The Pennsylvania State University

The Graduate School

Department of Ecosystem Science and Management

MONITORING WILD RING-NECKED PHEASANT POPULATION RESTORATION IN PENNSYLVANIA

A Thesis in

Wildlife and Fisheries Science

by

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Submitted in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science

December 2017

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ABSTRACT

Ring-necked pheasants (*Phasianus colchicus*) are a non-native species that has become naturalized and a popular game bird in the United States. The population in Pennsylvania has been declining since the 1970s despite stocking and habitat restoration efforts. One of the management objectives of the Pennsylvania Game Commission is to provide quality pheasant hunting which requires restoration of the wild pheasant population so that it is naturally reproducing and able to withstand hunting pressure. The current best potential habitat for pheasants within the state was identified and 4 wild pheasant recovery areas (WPRAs) were created to monitor pheasant restoration efforts. At these areas, it was illegal to release stocked pheasants, hunt and harvest either sex, or train dogs. Wild-trapped pheasants from South Dakota and Montana were released at the study areas to ensure there would be an adequate founding population for restoration purposes. The Pennsylvania Game Commission set objectives for a density of 3.86 female pheasants/km^2 and that would be adequate for maintaining a sustainable population with hunting pressure. To assess the success of the project and aid in future management decisions, we explored methods of estimating the density by incorporating multiple detection probabilities and a model for predicting potential female pheasant density based on micro-habitat data.

As opposed to requiring multiple years of monitoring to obtain population trends using indices of abundance, we used crowing counts and adjusted for detection probabilities to estimate density at each of 12 study areas from 2013 to 2016. Our density estimates were adjusted for the probability a male pheasant crowed in a 3-minute survey

period, the probability an observer was able to detect a pheasant given that it crowed, and the probability of flushing a male pheasant. We found the probability a male crowed in the survey period to decrease linearly during the breeding period (21 April–23 May) from 0.659 to 0.464. The probability of detecting a crowing pheasant at 0.80 km was >0, indicating that there was no distance at which it was reasonable to assume no birds could be detected. Instead, the effective area was used and is robust to choice of radius. Because the male pheasants are recorded during the crowing counts and female densities are required to meet objectives, we estimated the probability of flushing a male pheasant to be 0.495 yielding an almost 1:1 sex ratio. Only one of 12 study areas achieved the female density goal of 3.86 females/km^2 from 2013 to 2016. The methods used to obtain these density estimates simplified the crowing count protocol and can easily be used and adjusted for other species, detection probabilities, or survey areas to estimate density.

To assess habitat or landscape composition at the WPRAs, we conducted a micro-habitat analysis by identifying all vegetation types within a 0.56 km radius of the survey point (hereafter referred to as *survey circle*) resulting in digitized maps of micro-habitat within a survey circle. Our objective was to create a model that would be able to predict potential female pheasant densities based on proportion of habitat type in a survey circle. We had 37 vegetation types that were combined into 8 habitat types *a priori* and used these as independent variables in our predictive models. We used our methods of estimating pheasant densities (Chapter 2) to estimate female density at the survey circle to be used as the dependent variable. For the model, we used 2 years of micro-habitat data (2013–2014) and density estimates (2014–2015). We estimated that female pheasant densities were influenced most by the proportion of idle grasses and forest. We found the proportion of idle grass to positively influence pheasant densities, while forest had a negative influence. This model will be important for improving habitat to meet a desired pheasant density goal by allowing managers to make recommendations for quantity and proportions of habitat needed to achieve desired pheasant density goals.

Only one study area, Washingtonville West, was successful in meeting the density goal of 3.86 female pheasants/km^2, while all other study areas did not exceed a density of 2 females/km^2. Washingtonville West had the lowest average proportion of forest in a survey circle of any study area. From 2013 to 2015, the average proportion of forest ranged from 4.3% to 9.3% at Washingtonville West, compared to an overall average at all the WPRAs ranging from 15.6% to 17.6%. Given that roughly 60% of the overall landscape in Pennsylvania is forested, the WPRAs represent a small section of the state that is potentially suitable pheasant habitat. Even at this suitable habitat, we only achieved a self-sustainable pheasant population that can withstand hunting pressure at one study area which had <10% forest. Because forest has a negative effect on pheasant densities and so much of the Pennsylvania landscape is forested, it will be difficult to locate enough suitable habitat to support sustainable pheasant populations in order to provide hunting opportunities across the state

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ACKNOWLEDGMENTS

I would like to thank all those who contributed to make this project possible. I thank both of my advisers, David Walter and Duane Diefenbach, for their support, trust, and guidance in completing this project. Thank you to my other committee member, Matt Marshall, for the suggestions and input along the way. A special thanks to Scott Klinger for all his work on the pheasant restoration project and helping me to find answers that would be useful for management purposes. Additionally, I'd like to also especially thank Colleen Delong, Wild Pheasant Project Coordinator in the Pennsylvania Game Commission (PGC), for nearly 8 years on this project and Jesse Putnam, Habitat Forever, who coordinated and trapped all wild pheasants in Montana and South Dakota for this project. I thank Thomas Keller and Ian Gregg from the PGC for their efforts in collecting data and ensuring I answered the important questions. I appreciate all the hard work and help from other PGC staff, especially Megan Rake, Brandon Black, Ray Grater, and Wyatt Knepp. Special thanks to the PA Pheasants Forever chapters, volunteers, and private landowners. Without these people, the project would not have been possible.

I would also like to thank everyone in the Department of Ecosystem Science and Management, as well as the Cooperative Research Unit. Their advice, support, and friendship were crucial to keeping my sanity and spirits up. I really enjoyed my time at Penn State because of them and I'm so thankful to have found such a large group of people to call my friends and who I can lean on. I'd also like to thank my friends back home and my family for their continued support in the pursuit of my dreams.

Chapter 1

The current status of ring-necked pheasants in a forest-dominated landscape: where do we go from here?

Chapter 1 was written in collaboration with Duane R. Diefenbach, Scott R. Klinger, and W. David Walter. I have included this manuscript on the following pages as formatted for The Journal of Fish and Wildlife Management.

Ring-necked pheasants (*Phasianus colchicus*) are an iconic and popular game bird. While pheasants are native to Asia, they have been introduced successfully on multiple continents and countries, including Europe, North America, Chile, and New Zealand (Hill and Robertson 1988). The first attempted introduction of pheasants in the United States occurred in New York in 1733 (Allen 1956), but pheasants were not successfully recorded as introduced until 1881 in the Willamette Valley of Oregon. Although pheasants are a non-native species, they have become naturalized (Frey et al. 2003) and an iconic symbol of the midwestern United States, including being the state bird in South Dakota. In 1954, the reported pheasant range stretched across the majority of the United States, with the exception of the Southeast (Edminster 1954).

Pheasants have been declining throughout their range in the United States since the 1970s (Labisky 1976, Sauer et al. 2017). In the Midwest from 1971 to 1986, pheasants declined by 33% and collectively by 67% in the rest of the country (Dahlgren 1988). The decline of one of the most popular game birds in the nation has spurred an increase in pheasant research focusing on aspects that may influence the population, such as the hardiness of stocked birds (Krauss et al. 1987), survival (Wilson et al. 1992, Gabbert et al. 1999, Homan et al. 2000), nest success (Haensly et al. 1987, Clark et al. 1999), and habitat use in different seasons (Hill and Ridley 1987, Gatti et al. 1989).

Pheasants are an agriculturally dependent bird (Gerstell 1937, Edminster 1954), but utilize multiple habitat types throughout the year. During the breeding season, pheasants will use grasses, pastures, and shrubs for nesting (Hartman and Sheffer 1971, Schmitz and Clark 1999, Shipley and Scott 2006), but rely on wooded areas, wetlands, and food plots during the winter months (Hartman and Sheffer 1971, Gabbert et al. 1999, Homan et al. 2000). Much of the pheasant decline is thought to be attributed to habitat loss and changes in farming practices. Some of the expected reasons contributing to the declining pheasant populations across the nation are increased monocultures of row crops (Taylor et al. 1978, Warner 1984), increased use of pesticides reducing the weeds and insects available for brood rearing (Hill 1985, Rands 1986), early mowing (Hartman et al. 1984, Warner and Etter 1989), and the reduction of a mosaic landscape attributed to increasing farm and field sizes (Taylor et al. 1978).

To combat the changing landscape and land use, efforts to address pheasant population declines have focused on improving habitat. The Conservation Reserve Program (CRP) was created under the Food Security Act of 1985 with the purpose of paying farmers to remove environmentally sensitive agricultural land from production. Land was enrolled for 10–15 years and converted from crops or pasture to other vegetation that provided wildlife cover (Osborn 1993). Habitat created from government assistance programs, such as the CRP, has benefitted pheasant populations and helped to maintain crucial habitat for nesting (Haroldson et al. 2006, Nielson et al. 2008, Matthews et al. 2012).

The northeastern United States is considered less favorable habitat compared to the western United States (Allen 1956) because of a smaller percentage of the landscape in agricultural use and the large amount of mountainous and wooded terrain (Rue 1973). The eastern U.S. has had difficulty maintaining a wild pheasant population that can sustain hunter harvests (Allen 1956), but Pennsylvania has a rich history of pheasant hunting. In 1902, Pennsylvania had the first hunting season for pheasants in the northeastern U.S. (Allen 1956). There were no harvest limits until 1915 when daily, weekly, and seasonal bag limits were established and there was a harvest of 796 birds (Klinger and Riegner 2008). The Pennsylvania Game Commission (PGC) started stocking (i.e., pen-reared, artificially propagated, or captive raised birds released to increase hunting opportunities hereafter referred to as stocked) pheasants in 1915 and released 2,096 pheasants in the spring, with the intention that they could naturally breed and be hunted in the fall (Gerstell 1937, Edminster 1954). In the early years that PGC stocked pheasants, the prediction was that "pheasants will never become established in Pennsylvania because they cannot stand hard winters and hard hunting both" (Edminster 1954). The hard winters were found not to inhibit population growth and the wild population soon started to increase (Edminster 1954). In 1936 and 1937, a total of 17,850 banded male pheasants were stocked in fall and spring as part of the PGC's annual restocking program. With the spring release of pheasants, the intention for stocked birds was to supply both a population that could naturally breed in spring and hunting opportunities during the fall. The fall stocking of banded male pheasants weeks prior to the hunting season resulted in a reported harvest of 19.1% in 1936 and 24.2% of banded birds in 1937 (Gerstell 1938).

Stocking efforts and artificial propagation resulted in some individuals surviving long-term to create a wild pheasant population (Gerstell 1937). The majority of birds released in the autumn, however, did not survive to the breeding season with the survival rate of stocked birds <6% within 30-days post-release (Diefenbach et al. 2000). This survival rate negated the ability of stocked birds to contribute to a self-sustaining wild pheasant population. Krauss et al. (1987) found that wild-caught male pheasants had higher survival than stocked males when released at the same time and location, possibly due to stocked birds being less fearful of humans, thus making them more approachable by predators. To solely provide hunting opportunity, more than 7,916,000 pheasants were raised and released in Pennsylvania between 1929 and 1998 by the PGC. In 1998, 2.8 million USD was spent on stocked pheasants by the PGC and almost 200,000 pheasants were released for hunter harvest (Diefenbach et al. 2000). Similar numbers of stocked pheasants have been released annually to the present day.

