Management and Conservation Article

Eradication of Feral Pigs From Pinnacles National Monument

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ABSTRACT Feral pigs (*Sus scrofa*) have caused considerable damage where they have been introduced around the world. At Pinnacles National Monument, California, USA, managers were concerned that feral pigs were damaging wetland habitats, reducing oak regeneration, competing with native wildlife, and dispersing nonnative plant species through soil disturbance. To address these threats the National Park Service constructed an exclosure around 57 km^2 of monument land and through cooperation with the Institute for Wildlife Studies eradicated all feral pigs within the area. Trapping, ground-hunting, hunting dogs, and Judas techniques were used to remove feral pigs. Trapping techniques removed most pigs, but a combination of techniques was required to cause eradication. A series of bait sites and transects across the monument helped focus removal efforts and facilitated detection of the last remaining feral pigs in the exclosure. Consistent funding and cooperation from the National Park Service allowed for a seamless and comprehensive program that provided intensive removal of feral pigs. The successful eradication of feral pigs at Pinnacles National Monument should encourage managers in other areas to implement future control or eradication programs. (JOURNAL OF WILDLIFE MANAGEMENT 72(6):1287–1295; 2008)

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Feral pigs (*Sus scrofa*) have caused many ecological and economic damages as a nonindigenous species where they have been introduced around the world (Tisdell 1982). High reproductive potential, adaptability to varying habitats, and capability to expand their range after introduction have allowed feral pigs to successfully colonize a variety of landscapes (Tisdell 1982, Mayer and Brisbin 1991). Feral pigs found at Pinnacles National Monument (PNM), California, USA, originated from domestic swine introduced to the area by 18th-century Spanish missionaries and from European wild pigs or hybrids that were first introduced by ranchers in the 1920s (Pine and Gerdes 1973, Barrett and Pine 1980, Mayer and Brisbin 1991). Numerous subsequent releases and regional translocations of feral and domestic swine also have occurred (Waithman et al. 1999). Prior to 1960 feral pigs were not known at PNM. However, shortly thereafter the first feral pig was sighted, and by the 1980s they had expanded their range to populate all monument land and adjoining properties.

At PNM, there was great concern that feral pigs negatively impacted limited wetland areas, which are a vital resource for native wildlife, including the threatened California red-legged frog (*Rana aurora*) and California tiger salamander (*Ambystoma californiense*; National Park Service [NPS] 2003). Managers also were concerned that an abundance of feral pigs may reduce oak (*Quercus* spp.) regeneration through consumption of mast (Peart et al. 1994, Loggins et al. 2002, Gomez et al. 2003, Shucun et al. 2004). Additionally, considering the limited food resources for native wildlife at PNM, feral pigs were viewed as potential competitors with native animal species (Focardi et al. 2000, Sweitzer and Van Vuren 2002). Direct consumption of native small mammals, such as ground squirrels (*Spermophilus beecheyi*) and voles (*Microtus* sp.) also was identified as a potential negative impact of feral pigs (Loggins et al. 2002). Finally, it is believed that pigs have facilitated dispersal of nonindigenous plant species throughout the monument by exposing soil for colonization (Kotanen 1995, Cushman et al. 2004).

Because of these threats NPS managers were compelled to take action and elected to remove feral pigs permanently from a portion of PNM using an exclosure and a concentrated eradication program. To this end, NPS initiated construction of a perimeter fence in 1985. In 2002 NPS started coordinating efforts with the Institute for Wildlife Studies (IWS) for design and implementation of a feral pig eradication program. Eradication began in October 2003 upon completion of the exclosure. Our objectives were to remove all feral pigs from the exclosure and to document and analyze the eradication process to provide useful information for managers implementing future feral pig control and eradication programs.

STUDY AREA

Pinnacles National Monument encompassed >97 km^2 of chaparral, oak woodlands, riparian areas, and rock formations, with nearly 65 km^2 designated as wilderness area. Contiguous stands of thick vegetation occurred across most canyons and ridge tops, ranging in elevation from 254 m to 1,007 m. Chaparral comprised 80% of vegetative cover, consisting primarily of chamise (*Adenostoma fasciculatum*), ceanothus (*Ceanothus cuneatus*), and manzanita (*Arctostaphylos* spp.). There was a dry season from May to October and a winter wet season that produced an average annual rainfall of 30 cm. Winter lows approached 0° C and summer highs regularly reached 43° C. The entire monument was bounded by private land with little access to its perimeter, and there

