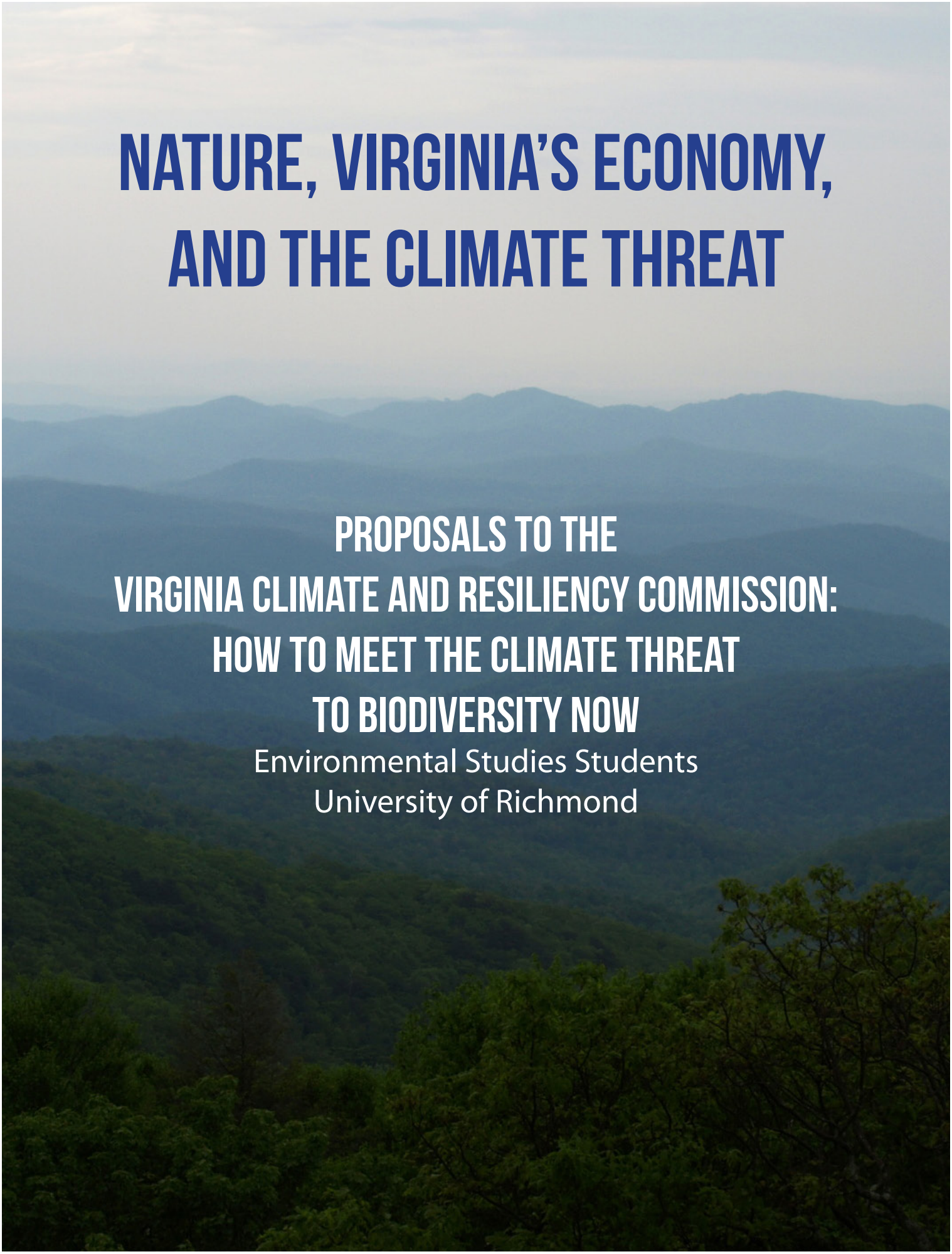

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT

PROPOSALS TO THE VIRGINIA CLIMATE AND RESILIENCY COMMISSION: HOW TO MEET THE CLIMATE THREAT TO BIODIVERSITY NOW

Environmental Studies Students
University of Richmond

TABLE OF CONTENTS

The Honorable Terry McAuliffe
Governor of Virginia
1111 East Broad Street
Richmond,Virginia 23219

April 21, 2015

Dear Governor McAuliffe, co-chairs, and members of the Commission,

We welcome the Governor's Commission on Climate and Resiliency to the University of Richmond for its meeting today and for a Symposium on Nature, Virginia's Economy, and the Climate Threat.

The Commission's charge is to propose solutions to you for climate-related issues facing the Commonwealth. Our Symposium today also takes up that challenge. In this booklet you will find research and recommendations for you -- and all of Virginia's governing bodies – for how best to protect our state's priceless and economically essential natural heritage as climate changes disrupt our ecosystems.

Those natural assets are often overlooked by conscientious public servants as they plan for climate impacts on urban areas and infrastructure. We hope that this research, produced by students in an Environmental Studies seminar during the past few months, begins the urgent planning needed to make our forests, wetlands, riparian areas and the Bay, already under great stress, more resilient.

These are recommendations for immediate action and for funding. They include a new prioritization of conservation tax incentives and an agroforestry initiative, both of which will protect vital migration corridors for forests and wildlife; measures to retain our economically vital natural wetlands; new sanctuaries for oysters and the rest of the Bay fishery; programs to make the state's anti-invasive species and riparian restoration campaigns more effective as climate change arrives. We are confident that these recommendations deserve careful consideration from your administration.

We're grateful that the Commission has accepted our invitation to meet at here at the University, and we also thank the UR Class of 1992 Environmental Awareness Endowment, and the UR Center for Civic Engagement, whose support made today's Symposium possible.

On behalf of the students of the Environmental Studies Senior Seminar Class, 2015, we thank you for your attention.

Sincerely,

Peter D. Smallwood
Associate Professor of Biology
University of Richmond

Stephen P. Nash
Senior Research Scholar, Journalism
University of Richmond

1. Seed Banks: An Insurance Policy Against Extinction From Climate Change

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Casey Schmidt
Environmental Studies and English Major, 2015.

Abstract

Climate change is causing the ranges of native species to shift northward at a pace that outstrips the ability of many plant species to migrate and adapt (Walther et al. 2002; Renwick & Rocca 2014). Although assisted migration, the process of relocating individuals or spread of seeds through human intervention, has been used successfully in some cases to preserve species, it comes saddled with potential ecological damage and legal complications arise when these ranges cross state lines.

These complications threaten Virginia's biological diversity, especially among rare plants and those plants from habitats affected most by climate change. In order to preserve the genetic diversity of native species before populations become isolated and inbred, this paper proposes that Virginia create a seed bank. Seed banks have been used for a variety of reasons worldwide to preserve the genes of plants species, including for the preservation of crop species and for research purposes (Laliberte 1997). For this proposed seed bank, Virginia would use information collected by the state Natural Heritage Program to identify eligible species that face the greatest threat from climate change in order to preserve biodiversity, establish a genetically diverse sample for research, and potentially reestablish these endangered species in the future.

Introduction

As the climate changes, the average temperature in Virginia will rise, shifting once-stable ranges of native species northwards and upwards in elevation (Walther et al. 2002). Global climate change has affected the phenology, or timing of the seasons, for the region which alters environmental cues to plants and animals, especially in the spring (Walther et al. 2002). When this change misaligns the reproductive and activity cycles of different species, reproduction is affected. Climate change also impacts rainfall and soil moisture which are important factors in determining species range (Kane et al. 2013). While some animal species will be able to migrate with this change, the shift will likely outpace the ability of plant species to adapt and migrate. Because individuals are immobile, this can only occur through reproduction (Renwick & Rocca 2014). Additionally, studies predict that habitat fragmentation will increase in the coming

decades, which decreases habitat connectivity and corridors through which species can migrate (Vitt et al. 2010).

The native flora of Virginia provide invaluable ecological services such as carbon sequestration and water quality maintenance, as well as providing habitat for Virginia's native species. Plants have always been an important part of Virginia's heritage; the first book on the flora of Virginia was published more than 250 years ago. The trees that make up an integral part of the state's viewshed are at risk of disappearing.

Though one solution would be to relocate at-risk species northward, this method poses unknown risks to the ecology and integrity of the new landscape (Vitt et al. 2010). Additionally, many of these new ranges would cross state lines and good precedents have not yet been set for interstate large-scale assisted migrations. Additionally, while in situ conservation -- or conservation of the species' native habitat -- is ideal, 90% of endangered species exist on private property, land acquisition is expensive, and current important areas of biodiversity may not be as important as ranges shift.

Instead, the state should consider an ex situ, or out of habitat, form of conservation: the seed bank, in which the state can preserve the genetic diversity of native species while legal regulations and research catch up to the evolving realities of our new climate.

Across the globe, there are over 1,500 seed banks currently preserving the genetic material of flora species (Laliberte 1997). The purposes of seed banks range from medical to agricultural to ecological, but all aim to preserve the seeds of plants by storing them in a controlled environment to keep them in a dormant state. This paper discusses the science behind seed banks and how they are used to protect biodiversity for the future. Additionally, it proposes partnerships and sources of funding for the creation of a seed bank for the state of Virginia in order to preserve the specific genes of Virginia's native and endangered flora.

The Science of Seed Banks

Seed banks are facilities in which the seeds of plants, for a multitude of reasons, are kept cool so that they do not germinate or die and can be planted at a later time. Seed banks have been used for a variety of purposes across the world and often in the United States for the preservation of crop species. More recently, seed banks have been employed to preserve endangered native species as in the case of Rancho Santa Ana Botanical Gardens in California and medicinal in the case of the North Carolina Germplasm Depository (Volis & Blecher 2010). Similar to seed banks, germplasm banks store genetic material, such as pollen, in addition to seeds which can be used for reproduction later. Seed banks act as insurance to protect species in order to garner more knowledge about them for wider conservation efforts, to gather a controlled population for research purposes, and to offer the possibility of future reintroduction into the environment (BLM 2003).

Seed banks mimic a phenomenon in nature in which seeds do not germinate because of limiting factors in their environment, sometimes called "enforced dormancy," other times "seed persistence" (Ellis et al. 1985; Long et al. 2014). During this time seeds remain alive, but do not grow or germinate until environmental conditions improve. Limiting factors include moisture, light, heat, and dissolved oxygen (Ellis et al. 1985). Seed dormancy in nature can preserve the seed anywhere from a few weeks to years in the soil until conditions become ideal for germination (Ellis et al. 1985). This persistence spreads the risk of reproductive failure by distributing germination over time and variable environmental conditions (Long et al. 2014).

Seeds and genetic material are kept at a low humidity, below 8%, and at a cold temperature, below 20°C, while in the seed bank (Laliberte 1997). The seeds are collected, important data recorded, and then the seeds are dried which causes a hardening of the outer shell (Ellis et al. 1985). Seeds are generally kept in containers that prevent exposure to moisture, such as glass jars or vacuum-sealed bags. Seeds are tested every few years for viability, which allows for the opportunity to garner information about the longevity and germination success of different species. Seed banks are the most popular form of ex situ conservation for plants because of their low cost of maintenance, ease of storage, and their insusceptibility to invasive species and predation (Volis & Blecher 2010).

Large samples of seeds are preferable to provide a representative sample of the population and to prevent inbreeding and genetic drift. The Millenium Seed Bank, a project which aims to preserve 10% of the world's flora species, suggests an ideal number of 10,000 to 20,000 seeds (Smith et al. 1998). Proper collection numbers vary between studies, from 50 sampled individuals per population to around 170 total individuals across populations seeds (Hoban and Schlarbaum 2014). When the number of samples is limited, studies have found that it is more effective to sample across spatially heterogeneous populations rather than gather more samples from a constrained population (Hoban and Schlarbaum 2014). Such large samples are required for a base collection, test samples for viability, distributing duplicates to other facilities for safety, and distribution for research purposes. Smaller collections will limit opportunities for research and distribution (Smith et al. 1998).

Though seed banks act as an insurance policy against extinction, seed collection should not compromise the ability of plants to reproduce in the present (Thompson 2008). Although human intervention in many cases is needed, natural migration is still the preferable method for plants to adapt to climate change. In order not to over-sample, no more than 10-20% of available seeds should be collected at any given point and seed collection protocol set forth by the Bureau of Land Management should be strictly followed (Vitt et al. 2010; BLM 2003). All collected seeds are carefully cataloged with essential information about their species and where and when the sample was taken. This information, even if it is discovered that a species is not suited to seed bank preservation, can be used to track the native ranges of species which can be invaluable information as the climate changes.

Determining What Species to Preserve

Seed banks provide a place for preserving seeds for a variety of purposes which gives the state some flexibility with which to work in preserving species. As mentioned earlier, though traditionally many seed banks housed seeds for agriculture, an increasing number of seed banks are devoted to biodiversity which is what this paper proposes for Virginia's seed bank. The species that should be preserved in the Virginia seed bank will be determined partially by funding, which will restrict the size of the seed bank and therefore the number of samples and species that the seed bank can hold. For example, Ranch Santa Ana Botanical Gardens, which is dedicated to protecting species native to California, had a species goal of fifty which was reduced to thirty-six once funding was determined to be insufficient (Showers 2010). There are nearly 3,200 species of plants found in Virginia so priority should be given to native species that are already threatened or from habitats most at risk from climate change and with a lower ability to disperse seeds to adapt to changes (Weakley et al. 2012). This priority differs from the federal program through the Bureau of Land Management, Seeds of Success, which prefers "workhorse" native species rather than protecting at-risk species (BLM). The Natural Heritage Program, under the Department of Recreation and Conservation, has studied the ranges of endangered species and has already published a list of rare plant species, of which eleven are considered threatened and sixteen endangered on the state level (Townsend 2014).

Virginia is fortunate in the vast amount of data already collected on the subject of native flora with over 3,200 cataloged species and detailed lists of rare plant species as mentioned above. Both endangered habitats and species have been well documented by the Natural Heritage Program. The Bureau of Land Management seed collection protocol lists among its exclusions for seed collection any species that are on or are candidates to be listed as endangered or threatened and any species that are classified as G1, G2. S1, or S2 species, which are species considered critically threatened at the global (G) and state (S) levels (BLM). Collecting from these species would likely have a detrimental effect on species survival in the wild and would not yield a genetically diverse sample. Although not all plant species are suited for seed banks, and all seeds have a limited dormancy period while remaining viable, 89% of the 7,000 species preserved worldwide have seeds that are expected to remain viable for 200 years (Smith et al. 1998).

Partnerships and Funding

Obviously, a project of this scale requires significant funding, although the amount would be largely dependent on the type and size of the facility. Seed banks are the most cost-effective method to preserve floral genetics (Laliberte 1997). Funding for other seed banks in the United States has been found in the form of state and federal grants, non-profit and private donations, as well as through partnerships with academic and public institutions (McCoy 2015, pers. comm.; Showers 2010). For example, the University of North Carolina is partnered with the North Carolina Germplasm Depository

in order to conduct research and has made one of its missions to research medical uses of native plants, which allows for greater variety of interested parties. Other seed banks partner with private botanical gardens, such as the Rancho Santa Ana Botanical Gardens in California where the seed bank was created specifically to preserve biodiversity (Showers 2010).

Outside of the initial investment to construct the facility, a yearly operating budget is required to continue conservation work. One of the major contributions to the failure of seed banks worldwide is the lack of annual funding. Seed banks require few full time employees, the number of which depends upon the size of the facility and types of projects being researched. For example, the North Carolina Germplasm Depository employs three to five researchers per year along with volunteers and interns (McCoy 2015, pers. comm.). Collection is one of the associated costs of operation which could be mitigated by the use of volunteers and students with proper training. Additionally, it could be helpful to engage the public by having them help identify areas where endangered plants may exist and have trained researchers collect the seeds from there according to national standards.

Communication between Virginia's seed bank, other seed banks, and partners will be essential for the most effective conservation. There are regional and national seed banks run by the Bureau for Land Management through their Seeds of Success program which will have similar interests to that of the Virginia Seed Bank. Seeds of Success not only preserves native species for their biodiversity value, but for waterway stabilization, roadside revegetation, emergency fire rehabilitation and restoration, and landfill and corporate land recovery which could help increase habitat connectivity (BLM 2014). Additionally, it will be important to work with seed banks in neighboring states as some species distributions will cross state borders. Although there may be some overlap in species, it is important to emphasize that genetic diversity is related to spatial distance so it is just as important to preserve genes from Virginia. Having species protected in multiple seed bank also prevents the loss of all collections were something to happen to one of the facilities that destroyed the collections such as fire, or improper conditions for dormancy.

Many organizations have expressed interest in preserving native plants in Virginia, including but not limited to The Nature Conservancy, Virginia Polytechnic and State University, Virginia Department of Agriculture and Consumer Services, Virginia Department of Forestry, Virginia Department of Game and Inland Fisheries, and Virginia Department of Transportation. Partnerships with organizations such as Lewis Ginter Botanical Gardens could provide a place for germinated plants to be stored or planted. All of these organizations could be possible sources of funding, fundraising, or manpower for the creation of this facility.

Acknowledgements:
Thank you to Dr. John Hayden of the University of Richmond who provided invaluable information and personal experience about his work with seed banks. Thank you to Johnny Townsend of the Virginia Natural Heritage Program for his advice and research.

Literature Cited

BLM 2003. Bureau of Land Management technical protocal for the collection, study, and conservation of seeds from native plants for Seeds of Success. (2003).

Ellis, R.H., Hong, T.D., & Roberts, E.H. (1985). *Handbook of Seed Technology for Genebanks. Volume 1. Principles and Methodology.* 1-77.

Hoban, S., & Schlarbaum, S. (2014). Optimal sampling of seeds from plant populations for ex-situ conservation of genetic biodiversity, considering realistic population structure.*Biological Conservation, 177*, 90-99. doi:doi:10.1016/j.biocon.2014.06.014

Kane, A., T.C. Burkett, S. Kloper, and J. Sewall. 2013. Virginia's Climate Modeling and Species Vulnerability Assessment: How Climate Data Can Inform Management and Conservation. National Wildlife Federation, Reston, Virginia.

Laliberte, B. (1997). Botanic garden seed banks/genebanks worldwide, their facilities, collections and networks. *Botanic Garden Conservation International*. Retrieved from http://www.bgci.org/worldwide/article/0032/

Long, R. L., Gorecki, M. J., Renton, M., Scott, J. K., Colville, L., Goggin, D. E., . . . Finch-Savage, W. (2014). The ecophysiology of seed persistence: A mechanistic view of the journey to germination or demise. [Abstract].*Biological Reviews of the Cambridge Philosophical Society, 90*(1), 31-59.

McCoy, J. (2015, personal communication). Questions about NC Seed Bank [E-mail to the author March 18 2015].

Renwick, K., Rocca, M. (2014). Temporal context affects the observed rate of climate-driven range shifts in tree species. *Global Ecology and Biogeography*. 24:1: 44-51.

Sapir, Y., Shmida, A., Fragman, O. (2003). Constructing Red Numbers for setting conservation priorities of endangered plant species: Israeli flora as a test case. *Journal for Nature Conservation,* 11, 91-107.

Smith, R.D., Liningston, S.H., and Wechsberg, G.E. (1998). 'The Millennium Seed Bank, the Convention on Biological Diversity and the dry tropics.' In H.D.V. Prendergast, N.L. Etkin, D.R. Harns, and P.J. Houghton (eds), Royal Botantic Gardens, Kew.

Showers, M. A. (2010). *E-2-P-31 Seed Collection and Banking of 50 Plant Species of Critical Conservation Concern* (United States of America, California Department of Fish and Game, Habitat Conservation Planning). Santa Ana.

Townsend, John F. 2014. Natural Heritage Resources of Virginia: Rare Plants. Natural Heritage Technical Report 14-02. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. Unpublished report. February 2014. 58 pages plus appendices.

Thompson, K. (2008). Seeds and seed banks. *New Phytologist,106:* 23-34.

Vitt, P., Havens, K., Kramer, A. T., Sollenberger, D., & Yates, E. (2010). Assisted migration in plants: Changes in latitudes, changes in altitudes. *Biological Conservation,* 143:1: 1-10.

Volis S., & Blecher, M. (2010). Quasi in situ: a bridge between ex situ and in situ conservation of plants. *Biodiversity Conservation*. 19: 2441-2454.

Walther, G., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T., Fromentin, J., Hoegh-Guldberg, O., & Bairlein F. (2002). Ecological responses to recent climate change. *Nature.* 416, 389-395.

Weakley, A. Ludwig, J., Townsend, J., Crowder, B. (2012). *Flora of Virginia.* Botanical Research Institute of Texas Press.

2. Branching Out: How Virginia Can Use Trees Strategically to Combat Biodiversity Loss

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Taylor Pfeiffer
Environmental Studies and Biology Major, 2015.

Abstract

Biodiversity loss is a consequence of climate change. As greenhouse gas emissions increase global temperatures, decreases in the abundance and diversity of species has reduced ecosystem resiliency during these changes (Verchot et al. 2007). Weakened ecosystems decrease the environment's capacity to provide humans with services like safe drinking water, fuel, and protection from natural disasters (US EPA 2013).

The agricultural industry plays a unique role in this environmental conversation, as farmland both contributes to climate change and is jeopardized by the negative effects created by the issue in a complex reciprocal cycle. This relationship, along with the presence of 8.3 million acres of farmland in Virginia, suggests that agriculture should be incorporated into the state's climate change adaptation and mitigation strategies (VDACS 2015b).

Agroforestry, the strategic integration of trees in agriculture to create a sustainable land-use system, has been utilized for environmental benefits in the past (Bentrup 2014, USDA NAC 2012). This paper proposes the creation of a statewide program that requires the use of agroforestry on large farms in order to preserve biodiversity in the wake of climate change. An alternative solution is a certification program for farmers who use agroforestry practices to enhance wildlife habitat. Economic incentives and implementation assistance will encourage participation, while funding for the establishment of this program, creation of publications, and organization of events will be sourced from governmental and private grants.

Introduction

Climate change has become an increasing concern of scientists and environmental researchers as evidence of the shift in global patterns becomes more abundant. Increased atmospheric greenhouse gases (GHG) have caused changes in biogeochemical cycles,

resulting in increased air temperatures, increased ocean temperatures, and ocean acidification (Verchot et al. 2007).

Some attempts have been made to remedy this issue, including the European Union's Emission Trading System and Australia's carbon tax program (Schieffer and Dillon 2015). The United States Environmental Protection Agency (EPA) and Army Corps of Engineers have worked to reinforce flood controls and encourage use of water efficient appliances because climate change-induced weather events have depleted the water supply in some communities (US EPA 2013). Finally, biodiversity loss and decreased ecosystem resiliency, due to the problems listed above, have been addressed through international programs such as the Mesoamerican Biological Corridor (DeClerk et al. 2010).

Attempts to mitigate effects of climate change are widespread and diverse in their focuses. However, agriculture in particular serves a unique role in this environmental discussion because of its contributions to climate change and biodiversity loss, but also the negative effects the industry is facing because of the issue. Tension exists between the need for profitable operations that provide global food security and efforts to reduce environmental impacts of intensive food production (Robertson and Swinton 2005). The agriculture sector accounts for about 13.7% of global GHG emissions, consistently ranking as one of the major contributors to carbon dioxide levels in the atmosphere (Tubiello et al. 2013, Schieffer and Dillon 2015). Farm runoff contains chemical fertilizers, livestock waste, and sediment, which all flow into waterways to disrupt nutrient balance, cause bioaccumulation of toxins, and decrease habitat suitability (Rodriguez et al. 2004, Matson et al. 1997). In fact, agricultural practices in the Piedmont region of Virginia have already caused problems for river species (Costa 1975, Reusser et al. 2015).

These impacts of agriculture alter the species composition in marine environments, but the more direct threat to biodiversity is what some call agriculture's "planned diversity" and tendency to fragment landscapes (Matson et al. 1997, USDA NAC 2012). Monocultures in farming systems artificially restrict the amount of crop species on a plot of land (Matson et al. 1997). However, plant biodiversity is only one piece of a much larger and complex puzzle. As plant biological diversity decreases, so does the abundance of associated species, such as pollinators and soil biota (Matson et al. 1997). Vast areas of farmland fragment the habitat of plant and animal species, making it harder for them to migrate and persist as a population (USDA NAC 2012, Bentrup 2014).

As climate change continues to threaten our current understanding of landscapes and ecological processes, decreased biological diversity has become a more prominent concern. Research has shown that climate change and its underlying causes are the most important drivers of biodiversity loss on a global scale (Sala et al. 2000). Future ecological changes may be concentrated or accelerated in certain regions, but all biomes will experience a decrease in the abundance of species by the year 2100 (Sala et al 2000). In addition, temperatures in North America are projected to increase by up to 4.4 degrees Celsius by the end of the century, depending on the extent of human behavioral changes

and greenhouse gas emissions (Gonzalez et al. 2010). The Virginia Department of Conservation and Recreation (DCR) has identified landscape corridors in Virginia that allow for movement among habitat patches so that species can adapt to this shifting climate by migrating, and therefore have a better chance at survival (Virginia DCR 2007). However, complications arise when species cannot adapt quickly enough to keep up with climatic changes. Efforts to lessen these adverse effects will require the collaborative work of environmentalists, researchers, and policy makers (Sala et al. 2000).

