

REPRODUCTION AND HERPETOFAUNA DEPREDATION OF FERAL PIGS AT
FORT BENNING, GEORGIA

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REPRODUCTION AND HERPETOFAUNA DEPREDATION OF FERAL PIGS AT
FORT BENNING, GEORGIA

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THESIS ABSTRACT

REPRODUCTION AND HERPETOFAUNA DEPREDAATION OF FERAL PIGS AT
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The continued range expansion of feral pigs (*Sus scrofa*) in North America is an increasing cause for concern due to the numerous negative impacts that feral pigs can have on ecosystem structure and function. Once populations are established, feral pigs have proven to be extremely difficult to control, and close to impossible to eradicate. I examined two aspects of feral pig ecology: reproduction in conjunction with population control, and depredation of herpetofauna by feral pigs.

If effective control and removal techniques are to be developed, it is critical to understand if feral pig populations respond to reductions in density that are associated with removal efforts by increasing reproductive output. I compared reproductive parameters and condition of adult sows that were collected between a control area and a treatment area where lethal removal occurred. From October 2004 to April 2006, we implemented a concentrated removal effort within the treatment area. Although the population density was 50% greater in the control area than the treatment area, I did not

detect differences between areas for condition, litter size, ovarian mass, corpora lutea mass, and corpora lutea number. It is possible that several years of heavy mast production during the study may have negated any affect on condition and subsequent reproduction between the two study areas. These data suggest that reproductive parameters of feral pigs do not exhibit density-dependence during periods when pig populations are in good condition. However populations experiencing nutritional stress may be more reproductively responsive to reductions in density.

With herpetofauna populations decreasing worldwide and the range of feral pigs expanding, the negative effect that feral pigs can have on threatened reptile and amphibian populations due to depredation could be substantial. From April 2005 to March 2006, I collected feral pigs ($n = 68$) with the use of firearms and examined stomach content for reptiles and amphibians. By estimating foraging time based on food passage rate and activity patterns, I was able to characterize daily and annual consumption rates of herpetofauna. I found 64 individual reptiles and amphibians, composed of 6 different species, which were consumed by feral pigs during an estimated 254 hours of foraging. Herpetofauna consumption showed distinct summer and winter peaks. Species (*Anolis carolinensis*) that are primarily arboreal became more vulnerable to depredation when temperatures were low due to their need to seek thermal shelter. Other species (*Scaphiopus holbrooki*) that exhibit explosive breeding behavior coinciding with mass terrestrial migrations also faced increased vulnerability to pig depredation. Results suggest that feral pigs are opportunistic consumers that can exploit and potentially have a negative impact on species that exhibit similar life-history characteristics as those species reported in this study.

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I. REPRODUCTIVE RESPONSE OF A POPULATION OF FERAL PIGS (*SUS SCROFA*) SUBJECTED TO LETHAL CONTROL

ABSTRACT

The continued range expansion of feral pigs (*Sus scrofa*) in North America is an increasing cause for concern due to the numerous negative impacts that feral pigs can have on ecosystem structure and function. Once populations are established, feral pigs have proven to be extremely difficult to control, and close to impossible to eradicate. If effective control and removal techniques are to be developed, it is critical to understand if feral pig populations respond to reductions in density that are associated with removal efforts by increasing reproductive output. This study was designed to examine if reproductive parameters of female wild pigs display a density-dependent response following a concentrated removal effort. I compared reproductive parameters and condition of adult sows that were collected between a control area and a treatment area where lethal removal occurred. From October 2004 to April 2006, we focused a concentrated removal effort within the treatment area. Although the population density was 50% greater in the control area than the treatment area, I did not detect differences between areas for condition, litter size, ovarian mass, corpora lutea mass, and corpora lutea number. It is possible that several years of heavy mast production during the study may have negated any affect on condition and subsequent reproduction between the two

study areas. These data suggest that reproductive parameters of feral pigs do not exhibit density-dependence during periods when pig populations are in good condition. However populations experiencing nutritional stress may be more reproductively responsive to reductions in density.

INTRODUCTION

The feral pig (*Sus scrofa*) is an introduced species in North America that is a source of ecological concern due to the variety of negative impacts that pig populations have on the ecosystem. Feral pigs are known to alter soil chemistry (Singer *et al.* 1984), decrease plant diversity (Singer *et al.* 1984), and directly and indirectly compete with native wildlife for resources (Coblentz and Baber 1987; Mayer and Brisbin 1991). These impacts occur across the current range of feral pigs and, to compound the problem, the range of the feral pig has expanded rapidly in recent years, with populations now present in the majority of the United States (Gipson *et al.* 1998).

After feral pigs become established, one of the reasons they are difficult to control and nearly impossible to eradicate is due to their high rate of reproduction (Dzieciolowski *et al.* 1992). Humans have increased the reproductive capacity of domestic, and subsequent feral pigs, from the less-fecund wild swine that were originally domesticated in Europe (Hagen and Kephart 1980; Mauget 1991; Mayer and Brisbin 1991). Female feral pigs are non-seasonal polytocous species that have recurring estrous cycles approximately every 21 days and are capable of reaching sexual maturity at 5 months (Dzieciolowski *et al.* 1992), a relatively young age compared with other large mammals (Read and Harvey 1989). Mean litter size ranges from 4.8 to 7.5 piglets, but can be as

great as 12 (Henry 1968; Barrett 1978; Sweeney *et al.* 1979; Baber and Coblenz 1987; Taylor *et al.* 1998; Geisert 1999). Adult females are prolific breeders that typically produce 2 litters a year but are capable of producing 3 litters within 14 months (Baber and Coblenz 1987; Dzieciolowski *et al.* 1992).