In areas that did not support wild pheasants, stocking supplemented the population to continue providing hunting opportunities. When the pheasant decline occurred, stocking efforts increased in an attempt to prevent further decline of the population, but were unsuccessful. It was eventually realized that the stocked pheasants supplied the majority of hunting opportunities while the wild population continued to decline (Klinger and Riegner 2008). In recent years, there has been a push to decrease the amount of stocked pheasants in the state, but still have pheasant hunting opportunities. To do this, the PGC attempted to restore the wild pheasant population to densities that can withstand hunter harvest in a sustainable manner. In an effort to stock a hardier bird, the PGC was hopeful that Sichuan pheasants (*Phasianus colchicus strauchi*), a subspecies of ring-necked pheasants, would be better suited to nest in brushy areas instead of the hay fields relied upon by ring-necked pheasants. Stocking Sichuan and ring-necked pheasants indicated no differences between the subspecies in habitat selection, survival, or reproduction in Ohio (Shipley and Scott 2006).

While the increase in research has aided in the management of pheasants, additional research, specific to Pennsylvania’s land use and ecosystem, was needed to restore a wild pheasant population to Pennsylvania. The majority of the research on pheasants has occurred in the Midwest, which has a different landscape compared to Pennsylvania. While previous research offers some insight into the habitat types pheasants might use in Pennsylvania, there is no indication if an adequate amount of habitat exists to support pheasant populations that could withstand hunting, if the population utilizes other habitat types, or possible habitat improvements that could support pheasant density goals.

By 1937, pheasants had become established in every county within Pennsylvania (Gerstell 1937). Hartman and Sheffer (1971) classified 63,536 km^2 of Pennsylvania, mainly in the Southeast, as being able to support pheasants and falling into either first, second, or third class categories. The first class category (21,448 km^2) had almost all natural reproduction and a majority of the pheasant harvest. The second class category (18,211 km^2) accounted for about 20–30% of Pennsylvania's male harvest with stocked birds making up about half of the birds harvested. The third class category (23,471 km^2) made up a low proportion of harvest (10%) with about 90% of the harvest from stocked birds. Latham (1973) reported the western part of Pennsylvania as being prime pheasant hunting, while Hartman and Sheffer (1971) listed that part of the state as being second or third class habitat. In 1971, the highest reported pheasant density in Pennsylvania occurred in the Southeast and exceeded 15.8 females/km^2, but by 1986 the highest reported density in the entire state was 3.9 females/km^2 (Dahlgren 1988).

Peak pheasant harvests occurred in 1971 and 1972 with >1.3 million birds harvested each year (Klinger and Riegner 2008), but annual harvest in 1998 declined to 217,000 (Diefenbach et al. 2000). By the 2000s, pheasant populations in Pennsylvania had reached the lowest recorded numbers during the Christmas Bird Counts since the

1920s (National Audubon Society 2010). There are no records on the number of pheasant hunters before 1971, but the lowest recorded number of hunters was in 2010 with 71,579 hunters (Johnson 2015).

Since the first pheasant hunting season, the Pennsylvania landscape and land use has changed. The average size of a farm was lowest in 1935 with 0.34 km^2 (U.S. Bureau of the Census 1967) and highest in 1992 with 0.65 km^2 and corresponds with an increase in monoculture row crops. In 1930, 6.2% of the land at farms was used for grain or seed corn, 8.9% in 1950, 12.1% in 1974, and 13.0% in 2012 (U.S. Bureau of the Census 1940;1954;1967;1977, U.S. Department of Agriculture 2014). From 1920 to 1977, the proportion of Pennsylvania that was forested increased from 42.5% to 57.1% and then stayed relatively stable through 2012 (Figure 1-1; Oswalt et al. 2014). Within this same time, the proportion of land in agriculture decreased from 59.9% in 1920 to 27.8% in 1974, but leveled out at about 26% from 1987 to 2012 (U.S. Bureau of the Census 1940;1967;1983, U.S. Department of Agriculture 2014). The increase of forested land and decrease in agriculture appeared to coincide with the pheasant declines in the 1960s and 1970s. These changes in Pennsylvania may have limited the amount of habitat available for pheasants and help to explain the population decline.

In 2000, the Conservation Reserve Enhancement Program (CREP), which is a part of the CRP, was created with the intention that private farmland would be converted to wildlife habitat and also improve water quality in the Chesapeake Bay watershed (Klinger and Riegner 2008). Pabian et al. (2015) conducted a study to examine the effect of CREP habitat on pheasants and found that pheasant abundance was positively influenced by CREP habitat in south central and southeastern Pennsylvania. It is unclear whether it is possible to enroll enough land in CREP to reverse the pheasant population decline.

A management objective of the PGC was to provide quality pheasant hunting in Pennsylvania, which was initially explored at a small spatial scale. In 2002, Pike Run, a study area in southwestern Pennsylvania, was created and used as an experimental area to validate restoration as a management option for pheasant. This 125.3 km^2 study area was involved in recent habitat improvement efforts for the first translocations of wild-trapped pheasants (Klinger and Riegner 2008). A total of 591 wild pheasants from South Dakota were translocated to the area with 14 pheasants fitted with radiotransmitters to track their survival (DeLong and Klinger 2008). Fifty percent of birds with a radiotransmitter died within 2 weeks post-release and 86% died by the end of the nesting season. Crowing routes and flushing surveys were used to monitor the population and the density was estimated at 0.77 females/km^2 in 2008 (Klinger and Riegner 2008). Because the estimated density was less than the density goal established by the PGC (3.86 females/km^2), the Pike Run study area was closed and reintroduction efforts at this site ended in 2012 (Klinger et al. 2013).

Although the Pike Run study area did not meet density goals, efforts to locate other areas that have the ability to support a wild pheasant population continued. Ideal areas would require minimal habitat improvement initially and would need to meet the criteria of <20% forest, >50% agriculture, >20% hay, and <10% developed land (Klinger and Riegner 2008). The PGC created wild pheasant recovery areas (WPRAs) that met the landscape criteria, were ≥40.5 km^2 within contiguous agriculture, and had >5% nesting cover which may include CREP, hay with delayed mowing, or small grains. Release of stocked birds, pheasant hunting, and dog training were prohibited at WPRAs during restoration efforts. Due to the low wild pheasant population at the WPRAs and the low survivability of stocked birds, wild pheasants were trapped in South Dakota and Montana and released on each WPRA.

At these WPRAs, a more detailed assessment of pheasant density estimates and habitat composition was needed to assess the success of the areas and the validity of pheasant restoration in Pennsylvania. A population density goal of 3.86 female pheasants/km^2 was set by the PGC and believed to be necessary to maintaining self-sustaining pheasant populations that experience hunter harvest (Klinger and Riegner 2008). To assess the ability of having a wild pheasant population in Pennsylvania, accurate density estimates and knowledge of what habitats are present and being used by wild pheasants are necessary.

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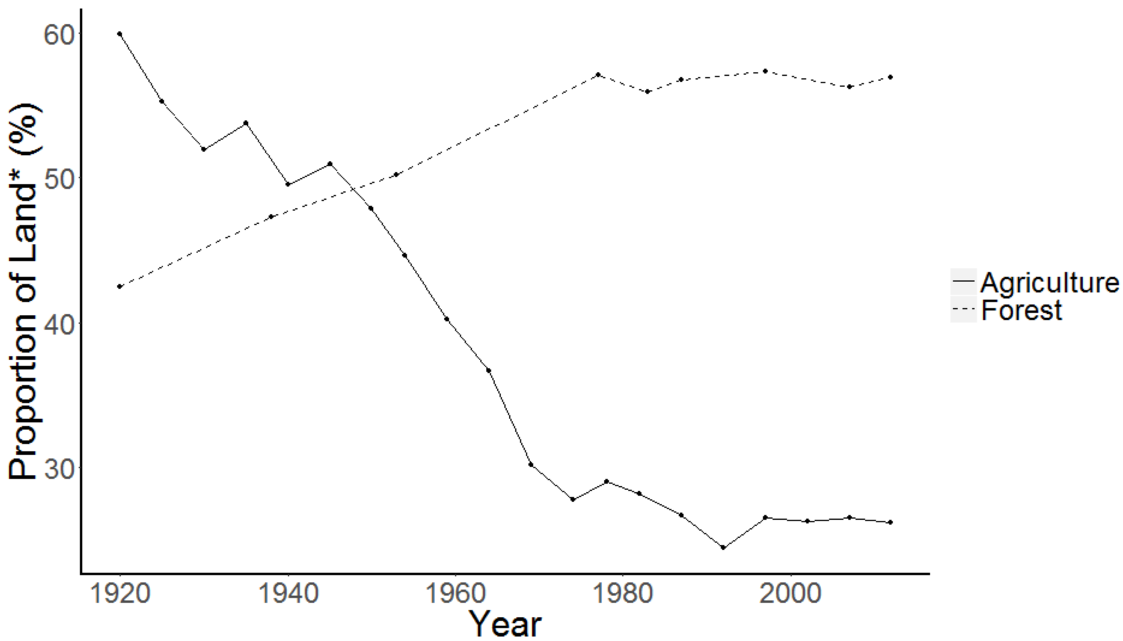
Figure 1-1.The proportion of land (%) in agriculture and forest in Pennsylvania (U.S. Bureau of the Census 1940;1967;1983, Oswalt et al. 2014, U.S. Department of Agriculture 2014), 1920–2012.

Figure 1-1.



*Proportions were calculated from multiple sources and may not sum to 100%.

Chapter 2

Estimating detection probability for bird population density estimates

Chapter 2 was written in collaboration with W. David Walter, Scott R. Klinger, and Duane R. Diefenbach. I have included this manuscript on the following pages as formatted for The Journal of Wildlife Management.

ABSTRACT Indices of abundance, such as calling counts, are commonly used to monitor trends in bird populations. In some circumstances, however, an index of abundance provides insufficient information for making management decisions and accurate density estimates are necessary. Wild ring-necked pheasants (*Phasianus colchicus*) were translocated to 10 study areas with the goal of establishing female densities of 3.86 pheasants/km^2. We developed a population density estimator that used 3-minute crowing counts adjusted for probability of detection to estimate male pheasant density and flushing surveys to estimate the female:male ratio. To account for detection probability, we estimated the probability a pheasant was available to be detected by monitoring crowing frequency of male pheasants fitted with radiotransmitters and the probability an observer was able to detect a crowing pheasant at distances from 0 to 0.933 km. We found the probability a pheasant crowed decreased linearly over our survey period from 0.659 in mid-April to 0.464 by the end of May. We found that the probability of detecting a pheasant at 0.80 km was 0.019 (SE = 0.005), which means that we could not assume any fixed distance beyond which crowing birds could not be detected. Therefore, we replaced the probability of detection in the standard distance sampling estimator with the effective area of detection. The estimation of the effective area of detection is robust to choice of radius of the point transect and did not require observers to estimate the distance to crowing pheasants. We estimated the female:male ratio to be 1.02:1, despite the ratio of released pheasants being 4.46:1. Only one study area achieved the female density goal ($\hat{D}$ = 4.16) with the maximum density at all other study areas of <2 females/km^2. The estimator we developed incorporated multiple detection probabilities to provide density estimates and simplified the crowing count protocol by eliminating the need for observers to estimate their distance from a detected bird, which makes the estimator useful for population estimation of calling birds that require more precision than an index can provide.