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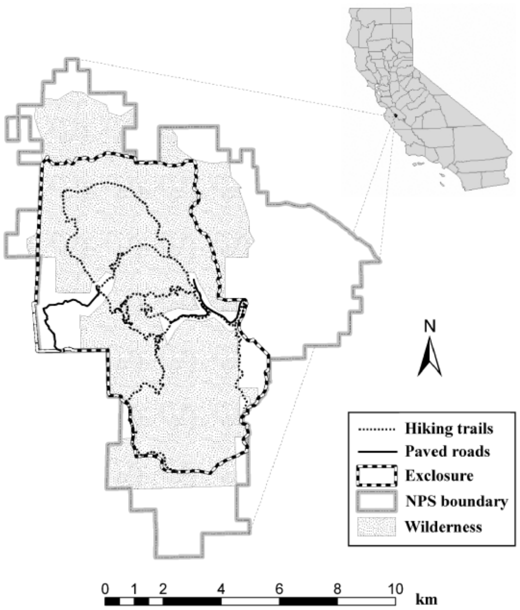

Figure 1. National Park Service (NPS) boundaries, designated wilderness area, and routes of access during October 2003–March 2006 when we eradicated all feral pigs from the 57-km^2 exclosure at Pinnacles National Monument, California, USA.

were only 2 roads, resulting in limited access to much of the interior.

METHODS

Construction on the exclosure began in 1985, and was completed in 2003 at a cost of nearly $2 million (United States currency; D. Louie, NPS, personal communication). The NPS erected 42 km of fence enclosing approximately 57 km^2 of PNM land, including $>70\%$ of the designated wilderness within the monument (Fig. 1). Mangers chose a tensioned fence design using woven wire mesh to a height of 65–70 cm with strands of barbed wire strung directly along the top and bottom of the woven wire and 2 additional strands 10 cm and 40 cm above the woven wire, which created a fence with a total height of 110 cm. Workers fastened fencing material to metal pickets at 2.4-m intervals and secured the fence to the ground midway between pickets with a spade-type anchor affixed to steel cable. Workers built bracing structures with treated wood posts and spaced them ≤ 50 m apart. All anchors, pickets, and bracing structures were set to a depth of 0.6 m. Workers periodically cleared brush from the fence to facilitate access for repairs and detection of damage. The entire fence was walked for repair purposes at least monthly and after any substantial storm.

A variety of techniques have been used to control and eradicate feral pigs, including trapping, tracking dogs, ground-hunting or shooting, aerial-shooting, snaring, poisoning, and Judas animals (Katahira et al. 1993, Saunders et al. 1993, McIlroy and Gifford 1997, Choquenot et al. 1999, Cruz et al. 2005). However, because of administrative constraints regarding allowable activities on designated wilderness lands and potential conflicts with native wildlife and humans, we identified trapping, hunting with dogs, ground-hunting, and Judas animals as the most practical and least intrusive methods of achieving eradication at PNM. Additionally, to avoid lead poisoning of California condors (*Gymnogyps californianus*) from scavenged pig carcasses we used only nonlead ammunition (Barnes-X, American Fork, UT; Hevishot, Sweet Home, OR).

An important consideration in any eradication program is work effort and associated costs. To assess program efficiency we recorded all hours spent in the field and all hours invested in administrative and other project-related duties. Additionally, we closely tracked associated costs of labor, travel, equipment, and care of hunting dogs. We then evaluated these data relative to number of pigs removed to attain rates of removal and costs associated with each aspect of the project.

During this program we adhered to animal welfare protocols for destruction of feral pigs defined by a NPS Environmental Assessment (NPS 2003). For each pig we recorded date, method of collection, sex, and age based on tooth eruption. Because of variation in accuracy of aging pigs by dentition, we assigned animals to 1 of 5 age categories: 1 (neonate), 2 (juv), 3 (yearling), 4 (subad), and 5 (ad) after Mayer and Brisbin (1991). We then used age and sex data to reconstruct demographics of the preeradication feral pig population.

Trapping Techniques

We used traps of rectangular configuration (2.4 m long $\times$ 2.4 m wide $\times$ 1.5 m tall) and galvanized steel construction, consisting of 4 tubular framed panels (3 side panels and 1 door panel) covered with 11.5-gage chain-link fence material. We shackled panels together at the corners with steel butterfly clamps and secured a 4-gage steel mesh to the bottom of the panels along the floor. We used a swinging door (0.6 m wide $\times$ 1.0 m tall) held open with a pivoting metal trigger mechanism fastened to one side panel and tethered to a bait bucket at the back of the trap. We selected this trap configuration because of its simplicity of design, effectiveness at other locations in California, and versatility of use, because traps could capture multiple feral pigs and also could be disassembled and moved easily by hand or helicopter (McCann et al. 2004).

