Connecting Deer, Forests, and Water Quality

Completed by the Students in ENVS 491
Senior Seminar, Fall 2008

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Forward

The Environmental Science and Studies (ESS) Senior Seminar class is taken by students who are completing their academic major and getting ready to graduate. The course consists of a semester long project. The course objective is for the students to bring to the project the knowledge, skills and abilities they have developed through their academic study and use them to address a specific question or problem. This year Mr. Don Outen, a Natural Resource Manager with the Baltimore County Department of Environmental Protection and Resource Management, suggested we look at the issue of deer management on the forested lands surrounding Loch Raven and Prettyboy Reservoirs, reservoirs that serve the region but are under the jurisdiction of Baltimore City. Initial contact with the Reservoir Natural Resources Section, Environmental Services Division, Bureau of Water and Wastewater, Department of Public Works of Baltimore City were positive; we accepted this challenging project knowing we had the support of Baltimore City and Baltimore County. This was a particularly challenging year in which to undertake this project. During the course of the semester the City approved deer hunting at Loch Raven for the first time. Unlike Loch Raven, hunting has been allowed at Prettyboy Reservoir for over 35 years. This gave us the opportunity to explore forests with and without some measure of deer control.

The health of the reservoir forests have an impact on the reservoir which supplies water to thousands of residents and businesses in the area. The deer appear to be impacting the forest's health by inhibiting its ability to regenerate and maintain its integrity as a forest which, in turn, affects the water. These relationships seem simple, but addressing the issue of controlling these charismatic animals isn't.

The students have worked on their own. I provided limited guidance and help as requested. The students deserve the credit for their success.

Jane L. Wolfson, Ph.D., Director, Environmental Science and Studies Program
Instructor, ENVS 491 Senior Seminar, Fall 2008

Introduction

Loch Raven and Prettyboy reservoirs are two of three reservoirs that collectively supply drinking water to over 1.8 million people in the Baltimore metropolitan area (MD DNR, 2003b). This service area includes Baltimore City and portions of Baltimore County, Howard County, Harford County, Carroll County, and Anne Arundel County (BMC, 2008). Both reservoirs are fed by the Gunpowder River. Prettyboy reservoir is located upstream of the Loch Raven reservoir, and the Prettyboy Reservoir primarily serves to replenish the Loch Raven reservoir (BC DPW, 2007). Loch Raven and Prettyboy watersheds, the land that drains into those water bodies, total 303 square miles in area (BC DPW, 2007). Both reservoirs are bordered by forests to protect water quality.

Forests provide a multitude of ecological services. For instance, forests are critical players in the water cycle. Trees take up water from the soil and release it back into the atmosphere by evapotranspiration (Karimzadegan et al., 2007). Forests are also important carbon sinks because they sequester carbon in the plants and the soil, thereby reducing the amount of atmospheric CO_2, a key climate-altering greenhouse gas (Daily, 1997). Forests promote biodiversity by providing habitat and food for animals (Daily, 1997). In addition, forests provide invaluable hydrologic services, such as filtration and interception, to water systems such as our reservoirs. Intact, densely-vegetated forests prevent erosion by anchoring the soil and trapping sediments, keeping them from reaching our local reservoirs (Karimzadegan et al., 2007). Forests also absorb nutrients, such as nitrogen and phosphorus, and filter surface water runoff that drains into our reservoirs (Rhoads, 1996). Moreover, the natural ground cover of forests intercepts pollutants that are carried by runoff. By slowing the velocity of runoff, this allows for pollutants to drop out of the water and deposit into the soil.

Although all ecological functions of forests are important, the most critical function for the people of Baltimore City and Baltimore County is protecting the drinking water in their reservoirs. Since forested buffers are so important to maintaining the quality of public water supply, the City of Baltimore maintains a total of 17,580 acres of forested land around the three drinking water reservoirs, including Loch Raven and Prettyboy (MD DNR, 2003b). Over the years, land use changes in the watersheds, particularly the conversion of natural landscapes into agricultural, residential, and industrial developments, have threatened the quality of reservoir water. Fertilizer use by homeowners and fertilizer use in agriculture introduces excess nutrients to the landscape, which is then carried by surface runoff and deposited in the reservoirs (Lilly, 1997). Residential and industrial developments in the watersheds also contribute to decreased water quality, because impervious surfaces such as rooftops, roads, and parking lots prevent the absorption of pollutants into the ground (Chesapeake Bay Program, 2008). As a result, a higher concentration of pollutants is carried in runoff, and ultimately, more polluted water drains into our local reservoirs (Chesapeake Bay Program, 2008).

Locally there is now an over-abundance of white-tailed deer *(Odocoileus virginianus)* in the forests surrounding the reservoirs, and it has become a water quality concern in recent years. The population of deer is above what the forest can sustainably support, so white-tailed deer are now over-browsing seedlings and saplings of native forest trees. Over-browsing the saplings and seedlings in the forests ultimately prevents forest regeneration. Human land use changes are partly responsible for the explosion of the white-tailed deer population. Since deer are edge-specialists, they thrive on boundaries of land fragmented by human activity (Kerkhoff, 2008). Also, the white-tailed deer population remains unchecked largely because the predator-prey relationship of animal populations has become imbalanced in our area. Natural deer predators in our area, such as mountain lions, have been eliminated by past human development patterns.

Since healthy, vigorous forests with a balanced ecosystem are critical to protecting the quality of reservoir water, the large white-tailed deer populations in Loch Raven and Prettyboy reservoir forests must be managed to maintain long-term health of the forests. We must consider a variety of management options to restore the checks and balances of the ecosystem. The area around Prettyboy Reservoir has a relatively low residential density and hunting has been used as a management option to control the deer population. Deer management has been more problematic around Loch Raven, where the human population density is much higher. One impediment might be a general misunderstanding about the relationship between deer, forests, and water quality. We hope the following begins to address that issue.

Loch Raven and Prettyboy Reservoirs

Current Land Use in Prettyboy and Loch Raven Reservoirs

Prettyboy Reservoir is located on the Gunpowder Falls and contains the headwaters of the Gunpowder River Basin (BC DEPRM, 2008a). Portions of the watershed are in Carroll County and Baltimore County in Maryland, and York County in Pennsylvania (BC DEPRM, 2008a). Prettyboy is located in the Piedmont Region of Maryland and Pennsylvania. The Prettyboy landscape is described as having a healthy ecosystem which consists of abundant forest cover and healthy soil composition that sits on weathered bedrock (BC DEPRM, 2008a).

Prettyboy Reservoir’s watershed is largely rural. Within the Maryland portion of the watershed, 50% of the watershed land is currently being used for agriculture (BC DEPRM, 2008a). Corn, soybeans and wheat are grown on approximately 39% of the watershed land in Maryland; the remaining 11% of the agricultural land is used for pastures, orchards, and of course, farm infrastructure (BC DEPRM, 2008a). The other 50% of the Prettyboy watershed is either forested (38%) or covered by suburban and urban development (13%); 11 out of the 13% land use that is categorized as suburban/urban development is described as low-density residential land use (BC DEPRM, 2008a). An estimated 2.5% of the Prettyboy watershed consists of impervious surfaces (BC DEPRM, 2008a).

The Loch Raven Reservoir watershed is located on the Gunpowder Falls, downstream of the Prettyboy Reservoir (BC DEPRM, 2008b). The watershed for Loch Raven is located north of the Baltimore Beltway in central Baltimore County; it too drains waters from Pennsylvania in its northern most section (BC DEPRM, 2008b). Within the Maryland portion of the watershed, agriculture accounts for 37% of land use (BC DEPRM, 2008b). Therefore, Loch Raven has comparatively less agricultural land use than Prettyboy; whereas Loch Raven has 37% agricultural land use, Prettyboy has 50% agricultural land use. Another major difference between the two watersheds is that urban development accounts for 25% of the land use in Loch Raven, which is much greater than the 13% urban development in Prettyboy. Also, suburban/urban development in Loch Raven tends to be higher density than in Prettyboy. In the Loch Raven watershed, roughly 5% of the land consists of impervious surfaces (BC DEPRM, 2008b). Like Prettyboy though, forest cover accounts for 38% of the land in the Loch Raven watershed (BC DEPRM, 2008b).

Historical Land Use in Prettyboy and Loch Raven Reservoirs

It is estimated that Maryland had 95% forest cover prior to European colonization (BC DEPRM, 2008a). The original ancient forests that were once present have all but disappeared, but large areas have re-grown into mature or secondary succession forests (BC DEPRM, 2008a). These areas have re-grown from agricultural lands and from timber harvest areas (BC DEPRM, 2008a). The amount of forest cover in Prettyboy and Loch Raven, though considerably reduced by development, is greater in extent than many similarly urbanized watersheds (BC DEPRM, 2008a). Much of the forested area we see around Prettyboy and Loch Raven is protected, because of the range of benefits – from ecological to recreational – that these forests provide (BC DEPRM, 2008a).

The Prettyboy and Loch Raven Reservoir drainage basins were changed dramatically as the region was settled during the eighteenth century (BC DEPRM, 2008a). Lush forests were cleared for agricultural use, which rose steadily until peaking during the 1880’s-1890’s (BC DEPRM, 2008a). During the twentieth century, the natural landscape was altered further due to increasing urbanization (BC DEPRM, 2008a). The intensity of urbanization has increased over time, resulting in environmental impacts to the local watersheds (BC DEPRM, 2008a). Human impacts from urbanization include forest cover loss, an increase in impervious surfaces, and an increase in storm run-off (BC DEPRM, 2008a).

Forests

Role in Maintaining the Health of the Reservoirs

Forests help maintain the health of the reservoirs by slowing the flow of runoff, allowing sediments to be deposited into the forest floor instead of being deposited into the nearby body of water (Virginia Department of Forestry, 2008). Nutrient loading and sediment loading are particularly important concerns in the Loch Raven and Prettyboy Reservoirs because these bodies of water have recently been identified as being impaired by sediments and nutrients (nitrogen and phosphorus) (Environmental Protection Agency, 2007).

Forests can ameliorate many of the impacts on water quality that can be created by other land uses. In particular, some land uses can increase the amount of nutrients in run-off. On agricultural lands, there is an increase in nitrogen and phosphorus loading, due to the fact that these nutrients are found in fertilizer (Lilly, 1997). Fertilizer use on lawns in suburban areas is also a major source of nutrient-laden runoff (Lily, 1997). In addition, human use of phosphates to enhance the cleansing power of detergents has altered the amount of readily available phosphorous (Knud-Hansen, 1994). Waste water containing these nutrients can end up in our reservoirs and groundwater that is assumed to be a reliably safe drinking source.

Elevated nitrogen and phosphorus in the water especially pose a problem for water quality, because these nutrients enable excess growth of algae (Lilly, 1997). Excess growth of algae becomes a problem when it blocks a significant amount of sunlight from underwater vegetation, and thus decreases the amount of underwater vegetation (Moncure, 2007). These underwater plants are not only used as a habitat for aquatic life, but also increase the amount of dissolved oxygen in the water (Moncure, 2007). The loss of underwater vegetation, in addition to the eventual decomposition of the algae, leads to an overall decrease in dissolved oxygen in the water (Moncure, 2007).

Dissolved oxygen (DO) is defined as oxygen freely available in water (DRBC, 2007). Oxygen can be absorbed into the water from the atmosphere, or it can be added to the water through plant photosynthesis (DRBC, 2007). DO levels are considered the most important indicator of a water body's ability to support desirable aquatic life, because aquatic life uses the oxygen in the water for respiration (Murphy, 2007). Dissolved oxygen is also used by aerobic bacteria during the process of decomposition (DRBC, 2007). Low oxygen levels in the water can cause anaerobic decomposition of organic matter on the bottom of reservoirs, which gives the water an unpleasant odor, and may make the water unsuitable for drinking (Cutter & Renwick, 2004). It should be noted that low dissolved oxygen impacts the flavor of the water, and does not impact human health by itself; however, low dissolved oxygen levels can indicate serious pollution in a water body (Water Test, Inc., 2008).

Impervious Surfaces

Impervious surfaces contribute to excess nutrients in runoff (Chesapeake Bay Program, 2008). Impervious surfaces include roads, sidewalks, parking lots, rooftops, and any other surface which prevents water from seeping into the soil (Chesapeake Bay Program, 2008). Impervious surfaces cause less water to be absorbed into the ground. Also, the reduced plant cover means that less water is absorbed by plants too. As a result, water with greater nutrient loads can be carried off to a major water body (Chesapeake Bay Program, 2008).

Excessive sediment in runoff can cloud water, blocking sunlight from reaching submerged plants (MDE, 2008). Also, sediments settle to the bottom of streams, clogging the gravel beds used by fish for laying their eggs (MDE, 2008). Furthermore, the amount of sedimentation is an important factor in reservoir maintenance, because the accumulation of sediment reduces the amount of water that the reservoirs can hold (Ortt et al., 2000). It is estimated that between 1913 and 1997, sedimentation resulted in a lost storage capacity of 2.3 billion gallons in the Loch Raven Reservoir (Ortt et al., 2000). The annual rate of lost storage capacity for Loch Raven Reservoir is 26.8 million gallons per year (Ortt et al., 2000). Prettyboy Reservoir loses a slightly smaller amount at 23.1 million gallons of storage capacity per year (Ortt et al., 2000). Despite these staggering numbers, both reservoirs are significantly below the average for lost storage capacity in reservoirs (Ortt et al., 2000).