Agriculture is an industry that depends on variables like water availability, growing season conditions, and interactions among species, so climate change and its implications for biodiversity could have far-reaching effects on farms. Agriculture may contribute to climate change, as discussed above, but it inherently relies on the threatened species in a type of reciprocal cycle. Pollinators are needed in cropland ecosystems to fertilize plants and allow for adaptation, for example (Matson et al. 1997). Soil microbes are vital to biological processes necessary for plant growth (Matson et al. 1997).

Warmer temperatures have caused geographic range shifts of species, prompting these beneficial symbiotic organisms to migrate out of areas or become extinct if adaptation is not possible (Verchot et al. 2007). The codependent species of symbionts are weakened as a result, and biodiversity as a whole decreases (Verchot et al. 2007). The decrease in availability of these organisms can lead to socioeconomic effects as well, such as crop damage, a decrease in food output, and loss of profits for farmers (Matson et al. 1997). However, it is not just the absence of organisms that can cause widespread changes in the species composition of a landscape. Some populations are immigrating into previously inhospitable areas, creating novel invasive species and pests that can also pose threats to biological diversity (Nair and Garrity 2012). This can increase the need for pesticides, herbicides, and fungicides, placing a financial burden on farmers (Nair and Garrity 2012).

Integrated pest management (IPM), genetically modified crops, and farmland preservation have all been suggested as tools to address climate change and its consequences for biodiversity (Stamps et al. 2009, Smith and Oleson 2010). In Virginia, the DCR facilitates the Conservation Reserve Easement Program (CREP), which focuses on improving water quality through the use of buffers and wetlands on farms (Virginia DCR 2014). The United States Department of Agriculture (USDA) has also attempted to address environmental issues with farms more specifically by implementing the Farmable Wetlands and Conservation Reserve programs, which run through the Natural Resources Conservation Service and Farm Service Agency (USDA FSA 2014). However, of Virginia's 8.3 million acres of farmland, only 58,283 acres were included in these programs as of 2012 (USDA NASS 2012, VDACS 2015b). With farms accounting for 33% of Virginia's land cover and functioning as the largest sector of the state's economy, a great deal of potential still lies in these lands for climate change adaptation and mitigation (VDACS 2015b). The programs mentioned above may have good intent, but have limited realms of focus in their goals and participation is voluntary (USDA FSA 2014, Virginia DCR 2014). An effective program concentrated on combatting climate

change-induced biodiversity loss and tailored to the unique landscapes of Virginia is needed.

Recommendation

For the reasons stated above, Virginia should implement an agroforestry program aimed at mitigating the loss of biodiversity occurring as a result of climate change. This paper proposes that farms larger than 50 acres be required to implement at least one of the five agroforestry practices outlined in the USDA's Agroforestry Strategic Framework (2011). These practices are:

1. Field, farmstead, and livestock windbreaks
2. Riparian forest buffers along waterways
3. Silvopasture systems with trees, livestock, and forages growing together
4. Alley cropping that integrates annual crops with high-value trees and shrubs
5. Forest farming where food, herbal, and decorative products are grown under the protection of a managed forest canopy.

The 50-acre threshold of implementation results from two considerations of farm size in Virginia. The average farm size in the state is 181 acres, but the median farm size is about 50 acres, which suggests that about half, or 25,000, of the farms in Virginia will be affected by this program (USDA NASS 2012, VDACS 2015b). The threshold is intended to exclude small subsistence farms, considering that almost 90 percent of farms in Virginia are owned and operated by families or individuals (VDACS 2015b). However, it is also meant to affect the larger farms in Virginia that currently have the largest carbon footprint and most significant impact on biodiversity. By targeting the leading farm operations, there is more potential for a substantial, widespread solution to take hold.

Firm regulations, however, tend to face opposition and obstacles in the policymaking process. As an alternative to this agroforestry requirement, a certification program could be established in Virginia that awards farms a biodiversity conservation designation based on the extent to which they use agroforestry on their land. In order to cater to the small scale and unique needs of each individual farmer, this program would be modeled after initiatives such as the grassroots Certified Naturally Grown program or South Carolina's Certified SC Grown program (CNG 2015, South Carolina Department of Agriculture 2015). This program would be incentive-based in the sense that farmers would not only gain direct environmental and economic benefits from agroforestry practices, but they could use green marketing to increase profitability and public relations with consumers and citizens.

Technical information can easily be provided to farmers across the state to aid them in choosing the most advantageous practice for their land. A type of User's Guide

will be published and distributed to all owners of farmland in Virginia, modeled after the Training Manual put together by The Center for Agroforestry at the University of Missouri (University of Missouri Center for Agroforestry 2013). This document will include a detailed explanation of agroforestry practices, as well as the benefits of agroforestry to the environment and farmers. An assessment template will be included that allows farmers to determine which of the five practices are best for a farm based on its size, main commodity, and terrain. To help ensure the longevity of this recommendation, the Guide will contain information on how to maintain the forested land and guarantee the future persistence of farmers' efforts. The Guide will also breakdown what qualifies as each agroforestry practice, as described in the Natural Resources Conservation Service's National Conservation Practice Standards (NRCS 2011).

A concern of farmers is that increasing species habitat through agroforestry will increase wildlife damage to crops, particularly by Canadian geese and white-tailed deer (Frazier, pers com). Therefore, the Guide will contain information on how to manage for these species and lessen the environmental and economic harm they may cause farmers. Examples include exclusion methods, repellents, frightening tactics, and state-implemented contraception programs (Craven and Hygnstrom, Cleary 1994).

Finally, the publication will include relevant success stories from various forms of agriculture and climates similar to those found in Virginia, in which agroforestry practices have already been used to combat biodiversity loss by connecting fragmented landscapes, building an ecosystem's resistance to pests, and mitigating for the loss of beneficial species.

The two current agroforestry demonstration sites designated by the USDA in Virginia will be described in the Guide in order to provide a tangible, realistic point of reference for farmers. These sites are located in the southwest region of the state and serve as prime examples of forest farming and the use of riparian forest buffers for the benefit of farmers (USDA 2013).

The Guide will be compiled by several entities, including the USDA National Agroforestry Center, the Virginia DCR, and the Virginia Cooperative Extension, all of which have expertise in agroforestry practices or wildlife conservation. Current knowledge of temperate agroforestry will be drawn from the proceedings of 13th North American Agroforestry Conference and the comprehensive book, North American Agroforestry: An Integrated Science and Practice by (Garret et al. 2000, Kort et al. 2014).

To further assist landowners in using agroforestry techniques on their property, workshops will be offered that provide demonstrations and examples of how to feasibly carry out these projects. Workshops may focus on the use of a specific crop or tree species in a landscape, or provide exercises regarding general implementation of agroforestry. Workshops will be open to all farmers, regardless of whether they fall under the proposed requirement. However, owners and operators of the farms larger than 50 acres, or those who become accredited through the certification program, will be required to attend at least one workshop every other year. The workshops offered by Virginia

Polytechnic Institute and State University and Virginia Cooperative Extension will count towards the requirement, but the Virginia Farm Bureau Federation and the USDA National Agroforestry Center will also collaborate with these institutions to organize additional workshops throughout the state (Virginia Tech 2014). Ideas for topics and examples of how to demonstrate the profit potential in agroforestry will also be drawn from the workshops organized by the University of Missouri's Center for Agroforestry and proceedings from the 12th North American Agroforestry Conference (Moorhead and Dickens 2012, University of Missouri Center for Agroforestry 2013).

Landowners who employ agroforestry tools will secure benefits of diversified income. The Center for Agroforestry in Missouri has supported the use of elderberry, black walnuts, and specialty mushrooms as profitable products to pair with agroforestry practices such as cover cropping and alley cropping, and has shown that landowners receive significant returns for cultivating these commodities (Missouri Center for Agroforestry 2013). Long-term value in lumber production also exists in agroforestry, and strategic use of trees reduces the need to purchase fertilizers and pesticides (Missouri Center for Agroforestry 2013).

Farmers who implement these practices will also be eligible for federal tax incentives currently in place through the Internal Revenue Code (IRC) in areas of cost-share payment exclusions, conservation deductions, qualifying business property deductions, and reforestation deductions (Godsey 2007). In addition to these existing tax advantages, landowners who exceed the minimum of one agroforestry practice, farms smaller than 50 acres that voluntarily participate in the regulatory recommendation, and farms that use agroforestry to connect their land to existing conservation easements or preserved land will receive an additional state property tax break.

The integration of trees in multiuse landscapes is not a novel concept, as agroforestry has already been researched and used effectively to benefit humans and the environment. On a basic level, planting new tree species increases the species abundance and biological diversity of a landscape. However, studies have found that agroforestry accomplishes much more. Puckett et al. (2009) discovered that riparian buffers do not require the use of pesticides, which allows more avian predators to inhabit the land while maintaining profitable crop production for the farmer. Roy and de Blois (2008) found that as adjacent forest area increased, so did native herb species richness, abundance, and diversity. All species, whether plant or animal, have maximum dispersal distances that they are able to travel through inhospitable land in order to reach hospitable habitat (Jose 2009). Ultimately, strategically placing trees in a landscape increases the connectivity of fragmented landscapes by decreasing the distance between hospitable patches, allowing species to move more freely throughout an area (Bentrup 2014). This has been shown to be particularly beneficial, considering the previously mentioned effects of climate change on species migration and range shifts (Bentrup 2014).

The USDA also acknowledges that riparian buffers filter runoff, which improves aquatic habitat and biodiversity (USDA NAC 2012). Stamps et al. (2008) found that alley cropping greatly reduced the survival of the alfalfa weevil, a major pest that greatly

reduces alfalfa yield loss in Missouri. Finally, research conducted by Green America, EcoVentures International, and The Association for Enterprise Opportunity in 2013 found that 75% of businesses who used green marketing (what farmers could use if participating in the agroforestry certification program) saw an increase in sales of their products, even in the down economy from 2008 to 2011. The scientific research presented above, as well as the concrete environmental and economic results of the University of Missouri Center for Agroforestry, serve as evidence that an agroforestry program in Virginia will greatly benefit the biological diversity of the environment and the prosperity of our communities.

Funding for this recommendation will be sourced from federal and state grant programs. Governor McAuliffe's Agriculture and Forestry Industries Development Fund (AFID) finances political undertakings that support local agriculture and forestry-based businesses, and could be used to create the workshops and demonstration sites in certain jurisdictions (VDACS 2015a). The USDA Agriculture and Food Research Initiative also oversees the Agriculture and Natural Resources Science for Climate Variability and Change Challenge Area. This grant opportunity supports initiatives that reduce GHG emissions, increase carbon sequestration in agriculture and forest production systems, and prepare the nation's agriculture and forests to adapt to variable climates (USDA National Institute of Food and Agriculture 2015). These objectives coincide entirely with the goal of the current recommendation, so the funds could be used to create the User's Guide or workshops previously described.

Private funding is also an option for either of the two proposed agroforestry programs. The National Fish and Wildlife Foundation (NFWF) Conservation Partners Program offers financial and technical assistance to landowners for conservation initiatives (NFWF 2015). This program recently allowed the city of Lake Springfield, Illinois to plant and monitor the use of experimental cover crops in agricultural systems and also prioritizes projects in the Chesapeake Bay watershed, which demonstrates the program's dedication to agroforestry initiatives and its relevance to the current recommendation (NFWF 2015).

Through the use of these funding resources, expertise of diverse governmental and non-governmental entities, and the cooperation of private landowners, the proposed agroforestry programs have incredible potential to mitigate for climate change-induced biodiversity loss in Virginia. This is not to say that the recommended programs are narrow in their focus, however. Agriculture is the largest economic sector in Virginia, having a total economic impact of $52 billion annually, but also provides food, recreation, tourism, and cultural benefits to the state's citizens (VDACS 2015b). The imminent risk of global environmental changes poses threats to these commodities, which is why agroforestry would be a step in the right direction towards effective climate change mitigation, biological diversity preservation, and assurance of continue economic stability in Virginia.

Acknowledgements:

Thank you to the following individuals, whose advice and guidance helped shape this recommendation:

Gary Bentrup, Research Landscape Planner at the USDA National Agroforestry Center
Katie Frazier, President of the Virginia Agribusiness Council
Chris Burkett, Wildlife Action Plan Coordinator of the Virginia Department of Game and Inland Fisheries

Literature Cited

Bentrup, G. 2014. A win-win on agricultural lands: creating wildlife habitat through agroforestry. The Wildlife Professional, Summer 2014.

Bentrup, G. personal communication. Research Landscape Planner at the USDA National Agroforestry Center. April 1, 2015.

CNG (Certified Naturally Grown). 2015. Program Requirements. https://www.naturallygrown.org/programs/requirements. Accessed March 31.

Costa, J.E. 1975. Effects of agriculture on erosion and sedimentation in the Piedmont province, Maryland. Geological Society of America Bulleting 86: 1281-1286.

Craven, S.R., and S.E. Hygnstrom, E.C. Cleary. 1994. Deer, Waterfowl in S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension, US Department of Agriculture/APHIS/ADC, and Great Plains Agricultural Council. D25-D40, E129-E138.

DeClerk, F.A.J., R. Chazdon, K.D. Holl, J.C. Milder, B. Finegan, A. Martinez-Salinas, P. Imbach, L. Canet, and Z. Ramos. 2010. Biodiversity conservation in human-modified landscapes of Mesoamerica: Past, present and future. Biological Conservation 143: 2301-2313.

Garrett, H.E., W. J. Rietveld, and R. F. Fisher, eds. 2000. North American Agroforestry: An Integrated Science and Practice. Madison: American Society of Agronomy, Inc.

Godsey, L.D. 2007. Tax Considerations for the Establishment of Agroforestry Practices. Agroforestry in Practice 1-12.

Gonzalez, P., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecology and Biogeography 19: 755-768.

Green America, Association for Enterprise Opportunity, and EcoVentures International. 2013. Small Business Sustainability Report: The Big Green Opportunity for Small Businesses in the U.S.

Frazier, K. personal communication. President of the Virginia Agribusiness Council. April 1, 2015.

Jose, S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems 76: 1-10.

Kort, J., J. Richardson, R. Soolanayakanahally, and W. Schroeder. 2014. Innovations in temperate agroforestry: the 13th North American Agroforestry Conference. Agroforestry Systems 88: 563-567.

Matson, P.A., W.J. Parton, A.G. Power, and M.J. Swift. 1997. Agricultural intensification and ecosystem properties. Science 277: 504-508.

Moorhead, D.J., and E.D. Dickens. 2012. Agroforestry: a profitable land use. An overview of the 12th North American Agroforestry Conference. Agroforestry Systems 86: 299-302.

Nair, P.K.R. and D. Garrity. 2012. Climate change mitigation: A low-hanging fruit of agroforestry. Advances in Agroforestry 9: 31-67.

NFWF (National Fish and Wildlife Federation). 2015. Conservation Partners Program. http://www.nfwf.org/conservationpartners/Pages/home.aspx#.VRtZTksxf7X Accessed March 25.

NRCS (Natural Resources Conservation Service). 2011. National Conservation Practice Standards. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/ Accessed April 1.

Puckett, H.L., J.R. Brandle, R.J. Johnson, E.E. Blankenship. 2009. Avian foraging patterns in crop field edges adjacent to woody habitat. Agriculture, Ecosystems and Environment 131: 9-15.

Reusser, L., P. Bierman, and D. Rood. 2015. Quantifying human impacts on rates of erosion and sediment transport at a landscape scale. Geology 43: 171-174.

Robertson, G. P., and S. Swinton. 2005. Reconciling agricultural productivity and environmental integrity: a grand challenge for agriculture. Frontiers in Ecology and the Environment 3: 38–46.

Rodriguez, E., R. Sultan, and A. Hilliker. 2004. Negative effects of agriculture on our environment. The Traprock 3: 28-32.

Roy, V., and S. de Blois. 2008. Evaluating hedgerow corridors for the conservation of native forest herb diversity. Biological Conservation 141: 298-307.

Sala, O.E., F.S. Chapin III, J.J. Armesto, E. Berlow, J. Blomfield, R. Dirzo, E. Huber-Sanwald, L.F. Henneke, R.B. Jackson, A. Kinzig, R. Leemans, D.M. Lodge, H.A. Mooney, M. Oesterheld, N.L. Poff, M.T. Sykes, B.H. Walker, M. Walker, D.H. Wall. 2000. Global biodiversity scenarios for the year 2100. Science's Compass 287: 1770-1774.

Schieffer, J., and C. Dillon. 2015. The economic and environmental impacts of precision agriculture and interactions with agro-environmental policy. Precision Agriculture 16: 46-61.

Smith, P. and J.E. Olesen. 2010. Synergies between the mitigation of, and adaptation to, climate change in agriculture. Journal of Agricultural Science 148: 543-552.

South Carolina Department of Agriculture. 2015. Certified SC. https://agriculture.sc.gov/faq/certified-sc/ . Accessed March 31.

Stamps, W.T., R.L. McGraw, L. Godsey, and T.L. Woods. 2009. The ecology and economics of insect pest management in nut tree alley cropping systems in the Midwestern United States. Agriculture, Ecosystems and the Environment 131: 4-8.

Tubiello, F.N., Salvatore, M., Rossi, S., Ferrara, A., Fitton, N. & Smith, P. 2013. The FAOSTAT database of greenhouse gas emissions from agriculture. Environmental Research Letters 8: 015009.

USDA (United States Department of Agriculture). 2011. USDA Agroforestry Strategic Framework, Fiscal Year 2011-2016.

USDA (United States Department of Agriculture). 2013. Agroforestry: USDA Reports to America, Fiscal Years 2011-2012—In-Brief.

USDA (United States Department of Agriculture). 2014. Agricultural Conservation Easement Program Factsheet.

USDA (United States Department of Agriculture) National Institute of Food and Agriculture. 2015. AFRI Climate Variability and Change Challenge Area. http://nifa.usda.gov/program/afri-climate-variability-and-change-challenge-area
Accessed March 25.

USDA FSA (United States Department of Agriculture Farm Service Agency). 2014. Conservation Programs. http://www.fsa.usda.gov/programs-and-services/conservation-programs/index. Accessed March 22.

USDA NAC (United States Department of Agriculture National Agroforestry Center). 2012. Agroforestry: Working Trees for Agriculture.

USDA NASS (United States Department of Agriculture National Agricultural Statistics Service). 2012. Virginia State and County Data. 2012 Census of Agriculture 1: 1-756.

US EPA (United States Environmental Protection Agency). 2013. Climate Change: Water Resources. http://www.epa.gov/climatechange/impacts-adaptation/water-adaptation.html. Accessed March 17.

University of Missouri Center for Agroforestry. 2013. Training Manual for Applied Agroforestry Practices.

VDACS (Virginia Department of Agriculture and Consumer Services). 2015a. Agriculture and Forestry Development Services (AFDS). Accessed March 25.

VDACS (Virginia Department of Agriculture and Consumer Services). 2015b. Virginia Agriculture- Facts and Figures. http://www.vdacs.virginia.gov/agfacts/. Accessed February 20.

Verchot, L.V., M. Van Noordwijk, S. Kandji, T. Tomich, C. Ong, A. Albrecht, J. Mackensen, C. Bantilan, K.V. Anupama, and C. Palm. 2007. Climate change: linking adaptation and mitigation through agroforestry. Mitigation and Adaptation Strategies for Global Change 12: 901-918.

Virginia DCR (Department of Conservation and Recreation). 2014. CREP Buffers: Good for your bottom line, good for Virginia [Brochure]. N.P.: Virginia DCR.

Virginia DCR (Department of Conservation and Recreation), Division of Natural Heritage. 2007. Virginia Natural Landscape Assessment, Natural Land Network.

Virginia Tech. 2014. Virginia Tech and Virginia Cooperative Extension offer workshop on agroforestry practices. http://www.vtnews.vt.edu/articles/2014/10/100114-cnre-agroforestryworkshop.html. Accessed March 17.

3. Land Conservation in a Changing Climate: Recommendations for Conservation Easement Reform

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Amy Murphy
Environmental Studies and Biology Major, 2015.

Abstract

Natural lands in Virginia are under constant threat from development and climate change (Anderson et al. 2014). Undeveloped lands provide an estimated $21.8 billion in ecosystem services annually in Virginia and are vital to the survival of the state's wildlife (Paul 2011; VDGIF et al. 2009). Conserving these lands will play a major role in protecting the environment itself, biodiversity, and economic interests as the climate changes in coming decades. Conservation easements—established when a public or private organization buys or receives a donation of select land rights such as development or subdivision rights—have become the most popular means of protecting privately owned lands (Korngold 2007).

Virginia has a well-established easement program which offers landowners a state income tax credit in return for donating land rights such as development and subdivision rights. Currently, there are inefficiencies with easements which could be lessened with reform (Owley 2011, Rissman 2011). This paper proposes that Virginia establish statewide conservation priorities and switches from a flat rate credit for easement donations to a tiered system which provides greater incentives for easements on land with high conservation value (McLaughlin and Pidot 2013). Additionally, this paper proposes that Virginia require adaptive language in easement terms and standardize monitoring procedures.

Introduction

Climate change presents a real and imminent threat to the land, life, and livelihood of Virginia (IPCC 2014). According to a recent review by the Intergovernmental Panel on Climate Change (2014) the global climate is predicted to transition at higher rate than at any previous point in human history, even if mitigation measures are adopted. Approximately half of the planet's land is considered to be highly vulnerable to large scale biome and vegetation shifts (Gonzalez et al. 2010). Natural lands help buffer some of the impacts of climate change and provide greater opportunities for adaptation (Anderson et al. 2014). Nature facilitates human and nonhuman life alike by providing crucial ecosystem functions and services such as maintaining air and water quality, preventing erosion, and offering recreational opportunities (Paul 2011). Loss of

some wild land and the services it provides can lead to the loss or degradation of more. For example, trees are natural carbon sinks. Deforestation and consumption of wood results in the return of this stored carbon into the global cycle and contributes to increased atmospheric carbon dioxide levels and climate change (Woodell et al. 1983; Scherr and Sthapit 2010). This same deforestation may harm the local environment in ways such as decreasing soil stability and reducing the land's pollution controlling ability, leading to further instabilities in other facets of the local environment (O'Loughlin 1974; Anderson et al. 1976). In addition to the environmental effects of developing land, the loss of nature has steep economic costs (Balmford et al. 2002). Undeveloped lands in Virginia provide an estimated $21.8 billion annually in ecosystem services (Paul 2011). Perhaps most importantly, land development greatly limits opportunities in the future to adapt to change. This inability to respond to the impending changes increases the vulnerability of ecosystems and poses a large threat to biodiversity.

Due to the predicted rate of climate change and constraints on genetic adaptation, it is assumed that many species will initially respond to climate change through spatial changes (Opdam and Wascher 2004). If a species' present habitat changes so it is no longer suitable and it cannot migrate to a new location with suitable habitat, the species will be unable to survive. Moderate climate change models predict 15-37% of species will be "committed to extinction" by the midpoint of the century (Thomas et al. 2004).

Virginia's Wildlife Action Plan identified 900 species native to the state which are already greatly affected by habitat loss and fragmentation and notes that climate change and further land development will exacerbate this problem (VDGIF et al. 2009). Habitat loss can cause declines in species richness, abundance, and distribution—all measures of biodiversity; limit genetic diversity; negatively affect population growth rates; and alter animal behavior among other effects (Fahrig 2003). Habitat loss is a further detriment to species because it reduces the amount of unique and high quality habitats.

Microclimates, the result of a diverse landscape which may exist on a scale of tens of meters, provide refuges which allow organisms to exist in regions where they may not otherwise and are expected to provide a buffer protecting against certain local effects of climate change (Anderson et al. 2012). Altering the landscape in these areas can destroy the microclimates and make the land unsuitable for its inhabitants.

Additionally, habitat loss creates habitat fragmentation by splitting suitable habitat into isolated patches. Fragmentation increases the ratio of edge habitat to core habitat. Although some species do thrive in the microhabitats and niches found in habitat edges, many others are dependent on the core habitat for survival (Laurance 2008). If the habitat fragmentation is caused by development or road construction, remaining habitat may be subjected to additional detriments such as the road effect (Forman and Deblinger 2000).

Fragmentation—whether it is by presenting physical blocks such as roads, dams, or development or juxtaposing different land covers—decreases permeability and connectedness of landscapes. High permeability and connectedness allows for easier

migration by species (Anderson et al. 2014). Depending on the degree of fragmentation, migration can be inhibited or entirely blocked (Opdam and Wascher 2004).

Virginia is filled with valuable natural lands, spanning from the Atlantic coastline to the Allegheny Mountains. The vegetation of much of the state is among the half of the planet identified as highly vulnerable to change in response to climate change (Gonzalez et al. 2010). However, the Nature Conservancy has identified many highly resilient lands throughout the state. This is not to say the land will not change. Rather, because of its combination the diversity and connectedness of the landscape, this resilient land has a high likelihood of maintaining its diversity and ecological function as it adapts to climate change (Anderson 2012; 2014). To protect the state and its inhabitants, both human and not, Virginia must conserve the resilience of its land.