For trapping and all other baiting purposes we used corn-based commercial pig pellets (Nutrena, Minneapolis, MN) as bait. To maximize trapping effectiveness we prebaited traps and left the door locked open for a period of 7 days before they were set for capture (Saunders et al. 1993). We typically set traps 2 hours before sunset and checked them before sunrise, which allowed us to avoid exposing trapped pigs to elevated midday temperatures and to prevent visitors from viewing them. In an additional effort to be discrete we used suppressed 9-mm handguns to dispatch trapped pigs. We also shot (with rifle or shotgun) feral pigs that were encountered along the trap line. We considered these animals as being removed by the trapping technique because personnel were in the field for the primary purpose of trapping. However, for each trap-night (a period ranging from 3 hr to 24 hr) we recorded date and number of pigs captured per trap separately from free-ranging feral pigs collected while checking traps.

Hunting Techniques

We used stand-hunting and spot-and-stalk techniques in early morning or late evening hours when pigs were found to be most active and personnel could easily view and traverse the landscape. We conducted hunting over bait and spotlighting primarily in the evening hours after sunset, but we occasionally used these techniques in the early morning hours before sunrise to coincide with activity patterns of certain feral pigs. To aid in reduced light situations we used a variety of weapon sights and illumination devices, including night-vision rifle scopes (B. E. Meyer Co., Redmond, WA), night-vision goggles (ITT Industries, White Plains, NY), and hand-held and firearm-mounted spotlights (SureFire LLC, Fountain Valley, CA).

We used teams of 3–6 trained hunting dogs, primarily of Catahoula and Plott crossbreeds, to track and corner or bay feral pigs. Once a pig or group of pigs was bayed, we quietly moved to the site to dispatch them by gunshot. We used this technique in the early morning hours of the day and during cool, wet periods of the year to facilitate effective tracking of pig scent and to prevent overheating of dogs. We fitted our dogs with protective collars and vests to protect them from pigs, and we used radiotelemetry (Communications Specialists, Inc., Orange, CA) to locate them when tracking pigs out of sight or hearing range.

Judas methods have been used extensively on feral goat (*Capri hircus*) removal projects (Taylor and Katahira 1988, Keegan et al. 1994, Campbell et al. 2005) and to a lesser extent for feral pig control and eradication (McIlroy and Gifford 1997, Wilcox et al. 2004). Based on Wilcox et al. (2004) we used adult sows as Judas animals. When we trapped sows we anesthetized them using Telazol (Tiletamine + Zolazapam) at a dosage of 4 mg/kg, delivered via a jab-pole syringe. We then marked them with numbered ear tags and fitted them with a radiotelemetry collar (Communications Specialists) before release. We trapped and processed 7 feral pigs in this manner within the exclosure at PNM during summer and autumn 2004 and an additional 3 pigs on NPS property outside of the exclosure in summer 2005. We surgically spayed the latter 3 pigs before release within the exclosure.

Upon release we allowed Judas pigs 2 weeks to acclimatize to the collars and reestablish normal behavior before being hunted. We pursued Judas pigs in the early morning or late evening hours, operating singly or through coordinated efforts of 2–3 hunters. When we received a signal from a collared pig, we homed in to the location and positioned ourselves to observe the Judas animal, at which time we attempted to dispatch any uncollared feral pigs associated with the Judas pig.

Because of the success of prior studies using transects to survey for feral pig sign to determine eradication (Barrett et al. 1988, Katahira et al. 1993) and those using bait to attract pigs to trapping or poisoning sites (McIlroy et al. 1993, Saunders et al. 1993, Twigg et al. 2005), we felt confident that a combination of the 2 techniques would be a viable approach for monitoring. Additionally, the success of our trapping campaign gave reason to believe that our monitoring program using the same bait would be effective. Therefore, we established 8 transects and 89 bait sites along approximately 110 km of existing hiking trails, game trails, and watersheds traversing the exclosure. We placed bait sites $\geq$0.3 km apart and arranged them to ensure that all points within the exclosure were within 2 km of $\geq$1 bait site, within a typical home-range size of feral pigs in California (Sweitzer et al. 2000, Wilcox et al. 2004). To establish each bait site we raked and smoothed the ground to create a 1.5-m-diameter track pan, then placed bait (1.0–1.5 kg) in the center of the area to attract pigs. We checked transects and bait sites for evidence of fresh pig sign (e.g., tracks, scat, and rooting), smoothed the track pan, and refreshed bait bimonthly or on a weekly basis when possible. However, monitoring efforts were sometimes discontinued when other eradication activities (e.g., removal of a detected pig) required the full attention of our staff. Whenever we located feral pig sign we positioned a digital trail camera (Bushnell Corporation, Overland Park, KS; Nature Vision, Inc., Brainerd, MN) at the site along with 10–15 kg of bait. If pigs returned to the site a photograph was captured along with the time and date of the visit. We then hunted the bait site at the appropriate time. In this way monitoring activities worked hand in hand with removal activities to identify pigs and to facilitate their removal.

