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ABSTRACT The snowshoe hare (*Lepus americanus*) is a species of maintenance concern in Pennsylvania's 2005 Wildlife Action Plan due to sensitivity to habitat alteration and being on the southern edge of the species' distribution (Steele et al. 2010). Pennsylvania also serves as a genetic link between snowshoe hare populations in New York and West Virginia. Harvest information from the Pennsylvania Game Commission's (PGC) annual Game Take Survey is currently the only source of data for population analysis. Likewise, the Appalachian cottontail (*Sylvilagus obscurus*) is one of two cottontail species found in Pennsylvania and is a species of high-level concern in the Commonwealth's 2005 Wildlife Action Plan. Harvest information from the PGC's annual Game Take Survey is currently the only source of data for long-term population analysis, but the survey groups together all cottontail harvests and is not a good measure of *obscurus* populations. The Appalachian cottontail is a Northeast Region priority species and Pennsylvania is believed to have a genetically distinct population that accounts for 5 % of the world's breeding population. The most recent statewide surveys for mammals were conducted over 60 years ago (Harnishfeger 2004). The PGC seeks to enhance understanding of snowshoe hare and Appalachian cottontail distribution and abundance in Pennsylvania through field based research to better manage these species' populations and the habitats that support them. Information gained from this research will assist with management of these species directly related to hunting seasons, bag limits, and habitat management. These efforts are directly supported by the Pennsylvania Game Commission's 2009-2014 Strategic Plan and addresses Strategic Objectives 1-5 as well as fulfilling goals of the 2005 Wildlife Action Plan.

OBJECTIVES

1. Determine statewide distribution and relative abundance of Appalachian cottontails and snowshoe hares throughout Pennsylvania.

2. Estimate habitat selection of Appalachian cottontails and snowshoe hares in Pennsylvania.

INTRODUCTION

The snowshoe hare and Appalachian cottontail are members of the order Lagomorpha, family Leporidae, and genuses *Lepus* and *Sylvilagus* respectively. Both species are habitat specialists who, in Pennsylvania, live primarily in the colder climates of higher elevations and northern regions. The snowshoe hare is limited to these colder locations due to adaptations including a specialized pelt and foot morphology which increase survival in areas with greatest duration of snow cover. Appalachian cottontails have evolved to survive the colder climates of higher elevations through physiological adaptations related to stress levels during winter. Despite sharing some basic similarities regarding habitat and likely distribution in Pennsylvania, there are some notable differences between the 2 species.

Snowshoe hares are unique in the Leporidae family because of their hind feet which measure 11-14 cm in length and have dense stiff hairs on the pad area giving the hare its name and promoting fast, easy maneuvering in deep snow (Merritt 1987). Snowshoe hares are found only in North America and range from Alaska to Newfoundland, and south into areas of higher elevation. They are the only Pennsylvania lagomorph whose pelt changes color. Their ability to change from a rusty brown color to white in the winter has given them the nickname varying hare. Due to a changing global climate, this antipredatory strategy is causing a mismatch between white-phased hares and their habitat and may be increasing predation rates (Mills et al. 2013).

In Pennsylvania, there are 2 areas where hares are thought to be most densely populated. In northeast Pennsylvania hare habitat includes high elevation wetlands and scrub oak barrens while habitat in the central and northwestern part of the state around McKean County is shrubby wetlands and conifer forest stands (Diefenbach et al. 2005). Associated hare habitat types in Pennsylvania also include regenerating stands of hardwoods (5-15 years), and scrub shrub wetlands (Merritt 1987) at higher elevations (>450 m; Brown 1984). These habitats are considered to be high quality habitat for snowshoe hares in Pennsylvania (Carreker 1985). Diefenbach et al. (2005) described hare distribution north of Interstate 80 to be patchy and related to specific habitat type, but there has been very little work done to analyze the distribution of hares in southern areas of the state. Recently, hares have been found in the Laurel Highlands of southwestern (SW) Pennsylvania and the ridge and valley of southcentral (SC) Pennsylvania, but very little is known about their habitat use in these regions.

