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Sustainable Decision-Making to Address the Nexus on Water Quality and Food Production.

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ABSTRACT

Information needs and response options for watershed protection and restoration incorporates integrated storm-water management so as to improve the environmental footprint of cities by controlling pollutants. The challenge of protecting and restoring our nation's water resources is exacerbated by climate variability and change which further complicates efforts to protect and enhance water quality. Projected changes in temperature and rainfall patterns may diminish water quality by impacting stream flow, thus altering the concentration and mobility of nutrients and sediments into surface waters. To make informed decisions about storm-water runoff control, policy-makers will need timely and useful information about the possible consequences, associated risks, and available policy options. For policy makers at the local level, the implementation of ordinances offers integrated water pollution strategies aimed at minimizing storm-water runoff and improving the quality of surface waters. This study utilized a multimode survey approach assess the knowledge, perceptions and adherence of a stratified sample of residents in the Chesapeake and Virginia Beach areas to local fertilizer ordinances, and their willingness to support proposed environmental regulations that seek to address the declining water quality of the Chesapeake Bay. The survey instrument was employed to collect data on the extent of fertilizer use, irrigation and fertilizer practices, awareness of local fertilizer ordinances, decision-making influences with respect to fertilizer application, and motivators for residential maintenance decisions. Response options should be modified to include investments in research to reduce key policy-relevant uncertainties, and measures to adapt to a changing climate in order to increase society's resilience to climate change. As a result, research of this nature will help policy makers and practitioners make well-informed decisions regarding watershed protection and restoration thus limiting current and future vulnerabilities.

Introduction

Storm-water runoff is one of the fastest growing sources of pollution and a major contributor to the declining health of surface waters in the United States. In urban and residential landscapes, storm-water runoff is a primary stressor on surface waters, and resource managers concerned with water quality protection in these areas must deal with the adverse impacts of polluted runoff. As such, a key initiative of water pollution management by municipalities nationwide is minimizing non-point source pollution (NPS) from impervious surfaces and reducing the impacts on waterways. Impaired water quality can be attributed to urban development, poor water management, economics and agricultural practices (Zia et. al., 2013), which poses huge challenges for stakeholders, planners, and policy makers in their efforts to regulate NPS pollution. The detrimental effects of urbanization on watershed areas have prompted the adoption of Best Management Practices (BMPs) and policies that seek to mitigate non-point source pollution, control storm-water runoff, and thus protect water quality. Urban and residential sources present potential storm-water and non-point source pollution challenges and pose significant threats to the health of water bodies as pointed out by Stenstrom and Strecker (1993), in that "runoff from urban activities has been estimated to account for substantial proportions of the total mass of pollutants in some receiving waters."

The Chesapeake Bay is the largest estuary in the United States *(Figure 1)* stretching 64,000 square

miles, about 195 miles in length, and between four to thirty miles in width at different intervals (United States Geological Survey, 2000). As with most large lake systems, water quality in the Chesapeake Bay is largely determined by the quality of surface runoff from its contributing watersheds. The water quality in a watershed is not only altered by natural elements, but also by anthropogenic actions (Debrewer et al., 2000). Human activities such as land clearing, construction, agricultural practices, industrial processes, the altering of wetlands, and the creation of impervious surfaces give rise to increased pollution and storm water runoff that contribute to the diminished water quality of the Chesapeake Bay.

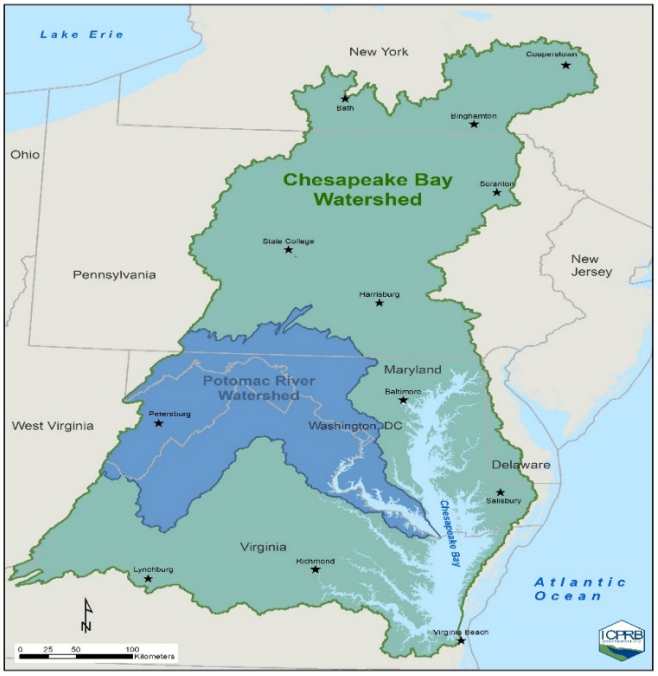

Figure 1: Chesapeake Bay Watershed www.potomacriver.org/focus-areas/water-quality/icprb-and-the-chesapeake-bay/

