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Pennsylvania Game Commission's Public Management of the PA Common Pool Resource White-Tailed Deer Herd

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Pennsylvania Game Commission's Public Management of the PA Common Pool Resource
White-Tailed Deer Herd

A Dissertation

Presented to the Faculty of the

Department of Public Management

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In Partial Fulfillment of the Requirements for

the Degree of

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By

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My dissertation is dedicated to my loving and beautiful wife Shelby and my wonderful children Nathan and Elijah.

Thank you for putting up with me, we all know how pleasant I was during this process.

Abstract

The white-tailed deer herd of Pennsylvania is a common pool resource. Effective management of this resource is important as the herd impacts many facets of everyday life in the Commonwealth and is an essential part of Pennsylvania's ecosystem. Responsibility for management of the resource rests with the Pennsylvania Game Commission (PGC). The purpose of this study was to consider the efficacy and fidelity of the PGC's methods of managing the herd through the allocation of antlerless hunting permits. Additionally, this study considered whether current herd management tactics resulted in an optimal herd allocation among wildlife management units (WMUs).

To answer the questions posited by this study, data from a series of publicly available data sources was accumulated and consolidated into a single database. The information collected was designed to test the fidelity of the Deer management Recommendation Process (DMRP) utilized by the PGC to manage the deer herd. Regression analysis was prepared for each WMU to determine if the variables used by the PGC in their decision process did in fact effectively predict herd size. The regression outputs provided mixed results. None of the variables used in the regressions were statistically significant at the .05 level on a consistent basis. The research concluded that managing the antlerless permits was the most effective method of her control. Further, the research points out that the reliability of the data used was such that the DMRP model is best considered as a long-term rather than a short-term model for herd management.

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Chapter 1

Statement of the Research Problem

Introduction

Equitable and fair administration of public assets is vital to the health of both the general

population and the underlying resource. The Commonwealth of Pennsylvania has entrusted

management of its deer herd to the Pennsylvania Game Commission (PGC). "The Pennsylvania

Game Commission is legally mandated to manage wildlife, including deer, for the benefit of all

Pennsylvanians, as well as all wildlife and the habitat that supports their existence.

Pennsylvania's Constitution and Game and Wildlife Code direct the Game Commission to

protect, manage, and preserve wildlife and their habitat within the Commonwealth for the benefit

of all people, including generations yet to come." (Kosack, 2009, p. 3). Put simply, the PGC is a

public management entity responsible for a common pool resource.

White-tailed deer in the Commonwealth of Pennsylvania (PA) are more than wild

animals with whom suburbanites share their backyards and hunters look to harvest. The deer

herd impacts many aspects of everyday life and is an essential part of the fabric of PA's human

and natural ecosystems. As such, the herd must be effectively managed to ensure its continued

survival and in a manner that is beneficial to as many people as possible and detrimental to as

few people as possible.

The PGC's primary tool for managing the deer herd is by manipulation of the recreational

hunting seasons. It manages the hunting seasons by setting bag limits for harvesting animals,

managing the season beginning and end dates, controlling the number of licenses available to

issue and restricting the various hunting methods. Additionally, the PGC has divided the

Commonwealth into 23 wildlife management units (WMUs) allowing them to customize the seasons to accommodate particular geographic characteristics.

The PGC chooses or adjusts the use of tools at its disposal to manage the herd based on multiple factors. Those factors, or decision points, include the residents desire for more or fewer deer, the health of the herd, the fawn to doe ratio, the status of the forest habitat, and the stability of the deer population. While there are multiple tools at the PGCs disposal, and the choice and use of those tools is also at their discretion, the key control point is the annual antlerless license allocation. The PGC can increase or decrease the number of antlerless licenses and thereby the deer population, at their discretion.

The purpose of this study is to consider the efficacy and fidelity of PGCs methods in managing the white-tailed deer herd in PA. While there is no universal answer to herd management given the many constituency interests, the PGC has developed a process through which they attempt to increase, stabilize, or reduce the deer herd. The purpose of this study is to determine the efficacy of the PGC model be developing a regression model to include the various markers in the PGC model. Secondarily, the research will consider the efficacy of the model on Northern tier WMUs compared to Southern tier WMUs given the geographical differences between the two tiers.

Common Pool Resource

A common pool resource (CPR) is a natural resource that is large enough so that it is expensive to control access in such a way as to limit beneficiaries from deriving neither enjoyment, nor economic, nor any other benefit from the item in questions (Gardner, Ostrom, and Walker, 1990). When this situation occurs, it falls on the government in some way, shape or form to step in and attempt to manage the asset effectively.

CPR is a term whose derivation can be traced at least as far back as Aristotle. In fact, Elinor Ostrom (one of the more prolific CPR researchers) began her book with a nod to the great Greek Philosopher. "Aristotle long ago observed that what is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest" (Ostrum, 2015, p. 3). Put simply, people are selfish and will work for the common good as long as it benefits them individually. It is a rare situation when the greater good is put above one's own interests.

Using this brief definition of a CPR as a guide, the PA deer herd would qualify since it is a natural resource which impacts the entire state from economic, recreational, human health and human safety perspectives. Deer have very few natural predators remaining in PA. The mortality of the herd is mostly limited to recreational activities, also known as hunting. "With inadequate harvest, the deer population could become overabundant for the existing habitat conditions" (D'Angelo, 2009, p. 2).

Background for the Study & Importance

The entity in PA tasked with responsibility for managing the white-tailed deer herd is the Pennsylvania Game Commission. While it is difficult enough to manage a living/breathing creature such as a deer, the task is further confounded by the fact that views on the methods used as well as the perceived overall effectiveness are often split among various constituencies. Further, when a program is run by the government or an agency of the government, customer satisfaction or dissatisfaction has little impact. These kinds of programs continue no matter what the demands or the level of client satisfaction (Weiss, 1972).

Pennsylvania Game Commission. In the 1890's, Elk in Pennsylvania were nearly extinct, and the deer population had declined significantly. Realizing something needed to be

done, the Pennsylvania Game Commission (PGC) was formed on 6/25/1895 as a result of lobbying efforts by hunters. "Through the first 125 years, the game commission has restored once-dwindling population of deer" (Pennsylvania Game Commission, 2020). The PGC's 2009 - 2020 deer management plan lists its goals as (Kosack, 2009, p. 3):

1. Manage deer for a healthy and sustainable deer herd.

2. Manage deer-human conflicts at levels considered safe and acceptable to Pennsylvanians.

3. Manage deer impacts for healthy and sustainable forest habitat.

4. Manage deer to provide recreational opportunities.

5. Improve the public's knowledge and understanding of deer and the deer management program.

Environmental and economic impact of deer. Management of the deer herd meets the needs of parties other than just hunters. Ornamental vegetation and landscape plantings are favorite meals for deer. They damage homeowners' properties as well as the companies (suppliers) who sell to nurseries and other retailers causing them to spend money to discourage deer from destroying their products. Crops such as fruit trees and grains are also targets of deer browsing (Curtis & Sullivan, 2001).

Deer browsing impact the timber industry because deer prefer certain varieties of tree saplings more than others. The ones they are drawn to eating tend to be the species that are marketable (e.g., oak, cherry) as opposed to species that are not in as great a demand. This hurts the profitable regeneration of forest timber. Once a forest of oak or cherry is cut and sold, the lumber company plants young trees to aid in the regeneration of their product. Deer herds come along and devour these new plantings leaving only moss and other non-marketable varieties (Parker, Larkin, Heggenstaller, Duchamp, Tyree, Rushing and Larkin, 2020).

The Cornell University Cooperative Extension published a white-tailed deer fact sheet which the PGC has on their site for public dissemination. Regarding economic impacts, "annual estimates of deer damage are reported to exceed $2 billion nationwide, including $1 billion in car damages, more than $100 million in agricultural crop damage, $750 million in damage to the timber industry, and more than $250 million in damage to metropolitan households (e.g. landscape plantings). These estimates are conservative, and it is often difficult to obtain reliable statistics for wildlife-related losses" (Curtis & Sullivan, 2001, p. 2).

While hunting may not be best known as a revenue generating endeavor, for the Commonwealth of PA it most certainly is. In total for the fiscal year ended June 30, 2020, the PGC had revenues of $156 million and of that, $18.3 million resulted from the sale of resident and non-resident hunting licenses. Over $5.2 million was as a result of antlerless deer license sales and another $14.9 million came from the sale of other game hunting licenses. Taken together, the aforementioned categories total almost 25% of annual revenue. An additional $3.8 million in revenues were generated by the sale of timber from the lands it owns (PA Game Commission, 2020).

Herd health. Deer are at risk for disease just like all living creatures. Some illnesses only impact the deer itself while others may be spread to either humans or other animals. The existence of disease is another reason for effective herd management. Three examples of deer borne sickness that governmental agencies, such as the PGC and United States Department of Agriculture (USDA), track are as follows (Kosak, 2009):

- Lyme Disease: Humans are susceptible to Lyme disease. When infected, humans become susceptible to nervous system symptoms, cognitive decay, and other health issues. It was initially thought that deer were the cause of the disease, but research

has shown that the deer tick is the culprit. While this species of tick does feed on the blood of deer, the deer is not responsible for the transmission of the illness. That distinction rests with the tick.

- Chronic Wasting Disease (CWD): CWD is a fatal illness that impacts the central nervous system of the host and can be found in animals and humans. While the official name of the disease is slightly different depending upon the creature infected (e.g., mad-cow in cows and Creutzfeldt-Jakob in humans), it is thought to be spread within the species via fecal matter, bodily fluids or the like. The concern is that it could potentially be transmitted not just *among/within* a species but between differing species as well.

- Tuberculosis (TB): A disease that impacts the respiratory system in both humans and animals. Transmission occurs via close contact and, much like CWD, the PGC and the USDA track occurrences of TB in free-ranging deer herds.

Northern tier vs southern tier. The PGC uses Wildlife Management Units (WMU) to help them control the deer population. Predominantly used for the allocation of hunting licenses, WMU's are smaller areas that have been created by dividing the state into bite size geographic units. Each one is viewed as its own world containing similar wildlife population (species) and habitat. The manner in which the WMUs were created took into consideration both biological and social factors. Biologically, the land in each WMU should be physically large enough to support the target species and provide the appropriate habitat necessary (Rosenberry & Diefenbach, 2019).

For purposes of this study, the State has been split into two tiers: Northern and Southern. The boundary used to do the split was Interstate-80 as it is an East/West interstate that closely

bifurcates the state. The following table summarizes which WMU's are considered Northern and which are considered Southern.

Northern Tier WMUs	Southern Tier WMUs
1B	1A
2F, 2G, 2H	2A, 2B, 2C, 2D, 2E
3A, 3B, 3C, 3D	4A, 4B, 4C, 4D, 4E
	5A, 5B, 5C, 5D

The Northern tier is both less populated in total as well as less densely populated. Philadelphia and Pittsburgh, the two largest population centers in PA, are both located in the Southern tier. In the North, hunting and hunting related activities are relied upon to supply much needed revenue to the local economies while, in the South, the revenue is welcome but not as critical to the survival of more well-off locales. Northern counties have a greater reliance on natural resources industries (e.g., lumber, coal mining and natural gas fracking) but the South has evolved towards a more service sector economy. This presents a problem for the PGC as they have the responsibility to manage the herd effectively across the state but must keep in mind the variations in each tier.

Statement of the Problem

While the deer herd in the Commonwealth should be considered a valuable resource, the herd has proliferated into areas that were once people-only dominated. The loss of natural habitat in some areas has forced deer to populate suburban neighborhoods creating the potential for increased negative interactions with humans such as vehicle accidents, damage to ornamental shrubbery, and increased incidence of deer borne illness such as Lyme disease. The problem of herd management is more complicated than simply human interaction.

