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Feral swine management for conservation of an imperiled wetland habitat: Florida's vanishing seepage slopes

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ABSTRACT

Only 1% of the original extent of Florida's seepage slope habitat remains, with Eglin Air Force Base containing some of the largest tracts. Feral swine damage is one of the greatest threats to this wetland habitat. We conducted a multi-year study to evaluate the impacts of sport hunting and supplemental swine removal on damage to seepage slopes. Prior to initiation of removal in 2003, swine damage to seepage slopes in the portion of the base closed to hunting averaged 25.0%, over twice the 10.9% losses in the portion open to hunting. After less than one year of supplemental removal, damage in the closed-to-hunting area dropped to 7.2%. Although supplemental removal was not applied in the open hunting area, damage dropped significantly to 5.6%, statistically indistinguishable from the swine-controlled (closed) portion. After another year of removal, average damage in the closed hunting area dropped further to 5.6%, while the open hunting area dropped to 4.3%, again statistically indistinguishable. Even though removal was only applied to the area closed to hunting, it also produced damage reductions in the open hunting area, as swine were free to move among areas. Declines in damage following implementation of removal corresponded with large drops in swine population indices for the base. Economic valuations of seepage slope damage losses demonstrated substantial benefit–cost ratios for application of removal. Prior to removal, the combined value of swine damage to seepage slopes in areas open and closed to hunting was estimated at \$5.3 million. After only 1.7 years of removal, the value of damage losses was reduced by nearly \$4 million to \$1.5 million. The benefit–cost ratio over the 1.7 years of removal was an impressive 27.5. Moreover, the economic benefits of removal exceeded the costs 55.2-fold for the first year, when management impact would be greatest.

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1. Introduction

Feral swine *Sus scrofa* can be a highly destructive exotic species that degrades habitats, preys on native species, and competes with native species (Choquenot et al., 1996; Taft, 1999; US Department of Agriculture, 1999; Seward et al., 2004). They

also harbor a number of diseases transmittable to wildlife, livestock or humans (e.g., Conger et al., 1999; Romero and Meade, 1999; Taft, 1999). Florida joins Hawaii as the two states of the United States with the most severe invasive species problems (US Congress, 1993), and swine were one of the first invasive exotic species to take hold in Florida after their intro-

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duction by DeSoto in 1539 (Towne and Wentworth, 1950). The species possesses the highest reproductive potential of any large mammal in North America (Wood and Barrett, 1979; Hellgren, 1999) and, with subsequent introductions, the range of feral swine in the US continues to expand (Gipson et al., 1997). Feral swine currently inhabit many areas in such large numbers that they adversely impact wildland and agricultural ecosystems. Feral swine have been implicated by some as the single greatest vertebrate modifier of natural plant communities (Bratton, 1977; Wood and Barrett, 1979). Rooting may damage population structures of plants, set back succession, and change species composition (Bratton, 1977). Swine have been implicated for facilitating dieback disease in native vegetation by spreading rootrot fungus (*Phytophthora cinnamomi*) (Kliejunas and Ko, 1976). Habitat damage by swine is most pronounced in wet environments (e.g., Choquenot et al., 1996). We focus here on swine damage to a unique and disappearing wetland habitat in Florida: seepage slopes (FNAI, 1990).

Seepage slopes are wetlands at the base of a slope, characterized by boggy grassy meadows or shrub thickets (FNAI, 1990). They are maintained by downslope groundwater seepage resulting from a water table perched above an impermeable layer of clay or rock. Seepage slope soils are saturated but are rarely inundated by water. Many rare and endemic species are found on seepage slopes including insectivorous plants and several species of orchids and lilies (Florida Natural Areas Inventory [FNAI] 1990, Kindell et al., 1997; Harper et al., 1998). Only 1% of the original extent of seepage slopes in Florida is estimated to remain, with Eglin Air Force Base (Eglin AFB) in northeast Florida containing some of the largest remaining tracks, thus making the base particularly important for conservation of this habitat (FNAI, 1990; Kindell et al., 1997).

One of the major threats to the seepage slopes on Eglin AFB is damage by feral swine (Kindell et al., 1997; United States Air Force, 2002). We carried out a multi-year investigation to: (1) assess the extent of swine damage to seepage slopes on Eglin AFB, (2) evaluate the impacts of sport hunting and swine removal towards damage reduction, (3) apply economic valuations to damage, (4) conduct bioeconomic analyses, including benefit–cost ratios for swine removal.

