ANALYZING POPULATION TRENDS FOR AN ACTIVELY POACHED PLANT SPECIES: *GALAX URCEOLATA* IN THE BLUE RIDGE PARKWAY

by

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(Under the Direction of Brian Irwin)

ABSTRACT

Exploitation is a key factor in global biodiversity declines and poaching as a subset of exploitation threatens many plant species. Non-timber forest products (NTFPs) are harvested for a variety of uses and poaching is a major concern for their conservation. The southern Appalachians are a hotspot of NTFP biodiversity and harvest, and a variety of measures have been used to prevent poaching and overharvest of NTFPs. Leaves from *Galax urceolata* (galax) are harvested for use in the floral industry, and galax poaching occurs in the Blue Ridge Parkway (BRP). We assessed potential poaching prevention strategies for galax, using mixed-effects modeling approaches to analyze trends in galax density, large-leaf counts, and patch extent at nine sampling locations. Poaching type was positively associated with some of these galax metrics, potentially indicating site-selection preferences of poachers. Park-wide estimates indicated that galax trends are stable, but some plot-level estimates showed more substantial declines.

INDEX WORDS: Galax, *Galax urceolata*, Non-timber forest products, Poaching, Protected areas, Mixed-effects modeling, Southern Appalachians

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DEDICATION

This thesis is dedicated to my parents, for their support and encouragement throughout my education and career. To my dear friends Carlin and Murie—our calls over the course of the pandemic helped keep me sane and I can’t thank you enough for lending an ear. Thank you for your support and friendship, and for sharing your confidence in my abilities when I needed it most. For listening to my frustrations and anxieties and lending your abundant support, I couldn’t have done this without you.

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CHAPTER 1

INTRODUCTION

Exploitation is a major factor linked with global declines in biodiversity and poaching as a subset of exploitation poses a considerable threat to many species (Chen et al., 2019; Gavin et al., 2010; Linares et al., 2012; Reynolds, 2001). Non-timber forest products (NTFPs) represent a wide range of species harvested from forest ecosystems for a variety of different uses, from food and medicine to use in the floral industry and decorations. Harvester communities of NTFPs are also very diverse in terms of their demographics, motivations for harvest, and harvest stewardship practices. The range of species harvested as NTFPs as well as the diversity of harvester communities present unique challenges to their conservation (Chamberlain et al., 2018; Molina et al., 1997). Additionally, NTFPs have traditionally been understudied when compared with more conventional forest products like timber and these subsequent gaps in knowledge represent a barrier to the effective conservation of NTFPs.

The temperate forests of the southern Appalachians of the United States are a hotspot of biodiversity in NTFPs as well as their harvest. Overharvest and poaching may be leading to declines in the populations of NTFP species. Considerable research has been done on the impacts of harvest on the demographics and population viability of some of these species (Mooney and McGraw, 2009; Robbins, 2000; Small et al., 2011; Small and Chamberlain, 2018). This research has shown that differences in harvest practices can have dramatically different impacts on population vital rates (survival, growth, reproduction) and can have major implications for the sustainability of harvest.

Poaching is simply illegal harvest. The nature of the violation can be based on a variety of factors including the time or place of harvest as well as the type of organism harvested, and the method or amount of harvest. Motivations for poaching can differ among individual harvesters, and they can also overlap so that a person might choose to poach for a variety of reasons (Muth and Bowe, 1998). Conventional approaches to poaching prevention have focused on restricting or preventing access to natural resources, as well as increasing the penalties for individual poachers (Hübschle, 2017). These 'fences and fines' strategies, which typify the 'fortress' approach to conservation, have been limited in their success at preventing poaching from protected areas (Challender and MacMillan, 2014; Jacoby, 2014; Lemieux, 2014; Outland, 2018). In addition, these methods often fail to adequately address the root causes of poaching conflicts and can exacerbate cycles of poverty and violence (Lunstrum, 2014; Massé, 2020). More recently, researchers have explored how situational crime prevention strategies might be applied to natural resource crimes like poaching (Lemieux, 2014). In Chapter 2 we review a number of these approaches and how they might be leveraged towards effective and equitable conservation of *Galax urceolata*, (galax), a plant harvested for its leaves which are used in the floral industry. Galax is currently being poached from the Blue Ridge Parkway (BRP).

Galax urceolata is a perennial understory forb whose range is centered in the Southern Appalachians of the United States (Predny and Chamberlain, 2005; Spira, 2011). The glossy, heart-shaped leaves of galax are used as background foliage in bouquets and in other kinds of floral decorations (Greenfield and Davis, 2003). Galax is monotypic in its genus and is regarded as a 'classic' example of autopolyploidy, with two main varieties: the diploid (2n) variety has smaller leaves, usually under 3.5″ across while the rarer tetraploid (4n) variety may have leaves as large as 6″ across (Barringer and Galloway, 2017; Nesom, 1983). The tetraploid variety is also more restricted in its range to an area of the southern Appalachians known as the Blue Ridge Escarpment (Johnson et al., 2003). Galax poaching takes the form of either partial (snipping) or whole (uprooting) removals of plants, and it is unclear to what extent these differences in poaching type differentially impact galax populations.

Monitoring is an essential aspect of conservation, and the Inventory and Monitoring Program of the National Park Service is tasked with gathering and analyzing monitoring data on natural resources in the National Parks. The Appalachian Highlands Monitoring Network monitors several species of plants vulnerable to exploitation and poaching from the National Parks, including galax (National Park Service, 2018). In Chapter 3, we quantitatively assess the status and trends of the BRP galax population, using mixed-effects models to analyze observations of three galax metrics collected at sites along the Blue Ridge Parkway. We analyze trends in 1) total galax counts, 2) counts of large leaves, and 3) patch extent, and we assess the effect of poaching type (none, snipping, uprooting) on each of these metrics. Mixed-effects models are often utilized in the analysis of monitoring data because they can account for nested structures in sampling methods and the repeated sampling of locations over time with random effects to partition variance in the observations (Bolker et al., 2009).

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CHAPTER 2

POACHING AND CONSERVATION OF NON-TIMBER FOREST PRODUCTS IN THE SOUTHERN APPALACHIAN REGION OF THE UNITED STATES: A LITERATURE REVIEW

2.1 Introduction

Non-timber forest products (NTFPs) encompass an enormous range of species and a variety of harvested products including leaves, roots, berries, mushrooms, nuts, bark, saps, and resin. NTFPs are harvested for a variety of uses including as food or medicine as well as floral or other decorative products. The gathering of NTFPs plays an important role in many people's livelihoods (Bailey, 1999; Emery et al., 2003; Greenfield and Davis, 2003; Mitchell, 2014; Paumgarten, 2005; Pierce, 2014; Poe et al., 2013). Overharvest has the potential to seriously impact the distribution, demographics, and population viability of some NFTP species including ginseng (*Panax quinquefolius*), ramps (*Allium tricoccum*), black cohosh (*Actaea racemosa*), bloodroot (*Sanguinaria canadensis*) and goldenseal (*Hydrastis canadensis*) (Mooney and McGraw, 2009; Robbins, 2000; Rock et al., 2004; Small et al., 2011; Small and Chamberlain, 2018; van Manen et al., 2005; Young et al., 2011). Conservation of NTFP species is complicated by this diversity of species and associated life histories, habitat requirements, and responses to harvest. In addition, harvesters of NTFPs are also demographically diverse with a wide variety of motivations for harvest and harvest practices. NTFPs and their harvest have traditionally been understudied, when compared with traditional forestry and forest products (e.g., timber), and this lack of knowledge continues to be a major challenge to their conservation. The southern

Appalachians are a hotspot for NTFP diversity and harvest. Poaching and overharvest of NTFPs are a concern for managers of protected areas and harvester communities in the region.

In this chapter, we review motivations for poaching and provide some historical context with a focus on poaching prevention strategies used in the southern Appalachian region of the United States. We provide examples of NTFPs to demonstrate the breadth of differences in ecology, harvest, and management that play a role in their conservation. Lastly, we synthesize across these examples to identify some strengths and weaknesses of different strategies with regards to their potential to prevent and address poaching of *Galax urceolata* (galax) from the Blue Ridge Parkway.

