PROHUNT INCORPORATED

Island Restoration and Wild Animal Control Specialists

A New Approach for Ungulate Eradication; A Case Study for Success

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1.0 Acknowledgements

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2.0 Executive Summary

Extinction rates on islands globally are alarmingly high and often due to human related impacts and the presence of non-native species. To conserve biodiversity on islands inhabited by feral ungulate populations, land mangers may need to implement eradication programs to protect endemic species. However, eradication projects in general tend to have a high risk of failure for a variety of reasons. Recently, an island feral pig eradication was accomplished that successfully managed this risk and now provides a model for an efficient approach and methods that can be applied to eradication projects elsewhere.

Santa Cruz Island, off the coast of California, supports numerous endemic plant and animal species and also had a feral pig population negatively impacting natural and cultural resources on the island. Land managers, The Nature Conservancy and Channel Islands National Park, recognized the need for pig eradication and hired Prohunt Inc. of New Zealand to conduct the project.

Just two years after project implementation the feral pig population (totalling over 5000) was removed from Santa Cruz Island. The hunting began on the >60,000 acre island preserve in March 2005 and was followed by intensive monitoring and an eradication certification phase. The last pig on the island (a radio collared Sentinel pig) was removed in January 2007. Only 22 months after hunting began, the island was certified 'pig-free' by using hunting data in quantitative analyses to assess the probability that all pigs had been detected and dispatched. This project's success was due to several factors, especially the short time frame within which it was completed.

By reducing project duration, common obstacles that can prematurely halt a project, such as funding or legal restrictions, were limited. The project's short time frame also reduced overall population replacement, thereby lowering the total number of animals that ultimately needed to be removed from the island. However, it was Prohunt's project design and approach that was critical in achieving an eradication of this size and at such an accelerated rate.

Prohunt's strategic hunting approach was specifically designed to address and avoid the most common causes of failure in eradication projects from the onset. Keeping pigs naive to hunters throughout the project was vital. The greatest threat to success would have been creating an educated population that was skilled in avoiding hunters. Hunting expertise and the strategic application of trapping, aerial hunting, and ground hunting (in that order) were the foundation of Prohunt's methods. The adaptive approach of this project enabled Prohunt to collaborate with Landcare Research, The Nature Conservancy, and the National Park Service to improve monitoring and certification methods and apply them successfully in the field. The monitoring and certification phases ensured hunting had been effective at removing 100 percent of the pig population from Santa Cruz Island. The project was adaptive when unexpected challenges arose, yet remained ahead of schedule despite modifying methods as needed.

The challenges of completing an eradication project of this size and intensity, in addition to the risk land managers accept when funding one, are substantial. This project stands out because it successfully addressed these challenges and the high risk of failure inherent to all eradication projects due to: a loss of animal naivety, a lack of detection of pigs at low density, and funding or legal challenges that may halt a project prior to completion. The Santa Cruz Island feral pig project is both a conservation achievement and a testament that the risks involved in eradications can be managed. In addition, the accelerated project timeline demonstrated how strategic project planning can achieve conservation goals much faster than previously believed.

Prohunt is highlighting this project as a case study to demonstrate that applying the best hunting approach, followed by a thorough monitoring program, can lead to successful ungulate eradications even in topographically diverse regions. We believe that successful and efficient feral animal eradications will result in increased conservation around the world.

Santa Cruz Island, California. Photo: S. Francis

3.0 Introduction

3.1 Preserving Island Biodiversity

Islands are home to high numbers of endemic and rare species. Unfortunately, island species are also frequently threatened or endangered, and many have already gone extinct worldwide. One of the dominant causes of high extinction rates and threats to unique island species is the introduction and proliferation of non-native species. Non-native vertebrates (often introduced by humans) can directly or indirectly lead to species extinction and land managers globally must address these threats with ambitious eradication efforts (Myers et al. 2000; IUCN 2002). Feral ungulates, a remnant from ranching industry and a food source for island residents, have been a target in many areas, including the Channel Islands of California.

SCI's dry, southern side

3.2 Santa Cruz Island Project Background

The California Channel Islands are renowned as "California's Galapagos". Of the eight islands, Santa Cruz is the largest and most diverse. Totalling 60,784 acres (24,599 ha), it lies 22 miles across the Santa Barbara Channel from the nearest mainland point. The island is jointly owned by The Nature Conservancy (owning 76%) and the National Park Service, which owns the eastern 24% of the island. The island is incredibly rich biologically and is home to 12 endemic species; nine endangered or threatened plants, and the endangered Santa Cruz Island Fox (*Urocyon littoralis santacruzae*). In addition, there are an estimated 3000 Native American archaeological sites (some 10,000 years old) that are protected by law.

Non-native species (domestic sheep, cattle, and pigs) were introduced to the island in the 1800's and caused extensive damage to the island's biological and cultural resources. Domestic pigs (*Sus scrofa*), first introduced to California by the Spanish in 1769, were brought to Santa Cruz Island in 1852 (Schuyler 1998). By 1857 they had escaped and become feral. Annual estimates of the feral pig population on the island had ranged from 1,500 to over 4,000 and were reportedly at higher densities on the island than populations using similar areas on the mainland (Sterner 1990). In 2003, The Nature Conservancy (TNC) and the National Park Service (NPS) estimated pig numbers could be as high as 5000.

Since the 1990's, feral pigs on Santa Cruz Island (SCI) were closely linked to severe island fox declines (Roemer 2001) and the endangered status of nine plants (USFWS 2000). In addition, the pigs negatively impacted and destroyed many island archaeological sites. Feral pig removal became an important component of Santa Cruz Island's science-based restoration program, jointly developed

and funded by The Nature Conservancy (TNC) and Channel Islands National Park (NPS) to protect archaeological resources and preserve biodiversity.

To determine the best methods for the restoration program, NPS completed an Environmental Impact Statement (NPS 2002). It documented the need to conduct an island-wide feral pig eradication to protect the unique resources found on SCI. The EIS outlined project alternatives and eradication by fenced zone was preferred to maximize project efficiency and the likelihood of success. Following EIS completion, NPS and TNC worked together to raise the necessary funds and support for the project. Both land managers recognized that an eradication of this scale would be challenging and they mitigated the risks through careful pre-implementation planning.

