause large-scale ecological destruction. One of the big environmental threats is the continual addition of chemical fertilizers to maintain turfgrass.

Fertilizers contain three main nutrients to maintain bright green grass: nitrogen, phosphorus, and potassium (Gartner 2001). All three nutrients are important for soil fertility. Nitrogen increases plant growth and color; atmospheric nitrogen and nitrogen from animal wastes enter the soil, where nitrogen-fixing bacteria and decomposers break these forms of nitrogen into nitrates and nitrites. The nitrates and nitrites are then taken up by plants; when the plants die, their nitrogen goes back into the soil. Denitrifying bacteria change the nitrogen back into atmospheric nitrogen. Phosphorus increases growth; the weathering of rocks releases inorganic phosphorus into the water and soil. Organic phosphates come from the decomposition of plants and animals; these become inorganic phosphates in the soil and are then take up into other plants. Potassium increases root growth and plant tolerance to cold, drought, and heat; it also decreases disease tolerance. Potassium adsorbs to soil particles, where it is taken up by plant roots. When plants and animals die their potassium absorbs back into the soil. The addition of these three nutrients through fertilizers alters their cycles by providing an excess of nutrients than would normally be available.

Threat to Biodiversity

There are many threats that fertilizer application poses to biodiversity. The Sewanee golf course overlooks Shakerag Hollow; which is home to a number of the most unique floral communities on the Domain. Fertilizer runoff can adversely affect this ecosystem, greatly affecting
biodiversity as well as the area’s aesthetic value. There are many species that are affected by fertilization runoff; these include soil nematodes, amphibians, stream invertebrates, and plant species. Nematodes can be used as bioindicators for changes in soil ecosystems; parasitic plant nematodes are less abundant in soil with fertilizer but fungivores increase growth (Pan et al. 2010). In addition, bacterivores are directly related to the amount of soil carbon, phosphorus, and nitrogen, which demonstrates soil fertility (Pan et al. 2010). Amphibians are particularly vulnerable to fertilizer runoff because of their dependence on water for reproduction (Hecnar 1995), which, when one considers the great diversity of salamanders found in the streams of Shakerag Hollow, is a major concern. Nitrate fertilizer coupled with UV-B radiation decreased survival and/or growth by affecting breeding ponds (Hatch and Blaustein 2003). Stream invertebrates are particularly vulnerable to fertilizer runoff; many species of mayflies, stoneflies, and caddisflies, considered rare in the Southern Appalachians, require very specific abiotic conditions (Morse, Stark, and McCafferty 1995). Furthermore, golf course streams contained a higher percentage of the taxa Amphipoda, Isopoda, Trombidiformes, Turbellaria, and Zygoptera; non-golf course streams contained a higher percentage of Culicidae, Ephemeroptera, Megaloptera, and Plecoptera (Winter 2002). This indicates that runoff from golf courses can change the species composition of the aquatic ecosystem.

Nutrient pollution interacts with other threats to biodiversity. In addition to fertilizer, pesticides are applied to fields to kill weeds and maintain attractive turfgrass. Increased nutrient availability encourages population of invasive species (Davis et al 2000). There are also changes in plant composition from heterogeneous to homogeneous in favor of commercial grass. The actual building of the golf course causes habitat fragmentation and creation of edge effect. This can reduce the desire of some species such as birds to live in the area and increase attacks on humans during breeding/nesting season (Terman 1997). Erosion can be induced by low cut grass (1/8 inch or less), which increases damage from ball marks and golf clubs and increases drought stress, disease, winterkill, and erosion (Nelson and Gilhuly 2006). In addition, lost golf balls and tees could be ingested by wildlife and could damage the digestive tract or even cause death.