2. Methods

2.1. Study area, site selection and observation methods

Eglin AFB covers a large area (187,780 ha, \approx 82 km E–W and 31 km N–S). Approximately 86% of Eglin AFB is forested, 12% dedicated solely to military activities (i.e., airfields, cleared test ranges, test sites, rights-of-way, and administrative areas), and the remaining 2% is comprised of water, marshes and barrier island (Kindell et al., 1997). Eglin AFB lands are used extensively for recreation, including sport hunting for a variety of bird and mammal species. Approximately half of the base may be hunted during various seasons, with opportunities to hunt feral swine during seasons running from mid-October through mid-February (by varying hunting methods, with a three week break for small game season in January). Swine are considered feral animals on Eglin AFB

and are not subject to bag limits (United States Air Force, 2002).

In spring of 2003, we randomly selected 28 of the 237 known seepage slopes from across the base for study. To evaluate the impact of sport hunting on swine damage to seepage slopes, half of these study seepage slopes were randomly selected from areas open to public hunting, and half in areas closed to hunting. Damage and habitat variables were measured at 20 randomly selected 1 m² plots within each seepage slope. Seepage slopes were observed in May/June of 2003, 2004, and 2005. The same plot locations were used on each observation occasion to optimize inferences over time (Ryan and Heyward, 2003).

In each 1 m² plot at each seepage slope, the percent cover of swine damage and presence/absence of root exposure were measured as direct observations of swine damage. Swine damage was defined by broken vegetative surface within the 1 m² plot caused by swine rooting or tracks. A number of additional vegetation and habitat measures (Table 1) were made in each plot that might relate to feral swine impacts, although each of these measures is influenced by many environmental factors. The metrics for the observations made in each plot included percent cover (measured visually by assignment to one of nine percentage categories), presence/absence, and stem density, depending on the variable being measured (Table 1). The total number of plant species observed in each plot was also recorded. Among the measured vegetative variables listed in Table 1, the percent cover of toothache grass *Ctenium aromaticum*, wiregrass *Aristida beyrichiana*, and herbaceous cover (forbs and graminoids) were of particular interest, as coverage by these grasses is an indicator of seepage slope health (Harper et al., 1998). Also of particular interest among the variables in Table 1 were several state-listed threatened and endangered species including: whitetop pitcher plant *Sarracenia leucophylla*, red-flowered pitcher plant *Sarracenia rubra*, spoonflower *Peltandra sagittifolia*, as well as species groupings, such as bogbuttons and asters that could include other state-listed species.

2.2. Swine population indices

Feral swine were monitored using a passive tracking index methodology similar in principle to the methods successfully applied by Engeman et al. (2001) to a state park in eastern Florida. Because Eglin AFB covers a large area, tracking plot construction was adjusted to allow efficient sampling on a much larger scale. Tracking plots were located randomly along roads throughout Eglin AFB as an efficient design for sampling the area (Pearson and Ruggiero, 2003). The plots were created and their tracking surfaces prepared by dragging 2 m-wide chain loops behind a pickup truck for 1.6 km. The minimal distance between plots was 1.6 km. Plots were inspected the following day and the number of swine intrusions (number of sets of tracks) were recorded in the same manner as Engeman et al. (2001) for smaller plots and landscapes. The process of preparing the tracking surfaces and recording the number of swine intrusions was repeated for three consecutive days. Plot locations were recorded by GPS and the same plot locations were used on each sampling occasion (e.g., Ryan and Heyward, 2003; Engeman, 2005). Tracking data were collected from 17 permanent plot

Table 1 – Damage, vegetative, and habitat variables measured at each of twenty 1 m² plots on 28 seepage slopes at Eglin Air Force Base, Florida