3.3 The Challenge and Risks that Eradications Present

The challenge that eradication projects present cannot be over-emphasized and success of such projects tends to be scale dependent. The eradication of feral pigs had only ever been accomplished on islands of 21,450 hectares or less (Lombardo and Faulkner 2000; Morrison et al. 2007), with the exception of Santiago Island (58,465 ha), which took 30 years to complete (Cruz et al. 2005). In general, eradication projects have a much greater probability of failure than success. They tend to be expensive, controversial, require excellent technical skills and planning, and the target species is typically reproducing throughout the project. In addition, if animals have the opportunity to escape from a lethal encounter with a hunter and become 'educated' about the hunting methods being used, they become wary and significantly more difficult to detect and remove.

Because animal control is controversial, the likelihood of legal action against an eradication project is high. This can create additional financial demands on land managers. Legal action could prevent project completion or public pressure can sway a land manager's commitment to a project, even if the eradication was considered the only solution to a conservation problem. If a project is halted due to loss of funding, diminished support, or legal action after 90 percent of the effort is completed, all previous investment in the project will be lost as the remaining population recovers to levels that existed prior to any eradication effort.

To reduce these risks, eradication projects must operate efficiently, which requires intensive planning and commitment by the organization conducting the field activities. It is very plausible that 10 percent of the field effort could remove 90 percent of the population and that the remaining population will require 90 percent of the work effort. Therefore, carefully designed field methods that consider how the final 10 percent of the population will be removed are necessary. In addition, follow up monitoring as well as the passage of time are necessary to ensure all animals were detected and dispatched. A critical question that may arise during an eradication project is: How do you know when there are no remaining undetected animals? Projects must be designed to manage this question in advance.

4.0 Eradication Approach and Contracted Work Plan

4.1 Request for Proposals

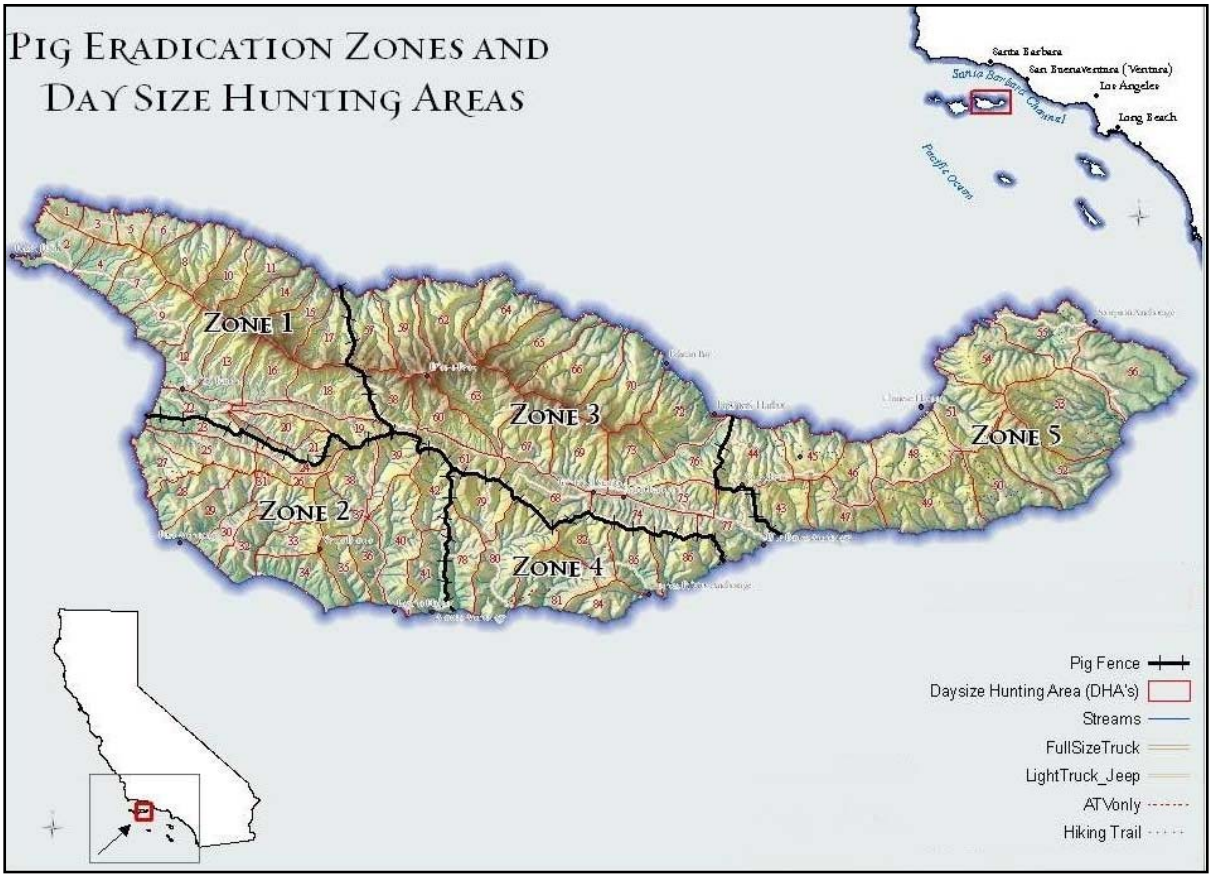
TNC and NPS produced a Request for Proposals (RFP) for the feral pig eradication project on SCI that had components that would reduce project risk and measure project success. First, the RFP limited the number of years that contractors would have to complete the project and created major incentives (payments were linked to project deliverables) that would motivate the contractor to keep on schedule. The faster the project could be completed, the greater the chance of success. The RFP required a strategic approach that would take advantage of smaller hunting units (five fenced zones) to increase the chance of eradication in each zone and ultimately across the whole island. It also mandated humane methods for all dispatches, thereby addressing public concerns for animal welfare. Finally, the RFP required a monitoring phase to search for any pigs that might remain after the hunt. TNC would assess whether the contractor had achieved eradication by conducting a certification phase. All interested project bidders had to consider the following for their proposed project design, methods, timeline, and budget:

- Conduct an eradication (not control) of all feral pigs on SCI in < 3 years
- Work within fenced zones using a strategic hunting approach
- Use lead free ammunition and humane dispatch methods
- Implement a monitoring phase for additional pigs following hunting in each zone
- Have no adverse effects on SCI native flora, fauna, or archaeological sites
- Forego substantial payment until deliverables (pig free zones) are accomplished
- Report on project success bi-weekly, monthly, and at project completion
- Manage project logistics from a remote island preserve