Assessment of Threat

Monitoring is a big part of reducing this problem. Properly maintaining and monitoring can drastically reduce the amount of excess nitrogen, phosphorus, and potassium that enter the environment (Mankin 2000). Water and soil samples should be collected monthly or seasonally (Witthers 2001). The first year establishes the base line and samples should be continually retested every year (Audubon “Environmental” 2006). Environmental factors that should be monitored include dissolved oxygen, pH, temperature, specific conductivity, nitrogen, nitrate, ammonia, total phosphorus, and stream microinvertebrate surveys along the golf course and in Shakerag (Audubon “Environmental” 2006). The amount of fertilizer used should equal the need, which can be determined by monitoring techniques (Carpenter 1998; Audubon “Environmental” 2006). The amount and frequency of fertilizer applied depends on the type of grass used, precipitation, soil fertility, and size of the course. A soil sample can be obtained and sent off for testing to determine what is already in the soil and what the soil needs; the testing facility may provide recommendation for fertilizer application (SOCWA and Healthy 2007).

Recommendations for Action

If maintained properly, golf courses can preserve natural ecosystems and remain aesthetically pleasing. Audubon International has established guidelines for developing and maintaining “green,”
environmentally friendly golf courses that are enjoyable for humans and wildlife. Golf courses must be members of the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP) to apply for certification and must renew certification every two years; ACSP membership is $200 without any addition fees to apply for certification (Lampman 2009). There are six categories that are examined and satisfactorily maintained for certification: environmental planning, wildlife and habitat management, chemical use reduction and safety, water conservation, water quality management, and outreach and education (Lampman 2009). The specific requirements in each category are available in the Certification Handbook, which is only available for viewing by ACSP members. Certification varies from 1-3 years depending on how well the golf course management prepares the required documentation (Lampman 2009). To be certified, an organization must submit a Site Assessment and Environmental Plan to Audubon International, which reviews the plan and provides feedback to the management (Lampman 2009). Golf course management is then required to submit written and photographic documentation that the course meets standards set in the Certification Handbook; if certification is granted, a third-party must verify that the course meets standards within two years (Lampman 2009). Only 826 golf courses throughout the world have obtained certification through the Audubon Cooperative Sanctuary Program (ACSP) for Golf Courses; most of which are in the United States. However, as of now, the golf course in Sewanee, Tennessee has not obtained certification from Audubon International.

There are several general practices that a golf course can use to reduce fertilizer runoff and subsequent nutrient pollution. Planting riparian vegetation can reduce runoff of fertilizer, pesticide, and herbicides into water by acting as buffer zones (Carpenter 1998). Buffering strips reduce runoff into watersheds (“no mow” zones) when established in strips of at least 30m (Gartner 2001). The grass used in the buffer zone should be at least 3 inches to provide maximum protection against runoff (Baird 1998). Maintaining very thick turfgrass can reduce the use of pesticides. This turfgrass will prevent sunlight from reaching the soil and causing weed germination.

Storm water management can reduce runoff by diffusing water or collecting it into ponds so it doesn’t go immediately into surface water (Gartner 2001). When mowing the turf grass, only 1/3 of grass should be cut with sharp blades to promote recovery and resistance to disease; the grass cuttings should then be returned to the turf to reduce the amount of fertilizer required (Gartner 2001). Taller grasses should be allowed to increase habitat and diversity, provide wildlife corridors, reduce need for application of fertilizer/pesticides, and reduce water use and erosion (Audubon “Tall grasses” 2006). The Best Management Practices set by Audubon International include slow-release fertilizers, spoon-feeding, and drainage filtering through plants before the water reaches the watershed (Audubon “Environmental” 2006). Some fertilizer in the late fall/early winter will help growth in spring and reduce the amount that will be needed during spring and summer because at this time, the grass will store the nutrients in their roots (Gartner 2001). Addition of lime to acidic soils increases fertilizer absorption and decreases runoff (Gartner 2001). Fertilizers should not be applied to the turfgrass when it’s hot/dry because roots cannot absorb them unless there is water in the soil; after application the turf should be lightly watered to allow the fertilizer to soak into ground (Gartner 2001).