2.2 Motivations for poaching

Poaching is illegal harvest, and the specific violation can be based on the harvester, the time or season, the location of harvest, the method of take, the type of organism or resource harvested, or the amount of harvest. Given the variety of forms that poaching can take, the motivations for poaching are equally diverse (Duffy et al., 2016; Forsyth et al., 1998; MacKenzie, 2018; Muth and Bowe, 1998; Outland, 2018; Pokladnik and Maltz, 2008). Muth and Rowe (1998) outlined motivations for poaching including commercial gain, subsistence use, recreational satisfaction, trophy poaching, poaching as rebellion, and poaching as traditional right, among several others. While some motivations for poaching (recreation, personal consumption, tradition) are similar to those of ordinary harvest, others such as retaliatory poaching and 'thrill-seeking' by law-breaking are more akin to other kinds of criminal activity and have no clear parallel in conventional harvest. Poaching motivations also often overlap, so that someone may poach for their own subsistence use of an NTFP but also for the recreational satisfaction gained from spending time in the outdoors. Poaching as rebellion/retaliation and as engaging in a traditional right may overlap where land tenure changes and ‘green land grabs’ have displaced local people from their traditional places of harvest (Fairhead et al., 2012; Massé and Lunstrum, 2016; Muth and Bowe, 1998). While discourses around poaching from protected areas are sometimes sensationalized and poachers villainized as the ruthless enemies of conservation, poverty and economic instability are significant drivers of many poaching conflicts (Duffy et al., 2016; Margulies et al., 2019; Outland, 2018). Many poachers of NTFPs are driven by economic need and harvest NTFPs to sell out of a lack of other options for employment. Understanding the nature of the violation and the motivations of poachers is likely crucial to effective and equitable poaching prevention because both economic and political circumstances can lead people to poach NTFPs.

2.3 Harvest of NTFPs

Historically NTFPs have been harvested primarily to meet the needs of the local community, but NTFP markets and harvester communities have expanded to meet the desires for these products internationally with increased globalization and industrialization. Incorporating NTFPs as valuable commodities may be one way of offsetting declining incomes from other industries and work sectors, or to provide economic value to rural communities that does not necessitate logging (Kusters et al., 2006). Markets for NTFPs are sometimes promoted in the context of products of ‘women’s work’ or labor where they are proposed as an option to promote self-sufficiency or economic advancement for women in post-colonial nations and in rural or poorer areas (Pouliot, 2012; Sunderland et al., 2014). But the benefits of markets for NTFPs have not materialized in many areas, and these new markets bring with them a host of complex conflicts surrounding price-setting, supply chain management, and regulation of harvest, among others (Belcher and Schreckenberg, 2007). With this increased commercialization and expansion of NTFP markets, there comes a broad array of concerns about the type and sustainability of harvest, as well as how to regulate new harvester communities. This process of moving from small scale, self-regulated and norms-based harvest at local scales transitioning to large scale commercial harvest, sale, and distribution is also seen in other underregulated and de-facto open access natural resources (Stevens et al., 2014).

There is a long history of NTFP harvest and trade in the Southern Appalachians of the United States (Chamberlain et al., 1998; Greene et al., 2000). This region's diverse temperate forest ecosystems provide habitat for a variety of NTFP species (Greenfield and Davis, 2003). For instance, of the 175 plants native to the United States currently sold as part of non-prescription herbal medicines, nearly half are found within the Southern Appalachians (Greenfield and Davis, 2003). Economic instability, high rates of unemployment, and low wages may influence the harvest rates of NTFPs. For example, ginseng harvest is associated with local and regional economic trends (Duffy et al., 2016; Paumgarten, 2005; Schmidt et al., 2019; Wunder et al., 2014). The use of forest products as a 'safety net' occurs in rural communities around the world, though the specific circumstances surrounding the reliance on or use of forest products vary considerably (Paumgarten, 2005; Wunder et al., 2014).

Research on NTFPs continues to develop based on a growing understanding of the social, economic, and ecological impacts of harvest. Recent literature explores the status and trends of NTFP species, differences in harvester communities, and conservation challenges (Chamberlain et al., 2018). But even with this information, challenges remain for deterring illegal harvest.

2.4 Strategies for preventing poaching of NTFPs

Approaches to poaching prevention and the conservation of NTFPs take a variety of forms (Table 2.1). Traditionally, strategies to prevent poaching have focused on policing and exclusion, typifying the 'fortress' model of conservation (Hübschle, 2017). However, conventional enforcement strategies like borders, fences, patrols, and fines are often not enough to stop the flow of poached goods from protected areas (Challender and MacMillan, 2014; Jacoby, 2014; Lemieux, 2014; Outland, 2018). Equitably and effectively addressing poaching requires not only robust monitoring of harvested populations but also an understanding of the variety of factors that lead people to engage in poaching, and how certain tactics meant to discourage poaching may end up making the problem worse (Wilson and Boratto, 2020). Green militarization, or the use of militarized agents and tactics to secure and control protected areas, can perpetuate and exacerbate cycles of violence between protected area managers and local communities (Lunstrum, 2014; Massé, 2020). Poachers are embedded in social-ecological systems and focusing solely on one part of that system is unlikely to lead to effective or equitable conservation. More recently researchers have explored applying criminological methods to natural resources crimes like poaching. Several researchers have explored the spatial and temporal components of poaching risk, drawing on theories of situational crime prevention to determine hotspots for poaching and redirect prevention efforts toward these areas (Critchlow et al., 2015; Kurland et al., 2018; Lemieux, 2014; Young et al., 2011).

One difficulty in dealing with NTFP harvest and poaching is that there are relatively limited legal frameworks for dealing with NTFP poaching as compared with wildlife (Chamberlain et al., 2018; Outland, 2018). The legal frameworks currently in place to conserve

Box 2.1 Ramps (*Allium tricoccum*)

Ramps are a spring ephemeral species that grows in rich forest habitats. Ramps are harvested as an early spring green, rich in minerals with a sweet garlicky taste prized by many. Harvest of ramps occurs in multiple forms, including partial (leaves only) or whole (uprooting) removals. After a study (Rock et al., 2004) projected precipitous declines of ramp populations under harvest, a park-wide ban on ramp harvest was enacted for the Great Smoky Mountains National Park (GSMNP). A high-profile series of arrests of Eastern Band of Cherokee Indians (EBCI) tribal members charged for poaching ramps led to a realization that traditional ecological knowledge (TEK) developed and practiced by EBCI members, namely harvest of only the leaves and stem of the ramps and not the root bulb, had not been fully considered. Since that time, the Culturally Significant Plant Species Initiative (CSPSI) has formed as a collaborative conservation effort between EBCI and the Southern Appalachian Man and Biosphere Cooperative, of which GSMNP is a part.

This example suggests that research that fails to contact or communicate with harvester communities can lead to contentious or inefficacious strategies. Likewise, different methods and levels of harvest can have dramatically different impacts on NTFP populations. Further, incomplete discourses of scarcity can lead to conservation policies that disenfranchise already vulnerable populations of harvesters (Lewis, 2012; Mitchell, 2014). The current conservation and monitoring of ramps in the southern Appalachians may now serve as an example of cooperative conservation and a reprioritization of Indigenous sovereignty and traditional ecological knowledge in the monitoring of NTFP species. The ongoing work of CSPSI combines harvester knowledge with experimental harvest studies to better provide positive outcomes for both NTFP species and harvesters while improving understanding about the differences in effect between harvest types.

species and manage harvest primarily focus on wild animals rather than plants or plant parts. However, plants can be even more vulnerable to harvest, and plant poaching presents unique problems. Most wildlife is mobile and can, in theory, avoid or escape harvesters. Likewise, the location of an individual animal at any given moment is often unknown. Conversely, the locations of sessile NTFPs are especially vulnerable to discovery by poachers. As Outland (2018) mentions, Endangered Species Act critical habitat protections have not been implemented for many plant species because the knowledge of such habitat requirements could potentially put threatened plant species at even *more* risk. Several NTFP species are currently listed under CITES and the increased scrutiny, tighter regulations, and higher penalties on illegal trade in these NTFPs can disincentivize their harvest but can also create perverse incentives and increase harvest if the items and products have price-inelastic demand or a backward-bending supply curve (Frey et al., 2018).