The problem of increased impervious surfaces leading to degraded water quality is comparatively obvious, what is less obvious is that the quality of forest cover is also a factor in water quality. A decrease in healthy vegetation in riparian buffers decreases the ability of forests to perform the function of absorbing and slowing runoff (Virginia Department of Forestry, 2008). Also, the soil in forested areas is a significant nutrient reserve for the community as a whole, because the top layer of soil is rich with nutrients that are necessary for a healthy ecosystem (Rhoads, 1996). However, the gradual thinning of this soil, due to decreasing forest growth in the area, can increase the amount of nutrients reaching the water as well (Rhoads, 1996).

Deer Paths' Impacts on Forests

Deer tend to travel on the same paths and deplete vegetation (Heys & Keys, 2006). This clearing of vegetation permits entry deeper into the forest for predators such as raccoons (Heys & Keys, 2006). One study found that bird nests located near deer-traveled paths were at a higher risk of nest predation than those located deeper in the forest (Heys & Keys, 2006). Aside from the indirect effects of deer paths on songbirds, deer directly affect ground-nesting bird habitats by extensive browsing (Bill McShea, qtd. In Ness, 2003). Deer are browsing many native tree seedlings and understory layers (DeCalesta, n.d.). With so much vegetation reduced or completely depleted from extreme deer browse, understory-nesting birds are much more limited in terms of finding a suitable location for nesting (Bill McShea, qtd. in Ness, 2003). Several bird species, such as the Kentucky warbler (*Oporornis formosus*) have actually shown a decline in population linked to deer overpopulation; one scientist monitored the population of these birds as it dropped over a span of 13 years after deer hunting was stopped in his study area (Bill McShea, qtd. in Ness, 2003).

Transition Away from Oak Forests

Oaks are a preferred browse species for deer (Outen, 2008). Maple is more palatable than oak, but oak is more biologically important (Penn State, 2003). Red maple in particular is shade-tolerant and tends to regenerate faster than oaks when larger forest trees are removed (Nix, 2003). One survey, which involved simulated deer browse, showed that maple regenerated faster than oak (Penn State, 2003). This is important to note because oaks are more beneficial to forest-dwelling organisms than maples. Oak bark is thick and can harbor insects, and acorns produced by oaks are essential food sources for many birds and mammals (Penn State, 2003). Black bear, red-headed woodpecker, blue jay, wild turkey, ruffed grouse, and deer are known to consume acorns (Outen, 2008). Historically, oak forests were prominent and stately habitats which were rich in wildlife, but many have been replaced by predominately maple forests which support a less diverse range of species (Penn State, 2003).

Deer are a factor in the transition of oak to maple forests, but some scientists argue that acid rain is a main cause of oak regenerative failure (Penn State, 2003). Acid rain promotes aluminum, calcium, and magnesium to leach from the soil (Penn State, 2003). All of this is detrimental to plant growth, but maple is more tolerant of such conditions than oak (Penn State, 2003). Some scientists argue that deer are not responsible at all for the transition of oak to maple, especially since they prefer to browse maple over oak (Penn State, 2003).

Deer as a Disperser of Exotics

In addition to the transition to maple forests, invasive plants are also a serious problem in Maryland's forests and their spread is connected to deer. Invasive species quickly replace native species, which causes a change in ecological processes and reduces biodiversity (Maryland Invasive Species Council, 2008). Williams and Ward (2006) found that fifty-six percent of the seeds that germinated from deer pellets sampled in Connecticut were exotics. They concluded that deer are an important disperser of invasive species' seeds, especially since they freely move between forested areas and gardens with ornamental invasive species (Williams, & Ward, 2006). It was also found that high deer populations can have a devastating impact on vegetation; the deer can spread invasive plant seeds as well as decimate native plant populations, leaving no competitors for the invasive seeds they spread (Williams, & Ward, 2006).

According to the National Invasive Species Council [NISC], an invasive species (also known as alien, exotic, or nuisance species) is defined as a "non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human, animal or plant health" (NISC, 2006). Invasive species can be very detrimental to the environment because they can alter entire ecosystems by limiting biodiversity (Parks et al., 2007). Invasive species usually thrive after a disturbance and are dispersed by water, wind, or animals (Parks et al., 2007).

White-tailed deer browse mostly on native vegetation because they have evolved to recognize and forage on these specific species (Outen, 2008). When white-tailed deer browse preferentially on the native fauna in Loch Raven and Prettyboy reservoirs, invasive species with relatively few natural predators are allowed to thrive (Outen, 2008). Invasive plant species alter the Loch Raven and Prettyboy habitats, limiting biodiversity and outcompeting native species; this is especially true at Loch Raven which had not been open for hunting until 2008. The overpopulation of deer in that watershed has led to an increase in the spread of invasive plants.

There are many invasive plant species in the Prettyboy and Loch Raven watersheds. These invasive plants include, but are not limited to, the tree of heaven (*Ailanthus altissima*), Japanese barberry (*Berberis thunbergii*), Oriental bittersweet (*Celastrus orbiculatus*), mile-a-minute or tearthumb (*Persicaria perfoliata*), Japanese honeysuckle (*Lonicera japonica*), and Japanese stiltgrass (*Microstegium vimineum).* These species have diverse impacts on the native habitat of oak trees and we suspect they are in some way related to the overpopulation of deer.

The tree of heaven (*Ailanthus altissima*) is a shade-intolerant deciduous tree, mostly found along forest edge habitats: roadsides, ditches, and cracks of sidewalks (Huebner et al., 2006). Huebner et al. (2006) stated that the seeds of the trees are consumed by deer, which means deer possibly serve as dispersers of the seeds. Also, the tree of heaven secretes a detrimental natural herbicide. This enables the tree of heaven to outcompete native vegetation (Huebner et al., 2006).

Japanese barberry (*Berberis thunbergii*) is a deciduous shrub that has "an association with non-native earthworms" and can alter the soil by increasing pH, nitrification and nitrate levels (Huebner et al., 2006). Alteration of soil may or may not cause problems for native vegetation that has evolved in specific soil conditions. According to Huebner et al. (2006) deer are said to browse the shrub, but it is only when their preferred food is depleted.

Oriental bittersweet (*Celastrus orbiculatus*) is a deciduous vine that tends to grow on host trees (Huebner et al., 2006). The vine wraps itself around the host, interfering with the host's ability to photosynthesize (Huebner et al., 2006). The vine is also said to cause structural damage to its host (Huebner et al., 2006). The vine's seeds are dispersed by humans, birds, and other mammals (Huebner et al., 2006). This vine also has the potential to interbreed with our native American bittersweet vine (*C. scandens*), creating a more fertile offspring (Huebner et al., 2006).

Mile-a-minute weed (*Persicaria perfoliata*), also known as Asiatic tearthumb, is an open and shade-tolerant annual vine (Huebner et al., 2006). It has a seed bank that lasts three years and is dispersed by humans, birds, and small mammals (Huebner et al., 2006). Mile-a-minute will destroy native plant species by blocking their ability to photosynthesize and breaking down their structure, much like the Oriental bittersweet and Japanese honeysuckle (Hough-Goldstein et al., 2008).

Japanese honeysuckle (*Lonicera japonica*), is a full sun and shade-tolerant invasive perennial (Bravo, 2008). It has a negative impact on the natural vegetation by wrapping itself around a tree or native plant, therefore inhibiting the host from photosynthesizing; it also has the potential to inhibit water uptake by its tight entanglement (Bravo, 2008). According to Buck Manager (2008), Japanese honeysuckle is a preferred food for white-tailed deer. The deer, along with birds and many other animals, are attracted to the fragrant flowers therefore consume it and disperse the seeds through their fecal matter (Bravo, 2008).

Japanese stiltgrass (*Microstegium vimineum)* is an annual plant that is usually found along edges and in open patches of the forest and has been observed in shady areas (Clatterbuck et al., 2007). According to Clatterbuck et al. (2007) it has the potential to outcompete shade tolerant plants when there is more direct sunlight. This plant is very well adapted to a variety of conditions, ranging from moist shady areas to dry sunny areas (Huebner et al., 2006). It increases soil pH, nitrification, and bacterial activity and lowers ammonium concentrations (Ehrenfeld et al., 2003). The Japanese stiltgrass has been recorded to have a high negative impact on diversity and seedling densities, as it can form very dense patches which may make it more difficult for native species to establish and grow (Clatterbuck et al., 2007, Huebner et al., 2006).

Deer can be major seed dispersers in a forest through endozoochory, the ingestion of seeds which are dispersed in fecal matter and epizoochory, the attachment of seeds to their fur (Parks et al., 2007). Deer tend to browse non-preferred food such as invasive plants when their preferred food is gone, and due to their increased population, they are a major contributor to the spread of invasive species (Parks et al., 2007).

On average, deer produce anywhere from 20 to 35 fecal pellets per day (Rollins et al. 1984). One survey estimated that deer may disperse an average of 15,000 "viable" invasive plant seeds per hectare every six months (Williams et al*.,* 2007). The study also found that on average over 20 seeds successfully germinated from each pellet group (Williams et al., 2007). Using "conservative" estimates of pellet deposition rates from the literature and their estimated germination rates, the authors suggest that during the time that seeds are commonly present (July through December) and using the percentage of germinated seeds that were from exotic species (70%), deer were a major source of exotic seed dispersal (Williams et al., 2007).

A thick forest canopy is a limiting factor for many exotic species which require direct sunlight for optimum growth (Williams et al., 2007). Currently, this is preventing growth of many exotic species; however, mature trees will die off and leave tree fall gaps which will allow greater light to reach the exotic species at ground level (WET Partnership, 2008). Native ferns also benefit from canopy gaps and deer browse (WET Partnership, 2008). Ferns can quickly establish an extensive population when woody plants are removed by deer browse (WET Partnership, 2008). Canopy gaps provide extra light to ferns, which absorb it before it can reach any would-be seedlings on the forest floor (WET Partnership, 2008).

Deer

Deer Biology

In the U.S., does weigh an average of 100 lbs and bucks 150 lbs (DeNicola et al., 2000). The average weight of the white-tailed deer varies over geographical location (DeNicola et al., 2000). In the southern edge of their range, white-tailed deer weigh less than their northern counterparts (DeNicola et al., 2000). Coat color differs by season; in the summer, deer will tend to have redder coats and in the winter, greyer coats which helps them to blend in with their surroundings (Michigan DNR, 2008). Whitetails have scent glands in their hooves, which are used to communicate with other deer (Dewey et al., 2003). They also communicate by snorting, whistling, and stomping their feet (Dewey et al., 2003). When nervous, white-tailed deer will stick up their tails and wag them, exposing the white color which gives them their common name (DeNicola et al., 2000). This is also a cue to other deer that danger may be present (Michigan DNR, 2008). White-tailed deer are extremely fast and agile; they can reach speeds up to 36 mph and can jump as high as 8 ft (DeNicola et al., 2000). They also have the ability to swim (Dewey et al., 2003). Their speed and agility makes it extremely easy for white-tailed deer to escape predators (DeNicola et al., 2000). The lifespan of a typical white-tailed deer depends on whether or not the area is hunted (DeNicola et al., 2000). In non-hunted areas they live on average 8-12 years but in hunted areas that number is reduced to 4-5 years (DeNicola et al., 2000).

White-tailed deer have been observed to have a very specific home range (DeNicola et al., 2000). The average home range can be as small as one square kilometer, but may be expanded in order to fulfill the basic needs of the deer (DeNicola et al., 2000, Dewey et al., 2003). Bucks have a larger home range than does because they will venture further to find a mate during mating season (DeNicola et al., 2000). Whether or not deer actually migrate is a disputed topic. Studies show white-tailed deer often have different summer and winter area preferences within their home ranges and the amount of seasonal movement between these areas depends greatly on the availability of food (DeNicola et al., 2000). At the local latitude (39°N) very little movement between summer and winter feeding areas is observed (DeNicola et al., 2000).

Bucks grow and shed their antlers seasonally in December or January, after mating season (DeNicola et al., 2000). Surprisingly, antlers are not often found lying around in forests; instead, they are quickly eaten by other forest creatures, which use them as a source of calcium (Michigan DNR, 2008). Antlers begin to re-grow in April in preparation for the next mating season (DeNicola et al., 2000). During mating season, also called the rut, bucks will fight with one another by charging and pushing in order to establish dominance and gain a mate (Dewey et al., 2003).

White-tailed deer breed once a year generally beginning in October and ending in December (DeNicola et al., 2000). If a doe is not impregnated during her first seasonal heat, which lasts about 24 hours, than she will go into a second heat about a month later (Dewey et al., 2003). The gestation period is six months with most fawns born in May through July (Dewey et al., 2003; DeNicola et al., 2000). The first time a doe gives birth she will only have one fawn, but in the following years she may have up to four fawns per birth (Dewey et al., 2003). At birth, fawns weigh about 4.5-5.5 lbs depending on their gender (Dewey et al., 2003). In general, young females stay with their mother longer than bucks do, though does may reach sexual maturity earlier than bucks (Dewey et al., 2003). The average age of sexual maturity for both males and females is 2 years (Dewey et al., 2003).

White-tailed deer are strict herbivores (Dewey et al., 2003). They have lower incisors, which they push against their upper pad for biting, and large molars for chewing (Fox & Myers, 2001). A twig that has been browsed by a deer is distinctive; since they do not have upper incisors, they leave an unclean, ragged tear, whereas a different animal like a rabbit would leave a clean cut (Michigan DNR, 2007). They are primarily grazers in the summer, feeding on herbaceous plants and the leaves and seeds of woody plants. During the fall, nuts, especially acorns, and other available fruits are preferred (Rawinski, 2008). Browsing of buds and stems of woody plants makes up most of the diet of a deer as other food becomes limited in the winter (Rawinski, 2008). Deer also depend heavily on evergreen leaves of woody and non-woody plants during the winter (Cypher et al., 1988). They are ruminants, which allow them to digest a variety of foods (Michigan DNR, 2008). They generally feed at dawn and dusk (New Hampshire Public Television, 2008). Deer have adapted very well to live within the same areas as humans and feed frequently within yards and gardens (Hall et al., 1999). They are known to eat many ornamental plants such as winged euonymus (burning bush), and honeysuckles (Kays et al. 2003), that are frequently found in the woods (Maryland Invasive Species Council 2008).