In order to reduce runoff and the need for additional applications, fertilizers should not be applied right before a heavy rain to reduce runoff and the need for additional applications (Audubon “Environmental” 2006). More precipitation causes a larger percentage of nutrient runoff (King 2007). Therefore, it is important to take into account the amount of precipitation that a given area receives; this is important in regards to irrigation practices, particularly in the summer. Too little
irrigation of the golf course and the fertilizer will not be absorbed into the ground and taken up by the roots. On the other hand, too much irrigation and the roots will not have enough time to take up the fertilizer, which will wash right out of the application area. More fertilizer will then need to be added, increasing nutrient pollution. Because of its ability to go into solution with water, fertilizer should be stored in a covered area so there is no unintentional leeching of fertilizer into the soil through exposure to precipitation.

Also, on a bag of fertilizer, there are generally three numbers representing the percentage by weight of nitrogen, phosphate, and potash (potassium). Slow-release fertilizers, which are either organic or have at least a 50% content of water soluble nitrogen, should be used because they promote continual growth of turfgrass and help reduce runoff; this makes the turfgrass low maintenance, which is more cost effective (SOCWA and Healthy 2007). Initially, the slow-release fertilizers are more expensive than fast-release fertilizers, but slow-release fertilizers last longer (about 2-3 months) and require fewer applications; they also protect soil and water biodiversity (SOCWA and Healthy 2007). In addition, the calibration of fertilizer application equipment before use increases the accuracy of the application (Golf 2009). The amount of required fertilizer can be reduced by 25% or more if grass cuttings are left on the turfgrass or if there is some shade of the course (SOCWA and Healthy 2007). The national average for application rates are as follows: nitrogen 3.5 pounds per 1,000 square feet; phosphate 1.5 pounds per 1,000 square feet; and potassium 3.6 pounds per 1,000 square feet (Golf 2009). These numbers are the average application rates for an 18-hole golf course; the actual application rate should be based on the previously mentioned criteria.

Fertilizer pollution provides several opportunities for student learning. Students can take part in monitoring the application of fertilizer to the golf course. Flora and fauna censuses can be conducted to examine the species and populations that are present throughout the year. Workshops, seminars, and committees can be set up to teach students as well as community members about golf course maintenance. Such information can also be applied to private lawns. Students and professors can conduct research to determine the extent of fertilizer pollution on the environment and wildlife by finding out how much is there and how it has altered the ecosystem.
Conclusions Regarding Pollution

*Air Pollution*

Protecting biodiversity does not simply mean reducing air pollution. Air pollution is a large part in a complex system of threats that coincide with each other. However, reducing emissions and eliminating some air pollutants from commercial and industrial producers can be done. It begins with educating the public about the types of pollution, how they affect the environment, and what can be done to reduce or stop these pollutions. The most effective way of getting the populace to agree on these reductions and eliminations is to incorporate human health and survival. Air pollution presents health hazards and lowers agricultural productivity, and if the public knew one reason behind such problems as asthma and low crop yields was air pollution, they might be more willing to change and speak against such pollution.

*Light Pollution*

The sources of light pollution in Sewanee, TN are a direct result of urbanization. As a diurnal species, humans have continued to expand artificial light technology in order to compete and be productive during nighttime hours. These sources also provide safety from crime and injury. Recently, light pollutants have been measured in lux. This non-SI unit was developed as a means to communicate the degree of light depending strictly on the wavelengths of light that the human retina can perceive. However, this system of measurement does not take into account the effects of wavelengths on other organisms. In order to protect biodiversity, calculated research needs to be developed in order to predict the wavelengths perceived by various organisms in order to correct measurements of light. With this baseline data, the University could begin researching alternative light sources needed to protect biodiversity while maintaining safety for the students.