Box 2.2: Ginseng (*Panax quinquefolius*)

Ginseng is a slow-growing habitat specialist of rich forests (Spira, 2011). Ginseng root is used in traditional herbal medicine and has a long history of trade stretching back over 250 years—it was one of the first NTFPs traded from the Appalachians to Europe and Asia (Cruse-Sanders et al., 2005). Ginseng root is highly valued commercially and is bought from harvesters at prices of over $200 per pound of dry root (Greenfield and Davis, 2003). Forest farming of ginseng may alleviate some of the harvest pressure on wild populations on public land, but wild ginseng is perceived as of higher quality than cultivated or wild-simulated ginseng (Burkhart and Jacobson, 2011; Frey et al., 2021). Ginseng harvest leads to mortality because the rootstock is the desired product, though some harvest practices include replanting ginseng berries (Van der Voort and McGraw, 2006). Extensive research has been done analyzing the impacts of harvest on ginseng population viability and genetics (Cruse-Sanders et al., 2005; Farrington et al., 2009; Van der Voort and McGraw, 2006). Researchers have also explored the spatial and temporal patterns of poaching, from exploring how poverty and unemployment to road access and geographic characteristics affect the prevalence of ginseng harvest and poaching (Schmidt et al., 2019; Young et al., 2011). Other approaches to prevent ginseng poaching have included marking or flagging ginseng roots with a powder that could be used to identify the location of harvest and target those who poached the marked ginseng from a protected area (Nickens and Richardson, 2001).

Ginseng poaching in the southern Appalachians may fall under the category of a 'folk' crime, (Pokladnik and Maltz, 2008). Ginseng harvesters and poachers have been glamorized through folklore and more recently through media and reality television profiling charismatic 'sangers' as they tromp through the woods in search of roots to sell (Pokladnik and Maltz, 2008, Taylor, 2016). Ginseng is currently a listed species under CITES and the additional scrutiny placed on both harvesters and buyers confers some additional protection for ginseng against poaching. The combination of expanding alternative sources for ginseng root (cultivated ginseng), extensive research on harvest impacts and ginseng life history, as well as the additional regulatory protections afforded under CITES represent a multi-pronged approach to protecting ginseng from poaching.

Shifts in harvester communities and their demographics also present complications for poaching prevention. NTFP harvester communities in the Pacific Northwest have experienced a shift in demographics with an increasing number of harvesters from East Asian or Latin

American immigrant communities (Ard and Sis, 1998; Chamberlain et al., 2018). Many harvesters of NTFPs in southern Appalachia are Mexican immigrants who first entered the country to work in the agricultural or horticultural sector and use NTFPs as temporary or seasonal sources of income (Emery et al., 2007; Greenfield and Davis, 2003). Differences in norms and expectations between harvester communities (e.g., between Anglo and Latino harvesters or between Indigenous and settler harvesters) as well as language gaps between protected area managers and harvester communities present challenges for communicating regulations (Ard and Sis, 1998; Emery et al., 2007). These language gaps also mean some harvester communities are left out of conservation initiatives or involvement in shaping harvest policy. Incorporating multilingual and multi-channel dispersal of harvest regulations, changes in harvest rules, and the rationale behind those regulations will likely assist compliance with those regulations.

Research and monitoring also play an important role in preventing poaching of NTFPs. Research into the specific impacts of harvest on the life history and population viability of NTFP species have provided insights that can be used to set harvest rules and keep track of population trends (Farrington et al., 2009; Ghimire et al., 2007; Nantel et al., 1996; Shanley, 2002). Monitoring harvest and poaching trends also provides insights into the spatiotemporal patterns of poaching and can make other prevention strategies more efficient (Critchlow et al., 2015; Gaoue et al., 2011; Kurland et al., 2018; Risdianto et al., 2016; Schmidt et al., 2019). Human dimensions research on harvesters, rangers, and protected area managers provide insights into the motivations, norms, and behaviors of different harvester groups that can also be useful in planning outreach as well as in involving harvester knowledge and preferences into regulations and management plans (Ard and Sis, 1998; Ballard and Huntsinger, 2006; Emery et al., 2007; Endress et al., 2004; Pierce, 2014).

2.5 Addressing poaching of *Galax urceolata* in the Blue Ridge Parkway

Galax is an evergreen perennial understory forb which grows in a variety of forest habitats in the southern Appalachians (Spira, 2011). Galax leaves are harvested for use in the floral industry as part of bouquets or other decorations (Greenfield and Davis, 2003). Although regulated harvest within U.S. National Forests is permitted, an unknown amount of illegal harvest occurs in the Blue Ridge Parkway (BRP) (Predny and Chamberlain, 2005). Two types of harvest are commonly practiced: snipping, which removes only the leaves, and uprooting, which pulls up the roots with the leaves. Because galax is harvested for its leaves it may be more resilient to harvest pressure than plants harvested for their roots like ginseng (Young et al., 2011). However, monitoring teams with the National Park Service have reported that uprooting as a harvest method has increased, and it is unclear to what extent this may be causing galax populations to decline (Emery et al., 2007; Murdock et al., 2015).

In the last few decades, the level of galax harvest has increased due to growing commercial demand. In addition, the racial makeup of galax permit applicants has shifted to include a greater proportion of Latino harvesters, so race continues to play a part in how issues surrounding natural resource conservation are both constructed and addressed (Emery et al., 2007). Even though the US Forest Service does not require evidence of legal status in harvest permit applications, the permit process has become linked with the process for documenting citizenship through changes in the documents needed to acquire the photo identification that is now required to purchase a harvest permit. Emery et al. (2007) outlines the connection:

> The Forest Service has begun to require applicants to provide photo identification with their permit application. This change occurred at about the same time that the North Carolina Division of Motor Vehicles, which provides the two most common forms of photo identification (driver's license and state identification card), was directed by the state legislature to change the documents required as a part of their application process. Statutory provisions, passed in 2001, required applicants to provide proof of residency in the state of North Carolina and two forms of identification (NC Sess. Law 2001-424 Sec. 27.10A; NC Gen. Stat. § 20-7). This included a requirement that applicants provide either a social security number or taxpayer identification number as a part of their application for a driver's license or state identification card. Because the application for a social security number requires original documents showing citizenship or lawful noncitizen status, changes in the permit process in the Forest Service became linked […] to the system that seeks to verify the legal status of immigrants.

Clarity about harvest regulations and particularly changes in regulations need to be communicated effectively to harvesters. This is especially the case when dealing with only temporary or transient harvesters unfamiliar with harvest regulations and doubly so with immigrant harvester communities where cultural norms may be different and where language gaps may exist between harvester communities and protected area managers. Efforts have been made to translate galax harvest regulations and harvest permits into Spanish (Emery et al., 2007).

While controlling or preventing access to protected areas and plant populations may be possible to limit poaching in some cases, in the case of galax the parkway road makes such an approach unfeasible. The Blue Ridge Parkway is an extremely narrow and linear park, stretching 469 miles through Virginia and North Carolina, ending at the Great Smoky Mountains National Park. Much of the parkway is less than 500m wide, and the park draws in millions of visitors each year. While steep terrain and dense vegetation make some areas more difficult to traverse on foot than others, the parkway road itself provides access to otherwise remote populations of galax. Other approaches must be considered to protect galax from overharvest and poaching if only because preventing access to galax in the BRP is likely impossible.

The initial floral supply buyers who purchase leaves from harvesters represent a considerable bottleneck for the trade and transport of galax leaves. Fewer than a dozen buyers clustered in just a few counties in western North Carolina likely account for the vast majority of galax leaves purchased (Emery et al., 2007). This means that changes made to the practices of the floral supply buyers could have dramatic effects on the rates of galax poaching and harvest. In addition to being easier to communicate with and keep track of, the galax buyers may serve as a conduit for communication of new rules and regulations to harvesters. The relatively stationary buyers interact with many harvesters that are much more mobile and transient. Outland (2018) suggests that more poaching prevention effort should be placed towards the buyers and sellers of poached products rather than on finding, apprehending, and punishing individual poachers. Lacey act protections against illegal trade in plant parts could be more effectively levied against the less numerous floral supply buyers and incentivize them to be more scrupulous about where their galax comes from.