With feral pigs increasing in range and distribution, the development of population control programs has become more critical to protect native ecosystems. Population control efforts directed at feral pigs can be effective for short time periods (Hone and Pedersen 1980), however early puberty combined with large and frequent litters enables populations to rebound quickly (Dzieciolowski *et al.* 1992). A model based on a New Zealand pig population estimated that a population reduced by 70% will recover to pre-control levels in 2.5 years (Dzieciolowski *et al.* 1992).

As is common in most wildlife species, body condition is positively associated with feral pig reproduction (Warren and Ford 1997). On Santa Catalina Island, California, Baber and Coblenz (1987) found that body condition positively influenced reproduction in feral pigs. They suggested that conception in sows was dependent on attaining a certain threshold of body condition. They also reported that pregnant sows had markedly greater levels of body fat than non-pregnant individuals, suggesting that availability of food resources was a strong influence on reproduction. This association between body condition and reproduction has been found in other mammal species, including the collared peccary (*Tayassu tajacu*; Lochmiller *et al.* 1986), North American elk (*Cervus elaphus*; Stewart *et al.* 2005), black bear (*Ursus americanus*; Roger 1976) feral house mouse (*Mus musculus*; Meikle and Westburg 2001), and feral donkey (*Equus asinus*; Choquenot 1991). When Lochmiller *et al.* (1986) fed confined, female collared

peccaries a low quality diet (6.3% crude protein and 1,921 kcal digestible energy / kg), they documented reduced estrus and pregnancy rates when compared with females fed a high quality diet (15.2% crude protein and 3,300 kcal digestible energy / kg). Body condition can be strongly influenced by population density (Choquenot 1991; Mattioli and Pedone 1995; Stewart *et al.* 2005), and thus changes in population density can ultimately influence reproductive rates in free-ranging animals. Choquenot (1991) found that feral donkeys living at higher densities exhibited poorer physical condition and lower fecundity than donkeys living at low density. Similarly, Singleton *et al.* (2001) found that the feral house mouse, an exotic species to Australia, exhibited an inverse relationship between litter size and population density.

The positive association that has been reported between body condition and reproduction in feral pigs (Matschke 1964; Baber and Coblenz 1987) suggests that feral pigs could respond to control efforts and subsequent reductions in population density by increasing their rate of reproduction. Because no study has attempted to measure whether feral pigs respond to changes in density by increasing reproduction it is imperative that we improve our understanding of this aspect of feral pig ecology so that we understand how population control programs will ultimately affect reproduction. This knowledge may help increase the effectiveness of those programs. My specific objective in this study was to determine if pig reproduction was associated with population density. I predicted that pigs in an experimentally-reduced population would have greater fat reserves and increased rates of fecundity than pigs from a control population.

STUDY AREA

Fort Benning Military Installation 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, the Piedmont and Upper Coastal Plain, and was 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 long-leaf pine (*Pinus palustris*) ecosystem 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 long-leaf pine and reduce understory plants. Sandy ridges were dominated by pine (*Pinus* spp.) forests, and were separated by hardwood bottoms. Pine forests at Fort Benning were composed of loblolly pine (*P. taeda*), longleaf pine, shortleaf pine (*P. echinata*), and mixed pine-hardwoods. Oak/hickory (*Quercus* spp./ *Carya* spp.) forests dominated the low hardwood areas of the installation (Doresky *et al.* 2001).

METHODS

Fort Benning was separated into two areas for the purposes of this study. One area of 50 km² was used as the treatment area (e.g., lethal removal), and the remaining area on the installation, not including a 1 km buffer surrounding the treatment area, served as the control. In the treatment area, feral pigs were collected by a combination of trapping and shooting from August 2004 to May 2006. Traps were spring-loaded box traps (1.2m x 2.4m x 1m) baited with corn. Throughout the study we used 15-20 traps

per night on average for a total of 2600 trap nights, with traps being set on average between 4-5 nights each week. In conjunction with trapping, we also located and collected pigs using a 75mm Raytheon Palm IR 250 digital thermal camera (24 x 10 x 10 cm; Raytheon Commercial Infrared, Dallas, Tex.) attached to 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). Roads throughout the installation were driven until pigs were spotted and collected using firearms aided by spotlight. Collection of pigs in the control area was limited to this technique, as all trapping effort was focused on the treatment area. Fort Benning was managed primarily for military training, however recreational hunting was allowed when it did not interfere with military training. Therefore pig hunting occurred on the majority of the installation throughout the study. Hunting pressure was considered to be comparable between the treatment and control areas.