RESULTS

Program Efficiency

We removed 200 feral pigs from the exclosure at PNM, including 3 pigs that were trapped outside of the exclosure and released within for Judas purposes. We achieved eradication with 13,489 hours at a cost of $623,601 (United States currency), reflecting only contracted eradication work conducted by IWS (Table 1). Additional costs of fence construction have been estimated at $2 million (United States currency), but cumulative costs born by the NPS for implementation and support of the project have not been estimated. Field hours in pursuit of feral pigs accounted for 35.8% of project time, at an effort of 24.2 hours per pig removed across all techniques. Total hours spent on all aspects of the project (field work, travel, and administrative duties) resulted in a comprehensive effort of 67.5 hours per pig. Travel and project support duties required 22.5% and

Table 1. Expenditures during the period October 2003–August 2006 for contracted feral pig eradication by the Institute for Wildlife Studies at Pinnacles National Monument, California, USA.

Category	Description	Cost[a]
Personnel	Salary for 2–3 full-time biologists	321,437
Transportation	2 vehicles (4-wheel drive), fuel, and maintenance	59,610
Dogs	Kennel, veterinary care, feed, and equipment	28,169
Housing	3-bedroom house with office facilities	47,659
Traps	Fabrication and delivery of 20 traps	9,025
Trapping support	Bait, steel mesh, wire, and tools	5,760
Firearms	10 firearms and nonlead ammunition	9,109
Miscellaneous supplies	Field tools, backpacks, etc.	14,200
Administrative	Other project support and maintenance	128,632
Total		623,601

[a] Costs are in United States dollars.

31.5% of project time respectively. Monitoring for feral pig sign accounted for the remaining 10.2%.

We initiated the program with an intensive trapping campaign, which removed a large portion (>70%) of the feral pig population in a short period (Figs. 2, 3). When traps became less effective we began using hunting techniques to further reduce the feral pig population. In the first quarter of the program feral pig removal/hour was most efficient. From that time forward effort per pig fluctuated but trended toward an increase per quarter until all feral pigs were removed (Fig. 3). The most notable fluctuation in effort occurred during winter 2004 when the feral pig population approached zero, then rebounded slightly after our Judas animals reproduced in spring 2005.

The initial feral pig population at PNM numbered approximately 165 individuals and was highly stratified, >90% consisting of adult and juvenile pigs (Table 2). During the first 3 months of the project we removed 71.5% of the pre-eradication feral pig population, after 6 months we removed 89.0%, and during the first year we removed 96.4%, along with all offspring produced during that period (Fig. 2). Overall we removed 100 (50.0%) feral pigs by capture in traps with a trap success of 0.26 pigs per trap-night, and we took another 23 (11.5%) feral pigs opportunistically along the trap line. Ground-hunting accounted for 48 (24.0%) feral pigs, and we used tracking dogs to remove 6 (3.0%) pigs. We used the Judas technique to remove 21 (10.5%) feral pigs. However, it should be noted that Judas techniques were not directly responsible for the removal of any feral pigs other than Judas offspring and Judas pigs. Two of the 10 Judas pigs died of unknown causes and we counted them as removed by other (1.0% of all pigs) but they were not reflected in population reduction calculations. The destruction of the remaining Judas pigs contributed to the overall totals for the techniques by which they were removed: trapping (2), dogs (3), Judas hunting (3).

Monitoring for Detection of Residual Feral Pigs

From 1 December 2004 to 31 August 2006 we checked 3,083 bait sites along 281 transects for evidence of feral pig sign, including 38 transects checked by NPS personnel. We detected feral pig sign at 2.3% of all bait sites and on 19.2% of all transects. Percentage of bait sites and transects with pig sign generally followed feral pig density as it varied over time (Fig. 4). However, we collected insufficient or no data during March 2005–June 2005 when monitoring ceased for