Galax is less commercially valuable than some other NTFPs, with harvesters receiving only pennies per leaf from buyers (Greenfield and Davis, 2003). These lower retail prices and the opportunity costs of labor that would be associated with galax cultivation likely make galax a poor choice for forest farming (Burkhart and Jacobson, 2009). Galax is also likely a victim of poverty poaching so that the economic situation of harvesters may be an important driver of patterns and trends in poaching. Labor rights frameworks for increasing the organization and agency of harvesters may help relieve some of the pressure harvesters feel to poach galax, and communication between buyers and harvesters about price and quality expectations could help prevent galax leaves from being harvested unnecessarily when demand is low (Mitchell, 2014). Many galax harvesters work as agricultural or horticultural laborers and so farmworker advocacy groups may offer a way to communicate regulations and stewardship practices to galax harvesters and spread that information to new harvesters.

Continued research and monitoring of the galax population in the BRP will provide insights into the status and trends of galax and on the prevalence and impact of poaching. Addressing and preventing galax poaching in the BRP will likely require a variety of techniques and a multi-faceted approach. These approaches must consider the economic precarity of harvesters which may be leading them to poach galax and avoid exacerbating divisions between white locals and Latino immigrants. Approaches which target the bottleneck of the floral supply buyers may be more effective at deterring poaching and may serve as an opportunity to increase communication between harvesters and buyers as well as among the harvester community. Incorporating both social and economic considerations as well as research and monitoring of galax population trends is likely to lead to effective and equitable protection of galax from poaching.

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Tables

Table 2.1 Strategies and techniques to prevent poaching of NTFPs; strategy categories adapted from Lemieux (2014).

Strategy	Techniques	Description	Citations
Increase effort	Control access	Fences, restrict visitation	(Jacoby, 2014; Kurland et al., 2018; Warren, 1997)
Increase risks	Stricter penalties for poachers	Larger fines, longer sentencing, felony v. misdemeanor charges	(Outland, 2018; Risdianto et al., 2016; Wilson and Boratto, 2020)
	Stricter penalties for buyers/sellers of poached goods	Larger fines, longer sentencing, felony v. misdemeanor charges	(Outland, 2018)
	Increase patrol effort/surveillance	Ranger training, patrol hotspots, more and more frequent visitations	(Risdianto et al., 2016)
	Harvester community involvement/engagement	Set and promote harvest and stewardship norms, promote self-governance	(Challender and MacMillan, 2014; Frey and Chamberlain, 2015; Lewis, 2012)
Reduce rewards	Cultivating NTFPs (demand offsetting)	Reduce relative value of poached product; increase supply	(Burkhart and Jacobson, 2009; Chen et al., 2019; Williams et al., 2014)
	Demand reduction campaigns	Certification labels for NTFP products; public education	(Belcher and Schreckenberg, 2007; Margulies et al., 2019)
	Damage or alter salability of NTFPs	Marking NTFPs in protected areas	(Nickens and Richardson, 2001)
Reduce provocations	Prevent exploitation of harvesters	Improve economic and social standing of harvesters	(Ard and Sis, 1998; Hübschle, 2017; Mitchell, 2014)
	Alternative economic opportunities	Promote harvester agency	(Duffy et al., 2016; Hübschle, 2017)
Remove excuses	Allow legal harvest	Straightforward regulations may assist compliance	(Mitchell, 2014)
	Clear boundaries/instructions	Clear signage, harvester education campaigns	(Emery et al., 2007)

CHAPTER 3

QUANTITATIVE ANALYSIS OF MONITORING TRENDS FOR *GALAX URCEOLATA* IN THE BLUE RIDGE PARKWAY[1]

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[1] Fonda, M., Irwin, B., Schmidt, J.P., Cruse-Sanders, J., to be submitted to *Biological Conservation*

Abstract

Galax urceolata (galax) is an understory forb endemic to the southern Appalachians, where it is being poached from areas along the Blue Ridge Parkway. The motivation for harvest is sale to the floral industry, and the impact of poaching on galax populations is uncertain. Using monitoring data collected from the Parkway between 2010 and 2019, we analyzed trends in total galax density, the counts of large leaves, and galax patch extent at nine sampling locations. Eight plots were sampled within park boundaries and one plot was located outside the park on private land. Mixed-effects models predicted that park-wide trends for galax are stable, though some plot-specific trends showed more substantial declines. An index of poaching type was positively associated with some galax trends, potentially indicating site-selection preferences of poachers.

3.1 Introduction

Exploitation is one of the major factors linked with global biodiversity loss and poaching as a subset of exploitation presents special challenges to conservation (Chen et al., 2019; Gavin et al., 2010; Linares et al., 2012; Reynolds, 2001). In addition to timber harvest, a variety of less well-known species and products are also removed from forested landscapes. Non-timber forest products (NTFPs) have traditionally been understudied or seen as trivial in comparison with other traditional forest products, and this perception and consequent gaps in understanding act as barriers to effective conservation (Alexander and McLain, 2001; Frey and Chamberlain, 2015; Lynch et al., 2004; Molina et al., 1997; Ticktin, 2004). The temperate forests of the US southern Appalachians are a hotspot of biodiversity and with it the overexploitation and poaching of many rare and valuable plant species (Braun, 1950; Dyer, 2006). Several researchers have shown that overharvest and poaching can negatively impact the distribution, demographics, and population viability of plants including ginseng (*Panax quinquefolius*), ramps (*Allium tricoccum*), black cohosh (*Actaea racemosa*), bloodroot (*Sanguinaria canadensis*) and goldenseal (*Hydrastis canadensis*) (Dion et al., 2016; Mooney and McGraw, 2009; Robbins, 2000; Small et al., 2011; Small and Chamberlain, 2018; van Manen et al., 2005; Young et al., 2011).

3.1.1 Study organism

Galax urceolata (Poiret, Brummitt) (common names: galax, wandflower, beetleweed; hereafter “galax”) is a perennial understory forb in the family Diapensiaceae. Galax grows in a variety of forest habitats in its range, which is centered along an area in the southern Appalachians known as the Blue Ridge Escarpment (Predny and Chamberlain, 2005). It is monotypic in its genus and is regarded as a ‘classic’ example of autopolyploidy, with two common varieties: the diploid variety has smaller leaves that are typically under 3.5” (~9 cm) across while the tetraploid variety may have leaves up to 6″ (~15 cm) across (Barringer and Galloway, 2017; Nesom, 1983). Galax is harvested for its large and glossy heart-shaped leaves, which keep well in storage and are used in a variety of floral arrangements and decorations. Larger leaves fetch a higher price from buyers and in the floral industry, so the tetraploid variety may be preferentially harvested (Emery et al., 2007; Greenfield and Davis, 2003). Although regulated harvest on U.S. Forest Service lands is permitted, an unknown amount of illegal harvest occurs on adjacent lands of the U.S. National Park Service (NPS), particularly the Blue Ridge Parkway (Predny and Chamberlain, 2005).

Galax is somewhat more generalist in habitat preference than other exploited species of the area and is found in a broad range of plant communities (Spira, 2011), although the tetraploid variety may be limited to more mesic areas with less woody and more herbaceous vegetation (Johnson et al., 2003; Nesom, 1983). Climatic niche models by Gaynor et al. (2018) suggest that galax may be at risk of extinction from range shifts as a result of climate change. In the wild, galax appears to spread primarily through asexual or clonal propagation, and only weakly through seed. Barringer and Galloway (2017) found that galax is self-incompatible and likely pollen-limited, and that there is little differentiation in the reproductive ecology between the diploid and tetraploid varieties. McCarron (1995) found that individual leaves are maintained by the plant for about 2 years before dying. Because galax is harvested primarily for its leaves, it may be more resilient to harvest pressure than plants harvested for their roots, such as ginseng, goldenseal, and black cohosh (Young et al., 2011). However, uprooting plants rather than just snipping the leaves has increased as a harvest method per park officials and other sources, and uprooting may be more damaging to galax populations (Emery et al., 2007; Murdock et al., 2015). Dion et al. (Dion et al., 2016) and other researchers, including those working as part of the Culturally Significant Plants Species Initiative, have shown that for ramps (*Allium tricoccum*) harvesting only the leaves and not uprooting the bulbs can be a more sustainable form of harvest, and this is the method preferred by Cherokee harvesters (Clabby, 2016). Several attempts have been made to explore ex-situ propagation of galax, through seeds, rhizome cuttings, and tissue culture, potentially as a way of offsetting the demand for wild-picked galax, though at this point nearly all commercially available galax is still harvested from the wild (Yang et al., 2013). Overall, the level of harvest and its impact on galax populations remains uncertain.