*Fertilizer Pollution*

Golf courses require fertilizers to maintain the desired green color of the turfgrass. This added pollutant affects the surrounding habitats with sediment and fertilizer runoff, which ultimately affects terrestrial and aquatic ecosystems. The main stakeholders that are associated with this threat are the people who want the golf course to play golf and want the green golf courses. On the other hand, there are the individuals who prefer to preserve natural ecosystems and decrease environmental pollution. These two groups can work together to maintain a golf course that is environmentally friendly and aesthetically enjoyable. A golf course should be an extension of the landscape, establishing a unique and harmonious relationship.

*General Conclusions*

- Educate the public about the types of pollution, how they affect the environment, and what can be done to reduce or stop these pollutions
- The most effective way of getting the populous to agree on these reductions and eliminations is to incorporate human health and survival
- The University could provide community service opportunities to educate the general public in the Sewanee community on the potential threats on the environment including air, light, and fertilizer
- The University could sponsor an event in which all lights around campus be turned off for a dark night including the Cross
- The streetlights can be replaced with censored, solid-state lighting that emits light vertically to the ground
- Students could test light sources around campus to study the effect of wavelengths on various species
- Students can take part in monitoring the application of fertilizer to the golf course
- Fertilizers should not be applied right before a heavy rain to reduce runoff
- Planting riparian vegetation can reduce runoff of fertilizer, pesticide, and herbicides into water by acting as buffer zone

The Sewanee golf course could apply to become members of the Audubon Cooperative Sanctuary Program for Golf Courses (ACSP)
Opportunities for Students

This document has its roots in the 2008 "Strategic Plan for Environmental Education and Sustainable Living" addendum to the university's Strategic Plan. One of the stated objectives of this document is that "Domain and campus management will support the educational mission of the University and engage in an inclusive planning process focused on conservation and appropriate use of present resources." Domain management is not too be conducted in a vacuum, but is meant to be informed by the values and concerns of students, and in such a way that it best promotes educational opportunities for the entire student body. With the Domain as a resource and the growing commitment to Environmental Studies, Sewanee is in a unique position to provide students to play an integral part in active conservation of biodiversity around them.

The threats to biodiversity described above create manifold opportunities for teaching and research. Reading through all of the sections, what becomes clear is that in order to make informed management decisions regarding biodiversity on the Domain, extensive research is needed. This will involve further research of how management decisions have been made elsewhere and how effective these have been, but more importantly will be focused on assessing the threats in relationship to the Domain. The overall body of research on threats to biodiversity on the Domain is limited. All threats mentioned in this document are in need of qualification relative to the Domain. It is one thing to understand the threats from research conducted elsewhere, but it is only when research is performed evaluating threats as they are manifested on the Domain that a full understanding of how they should be managed can be formed. Any management decisions related to threats to biodiversity should be backed up by student research and evaluation. To make hasty uninformed decisions would be to deny the educational opportunities that quantifying these threats provides and runs the risk of causing more harm to native flora and fauna than good.

When addressed with educational opportunities as a principal goal threats to biodiversity become much more complex. Alleviating and eliminating threats will not always be in the best interest of students from an educational standpoint, insofar as eliminating a threat precludes further study of that threat on the Domain. The goal of researching these threats must balance interests of conserving biodiversity with educational values. With many threats this should not be a problem, as the elimination of that threat is largely unfeasible and impractical. In all situations, educational values of managing threats should be balanced with educational values of studying threats and their ecological impacts.

Habitat Loss and Fragmentation

Roads:

In recent years, interest in the ecological threats of roads on forested habitats has increased significantly, evidence by a number of review papers published in scientific journals (Bennett 1991). This interest has created a surge for future landscape ecologist and conservation biologist to study roads, assess their effects on biodiversity, and address these effects through conservation planning.
There is also a need for civil engineers and road-planners to develop a safe transportation infrastructure that will promote a sustainable future for the landscape and wildlife, prospective policy makers to enact and enforce regulations to mitigate the ecological impact of existing roads, and teachers to inform future generations of the effects of habitat fragmentation. Although roads may negatively affect ecosystems around them they provide a wealth of material for students to study. Students can research the abiotic and biotic changes of landscapes caused by roads, such as changes in hydrology and increased mortality of animals by vehicle collision, and edge effects, like the change in microclimate and colonization of exotics.