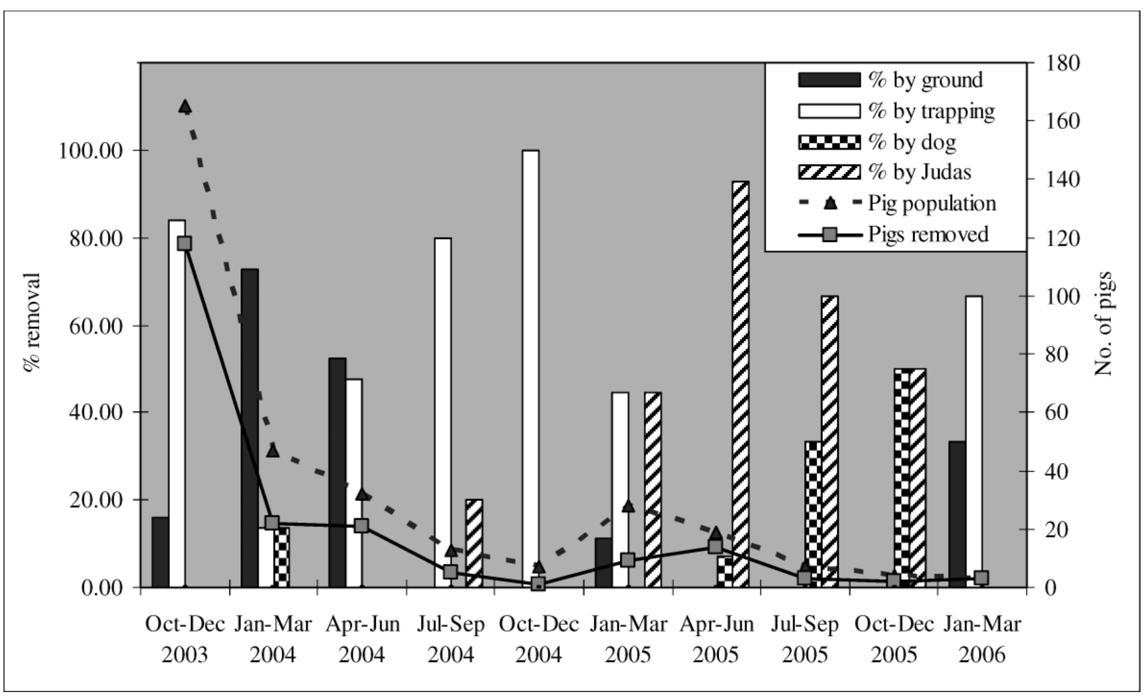

Figure 2. Techniques we used to remove feral pigs at varying population levels during the period October 2003–March 2006 when we eradicated all feral pigs from the exclosure at Pinnacles National Monument, California, USA.

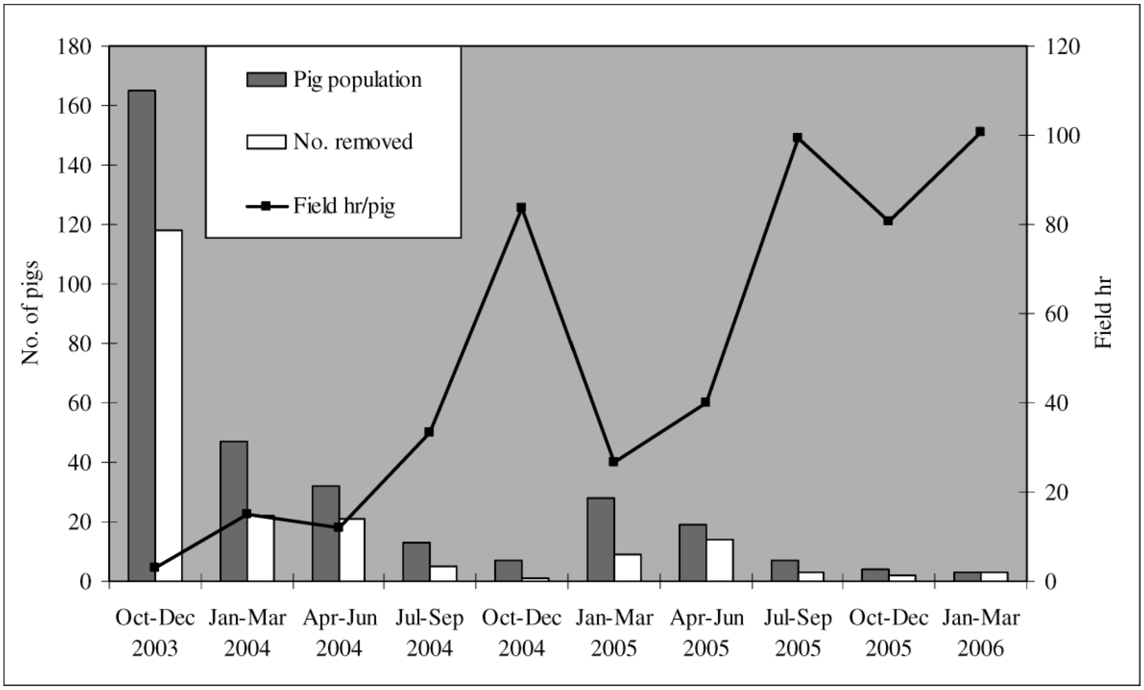

Figure 3. Feral pig eradication program efficiency during the period October 2003–March 2006 at Pinnacles National Monument, California, USA.

efforts to be focused on the removal of 22 offspring born to our Judas pigs and during October and December 2005 because of staffing commitments to other project duties.