Successful deer herd management has to include the ecosystem of which they are a part. Deer need food, water, protection from predators, etc. and, without healthy forests, none of that exists (DeCalesta & Stout, 1997). Deer are not simply "takers", however, as they aid natural resource managers in the form of foraging which helps keep invasive species of plants at bay. Hunters are a part of the herd management system in that they are needed to help control the population. Accordingly, annual harvests must be such that the hunters believe they will be successful or at least have good chances of seeing deer and being successful.

In the absence of natural death, people have a responsibility to properly manage the deer herd in the best interests of both citizens and the deer. CPR management systems become more complex with increased numbers of users/constituents and geographic size. While agreement of all stakeholders seems unlikely, it becomes important to know that any agency charged with the management of a CPR does so with fidelity to its goals and objectives and, to the extent possible, in the best interests of all concerned parties.

Purpose of the Study

The purpose of this study is to consider the efficacy and fidelity of PGCs methods in managing the white-tailed deer herd in PA. While there is no universal answer to herd management given the many constituency interests, the PGC has developed a process through which they attempt to increase, stabilize, or reduce the deer herd. The purpose of this study is to determine the efficacy of the PGC model be developing a regression model to include the various markers in the PGC model. Secondarily, the research will consider the efficacy of the model on Northern tier WMUs compared to Southern tier WMUs given the geographical differences between the two tiers.

Research Questions

The white-tailed deer herd is a valuable resource to the Commonwealth and the efficacy of its management by the PGC is confounded by the many interested constituencies often driven by very different goals and objectives. All constituencies should, however, be concerned that the herd is being managed consistent with the best interests of the Commonwealth as implemented by the goals and objectives of the PGC process. Accordingly, this study endeavors to answer the following questions:

1. How effective is the PGC in the management of the white-tailed deer herd as determined by analysis of its Deer Management Recommendation Process (DMRP)?

2. Is controlling the number of antlerless permits by WMU an effective method of controlling herd size as measured by reported antlerless harvests?

3. Are current herd management tactics resulting in an optimal herd allocation between Northern and Southern tier WMUs that is the best use of resources for the citizens of the Commonwealth of PA?

Significance to the Field

PGC is tasked to protect and enhance human health and safety and provide for the equitable distribution of resources with an example being the management of the white-tailed deer herd in the Commonwealth of Pennsylvania. Public administration, as a discipline, is designed to serve the population in a manner which will support and expand the common good. A common pool resource fulfills this description since, by definition, it impacts the populous in total and it has an inherent need to be managed by public administrators. As a natural resource, white-tailed deer provide a wide array of benefits to communities across the Commonwealth of

PA. Additionally, there are economic, human health and human safety factors involved in addition to the more commonly held view that deer are only good for hunting.

Definitions of Terms

- Common Pool Resource: A natural resource that is large enough so that it is expensive to control access in such a way as to limit beneficiaries from deriving neither enjoyment, nor economic, nor any other benefit from the item in questions (Garder et al., 1990).

- Common Pool Resource Situation: A situation exists if the definition of a CPR is met in addition to there being multiple appropriators removing the resource and once a resource unit is used, it is not available to another appropriator (Garder et al., 1990).

- Common Pool Resource Dilemma: A CPR *situation* become a *dilemma* if, in addition to the definition of a *situation*, two additional factors are added. A possible negative outcome resulting from appropriators not functioning according to CPR rules and there must be a possible legal governmental intervention allowing it to manage the resource (Garder et al., 1990).

- Stock: The resource unit being analyzed (deer) (Garder et al., 1990).

- Appropriators: The person or group of people removing the stock from the resource system (hunters) (Garder et al., 1990).

- Resource System: The environment in which the CPR exists. For our purpose, the system includes the hunting grounds, deer sighting (which provides harvesting possibilities), the natural environment upon which the herd impacts such as humans, vehicles, farmland, etc. (Ostrom, 2015).

- Resource Units: That which is being appropriated from the system. Since we are focusing on herd size, herd health and herd management, our unit to be harvested will be antlerless deer (doe) (Ostrom, 2015).

- Providers: The people or entity (the Commonwealth of PA and the PA Game Commission(PGC)) that create the CPR (Ostrom, 2015).

- Producers: The ones who construct or take care of the CPR (both the PBC and the game warden service) (Ostrom, 2015).

Summary

This chapter began with an introductory definition of Common Pool Resources. That was followed by background information of the study including the Pennsylvania Game Commission, the environmental and economic impact of the deer herd, deer health and a brief description of the Northern and Southern tiers. Next was the statement of problem this paper is addressing followed by a description of the study's purpose. The research questions were then presented followed by a description of the significance of this topic to the field of public management. Finally, a section containing definitions of terms was included to help preempt any confusion as the reader moves through this study.

Chapter 2

Review of the Relevant Literature

Introduction

The first section provides the theory on common pool resources (CPR). The deer herd in the Commonwealth of Pennsylvania is relevant for more than just hunters as there are economic, human health and human safety factors involved as well. PGC is the public entity tasked with managing the herd to protect and enhance human health, safety, and provide for the equitable distribution of resources with an example being the management of the white-tailed deer herd in the Commonwealth of Pennsylvania. The herd itself is a common pool resource and, as such, needs to be managed appropriately to ensure the needs of all constituencies are met as successfully as possible. The second section provides background information on the Pennsylvania Game Commission (PGC), the agency charged with managing the CPR. Finally, the chapter concludes with a discussion of the recreational value of the deer herd.

Common Pool Resources

CPR is a term whose derivation can be traced at least as far back as Aristotle. In fact, Elinor Ostrom (one of the more prolific CPR researchers) began her book with a nod to the great Greek Philosopher. "Aristotle long ago observed that what is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest" (Ostrum, 2015, p. 3). Put simply, people are selfish and will work for the common good as long as it benefits them individually. It is a rare situation when the greater good is put above one's own interests.

In 1968, Garrett Hardin published his article in which he likens the CPR problem to the cold war nuclear situation of that era. "Both sides in the arms race are … confronted by the dilemma

of steadily increasing military power and steadily decreasing national security. It is our judgment that this dilemma has no technical solution. If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation" (Hardin, 1968, p. 1243). A *technical solution* is an answer that is based on the absolute of science and/or technology and does not consider that human thoughts or actions must be changed. The unfortunate tragedy referred to in the title of his article is that to solve CPR issues it is often necessary to search for a scientific solution **in addition** to convincing people to modify their beliefs, understanding or behavior.

While there is no shortage of CPR definitions, the definition put forth by Gardner seems appropriate given the subject matter of this paper. It comes from a 1990 article published in *Rationality and Society* authored by Gardner. "Common-pool resources are defined to be sufficiently large natural or manmade resources that are costly (but not necessarily impossible) to exclude potential beneficiaries from obtaining benefits from their use" (Garder et al., 1990, p335). In his article, *Platforms for Collective Action in Multiple-Use CPRs*, Steins details some additional features of a CPR as follows (Steins & Edwards, 1999, p. 242):

- "Used by multiple-users and/or multiple-user groups

- Joint use involves subtractability

- Difficult to exclude users"

Tragedies and dilemmas. Certain criteria must be met before a situation can be considered a CPR dilemma. Gardner used four conditions to indicate if a problem qualifies. Using the deer herd to help explain (Garder et al., 1990):

Condition 1 - Resource Unit Subtractability. Once the resource or *stock* (deer) is harvested, it is not available to another hunter. The gender of the deer harvested (doe vs. buck) creates a

possibility that each unit of resource is not equal since a doe represents future replenishment of the resource and if the ratio of male/female is not kept at optimal levels, then the herd could become too large, too small, genetically unhealthy, etc. None of those outcomes is desirable.

Condition 2 - Multiple Appropriators. More than one person or group (appropriators) are removing the stock (hunters).

Condition 3 - Suboptimal Outcomes. Given how resource takers (appropriators) function (following the rules vs. not), there has to be a possible negative outcome. In our deer case, that outcome once again could be the herd becoming too large, too small, genetically unhealthy, etc.

Condition 4 - Constitutionally Feasible Alternatives. There must exist legal strategies for governments or organizations to manage the CPR for the better.

Both 1 & 2 have to exist in addition to the CPR definition being true in order for there to be a CPR *situation*. A situation could be categorized as either good or bad for the public and this is where the analysis ends unless conditions 3 & 4 also exist. If all four are present, then the *situation* becomes a CPR *dilemma*. "If suboptimal outcomes are not produced for at least one combination of the physical system, technology, rules, market conditions and attributes of the appropriators, then there is nothing problematic about the situation" (Garder et al., 1990, p. 337). In the case of the deer herd, all four conditions are met which allows us to refer to the management of the deer as a CPR management dilemma.

Deer are renewable resources with the ability to replenish itself, the management of which is critical to the success of CPR sustainability. While renewable, they are not a joint use resource since once a deer is harvested it is not available to be hunted again. The goal is to

support harvesting the resource (hunting) without harming the long-term health of the herd across the state.

While hunters are certainly appropriators of deer, they are not the only ones relying on the CPR. Non-hunters enjoy seeing and observing them. Additionally, the state forests rely on deer to keep the various species of non-invasive plants alive by grazing on invasive species, making deer an integral part of the overall natural ecosystem. The Commonwealth of PA manages (via the PGC) over 1.5 million acres comprising 308 state game lands (PGC, 2021b). Additionally, through the Deer Management Assistance Program (DMAP), managed jointly by the PGC and The Pennsylvania Department of Conservation and Natural Resources (DCNR), state forests and state parks are huntable with the purchase of special permits. This adds thousands more acres for harvesting opportunities (DCNR, 2021).

"If the appropriators of a resource gain considerable market power" (Ostrom, 2015, p. 31) then they have outsized influence on the CPR management and their wants and strategies impact all other users. In the case of the deer herd, hunters are a group that has the potential to be an outsized presence in the management discussion. That suggests that not all user needs are always being met. When CPRs evolve into more complex systems, resource use by separate user groups becomes increasingly interdependent (Steins & Edwards, 1999, p. 241). The more complex a CPR (number of users, geographic size, etc.) becomes, the more difficult (and necessary) it is to balance all of the different interests. "Policy-makers often fail to recognize the complexities associated with managing multiple-use CPRs due to poor communication structures between policy-makers and users" (Steins & Edwards, 1999, p. 242).

A classic tragedy of the commons is "A situation in which most users understand that the existing way of using the CPR will eventually lead to its ruin, but no one is willing to reduce

one's use or contribute to its replenishment if no credible means exists to overcome the inherent collective action problem" (Tang, Callahan & Pisano, 2014, p. 791). An important part of CPRs are property rights since natural resource CPRs (such as deer) exist on various types of properties. Steins details four basic classifications of property (Steins & Edwards, 1999, p. 242):

1. "Open Access: No use rights are attached to a specific group, resulting in a "free for all"

2. Public-Property: Access for the public is held in trust by the state

3. Common Property or "Commons": Use rights are attached to a specific user group

4. Private property: Tradable rights are owned by an individual, household or company"

As will be discussed later, the CPR we are evaluating makes use of all four classifications which only serves to further complicate the management.

According to Gardner, there are two types of CPR dilemmas: appropriation problems and provision problems. In appropriation problems "production relationship between yield and level of inputs is assumed to be given, and the problem to be solved is how to allocate yield" (Garder et al., 1990, p. 340) and provision problems "relate to creating a resource, maintaining or improving the production capabilities of the resource or avoiding the destruction of the resource" (Garder et al., 1990, p. 340). The act of effectively managing a CPR needs to take both problems into consideration.