Observed variable	Unit of measure at each plot	Value contributed by each seepage slope for analyses
Swine damage	% Cover	Average % cover over 20 plots
Root exposure	Presence/absence	% of 20 plots where present
Plant species	# Plant species in plot	Average # species over 20 plots
Toothache grass <i>Ctenium aromaticum</i>	% Cover	Average % cover over 20 plots
Wiregrass <i>Aristida beyrichiana</i>	% Cover	Average % Cover over 20 plots
Panicgrass <i>Dichantherium</i> spp.	% Cover	Average % Cover over 20 plots
Other graminoids (grasses, sedges, rushes)	% Cover	Average % cover over 20 plots
Nongraminoids (forbs – nonwoody plants)	% Cover	Average % cover over 20 plots
Woody plants	% Cover	Average % cover over 20 plots
Saw palmetto <i>Serenoa repens</i>	% Cover	Average % cover over 20 plots
Total vegetative cover	% Cover	Average % cover over 20 plots
Litter	% cover	Average % cover over 20 plots
Bare ground	% Cover	Average % cover over 20 plots
Spoonflower <i>Peltandra sagittifolia</i>	Presence/absence	% of 20 plots where present
Whitetop pitcher plant <i>Sarracenia leucophylla</i>	Presence/absence	% of 20 plots where present
Red-flowered pitcher plant <i>Sarracenia rubra</i>	Presence/absence	% of 20 plots where present
Yellow pitcher plant <i>Sarracenia flava</i>	Presence/absence	% of 20 plots where present
Parrot pitcher plant <i>Sarracenia psittacina</i>	Presence/absence	% of 20 plots where present
Pink sundew <i>Drosera capillaris</i>	Presence/absence	% of 20 plots where present
Dew-threads <i>Drosera filiformis</i> , <i>D. intermedia</i>	Presence/absence	% of 20 plots where present
Thistleleaf aster <i>Eurybia eryngiifolia</i>	Presence/absence	% of 20 plots where present
General asters <i>Asteraceae</i> family	Presence/absence	% of 20 plots where present
Hummingbird flower <i>Macranthera flammea</i>	Presence/absence	% of 20 plots where present
Spaghnum moss <i>Spaghnum</i> spp.	Presence/absence	% of 20 plots where present
Butterworts <i>Pinguicula</i> spp.	Presence/absence	% of 20 plots where present
Clubmosses <i>Lycopodium</i> spp.	Presence/absence	% of 20 plots where present
Hatpins/bogbuttons <i>Eriocaulon</i> spp. <i>Lachnocaulon</i> spp.	Presence/absence	% of 20 plots where present
Orchids	Presence/absence	% of 20 plots where present
Exotic plants	Presence/absence	% of 20 plots where present
Red titi <i>Cyrtilla racemiflora</i>	Stem density	Average stem density over 20 plots
Black titi <i>Cliftonia monophylla</i>	Stem density	Average stem density over 20 plots
Gallberry <i>Ilex glabra</i>	Stem density	Average stem density over 20 plots
Largeleaf gallberry <i>Ilex coriacea</i>	Stem density	Average stem density over 20 plots
Longleaf pine <i>Pinus palustris</i>	Stem density	Average stem density over 20 plots
Slash pine <i>Pinus elliotii</i>	Stem density	Average stem density over 20 plots
Charred stems	Presence/absence	% of 20 plots where present
Upland species	Presence/absence	% of 20 plots where present

locations in September 2003 prior to implementation of swine removal, and subsequently from those same plots, plus an additional 11 (28 total) in September 2004 and 2005, after one and two years of removal.

2.3. Swine removal

After all 28 seepage slopes had been sampled and swine index data collected for 2003, swine removal was applied to the portion of Eglin AFB closed to hunting. Removal was initiated in fall 2003 and has continued to the present by agreement with US Department of Agriculture/Wildlife Services (WS), the Federal agency responsible for managing conflicts with wildlife (US Department of Agriculture, 1997). WS uses only approved and humane methods to euthanize animals, which conform to the guidelines laid out in the 2000 Report of the American Veterinary Medical Association Panel on Euthanasia (American Veterinary Medical Association, 2001) and set forth as agency policy in USDA/APHIS/WS Directive 2.505. Swine were primarily removed by capture in pen traps and euthanized, but some were removed by control hunting (not sport hunting).

2.4. Data analyses

The seepage slopes were the experimental units for analytical purposes, with the 20 randomly located 1 m² plots providing unbiased estimates of the variables used in the analyses (e.g., Thompson, 2002). The mean cover of swine damage across the twenty 1 m² plots and the percent of those plots with exposed roots for each seepage slope were analyzed as a two-factor repeated measures design (e.g., Winer, 1971), with sport hunting and years as the fixed effects. Seepage slope was a random effect nested in area of open or closed hunting. The data were analyzed in a mixed linear model framework (McLean et al., 1991; Wolfinger et al., 1991) using SAS PROC MIXED with restricted maximum likelihood estimation (REML) (Littell et al., 1996; SAS Institute, 2004). Linear contrasts (e.g., Littell et al., 1996) were applied to specifically test whether the year prior to supplemental swine removal (2003) differed from the two following years with supplemental swine removal, and to annually compare seepage slopes in areas open to hunting with those in areas closed to hunting (without and with removal, respectively).

