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RESEARCH ARTICLE

Population response of eastern wild turkey to removal of wild pigs

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Abstract

There is insufficient understanding of interspecific interactions with the eastern wild turkey (*Meleagris gallopavo silvestris*) and wild pigs (*Sus scrofa*). Wild pigs compete with wild turkeys and predate nests and adults; however, population-level effects on wild turkeys are not clear. Using cameras, we assessed responses of wild turkey populations to wild pig removal in central Alabama, USA, from 2018–2021. We compared wild turkey relative abundance and occupancy on 3 large-scale pig-removal treatment sites (3,407–5,531 ha) relative to a control site (2,510 ha) during 1 pre-treatment year and 2 post-treatment years, with analyses including a covariate expressing the cumulative number of pigs removed from each site standardized by the initial pig abundance on the site. We removed 1,851 wild pigs from the 3 treatment sites over 22 months. Based on N-mixture modeling, when the number of pigs removed was equal to our baseline population estimates (i.e., 100% removal relative to initial population), there were 1.50 (95% CL = 1.01–2.23) times as many wild turkeys, and detection of wild turkeys was 2.01 (95% CL = 1.49–2.70) times as likely. Additionally, poults were 3.49 (95% CL = 1.12–10.89) times as likely to occupy an area when the number of pigs removed was equal to our baseline population estimates compared with poult occupancy at baseline pig abundance. Our data suggests that reduction of wild pig populations may lead to a localized increase in populations of wild turkeys.

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KEYWORDS
camera survey, detection, management, *Meleagris gallopavo*, population, relative abundance, *Sus scrofa*

Wild pigs (*Sus scrofa*) are a well-established invasive species in North America. Wild pigs are native to Eurasia, where they were domesticated for agricultural purposes, and were first brought to the United States in the sixteenth century as free-ranging livestock (Mayer and Brisbin 2009). In the twentieth century, Eurasian boars were introduced when they escaped a hunting preserve in North Carolina and subsequently hybridized with feral domestic pigs (Mayer and Brisbin 2009). For much of the time after their arrival, wild pig populations in the United States were limited to a few areas occurring mostly in the Southeast. Since the mid-1970s, however, the range of wild pigs has expanded. This expansion has been largely facilitated by translocations, which occur because of their popularity as a hunted species (Mayer 2009, Lewis et al. 2019). This recent range expansion has brought attention to a number of negative economic, anthropogenic, and ecosystem effects that wild pigs can have in their nonnative range (Pimental 2007, McDonough et al. 2022). Wild pigs cause $272 million (US $) in annual crop damage across 12 states (McKee et al. 2020) and an additional $40 million lost each year to livestock predation and disease exposure in 13 states (Anderson et al. 2019). While researchers have begun to understand the economic effects of wild pigs in the United States, this is only a portion of the damages that wild pigs cause, as it is likely that they influence the ecosystems they invade (Bengsen et al. 2017, Beasley et al. 2018, McDonough et al. 2022).

Wild pigs, being generalist omnivores and efficient foragers (Ditchkoff and Mayer 2009), can successfully compete with native species in the ecosystems they invade, such as the eastern wild turkey (*Meleagris gallopavo silvestris*; McDonough et al. 2022). Wild pigs and eastern wild turkeys (i.e., turkey) have dietary overlap for hard mast such as acorns (Scott 1973, Barnett and Barnett 2008, Elston and Hewitt 2010, Fay et al. 2023). Acorns are a pulse resource that is limited spatially and temporally (Ostfeld and Keesing 2000), and are sought after by both species, composing up to 65% of the wild pig diet and 20% of the turkey diet (Dalke et al. 1942, Henry and Conley 1972). Wild pigs compete with turkeys as mast consumers because of dietary overlap and constrained availability of this resource (Elston and Hewitt 2010). This competition is likely to be exacerbated during years of low acorn production (Henry and Conley 1972, Barnett and Barnett 2008).