3.1.2 Objectives

Our goal is to quantitatively assess the status and trends of the galax populations in the Blue Ridge Parkway (BRP) to assist with ongoing monitoring and management efforts. More specifically, we examine NPS monitoring data to detect potential temporal trends in 1) galax density, 2) large leaf counts, and 3) galax patch extent at sites across the BRP. We also assess the effect of poaching type on these response variables.

3.2 Methods

3.2.1 Study area

The BRP is one of the most-visited units managed by the NPS and drew in 14.9 million visitors in 2019 (NPS, 2021). The BRP is an extremely narrow and linear park, stretching 750 km (469 miles) from Shenandoah National Park in the north to the Great Smoky Mountains National Park in the south, and much of the BRP is less than half a kilometer wide (Fig. 3.1). Dense vegetation and high relief make some areas quite difficult to traverse on foot, but the parkway road itself provides access to areas that would otherwise be extremely remote and difficult to reach (Murdock et al., 2015). Access is particularly relevant in the context of poaching, where harvesters may enter or exit at a variety of points and BRP boundaries are quite porous. Management and monitoring of harvest and poaching is also complicated by the surrounding landscape, as the BRP is bordered by National Forests managed by the USFS as well as state parks and private land. Due to the sensitive nature of the location data, we only present spatial information at a coarse scale.

3.2.2 Data collection

The monitoring data used in this analysis were collected by the Appalachian Highlands Inventory and Monitoring Network (APHN) for the Blue Ridge Parkway (Fig. 3.1), as part of a broader program of monitoring for poached plants in the National Parks. Eight sites (i.e., quantitative plots) along the BRP and one site (Plot 18) located off the BRP on private property were selected to monitor total counts of galax leaves, counts of large leaves, and galax patch extent between 2010 and 2019 (Fig. 3.2). Each quantitative plot consisted of multiple (3 – 10) transects extending perpendicularly from a fixed baseline that spanned the major axis of the galax patch. Transect length varied across plots and sampling years. Thus, annual patch extent for each plot was calculated based on that year’s average transect length and the time-invariant baseline length. Patch extent was assessed at the level of the plot, while point-intercept counts along the transects provided the data for assessing galax total counts and large-leaf counts. Leaf size was coded as either large (>3.5”) or small (<3.5”). Transect length was assessed based on the last point at which the transect tape passed through galax, where there was a 10m or larger gap to the next galax. In the database, a transect length of zero therefore indicates that no galax was present within 10m of the baseline. Point intercepts were taken at half-meter intervals along the transect but transect length was measured to the nearest centimeter. Poaching type was assessed at the plot level and was quantified on a three-level scale (coded as 0 = no evidence of poaching, 1 = snipped leaves observed, or 2 = signs of uprooted plants). More extensive details on the monitoring protocol can be found in Murdock (2015).

3.2.3 Data analyses

We analyzed galax trends with a combination of mixed-effects models in R using RStudio with the lme4 package (Bates et al., 2015; R Core Team, 2020; RStudio Team, 2019), where distributional assumptions differed for some of the response variables (Table 3.1). We modeled the total counts of galax leaves and the counts of large leaves according to a negative binomial distribution because initial assessment of the point-count data (Fig. 3.2) showed evidence of overdispersion (Reitan and Nielsen, 2016). The models for galax total counts and counts of large leaves also included an effort offset for surveyed transect length (m) (Table 3.1). In some cases, a "0" length transect was recorded when galax was not observed within the first ten meters from the baseline. Thus, a 'surveyed' transect length was constructed as the observed transect length (i.e., the last intersection of the transect tape with galax used in the calculation of patch extent) plus 10m to account for the additional 'surveying' that was used as a stop-procedure to terminate the transect when no additional galax was observed. We used this surveyed length (i.e., observed transect length + 10) for the effort offset parameter because the model cannot account for a log of zero effort but used the observed transect length for calculations of patch extent. We analyzed patch extent (m^2) with a simple mixed-effects linear model assuming normally distributed residual errors. When random effects were included for plot or transect within plot, we assumed that they were normally distributed. We assessed the significance of temporal trends at an alpha level of 0.05. Variance estimates for the random effects were considered on the scale of the linear model and are not directly compared across models on account of using different link functions.

The model for galax density predicts the count of galax 'hits' on transect k at plot i in year j, assuming a negative binomial distribution with mean μ_{ijk} and dispersion parameter θ. The log of μ_{ijk}, n_{ijk}, is predicted from a linear combination of coefficients (i.e., a log link). For the temporal trend, year was shifted to years since the beginning of the monitoring program (i.e., 2007 = year 0) to facilitate model convergence. Random intercepts were included for plot and transect within plot (a_i and b_{ik}) and random slope adjustments were modeled at the plot level (c_i). The (year coefficient estimates the presence of a longer-term temporal trend. Poaching level (none, snipping, uprooting) was included as an additional categorical predictor, and the associated coefficients estimate the impact of the differing levels of poaching observed at each plot in each year. The count models also include an effort offset corresponding to the surveyed length (in meters) of transect k at plot i in year j.

The model for size structure predicts the count of large-leaf 'hits' on transect k at plot i in year j, assuming a negative binomial distribution with mean μ_{ijk} and dispersion parameter θ. The log of μ_{ijk}, n_{ijk}, is predicted from a linear combination of coefficients (i.e., a log link), again using shifted year and poaching type as predictors, as well as the random intercepts for plot and transect within plot as described above. This model also includes an effort offset corresponding to the length (in meters) of transect k at plot i in year j. We initially attempted a model for counts of large leaves that included random slope adjustments for plot, but this model had convergence issues, and so we removed plot-specific slopes from this analysis.

The model for patch extent follows a normal distribution (i.e., an identity link) as the response is a continuous measure of patch size in m^2. Because patch extent is assessed at the plot level, this model lacks the transect-specific intercept adjustments, but the covariates included (shifted year and poaching type) are the same as for the density and size structure models.

3.3 Results

The nine quantitative plots were sampled for 10 years from 2010 to 2019, with plot 18 being added in 2013 and being the only plot sampled in 2014 (Fig. 3.3). Accounting for these differences in sampling effort, the total number of plot-level sampling events (site *i* in year *j*) was 79. Accounting for the differences in baseline length, the number of transects at plots varied from 3 to 10. By the end of the time series, the number of transects (transect *k* at site *i*) sampled each year was 76. The mean observed transect length across all sites and years was 20m. The total number of galax hits was 4,254 and the number of large-leaf hits was 694 (Fig. 3.3). Although model predictions were made at the level of the transect to represent the way the data was collected and structured, for presentation and interpretation purposes we summarize results at the plot-level in the following figures and tables.

3.3.1 Results for density

The density model did not predict a significant slope for the year coefficient, indicating no significant average change across years during the sampling period (Fig 3.4a, Table 3.2). The coefficients for poaching type (0.243 for snipping and 0.255 for uprooting) were significant, but in the opposite of the hypothesized direction so that poaching type was correlated with higher total counts. Only two sites (17 and 18) had a positive slope after accounting for the slope adjustments (0.010 and 0.016, respectively), and site 9 had the most negative slope after the random slope adjustment, at -0.069 (Table 3.3).

3.3.2 Results for size structure

Large-leaf counts accounted for 16.3% of the total hits in the dataset and were quite variable from year to year (Fig. 3.3b). Several sampling events had no hits from large leaves, and the highest proportion of large-leaf hits observed at a site during the sampling period was 0.667. The model for large-leaf counts did not predict a significant slope for the year covariate (estimate 0.031), indicating no significant average change in the counts of large leaves over the sampling period (Fig. 3.4b, Table 3.2). The estimated adjustment for snipping was also negative (-0.047) but was positive for uprooting (0.057), although neither of these coefficients were significant. Site 8 had the most negative intercept adjustment of -2.595 and was the only site at which no large leaf hits were encountered during the study period (Table 3.3). Site 18 had the most positive intercept adjustment at 2.222.