KEY WORDS density estimation, detection probability, Pennsylvania, *Phasianus colchicus*, restoration, ring-necked pheasant.

Ring-necked pheasants (*Phasianus colchicus*) have been monitored by roadside calling counts, minute-long calling counts, scat counts, and even using detonations to prompt male pheasants to respond with a crow (McClure 1945). Calling counts, such as the Breeding Bird Survey (Nielson et al. 2008), are a commonly used index of abundance and make the assumption that the individuals detected are a constant, proportional representation of the actual population (Luukkonen et al. 1997, Thompson 2002, Farnsworth et al. 2005). For calling counts to provide an index of abundance and be reliable indicators of change in abundance over time, the detectability of birds must be constant despite potential sources of error including: observer ability to detect birds correctly (Carney and Petrides 1957, Rosenstock et al. 2002), seasonal trends (Nelson et al. 1962), differences in the time and duration of maximum calling (Kimball 1949), and variation and effect of environmental factors (Buckland et al. 2001). Without including detection probabilities, it is unclear whether a change in an index of abundance is due to differing detection probabilities, an actual change in population size, or a combination of detection probability and population (Farnsworth et al. 2005).

Whereas an index of abundance can be used to monitor population trends over time, there are instances when density estimates with measures of precision are necessary, such as when assessing success of population restoration efforts (Farnsworth et al. 2005) or comparing populations (Gates 1966). By adjusting calling counts for detection probabilities, we are able to estimate the population size and density. The need for accurate density estimates has led to the development of monitoring techniques that account for detection probability of <1.0. Some of the methods developed to estimate detection probability for calling counts include distance sampling (Buckland et al. 2001), double observer sampling (Nichols et al. 2000), removal models (Farnsworth et al. 2002), and a combination of these techniques (Farnsworth et al. 2005, Amundson et al. 2014). Issues with detection probability, such as differences among observers in the ability to detect individuals, can increase variance and lead to less precise population estimates (Diefenbach et al. 2003). Multiple factors that influence detection probability likely are important to consider and account for when estimating abundance, such as the probability a bird is available to be detected by an observer and the probability an observer is able to detect a bird given it is available to be detected (Farnsworth et al. 2005, Diefenbach et al. 2007).

We monitored wild pheasants by conducting crowing counts, which are a type of calling count, to be used for density estimates. Wild pheasant recovery areas (WPRAs) were created in 2007 and these sites were closed to pheasant hunting and stocking. The survival rate of stocked pheasants is poor, thus negating the ability of these birds to contribute to a self-sustaining wild pheasant population (Krauss et al. 1987, Diefenbach et al. 2000).To initiate a self-sustaining population, wild pheasants were translocated from Montana and South Dakota, USA instead of the release of stocked pheasants. To assess if these pheasant restoration efforts were a success, density estimates were needed rather than an index of abundance typically used to monitor population changes over time. A population density goal of 3.86 females/km^2 was established, with the expectations that the population would be self-sustaining and provide hunting opportunity if this density could be attained. Our objective was to develop methods to estimate density of pheasants on WPRAs and use the resulting density estimates to assess whether the population density goal was achieved. To estimate male pheasant density, we used counts from crowing count surveys and data collected from male pheasants fitted with radiotransmitters to estimate the probability a pheasant was available to be detected during the survey period and the probability an observer detected a pheasant given that it was available to be detected. We estimated female pheasant density by multiplying the male density by the ratio of female to males when conducting flushing surveys.

STUDY AREA

We monitored wild, translocated pheasant populations at 2–5 study areas in each of 4 WPRAs that had >40.5 km^2 of potentially suitable breeding and overwintering habitat for pheasants in Pennsylvania (Table 2-1, Figure 2-1). The topography of WPRAs consisted of ridges and valleys ranging in elevation from 106 m to 818 m (U.S. Geological Survey's Center for Earth Resources Observation and Science 2010). The median frost-free growing days on WPRAs ranged from 143 days to 193 days (National Oceanic and Atmospheric Administration [NOAA] 2017a) and the average yearly precipitation ranged from 104 cm to 117 cm (National Oceanic and Atmospheric Administration [NOAA] 2017b).

The majority of the landscape in the Somerset WPRA was used for agriculture (61.5%) and other major habitat types were forest (14.1%), and developed (10.7%; USDA National Agricultural Statistics Service Cropland Data Layer 2015). The Central Susquehanna WPRA had a similar landscape composition with 54.4% agriculture, 16.0% forested, and 10.6% developed. The Hegins-Gratz WPRA had a large proportion of the area in agriculture (63.8%) and forest (19.6%) with only 8.8% developed. The Franklin WPRA was 63.5% agriculture, 13.5% forest, and 12.8% developed. The majority of the area within WPRAs was private, which was primarily used for corn production, except one WPRA where hay was the most common crop.

METHODS

We trapped wild pheasants in South Dakota (2007, 2010, 2011, and 2014) and Montana (2007–2009) from January to March and translocated them to WPRAs. We used standard wire funnel traps (1 m^2) and bait. We checked the traps daily and held pheasants in pens until 100–300 birds were available for shipment. Before transporting pheasants, we tested all birds for avian influenza and parasites. We placed 4–9 pheasants in each crate for transportation. All birds received a leg band and some pheasants received necklace-style radiotransmitters (11 g; Lotek Engineering Inc., Ontario, Canada) upon release. As control sites, we did not release pheasants in two study areas (Washingtonville South and

North Franklin) at 2 different WPRAs to test if pheasants would naturally establish a population if habitat was available.

We conducted crowing count surveys at the location on a road nearest to randomly placed points across a study area. Unlike traditional crowing count surveys, we did not conduct surveys as transects, but as individual survey points. Observers conducted crowing counts between 16 April and 31 May, 2013–2016. We conducted surveys beginning 30 minutes prior to sunrise and completed them no later than 0900 hours in acceptable weather and noise conditions (i.e., low wind speed, temperature >0°C, and no persistent precipitation). Observers conducted surveys for 3 minutes and recorded the number of individual male pheasants that crowed during the survey period and did not have distance boundaries. We visited survey points 1–12 times during the breeding period.

To increase precision of pheasant density estimates, crowing counts must be adjusted for 2 factors related to the probability of detecting a pheasant (Farnsworth et al. 2005, Diefenbach et al. 2007): the probability a pheasant crowed during the 3-minute interval and the probability a crowing pheasant was heard by an observer. To estimate male pheasant density, we began with the modified distance sampling estimator (Diefenbach et al. 2007):

$$\hat{D}_{males} = \frac{n}{\hat{p}_A \times \hat{p}_{D|A} \times \pi r^2 \times t},$$

where $\widehat{D}$ is the estimated density; n is the number of detected males crowing; $\hat{p}_A$ is the estimated probability that a male pheasant will crow during the survey period; $\hat{p}_{D|A}$ is the estimated conditional probability that the observer detected the crowing male pheasant given that it is available to be detected; πr^2 was the area surveyed; and t was the number of surveys completed. We used the estimated male pheasant density and the estimated population sex ratio from flushing surveys to estimate female density.

To estimate p_A, we observed male pheasants on 2 WPRAs (Franklin and Central Susquehanna) located via radiotransmitters during the breeding season (20 April–31 May) in 2014 and 2015 for a 30 minute time interval between a half hour before sunrise to 0830 h. We recorded the number of times a bird crowed within a three minute survey, yielding 10 3-minute surveys for each observation session per pheasant. We monitored each male pheasant at least 3 times throughout the breeding season under conditions matching the crowing count protocol. We classified a bird as available to be detected if it crowed ≥1 time within a 3 minute period. We used a generalized linear mixed-effects model and specified a binomial distribution (Bates et al. 2015). To estimate how p_A changed over time, we created models including a linear effect of calendar day, a linear and quadratic effect, and an intercept only model. We treated the individual birds as a random effect to account for heterogeneity in crowing frequencies among individuals. We stratified the surveys into three periods (21 April–1 May, 2–12 May, 13–31 May). We estimated p_A for the midpoint of each period and used this in the density estimator (see equation 1).

To estimate $p_{D|A}$, we monitored the ability of observers to detect crows of 21 male pheasants at distances of 0.03–0.93 km on 2 WPRAs (Somerset and Central Susquehanna). During the 2010–2013 breeding season, two observers located a male pheasant via its radiotransmitter and waited for a 2-minute adjustment period. Subsequently, both observers recorded the number of times they heard the pheasant crow for 10 minutes. The first observer remained near the pheasant while the second observer moved away from the bird at 0.18 km intervals and the listening periods were repeated. By documenting which crows were missed by the second observer we were able to estimate $p_{D|A}$ as a function of distance from the observer. We estimated $p_{D|A}$ using logistic regression with the logistic function scaled by the probability of detection at distance 0 so that $\hat{p}_{D|A}$ = 1.0 at distance 0. We used the logistic detection function to estimate the effective area of detection (Buckland et al. 2001). Effective area is the area in which the number of detections beyond a specified distance is equal to the number of missed detections within that distance (Buckland et al. 2001). By using the effective area we avoided arbitrarily defining a detection radius for the crowing counts, which resolved the problem of not being able to measure the distance of a crowing pheasant from the observer during the count surveys. Therefore, we modified the male density estimator:

$$effarea = \hat{p}_{D|A} \times \pi r^2 \qquad \hat{D}_{males} = \frac{n}{\hat{p}_A \times effarea \times t}.$$

Due to variation in crowing frequency based on calendar day, we estimated male density, $\hat{M}_v$, and $\hat{\mathrm{var}}(\hat{M}_v)$, for each period separately. By including t_v, the number of visits in survey period *v*, in the density estimation, we accounted for an unequal number of surveys per survey point.

$$\hat{M}_v = \frac{n_v}{\hat{p}_{Av} \times t_v} \qquad \hat{\text{var}}(\hat{M}_v) = \hat{M}_v^{\,2} \times \{(cv(n_v))^2 + (cv(\hat{p}_{Av}))^2\} \quad [1]$$

where n_v = number of male birds heard in period *v*, t_v = number of surveys across all points in a study area during period *v*, and $\hat{p}_{Av}$ = estimated probability a male pheasant crows in period *v*.

