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# Estimate of herpetofauna depredation by a population of wild pigs

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Herpetofauna populations are decreasing worldwide, and the range of wild pigs (*Sus scrofa*) is expanding. Depredation of threatened reptile and amphibian populations by wild pigs could be substantial. By understanding depredation characteristics and rates, more resources can be directed toward controlling populations of wild pigs coincident with threatened or endangered herpetofauna populations. From April 2005 to March 2006 we used firearms to collect wild pigs ($n = 68$) and examined stomach content for reptiles and amphibians. We found 64 individual reptiles and amphibians, composed of 5 different species, that were consumed by wild pigs during an estimated 254 hours of foraging. Primarily arboreal species (e.g., *Anolis carolinensis*) became more vulnerable to depredation when temperatures were low and they sought thermal shelter. Other species (e.g., *Scaphiopus holbrookii*) that exhibit mass terrestrial migrations during the breeding season also faced increased vulnerability to depredation by wild pigs. Results suggest that wild pigs are opportunistic consumers that can exploit and potentially have a negative impact on species with particular life-history characteristics. DOI: 10.1644/09-MAMM-A-129.1.

Key words: *Anolis carolinensis*, consumption, feral pig, predation, *Scaphiopus holbrookii*, *Sus scrofa*, wild pig



Invasive species compete for resources with native species, decrease biodiversity, and alter trophic interactions in ecosystems (Gibbons et al. 2000; Roemer et al. 2002). One invasive species that is becoming increasingly problematic in North America and other parts of the globe is the wild pig (*Sus scrofa*). Once found primarily in the southeastern United States and a few other states, wild pigs now are believed to inhabit 40 of the 50 states (Gipson et al. 1998; Mayer and Brisbin 1991). Range expansion, which is occurring throughout both the native and introduced portions of the species' global distribution, indicates that the impacts of wild pigs on native ecosystems will increase in coming years.

Wild pigs negatively affect almost all aspects of ecosystem structure and function. Their rooting disturbs soil layers and natural decomposition cycles, which can lead to changes in nutrient cycling (Bratton 1975; Lacki and Lancia 1986). Singer et al. (1984) noted that understory plants in hardwood stands were absent where wild pigs regularly root. Wild pigs also negatively influence other wildlife species by competing for resources, altering habitat structure and quality, and through direct predation (Taylor and Hellgren 1997). Ilse and Hellgren (1995) found that herds of collared peccaries (*Pecari tajacu*) are smaller when high densities of wild pigs inhabit the same area. Similarly, Bratton (1975) found that species richness of small mammal and herpetofaunal communities was reduced due to habitat deterioration where wild pigs forage.

Numerous studies have documented predation of wildlife species by wild pigs (Coblentz and Baber 1987; Oliver and Brisbin 1993; Taylor and Hellgren 1997). Loggins et al. (2002) noted large amounts of intact rodent remains in stomachs of wild pigs, and pigs have been observed hunting and consuming young lambs in Australia (Pavlov and Hone 1982). Wild pigs destroyed up to 28% of northern bobwhite (*Colinus virginianus*) nests in north-central Texas (Tolleson et al. 1993) and were so destructive to ground-nesting birds in New Zealand that local authorities were forced to respond with the use of poison (Merton 1977). In locations where native species already are struggling (e.g., threatened or endangered species), additional pressure by wild pigs can be particularly threatening.

Of particular concern are the impacts that wild pigs have on reptile and amphibian populations, many of which are very susceptible to invasive species (Gibbons et al. 2000). In addition to causing indirect effects through rooting and habitat alteration, wild pigs can affect herpetofauna populations through depredation. Numerous studies have documented wild pigs predating reptiles and amphibians, but the extent of depredation has never been quantified. In Texas wild pigs have been observed preying on the endangered Texas tortoise (*Gopherus berlandieri*—Taylor and Hellgren 1997) and are known to consume the eggs and adults of some reptiles, including the ground iguana (*Cyclura stejnegeri*) in Puerto Rico and the spur-thighed tortoise (*Testudo graeca*) in Sardinia (Oliver and Brisbin 1993). Additionally, Coblentz and Baber (1987) noted that wild pigs consume lava lizards (*Tropidurus jacobii*), green turtles (*Chelonia mydas*), and giant tortoises (*Geochelone elephantopus*) in the Galapagos Islands.