After collection, all reproductive tracts were removed from sows and frozen until later analysis. Only sows estimated to be 5 months or older according to Matschke (1967) were included in this study because that is the minimum reported pubertal age for feral pigs (Dzieciolowski *et al.* 1992). In the laboratory, reproductive tracts were thawed to room temperature and the ovaries removed. They were then examined for fetuses, and fetus count and sex were recorded. The length of the fetus from the crown of the skull to the base of the tail (crown-rump) were recorded to the nearest 1 mm and were used to estimate time of conception and projected parturition (Henry 1968). Ovaries were weighed to the nearest 0.001 g and examined for corpora lutea (CL). After removal from the ovary, individual CL were weighed to the nearest 0.001 gram. To assess physical condition, kidneys with the attached perirenal fat were removed and frozen in sealed

plastic bags for lab analysis. In the laboratory, kidneys were thawed and the surrounding fat was trimmed perpendicular to the long axis at both ends of the kidney. The kidney with remaining attached fat was then weighed to the 0.01 g. The attached fat was then completely removed from the kidney and the kidney was weighed. The ratio of the weight of the remaining fat to the kidney x 100 was calculated as a kidney fat index (KFI; Riney 1955).

A repeated measure ANOVA (PROC GLM; SAS 1990) was used to compare ovary and CL mass between treatment areas where ovary and CL mass were nested within individual pigs. Litter size, CL number, and KFI were compared between treatment areas with ANOVA. All models were evaluated for normality and homogeneity of variances and transformed with appropriate transformations when deviations were found.

RESULTS

From August 2004 to May 2006 a total of 298 pigs were removed from the installation for research purposes. Of those, 162 (3.24 pigs/km²) pigs were removed from the treatment area and 136 (0.21 pigs/km²) were removed from the control area. Of the 63 sexually mature sows collected, 55% ($n = 35$) were pregnant: 35 of these were collected in the treatment area and 28 were collected in the control area. Mean litter size (*in utero*) for this population was 5.89 and litter size ranged from 3 to 11 pigs (Table 1). Mean ovary mass, CL number, and CL mass of reproductively active pigs were 2.57 g, 7.19 g, and 0.32 g, respectively. Mean litter size, ovary mass, CL number, and CL mass

were greater ($P \leq 0.05$) in sows older than 1 year than in sows younger than 1 year of age (Table 1). There was no difference in KFI between age classes of sows ($P = 0.133$).

Adult sows reproduced throughout the year, with two general peaks of conception and parturition (Fig. 1). The first and most prominent conception peak occurred between February and April. The second peak was broader and encompassed the months of September through January. Parturition followed the same trend, but approximately 114 days later, due to gestation length.

There were no differences in litter size ($P = 0.729$), ovarian mass ($P = 0.528$), KFI ($P = 0.283$) corpora lutea mass ($P = 0.400$) and number ($P = 0.103$) between the treatment and control areas (Table 2). The KFI showed a tri-modal trend with the mode peaks occurring during December 2004, May 2005, and December 2005 (Fig. 2a). The lowest point in the index was during the first three months of the study where the KFI dipped to 14% during September and October 2004. Beginning in November 2004 the KFI increased to 26% and never decreased below 20% for the remainder of the study period.

DISCUSSION

The data did not support our original hypothesis that reproductive output would be greater in feral pigs subjected to intense lethal removal than pigs that were not subjected to a removal program. One possible explanation for this finding is that our sample sizes may have been inadequate to detect statistical difference between the two areas. If reproduction had been greater in the treatment area due to our removal efforts and we were unable to detect the differences due to low statistical power, we would have

expected most or all of the parameters to have shown a trend to be greater in the treatment area. However, this was not the case. Mean values of some parameters (CL mass and CL number) were greater in the treatment area while mean values of the rest were greater in the control area. This lack of a defined trend confirms that our control efforts had little if any effect on reproduction.

The lack of difference in reproductive parameters between the two areas suggests that there was no difference in body condition of pigs between the treatment and control areas. This was confirmed by the KFI data. As demonstrated previously, feral pigs increase reproductive output during times of elevated food availability or when body condition is high (Warren and Ford 1997). In addition, Baber and Coblenz (1987) found that pig reproduction was strongly associated with body fat as measured by KFI. When their population of feral pigs had a mean KFI of 10%, reproduction was relatively low compared to times when the KFI was greater than 10%. The Fort Benning KFI increased to >20% after November 2004, was as high as 42%, and never decreased below 20% throughout the study. If there is a KFI threshold where condition negatively influences reproduction, as suggested by Baber and Coblenz (1987), then it is likely that the Fort Benning population was not nutritionally-restricted for most of the study. The large mast crops that occurred during the time of this study may have confounded our ability to reduce population density to the point that condition changes would influence reproduction. A density-dependent response in reproduction assumes that the higher density population is limited by resources. During the time of this study, the Fort Benning population of feral pigs was in very good condition, as indicated by the high KFI measurements. When examining 4 years of mast (e.g., hard and soft) data from the

installation, the 2004 to 2005 and 2005 to 2006 year crops were 64% and 13% greater than the 4 year average, respectively (Fig. 2b, Jolley, R. L. unpublished data).

Considering the nutritional influence that mast crops can have on condition of wildlife populations (Rogers 1976; Wolff 1996) and the influence that condition has on reproduction in feral pigs (Matschke 1964; Baber and Coblenz 1987), we suspect that the mast crops masked any density-dependent differences that may have been incurred by our removal efforts. If the high density population (control area) had been limited by food resources during the time of the study, the pigs would have exhibited conditional and reproductive differences between the two areas. In a demographic analysis conducted concurrently with this study (Hanson 2006), population density was estimated to be 51% greater in the control area than the treatment area. However, density increased 66% in both areas from 2004 to 2006, regardless of our removal efforts. If the populations were increasing in both areas, then it suggests that either the pigs were not saturated in the control area, or some other factor (e.g. nutrition) was playing a role in increasing the pig population over the entire installation, and our removal efforts had little impact.