3.3.3 Results for patch extent

The model for patch extent did not predict significant effects for year or poaching type (Table 3.2). The estimate for the year coefficient was negative but insignificant (-41.252). The estimated adjustment for snipping was also negative (-42.176) but was positive for uprooting (8.011). The variance estimate for the site-level intercept adjustments was 12.249×10^6, and the variance estimate for the site-level slope adjustments was 3363. When the plot-level slope adjustments were combined with the global slope estimate, only plot 15 was estimated to be increasing over time with the other eight locations displaying varying declines (Table 3.3). The largest rate of temporal decline was estimated for plot 8. Two plots (14 and 15) had positive intercept adjustments while the other seven had negative adjustments in the patch-extent model.

3.4 Discussion

The models for density, size structure, and patch extent indicate the possibility of slight decreases but no significant average change over the sampling period. Only two (17, 18) of the nine plots were estimated to be increasing in overall counts and one of these (18) is outside of the park boundaries (Table 3.3). Only one plot (15) was estimated to have increased in patch extent. Plot 15 is notable for both its total counts and patch extent. This plot had the largest number of observations for both overall counts and counts of large-leaf plants, making up 62.7% of the total counts in the dataset and 34.8% of the counts of large leaves. Plot 15 is much larger in extent than any of the other plots, though not much denser in terms of counts of large leaves or counts per transect meter (Fig. 3.3, 3.4). Contrary to our expectations, poaching type was positively correlated with total counts (0.243 for snipping and 0.255 for uprooting) but the coefficients were not significant for size structure or patch extent. This correlation may be capturing elements of the site-selection preferences of poachers, such that poachers may be more likely to harvest from larger, denser patches with more large leaves. Our models do not provide evidence to suggest that poaching is causing galax populations to decline on average, and more specific information on the impact of different levels and types of harvest would be needed to make specific conclusions about more localized impacts of poaching type on galax. However, significant declines may be happening at some of the plots, and this could be cause for concern. For example, the models for total counts estimated a 47% decline at plot 9 from 2010 to 2019. The model for patch extent predicted similarly drastic declines for plot 8 over the sampling period. We were not able to include random slopes in the model for large leaf counts due to convergence issues, but visual inspection of the model predictions suggests that some of the higher-count plots may be declining. Additional investigation into site-level characteristics and the impact of poaching could help determine whether it is poaching or some other factor causing discrepancies in galax trends across sites. Discrepancies in the counts of large leaves may be due to habitat suitability differences for diploid (small-leaf) versus tetraploid (large-leaf) galax, as reported by Johnson (2003) and Nesom (1983), but detailed vegetation community data for the galax sampling locations was not available at time of writing.

The response variables considered here (counts of galax leaves, counts of large leaves, and patch extent) were all directly measured through standardized field survey methods. On the other hand, the incidence of poaching, used as a predictor variable in the models, was primarily identified based upon visual assessment of the potential evidence for poaching at the plot level. Because poaching of galax is thought to occur primarily through two methods (snipping leaves or uprooting of entire plant), we coded reports of poaching occurrence as a three-level categorical variable. We think this categorization captures some of the contrast in poaching intensity, but it is a limited indicator of actual exploitation rates. In the case of no-evidence of poaching, the occurrence of poaching could be well disguised or simply missed, but we expect outright missed detections to be unlikely given the typical familiarity of the monitoring crews with the study area. In the case of snipping, harvested leaves may be replaced over time and observed damage to plants could be from other natural predators. In either of those cases, the presence of snipped leaves due to poaching could be more difficult to detect. The primary cause of uprooted plants is presumed to be from poaching. Increasing the resolution of poaching assessments would likely make them more costly to obtain, but perhaps would provide a better indicator of changes in poaching severity. For example, attempting to count evidence of uprooting would be difficult (presuming most of these plants have been removed from the site) but perhaps would better separate a low-poaching year from a high-poaching year or a severely poached plot from a less impacted site. Assessing poaching severity at multiple time points within a single sampling season (such as in fall and again in spring) could also help distinguish plots with more poaching pressure.

Experimental harvest impact and population viability analysis studies have been done for other NTFPs, including several species harvested from the southern Appalachians, such as ramps, black cohosh, and ginseng (Dion et al., 2016; Nantel et al., 1996; Small and Chamberlain, 2018; Van der Voort and McGraw, 2006). Such a study would likely provide useful insights for galax. Additionally, incorporating patch quality (extent, density, proportion of large leaves) into models of poaching risk may be important for galax to account for harvester selection behavior.

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Tables

Table 3.1 Response variables (Metric), data types, distributional assumptions (Dist.), link functions (Link), and model statements. Covariates include centered year (x_1), and poaching type (x_2), which was annually assessed at the plot level. Subscripts represent plot (i), year (j), and transect (k). The density and size structure models include an offset variable for surveyed transect length (t). Residual error terms (ε) and random effects at the plot (a, c) or nested plot-transect (b) level were assumed to be normally distributed (not shown).

Metric	**Data type**	**Dist.**	**Link**	**Model statement**
Density	Discrete counts	$N_{ijk} \sim NB\left(\mu_{ijk}, \theta\right)$	log	$n_{ijk} = \alpha + \left(\beta_1 + c_i\right)x_{1j} + \beta_2 x_{2ij} + \log\left(t_{ijk}\right) + a_i + b_{ik}$
Size structure	Discrete counts	$N_{ijk} \sim NB\left(\mu_{ijk}, \theta\right)$	log	$n_{ijk} = \alpha + \beta_1 x_{1j} + \beta_2 x_{2ij} + \log\left(t_{ijk}\right) + a_i + b_{ik}$
Patch extent	Continuous	$m_{ij} \sim N\left(\mu_{ij}, \sigma^2\right)$	identity	$\mu_{ij} = \alpha + \{(\beta\}_1 + c_i)x_{1j} + \beta_2 x_{2ij} + a_i + \varepsilon_{ij}$

Table 3.2 Parameter estimates for coefficients and random-effect variances of the linear regression models. Values are presented on scale of the linear model. Asterisks indicate significance at an alpha of 0.05.

Model	Density	Size structure	Patch extent
Link	log	log	identity
Parameters:			
α	-2.538*	-4.469*	3632.765*
β_1	-0.022	-0.031	-41.252
$\beta_{2,1}$	0.243*	-0.047	-42.176
$\beta_{2,2}$	0.255*	0.057	8.011
σ_a^2	0.639	3.384	12249039
σ_b^2	0.556	0.388	
σ_c^2	0.001		3363

Table 3.3 Random effect adjustments for plot.

Model	Density		Size Structure	Extent	
Link	log		log	identity	
Site	**Intercept**	**Slope**	**Intercept**	**Intercept**	**Slope**
8	-0.835	-0.008	-2.595	-970.748	-79.496
9	0.307	-0.047	-1.615	-265.690	29.934
11	-1.107	-0.011	-1.630	-2579.954	16.970
12	0.255	0.015	1.597	-2954.207	23.026
13	-0.281	-0.014	1.034	-718.384	-69.212
14	0.433	-0.011	1.587	1476.339	-36.896
15	1.364	0.009	1.213	8645.996	72.756
17	-0.348	0.032	-0.499	-1635.998	15.768
18	0.524	0.038	2.222	-997.352	27.148