Although these studies have improved our understanding of how wild pigs can affect ecosystems, they are of limited value in predicting effects on populations of herpetofauna because they list species that were consumed without indicating rate of consumption. Because reptiles and amphibians account for a significant portion of threatened and endangered species in many regions, we need accurate estimates of the number of reptiles and amphibians that are consumed by wild pigs. These data could be valuable in developing recovery plans and managing critical herpetofaunal habitat that also is inhabited by wild pigs.

## Materials and Methods

We conducted our research on the Fort Benning Military Installation, which was 73,655 ha in size and located in west-central Georgia and east-central Alabama (32°21′N, 84°58′W). The installation was split by 2 physiographic regions (Peidmont and Upper Coastal Plain), and characterized by level sandy ridge tops and gentle slopes with an average annual rainfall of 124 cm (Dilustro et al. 2002). Forests at Fort Benning were managed primarily for the longleaf pine (*Pinus palustris*) ecosystem, which was driven by the conservation mandate to protect the federally endangered red-cockaded woodpecker (*Picoides borealis*). Therefore, a frequent fire regime was used as a management tool to regenerate longleaf pine and reduce competing understory plants. Pine (*Pinus* spp.) forests dominated ridges and were separated by hardwood bottomlands. Pine forests at Fort Benning were composed of loblolly pine (*Pinus taeda*), longleaf pine, shortleaf pine (*Pinus echinata*), and mixed pine–hardwoods. Oak (*Quercus* spp.)–hickory (*Carya* spp.) forests dominated the low hardwood areas of the installation (Doresky et al. 2001).

We collected wild pigs during all months from April 2005 to March 2006. We drove the extensive road network at Fort Benning until pigs were sighted with a 75-mm Raytheon Palm IR 250 digital thermal camera (10 × 10 × 24 cm; Raytheon Commercial Infrared, Dallas, Texas) mounted on a vehicle window mount with the visual signal routed to a 19-cm television affixed on the dash of the vehicle (Ditchkoff et al. 2005). When wild pigs were identified they were collected with the use of firearms both day and night with the aid of spotlights when needed. However, we collected most after sunset due to the crepuscular/nocturnal activity patterns of wild pigs on the installation. We determined age of pigs (6 weeks to 26+ months) according to Matschke (1967). Once a pig was collected, we removed its stomach contents and froze them in a freezer bag until later analysis. In the laboratory we thawed samples in a warm water bath and separated materials using 2 successive sieves (5.6 and 3.2 mm) to rinse smaller, unidentifiable particles from the sample (Fournier-Chambrillon et al. 1995; Groot-Bruinderink et al. 1994). We thoroughly searched all samples for vertebrate remains, and we preserved all remains in 95% ethanol. We identified all remains to at least genus. Research with live animals followed American Society of Mammalogists guidelines (Gannon et al. 2007) and was approved by the Auburn University Institutional Animal Care and Use Committee (PRN 2003-0531). State of Georgia collection permit number 29-WSF-05-20 was obtained for specimen collection.