In an appropriation problem, rent dissipation is the main issue. Rent dissipation happens when a CPR can be accessed with no restriction until the CPR "rent" (in this case deer) is fully depleted (Fudenberg, 1987). Since the natural resource is not private property, the "rent" is not able to be appropriated by anyone. However, each hunter is more or less free to hunt wherever he pleases which results in a pattern of competition among hunters that, left unchecked, would culminate in the dissipation of the rent, or the herd in this case (Gordon, 1954).

Provision problems "focus on behavioral incentives for appropriators to (a) contribute resources for provision or maintenance of a CPR and (b) alter appropriation activities within an existing system to change the withdrawal patterns from the CPR so as to maximize multiple-period returns or avoid the destruction of a resource" (Garder et al., 1990, p.344). Part (a) of the provision description is also know by managers as the supply-side and part (b) as the demand-side.

Game theory. Game theory is an analysis approach which allows researchers to think through complex situations that have many possible outcomes and develop responses that they feel would satisfy the problem being looked at before the events actually occur. It can also be used as a tool as time moves on to help update and possibly modify the response to a given problem. Ostrom frequently used this method to help describe CPR management. There are three game theory structures utilized in a paper she wrote with Gardner (Garder et al., 1990) which help explain the problem faced in PA:

- One-Shot Games

- Time-Independent Repeated Games

- Time-Dependent Repeated Games

The first two have a natural replacement rate which is greater than or equal to the future withdrawal rate and does not apply to our situation. However, in time-dependent repeated games "appropriators face an environment in which the strategies they have undertaken in time periods t-1, t-2, … affect the strategies available to them in periods t, t+1, t+2, …" (Garder et al., 1990, p.346). In simple terms, if the CPR management results in an overuse situation in any year, it will affect subsequent years. If a deer herd is hunted to extinction, you do not get to start with a new herd the next year, you start with an extinct species and have to start from scratch. There

are five variables identified that are useful in organizing analyses of CPRs (Garder et al., 1990, p. 355). They are:

1. Resource and response units

2. Production technologies and market structure

3. Operational rules

4. Collective and constitutional choice mechanisms

5. The structure of the operational action situation facing appropriators

Despite all of the positive research done on managing CPRs, it is also important to realize that the various models and theories surrounding them do have limitations. As Elinor Ostrom said, "All theories have limits" (Ostrom, 2015, p. 24). CPR theories and models are only as good as the CPR managers and appropriators that use them.

Poaching. A glaring hole in any management problem, but especially with a CPR, is what happens when individuals begin to act on their own. There will always be people that take advantage and only do what is best for themselves, which for deer management is illegal harvesting, or poaching. The counter to this sort of behavior falls to the other appropriators (hunters) to enforce what is best for the CPR. This is not always an easy task (Ostrom, 2015).

When a deer is illegally taken (harvested) it is deemed as poaching. The official definition from the PGC as codified in Title 34 of the Pennsylvania General Assembly is "To unlawfully take game or wildlife by means of or as a result of multiple violations of the provisions of this title or the regulations thereunder". (*Title 34*, 2021). This can include out of season hunting, hunting without a valid license or simply harvesting a deer on posted private property. Regardless of how it occurs, poaching circumvents the rules and regulations put forth by the governmental agencies responsible for herd management. This, in turn, adds a

unexpected and unwanted variable into the calculation of antlerless permit allocation and population projection. Estimating how much of an impact poaching has on the herd population is impossible to calculate since, by definition, it is illegal, and perpetrators are not reporting their acts. However, each year the PA game wardens pursue reports of poaching via citizen reports on the PGC online tip portal.

As Hardin discussed in his article addressing collective action in CPRs, damage to resources consumed and/or used by multiple users (or groups of users) comes about because each individual looks to maximize their own use/enjoyment (Hardin, 1968). This is commonly known as the prisoner's dilemma and is another well-known game theory. Put simply, cooperation only goes so far and when it conflicts with individual desires or needs, the entire system breaks down and managing a CPR gets nearly impossible. An article published in the *Annual Review of Anthropology* by Agrawal says it best: "…the research of commons may have ignored the possibility that all successful enforcement institutions are also coercive, and the burden of coercion tends to fall unequally on those who are less powerful" (Agrawal, 2003, p. 257).

PA Game Commission

In the 1890's, Elk in Pennsylvania were nearly extinct, and the deer population had declined significantly. Realizing something needed to be done, the Pennsylvania Game Commission (PGC) was formed on 6/25/1895 as a result of lobbying efforts by hunters. "Through the first 125 years, the game commission has restored once-dwindling population of deer" (PA Game Commission, 2020).

The mission statement of the PGC is to "Manage and protect wildlife and their habitats while promoting hunting and trapping for current and future generations" (PGC, 2021a). The PGC is not a recipient of State fund appropriations (aka the State Budget). Instead, it is self-

supporting and funded by license sales, timber sales from its game lands, oil and gas revenues and an excise tax on ammunition.

The PGC's 2009 - 2020 deer management plan lists its goals as (Kosack, 2009, p. 3):

1. "Manage deer for a healthy and sustainable deer herd

2. Manage deer-human conflicts at levels considered safe and acceptable to Pennsylvanians

3. Manage deer impacts for healthy and sustainable forest habitat

4. Manage deer to provide recreational opportunities

5. Improve the public's knowledge and understanding of deer and the deer management program"

The accomplishment of the above goals is facilitated by adhering to the seven components of the North American model of Conservation. These include (Organ et al., 2012):

1. "Wildlife resources are a public trust

2. Markets for game are eliminated

3. Allocation of wildlife is by law

4. Wildlife can be killed only for a legitimate purpose

5. Wildlife Is considered an international resource

6. Science is the proper tool to discharge wildlife policy

7. Democracy of hunting is standard"

While the PGC used to count the density of deer as a goal, that is no longer true. Additionally, deer management is not based on popularity. "As PA's history demonstrates, deer management was, is, and will continue to be an issue where complete agreement by all stakeholders is unlikely" (Kosack, 2009, p. 4).

In 2009, West Chester University (WCU) in Pennsylvania requested that the United States Department of Agriculture review and create a plan for the school's 150-acre nature area known as the Robert B. Gordon Natural Area (RBG). The plan was to encompass the management of white-tailed deer as well as a non-native invasive plant impact study. While it may seem silly to evaluate plants and deer together, as noted earlier, deer have an impact on their entire ecosystem. This report also has the added benefit of focusing on a Pennsylvania forest which serves as an analog for the state's issues regarding deer as a whole. It is located in a suburban setting where human interaction is commonplace, and the management issues faced by WCU at RBG are the same as what the PGC faces each day.

Herd Management.

Deer have very few natural predators remaining in PA. The mortality of the herd is mostly limited to recreational activities, also known as hunting. "With inadequate harvest, the deer population could become overabundant for the existing habitat conditions" (D'Angelo, 2009, p. 2). Although on the brink of extinction last century, white-tailed deer have rebounded both in terms of population size/growth and adaptability. In the late 19th century, unregulated hunting and habitat loss caused the species to almost disappear totally. "The reestablishment of white-tailed deer population has been regarded as one of the greatest successes in the history of wildlife conservation" (D'Angelo, 2009, p. 3). Who would have thought that with the urbanization of farmland throughout the state together with the encroachment of humans into their environment there would have been little negative impact on the herd, and, instead, it would thrive?

Birth and death rates within a population have to be carefully monitored and, if necessary, adjusted in order to manage the population. This is required not just to control

population numbers, but also to maintain the overall health of the herd, protect fragile

ecosystems and reduce the risk of disease. The USDA referred to two capacity limit ideals in

their analysis of deer density: social carrying capacity and biological carrying capacity. "Social

capacity is the level at which deer and humans can coexist without any negative impacts" and the

"biological capacity is the deer limit that the natural setting can support" (D'Angelo, 2009, p. 4).

Neither of these capacity numbers are static nor do they move in concert with each other.

   Left to their own devices, a deer herd expands at a rate of 30% per year (D'Angelo, 2009).

This makes population control all the more important because the added 30% are not guaranteed

to be safely supported by either of the capacity limits.

   It may seem counterintuitive, but a lower deer density can have positive impacts. The USDA

points out four specific impacts in their report (D'Angelo, 2009, p. 11):

- Less damage to **native** vegetation

- Healthier deer population well below the biological carrying capacity

- Reduction in deer-vehicle collisions and other human health and safety risks (Lyme
  disease)

- Positive relationship with the community

Deer population management objectives are different among different groups. Hunters, the

timber industry, homeowners, and farmers all have very different definitions of the optimal

number. "The majority of hunters agreed that controlling deer population was necessary, that

deer population should be kept in balance with natural food supplies, and that deer affected plant

and animal communities" (Diefenbach, Palmer, & Shope, 1997, p. 244). Basic logic will tell you

that the more deer there are and the higher the density of deer, the greater the negative impact

they can have on forests and other habitats. This could cause a domino effect as birds, other

large game species, and plant life would all suffer, or at least dramatically change.

Despite what non-hunters believe, hunters do not simply gamble about the woods aimlessly

shooting at any deer they come across. There are rules governing the gender, size, and dates that

a harvest can occur as well as having defined seasons for each type of hunting (e.g. rifle, archery,

muzzleloader). The rules are established in an effort to satisfy many different constituencies,

each with its own goals and "although the PGC has many deer programs, not one goal has been

attained to the satisfaction of any special-interest group" (Diefenbach, et al., 1997, p. 245).

While the PGC was originally created at the behest of hunters, it has evolved into an important

financial tool for the state as deer are both a source and use of economic impact for PA.

The 2020 license fees alone were $48.0 million and revenues for product sales and services

were another $77.8 million (PGC, 2020, p. 35). Without the positive forest regeneration impact

of management, the timber and farming industries in PA would suffer. It is safe to say that the

number of people who want fewer deer and the number of people who want more deer will never

equal each other.

Deer browsing impact the timber industry because deer prefer certain varieties of tree

saplings more than others. The ones they are drawn to eating tend to be the species that are

marketable (e.g. Oak) as opposed to species that are not in as great of demand. This hurts the

profitable regeneration of forests timber is harvested. Once a forest of oak is cut and sold, the

company plants young trees to aid in the regeneration of their product. Deer herds come along

and devour these new plantings leaving only moss and other non-marketable varieties (Parker, et

al., 2020).

The Cornell University Cooperative Extension published a White-Tailed Deer fact sheet which the PGC has on their site for public dissemination. Regarding economic impacts, "annual estimates of deer damage are reported to exceed $2 billion nationwide, including $1 billion in car damages, more than $100 million in agricultural crop damage, $750 million in damage to the timber industry, and more than $250 million in damage to metropolitan households (e.g. landscape plantings). These estimates are conservative, and it is often difficult to obtain reliable statistics for wildlife-related losses" (Curtis & Sullivan, 2001, p. 2).

While hunting may not be best known as a revenue generating endeavor, for the Commonwealth of PA it most certainly is. In total for the fiscal year ended June 30, 2020, the PGC had revenues of $156 million and of that, $18.3 million resulted from the sale of resident and non-resident hunting licenses. Over $5.2 million was as a result of antlerless deer license sales and another $14.9 million came from the sale of other games hunting license sales. Taken together, the aforementioned categories total almost 25% of annual revenue. An additional $3.8 million in revenues were generated by the sale of timber from the lands it owns (Pennsylvania Game Commission, 2020).

Wildlife Management Units.