The Appalachian cottontail is a medium sized rabbit and 1 of 2 *Sylvilagus* species found in Pennsylvania. The Appalachian cottontail is distinguished from its relative, the eastern cottontail (*Sylvilagus floridanus*), by a black blaze on the forehead, a black leading edge of the ear, smaller size, darker color, and skull morphology (Merritt 1987). Historically the 2 species lived in separate habitats with eastern cottontails found mostly in lower elevation fields while Appalachian cottontails, also known as “woods rabbit”, were found in forests typically on ridge-tops (>800 ft), however, the release of eastern cottontails from the Midwest and translocation of problem rabbits into *S. obscurus* habitat is thought to have increased competition for resources

and caused a decline in *S. obscurus'* populations and distribution (Harnishfeger 2004, Holderman 1978, Merritt 1987).

Once considered to be conspecific with the federally Threatened New England cottontail (*Sylvilagus transitionalis*), the Appalachian cottontail ranges disjunctly from Pennsylvania to Alabama along the ridge tops of the Appalachian Mountains (Chapman et al. 1992, Chapman 1999). Harnishfeger (2004) investigated historical population sites of Appalachian cottontails in north-central and Laurel Highlands regions of Pennsylvania, but only found 3 populations remaining in Clinton and Centre counties. A statewide survey has not occurred in over 60 years. Regional mammal surveys conducted between 1948 and 1952 possibly inflated *S. obscurus* distribution estimates within the state because of misidentified eastern cottontails. Museum specimens confirmed recent historical Appalachian cottontail population presence in 15 Pennsylvania counties (Harnishfeger 2004). One reason for concern for Appalachian cottontail populations declining in recent decades is due to habitat loss and fragmentation on ridge tops which are already discontinuous in nature. Consequently, the Appalachian cottontail is a species of high-level concern in Pennsylvania's 2005 Wildlife Action Plan due to their sensitivity to habitat alteration, reduced distribution, and introductions of the eastern cottontail (Steele et al. 2010).

Snowshoe hares and Appalachian cottontails are found in areas with dense vegetation that provides food, thermal cover, and protection from predators especially during winter (Berg et al. 2012, Boonstra et al. 1998). Both snowshoe hare and Appalachian cottontail populations need contiguous habitats to persist (Ausband and Baty 2005, Berg et al. 2012, Carreker 1985). Suitable habitat in Pennsylvania includes high elevation; brushy forest clearings, tornado blow-downs, scrub or shrub woodlands, dense conifer stands, and mountain laurel (*Kalmia latifolia*). Though the 2 species have slightly different habitat requirements they essentially depend on areas with high stem density (>10,000 stems/ha) that is high to provide vertical cover from aerial predators (Carreker 1985, Litvaitis et al. 1985, Wolfe et al. 1982). Hares require slightly higher vegetation at >2m (Brown 1984) and typically occupy clearcuts 10-15 years post cut, while Appalachians likely occupy stands earlier. Appalachian cottontails can also occupy areas with lower understory cover such as blueberry (*Vaccinum sp.*). Areas with mountain laurel or eastern hemlock (*Tsuga canadensis*) were used less by hares than 5-15 year old clearcuts when all habitat types were in proximity (Brown 1984) suggesting that early successional habitat is preferred. Hardwood clearcut stands in Pennsylvania may be suitable, but marginal, habitat for snowshoe hares and used because Pennsylvania has little coniferous habitat which is generally considered to be preferred by hares (Ausband and Baty 2005, Carreker 1985, Diefenbach et al. 2005). Edge habitats between mature forests and regenerating clearcuts have potential to be high-quality habitat, despite having greater predator densities, because they offer both cover and food in close proximity (Forsey and Baggs 2001, Litvaitis et al. 1985).

Both species are generalist herbivores; in summer they feed on grasses, legumes, wild berries, sedges, ferns, wild flowers, clover, horsetails, and new growth of trees and shrubs while, in winter, their diet consists of twigs, bark, lichens, moss, and conifer needles (Carreker 1985, Chapman 1999). Vegetative structure is more influential in hare habitat use than vegetative composition (Carreker 1985) because of the role structure plays in predator avoidance.