The following is a list of local trees, shrubs, vines, and herbaceous plants arranged by the frequency of damage. It is divided into four categories: rarely damaged, seldom damaged, occasionally damaged, and frequently damaged.

Table 1: Frequency of Damage to Select Local Vegetation from the Maryland Cooperative Extension Deer Feeding Fact Sheet 665 Prepared by Kays, Bartlett, and Curtis (2003), Michigan Department of Natural Resources (2008), Washtenaw County Conservation District (2008)

Rarely Damaged

Trees

Aesculus parviflora Bottlebrush Buckeye
Amelanchier Serviceberry
Pinus sylvestris Scotch Pine
Castenea dentata Chestnut
Carya Hickory

Shrubs and Climbers

Arctostaphylos uva-ursi Bearberry
Asimina triloba Pawpaw
Berberis spp. Barberry
Calastrus scandens American Bittersweet
Gaultheria procumbens Creeping Wintergreen

Annuals, Perennials, and Bulbs

Arisaema triphylum Jack-in-the-Pulpit
Matteuccia struthiopteris Ostrich Fern
Onoclea sensibilis Sensitive Fern
Ranunculus spp. Buttercup

Seldom Damaged

Trees

Cornus florida Flowering Dogwood
Gleditsia triacanthos Honey Locust
Ilex opaca American Holly
Lindera benzoin Spicebush
Sassafras albidum Common Sassafras
Picea Spruce
Fagus grandifolia Beech
Pinus resinosa Red Pine

Shrubs and Climbers

Lonicera spp. Honeysuckle

Occasionally Damaged

Trees

Acer rubrum Red Maple
Acer saccharinum Silver Maple
Acer saccharum Sugar Maple
Aesculus hippocastanum Horse Chestnut
Juniperus virginiana Eastern Red Cedar
Liquidambar styraciflua Sweet Gum
Quercus alba White Oak
Quercus prinus Chestnut Oak
Quercus rubra Red Oak
Rhus typhina Staghorn sumac
Robinia spp. Locust
Salix spp. Willow
Populus Aspen
Fraxinus Ash
Betula papyrifera White Birch

Shrubs and Climbers

Hamamelis spp. Witch Hazel
Parthenocissus quinquefolia Virginia Creeper
Carpinus caroliana Musclewood
Rhododendron spp
Rosa multiflora Multiflora Rose

Frequently Damaged

Trees

Cercis canadensis Redbud
Thuja White cedar (Arborvitae)
Pinus strobus White Pine
Betula alleghaniensis Yellow Birch

Shrubs and Climbers

Ilex verticillata Common Winterberry

Annuals, Perennials, and Bulbs
Asarum spp. Ginger
Aster spp. Aster
Oxalis spp. Sorrel

Kalmia latifolia Mountain Laurel
Vaccinium corymbosum Highbush Blueberry
Viburnum sp. Viburnums

Annuals, Perennials, and Bulbs
Polygonatum biflorum Solomon's Seal
Ranunculus asiaticus Buttercup
Trillium spp. Trillium
Vinca minor Periwinkle

Deer and People

For the Native Americans, deer were a critically important resource providing food, shelter, and clothing. European settlers also enjoyed the bounty, but the role of deer and the citizens of the country have changed. Currently deer are perceived differently by different constituencies: gardeners and farmers see them as pests, hunters see them as sport, foresters see them as browsers capable of hurting forest regeneration, nature lovers see them as icons of 'wildness,' etc.; in reality they can be all of these things.

History of the Deer Population

The deer population in Maryland has undergone dramatic changes from pre-colonial times to present. In pre-colonial times, Native Americans, in what would become Maryland, hunted deer the entire year. They used deer for both food and clothing (Hotton, 2008). It is estimated that 2.3 million Native Americans lived in the pre-colonial range of the white-tailed deer population in Maryland (MD DNR, 2008d). Unfortunately, there are no estimates of the deer population specifically for pre-colonial Maryland (MD DNR, 2008d). Native Americans took 4.6 to 6.4 million deer each year from this region, in addition to the deer taken by mountain lions and wolves (MD DNR, 2008d). It has been estimated that around the 1600's there was a herd size of 23.6 to 32.8 million deer in the United States and other parts of North America (Feldhamer et al., 2003).

When European settlers arrived, they quickly learned that deer were a primary food source for Native Americans (Hotton, 2008). As the human population increased, the demand for deer increased as well (Hotton, 2008). European settlers also harvested deer for food and clothing (MD DNR, 2008d). The pressure on the deer populations became so great that the population quickly declined (MD DNR, 2008d). In 1729, a law was passed that prohibited the killing of deer between January 15 and July 31 (MD DNR, 2008d). Even though this conservation act was established, enforcement of the law was ineffective due to the high demand for deer (MD DNR, 2008d). However, this act suggests that it was obvious deer conservation was needed (MD DNR, 2008d).

European settlers were also clearing forests for farmland and lumber at this time (MD DNR, 2008d). Throughout the 1800s and 1900s, the population of deer and other woodland animals were greatly diminished in the state of Maryland as a result of over-hunting and loss of habitat (MD DNR, 2008d). By 1902, the deer population had dropped very low and Maryland's remaining deer population was only found in Garrett County, Allegany County, Washington County, and Frederick County (MD DNR, 2008d).

At the beginning of the twentieth century, there were an estimated 500,000 white-tailed deer in the United States (Cornell University Cooperative Extension, n.d.). Throughout the twentieth century some agricultural areas regenerated into woodland areas (MD DNR, 2008d). Starting in 1914, deer breeding farms were established in Maryland, leading to increased deer populations across Maryland by the late 1920's. Hunting was re-established in Alleghany County in 1927, other parts of Western Maryland opened to hunting soon after (MD DNR, 2008d).

A game farm in Harrisburg, PA played a significant role in increasing the local deer population. Deer were transported from this farm and released in Aberdeen Proving Grounds in the 1930's (MD DNR, 2008d). By 1940, the deer population at Aberdeen Proving Grounds grew so large that the deer were collected and released statewide (MD DNR, 2008d). This effort to re-locate deer lasted until the end of the 1960's (MD DNR, 2008d). The deer from Aberdeen Proving Grounds and other small breeding farms helped to re-establish the deer population state-wide (MD DNR, 2008d). In 1954, the deer population was so healthy that deer hunting was once again allowed statewide (Aughenbaugh, 2008).

Today, the population of deer is estimated to be 27 million deer for the entire United States, and this number is continuing to rise (Bailey, 2001). According to the Maryland DNR, prior to the 2007-2008 hunting season, there were an estimated 228,000 deer in Maryland (Griffin et al., 2008). As of 2003, it is estimated that hunters kill an average of 85,000 deer per year in Maryland (Fergus, 2003).

Deer Predators

Deer can face predation pressures from both humans and natural predators such as coyotes, mountain lions (also called cougar, puma, and panther), bobcats and lynx (Koerth, n.d.). Coyotes in some areas are considered major deer predators because of their large numbers and extensive range (Koerth, n.d.). Coyotes are newcomers to Maryland's ecosystems and were first reported in Cecil, Frederick, and Washington counties in 1972 (Colona, 2004). The state of Virginia has recently calculated that there has been a twenty-nine percent annual increase in their coyote population from 2003 to 2004 (Colona, 2004). Since Maryland and Virginia have similar land use and habitats, it is possible that this population increase mirrors the coyote population growth in Maryland (Colona, 2004). While it may seem that having another deer predator would be helpful in terms of controlling the rising deer population, the Department of Natural Resources reports the public is concerned with domestic pet loss and loss of livestock due to the increase in the coyote population (Colona, 2004). To alleviate public concerns, the DNR is developing coyote trapping seasons that are parallel with fox trapping seasons (Colona, 2004). The mountain lion is another native predator of deer (Mueller, 2008). They were hunted in the state of Maryland until the 1800s, after which time mountain lions were considered to no longer inhabit the Maryland region (Mueller, 2008).

Deer as Edge Specialists

The past few decades have seen an increase in the human population, leading to increasing development of the natural land. Typically human development and forest fragmentation are signs of habitat degradation and loss of ecological integrity; however, some wild animals may be thriving in urban environments (Shaw, 2004). While urban sprawl may lead to an increase in impervious surfaces and a decrease in forested land, new habitats and food sources are created which may be exploited by some species (Shaw, 2004). White-tailed deer are one of these urban-exploiters, because they have narrow forest requirements and can find ample places to forage, nest, and thrive in a suburban landscape (Shaw, 2004). The suburban environment has created ideal edge conditions for deer to exploit including a refuge from natural predators and hunters, forested patches for seclusion, and supplemental vegetation in gardens and landscaping.

Deer as Vectors of Disease

Deer are the primary host for black-legged ticks (Allan et al., 2006). Deer ticks are vectors for transmission of several diseases to humans including: Lyme disease, Human Anaplasmosis, or Babesiosis (ALDF, 2006). Open areas, adjacent to woods, are created through abandoned farms and developers who increasingly build homes in such locations; this provides an ideal habitat for ticks ("The Deer Tick," 2003). Deer ticks prefer wooded, brushy and grassy areas and search for a host from the tips of grasses and shrubs and grab onto passing animals, including people, who walk by ("The Deer Tick," 2003).

Deer ticks live for approximately two years (ALDF, 2006). From May through September, eggs hatch into larvae, which may pick up diseases through feeding on a diseased host animal (ALDF, 2006). The larvae usually feed upon small mammals, such as mice, which are primary vectors for the bacteria that cause Lyme disease (Allan et al., 2006). The larva feeding on an infected host will then become infected and is able to transmit the disease during its second feeding (ALDF, 2006). In the tick's subsequent life stages, they may pick up diseases from an infected mammalian host or transmit the diseases which they have picked up to a previously uninfected host (ALDF, 2006). Forest fragmentation favors white-footed mice, which are the main carriers of *Borrelia burgdorferi*, the bacterium which causes Lyme disease (Allan et al., 2006). As mentioned above, fragmented forests host few to no large predators so not only deer, but also white-footed mice, flourish. More mice, coupled with more deer, result in more Lyme disease overall (Allan et al., 2006).

Lyme disease is caused by the bacterium *Borrelia burgdorferi,* transmitted to humans by the bite of infected blacklegged ticks (CDC, 2008). Symptoms of Lyme disease include: fever, headache, fatigue, and erythema migrans (CDC, 2008). Erythema migrans is a skin rash with a reddish edge with normal-colored skin in the middle, frequently called a 'bullseye', and if observed after a tick bite, it is a strong indicator of someone with Lyme disease (CDC, 2008). The symptoms usually develop anywhere from three to thirty days after the tick bite (CDC, 2008). If left untreated, infection can spread to joints, the heart, and the nervous system (CDC, 2008). The most common later problem associated with Lyme disease is arthritis, which may occur months after the tick bite (CDC, 2008). Lyme disease is diagnosed based on symptoms, physical findings (i.e. rash), and the possibility of exposure to infected ticks (CDC, 2008). Most cases of Lyme disease can be treated successfully with a few weeks of antibiotics (CDC, 2008).

There are two less common diseases associated with or carried by deer ticks: human anaplasmosis, and babesiosis. The symptoms of human anaplasmosis are fever, severe headache, muscle aches, and chills (ALDF, 2006). This disease can be treated with antibiotics. Babesiosis symptoms include mild fevers and anemia (ALDF, 2006). In more severe cases, there are symptoms similar to malaria, with fevers up to 105 degrees Fahrenheit, shaking chills, and severe anemia (hemolytic anemia) (ALDF, 2006). Organ failure may also follow, including adult respiratory distress syndrome (ALDF, 2006). In both of these diseases, more severe cases occur in people with weakened immune systems or elderly people (ALDF, 2006).

Deer Impacts on Auto Accidents

Diseases are not the only impact deer have on their human neighbors. Deer-car collisions are an important issue in communities in close proximity to large deer populations. Commonly impacted parts of vehicles in deer-car collisions include: the windshield, bumper, and headlights. The expenses of repairs from these collision types will be discussed below, examining a type of sedan (the Honda Civic), one type of truck (the Ford F-150), and one type of SUV (the Chevy Suburban). All of these vehicles are commonly seen on the road on a daily basis.

Windshields are easily broken in a front-end collision with a deer. The average cost to replace the windshield for the Honda Civic is $398, for the Suburban $304, and for the F-150 $284 (Glass.net, LLC, 2008). Bumpers, another part of the car that can be easily damaged in a front-end collision with a deer, generally have multiple parts, including the cover, filters for the driver and passenger side, an absorber, a reinforcement bar, and various brackets (Auto Parts

Warehouse, 2008). Repair fees for bumper damage to a Civic can include the following: bumper cover $180-$220, absorber $57-$72, reinforcement bar $110-$135, brackets $27-$37, a single headlight $87-$350, and headlight cover $64 (Auto Parts Warehouse, 2008). Repair fees for bumper damage to an F-150 can include the following: bumper cover $415- $337, bracket $231, a single headlight $250-$326, and headlight cover $65 (Auto Parts Warehouse, 2008). Repair fees from bumper damage to a Suburban can include the following: bumper cover $465-$238, brackets $74-$23, and a single headlight $133-$148 (Auto Parts Warehouse, 2008). Car insurance can cover damage associated with deer-car collisions through comprehensive coverage, but even if covered there is cost to the community and the owner of the vehicle (Auto Parts Warehouse, 2008).