The ecological impacts of roads create important educational opportunities for students. Roadside ecosystems are a lab within themselves, creating potential for lessons in biology, ecology, forestry, hydrology, and environmental policy. There are great opportunities for students to become familiar with the methods of ecosystem assessment used by federal agencies.

The faculty and student body of the University could potentially use existing roads and the construction of new roads as a research tool to examine the ecological impacts that roads may or may not have. There are endless possibilities for research topics concerning roads and the Domain. The University of California-Davis has a Road Ecology Center dedicated to researching the ecological impacts of roads (UC Davis 2010). Such collaboration between students and faculty would invariably yield useful opportunities for research on the Domain.

Roads are often included in community service efforts led by students, particularly roadside grooming.

Roads provide access to trails, lakes and scenic vistas that are of great recreational value. The construction of new roads would undoubtedly create more opportunities for recreation.

Dams:

Both allowing for the failing of some dams and directly deconstructing others in Sewanee would provide students with the opportunity to study natural watershed restoration on the domain. However, it is unlikely and probably too costly to actively deconstruct dams, so I recommend that the University simply allow unnecessary dams that would fail on their own to do so.

Restored wetlands would support greater biodiversity, which would allow for the possibility of more species and a greater abundance of individuals to study on the domain.

Maintaining some dams will allow for the opportunity to study in conjunction naturally flowing stream habitats and disturbed (impounded) stream habitats. For example, John Roberts and Dr. Haskell performed a study on the abundance and diversity of salamanders in free flowing streams as opposed to impounded streams.

Dams allow us to study the yellow boy effect in streams on the domain and biological communities in a lake habitat. For example, students did a study on the abundance and diversity of fish species in different lakes across the domain. We can study pollution in lakes on the domain, as was done in a study by Benton on the high content of chemocline in Lake Dimmick, Cheston and O'Donnell.

Lakes on the domain provide the university with the opportunity for its students to study limnology and hydrology. Students can also compare among different lake habitats, because the
lakes have a variety of depths, pH levels, and different abiotic and biotic variables. I recommend that the University create a database, documenting these different factors for each lake on the domain, so that students may use the information to study species and ecological processes in relation to these factors.

**Power Lines:**

As this is a university with the ultimate objective of education of students, and all management decisions should be made with this in mind. These powerline right-of-way sites offer a great opportunity to study edge effects as well as to study a diverse and unique flora not found elsewhere on the domain. From the standpoint of ecology these linear cuts of early successional habitat are perfect grounds for comparative studies. Having these created transects allows for the easy creation of plots of early successional habitat with a composition, structure, and function that can readily be compared with that of the interior forest. There are also opportunities to compare these anthropogenic and maintained disturbances with more natural disturbances such as fire. As a fire regime has been reintroduced experimentally on the domain there are opportunities to compare the two distinct disturbance areas. These artificial edges also provide opportunity for the study of edge effects and edge habitat dynamics across different habitat types, from the tops of the plateau to the bottoms of the coves. These habitats contain unique composition and structures of communities, with species abundances, distributions, and behavior that is not found in the interior forest.

From the side of applied biology and ecosystem management there are education opportunities in the actual implementation of management methods. If the university works with the utility companies, opportunities will arise to experiment with a variety of management techniques. If a variety of management techniques are implemented, then the effects of each on the flora and fauna would provide research opportunities. As these areas are utilized in education, a further understanding of the dynamics of these communities can be achieved, which will in turn direct those students interested in ecosystem management and will better inform the techniques used in these rights-of-way. The realization of educational opportunities will be important as time goes on in order to ensure that management strategies are being implemented that offer maximal benefit to biodiversity. Powerline corridors are a unique threat insofar as they bring have both positive and negative effects on biodiversity. It will be the task of student research to discover how the balance between the negative and positive can best be struck to promote the goals of the maximization of biodiversity.