The dependence of these habitat specialists on suitable habitats is the greatest concern for management as the habitats have a limited distribution in Pennsylvania. The loss of many historical disturbances (fire and agricultural clearing), combined with land use change, has precipitated a steep decline in these habitats in recent decades (Brooks 2003, Litvaitis 2003, Lorimer and White 2003). Remaining habitats within the species' range are disjunct and small, preventing them from sustaining sizeable populations and making them highly susceptible to local extinction (Litvaitis and Villafuerte 1996) while also impeding re-colonization of increasingly isolated patches (Fenderson 2010). Managers can use many methods to increase habitat suitability for Appalachian cottontails and snowshoe hares including timber management, prescribed fire, shrub cutting, and invasive species management (Berg et al. 2012). Conifer plantings in areas where eastern hemlocks have been adversely impacted by hemlock wooly adelgid, or areas that have been disturbed may be important to provide thermal cover to otherwise suitable habitat (Yamasaki et al. 2000).

Responsibility species that fall within the High Level Concern category, such as the Appalachian cottontail, represent high-priority targets for the Wildlife Action Plan. This tier is comprised of nationally or regionally significant species that are vulnerable in Pennsylvania. Goals listed for species of high-level concern on the Wildlife Action plan include: 1) gather adequate information to make a status determination and 2) ensure the continued viability of populations and protect key habitats to the point that vulnerable populations are secure and risks are minimized. Direct and focused habitat management and protection are necessary to create stable populations.

Wildlife researchers have developed a variety of sampling techniques to monitor rare or elusive species (Hettinga et al. 2012, Hodges 2000) including tracks, hair, visual detection, fecal pellet samples, road kill, and hunter harvest (Berg and Gese 2010, Keith et al. 1968, Murray et al. 2002). Winter track counts are restricted to periods of snow cover and may suffer from effects of weather or other factors influencing track observability. DNA from fecal pellets can be used to estimate population size through mark recapture methods and to determine relative abundance (Hettinga et al. 2012, Schwartz et al. 2007). Animals harvested by hunters or killed on road ways can be identified by physiological markers such as skull morphology and DNA.

It is the responsibility of the PGC to manage mammals for current and future generations. The Appalachian cottontail and snowshoe hares are game species with great uncertainty as to the actual current distribution, abundance, and habitat selection in Pennsylvania, but much to be gained from focused habitat management practices. The purpose of this research is to determine abundance and distribution of snowshoe hares and Appalachian cottontails in Pennsylvania through indirect sampling methods; transects for tracks, pellet collection, and visual observation to better the scientific basis for hunting seasons, bag limits, and habitat management practices.

METHODS

Reports of snowshoe hares, high elevation cottontails, and ArcGIS were used to guide surveys for opportunistic pellet collection for DNA analysis. We surveyed multiple state, federal, and privately owned properties for lagomorph fecal pellets to detect Appalachian cottontails and snowshoe hares and to gain a better idea of their statewide distributions. Cottontail skulls from

legally harvested rabbits were also collected. We approached beagle clubs and members of the Pennsylvania Sporting Dog Association for participants.

During 2014 and the first part of 2015 we focused on determining the status of snowshoe hare populations in the Laurel Highlands of southwestern Pennsylvania. Transects for tracks and pellet were repeated on State Game Lands (SGLs) 42, 111, and 228 with assistance from region staff. These SGLs were targeted because they are where introductions most recently occurred about 15 years ago. Habitat considered for transect placement had vegetation composed of early successional northern hardwood, mountain laurel, rhododendron, birch, and hemlock-northern hardwood with diameter at breast height (dbh) <6" (T. Hoppe, 2013. Pennsylvania Game Commission, unpublished report) and scrub or shrub (particularly scrub oak) habitat types (Diefenbach et al. 2005). Transects were 200 m long, ran north to south, and were at least 160 meters apart to account for hare home range (Dolbeer and Clark 1975). Thirty transects were established on each game lands for a total of 18,000 m of transect surveyed in the Southwest Region. Tracks found on transects were used to determine relative species abundance at each study site. Given the difficulty of distinguishing between lagomorph species' fecal pellets and the high elevation of these SGLs, all lagomorph pellets were collected with date, location, and general habitat information recorded. The DNA in the pellets has and will continue to identify species of lagomorph (Hettinga et al. 2012; Schwartz et al. 2007). Pellets were frozen until analysis was run at the Huck Institute of Life Sciences at Penn State University. Considering the similarity in habitat requirements for snowshoe hare and Appalachian cottontail, it is anticipated that this research will continue to lead to a better understanding of *S. obscurus* distribution in Pennsylvania as well. Locations of all snowshoe hare tracks and pellet samples were recorded using a handheld global positioning system unit. This transect survey in the Southwest Region will not be a density estimate.