Deer as Part of Recreational Use of Forest

There are many social values associated with deer as well as aesthetic, recreational, and economic benefits. First, there is the aesthetic value of watching a doe attend to her fawns, especially when the deer are viewed as part of the beauty of a natural landscape (Adams et al., 2006). This is perhaps a more abstract value, but no less important to the people that hold this value. Aesthetics can also have a positive impact on health. Wildlife recreation is associated with health benefits (Decker et. al, 2002).

Another recreational value of deer is hunting. In fact, hunting provides a great deal of tangible, economic benefits to local economies through hunting related expenditures. It is estimated that expenditures by some 10,272,000 hunters in the United States grossed over $10 billion in sales in 2001 (MD DNR, 2008h). Researchers at the University of Arizona conducted an extensive study by questionnaire that examined the value of deer for hunting purposes (Allison, 2007). It found that wildlife managers valued deer for hunting purposes much more than the general public (Allison, 2007). Eighty-three percent of wildlife managers hunt, whereas only one-quarter of the general public hunts (Allison, 2007). This means that wildlife managers are much more likely to advocate the value of deer for hunting purposes, instead of the aesthetic value of deer that is usually held by the general public (Allison, 2007).

According to this study, farmers were in the middle, between wildlife managers and the general public (Allison, 2007). Some farmers valued deer for their aesthetic value, whereas others liked to hunt deer; however, most farmers liked deer for both reasons (Allison, 2007). In fact, most farmers said that they were willing to incur a small amount of damage from deer in exchange for the aesthetic value of viewing the deer, which reflects the somewhat conflicting feelings that farmers have about deer (Allison, 2007). Since people have a tendency to value deer for aesthetic and recreational purposes that are not associated with hunting, wildlife managers need to take this into account when discussing deer management options to the general public.

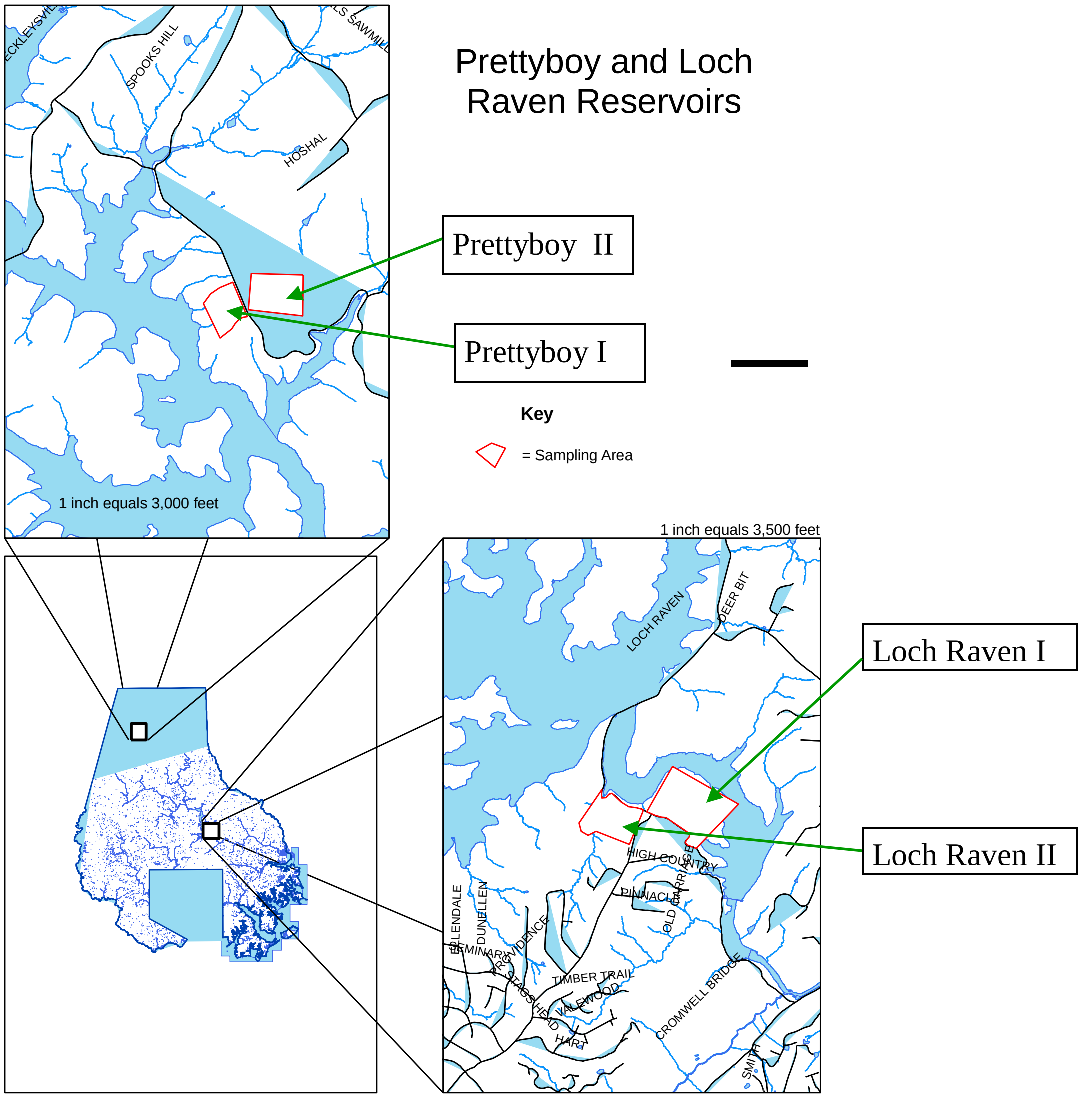
How Large is Our Deer Population?

In an attempt to become more familiar with the forests and the deer management issues, we estimated the local deer population density and assessed the amounts of browsing damage adapting the methods that are used by the City of Baltimore, Environmental Services Division of the Bureau of Water and Wastewater, which is responsible for developing deer management programs on the reservoir lands. The method used is based on deer pellet group count (Donoughe & Wolf, 2007a) accompanied by a survey of plant regeneration and browsing (Donoughe Wolf, 2007b). These were carried out at both the Loch Raven and Prettyboy reservoir forests.

Methods

In each reservoir forest, we were directed to two study areas provided by Baltimore City, Environmental Services Division of the Bureau of Water and Wastewater. The locations of the particular sites are indicated on Map 1. On each site, 10 evenly spaced parallel potential transect lines were identified. Four of these transects were randomly selected. Using the compass direction given for these transects, we walked each transect, sampling at 100 foot intervals until 25 samples had been obtained. Our sampling unit consisted of a circular plot 8 feet in diameter. This resulted in 1 lineal mile of coverage and 100 sample sites per area. The first site on all transects began 100 feet from the edge of any road.

To collect samples at each plot location, a stake marked the center of the site and a 4 foot rope was used to scribe a circular plot. All woody vegetation above 6 inches and below 6 feet tall was recorded, as well as the number of deer pellet groups within the plot. Impact level was recorded for regenerating oak, hickory, maple, tulip poplar, beech or pine trees; these are the species that Baltimore City scores and which they use to reflect browse damage. Impact was described in five different levels: no impact, light, moderate, heavy or severe impact. In addition, we decided to give special attention to invasive species and we noted their presence within the plots . Our method deviated from the “traditional” methods of browse level and deer pellet counts; we assessed vegetation at every plot and we performed our survey in the fall, not late winter.



Map 1: Location of sampling sites at Prettyboy and Loch Raven Reservoirs

Prior to data collection, we reviewed descriptions of deer pellets including the description of size, textures, colors, and distribution. Our sampling was started on Sept 27 and was completed by Oct 12. Different groups of students were involved in sampling over this period. Four groups of six students sampled two neighboring transects at both the Loch Raven and Prettyboy site.

Results and Discussions

The “traditional” deer pellet count method is performed at the end of the winter. Under those conditions, pellets that are above the leaf layer are counted and the pellets are assumed to have accumulated since the date of leaf drop, usually sometime in the late fall. Our fall sampling time precluded such an assumption. We noticed that severe rain seemed to wash away or render the pellets non-identifiable. Therefore, we selected a severe weather event on Sept 27 as our “start” time and completed our counts prior to a second heavy rain.

We calculated deer density for each of the four sites using the following formula: Deer density = Total number of pellet groups/ PDR * T * SA, where PDR is the pellet deposit rate, T is the time since the last big rain, and SA is the total sample area in square miles (Donoughe & Wolf, 2007a). Based on our deer pellet survey, we found deer population estimates of 888 deer per sq. mi. and 442 deer per sq. mi. for our sample sites in Loch Raven reservoir, and 722 deer per sq. mi. and 111 deer per sq. mi. for our sites in Prettyboy reservoir forest. If averaged this would come to 665 deer/mi^2 for Loch Raven and 416.5 deer/mi^2 for Prettyboy Reservoir.

Summary Data:

Table 1

Sampling By	**Site**	**Estimated Deer Density (deer/ mi^2)**	**Total # select spp. Trees w/in Site****
Us	Loch Raven I	888	15
Us	Loch Raven II	442	7
Us	Prettyboy I	722	166
Us	Prettyboy II	111	153
Baltimore City	Loch Raven	405	0
Baltimore City	Prettyboy	43	50*

*Multiplied by 2, as they sampled every other plot
** Total number of individuals noted of selected spp. [oak, maple, hickory, pine, poplar, beech] between 6” and 6’ in sampled plots

Site Specific Data:

Table 2: Detailed data from Loch Raven site I.

Transect Line	**Group**	**Date of Sampling**	**# Pellet Groups Found**
2	Jess et al.	10/4/08	12
6	Jess et al.	10/4/08	9
8	Grant et al.	10/5/08	4
10	Grant et al.	9/27/08	0

Deer Density of Transect Lines 2 & 6:
Density = 21 / (25 * 7 * .0000901) = 1332 deer/ mi^2

Deer Density of Transect Line 8:
Density = 4 / (25 * 8 * .00004505) = 444 deer/ mi^2

Deer Density of Transect Line 10: Omitted [major rain event]

Average # of Deer: 1332+444/2 = 888 deer/ mi

Table 3: Detailed data from Loch Raven site II.

Transect Line	Group	Date of Sampling	# Pellets Found
7	Tim et al.	10/4/08	9
4	Tim et al.	10/4/08	4
10	Laura et al.	10/12/08	0
8	Laura et al.	10/12/08	2

Deer Density of Transect Lines 7 & 4:
Density= 13 / (25 * 7 * .0000901) = 825 deer/ mi^2

Deer Density of Transect Lines 10 & 8:
Density = 2 / (25 * 15 * .0000901) = 59 deer/ mi^2

Average # of Deer: 825 + 59 / 2 = 442 deer/ mi^2

Table 4: Detailed data from Prettyboy site

Transect Line	Group	Date of Sampling	# Pellets Found
9	Tim et al.	10/5/08	2
6	Tim et al.	10/5/08	1
4	Laura et al.	10/5/08	10
5	Laura et al.	10/5/08	13

Deer Density: Density = 26 / (25 * 8 * .000180) = 722 deer/ mi^2

Table 5: Detailed data from Prettyboy site II:

Transect Line	Group	Date of Sampling	# Pellets Found
5	Jess et al.	10/11/08	0
3	Jess et al.	10/11/08	0
8	Grant et al.	10/11/08	2
9	Grant et al.	10/11/08	5

Deer Density: Density = 7 / (25 * 14 * .000180) = 111 deer/ mi^2

The Baltimore City pellet survey from winter of 2008, which was carried out the "traditional" way, produced deer estimates of 405 deer per sq. mi. in Loch Raven Reservoir forest and 43 deer per sq. mi. in Prettyboy Reservoir forest. Our data is very different from Baltimore City's data and for reasons discussed below, we do not think our data provide a reliable population estimate. Therefore, none of our collected data can be used to predict the actual deer population size in either reservoir forest. We reject our data for a variety of reasons.

Within Loch Raven or Prettyboy Reservoirs we sampled two areas that were in close proximity (see map); one might expect that these neighboring areas would have similar deer density, but based on our data they did not. Different observers were involved in sampling each transect, and these observers may have different abilities to detect pellets. The probability of detection of deer pellets often varies widely between observers, which could create bias in the number of pellets counted (Jenkins & Manley, 2008). In addition, the time of day that sampling took place may affect the probability of deer pellet detection (Bennett et al., 1940). Groups of students sampled plots at various times of day, and similarly, different groups sampled the two neighboring locations within each reservoir; this could contribute to the variation in pellet numbers we observed among nearby transects.

Another reason for variation in population estimates is that deer may be concentrated in certain regions of the reservoir forest at different times. This may be due to heterogeneity of forest composition that makes some areas more favorable for deer. Sampling pellets deposited over a long period of time, which is what happens during the late winter survey, would tend to reduce the site-to-site variation. By sampling over a very brief period of time (2 week maximum) we would have maximized that source of variation. We knew where deer had recently been but we could not witness the longer term pellet deposition pattern of many deer covering a section of forest over months. The large difference in population estimates generated by our class and Baltimore City may be also due to deer migration. Deer migrate between ranges due to differing food availability in different seasons (Bennett et al., 1940). Thus, deer pellet sampling in a given area may differ between seasons, leading to differing population estimates.