Though much of the wild pig diet consists of plant matter, the same generalist omnivorous diet that makes wild pigs successful competitors also leads to the consumption of animal matter as a protein source, and this occurs at a greater rate in their invasive range than their native range (Wilcox and Van Vuren 2009, Ballari and Barrios-García 2014). Although most animal matter consumed by wild pigs is composed of insects, herpetofauna, and small mammals (Wilcox and Van Vuren 2009, McDonough et al. 2022), wild pigs also behave as predators of nests and individuals of all age classes of turkeys (Miller and Leopold 1992, Ditchkoff and Mayer 2009, McDonough et al. 2022). Eggs of ground-nesting birds are particularly susceptible to predation by wild pigs. For example, the probability of an artificial turkey nest being depredated by wild pigs was 29% (Sanders et al. 2020*b*) similar to the predation rate on Rio Grande turkey (*Meleagris gallopavo intermedia*) nests (Dreibelbis et al. 2008) in 2006, though in 2007 there was a predation rate of around 9%.

Although wild pigs negatively affect turkeys, the cumulative effect of these influences on turkey relative abundance and other population parameters is poorly understood. Given that turkeys are declining in some areas of the southeastern United States (Byrne et al. 2015, Chamberlain et al. 2022), a region with high densities of wild pigs, information on effects of wild pigs on turkey populations could provide insight into the dynamic of the turkey decline in the states where these species co-occur. The goal of this study was to assess the effects of wild pigs on turkey populations using camera surveys to compare population metrics of turkeys before and after intensive wild pig removals and relative to a control site that had no wild pig removals during the study. Following wild pig removals, we expected relative abundance of turkeys of all sex and age classes to increase on treatment sites.

STUDY AREA

We conducted the study from July of 2018 until March of 2021 on 4 privately owned sites in the upper coastal plains region of Alabama, USA, ranging from 2,510–5,531 ha in size. For the purposes of this study, we defined spring as February-April, summer as May-August, fall as September-November, and winter as December-January. The topography of the region was characterized by rolling upland hills intersected by lowland drainages with elevation ranging from 80-200 m above sea level. The region consisted of sandy soil intermixed with ferrous clay in the higher elevations (De Steven and Toner 2004). Forests in the upper coastal plains were dominated by loblolly (*Pinus taeda*) and longleaf (*Pinus palustris*) pine in the uplands intermixed with lowland hardwood and mixed forests (De Steven and Toner 2004). This region averaged 131 cm of annual rainfall and had an average annual temperature of 19°C (Cope et al. 1962, Outcalt and Brockway 2010).

Following a before-after control-impact (BACI) design (Stewart-Oaten et al. 1986), 1 of the 4 sites remained as a control, where we did not remove wild pigs during the study. On the remaining 3 sites, we conducted the treatment of wild pig removals after 1 year of baseline data collection. Treatment site 1 was a 3,407-ha plantation that was the most forested treatment site; 61% of the site was either hardwood (20.1%), pine (17.5%), or mixed pine-hardwood forest (23.3%). Water on this site was isolated to ponds, a creek, and a large wetland that made up 30.9% of the treatment site. Treatment site 2 was a 4515-ha plantation that was 59.5% forested with interspersed wetlands that totaled 15.9% of the site. Of the forested areas, hardwood bottoms were the predominant forest type (31.9%), followed by pine (15.6%), and mixed pine-hardwood forests (12%). Treatment site 3 was the largest of the sites at 5,531 ha and was the least forested with total forest cover of only 45.2%. Most of the forest was pine (23.5%), followed by mixed pine-hardwood (11.3%), and hardwood (10.5%). This site also had a large proportion of early successional vegetation (19.5%) and cultivated fields (18.5%). The control site was 2,510 ha and was 59.5% forested (32.4% hardwood, 10.8% pine, and 16.3% mixed pine-hardwood), and approximately 14% of the site was composed of early successional unforested cover types and 14% of the site was wetlands (Dewitz and U.S. Geological Survey 2021).

The study sites were privately owned and managed primarily for game species such as white-tailed deer (*Odocoileus virginianus*), turkey, and northern bobwhite (*Colinus virginiana*), and for pine timber production. We selected the study sites based on their well-established wild pig populations with densities near 9 pigs/km^2, the average in the Southeast (Mayer et al. 2020). All 4 properties had active control programs for wild pigs; however, they consisted primarily of opportunistic shooting and a few permanently placed traps in areas that were historically occupied by pigs.