1.1 Impervious Surfaces

Urban development in the Chesapeake Bay watershed continues at a rapid pace and runoff from impervious surfaces in these watersheds continues to be a major cause of degradation to freshwater bodies and estuaries, including the Chesapeake Bay. The watersheds of urbanized residential and commercial regions are increasingly becoming degraded environments, and the Chesapeake Bay watershed is no exception. Residential development produces large scale pollution stemming from the use of fertilizers, pesticides, and other hazardous household chemicals. Williams et al., (2003) from the Alabama Cooperative Extension System, asserts that lawns and gardens are huge contributors of non-point source pollution which are increasingly flowing into our water resources. The excessive application of fertilizers and pesticides to lawns, gardens and other facilities such as golf courses can contaminate surface waters through different pathways such as: direct surface runoff, seepage through soil, and percolation into wells and groundwater.

1.2 Water quality and impacts on fertilizer use and food production

Weather fluctuations give rise to water availability which have profound effects on agricultural productivity, water resources, energy (hydroelectric power) production, human health and food production. Routine and extreme weather-related events are of primary concern to water quality as the frequency and magnitude of high temperature extremes, coupled with more frequent and intense heavy precipitation events impact the healthy functioning of watersheds. These events have induced unprecedented algae outbreaks, increased the amount of runoff into rivers and lakes, and intensified saltwater intrusion into freshwater areas and coastal groundwater due to rising sea levels. Furthermore, projected changes in temperature and rainfall patterns may diminish water quality by impacting stream flow, thus altering the concentration and mobility of nutrients and sediments into surface waters.

Hot and dry weather conditions often result in poor nutrient uptake, reduced leaching and denitrification, and decreased forage yields which have grave implications for fertilizer usage. Higher rates of residual soil nitrates occur due to decreased downward movement of soil water, and reduced nitrate uptake by drought-affected plants. Subsequently, increased fertilizer application typically occurs so as to maximize agricultural production, for maintaining residential lawns and gardens, upkeep of sporting fields and golf courses, and other landscaping activities. During extreme weather conditions, pollutants from a variety of non-point sources such as impervious surfaces, lawns, and agricultural lands accumulate on land and are eventually transported into lakes, rivers, streams, wetlands and estuaries, thus resulting in the declining water quality of these surface waters. Water shortages also pose tremendous challenges for

policy makers and economists alike, thus the availability of water as well as improved water quality to meet current and future needs for agriculture, food production, industry, and human consumption have gained increasing attention by lawmakers worldwide.

Materials and Methods

2.1 Study Site

The population sample is a statistical representation of the Tidewater (coastal) region, a geographic area in the eastern portion of the Commonwealth of Virginia *(Figure 2).* Participants were selected from the Chesapeake and Virginia Beach areas, both independent cities included in the Hampton Roads metropolitan area. The city of Chesapeake incorporates many square miles of protected farmland, forests, and wetlands, and comprises the northeastern portion of the Great Dismal Swamp National Wildlife Refuge. East of Chesapeake, Virginia Beach is the largest city in the state of Virginia by total area and the third-largest city by land area. A major portion of the city drains to the Chesapeake Bay by way of the Lynn haven River and its tributaries. The topography of the Tidewater region is characterized by low, flat coastal plains or flat lands originating at the Atlantic Coast and extending inland to the Fall Line.