Land Conservation in Virginia

Land conservation is necessary to minimize the loss or degradation of natural habitats (Owley 2011). The most powerful tool of conservation is buying land and removing decision-making powers from other individuals (K. Duhring, pers. comm.). However, it is impossible to protect biodiversity and natural habitats strictly through obtaining land. Land is expensive. It is financially unfeasible, even through the combined efforts of every environmentally interested party, to purchase enough land to provide adequate protection to everything which needs protecting.

Purchasing land also comes with additional responsibilities such as land management which add to the economic burden (Owley 2011). Although publically owned land is an important facet of conservation, it alone is not enough to protect and prepare the state. Many privately owned lands have features which make them of high conservation value. For example, over 90% of endangered species in the United States can be found on private lands (Scott et al. 2001). Although habitat critical to the survival of endangered species may get some protection from the Endangered Species Act, private landowners are limited in their obligations in protecting the land. Alternative means of conservation are necessary to guide decision making on private land.

Easements are the most prominent way of conserving privately owned land, with holdings increasing by almost 150% in the first five years of the century and continuing to grow rapidly (Korngold 2007). An easement—whether a conservation easement held by a private nonprofit organization or an open space easement held by a public body—is a legal agreement between a landowners and an easement-holding organization in which the landowner surrenders certain property rights. The specific rights which are surrendered vary between agreements, but typically limit developing and subdividing the property at a minimum (Owley 2011). Regardless of the specific terms within the easement agreement, the easement is perpetual and permanently bound to the deed of the property. Allowing the purchase or donation of partial interests in the land through easements can be more efficient that outright purchasing land as it allows for the transfer of only the rights deemed necessary to conservation (Korngold 2007). This allows conservation to occur at a lower cost and therefore allows for greater amounts of conservation.

Virginia currently has a strong easement program. Currently, Virginia offers landowners a state tax credit worth 40% the fair market value of a donated easement, allowing deductions of up to $100,000 for the year of donation and the subsequent 10 years. Landowners with a low tax burden can sell unused credits. Up to $100 million in tax credits may be issued annually (Va. Code § 58.1-512). To qualify for donation, the land must meet at least one of eight conservation purposes, including agricultural use, forestal use, historic preservation, or natural habitat and biological diversity. The terms of the easement must be set to protect that purpose of conservation.

Easements are a strong tool for conservation, but the system has room for improvement. The current approach to easements results in inefficient conservation and consequentially inefficient use of public money. Some of these inefficiencies may be in the nature of easements and are difficult to address; others, however, can be addressed through a series of reforms.

Recommendation

Establish Statewide Conservation Priorities & Use a Tiered Incentive System

Two primary criticisms of easements are that they are not conserving the most valuable land and haphazard acquisition of easements is reducing their effectiveness. These faults are the consequence of a number of factors.

Firstly, conservation and open space easements are entirely voluntary. Many landowners cite desire to protect the land as a motivating factor in accepting an easement, but this alone is often not incentive enough (Rissman 2011). The state tax credits provide additional encouragement to landowners to agree to easements, but ultimately, they cannot be forced to place an easement on their land (Owley 2011). Lands with high ecological value which should be of highest priority for conservation tend to have high economic value, so landowners are less willing to give up perpetual rights (Rissman 2011; Margules and Pressey 2000). Rissman (2011) notes that because landowners face less significant lost opportunity costs, owners of lower value lands are more likely to agree to the terms of an easement. Such lands frequently are less threatened by development or land use change (Rissman 2011). This lower threat in addition to lower conservation value results in public money not being used to maximize the public benefit. This logic may fail because maximum benefit might be achieved through conserving lower value land if that lower value land is the highest quality being offered. Regardless action should be taken to reduce this inefficiency and maximize the value of land conserved through easements.

Additionally, because easements are often established wherever qualifying land is offered, easements across the state generally are patches isolated from other conserved lands and therefore vulnerable to becoming habitat fragments as the surrounding area is developed (Owley 2011). Even under ideal conditions where large quantities of landowners were interested in creating easements, patchiness is still likely because there no unified plan and all easement-holding organizations are acting independently (Margules and Pressey 2000). While these patches may act as refuges for some species,

their effect on the imminent climate change-caused migrations is limited as most wildlife movement occurs on a scale larger than most property boundaries (Rissman 2013). Virginia does require easement holders to register their holdings and this information available in a public database (Va. Code § 10.1-1012), and multiple Virginia agencies and organizations have created models to identify targets for conservation (e.g. Department of Conservation and Recreation (DCR)'s Virginia ConservationVision), but it is unclear what influence these data have on decision making by various groups.

To address the above inefficiencies, this paper proposes that Virginia switch from a flat rate credit for easement donations to a tiered system which provides greater incentives for easements on land with high conservation value and reduces the credit provided for easements on lower value land (McLaughlin and Pidot 2013).

To enable this reform, Virginia should first create a statewide plan which ranks and prioritizes land based on its conservation value. Factors which should be considered when determining conservation value for easements with ecology-related purposes should include—but are not limited to—biodiversity, land resilience, land cover, threat of development, and proximity to existing protected lands (Margules and Pressey 2000; Parkhurst et al. 2002). Easements with a historical conservation purpose should be evaluated on separate criteria. An organization should be delegated the task of creating this plan. The DCR is a natural option for a lead agency for this project as it already is tasked with creating the Virginia Outdoors Plan, maintaining Virginia ConservationVision, and leading the Virginia Land Conservation Foundation—all of which relate in part to evaluating the conservation value of land. However, other agencies and organizations should be given opportunities to provide relevant data and voice ideas regarding what factors should be weighed. This valuation and the resulting priorities should be updated semi-regularly to account for changes to the land caused by human action, climate change, or any other events.

Ideally, implementing these changes will result in obtaining easements on more land of high ecological importance without altering the total amount of tax credits given annually. None of these changes affect the fundamental processes of the easement program. Landowners will still enter it voluntarily and easement-holding organizations are free to establish easements on any qualifying land. These recommended changes will hopefully influence the decision making processes to increase the likelihood of easements being established in clumps on high quality land, maximizing the ecological and public benefit.

Require Adaptive Management Plans in Easement Deeds

Easements are unique in the perpetual protections that they offer. However, if easements are written to be fully static, this perpetual nature can cause a future loss of efficiency. Although there are many models of what may happen because of climate change, it is unlikely that a static easement will properly serve the conservation purpose of the agreement both now and decades from now without a loss of efficiency.

In order to protect the conservation purpose, some easement holding organizations and landowners desire strict language which clearly defines responsibilities so expectations are known from the beginning and the current and future landowners have no room for interpretation (T. Smith, pers. comm.). However, such agreements greatly limit adaptation in response to changes in scientific knowledge or climate change and can result inefficient behaviors or burdens on future generations (Greene 2005; Richardson 2010).

This paper proposes that Virginia require the inclusion of adaptive management plans in easement terms. These plans should require that the landowner manages the land in a manner consistent with preserving the conservation purpose of the easement rather than require specific management techniques. Many agencies including the DCR and Department of Forestry already recognize that environmental factors will change in the future and use such language when preparing easements (T. Smith, pers. comm.). This reform would only impact the remaining organizations which still avoid dynamic terms.

Set a Minimum Monitoring Requirement

Dynamic easement terms increase the importance of monitoring by easement holders. If the land is not properly managed to reasonably protect the stated conservation purpose, the value of the easement is lost. Monitoring places a perpetual financial burden on easement-holding organizations, but monitoring is a necessity to ensure proper stewardship of the land (McLaughlin and Pidot 2013). All major easement-holding organization within Virginia alert landowners that they should expect monitoring for compliance if they agree to an easement. However, Virginia has no mandated standard for monitoring. Currently, Maine, following its successful 2007 easement reforms, is the only state with a monitoring requirement (McLaughlin and Pidot 2013). This paper proposes that Virginia follow in Maine's lead and establish a minimum monitoring requirement.

Regular monitoring, though a small burden, should not be prohibitive. In Maine, where 10% of the state's land is covered by easements, 90% of easements were in compliance with the monitoring requirement (Pidot 2010). To control the financial burden of monitoring, opportunities to involve the landowner in the monitoring process should be considered. Potential means for this include self reporting land use annually to supplement biennial or triennial monitoring by the easement-holding organization. Ultimately, these additional burdens may have a positive influence as they may force easement holders to limit their holdings so they can provide proper stewardship to them. This may cause a selective pressure away from low value easements.

Conclusion

Climate change is forcing states to reconsider how they approach land conservation in the interest of both human and nonhuman lives. Although Virginia is ahead of many other states by offering high incentives for the creation of easements and allowing for the transfer of state tax credits (CRC 2007), the easement program needs to adapt to decrease inefficiencies and allow for flexibility in an uncertain future. Focusing

the creation of easements towards priority areas will help maximize benefit gained from the program. Adjusting how easements are written and monitored will ensure that easements continue to benefit the public perpetually. Together, these changes will assist Virginia in adapting to the stresses of climate change.

Acknowledgements

The author thanks Tom Smith, Natural Heritage Director at the Virginia Department of Conservation and Recreation; Nancy McLaughlin, J.D, professor of law the University of Utah College of Law.; and James McLaughlin, J.D., Policy Director at Conservation Partners LCC for their guidance throughout this project.

Literature Cited

Anderson, H, M Hoover, and K Reinhart. 1976. Forests and water: effects of forest management on floods, sedimentation, and water supply. USDA For. Serv. Gen. Tech. Rep. PSW-18, 115.

Anderson, M, A Barnett, M Clark, C Ferree, A Sheldon, and J Prince. 2014. Resilient Sites for Terrestrial Conservation in the Southeast Region. The Nature Conservancy, Eastern Conservation Science. https://easterndivision.s3.amazonaws.com/Terrestrial/Resilient_Sites_for_Terrestrial_Conservation_In_the_Southeast_Region.pdf, accessed April 2, 2015.

Anderson, M, M Clark, and A Sheldon. 2012. Resilient sites for terrestrial conservation in the northeast and mid-atlantic region. The Nature Conservancy. https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/TerrestrialResilience020112.pdf, , accessed April 2, 2015.

Balmford, A, A Bruner, P Cooper, R Costanza, S Farber, R Green, and R Turner. 2002. Economic reasons for conserving wild nature. Science, 297(5583), 950-953.

CRC (Conservation Resource Center). 2007. State conservation tax credits: impact and analysis. http://www.landtrustalliance.org/policy/tax-matters/documents/state-tax-credits-report.pdf, accessed April 13, 2015.

Gonzalez, P, R Neilson, J Lenihan, and R Drapek. 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. Global Ecology and Biogeography, 19(6), 755-768.

Duhring, K. Personal communication. Marine Scientist Supervisor, Virginia Institute for Marine Science. April 1, 2015.

Greene, D. 2005. Dynamic conservation easements: facing the problem of perpetuity in land conservation. Seattle University Law Review, 28(3), 883-923.

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. Annual review of ecology, evolution, and systematics, 487-515.

Forman, R and R Deblinger. 2000. The ecological road-effect zone of a Massachusetts (USA) suburban highway. Conservation biology, 14(1), 36-46.

IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Korngold, G. 2007. Solving the contentious issues of private conservation easements: promoting flexibility for the future and engaging the public land use process. Utah Law Review, 1039.

Laurance, W. (2008). Theory meets reality: how habitat fragmentation research has transcended island biogeographic theory. Biological conservation,141(7), 1731-1744.

Margules, C and R Pressey. 2000. Systematic conservation planning.Nature, 405(6783), 243-253.

McLaughlin, N and J Pidot. 2013. Conservation Easement Enabling Statutes: Perspectives on Reform. Utah Law Review, 3, 811.

O'Loughlin, C. 1974. The effect of timber removal on the stability of forest soils. Journal of Hydrology (NZ), 13(2), 121-134.

Opdam, P. and D. Wascher. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. Biological conservation, 117(3), 285-297.

Owley, J. 2011. Changing Property in a Changing World: A Call for the End of Perpetual Conservation Easements. Stanford Environmental Law Journal, 30(12), 121-173.

Parkhurst, G. M., Shogren, J. F., Bastian, C., Kivi, P., Donner, J., & Smith, R. B. (2002). Agglomeration bonus: an incentive mechanism to reunite fragmented habitat for biodiversity conservation. Ecological economics, 41(2), 305-328.

Paul, A. 2011. The economic benefits of natural goods and services. http://www.pecva.org/library/documents/Resources-Publications/Reports/Land-Conservation/2011-the-economic-benefit-of-natural-services-report.pdf, accessed April 14, 2015.

Pidot, J. 2010. Conservation Easement Reform: As Maine Goes Should the Nation Follow?. Duke Journal of Law and Contemporary Problems, 74(4),1-28.

Richardson Jr, J. 2010. Conservation easements and adaptive management. Sea Grant L. & Pol'y J., 3, 31.

Rissman, A. 2011. Evaluating conservation effectiveness and adaptation in dynamic landscapes. Law & Contemporary Problems, 74, 145.

Rissman, A. 2013. Rethinking property rights: comparative analysis of conservation easements for wildlife conservation. Environmental Conservation,40(03), 222-230.

Scherr, S and S Sthapit. 2010. Mitigating climate change through food and land use. Worldwatch Institute.

Scott, J, F Davis, R McGhie, R Wright, C Groves, and J Estes. 2001. Nature reserves: Do they capture the full range of America's biological diversity?. Ecological Applications, 11(4), 999-1007.

Smith, T. Personal communication. Natural Heritage Director, Virginia Department of Conservation and Recreation. April 2, 2015.

Thomas, C, A Cameron, R Green, M Bakkenes, L Beaumont, Y Collingham, and S Williams. 2004. Extinction risk from climate change. Nature, 427(6970), 145-148.

Virginia Conservation Easement Act. 1988. Va. Code § 10.1-1012.

VDGIF (Virginia Department of Game and Inland Fisheries), National Wildlife Federation, and Virginia Conservation Network. 2009. Virginia’s Strategy for Safeguarding Species of Greatest Conservation Need from the Effects of Climate Change. Virginia Department of Game and Inland Fisheries, Richmond, Virginia.

Virginia Land Conservation Incentives Act. 1999. Va. Code § 58.1-512.

Woodwell, G, J Hobbie, R Houghton, J Melillo, B Moore, B Peterson, & G Shaver. 1983. Global deforestation: contribution to atmospheric carbon dioxide. Science, 222(4628), 1081-1086.

4. Climate Change and Invasive Species: Invasive Management Teams

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia: April 21st 2015

Virginia Frediani
Environmental Studies Major and Studio Arts Minor, 2015

Abstract

In Virginia, invasive species cost the state approximately $1 billion annually due to forest loss and crop damage (Pimentel et al. 2005). There are approximately 38 invasive species managed and monitored in Virginia (VISWG 2012). Native species are not adapted to compete with invasive species and suffer as a result, which affects biodiversity (Tausch 2008). Invasive species alter the balance of ecosystems, reducing biodiversity and ecosystem health (Gamfeldt et al. 2008). Climate change is another driver in the success of invasive species as they are better adapted to withstand climate changes over native species (Duke and Mooney 1999). To combat invasive species in Virginia this recommendation proposes the establishment of early detection and rapid response Invasive Management Teams (IMTs). IMTs will be responsible for locating, assessing, monitoring, and removing invasive species across the state. IMTs will be lead by qualified invasive species individuals from the Virginia Invasive Species Working Group. IMTs will be under the advisement of the Virginia Invasive Species Working Group with operations overseen by the Virginia Department of Conservation and Recreation and collaboration from other state and federal governmental agencies. Funding for the taskforce will stem from the current state and federal governmental funding for invasive species (NISC 2014). Virginia needs a stronger initiative to combat invasive species and protect its unique biodiversity.

Introduction

The Southeastern United States is exceptionally vulnerable to climate change in the form of sea level rise, extreme heat events, intense hurricanes, and decreased water availability (Carter et al. 2014). Temperatures since 1970 have increased an average 2°F across the Southeast with annual temperatures continuing to increase during this century (Carter et al. 2014). By the end of the century the average temperatures in Virginia will increase by 5.6°F (Governor's Commission on Climate Change 2008). The major consequences of warming include significant increases in the number of hot days and a decrease in freezing events that throw off the balance of ecosystems along the Southeast (Montoya and Raffaelli 2010). Specifically in Virginia, climate change is likely to experience climate change impacts from sea level rise along the coast, increasing air and water temperatures, and changes to precipitation patterns (Kane et al. 2013). Research

indicates climate change is already having a significant impact on natural systems across the Virginia regions of the Chesapeake Bay and further changes are projected in the next few decades (Pyke et al. 2008).

The Southeast is home to several unique ecosystems, such as the Chesapeake Bay, and as climate change tightens its grip these special places will experience detrimental shifts. Ecosystems are comprised of species and elements embedded in a complex network of interactions (Gamfeldt et al. 2008). These interactions support integral ecosystem services that provide humans with clean water, clean air, natural resources and protection from weather events (Lant et al. 2008). Ecosystems are altered through climate change impacts including sea level rise and increased temperatures. Not only are ecosystems important to humans through ecosystem services but they also support biodiversity (Gowdy 1997).

An important aspect of a healthy ecosystem is a high level of biodiversity. The diversity of species and communities is an important aspect of biodiversity that governs the efficiency of ecosystem processes and successfulness (Gamfeldt et al. 2008). Biodiversity is critically important for the long-term survival of the human species and biodiversity is being lost at an alarming rate (Gowdy 1997). Virginia is ranked 12th in regards to species diversity for the United States and with over 900 species threatened by the loss or degradation of habitat (Kane et al. 2013).

One of the threats to biodiversity in the Southeast and Virginia comes from the increase of invasive species. Invasive species are a serious problem in the United States and these intruders are thriving because of climate change. Invasive species are defined as non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order No. 13112).

Invasive species are likely to increase with climate change as they succeed in environments where there are increased ecosystem disturbances, altered weather changes and increased stress to native species (Tausch 2008). As invasive species flourish in climate change pressured environments, they outcompete and eventually force out native species, as the native species cannot adapt as rapidly to climate change affects (Duke and Mooney 1999). Invasive species are so successful at outcompeting native species because they grow and disperse their seeds rapidly and have little to no natural predators. If the climate becomes more suitable to invasive species, the damage they are likely to cause, and the possible collateral impacts related to their control, could both be intensified (Kane et al. 2013).

With invasive species taking over and outcompeting native species, Virginia ecosystems become less diverse and the overall biodiversity is threatened. In Virginia the Virginia Department of Conservation and Recreation Natural Heritage Program has identified 90 invasive alien plant species that threaten protected lands in Virginia (Heffernan et al. 2014). Invasive species are a serious problem in Virginia as the state has 12 invasive species of high concern (VISWG 2012). Invasive species also caused an annual economic loss in the United States of $120 billion including crop damage, forest

loss and human diseases and approximately $1 billion annually in Virginia (Pimentel et al. 2005). All of these invasive species either outcompete or harm native species and have the potential to threaten biodiversity throughout the state (Wilcove et al 1998).

A few invasive species that currently threaten Virginia include:

- Kudzu (*Pueraria montana*) is an invasive plant native to Japan. Kudzu rapidly grows up and over other vegetation creating a dense canopy with its large leaves, blocking sunlight from reaching other plant species (VISWG 2012). Annual costs to control kudzu by power companies in the Southeastern United States have been estimated at $1.5 million (Britton 2002).

- Northern snakehead fish (*Channa argus*) is an aggressive predator that can reach up to lengths of four feet. Snakeheads have the potential to drastically alter freshwater ecosystems by out competing native fish species (VISWG 2012). This species also has the ability to breath out of water to travel between water bodies (VISWG 2012).

- Phragmites (*Phragmites australis*) is a tall grass species that invades brackish wetlands (VISWG 2012). Phragmites engulfs other marsh plants and creates a habitat lacking value to wildlife (VISWG 2012). Once established in an area it is difficult and expensive to control (Marks et al. 1993).

- Emerald ash borer (*Agrilus planipennis*) is a small beetle native to Asia. The larvae feed on the inner bark of ash trees, disrupting the tree's natural ability to transport water and nutrients (VISWG 2012). Emerald ash borers have killed millions of ash trees, potentially costing hundreds of millions to billions of dollars to forestry industries (Snydor et al. 2007).

Measures have been taken nationally to combat and deal with invasive species through the creation of the National Invasive Species Council (NISC 2005). The NISC was established to prevent the introduction of invasive species, provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause (Executive Order No. 13112). NISC is comprised of members from thirteen federal departments and agencies that work together set national goals as well as advise state level initiatives. Virginia has established its own Invasive Species Advisory Committee (VISAC) and Invasive Species Working Group (VISWG) to specifically deal with invasive species within the state. VISAC includes representatives from the Department of Transportation, the Department of Health and Human Services, academic researchers, private citizens, non-profit conservations organizations, and private business associations (VISWG 2012).

VISWG members include the Department of Conservation and Recreation, Department of Game and Inland Fisheries, Department of Environmental Quality, Department of Forestry, Department of Agriculture and Consumer Services, Department of Health, Department of Transportation, the Marine Resources Commission, the

Virginia Cooperative Extension, Virginia Institute of Marine Sciences, representatives of the agricultural and forest industries, the conservation community, interested federal agencies, academic institutions, and commercial interests (VISWG 2012). The VISWG works to prevent additional introductions of invasive species, maintain native species to replace invasive species, implement targeted control efforts, identify and report appearance of invasive species, implement immediate control measures, and recommend legislative actions or pursue grants (VISWG 2012).

The establishment of the VISWG is a productive start to protect Virginia from invasive species. Despite these efforts, many invasive species have been able to persist in Virginia (Kane et al. 2013). The VISWG needs an operational group, and the resources to support it, that will respond to invasive species calls, assess the situation first hand, and report findings efficiently.

Invasive Management Team

In order to prevent the continuous growth and movement of invasive species in Virginia an early detection and rapid response group, Invasive Management Team (IMT), is needed to monitor and remove invasive species. These teams will be established around the state and divided up into regions using the Virginia State Park Regions already established (Figure 1). The IMTs will be under the advisement of the VISWG with daily operations overseen by the Virginia Department of Conservation and Recreation (VDCR). IMTs will also collaborate with other state and federal governmental agencies with the control remaining under the VDCR. Representatives from the VISWG will lead IMTs, as they are experienced in dealing with invasive species. The IMT will serve as the operational taskforce of the VISWG to complement to the strategic planning of the VISWG. Instead of having several state agencies monitoring and responding to sightings of different invasive species these groups will be at the forefront handling invasive species incidents and infestations. Federal agencies will collaborate with VISWG and the VDCR as invasive species do not stay within state boundaries and a working relationship is needed to combat invasive species. IMTs respond to calls from local communities about invasive species sightings and go to the locations and assess the invasive species prevalent.

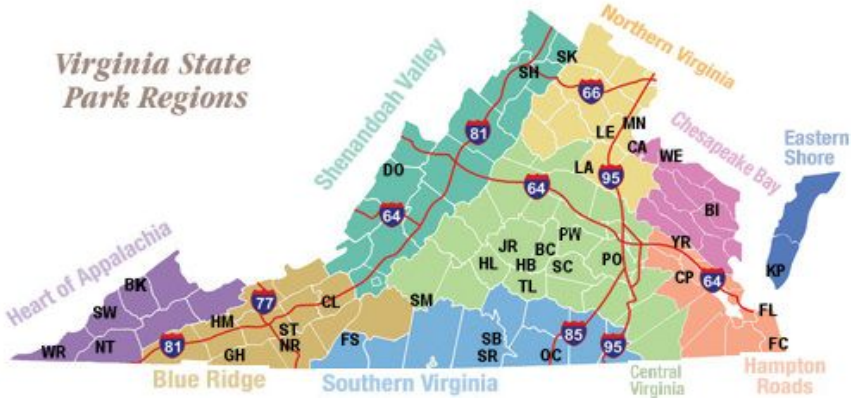

Figure 1. Virginia State Park Regions

The structure of the IMTs in Virginia would be based on the National Park Service Exotic Plant Management Team. The National Park Service (NPS) has already implemented a management team to handle invasive plants in national parks. The Exotic Plant Management Team (EPMT) assists parks in preventing introductions of new species, reducing infestations, and restoring native plant communities and ecosystem functions (NPS 2007). Individuals with specialized knowledge and experience in invasive plant management lead the EPMTs. This would be the same for the IMT with the leaders being experts from the various agencies in the VISWG. EPMTs cooperate and collaborate with parks and agencies to utilize invasive species experts, volunteers and landowners in managing invasive species in the parks (NPS 2007). EPMTs inventory and monitor invasive species in order to have accurate information when developing management strategies, such as treatment and control (NPS 2007). The NPS EPMT program also employs an early detection and rapid response aspect to identify new invasive species in an area and treat the area before the invasive species spreads (NPS 2007). The annual report from 2012 indicated that the Mid-Atlantic EPMT, including a Shenandoah EPMT, treated or retreated 410 acres, inventoried 4358 acres, monitored 370 acres, measured 4729 acres of gross infested area, and measured 484 acres if infested area (Beard and App 2012). The Shenandoah EPMT treated a 20-acre area for mile-a-minute (*Persicaria perfoliata*) and assisted Shenandoah National Park staff in a fuels reduction project to remove brush and trees around vital park buildings (Beard and App 2012). The NPS EPMT program is successful in collaborating, monitoring and controlling invasive species in the Southeast and the IMT program should utilize a similar structure.