We combined these 3 separate density ($\hat{M}_v$) estimates by averaging and the variance ($\hat{\text{var}}(\hat{M}_v)$) estimates by summing them to obtain an average male density ($\hat{M}$) and $\hat{\text{var}}(\hat{M})$. We incorporated *effarea* to estimate the overall male density:

$$\hat{D}_{males} = \frac{\hat{M}}{effarea} \quad \text{and} \quad \hat{\text{var}}(\hat{D}_{males}) = \hat{D}_{males}^{\,2} \times \{(cv(\hat{M}))^2 + (cv(effarea))^2\}.$$

We conducted flushing surveys in winter months (January and February) from 2013 to 2016 on all of the WPRAs to estimate sex ratio. Observers completed flushing surveys prior to the release of translocated wild pheasants. We used radio telemetry, roadside inspections, and input from landowners to identify areas known to have wild pheasants in which we could conduct flushing surveys. Teams of 5–10 people and 4–8 dogs flushed pheasants and surveyed all cover within their defined search area and recorded the sex of pheasants as they were flushed. Observers noted where flushed birds landed to ensure birds were not double counted. Between 2013–2016, 1,160 flushing and sex identification events occurred.

We used logistic regression with a binomial distribution to estimate the probability of flushing a female pheasant (Bates et al. 2015). To investigate if the probability of flushing a female was influenced by year and to account for heterogeneity among WPRAs, we considered 3 candidate models including: an intercept model with year as a random effect, a model including year as a predictor variable and WPRA as a random effect, and a model with both year and WPRA as random effects. We estimated the female:male ratio as the logit of the estimated probability of flushing a female obtained from the best model.

To estimate female density, we multiplied the estimated male density by the sex ratio (the logit of the probability of flushing a female pheasant):

$$\hat{D}_{females} = \hat{D}_{males} \times \frac{\hat{P}(female)}{1 - \hat{P}(female)}.$$

We used the delta method to estimate standard error for female pheasant density (Williams et al. 2002). We analyzed all data and fit models using Program R (R Core Team 2015) and selected the best model according to Akaike's Information Criterion adjusted for sample size (AIC_c; Akaike 1985, Burnham and Anderson 2002).

RESULTS

We released 2,328 pheasants with 1,902 of those pheasants being female (Table 2-2). The density of released females ranged from 0.85 to 15.12 female pheasants/km^2 at the study areas. For estimating p_A, the best model included an intercept ($\hat{\beta}$ = 0.29 SE = 0.137) and calendar day covariate ($\hat{\beta}$ = −0.23 SE = 0.072) and indicated that crowing frequency declined linearly over time (21 April–23 May; Table 2-3; Figure 2-2). Consequently, we stratified our crowing surveys into 3 periods and estimated the probability a pheasant crowed ($\hat{p}_A$) for the median date of surveys for each period (calendar day 115, 127, and 139). The estimated probability a pheasant crowed during a 3-minute survey period was 0.64 (SE = 0.037) for period 1, 0.56 (SE = 0.034) for period 2, and 0.49 (SE = 0.043) for period 3.

We pooled observer detection data across both WPRAs and years (2010–2013). We estimated the probability an observer was able to detect a pheasant given that it was available to be detected ($\hat{p}_{D|A}$ = 0.41, SE=0.005) at 0.436 km. We estimated the effective area to be 0.60 km^2 (SE = 0.026). The best model for female:male ratio included the intercept and year as a random effect (Table 2-4). We estimated the probability of a flushed bird being female to be 0.505 (SE = 0.024) and a sex ratio of 1.02 (SE = 0.098) female pheasants for every male pheasant.

The female pheasant density increased on the North Gratz study area (Table 2-5) from 2013 ($\hat{D}$ = 0.19) to 2016 ($\hat{D}$ = 0.93) but failed to achieve the density goal. The

North Somerset study area had a higher density estimate in 2013 ($\hat{D}$ = 1.03) than in 2016 ($\hat{D}$ = 0.31). South Somerset also had higher density estimates in 2013 ($\hat{D}$ = 1.06) than 2016 ($\hat{D}$ = 0.35). The North Franklin study area, where no pheasants were introduced, never had pheasants detected during crowing surveys. The South Franklin study area did not have density estimates for 2013, but did have an increasing density from 2014 ($\hat{D}$ = 0.16) to 2016 ($\hat{D}$ = 0.64; Table 2-6). Only one study area, Washingtonville West, achieved and exceeded the female density goal of 3.86 pheasants/km^2 where the highest female density occurred in 2015 ($\hat{D}$ = 4.16) but had a lower density ($\hat{D}$ = 2.85) in 2016.

DISCUSSION

Calling counts may be a cost-effective and simple index to assess bird population trends, but are insufficient to assess success of population restoration efforts where a population density estimate is required. Our method of density estimation incorporated two separate detection probabilities that influenced the number of birds detected during calling counts. Moreover, we simplified the crowing count protocol and only required observers to count the number of individuals heard crowing without estimating distance.

Gates (1966) found crowing frequency to plateau from 25 April to 15 May and we expected to capture the peak of crowing by conducting our crowing counts during this time. We anticipated a quadratic relationship to explain crowing frequency, but our results indicated that we initiated crowing count surveys at or after peak crowing activity by the pheasants in our study. We found the probability of a male pheasant being available for detection (i.e., crowing) decreased linearly over time. Without accounting for the linear decrease, we would have inaccurately estimated the probability of a male pheasant being available for detection, leading to inaccurate density estimates. Farnsworth et al. (2005) presented a model that accounted for the probability of a bird being available for detection during a survey, but an assumption of the model was that the probability of a bird vocalizing was constant throughout the survey period. However, our study did not find a constant crowing frequency and our model allows for a changing probability that a bird is available to be detected. Alternatively, crowing count surveys used as an index of abundance to monitor population trends could be designed to revisit sampling points during the same 1- or 2-week period each year to ensure relatively constant $\hat{p}_A$ over time.

Many methods of conducting point counts for density estimation that incorporate detection probability ($p_{D|A}$) require two observers at all point counts (Nichols et al. 2000, Koneff et al. 2008), observers to measure the distance from the bird when detected (Buckland et al. 2001, Rosenstock et al. 2002), or observers to record the time interval they first detected a bird (Farnsworth et al. 2002). As expected, the farther an observer was from a crowing pheasant the probability of detecting the pheasant decreased. Rather than directly incorporating the probability an observer detected a male pheasant given that it was available to be detected ($\hat{p}_{D|A}$) in our estimator, we used the estimated effective area of detection. Using the effective area of detection makes the density estimator robust to estimating the detection probability at different point-transect halfwidth distances (Thomas et al. 2002) and eliminated the need for arbitrary distance restrictions when counting crowing pheasants. Studies that rely upon observers to accurately estimate the distance to each crowing bird would violate a key assumption of distance sampling (Buckland et al. 2001). Our estimated detection function indicated that detection probability at 0.80 km was small but >0, indicating that we could not assume that we only heard birds within 0.80 km.

Although we were able to estimate detection probability based on distance from the bird, we were unable to account for detection differences among individual observers. Detection differences among observers may result from hearing abilities, sensitivity to specific species' songs, or species favoritism (Farnsworth et al. 2002) and can reduce the precision of the density estimates (Diefenbach et al. 2003). Koneff et al. (2008) reported that detection models including observer effects were favored, but encountered issues obtaining estimates of observer detection rates due to small sample sizes. Our estimation of $p_{D|A}$ involved many observers over multiple years, but not all of the observers who conducted crowing counts were involved with estimating $p_{D|A}$. Therefore, we were not able to incorporate observer-specific detection probabilities into the estimator, although it is likely that there are detection differences for individual crowing count observers. Observer-specific estimates of $p_{D|A}$, however, could be readily incorporated into the estimator.

Gates and Hale (1974) reported that the sex ratio during the breeding season could be accurately estimated from a winter (December–March) field count, as we did with our flushing surveys. We found the sex ratio to be nearly 1:1 despite the sex ratio of released translocated birds being 4.46:1 female to male pheasants. The change in sex ratio likely is the result of both differential survival between sexes throughout the year and the fact that our wild pheasant population does not have any hunting pressure. Gates and Hale (1974) reported female survival to be correlated with winter weather conditions, while winter weather did not greatly influence male survival. Other populations without hunting pressure reported similar sex ratios to our results (Allen 1938, Shick 1947). Therefore, despite a greater proportion of females released on the study areas, differential survival and no hunting pressure could explain the sex ratio becoming equal over a short period of time.

We estimated p_A and $p_{D|A}$ using the wild, translocated birds that were part of the released population. Because p_A can vary due to timing of crowing counts and $p_{D|A}$ could vary among observers, detection probabilities will likely differ for other monitoring programs. We do not recommend use of our estimates of p_A and $p_{D|A}$ in other studies. Use of the estimator we developed could apply similar methods for estimating these detection probabilities specific to a study's population to obtain density estimates.

Only one of our study areas reached the female pheasant density goal of 3.86 females/km^2 and appeared to achieve a self-sustaining pheasant population. All other study areas failed to reach female densities greater than 2 females/km^2. The WPRAs represent some of the best available pheasant habitat in Pennsylvania, but despite this, most study areas (11 of 12), seemed to have inadequate recruitment despite no hunting. It does seem to be possible to have a self-sustaining pheasant population in parts of the state, but the areas that seem able to support a population appear to be very limited and may not be suitable to meet the overall goal of the Pennsylvania Game Commission. Although two of the study areas failed to reach the density goal, densities on the areas increased from 2013 to 2016 and continued monitoring over time would provide information to determine if those populations reach the density goal given enough time.

MANAGEMENT IMPLICATIONS

By estimating density instead of using indices of abundance to monitor the populations, we adjusted for changing detection probabilities, such as the probability a male pheasant crowed throughout the season, and avoided violating the assumption that the proportion of individuals detected is constant. The estimator we developed could be used in instances where an index of abundance is inadequate for assessing a population, such as reintroduction and restoration efforts. Also, incorporating our estimate of the effective area of detection allowed us to simplify the crowing count procedure by not requiring observers to estimate distance to a detected bird or record in which time period the bird was detected, which thereby eliminated some assumptions of other methods. Our density estimator did not include variation in detection probabilities among observers and adaptations of this estimator could account for this detection probability to reduce sampling variance and possibly improve density estimates. One study area achieved a wild, sustainable pheasant population for hunting, but assessment of the available habitat and how the habitat can be improved is required to expand on areas that can maintain pheasants.

ACKNOWLEDGMENTS

Support for this research was provided by the Pennsylvania Game Commission. We thank J. L. Laake for the R code to estimate the effective area of detection of crowing pheasants. We thank volunteers who assisted with monitoring efforts and all landowners who have participated in the project by maintaining pheasant habitat and allowing permission for the access and research on their property. We would also like to thank all Pheasants Forever and Pennsylvania Game Commission staff who assisted with the project over the years.

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Figure 2-1. The locations of wild pheasant recovery areas (WPRAs) and county outlines in Pennsylvania, 2013–2016.

Figure 2-2. Raw probability that a pheasant equipped with a radiotransmitter ($n = 21$) crowed during a 3-minute survey period based on calendar day plotted with the line of best fit, Pennsylvania, 2014–2015.

Table 2-1. Number of survey points at which crowing counts were conducted and the size of the wild pheasant recovery areas (WPRAs), Pennsylvania, 2013–2016.