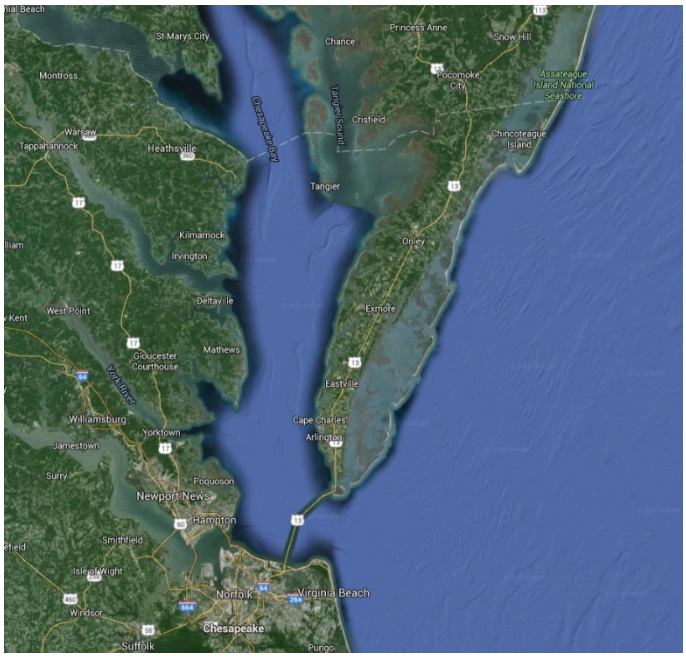

Figure 2: Tidewater Region, Virginia www.google.com/maps/place/Chesapeake/VA

2.2 Data Collection

A multimode survey approach was utilized for this study which was administered to a stratified sample of residents in the Chesapeake and Virginia Beach areas to determine the extent of fertilizer use and level of homeowner support for proposed ordinances. In designing the methodology, scientific and factual information pertaining to the Chesapeake Bay watershed, pollutants contributing to pollution in the watershed, possible pollution sources and management practices, as well as other pertinent information were collected and combined to assist in the development of the survey.

The survey instrument was designed using the online Qualtrics software, and was tested and validated by an expert panel of representatives from Florida Agricultural and Mechanical University and Virginia State University, and was determined to be a Minimal Risk project by the Institutional Review Board (IRB) at Florida Agricultural and Mechanical University. The participants were recruited from a directory provided by the Virginia Department of Environmental Quality and from online listings of local homeowners' associations. The purpose of the survey instrument was to develop questions to elicit responses regarding current irrigation and fertilizer practices, awareness of local fertilizer ordinances, decision-making influences with respect to fertilizer application, motivations for residential maintenance decisions, concerns regarding declining water quality, and support for existing and proposed fertilizer ordinances.

3. Results

3.1 Homeowners' concerns of water quality issues

Deteriorating water quality has become a global issue of concern as land use transitions increases, anthropogenic activities multiply, and urban and residential activities expand. The most prevalent water quality issue is the over-enrichment of surface waters due to excessive inputs of nutrients (eutrophication) which significantly impairs beneficial uses of water. Survey results revealed that most residents were concerned about the declining water quality of the Chesapeake Bay and other waterbodies in their region. Similarly, many residents were also concerned about the impacts of excessive fertilizer practices that contributed to the

over-enrichment of nutrients in the Chesapeake Bay. These responses indicated that respondents in the Chesapeake Bay watershed are concerned with pollution in the water channels and consider restoration efforts to be a well-needed and vital venture. However, this concern is not often complemented with comparable levels of environmental stewardship, as residents may not necessarily adopt new practices and behaviors that contribute to minimizing non-point source pollution. Water pollution policies incorporate different management methods that seek to control the discharge of pollutants into various water bodies. Such policies are warranted where water bodies have been severely degraded and are not functioning at peak capacity. The perceptions of homeowners towards suitable fertilizer practices and the scope of fertilizer ordinances were not highly favorable. However most felt that the implementation of fertilizer ordinances would contribute to improving the water quality of the Chesapeake Bay and other water bodies.

3.2 Residential practices and knowledge of ordinances

Research data indicated that homeowners engaged in fertilizer and irrigation practices to a large extent as most respondents reported personally applying fertilizers to their lawns, while a small percentage indicated that they employed the services of a professional lawn care providers. Survey results further revealed that granular fertilizers (solid granules) was the most commonly used fertilizer, and that residents irrigated their lawns at least once a week. The most common method of fertilizer application was broadcasting (hand-held spreaders or walk-behind drop spreaders), with the seasons of spring and summer as the time of year for highest fertilizer application. Despite homeowners' minimal knowledge of fertilizer ordinances and state requirements for irrigation and fertilizer practices, most residents reported their willingness to follow Virginia's "*fertilizer recommendation rules"* and *"irrigation and lawn management recommendations."* Furthermore, there was a general consensus among respondents for the provision of incentives to homeowners in promoting more suitable fertilizer practices by the government. Very few homeowners were aware of current local fertilizer ordinances in their county, and an even smaller number knew what the ordinances allowed or prohibited with regards to fertilizer usage. Similarly, respondents were not knowledgeable of the effectiveness of water pollution policies and how these fertilizer ordinances assisted local governments in managing non-point source pollution from residential areas