Education seminars conducted by IMTs will be taught in local communities to train locals about identifying invasive species in the area. By connecting with communities, volunteer programs can be established to provide IMTs with more assistance in the monitoring and removal of invasive species. IMTs can work with the Virginia Master Natural Program to access conservation-minded volunteers to aid IMTs. Another method to gain more assistance is to connect with universities as well as communities. Connecting with universities throughout the state will supply the needed manpower to monitor, assess, remove and report on invasive species findings. Working with universities could potentially provide funding to the IMTs through state-level grants. University students and professors can work with IMTs to better understand invasive species and their movements around Virginia. Students can also volunteer their time in assisting the IMTs as they manage invasive species or educate the community. Education will be another key element in implementing IMTs successfully in Virginia. The public needs to be trained and educated about identifying and handling invasive species. This is so they are able to accurately inform IMTs about the sighted species and join in the effort to reduce their impact on the environment.

The IMT will map and monitor the spread of invasive species to predict where they have the potential of moving to next. By creating these early detection and rapid response groups the process of detecting and responding to invasive species is streamlined. As well as removing invasive species where possible, the movements of

invasive species can also be monitored. There are different methods in removing invasive species including reducing the overall spread and ground control and management. Preventing the spread of invasive species can be achieved through more cleaning treatments near nature trails and limiting the movement natural resources, such as firewood and all of which would be led by IMTs. Ground control and management include lobbing plants and spraying certain pesticides to prevent re-growth in areas where invasive species have been removed. For invasive wildlife specialized hunting permits can be issued to professional licensed hunters to reduce population numbers. IMT leaders would assist professional hunters to ensure safe and humane protocols for both hunters and invasive species. IMTs would also utilize human traps to capture invasive species in areas where hunting is not a safe method.

Funding to finance IMTs and their efforts can come from the VDCR as the VISWG does not have the funding to support this program. The IMT will be implementing the actions put forward by the Virginia Invasive Species Management Plan, recommended by the VDCR and VISWG, with part of the allocated invasive species budget from VDCR covering the IMT efforts. VDCR currently has invasive species programs, Recreation Division of Natural Heritage, so part of the funding that goes into those efforts can be divided with the IMT program.

Applying for grants from universities, state and federal programs could provide the IMT the funding to maintain operations. Connecting with universities could open up the IMT to state-level research grants from universities completing research and projects on invasive species. Grants could also come from the Virginia State Wildlife Grant Program as they recently funded the eradication of invasive zebra mussels from a Virginia Quarry in 2006 (VDGIF 2010). VISWG could also apply for federal grants to support the IMT's work in combating invasive species. Some of these grants include Native Plant Conservation Initiative, U.S. Department of Agriculture Grant and Partnership Programs for Invasive Species and Program of Research of the Economics of Invasive Species Management.

If grants and reallocating funds from the VDCR then funding could also come from the federal level. Invasive species do not follow or abide by state boundaries and regulations and collaborating with federal agencies could provide the financial backing to support the IMT program. The federal governmental agencies that receive invasive species funding are the Department of Agriculture, Department of Commerce, Department of Defense, Department of Homeland Security, Department of the Interior, Department of State, and Department of Transportation. The 2014 federal governmental agency funding for invasive species efforts focused on prevention, early detection and rapid response, control and management, research, restoration, education and public awareness, and leadership and international cooperation (NISC 2014). The total actual funding was reported at $2 billion divided up between the federal governmental agencies for the different invasive species categories (NISC 2014).

Implementing Invasive Management Teams is a proactive step to protect Virginia from invasive species currently and into the future.

Acknowledgments

I am grateful to Stewardship Biologist Kevin Heffernan from the Department of Conservation and Recreation for his advice and guidance. From the University of Richmond, I want to thank Dr. Todd Lookingbill for his help during the editing of my recommendation.

Literatures Cited

Beard, Rita and Rick App (2012) "Exotic Plant Management Team Program: 2012 Annual Report" Natural Resource Report NPS/NRSS/BRMD/NRR – 2013/674. National Park Service, Fort Collins, Colorado

Britton, Kerry O. (2002) "Kudzu." *Biological Control of Invasive Plants in the Eastern United States*. USDA Forest Service Publication pp. 413

Carter, Lynne M., James W. Jones, Leonard Berry, Virginia Burkett, James F. Murley, Jayantha Obeysekera, Paul J. Schramm, and David Wear (2014) Ch. 17: Southeast and the Caribbean. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, pp. 396-417. doi:10.7930/J0NP22CB.

Duke, Jeffrey S. and Harold A. Mooney (1999) "Does global change increase the success of biological invaders?" *ScienceDirect*. Trends in Ecology & Evolution 14: pp. 135–139

Executive Order No. 13112, 3 C.F.R. 64.25: pp. 6183-6186 (1999)

Gamfeldt, Lars, Helmut Hillebrand and Per R. Jonsson (2008) "Multiple Functions Increase the Importance of Biodiversity for Overall Ecosystem Functioning" *Ecology* 89.5: pp. 1223-1231

Governor's Commission on Climate Change (2008) "A Final Report: Climate Action Plan http://www.sealevelrisevirginia.net/main_CCC_files/.

Gowdy, John M. (1997) "The Value of Biodiversity: Markets, Society, and Ecosystems" *Land Economics* 73.1: pp. 25-41

Heffernan, Kevin E. (1998) “Managing Invasive Alien Plants in Natural Areas, Parks and Small Woodlands” *Natural Heritage Technical Report* pp. 25-98. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Richmond, Virginia.

Heffernan, Kevin E., E. Engle and C. Richardson (2014) “Virginia Invasive Plant Species List” Virginia Department of Conservation and Recreation and Division of Natural Heritage. Natural Heritage Technical Document. pp 11-14. Richmond, Virginia.

Kane, Ausin, Chris Burkett, Scott Klopfer, and Jacob Sewall (2013) “Virginia’s Climate Modeling and Species Vulnerability Assessment: How Climate Data Can Inform Management and Conservation” National Wildlife Foundation. Reston, Virginia. pp. 1-63

Lambert, Charles (2004) “Prevention, Early Detection and Rapid Response to Invasive Plants. Presented by Deputy Under Sectretary Lambert at the Conference of Invasive Plants in Natural and Managed Systems, International Conference on Ecology and Management of alien Plant Invasions” *Invasive Weed Symposium* 18: pp. 1182-1184

Lant, Christopher L., J.B. Ruhl and Steven E. Kraft (2008) “The Tragedy of Ecosystem Services” *BioScience* 58.10: pp. 969-974

Marks, Marianne, Beth Lapin and John Randall (1993) “Element Stewardship Abstract for *Phragmites australis*, Common Reed” The Nature Conservancy. http://www.invasive.org/weedcd/pdfs/tncweeds/phraaus.pdf

Montoya, Jose M. and Dave Raffaelli (2010) “Introduction: Climate change, biotic interactions and ecosystem services” *Philosophical Transactions: Biological Sciences* 365.1549: pp. 2013-2018

Mooney, Harold A. and Richard J. Hobbs (2000) Invasive species in a changing world. Washington DC Island Press pp. 457

NISC 2003. National Invasive Species Council; General Guidelines for the Establishment and Evaluation of Invasive Species Early Detection and Rapid Response Systems. Version 1. pp. 16

NISC 2005. National Invasive Species Council . Five-year review of Executive Order 13112 on Invasive Species. pp. 44. Available online at http://www.invasivespeciesinfo.gov/docs/council/fiveyearreview.pdf

NISC 2014. National Invasive Species Council, Invasive Species Interagency Crosscut Budget. pp. 1-6

NPS 2007. National Park Service (2007) “Exotic Plant Management Teams” U.S. Department of the Interior. Natural Resources Program Center. http://www.nature.nps.gov/biology/invasivespecies/EPMT_teams.cfm

Pimentel, David, Lori Lach, Rodolfo Zuniga, and Doug Morrison (2005) Update on the environmental and
economic costs associated with alien invasive species in the United States. *Ecological Economics*. 52: pp. 273-288

Pyke, Christopher R., Raymond Najjar, Mary Beth Adams, Denise Breitburg, Michael Kemp, Carl Hershner, Robert Howarth, Margaret Mulholland, Michael Paolisso, David Secor, Kevin Sellner, Denice Warhop, and Robert Wood (2008) “Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations” A Report from the Chesapeake Bay Program Science and Technical Advisory Committee. Annapolis, MD.

Snydor, Davis T., Matthew Bumgardner, and Andrew Todd (2007) “Potential economic impacts of emerald ash borer (*Agrilus planipennis*) on Ohio, U.S., communities” *Aboriculture and Urban Forestry* 33.1: pp. 48-54

Stein, Bruce A. (2002) “States of the Union: Ranking America’s Biodiversity” *NatureServe*. Arlington, Virginia

Tausch, Robin J. (2008) “Invasive Plants and Climate Change”. *U.S. Department of Agriculture, Forest Service, Climate Change Resource Center*: http://www.fs.fed.us/ccrc/topics/invasive-plants.shtml

VDOF 2013. Virginia Department of Forestry “Economic Benefits of the Forest Industry in Virginia” Virginia Department of Forestry, Charlottesville, Virginia. http://www.dof.virginia.gov/econ/index.htm.

VDGIF 2010. Virginia Department of Game and Inland Fisheries State Wildlife Grants and Projects http://bewildvirginia.org/swg/#bookmark-invasive-species

VISWG 2012. Virginia Invasive Species Working Group “Virginia Invasive Species Management Plan.” *Natural Heritage Technical Document* 12-13. Richmond, Virginia pp. 1-55.

Wilcove, David S., David Rothstein, Jason Dubow, Ali Phillips, Elizabeth Losos (1998) “Quantifying Threats to Imperiled Species in the United States” *BioScience* 48.8: pp. 607-615. American Institute of Biological Sciences.

5. Riparian Zone Protocol: A Necessary Addition to an Existing Program

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Natalya Ares
Environmental Studies Major, 2016

Abstract

As temperature trends increase on Earth and the negative effects of anthropogenically driven climate change become clearer, the diversity and health of our natural resources continues to be threatened at a growing rate. Riparian, or streamside, zones are one of these natural resources that under normal conditions, provides an enormous variety of ecosystem services: habitat, food, and shelter for organisms; biological and physical buffers to pollution and sedimentation. As temperatures increase, the patterns of the season change causing abnormal flooding and drying, which both can be detrimental to the ecosystem (National Park Service, 2006) and this natural riparian buffer. Future stewards of these zones will need to consider what and where to plant in order to mitigate the effects of temperature change, and cointinue to carry out ecosystem services (Kane et al. 2013).

Virginia should add a riparian zone protocol to the Adopt-a-Stream program run by the Virginia Department of Conservation and Recreation to assist in the migration of plants, as well as restore existing resilient species and those plants that successfully compete with invasive species. Trained volunteers could choose between planting in the riparian zone and submitting reports of the species they find to program coordinators, to collect useful and usable data for future use by the VADCR.

Introduction

Greater understanding of the impact of anthropogenic activity coupled with more accurate and detailed geological data has begun to show that what we once believed to be a slow climate change process is now speeding up at an unprecedented rate. The general warming of the Earth is now predominantly caused by human activity, which since 1750 has increased concentrations of carbon dioxide (primarily from fossil fuel activity and

changes in the usage of land) and increased levels of methane and nitrous oxide due to agriculture (IPCC Secretariat 1997). These temperature increases are causing changes in rainfall and runoff patterns, and disturbances in biological communities (Palmer et al. 2013). Proactive responses must begin now at the watershed level, taking into account the unique makeup of each individual system and each jurisdiction's financial capacity (Palmer et al. 2013). Although the environment has natural protections against such climate oscillations, the changes that are occurring now are beginning to overwhelm this balance.

One of the most important barriers that the natural world has devised is found on the banks of a water body, commonly known as the riparian or streamside zone, "the interface between terrestrial and aquatic ecosystems...they encompass sharp gradients of environmental factors, ecological processes, and plant communities" (Naiman and Decamps 1997). Because riparian zones act somewhat like a semipermeable membrane, they are difficult to define in terms of their geographical and spatial extent, but their value cannot be understated. This part of our environment can be observed at various scales. At the finest scale, it is the area where water and plants meet, and here it is immediately clear that it is an area of transition (Gregory et al. 1982) or ecotone. These are known to be areas of high biodiversity extremely responsive to changes in climate (Risser 1993). Riparian zones can also be viewed as the surrounding streambanks of flood plains. At this level, we can begin to better understand the dynamic nature of this ecosystem and the disturbances that go along with it such as fires or insect outbreaks, which helps develop better large scale management practices (Moore and Richardson 2012).

The largest scale we can use to observe riparian zones encompasses their biological, physical, and chemical inputs, which influence their above- and below-ground processes. This ultimately creates a "zone of interaction extending upward and outward from the stream through the overhanging canopy" (Gregory et al. 1982). For Virginia, riparian zones can impact the health of larger water bodies such as the Chesapeake Bay, because of the adaptations or properties of the plant life and soils in those ecotones (Kaushal et al. 2008).

Under normal conditions, riparian zones provide an extensive list of benefits to the surrounding area. First, they prevent mass erosion and flooding through specialized root systems that not only hold large amounts of water, but are also adapted to allow the transfer of oxygen even when the plant is submerged underwater (Svejcar 1997). Furthermore, the streamside zones provide habitat and food for a wide array of both terrestrial and aquatic organisms, create microclimates by providing shade or blocking wind, and act as passages or corridors for organisms on the move (Naiman and Decamps 1997). For example, a study conducted on birds described major population decreases

when riparian strips were removed from the environment, likely indicating that the presence of this transition area provided the necessary habitat and food many of the birds needed to survive (Darveau et al. 1995).

Even more remarkably, especially when considering the massive toll human activity is taking on the environment, riparian zones act as a natural nutrient and pollutant filter. North Carolina has riparian zones to thank for removing 80-90% of the sediments that flow out of agricultural fields in the state (Naiman and Decamps 1997). Physical barriers such as soil structure held together by riparian areas have been shown to trap more that 50% of the sediments that flow in from the uplands (Naiman and Decamps 1997). This zone also provides biological barriers to pollutants and sediments: “Riparian forests are especially important sites for biotic accumulations of nutrients because transpiration may be quite high, increasing the mass flow of nutrient solutes toward root systems, and because morphological and physiological adaptations of the many flood-tolerant species facilitate nutrient uptake under low-oxygen condition” (Naiman and Decamps 1997).

Clearly, the health of the riparian zone is key to maintaining the stability of vast food webs that interact in this part of the environment as well as aiding in the chemical balance our waters. Unfortunately, this natural barrier and the biodiversity it supports is under threat due to human action.

Climate change poses a serious threat to riparian zone health, especially in the overall increase in temperatures. The U.S. Fish and Wildlife Service found that increasing temperature plays an enormous role in changes in the timing of streamflow and the interactions between the atmosphere and the water. Higher water temperatures increase the transfer of volatile and semi-volatile compounds from the water to the air. Climate change also leads to more plentiful algal blooms and larger amounts of bacteria and fungi, which all reduce water quality (Tillmann and Siemann 2007).

Changes in temperature can impact the cycles as well as the amount of freezing and melting of snow. This alters the width and character of stream channels and the erosion of stream banks. River systems are also areas of frequent disturbance which make them more prone to invasive species (Richardson et al. 2007). Major increases in the water levels drive out the roots of old plants and make room for new invaders while drying exposes more soil and makes room for invasive species (Richardson et al. 2007). Intensification of the water cycle, seen in both floods and droughts, increases the disturbances of riparian habitats making them more susceptible to nonnative invasive species. This drives out native species and reduces ecosystem value, making that system degraded (Richardson et al. 2007).

Plants as well as animals can be negatively impacted by increasing temperatures. Temperature directly influences how plants retain and release oxygen and water in their leaves. Increases in temperature increase the rate at which plants lose water through evaporation and the rate at which water evaporates, which drives drying in the ecosystem (Tillmann and Siemann 2007). Not only does climate change negatively impact the biotic factors of the riparian zone, it also has the potential to alter soil makeup: "higher temperatures may raise the rate of mineralization of organic matter in catchment soils, releasing carbon, phosphorus and nitrogen, and particulate phosphorus input may also be raised from increased erosion of catchment soils" (Tillmann and Siemann 2007). Perhaps hardest to monitor is that organisms can have trouble adapting. Organisms from lower latitudes are beginning to migrate northward to find cooler temperatures and those that cannot move fast enough face local extinction (Tillmann and Siemann 2007). As human development reduces habitat, and as the effects of climate change alter habitat overall, this process is becoming more and more difficult, especially when one considers the role of the riparian zone as a corridor.

Recent studies carried out in the Piedmont Region of central Virginia have shown that riparian destruction and deforestation "will continue as long as humans assign a higher value to wood products and agriculture than to 'ecosystem services'...provided by the forest, such as watershed protection, wildlife conservation, and carbon sequestration" (Sweeney et al. 2004). Virginia should begin to focus on bolstering the health of its riparian zones, not only as a way to ultimately improve water quality in the state, but also as a way to assist migration of organisms.

Riparian Zone Protocol Recommendation:

The Virginia Department of Conservation and Recreation already has a volunteer program in place where citizens can join together in groups of nearly any size and propose cleanups to the area of their choosing. The VADCR's "Adopt-a-Stream" program encourages participants to pick a waterway for which they will be be responsible over for two years. They must conduct cleanups during this time and must also use resources set forth by the VADCR to advertise their cleanups to the public to get more volunteers.

A protocol to address riparian zone health should be added to the Adopt-a-Stream program.There will be two different types of volunteers. Type I volunteers will be provided with lists of different riparian and native plants that do well in Virginia. They will be given information about each plant on the list and information on where to purchase seeds or saplings. Furthermore, this list will include species of riparian plants

that are already migrating northward from places like North and South Carolina and have already been shown to do well in Virginia's environment.

Type I volunteers are therefore going to be very heavily involved in the assisted migration goal of the recommendation. Over the two-year span, they are responsible for tending the plants or replanting with different species from the approved list. It is prohibited to plant species that are not on the approved list, to prevent the spread of invasive or non-native species.

Type II volunteers would be responsible for plant identification during distinct seasons throughout their time in the program to ensure that the data collected can show the fullest range of life of plants in the area, along with date, time, temperature, and GPS coordinates. They could monitor the migration of species. Abundances of different species can also speak to the health of the area and the VADCR will be able to use this data to better target riparian and deforestation mitigation efforts. Volunteer safety, age, and group requirements would not be different from those in the existing Adopt-a-Stream program.

Species of Note

When considering what plants will be on the approved list for type I volunteers to use, we must consider 3 things: whether the species is native, whether the species does well in the riparian zone, and whether the species has or will migrate into Virginia. Sheila Barnett of the Adopt-a-Stream program (VADCR) explains that current suggestions mainly focus on planting native plant species as a way to fight invasives- plants that are introduced into an area and reduce the ability of native plants to compete for resources and survive. As of 2012, the VADCR reports that, "losses due to invasive species in Virginia may be as high as one billion dollars annually" (Virginia Invasive Species Working Group 2012) and that, "90 invasive plant species...threaten or potentially threaten our natural areas, parks and other protected lands in Virginia" (Virginia Department of Conservation and Recreation 2015).

Depending on the type of invasive plant plant species, certain native species can be planted that will still survive even in the presence of the invader. For example, Chinese Silvergrass (*Miscanthus sinensis*) and Rough Bluegrass (*Poa trivialis*) are both invasive grasses found in Virginia. However, hardwood trees can still survive in the presence of invasive grasses. Such tree species include Black Walnut (*Juglans nigra*) or the Shagbark Hickory (*Carya ovata*) which are both are native to Virginia and, according to the *Common Trees of Virginia Identification Guide*, do especially well along streams and in moist soil.

Next, type I volunteers can be directed to look at plants that already are doing well along riparian zones. Black Willows (*Salix nigra*), for example, are found all over the state of Virginia and are, "common along streams, in wet depressions and other areas with the water table close to the surface" (*Common Trees of Virginia Identification Guide* 2007). Other smaller plants that are both native and found in the riparian zone include the herbaceous Flat-top White Aster (*Aster umbellatus*), the Virginia Wild Rye grass (*Elymus virginicus*), and the American Beautyberry shrub (*Callicarpa americana*).

Virginia state agency research already makes it clear that it will "be necessary to consider climate impacts on the vegetation selected to make sure that we are planting trees in the right places to ameliorate increases in temperatures and that the trees that will themselves be resilient under changing climate conditions. Selecting appropriate tree species and encouraging healthy forests will also help facilitate the infiltration of water from the surface into groundwater systems" (Kane et al. 2013). Therefore, Virginia should consider recommending the Bald Cypress (*Taxodium distichum*) to type I volunteers. This particular tree, "is currently found within Virginia's coastal plain, south of the James River...It occurs along wet stream banks, Virginia's Climate Modeling and Species Vulnerability Assessment 19 bottomlands, swamps, and other areas that usually flood for long periods of time...By mid-century, both the lower and higher emissions scenario models project lowlands throughout Virginia could be climatically suitable for bald cypress based on temperature and precipitation related factors" (Kane et al. 2013). Current research on assisted migration is thin in the United States (McMachlan et al. 2007), meaning that this proposal would likely be one of the first of its kind.

Increased awareness through reliance on volunteers may lead to more public awareness of problems facing the local environment, and may make citizens more likely to act in order to improve it (Forsyth et al. 2004). Funding for such a project will not impact state entities financially because purchasing and monitoring the riparian zone is a cost incurred by concerned citizens. Ultimately, they are taking responsibility for issues caused by human-induced climate change as a way to protect the biodiversity and health of Virginia.

Acknowledgements:

Special thanks to Chris Burkett of the Virginia Department of Game and Inland Fisheries, Sheila Barnett of "Adopt-a-Stream" (VADCR), and the Merrifield Garden Center.

Literature Cited

Barnett, personal communication. Adopt-a-Stream Program Coordinator, Virginia Department of Conservation and Recreation. March 30, 2015.

"Climate Change and the Water Cycle." Crown of the Continent Research Learning Center. June 2006. http%3A%2F%2Fwww.crownscience.org%2Fdownload_product%2F1132%2F0.

Darveau, Marcel, Patrick Beauchesne, Louis Belanger, Jean Huot, and Pierre Larue. "Riparian Forest Strips as Habitat for Breeding Birds in Boreal Forest."*The Journal of Wildlife Management* 59, no. 1 (1995): 67-78. doi:10.2307/3809117.

Department of Conservation and Recreation. "Invasive Plant Species." January 15, 2015. Accessed April 07, 2015. http://www.dcr.virginia.gov/natural_heritage/invspinfo.shtml.

Forsyth, Donelson R., Margot Garcia, Linda E. Zyzniewski, Paul A. Story, and Natalie A. Kerr. "Watershed Pollution and Preservation: The Awareness-Appraisal Model of Environmentally Positive Intentions and Behaviors."*Analyses of Social Issues and Public Policy* 4, no. 1 (2004): 115-28. doi:10.1111/j.1530-2415.2004.00037.x.

Gregory, Sedell, and Campbell. "Chapter 9: Land-water Interactions: The Riparian Zone." In *Analysis of Coniferous Forest Ecosystems in the Western United States*, by Swanson. Stroudsburg, PA: Hutchinson Ross Pub., 1982.

IPCC, 1997. Change, Intergovernmental Panel on Climate. *Summary for Policymakers: The Regional Impacts of Climate Change: An Assessment of Vulnerability*. S.l.:.

Kane, A., T.C. Burkett, S. Kloper, and J. Sewall. 2013. Virginia's Climate Modeling and Species Vulnerability Assessment: How Climate Data Can Inform Management and Conservation. National Wildlife Federation, Reston, Virginia.

Kaushal, Sujay S., Peter M. Groffman, Paul M. Mayer, Elise Striz, and Arthur J. Gold. "Effects Of Stream Restoration On Denitrification In An Urbanizing Watershed." *Ecological Applications* 18, no. 3 (2008): 789-804. doi:10.1890/07-1159.1.

Mclachlan, Jason S., Jessica J. Hellmann, and Mark W. Schwartz. "A Framework for Debate of Assisted Migration in an Era of Climate Change."*Conservation Biology* 21, no. 2 (2007): 297-302. doi:10.1111/j.1523-1739.2007.00676.x.

Moore, R. Dan, and John S. Richardson. "Natural Disturbance and Forest Management in Riparian Zones: Comparison of Effects at Reach, Catchment, and Landscape Scales." *Freshwater Science* 31, no. 1 (2012): 239-47. doi:10.1899/11-030.1.

Naiman, Robert J., and Henry Decamps. "The Ecology of Interfaces: Riparian Zones." *Annual Review of Ecology and Systematics* 28 (1997): 621-58.