**Pine Plantations:**

The contrast between a pine plantation and a native hardwood forest is striking and quite obvious. This makes them a valuable teaching tool for the concepts of structural and compositional diversity. There is the capability to collect a lot of very interesting and valuable data about plantations using the striking contrast of the domain’s diversity.

**Fire suppression:**

Controlled fires on the domain create many learning and research opportunities for students. They will be able to document the effects of fires and disturbances on ecosystems. Students will be able to compare and contrasts burned areas vs fire suppressed areas. An extensive study and inventory of the area should be completed prior to the burning so that the exact changes in the process of regeneration could be documented year to year. There will be opportunities to observe
invasive species movement into a disturbed habitat. Also, teaching and learning opportunities for forestry, biology, environmental studies, and natural resource courses will be created. Ample data and statistics on soils and rate of plant and tree growth will be derived from this study which would be useful for forest management for the entire Cumberland Plateau. Students will be able to help organize, watch, and even control the burns. Dr. Ken Smith’s Forestry classes have aided in the implementation of the fires on the two current test sites. These students have had the opportunity to learn proper technique, how to use equipment such as drip torches, and how to obtain a burn permit. The reintroduction of fire to the domain presents an opportunity to bring the whole community together.

Overpopulation of Deer

- Deer Management Council
- Comparisons of biological data obtained from cullings from subsequent years
- Exclosure studies of the forest recovery as a factor of deer density
- Donation of deer meat to charities such as Hunters for the Hungry
- Composition of a working deer management plan
- Creation of exclosures coupled with research in subsequent years (useful for class studies as well as independent research)

Invasive Species

*Tree of Heaven (Ailanthus altissima)*

*A. altissima* can serve as a very valuable tool for students in terms of teaching and research. As research shows, it would be a good model for aggressive invasives, in terms of invasion, succession, and management. The soil samples taken from the area near King’s Farm could serve as a model of allelopathic chemicals and their effect on native species. It also provides excellent opportunities for research on the domain. Again, succession and management could be topics of research to augment the existing science. The control of suckers and the extermination of the expansive root system is an especially important aspect of this research. The controlled burn going on near King’s Farm presents an opportunity to study the succession of *A. altissima*. Seeds have been found in soil samples taken from the area. In light of this fact, its well-known affinity for disturbance, its rapid growth rate, and its utilization of an allelopathic chemical, this burn has the potential to create a plot of heavily *A. altissima* dominated forest. I found very little research on the effect of community function by *A. altissima*, such as nitrogen fixation and nutrient recycling which presents another opportunity. The expansive root system may also have an effect on soil invertebrate community composition. The mechanisms of ailanthone and and allelopathic chemicals in general could be used for teaching and these chemicals can also be used for research. The exact mechanism of transport of ailanthone is unknown so this could be a topic of research.

*Invasive Aquatic Plants*

Aquatic ecosystems and habitats can be easily integrated into academics, especially in the biology, chemistry, forestry, and geology departments. There are possibilities for field trips, research projects, and chemical analyses on the watershed, nutrient cycles, and disturbances in affected water systems. The lakes and reservoirs present an opportunity to examine the vulnerability of aquatic systems to invasives, how invasives are propagated, and the effect of aquatic invasives on wildlife.
and natives, especially the interactions of red-spotted newts and salamanders, turtles, and water insects. Students could research the effective competitiveness of the invasives, including the use of allelopathy in an aquatic system, light and nutrient domination, rapid reproduction, or other advantages. One research project in particular could involve the breaking of a dam, as many of the lakes on the Plateau had no original utilitarian purpose, and the after-effects on diversity, composition, succession, and terrestrial invasives.