Reproductive parameters (e.g., litter size, ovary mass, CL mass, and CL number) of female feral pigs at Fort Benning were similar to data reported for other populations (Henry 1968; Barrett 1978; Sweeney *et al.* 1979; Baber and Coblenz 1987; Taylor *et al.* 1998). Patterns in conception and parturition also mirrored reports for other feral pig populations, where reproduction occurred during all months of the year, but primarily during 2 peaks. It is not surprising that feral pigs in the Southeast would breed year-round because of the moderate seasonal variation in the region and high availability of food throughout the entire year. Conception occurred year round but showed a bi-modal

pattern with conception decreasing between May and August. Although nutrient availability is often considered to be abundant during the warm summer months due to lush vegetation, fewer pigs were conceived during this period. This may stem from the warm temperatures (27-32° C) typically associated with summers at Fort Benning. Heat stress is known to decrease reproductive output of domestic sows (Omtvedt *et al.* 1971) and has been attributed to decreased pig reproduction in South Texas (Taylor *et al.* 1998).

Our efforts at lethal removal were not substantial enough to cause a measurable change in reproduction. This suggests that moderate efforts toward reduction of feral pig populations that would be found in most management scenarios (public and private) will not cause substantial enough changes in pig densities to result in concomitant increases in reproduction. Because most public and private agencies cannot mobilize the resources (logistic or economic) required to sustain a large removal effort, their results will most likely be similar to ours. In addition, confounding effects of fluctuating food availability (e.g., mast production) and resulting body condition changes, as well as the opportunistic manner in which feral pigs are able to utilize available food sources, may serve to ensure that density of feral pig populations are only rarely reduced to the point that density-dependent effects in condition and reproduction can be found. As a result, we expect that most land managers will not witness measurable changes in reproduction of pigs as a result of removal efforts.

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Table 1. Reproductive parameters and condition measurements in 2 age classes of female feral pigs that were collected from Fort Benning, GA from August 2004 to May 2006.

Parameter	Overall			Sows<1 year			Sows>1year			<i>P</i>
	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE	
CL mass (g)	277	0.331	0.007	77	0.285	0.009	200	0.338	0.009	0.130
CL #	37	7.2	0.3	12	6.1	0.2	25	7.7	0.4	0.048
OV mass (g)	58	2.527	0.238	26	1.825	0.186	32	3.097	0.378	0.004
Litter size	38	5.9	0.31	12	4.8	0.25	26	6.4	0.39	0.010
KFI	35	36.89	3.18	15	42.42	5.78	20	32.74	3.31	0.133

Table 2. Reproductive parameters and condition measurements in female feral pigs collected from a population subjected to a lethal removal program and a control population from Fort Benning, GA from August 2004 to May 2006.

Parameter	Control			Treatment			<i>P</i>
	<i>n</i>	\bar{x}	SE	<i>n</i>	\bar{x}	SE	
CL mass	77	0.323	0.031	124	0.338	0.262	0.400
CL #	18	6.6	0.5	19	7.7	0.4	0.103
OV mass	18	3.606	0.664	14	3.173	0.307	0.528
Litter size	17	5.9	0.4	20	5.8	0.4	0.789
KFI	19	40.06	4.88	16	33.12	3.79	0.283

Figure 1. Annual conception and parturition of female feral pigs collected on Fort Benning, GA from August 2004 to May 2006.