National Park Service. "Climate Change and the Water Cycle." *Crown of the Continent Research Learning Center*, 2006.

Palmer, Margaret A., Dennis P. Lettenmaier, N. Leroy Poff, Sandra L. Postel, Brian Richter, and Richard Warner. "Climate Change and River Ecosystems: Protection and Adaptation Options." Environmental Management 44, no. 6 (2009): 1053-068. doi:10.1007/s00267-009-9329-1.

Powell, Ellen. *Common Native Trees of Virginia: Tree Identification Guide*. Charlottesville, VA: Virginia Department of Forestry, 2007.

Richardson, David M., Patricia M. Holmes, Karen J. Esler, Susan M. Galatowitsch, Juliet C. Stromberg, Steven P. Kirkman, Petr Pyšek, and Richard J. Hobbs. "Riparian Vegetation: Degradation, Alien Plant Invasions, and Restoration Prospects." Diversity and Distributions 13, no. 1 (2007): 126-39. doi:10.1111/j.1366-9516.2006.00314.x.

Risser, Paul G. "Ecotones at Local to Regional Scales from Around the World." *Ecological Applications* 3, no. 3 (1993): 367-68. doi:10.2307/1941904.

Sweeney, B. W. "Riparian Deforestation, Stream Narrowing, and Loss of Stream Ecosystem Services." *Proceedings of the National Academy of Sciences* 101, no. 39 (2004): 14132-4137. doi:10.1073/pnas.0405895101.

Svejcar, Tony. "Riparian Zones: 1) What Are They and How Do They Work?"*Rangelands* 19 (August 1997): 4-7.

Tillmann, Patricia, and Dan Siemann. *Climate Change Effects and Adaptation Approaches in Freshwater Aquatic and Riparian Ecosystems in the North Pacific Landscape Conservation Cooperative Region.*Report. August 2007.

Virginia Department of Conservation and Recreation. "Adopt A Stream." March 4, 2015. Accessed April 07, 2015. http://www.dcr.virginia.gov/environmental_education/adopt.shtml.

Virginia Department of Conservation and Recreation. "Native Plants: Riparian Plants." http://www.dcr.virginia.gov/natural_heritage/documents/natvripa.pdf.

Virginia Invasive Species Working Group. 2012. Natural Heritage Technical Document 12-13. Richmond, VA. 55 pages.

6. Preventing Shoreline Hardening to Mitigate Climate Change Impacts

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

George Appling
Environmental Studies Major; Finance Major, 2015.

Abstract

As a result of global climate change, sea level has risen and will continue to rise throughout the 21st Century. Sea level rise has been higher in Virginia than any other state over the past 100 years (U.S. Climate Change Science Program 2009). Varied projections show that sea level could rise 1.2 to 5.5 feet above 1992 levels by 2100 (Boon et al. 2010; Ezer and Corlette 2012; Sallengar et al. 2012). Sea level rise threatens to drown intertidal wetlands (Craft et al. 2009; FitzGerald et al. 2010; Kirwan and Guntenspergen 2010; Menon et al. 2010).

Wetlands are key biodiversity hotspots and provide a number of ecosystem services (Barbier et al. 2011). Wetlands have the ability to adapt to sea level rise by migrating inland as long as shoreline hardening, such as a bulkhead, is absent (Kirwan and Megonigal 2013). In Virginia, private landowners must be granted a permit by local citizen wetlands boards to alter or harden their shoreline. Although wetlands boards have been given sufficient guidance by government agencies, they have mostly failed to achieve Virginia's goal of preserving wetlands (VIMS 2012). If this practice continues, Virginia can expect a significant loss of wetlands, biodiversity and ecosystem services.

To avoid losing wetlands, landowners should be required to discuss the environmental impacts of and alternatives to shoreline hardening with a Virginia Institute of Marine Science scientist before submitting an application. Permit decisions should move from local wetlands boards to the Virginia Marine Resources Commission. These recommendations would limit future shoreline hardening and preserve wetlands and their associated biodiversity in the face of climate change.

Introduction

Climate change will cause numerous negative impacts to the natural environment and to Virginia citizens, including sea level rise. As global temperatures rise, thermal expansion of the oceans and melting of polar ice caps and glaciers cause sea level to rise (IPCC 2007). The rate of future sea-level rise is uncertain, but estimates range from 0.85 to 6.23 feet of sea level rise above current levels by 2100. (IPCC 2013; Church and White 2011; Milne et al. 2009; Pheffer et al. 2008). In particular, Virginia is vulnerable to sea

level rise. Measured sea level rise, caused by both rising sea level and ground subsidence, has been higher in Virginia than any other state over the past 100 years, rising at a rate of 1.44 feet per century (U.S. Climate Change Science Program 2009). Projections in Virginia vary from 1.2 to 5.5 feet above 1992 levels by 2100 (Boon et al. 2010; Ezer and Corlette 2012; Sallenger et al. 2012) Sea level rise is expected to cause a number of negative impacts for humans and ecosystems in coastal areas.

Specifically, climate change and an increase in extreme weather events will likely be the strongest factors threatening tidal wetlands and their biodiversity (Craft et al. 2009; FitzGerald et al. 2008; Kirwan and Guntenspergen 2010; Menon et al. 2010). Coastal wetlands are highly productive areas and are some of the most economically important ecosystems on Earth (Barbier et al. 2011; Kirwan and Megonigal 2013). Marshes provide a number of ecosystem services such as protecting coastal areas from storms, carbon sequestration, and serve as a nursery ground for many commercially important fish (Barbier et al. 2011). Sea level rise adversely affects tidal wetlands because the water depth rises above the optimal level for wetlands, effectively drowning them (Craft et al. 2009; FitzGerald et al. 2010; Kirwan and Guntenspergen 2010; Menon et al. 2010).

However, wetlands are able to mitigate the impacts of sea level rise by migrating inland and accreting upward (Kirwan and Megonigal 2013). Migration and accretion are only possible if shoreline hardening, such as seawalls, bulkheads, or riprap, are absent from the shoreline. Shoreline hardening squeezes wetlands between rising water and an impermeable structure (McFadden et al. 2007). Although shoreline hardening will likely limit the future of wetlands, landowners continue to build on shorelines.

Landowners desire shoreline hardening for a variety of reasons, but need to be granted a permit to alter their shoreline in any way. Typically, landowners harden shoreline to protect property from storms and erosion or just for aesthetic reasons.

Before being granted a permit landowners must complete a lengthy Joint Permit Application (JPA) that describes the purpose and specifics of the proposed project. Once landowners complete the JPA they send it to a local wetlands board for evaluation in a public hearing. A wetlands board is a group of five to seven local community members who determine whether landowners may alter their coastal property. The Tidal Wetlands Act gives the Virginia Marine Resources Commission (VMRC) authority over tidal wetlands, but coastal localities can assume this responsibility and implement the Act through a wetland board (Code of Virginia 1972). Wetlands boards are supposed to evaluate proposals based on evolving, extensive guidelines provided by the Center for Coastal Resources Management (CCRM) at the Virginia institute for Marine Science (VIMS 2012).

The current shoreline hardening permit process, designed under the Tidal Wetlands Act, allows shoreline hardening to continue at steep rates that do not properly balance the use and preservation of wetlands. The Tidal Wetlands Act was created to balance the preservation and use of tidal wetlands in order to protect the various ecosystem services they provide. The ecosystem services identified by the Act include: production of wildlife, waterfowl, finfish, shellfish and flora; protection against floods,

tidal storms, and erosion; absorption of silt and pollutants; and provision of recreational and aesthetic opportunities (Code of Virginia 1972). Additionally, Virginia has established a state policy of "no net loss" of wetlands resources (Code of Virginia 2007). Given Virginia's effort to protect wetlands, wetlands boards are not effectively implementing the Act or Virginia's policy of "no net loss" of wetlands (VIMS 2012).

Wetlands boards have consistently failed to adequately consider the public benefits and detriments of applications as explained in technical guidelines and have approved a proliferation of shoreline hardening projects. From 2009-2011, over 1200 JPAs were submitted to wetlands boards. During this time over 99 percent of JPAs that complied with guidelines in some form were approved. Moreover, 89 percent of JPAs that did not comply with guidelines in any way were approved (VIMS 2012). Wetlands boards overwhelmingly approved JPAs, based mostly on private benefits and not public benefits and detriments, regardless of their conformity to the technical guidance.

Shoreline hardening compromises future existence of critical tidal wetlands. In Virginia, 39 percent of coastal land is well-developed and 22 percent is less developed. 32 percent of land is undeveloped and 7 percent of land is in conservation (Titus et al. 2009). Meanwhile, 11.1 percent or 459 miles of shoreline has been hardened out of 4432 miles and it is estimated that 18 miles of shoreline is hardened each year (Bilkovic et al. 2009).

Although a significant amount of wetlands have been already lost, there is still an opportunity to preserve wetlands in the future. With over 92 percent of the shoreline not hardened and 32 percent of coastal land undeveloped, Virginia has an opportunity to preserve a substantial portion of wetlands during the coming sea level rise by limiting future shoreline hardening.

Recommendation

Overview

In order to limit shoreline hardening and conserve tidal wetlands and their biodiversity in the face of climate change, Virginia should make two changes to the JPA process. First, landowners and permit agents should be required to consult with a member of VIMS on the property before the permit is submitted in order to discuss all the viable options for shoreline alteration. Second, local wetlands boards should no longer evaluate permit applications. Instead, permits should be evaluated by VMRC.

Recommendation One

The JPA for shoreline alteration should require that landowners and their permit agent (if an agent is used) consult a VIMS wetland scientist on the proposal site before the application is submitted. The goal of the consultation would for the landowner and agent to better understand the technical guidelines created by VIMS in order to preserve and maintain tidal wetland ecosystems.

Currently, many landowners and agents do not generally understand the guidelines. From 2009-2011, 56 percent of JPAs did not meet the guidelines in any form (VIMS 2012). Consulting with VIMS staff would assist in educating landowners and agents of the guidelines and provide an opportunity to educate landowners and agents of alternatives to traditional shoreline hardening. VIMS scientists would also discuss the environmental impacts of each option. The consultation would serve to educate landowners, agents on the importance of the technical guidelines, make them aware of the options other than the traditional stabilization approaches available and potentially reduce future impacts from projects, ultimately benefiting the marine environment.

VIMS is an ideal organization to serve this role due to their historic capacity in wetlands advisory services. Part of VIMS' mission is to provide advisory service to policy makers, industry and the public (VIMS 2015). VIMS staff have been trained in wetlands conservation and possess the technical knowledge to discuss the costs and benefits preferred shoreline best practices. Consultation with VIMS staff would help landowners better follow existing guidelines on JPAs and help them better understand alternatives to shoreline hardening.

Educating landowners may help to increase the use of viable alternatives to shoreline hardening (Forsyth et al. 2004). In many cases, alternatives to traditional shoreline hardening exists, but only 10-14 percent of JPAs from 2009-2011 used alternatives to shoreline hardening, such as planting vegetation or living shorelines[1] (CCRM 2012). Additionally, 38 percent of surveyed landowners who hardened shoreline were not aware of living shorelines as an alternative (CCRM 2013).

Landowners and agents also often meet with contractors to survey their land and offer alteration recommendations. Landowners who hardened shorelines used contractors for advice more than any other source of information (CCRM 2013). Logically, contractors recommend riprap or bulkheads as a solution because that is their expertise and contractors are actively seeking business. Most contractors are not knowledgeable in installing vegetation or living shorelines and solely offer shoreline hardening options. By meeting with a VIMS official and a contractor, landowners and agents will be informed of all construction options and the impacts of their decisions.

Wetlands boards are supposed to consider whether alternatives to shoreline hardening were considered, but this does not happen until the end of the application process. When the application is actually completed and submitted, landowners have already spend significant time and effort into the process.

For a wetlands board, whose members may have personal relationships with applicants, to deny an application is a challenging decision to make because wetlands boards do not want to raise conflict with their own community members. Wetlands boards most often approve applications, whether or not they followed the actual

[1] A living shoreline is a "shoreline management practice that provides erosion control and water quality benefits; protects, restores or enhances natural shoreline habitat; and maintains coastal processes through the strategic placement of plants, stone, sand fill, and other structural and organic materials" (Code of Virginia, 2011). Living shorelines allow migration of wetlands as sea level rises.

guidelines (VIMS 2012). Since wetlands boards approve the majority of applications, it is important to have applications more closely follow the guidelines. By requiring landowners to meet with VIMS, landowners are more likely to conform closer to the guidelines and are more likely to seek alternatives to shoreline hardening.

In order to implement participation of VIMS officials in the application process, the JPA would require modification. Under "Part 2-Signatures" of the current JPA, the landowner, agent, contractor and adjacent landowners are all required to provide signatures. Another signature should be required by a VIMS official, acknowledging that they have fully explained the viable options for shoreline alteration, as well as the environmental impacts of each option. Another signature should be required by the land owner and agent to acknowledge that they understand the options and impacts that have been described to them. These signatures would be required for the JPA to be considered complete.

Such a program would require additional financial and human resources for VIMS. Funding would be needed for the cost of man-hours for each visit to each site and the cost of vehicles and gasoline. VIMS is primarily funded through various grants. VIMS could apply for funding from the Virginia general assembly. Shorelines are state resources and the cumulative impacts of shoreline hardening will be felt by stakeholders throughout the state.

Recommendation Two

Local wetlands boards have shown they are not appropriate groups to evaluate JPAs and they should be evaluated by VMRC instead. VMRC would be an optimal agency to run the JPA process because of their technical knowledge, they are a state-level organization and are less influenced by local politics.

VMRC has the technical knowledge to properly evaluate applications based on the technical guidance developed by this agency and VIMS. Wetlands boards are typically comprised of unpaid volunteers with a varying degree of knowledge of wetlands or the impacts of shoreline hardening. Efforts to educate boards has proven to be difficult and ineffective (VIMS 2012). The VMRC has staff dedicated to habitat management and has a close relationship with VIMS.

As a state-level agency, VMRC is better able to understand the cumulative impacts of shoreline hardening compared to local wetlands boards. VMRC serves to protect tidal wetlands and homelands and are stewards of marine and aquatic resources. A state-level agency should evaluate permits because shoreline hardening has a cumulative environmental impact and may even be a breach of the Clean Water Act (Titus et al. 2009).

The loss of wetlands' ecosystem services will have impacts beyond local communities. Local wetlands boards often do not consider the cumulative impacts or impacts beyond their jurisdiction. Projects that impacted a small amount of wetland or

only a portion of the wetlands affected were in their jurisdiction were approved (VIMS 2012). If one agency reviewed all applications, it would be able to see the cumulative and significant impacts of over 500 applications per year and better balance the preservation and use of wetlands.

Additionally, VMRC would be able to make more impartial decisions because they are not intimately tied to communities like wetlands boards are. Members of wetlands boards are community members and often have close ties with applicants. Wetlands boards frequently do not grant permits based on the technical guidelines (VIMS 2012). Having close relationships with applicants can cloud judgement in decision making. Being empathetic to neighbors, colleagues and friends is understandable and board members likely want to avoid conflict with community members they interact with on a daily basis. VMRC is removed from local politics and lacks a close relationship with applicants and will be able to evaluate permits in a logical manner and follow the technical guidelines.

VMRC would be more capable and more likely to follow the guidelines and limit shoreline hardening. Additionally, because VMRC is a government agency instead of a group of volunteers, it must be more accountable for its decisions. VMRC could be viewed critically to evaluate their effectiveness. A volunteer group of board members has no real process of review or accountability.

In order to implement a state-run permit program, VIMS would continue to provide technical guidance to landowners and VMRC and VMRC would use guidance to evaluate applications. Instead of a public hearing and non-technical peer review, VMRC would evaluate permits based on technical criteria and specifications. VIMS would continue to develop technical guidelines to assist VMRC with site-specific decisions. VIMS has the technical knowledge to develop guidelines and VMRC has the ability to evaluate these guidelines. Local governments could assist VMRC with enforcement.

VMRC may not need additional funding to oversee the permit process, but staffing would need to be altered. Currently, VMRC serves as the agency that hears appeals from wetland board decisions. Although the appeals staff have other responsibilities, they would stop hearing appeals and start evaluating permits. However, additional staff would likely be needed to evaluate around 500 proposals per year. Currently, a VMRC wetlands staff member is required at every wetlands board hearing in order to ensure hearings are run legally and correctly. In general, VMRC staff are already involved in the decision-making process. If wetlands boards are eliminated, VMRC staff will be reassigned from wetlands board decisions to evaluate applications.

Conclusion

Tidal wetlands are essential productive ecosystems that provide environmental, economic and social benefits to people and nature both close and far. Because of their critical importance, tidal wetlands should be a conservation priority. Climate change and sea level rise threaten tidal wetlands, but if shoreline hardening is limited then wetlands will be more able to migrate inland naturally.

These recommendations would make a strong impact on limiting the amount of shoreline hardening and would preserve wetlands and their associated biodiversity in the face of climate change. Individually, each recommendation would make a significant move toward achieving this same goal and would help pave the way for future policy changes.

Individually or separately, the recommendations would not be a panacea. Educating landowners, developers and contractors about future sea level rise and its environmental implications will be critical. Humans will likely continue to live and build in coastal areas as sea level continues to rise. This will bring a number of issues, beyond preserving wetlands, to coastal communities. National, state and local government agencies and local communities must work together to best prepare for future impacts of climate change and sea level rise.

Acknowledgements:

I would like to thank the following individuals for their assistance with this recommendation: Timothy Hamilton, Economics Professor at the University of Richmond; Karen Duhring, Marine Scientist Supervisor at the Virginia Institute of Marine Sciences; Christine Tombleson, Marine Scientist at the Virginia Institute of Marine Sciences; Skip Stiles, Executive Director at Wetlands Watch; and Chip Neikirk of the Virginia Marine Resources Commission.

Literature Cited

Barbier, E, S Hacker, C Kennedy, E Koch, A Stier, and B Silliman. 2011. The Value of Estuarine and Coastal Ecosystem Services. Ecological Monographs 81 (2): 169-193.

Bilkovic, D, C Hershner, T Rudnicky. 2009. Vulnerability of Shallow Tidal Water Habitats in Virginia to Climate Change. Virginia Institute of Marine Science.

Boon, J, J. Brubaker, and D. Forrest. 2010. Chesapeake Bay Land Subsidence and Sea Level Change: An Evaluation of Past and Present Trends and Future Outlook A Report to the U.S. Army Corps of Engineers Norfolk District. Applied Marine Science and Ocean Engineering, 425. Special Report.

CCRM 2012 (Center for Coastal Resources Management) at VIMS. 2012. Shoreline Permit Application Records, 1970–2011. http://ccrm.vims.edu/perms/newpermits.html

CCRM 2013. (Center for Coastal Resources Management) at VIMS. 2013. Living Shoreline Funding Questionnaire

Church, J and White N. 2011. Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics 32(4–5): 585–602.

Code of Virginia 1972. § 28.2-1302

Code of Virginia 2007. § 62.1-44.15:21.

Craft, C, J Clough, J Ehman, S Joye, R Park, and S Penning. 2009. Forecasting the effects of accelerated sea level rise on tidal marsh ecosystem services. Frontiers in Ecology and the Environment, 7: 73–78.

Ezer, T, and W. Corlett. 2012. Is Sea Level Rise Accelerating in the Chesapeake Bay? A Demonstration of a Novel New Approach for Analyzing Sea Level Data. Geophysical Research Letters 39 (19).

FitzGerald, D, M. Fenster, B. Argrow, and I. Buynevich. 2008. Coastal impacts due to sea-level rise. Annual Review Earth Science , 36, 601–647.

Forsyth, D, M. Garcia, L. Zyzniewski, P. Story, and N. Kerr. 2004. Watershed Pollution and Preservation: The Awareness-Appraisal Model of Environmentally Positive Intentions and Behaviors. Analyses of Social Issues and Public Policy 4 (1): 115-128.

IPCC 2007. (Intergovernmental Panel on Climate Change) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

IPCC 2013. (Intergovernmental Panel on Climate Change). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Kirwan, M.L. and Guntenspergen, G.R., 2010. Influence of tidal range on the stability of coastal marshland. Journal of Geophysical Research , 115(F2), 1–11.

Kirwan, Matthew L., and J. Patrick Megonigal. 2013. Tidal Wetland Stability in the Face of Human Impacts and Sea-level Rise. Nature 504 (7478): 53-60.

McFadden L, Spencer T and Nicholls R J. 2007. Broad-scale modeling of coastal wetlands: what is required? Hydrobiologia 577: 5–15.

Menon, S, J Soberón, X Li, A Peterson. 2010. Preliminary Global Assessment of Terrestrial Biodiversity Consequences of Sea-level Rise Mediated by Climate Change. Biodiversity and Conservation 19 (6): 1599-1609.

Milne G, Gehrels W, Hughes C, Tamisiea. 2009. Identifying the causes of sea-level change. Nature Geoscience 2(7): 471–478.

Pfeffer W T, Harper J T and O'Neel S 2008 Kinematic constraints on glacier contributions to 21st-century sea-level rise Science 321 1340–1343.

Sallenger, A., K. Doran, and P. Howd. 2012. Hotspot of Accelerated Sea-level Rise on the Atlantic Coast of North America. Nature Climate Change 2 (12): 884-888.

Titus, J.G., D.E. Hudgens, D.L. Trescott, M. Craghan, W.H. Nuckols, C.H. Hershner, J.M. Kassakian, et al. 2009. State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level Along the U.S. Atlantic Coast. Environmental Research Letters 4 (4): 044008

US Climate Change Science Program. 2009. Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region (Synthesis and Assessment Product 4.1). Washington, DC.

VIMS (Virginia Institute of Marine Science), Center for Coastal Resources Management. 2012. Regulatory Fidelity to Guidance in Virginia's Tidal Wetlands Program.

VIMS (Virginia Institute of Marine Science). 2015. http://www.vims.edu/about/mission/index.php.

7. Protecting the Chesapeake Bay From A Changing Climate

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia: April 21st 2015

Emma Thomson
Environmental Studies Major, 2015

Abstract

The Chesapeake Bay is not sufficiently protected by the states around it, and is suffering the consequences of a changing climate (McLeod 2009). It requires more protection to increase resiliency, and in order to ensure the long-term survival of the wildlife it sustains and the ecosystem services it provides. Creating a Marine Protected Area (MPA) at the mouth of the Chesapeake Bay extending into the Atlantic Ocean will protect multiple habitats and fish populations, which will in turn improve the health of the Bay (Narula 2014).

Most of this MPA will restrict harmful fishing, drilling, dumping, and extraction while allowing large-scale commercial fishing (Brown et al. 2010). It will also include no-take zones, a vitally important part of any MPA, to protect commercially important species and to ensure their long-term survival (Wenzel 2011). A no-take zone is a designated area where any and all extractive fishing practices are prohibited.

Designation of an "MPA" is a federal status change, meaning the state government is not going to be entirely responsible for funding and enforcing this sanctuary. Instead, the National Oceanic and Atmospheric Administration, the U.S. Fish and Wildlife Service, and the U.S. Coast Guard will have responsibility for enforcement. (NOAA 2005).

Introduction

The Chesapeake Bay is a vital habitat for plants, animals, and humans. It provides food, recreation, jobs, and offers exceptional economic benefits to the states surrounding it in the form of tourism, fishing, and recreation (Prager 1996). Commercially, the most important species in the Chesapeake is the blue crab (*Callinectes sapidus*), which provides the state with millions of dollars in income every year (Prager 1996). During prime blue crab hunting season, the female crabs move from areas of low salinity, such as the upper Bay and river estuaries, to the mouth of the Chesapeake where they lay their eggs in the water column (Lipcius et al. 2003).

The Atlantic menhaden (*Brevoortia tyrannus*), which "represent 23.5% of United States commercial fishery" (Hale et al. 1991), have a major part of their habitat in the Chesapeake Bay. Menhaden are catadromous fish, meaning they live in low salinity waters and travel to the ocean to spawn, just like the blue crab. The Atlantic menhaden is part of one of the largest fisheries in the U.S., with catches of circa 1 billion pounds a year (Coleman et al. 2004), and is subject to large-scale commercial fishing in the Chesapeake Bay and the Atlantic where they spawn. These

fish are an integral part of the Chesapeake food web, because they are a major food source of striped bass, Atlantic sturgeon, osprey, and other predatory species (NOAA 2012). Additionally they regulate invertebrate and plankton populations within the Bay by feeding on the small organisms and keeping their populations in check.

The connection between these species is their spawning waters at the mouth of the Chesapeake and into the Atlantic, making it an area of high ecological and economic value. However this area is under no protection by state or federal governments. In fact, Virginia protects only about one percent of its territorial waters, compared to roughly 15 percent of the land ("Virginia Conservation Lands Database", "SeaStates" 2014). There are some sanctuaries and protected areas for specific species such as oysters or seagrass, but no large-scale Marine Protected Area that would offer widespread protection to many species.