METHODS

Camera surveys

We used camera surveys to assess turkey and wild pig populations, conducting surveys for 1 year prior to the beginning of wild pig removals, and for 2 years during removals. For turkeys, we conducted camera surveys for 7 days during summer (in Jul and Aug) from 2018–2020 to maximize poult detection. We again conducted camera surveys for 7 days during spring (in Feb and Mar) from 2019–2021 to measure the population prior to the spring hunting season. While a 7-day survey may not encapsulate real time changes of turkey detection and relative abundance, the surveys being conducted twice a year on 4 different sites would allow us to account for spatio-temporal variation related to the sampling window. The survey design consisted of establishing a 1-km^2 grid over each study site using the fishnet tool in ArcMap™ (Esri, Redlands, CA, USA) and placing a camera within a 100-m buffer zone around the center of each grid cell, with camera station locations constant throughout the study. Grids were sized at 1 km^2 to reflect the home range of turkey broods at the time of summer surveys (Healy 1992).

Summer surveys consisted of surveying every grid cell that fell at minimum 75% within the study area. During the summer surveys, we placed 29 cameras on treatment site 1, 39 cameras on treatment site 2, 47 cameras on treatment site 3, and 20 cameras on the control site. We conducted spring surveys using a random subset of 20 of the grid cells selected at the beginning of the study. We placed 11.3 kg of cracked corn for bait at each camera location 7 days prior to cameras being deployed, then repeated the baiting 3–4 days later. After 7 days of baiting, we set up a camera (Reconyx™ PC800 Hyperfire Professional IR Cameras, Reconyx, Holmen, WI, USA) with 11.3 kg of bait, and repeated the baiting cycle until the end of the 7-day survey period. We used this bait cycle to maintain bait in front of the camera for the duration of the survey. We set cameras on trees at a height of 1 m, faced them north or south to minimize overexposure at sunrise and sunset, and placed bait 4 m in front of the camera. We programmed cameras to take a time-lapse image on a 4-minute interval, and to also take motion-triggered images in sets of 3, each with a delay of 2 seconds apart with a 1-minute rest period where the camera could not be triggered. We removed the cameras from bait sites 7 days after they were deployed.

We used additional camera surveys in April 2019 to assess the initial population of wild pigs prior to removals. We determined the location of the cameras by overlaying a grid with 1-km^2 cells over the sites in the same manner as the turkey surveys. From this, we sampled grid cells, which were at minimum 50% in the study area. We used this inclusion criteria to allow us to sample a greater proportion of the site to identify pigs that may have home ranges that overlap with the borders of our study sites. We then selected areas with the most pig sign in each grid cell for the camera location according to Holtfreter et al. (2008). Each camera location received 4 bait iterations of 11.3 kg of whole kernel corn every 3–4 days. The first 2 bait iterations of whole kernel corn began 7 days prior to camera deployment to habituate pigs to feeding at the location. After 7 days, we placed a Reconyx™ PC800 Hyperfire Professional IR Camera on the camera location and the baiting cycle was repeated for 2 more bait iterations. We used this bait schedule to allow for persistence of bait on the ground and continual feeding opportunities for wild pigs. We used bait consistently throughout the baseline and subsequent surveys on the treatment and control sites to mitigate confounding effects of baiting. We programmed the cameras to take a time-lapse image every 4 minutes and 3 consecutive images at the detection of motion and a minimum of 30 seconds between motion triggers. We used these settings to allow personnel who reviewed the images to gather more information to better identify individuals and groups.