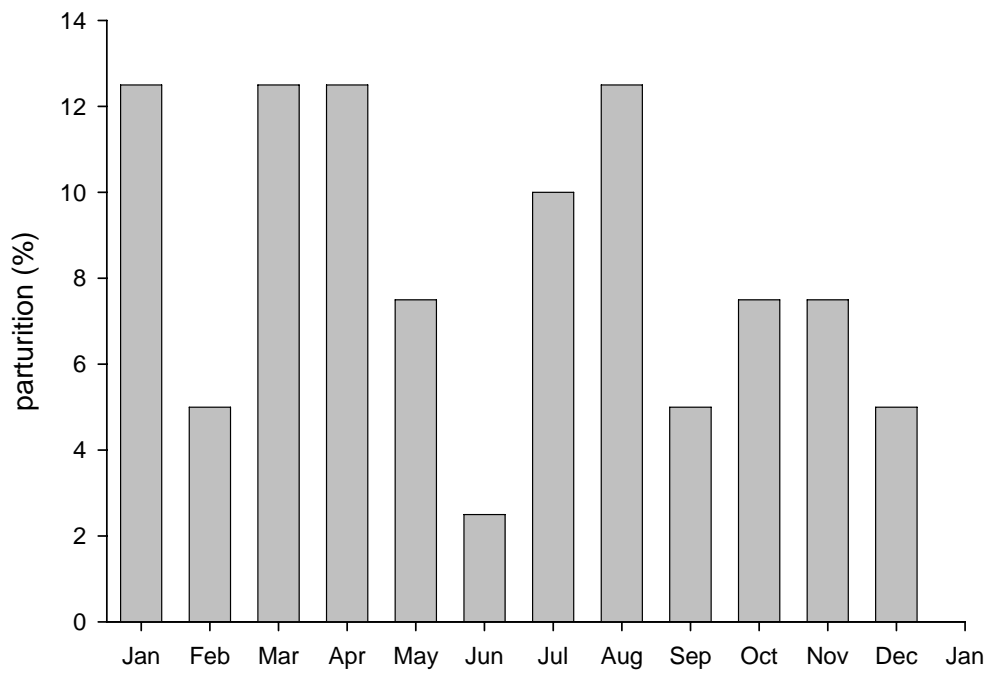
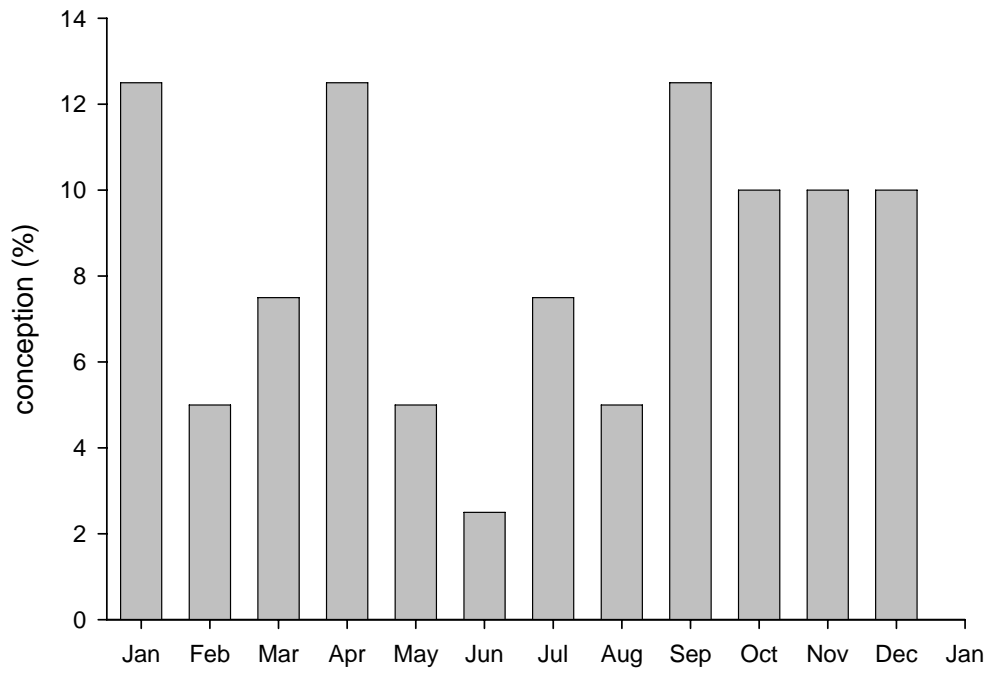


Figure 2. Mean kidney fat index of adult feral pigs removed from Fort Benning, GA from August 2004 to May 2006.

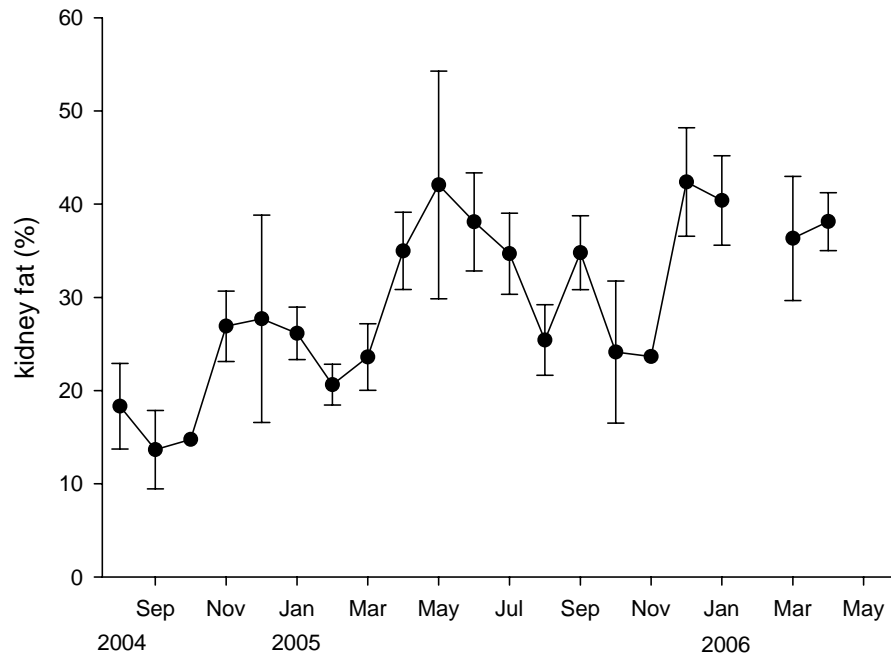
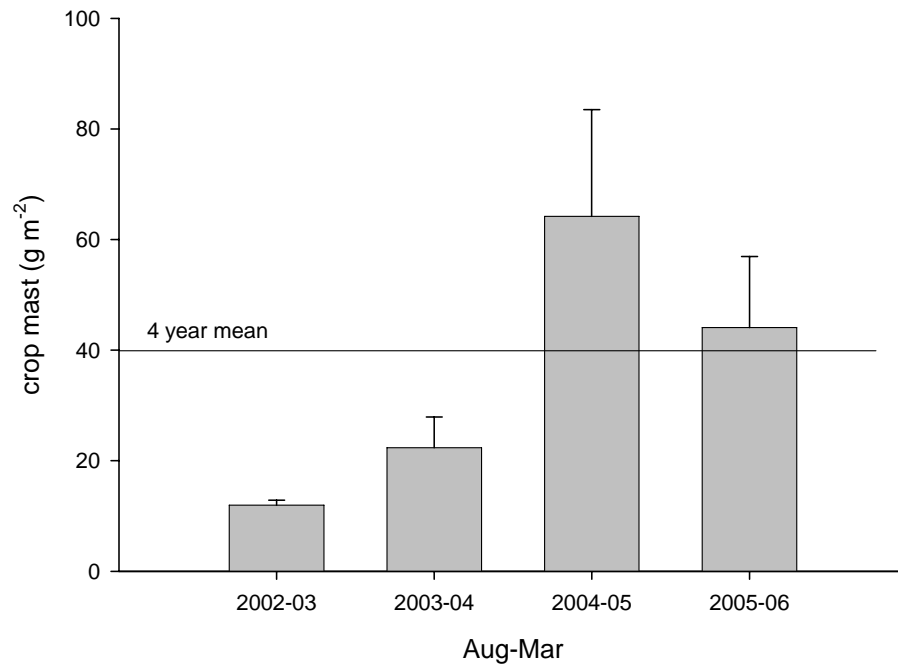