Although we did not always conduct the monitoring program consistently we were able to effectively track the feral pig population and detect movements of both residual and new feral pigs in the exclosure. For example, during February 2006 a pig breeched the exclosure through what we believe was an open gate, because PNM staff recorded the incident and no breaks in the fence could be detected. Our monitoring efforts located this pig within 1 month of its entry to the exclosure, and information from cameras positioned at monitoring sites allowed us to ambush the pregnant sow and dispatch her before she gave birth. Several offspring of Judas pigs and the last uncollared mature feral pig were previously removed in a similar manner.

In addition to transects and bait sites we used experience gained while hunting with dogs and pursuing Judas animals to indicate that the feral pig population was approaching zero. After March 2006, when the last known feral pig was removed from the exclosure, we began an intensive monitoring phase. During this time no feral pigs were detected by tracking dogs, there were no visual observations, and we detected no feral pig sign at any bait sites or along any transects (Fig. 4). Based upon this information we declared the exclosure free of pigs in June 2006. To ensure that all feral pigs were in fact removed, intensive monitoring continued through August 2006 but produced no feral pig sign (Fig. 4).

DISCUSSION

Eradication of feral pigs requires the ability to alter techniques in response to changing animal densities, environmental conditions, and changes in animal behavior to avoid removal efforts (Saunders and Bryant 1988, Morrison et al. 2007). At PNM we used a suite of techniques and varied their application to respond to these factors as the feral pig population declined. Although fence construction occurred over an 18-year period, the eradication was swift. Once eradication began we maintained an

Table 2. Feral pig population demographics (age and sex) before eradication began and total numbers we removed by technique in each age class during October 2003–March 2006 at Pinnacles National Monument, California, USA.

	Demographics of pre-eradication feral pig population ($n = 165$)				No. pigs removed by age class and technique ($n = 198$)[a]			
Age class	F	M	% of total	Total	Trapping	Ground	Dogs	Judas[b]
1 = neonate	3	2	3	5	13	0	0	17
2 = juv	43	50	56	93	59	24	1	1
3 = yearling	4	1	3	5	4	8	0	0
4 = subad	1	1	1	2	5	0	0	0
5 = ad	43	17	37	60	42	16	5	3
Total	94	71	100	165	123	48	6	21

[a] Two Judas pigs died of unknown causes and we did not include them in the analysis of pig removal.
[b] We removed only Judas animals and their offspring with the Judas technique.