Figures

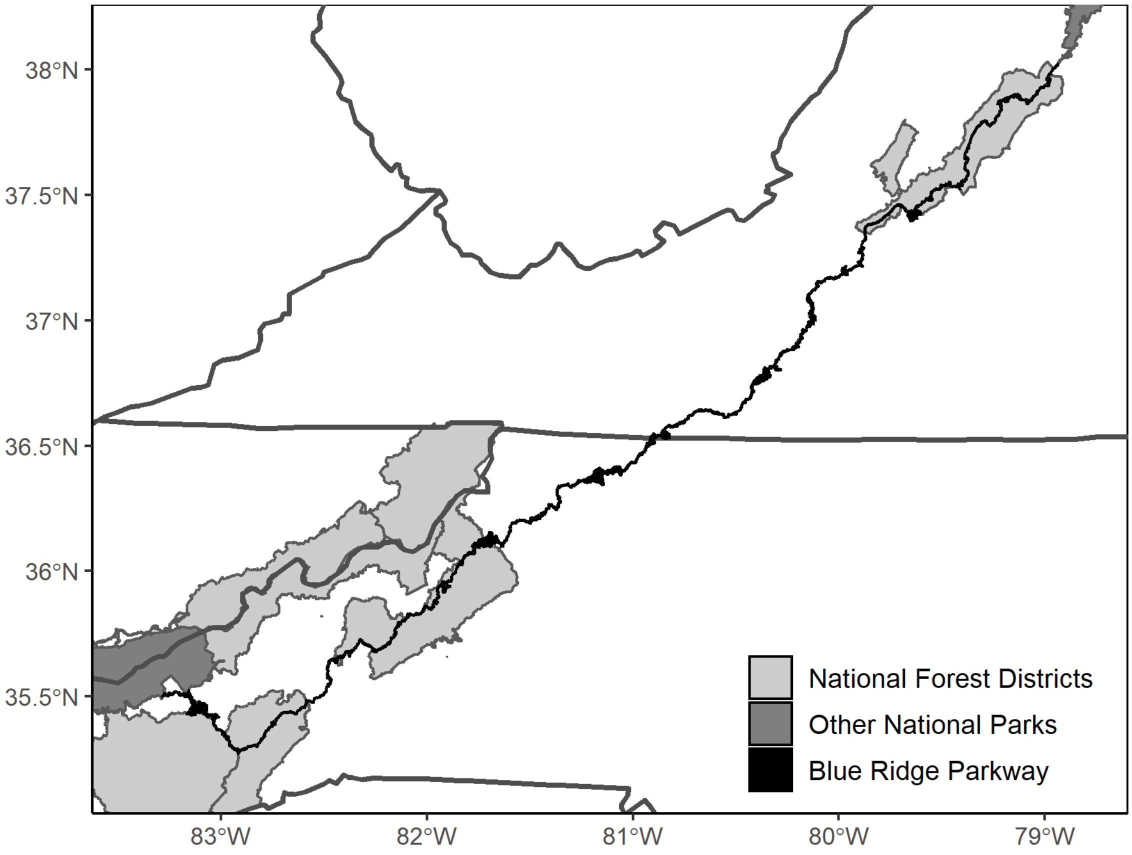

Figure 3.1 A map of the Blue Ridge Parkway boundary with neighboring National Parks and National Forest districts in the southeastern US. The parkway spans through portions of North Carolina and Virginia (state outlines in grey). Data for this project were collected from North Carolina.

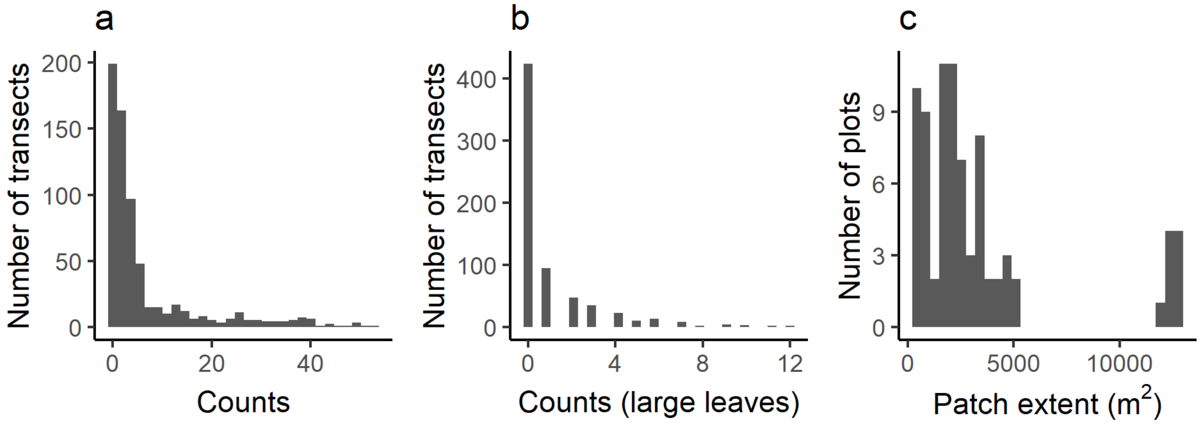

Figure 3.2 Histograms of galax observations: a) density (total counts), b) size structure (counts of large leaves), and c) patch extent.

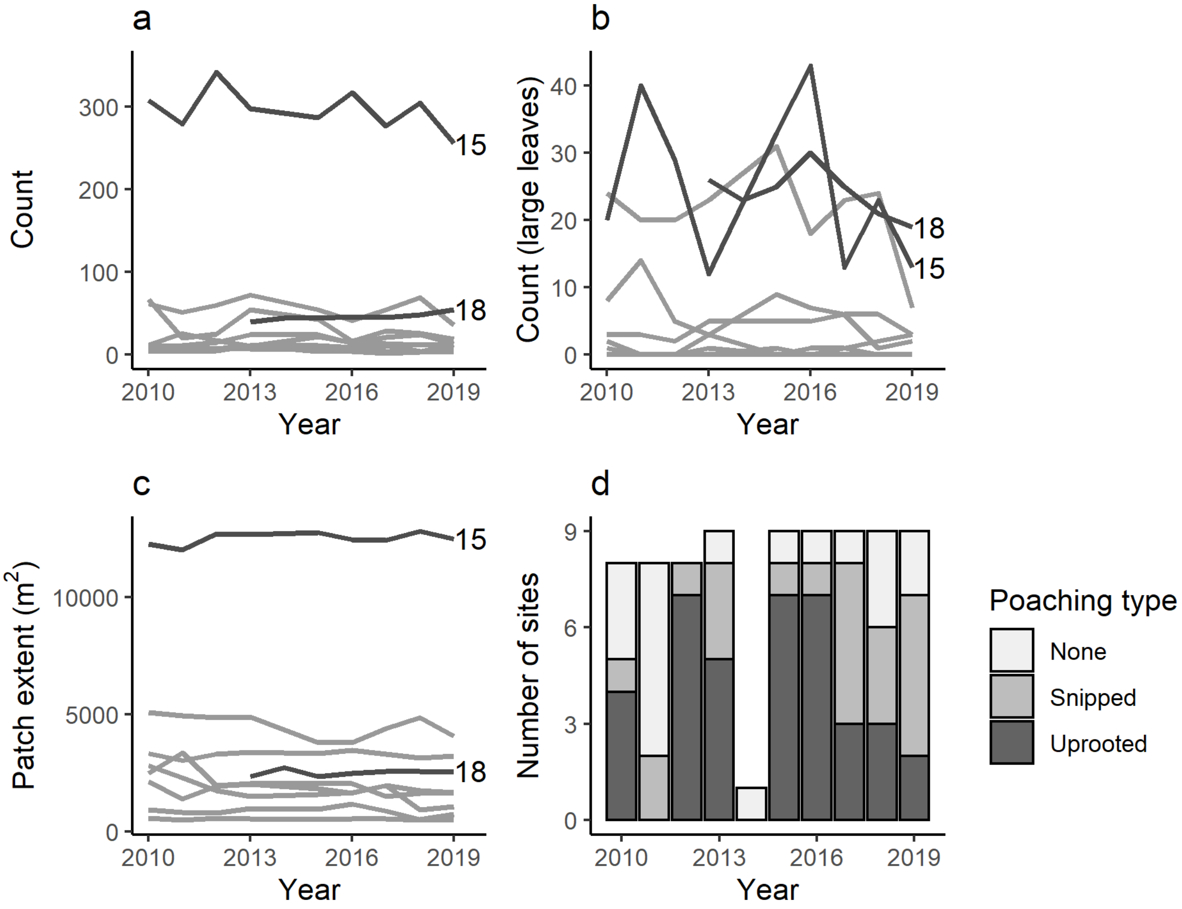

Figure 3.3 Galax observations over time at nine quantitative plots: a) density (total counts), b) size structure (counts of large leaves), c) patch extent, and d) poaching type. Plot 15 (the largest plot) and Plot 18 (outside of the park boundaries) are numerically identified. Plot 18 was added for monitoring in 2013 and was the only quantitative plot sampled in 2014. Other plots are shown in gray.