We calculated daily consumption estimates for each species in the following way: average number of herpetofauna found in stomach samples multiplied by 6 (food stays in the pig stomach on average for 4 h, or one-sixth of a day—Latymer et al. 1990), divided by 2 (foraging bouts are an estimated 12 h, or one-half of a day—Hanson 2006), and multiplied by the estimated density of wild pigs (pigs/km$^2$). We estimated that each stomach sample represented the last 4 h of foraging before collection on the basis of passage rates of digesta reported for domestic pigs (Latymer et al. 1990). To ensure that estimated rates of consumption were as conservative as possible, we used the longest estimated passage rate from mouth to ileum provided by Latymer et al. (1990). We used data derived from game cameras (Hanson et al. 2008) to estimate mean foraging time for an individual wild pig during a 24-h period. On the basis of the estimated times that wild pigs visited baited camera sites, we judged that wild pigs were active and foraging during an approximately 12-h period each day. We assumed that wild pigs traveling to and from feeding areas would depredate herpetofauna that were encountered. Hanson et al. (2008) estimated the density of wild pigs at Fort Benning to be 6.13 (95% confidence interval [*CI*]: 3.72–10.04) pigs/km$^2$ and the total population to be 3,196 (95% *CI*: 2,739–7,394) during the study. Percentage occurrence of herpetofauna consumption by wild pigs was estimated by dividing the number (×100) of stomachs containing specific herpetofaunal species by the total number of stomachs containing herpetofaunal remains. Percentage frequency of herpetofauna consumption by wild pigs was estimated by dividing the number (×100) of stomachs containing specific herpetofaunal species by the total number of stomach samples collected.

**Table 1.**—Total number of each herpetofaunal species consumed, percent occurrence of each species in stomachs ($n$ = 14) with herpetofaunal remains, percent frequency of all stomachs ($n$ = 68) in which each species was found, and month of consumption of herpetofauna in stomach samples collected from wild pigs on Fort Benning, Georgia, from April 2005 to March 2006.

| Species | $n$ | % Occurrence | % Frequency | Months |
|---|---|---|---|---|
| Eastern spadefoot toad | 52 | 21.4 | 4.4 | April, July, August |
| Green anole | 9 | 57.1 | 11.8 | December, January |
| *Hyla* sp. | 1 | 7.1 | 1.5 | December |
| Red-bellied snake | 1 | 7.1 | 1.5 | July |
| Eastern fence lizard | 1 | 7.1 | 1.5 | December |

To account for seasonal availability we calculated daily consumption rates by using the stomach samples that were collected during the season that a species was likely available. We calculated annual consumption rates by multiplying the daily consumption rate by the number of days contained within the season of availability. We estimated that eastern spadefoot toads (*Scaphiopus holbrookii*) and red-bellied snakes (*Storeria occipitomaculata*) were available from April to October on the basis of their climatological activity preferences (Pearson 1955). Seasonal availability of 3 species—green anole (*Anolis carolinensis*), eastern fence lizard (*Sceloporus undulatus*), and Cope's gray tree frog (*Hyla chrysoscelis*)—was estimated to be from December to March on the basis of low ambient temperatures and the potential increased vulnerability of these species to predation when seeking thermal shelter in litter on the forest floor (Jenssen et al. 1996).

## Results

From April 2005 to March 2006, 68 stomach samples were collected from wild pigs. Sample sizes ranged from 0 to 10 per month. February 2006 was the only month during which no wild pigs were collected. Herpetofauna were present in 20.6% ($n$ = 14) of the samples. A total of 64 individual reptiles and amphibians was identified comprising 5 different species (Table 1). The eastern spadefoot toad was consumed in the greatest quantity and had the 2nd greatest percentage occurrence of consumption by pigs. One individual wild pig consumed 49 eastern spadefoot toads. Additional species found included the green anole, the species consumed most frequently by wild pigs. Green anoles were found individually in stomachs, except in 1 sample that contained 2 anoles. One eastern fence lizard, 1 red-bellied snake, and 1 tree frog, *Hyla*—either Cope's gray tree frog or bird-voiced tree frog (*Hyla avivoca*)—were found in our samples. Percentage frequency of consumption ranged from 1.5% to 11.8% for each species.

Distinct seasonal peaks in herpetofauna consumption by wild pigs occurred in July–August and December–January (Fig. 1) and varied by species. The daily and annual rates of consumption of herpetofauna on Fort Benning were estimated to be 19/km$^2$ and 3,864/km$^2$, respectively (Table 2). Extrapolating these estimates to the entire population of wild pigs at Fort Benning yielded an estimate of 3.16 million herpetofaunal individuals consumed annually. Annual consumption estimates for each species ranged from 26/km$^2$ for the eastern fence lizard and *Hyla* sp. to 3,533/km$^2$ for the spadefoot toad.