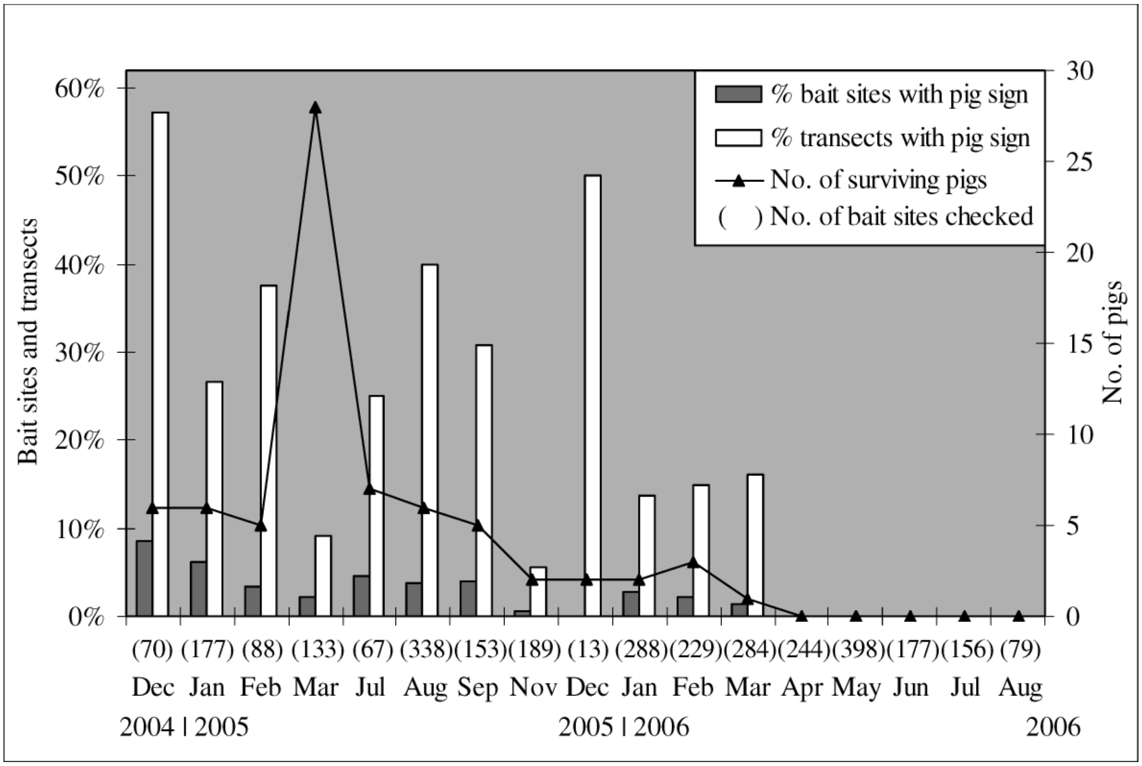

Figure 4. Monitoring efforts for detection of feral pig sign during the period December 2004–August 2006 at Pinnacles National Monument, California, USA.

intensive level of removal pressure on the feral pig population and were able to complete the project within 3 years.

There are many advantages to implementing an intensive eradication program. First, a high-intensity program is necessary to cause eradication in a short period (Dzieciolowski et al. 1992, Morrison et al. 2007). Second, as discussed by Morrison et al. (2007) fewer animals need be destroyed, because populations are not allowed to mount an effective reproductive response. Third, although the cost of an intensive eradication program is high it will be less than the cost of perpetual control or an eradication program that continues for decades. These trends are apparent when comparing duration, number of pigs removed, and costs between eradication programs in California and elsewhere (Table 3). Finally, although public outcry against an eradication or control program can be intense, a short and well-managed program might ultimately receive less scrutiny.

The cost of eradication at PNM fell within the range of costs reported elsewhere in California (Table 3) but expenditures can vary greatly depending upon factors specific to the eradication site. For example, projects that do not require fence can realize considerable savings (Table 3). However, where eradication is attempted at mainland locations fencing is necessary to isolate the population (Barrett et al. 1988). Fencing has added benefits, such as the ability to subdivide large eradication sites into manageable units (Katahira et al. 1993, Schuyler et al. 2002). Another consideration is relative cost of the different techniques. Where cost-effective methods (e.g., trapping) can be used to remove most feral pigs, savings would be experienced over more labor-intensive methods of feral pig removal (e.g., dogs), especially when considering the high cost of personnel (Table 1). Thus, cost is linked to technique and overall program efficiency. At PNM program efficiency was not as high as that reported at other locations (Katahira et al. 1993, Lombardo and Faulkner 2000). However, several factors help explain this result. Thick vegetation occurring throughout the site and limited vehicle access reduced the efficiency of field techniques, and off-site housing of staff reduced overall efficiency because of work time devoted to travel. Undoubtedly, the amount of effort devoted to the Judas pig program and a lengthy period for determining that the exclosure was free of pigs also contributed low program efficiency when measured as hours per pig removed.

Removal Techniques

Effectiveness of removal techniques depends upon local environmental factors (e.g., natural forage, vegetative cover, topography, climate) influencing feral pig behavior (Saunders and Bryant 1988, Saunders et al. 1993, Caley and Ottley 1995). Therefore, it is difficult to directly compare techniques between programs. For example, a high level of bait acceptance was our greatest advantage at PNM. However, bait acceptance is often inconsistent, depending upon seasonal variations in natural forage or alternate nutrition present in the environment (McIlroy et al. 1993, Saunders et al. 1993, Choquenot and Lukins 1996). Thus, effectiveness of techniques relying on attracting feral pigs

Table 3. Seven feral pig eradication programs occurring during 1973–2006 in California, USA, and elsewhere.

Program characteristics	Annadel State Park, USA[a]	Hawaii Volcanoes National Park, USA[b]	Pinnacles National Monument, USA	Santa Catalina Island, USA[c,d]	Santa Rosa Island, USA[e]	Santa Cruz Island, USA[f]	Santiago Island, Ecuador[g]
Project duration	1985–1987	1983–1989	2003–2006	1990–2005	1991–1993	2004–2006	1973–2003
No. pigs removed	144	175	200	>12,000	1,175	5,036	18,800
Area (km^2)	20	30	57	194	215	249	585
Cost of fencing (United States currency)[h]	90,000	>600,000	2,000,000	941,672	0	1,224,001[i]	0
Total expense (United States currency)[h]	165,000	[j]	2,623,202	3,402,290[i]	795,000	[j]	[j]
Removal techniques employed	Trapping and dogs	Dogs, aerial-shooting, trapping, and snaring	Trapping, ground-hunting, dogs, and Judas animals	Trapping, dogs, ground-hunting, and sport-hunting	Dogs, ground-hunting, aerial-shooting, and trapping	Trapping, aerial-shooting, ground-hunting, and dogs [j]	Ground-hunting, dogs, poisoning, trapping, and snares
Monitoring techniques	Transects	Transects	Transects and bait sites	Transects and searching	Transects and aerial survey	Transects and searching	Searching and bait sites