MPAs are starting to gain support in the U.S. because federal and state governments are beginning to realize the importance of the marine habitats and the ecological services they offer (Agardy 1994). A recent study showed that MPA success was dependent on five variables; size, age, no-take zones, isolated, and enforcement (Edgar et al. 2014). The perfect MPA, according to this study, is over $60mi^2$, is 10 years old, is a complete no-take zone that is isolated from other habitats, and its restrictions are fully enforced.

There are many different ways to alter an MPA for the specifics of the region to be protected including different levels of restrictions and enforcement. This paper proposes an MPA specific to its needs that also follows these five variables to ensure effective conservation.

Stellwagen Bank National Marine Sanctuary

Many states are concerned with the coastal Atlantic within their jurisdictions. In the U.S., the top states for quantity of marine reserves are Hawaii, California, and Oregon, and in 1992, one more state joined the group. Massachusetts is home to a very successful fishing industry in and around Cape Cod, aptly named for the historically massive quantities of cod found in the bay.

This area is important because humpback whales migrate through its center, it is home to rare algae, and because of the fishing industry. Commercial fishing can reduce populations and damage the sustainability of the human economy. In order to ensure the long-term survival of the fishery, Congress in 1992 created the Stellwagen Bank National Marine Sanctuary, an 842-square mile protected area at the opening of Cape Cod. This sanctuary seeks to rebuild fish populations but does so without interfering with the fishing industry in the area ("Designation Document").

Harmful practices such as dumping waste, extracting materials, drilling, dredging, anchoring, removing any animals other than the fish, or removing historic artifacts ("Designation Document") are all banned. Essentially this sanctuary exclusively allows recreational or commercial fishing as long as it doesn't disturb the habitat. Boats are allowed to pass through, including large barges carrying waste or oil, though they aren't allowed to anchor or stop.

Studies have shown that Marine Protected Areas like the Stellwagen Bank Sanctuary "increased abundances and biomasses of some commercial groundfish species in the protected area" (Brown et al. 2010), because the fish were able to grow to maturity and spawn appropriately without their numbers being depleted prematurely. This increased catches and helped stabilize

the fish stocks. This sanctuary offers a guideline for Virginia to use to adapt and create its own version of a Marine Protected Area.

Virginia's MPA

The water at the mouth of the Chesapeake Bay and out into the Atlantic is vitally important to the health of the Bay and to Virginia fisheries. This area acts as a spawning zone for two very important Chesapeake species, blue crabs and Atlantic menhaden. The female blue crabs migrate down the Bay towards more saline waters near the Atlantic Ocean where they release their eggs to develop (Prager 1996). Menhaden do the same, releasing their young near open water instead of inland. These two species are important to the health of the bay and the economy as an income source and as part of the food web (Lipcius et al. 2003). Protecting spawning grounds will ensure the survival of more offspring, and strengthen the stock of fish and crabs for years afterwards.

This MPA would not only be protecting the mouth of the Bay, however. It will cover an area roughly 500mi^2 and spread up the Eastern Shore to encompass sensitive wetlands there. Most of these lands are already controlled by federal wildlife reserves, conservation easements, or The Nature Conservancy, though they only protect a small strip of water down to the lowest low tide (U.S Virginia Field Project). The proposed MPA would fill in the gaps in this coverage.

Virginia would apply for an MPA through the National Oceanic and Atmospheric Administration, with regulations similar to Massachusetts'. There are several different ways to classify an MPA, but this one will be specific for the purpose of sustainable production which means "zones established and managed wholly or in part with the explicit purpose of supporting the continued extraction of renewable living resources" (Wenzel and D'Lorio 2011), meaning the animals that live in the boundaries of the new site.

Another classification for the MPA would be 'zoned multiple use'. In most of the MPA, activities such as boating, swimming, and large-scale fishing would be permitted. The seafloor in this area is vital to the health of the fish and crab populations the MPA seeks to protect, so there would be restrictions to ensure a pristine seafloor. As at Stellwagen Bank, this MPA will prohibit dumping chemicals or materials in the water, drilling, dredging, extracting or producing minerals, removing anything from the bottom including historic artifacts, and hunting wildlife other than fish.

This MPA would be considered 'zoned', because there would be a small no-take zone in the middle. A no-take zone is an area in the water where all fishing and extracting practices are prohibited. The purpose is to preserve as much area as possible as pristine habitat for fish and wildlife to proliferate. The no-take zone for this MPA will surround Cape Charles National Wildlife Refuge, and go through Fisherman's Inlet up to Skidmore Island, hugging Raccoon Island and Raccoon creek. Out of the roughly 4,500mi^2 that make up the Chesapeake Bay, this no-take zone will cover only about 10mi^2 ("Facts and Figures"). However, because it surrounds a National Wildlife Refuge, this whole area would be some of the most pristine habitat in all of Virginia.

Looking back on the five variables suggested in the research literature for a successful MPA, the minimum area for successful protection was 60mi^2, increased fivefold in this recommendation. In addition, the bottom habitat in this area contains seagrass beds, oyster reefs, and sandy bottom, a variety of habitats to ensure complete protection. With the addition of

federal protections and the no-take zone, this MPA would likely become a model sanctuary once it reached the 10-year mark.

Many fish populations cannot recover their numbers without protection once they have been severely damaged. Hutchings (2002) found that 40 percent of the commercial fish populations he studied were still not showing signs of recovery even 15 years after fishing pressure stopped. MPAs have been shown to increase fish populations and biomass in multiple different studies (Brown et al. 2010), back to almost virginal population sizes. Large international organizations for biodiversity have agreed, "areas closed to all extractive use … should form the core of national networks of marine protected areas" (Roberts et al. 2005) with the IPCC even issuing a recommendation to create a global system of Marine Protected Areas, "including strictly protected areas amounting to 20-30% of each habitat, by 2012" (IPCC 2008).

This MPA will only have roughly 5 percent of its waters classified as no-take zones, but the framework is in place to continuously increase this percentage. The need for no-take zones is backed by findings that "stocks of exploited species within reserves typically increase three to fivefold within 5-10 years of protection" (Roberts et al. 2005), as opposed to those species that cannot recover population sizes even after 15 years when left unprotected.

Funding and Support

The US Coast Guard, the US Fish and Wildlife Service, and the National Oceanic and Atmospheric Administration (NOAA 2005) are in charge of patrolling federal MPAs so that duty would not fall to state personnel. Federal agencies such as the Coast Guard, are already policing Virginia's waters and enforcing a variety of fisheries laws that differ across the country ("Protecting Our Marine Life"). Because the proposed no-take zone already borders a National Wildlife Refuge, the infrastructure for enforcement and patrol is in place.

The Marine Protected Area Fund provides the money to start an MPA for the first year it is enacted ("Funding"). After this, it is up to NOAA, the USFWS, Virginia's conservation departments, and non-governmental organizations to supplement funding for the sanctuary. Estimates for annual costs range, with the average falling somewhere around $775 per square kilometer (Balmford et al. 2004), or roughly $465.6 per square mile. At this rate, this MPA will cost roughly $575,000 annually, split between non-governmental organizations, and state and federal governments. Many factors that influence the cost of running an MPA, but "the strongest correlation was with MPA size: per unit area, bigger MPAs cost substantially less to run" (Balmford et al. 2004). This strengthens the case for a larger Chesapeake sanctuary.

Conclusion

This recommendation seeks to provide Virginia with a way to combat negative effects of climate change, conserve biodiversity, support commercial fishing industries, preserve the Chesapeake Bay, in a low-cost manner. The best way to reach all of these goals is to create a Marine Protected Area at the mouth of the Chesapeake.

Literature Cited

Agardy, M. Tundi. "Advances in Marine Conservation: The Role of Marine Protected Areas." *Trends in Ecology & Evolution* 9.7 (1994): 267-70.

Balmford, A. "The Worldwide Costs of Marine Protected Areas. "*Proceedings of the National Academy of Sciences* 101.26 (2004): 9694-697.

Brown, Briana, Elizabeth Soule, and Les Kaufman. "Effects of excluding Bottom-disturbing Mobile Fishing Gear on Abundance and Biomass of Groundfishes in the Stellwagen Bank National Marine Sanctuary, USA."*Current Zoology* 56.1 (2010): 134-43.

Coleman, F. C. "The Impact of United States Recreational Fisheries on Marine Fish Populations." *Science* 305.5692 (2004): 1958-960.

"Designation Document for the Stellwagen Bank National Marine Sanctuary." *Gerry E. Studds Stellwagen Bank National Marine Sanctuary*. National Ocean Service.

Edgar, Graham, Rick Stuart-Smith, Trevor Willis, Stuart Kininmonth, Susan Baker, Stuart Banks, Neville Barrett, Mikel Becerro, Anthony Bernard, Just Berkhout, Colin Buxton, Stuart Campbell, Antonia Cooper, Marlene Davey, Sophie Edgar, Gunter Forsterra, David Galvan, Alejo Irigoyen, David Kushner, Rodrigo Moura, P. Ed Parnell, Nick Shears, German Soler, Elisabeth Strain, and Russell Thomson. "Global Conservation Outcomes Depend on Marine Protected Areas with Five Key Features." *Nature* 506 (2014): 216-20. Print.

"Facts and Figures." *Chesapeake Bay Program*. The Chesapeake Bay Program, n.d.

"Funding." *Marine Conservation Agreements*. The Nature Conservancy, n.d.

Hale, Malcolm, and Paul Bauersfield. "New Products and Markets for Menhaden, Brevoortia Spp." Marine Fisheries Review 53.4 (1991): 42.

Hutchings, Jeffrey. "Collapse and Recovery of Marine Fishes." *Nature* 406 (2000): 882-85.

IPCC 2008. Intergovernmental Panel on Climate Change. World Commission on Protected Areas. *Parks: Protected Areas Program*. Ed. Paul Goriup. 2nd ed. Vol. 17.

Lipcius, Romuald, William Stockhausen, Rochelle Seitz, and Patrick Geer. "Spatial Dynamics and Value of a Marine Protected Area and Corridor for the Blue Crab Spawning Stock in Chesapeake Bay." *Bulletin of Marine Science* 72.2 (2003): 453-69.

Mcleod, Elizabeth. "Designing Marine Protected Area Networks to Address the Impacts of Climate Change." 7.7 (2009): 362-70. Commission for Environmental Cooperation.

Narula, Svati Kirsten. "A Blueprint for Protecting the World's Oceans." *The Atlantic*. Atlantic Media Company, 25 Apr. 2014.

NOAA 2005. National Oceanic and Atmospheric Administration. National Marine Protected Areas Service. *Enforcing U.S. Marine Protected Areas: Synthesis Report*. By

Braxton Davis and Greg Moretti. Silver Spring: NOAA, 2005.

NOAA 2012. "Menhaden." *NOAA Chesapeake Bay Office*. National Oceanic and Atmospheric Administration, Jan. 2012.

Prager, Michael. "A Simple Model of the Blue Crab Callinectes Sapidus, Spawning Migration in Chesapeake Bay." *Bulletin of Marine Science*58.2 (1996): 421-28.

"Protecting Our Marine Life." *Coast Guard Reserve*. United States Coast Guard.

Roberts, C. M., J. P. Hawkins, and F. R. Gell. "The Role of Marine Reserves in Achieving Sustainable Fisheries." *Philosophical Transactions of the Royal Society B: Biological Sciences* 360.1453 (2005): 123-32.

"SeaStates US 2014: How Much of Your Ocean Is Your State Protecting?" *Marine Conservation Institute*.

"U.S. Virginia Field Project." *Marine Conservation Agreements*. The Nature Conservancy, n.d.

“Virginia Conservation Lands Database." *Natural Heritage Program*. Department of Conservation and Recreation,

Wenzel, Lauren, and Mimi D'Lorio. "Definition & Classification System for U.S. Marine Protected Areas." *Marine Protected Areas*. National Oceanic and Atmospheric Administration. March 2011.

8. Life Cycle Cost Assessments; A Win-Win Solution for Virginia's Coastal Wetlands

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Austen Kelso
Environmental Studies Major, 2015.

Abstract

Virginia shorelines are facing some of the highest rates of sea level rise seen over the last five millennia and are among the most vulnerable coastlines in the country to the effects of sea level rise such as flooding and storm surge (Downs et al. 1994). In the face of these rising sea levels, coastal wetland habitats will be forced to migrate inland to avoid inundation (Akumu et al. 2011). However, increased development on the Virginia coast threatens these critical wetland habitats by blocking their inland movement as they try to avoid rapidly rising sea levels. Without a clear migratory path, wetland's ecosystem services and biodiversity will be lost to saltwater inundation.

To prevent the loss of wetland's migratory paths from development, this paper proposes that any new development behind coastal wetlands must undergo a Life Cycle Cost Assessment (LCCA). Completion of the LCCA will expose developers to both the future costs they will incur from rising sea levels, flood mitigation, and the costs associated with possible wetlands destruction. Exposing developers to the future costs they will incur has the potential to save a developer future property loss while also maintaining wetland's inward migration path by deterring development. Cost of the LCCA will fall on the developer of the coastal property.

Introduction

It is just before sunset in West Ocean City, Maryland, the town that sits quietly across the bay from the beach town of Ocean City. The author's uncle, Tom Kelso, watches the setting rays shine across the water onto the marsh grasses that stretch out into the bay from the backyard of his bay front property. Most people only dream of having such a view. However, this wetland is more than a picturesque scene; it is a powerful fortuneteller. Hidden among the low grasses and shallow waters are the remnants of old dock pilings, the tops now barely protruding out of the water that has been gradually swallowing them. These dock's pilings, once sitting high above the water like Tom Kelso's brand new dock sitting only yards away, are a jarring sign that sea levels are rising at unprecedented rates. Over the next few decades, Tom's dock, and eventually his house will face the same fate as these dock pilings, inundation by the rising sea.

Had Tom Kelso known before he built his house that the sea would eventually swallow his bay front investment, he might have considered building elsewhere. His sunken investment could have been saved had he known about the reality of sea level rise over the next fifty years. The wetlands that he built behind would also have the opportunity to escape these rising sea levels by migrating landwards. This path, now blocked by his house, is not an option. Tom did not know about sea level rise and was never required to consider its effects before building. Completing a Life Cycle Cost Assessment that looked at the rising sea levels prior to building could have saved him his million-dollar investment as well as the wetlands he trapped. This assessment, which would have cost a mere fraction of the house and dock, would have required him to evaluate if the damage to his property, house, and dock from rising sea levels over the next 50 years would be worth the investment of developing this piece of land. Chances are that such an assessment would have deterred him from building, ultimately saving him money as well as saving the wetlands he built behind.

This scenario, however, is not unique to a bay front property in Maryland; it is a phenomenon occurring all across the country. Virginia in particular is experiencing these harsh effects from rising sea levels along its entire coastline. Virginia's shorelines are facing some of the highest rates of sea level rise over the last five millennia and are second only to New Orleans as the most vulnerable coastline in the United States to flooding and storm surges from sea rise (Downs et al. 1994), in part because of the subsidence along the state's coastal zones, and in part because of global warming.

Water levels on the Virginia coast are expected to rise between 2.3- 5.2 feet over the next century, with low lying areas such as Virginia Beach and Hampton Roads experiencing the worst effects of this elevated sea level (Stiles et al. 2014). They are connected to the larger global problem of climate change. As global air temperatures on average become warmer, the water in the oceans is increasing as the result of two processes. First, the mass of water in the oceans is growing as ice on land melts and enters the oceans (Meier and Wahr 2002). Second, the volume of the water is increasing as the result of thermal expansion of ocean water (Meier and Wahr 2002). Ultimately, if Virginia wants to reduce the sea level rise affecting its shorelines, it must confront those factors contributing to climate change.

Virginia coastlines, in the face of sea level rise from climate change, will see an increase in flood and storm surge strength and frequency. This has already and will continue to destroy coastal development. It will also negatively affect coastal habitats, most notably coastal wetlands. Typically, wetlands are able to adjust to changing sea levels. Through a process called vertical accretion, wetlands raise themselves over time to keep pace with rising water levels (Akumu et al. 2011). However, the predicted rate of sea level rise over the next century is much faster than a wetlands vertical accretion rate. In this scenario, a wetlands contingency plan is to migrate landward in order to avoid inundation (Akumu et al. 2011). Development on the Virginia shoreline, however, will block wetland's landward migratory path. Without a clear path inwards, wetland's ecosystem services and abundant biodiversity will be lost to saltwater inundation.

Trapping wetlands between development and the rising tides will not only result in losing the physical wetlands, but also the value of their important ecosystem services and ecological functions. The Virginia Institute of Marine Science estimates that pressures from rising sea levels and coastal development in Virginia will result in a loss of 52% of tidal wetlands in a business-as-usual scenario (Bilkovic et al. 2009).

Coastal wetlands are habitats that provide very important ecological functions and services such as critical habitat for large amounts of Virginia's biodiversity, flood control, storm buffering, and water purification (Woodward and Wui 2000). Many of these ecological functions provide direct benefit to humans. For example, Virginia's largest commercial fishery, Atlantic menhaden, brings in over $30 million dollars annually (Kirkley 2011). These Atlantic menhaden depend on wetland habitats as a spawning and nursery ground for their young and thus a loss of wetlands will have a direct effect on the menhaden fishing industry in Virginia (Kier 1998). However, not all ecological functions of wetlands are as easy to quantity. It can be challenging to place an economic value on an ecosystem service.

A solution to this problem is to use non-market values to establish the worth of wetlands (Woodward and Wui 2000). One way of doing this is through the Hedonic Pricing method, which estimates economic value for ecosystem services that directly affect market prices, typically prices associated with the housing market (Mahan et al. 2000). Using the Hedonic Pricing method illustrates how wetlands directly influence residential property value. Increasing the size of the nearest wetland by one acre increases a properties value by $24.39 (Mahan et al. 2000). Additionally, decreasing a properties distance to a wetland by 1,000 feet increase the value of the property by $436.17 (Mahan et al. 2000). Wetlands, in terms of housing prices, can be assigned an economic value in this way. Also, because both proximity and size of the nearest wetland have a positive effect on property value, keeping wetlands healthy is a good thing for housing prices. Destroying wetlands, on the other hand, will negatively affect coastal property values.

Recommendation

To protect wetlands from perishing under saltwater inundation, Virginia should require that any new development behind coastal wetlands must undergo a Life Cycle Cost Assessment (LCCA). The LCCA is an assessment that will require developers to evaluate the future costs they will incur as a result of sea level rise over the next 50 years. While the complete assessment will cover the next 50 years, it will have benchmarks at 10, 20, and 50 years. In this way, instead of illustrating costs incurred over just a 50 year time period, it will show costs incurred over a 10-year period, 20-year period, and then finally the full cost incurred over the full 50 years.

LCCA completion will show the costs that developers may incur as a result of sea level rise under different scenarios if they build behind wetlands. The first scenario involves the construction of some type of flood mitigation structure. Building a

floodwall, dyke, jetty, or some type of bulkhead to reduce flooding and storm surge from sea level rise will require a significant investment. The second scenario is one with no flood mitigation structures. Without any structures to protect from flooding and storm surge, this scenario will evaluate the cost of future property damage that results from future flooding and storm surge.

This will also consider the value of property depreciation as water swallows land. This scenario also considers the flood insurance costs and the increase of these costs as floods and storm surge become stronger and more frequent. Both of these scenarios will also include the cost of the lost wetlands they are building behind. Flood mitigation structures and development will block the inward migratory path of these wetlands and will result in the loss of its ecosystem services, ecological functions, and biodiversity.

Enforcement of the LCCA will fall under the responsibility of the local municipality. Local municipalities must ensure that any new development has completed an LCCA before building. However, the completion will fall on a privatized third party group in order to minimize any conflict of interest. For example, this group may be some version of an environmental consulting group that will specialize in LCCA completion. Finally, payment for the completion of the LCCA will fall directly on the party that is financing the development.

Following completion, the LCCA must be given to the local municipality to ensure full disclosure. In the event that the developer finds future cost to be too high and chooses not to build, the LCCA must still be disclosed to the local municipality. Disclosing the LCCA to the locality allows the municipality to ensure potential developers are completing the assessment prior to any building. The municipality will not allow or disallow development based on the findings from the assessment. Rather, the LCCA is meant to deter development by helping developers to realize the potentially high cost they will incur over the next 50 years due to sea level rise. Based on the results of LCCA, developers are able to make a decision that is in their best self-interest.

While there is no direct example of a Life Cycle Cost Assessment, there are analyses in practice that are generally similar. One such analysis is the Life Cycle Cost Analysis created by the National Institute of Standards and Technology. This analysis helps developers minimize costs by analyzing operating and maintenance costs, building costs, and personnel costs over a 30-year period (Fuller 2010). Understanding these costs early in the design process allows developers to consider alternate building designs and ensures a reduction in total life-cycle costs (Fuller 2010). A Life Cycle Cost Assessment can be understood in the same way. However, instead of analyzing the costs associated with building and operation, the LCCA will analyze a properties future costs associated with sea level rise over 50 years. This will allow developers to consider alternate building locations or different courses of action to avoid these future costs.

Life Cycle Cost Assessment Strength

The strength of the Life Cycle Cost Assessment is that it saves wetlands migratory paths by targeting people's self-interests. Generally, those who are going to develop behind a coastal wetland do not have extensive knowledge of or interest in wetlands migratory paths. Thus, it is less effective to show developers the importance of wetland habitats than to show developers how and why they will lose money. Instead of convincing a potential developer of the importance of the wetlands that they may be harming, the LCCA targets their economic self-interest by showing them that this development will be a bad long-term investment of their money. By forcing developers to understand facts about future of sea level rise, it has the potential to both save wetlands and save developers money. In this way, the LCCA is a win-win solution for saving coastal wetlands.

Acknowledgments:

I would like to thank Dr. Timothy Hamilton of the University of Richmond for guidance and mentorship during the creation of this recommendation. I also would like to thank Skip Stiles of Wetlands Watch, Karen Duhring of VIMS, Chris Burkett of VDGIF, and Tom Smith of the Virginia Natural Heritage Program for inspiration and advice throughout the semester.

Literature Cited

Akumu, Clement Elumpe, Sumith Pathirana, Serwan Baban, and Daniel Bucher. "Examining the Potential Impacts of Sea Level Rise on Coastal Wetlands in North-eastern NSW, Australia." *Journal of Coastal Conservation* 15.1 (2011): 15-22. *JSTOR.* Web.

Bryant, L. Preston, Jr. *Governor's Commission on Climate Change Final Report: A Climate Change Action Plan*. Rep. N.p.: n.p., 2008. Print.

Bilkovic, Donna, Carl Hershner, Tamia Rudnickey, Karina Nunez, Dan Schatt, Sharon Killeen, and Marcia Berman. Vulnerability of Shallow Water Habitats in Virginia to Climate Change. Rep. N.p.: Marine Institute of Marine Science, n.d. Print.

Downs, Lynda, Robert Nicholls, Stephen Leatherman, and Joseph Hautzenroder. "Historic Evolution of a Marsh Island: Bloodsworth Island, Maryland." *Journal of Coastal Research* 10.4 (1994): 1031-044. *JSTOR*. Web.

Fuller, Sieglinde. "Life-Cycle Cost Analysis (LCCA)." Life-Cycle Cost Analysis (LCCA). National Institute of Standards and Technology, 28 June 2010. Web.

Germain, Tiffany. "Climate Change and the Commonwealth. How Ken Cuccinelli's Climate Denial Is Putting Millions of Virginians in Economic Danger." Center for American Progress Action Fund, 8 Oct. 2013. Web.

Groot, Rudolf S De, Matthew A. Wilson, and Roelof M.j Boumans. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services." Ecological Economics 41.3 (2002): 393-408. Web.

Kirkley, James E. An Assessment of the Social and Economic Importance of Menhaden (Brevoortia Tyrannus) (Latrobe, 1802) In Chesapeake Bay Region. Rep. no. 2011-14. N.p.: n.p., n.d. Virginia Institute of Marine Science. 2011. Web.

Lupi, Frank, Theodore Graham-Tomasi, and Steven J. Taff. "A Hedonic Approach to Urban Wetland Valuation." Department of Agricultural and Applied Economics, University of Minnesota (1991): n. pag. Web.

Mahan, Brent L., Stephen Polasky, and Richard M. Adams. "Valuing Urban Wetlands: A Property Price Approach." Land Economics 76.1 (2000): 100-13. JSTOR. Web.

McGary, James, Bill Kovarik, and Rae Tyson. Safe Coast Virginia: Climate Change Threats and Practical Solutions for Coastal Virginia. Rep. Chesapeake Climate Action Network, July 2014. Web.

Meier, Mark F., and John Wahr. "Sea Level Is Rising: Do We Know Why?" Proceedings of the National Academy of Sciences of the United States of America 99.10 (2002): 6524-526. JSTOR. Web.

Stiles, William A., Jr. *All Adaptation Is Local*. Publication. N.p.: n.p., n.d. Print.

Skip Stiles, A “Toolkit” for Sea Level Rise Adaptation in Virginia

Stiles, William, Shannon Jarbeau, Shereen Hughes, and Mary Stiff. *The Challenges of Mitigating Virginia’s Flooding and Sea Level Rise Impacts*. Publication. Wetlands Watch, Nov. 2014. Web

William M. Kier, comp. Fisheries, Wetlands and Jobs. Rep. Clean Water Network, Mar. 1998. Web.