TNC and NPS assured prospective contractors that pig-proof fencing would be in place prior to project implementation. Fencing was not only recommended by the EIS but was recognized as the only feasible way to parcel the >60,000 acre island into manageable hunting units. TNC and NPS hired a contractor to construct the fence to separate the island into zones ranging from 6,250-17,180 acres each (Map 1). The fencing project was a major endeavour but greatly increased the chance of project success. Over 27 miles of fencing were constructed across all island topography. The fence was made of hog wire and was four feet high. It was also buried into the ground to prevent animals

Pig fencing constructed to make five eradication zones across the island

from digging under the fence. Native island animals, such as foxes and the Island Spotted Skunk (*Spilogale gracilis amphialus*), could freely move through the fence. An archaeological survey was conducted in concert with fence construction to ensure no Native American sites were disturbed during construction. After hunting began, the fence would be checked after every weather event to be certain it was not compromised by erosion or any other factors that would allow pigs to move from one zone to another.



Map 1. Santa Cruz Island pig eradication fenced zones and day size hunting units.

4.2 Prohunt's Eradication Approach

We (Prohunt Inc. of New Zealand) responded to the RFP and submitted a proposal that was based on managing the three major elements of risk to any eradication project: 1) educating your target, 2) population replacement, and 3) the uncertainty of project completion – when do you know the last pig has been removed? Morrison et al. (2007) describe key attributes to a successful eradication project which address these risks. Eliminating education of the target animal (and resulting wariness and detection difficulty) is the responsibility of the organization conducting the field work and can be managed with specific field techniques. Population replacement can be reduced by implementing an intensive project that does not encounter delays. Completion uncertainty can be managed with hunting and monitoring data collection and quantitative analyses.

The key strategy in our proposal was to eliminate target animal education in every aspect of the project. Prior to project implementation and throughout its duration, Prohunt would focus on how the last pig would be detected and dispatched. Despite the high pig population on SCI, NPS and TNC had restricted hunting in the past and pigs had only been subjected to sporadic ground hunting (without dogs) for the previous 8 years. This resulted in a population that was relatively naive to nearly all the hunting techniques we planned to use. The main factor needed to achieve eradication would be 100 percent effectiveness at putting all pigs 'at risk' and dispatching them on the first encounter throughout the project. This factor would be considered during every operational decision throughout the planning and execution of the contract. Prohunt's goal would be keeping the last pig as naive as the first. The greatest risk to the project would be creating a pool of educated pigs that were skilled in the avoidance of traps, hunters, dogs, and helicopters. If a pig received a sub-lethal application of an eradication technique and survived, it was unlikely it would be caught again using that same technique. By eliminating opportunities for pigs to become educated, we would never compromise their naivety, and would keep them relatively easy to detect.

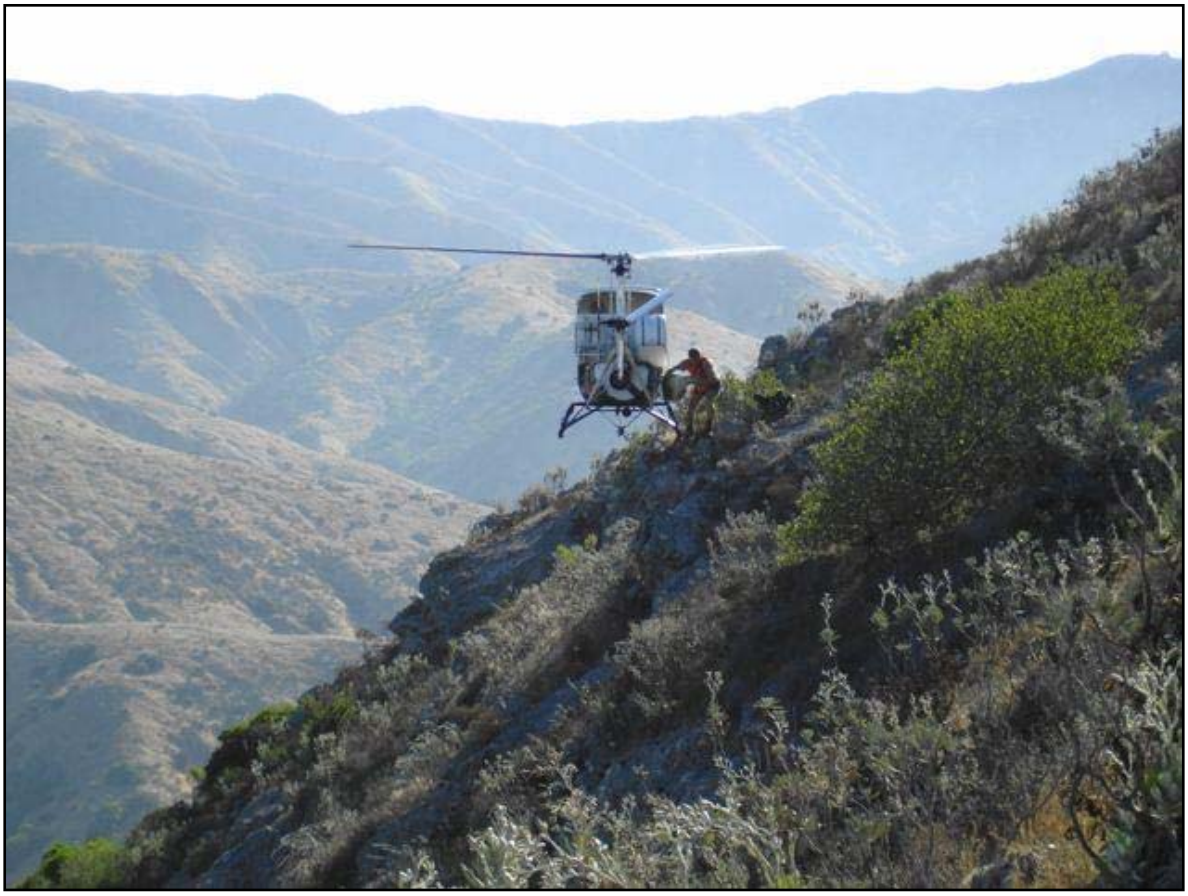
To reduce population replacement during the project, our proposed timeline and work plan for the project were based on a wide range of eradication and animal management projects we had undertaken over the past ten years. Hunting data collected during those projects were used to build an accurate estimate of hunter effort and helicopter hours needed to achieve the SCI pig eradication. Our goal was to accomplish eradication in the shortest time frame possible. Trapping would be employed first, followed by aerial hunting. Only after aerial hunting was complete would ground hunters mobilize using dogs. This approach would reduce the number of animals that ground hunters encountered and increase the chance of dispatching those they did. The length of time each hunting technique would be used in each zone would be determined by pig density, forest cover, and expected weather in each zone. This strategic application of trapping, aerial hunting, and ground hunting would enable us to dispatch the last pig well within the 3 year requirement.