Discussion

This study examined the extent of fertilizer use by residential homeowners, the mediating role of general attitudes and perceptions towards local fertilizer ordinances, and impacts on current and future environmental behaviors, as well as the moderating effect of objective knowledge and its influence on irrigation and fertilizer practices for the management of their lawns. Our findings however illustrate a common problem municipalities continue to face, that is, a lack of knowledge or awareness of regulatory policies/ordinances and minimal compliance. This study also determined that some uncertainty existed as to the appropriate use of fertilizers, as homeowners were grossly unaware of suitable fertilizer application times and recommended rates. Moreover, our results revealed that not only do these residents have relatively little knowledge of local fertilizer ordinances, but that existing fertilizer ordinances are not easily understood by local residents. Data from the research showed that although a significant portion of respondents indicated having general knowledge of environmental water pollution issues, they were not aware of the requirements contained in fertilizer ordinances, nor of the benefits they provide in managing non-point source pollution from residential landscapes.

Homeowners have a sizeable influence on the magnitude of non-point source pollution from residential areas stemming from fertilizer practices. As a result, their perceptions and opinions of fertilizer ordinances may give insight on personal attitudes and behaviors. A considerable percentage of the respondents strongly agreed that more appropriate fertilizer practices and current recommendations associated with existing fertilizer ordinances would contribute to reducing water pollution. Although the homeowners had minimal knowledge of Virginia's rules and recommendations regarding fertilizer and irrigation practices, they strongly agreed that the implementation of local

ordinances would assist in reversing the declining water quality of the Chesapeake Bay and other surrounding water bodies. However, since residential homeowners are often unaware of local fertilizer ordinances that govern the use and application of fertilizers, their residential activities continue to contribute to the declining quality of surrounding water resources due to lack of knowledge. Given the concerns for water quality issues in the Chesapeake Bay region, and residents being in favor of the use of government incentives as a means of promoting more appropriate fertilizer practices, this suggests that the level of support for proposed ordinance changes and future water pollution policies may be somewhat substantial.

Conclusion and Recommendations

Response options should be modified to include investments in research to reduce key policy-relevant uncertainties, and measures to adapt to a changing climate in order to increase society's resilience to climate change. Water quality protection and restoration management strategies should require the consideration of all major sources of water pollution. This extends to include non-point source pollution from residential landscapes, and addressing this threat to the Chesapeake Bay should incorporate a comprehensive approach in identifying the contributions of over-fertilization and understanding the options for control. This study has emerged from the rising concern of non-point source pollution to the Chesapeake Bay and regulatory efforts to minimize the excessive inputs of nutrients and sediments with policy infrastructure aimed at changing residential behaviors and practices.

The results of this survey demonstrated that multimode surveys are capable of shedding light on homeowners' knowledge and perceptions of fertilizer ordinances and their willingness to not only support future water pollution policies, but to adopt better environmental practices. As such, surveys prove to be a good tool for incorporating stakeholder participation into the watershed planning process, as public involvement can greatly enhance watershed management efforts. Furthermore, the information obtained from the surveys in this study may not only provide resource managers with useful homeowners' demographics and fertilizer practices, but also assist in identifying certain factors affecting increased adherence or compliance with fertilizer ordinances. From an environmental perspective great strides have been achieved in understanding, preserving and improving the water quality of the Chesapeake Bay. Crucial information essential to the design and development of efficient water pollution control policies is almost always lacking. Despite the informational, cost or legal constraints, policies can be established in such a way so as to achieve specific water quality restoration goals or other environmental goals. Water quality concerns of the Chesapeake Bay and improved watershed management should propel policy makers and local officials to implement more suitable educational and training programs, control measures, regulatory policies and land use practices to meet multiple objectives in the management of non-point source pollution. This study's contribution to the scientific literature provided additional insight on not only homeowners' behaviors, values and concerns regarding water pollution and other environmental issues, but also their perceptions, objections and expectations with regards to various environmental practices and future policies.

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