WPRA	Number of survey points				Area (km^2)
Study area	2013	2014	2015	2016	
Central Susquehanna	128	133	133	213	511.6
Greenwood Valley	20	20	20	29	66.0
Pennsylvania Power & Light	24	24	24	48	80.9
Turbotville North	30	30	30	40	78.9
Washingtonville South	24	29	29	41	90.9
Washingtonville West	30	30	30	55	80.2
Hegins-Gratz	60	60	60	80	255.8
Hegins	20	20	20	30	62.2
North Gratz	20	20	20	25	40.5
South Gratz	20	20	20	25	42.1
Somerset	31	31	31	35	69.2
North Somerset	20	20	20	23	51.3
South Somerset	11	11	11	12	17.8
Franklin	34	34	34	45	339.9
North Franklin	15	15	15	15	35.8
South Franklin	19	19	19	30	55.7

Table 2-2. Year of initial reintroduction, cumulative number of translocated ring-necked pheasants (only females are reported), and resulting densities (female pheasants/km^2) of released pheasants on wild pheasant recovery areas (WPRAs) and study areas within each WPRA. No pheasants were released at the Washingtonville South or North Franklin study areas. Densities represent the number of released female pheasants over a study area and are not adjusted for detection probabilities, Pennsylvania, 2007–2014.

				2010		2014	
WPRA Study area	Year of first release	Number released in the first year	Density	Cumulative number released	Density	Cumulative number released	Density
Central Susquehanna	2007	249	0.49	733	1.43	733	1.43
Greenwood Valley	2007	52	0.79	115	1.74	115	1.74
Pennsylvania Power & Light	2007	57	0.70	303	3.75	303	3.75
Turbotville North	2007	68	0.86	144	1.83	144	1.83
Washingtonville West	2007	72	0.90	171	2.13	171	2.13
Hegins-Gratz	2011	276	1.08			276	1.08
Hegins	2011	152	2.44			152	2.44
North Gratz	2011	60	1.48			60	1.48
South Gratz	2011	64	1.52			64	1.52
Somerset	2009	275	3.97	558	8.06	835	12.07
North Somerset	2009	216	4.21	499	9.72	776	15.12
South Somerset	2009	59	0.85	59	0.85	59	0.85
Franklin	2014	58	1.04			58	1.04
South Franklin	2014	58	1.04			58	1.04

Table 2-3. Model selection for linear mixed effects models (each individual bird was treated as a random effect) estimating the probability that a male pheasant will crow ≥1 time during a 3-minute period ($\hat{P}_A$), Pennsylvania, 2014–2015.

Model	K[a]	ΔAIC_c[b]	-2 × log-likelihood	w_i[c]
Intercept + calendar day	3	0.0	1239.6	0.57
Intercept + calendar day + (calendar day)^2	4	0.6	1238.2	0.43
Intercept only	2	8.5	1250.2	0.01

[a] K = number of parameters.

[b] ΔAIC_c = difference in AIC_c value from the model with the lowest AIC_c value.

[c] AIC_c weight.

Table 2-4. Model selection for the logistic regression models estimating probability that a flushed pheasant was male. Variables in parentheses were included as random effects, Pennsylvania, 2013–2016.

Model variables	K[a]	Δ AIC$_c$[b]	-2 × log-likelihood	w_i[c]
Intercept + (Year)	2	0.0	119.8	0.47
Intercept + Year + (WPRA)	3	0.9	117.8	0.30
Intercept + (WPRA) + (Year)	3	1.5	118.6	0.22

[a] K = number of parameters.

[b] ΔAIC_c = difference in AIC_c value from the model with the lowest AIC_c value.

[c] AIC_c weight.

Table 2-5. Density estimates (female pheasants/km^2) and standard errors for female pheasants in the Somerset and Hegins-Gratz wild pheasant recovery areas, Pennsylvania, 2013–2016.

	Somerset				Hegins-Gratz					
	North Somerset		South Somerset		Hegins		North Gratz		South Gratz	
Year	Density	SE	Density	SE	Density	SE	Density	SE	Density	SE
2013	1.03	0.193	1.06	0.211	0.65	0.147	0.19	0.049	0.29	0.076
2014	1.05	0.230	0.66	0.145	0.55	0.117	0.31	0.074	0.21	0.052
2015	0.63	0.136	0.54	0.140	0.51	0.108	0.54	0.115	0.02	0.008
2016	0.31	0.054	0.35	0.063	0.24	0.049	0.93	0.214	0.18	0.036

Table 2-6. Density estimates (female pheasants/km^2) and standard errors for female pheasants in the Central Susquehanna and Franklin wild pheasant recovery areas, Pennsylvania, 2013–2016.

	Central Susquehanna										Franklin[a]	
	Greenwood Valley		Pennsylvania Power and Light		Turbotville North		Washingtonville South		Washingtonville West		South Franklin	
Year	Density	SE	Density	SE	Density	SE	Density	SE	Density	SE	Density	SE
2013	0.96	0.189	1.32	0.262	0.84	0.168	0.56	0.112	3.75	0.787		
2014	0.78	0.170	0.45	0.104	0.80	0.169	0.39	0.087	4.12	0.869	0.16	0.034
2015	0.03	0.008	1.07	0.231	1.10	0.241	0.50	0.106	4.16	0.893	0.51	0.112
2016	0.14	0.030	0.46	0.087	0.45	0.103	0.24	0.056	2.85	0.602	0.64	0.138

[a] The North Franklin study area had no birds detected during crowing counts in all years.

Figure 2-1.

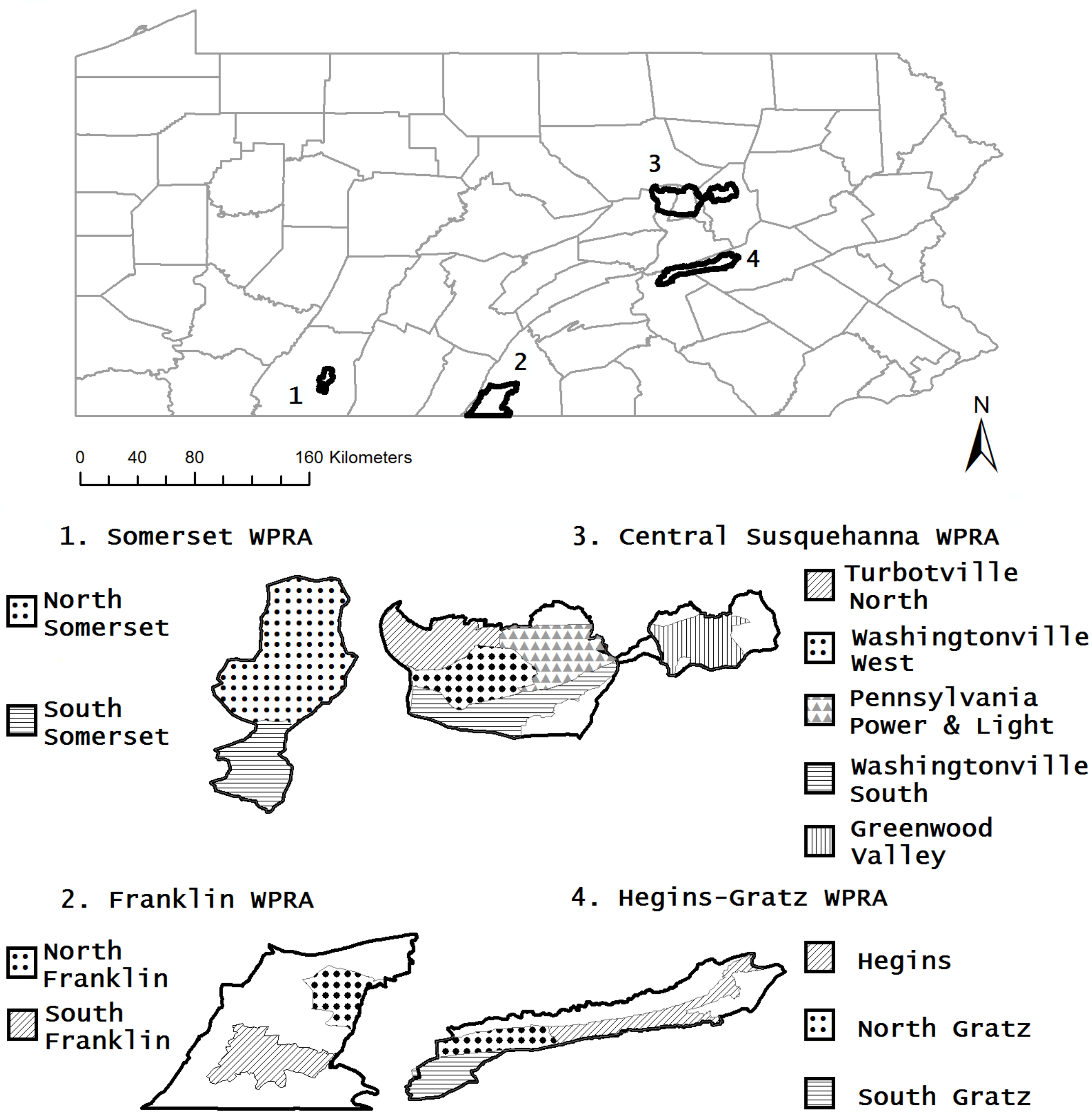
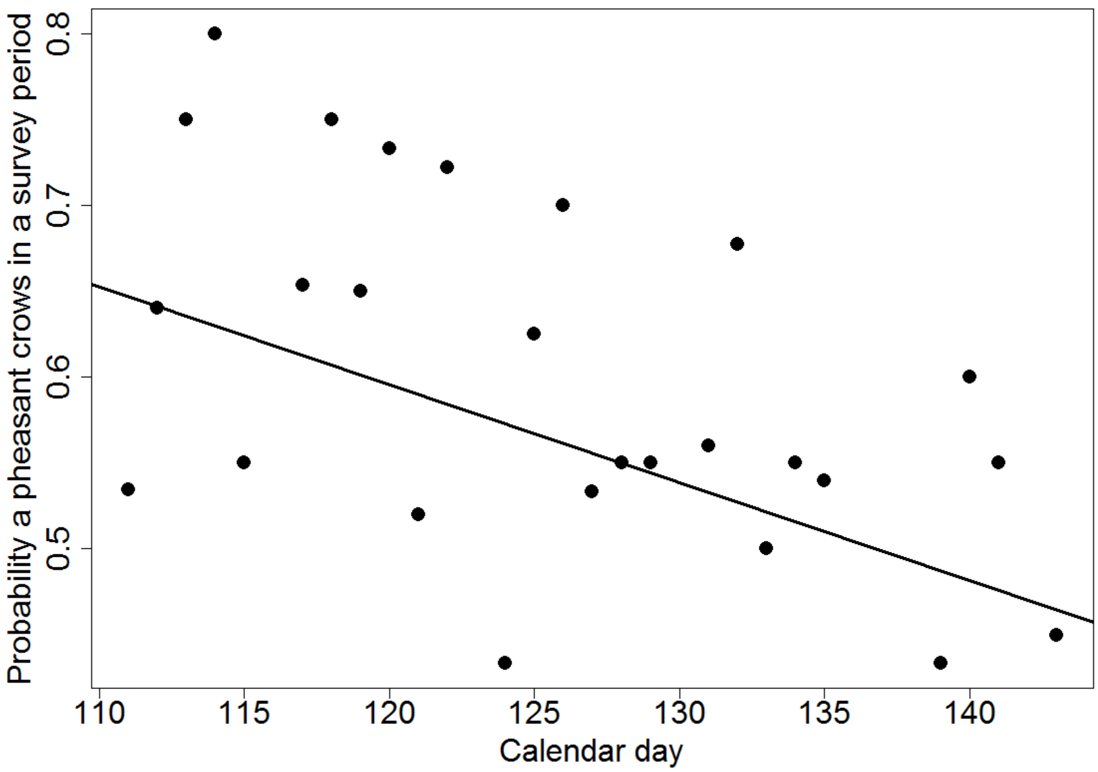

3
4
2
1
N
0 40 80 160 Kilometers
1. Somerset WPRA
North Somerset
South Somerset
3. Central Susquehanna WPRA
Turbotville North
Washingtonville West
Pennsylvania Power & Light
Washingtonville South
Greenwood Valley
2. Franklin WPRA
North Franklin
South Franklin
4. Hegins-Gratz WPRA
Hegins
North Gratz
South Gratz

Figure 2-2.