Figure 3. Annual hard and soft mast estimates from 2002 to 2006. (Mast data were obtained from R.L. Jolley and are part of her dissertation which had not been completed at the time of this publication.)



II. AN ESTIMATE OF HERPETOFAUNA DEPREDATION BY A POPULATION OF FERAL PIGS (*SUS SCROFA*)

ABSTRACT

With herpetofauna populations decreasing worldwide and the range of feral pigs (*Sus scrofa*) expanding, the negative effect that feral pigs can have on threatened reptile and amphibian populations due to depredation could be substantial. By understanding depredation characteristics and rates, more resources can be directed towards controlling pig populations that coincide with threatened or endangered herpetofauna populations. From April 2005 to March 2006, I collected feral pigs ($n = 68$) with the use of firearms and examined stomach content for reptiles and amphibians. By estimating foraging time based on food passage rate and activity patterns, I was able to characterize daily and annual consumption rates. I found 64 individual reptiles and amphibians, composed of 5 different species, which were consumed by feral pigs during an estimated 254 hours of foraging. Herpetofauna consumption showed distinct summer and winter peaks. Species (*Anolis carolinensis*) that are primarily arboreal became more vulnerable to depredation when temperatures were low due to their need to seek thermal shelter. Other species (*Scaphiopus holbrooki*) that exhibit explosive breeding behavior coinciding with mass terrestrial migrations also faced increased vulnerability to pig depredation. Results

suggest that feral pigs are opportunistic consumers that can exploit and potentially have a negative impact on species that exhibit similar life-history characteristics as those species reported in this study. These data indicate that more effort should be allocated to reducing feral pig populations that reside in close proximity to threatened herpetofauna populations and habitats.

INTRODUCTION

Proliferation of invasive species poses one of the most significant threats facing ecosystems today. 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 particular invasive species that is becoming increasingly problematic in North America and other parts of the globe is the feral pig (*Sus scrofa*). Once found primarily in the southeastern U.S. and a few other states, they now inhabit 34 of the 50 states (Mayer and Brisbin 1991; Gipson *et al.* 1998). This range expansion, which is occurring throughout their current range, ensures that their impacts on native ecosystems will only increase in coming years.

Feral pigs negatively impact 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 (1984) also noted that understory plants in hardwood stands were absent where pigs regularly root. Although not as visibly apparent, feral pigs also negatively influence other wildlife species by competing for resources, altering habitat structure and quality, and preying upon animals (Taylor and Hellgren 1997). Ilse and Hellgren (1995) found that collared

peccary (*Tayassu tajacu*) herds are smaller when high densities of feral pigs inhabit the same area. Similarly, Bratton et al. (1975) found that small mammal and herpetofauna species richness was reduced in areas where pigs forage due to habitat deterioration.

Numerous studies have documented predation of wildlife species (Merton 1977; Wood and Barrett 1979; Pavlov and Hone 1982; Coblenz and Baber 1987; Oliver and Brisbin 1993; Tolleson *et al.* 1993; Taylor and Hellgren 1997; Loggins *et al.* 2002). Loggins (2002) noted large amounts of intact rodent remains in pig stomachs, and feral pigs have been observed to actively hunt and consume young lambs in Australia (Pavlov and Hone 1982). Pigs destroyed up to 28% of northern bobwhite (*Colinus virginianus*) nests in north-central Texas (Tolleson *et al.* 1993), and pigs were so destructive to ground-nesting birds in New Zealand that they were eradicated by poisoning (Merton 1977). In locations where native species are already struggling (e.g., threatened or endangered species), additional pressure by feral pigs can be particularly threatening.

Of particular concern are the impacts that feral pigs have on reptile and amphibian populations, many of which have proven to be very susceptible to invasive species (Gibbons *et al.* 2000). In addition to indirect effects caused by rooting and habitat alteration, feral pigs possess the potential to negatively influence herpetofauna populations through depredation. Numerous studies have documented feral pigs preying on reptiles and amphibians, but the extent of depredation has never been quantified. In Texas, feral pigs have been observed preying on the endangered Texas tortoise (*Gopherus berlandieri*; Taylor and Hellgren 1997), and feral pigs are known to consume the eggs and adults of some reptiles, including the ground iguana (*Cyclura stejnegeri*) in Puerto Rico as well as the spur-thighed tortoise (*Testudo graeca*) in

Sardinia (Oliver and Brisbin 1993). Additionally, Coblenz and Baber (1987) noted that pigs consume lava lizards (*Trpidurus jacobii*), green turtles (*Chelonia mydas*), and giant tortoises (*Geochelone elephantopus*) in the Galapagos Islands.