Students could explore uses of invasive aquatic plants for human use as food or medicine, animal fodder, biomass, and fertilizer. As the drinking water reservoirs provide water for the University and community, the maintenance of the water bodies is essential, and students could explore how to improve the quality of the water, like through beneficial water-filtering plants. The Herbarium sponsors hiking trips aimed at removing invasives, especially privet and Oriental bittersweet, and these trips could be expanded to canoeing or wading shallow areas of the lakes to remove harmful invasives. This would provide education and invasive awareness as well promote use of the lakes for recreation. The use of the lakes for swimming, crew boats, and canoeing provides entertainment and exercise for surrounding communities.

**Feral Cats**

For students interested in activism, there are many opportunities regarding conservation biology however, it is necessary that these practices are explained and discussed to increase the understanding of the different issues involved with conservation biology. The domain is full of different opportunities to study conservation biology. Feral cats and their impacts on the domain is an important and pressing issue on the domain which does not have a clear plan of action. In addition, if cats are not managed, and bird populations continue to decline, educational opportunities of studying native songbirds on the domain will no longer exist.

**Brown Headed Cowbirds (Molothrus ater)**

Parasitism by Brown-headed Cowbirds is an important thing to monitor because ornithology is an important class that Sewanee has to offer. Numerous students take the class and subsequently go into ornithological graduate programs. In order to keep these students’ experiences rich with bird diversity, we need to preserve the 200+ species that live or travel through the Domain each year. If these species begin to decline because of nest parasitism by cowbirds, it will have educational as well as economic implications. Any ecotourism brought to the area as a result of bird diversity might decline if they stop seeing their favorite migratory songbird species due to nest parasitism.

**Invasive Insects**

There are many educational opportunities associated with monitoring and preventing invasive species. For example, students can research the effects that invasive fire ants have on the native invertebrate fauna. Understanding this relationship will help determine what treatment methods, if any, are most applicable. Students can also participate in monitoring gypsy moth populations in Sewanee forests. If gypsy moths do populate this region, students could conduct studies that evaluate treatment methods and their impacts on ecosystems. Furthermore, I think it would be beneficial to teach a class called Invasive Species at Sewanee: The University of the South. This class would provide an in depth analysis of invasive species using examples from the Sewanee forests. Projects in this class would involve understanding invasives and how they can alter landscapes.
Student organizations such as the Sewanee Natural History Society (SNHS) and Students for an Environmentally Responsible Planet (SERP) could also participate in the reduction of invasive populations. SERP and the SNHS could lead student trips that involve hanging gypsy moth pheromone traps on Sewanee trees or placing boiling water on ant mounds. The University could also allow students who need community service hours to do the same tasks. Thus, it appears that monitoring and removal of invasive species could become a community event.

*Multiflora Rose* (*Rosa multiflora*)

Classes could also study the spread of invasive species such as multiflora rose by observing the nature of the plant over time.

*Nepal Grass* (*Microstegium vimineum*)

Nepal grass provides educational opportunities for students of the university. This invasive grass provides many opportunities for lab work, independent studies, honors thesis or research projects for students of biology, forestry or environmental studies. Some students at the university have already conducted research projects on *M. vimineum* on the Domain. In 2003, John Wallace and John Williamson, both biology students at the university, conducted a semester long study on the invasion of *M. vimineum* into loblolly pine stands on the Domain. Another study was also conducted in 2009 by Biology professor Dr. McGrath and her student Meagan Binkley on the effects of *M. vimineum* to the soil on the Cumberland Plateau (McGrath and Binkley 2009). Further research could be continued by students in the future. Currently there is also a group of students evaluating the distribution of invasive plants on the Domain, including *M. vimineum*. Ultimately will use what they find to create an invasive plant management plan for the Domain. Other research projects are to be gained from 1) evaluating the threat that the grass has on the Domain, 2) assessing its distribution and 3) controlling *M. vimineum*.