The PGC uses Wildlife Management Units (WMU) to help them control the deer population. Predominantly used for the allocation of hunting licenses, WMU's are smaller areas that have been created by chopping up PA into bite size geographic units. Each one is viewed as its own world containing similar wildlife population (species) and habitat. The manner in which the WMUs were created took into consideration both biological and social factors. Biologically, the land in each WMU should be physically large enough to support the target species and provide the appropriate habitat necessary (Rosenberry & Diefenbach, 2019). Additionally, game

managers must be able to estimate and predict herd size. From a socially important perspective, hunters need to be able to identify the WMU boundaries.

Initially, PGC designated each county as a management unit but, in 2003, switched to the current WMU. Before the change, there were 67 CMUs. After the change, there are 23 WMUs. "The WMU system represented a necessary compromise between deer management requirements for adequate data collection and deer habitat distribution and public desires for smaller management units" (Rosenberry & Diefenbach, 2019, p. 71) since smaller WMUs may not provide sufficient area to contain the population of interest. Another differentiation is that CMUs followed political boundaries (Counties) while WMUs were based on physical, human and habitat considerations.

Recreational Use of the White-Tail Deer Herd (Hunting)

Thus far we have discussed the fact that white-tailed deer are a common pool resource worthy of study and we addressed the importance of the species to various constituencies including recreational users, homeowners, industry and even the environment. It is time to focus on the role hunters play in the overall management of deer in the Commonwealth of PA. While not limited to one state, within PA, hunting is a topic with passionate supporters on both sides. Regardless of one's view, however, "it is not feasible to regulate deer populations on a statewide basis without the harvest of adult female deer through recreational hunting (Decker & Connelly, 1989, p. 455). Further, the USDA has stated that "hunting should be encouraged as it is generally the most economically feasible strategy to manage deer" (D'Angelo, 2009, p.6) when compared to other methods such as deterrents, sharpshooters, relocation and/or fertility control. That is why PGC's mission includes protecting and managing wildlife resources in such a way as to provide and maintain recreational activities (Miller and Graefe, 2001).

Hunters classify a day in the woods as enjoyable or not. Studies have been performed over the years attempting to determine the cause-and-effect relationship between hunters' satisfaction with a day in the woods and their success or failure of harvesting a deer. The findings have been mixed. Miller and Graefe (2001) found that successfully harvesting a deer was significant in predicting satisfaction with deer management. The conclusion of a study performed by Decker yielded results that were different than Miller. He stated, "the primary motivation for participation in deer hunting for most hunters is neither a desire for venison nor as desire to manage deer" (Decker and Connelly, 1989, p. 462). Other motivations have been found to include enjoying the outdoors, friendship, family time and simply the enjoyment of quiet and solitude.

Regardless of the view each person has, hunters are needed to help control the population. If a hunter does not believe success (by their own definition) is possible, fewer people will participate in the sport and deer overpopulation could occur. "License-based hunting is the most obvious management strategy for controlling abundant game animals and has indeed been used to lower [deer] density and thereby limit adverse ecosystem impact" (Anderson, Wam, Mysterud, & Kaltenborn, 2014, p. 1282). Back to the results of Decker, "In situations where antlerless-deer-harvest systems are not achieving the desired degree of deer population control because of inadequate harvests, it is important for deer managers to develop ways…" (Decker & Connelly, 1989, p. 461) to encourage harvest opportunities based on other motivations.

Hunter satisfaction has been found to be subjective. While it might be easy to say that successfully harvesting a deer is how success is defined, that is not true for all hunters. What has been found to flow from the feeling of a trip's success is the feeling that the management of the herd has also been successful. Miller found that "hunters harvesting deer may be less likely to

state they see fewer deer and thus more likely to express satisfaction with the deer management efforts" and "successful hunters may feel that the annual harvest is balanced and may be more supportive of the management program" (Miller & Graefe, 2001, p. 200).

The importance of hunters cannot be overstated. It is the lynchpin of a management program since, without it, the population will go unchecked. That extends to the need for effective management of the entire ecosystem starting with plants (food) and ending with the deer themselves. A habitat must contain a diverse enough food source to encourage the deer to forage. No foraging availability translates into a lower density of deer which leads hunters to feeling less successful which will cause hunters to stop hunting which ultimately has an adverse effect on the entire state.

Simply increasing the number of deer that each hunter can harvest may seem like an effective strategy, but without considering birth, death, and health patterns as well as densities individual to each WMU, a negative effect on the herd is very possible. Wildlife managers need to be mindful that harvesting is not simply killing a deer, but also processing and butchering after the fact. The amount of butchering and processing time available need to be commensurate with the harvest limits.

Summary

This chapter reviewed the theory behind common pool resource management and made the linkage between a CPR and the white-tailed deer herd in the Commonwealth of Pennsylvania. This was followed by an in-depth discussion of the Pennsylvania Game Commission including its history and the complex issues it faces in managing the herd. Finally, this chapter concluded with a discussion of recreational issues with the deer herd (specifically hunting) and hunters being key stakeholders in herd management.

Chapter 3

Methodology

Introduction

This chapter presents the research questions, describes the archival data utilized, and the planned analysis. Additionally, this chapter provides an overview of the PGCs step-by-step deer management program. An understanding of the model is necessary as it will form the basis of the analysis.

Purpose of the Study

The purpose of this study is two-fold. One is to evaluate the PGC as a public administration entity managing a common pool resource and the other is to consider the efficacy and fidelity of PGCs methods in managing the white-tailed deer herd in PA. While there is no universal answer to herd management given the many constituency interests, the PGC has developed a process through which they attempt to increase, stabilize, or reduce the deer herd (see Figure 1). The purpose of this study is to determine the efficacy of the PGC model by developing a regression model to include the various markers in the PGC model.

Research Questions

The white-tailed deer herd is a valuable resource to the Commonwealth and the efficacy of its management by the PGC is confounded by the many interested constituencies often driven by very different goals and objectives. All constituencies should, however, be concerned that the herd is being managed consistent with the best interests of the Commonwealth as implemented by the goals and objectives of the PGC process.

Accordingly, this study endeavors to answer the following questions:

1. How effective is the PGC in the management of the white-tailed deer herd as determined by analysis of its Deer Management Recommendation Process (DMRP)?

2. Is controlling the number of antlerless permits by WMU an effective method of controlling herd size as measured by reported antlerless harvests?

3. Are current herd management tactics resulting in an optimal herd allocation between Northern and Southern tier WMUs that is the best use of resources for the citizens of the Commonwealth of PA?

Design of the Study

This research could correctly be categorized as a program evaluation. Some program evaluations focus on the process or how things are getting done. Specifically, is the program being administered with fidelity in terms of its goals and objectives. Other program evaluations focus on outcomes and effects of the program or are participants gaining the benefits they were intended to receive. This research intends to look at both process and outcome.

This will be a quantitative study utilizing multiple regression techniques. The deer herd in PA is managed through the Deer Management Recommendation Process (DMRP) model administered by the PGC. This research will build a multiple regression model using the markers of the DMRP as well as other markers as a guide to predict the antlerless deer kill, the key control point of deer herd size. An analysis of the regression model using statewide data will be used to answer research questions 1 and 2. Variations of the model comparing data from northern tier WMUs versus southern tier WMUs will be used to answer research question 3.

Methods of Data Collection

This study makes use of archival data produced by governmental agencies. In addition to the Pennsylvania Game Commission and the United States Department of Agriculture, the

Pennsylvania Legislature and others produce information which is publicly available. The data which will be used in the regression models have been sourced from multiple publicly available data bases obtained from a variety of governmental and public entities. While "government issued" does not mean it is perfect data, the fact that these entities have a fiduciary duty to present data to the citizenry that is vetted to the best of their ability provides for a high degree of reliability. While the reliability of the source data is certainly important, the validity of each measure used in this analysis is of equal importance. A reliable variable is only an effective measure if it actually quantifies what it purports to quantify.

WMUs. Initially, PGC designated each county as a management unit but, in 2003, switched to the current WMU mapping (see Figure 1).
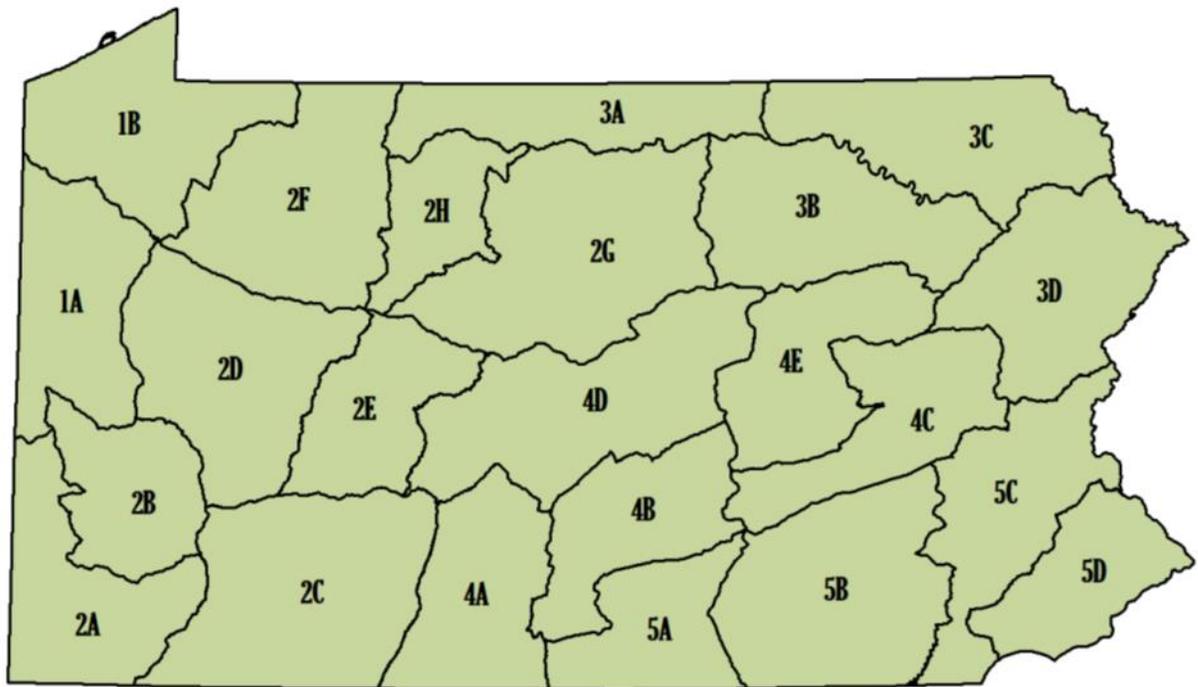

Figure 1. Wildlife Management Units (WMUs)

Note: Adapted from the Pennsylvania Game Commission, Bureau of Wildlife Management Deer and Elk Section. (2021). *Annual Deer Population Report & 2021–22 Antlerless License Allocations Recommendations*. https://www.pgc.pa.gov/Wildlife/WildlifeSpecies/White-tailedDeer/Pages/default.aspx

Before the change, there were 67 CMUs. After the change, there are 23 WMUs. "The WMU system represented a necessary compromise between deer management requirements for adequate data collection and deer habitat distribution and public desires for smaller management units" (Rosenberry & Diefenbach, 2019, p. 71) since smaller WMUs may not provide sufficient area to contain the population of interest. An important differentiation is that CMUs followed political boundaries (counties) while WMUs were based on physical, human and habitat considerations.