Woodward, Richard T., and Yong-Suhk Wui. "The Economic Value of Wetland Services: A Meta-analysis." Ecological Economics 37.2 (2001): 257-70. Web.

Zedler, Joy B. “Wetlands at your service: Reducing Impacts of Agriculture at the Watershed Scale.” *Frontiers in Ecology and the Environment* 1.2 (2003): 65. *JSTOR*. Web.

9. Requiring Responsible Mitigation Banking

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Julia Baer
Environmental Studies Major, 2015.

Abstract

Virginia faces widespread loss of its tidal wetlands due to sea level rise. Sea level rise is occurring at a rate faster than wetlands can adapt and move to higher ground, resulting in marsh submergence (Kirwan et al. 2010). Tidal wetlands provide innumerable ecosystem services that benefit both humans and general biodiversity, including pollutant filtration, erosion prevention and flood control (Hansson et al. 2005). The issue of wetland loss is particularly relevant to Virginia because Virginia is experiencing the fastest sea level rise of any state on the eastern seaboard (Tompkins and Deconcini 2014).

Because of federal and state programs that attempt to achieve "no net loss" of wetlands, the business of wetland mitigation banking has experienced enormous growth over the past few decades. These businesses contract with developers to restore and/or create new wetlands to compensate for wetland loss due to development. While this mitigates the rate of wetland loss, "no net loss" is not truly achieved because federal law requires the replacement of wetlands only if their loss is due to development.

Wetland mitigation banks should be required to take sea level rise into account when selecting new sites, and forbidden from using sites where function losses exceed 5 percent within 50 years, using the "low" sea level rise projections included in the Virginia Institute of Marine Science's Recurrent Flooding Study in 2013. This will ensure longer lasting protected wetlands in the mitigation banks, and decrease developer-based wetland destruction.

Introduction

In the United States, wetlands have historically been viewed as undesirable and uninhabitable environments due to their trademark odors and large insect populations (VA DEQ 2015). Since the 1600s, over half of the wetlands in the United States have been drained and filled in for human use (EPA 2013).

As scientific understanding advanced during the 20th century, the ecological functions of wetlands and the value of the ecosystem services they provide became clear. These ecosystems improve water quality through pollutant filtration, provide habitat for fish and wildlife, store floodwaters, protect against storm surges, control erosion and sedimentation, recharge aquifers and efficiently sequester carbon (VA DEQ 2015, Dahl 2000).

Wetlands are biodiversity hotspots, providing habitat for both aquatic and terrestrial species alike and operating as spawning sites and nurseries (Keddy et al. 2009, Hansson et al. 2005). Findings from a recent study in Australia suggest that wetlands may be up to 50 times more effective than forests at sequestering carbon, making them an extremely unique and valuable ecosystem (Gallucci 2015). Due to this ecosystem's wealth of services and benefits, wetland loss has a high cost to humans.

Recognizing the need to protect wetlands, the United States adopted a policy of 'no net loss' in 1989 (Bendor 2007). Section 404 of the Clean Water Act also sets forth the need for a permit from the U.S. Army Corps of Engineers when one's development will drain, fill, dredge or otherwise harm an area of wetland. Since 'no net loss' is the goal, federal law states that wetland loss in one area must matched by the addition of wetland elsewhere. This is called compensatory mitigation. Only after determining that, after avoidance and minimization techniques have been implemented, the development will result in some form of wetland damage, may the developer turn to compensatory mitigation.

There are three forms of compensatory mitigation: permittee-responsible mitigation, in-lieu fee mitigation and mitigation banks. In 2008, the Environmental Protection Agency and U.S. Army Corps of Engineers released the Compensatory Mitigation Rule for Losses of Aquatic Resources revising the regulations associated with compensatory mitigation and stating clearly that mitigation banks are the federally preferred form of compensatory mitigation (DOD/EPA 2008).

According to the Virginia Department of Environmental Quality, "the purpose of mitigation banks is to replace the biological, chemical and physical functions of wetland resources by quantifying the replace function as a 'credit', which can be purchased by third parties to compensate for unavoidable wetland losses" (VA DEQ 2015).

Three stakeholders are involved: the developer, the credit vendor and regulatory bodies. Typical developers that impact wetlands include transportation agencies, residential and commercial developers, the Department of Defense, extractive industries and utilities (Ecosystem Marketplace 2015). Credit suppliers come in various forms but are typically private mitigation bankers, nonprofit organizations or government agencies (Ecosystem Marketplace 2015). The regulatory bodies that form the Mitigation Banking Review Team for a specific mitigation bank site proposal include the U.S. Army Corps of Engineers and the EPA in addition to relevant state and local regulatory agencies. In Virginia, the standard list includes the Norfolk District Corps of Engineers, Virginia

Department of Environmental Quality, US Fish and Wildlife Service, Virginia Department of Game and Inland Fisheries and Region III of the EPA.

Mitigation banks' creation of wetland loss offsets may take one of four forms: restoration, enhancement, creation or preservation of wetlands. The process begins when a credit supplier submits a permit application for the establishment of a new mitigation bank site to the regulatory agencies. The agencies then form an intra-agency review team, or an IRT, and either approve or reject the application based on site design, performance and monitoring criteria.

In Virginia, there is a checklist for mitigation bankers to follow, coordinated by the Norfolk District Army Corps of Engineers and the DEQ. If approved, the team works with the credit supplier to determine how many credits the site will be worth based on the site's functional capabilities, such as pollutant filtration, water storage, erosion control, etc. The credit supplier is responsible for the maintenance and monitoring of the site, ensuring that it continues to perform ecological functions. The regulatory bodies perform routine check-ups for a ten-year period after the creation of a new bank to ensure this is happening. Then, when a developer proposes a project that will impact wetlands and they have demonstrated that they have made all efforts to avoid and minimize negative impacts, they may purchase credits from the new bank to compensate for the aquatic function loss they caused.

There are restrictions mandating how developers can select where they go for their mitigation needs. According to the Virginia Off-Site Mitigation Location Guidelines, off-site mitigation must be within the same 8-digit HUC Catalog Unit or an adjacent HUC Catalog Unit within the same river basin as the developer's wetland damage (USACE, Norfolk District 2008). It must also be in-kind, meaning that estuarine impacts must be compensated using estuarine wetlands, etc. (USACE, Norfolk District 2008).

While wetland mitigation banks have been useful in restoring, protecting and creating wetlands in the United States, they ignore one of the greatest threats tidal wetlands face today: sea level rise. The result of thermal expansion and polar ice cap melting due to anthropogenic greenhouse gas emission, plus regional land subsidence, sea level rise is rapidly accelerating and causing the inundation of wide expanses of wetlands (Nicholls et al. 1999).

As wetlands (especially tidal wetlands) are such biodiversity hotspots, this has disastrous effects on countless species. Wetlands do have limited ability to migrate upland, but the projections of sea level rise far outpace this ability (Kirwan et al.). Inundation of wetlands will also nullify many of their countless ecosystem services.

Virginia is experiencing the fastest sea level rise of any state on the eastern seaboard, and projections estimate that 50 to 80 percent of vegetated tidal wetlands in Virginia could disappear by the end of the century (Tompkins and Deconcini 2014). There is currently no law or regulation stating that wetland mitigation banks must plan

for/take into account the potential effects of sea level rise on their mitigation sites, a shortcoming that will inevitably result in the failure of 'no net loss.'

For example, the City of Virginia Beach recently submitted an application for the establishment of a tidal wetland mitigation bank in the northern portion of the city for the purpose of offsetting the development impacts on tidal wetlands there. The Pleasure House Point Mitigation Bank would be 13.12 acres and credits would be sold exclusively to the City of Virginia Beach (Kerr Environmental Services Corp. 2014). The Virginia Institute of Marine Science's 2013 Recurrent Flooding Study found that Virginia Beach has the third highest vulnerability to inundation of any county in the state, and is projected to lose 59.8 square miles of land over the next century (Mitchell et al. 2013). If approved, the proposed mitigation bank will likely not survive the century, and neither will its mitigation value.

Recommendation

The current system of compensatory mitigation presumes the offsetting of wetland loss to be permanent, but in the case of tidal wetlands, it is not. A low projection by the Virginia Institute of Marine Science predicts a 1.5-foot rise in sea level over the next 50 years (Mitchell et al. 2013). If sea level rise destroys wetlands inside a wetland mitigation bank, the bank would no longer provide the ecosystem services promised and the result would be a net loss of wetlands.

It makes very little sense for these wetland mitigation banks to devote time, money and research in planning for new tidal bank sites without considering the likelihood that their investment may drown in the Atlantic within a few decades. These bankers already have a checklist with rules and regulations they must follow for their anticipated site to be approved, as put forth by the Norfolk District of the U.S. Army Corps of Engineers and the Virginia Department of Environmental Quality, and consideration of the impacts of sea level rise is not among the listed rules.

I propose that the Wetland Mitigation Checklist include a stipulation that the proposed bank site must not be projected to lose 5 percent or more of its ecological function due to sea level rise during the 50-year period following its establishment, using the Recurrent Flooding Study for Tidewater Virginia's "low" projection released in 2013.

This recommendation is logical, simple, cheap and easy to implement. Both the federal government and the state of Virginia are striving for 'no net loss' of wetlands and this is the way to help us achieve that far into the future. The issue of wetland mitigation banks failing to consider sea level rise when applying for new bank sites is already a recognized problem among wetlands experts. Skip Stiles, the Executive Director of Wetlands Watch, has urged the U.S. Army Corps of Engineers to reject permit applications for proposed bank sites in areas at high-risk for inundation for years.

Wetland mitigation bankers already perform extensive research in surveying where next to place a new bank, and data regarding projected sea level rise in the coming years is abundant and readily available. Thus it would not be a difficult task for them to calculate the risk of sea level rise affecting their prospective sites.

The addition of one requirement to the existing checklist that mitigation banks must follow would also be simple, entailing only an agreement by the relevant regulatory agencies that this additional condition makes sense and should be met. The necessary document of guidelines is already in use today, and would only need to be amended.

This proposal would require no additional funding and would be a one-time fix. The cost of this change would fall on the wetland mitigation banks, as they would likely face higher property costs. They would no longer being able to buy up properties whose value is rapidly decreasing due to frequent storm surges and other sea level rise-related problems, and this would raise their initial costs. As a result, credit cost may rise, shifting higher costs to the developers. If credits are deemed too expensive, developers may be more hesitant to take action that would damage wetlands and cause a need to purchase credits. In that sense, this recommendation protects wetlands from anthropogenic damage from the beginning.

Again, scientists have found that wetlands sequester carbon up to 50 times more efficiently than forests (Gallucci 2015). While the government recognizes the innumerable services performed by wetlands and has taken action to protect them, it must adjust the mitigation system to face new threats posed by climate change. Protecting wetlands from the greatest threats they faced decades ago will no longer be enough to ensure that these precious ecosystems survive.

This proposal requests the termination of the waste of time and money associated with creating new wetland mitigation banks in places they will not last. Both the United States and the Commonwealth of Virginia have explicitly stated that they are striving for ‘no net loss’ of wetlands, and this recommendation helps assure that their goal will be met far into the future.

Acknowledgements:

I would like to thank Dr. Tundi Agardy of Sound Seas, Skip Stiles of Wetlands Watch, Karen Duhring of the Virginia Institute of Marine Science, Nathaniel Carroll of Forest Trends, Palmer Hough of the Environmental Protection Agency and Aaron Revere of Falling Springs LLC for their time, guidance and support during the completion of this project.

Literature Cited

Bendor, Todd. 2007. A dynamic analysis of wetland mitigation process and its effects on no net loss policy. Landscape and Urban Planning 89(1-2): 17-27.

Dahl, Thomas E. 2000. Status and Trends of Wetlands in the Conterminous United States 1986- 1997. Onalaska (WI): US Fish and Wildlife Service.

DOD/EPA (Department of Defense & Environmental Protection Agency), 2008. Compensatory Mitigation for Losses of Aquatic Resources, Final Rule. http://water.epa.gov/lawsregs/guidance/wetlands/upload/2008_04_10_wetlands_wetlands_mitigation_final_rule_4_10_08.pdf, accessed March 14, 2015.

Ecosystem Marketplace: A Forest Trends Initiative. US Wetland Banking, Market Features and Rules. http://www.ecosystemmarketplace.com/pages/dynamic/web.page.php?section=biodiversity_market&page_name=uswet_market, accessed April 1, 2015.

EPA (Environmental Protection Agency), 2013. Wetlands-Status and Trends. http://water.epa.gov/type/wetlands/vital_status.cfm, accessed March 24, 2015.

Gallucci, Maria. 2015. Climate Change Solutions: Wetlands Are More Powerful In Fighting Climate Change Than Previously Thought. International Business Times.

Hansson, Lars-Anders, C. Bronmark, P. A. Nilsson, and K. Abjornsson. 2005. Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? Freshwater Biology 50(4): 705-714.

Keddy, P. A., L. H. Fraser, A. I. Solomeshch, W. J. Junk, D. R. Campbell, M. T. K. Arroyo, and C. J. R. Alho. 2009. Wet and Wonderful: The World's Largest Wetlands Are Conservation Priorities. BioScience 59(1): 39-51.

Kerr Environmental Services Corp. 2014. Pleasure House Point Mitigation Bank Final Prospectus. City of Virginia Beach.

Kirwan, M. L., G. R. Guntenspergen, A. D'Alpaos, J. T. Morris, S. M. Mudd, and S. Temmerman. 2010. Limits on the adaptability of coastal marshes to rising sea level. Geophysical Research Letters 37(23): 1-5.

Malmquist, David. 2013. VIMS calls for flexible, multi-step approach to deal with flood risk. Virginia Institute of Marine Science.

Mitchell, M., C. Hershner, J. Herman, D. Schatt, E. Eggington and S. Stiles. 2013. Recurrent Flooding Study for Tidewater Virginia. Center for Coastal Resources Management. Virginia Institute of Marine Science.

Nicholls, R. J., F. M. J. Hoozemans, and M. Marchand. 1999. Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environmental Change 9(1): S69-S87.

Revere, Aaron. President and General Manager, Falling Springs LLC, personal communication. April 3, 2015.

Stiles, Skip. Executive Director, Wetlands Watch, personal communication. March 31, 2015.

Tompkins, F. and C. Deconcini. 2014. Sea-level rise and its impact on Virginia. World Resources Institute.

USACE (U.S. Army Corps of Engineers) Norfolk District. 2008. Virginia Off-Site Mitigation Location Guidelines. http://www.deq.virginia.gov/Portals/0/DEQ/Water/WetlandsStreams/VA_Offsite_MitGuidelines.pdf, accessed March 10, 2015.

VA DEQ (Virginia Department of Environmental Quality). Mitigation http://www.deq.virginia.gov/Programs/Water/WetlandsStreams/Mitigation.aspx accessed March 24, 2015.

10. The Adopt-A-Wetland Program

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

Lindsey Hines
Environmental Studies and Leadership Studies Major, 2015.

Abstract

Wetlands are a "biological super system" hosting a vital reservoir of biodiversity potential. Conserving wetlands and protecting their biodiversity is instrumental in upholding the ecosystem services wetlands provide. These ecosystem services include flood control, food supply, clean water, and recreational areas. All act as major contributors to Virginia's economy (Hansson et al, 2005)

Current models projecting climate change impacts on the Virginian coastline predict sea-level rise to be incompatible with rate of migration and adaptation needed for wetlands. (Titus et al, 2009) Existing wetland conservation efforts lack the required action to combat these imminent problems, because land acquisition is imminent to their health and survival. The implementation of an Adopt-A-Wetland Program would accomplish this goal while increasing public awareness about wetland biodiversity.

The proposed program would focus on marketing strategies to persuade target parties such as fisheries, academia, similarly minded non-profits, individuals, and major corporations to "adopt" wetland areas by acquiring them. Coastal property is expensive. This program will capitalize on marketing strategies, the current trends of environmentally friendly consumer preferences (Chen and Chai, 2010), and stakeholders' interests in the health of local wetlands.

Introduction

The Issue: Wetland Loss

A wetland is defined under the Clean Water Act as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Wetlands generally include swamps, marshes, bogs and similar areas (epa.gov). Wetlands provide crucial ecosystem services to local regions (Hansson et al, 2005).

The types of ecosystem services can be broken down into four benefits categories; provisioning, supporting, regulating, and cultural. (Duhring, 2014) Provisioning benefits include providing habitat for an array of fish and wildlife. This includes many economically important species such as the blue crab and eastern oyster. Most importantly, 43% of threatened endangered species rely, either directly or indirectly, on wetland habitats. (Dahl, 2011) Supporting benefits include soil formation and nutrient cycling. Regulating benefits include pollution control through nutrient uptake and sediment trapping; flood regulating by reducing flood crests and flow rates; erosion regulating through the dissipated wave energy and soil stabilization; and finally greenhouse gas regulating through carbon sequestration. Lastly, cultural benefits include aesthetic and recreational enjoyment as well as economic benefits through commercial fishing.

According to the EPA's Virginia Wetland State Profile, wetlands originally covered 7% of the state and now they cover about 4%. There are 1 million acres of wetlands remaining. (epa.gov) This loss of wetlands is caused principally by land subsidence and climate change. Sea level has risen and fallen with a general pattern for the last 400,000 years due to rotations orbit and position to the sun. (World Resources Institute) Sea level rise is currently rising at a faster pace due to anthropogenic influences than previously seen. (Titus et al, 2009) Vertical accretion through sedimentation and peat formation had enabled wetlands to keep pace with the relatively slow rate of sea level rise during this time. (Titus, 2011) Now the mid-range estimate from the Old Dominion University study "Climate Change, Global Warming and Ocean Levels," is a 3.7-foot increase in local sea level by 2100 for Hampton, VA.

Wetlands are forced to "migrate" inland at a faster pace or risk being drowned. "Current trends suggest tidal marshes will not be able to maintain themselves at present and projected rates of sea level rise." (Davis, 2011) Not only are the wetlands unable to adapt to this increased rate of sea level but also due to human development and shoreline hardening there is no space for them to move to. "If landward margins are armored, effectively preventing inland migration, then wetlands could be lost if they are unable to accumulate substrate at a rate adequate to keep pace with future increased rates of sea-level rise." (Scavia et al, 2002)

The Solution: Land Acquisition

The future of wetlands and exactly how they will respond to sea level rise and other climate change effects can be projected but not definitively known. That is why the most practical and effective solution to mitigate the loss of wetlands is through land acquisition. Land acquisition is a direct way to ensure wetlands and the surrounding area are preserved from development. The majority of current conservation efforts in Virginia are focused on monitoring, assessing and promoting living shorelines. (Davis, 2011) There is no intensive pro-active government program that focuses on land acquisition for wetland conversation.

Recommendation

Adopt-A-Wetland Program

This "Adopt-a-Wetland" program is inspired by the well-known and successful (Sunderland et al, 2013) "Adopt-a-Highway" and "Adopt-a-Beach" programs. The central idea is to create a program that can capitalize on the persuasion tactics inherent to marketing strategies, the current trends of environmentally friendly consumer preferences, (Chen and Chai, 2010) and target parties' individual stake in the health of local wetlands. The proposed program would focus on marketing strategies to persuade suggested target parties of fisheries, academia, similarly minded non-profits, individuals, and major corporations to "adopt" wetland areas.

Structure

The program would be best integrated into the Virginia Marine Resources Commission. The VMRC, established in 1875, is one of the oldest agencies within the Virginia State government, and has managed the Virginia Wetlands Act since 1972. The program would be broken into three main divisions; environmental monitoring and assessment of wetland areas, marketing and new business, and administration. The new 2015 state budget, which goes into effect April 1, supplied the VMRC with sufficient funds to allow them to reduce the cost of recreational saltwater fishing licenses. (Ward and Bull, 2015) This suggests that it can accommodate additional costs such as the creation of the proposed program.

Purpose

The central purpose of the program is to acquire more land to preserve wetland migration, but its public education impact is important as well. Similar programs in Texas, Georgia and Delaware focus on active community outreach.

Delaware's Adopt-A-Wetland program is funded by grants from the U.S. Fish and Wildlife Service and the Environmental Protection Agency. (ELI, 2010) The goals of the program are to increase awareness, educate the public, and recruit volunteers to assist in monitoring and protecting. The program is also used to collect data on priority areas for the state to use in a larger, comprehensive plan. (ELI, 2010) The Environmental Law Institute's Delaware Wetland Program Review of 2010 highlights the need for increased collaboration of information collected to help better inform local governments land use decisions.

Georgia's coastal wetland programs conduct enforcement separately from the state's water quality programs and are quite active, performing regular overflights to locate and investigate possible violations to the state's coastal protection laws. (ELI, 2005) Georgia's Adopt-A-Wetland, which began in 2001, is a good example of creating a

successful public private partnership and building community responsibility for the care of local wetlands. (EPA, 2011)

Texas' program is primarily educational. The program was founded in 1991 with a central goal to encourage teachers to pro-actively use wetlands as a laboratory to increase awareness of the importance of wetlands. (EPA, 2001) The program earned the Gulf Guardian Award in 2001. The Gulf of Mexico Program Partnership developed the Gulf Guardian awards as a way to recognize and honor businesses, community groups, individuals, and agencies in their wetlands preservation work. (EPA, 2001)

These programs provide some cautionary guidance on how to efficiently share data with other agencies. Unlike this paper's proposal, they do not entail land acquisition along with increased community involvement and awareness. Virginia's marketing approach to an Adopt-A-Wetland program should use advertising and corporate engagement strategies. Certification programs, for example, could encourage schools to incorporate wetland conservation education and fieldwork projects into their curriculum.

Stakeholders

The party most likely to participate in the proposed program would be the fishing industry, due to their direct, financial connection to wetlands' health. Multiple studies gauge consumers' level of interest in projects by surveying their "willingness to pay." According to a study on wetland restoration efforts in Louisiana, increases in fisheries productivity is among the highest rated factors in overall willingness to pay for wetland restoration. (Petrolia et al, 2013) Wetlands are nurseries for aquatic species of immense ecological, cultural and economic importance. (Sheaves et al, 2015) In Virginia, wetlands act as breeding grounds and nursery areas for many species critical to the fishing industry such as blue crabs and menhaden. (U.S. Department of the Interior, 2010) The fishing industry in Virginia is one of the most important economic contributors. In 2004 recreational and commercial fishing contributed $1.23 billion in sales, $717 million in income, and more than 13,000 jobs in Virginia. (Kirkley, et. al. 2005) Purchasing a wetland provides the fishery with insurance and could create shared value through additional marketing tactics. (Porter and Kramer, 2011) For example, creating "responsible wetland conservation contributor" certification stickers for products to inform consumers of the respectful environmental responsibilities of the fishery.

Overviews of other target parties and why they would be interested in participating in such a program are as follows.

Research institutions and universities would be interested in purchasing wetland area to provide direct access for research opportunities, and help recruit students and faculty. (Lombardi et al, 2001)

Conservation non-profits may not be financially inclined to purchase a wetland but partnerships could be developed to create shared value via research and volunteer efforts. (Porter and Kramer, 2011)

Individual efforts could participate. In an effort to fund a large-scale restoration project in the Barataria-Terrebonne National Estuary in coastal Louisiana a study was conducted in 2011 to estimate individuals' willingness to pay. The survey estimated the mean willingness to pay for an intermediate-scale restoration program ranges between $909 and $1751 per household. (Petrolia et al, 2013)

Crowdsourcing via various social media platforms could spread awareness of the program across the state. Incentives could be put in place such as a free t-shirt, toy stuffed animal, or Chesapeake Bay Foundation license plate. Another approach to attract more involvement could be setting up a tracking/adopting of a charismatic wetland species.

Due to increased pressure from government regulations, activists, and media, major corporations often perceive the need to make social responsibility a priority. (Porter and Kramer, 2006) The National Fish and Wildlife Foundation (NFWF) already has a collection of established corporate partners including Altria, Bank of America, Monsanto, and others. (NFWF, 2015)

Success factors

Market research shows that "green" marketing is a profitable and increasingly popular business move. (Smith and Perks, 2010) Resource Advantage Theory (R-A theory) says that a firm can sustain a competitive advantage if it continually strives to meet and exceed customer expectations; today environmentally friendly projects are part of consumer's expectations. (Richey, 2012) The target parties listed above all have some kind of "stake" in conserving wetlands. This will cause them to have initial interest (Bryson, 2004) then through client meetings, research etc. an individualized plan can be worked out with a party to ensure their wetland purchase is a "win-win" endeavor.

Second, Virginia is primed for such a program focus due its proximity to the Chesapeake Bay. Awareness about environmental conservation, specifically wetlands, will positively influence behavior towards positive action. (Forsyth et al., 2004), and strong background knowledge is likely to boost support.