Probability a pheasant crows in a survey period
0.5
0.6
0.7
0.8
110
115
120
125
130
135
140
Calendar day

Chapter 3

Modeling potential habitat for restoration of ring-necked pheasants

Chapter 3 was written in collaboration Duane R. Diefenbach, Scott R. Klinger, and W. David Walter. I have included this manuscript on the following pages as formatted for The Journal of Wildlife Management.

ABSTRACT Ring-necked pheasant (Phasianus colchicus) are a declining game species in much of the United States. While there has been a large amount of research concerning habitat requirements and use of pheasants in the Midwest and western United States, there has been less research conducted in areas with a more forest-dominated landscape. To restore and maintain a sustainable pheasant population, knowledge of habitat requirements in predominately forested landscapes was needed. We conducted micro-habitat surveys (25 May–11 July) by identifying each individual habitat patch and its vegetation characteristics within a 0.56 km radius survey circle at randomly selected sites where we conducted crowing counts to estimate female pheasant densities. We identified 8 habitat categories *a priori* based on literature review and expert opinion. The proportions of those categories within the survey circle would become the covariates in our predictive habitat model. We found the best model for explaining female pheasant density to include the proportion of idle grass and the proportion of forest within a survey circle. We estimated female density to be positively influenced by the proportion of idle grass (β = 2.612 SE = 0.344) and negatively influenced by the proportion of forest (β = −1.050 SE = 0.317). To check the predictability of our model, we predicted densities using the model and 2015 habitat data and found our model was useful in predicting density but may be under-predicting compared to the actual density estimates. This model offered insight into which habitat characteristics within appropriate pheasant habitat were the most influential for wild pheasants during the breeding season. Using this model, managers may be able to make more informed habitat recommendations based on the existing habitat to meet pheasant density goals.

KEY WORDS habitat modeling, Pennsylvania, *Phasianus colchicus*, pheasant, restoration, ring-necked pheasant

Ring-necked pheasant (*Phasianus colchicus*) use different habitat types depending on the time of year, available habitat, and weather conditions. Wetlands have been found to be crucial habitat for pheasants during the winter for thermal cover (Gates and Hale 1974, Larsen et al. 1994, Gabbert et al. 1999), whereas grasslands are important habitat during spring due to the vegetation they provide for nesting and rearing chicks (Schmitz and Clark 1999). The configuration of available habitat can influence the success of nesting pheasants more than the actual cover type or vegetation (Haensly et al. 1987, Clark and Bogenschutz 1999, Clark et al. 1999). Leif (2005) reported male pheasants chose woody cover and idle herbaceous habitat, but require pastures and crop fields during breeding season to improve their chances of finding a mate.

Although pheasant are a non-native species that has been declining throughout its range in the United States since the 1970s (Labisky 1976, Sauer et al. 2017), the popularity of this game bird throughout the nation has resulted in a large amount of research on habitat use in the Midwest. Much of the research focused on general habitat selection (Gatti et al. 1989, Nielson et al. 2008), survival as influenced by habitat type (Gabbert et al. 1999, Schmitz and Clark 1999, Homan et al. 2000), and reproductive success due to site selection (Clark and Bogenschutz 1999, Clark et al. 1999, Matthews et al. 2012). These studies were done in the Midwest or western part of the country (e.g., Iowa, Minnesota, Nebraska) in study areas with low proportions of wooded habitat (<10%) compared to states in the eastern U.S. Although Pennsylvania was ranked second for the harvest of male pheasants in 1975 (Labisky 1976), there has been less research on the pheasant population in comparison to the Midwest states and it was not included in a study estimating pheasant response to habitat across multiple states (Nielson et al. 2008).

In 1971, the reported average winter density ranged from 15.4 to 30.9 female pheasants/km^2 in pheasant habitat in Pennsylvania (Hartman and Sheffer 1971) but in 1993 pheasant densities ranged from 0.0 to 1.47 birds/km^2 (Hardisky 1993). Pheasant decline has been partially attributed to a loss of habitat and diversity (Taylor et al. 1978, Warner 1984). Changes in farming practices, such as converting prime nesting habitat into crops or using insecticides and herbicides, could decrease survival by reducing cover and reducing the amount of food available (Warner 1984, Dahlgren 1988, Etter et al. 1988). Along with farming practices reducing the amount of habitat available to pheasant, farming operations directly caused nest losses and led to an average mortality of 35% for females (Hartman and Sheffer 1971). Hartman and Sheffer (1971) studied pheasant populations in York (94.1% agricultural and 3.7% forest) and Lebanon (83.9% agricultural and 3.9% forest) Counties that are within the 21,448 km^2 of Pennsylvania considered to be pheasant habitat. A recent study in these counties reported having a lower proportion of agriculture (65%) and a higher proportion of forest (22%; Pabian et al. 2015). This demonstrates how the Pennsylvania landscape has changed with an increase in the proportion of forest and a decrease in the proportion of agriculture since pheasant populations started to decline.

Habitat established by the Conservation Reserve Program has had a positive influence on pheasant abundance (Riley 1995, Haroldson et al. 2006, Nielson et al. 2008).

The Conservation Reserve Enhancement Program (CREP) uses both state and federal funding that is a subset of the federal Conservation Reserve Program with both programs focusing on conversion of private land from agricultural production into conservation practices to improve water quality habitat. These government funded programs help to provide important potential habitat for grassland birds and other wildlife by ensuring that there will be adequate security and thermal cover, while also providing adequate brood-rearing habitat with grasslands. The CREP habitat of warm- and cool-season grasses had a positive influence on pheasant populations but the estimated amount of CREP habitat needed to prevent declines would not be attainable in Pennsylvania (Pabian et al. 2015). Although Pabian et al. (2015) provides information about habitat currently available for pheasants, the study only focuses on the relationship between CREP habitat and pheasants documented at roadside counts but does not provide insight into habitat types used by pheasants.

In an effort to restore a self-sustaining and huntable population of pheasant in Pennsylvania, the Pennsylvania Game Commission translocated wild-trapped pheasants from South Dakota and Montana to designated wild pheasant recovery areas (WPRAs). To gain an understanding of the habitats the translocated pheasants were using, a habitat use analysis on the micro-habitat level was necessary. Our objective was to assess the habitat available on the WPRAs and create a model to predict female pheasant density based on habitat characteristics. We expected greater pheasant densities in areas that had high proportions of agriculture and less-intensively used habitat (e.g., warm- and cool-season grasslands). In areas with higher proportions of forest, we expected to find lower pheasant densities. With this predictive model, we can evaluate what landscape characteristics are required to achieve a self-sustaining population to improve existing habitat conditions on the WPRAs, as well as identify other locations in Pennsylvania where it may be possible to restore wild pheasant populations.

STUDY AREA

Our study area included WPRAs in Pennsylvania that had >40.5 km^2 of potentially suitable breeding and overwintering habitat for pheasants. We monitored pheasant populations in 2–5 study areas within each of the 4 WPRAs: 1) *Central Susquehanna WPRA* was primarily agriculture (54.4%) with forest (16.0%) and developed land (10.6%) (USDA National Agricultural Statistics Service Cropland Data Layer 2015) composing the remaining habitats, 2) *Somerset WPRA* had a similar landscape composition with 61.5% agriculture, 14.1% forested, and 10.7% developed, 3) *Hegins-Gratz WPRA* was 63.8% agriculture, 19.6% forested, and had low development (8.8%), and 4) *Franklin WPRA* was 63.5% agriculture, 13.5% forest, and 12.8% developed land.

The Central Susquehanna WPRA had the highest percentage of land enrolled in CREP (7.1%), while the Hegins-Gratz (3.7%), Somerset (0.9%), and Franklin (0.9%) WPRAs had lower percentages (Farm Service Agency, Washington, D.C., USA). The Somerset WPRA had the largest percentage of wetland and shrub habitat (10.1%), followed by Central Susquehanna WPRA (7.0%), Franklin WPRA (3.7%), and Hegins-Gratz WPRA (1.6%; Table 3-1). The topography of the WPRAs was ridges and valleys ranging in elevation from 106 m to 818 m (U.S. Geological Survey's Center for Earth

Resources Observation and Science 2010). The median frost-free growing days on the WPRAs were 143 at Somerset, 178 at Central Susquehanna, 183 at Hegins-Gratz, and 193 at the Franklin WPRA (National Oceanic and Atmospheric Administration [NOAA] 2017a). The average yearly precipitation for the WPRAs ranged from 104 cm to 117 cm (National Oceanic and Atmospheric Administration [NOAA] 2017b).

METHODS

Pheasant densities

We estimated female pheasant densities (pheasants/km^2) at each survey circle to be the dependent variable in the habitat model for predicting female pheasant density (Chapter 2). Because we conducted habitat surveys after the breeding season, pheasant density estimates for the 2014 breeding season were paired with the habitat data from 2013, 2015 density estimates with 2014 habitat data, and 2016 density estimates with 2015 habitat data.

Habitat variables

We randomly selected survey points for each study area and then moved the independent point to the nearest road. We conducted habitat surveys at these survey points on study areas between 25 May and 11 July, 2013–2015. We collected habitat data within a 0.56 km radius of the survey point (hereafter referred to as survey circle) because 96.9% of birds that observers detected were within 0.56 km of the observer. At this distance, we assumed that if observers detected a bird, then it would be using the habitat within that

0.56 km radius. We used digital aerial photographs from the National Agriculture Imagery Program (USDA 2011) as the baseline imagery to delineate habitat patches. To accurately assess the available habitat, it was necessary to evaluate the habitat annually on a micro-habitat level instead of using aerial imagery. While aerial imagery can be useful for identifying where different habitat types meet and the size of habitat patches, it can be difficult to accurately delineate the actual habitat present and update changes on an annual basis. We defined a habitat patch as an area that differed from the surrounding area in both vegetation and appearance and this was done within each survey circle. To create a layer of habitat at a micro-habitat scale, we assigned all patches a habitat code according to Anderson-level land use and habitat types (Anderson 1976). We digitized the habitat data using ArcGIS® 10.2.2 software (Environmental Systems Research Institute, Redlands, CA, USA).