RESULTS

We completed all 90 transects (total 18,000 m) to survey for snowshoe hare on 3 SGLs in the Southwest Region (SWR). We collected 10 total lagomorph fecal pellet samples in the SWR, 6 of which were from cottontail tracks on transects**.** One pellet sample was collected from hare tracks**.** No hare tracks were found on transects. SGL 228 has been found to have hare tracks 2 years in a row, but no hare tracks have been detected on the other SWR SGLs.

During the 2015 field season we visited multiple state, federal and privately owned properties to survey for lagomorph fecal pellets (Table 1). Mount Davis Natural Area, Somerset County, and Allegheny National Forest, McKean County, were also surveyed, but no pellets were found. Surveys at these locations were not exhaustive, however, and these areas are still worthy of further survey as both are historical locations for snowshoe hare and Appalachian cottontail.

One hundred seventy-nine total samples have been collected and analyzed between the 2 years of pellet collection (52 Appalachian cottontails, 51 eastern cottontails, 52 snowshoe hares, and 28 samples have not amplified). Pellet samples that have not amplified are from across the Commonwealth, but seem to have been from collections that occurred during warmer months, or from samples that were grouped. Though we have focused on sampling areas that are higher in

elevation and likely experience greater periods of snow cover, the 3 lagomorph species have been sampled at almost the same rate.

During the 2014 season snowshoe hares were only found on SWR SGL 228. Appalachian cottontails were found on SWR SGL 111 and Southcentral Region (SCR) SGLs 048 and 104. There are a few interesting observations from this season's results. During the 2014 collecting season, SGLs with Appalachian cottontails had a majority of Appalachians compared to eastern (SGL 111 over 2/3 Appalachians, SGL 048 - 25 Appalachians: 1 eastern, SGL 104 - 5 Appalachians: 1 eastern). Pellet samples ranged in elevation from about 1,100 ft to over 2,600 ft. The lowest elevation with Appalachian cottontails was 2,100 ft. Snowshoe hares were found at the highest elevations along with eastern cottontails. All Appalachian cottontail samples were from previously undocumented locations and no Appalachian cottontails have been previously recorded in Bedford County. The Appalachian cottontail population detected on SGL 111 (Fig. 1) is not far from a historical location in Ohiopyle State Park, Fayette County. A metapopulation of Appalachian cottontails may yet exist here. The historical location was not resurveyed by Harnishfeger (2004) as the site was found to have slopes that were too steep for Appalachian cottontails.

The 2015 pellet collection season found a previously undocumented population of Appalachian cottontails in McKean County in an area that also contained snowshoe hares. Snowshoe hares have been identified on the stretch of Shade Mountain between SCR SGL 107 and Bald Eagle State Forest, encompassing parts of Mifflin, Snyder, and Juniata counties. Hares have also been confirmed on SGL 067 in Huntingdon County. Most of these counties have historical records of hares, but reports on the Game Take Survey have decreased over the years, and absent in most recent years.

The pilot study for the Appalachian cottontail head collection resulted in 66 cottontail heads from 12 Pennsylvania counties being submitted for analysis. The heads have been delivered to the dermestid beetle colony at Delaware Valley University for final processing. Once cleaned, the skulls will be used to identify the cottontails to species. DNA samples were collected from 6 skulls before processing began and we have been able to confirm Appalachian cottontail skulls were collected at SGL 111 and eastern cottontails were collected in York, Clearfield, and Cumberland counties.