This study considered the period from 2006 to 2020. In 2013, WMU 2G was split into two different WMUs (2G & 2H) and, where available, data prior to 2013 was retroactively split between the two locations. The 2G/2H data split was not determined by the author of this study. The agencies owning the data performed the split and provided the information. Additionally, there are three WMUs (2B, 5C and 5D) that are considered highly developed. WMU 2B includes metropolitan Pittsburgh while 5C and 5D largely make up the five county Philadelphia metropolitan area. "The PGC is not using the PASAK to estimate deer populations in these WMUs. The assumption regarding the relationship between hunter effort and antlered harvest rates may be invalid in these WMUs. For this reason, the PGC does not use PASAK estimates to track deer population trends in these WMUs (Rosenberry, Fleegle, & Wallingford, 2011, p. 8)". Data for this research, to the extent possible, was gathered by WMU.

DMRP. The PGCs deer management program begins with a decision tree / algorithm designed to arrive at a deer population recommendation, specifically, stabilize the herd, increase the herd, or decrease the herd (see Figure 2). The PGC considers data for each decision point in arriving at its recommendation. Once the herd recommendation is determined, the PGC

considers various factors including estimated herd size to determine which tools it will

manipulate to operationalize the recommendation.
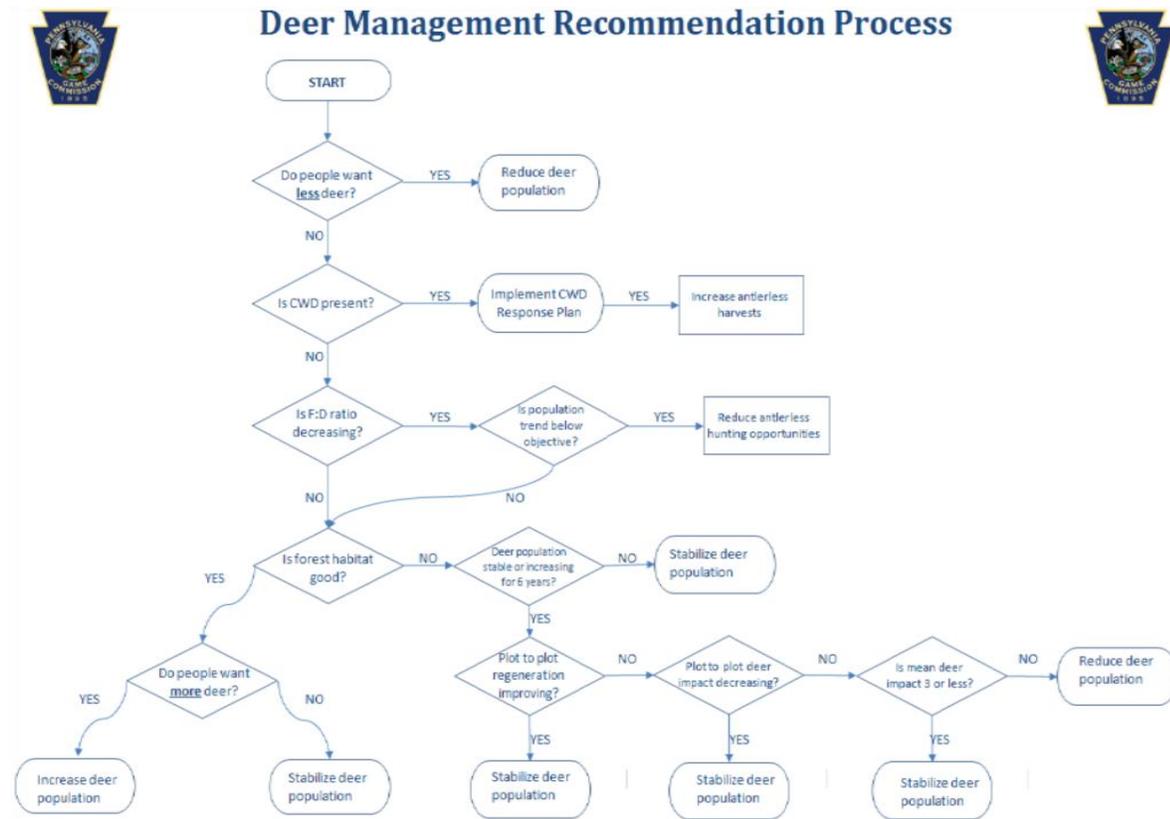
Figure 2. Deer Management Recommendation Process (DMRP)

Note: Adapted from the Pennsylvania Game Commission, Bureau of Wildlife Management Deer and Elk Section. (2021). *Annual Deer Population Report & 2021–22 Antlerless License Allocations Recommendations*. https://www.pgc.pa.gov/Wildlife/WildlifeSpecies/White-tailedDeer/Pages/default.aspx

The deer herd in Pennsylvania is a CPR. As such, there are many governmental entities

that have jurisdictional responsibilities which are served by data collection. Additionally, there

is a large amount of data collected on both a scheduled basis (e.g., annual, bi-annual, every 5

years) and on an ad hoc basis (e.g., once for a specific purpose). This research gathered the

needed information made available to the public through public access websites and organized it into a usable data base.

The metrics or markers monitored to determine the success or failure of CPR management are varied. There is no one universal answer since each CPR is managed by a different authorized body, each CPR represents a different challenge, and each CPR has different goals. This study is specifically focused on determining if the PGC effectively manages the deer herd by considering the following decision points used by the PGC in the DMRP:

- The presence of CWD

- Status of the fawn / doe ratio

- Status of the forest habitat

- Citizens desire for more / less deer

The PGC has various tools at their disposal the purpose of which is to operationalize the outcomes of the DMRP. Those outcomes would be to increase the deer population, stabilize the deer population, or decrease the deer population. Those tools would involve manipulating:

- Annual antlerless license allocations, both in total and by Wildlife Management Unit

- Length of regular firearms hunting season

- Starting day of regular firearms hunting season

- Starting day of the antlerless season

- Antlerless permits authorized by WMU

Finally, the PGC compiles the following summary information to aid in evaluating the success or failure of the model:

- Pennsylvania annual deer population, both in total and by Wildlife Management Unit

- Annual antlerless harvest, both in total and by Wildlife Management Unit

- Annual antlered harvest, both in total and by Wildlife Management Unit

- Total annual hunting licenses issued.

This research considered data on the DMRP decision points, data relative to the manipulative tools, and summary data collected by the PGC and others.

    While there is seemingly a large amount of data available, disparate sources had to be located through a labyrinth of websites and governmental bureaucracies and then assembled into an organized and usable database appropriate for this research. The data for this study is organized by wildlife management unit (WMU). The following table provides a summary of the above data points and the data source:

Table 1

Variables and Sources

Data Point	Source	Years of Data
The presence of CWD	Pennsylvania Game Commission	2013 - 2020
Status of fawn / doe ratio	Pennsylvania Game Commission	2008 - 2020
Status of forest habitat	Pennsylvania Game Commission / USDA Forest Service	2007 - 2019
Citizens desire more / less deer	Pennsylvania Game Commission	2011 & 2019
Annual antlerless license allocations	Pennsylvania Game Commission	2005 - 2020
Annual post hunt deer population	Pennsylvania Game Commission	2006 - 2020
Annual antlerless harvest	Pennsylvania Game Commission	2005 - 2020
Annual antlered harvest	Pennsylvania Game Commission	2005 - 2020
Length of regular firearms season	State of Pennsylvania State Agency Bulletin	2005 - 2020
Starting day of the regular firearms season	State of Pennsylvania State Agency Bulletin	2005 - 2020
Starting day of the antlerless season	State of Pennsylvania State Agency Bulletin	2005 - 2020
Total hunting licenses issued	Unites States Fish & Wildlife Service	2006 - 2020

CWD. Chronic Wasting Disease (CWD) is a fatal illness that impacts the central nervous system of the host and can be found in animals and humans. While the official name of the disease is slightly different depending upon the creature infected (e.g., mad cow in cows and Creutzfeldt-Jakob in humans), it is thought to be spread within the species via fecal matter, bodily fluids or the like. The concern is that it could potentially be transmitted not just *among/within* a species but between differing species as well (Kosak, 2009).

Thousands of free-ranging deer get tested each year and the results are accumulated and published on the Game Commission's CWD Results and Surveillance interactive website. This is kept up to date in real time and contains instances of CWD dating back to when the first instance of CWD was discovered in PA deer (2012). The information can be used by the public to determine if their WMU harvest is at risk, and it also allows for searching by harvest tag number to see if that animal was specifically tested and what the results were.

Fawn / doe ratio. This ratio provides an index of reproductive rates and is an essential component in models used to estimate herd size. Employees at the PGC have been trained as *agers* which allows them to test samples of harvested antlerless deer to determine how many fawns were taken. The proportion of fawns in the antlerless harvest is called the *fawn to doe* ratio (Pennsylvania Game Commission Bureau of Wildlife Management Deer and Elk Section, 2021). Depending upon the status of this ratio (declining, stable or increasing) the PGC uses this to assist in the antlerless license allocation numbers for each WMU.

Citizens opinions. The PGC has periodic surveys performed to determine Pennsylvania residents' opinions on deer management in general and, more specifically, if the deer population in the WMU where they live is too high, just right, or too low. These surveys are conducted every few years by *Responsive Management* a third-party company contracted by the PGC. The

most recent results were based on a survey performed in 2019. The entire survey document has

not been made available as of the writing of this study, but the results needed for testing have

been published as part of the *Annual Deer Population Report & 2021-22 Antlerless License*

Allocations Recommendations document.

The survey performed in 2012 has been published and the methodology described in that

survey is as follows: "This study was conducted for the Pennsylvania Game Commission (PGC)

to determine Pennsylvania residents' opinions on and attitudes toward deer and deer

management, including their participation in deer-related and other wildlife-related activities,

their opinions on management efforts and management goals, their opinions on methods for

managing deer, and their concerns about deer nuisance problems. The study entailed a telephone

survey of Pennsylvania residents 18 years old and older" (Duda et al., 2012).

Deer harvest information. All data about the deer harvest in the Commonwealth of

Pennsylvania is provided each season by the PA Game Commission by WMU. The harvest

numbers for both antlered and antlerless deer are based on hunter harvest reports. Each deer,

immediately upon harvest, must have a tag attached to it detailing the time, the WMU where

harvested and other pertinent information. Upon returning from the field, hunters are required to

report their harvest to the PGC. At the end of the season, harvest numbers are aggregated and

reported to the public. The tag also has the hunting permit number pre-printed on it so that the

deer can be tracked back to individual hunter, if ever needed. Each report of a deer kill equals

one unit of harvested antlered or antlerless deer.

The process of deer hunting requires each hunter to purchase a general permit. This general

permit affords the hunter the opportunity to harvest, among other game, a single antlered deer.

These permits are available through a network of issuing agents of sporting goods stores,

department stores, and county treasurers who must print out the licenses from a proprietary system. In addition, the individual has the ability to apply for and purchase the right to hunt an antlerless deer (doe). The PGC sells these permits via individual county treasurers. As a result, each tag sold is recorded and the PGC has data which details the exact amount of all hunting permits sold.

Post deer hunt population. The post hunt deer population as calculated by PGC is the measure used to estimate the number of deer after hunting season. This helps the Commission determine what the harvest amounts for both antlered and antlerless deer should be. Based on this estimate, they determine the number of antlerless tags to issue which would result in that targeted population. The number of hunting licenses sold determines the total population of hunters attempting to meet the harvest numbers needed/wanted by the PGC.

