Prevalence and economic value of feral swine damage to native habitat in three Florida state parks

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SUMMARY

Feral swine (*Sus scrofa*) adversely affect the environment in many of the places where they have been introduced. Such is the case in Florida, but quantification and economic evaluation of the damage can provide objective bases for developing strategies to protect habitats. Swine damage to native wet pine-flatwoods at three state parks in Florida was monitored from winter 2002 to winter 2003. Economic valuations of damage were based on the US dollar amounts that wetland regulators have allowed permit applicants to spend in attempts to replace lost resources. The parks had different swine management histories and the damage patterns differed among them over time. Swine were intensively removed in 2000 from the first park, and it initially had the lowest habitat damage at 1.3%, but as a result of natural and artificial population growth this damage rose to 5.4% by the conclusion of the study, and was valued at US$ 19 193–36 498 ha^{-1}. The second park had no history of swine harvest and, over the monitoring period, damage escalated from 2.6%–6.4%, with an associated value of US$ 22 747–43 257 ha^{-1}. Swine were managed as game animals in the third park prior to its inclusion into the state parks system in 2000. Within this park, the proportion of area damaged decreased from 4.3%–1.5%, valued at US$ 5 331–10 138 ha^{-1}. This decrease may be a result of human activities associated with development of the park's infrastructure causing dispersal of animals conditioned to avoid humans by hunting. Damage was highly scattered in each park, as evidenced by a much higher proportion of sampling sites showing damage than the actual proportion of land area damaged. The dispersed nature of small amounts of damage would increase the effort required to recover habitat and thus damage value estimates are probably conservative. It was also impossible to incorporate values for such contingencies as swine impact to state and federally listed endangered plants in the parks, some of which are found nowhere else in the world.

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INTRODUCTION

Feral swine (*Sus scrofa*) can be a particularly destructive exotic species in the places where they have been introduced (USDA [US Department of Agriculture] 1999); they degrade habitat, and predate on and compete with native species (Choquenot *et al.* 1996; Taft 1999). In North America, DeSoto first introduced swine to Florida in 1539 (Towne & Wentworth 1950) and, with additional introductions, the range of feral swine in the USA continues to expand (Gipson *et al.* 1997). The species possesses the highest reproductive potential of any large mammal in North America (Wood & Barrett 1979; Hellgren 1999), and currently inhabits many areas in large numbers. Feral swine can also harbour a number of diseases transmissible to livestock or humans (see Becker *et al.* 1978; Conger *et al.* 1999; Romero & Meade 1999; Taft 1999). In particular, the swine industry in the USA has nearly eradicated swine brucellosis and pseudorabies, but feral swine serve as a potential reservoir from which these diseases can be transmitted back to domestic stock (Taft 1999; Taylor 1999).

Funding to manage feral swine and restore habitat is finite and must be applied carefully to optimize the positive impact on the protected resources. Decisions on management actions towards destructive invasive species are based on economic constraints, but the metric for success of management actions is measured in resource improvement. Therefore, a means to estimate efficiently feral swine damage to habitats, and to apply a monetary value to the damage, would permit economic analyses to help guide and evaluate management actions. Here, in three Florida state parks with similar habitats, we estimate and monitor habitat damage by feral swine over a year, and apply economic valuations of that damage.

METHODS

Study areas

This study was conducted in the Jonathan Dickinson State Park, Atlantic Ridge Preserve State Park, and Savannas Preserve State Park, Florida, USA. Each park is centrally

located along Florida's east coast and preserves similar, dwindling native habitats. All three parks share some characteristics. The habitat in each study area was a wet pine-flatwoods (Hartman 1978; Kautz 1987) dominated by South Florida slash pine (*Pinus elliottii*), with saw palmetto (*Serenoa repens*) as the primary understorey species. None of the parks presented barriers for swine movement in and out of their boundaries. Each park was wilderness surrounded by suburban and some urban encroachment. Therefore, even though the surrounding areas provided areas of habitat for feral swine, hunting or other public removal methods could not be applied for human health and safety reasons.

An 8300 ha area of Jonathan Dickinson State Park (JDSP) was studied. In recent years feral swine have been removed consistently from JDSP in order to eradicate an exotic species. The US Department of Agriculture/ Wildlife Services (USDA/WS) undertook an intensive supplemental effort to remove swine from JDSP in 2000.

The 1720 ha area surveyed in the Atlantic Ridge Preserve State Park (ARPSP) had a similar habitat to the area within JDSP. This park became part of the Florida State Park system in 2000 and hunting has been banned since then. Before 2000, it was used as a private hunting area, where, in addition to other species, feral swine were managed and hunted as game animals, rather than removed as an exotic pest species. Since its admission to the Florida park system, administrative attention to ARPSP has been devoted to the development required in order to open it to the public. Feral swine were first managed as a renewable resource, followed by a potential recovery period and human disturbance.