While, these studies have improved our understanding of the ecological impacts that feral pigs are capable of, they are of limited value in predicting effects on populations of herpetofauna because they only list species that were consumed without indicating rate of consumption. Considering that reptiles and amphibians account for a significant portion of threatened and endangered species in many regions, it is essential that we have an accurate estimate of the number of reptiles and amphibians that are consumed by feral pigs. These data could be valuable in developing recovery plans and managing critical herpetofauna habitat that is also inhabited by feral pigs. The objectives of this study were to characterize feral pig depredation of herpetofauna on Fort Benning and estimate rates of consumption.

STUDY AREA

Fort Benning Military Installation 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 (Piedmont and Upper Coastal Plain), and was 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 long-leaf 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

long-leaf pine and reduce competing understory plants. Pine (*Pinus* spp.) forests dominated ridges and were separated by hardwood bottoms. Pine forests at Fort Benning were composed of loblolly pine (*P. taeda*), longleaf pine, shortleaf pine (*P. echinata*), and mixed pine-hardwoods. Oak (*Quercus* spp.)/hickory (*Carya* spp.) forests dominated the low hardwood areas of the installation (Doresky *et al.* 2001).

METHODS

Feral pigs were collected from April 2005 to March 2006. The extensive road network at Fort Benning was driven until pigs were sighted with a 75mm Ratheon Palm IR 250 digital thermal camera (24 x 10 x 10 cm; Raytheon Commercial Infrared, Dallas, Tex.) 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). I collected pigs with the use of firearms both day and night with the aid of spotlights. However, most were collected after sunset due to the crepuscular/nocturnal activity patterns of pigs on the installation. All ages of pigs (6 weeks to 26+ months) were collected. Once collected, total stomach content was removed and frozen in a freezer bag until later analysis. In the laboratory, samples were thawed in a warm water bath and materials were separated using 2 successive sieves (5.6 and 3.2 mm) to rinse smaller, unidentifiable particles from the sample (Groot-Bruinderink *et al.* 1994; Fournier-Chambrillon *et al.* 1995). Finally, samples were thoroughly searched for vertebrate remains. All remains that were found were preserved in 95% ethanol and were later identified to at least the genus level.

I calculated daily consumption estimates for each species using the average number of herpetofauna found in stomach samples divided by 4 hours (mean time that

food stays in the pig stomach) and multiplied by 12 hours (foraging time per day) and multiplied by the estimated pig population/area. I estimated that each stomach sample represented the last 4 hours of foraging prior to collection based on feeding rates reported for domestic pigs (Latymer *et al.* 1990). To ensure my estimated rates of consumption were as conservative as possible, I used the longest estimated passage rate from mouth to ileum provided by Latymer *et al.* (1990). I used data derived from game cameras (Hanson 2006) to develop an estimate of mean foraging time for an individual pig during a 24-hour period. Based upon the estimated times that pigs visited baited camera sites, I estimated that pigs were active and foraging approximately 12 hours each day. This estimate does not indicate that pigs were consuming forage for 12 hours during each day, but rather were capable of consuming herpetofauna during 12 hours each day. I assumed that pigs traveling to/from feeding areas would deplete herpetofauna that were encountered. Hanson (2006) estimated the density of feral pigs at Fort Benning to be 4.34 (95% CI: 2.65-7.87) pigs/km², and the total population to be 3,196 (95% CI: 1,952-5,796) during the study. Frequency of herpetofauna consumption was estimated by dividing the number of stomachs found to contain specific species by the total number of stomachs containing herpetofauna.

To account for seasonal availability, I calculated daily consumption rates by using the stomach samples that were collected during the season that a species was likely available. I calculated annual consumption rates by multiplying the daily consumption rate by the number of days contained within the season of availability. I estimated that spade-foot toads and red-bellied snakes were available from April – October based on their climatological activity preferences (Pearson 1955). The seasonality of three species

was based on low ambient temperatures and estimated December – March for green anole, eastern fence lizard, and Cope’s gray tree frog because they become most vulnerable when seeking thermal shelter (Jenssen *et al.* 1996).

RESULTS

From April 2005 to March 2006, 68 stomach samples were collected from feral pigs. Sample sizes ranged from 0 - 10 per month. February 2006 was the only month that no pigs were collected. Herpetofauna were present in 17.6% ($n = 12$) of the samples. A total of 64 individual reptiles and amphibians were identified comprising 5 different species (Table 1). The spade-foot toad (*Scaphiopus holbrooki*) was consumed in the greatest quantity ($n = 52$) and had the second highest frequency of consumption (27%). One individual pig had consumed 49 spade-foot toads. Additional species found included the green anole (*Anolis carolinensis*), which was most frequently consumed (55%) by feral pigs. When a green anole was found in a stomach, it was found individually except in one sample that contained 2 anoles. One eastern fence lizard (*Sceloporus undulatus*), one red-bellied snake (*Storeria occipitomaculata*), and one tree frog of the genus *Hyla* [either Cope’s gray tree frog (*H. chrysoscelis*) or a bird-voiced tree frog (*H. avivoca*)] were found in our samples. Timing of herpetofauna consumption exhibited 2 distinct seasonal peaks in July-August and December-January (Fig 1) and varied by species. Daily and annual consumption estimates were calculated for each species (Table 2).