Status of forest habitat. Having access to an appropriate habitat which provides food, shelter and water is a critical component to the health of a species. However, it is a fine line between a healthy deer herd and a healthy forest. The U.S. Department of Agriculture performs an ongoing forest regeneration study in an effort to quantify the health of the Commonwealth's forests. An analysis of the study demonstrates that "white-tailed deer (*Odocoileus virginianus*) have emerged as the keystone herbivore that drives understory composition and structure" (McWilliams et al., 2017,p. 280). Put simply, forest health is directly linked to deer health. Hunting deer (harvesting deer, actually) is what helps control the deer population which, in turn, helps the state's forests survive. The goal is homeostasis (balance) between the deer and forest regeneration.

Each year, the Commonwealth of PA performs a forest regeneration study which produces a result measured in a percentage. There are then three tiers into which the percentage

is placed based on the value. "If 70% of forested plots have adequate regeneration, forest habitat is considered good. If less than 50% of forested plots have adequate regeneration, forest habitat is considered poor. If 50% to 70% of forested plots have adequate regeneration, forest habitat is considered fair" (PGC, 2021b).

Season characteristics. Each year, the PGC publishes the dates of all hunting seasons. The seasons listed for deer are broken out by antlered and antlerless deer. For purposes of this study, these dates were converted to number of hunting days available for both antlered and antlerless deer. This results in two additional independent variables. While it may seem like the seasons should be the same for all of the WMUs, the PGC uses hunting days as another tool in their population managing arsenal and the number of days is not consistent across all WMUs. Other tools used by the PGC in deer population management are the length of the various hunting seasons and the days on which they begin. Over the years, the start day of the regular firearm season for both antlered and antlerless deer has moved between various days (Friday, Saturday, or Monday). The season start dates are relevant as they are believed to have an impact on harvest numbers.

 Historically, antlered season opened statewide the Monday after Thanksgiving and lasted for two weeks. Antlered season closed on a Saturday and antlerless season opened the following Monday for a period of three days for those hunters with antlerless permits. During more recent times season opening dates, managed at the WMU level, and Sunday hunting have made season characteristics a bit more complex.

These various season characteristics are considered relevant for this research as they are presumed to impact the harvest. A Monday start date eliminates a weekend day of hunting. Most recently seasons have opened on a Saturday which is believed to be more convenient for

sportsman. Additionally, a Saturday start date is presumed more convenient for student or youth hunters in that they do not need to miss school for the seasons opening day.

The date that antlerless begins and how long the season lasts has also changed over time. Historically, the antlerless season began after the close of the antlered season and lasted for only three days. In more recent times, antlerless has opened the second week of regular season and for some seasons, antlerless has opened concurrently with antlered. The effect of this manipulation is believed to be increased or decreased antlerless harvest. Given the possible variations in season length and start, season characteristics will have multiple variations.

Annual deer population. The deer population is calculated using a wildlife management model known as sex-age-kill. The Commonwealth of Pennsylvania simply added the "P" and "A" in front of it and calls it the PASAK model. PASAK was developed in 2005 by PGC biologists. The PGC runs the PASAK model in order to determine the population of deer in each WMU. The population amount allows the commission to determine how many deer need to be harvested to hit the desired post hunt population number. Each deer is scored as one unit of the population number.

Peer reviews were performed on the model by biologists and biometricians from around the country and Canada. Upon completion of the review in 2010, the Wildlife Management Institute (WMI) concluded that "The PGC has developed a credible model that factors in necessary adjustments to reflect antler restrictions. WMI also documented that the PGC strives continually to improve the precision of the model inputs by conducting field research. All parties interested in deer management in Pennsylvania can be confident in the ability of the PGC to track deer population trends at the statewide and WMU levels through the use of the PASAK

as long as PGC data collection thresholds for data input are met or exceeded (Rosenberry et al.,

2011, p. iii).

Limitations on Research

The WMU system was introduced starting with the 2003 hunting season. As more fully

described in the literature review, WMUs replaced counties as the "hunting zones" in the

Commonwealth. However, the PGC did not settle on consistent deer population reporting

standards until 2005 when the PASAK model was instituted. As a result, starting with 2006 all

deer population numbers reported were based on PASAK while 2003-2005 were not. For

consistency, 2006 is the first year used in this study.

In 2013, WMU 2G was split into two separate WMUs (2G & 2H). The data for 2006-

2013, therefore, had to be retrospectively split into the new geographic breakdown.

The PGC does not publish (nor calculate) deer populations for 2B, 5C nor 5D. "The PGC

is not using the PASAK to estimate deer populations in WMUs 2B, 5C, and 5D. These WMUs

are highly developed compared to other WMUs. The assumption regarding the relationship

between hunter effort and antlered harvest rates may be invalid in these WMUs. For this reason,

the PGC does not use PASAK estimates to track deer population trends in these WMUs"

(Rosenberry et al., 2011, p. 8). Being highly developed, the USDA's PA Forest Regeneration

Study also ignores these three WMUs so there is no "adequacy" rating for these locations. As a

result, neither deer population nor forest regeneration were independent variables analyzed for

these three WMUs.

Chapter Summary

This research can be considered a program evaluation and is characterized by a large

cache of publicly available data. This chapter presented the research questions and followed

with a detailed analysis of the type and source of archival data used in this research as well as a

brief overview of the planned data analysis. Succinctly, the quantitative methodology was

outlined in this chapter.

Chapter 4

Findings and Results

Introduction

This research sought to investigate the manner in which the PGC manages the deer herd in Pennsylvania. This chapter presents the findings and the quantitative results of the various models used in exploring, researching, and answering the research questions.

A common pool resource (CPR) is a natural resource that is large enough so that it is expensive to control access in such a way as to limit beneficiaries from deriving neither enjoyment, nor economic, nor any other benefit from the item in question (Garder et al., 1990). As such, it is incumbent upon the entity responsible for its management to consider what is best for the resource, what is best for the users and what is best for the citizenry at large. The Pennsylvania Game Commission bears ultimate responsibility for setting the rules and regulations to ensure effective CPR management.

As will be more fully developed below, the model which PGC uses takes into consideration the various elements in the CPR definition. The quantitative inputs used in this study include data designed to measure the health and welfare of the herd and its habitat, the views and feelings of community members, and the effectiveness of its management by looking at harvest data and what is needed to keep the population healthy. While there is a clear attempt to keep all parties happy, that is difficult given their sometimes-opposing views. This difficulty of management is not a negative, but rather goes to support the importance of public management in the arena of CPRs.

Purpose of the Study

The purpose of this study is to consider the efficacy and fidelity of PGC's methods in managing the white-tailed deer herd in the Commonwealth. While there is no universal answer to herd management given the many constituency interests, the PGC has developed a process through which they attempt to increase, stabilize, or reduce the deer herd (see Figure 2). The purpose of this study is to determine the efficacy of the PGC model by developing a regression model to include the various markers in the PGC model.

Research Questions

The white-tailed deer herd is a valuable resource to the Commonwealth and the efficacy of its management by the PGC is confounded by the many interested constituencies often driven by very different goals and objectives. All constituencies should, however, be concerned that the herd is being managed consistent with the best interests of the Commonwealth as implemented by the goals and objectives of the PGC process. Accordingly, this study endeavors to answer the following questions:

1. How effective is the PGC in the management of the white-tailed deer herd as determined by analysis of its Deer Management Recommendation Process (DMRP)?

2. Is controlling the number of antlerless permits by WMU an effective method of controlling herd size as measured by reported antlerless harvests?

3. Are current herd management tactics resulting in an optimal herd allocation between Northern and Southern tier WMUs that is the best use of resources for the citizens of the Commonwealth of PA?

Data

The data required for this research was assembled from a variety of sources (see Table 1). While the Pennsylvania Game Commission website provided much publicly available information, it is not located in one centralized location, nor is it organized in a consistent format in a singular report. As a result, the database used for this research was compiled from several disparate sources.

The presence of Chronic Wasting Disease (CWD) within the herd is tracked by the PGC to ensure the health of the herd. If CWD is present in a specific WMU, then the license allocation will be increased to reduce herd size with the goal of lowering or eliminating the occurrences of deer infection. The number of harvested deer sampled and the number of positive results for each WMU for every year between 2013 and 2021 were accumulated for this research. The first year CWD was detected in PA was 2012, so program testing did not begin until the 2013 hunting season.

Using the PGC data source for CWD, each WMU was researched and the CWD variable was given a value of a "0" or "1". A 0 value was assigned indicating that there were no cases of CWD detected in the WMU and a value of 1 if any number of cases above "none" were detected (anything greater than 0 cases was given a 1 value).

The Annual Deer Population Report & 2021-22 Antlerless License Allocations Recommendations published by the Pennsylvania Game Commission Bureau of Wildlife Management Deer and Elk Section contributed information to the study related to the status of the fawn/doe ratio, the status of forest habitat, PA citizen deer survey, annual antlerless license allocations, annual post hunt deer population (PASAK), annual antlerless harvest, and annual antlered harvest for the periods from 2006 to 2020.

The Annual Deer Population Report did not provide PASAK data for the period 2006 –
2007 for any WMU except 2B, 5C and 5D. Neither did it present the antlerless license
allocations for 2G from 2006 - 2012. This information was obtained from the Deer Health,
Forest Habitat Health, Deer Harvests, and Deer Population Trends by Wildlife Management Unit
reports published by PGC. Other exceptions include WMU 2G which was split into two
different WMUs (2G & 2H) in 2013 and, where available, data prior to 2013 was retroactively
split between the two locations. The 2G/2H data split was not determined by the researcher.
The agencies owning the data performed the split and provided the information.

The method used for calculating healthy forest habitat was changed by the USDA in 2007
so there was no value used for this variable for any of the WMUs in 2006 to avoid any
comparability problems. At this writing, the 2020 results were not yet made public.

Forest habitat is determined by the USDA's PA Regeneration Study. The percentage
results yielded by the USDA study were converted to a Good/Fair/Poor scale by the USDA and,
for purposes of this paper, a dummy variable was created. If > 70% of forest plots have
regenerated over a three year period than it is deemed "Good" and a "1" was assigned to the
dummy variable. Regeneration between >=50% and <=70% is considered "Fair" and assigned a
"2" while <50% regeneration is "Poor" and given a "3".

PGC does citizen surveys on a periodic basis. The most recent surveys completed and
made available were from 2011 and 2019. The two PGC surveys of residents' opinions on deer
were dated 2011 and 2019. Results from the 2011 survey were assigned to years 2011 – 2019
and the 2019 results were assigned to 2020. The values possible were a "1", "2" or "3". A 1
indicates that > 25% of respondents think deer population is too high, a 3 indicates that >25% of

respondents think deer population is too low and a 2 indicates that <25% think deer population is too high and <25% think deer population is too low.

Three WMUs, 2B, 5C and 5D, are considered highly developed. WMU 2B includes metropolitan Pittsburgh while 5C and 5D largely make up the five county Philadelphia metropolitan area. "The PGC is not using the PASAK to estimate deer populations in these WMUs. The assumption regarding the relationship between hunter effort and antlered harvest rates may be invalid in these WMUs. For this reason, the PGC does not use PASAK estimates to track deer population trends in these WMUs (Rosenberg et al., 2011, p. 8)". In addition to PASAK, the PGC ignores the forest habitat condition in these highly developed WMUs.

A variable was defined for this research that considered the starting day of the antlered regular firearm season and the starting day and length of the regular antlerless firearm season. Season start dates and length were obtained from the Pennsylvania Bulletin (published by the PA Legislative Reference Bureau) for the years 2006 through 2020.

The variable was created to distill the various changes in the general firearm hunting season into a usable SPSS format. Three different variable definitions were identified: "1" indicates an antlerless season concurrent with the antlered season, opening day on Monday; "2" indicates an antlerless season concurrent with the second week of antlered season only; and "3" indicates an antlerless season concurrent with the antlered season, opening day on Saturday. It is important to distinguish between a Monday and a Saturday opening day as a Saturday opening day allows for an extra weekend hunt in the season.