In addition to the strategic use of hunting techniques, we employ a very skilled and disciplined team of hunters. During both aerial and ground hunting, hunters would have to be willing to forgo a pig dispatch if the situation did not meet the following criteria: 1) there was certainty that the pig would be dispatched and not escape, 2) if other pigs were nearby, every pig had a high probability of being dispatched, and 3) it was safe for hunters and dogs to dispatch the pig. Not only is this approach more humane, but it would be instrumental in reducing project duration, and therefore population replacement and the total number of pigs ultimately dispatched. Shortening project duration would have the added benefit of reducing the chance of financial or legal issues halting the project.

We planned to use technology and infrastructure to further improve project efficiency. We would use fully integrated global positioning systems (GPS), a geographic information system (GIS), and radio telemetry technology to collect data throughout the course of the project. These technologies and data would become the foundation for monitoring and establishing criteria for eradication certification. Helicopter use can greatly increase project intensity by efficiently deploying a hunting team daily. On SCI, the helicopter would service most daily activities, including hauling and placement of traps, trap baiting, aerial hunting, hunter pick up and drop off, radio-tracking, and sign surveys. It would also eliminate the need to rely on poor road

access, especially during the rainy season. We believed our application of efficient techniques and strategies would play a significant role toward achieving project success.

Prohunt's hunting methods proposed for SCI (and used on all our projects) are humane and met NPS and TNC requirements in their RFP. To address concerns for animal welfare NPS and TNC wanted the project to follow the American Veterinary Medical Association's stringent guidelines for humane euthanasia of animals (AVMA 2001). No snares or poison would be used for the project and every effort would be made to dispatch animals with a single shot. Any pig wounded during hunting would be followed and immediately dispatched. Hunting dogs could be used to track and bale but would not be used to restrain or hold a pig. To further protect island resources, no lead ammunition would be used during the project.



Typical hunter and dog pick up via helicopter

4.3 Contract Components and Timeline

Our proposal and approach were accepted and in November 2004 we signed a contract with TNC (the managing entity) to conduct the pig eradication on SCI. The contract was structured in three phases: 1) implement Prohunt's hunting approach, 2) include a strong monitoring component, and 3) provide for a certification phase to assess whether the island was pig-free at the

completion of the hunting and monitoring phases. The contract allowed for adaptive implementation for new techniques as various methods were assessed.

The work plan and project timeline (Table 1) were structured around these three phases and included detailed components and activities within each phase. We planned to hunt the zones in order of adjacency so that as each zone was cleared it reduced the chance of pig infiltration into neighboring zones in case of a breach in the fence. However, because each zone was an independent unit, hunting, monitoring, and certification activities took place simultaneously across multiple zones to maximize efficiency. For example, while one zone was hunted, another could be monitored simultaneously. The specific hunting techniques, however, were only ever employed in the following order: trapping, aerial hunting, and ground hunting.

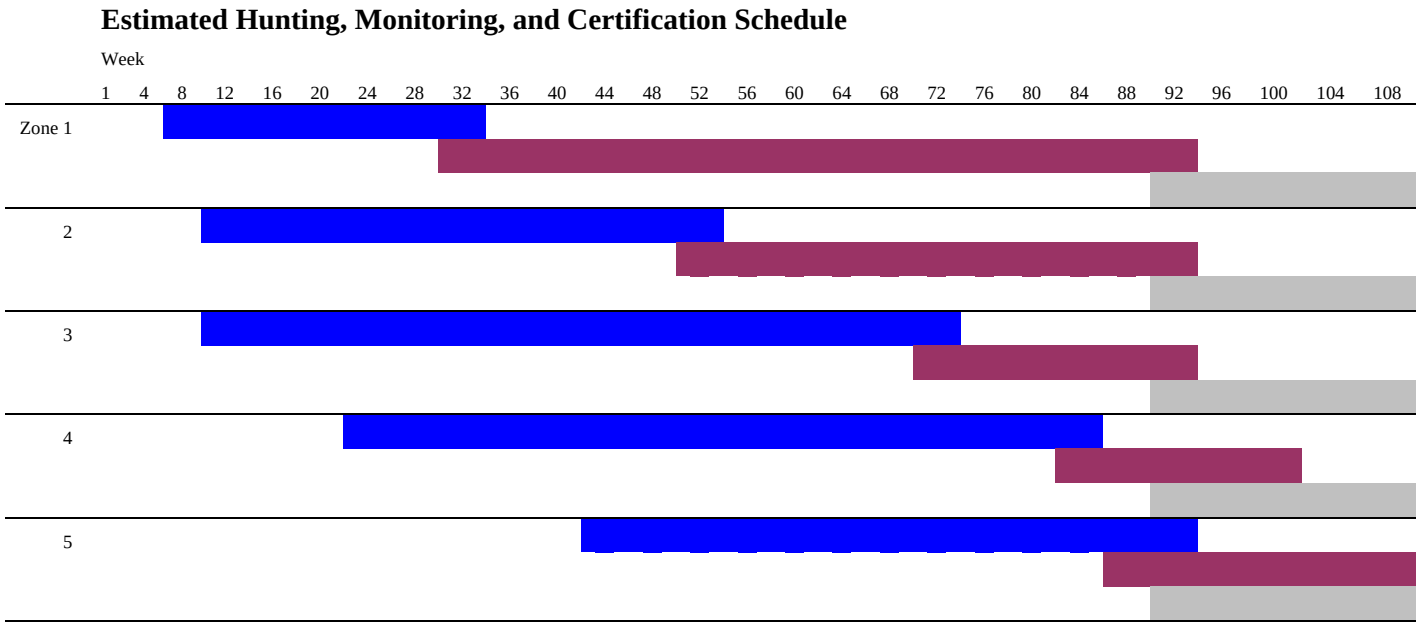
The contract specified the use of trapping, hunting, and monitoring techniques, including mark-recapture methods, the use of Judas and Sentinel pigs, forward-looking infrared (FLIR), and a pig detection and notification protocol. It proposed visual sign transects, remote cameras, and bait stations as certification techniques. One of the most important components of the contract was that it was designed with an adaptive approach to proposed techniques, which allowed Prohunt to improve techniques as needed. This ultimately increased the effectiveness of each project phase. Finally, the contract was intentionally incentive based, meaning that payments to Prohunt were only made upon deliverables (such as a zone being pig-free). This contract design pressures the contractor to perform in order to be paid and simultaneously creates the incentive to accomplish project deliverables ahead of schedule. If a contractor does not accomplish eradication, they are not paid by the land manager. However, if the contractor completes the eradication in advance of deadlines, they are paid in advance and can save on staff and other costs by demobilizing sooner. Ultimately, designing a contract this way is a win-win scenario for both the land manager and the contractor.