The assumption of deer pellet deposit rate may also cause variation in population estimates obtained by our class and Baltimore City. Pellet deposit rate may vary between seasons due to differing diets, as diet has been proven to change pellet deposit rate (Eberhardt & Van Etten, 1956). Pellet deposit rate may also vary between fawns and adults (Eberhardt & Van Etten, 1956).

While our sampling window forced us to deviate from the accepted method, we think that a sampling method could be developed for use prior to the hunting season. In order to more accurately estimate deer populations, more transects in multiple areas of the reservoirs must be sampled. A heterogeneously distributed population cannot be estimated using one or two sampling areas. Sampling in an area of high deer density may overestimate deer populations in the reservoir forests, while sampling in an area of low deer density may underestimate deer population in the reservoir forests. By sampling in multiple areas, this heterogeneity is averaged together giving a more accurate population estimate. This will help to identify locations where deer are concentrated, and locations deer avoid. The potential to use a summer thunderstorm as the “leaf-off date” should be explored. We would suggest using a single sampling team to avoid individual variation.

Deer and regeneration surveys are currently performed at the same time. We suggest that combined surveys are unnecessary and may be subject to considerable error. Regeneration surveys in winter months may lead to difficulty distinguishing between tree species as much vegetation is without leaves. Therefore, regeneration surveys throughout the wamer parts of the year may serve as a better indication of the regeneration of the forest.

Should Baltimore City wish to demonstrate the impact deer are having on forest regeneration, enclosures that exclude deer but allow the entry of smaller animals could be used (BRNR, n.d.). Results are usually visible in about three years (BRNR, n.d.). This method would also give us information about the time span and anticipated effectiveness of forest recovery if the deer population is reduced to proper levels (G, 2008). Enclosure experiments could help the community visualize the regeneration of the forest if deer density were to return to a healthy level in Loch Raven.

Alternative Sampling Methods

Deer density can be calculated using both indirect and direct methods (DCNR, 2006). Indirect methods include counting deer trails or tracks, deer sightings, browsing intensity, counting deer killed along roads, and hunting data (DCNR, 2006). Direct methods consist of camera surveys, spotlight counts, aerial surveys, infrared videography and mark-recapture (DCNR, 2006). Direct methods require the counting of deer based on those that are actually seen in a given area (DCNR, 2006). Some of these direct methods are less preferred because of the difficulty and lack of reliability (Gregory, 2002).

One of the more difficult methods is aerial surveys. The direct method of aerial surveys involves a plane or helicopter flying over an area and counting the deer directly (DCNR, 2006). This method has been used annually from 1980 until 2004 to monitor deer populations in Presque Isle State Park in Pennsylvania (DCNR, 2006). Deer are constantly moving and spend a lot of time out of sight which makes the aerial surveys and spotlight counting processes less accurate (Gregory, 2002). Infrared videography can help reduce error associated with hiding (Gregory, 2002). Infrared surveys can help detect deer that may be more difficult to note by the naked eye alone (Gregory, 2002). Although infrared can help locate deer in hiding, they can still go unnoted if under canopy vegetation (Gregory, 2002). The canopy can absorb the radiation and re-radiate at the temperature of the canopy instead of the deer below (Gregory, 2002). For this reason data collection in the winter, when leaves are down, is more favorable (Gregory, 2002). To help with the vegetation interference, the noise from the helicopter can cause the deer to come out of hiding (Gregory, 2002). However, this could also cause error in the density calculation if they scatter (Gregory, 2002).

Suggested Methods for Adoption

The pellet method used locally is widely used but there are shortcomings that different groups have tried to address. A pellet group survey similar to the one used locally was conducted in Michigan during the 2001-2002 season (Hill, 2002). In that survey, data analysis included adjusting the deer estimates for deer that were legally killed during the season (Hill, 2002). Including deer kill in developing population estimates should improve the accuracy of the locally collected data, especially because of new hunting practices in Loch Raven. Deer that have been killed this season are likely to have left droppings in the sampled plots, and could create an over-estimate of deer density. This experiment was strictly to deer density, and browse level was not a factor (Hill, 2002).

In another survey, paint applied to limestone fragments placed within pellet groups was found to be the best way to mark pellet groups that were already counted to avoid a recount in yearly surveys (Kufeld, 1968). The markings were noticeable on 96% of the pellet groups they were placed on 10.5 months after initial marking (Kufeld, 1968). This method could also be used to record changes in the appearance of pellets over time (Kufeld, 1968). Older pellet groups appeared smaller and more scattered and did not hold paint as well as newer groups (Kufeld, 1968). Recount error from deteriorating marks could be avoided by removing the pellet groups from the sampling plots instead of marking them (Kufeld, 1968). Removal is recommended in plots where the pellet groups are scattered and would be difficult to clearly mark, otherwise, painted limestone appears to be an effective method (Kufeld, 1968).

While the Kufeld study was looking at how to avoid duplication of counts, a more pressing problem could be assumptions about the longevity of pellets. Pellet counts are often used in areas known for high snowfall and very cold winters. Under those circumstances, pellets might be expected not to decomposed during the winter. Locally, our winters have warm spells and cold spells and our average winter temperature is above freezing. In order to know whether a late winter pellet count does reflect accumulated pellets from the 'leaf off date' a study needs to be initiated. The local rate of disappearance or longevity of pellet groups needs to be determined and as far as we can ascertain no one seems to have done that for any region.

An alternative indirect method used in Wisconsin was deer trail counts (McCaffery, 1976). With this method, researchers noted trails that showed evidence of repeated use by deer such as "paths in ground vegetation and forest litter" (McCaffery, 1976). The trails crossing given transects were counted and their location was also noted so that experts could record if those trails were still around over time (McCaffery, 1976). The dominant forest types surrounding deer trails were also recorded (McCaffery, 1976). This method would not be ideal for Loch Raven because the lack of vegetation would make deer trails difficult to identify. In addition, the presence of local hiking trails which can also be used by deer could confound sampling.

Although many sampling methods, both direct and indirect, can be used to estimate deer populations, different sampling methods can yield quite different population estimates. For instance, Baltimore City's deer density estimates in Loch Raven using the deer pellet count differs considerably from the estimate they obtained using the infrared survey method. According to the 2008 infrared survey, deer population in the Loch Raven reservoir forest was estimated to be 83 per sq. mi (Malarkey, 2008) compared to its estimate of 405 deer per sq. mi. using the pellet count method (see Appendix 1).

Studies show that mature forests, like those surrounding Loch Raven and Prettyboy reservoirs, are able to support 10 to 20 deer per sq. mi. during winter (McGuiness, n.d.). Compared to early successional forests, mature forests are able to support lower densities of deer because they have limited number of young, low-lying trees and shrubs (McGuiness, n.d.). As mentioned above, the estimated deer populations in the reservoir forests are significantly greater than the carrying capacity of the forests regardless of the sampling method. We understand the desire of Baltimore City to maintain deer populations at or below what can be sustainably supported by the forests to ensure long-term health of the forests, and we wonder whether an excessively high density might contribute to the challenge of obtaining an accurate estimate.

Methods of Deer Population Control

Lethal Methods

Hunting

Maryland Department of Nature Resources [DNR] states that "DNR's long-term goals for deer are to ensure the present and future well-being of deer and their habitat; maintain deer populations at levels necessary to ensure compatibility with human land uses and natural communities; encourage and promote the recreational use and enjoyment of the deer resource; inform and educate Maryland citizens about deer biology, management options and the impacts that deer have on landscapes and people" (MD DNR, 2008a). There are multiple management strategies used to control deer populations in communities and forests where their increasing population has caused negative impacts. Lethal means of controlling deer populations include regulated hunting and the use of hired sharpshooters. Hunting has been shown to be a consistent source of revenue for both businesses and county governments, and has proven to be an effective, efficient, and cost-effective means for managing deer populations (MD DNR, 2008b).

Hunting has historically been allowed in Prettyboy and Liberty reservoirs, and as of 2008 limited hunting has been allowed in Loch Raven. In 2007, 3,005 hunting permits were sold for hunting in the Prettyboy and Liberty watersheds (MD DNR, 2003a).

Maryland has many laws and regulations to ensure the safety of hunters, the public, and the deer population itself. Prior to engaging in hunting in Maryland, a hunting license must be obtained (MD DNR, 2008a). Hunters must purchase a hunting license yearly (MD DNR, 2008a). Hunting without a license is only permitted on private property (MD DNR, 2008a). In order to qualify for a hunting license, a DNR implemented safety course, Firearms and Hunter Safety Training, must be completed with a minimum 80% test score (MD DNR, 2008f) This course is required prior to purchasing a Maryland Hunting License unless one can prove they held an official state-hunting license before July 1, 1977 (MD DNR, 2008f). DNR also offers more focused non-required safety classes for bowhunter, muzzleloader, and trapping education (MD DNR, 2008f).

DNR also sets hunting seasons, which limit the months in which hunting is permitted. Hunting on public lands is permitted between September and January. Bow hunting is permitted between September and January, muzzleloader hunting is allowed from October to early January, and firearm season is between late November to early January (MD DNR, 2008a). Hunting is also limited to one half hour before sunrise to one half hour after sunset (MD DNR, 2008a). While hunting, it is prohibited to drive with a loaded firearm or a cocked crossbow in your vehicle or shoot from or across a public road (MD DNR, 2008a). Hunters are also prohibited from using electric deer calls, using dogs to aid in deer hunting, shooting deer that are swimming or in water, or bait deer on state land (MD DNR, 2008a). Hunters are also required to wear fluorescent orange, in order to remain visible to other hunters and reduce accidents (MD DNR, 2008a).

Bag limits are set in all counties in Maryland, except Garrett and Allegany, which set the number of deer a person can harvest in a season (MD DNR, 2008a). The current bag limit allows the harvest of 2 antlered deer and 10 antlerless deer per hunter (MD DNR, 2008a). An antlered white-tailed deer is defined as having two or more points on one antler, or as having one antler at least three inches in length, measured from the top of the skull (MD DNR, 2008a). An unlimited number of antlerless deer can be taken in Anne Arundel, Baltimore, Howard, Montgomery, and Prince George's counties (MD DNR, 2008a). Poaching in Maryland is strictly prohibited, and punishable by law. Reporting of any observed poaching can be reported to a 24 hour phone number (MD DNR, 2008g).

Maryland attempts to keep a record of all deer harvested by requiring hunters to fill out a Field Tag and attach it to the animal as well as fill out a block on the Maryland Big Game Harvest Record within 24 hours of a deer kill (MD DNR, 2008a). A confirmation code is then given which must be used if the deer is delivered to a taxidermist or butcher (MD DNR, 2008a). Hunters that do not wish to keep the meat from the deer can donate it to organizations such as Farmers and Hunters Feeding the Hungry, where the deer is butchered and distributed to food banks, which provide meat at low costs to those in need (MD DNR, 2008e).

While hunting has proven to be a successful means of controlling the deer population in several states, several issues surrounding hunting must still be considered. First, the number of recreational hunters has been in decline, bringing into question if recreational hunters should be required to pay to hunt (Brown et al., 2000). In some studies, hunting has also been shown to modify feeding grounds for white-tailed deer, which could cause the deer population to move to another location where hunters are not present (Nixon et al., 2008). In that case it could potentially push deer out of the reservoirs and onto private land. The modification of feeding grounds and behavior can lead to more car accidents, especially in areas with high traffic roadways like Loch Raven reservoir (Sudharsan et al., 2006),.

In order to ensure the effectiveness of hunting as a deer management method, accurate deer population estimates must be made in hunted areas (DeNicola et al., 2000). Current management plans require deer population estimates in order to ensure that proper sex and age ratios are maintained (DeNicola et al., 2000). In addition to population estimates, physical condition, mortality, and reproductive success of deer will need to be assessed to develop a proper management plan (DeNicola et al., 2000). Hunters tend to select male deer, favoring the survival of older female individuals (DeNicola et al., 2000). In addition, male mortality is increased after breeding season due to their depleted physical condition, again favoring female survival (DeNicola et al., 2000). There are many different methods of estimating deer population size, some of which are discussed in the data and methods portion of this paper.

According to a Texas based study, management of overabundant deer populations should be separated into two phases (Creacy, 2006). First, there must be an approximate 50% reduction of the deer population size, by means of hunting and/or relocation over a short period of time (Creacy, 2006). After the initial reduction phase a maintenance phase is implemented, which can include various deer management options such as hunting, fencing, relocation, and birth control (Creacy, 2006). Like any management scheme, site specific and landscape level management options will also need to be addressed (Creacy, 2006).

Hunting as a Source of Revenue

Hunters provide economic benefits for local economies through hunting related expenditures, which grossed an estimated $10 billion in sales in 2001 (MD DNR, 2008b). Sales of permits and licensing fees are also a key contributor to funding multiple Maryland DNR projects. Regulated hunting not only removes deer from the population with little cost to the public, but is also shown to alleviate costs associated with other population management strategies (MD DNR, 2008b). Deer hunting in Maryland is a big business. In 2001 approximately $156 million was generated in Maryland through the combined revenues associated with hunting [MD DNR 2003a]. Sources of income include such things as hunting license sales, retail sales associated with hunting supplies and equipment needed for hunting, fuel taxes associated with travel to sites and income tax generated by those supported by the hunting industry [MD DNR 2003a]. The sources of funding for Maryland's wildlife program are presented below in Figure 1. It is clear that most of the funding comes from hunting licenses and fees. The federal excise tax on sport hunting devices and ammunition derived from an 11% tax on sport arms and ammunition helps considerably (MD DNR, 2008c). The following figure shows a summary of Maryland's revenue for the fiscal year ending June 30, 2007 (MD DNR, 2008c).