Wild pig removal

We began wild pig removals in May 2019 and ended removal efforts in March 2021, following completion of the last turkey survey. We removed wild pigs primarily by trapping and euthanasia, given its efficiency and effectiveness (Garcelon et al. 2005), with additional removals accomplished with aerial operations, which consisted of lethal removal using a helicopter. We used corral-style traps with guillotine style doors and a combination of animal-activated and manual trigger mechanisms to capture wild pigs. We built traps in areas where wild pig sign was present (i.e., rubs, rooting, tracks) or where pigs were observed, either directly by personnel or during a camera survey. Animal-activated traps were constructed similarly to those described in Garcelon et al. (2005) except we employed a wooden guillotine-style door inside a metal frame attached to a trip line, rather than a swing door. We pre-baited traps until the entire sounder was comfortable feeding in the trap, at this point we set the trigger at a height to allow the smaller pigs in the sounder to pass under the trip line without triggering the trap, as these are typically the first to enter a feeding area (Forcardi et al. 2015), allowing us to target the entire sounder. On sites with adequate cellular service, for manual triggers, we used Jager Pro® M.I.N.E.™ trapping systems (Jager Pro®, Fortson, GA, USA), which we triggered when the entire sounder had entered the trap. We also employed aerial operations to shoot pigs 3 times on treatment site 1, 5 times on treatment site 2, and twice on treatment site 3. Aerial operations occurred between November to March when the leaves in the canopy had fallen. All aerial operations were performed by United States Department of Agriculture Animal and Plant Health Inspection Service

Wildlife Services trained employees and pilots. We conducted aerial operations at varying efforts at each of our treatment sites because of weather constraints and availability of the helicopter.

Image classification and statistical analysis

Using the program TimeLapse2 V2.2.3.9 (University of Calgary, Calgary, Canada), we used physical characteristics to classify all turkeys observed in images into 5 categories: adult male (>1.5 yr old), juvenile male (0.5–1.5 yr old), female (≥0.5 yr old), poult (<0.5 yr old of either sex), and unknown (sex and age indistinguishable because of visual obstruction or distance; Pelham and Dickson 1992). For wild pig surveys, we used sounder size, demographics, and unique individual characteristics to identify each sounder on camera (Gomez-Maldonado et al. 2024) and thereby produced an assumed census of wild pigs on the study areas similarly to Lewis et al. (2022). Detectability of wild pigs was between 0.82–0.9, depending on the age-class (Holtfreter et al. 2008). Therefore, while this assumed census likely had imperfect detection, it would still provide a minimum number of wild pigs on a site.

For turkeys, we binned detections from images into 1-hour bins using the maximum count for each age and sex class from a single image in each hour bin to create an encounter history for each camera in the survey. For example, if there was an image with only males and another with only females within the same hour bin, the total population count would be the sum of the 2 images. We analyzed the male age classes together because of low detections. We used N-mixture models with package unmarked (Fiske and Chandler 2011) in R (version 4.2.1; R Core Team 2023) to assess effects of pig removal and other factors on turkey abundance (Royle 2004). Estimates of absolute abundance using N-mixture models applied to camera data may be of questionable accuracy when detection probabilities are low and heterogeneous among individuals (Barker et al. 2018). Therefore, we treated N-mixture estimates as indices of abundance (i.e., relative abundance). These models can provide useful information on relationships between covariates of interest and changes in relative abundance (Barker et al. 2018), which was our focus.

We first created a global model using year, study site, season (spring or summer), and number of pigs removed as covariates for both detection and relative abundance. Our wild pig removal variable was the number of wild pigs removed on each treatment site that was standardized as the proportion of the number of pigs removed at the time of each survey to the estimated wild pig baseline population numbers prior to removal efforts. This variable could not account for the reproduction and immigration of wild pigs once removals began, but it served as an index of removal success at the time of each turkey survey relative to the number of pigs at the beginning of the study. We did not remove any pigs from the control site during the study; therefore, this variable remained at zero for surveys of the control site for the duration of this study, while each treatment site had an independent index of the number of pigs removed on that site, standardized to the initial population. We treated the model created from spatial and temporal covariates (year, study site, and season) as the null model for both detection and relative abundance portions of the mixture model. We then compared 3 additional models: the null model with the covariate of wild pig removals for detection, the null model with the covariate of wild pig removals for relative abundance, and the universal model, the null model with the addition of the wild pig removal covariate for both the detection and relative abundance portions of the mixture model (Table S1, available in Supporting Information). Based on Akaike's Information Criterion adjusted for small sample sizes (AIC_c; Sugiura 1978), we ranked all models in the model list and considered models that had an AIC_c within 2 from the best model (lowest AIC_c score). We confirmed identifiability of parameters by examining the convergence of the beta estimates at varying levels of K, the upper limit of population size in the maximum likelihood estimation search region (Royle 2004, Kéry 2018). We also compared the distributions of Poisson, negative binomial, and zero-inflated Poisson using AIC_c prior to comparing models within a model set (Ward et al. 2017). We continued with the Poisson distribution, as this distribution performed best while remaining identifiable. We repeated this process for each age and sex class of turkey and for a comprehensive total population model.