## Discussion

The data suggest that a substantial number of herpetofauna are consumed by wild pigs on Fort Benning each year. These data are in sharp contrast to those presented by Wilcox and Van Vuren (2009), who reported that herpetofauna predation by wild pigs in California was uncommon. Although no published data estimate herpetofauna consumption by wild pigs, examination of data from other predator–prey associations suggests that these estimates are not unreasonable. Johnson et al. (1987) reported that 310,000 grasshoppers were consumed in a 30-day period by 76 Swainson's Hawks (*Buteo swainsoni*). Similarly, gulls (*Larus delawarensis* and *Larus californicus*) were estimated to have consumed up to 195,279 juvenile salmonoids (*Oncorhynchus tshawytscha*) behind one dam on the Yakima River, Washington, within a 2-month period (Major et al. 2005). Considering that Fort Benning encompasses 736 km$^2$, it is not unreasonable that an entire population of wild pigs could consume 3.16 million reptiles and amphibians per year. Because estimates of population and subpopulation abundance and dynamics are unavailable for most herpetofauna, it is difficult to estimate the impact that

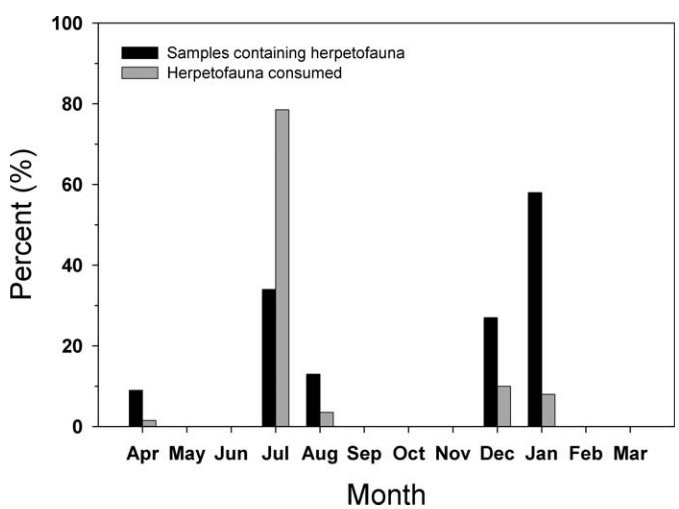


**Fig. 1.**—Percentage of stomachs (samples) that contained herpetofauna and percentage of total herpetofaunal individuals collected (consumed), by month, for wild pigs sampled on Fort Benning, Georgia, from April 2005 to March 2006.

**TABLE 2.**—Estimated daily and annual rates of consumption of herpetofauna (individuals) by wild pigs at 736-km$^2$ Fort Benning, Georgia, from April 2005 to March 2006.

| | Daily consumption | | | | Annual consumption | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Herps/km$^2$ | 95% *CI* | Ft. Benning | 95% *CI* | Herps/km$^2$ | 95% *CI* | Ft. Benning (millions) | 95% *CI* (millions) |
| Spadefoot toad | 16.5 | 10.1–29.9 | 12,162 | 7,426–22,054 | 3,533 | 2,157–6,408 | 2.60 | 1.59–4.72 |
| Green anole | 4.7 | 2.9–8.5 | 3,452 | 2,108–6,260 | 567 | 346–1,029 | 0.42 | 0.26–0.76 |
| *Hyla* sp. | 0.5 | 0.3–0.9 | 384 | 234–696 | 63 | 39–114 | 0.05 | 0.03–0.08 |
| Red-bellied snake | 0.3 | 0.2–0.6 | 234 | 143–424 | 68 | 42–123 | 0.05 | 0.03–0.09 |
| Eastern fence lizard | 0.5 | 0.3–0.9 | 384 | 234–696 | 63 | 39–114 | 0.05 | 0.03–0.08 |
| Total | 18.8 | 11.0–34.0 | 13,803 | 8,350–24,797 | 3,889 | 2,359–7,007 | 3.16 | 1.93–5.74 |

depredation by wild pigs might have on any individual species. However, careful examination of the life-history characteristics of these species can provide some insight.