To accommodate variables not conforming to normality, Spearman's correlations were calculated to indicate the level of relationship between mean swine damage and the mean cover, mean height, or mean percent occurrence of the other vegetative and habitat variables, depending on whether cover, presence/absence, or stem density was measured in each plot.

Passive tracking indices (PTI) for swine were calculated for 2003–2005, by applying the indexing paradigm presented in Engeman (2005) and specifically applied to tracking plots for swine by Engeman et al. (2001). The mean measurement across plots was calculated for each day. The index values were the means of the daily means:

$$PTI = \frac{1}{d} \sum_{j=1}^d \frac{1}{s_j} \sum_{i=1}^{s_j} x_{ij}$$

where x_{ij} represents the number of swine intrusions at the i th tracking plot on the j th day, d is the number of days of observation, and s_j is the number of plots contributing data on the j th day. SAS PROC VARCOMP, using restricted maximum likelihood estimation (REML) (SAS Institute, 2004) was used to calculate the variance components (Searle et al., 1992) needed in the variance estimation formula (Engeman, 2005). Note that independence among plots or among days is not required for these calculations (Engeman, 2005). PTI values were calculated for Eglin AFB as a whole, and not for hunted and unhunted areas separately. Because swine could move freely between the hunted and unhunted areas, attempting to define separate index values for those areas would have had little meaning.

$$BCR = \frac{(\text{US\$ value of pre-removal damage} - \text{US\$ value of 2004 swine damage})}{\text{US\$ cost of swine removal}}$$

2.5. Damage valuations

Credible valuation of special habitats is not straight-forward (Engeman et al., 2004a). Special habitats such as wetlands have limited market value, and when selectively protected, the market value diminishes further (King, 1998). Nevertheless, multiple approaches have been considered for valuing such habitat. The use of contingent valuation surveys is a common economic procedure, but for special habitats it tends to provide abstract appraisals of habitat value (King, 1998), and rarely forms the basis for policy decisions (Adamowicz, 2004).

One defensible, logical, and applicable valuation for damaged habitat is to use expenditure data for permitted mitigation projects. Such data represent an empirical demonstration of willingness-to-pay value, and are most generally available for wetland habitats. The US dollar amounts per unit area spent in efforts to restore various wetland habitat types has been presented by King (1998). 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). Use of these figures, coupled with appropriate adjustments for annual rates of inflation

(Zerbe and Dively, 1994), leads to credible habitat valuations and has been successfully applied to other special, protected wetland habitats damaged by swine in Florida (Engeman et al., 2003b, 2004b). Because seepage slopes are an uncommon wetland type, they are not specifically listed in the surveys provided by King (1998). Therefore, we used the median figure over the listed wetland types as the “willingness to pay” value for restoration. The 2005 value for this restoration cost estimate after adjusting for a 3% annual rate of inflation since the values were presented was \$244,782/ha (Zerbe and Dively, 1994; King, 1998).

2.6. Economic analyses

A benefit–cost analysis (BCA) was used to determine in monetary terms the net benefit of swine removal relative to its cost (Zerbe and Dively, 1994; Boardman et al., 1996; Nas, 1996). Reduction of swine damaged habitat is seen as a benefit. In other words, if management action in the form of swine removal reduced the amount of swine-damaged seepage slope habitat, then the benefit of that management effort is the monetary value of that amount of habitat versus the costs of the effort. The BCA of the swine removal involved estimating the benefit–cost ratio (BCR), measured as the value of the reduction in area of seepage slopes suffering swine damage from 2003 to each of the years with swine removal, versus the cost of the swine removal. The analyses were carried out for hunted and unhunted areas separately, as well as their combination. For example, the equation to calculate benefit–cost ratios BCRs for the first year of removal can be written as:

Swine were removed by agreement between WS and Eglin AFB. The objectives for entering into the swine removal agreement were to protect multiple special habitats from swine damage, including seepage slopes, steephead ravines, and some small sites also vulnerable to swine damage. Approximately 65%, 30%, and 5% of removal effort and resources were respectively directed towards seepage slopes, steephead ravines, and the other situations. The total amounts paid for the two years of control were respectively \$95,301 and \$120,000. Thus, the proportional amounts assigned for protection of seepage slopes were \$61,946 and \$78,000, respectively.