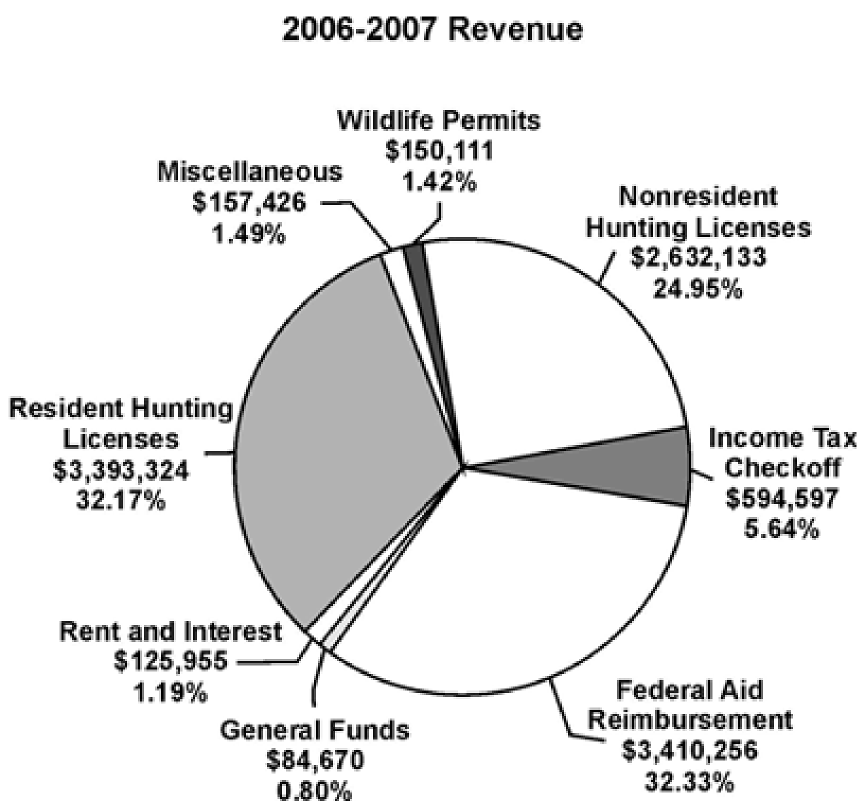


Figure 1: A summary of Maryland's revenue for the fiscal year ending June 30, 2007 (MD DNR, 2008c).

Sharpshooters

The use of sharpshooters is another lethal deer population control method. This method has been proven effective in suburban areas where deer populations are high and there is too little undeveloped land to support traditional hunting (MD DNR, 2008b). Hiring sharpshooters comes at a relatively high cost to taxpayers. In several areas in the country, the use of sharpshooting to control the deer population costs anywhere from $91 to $260 per deer removed (MD DNR, 2008b).

Non-Lethal Methods of Managing Deer

There are additional management techniques used for controlling overabundant deer populations and the negative impacts that they have on the forest. The following section discusses various non-lethal deer management options.

Relocation/ Trap and Translocation

One management option includes trapping of deer and relocating them to a suitable environment with a currently low deer population. Issues that must be considered when examining trap and translocation as a viable deer management option are mortality, cost, ecological impacts, and the location selected for translocation. Although usually perceived as a non-lethal method of removing deer, trap and translocation efforts can actually be fairly lethal (Creacy, 2006). High mortality rates are incurred from capture myopathy (weakness of muscles from capture and transport), through the first year after re-location (Creacy, 2006). Integrating individual populations can have dramatic and unforeseen consequences for both translocated and native populations, as well as the region to which they are moved (Doerner et al., 2005). It is estimated that 25% of translocated deer die within the first 2 months and that 65% die within the first year (Creacy, 2006). A study conducted in Missouri noted a 30% survival rate compared to 69% for the native population over one year (Beringer et al., 2002). Of those which experienced mortality, 29% were the result of capture myopathy (Beringer et al., 2002). Spreading of disease may also occur through mixing populations. One population of deer may have or bring a disease that completely ravages the other. In order to minimize these problems, relocation should occur to nearby areas. This may not be a viable option in the reservoirs, the focus of our study, as most areas in Maryland and the surrounding states are facing deer overpopulation (Levy, 2006; Crissey, 2003). Costs of this method are also high at $150-$500 per deer (Creacy, 2006). Thus this method is not a suggested method for managing deer populations in the Loch Raven and Prettyboy reservoirs.

Contraceptives

Contraceptives are another non-lethal option for deer population control and have been researched by the National Wildlife Research Center in Colorado since 1992 (National Wildlife Research Center, 2004). Contraceptives for wild animals need to be safe for the animal, and other animals that may be exposed to the vaccine either directly or indirectly, and have minimal negative side effects (National Wildlife Research Center, 2004). Most importantly, they need to be able to make the animal infertile, yet have the ability to resume fertility when the vaccine is stopped (National Wildlife Research Center, 2004).

GonaCon

These standards have been met in one of the primary options for contraceptives, GonaCon (Killian et al., 2005). GonaCon is a gonadotropin-releasing hormone (GnRH) immunocontraceptive vaccine developed by the USDA Wildlife Services (Killian et al., 2005). Currently, applications of GnRH are being researched in controlled field studies for potential commercial use (Killian et al., 2005). GonaCon is a single shot, multiyear (two to four years) vaccine that stimulates the production of antibodies that bind to GnRH (APHIS, 2008). GnRH is a hormone present in animals that signals the production of both female and male sex hormones. If the antibodies bind to this hormone, the antibodies reduce GnRH's ability to stimulate the release of sex hormones, and therefore suspend sexual activity (APHIS, 2008). The animal then remains in a non-reproductive state as long as the antibody is present (APHIS, 2008). The vaccine must be injected into the animal's tissue or muscle, and can result in an infertile deer for up to four years (APHIS, 2008). When the vaccine is stopped, and the number of antibodies released is reduced, the animal will resume its normal reproductive state (APHIS, 2008). Animals given the vaccine in field and pen studies showed no inflammation at the injection sites, and their blood chemistry was similar to a control group (National Wildlife Research Center, 2004).

Many of the concerns regarding vaccines and birth control are related to the health effects they have on the deer and anyone who may hunt and eat the deer (National Wildlife Research Center, 2004). Negative health effects from the vaccine are claimed to be minimal (National Wildlife Research Center, 2004). There are few dangers connected with eating deer vaccinated with GonaCon, however, treated deer are often tagged so hunters can avoid them (National Wildlife Research Center, 2004).

The vaccine can be used in urban and residential areas, and costs $2 to $10 per dose (APHIS, 2008). However, the cost of either trapping the deer or darting them can range from $500 to $1,000 (APHIS, 2008).

GonaCon is not intended to eliminate the need for hunting; contraception needs to be combined with other wildlife management methods in order to reduce deer populations to healthy levels (National Wildlife Research Center, 2004). One of the main reasons this vaccine is not widely distributed is that it is not yet approved by the FDA for non-investigational use on wildlife populations (National Wildlife Research Center, 2004). It is, however, being used in studies in Maryland, New Jersey, and Pennsylvania (National Wildlife Research Center, 2004). Currently, there are field studies in Maryland at a fenced facility where 28 does were captured, tagged with ear tags and radio transmitters, and injected with GonaCon (National Wildlife Research Center, 2004). Their reproductive behaviors were monitored for two years, and compared with unvaccinated adult does in a nearby fenced area with a similar habitat (National Wildlife Research Center, 2004).

At the Deer Research Center at Pennsylvania State University, researchers studied the effects of GonaCon specifically on the reproductive functions of bucks from 1994 to 2004 (Killian et al., 2005). One of the major affects of the vaccine was altered antler development (Killian et al., 2005). Vaccine treated males shed their antlers earlier than non-treated males and some treated males showed a lack of muscular form typically seen in males during the rutting period (Killian et al., 2005). Death rates in vaccinated males were also significantly higher than in the control group (Killian et al., 2005). Overall, the study concluded that both single and two injections of GonaCon were successful in changing reproductive functions of male white-tailed deer for many years (Killian et al., 2005). However, because of reduced antler development, and higher death rates from pulmonary disease, the vaccine is not being considered for use in bucks (Killian et al., 2005).

PZP:

Porcine Zona Pellucida (PZP) is another immunocontraceptive that has been studied in deer. It is a protein found in the eggs of pigs, and when injected it stimulates the production of antibodies that block sperm receptors on the egg, making fertilization impossible (NIST, 2000). By inhibiting the ability to become pregnant, deer are induced to have two to four additional estrous cycles per year (NIST, 2000). PZP does not enter the food chain, and shows no side effects (PNC, 2008). The EPA is currently testing PZP and the US Food and Drug Administration has issued an Investigational New Animal Drug Document (INAD), which only allows the shipment of the vaccine for research purposes (PNC, 2008). The vaccine costs between $10 and $25 per dose, however, labor costs are more costly (PNC, 2008).

The NIST has tried PZP over many years on the deer population in Gaithersburg, Maryland (NIST, 2000). Although the first few trials had problems with the adjuvant, subsequent vaccinations have proved to be successful (NIST, 2000). Between 1997 and 2000, births were reduced by approximately 72% (NIST, 2000). It is thought that the newborn fawns were the product of does that did not receive a shot, only received one dose, were stray does that moved in after vaccinations were complete, or were the result of failed vaccinations (NIST, 2000). In 1999, 12 does were not given the vaccine, and they all produced healthy fawns (NIST, 2000). Birth rates have continued to remain low since 2000 as a result of the PZP vaccine (NIST, 2000). Although the time needed to reduce herd size is dependent of many factors including the rate of reproduction, mortality, immigration, emigration, disease and weather, after 3-4 years of using PZP there has been a 20% reduction in deer at this site, (PNC, 2008).

When using fertility control agents, it is necessary to treat a large proportion of the does, 70% to 90%, to reduce population growth (DeNicolla et al, 2000). This is due to frequently low annual mortality rates for suburban deer (DeNicolla, et al, 2000). In spite of these successes, effective contraceptive programs for fertility control of free ranging wildlife are not yet fully developed (DeNicolla, et al, 2000). It is expected that a safe and cost-effective fertility control method will not be presented within the next five to ten years (DeNicolla, et al, 2000). No anti-fertility agents for wildlife are currently commercially available, and are classified as experimental drugs (Curtis, et. al, 2000). In order to test deer with drugs, a federal Investigational New Animal Drug permit and approval from a state wildlife agency are required (DeNicolla, et al, 2000).

Deterrents

Another option for curbing the impacts overabundant deer populations have on forest regeneration is the use of various deterrents to keep deer away from specified areas (DeNicola et al., 2000). However, many of these methods are only intended for short-term use (DeNicola et al., 2000). Plants treated with repellents are less appealing for consumption compared to other non-treated plants (DeNicola et al., 2000). The effectiveness of these deterrents is dependent on how much other forage is present (DeNicola et al., 2000). In addition, the effectiveness of many repellants decreases as deer density increases (DeNicola et al., 2000). Different deterrents include scare devices, dogs, and visual deterrents (University of Missouri Extension, 1997). Scare tactics or hazing deer may prove to be effective initially; however, deer can adjust to noises and ignore them with time (University of Missouri Extension, 1997). In addition, scare tactics only cause deer to move on into different areas (University of Missouri Extension, 1997).

While chemical deterrents may be useful in assisting with forest regeneration, some commercially available repellants are only intended for use on ornamental shrubs, fruit trees, and edible crops (University of Missouri Extension, 1997). To deter deer in urban and suburban settings, using noncommercial repellents may be successful (University of Missouri Extension, 1997). Adding new and unique odors to the area can help deter deer browsing (University of Missouri Extension, 1997). One repellant is tankage, composed of slaughterhouse byproduct, and is typically used as a repellant in orchards by repelling animals from its odor (University of Missouri Extension, 1997). However, some other animals may find the smell attractive, and destroy the cans or cloth bags placed in the designated repellent area (University of Missouri Extension, 1997). To fill 300 small cloth bags to cover a 2 acre area, a 50-pound bag can be purchased at around $20 (University of Missouri Extension, 1997).

Human hair is another noncommercial repellant; it is inexpensive but inconsistent in its ability to repel deer (University of Missouri Extension, 1997). Hair bags are typically hung on the outer branches of trees, or around the perimeter of an area to be protected (University of Missouri Extension, 1997). The large size of impacted area in the reservoirs makes the use of individual hang bags ineffective unless certain areas are designated for regeneration priority areas. In addition, the plants in need of protection are small and may not be able to support the bags (University of Missouri Extension, 1997). Bar soap is also used as a deterrent, and has proven to be more effective in deterrence than human hair. Bar soap needs to be reapplied to trees as they grow older and may not be useful for the smaller plants that contribute to the regeneration of the forest (University of Missouri Extension, 1997).

Casein:

Casein, an animal protein precipitated from milk, has been identified as additional chemical deterrent and tested on plants (Kimball et al., 2005). When applied to shrubs and seedlings, it minimizes browsing damage from deer because of its sour and bitter taste. It was found that pure hydrolyzed casein (HC) is most effective (Kimball et al., 2005). Casein can be used as a repellant in nurseries, orchards, and reforestation projects. It has been tested as a deer repellant on salal leaves and western red cedar seedlings (Kimball et al., 2005). In both cases, browsing damage was reduced to levels compared to using a commercial repellent. However, intact casein did not prove to be as effective as the hydrolyzed formula (Kimball et al., 2005).