Due to the sparsity of detections for poults, we used occupancy modeling (MacKenzie and Nichols 2004, Ward et al. 2017) with package unmarked (Fiske and Chandler 2011) to assess poult occurrence. As the global model used for N-mixture modeling was too complex for the poult occupancy data, we used a bottom-up modeling approach and created models by adding variables to the null model to test for significance of the variable and lack of singularities from our data to create a model set. We then selected the model with the lowest AIC_c score as our top model. We used the same variables to create occupancy models as in the N-mixture models.

RESULTS

We initially estimated 1,270 pigs across the treatment sites: 291 pigs (9 pig/km^2) on treatment site 1, 701 (16 pig/km^2) on treatment site 2, and 278 (6 pig/km^2) on treatment site 3, and 235 (9 pig/km^2) on the control. We removed 1,851 pigs across the treatment sites during 22 months: 657 on treatment site 1, 879 pigs on treatment site 2, and 315 on treatment site 3. The numbers of wild pigs removed on these sites were 2.26, 1.25, and 1.13 times larger, respectively, than the initial population estimates on the treatment sites. Of those pigs removed, 70 pigs on treatment site 1, 298 pigs on treatment site 2, and 78 pigs on treatment site 3 were removed by aerial operations.

In N-mixture modeling, the top models for both detection and relative abundance of turkeys (all age and sex classes combined) included the effect of pig removal. Effects of pig removal on detection were also included in the top model for females (Table 1; Table S1). While the universal model was a competing model for the female age class, this model was not identifiable and therefore we did not consider it further. The effect of pig removal was not included in the top model for male turkeys. Based on the analysis of total turkey detections, turkeys were 2.01 (95% CL = 1.49–2.70) times as likely to be detected when the number of pigs removed was equal to our baseline population estimates (i.e., 100% removal relative to initial population) compared with when none were removed (Figure 1). There were 1.50 (95% CL = 1.01–2.22) times as many turkeys when the number of pigs removed was equal to our baseline population estimates compared with when none were removed (Figure 2). Female turkeys were 4.06 (95% CL = 2.78–5.94) times as likely to be detected when the number of pigs removed was equal to our baseline population estimates compared with when none were removed.

The top occupancy model for poults included effects of site on detection and, for poult occupancy, percent of the initial population of wild pigs that was removed (Table 2; Table S2, available in Supporting Information). Poults

TABLE 1 Beta and standard error (SE) coefficient estimates for detection (*p*; logit scale) and relative abundance (λ; log scale) for the top model of a population of wild turkeys, male wild turkeys, and female wild turkeys from 4 sites in south-central Alabama, USA, using biannual camera surveys beginning in the summer of 2018 until the spring of 2021.

	Total				Male				Female			
Estimate	*p*	SE	λ	SE	*p*	SE	λ	SE	*p*	SE	λ	SE
Intercept	−3.123	0.119	−0.828	0.203	−7.658	0.637	3.205	0.633	−2.826	0.165	−1.229	0.242
Treatment site 1	−0.973	0.252	−0.053	0.362	0.661	0.830	−0.435	0.817	−1.963	0.295	0.438	0.252
Treatment site 2	−0.273	0.151	−0.316	0.231	−0.026	0.167	−0.003	0.147	−0.442	0.186	−0.435	0.283
Treatment site 3	−0.032	0.127	0.350	0.201	1.446	0.316	−1.305	0.304	−0.200	0.167	0.721	0.233
Year 2	−0.748	0.124	0.339	0.181	0.461	0.576	0.376	0.572	−1.188	0.151	0.341	0.204
Year 3	−0.790	0.196	0.605	0.257	0.849	0.567	0.409	0.563	−1.652	0.245	0.687	0.191
Summer	0.351	0.103	−0.437	0.130	−1.349	0.366	1.159	0.371	0.527	0.135	−0.879	0.151
Pig removal	0.696	0.152	0.403	0.203					1.401	0.194		