The 350 ha area within the Savannas Preserve State Park (SPSP) consisted of similar habitat to that in JDSP and ARPSP. Within the SPSP, feral swine were not managed as either exotic pests or game animals. SPSP also implemented a contract with the USDA/WS to carry out intensive swine removal beginning mid-winter 2003 (approximately the conclusion of our study).

Sample design

Sites for sampling damage were located using the low-use, single-lane dirt (primitive) roads that permeated each of the study areas. We also wanted the sample sites to be suitable for future swine population indexing procedures (Engeman *et al.* 2001) to monitor the impact of management actions on populations through the course of their implementation. Thus, we located sampling sites in association with dirt road locations devoid of vegetative growth in the road to ensure that, after tracking areas were installed, swine would not be able to visually distinguish the plots from the roadway. The saturation of the study areas with primitive roads, coupled with the random occurrences of potential sampling site locations devoid of vegetation, and our random selection among those locations, produced a random spatial pattern of sampling sites throughout the study areas. The distribution of sites was plotted and verified on maps, because the locations of all sites

were recorded using a global positioning system (GPS) unit. Thirty-six sampling sites were located in ARPSP, 28 in JDSP, and 31 in SPSP. Swine populations were monitored and subject to consistent population control in JDSP (see Engeman *et al.* 2001), but no prior data existed for ARPSP and SPSP. Therefore, ARPSP and SPSP were sampled more heavily relative to their areas.

Damage measurements

Each sampling site location along the road system defined the positioning for two damage assessment plots. On one side of the road, a damage plot was established 1 m perpendicularly outward from the road edge. Each damage plot was a $5 \times 1\,m^2$ rectangle, established using a $1 \times 1\,m^2$ square constructed of PVC pipe, folded over four more times beyond its initial placement. Cryptically placed, sand-coloured, wooden stakes in diagonal corners defined the plot for future reference. The second damage plot defined at the same road location was constructed in the same manner on the opposite side of the road with its placement beginning 3 m in the opposite direction from the first plot, and leading away from the opposite damage plot. Damage was sampled in late winter 2002, spring 2002 and mid-winter 2003.

The $1 \times 1\,m^2$ squares were used to provide accurate and repeatable measurements of the area damaged within the $5 \times 1\,m^2$ plots to the nearest 5%. String was placed in a ' + ' sign across the $1 \times 1\,m^2$ square to divide the area into four equal quadrants. Thus, damage was measured over 20 of these $0.25\,m^2$ quadrants for each of the $5 \times 1\,m^2$ plots. Swine damage was defined as overturned ground during foraging (rooting) activity. Tracks verified the species responsible. Armadillos (*Dasypus novemcinctus*) were the only other species in the parks that could produce similar (very small) patches of damage, but they were easily distinguished from swine damage by examining tracks and whether the ground was overturned or dug by forefeet.

The areas within the state parks that were sampled for damage (described earlier) were derived from GIS maps of the parks. The percentage of those areas damaged by swine was calculated in two ways. First, the percentage of the plots containing damage provided a rough estimate. The mean area damaged among all sample sites (two damage plots per site) provided a more accurate and precise estimate of damage.

Data analyses

The area of damage at each sampling site followed a two-factor repeated measures design, with season as the repeated factor (Winer 1971). Park represented the fixed factor and season had three (repeated) levels (late winter 2002, spring 2002, mid-winter 2003). The data were analysed as a mixed linear model (see McLean *et al.* 1991; Wolfinger *et al.* 1991). The calculations were performed using SAS PROC MIXED, with a restricted maximum likelihood estimation procedure (REML; Littell *et al.* 1996).

Damage valuation

Special habitats such as wetlands have limited market value, and if such habitat is selectively protected, the market value diminishes further (King 1998). The use of contingent valuation surveys for special habitats, analogous to those applied to endangered animals (Engeman *et al.* 2002, 2003), tend to be even more abstract appraisals of value (King 1998). Estimated costs for restoring habitat to pristine condition (replacement costs) frequently produce values well in excess of the public's willingness-to-pay, and therefore do not represent a realistic valuation. The most defensible, logical and applicable valuation for the damaged habitat characteristic of the three parks in which our study took place was to use expenditure data for permitted wetland mitigation projects in the USA. Such data represent an empirical demonstration of willingness-to-pay value. King (1998) presented the US dollar amounts per unit area spent in efforts to restore a spectrum of wetland habitat types. The numbers represent the US dollar amounts that environmental regulators, and to a degree elected governments, have allowed permit applicants to spend in attempts to replace lost wetland services and values (King 1998). We identified the dollar value for the appropriate wetland habitat category from each of the two studies in King (1998). For these two studies, the habitats from our study areas would be classified as freshwater forested or emergent forested, with respective 1997 empirical willingness-to-pay dollar values of US\$ 306 404 ha^{-1} and US\$ 582 659 ha^{-1} (King 1998). The 2002 values for each of these willingness-to-pay dollar amounts after adjusting for a 3% annual rate of inflation (Zerbe & Dively 1994) were US\$ 355 429 ha^{-1} and US\$ 675 884 ha^{-1}, respectively. The cost-per-unit area of swine damage in each of the parks was calculated by multiplying the estimated proportion of area damaged by swine by the cost-per-unit area for habitat restoration.