DISCUSSION

The data suggest that a substantial number of herpetofauna are consumed by feral pigs on Fort Benning each year. Although there are no published data that estimate herpetofauna consumption by feral pigs, examination of data from other predator-prey associations suggests 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, it has been estimated that gulls (*Larus delawarensis* and *L. californicus*) consumed up to 195,279 juvenile salmonoids (*Oncorhynchus tshawytscha*) behind one dam on the Yakima River, Washington, USA within a two month period. When you consider that Fort Benning encompasses 736 km², it is not unreasonable that an entire population of feral pigs could consume 2.85 million reptiles and amphibians per year. Because population/subpopulation estimates and dynamics data are unavailable for most herpetofauna, it is difficult to estimate the impact that depredation by pigs may have on these 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 would not be normally vulnerable to foraging 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 feral pigs. The data confirm this assumption as all predation of green anoles in this study occurred during December and January. This type of predation seems random and most likely does not affect the population because green

anoles do not seek shelter in concentrated locations. Therefore it would be unlikely for pigs to consume them in great quantity or influence population dynamics.

Predation of the spade-foot toad illustrates how feral pigs could potentially pose a threat to herpetofauna populations. For most of the year, the spade-foot 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 (Pearson 1955; Conant and Collins 1991). During these breeding periods, spade-foot toads can be found concentrated at extremely high densities. It is possible that pigs respond to this concentrated food source by focusing their foraging efforts and hunting toads when they are available. I collected an individual pig stomach containing 49 spade-foot toads that supports this hypothesis. Before this pig was collected it was observed foraging with another pig (the second pig was not collected), where each pig would repeatedly make 1-meter lunges as if pursuing prey. They appeared to be hunting the toads that were observed in great numbers that night. This selective foraging by feral pigs leads to concerns that they could negatively impact species that exhibit similar life history characteristics.

Originally I had hypothesized that pigs only consumed herpetofauna when they were randomly encountered. However, pigs may actively hunt specific prey items when conditions are optimal. Feral pigs are known to depredate snake-necked turtles (*Chelodina rugosa*) when they are most vulnerable (Fordham *et al.* 2006). Species with breeding strategies similar to the spade-foot toad such as the threatened gopher frog (*Rana capito*) could be negatively impacted when feral pigs occupy the same habitat. If a small population of gopher frogs is limited to a few breeding ponds, a local feral pig

population may be capable of consuming a significant number of breeding adults when they are most vulnerable.

I had originally hypothesized that herpetofauna consumption 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). My data supported this hypothesis, as there was a peak in herpetofauna consumption during mid-summer. However, there was also a second peak of consumption (17.2% of animals consumed) that occurred during December and January which are the coldest months of the year at Fort Benning. I suspect that temperatures caused some herpetofauna to become more vulnerable to pig predation for two reasons. First, the cold weather forces herpetofauna to seek thermal refuge on the ground in leaf litter and other debris. For species such as the green anole, which are often found on branches above the reach of ground-dwelling predators, their vulnerability to depredation increases during these periods. Second, the cold weather makes the normally quick animals slow to react when they are located by feral pigs. While an increased number of reptiles and amphibians become more vulnerable to pig predation during times of low temperature, the type of foraging that is occurring during these situations most likely does not substantially affect any particular species of reptile or amphibian.

The combination of actively hunting herpetofauna and large sounder sizes that are common in feral pig populations (Mayer and Brisbin Jr. 1991) could 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. Feral pig densities should be monitored regularly and, when eradication is not

possible, should be 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 pig depredation on herpetofauna populations.

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Table 1. Total number and frequency of herpetofauna in stomach samples ($n = 68$) collected from feral pigs on Fort Benning, Georgia from August 2004 to April 2006.

Species	n	Frequency	Month
Spade-footed toad	52	27	April, July, Aug
Green anole	9	55	Dec, Jan
<i>Hyla spp.</i>	1	9	Dec
Red-bellied snake	1	9	July
Eastern fence lizard	1	9	Dec

Table 2. Estimated daily and annual consumption rates of herpetofauna by feral pigs at Fort Benning, Georgia from August 2004 to April 2006.

Species	Daily				Annual			
	per/ km ²	95% CI	population	95% CI	per/ km ²	95% CI	Population (million)	95% CI (million)
Spade-foot 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	1.6	1.0, 2.8	1,151	703, 2,087	236	144, 428	1.74	1.06, 3.15
Red-bellied snake	0.3	0.2, 0.6	234	143, 424	68	43, 123	0.05	0.03, 0.09
Eastern fence lizard	0.2	0.1, 0.3	128	78, 232	26	16, 47	0.02	0.01, 0.04
Tree frog (<i>Hyla sp.</i>)	0.2	0.1, 0.3	128	78, 232	70	16, 47	0.02	0.01, 0.04
All herpetofauna	19.0	11.0, 34.0	13,674	8,350, 24,797	3,864	2,359, 7,007	2.85	1.74, 5.16

Figure 1. Percent of herpetofauna and stomachs that contained herps by month for feral pigs sampled on Fort Benning, GA from April 2004 - March 2005