RECOMMENDATIONS

1. Finalize species management plans for snowshoe hares and Appalachian cottontails.

2. Expand focus of SWR snowshoe hare survey to other high elevation areas along the Laurel Highlands as well as expanding pellet collections along the borders of known snowshoe hare populations.

3. Identify areas to begin habitat treatment studies for both snowshoe hare and Appalachian cottontails. We have identified an area of 1,000s of acres of variously aged clear cuts in McKean, Elk, and Cameron counties that create a unique matrix of diverse habitats. The habitats are on large tracts of state owned properties (Elk State Forest and SGLs 25, 30, and 62)

as well as privately owned timber land. The diverse matrix of habitats available with new cuts planned for years to come would be a great opportunity for researching snowshoe hare habitat use in northern hardwoods, whether through collars or establishing track surveys in the area. It is also possible that the hare population in this area may be dense enough for density estimates based on pellet counts as well. There also seems to be an increase in the number of road killed hares in the area, perhaps suggesting that there is an increase in dispersal. This area may have better trapping success than SGL 029 since it's surrounded by cuts of various ages whereas SGL 29 is relatively isolated - surrounded by more mature woods. This area would be an ideal place to continue the objectives of current hare project with the Pennsylvania Cooperative Fish and Wildlife Research Unit.

4. Continue and expand Appalachian cottontail head collection efforts. We plan to approach Sportsmen's magazines, Game News, and other social media outlets to increase participation in the study. We also intend to attend rabbit hunt competitions so as to limit the submission of non-target cottontails. Increased participation in the study will benefit the effectiveness and increased processing will be allowed by the continued used of the dermestid beetle colony at Delaware Valley University.

5. Evaluate the cost and benefit of translocating snowshoe hares and Appalachian cottontails into areas which have suitable habitat, but are not currently occupied. Historical accounts indicate SGLs 12 and 36 in the Northeast Region used to have snowshoe hares until about 25 years ago. This area is very close to SGLs 13, 57, and 67 which have snowshoe hares, as well as being in close proximity to Loyalsock State Forest, Ricketts Glen State Park and other state owned properties that have had hares in the recent past. These SGLs may be a good place to target for snowshoe hare relocations once the current habitat condition has been evaluated. Snowshoe hares are already listed as possible species on these SGL plans. Also of note, Loyalsock State Forest has identified the snowshoe hare as a target species and is seeking to better their habitat management practices for the species.

6. We are in the process of creating a snowshoe hare hunter survey to be distributed this fall as well as developing a snowshoe hare collaborator's list. The hunter survey will seek to gain human dimension information including attitudes towards the hare hunting season and experience with hunting hares. This survey is necessary to get a better idea of how Pennsylvanians use the hare resource as the small percent of Pennsylvania hunters is largely overlooked by the Game Take Survey. A list of snowshoe hare collaborator's will benefit the PGC's knowledge of our state's hare resource. Snowshoe hare hunters are notoriously secretive about their hare haunts which makes finding remote populations of hares difficult.

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Table 1. Locations where pellets and rabbit heads were collected during the reporting period. Code for species identification; SH- snowshoe hare, AC-Appalachian cottontail, EC-eastern cottontail, NO AMP-DNA could not be obtained from sample.

Region	SGL	# Pellet Samples	# Rabbit Heads	Species
NC	Blueball Mountain Rd, Centre County	4		NO AMP
NC	Clearfield County, Frenchville TWP		2	EC
NC	Elk SF	4		SH
NC	McKean County	21		SH, AC, EC
NC	SGL 030	5		SH, EC
NC	SGL 062	1		SH
NE	SGL 057	5		SH
NE	SGL 066	2		SH
SC	SGL 048	29		AC, EC
SC	SGL 067	22		SH, EC
SC	SGL 088	3		NO AMP
SC	SGL 104	8		AC, EC
SC	SGL 107	3		NO AMP
SC	Bald Eagle SF - Shade Mountain	4		SH, EC
SC	Shade Mountain	4		SH
SC	SGL 112	2		NO AMP
SC	SGL 169		1	EC
SC	SGL 322	4		EC
SC	York County, Conawago TWP		1	EC
SW	SGL 042	9		EC
SW	SGL 111	33	4	AC, EC
SW	SGL 228	19		SH, EC