We documented 37 different micro-habitat types on 386 survey circles across all WPRAs and years. Due to the high number of habitat types in our survey circles, we combined habitat types by land use and biology of pheasants from a literature review and consultations with pheasant biologists. We selected 8 habitat categories *a priori* to condense our 37 possible habitat types that included (Figure 3-1): 1) *developed* – developed and barren areas, 2) *crop* – corn, soybeans, row crops, and grains, 3) *hay* – alfalfa and cool season grass fields used for hay production, 4) *pasture* – fenced in grasses used for grazing, 5) *idle grass* – unmanaged cool and warm season grasses, switchgrass monocultures, old fields, and herbaceous buffers, 6) *shrub* – areas with more than half of the habitat in shrubs <8 m in height, orchards, and hedgerows, 7) *wetlands* –

forested, emergent, and shrub areas that were saturated with water and able to support hydrophytes, and 8) *forest* – areas dominated by deciduous and mixed pine/hardwood trees. We used the proportion of each habitat within the survey circle, the proportion of land enrolled in CREP, and the distance of the centroid of the survey circle to the nearest release of wild pheasants as covariates in the predictive model.

Statistical Analysis

To create a predictive model for female pheasant densities based on habitat type, we used 2 years of micro-habitat data (2013 and 2014) and density estimates (2014 and 2015). Due to some of our estimated densities having a value of zero, we added one to the response variable prior to performing a log transformation. We used generalized linear mixed-effects models with a Gaussian distribution (Bates et al. 2015) to model female pheasant densities based on habitat variables. To account for differences in land use and repeat visits over years, we included study area and the survey circle identification as random effects. We considered 20 candidate models *a priori* (Table 3-2). We used Akaike's Information Criterion adjusted for sample size (AIC_c) to select the best approximating model and the model weight (w_i) to assess the likelihood of the best model given our data (Burnham and Anderson 2002).

To evaluate the predictive ability of the model, we used the parameter estimates and the 2015 habitat data to predict female pheasant densities for comparison against our estimated 2016 female pheasant densities. We used simple linear regression with the predicted densities (calculated using the best model and habitat covariates) as the independent variable and the estimated 2016 densities (estimated using the crowing count data) as the dependent variable. We used the adjusted R^2 value and the parameter estimates to assess the predictive ability of the model. We used Pearson's correlation coefficient to assess how well the estimated and predicted pheasant densities agreed. We conducted all spatial analysis, statistical tests, and model fit using R statistical programming language (R Core Team 2015).

RESULTS

We collected habitat data on 3 WPRAs at 110 survey circles in 2013 and had 6,270 different habitat patches. In 2014, we had 4 WPRAs with 176 survey circles and 10,215 different habitat patches. For both years, the habitat type with the most patches was corn (1,286 patches in 2013 and 1,654 patches in 2014) followed by developed land (925 patches in 2013 and 1,448 patches in 2014) and soybean (655 patches is 2013 and 946 patches in 2014). Corn was the dominant habitat type when looking at the total area within survey circles with 29.2 km^2 in 2013 and 32.3 km^2 in 2014.

Despite having relatively few patches (555 in 2013 and 812 in 2014), deciduous forest was the second most dominant habitat type by area with a total of 22.7 km^2 in 2013 and 28.3 km^2 in 2014. We documented CREP on 55 of 110 survey circles in 2013 and 84 of 176 survey circles in 2014. The maximum number of habitat patches in one survey circle in 2013 was 113 and the minimum was 23. In 2014, the maximum number of habitat patches at one survey circle was 105 and the minimum was 15. Crop was present at 99.1% of the survey circles in 2013 and 98.3% in 2014. Forest was present at 94.5% of survey circles in 2013 and 96.0% in 2014.

The best model for predicting female pheasant density (w_i = 0.84) included the intercept (β = 0.393 SE = 0.113), the proportion of idle grass (β = 2.612 SE = 0.344), and the proportion of forest ($\beta = -1.050$ SE = 0.317). Idle grass had a positive influence and forest had a negative influence on female pheasant densities. The mean proportion of forest (16.7%) and idle grasses (6.8%) observed across all survey circles predicted a female pheasant density of 0.485 pheasants/km^2. We would expect an estimated average 2.6% increase in female pheasant density with a 1% increase in the proportion of idle grasses within the survey circle. Conversely, we estimated a 1% decrease in female pheasant density with a 1% increase in the proportion of forest within the survey circle. The covariates for the distance to release site and the proportions of crop, hay, pasture, wetland, developed, shrub, or CREP were not useful in predicting female pheasant density (Table 3-2). Crop was moderately correlated ($|r|$ = 0.236–0.438) with the categories of developed, pasture, idle grasses, shrub, forest, and CREP.

For 2015, we collected habitat data on 4 WPRAs with 100 survey circles to evaluate the predictive ability of our models. The estimated slope of the regression between predicted and actual densities was 1.609 (SE = 0.249; n = 97, r = 0.548; Figure 3-2), which indicated that the model under-predicted actual density estimates.

DISCUSSION

Although pheasants have been reported to use multiple habitat types throughout the year (Hartman and Sheffer 1971, Hill and Robertson 1988, Smith et al. 1999), we found idle grass and forest to be the best predictors of pheasant densities on our study areas. Pheasants are considered to be an agriculturally dependent species, but we did not find crop to be useful in predicting female pheasant densities. In our models that included crop, the sign of the estimated parameter changed depending on the model. This switching of the parameter sign is expected when variables are correlated, and crop was negatively correlated with forest ($r = -0.438$) and idle grass ($r = -0.367$). However, crop was present at 99.1% of survey circles in 2013 and 98.3% in 2014.

The context in which the model was created and can be applied must be considered when using this model to identify potential pheasant restoration areas and making informed management decisions. The boundaries of the WPRAs had a relatively small proportion of forest, but the WPRAs were located in a landscape of about 60% forest. Given that WPRAs were selected to be areas where predominant land use was agriculture (>50%), our model is applicable only to areas with large proportions of cropland. Therefore, an assumption of our model is that it is most applicable in landscapes that are similar to land use characteristics of the WPRAs.

We conducted crowing surveys for the density estimates during the breeding season, which provides insights into what habitat pheasants are using during this time. Studies in Iowa, Ohio, and South Dakota found that grass was important for pheasant reproduction during the breeding season and our results are consistent with these findings (Schmitz and Clark 1999, Leif 2005, Shipley and Scott 2006). Because our density estimates were obtained during the breeding season, our model reflects the distribution of pheasants only during the breeding season and not at other times of the year. This may explain why we did not find wetlands and shrubs to be useful in predicting pheasant density. Previous research indicates that wetlands and shrub provide important habitat and cover for pheasants during the winter (Gatti et al. 1989, Gabbert et al. 1999, Homan et al. 2000). Smith et al. (1999) reported that shrubs and wetlands were the habitat types used most often during the nesting season, whereas our model suggests that pheasants are not using these habitats during the breeding season.

The proportion of forests in our WPRAs averaged 10.6–19.6%, which was comparable to or greater than studies in the Midwest (Gatti et al. 1989, Perkins et al. 1997, Schmitz and Clark 1999). However, the fact that Pennsylvania is predominantly forested complicates the objectives of having a sustainable, wild pheasant population because we found the proportion of forest had a negative influence on female pheasant densities. Given the amount of forest in Pennsylvania, it would be impossible to create sustainable, wild pheasant populations in many areas of the state.

Federal programs, such as the Conservation Reserve Program, have a positive effect on pheasants by creating critical habitat (Nielson et al. 2008, Matthews et al. 2012, Pabian et al. 2015). In our study, the proportions of idle grass and CREP were highly correlated ($r = 0.751$) and therefore we did not include both in the same model. Although CREP had a positive influence on pheasant densities, it was not included in the top model and was not a better predictor of female pheasant densities than idle grass. A large proportion of habitat we identified as idle grass was land enrolled in CREP (57.6% in 2013 and 40.5% in 2014).

Overall, our model predicted densities that were lower than the estimated pheasant densities, which may lead to more conservative predicted densities. This may be due partly to the large amount of survey circles in which no birds were detected leading to a density estimate of 0 pheasants/km^2. At survey circles used to create the habitat model, 36.0% did not have any birds detected.

MANAGEMENT IMPLICATIONS

Our predictive model can be used to make habitat improvements in attempts to meet desired goals for pheasant densities. In landscapes similar to WPRAs in Pennsylvania (>50% agriculture, <20% forest, <10% developed, and >20% hay), our model can identify the percentage of land needed to be converted to idle grasses to meet pheasant density goals, either through voluntary efforts of landowners or government-funded programs such as CREP. However, our model does not address habitats requirements for pheasants in Pennsylvania at other times of the year, which could be critical to population viability.

ACKNOWLEDGMENTS

Support for this research was provided by the Pennsylvania Game Commission. We thank volunteers who assisted with monitoring efforts and all landowners who have participated in the project by maintaining pheasant habitat and allowing permission for the access and research on their property. We would also like to thank all Pheasants Forever and Pennsylvania Game Commission staff who assisted with the project over the years.

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Figure 3-1. An example of a survey circle (0.56 km radius) with the different habitat patches categorized according to the Anderson-level land use (A; Anderson 1976) and the same survey circle combined using our 8 habitat categories (B).

Figure 3-2. The predicted female pheasant density (female pheasants/km^2) plotted against the estimated female pheasant density (female pheasants/km^2) with the line of best fit (solid) and a one-to-one ratio (dashed).

Table 3-1. Survey circles, size of wild pheasant recovery areas (WPRAs) and study areas, and the average proportion of habitat per survey circle (%). The Conservation Reserve Enhancement Program (CREP; Farm Service Agency, Washington, D.C., USA) habitat proportions were calculated separately and may overlap other categories, Pennsylvania, 2013–2015.