RESULTS

Damage estimates

The amounts and values of swine damage in the three parks varied over time (Table 1), and were reflected in the park-by-time interaction ($F_{3158} = 2.35$, $p = 0.07$). JDSP, where swine were targeted for intensive removal in 2000, had 1.3% of the area damaged in spring of 2002, but by mid-winter 2003 this level had risen to 5.4% (Table 1). SPSP, which had no history of swine harvest, showed 2.6% damage in late winter 2002 but this value climbed steadily to 6.4% by mid-winter 2003 (Table 1). ARPSP, where swine had been managed as a game animal followed by a two-year period during which no swine were harvested and the construction of the park infrastructure was initiated, had 4.3% of the area damaged in late winter 2002. This level remained steady (no habitat recovery) through spring 2002, but dropped to 1.5% by mid-winter 2003, indicating some habitat recovery (Table 1).

Damage was more widespread in each park than the average amounts of damage would indicate (Table 2). Over all parks and sampling periods, the prevalence of damage among the sample sites ranged from 1.9 to 15.5 times higher than the quantity of damage. The highly distributed nature of swine damage relative to the amount of damage is also reflected in the proportion of sampling sites with damage where damage was only recorded at one of the two $5 \times 1\,m^2$ plots (Table 2). Over all parks and sampling periods, the number of sampling sites where both plots displayed damage ranged from 0–50%, with 20% as the median. None of the sampling sites in ARPSP had damage recorded at both plots within one site during any sampling period.

Damage valuations

The restoration costs multiplied by the estimated proportion of the area in each park damaged by swine provided a range of two US\$ values for the average per hectare habitat damage inflicted by feral swine (Table 1). The respective values for freshwater forested and emergent forested swine damage per

Table 1 Estimated proportion of feral swine damage to wet pine-flatwoods over time in three Florida state parks (ARPSP = Atlantic Ridge Preserve State Park, JDSP = Jonathan Dickinson State Park, SPSP = Savannas Preserve State Park), and two economic valuations of that damage based on expenditure data for permitted wetland mitigation projects in the USA (King 1998) for 'freshwater forested' (FF) or 'emergent forested' (EF) habitat.

Park	Season	Year	Proportion damaged	FF value per ha of damage (US\$ ha^{-1})	EF value per ha of damage (US\$ ha^{-1})
ARPSP	Late winter	2002	0.043	15 283	29 063
	Spring	2002	0.043	15 283	29 063
	Mid-winter	2003	0.015	5331	10 138
JDSP	Spring	2002	0.013	4621	8786
	Mid-winter	2003	0.054	19 193	36 498
SPSP	Late winter	2002	0.026	9241	17 573
	Spring	2002	0.047	16 705	31 767
	Mid-winter	2003	0.064	22 747	43 257

Table 2 Indicators of the highly distributed nature of feral swine damage in three Florida State parks (ARPSP = Atlantic Ridge Preserve State Park, JDSP = Jonathan Dickinson State Park, SPSP = Savannas Preserve State Park) are the contrast of the estimated proportion of land damaged with the proportion of sampling sites exhibiting damage, as well as the low proportion of sampling sites with damage where both plots received damage.

Park	Season	Year	Proportion damaged	Proportion of sites with damage	Proportion of damaged sites with both plots damaged
ARPSP	late winter	2002	0.043	0.139	0
	spring	2002	0.043	0.139	0
	mid–winter	2003	0.015	0.028	0
JDSP	spring	2002	0.013	0.143	0.250
	mid–winter	2003	0.054	0.250	0.143
SPSP	late winter	2002	0.026	0.402	0.333
	spring	2002	0.047	0.425	0.429
	mid–winter	2003	0.064	0.402	0.500

hectare increased from US$ 4620 ha^{-1} and US$ 8786 ha^{-1} to US$ 19 193 ha^{-1} and US$ 36 498 ha^{-1} in JDSP, increased from US$ 9241 ha^{-1} and US$ 17 573 ha^{-1} to US$ 22 747 ha^{-1} and US$ 43 257 ha^{-1} in SPSP, and decreased from US$ 15 283 ha^{-1} and US$ 29 063 ha^{-1} to US$ 5331 ha^{-1} and US$ 10 138 ha^{-1} in ARPSP.