Reforestation

Removing Invasive Vegetation

Removing invasive species can be done biologically, chemically, manually or mechanically. Biological methods depend upon organisms that naturally destroy the invasive species (Swearingen, 2008). Chemical methods commonly involve some form of herbicide; the most commonly used being glyphosate (Swearingen, 2008). There are varying methods in which to apply the herbicide: basal bark application, cut stem application and foliar application (Swearingen, 2008). Basal bark application involves grinding the plant down to the base and applying the herbicide to the base (Swearingen, 2008). Cut stem application involves cutting a stem close to the ground and applying the herbicide to the stem (Swearingen, 2008). The final method is foliar application, which involves applying herbicide to the foliage of the plant itself (Swearingen, 2008). However, to ensure that damage is not done to the native vegetation, caution must be taken when using a chemical application (Swearingen, 2008). The manual method is done by removing the entire plant and its roots by hand (Swearingen, 2008). Mechanical method of removal involves cutting the invasive plant down immediately prior to seeding or at the time of lowest available nutrients within the plant (Swearingen, 2008). This method must be done every year until the seed bank is eventually depleted (Swearingen, 2008). The removal of invasive species is most effective when two or more methods are used together (Swearingen, 2008).

According to Pannill (2000) the tree of heaven can be managed by spraying herbicide such as glyphosate on it or by cutting it down. Cutting the tree of heaven down to the ground during the months of June or July over a period of three years will eliminate the tree completely, as will uprooting the tree and removing all roots (Pannill, 2000).

Japanese barberry can be managed through chemical and manual methods (Swearingen, 2008). A chemical application can be most effective if done during the fruiting season of the shrub, this is usually during the summer months (Swearingen, 2008). The manual removal of the shrub can be done at any time but best done when the soil is moist so all roots can be removed (Swearingen, 2008).

Oriental bittersweet can be managed chemically, manually and mechanically. However, before applying any method it is important to identify the vine correctly as the invasive plant, the hybrid or our native American bittersweet, as they all look very similar (Swearingen, 2008). Manual and chemical method will need to be used in combination to ensure that the plant does not regenerate (Swearingen, 2008).

Managing mile-a-minute vines can be done through biological, manual or chemical applications. A biological control method that is currently being tested is the introduction of the Asian weevil (*Rhinoncomimus latipe*), a beetle that feeds on the plant (Colpetzer et al, 2004). Adult weevils feed heavily on new leaves while their larvae burrow into the stem and feed, ultimately killing the plant (Colpetzer et al, 2004). Another management strategy would be removing the vines from the area by hand. This must be performed annually for a minimum of three years for the seed bank to be depleted (Hough-Goldstein et al., 2008). A chemical application of glyphosphate can also be used to remove the vine (Hough-Goldstein et al., 2008).

Japanese honeysuckle can be managed through chemical, manual and mechanical removal. The leaves of honeysuckle are semi-evergreen and continue to photosynthesize throughout winter months (Bravo, 2008). Applying herbicide to the leaves of the vine can be done in winter when native vegetation is dormant, thereby affecting only the invasive honeysuckle (Bravo, 2008). Cutting throughout the year during the months of July and September and manually removing whenever the plant is present can be effective in eliminating the vine (Bravo, 2008).

Stiltgrass can be managed by manual removal and chemical application. Removing stiltgrass manually for a minimum of three years will ensure the eradication of this grass.

Stiltgrass can also be managed by using herbicide (glyphosate) and the graminicide (sethoxydim) according to Grafton et al. (2008). The study concluded that the herbicide, glyphosate, was the most effective at killing the stiltgrass. The 1.5% concentrate of glyphosate with surfactant killed 100% of the stiltgrass (Grafton et al., 2008). Huebner (2007) suggests management of stiltgrass should be concentrated on the edges, due to its dispersal method. Huebner's (2007) study found that the stiltgrass seeds stay in a close vicinity of the parent plant and are not wind dispersed, therefore its main dispersal is by animals and humans. Huebner (2007) suggests with the increase in deer population, the spread of stiltgrass will also increase.

Fencing to Help Forest Regeneration

Deer population control is a long term management issue that will take time to accomplish. As a result, alternatives to restoring the forest need to be considered to prevent the forest from continuing to lose function. The major problem with forest regeneration within the reservoirs is the over-browsing of young seedlings, which inhibits forest regeneration.

A simple method for reforestation is fencing (MD DNR, 2006). This method would require establishing fenced enclosures at predetermined spots around the area that is to be reforested (MD DNR, 2006). Of the many management options available for forest regeneration, fencing is currently the most logical and economically feasible approach in light of the abundant deer population (MD DNR, 2006). Fencing off sections of a forest restricts deer from the area and allows for regeneration of plants and trees that would typically be subjected to browsing pressure (MD DNR, 2006).Fencing allows seedlings to grow and reach a height that would not be subject to browse by deer (MD DNR, 2006). After the enclosures have been allowed to regenerate fencing would be removed with the hope that regenerated sections will disperse increased seeds, promoting further regeneration in the non-fenced sections of the forest.

Fencing as a management option has both advantages and disadvantages. Advantages include the onetime expense to property owners (Ward &Worthley, 2008). Disadvantages include the long amount of time need for forest regeneration, aesthetic considerations, and soil erosion and wildlife impacts if the fencing is poorly implemented (Ward & Worthley, 2008).

When choosing fencing as a management method, there are important factors to consider including the cost of the fence, the height and design of the fence needed, the value placed on the land that is being protected and the size of the land parcel intended for enclosure (DeNicola et al., 2000). There are various types of fencing that can be used and selection depends on the needs of the property (DeNicola et al., 2000). The three most commonly used fences are electrical, barrier or combination (DeNicola et al., 2000).

Electrical fences are smooth wire fences that shock upon contact and can be either battery or solar powered (DeNicola et al., 2000). Generally, with this type of fence, an electrical impulse occurs with contact (45-65 pulses per minute) (DeNicola et al., 2000). This is a short enough duration to deter the deer while also allowing anything that gets caught time to free itself (DeNicola et al., 2000). There are many types of electrical fences that can be used. There is a 7 strand slanted fence which costs $6.30 per linear meter and can withstand moderate to high deer pressure (Jordan & Richmond, 1991). The second is a vertical 5-wire electric fence that costs $3.25 per linear meter and can withstand moderate to high deer pressure as well (Jordan et al., 1991). The last is a vertical 3-wire fence which would cost $2.59 per linear meter but the pressure it can withstand is unknown (Jordan & Richmond 1991). "One drawback to this type fence is if the deer hits the fence with an insensitive part of its body (back or chest). In this case, the shock is too weak to deter the deer" (Jordan & Richmond 1991).

A barrier fence is another fencing option. The most efficient type of barrier fences are 8-10 feet tall and made of 11-14.5 gauge high tensile woven wire and have a breaking strength of 1,800 lbs (DeNicola et al., 2000). The cost for a private contractor to construct this type of fence would be between $10,000 and $15,000 per mile for an 8-9 foot high fence (Creacy, 2006). However, another suggested price for this type of fence would cost $15.88 per meter for a 2.4m high fence (Jordan Richmond, 1991).

The following table is from a report done by Penn State showing the pros and cons of the two most widely used fencing methods.

Table 6. Comparison of high-tensile electric wire fencing to woven wire fencing [from Jacobson, 2006]

	Electric	Woven wire
Recommended height	Six to nine strands: 5–7 feet	8 feet
Costs (installed per linear foot)	$1.00–$1.50	$1.50–$2.50
Installation	Fewer posts and bracing	Requires more posts
Maintenance	High	Lower
Reusable?	Yes	No
Deer behavior	Learn to ignore it	More effective at keeping the deer out
Weather	Problems with grounding	No problem
Topography	Better on flatter terrain	No problem
Human contact	Make sure fence is well posted to prevent shock	No problem

The last option for fencing is a combination fence. Generally, a combination fence consists of "an electric fence that is combined with a repellant or attractant" (DeNicola et al., 2000). When this type of fence is used, deer are more likely to tap the fence with their nose or mouth and receive a shock, which in turn deters the deer from coming back (DeNicola et al., 2000). In places subject to deep snow a highly effective, yet more affordable, combination of electric fence on top and barrier fence underneath is used (DeNicola et al., 2000).

Fencing can also be used in collaboration with clearcutting or burning. Clearcutting and burning cannot be used as a management option alone because the deer will not be deterred from the area and simply return and browse on the regeneration. One option is to clearcut or burn an area and then erect fencing, eliminating deer from the area and allowing for proper regeneration (Ward & Worthley 2008).

Once the enclosures have been established they will have to be planted, then maintained, and monitored (Jacobson, 2006). This could be done in several ways. The enclosures could be “adopted” by different organizations or companies that would be responsible for monitoring and maintenance. The enclosures could be monitored by a government agency that is assigned to looking after them. After a predetermined amount of time, the enclosures will be assessed by experts and when appropriate, the fencing will be removed. Further monitoring will be necessary, but not as often and only to ensure the continued success of the plants.

Future Protection of the Reservoirs

Controlling Development

One threat to Maryland’s natural resources is development, which is in need of adequate management practices (1000 Friends of Maryland, 2008). Current development has lead to unmanaged suburban sprawl, allowing urban centers and villages to deteriorate. Suburban sprawl leads to construction projects that mainly benefit developers, not communities, forests or water ecosystems (1000 Friends of Maryland, 2008). Inefficient transportation methods such as suburban roads and highways have also supported sprawling development, deforestation, and forest fragmentation (1000 Friends of Maryland, 2008). Unmanaged growth and inadequate public transportation methods have led to degraded natural resources and a declining agricultural economy due to a loss of land (1000 Friends of Maryland, 2008). In many cases, this type of growth greatly exacerbates problems facing communities across Maryland, including managing deer populations and ensuring forest regeneration and healthy water quality in the Loch Raven and Prettyboy Reservoir systems (MD DNR, 2008d).

As mentioned previously, deer thrive on “edge” habitat created by forest fragmentation; as portions of forested areas are developed, new edges are created where woods meet grasslands such as fields, lawns, or suburban landscaping (1000 Friends of Wisconsin, 2008). This type of development provides a multitude of food and protective shelter for the deer (1000 Friends of Wisconsin, 2008). Therefore, if Baltimore County continues to allow development in areas surrounding the reservoir system it will only lead to a further rise in the deer population. It is vital to keep the forests intact, and to reforest any areas that are available around the current forested system surrounding the reservoir in order to limit the deer population and improve water quality.

Deer populations are also more difficult to control in a fragmented forest because deer management techniques such as hunting are almost always prohibited in suburban developments due to the close proximity to people (MD DNR, 2008d). However, this is not to say that the solution should be to allow hunting in these areas. Hunting may have to be implemented to quickly control the current deer population; however, long-term solutions such as decreasing the amount of forest fragmentation and sprawl surrounding the reservoirs systems should be seriously considered and implemented (1000 Friends of Wisconsin, 2008). In order to accomplish this, citizens should be educated about the importance of the forest system and its link to clean, sanitary drinking water (1000 Friends of Wisconsin, 2008). This will hopefully lead to citizens understanding the need to limit development on lands surrounding the reservoir system.

It is of vital importance that Baltimore City, Baltimore County, and non-profit groups focusing on smart growth techniques continue to build coalitions and work together to ensure the safety of the reservoir drinking water (1000 Friends of Maryland, 2008). Building such coalitions will ensure the county and city government agencies are considering all deer population management options to protect forested areas inside the Loch Raven and Prettyboy reservoirs. Smart growth includes focusing attention and resources on restoring city centers and older suburban developments, mass transit and pedestrian centered modes of transportation instead of using undeveloped lands for development purposes (Smart Growth Online, 2008). These kinds of long-term solutions are more likely to ensure safe drinking water for the city and surrounding areas.

Forest fragmentation can be reduced by reconnecting isolated and fragmented parts of the forest and by limiting development (1000 Friends of Wisconsin, 2008). Additionally, due to the great importance of water to people, the county must ensure further development on lands surrounding the reservoir system be severely limited. The small percentage of land the city owns surrounding the Loch Raven and Prettyboy reservoir systems is almost completely off-limits to any type of development (USGS, 2008). However, the county continues to allow some development to occur in close proximity to the forested areas of the reservoir; therefore, fragmentation in these areas continues to intensify (BC DEPRM, 2008b).

The state of Maryland is aware of the importance of smart growth, and this can be seen on the Maryland Department of Planning's website for smart growth (Maryland Department of Planning, 2007). Individual counties can support smart growth development techniques by passing rezoning laws that require larger areas of land to be preserved in between buildings, including homes and businesses. Specific smart growth strategies mentioned on the website include healthy and cohesive neighborhoods, support of transit-oriented and walkable developments, improvement of functional and efficient transportation networks, and reinvestment in existing infrastructure and aging housing stock (Maryland Department of Planning, 2007).

Increasing the city's land holdings is another viable management solution for the Loch Raven and Prettyboy reservoirs. Alverson et al. (1988) recommended that establishing large (200–400 km^2) areas along with hunting would be a "simple and inexpensive method" to maintain wooded areas and richness of species that are browsed by white-tailed deer. This would be beneficial for the reservoirs because both reservoirs have residential and agriculture land uses that could be reforested. Increasing land holdings was undertaken to establish both reservoirs. The taking of land for the reservoirs could be met by both support and opposition, as some land owners might be looking to sell land, while others could potentially be upset with relocation.

Valuing Water

Baltimore City has a very simple water plan. The City uses meters to keep track of water usage of Baltimore City residents (Baltimore City Council, 2005). Metered residents are given a bill for a set quarterly amount of water. When the resident exceeds this amount, they are charged at the regularly scheduled rate for the water (BC DPW], 2008).