**Research topics:**

- What are the impacts of *M. vimineum* on native communities of the Plateau?
- What are the mechanisms of *M. vimineum* invasion on the Domain?
- What species replace *M. vimineum* when control is successful?
- What is the most effective method of controlling *M. vimineum* at specific sites on the Domain? How can this method encourage the regeneration of native species?
- What is the ecological response of an environment to the removal of *M. vimineum*?
- What is the distribution of *M. vimineum* on the Domain?
- Which communities on the Domain are most likely to be invaded?
- What effect do the change is soil created by *M. vimineum* have on vegetation growth?
Princess Tree (Paulownia tomentosa)

Having the invasive species, *P. tomentosa* on the Domain presents many opportunities for the University. First is if the University elects to go forward with plans to control *P. tomentosa* it will provide students and student organizations and opportunity to do community service. It also gives students the opportunity to learn how to control and manage species as well as maintain a forest with a certain objective. It gives students a chance to apply what they have learned in classes in a real world situation. Additionally *P. tomentosa* gives professors a great resource to demonstrate what invasive species are and the numerous impacts they can have on a native ecosystem. The greatest opportunity though is the chance to do a wide variety of research. The possibilities are endless: How does *P. tomentosa* effect animals on the Domain, What plant species are impacted by *P. tomentosa*, How can *P. tomentosa* be better controlled, and the questions could continue. *P. tomentosa* on the Domain creates a set of issues and possible opportunities that can only be determined by the goals decided upon, whether they be biodiversity or education.

Privet (Ligustrum)

Privet provides a unique learning experience in the context of invasive species. There is no biological control for the species, which makes it hard to rid the area of it so it should be studied in the meantime. The study of the different methods of treatment has educational value in itself. Understanding why privet thrives along stream banks and fragmented forests holds educational value. Furthermore, information concerning the area of origin, genetic diversity and possible acquisition of germplasm through hybridization is fundamental to understanding the evolution, ecology and possible control measures for an introduced invasive plant species (Abbott and Milne 2004). Therefore, the study of this information is necessary in fully understanding which method, if any at all, should be used in riding the plateau of privet. A DNA and cpDNA analysis along with RAPD analysis of privet populations, in order to recognize what variations are in the area of concern, should be conducted (Abbot and Milne 2004). Furthermore, there is educational value in the Community members of the domain practicing mechanical control. Hand pulling or the use of a weed wrench is proven effective with seedlings and small shrubs (SE-EPPC 2007). The Greenhouse on Sewanee’s campus will be experimenting with this on April 24, 2010, in an act to pull up all the privet and other invasive plants present in their backyard. Privet could be hand-removed when it is sporadically dispersed, but not when it has formed an entire community where the entire ecosystem is dependent upon the presence of this invasive. In addition, there is educational value to be found in the study of privet by analyzing the impact of the species.

White Nose Bat Syndrome

Insofar as the presence of white nose bat syndrome has yet to be documented on the Domain, the most important educational opportunity related to this threat is the continued monitoring of bat populations. Effectively monitoring populations will require students to learn skills related to trapping the bats and recording data about them. In addition to acquiring information about white nose bat syndrome, this exercise could provide a sort of mammalogical survey that is largely absent from the current science curriculum.
Pollution

The threat of pollution is very closely associated with sustainability. Air pollution, light pollution, and pollution resulting from the golf course are all issues directly related to the sustainability of the university, opening up a unique set of educational opportunities that interface well with policies being implemented elsewhere in the university. In the Easter 2010 semester, a Sustainability Steering Committee formed under the direction of the university's sustainability coordinator, Marvin Pate. Through this committee, positions have been created for students to serve on the committee itself, participate in working groups focused on particular sustainability issues, and to participate in internships and independent studies researching and analyzing the status and direction of sustainability in Sewanee. The threat of pollution to biodiversity as well as to human health could be a very important element in drawing Sewanee closer to its sustainability goals, and so many of the education opportunities related to this threat fall within this category.
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