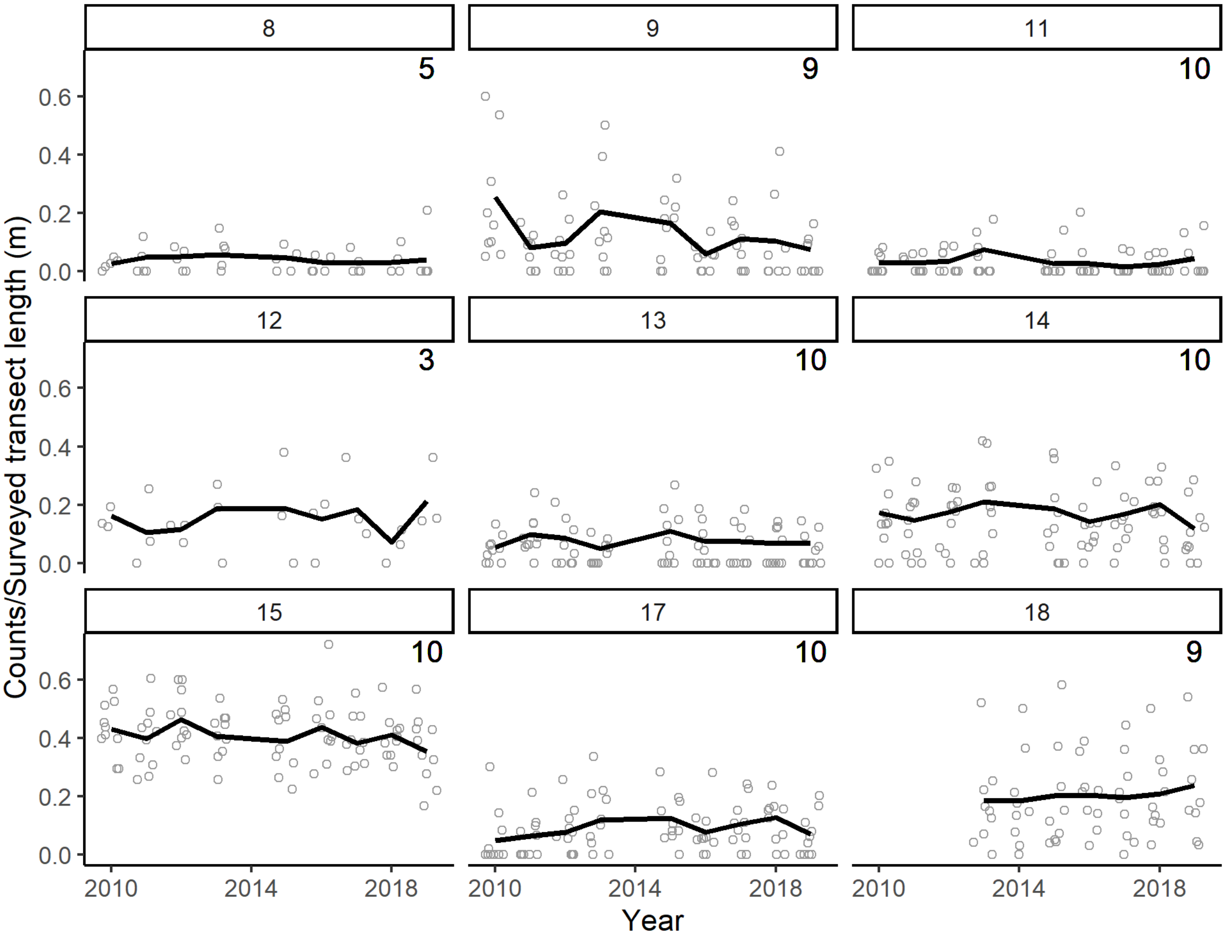

Figure 3.4 Total counts per unit effort (surveyed transect meter), summarized by plot. Points indicate individual transects and their counts while lines indicate the total counts divided by the total survey effort at that plot. Points are jittered horizontally within year to mitigate overlapping. The number of transects surveyed at each plot is presented in the upper right.

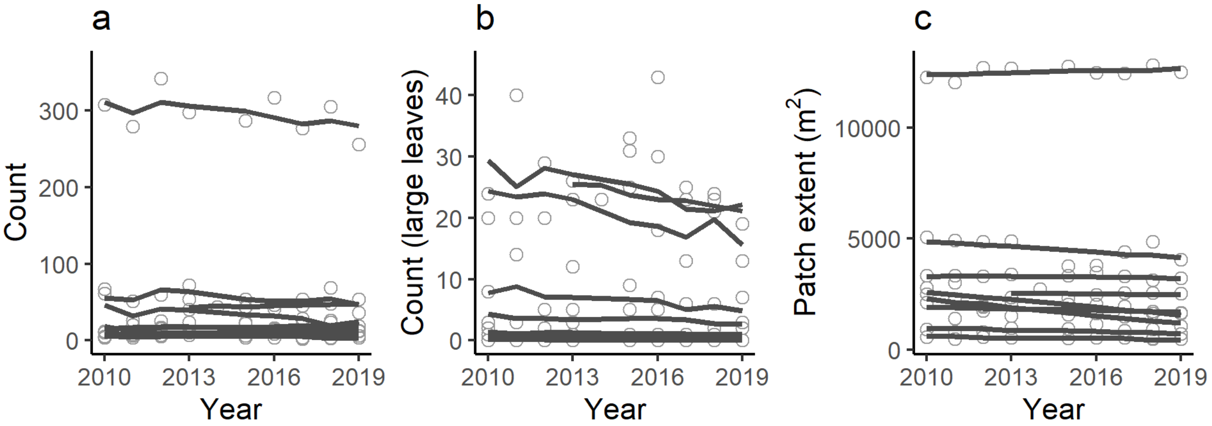

Figure 3.5 Galax model predictions (lines) and observations (points) over time, summarized by plot: a) total counts, b) size structure (counts of large leaves), and c) patch extent.

CHAPTER 4

CONCLUSIONS

In Chapter 2 we reviewed methods and strategies for poaching prevention in the context of non-timber forest products (NTFPs) in the southern Appalachians. We presented case studies of other NTFPs subject to poaching and considered the effectiveness of various strategies for preventing poaching of galax from the Blue Ridge Parkway (BRP). Due to the extremely narrow and linear geographic profile of the BRP, as well as the enormous number of visitors to the Parkway each year, we expect that an approach to poaching prevention which focuses primarily on preventing access to galax populations or on finding and apprehending individual poachers may be limited in its effectiveness or implementation. Galax is less commercially valuable than some other NTFPs of the region, so cultivation as a means of offsetting the demand for wild-harvested galax is less likely to be a viable option. Language barriers and cultural differences between land managers, galax buyers, and galax harvesters also present challenges to addressing the problem of galax poaching. In addition, it is likely that galax is a victim of poverty poaching, where financial need and economic circumstances may be driving harvesters to poach galax from the BRP. Facilitating communication among harvester groups, between harvesters and buyers, and between these groups and the managers of protected areas may be a more effective approach to reduce poaching (Frey and Chamberlain, 2015; Lewis, 2012; Mitchell, 2014). The vast majority of galax leaves sold internationally are thought to pass through a very small number of buyers concentrated in western North Carolina, and approaches which shift penalties and risk towards this bottleneck of more stationary buyers and away from the more mobile, transient, and numerous poachers may have more success (Greenfield and Davis, 2003). Continued monitoring of the galax population as well as of harvester communities will likely play an important role in informing the conservation of galax and protecting it from poaching.

In Chapter 3, we analyzed monitoring data on three galax metrics: total counts of galax, counts of large leaves, and patch extent at nine fixed sites. Poaching type was included in the models for each of these three metrics. We did not observe significant global trends in any of these three metrics over the sampling period in the BRP. However, more severe plot-level declines were estimated for several sites, and this could be cause for concern. Additional site-level characteristics such as vegetation community composition may be contributing to the differences in response between sampling locations. More severe poaching type was correlated with estimates of higher total counts of galax, but poaching type was insignificant for the other two metrics. Our models do not suggest that poaching is causing galax populations to decline on average over the monitoring period, but more information about the type and severity of poaching occurring at these sites and elsewhere within the BRP would be needed to form more solid conclusions about the impact of poaching on galax. Additionally, patterns of poaching risk may be correlated with patch quality.

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