The total number of general paid hunting licenses sold each year was obtained from the U.S. Fish and Wildlife Service (2021) from their National Historical Hunting License Database.

While this information was not relevant to the research questions, it informed the researcher as to the size of the hunter population in Pennsylvania.

Results

The PGC deer management program begins with a decision tree / algorithm, the DMRP, designed to arrive at a deer population recommendation to stabilize, increase, or decrease the herd (see Figure 2). The PGC considers data for each decision point in their algorithm in arriving at its recommendation. Based on the recommendation of the DMRP, the PGC considers estimated herd size and which tools it will manipulate to operationalize the recommendation.

The researcher's first consideration in answering the research questions was to build a multiple regression model by WMU with antlerless deer harvest as the dependent variable utilizing all of the markers of the DMRP and the various tools implemented as independent variables by WMU. Antlerless harvest was selected as the dependent variable because it is the prime tool used by the PGC to alter the deer herd. The independent variables included the presence of CWD, the fawn / doe ratio, status of the forest habitat, citizens desire for more / less deer, antlerless license allocations, and season length and starting day of the antlerless season. The model was run, on a test basis, for selected WMUs. Results of the model suggested that none of the independent variables chosen were significant at the .05 level in predicting the antlerless harvest.

Based on the disappointing results of the first all inclusive regression model, the researcher removed certain independent variables and viewed the PGC model for managing the herd as the two-step process that it is. The first step involves the DMRP. That model considers the results of the citizens survey, the presence of CWD, the status of the fawn to doe ratio, and the forest habitat to determine a targeted result: should the herd be stabilized, increased, or

decreased. Based on the results of the first step and an estimate of herd size, the PGC decides on how they will manipulate the tools they have to achieve their targeted result.

A second iteration of the model was run with antlerless harvest as the dependent variable and fawn to doe ratio, hunting season, and antlerless license allocation as the independent variables. The results of this model, presented at Table 2, suggested significance of various factors at the .05 level and mixed R^2 results.

Table 2 Predictors of Antlerless Deer Harvest

Table 2a Predictors of Antlerless Deer Harvest - Northern Tier

	Wildlife Management Unit (WMU)							
Variable	1B	2F	2G	2H	3A	3B	3C	3D
Constant	-23756.79	9601.85*	3284.38	-45.58	-1322.63	9756.40*	-4030.40	-811.40
Fawn to Doe Ratio	17833.67	-16634.11	-8301.67	-404.95	-7946.26	-16677.73*	8703.63	15899.72
Hunting Season	-699.43	-298.59			784.61	-289.67	1022.74	-1372.25*
Antlerless License Allocation	0.91*	0.15	0.17	0.27	0.39*	0.15*	0.28*	0.11*
R^2	0.85	0.59	0.32	0.20	0.78	0.74	0.86	0.77
F	17.45*	4.37*	2.08	0.62	10.58*	8.32*	17.70*	9.91*

*$P<.05$

Table 2b Predictors of Antlerless Deer Harvest - Southern Tier (Part 1)

	Wildlife Management Unit (WMU)							
Variable	1A	2A	2B	2C	2D	2E	4A	4B
Constant	34624.48	8134.06	-1118.22	-110.82	-14522.29	-5386.66	-1027.77	-17010.70
Fawn to Doe Ratio	-55442.62*	3960.79	11867.22	-2966.84	29513.09	11256.52	10577.72	63880.29
Hunting Season	-2580.65	-2297.27*	181.40	414.67	2809.17	413.33	224.04	7625.09
Antlerless License Allocation	0.10	0.13	0.17	0.25*	0.27*	0.29*	0.13	-0.45
R^2	0.56	0.73	0.33	0.89	0.51	0.80	0.38	0.13
F	3.86*	8.19*	1.49	23.32*	3.11	12.21*	1.82	0.43

*$P<.05$

Table 2b Predictors of Antlerless Deer Harvest - Southern Tier (Part 2)

	Wildlife Management Unit (WMU)						
Variable	4C	4D	4E	5A	5B	5C	5D
Constant	2796.03	3373.27	20456.13*	-1535.26	15487.39	711.89	3723.45
Fawn to Doe Ratio	-6735.74	-18264.44	-28814.81*	-2744.16	-15359.64	6954.58	-9647.33*
Hunting Season	-322.09	942.07	-1145.62	-407.66	1547.39	-204.02	-100.18
Antlerless License Allocation	0.23*	0.24	0.004	0.36	0.03	0.18*	0.24*
R^2	0.81	0.78	0.63	0.69	0.68	0.95	0.91
F	12.60*	10.72*	5.01*	6.73*	6.48*	53.94*	31.64*

*$P<.05$

Research Question 1

The first research question sought to consider the effectiveness of the PGC in managing the white-tailed deer herd as determined by analysis of its Deer Management Recommendation Process (DMRP). Assessing the overall effectiveness of the PGC's management of the herd would suggest a regression model using aggregated statewide data. However, the PGC manages the herd at the WMU level (N=23) each with very specific geographic characteristics and herd management requirements. The researcher believes a statewide regression model would have contributed little toward evaluating PGC's effectiveness.

The research model was run for each of the 23 WMUs with the intention to choose selected WMUs for further analysis. The WMUs chosen for analysis were based on their determined R^2; the higher the R^2 the more of the variation in antlerless harvest explained by the independent variables.. The WMUs selected were three with the highest R^2 and three with the lowest R^2. High R^2 might suggest effectiveness of the model in predicting antlerless harvest while low R^2 might suggest poor effectiveness or a need to better understand other factors. The WMUs selected and their respective R^2 are presented at Table 3.

To evaluate the effectiveness of PGC's efforts to manage the deer herd, the researcher first identified the apparent herd management goal for each of the six WMUs selected as evidenced by the number of antlerless permits issued. If allocated permits were increasing, the presumed goal would be to decrease the herd size. If allocated permits were decreasing, the presumed goal would be to increase the herd. With the herd management goal identified and using the data points of the DMRP for the years 2015 through 2020, the second step would be to review the markers of the DMRP to determine if the markers support the identified goal. Succinctly, the research would evaluate effectiveness by working in reverse from the identified

herd management goal and then consider whether the four main markers of the DMRP would

seem to support the PGC course of action. The data for the six WMUs used for this analysis is

presented at Table 3.

      Results of the citizen's survey were redefined to facilitate answering of question 1.

Citizen's opinions of the deer herd size were converted from percentages to just right (JR), too

high (TH), or too low (TL). Forest health was similarly scaled from percentages to good (G),

fair (F), or poor (P). There were no instances of good forest health. Where the percentages were

considered close WMUs were labeled F/P.

Table 3. Selected WMU DMRP Data Markers

	2015	2016	2017	2018	2019	2020
WMU 1B (Northern; R^2 = .85)						
Citizen opinion	JR	JR	JR	JR	JR	JR
CWD presence	N	N	N	N	N	N
Fawn/Doe ratio	.40	.37	.39	.35	.33	.31
Forest health	F	P	P	F/P	F/P	NA
PASAK (in thousands)	47.4	71.7	74.0	81.4	60.8	81.7
Permits (in thousands)	29	29	35	37	35	41
Observed PGC goal		STA	RED	RED	INC	RED
WMU 2C (Southern; R^2 = .89)						
Citizen opinion	JR	JR	JR	JR	JR	JR
CWD presence	Y	Y	Y	Y	Y	Y
Fawn/Doe ratio	.37	.35	.37	.34	.35	.33
Forest health	F	F	F	F	F	NA
PASAK (in thousands)	66.0	83.4	69.0	113.7	85.4	97.3
Permits (in thousands)	31	31	31	44	52	58
Observed PGC goal		STA	STA	RED	RED	RED
WMU 2G (Northern; R^2 = .32)						
Citizen opinion	JR/TL	JR/TL	JR/TL	JR/TL	JR/TL	JR/TL
CWD presence	N	N	N	N	N	N
Fawn/Doe ratio	.34	.31	.29	.35	.26	.24
Forest health	F	F	F	F	F/P	NA
PASAK (in thousands)	40.3	65.6	67.9	81.8	55.2	70.9
Permits (in thousands)	22	21	25	30	26	27
Observed PGC goal		STA	RED	RED	INC	STA
WMU 2H (Northern; R^2 = .20)						
Citizen opinion	JR/TL	JR/TL	JR/TL	JR/TL	JR/TL	JR/TL
CWD presence	N	N	N	N	N	N
Fawn/Doe ratio	.33	.24	.4	.35	.32	.22
Forest health	F	F	F	F	F	NA
PASAK (in thousands)	16.9	15.4	15.7	38.6	18.9	25.3
Permits (in thousands)	6	6	7	6	6	7
Observed PGC goal		STA	STA	STA	STA	STA
WMU 3C (Northern; R^2 = .86)						
Citizen opinion	JR/TH	JR/TH	JR/TH	JR/TH	JR/TH	JR/TH
CWD presence	N	N	N	N	N	N
Fawn/Doe ratio	.34	.38	.33	.32	.27	.29
Forest health	F	F	F/P	P	P	NA
PASAK (in thousands)	68.0	83.2	85.1	79.9	57.2	75.4
Permits (in thousands)	36	36	42	38	46	49
Observed PGC goal		STA	RED	STA	RED	RED
WMU 4B (Southern; R^2 = .13)						
Citizen opinion	JR	JR	JR	JR	JR	JR
CWD presence	N	N	Y	Y	Y	Y
Fawn/Doe ratio	.36	.35	.34	.30	.29	.32
Forest health	F	F	F	F	F	NA
PASAK (in thousands)	45.4	57.8	55.9	52.4	50.1	54.0
Permits (in thousands)	26	26	26	26	32	33
Observed PGC goal		STA	STA	STA	RED	RED

WMU 1B. The analysis of 1B suggests the PGC goal is to reduce the size of the herd. This research notes that while the fawn/doe ratio is decreasing, as is the case in 1B, the PASAK model herd population estimates are significantly increasing. That would seem counter to our expectation given the fawn/doe ratio definition. A decline in the ratio would suggest fewer yearlings were seen and harvested and more adult antlerless deer were harvested, both factors intuitively suggesting a decrease in herd size.

WMU 2C. Analysis of 2C suggests the PGC goal is to decrease the herd. All factors of the DMRP considered, the presence of CWD and the herd size appear to be the controlling factors in determining the goal. We again note a substantial increase in herd size for the period considered while the FD ratio remains relatively stable.

WMU 2G. The results of the citizen survey for 2G suggests that 84% of respondents believe the herd is just right to too low. The fawn to doe ratio is falling with the herd numbers increasing. While the PGC has moved the doe permit numbers up and down during the period observed, it appears the overall goal is to stabilize.

WMU 2H. The antlerless permit allocations for WMU 2H suggests that the PGC goal is to stabilize the herd. Herd size is again increasing while the fawn to doe ratio is falling. The results of the citizen survey for 2H also suggests that approximately 84% of respondents believe the herd is just right to too low.

WMU 3C. With approximately 85% of resident survey respondents suggesting the herd is just right to too high, the observed PGC goal appears to be to reduce the herd. The fawn to doe ratio is decreasing while the herd size is comparatively stable.

WMU 4B. The observed PGC strategy for 4B has been to change from one of stabilize to, in recent years, a goal to reduce the herd. Estimates of herd size did vary but, generally,

remained stable along with the fawn to doe ratio. This WMU has reported cases of CWD beginning in 2017.