DISCUSSION

In Florida, a premium is placed on sanctuaries for protection and preservation of habitats and species, especially as much of the natural habitat in Florida already has been lost to development. The three parks where our study took place are homes to myriad threatened and endangered plant and animal species, as well as their unique habitats (see Hartman 1978).

In estimating the monetary values of the swine damage to the habitat, we assumed standard costs for restoration. However, these parks contain a variety of threatened and endangered plant species (Gann *et al.* 2002), some of which are endemic. It is much more difficult to ascribe a monetary value to damage or loss of, such species (Engeman *et al.* 2003). In fact, values of endangered or threatened species have been deemed 'incalculable' in US Supreme Court case law (Tennessee Valley Authority vs Hill 1978). Thus, while we have provided monetary estimates of the value of swine damage in the parks, these values should be viewed as lower estimates for the value of potential damage. In addition, the magnitude of potential damage values is magnified further if the definition is broadened beyond habitat damage to include transmission of disease pathogens by swine to domestic livestock.

Clearly, when the value of swine damage per hectare in a park is multiplied by the total area sampled in that park, the total valuations for swine damage per park would run into millions of US dollars. That the park managed for swine removal initially had the lowest level of swine damage is intuitive. In 2000, an intensive swine removal effort was carried out at JDSP by contracting with USDA/WS, and resulted in both substantial reductions in the swine population and in an index of concomitant swine damage (Engeman *et al.* 2001). The additional cost to the park for that contract was approximately US$ 5000 (adjusting for inflation, US$ 5305 in 2002). This was only slightly greater than the average value for swine damage per hectare for the lowest observed damage level at JDSP when applying the lower of the two habitat valuation figures (Table 1). If the higher valuation figure was used, or if the mid-winter 2003 damage level was considered, then the contract cost was substantially less than the value of the average amount of swine damage to a single hectare. Even though swine continued to be removed by park personnel at every opportunity after conclusion of the intensive removal contract, damage increased as time elapsed after the completion of the intensive effort, with damage quadrupling from early 2002 to early 2003. The favourable conditions of a wet habitat and subtropical climate, coupled with the high reproductive potential of swine, would allow a rapid population growth within the time frame following that control effort (Wood & Barrett 1979; Hellgren 1999). In addition, swine at a neighbouring property were poorly contained and probably artificially contributed to the population at JDSP (J. Woolard, personal observation 2002–2003).

The park with no swine management (SPSP) initially had a lower damage level than that where swine had been managed as a game species (ARPSP). However, the amount of damage steadily escalated in SPSP over the course of our study. Concurrent with the conclusion of our study, SPSP had the highest damage levels among the parks and had commenced a contract with USDA/WS for intensive swine removal. The cost of this contract was US$ 7500, which was only a fraction of the value of the swine damage per unit area of habitat at the conclusion of our study, using either valuation figure.

At the time of our observations, two years had elapsed since the transfer of ARPSP to the state park system. Management of swine as a renewable hunting resource,

followed by two years of no removals in the face of high reproductive rates, may have allowed substantial population growth. Moreover, the elimination of hunting pressure initially may have reduced the wariness of the swine in terms of foraging and occupied range, hence the highest initial damage levels among the three parks. However, hunted feral swine have demonstrated remarkable learning and conditioning capabilities, as exemplified by feral swine acting dead during aerial surveys for swine shot from helicopters (Saunders & Bryant 1988). Thus, once the infrastructure development necessary to open the park to the public was implemented throughout the property (trail development, boundary marking and fences, etc.), animals previously conditioned to avoid humans through hunting might have been dispersed from this park, thus explaining the decreased damage levels at the conclusion of our study. At the time of our final damage assessment, an orange grove adjacent to the park was being harvested, with the dropped oranges providing a powerful attractant to draw feral swine away from the park, especially those that might have dispersed in that direction.

The use of the permanent damage plot locations provided a useful means to assess the changes in feral swine damage quantity and prevalence, while simultaneously providing information to describe the spatial distribution of their activity. Continued monitoring of these plots will provide data on the rates of habitat recovery after swine removal. We also established a realistic and defensible method for valuing swine damage using established empirical data for actual habitat restoration costs. The efficacy of swine management practices can then be evaluated on an economic basis, in addition to measures of population reduction (Engeman *et al.* 2001). Given the disparity between the costs for a control contract for an entire park and the average per unit area value of swine damage to land, we question how protection of such special and sensitive habitats from wholesale swine damage cannot be afforded.

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