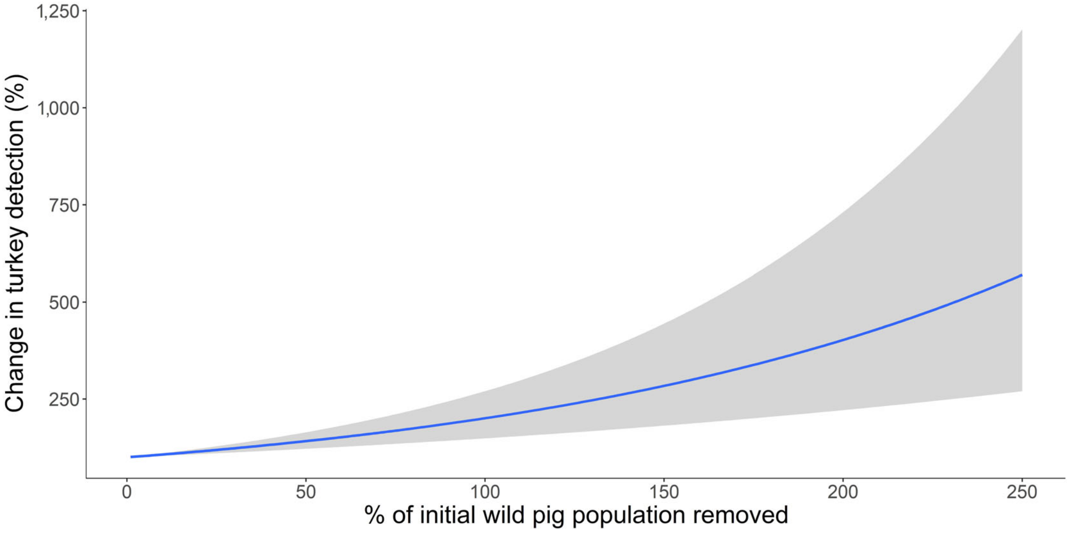

FIGURE 1 Effect size of wild pig removals, expressed as a percent of the initial population estimate that had been removed, on the percent change in detection of wild turkeys of all sex and age classes compared with estimated detection with no wild pig removals on 4 sites in Alabama, USA, 2018–2021.

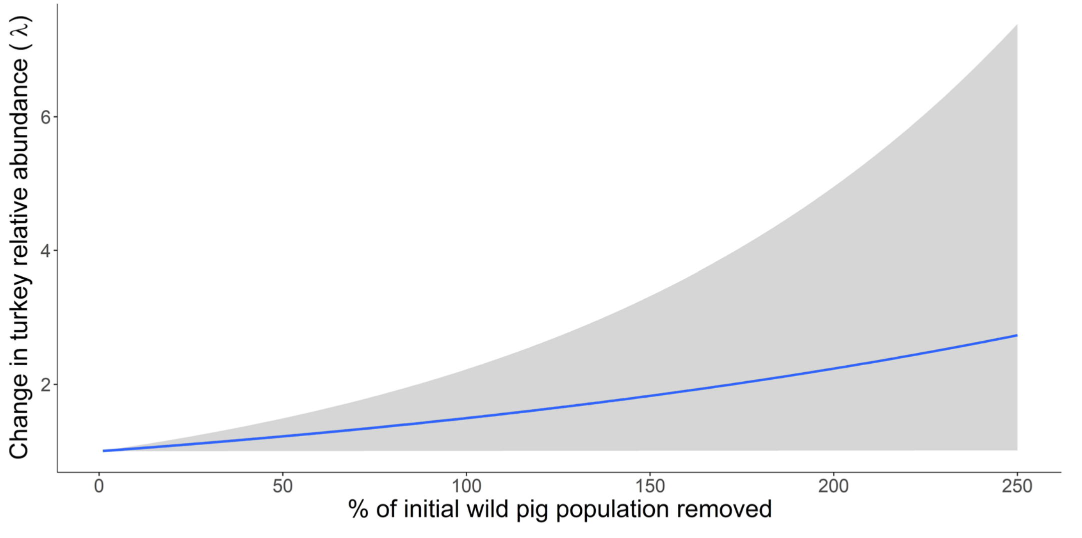

FIGURE 2 The effect size of wild pig removals, expressed as a percent of the initial population estimate that had been removed, on the proportional change in relative abundance (estimated relative abundance turkeys/ estimated relative abundance of turkeys if no pig removals had occurred) of wild turkeys of all sex and age classes on 4 sites in Alabama, USA, 2018–2021.