Research Question 2

The second research question asked whether controlling the number of antlerless permits by WMU was an effective method of controlling herd size as measured by reported antlerless harvests. To answer this question, the researcher considered the significance of the antlerless license allocation variable in the regression model of each WMU. The results of the regression were inconsistent.

Antlerless license allocations were significant in 11 of 23 WMUs including WMUs 5C and 5D (Philadelphia Metropolitan Area) which are deemed highly developed. The initial thought of the researcher was that antlerless license allocations would be significant in nearly all WMUs given its key role in controlling herd size. The raw data and the regression model results suggest that this is not consistently the case. By way of example, in 2019 the PGC authorized and issued 49,000 antlerless deer licenses in WMU 1A and kept this number constant in 2020. However, the antlerless deer harvest in 2019 was 13,160 deer and in 2020 it increased to 17,509 representing a 33.0% harvest increase with no license increase. While the results of the regression models suggest that there is not a singular variable that is consistently significant in predicting deer harvest, license allocation appears as significant on a more frequent basis than any other variable.

Research Question 3

The third and final research question asked whether herd management tactics resulted in an optimal herd allocation between Northern and southern tier WMUs that is the best use of resources for the citizens of the Commonwealth of PA. The researcher considered the regression

results of the northern tier WMUs versus the southern tier WMUs to answer this question. There was not a singular variable that was consistently shown to be significant in all WMUs or between or within the tiers.

Referring to Table 2, there were 24 total variables used as regression input for the Northern Tier (3 for each of the 8 Northern Tier WMUs). Of the 24, there were 7 occurrences of a statistically significant variable for an overall percentage of 29.2% (=7/24). There were 45 Southern tier total variables used as input for the southern tier (3 for each of the 15 southern tier WMUs) with 10 occurrences of a statistically significant variable for an overall percentage of 22.2% (=10/45). The average R^2 for the 8 North tier WMUs was .64 and the average R^2 for the 15 southern tier WMUs was .65.

R^2 is a measure of the predictability of the regression model. The fact that the average predictability of each tier is within .01 of each other, it is reasonable to conclude that the regression is equally as likely to predict deer harvest in the north as it is in the south. Additionally, the percentage of statistically significant variables in the north and in the south are also close to each other. The R^2 of the regression models of both tiers and the relatively low percentage of statistically significant variables in each tier suggests that the PGC model appears equally effective in managing the deer herd in both tiers.

Conclusion

The DMRP is the decision tree / algorithm developed and utilized by the PGC in determining what the deer herd size goal should be per WMU. The DMPR considers basically four markers in setting that goal. While certain of the markers considered in the DMRP seem consistent with our observed herd management goals for the six WMUs observed, other markers seemed to be of less influence on the model.

Antlerless license allocation is the variable that occurs as significant in PGC's management of the herd size most frequently. That frequency is not sufficient enough to conclude it is 100% reliable, but it is enough to conclude that it is the best of the worst. Both the Northern and southern tier WMUs have an equal average statistical reliability (R^2) as it relates to the predictability of the regression variables. However, this average is .64 & .65 which, when combined with the relatively low overall percentage of variables in both tiers that are significant, leads to a conclusion that both tiers are managed the same, but not necessarily that effectively.

Chapter 5

Discussion

Introduction

This research might be considered a program analysis. Generally, the purpose of program analysis is either to cut operating costs or, as is the current case, assess the effectiveness of the service provided. Unlike program analysis, this research is based on archival information and data available in the public domain. The researcher did not have access to any other PGC information that might have better informed these results.

Conclusions

The DMRP is the decision tree / algorithm developed and utilized by the PGC in determining whether the deer herd size per WMU should be increased, reduced, or stabilized. The DMPR considers basically four markers in setting that goal. While certain of the markers considered in the DMRP seem consistent with our observed herd management goal for the six WMUs observed, other markers seemed to be of less influence on the model.

Antlerless license allocation is the variable that occurs as significant in PGC's management of the herd size most frequently. That frequency is not sufficient enough to conclude it is 100% reliable, but it is enough to conclude that it is the best of the worst. Both the Northern and southern tier WMUs have an equal average statistical reliability (R^2) as it relates to the predictability of the regression variables. However, this average is .64 & .65 which, when combined with the relatively low overall percentage of variables in both tiers that are significant, leads to a conclusion that both tiers are managed the same, but not necessarily that effectively.

Discussion

While we know the basic factors of the DMRP, we are uncertain as to the relative weight, if any, that might be assigned to markers. The model begins by considering whether people want less deer; if they do then the goal is set to reduce the herd size and the model ends. That would suggest that the will of the people in wanting less deer is more powerful than any of the other markers. Further, whether people want more deer is the last consideration in the model suggesting the least importance to the PGC. We might wonder whether there is an unpublished hierarchy of markers.

Not considered in the data and not directly made a part of the DMRP, is the role potentially being played by the lumber and natural gas industry in the Northern Tier WMUs. It is no secret that the Northern Tier of Pennsylvania produces some of the best hardwood cherry in the country. Further, it is no secret that the fracking and drilling for natural gas has changed the face of many Northern Tier WMUs. Since deer potentially effect young forest growth and natural gas exploration impacts the forest with roads, wells and pipelines, it is uncertain what part these industries might play in the management of the deer herd.

The method for answering Question 1 was to look at the DMRP resulting goal based on the number of antlerless permits allocated and compare that observed goal with the model's underlying markers. This research noted some relatively large variations in PASAK model herd estimates year over year. Specifically, PASAK estimates suggested relatively large changes in herd size for most WMUs for 2018, 2019, and 2020. The research further notes the absence of a corresponding change in antlerless permit allocations. While variation itself is not indicative of error, variation and inconsistency with other markers might be cause to consider the reliability of the estimate.

The hunter survey is performed every 3 years and is an in-depth look at the opinions of the hunters in Pennsylvania. According to the PGC, the estimates of the results have "a 95% confidence interval of approximately +/- 2%" (Rosenberry, Wallingford, Fleegle, Gustafson, & Lupo, 2013, p. 3).

The survey has sections for different game species (e.g. deer, turkey, etc.), different season (e.g. firearms, bow, etc.) and asks questions about the markers used by PGC in their antlerless license allocation decision tree. Not surprisingly, hunters in PA believe that the deer population in each WMU is too low and this is consistent across the publicly available survey results. This is in contrast to the citizen survey, the results of which demonstrate that there is variation among WMUs as to the level of deer (too much, just right, not enough).

The fawn to doe ratio is the percentage of the antlerless harvest that are fawns. There appears to be a question about its sensitivity. As observed in several of the WMUs a drop in the ratio occurred in the same year with substantial increases in PASAK estimates of herd size. A decrease in the FD ratio should have lead to an expected decrease in herd size and a corresponding reduction in the related antlerless permit allocation. Only modest, if any, change in antlerless allocations was observed suggesting that while the model is determined each year, the PGC recognizes the potential imperfections in the data short-term and views the results on a more long-term basis. The results of the regression model run for all 23 WMUs suggested that the FD ratio was significant at the .05 level for only 4 WMUs.

One potential reason for the insensitivity could be the fact that PGC trains deer agers to go into the field and randomly select antlerless kills to determine deer age at the time of harvest. The deer are not aged like a tree in that the number of rings corresponds to the age of the tree. Rather, there is some subjectivity in the process which could artificially move the ratio up or

down.   Even a slightly skewed ratio could have implications since the fawn to doe ratio is a key determinant of the DMRP.

This research calls into question whether managing herd size on a short term, year over year basis is effective. PASAK model estimates suggest some large herd sizes and year over year variations. PGCs data suggest that it requires between 3 to 5 antlerless permits to harvest 1 deer, depending on WMU. That would suggest that 1,000 antlerless permits would result in approximately 200 to 300 deer being harvested.

Limitations

As a CPR, the public administration governing body (PGC) can only make effective management decisions based on the information available at their disposal. Despite the abundance of publicly available information provided by the PGC, it became clear during the research that there are some data limitations. Many of the data markers used by PGC are based on the self-reporting of information by hunters. While we would like to think that this information is reliable, this data is potentially confounded by accidental errors. Further, there are deer harvests that are not reported.

Of the key markers used by PGC, the number of deer harvested and the information that is submitted in support of the harvest, relies on the hunter providing important information. For example, a specific "antlerless" tag must be attached to any deer harvested indicating the WMU, date, time and weapon used in the harvest. A hunter could harvest a doe and use an antlered tag, therefore, overreporting the number of male and underreporting the number of female deer killed. This would also allow the hunter to harvest an extra doe since the doe tag would still be available for use. The hunter could also indicate the incorrect WMU if it was killed in a WMU where the hunter was not permitted and/or the wrong date, time, and weapon to make sure the

harvest was "in-season". Finally, there is the issue of unreported harvests . A general term which can be used to describe these mistakes or transgressions would be "poaching" and any or all could lead to incorrect assumptions by the PGC. As an example of an incorrect conclusion, if CWD was discovered in a deer that was reported in the wrong WMU, it could indicate the spread of the disease where none actually existed.

Citizen opinion polls are not conducted frequently. While an outside vendor performs the surveys on behalf of the PGC, the most recent polls were dated 2011 & 2019 leaving large gaps of time in between. The hunter survey (performed by the PGC) occurs more frequently but is still only on a 3-year cycle. For the research performed herein, the most recent years available were 2011, 2014 and 2017. The 2020 survey was not made available to the public as of the date of this paper.

Rather than 100% population testing, sampling is used to determine certain PGC markers. Forest health and fawn to doe ratio depend upon such sampling to select only certain forestry plots or deer to test. The forestry survey is designed, overseen and performed by the U.S. Department of Agriculture and the fawn to doe ratio is PGC controlled. It is possible that the sampling, while correctly performed, presents a flawed overall perspective.

PASAK herd size data seems to suggest that herd size can change significantly in a relatively short period of time. When combined with the above-mentioned time gaps in citizen and hunter surveys, it suggests that the survey results might carry less weight the older the data. A final limitation which is difficult, if not impossible to quantify, is the inherent difficulty of managing a state as large as Pennsylvania with its wide variety of geographic and socio-economic diversity as a singular entity with a common model applied to all WMUs.

Future Research

It would be premature to use this research as the penultimate conclusion of the Game Commissions' management of the common pool resource. Through the course of the research it was found that the PGC really wants to be transparent as to how and why they make decisions concerning the deer herd. However, it is a monumental task given the aforementioned data limitations and pure size of the state.

Future research could focus on ways to make the data collection portion of the process more effective and efficient and, if possible, make less of the information reliant on self-reporting. That is not an easy ask. The very nature of hunting makes it difficult to automate the reporting of harvests by anyone or anything other than the hunter. Even if there was a method to introduce more technology and/or game commission personnel into the equation, the issue of resource scarcity becomes all too clear. The last thing PA needs is an unfunded mandate.

Looking at the regressions and their corresponding output, there is great variability both within and between the geographic tiers. Future research should consider the possibility of other predictive or explanatory variables.

Summary

This chapter began with the conclusion of the research. A discussion of significant observations regarding the research followed. Limitations of the data collected for the research were then identified and described and, finally, a section on what future research regarding this topic could focus on was presented.

The purpose of program analysis is to assess the effectiveness of a program, in this case the effectiveness of the Pennsylvania Game Commission in managing the white-tailed deer herd in the Commonwealth. This research suggests that controlling the herd size through the use of

antlerless permit allocations is the most effective method at this time. This research suggests that the reliability of the data points available to and used in the DMRP are such that adjusting the herd size through short-term reactionary adjustments to the antlerless permit allocations may not be managing the herd in the best interests of the citizens of the Commonwealth. Rather, the results of this research would tend to support the need for a longer planning horizon for herd management.

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