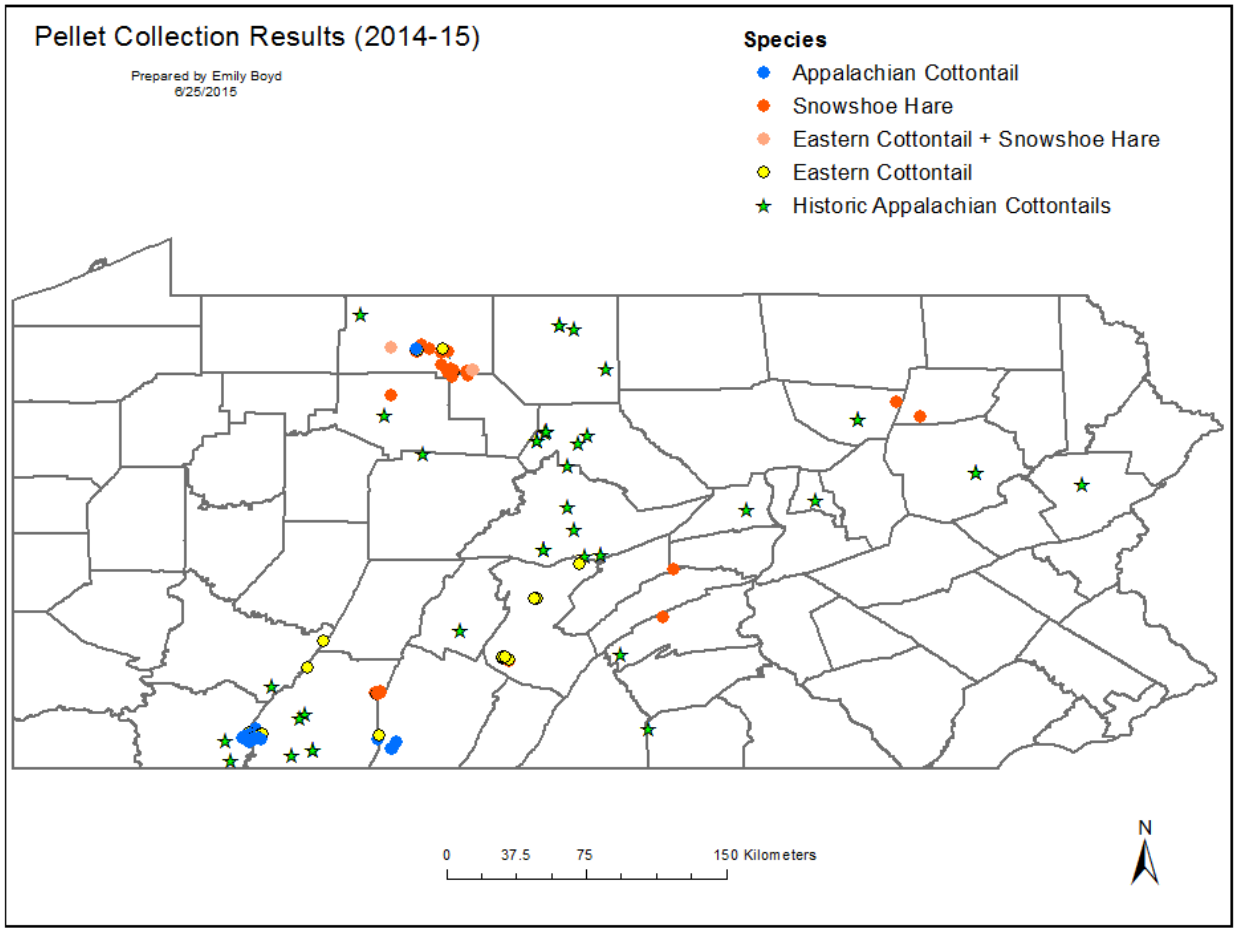

Figure 1: Species identified during the lagomorph fecal pellet collection (2014-15). Approximate locations are shown for historical Appalachian cottontail records.