3. Results

3.1. Damage and habitat variables

An interaction effect between sport hunting and years demonstrated a rapid convergence to similar low damage levels from higher, disparate initial damage levels in the hunted and unhunted areas (Table 2, $F = 6.42$, $df = 2, 52.1$, $p = 0.003$). In the 1.7 years after implementing supplemental swine removal, 631 swine were removed from the unhunted areas

Table 2 – Estimated damage and root exposure to seepage slopes in the hunted and unhunted portions of Eglin Air Force Base (AFB) before (2003) and subsequent to commencement of supplemental swine removal (2004,2005)

Year	Mean damage cover (%)		% Plots with root exposure		Swine PTI	# Swine removed
	Hunted (no control)	Unhunted (control)	Hunted (no control)	Unhunted (control)		
2003	10.5	25.0	25.3	45.7	10.72	NA
2004	5.6	7.2	18.9	29.3	4.55	432
2005	4.3	5.6	20.6	29.0	0.82	196

Passive tracking index (PTI) values and swine removal through control procedures (not sport hunting) are given for the base for the same time period.

and damage was reduced by 78% for those seepage slopes (Table 2). In addition, damage was reduced by 60% in the open hunting area where supplemental removal was not applied (Table 2). By way of contrast with supplemental removal, 92 swine were taken by sport hunting from 2003 to 2005. Prior to initiation of supplemental swine removal, mean damage on seepage slopes in areas open to hunting was less than half that for unhunted slopes (Table 2, $F = 13.85$, $p < 0.001$). Removal was initiated in fall 2003, and by the time post-removal damage was first measured the following spring (0.7 year), damage to seepage slopes in the open hunting area had decreased substantially. The damage losses in the closed hunting area experienced a greater decrease to the degree that damage losses in open and closed hunting areas were statistically indistinguishable (Table 2, $F = 0.18$, $p = 0.67$). By 2005, after 1.7 years of removal, swine damage to seepage slopes in open and closed hunting areas each continued to decrease and converge in magnitude (4.3% in hunted areas and 5.6% in unhunted areas, Table 2, $F = 0.11$, $p = 0.75$). Seepage slopes in areas receiving sport-hunting pressure, but not supplemental removal obtained significant benefit from the swine removal carried out in the closed hunting zone. This is not surprising because swine were not restricted in their movements between the hunted and unhunted areas. However, we did not expect the rapidity with which the damage levels between hunted and unhunted areas converged. Following implementation of swine removal, the percent of plots with roots exposed also showed substantial declines for seepage slopes in both hunted and unhunted areas (Table 2, $F = 7.28$, $df = 2$, 53.3,

$p = 0.002$). The gap between hunted and unhunted areas narrowed in that time, but an interaction similar to that for damage cover was not detected ($F = 1.83$, $df = 2$, 53.3, $p = 0.17$).

Swine damage levels to the seepage slopes displayed at most moderate correlations with the habitat/vegetation variables. Such modest magnitudes for correlations with swine damage can be expected in light of natural variability and the many environmental factors influence plant distributions. Swine damage at seepage slopes had detectable correlations with 11 habitat and vegetative variables (Table 3). Not surprisingly, the percent of plots with root exposure correlated well with swine damage, since swine damage often results in root exposure. Among the variables having detectable correlations with swine damage were the three indicators of seepage slope health: toothache grass, wiregrass and herbaceous cover, each of which was negatively correlated with swine damage. Whitetop pitcher plants are state-listed as endangered in Florida and their presence was negatively correlated with swine damage, as was the correlation for the more common yellow pitcher plant. In contrast, the redflower pitcher plant, state-listed as a threatened species in Florida, was positively correlated with swine damage.

3.2. Economic analyses

The mean area of the 28 sampled seepage slopes was 0.516 ha (s.e. = 0.107). Of the 237 seepage slopes on Eglin AFB, 117 are in areas open to hunting and 120 are in areas closed to hunting, resulting in estimates of 61.9 ha total of seepage slope habitat in the closed-to-hunting area and 60.4 ha in the open hunting area. The estimated total area of damage across all seepage slopes was reduced by two-thirds in unhunted areas, and halved in hunted areas. Further reductions in each area followed another year of removal (Table 4). Application of economic values to area of seepage slopes lost to swine damage revealed a \$3.4 million reduction in damage losses over the combined areas in the first year of supplemental removal, and \$3.8 million over both years with supplemental removal (Table 4). Both figures are substantial in comparison to the costs for removal: \$62,000 for the first year and \$140,000 for both years combined, producing first-year and overall BCRs of 55.2 and 27.5, respectively (Table 4). The figures for the second year take into account only the further reduction in damage beyond the first year of removal, and do not include cumulative benefits obtained during the first year of removal.