were 3.49 (95% CL = 1.12–10.89) times as likely to occupy an area when the number of pigs removed was equal to our baseline population estimates compared with when none were removed. We did not observe poults on the treatment sites until the second year after wild pig removals began; we observed poults on the control site during the study where no pigs were removed.

TABLE 2 Beta and standard error (SE) coefficient estimates (logit scale) for the top model for detection (*p*) and occupancy (Ψ) of wild turkey poults from 4 sites in south-central Alabama, USA, using biannual camera surveys beginning in the summer of 2018 until the spring of 2021.

Estimate	*p*	SE	Ψ	SE
Intercept	−1.179	0.233	−5.110	0.834
Treatment site 1	−1.389	0.356		
Treatment site 2	−0.208	0.338		
Treatment site 3	−3.989	1.228		
Pig removal			1.250	0.580

DISCUSSION

The positive relationship between removal of wild pigs and relative abundance of turkeys suggests that wild pigs negatively affect turkeys at a population level. Our results are similar to those reported for the Lord Howe Island woodhen (*Tricholimnas sylvestris*; Miller and Mullette 1985) and the Galapagos rail (*Laterallus spilonotus*; Donlan et al. 2007). These 2 species of ground-dwelling birds experienced similar interspecific effects from wild pigs prior to removals and population recoveries after removals, similar to how turkey populations responded. The populations of woodhens and rails were island populations, whereas our study took place on an open landscape where immigration by wild pigs was possible.

While the relative abundance of the total population of turkeys increased as we removed wild pigs, we did not initially find any indication of an increase in number of poults during the first year after removals began, which would suggest that the increase in the turkey population was a result of emigration rather than reproduction. Previous studies have reported that turkeys select for areas with lesser amounts of predatory pressure, whether that pressure is on adults or nests (Wood et al. 2019, Wakefield et al. 2020). While documentation of predation of adult turkeys by wild pigs is minimal (Miller and Leopold 1992, Ditchkoff and Mayer 2009), if pigs are perceived as a predator, then female turkeys would select for nesting areas with less perceived threat of predation (Fontaine and Martin 2006). The increase in turkeys could also be a result of reduced competition with wild pigs. These species have dietary overlap with pulse resource such as acorns (Dalke et al. 1942, Henry and Conley 1972). While this would not account for the initial increases prior to masting in the first fall after removals, consumption of acorns by wild pigs is significant and removing wild pigs resulted in increased availability of acorns on the treatment sites in subsequent years (Fay et al. 2023).

Poults were not present on camera surveys of the treatment sites until the third year of summer surveys (2 years post-pig removal), likely because the wild pig removals began after the peak of nesting season for turkeys during the first year. Therefore, any effects that pig removals may have had would have come too late in the breeding cycle to have an influence on reproduction until the second year. Most research that has examined effects of wild pigs on reproduction of other species has been focused on reproductive loss, typically in the form of nest depredation, and not an increase in reproduction after the removal of wild pigs (McDonough et al. 2022). Nest depredation by wild pigs is a function of both nest density and wild pig density because wild pigs locate nests through opportunistic feeding rather than searching behaviors (Sanders et al. 2020*a*). When a sounder is removed, there is a period when the home range is unoccupied (Bastille-Rousseau et al. 2021), which would reduce the chance that a pig would come into contact with a nest in that area; however, the relationships we observed could have alternative explanations.