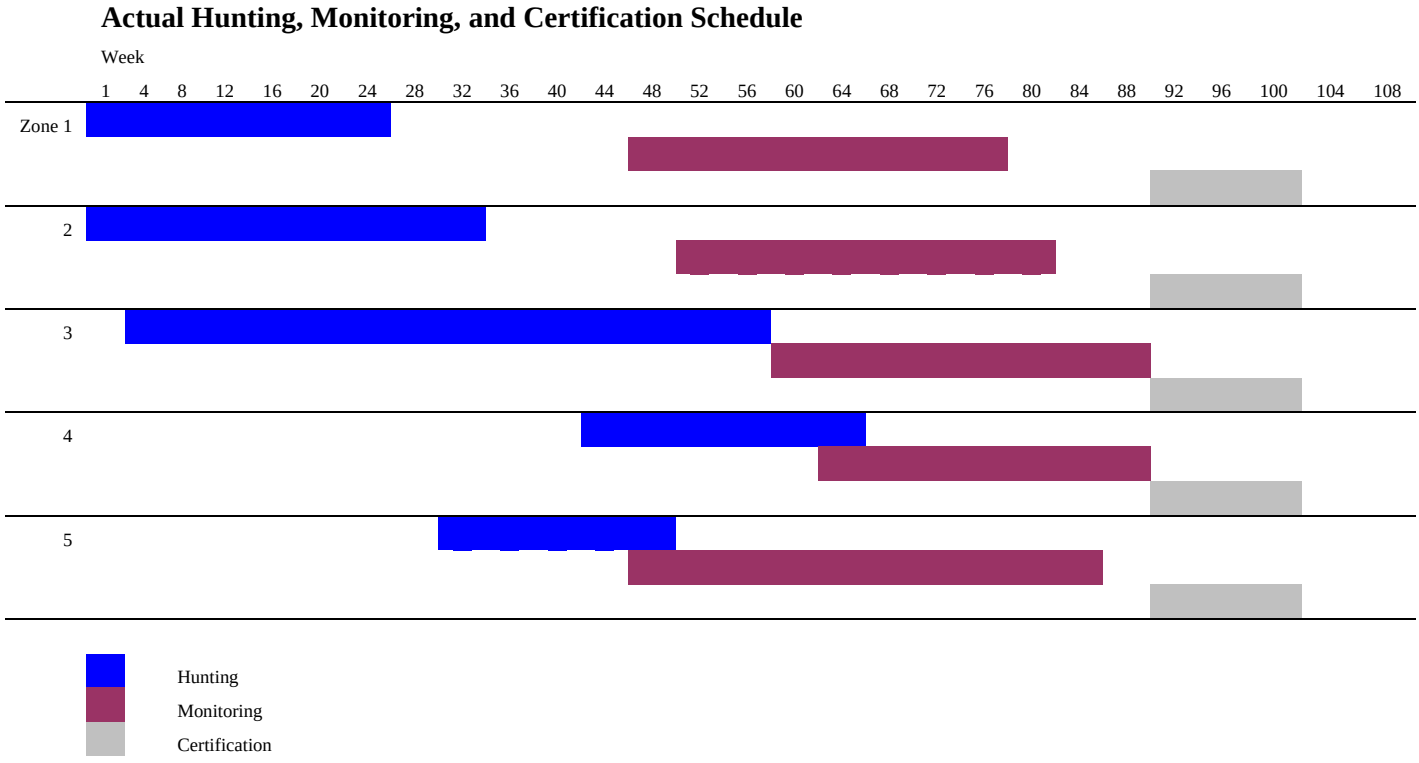
4.4 Safety

One of the considerations during the planning process was the awareness that a serious accident on Santa Cruz Island would have repercussions both politically and contractually. This risk was minimized by selecting professional hunters and pilots for the project that were working, or had worked, for Prohunt in the past. The hunters were well trained, extremely fit, used to working together as a team and working with the helicopter. The pilots were from New Zealand and had spent nearly all their flying careers undertaking venison recovery in the mountains and forests of New Zealand.

Using experienced team members minimized this risk substantially. The only injuries incurred over the 2.5 year span on SCI (with an average of 12 persons in the team) and over 1600 hrs helicopter flight time was a dislocated finger and a sprained ankle.

Table 1. Actual and estimated timeline summary.





5.0 Hunting

5.1 Methods

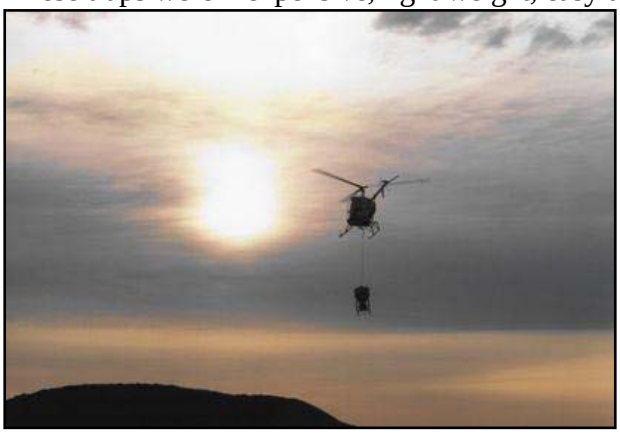
The hunting phase of the project consisted of trapping, aerial hunting, and ground hunting within each fenced zone. Hunting efficiency was greatly increased by our use of Judas pigs, hot spotting, and extensive helicopter support.