Third, this proposal combines government regulation and business interests, which suggests clearer communication to non-scientists -- typically lost in environmental regulations. (Bickford, 2012) This communication can lead to more efficient solutions and more probable success. (Porter and Kramer, 2011)

Conclusion

The stress of sea level rise and human development is drowning Virginia's wetlands. Conserving wetlands and protecting the biodiversity they host is instrumental in upholding the beneficial ecosystem services provided. Land acquisition ensures direct control over conservation. The proposed Adopt-A-Wetland program offers a spin on an old name. The program engages conservation efforts, with direct community involvement, and stakeholder economic interests creating a cohesive movement to save our wetlands. Virginia has the opportunity to be the front-runner in a new type of land acquisition with the use smart business strategy, persuasive marketing, and effective governance.

Acknowledgements:

Special thank you to Tom Smith, Natural Heritage Director, for inspiring me to see importance in land acquisition. Dr. Tim Hamilton, Assistant Professor of Economics at University of Richmond, for offering advice on quantifying ecosystem services. My classmates for editing, revising and questioning my idea to mold it into what it is now.

Literature Cited

Bickford, David, M Posa, L Qie, A Campos-Arceiz, E Kudavidanage. Science Communication for Biodiversity Conservation. *Biological Conservation.* 151 74-76

Bryson, John. 2004. What to Do When Stakeholders Matter. *Public Management Review*,6.

Chen, Tan and Chai, Lau. 2010. Attitude Towards the Environment and Green Products: Consumers' Perspective. *Management Science and Engineering.* 4, 2

Dahl, T.E. 2011. Status and trends of wetlands in the conterminous United States 2004 to 2009. U.S. Department of the Interior; Fish and Wildlife Service, Washington, D.C.

Davis, David. 2011. Comprehensive Wetland Program Plan Commonwealth of Virginia 2011- 2015) Virginia Department of Environmental Quality

Duhring, Karen. 2014. The Ecosystem Services of Wetlands, The Wetland Summit. http://www.thewetlandsproject.org/wp-content/uploads/2014/05/The-Ecosystem-Services-of-Wetlands.pdf

Environmental Law Institute (ELI) 2010. Delaware Wetland Program Review. http://www.dnrec.delaware.gov/Admin/DelawareWetlands/Documents/ELI%20Delaware%20Wetland%20Review.pdf

Environmental Law Institute (ELI) 2005. State Wetland Program Evaluation, Phase 1. http://www.eli.org/sites/default/files/eli-pubs/d15_06.pdf

EPA. 2011. Georgia EPD Wetland Program Plan 2011 – 2016. http://water.epa.gov/type/wetlands/upload/ga-wpp-2011.pdf

EPA. 2001. Adopt-A-Wetland Program Earns Gulf Guardian Award. http://www.epa.gov/gmpo/pubinfo/adoptwetland.html

Forsyth, D, M Garcia, L Zyzniewski, P Story, N Kerr, 2004. Watershed Pollution and Preservation: The Awareness-Appraisal Model of Environmentally Positive Intentions and Behaviors. *Analyses of Social Issues and Public Policy*, 4, 1

Hansson, Lars-Anders, C Bronmark, P Nilsson, and K Abjornsson. 2005. Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? *Freshwater Biology* 50, 705–714

Kirkley, et. al. 2005. Economic Contributions of Virginia's Commercial Seafood and Recreational Fishing Industries: A User's Manual for Assessing Economic Impacts. Virginia Institute of Marine Science (VIMS), VIMS Marine Resource Report No. 2005-9

Lombard, John, D Craig, E Capaldi, D Gater, S Mendonça. 2001 Quality Engines: The Competitive Context for Research. *The Top American Research Universities*. An Annual Report from The Lombardi Program on Measuring University Performance University Performance

NFWF, 2015. Corporate Partners. *National Fish and Wildlife Foundation* http://www.nfwf.org/partnerships/corporate/Pages/corporatepartnerlist.aspx#.VS07AvnF_aN

Petrolia et al, 2013. America's Wetland? A National Survey of Willingness to Pay for Restoration of Louisiana's Coastal Wetlands. Department of Agricultural Economics Mississippi State University

Porter, Michael and Kramer, Mark. 2006. Strategy and Society: The Link Between Competitive Advantage and Corporate Social Responsibility. *Harvard Business Review*

Porter, Michael and Kramer, Mark. 2011. The Big Idea: Creating Shared Value. *Harvard Business Review*

Richey, Robert, C Musgrove, S Gillison, C Gabler, 2014. "The effects of environmental focus and program timing on green marketing performance and the moderating role of resource commitment" Industrial Marketing Management 43, 7.

Scavia, Donald, C. Field, John, F. Boesch, Donald. 2002. Climate Change Impacts on U.S. Coastal and Marine Ecosystems. *Estuaries* 25,2

Sheaves, Marcus, R Baker, I Nagelkerken, R Connolly. 2015 True Value of Estuarine and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics. *Estuaries and Coasts* 38:401–414

Smith, E.E and S Perks. 2010. A Perceptual Study of the Impact of Green Practice Implementation on the Business Functions. *South African Business Review,* 14, 3.

Stull, Michael. 2009. *Balancing Market and Mission: A Nonprofit Case Study. The Business Renaissance Quarterly*: Enhancing the Quality of Life at Work
Sunderland, Valerie, K O'Neil, K Harrington-Hughes. 2013. TRCP Synthesis 103, Transit Station and Stop Adoption Programs. Transit Cooperative Research Program.

Titus, James. 2011. Rolling Easements. Climate Ready Estuaries, EPA

Titus, James, et al. 2009. State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level Along the US Atlantic Coast. Environmental Research Letters, 4.

U.S. Department of the Interior. 2010. Landscape Conservation and Public Access in the Chesapeake Bay Region. A Revised Report Fulfilling Section 202(e) of Executive Order 13508.

Ward, Molly and Bull, John 2015. Memo: The Virginia Marine Resources Commission has decided to reduce the cost of recreational saltwater fishing licenses, effective April 1.

11. Virginia's Chesapeake Bay, an Oyster Sanctuary

NATURE, VIRGINIA'S ECONOMY, AND THE CLIMATE THREAT
Richmond, Virginia; April 21st 2015

C. Andrew Denney
Environmental Studies and French Major, 2015.

Abstract

The population of the Easter oyster, *Crassostrea virginica,* in the Chesapeake Bay is now 1 percent of what it was during the 19th century (Kimmel et al. 2007). This decline is the result of various harmful effects such as disease, nutrient pollution, hydrological change, habitat loss and over-harvesting (Ermgassen et al. 2013), and is further threatened by warming temperatures associated with climate change and acidification via atmospheric greenhouse gas intensification.

C. virginica can recover and in addition help mitigate damage to the health and biodiversity of the Chesapeake Bay as climate change advances. The biodiversity of the Bay is directly correlated with oyster populations. Oysters provide reef habitat and water filtration for the Bay, so it is an especially effective species to mitigate acidification and species loss from climate change.

In order to recuperate Eastern Oyster populations in the Bay, this recommendation proposes that Virginia expand its oyster sanctuary by 9,000 acres, matching Maryland's sanctuary expansion in 2009. The costs of sanctuary establishment are minimal, but two possible funding sources are also proposed. The economic and ecological value returned to the region by healthy oyster reefs far surpasses the restoration costs in one to five years.

Introduction

Crassostrea virginica, our native Eastern Oyster, has seen a dramatic decrease in population levels that are now less than 1 percent of what they were in the late 19th century (Kimmel et al. 2007). The great Eastern Oyster reefs were once so abundant that they defined the Bay's ecosystem as a whole; they reached from the inlets of the James River past the mouth of the Chesapeake Bay and out into the Atlantic Ocean, a common nuisance for local boatmen.

Oysters around the world have declined by 85 percent, making oyster reefs the most imperiled marine habitat in the globe (Pelley 2009). In the USA alone, estimates

suggest that oyster reef extent declined by 64 percent and loss of oyster biomass amounted to 88 percent between the early 1900s and early 2000s (Ermgassen et al. 2013).

The output of atmospheric carbon dioxide through the burning of fossil fuels, a cause of climate change, will be a primary contributor to the future loss of oyster populations and their stability. As atmospheric carbon dioxide mixes into the Chesapeake's waters, a decrease in pH -- acidification -- occurs, which in turn alters shell formation rates, energy usage, and ultimately, the growth and survival of oyster larvae (Barton et al. 2012).

The destruction of oyster populations to date can be attributed to a combination of factors such as habitat destruction, overfishing, disease, reduced water quality. The Eastern Oyster is a keystone species on which other species depend. The loss of oysters translates into a loss of both critical habitats for marine species and a species that actively cleans the water of nutrients and pollution (Pelton and Goldsborough 2010).

The biodiversity of the Bay and the health of the oyster reefs are directly related. And as water becomes increasingly saturated with carbon dioxide, larval recruitment is less effective and thus decreases overall population (Hennige et al. 2014).

Ecologically, oysters filter water and act as a “natural water treatment”, provide habitat for an abundance of marine species, help to enhance fish production, sequester nitrogen, and control erosion (Pelley 2009). The oyster population is an economic asset to Virginia as a fishery resource, amounting to over 22 million dollars’ in 2010 (Hudons an Murray 2014).

Yet, this pales in comparison to the economic value that can be assigned to the ecosystem services that the *C. virginica* population provides for the Chesapeake Bay area. This accelerated loss of many habitats since the industrial revolution is widely documented but the ecological and economic ramifications of the loss have only recently gained recognition (Ermgassen et al. 2013).

In 2010, when Governor O’Malley announced the project, he said that “...the citizens of Maryland are becoming united in the view that we need to change course and take bold action to rebuild our oyster population - both for their ecological values and for the jobs and economic impact than an expanded aquaculture industry will provide for Maryland families for generations to come” (O’Malley 2010). Now is the time for Virginians to take substantial steps toward preservation and restoration.

This recommendation proposes that Virginia increase its oyster sanctuary network to 9,000 acres of remaining oyster bar habitat, matching Maryland’s expansion in 2009. Virginia currently has over a hundred sanctuaries but most are less than two acres (Pelton and Goldsborough 2010). Major expansions are necessary. Maryland sanctuaries have shown significant oyster population increases (Maryland Department of Resources 2014), indicating a strong model for Virginia to emulate.

Oyster Disease

Two protozoan (single-celled) parasites, *Perkinus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX), are major sources of oyster mortality in the Chesapeake (Chesapeake Bay Oyster Management Plan, 2004). Environmental conditions such as salinity and temperature affect the distribution, abundance, intensity and number of affected hosts of these parasites. Generally, low salinity (<12 ppt) areas experience low oyster population recruitment rates because salinity affects the production of gametes, larvae growth, and shell creation. Mid-salinity areas (12-14 ppt) are variable with climate fluctuations; in wetter periods, survival is generally higher but spat settlement and growth are poor, but during drier periods, the opposite is true.

Data shows us that oyster populations experience occasional sharp drops in infection rates during wetter periods when excess freshwater runoff lowers Bay salinity (Carnegie and Burreson 2009). Higher salinity areas (>14 ppt) tend to have a larger number of young or small oysters because population recruitment is much higher, however, fewer individuals survive to adulthood or are capable of producing appropriate shells (Chesapeake Bay Oyster Management Plan, 2004).

In 2004, *P. marinus* was present in all productive oyster grounds in the Chesapeake. Despite an increase in the abundance of disease-causing parasites in the Bay, research from VIMS shows that Chesapeake Bay oysters are increasingly showing more resistance to both *P. marinus* and *H. nelsoni* (Carnegie and Burreson 2009).In turn, improved growth can be realized through the development of stable oyster communities (which allows for disease resistant individual oysters to pass on their resistance).

Ocean Acidification

Today excess carbon dioxide, the dominant source of global climate change, dissolves into ocean waters and is converted into carbonic acid. This change in ocean waters is called acidification. Many studies show that acidification threatens shellfish. While emissions continue to rise, oceans will also continue to become more acidic, irreparably damaging our marine environments and bivalve populations (Talmage 2010).

When introduced to ocean or brackish Bay waters, carbon dioxide reacts with water molecules and forms the ‘weak’ acid known as carbonic acid; carbonic acid dissociates into hydrogen and bicarbonate ions. In turn, the increase in hydrogen ions reduces pH and the brackish Bay water becomes acidified (Raven et al. 2005).

In order to build their shells, oysters extract calcium and carbonate ions from seawater to combine and form crystallized calcium carbonate, the primary component of the shell. Increased acidity in Bay waters will make it more difficult for oyster larvae to extract the negatively charged carbonate ions because the positively charged hydrogen ions tend to bond with them, making them useless to *C. virginica* (Raven et al. 2005).

Yet, positive feedback has been identified between shell aggregations and healthy bivalve populations in temperate estuaries; this reveals a correlation between shell creation and alkalinity cycling (Waldbusser et al. 2013). Healthy filter-feeding populations couple the production of organic rich waste with the precipitation of calcium carbonate minerals in order to create favorable conditions for alkalinity regeneration.

Although the dynamics of bivalve shell creation have yet to be well understood, the Waldbusser et al. study suggests that oyster shell reefs act as an alkalinity sink, thus buffering the increasingly problematic effects of acidification. This study also estimated that current oyster populations now only contribute around 4 percent of Baywide acidity buffering; they were responsible for about 70 percent of Baywide acidity buffering in 1870 (Waldbusser et al. 2013).

Alkalinity in Bay waters is also integral to the health of most Bay species. It can best be summed up in the words of researcher Roger L. Mann: "As ocean water becomes more acidic, oyster shells begin to dissolve into the water, slowly releasing their calcium carbonate—an alkaline salt that buffers against acidity. An oyster reef is a reservoir of alkalinity waiting to happen." The preservation of Eastern Oyster communities is essential for the success of maintaining and recovering the alkalinity of the Bay.

Water Quality Protection and Restoration

The Eastern Oyster is negatively impacted by low water quality. Sedimentation, turbidity, and anoxic conditions are several key components of water quality (Chesapeake Bay Management Plan, 2004). The natural aging process of the Chesapeake Bay has been accelerated by human activity in its watershed. Humans are artificially introducing and steadily increasing sediment and nutrient loads delivered to the Bay (Bricker et al. 2014). These artificially introduced nutrients foster algal blooms which inhibit sea grasses to receive proper light, smother benthic species , and decrease dissolved oxygen levels (Bricker et al. 2014).

Historically, oysters were capable of improving water quality by means of filtering sediments and phytoplankton from the water column, thus having the opposite effect of algal blooms (Grabowski et al. 2012). However, the decline of oyster populations has led to higher concentration of sediments and phytoplankton in the water column. A recent study conducted throughout thirteen Gulf coast estuaries estimated the volume of water filtered by oyster populations under natural field conditions. It revealed that the filtration capacity of Eastern Oysters has declined, almost universally, by a median of 85 percent. Historically, oyster populations were successful in filtering their respective estuaries (a volume equivalent or greater than the volume contained by their estuary, within the residence time of water) (Ermgassen et al. 2013).

The decrease in water-treatment capacity can be attributed to the difficulties posed by unstable populations and record-low water quality. Nonetheless, the hardy Eastern Oyster is capable of overcoming these problems by means of filter-feeding,

thereby reducing eutrophication within the Bay. At current levels, the positive effect of bivalve filter feeding is minimal. Still, it is abundantly clear that *C. virginica* is capable of providing a valuable ecosystem service and by doing so, fosters biodiversity within the Bay.

Solution: Costs, Funding, and Benefits

In order to aid *Crassostrea virginica* and the Chesapeake Bay, this proposal seeks to create and sustain 9,000 acres of healthy Eastern Oyster habitat accordant with Maryland's 2009 sanctuary expansion of 9,000 acres. These areas will be considered 'no-take' zones where oyster harvesting is strictly forbidden. Virginia must coordinate with and follow Maryland's successful efforts in order to ensure effective and efficient sanctuary increase.

Enforcing the protection of these sanctuaries would fall under the Virginia Marine Police who are currently responsible for protecting oyster sanctuaries in Virginia's Chesapeake Bay. It will not be necessary to increase funding in order to maintain the enforcement of sanctuary policy.

The management of these sanctuaries would be handled by the Virginia Marine Resources Commission (VMRC) which would enlist the aid of multi-partner groups such as the Chesapeake Bay Program (CBP), the Virginia Oyster Heritage Program (VOHP), and the Chesapeake Bay Commission (CBC) as well as other non-profit partners.

Costs assumed by these agencies would come from the steps necessary to establish oyster sanctuary: identifying appropriate oyster bottom, establishing quality habitat with suitable clutch material and substrate, prohibiting shellfish harvest and enforce prohibition, maintaining suitable oyster production in the face of low water quality and disease and monitoring the state of protected oyster reef. (CBMP, 2004). The data demonstrates that environmental factors affect oysters physiological activities and larvae recruitment on a seasonal basis, a factor that is integral in selecting appropriate oyster sanctuary (Mann 2014).

If the oyster sanctuaries need maintenance and restoration in order to meet the criteria above, the cost of restoration per hectare of oyster ranges from $52,000 to $260,000: (2.47 acres to 1 hectare) ranging from $21,052 to $105,263 (Grabowski et al. 2012). One study by the Virginia Oyster Reef Heritage Foundation placed it at an average cost of $14,800 per acre, however, considering newer evaluations, the costs have gone up and may continue to do so (Hicks et al. 2004).

If every acre of sanctuary needs to be restored, using the Grabowski estimates, these costs could range from $189,468,000 to $947,367,500. The most commonly used form of oyster population restoration known to date is spat-on-shell cultivation. The main advantage of spat-on-shell cultivation is that it requires less labor and fewer materials

than single-oyster cultivation, thereby making it a more economically feasible option for producing large quantities of oysters (Hudson and Murray, 2014).

Two funding sources would have minimal to zero impact upon commercial fisheries. The state of Virginia could place a $0.10 tax on the 31 million individual oysters that Virginians eat each year, realizing $3.1 million dollars. In addition, the state of Virginia could raise the Potomac River Fisheries Commissions inspection tax from $1.5 to $2 per bushel identically to Maryland's Legislation HB 357/SB 344 PRFC Inspection Tax and Penalty. The Virginia Farm Bureau reported that the 2014 harvest topped 500,000 bushels. This would raise the realized taxes of inspections from $750,000 to $1,000,000 per year.

In the fiscal year 2009, the Virginia Department of Environmental Quality (VDEQ) water protection program totaled in $18,689,061. (McIlmoil et al. 2012). This program's Bay-associated costs could be diminished by fostering oyster growth and allowing the species to mitigate cleanup costs.

According to conservative estimates, the economic value of oyster reef services as described above, excluding oyster harvest, ranges from $5,500 to $99,000 per hectare per year: (2.47 acres to 1 hectare) ranging from $2,226 and $40,080 per acre per year (Grabowski et al. 2012). These profits per acre will only be realized when reefs recover their median restoration cost in 2-14 years (Grabowski et al. 2012). These potential profits will only be realized if the oyster reefs are not harvested.

The most valuable service provided by oyster reefs is shoreline stabilization, a service that is extremely sensitive according to the location of any given oyster reef, creating the significant range in oyster reef service evaluations. The potential economic benefits of 9,000 acres of sanctuary after 2 years could range from $40,068,000 to $721,440,000. The potential economic benefits after 14 years could range from $280,656,000 to $5,050,080,000 (calculated using values from Grabowski et al. 2012).

If restoration efforts were to become necessary for every acre of established sanctuary, the economic benefit from ecological services could exceed the costs of restoration in one to five years. In conclusion, if we are to realize that the benefits far outweigh the costs, then acidification will be mitigated and the biodiversity of the Chesapeake Bay will become increasingly secure.

Acknowledgements:

I would like to acknowledge the encouragement of Karen A. Duhring, VIMS Marine Scientist Supervisor. I would also like to thank Dr. Mann, Professor of Marine Science at VIMS and Ms. Southworth, Marine Scientist Senior at VIMS, who provided insight and expertise that greatly assisted in the research of this paper.

Literature Cited

Barton Alan, Hales Burke , Waldbusser George G., Langdon Chris , Feely Richard A., (2012), The Pacific oyster, *Crassostrea gigas*, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects, Limnology and Oceanography, 57, doi:10.4319/lo.2012.57.3.0698

Bricker, Suzanne B., Karen C. Rice, and Owen P. Bricker, III. "From Headwaters to Coast: Influence of Human Activities on Water Quality of the Potomac River Estuary." USGS Publications Warehouse RSS.

Carnegie, R., Burreson, E.M. 2009. "Status of the major oyster diseases in Virginia 2006-2008. A summary of the annual oyster disease monitoring program." Virginia Institute of Marine Science Marine Resource Report (2009).

Chesapeake Bay Oyster management plan 2004. adopted pursuant to Natural Resources Article, §4-215, Annotated Code of Maryland and Code of Maryland Regulations (COMAR) 08.02.01A directs the Department to establish oyster sanctuaries under Strategy 4.2. The authority of the Department to establish and regulate opening andclosing of Harvest Reserves as a fisheries management tool exists under NaturalResources Article §4-1009.1 of the Maryland Annotated Code and COMAR 08.02.04.14.
http://www.chesapeakeBay.net/content/publications/cbp_12889.pdf

Ermgassen, Philine S. E., Mark D. Spalding, Raymond E. Grizzle, and Robert D. Brumbaugh. "Quantifying the Loss of a Marine Ecosystem Service: Filtration by the Eastern Oyster in US Estuaries." Estuaries and Coasts 36.1 (2013): 36-43. Web.

"Governor McAuliffe Announces Virginia Oyster Harvest Are on the Rise." Virginia.gov. N.p., 21 July 2014. Web.

Grabowski, Jonathan H., Robert D. Brumbaugh, Robert F. Conrad, Andrew G. Keeler, James J. Opaluch, Charles H. Peterson, Michael L. Piehler, Sean P. Powers, and Ashley R. Smyth. "Economic Valuation of Ecosystem Services Provided by Oyster Reefs." *BioScience* 62.10 (2012): 900-09.Web.

Hennige, S. J.M. Roberts, and P. Williamson, eds. "Secretariat of the Convention on Biological Diversity." *An Updated Synthesis of the Impacts of Ocean Acidification on Marine CBD Technical Series No. 75.* (2014): 75-99. Web

Hicks, R. Haab, T.Lipton, D. “The Economic Benefits of Oyster Reef Restoration and Marine Preserve Establishment in the Lower Chesapeake Bay” *Chesapeake Bay Foundation*, 2004

Hudson, Karen, and Thomas J. Murray. *Virginia Shellfish Aquaculture Situation and Outlook Report*. Rep. Williamsburg: William and Mary, 2014. *VIMS*. Web

Kimmel, David G., and Roger I. E. Newell. "The Influence of Climate Variation on Eastern Oyster (Crassostrea Virginica) Juvenile Abundance in Chesapeake Bay." Limnology and Oceanography 52.3 (2007): 959-65. JSTOR. Web.

Kirkley, J. 2009. The NMFS Commercial Fishing & Seafood Industry Input/Output Model (CFSI I/O Model). Prepared for the National Marine Fisheries Service (NMFS). Virginia Institute of Marine Science. August 2009. 30 pp.

Maryland. Department of Natural Resources. *Maryland’s Oyster Population Continues to Improve, Highest since 1985*. By kking. n.p., 7 Apr. 2014. Web.

Mann, Roger, and Melissa Southworth. “The Status of Virginia’s Public Oyster 2013.” *Annual Report* (2014): Web.

McIlmoil, Rory, Laura Hartz, Anne Hereford, and Evan Hansen. “The Impact of Coal on the Virginia State Budget.” *Downstream Strategies* (2012): n. pag. Web.

O’Malley 2010. Governor Martin O’Malley’s Oyster Restoration and Aquaculture Development Plan Proposed Regulations, 2010.

Pelley, Janet. "Ecosystem Services on the Half-Shell." Frontiers in Ecology and the Environment 7.6 (2009): 293. JSTOR. Web. 15 Feb. 2015.

Pelton, Tom, and Bill Goldsborough. On the Brink: Chesapeake’s Native Oyster What It Will Take It Bring Them Back. Rep. Chesapeake Bay Foundation, July 2010. Web

Raven, J., Caldeira, K., Elderfield, H., Hoegh-Guldberg, O., Liss, P., Riebesell, U., ... & Watson, A. (2005). Ocean acidification due to increasing atmospheric carbon dioxide. The Royal Society

Talmage, Stephanie C. "Effects of Past, Present, and Future Ocean Carbon Dioxide Concentrations on the Growth and Survival of Larval Shellfish." Proceedings of the National Academy of Sciences of the United States of America 107.40 (2010): 17246-7251. JSTOR. Web. 15 Feb. 2015.

Waldbusser, George G., Powell, Eric N., Mann, Roger. “Ecosystem effects of shell aggregations and cycling in coastal waters: an example of Chesapeake Bay Oyster Reefs.” Ecology 94:895-903. http://dx.doi.org/10.1890/12-1179.1

Worm, B., E. B. Barbier, N. Beaumont, J. E. Duffy, C. Folke, B. S. Halpern, J. B. C. Jackson, H. K. Lotze, F. Micheli, S. R. Palumbi, E. Sala, K. A. Selkoe, J. J. Stachowicz, and R. Watson. "Impacts of Biodiversity Loss on Ocean Ecosystem Services." *Science* 314.5800 (2006): 787-90. Web.