WPRA Study area	Number of survey circles			Area (km^2)									
	2013	2014	2015		Develop	Crop	Hay	Pasture	Idle grass	Shrub	Wetlands	Forest	CREP
Central Susquehanna	55	97	47	511.6									
Greenwood Valley	10	19	9	66.0	11.6	26.8	8.9	7.2	10.7	9.1	2.4	20.8	8.5
Pennsylvania Power & Light	10	16	10	80.9	7.3	35.9	10.1	7.8	9.2	7.1	1.0	18.3	7.6
Turbotville North	11	22	10	78.9	13.9	39.8	7.6	4.5	9.4	6.6	0.5	16.5	4.7
Washingtonville South	5	20	6	90.9	8.8	37.9	9.2	4.0	8.0	5.9	0.5	19.6	7.3
Washingtonville West	19	20	12	80.2	9.5	53.3	10.0	6.4	9.3	3.4	0.1	6.9	7.9
Hegins-Gratz	32	45	23	255.8									
Hegins	12	16	9	62.2	10.3	39.1	9.3	1.8	9.5	2.2	0.1	26.4	6.7
North Gratz	10	15	7	40.5	8.6	55.0	12.0	5.4	2.2	1.5	0.1	14.2	0.6
South Gratz	10	14	7	42.1	7.5	47.2	17.4	7.0	2.8	0.7	0.0	16.1	2.8
Somerset	23	21	16	69.2									
North Somerset	15	14	12	51.3	10.9	33.8	26.6	4.1	2.2	0.9	6.7	13.6	0.7
South Somerset	8	7	4	17.8	10.5	25.7	24.0	4.3	6.2	7.3	6.4	14.8	1.0
Franklin	0	13	14	339.9									
South Franklin	0	13	14	55.7	12.4	35.1	18.7	9.8	5.8	3.3	0.1	13.1	0.4

Table 3-2. Parameters, number of parameters (K), difference in value from the model with the model having the lowest AIC_c value (Δ AIC_c), -2 × log-likelihood, and weights (w_i) for linear mixed effects models estimating female pheasant density (log(Female Density+1) based on micro-habitat variables in Pennsylvania, 2013–2015. Study area and circle identification were included in all models as random effects.

Parameters	*K*	Δ AIC_c	-2 × log-likelihood	w_i
Idle Grass+Forest	6	0.0	435.6	0.84
Idle Grass+Forest+Distance+ $Distance^2$	8	4.57	436.0	0.09
Crop+Idle Grass+Forest+Distance+$Distance^2$	9	6.29	435.5	0.04
Idle Grass	5	7.81	445.5	0.02
Crop+Idle Grass+Distance+$Distance^2$	8	8.13	439.5	0.01
Idle Grass+Distance+$Distance^2$	7	9.89	443.4	0.01
CREP+Forest	6	18.16	453.8	0.00
Crop+CREP+Forest	7	20.89	454.4	0.00
CREP+Forest+Distance+$Distance^2$	8	21.13	452.5	0.00
CREP	5	21.88	459.6	0.00
Crop+CREP+Forest+Distance+$Distance^2$	9	24.10	453.4	0.00
Forest+Distance+$Distance^2$	7	38.61	472.1	0.00
Distance+$Distance^2$	6	41.67	477.3	0.00
Developed	5	41.88	479.6	0.00
Forest	5	46.46	484.2	0.00
Wetland	5	49.32	487.0	0.00
Shrub	5	49.77	487.5	0.00
Pasture	5	52.93	490.6	0.00
Hay	5	52.98	490.7	0.00
Crop	5	54.75	492.4	0.00

Figure 3-1.

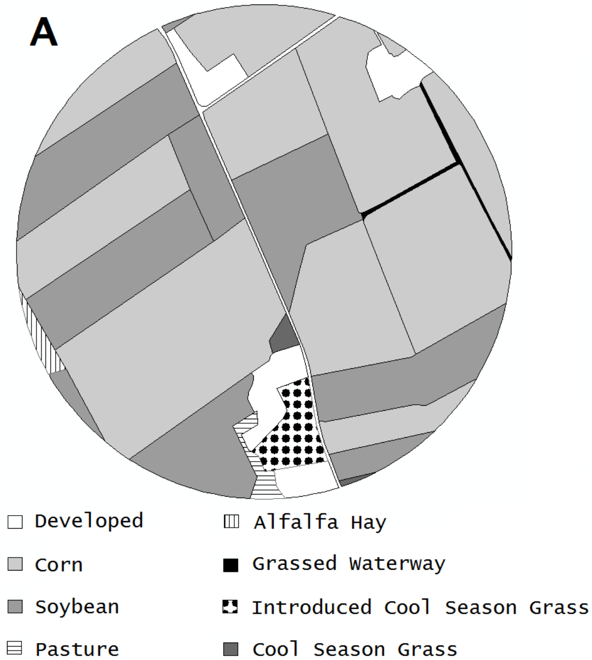
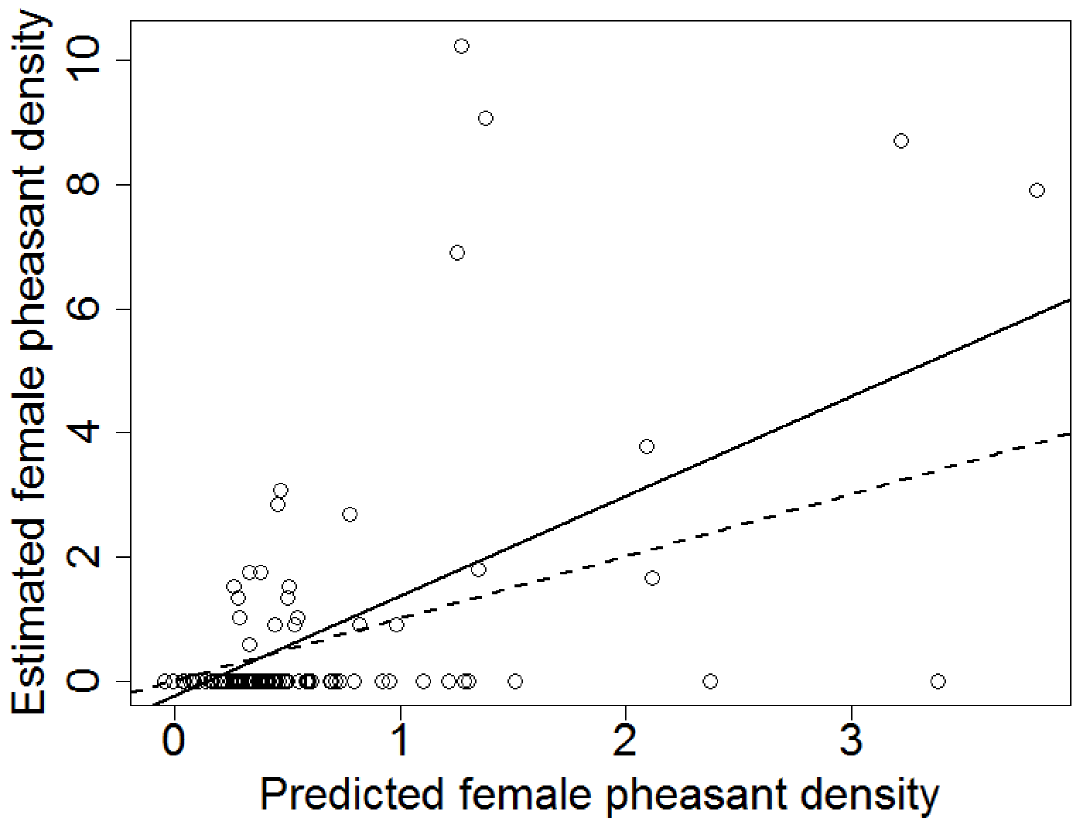

A
B
Developed
Corn
Soybean
Pasture
Alfalfa Hay
Grassed Waterway
Introduced Cool Season Grass
Cool Season Grass
Developed
Crop
Hay
Pasture
Idle Grass

Figure 3-2.


Estimated female pheasant density
0
2
4
6
8
10
0
1
2
3
Predicted female pheasant density

Chapter 4

The future of ring-necked pheasants in Pennsylvania

Overall, the reintroduction of wild pheasants to Pennsylvania was not successful because most study areas (11 of 12) did not reach the pheasant density goal of 3.86 females/km^2. At the only successful study area (Washingtonville West), the expected density (assuming no births, deaths, or movement since release of wild pheasants) based solely on the number of released birds was 2.13 female pheasants/km^2 with the last pheasant release on this study area in 2009. Because we estimated the female density in 2013–2016 to exceed the released density, it appears that reproduction is naturally occurring on the study area and the population is increasing.

Insight into why the Washingtonville West study area had a successful reintroduction can be gained from reviewing the habitat modeling results from Chapter 3. Washingtonville West had the lowest proportion of forest in the survey circles among all study areas, ranging from 4.3% to 9.3% across study years. The average proportion of idle grass in the survey circles from 2013 to 2015 was greater (7.9–10.8%) than some of the other study areas. At the average proportion of forest (6.5%), the model predicted that an average of 14.0% of the habitat in survey circles would need to be idle grass to achieve the density goal. The average proportion of idle grass in survey circles (9.1%) on Washingtonville West in 2015 was similar to what the model predicted (13.0%). Even with the low forest density that is present at Washingtonville West, the predicted proportion of idle grass needed to support the goal density of pheasants is barely sufficient and the amount of idle grass habitat on all study areas is likely the most challenging issue for pheasant population restoration.

No other study areas came close to meeting the expected habitat requirements necessary to reach the density goal and none exceeded a density of 2 female pheasants/km^2. Over all the study areas (including Washingtonville West), the average proportion of forest in survey circles was 16.5% and based on that, the model predicted an average of 18.0% idle grass to meet female pheasant density goals but the average proportion of idle grass in survey circles across all study areas was 7.0%. I believe the lack of idle grass in relation to the amount of forest that was present in these areas helped explain why almost all of the study areas failed to achieve density goals.

Pennsylvania is 65.8% forested (Nowak and Greenfield 2012) which limits the amount of landscape suitable for wild, sustainable pheasant populations due to the negative effect our study found forest to have on pheasant densities. When applying the model to other areas of Pennsylvania, the context in which the model was created is important. The model estimated the most influential habitat characteristics in a landscape that was first identified as being suitable for pheasants by meeting the WPRA criteria (<20% forested, >50% agriculture, <10% developed, and >20% hay). Model results indicated that in landscapes that achieved WPRA criteria, idle grass and forest were the habitat characteristics most influencing pheasant densities. When attempting to identify potential pheasant habitat, areas that meet or exceed WPRA habitat ideally would be prioritized. In these areas, randomly selected sites (as described in Chapter 3) could be used to evaluate habitat conditions. Wildlife managers could then use the habitat model to determine what improvements would be necessary to achieve the habitat needed for desired pheasant density goals. For example, areas with a low proportion of forest are given priority because they are expected to require less idle grass to support pheasants. Also, managers could then identify the amount of idle grass that needed to be created, via personal interest or government assistance programs. Although the Conservation Reserve

Enhancement Program (CREP) did provide idle grass habitat, it was not as good a predictor for pheasant densities as idle grass. Currently, there does not appear to be enough CREP or idle grass habitat to support sustainable pheasant densities in most places of the state. CREP does seem helpful in ensuring there is grassland habitat in Pennsylvania, but it does not appear to provide enough habitat to reverse pheasant declines (Pabian et al. 2015).

Due to the negative effect of forest on pheasant densities, it is probably unrealistic that Pennsylvania will be able to reach pheasant density estimates similar to the peaks in the 1960s and 1970s that many pheasant hunters experienced. This study does not examine the underlying cause of the pheasant decline or how it could be reversed, but it does offer important insight into future management for this iconic species in the Pennsylvania landscape. With proper management, regulation, and monitoring it is possible to maintain wild populations of pheasants in some areas of the state, although it is unlikely these small populations will be able to sustainably provide hunting opportunities to all of Pennsylvania's hunters. Based on Pennsylvania's current landscapes and land use, it is unlikely a sustainable wild pheasant population could be established statewide.

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