5.1.1 Trapping

Traps were a modified Australian silo trap. The design was a circular walk-in trap constructed of a single layer of hog wire, instead of silo mesh (not available locally). Traps were constructed using star pickets (t-posts), had self-closing one-way doors, were 1 meter high, and 4.5 meters in diameter. We reinforced the initial single layer of hog wire with a second offset layer to prevent large pigs from breaking wires and forcing their way out and small piglets from escaping through small openings at the bottom of the trap. The second layer doubled its strength and halved the size of the openings in the mesh, preventing escapes.

Norm MacDonald beside a corral trap on SCI

These traps were inexpensive, light weight, easy to transport by truck or helicopter, and were quick to construct. The simple walk-in, one-way door allowed for multiple captures of over 20 pigs, maximizing trap efficiency and taking advantage of pig's tendency to socialize. The traps were situated away from dense cover so when they were set, any pigs that remained outside the traps were vulnerable from the helicopter. After the traps were erected the one-way doors were wired open and the traps baited. This allowed pigs free access to the bait and got them accustomed to entering the trap. All subsequent baiting was done from the helicopter at a consistent time in the evening. This acted as positive conditioning for the pigs as the sound of the helicopter was associated with the appearance of food. The traps were set by the helicopter crew in the evening and cleared at dawn the next morning. All dispatches were done from the helicopter so that any pigs in the vicinity of the trap could also be dispatched.



Helicopter use for trap baiting

5.1.2 Aerial Hunting

The immediate goal of aerial hunting from Prohunt's Schweizer 269C helicopter was to reduce the pig population significantly so that the ground hunting team would only encounter pigs at low densities. This reduced the chance of detected pigs escaping from ground hunters. In most areas, traps were operational in easily accessible catchments while intensive aerial hunting concentrated on more

inaccessible areas. Aerial hunting took place in the early morning and late evening when pigs were most active. Starting at one end of a zone, the helicopter would systematically cover the terrain by working through each major catchment and gully, searching for pigs. At the beginning of each day, the aerial hunting team would continue from where they left off the previous day. This method ensured that all areas were covered equally. During every outing the pilot and shooter were extremely conscientious to leave no survivors from any encounter. Prior to engaging a pig (pursuing, shooting, or otherwise disturbing a pig), the aerial hunters would assess whether there were additional pigs near the one sighted. In many cases groups of pigs were not engaged because the shooter could not dispatch the entire group at that time. Once aerial hunting had reduced pig densities sufficiently, the crew transitioned to ground hunting.

5.1.3 Ground Hunting

Ground hunting success was based on a coordinated effort by hunters and dogs to cover areas in such a way that the likelihood of pigs escaping was eliminated. Comprehensive helicopter support enabled hunters and dogs to cover large areas efficiently without fatigue. Like aerial hunting, ground hunters worked systematically through a zone, starting each new hunting day where they stopped the day before. This approach ensured consistent and thorough coverage island-wide.

Two ground hunters in a team of 5 covering the terrain

Each zone was divided into Day-Size Hunting Areas (DHA), Map 1**.** DHA's were structured to ensure progress was continuous through the zone, from one DHA to the next. Day to day progression through adjacent DHA's became a rolling front that reduced the likelihood of pigs returning to areas already hunted. The boundaries of the DHA's were feature based, such as creeks or roads, and hunting would resume at that same point the following day, leaving no gaps. The hunters remained in constant communication with other team members using VHF radios and moved through each DHA with one or two experienced pig dogs. Hunters were spaced no more than 100-150 meters from one another and generally worked in a team of four to five.

Hunting dog entering the 'dog pod'

One of the keys to this technique was the use of well-trained dogs as short range finders and bailers (to prevent a pig's escape, dogs cornered them by barking until a hunter arrived to dispatch it). All hunting dogs were trained pig dogs and worked closely with

hunters. Dogs were radio-collared so hunters (and the helicopter pilot) always knew where they were during the hunt. In addition, every dog was trained using aversive conditioning to avoid island foxes (Appendix 1). The dogs were target-specific (focused solely on pigs) and stayed in a 150-200 meter arc around the hunter. This arc gave sufficient coverage to ensure pigs between hunters were detected. All dogs were trained so that when a pig was located, only the dog involved in tracking and following that pig pursued it. The remaining hunters and dogs kept positioned to detect additional pigs that tried to run up or down slope or back through the line of hunters. Once a pig was bailed, it was the nearest hunter that dispatched it. Following dispatch, the dog(s) involved returned to track any remaining pigs in the area.

Ground hunting on SCI was made up of two complete sweeps of each zone. We recorded all hunter and dog movements via GPS units that logged a position every minute. Hunters recorded every dispatch location and collected biological data (i.e. gender, weight, reproductive condition, number of foetuses) on the pigs. All data were downloaded daily and entered into the GIS. Following daily hunting, we displayed and proofed hunter tracks on a map of the hunting area to formulate a plan for the following day.

Radio-collared SCI hunting dog

5.1.4 Helicopter Support

One of the keys to effective ground hunting was helicopter use for hunter support. The helicopter transported hunters to the daily hunting area, repositioned them throughout the day and delivered supplies, water, or fresh dogs as needed. After positioning the hunters, the pilot remained at a vantage point to maintain radio contact and act as a spotter. If the pilot spotted pigs he directed hunters to intercept them or picked up a hunter and dog to respond. The helicopter was equipped with radio tracking equipment to locate missing dogs quickly. Helicopter use minimized travel and down time, allowed hunters and dogs to operate at peak efficiency, and resulted in thorough coverage of large areas.

Helicopter support of the ground hunt

5.1.5 Hot Spotting

Hot spotting is a technique used predominantly by ground hunters but was occasionally employed during aerial hunting. Hunters returned to areas that were 'hot spots' or had high pig

densities based on our dispatch data. These areas consisted of drainages with moist soil and water, habitats generally preferred by pigs. After the ground hunt sweeps were completed in each zone, we rehunted all areas that appeared to be favourable pig habitat. Hot spotting was used most following the ground hunt but was also applied again during monitoring.

5.1.6 Mark/Recapture

A Mark/Recapture program was initially proposed as a quality control method for ground-hunting. It would have involved capturing and collaring pigs and releasing them randomly into a zone prior to ground hunting. Marked pigs remaining in a zone following the ground hunt would indicate the relative proportion of unmarked pigs still present within the zone. Following discussion with TNC, this technique was rejected as inefficient and time intensive. Instead, other methods were developed to assess ground hunting success.