[a] Barrett et al. (1988).
[b] Adapted from Katahira et al. (1993).
[c] Schuyler et al. (2002).
[d] At least one pig may still remain on Santa Catalina Island (J. King, Catalina Island Conservancy, personal communication).
[e] Modified from Lombardo and Faulkner (2000).
[f] Morrison et al. (2007).
[g] Adapted from Cruz et al. (2005).
[h] Expenditures not adjusted for inflation.
[i] Sweitzer, R. A., and B. E. McCann. 2007. Natural areas ecological damage and economic costs survey report. Unpublished Report to the Exotic/Invasive Pest Management Program, University of California-Davis, University of California-Riverside, and United States Department of Agriculture. 39 pages.
[j] Complete information not available.

with bait will vary between locations. The manner in which techniques are applied and the ultimate goal of the program (e.g., control or eradication) are also important (Hone and Stone 1989). As such, short-duration eradication programs are difficult to compare to control operations, research projects, or even long-duration eradication programs because they are conducted on populations that decline quickly. Therefore, primary removal techniques are exposed to the greatest number of feral pigs, providing them an increased potential for success over those employed later in the project.

The closest comparison to the eradication at PNM is Barrett et al. (1988), which describes the removal of feral pigs from Annadel State Park (ASP), California. At ASP trapping and hunting with dogs were the methods of choice, and fencing was used along a portion of the removal area to prevent ingress of feral pigs from adjoining land. Similar to PNM, traps were successfully used and removed most feral pigs. Considering the success of traps at these 2 sites, and that reported at other locations in California (Sweitzer et al. 1997, Schuyler et al. 2002), trapping should be considered by others attempting control or eradication in similar environments. However, it should be noted that traps are not successful at all locations (Coblentz and Baber 1987, Katahira et al. 1993). At PNM the combination of trapping and opportunistic shooting along the trap line aided in a quick decline in feral pig numbers, especially with a population consisting mainly of adult females and juvenile pigs that were highly susceptible to this technique (Table 2). Tracking dogs, on the other hand, were not particularly successful at our location. Barrett et al. (1988) reported reasonable success with dogs, but application of the technique varied considerably between the 2 sites. It appears that there was all-terrain-vehicle access to ASP, and dogs were used consistently throughout their program. At PNM access to most of the exclosure was by foot, and we opted to use dogs primarily to detect and remove residual feral pigs, which could explain why we experienced lower success rates with dogs than reported at ASP or in other studies (Katahira et al. 1993, Lombardo and Faulkner 2000, Schuyler et al. 2002).

Although ground-hunting and Judas techniques were not used at ASP, we found them valuable for completing the eradication at PNM (Fig. 2). Because ground-hunting has been employed with such success at a number of eradication sites it should be considered by others attempting feral pig removal (Table 3). We found ground-hunting to be particularly useful when employed as a secondary technique to further reduce the feral pig population after trapping. Spot-and-stalk and hunting over bait sites were the 2 most valuable variations, and the use of night-vision at bait sites was especially valuable for removing feral pigs that eluded other techniques. We can report only marginal success with Judas pigs. However, few uncollared feral pigs (22 Judas offspring and $\leq$10 other uncollared pigs) shared the exclosure with the Judas pigs during their use, providing little opportunity for success. For those wishing to attempt this method we recommend that all Judas animals be spayed before release, as indicated for feral goats by Campbell et al. (2005), because we spent a considerable amount of time removing offspring of Judas pigs at PNM.

Monitoring

Though transects and bait sites were used successfully at PNM and elsewhere (Table 3), basic monitoring information alone is not sufficient to determine that eradication is complete. Field experience and knowledge of the removal site are also required. As stated by Cruz et al. (2005:476), about the feral pig eradication on Santiago Island, Ecuador, "... hunters were keenly aware of the few remaining pigs and could identify each individual's sign." It is this level of dedication that provides confidence that a program is reaching an end. Therefore, managers would benefit by developing an intimate knowledge of their removal area and employing personnel that are able to remain on-site for the duration of the project. Additionally, based on our experience at PNM a short-interval monitoring program (at least monthly) is valuable, providing useful information for directing removal activities. Finally, new approaches that facilitate a quick eradication and determination that the last animals have been removed, such as that described by Morrison et al. (2007), should be considered.

MANAGEMENT IMPLICATIONS

We hope that the success of this feral pig eradication program in a mainland setting encourages their eradication at other locations around the world. Considering the cost of perpetual control of feral pigs and their continued damaging effects even when controlled, eradication is a preferable alternative.

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