The green anole is an arboreal species that is common in the southeastern United States, is active year round, and spends most of its time in the foliage and tree canopy where it normally would not be vulnerable to foraging wild pigs (Conant and Collins 1991). However, during cold winter months when temperatures are close to freezing, anoles often seek thermal shelter in decaying logs, bark, and leaf litter. During this period they would be vulnerable to predation by wild pigs. Our data confirm this assumption as all predation of green anoles in this study occurred during December and January. The type of predation we witnessed seems opportunistic and most likely does not affect the population because green anoles typically do not seek shelter in concentrated locations. Therefore it would be unlikely for wild pigs to consume them in a quantity great enough to influence population dynamics.

Predation of the eastern spadefoot toad illustrates how wild pigs could potentially pose a threat to herpetofauna populations. For most of the year the spadefoot toad remains buried to hibernate and avoid desiccation. It emerges from the soil on warm, rainy nights to converge on breeding pools during the spring and summer months in the southeastern United States (Conant and Collins 1991; Pearson 1955). During these breeding periods eastern spadefoot toads can be found concentrated at extremely high densities. It is possible that wild pigs respond to this concentrated food source by focusing their foraging efforts and hunting toads when they are available. We collected an individual wild pig stomach containing 49 eastern spadefoot toads that supports this hypothesis. Before this wild pig was collected it was observed foraging with another wild pig (not collected), where each pig repeatedly made 1-m lunges as if pursuing prey. They appeared to be hunting the toads that were observed in great numbers that night. This selective foraging by wild pigs leads to concerns that they could threaten not only spadefoot toad populations but also other species that exhibit similar life-history characteristics.

Originally we had hypothesized that wild pigs consumed only herpetofauna that were encountered randomly. However, on the basis of our field observation of wild pigs actively searching for eastern spadefoot toads, we hypothesize that wild pigs may focus search patterns for specific prey items when conditions are optimal and rates of encounter are elevated. Wild pigs are known to depredate snake-necked turtles (*Chelodina rugosa*) when the turtles are most vulnerable (Fordham et al. 2006). Species with breeding strategies similar to the eastern spadefoot toad, such as the threatened gopher frog (*Rana capito*), could be affected negatively when wild pigs occupy the same habitat. If a small population of gopher frogs is limited to a few breeding ponds, it may be possible that a local population of wild pigs could consume a significant number of breeding adult frogs when they are most vulnerable.

We originally had hypothesized that herpetofauna consumption by wild pigs would be greatest during the warm season because it is during this period that reptiles and amphibians are normally most active (Conant and Collins 1991). Our data partially supported this hypothesis, as there was a peak in herpetofauna consumption during midsummer. However, a second peak of consumption (17.2% of animals consumed) occurred during December and January, the coldest months of the year in the Southeast. We suspect that temperatures caused some herpetofauna to become more vulnerable to predation by wild pigs for 2 reasons. First, cold weather forces herpetofauna to seek thermal refuge in rock crevices or on the ground in leaf litter and other debris (Bishop and Echternacht 2004; Hasumi et al. 2009). For species such as the green anole, which are often found on branches above the reach of ground-dwelling predators, vulnerability to depredation may increase during these periods. Second, cold weather may cause these normally quick animals to exhibit decreases in physical performance (Lailvaux and Irschick 2007) and be slow to react when they are located by wild pigs. Although an increased number of reptiles and amphibians become more vulnerable to predation by wild pigs at low temperatures, the type of foraging that is occurring during these situations most likely does not substantially affect a population of any particular species of reptile or amphibian.

The combination of actively hunting herpetofauna and large sounders common in wild pig populations (Mayer and Brisbin 1991) could potentially increase the risk to some threatened or endangered herpetofauna. Of particular concern would be those species that are temporarily more vulnerable due to environmental conditions or breeding behavior. Wild pig densities should be monitored regularly and, when eradication is not possible, reduced during periods when threatened herpetofauna populations become most vulnerable. If management resources are limited, even localized exclusion or population reduction may help mitigate the effects of depredation by wild pigs on herpetofaunal populations.

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