5.1.7 Judas Pigs

Radio-collared Judas pigs were monitored during aerial and ground hunting to detect other pigs that associated with them. The collared Judas pigs inadvertently exposed the location of those nearby. All Judas animals were surgically sterilized (but not neutered) using standard veterinary procedures (vasectomy and ovarectomy) prior to release in the field. Each animal was fitted with a radio transmitter and both ears were tagged with large yellow cattle tags (Allflex®) to aid hunters in identifying them from a distance and for individual identification in case of transmitter loss.

The use of Judas pigs increased hunting efficacy because pigs are social and tend to find each other. We located the Judas pigs by radio tracking them from the helicopter and dispatched any uncollared pigs in the vicinity. This was especially helpful once pig densities were low. Judas pigs were first used as a tool to detect pigs and improve aerial hunting performance before the ground hunt. Although we kept Judas pigs in the first zone we hunted (Zone 1) during the ground hunt, this proved to be inefficient as hunters had difficulty seeing collars from a distance and were unable to distinguish whether pig sign was from Judas or non-Judas animals. In all the other zones, Judas pigs were translocated out of a zone after aerial hunting and prior to the ground hunt. Following the ground hunt, they were released back into a zone again to detect pigs that may have evaded ground hunters.

Judas pigs were stocked in zones at a density of at least 1 per 1000 acres, with additional animals to account for natural mortality. Judas pigs were recaptured every three months by hunters and bailing dogs (after being located by helicopter) to check collars for damage or to refit them if a pig had lost or gained weight. Although we initially used harness mounted radio transmitters, pigs dropped them so we replaced the harnesses with standard radio-collars. We used three types of collars on Judas pigs. For traditional VHF telemetry tracking we used Kiwitrack® and Telemetry Solutions® collars, both of which had a battery life of five years. Our GPS collars (Lotek®, models 3300 LR and 2200 SR) also had VHF beacons with a five year battery, but the GPS data loggers needed to be downloaded and have batteries recharged every three months. The 3300 model collected a fix every 30 minutes and the 2200 model collected one per hour. Rather than hold a pig during the collar downloading and charging process, we simply replaced the collar with one that was charged. GPS data were used not only for monitoring and project certification, but for home range and movement studies not reported in this document.

Selecting the most effective Judas pigs based on gender and age depends on what gender and age the remaining pig in an area might be. Young boars are very social, older males may be solitary or associate with others, and females tend to be with boars. Since the gender and age of a remaining pig is typically unknown, the best practice is to introduce numerous Judas animals of various genders and ages into an area, which is what we did while using Judas pigs on SCI.

5.1.8 Hormone Implants

Early in the project, we conducted an experimental release of 'Super Judas" pigs in Zone 2. Super Judas pigs were surgically sterilized Judas females which also received hormone implants every three months that induced estrus. Prior research on goats suggested this method could lead to greater detection of unknown animals and therefore greater project success (Campbell 2007; Campbell et al. 2007). We wanted to examine its efficacy for pigs. Implanted females were constantly in estrus and very likely attracted a greater number of males than they would have without the hormone implants. Because of our work in Zone 2, eventually all female Judas pigs were implanted to be Super Judas pigs in all subsequent zones.

5.1.9 Data Management

Prohunt worked closely with TNC to develop a GIS (using a personal geodatabase in Arc Map 9.1, ESRI, that was compatible with Microsoft Office Access) for data management, storage, and display. Although some data collection requirements were listed in the project contract, additional ideas and needs arose during the project. As the project progressed, our dispatch, hunting effort, trap success, and Judas and Sentinel pig telemetry monitoring data all became more detailed and the project benefitted from collecting the additional data.

Movement data from hunters, dogs, and the helicopter were especially helpful in displaying area coverage and following up on any gaps. Each hunter, dog, and the helicopter carried GPS units (Garmin 12XL, Garmin Fortrex 201, Garmin GPS Map 196, respectively) that continuously collected location data. Our GIS specialist downloaded each GPS nightly to review coverage and proof the data for outliers or inconsistencies. We also recorded pig dispatch data in the GPS units so every dispatch type (trapping, aerial, or ground hunting) and location was saved. These data layers later allowed the crew to find areas especially high in pig density which deserved additional hunting effort.

We collected movement data on all Judas (and Sentinel) pigs wearing VHF collars every third day. GPS collars collected locations much more frequently. The data was downloaded and viewed routinely to assess what areas within each zone were covered by Judas pigs. During the monitoring phase of the project we sent all our data to Landcare Research to determine areas within zones that might require supplemental monitoring.

5.2 Results and Discussion

5.2.1 Significance of Project Results

Results from this project are widely applicable to feral ungulate eradication projects in other areas worldwide. We summarize dispatch data for the island below but emphasize that eradication was our goal throughout the project, not just increasing the number of dispatches. Applying our hunting approach strategically to achieve eradication is what made this project a success.

5.2.2 Overall Timeline

The hunting phase in all five zones was completed successfully and ahead of schedule, Table 1. The hunting began in April 2005 and continued until June 2006. Prohunt initiated hunting in Zone 1 first, followed by Zones 2, 3, 5, and ended in Zone 4. We often conducted hunting activities (trapping, aerial hunting, and ground hunting) in multiple zones at once to maximize the efficient use of the aerial hunting and ground hunting teams. The dispatch rate remained steady through 2005 and tapered off in 2006 once pig densities in all zones were low, Figure 1.