Baltimore City changes the regularly scheduled rate for water each year depending on what the City believes is necessary. This change is usually dependent on inflation rates but has been lowered and raised due to various economic constraints on the constituents (Baltimore City Council, 2005). This money is used to maintain water systems: "Revenues received from operations of the distribution system are derived primarily from charges for water service" (Baltimore City Council, 2005). One could argue that the health of Loch Raven Reservoir falls under the umbrella of maintaining the water. If this is true, then some of the money that is received from water bills should go towards maintaining the reservoir. Another option is to increase the water bill rate by no more than five percent and dropping the added revenue to a separate account whose sole purpose is to maintain and implement various initiatives concerning the reservoir.

Baltimore City submitted a draft Central System Report in 2003 which included various proposed projects (ranging into the millions of dollars) for the City to undertake (Baltimore City Council, 2005). In order to pay for education, fencing, or other options for caring for the reservoir, these projects could be included as proposed projects for the Baltimore City Council to consider. This may take longer because it is uncertain exactly when the next Central System Report will occur.

All of these options have the same goal: to fund the various projects that this research is proposing. These options are easy to implement, have a wide range of applications, and are at little to no cost (in terms of water rates) for the citizens of Baltimore City. These provisions provide funds and are vital to the success of any proposed project concerning the reservoir.

Educating Communities about the issue

As the deer population continues to grow and impact the forests and our water quality, it is important to inform the general public about the issue. Public education is necessary to gain acceptance of wildlife management practices – in this case, hunting (Green et al, 1997). There is a lack of consensus about how the deer population should be managed, and for many people, non-lethal methods of controlling the deer population are preferred (Green et al, 1997). Therefore, there is a need to educate the public about the costs and consequences of the overpopulation of deer, and establish accountability for the deer population (Green et al, 1997). It is important that not only the immediate community be informed but the regional community, as well. Water quality is not just a local issue. Everyone who lives in the watershed and receives water from Loch Raven and Prettyboy reservoirs needs to be educated on the importance of reducing the deer population to a sustainable level. The Maryland Department of Natural Resources maintains a long-term goal to educate the general public in Maryland about deer biology, management options to control the deer population, and the impacts that deer have on the land and people (MD DNR, 2008a). It is important these efforts be conducted effectively and reach every stakeholder involved.

The public should be aware of the magnitude of deer overabundance as well as the effects the overabundance has on the forests and subsequently the water quality. Next, they should be made conscious of the efficacy of different techniques. The popularity of ineffective methods, such as trap and translocation –see the non-lethal methods section above— indicates that there is a lack of reliable information on the efficacy of various management techniques (Green et al 1997).

It may be difficult for non-hunting individuals in the community to accept hunting as the only effective option for managing the deer population. As it is being used as the main mode of managing the population, the community has a right to know more about it. The concept of hunters coming into your community to hunt can be a scary thought. With more knowledge about the hunting regulations, bag limits, weaponry regulations, and safety tips for being in the forest during hunting season, community members may feel safer allowing hunting in their neighborhoods. Those who do not live in the neighborhoods immediately adjacent to the reservoirs, but still receive water from them, should also be informed. This could help increase hunter turnout, and increase profits from hunting licensure (from which DNR gains needed revenue) (Hotton, 2008).

Spreading the word to the general public can be difficult. It can be difficult to stretch out the arm of information to general populous. Many community organizations and local non-profits work directly with the people already and could prove valuable spreading information at the local level. Many regions have community-based organizations that take part in educating the public. For example, the Pennsylvania State Grange, working with the ecosystem management project has run public seminars based on deer management and the impact it has on our communities (Huber, 2006). There are many organizations that currently aim to inform the general public about the importance of maintaining forest health, maintaining water quality, and/or maintaining the deer population right here in Maryland.

Organizations presenting information on these topics may miss the interconnected nature of all of these issues. The Parks and People Foundation hosts several programs geared toward educating all ages about water quality and the impact that people have on their environment, but they do not connect the deer problem to water quality or forest health (Parks and People Foundation, n.d.).

It is important to note that the Parks and People Foundation has brought together numerous communities around the issue of environmental accountability. After several educational forums and tree planting programs, community groups popped up all over Baltimore City. For example, a group of concerned citizens formed a watershed council in southwest Baltimore (Parks and People Foundation, 2005). This demonstrates how individuals will mobilize if they are educated effectively. The Prettyboy Watershed Alliance is a citizen led group that was formed in response to a two-year study on the Prettyboy region that made the importance of protecting and restoring the watershed clear. The Prettyboy Watershed Alliance works across jurisdictions to educate and motivate landowners to become environmental stewards through its Prettyboy watershed landowner stewardship program. The Alliance partners with the Maryland Department of Natural Resources to support the Streamwaders Program, which trains volunteers' about stream monitoring techniques and builds public-private partnerships (Prettyboy Watershed Alliance, 2008).

The Department of Natural Resources could also send out mailings regarding the deer/forest/water quality issue. The DNR website already provides much useful information, but it can be difficult to find specific information on the issues facing Loch Raven and Prettyboy reservoir. It needs to be easier to find this information if the website is being used as the primary resource. The Water System Report that Baltimore City gives out presently contains information regarding water quality and public health notices (BC DPW, 2007). A section of this report could include a summary of the consequences of deer overabundance in the watershed. However, this would only reach individuals in Baltimore City, not those in other counties. Any action such as this should be spread to the other counties that receive water from Loch Raven and Prettyboy.

The Maryland Department of Natural Resources (DNR) has held at least one forum about hunting in Loch Raven and Prettyboy and posted information on the DNR website. Resources may lend themselves to online presentation but an in-person public forum may prove more useful and provide a better face to the community. Involvement in the forum could be encouraged by: contacting community groups, posting on the website, contacting local news stations, sending out newsletters, etc. Other possible ways to educate the community on the problem of deer overabundance and why hunting is the most effective method and necessary are as follows:

- Host an open house and discuss the issue in the form of a nature hike
- Sending out newsletters
- Hosting school assemblies
- Host school field trips

These events could be hosted in conjunction with other groups such as Hooked on Nature, Tributary Strategy program, and the Parks and People Foundation.

While many people already have an idea of the problems deer are causing in the Loch Raven area, much of this information comes from various sources with different levels of credibility. It is important that the people hear from their government agencies to increase their faith in the management methods the Department of Natural Resources plans on enacting. It is hoped that a more educated community could create a more empowered and proactive community that could work with the Department of Natural Resources to address this issue. Several organizations and programs are already in place, and can be utilized to facilitate accurate education which incorporates the highly interconnected relationships between people, water, the forest and the deer.

Monitoring Forest Regeneration and the Deer Population

In our earlier discussion of our sampling methods and results, we discuss our recommendations for deer and forest monitoring based on our experiences.   We also discuss methods used elsewhere that might be able to be deployed locally. We recap our recommendations for the deer pellet counting and vegetation survey briefly here:

- Ideally the same group of field personnel sample for deer pellets each time to minimize inter-individual ability to locate pellet groups.
- Similarly, pellets might be differentially visible at different times of day—this too can be minimized by common sampling times.
- Sampling in early winter and calculating total number of days from leaf-off date provides for normalization of area over which pellet deposition has occurred but assumes that pellets do not decompose. This is a questionable assumption locally because of our relatively warm average winter temperatures.
- Sampling during warmer weather and using a driving rain to set the ‘zero’ point for pellet accumulation results in high variability among neighboring sites but would allow you set

hunting limits based on recent population counts. Many sites would have to be sampled to reduce variation.

- The amount of variation we saw between local sites leads us to suggest that multiple sampling sites within a reservoir always be sampled to more effectively assess the size of the local population.
- Traditionally browse estimates and pellet counts are conducted at the same time which we think would lead to one or both being inaccurate. If sample of browse levels occurs after bud break so that trees can be identified it will be at a time when pellets are actively decomposing; if browse is assessed prior to bud break the plant identification is subject to a great deal more error. Therefore we suggest they be decoupled.

Suggestions

The issue of deer management, forest health and water quality is complex and critically important to the regional community. While the need to maintain the water quality of the reservoirs is obvious, the actions needed to ensure water quality are fraught with controversy. Human development has altered our local forest communities to the point that deer populations have exploded and deer now threaten to destroy, by preventing regeneration, their own habitat and the forests that protect the waters. Yet, deer are more than just too numerous forest herbivores; they have also become symbols of “nature” and “wild.” Reducing their numbers by re-introducing predators, in the form of human hunters, comes into direct conflict with their popular public role as charismatic mega fauna. Over the past semester we have investigated these issues and have developed the following suggestions.

The majority of the authors of this paper support hunting in some form as a method of deer control. While hunting might be the best solution in the short-term, we believe other deer management options need to remain under consideration. Furthermore, there are other management options for the reservoir forests that are not directly related to managing the deer population. In our opinion, addressing the deer population by itself will not resolve all of the forest regeneration/restoration problems.

First, education of the general public is very important. Wildlife managers are more supportive of deer hunting, as part of deer management, than most of the general public; therefore, it is important to provide an explanation to the general public about the rationale for controlling the deer population (Allison, 2007). Education should incorporate the three benefits of controlling the deer population: 1) maintaining a healthy herd, 2) maintaining a healthy forest, and 3) maintaining a healthy water supply. In order to justify hunting as the best deer management technique, it's important to sincerely examine, and compare the pros and cons of various deer management techniques with the general public. While other options are being developed, currently they have not been approved nor demonstrated to work under the situations found in our local reservoir forests.

The specifics of how hunting is managed need to be considered. Since the removal of female deer will be more effective at controlling the population of deer, the education program and hunting regulations should continue to encourage the removal of female deer over the removal of male deer (MD DNR, 2008b). Close monitoring of the deer population is important as well, because this can help to determine the effectiveness of current hunting regulations. It can also be used to set target harvest levels. Sampling techniques should be deployed that monitor for both the overall population of deer within the reservoir forest as well as the density variations of the deer population in different sections within the reservoir forest. In areas where hunting has been prohibited such as Loch Raven reservoir, deer densities are much higher than in areas where hunting has been allowed such as Prettyboy Reservoir (Mazeska & Felter, 2008). As previously closed areas are opened to hunting and given that deer are supposed to stay in one area, it would be necessary to switch and open new areas to hunting from time to time in order to decrease deer density throughout the entire forest, instead of just one portion of the forest. Members of the public will want to be kept informed about these changes, and it would be beneficial to provide meetings for the public about how these changes would affect them. This could address concerns that the public may have, such as should they be concerned about walking in certain areas of the reservoir forest.

While deer hunting is a vital component to deer management, it’s important to look at other management options, as well. Not only would this increase the chances of successful deer management, this would also provide a means for people who do not hunt to provide their support for controlling the deer population. In particular, the authors of this paper supported fencing as an additional management option. Fencing has been demonstrated to permit regeneration on the fenced-in portion of the forest, as seen in the picture on the cover of this report –the picture is of a fenced in area at Oregon Ridge installed by a homeowner. Specifically, when fencing is installed, trees within the plot should be allowed to grow to well above 5 feet tall, because this would be above the browsing line for deer (Clatterbuck et al., 2006). Once this has occurred, the fencing may be removed and moved to a different section of the forest. This would allow for the maximum area to regenerate within the forest while using the least amount of fencing.

In addition to the efforts of park personnel to maintain these enclosed or regenerated plots, volunteer help should be sought out through word-of-mouth at educational meetings or through advertisements for help. Local activist groups and educational institutions would be good places to call for help with forest conservation projects. In addition to the primary fencing to allow the forest to regenerate, secondary fencing could be installed to reduce vehicular collisions with deer and prevent damage to gardens. Keeping deer away from gardens has the additional benefit of preventing deer from encountering invasive species in gardens and spreading them into the forest.

Invasive species management is another important issue related to forest management that needs attention. A volunteer removal program for invasive species should be established in Loch Raven and Prettyboy. Work would start at the edges of the forests and employ two or more methods of invasive species removal, such as an herbicide and manual removal.

In addition to volunteer help to conserve the reservoir forests, funding for such forest conservation projects could be raised through additional taxes on water utility bills; after all, it is the water that is being protected. People should not be penalized for using water for necessities, such as drinking, bathing, cooking, washing clothes, and washing dishes; instead, the proposed tax could target water use amounts that are in excess of the average domestic use per capita water consumption within the watershed. In addition to helping fund restoration, this would have the added benefit of helping people to value their water through market mechanisms. In order to maintain a good image with the public, it is important that the funds not be diverted to other projects and should be used for reservoir forest conservation projects only through non-lethal methods, such as fencing, monitoring, and invasive species removal.

The most important impacts to water quality, outside of the deer population, occur from land use within the surrounding watershed. It’s important to maintain water quality by reducing sediment and nutrient loads in the area. In order to accomplish this, a study of the nearby area outside of the reservoir would need to be conducted to determine what areas are important contributors of these pollutants. Then, management plans for land uses that contribute to pollution would need to be developed and implemented. Agricultural best management plans have been effective at accomplishing the goal of reducing pollution, and their implementation should be continued; however, suburban areas continue to be unregulated. Suburban best management plans are particularly important in areas, such as Loch Raven Reservoir, that have a higher proportion of suburban land use in the surrounding area. As a result of uncontrolled runoff from suburban areas, the Loch Raven Reservoir may continue to suffer from high levels of non-point source pollution. Non-point source pollution has a significant impact on water quality, and the ecology of the area, so it is an important management option for the reservoir and reservoir forest (Environmental Protection Agency, 1998).

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