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

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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.

Keywords: *Pennsylvania Game, Pool Resource and Public Management*

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Background to the Study

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 targeting 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):

i. **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.
ii. **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.
iii. **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.

Table 1.

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.

Review of the Relevant Literature

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):

i. "Used by multiple-users and/or multiple-user groups
ii. Joint use involves subtractability
iii. 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 known 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:

i. One-Shot Games
ii. Time-Independent Repeated Games
iii. Time-Dependent Repeated Games

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.

References

Curtis, P. D., & Sullivan, K. L. (2001). *White-tailed deer: Wildlife Damage Management Fact Sheet Series. Ithaca, NY, Cornell Cooperative Extension*.

DCNR. (2021). *Deer Management*. Pennsylvania Department of Conservation & Natural Resources. https://www.dcnr.pa.gov/Conservation/Biodiversity/BiodiversityManagement/DeerManagement/Pages/default.aspx

D'Angelo, G. J. (2009). White-tailed Deer Management Plan, Robert B. Gordon Natural Area of West Chester University, Chester County, Pennsylvania.

Diefenbach, D. R., Palmer, W. L., & Shope, W. K. (1997). Attitudes of Pennsylvania sportsmen towards managing white-tailed deer to protect the ecological integrity of forests, *Wildlife Society Bulletin*, 244-251.

Fudenberg, D., & Tirole, J. (1987). Understanding rent dissipation: on the use of game theory in industrial organization. *The American Economic Review*, *77*(2), 176-183.

Gardner, R., Ostrom, E., & Walker, J. M. (1990). The nature of common-pool resource problems. *Rationality and society*, *2*(3), 335-358.

Gordon, H. S. (1954). The economic theory of a common-property resource: the fishery. In *Classic papers in natural resource economics* (pp. 178-203). Palgrave Macmillan, London.

Hardin, G. (1968). The tragedy of the commons: the population problem has no technical solution; it requires a fundamental extension in morality. *Science*, *162*(3859), 1243-1248.

Kosack, P. P. J. (2009). *Management and biology of white-tailed deer in Pennsylvania*.

Ostrom, E. (2015). *Governing the commons: the evolution of institutions for collective action*. Cambridge university Press.

Parker, H. A., Larkin, J. T., Heggenstaller, D., Duchamp, J., Tyree, M. C., Rushing, C. S., & Larkin, J. L. (2020). Evaluating the impacts of white-tailed deer (Odocoileus virginianus) browsing on vegetation in fenced and unfenced timber harvests, *Forest Ecology and Management*, *473*, 118326.

PGC. (2021a). *About Us. Pennsylvania Game Commission,* https://www.pgc.pa.gov/InformationResources/AboutUs/Pages/default.aspx

PGC. (2021b). *Frequently Asked Questions*. Pennsylvania Game Commission. https://www.pgc.pa.gov/InformationResources/Pages/FAQs.aspx

Pennsylvania Game Commission. (2020). *Fiscal 2020 annual legislative report*, https://www.pgc.pa.gov/InformationResources/MediaReportsSurveys/Documents/2020% 20PGC%20Annual%20Legislative%20Report.pdf

Pennsylvania Game Commission, Bureau of Wildlife Management Deer and Elk Section. (2021). *Annual deer population report & 2021–22 Antlerless license allocationsRecommendations*, https://www.pgc.pa.gov/Wildlife/WildlifeSpecies/White-tailedDeer/Pages/default.aspx

Rosenberry, C. S., & Diefenbach, D. R. (2019). Deer harvest variation in small and large management units in Pennsylvania, *Wildlife Society Bulletin*, *43*(1), 71-76.

Rosenberry, C., Wallingford, B., Fleegle, J. T., Gustafson, D., & Lupo, P. (2013,). *Deer health, forest habitat health, deer harvests, and deer population trends by wildlife management Unit* (No. 06210–21001). Pennsylvania Game Commission Bureau of Wildlife Management Project Annual Job Report.

Steins, N. A., & Edwards, V. M. (1999). Platforms for collective action in multiple-use common-pool resources, *Agriculture and Human Values*, *16*(3), 241-255.

Tang, S. Y., Callahan, R. F., & Pisano, M. (2014). Using common-pool resource principles to design local government fiscal sustainability, *Public Administration Review*, *74*(6), 791-803.

Weiss, C. H. (1972). *Evolution*. Saddle River: Prentice-Hall.