In the models of turkey relative abundance for all sex and age-classes combined, we documented an increase in detection of turkeys at baited sites following wild pig removal. These results are similar to those reported by

Walters and Osborne (2021) and Lewis (2021), who both theorized this relationship to be a function of temporary displacement of turkeys by wild pigs. Temporary displacement by wild pigs has been previously documented in turkeys (Sanders 2017), and other ground-dwelling birds such as the Lord Howe Island woodhen (Miller and Mullette 1985). This phenomenon has also been documented in mammals such as white-tailed deer (Taylor and Hellgren 1997), roe deer (*Capreolus capreolus*; Ferretti et al. 2011), white-lipped peccaries (*Tayassu pecari*; Galetti et al. 2015), and Pampas deer (*Ozotoceros bezoarticus*; Perez Carusi et al. 2017). Displacement of turkeys by wild pigs could influence space and resource use of turkeys, particularly at feeding areas. In white-lipped peccaries, avoidance of wild pigs resulted in feeding being constrained to those times that wild pigs were less active at feeding sites (Galetti et al. 2015). Similar shifts in bait site use by turkeys when wild pigs were removed from a site have been reported (Lewis 2021). We speculate that similar effects could occur with resources that are spatially and temporally limited such as acorns or other masting species of plants, food plots, bait piles, and feeders (Ostfeld and Keesing 2000). In our study, we may have detected increased relative abundance of turkeys because turkeys were responding to our manipulation of wild pig populations by moving into those areas where wild pig populations had been actively managed. Additionally, our observation that poult occupancy increased 2 years following the initiation of pig removal may be due to females selecting those areas for nesting and brood rearing.

There was an increase in detection of female turkeys but not male turkeys following wild pig removals. Females are more susceptible than males to predation because of their solitary behavior during nesting (Speake 1980, Miller and Leopold 1992, Vangilder 1995). Females are most vulnerable to predation when they are isolated during nesting or brood rearing when 95% of mortality occurs (Palmer et al. 1993). Additionally, nesting females experience greater rates of predation than non-breeding females (Miller et al. 1998). Whereas females actively avoid other turkeys during the pre-nesting and nesting seasons, males commonly exist in familial groups or large flocks for most of their life (Watts and Stokes 1971), and flock size is positively associated with group vigilance (Spears et al. 2003, Williams et al. 2003). Therefore, it is not surprising that females, who have a greater predation risk due to nesting, are more susceptible than males to displacement by wild pigs (Sanders 2017, Walters and Osborne 2021).

During our study, we removed more wild pigs than were initially detected prior to our treatment of wild pig removals. This discrepancy likely stems from either reproduction or immigration to our treatment sites from the surrounding properties and is common in removal programs (Kilgo et al. 2023). While we could not account for this by measuring the population over time because of the variance in sampling design of our camera surveys for wild pigs and turkeys, we believe that the standardized variable of wild pig removals accurately captures the degree of effect relative to the control site and the baseline measurements where no pigs were removed.

Turkeys have recently been on the decline in many states within the eastern United States (Byrne et al. 2015, Robinson et al. 2017, Crawford et al. 2021, Bakner et al. 2022, Chamberlain et al. 2022). Causes include loss of nesting and brooding habitat, harvest regulations, nest failure, and nest depredation (Little et al. 2014, Byrne et al. 2015, Robinson et al. 2017, Bakner et al. 2022). While the interspecific interactions between turkeys and wild pigs may not be the sole reason for the recent decline in turkey populations, increases in turkey relative abundance and poult occupancy after wild pig removals suggests that removing wild pigs could benefit declining turkey populations where these species co-occur.

MANAGEMENT IMPLICATIONS

It is unclear what may be influencing an increase in turkeys with the removal of wild pigs. Regardless of the proximate mechanism for increased turkey populations in our study, our data indicate that wild pig control can be an effective tool for land managers looking to increase the population of turkeys on their properties. We suggest that for this to be an effective tool for increasing the local turkey population, using a high-intensity and scientific approach is necessary. Lastly, monitoring areas for new sounders is essential to the success of managing wild pigs to increase turkey numbers, as our removal of more wild pigs than our original estimates likely stemmed from capturing those that immigrated into the area, or were produced by immigrating pigs or those remaining on the property.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

Animal capture, and euthanasia were conducted following the procedures approved by the Auburn University Institutional Animal Care and Use Committee (PRN 2017-3143; PRN 2020-3779).

DATA AVAILABILITY STATEMENT

Data may be available upon reasonable request, as determined by the authors.

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