Table 3 – Variables showing a detectable Spearman correlation with average swine damage from 28 Seepage slopes at Eglin Air Force Base, Florida

Variable	Spearman's ρ	p-Value
% Plots with root exposure	0.852	<0.0001
Average cover of toothache grass	−0.343	0.014
Average cover of wiregrass	−0.218	0.046
Average cover of panic grass	0.201	0.067
Average cover of nongraminoids	−0.234	0.032
Average total vegetative cover	−0.372	0.005
Average cover of bare ground	0.403	0.001
Average cover of saw palmetto	0.256	0.019
% Plots with whitetop pitcher plants	−0.289	0.008
% Plots with redflower pitcher plants	0.260	0.017
% Plots with yellow pitcher plants	−0.195	0.075

Table 4 – Estimated total area of swine damage to seepage slopes in the hunted and unhunted portions of Eglin Air Force Base (AFB) before (2003) and subsequent to commencement of supplemental swine removal (2004,2005)

Year	Open to hunting (no control)		Closed to hunting (control)		Combined		BCR of control
	Area of damage (ha)	Value of damage (\$)	Area of damage (ha)	Value of damage (\$)	Area of damage(ha)	Value of damage (\$)	
2003	6.34	1,551,918	15.48	3,789,225	21.82	5,341,143	NA
2004	3.38	827,363	4.46	1,091,728	7.84	1,919,091	55.2
2005	2.60	636,433	3.47	849,394	6.07	1,485,827	27.5

Estimated values of swine damage and the benefit–cost ratios for supplemental removal are also given for each year. Supplemental removal was initiated in the unhunted portions of Eglin AFB in 2003 after the damage measurements were completed.

4. Discussion

Seepage slopes are an imperiled wetland habitat in Florida (FNAI, 1990; Kindell et al., 1997), and feral swine are one of the destructive forces that threaten those that remain (Kindell et al., 1997; United States Air Force, 2002). Sport hunting for swine has always been in place at Eglin AFB, and swine management in the early 1960's was focused on increasing swine populations and improving genetics (e.g., Natural Resources, 1965). Besides recreation, sport hunting is now also viewed as a tool to curb swine populations. The results from our initial year of study (prior to commencing supplemental swine removal) indicated sport hunting had a beneficial effect towards reducing swine damage. However, managing a game animal for recreational purposes encompasses different objectives than managing a habitat for conservation. Hence, sport hunting over the three years of study removed less than 13% of the swine as removed by the supplemental removal effort in under two years. The differential impacts from the different management objectives are evidenced by the rapid benefit from supplemental swine removal applied only in the area closed to hunting.

Funding to manage feral swine and restore habitat is finite and must be carefully managed to optimize the positive impact on the protected resources. The use of the PTI has effectively aided the optimization of the timing and placement of removal activities in other damage reduction situations, in addition to monitoring population trends (e.g., Engeman et al., 2003). Similarly for Eglin AFB, the information gained from the PTI tracking plots facilitated economical deployment of resources for swine removal over a large area by indicating, based on activity, when and where traps should be placed and removed. In a broader fiscal context, administrative decisions on management actions towards destructive invasive species are based on economic constraints in addition to need. However, the metric for success of management actions is measured in resource quality. Therefore, estimation of feral swine damage levels, and application of a monetary value to the damage permits economic analyses to help guide and evaluate management actions. Here, we not only quantified damage by feral swine to the significant remnants of seepage slope habitat in Florida, but we also applied economic valuations to the damage and assessed the benefit–costs of introducing a management action (swine removal) for conserving seepage slope habitat. Economic benefits, as measured by the value of reductions in damage in the controlled area, were over \$2.6 million after initiation of removal. The ancillary

benefit from the same management action was damage reduction in the open hunting area, valued at nearly three-quarters of a million dollars (Table 4).

The initial impacts of a removal program would be expected to be the most noticeable, especially with damage so quickly reduced. Nevertheless, the value of the reduction in losses between the first and second years of removal was still over \$430,000. Due to the high reproductive potential of feral swine, the accrued benefits of removal could rapidly be lost. Therefore, the environmental and economic benefits of succeeding years of removal should be viewed not only in terms of subsequent reductions in damage levels, but also in terms of accrued value for maintaining damage at current low levels.

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