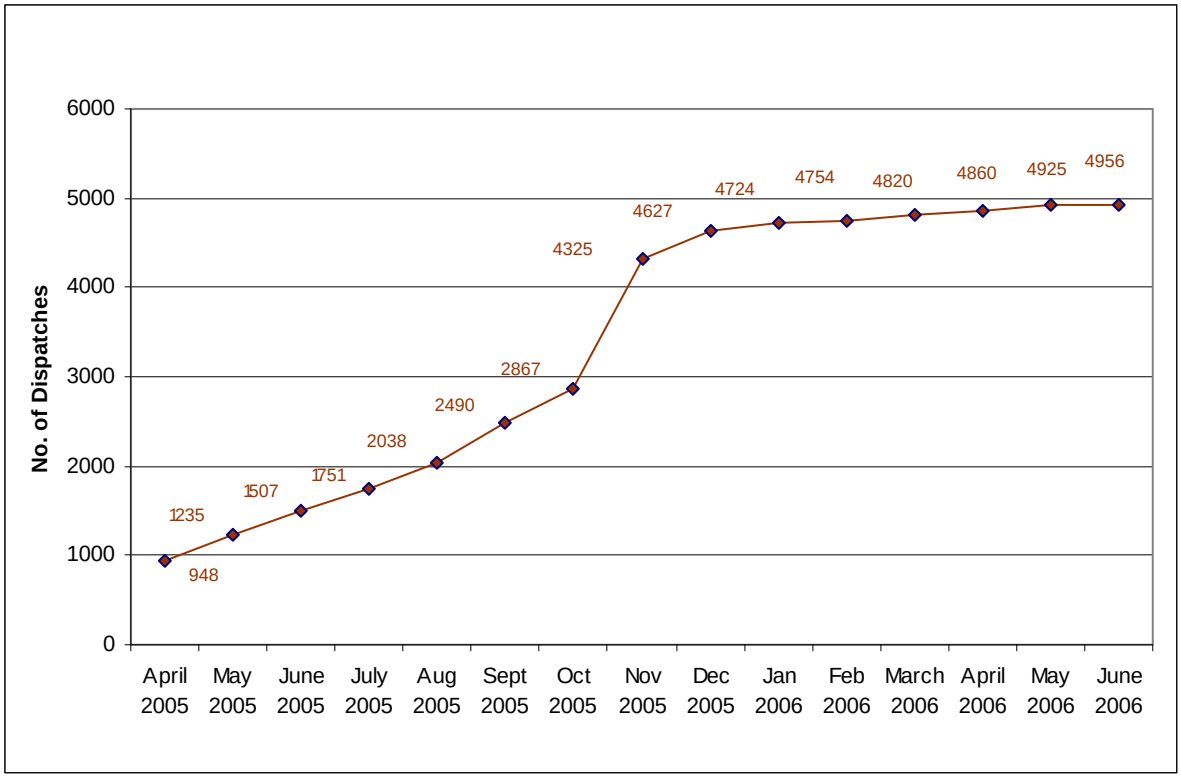
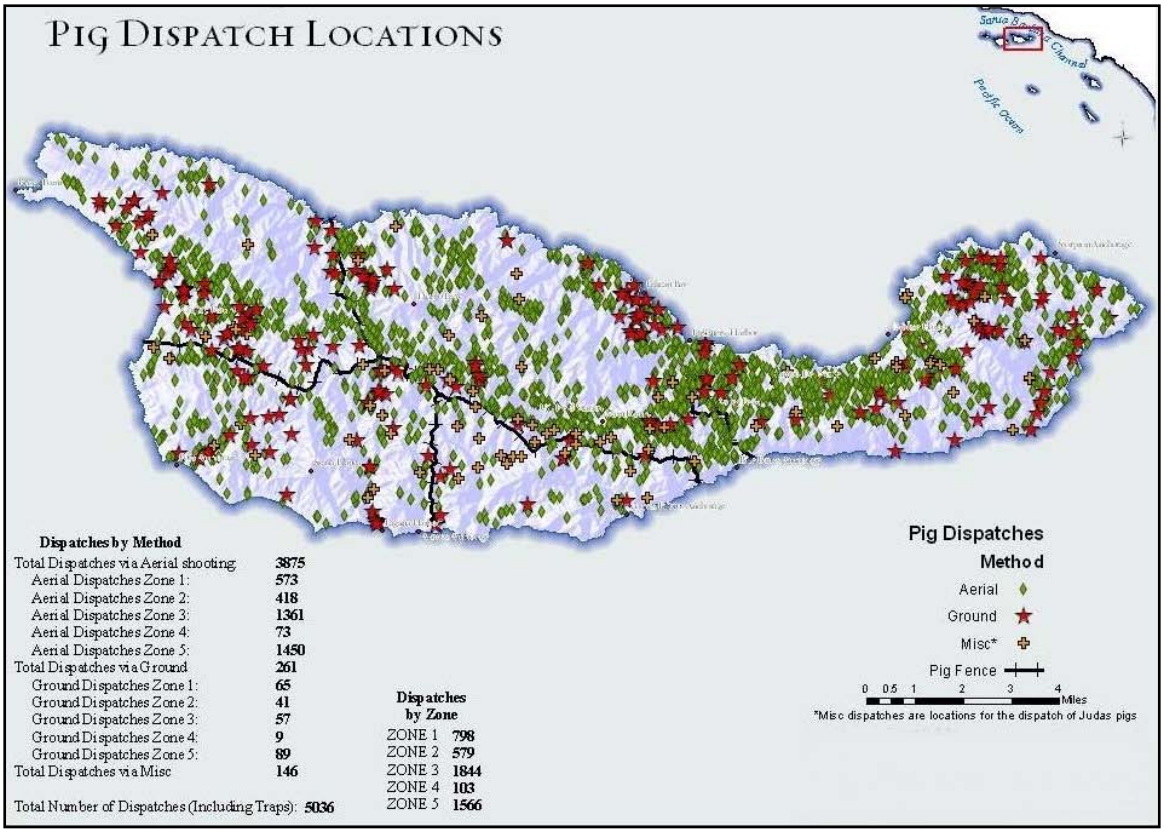


Figure 1: Hunting phase cumulative dispatches, April 2005 to June 2006.

5.2.3 Pig Dispatches and Effort

Although 5036 pigs were dispatched in total by project completion (Map 2), 4956 pigs were dispatched during the hunting phase alone.



Map 2. Santa Cruz Island pig dispatches by method and zone.

Pig density by zone was calculated using the hunting phase dispatches and the acreage of each zone, Table 2. The highest densities were in Zones 3 and 5 which contained the island's Central Valley, moist canyons of its north side, and dense fennel patches where pigs were known to forage. Zone 4 was on the dry, southern portion of the island and was dominated by coastal sage scrub. Zones 1 and 2 were on the west side of the island and consisted of grassland, chaparral, maritime scrub, and conifer forest habitats. We did not include Sentinel pig dispatches in our density calculations because many Judas and Sentinel pigs were ultimately dispatched in zones other than where they were captured originally.

Table 2. Dispatches by method and pig density by zone.

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Traps	160 (20.1)	120 (20.7)	426 (23.1)	21 (20.4)	27 (1.7)
Aerial	573 (71.8)	418 (72.2)	1361 (73.8)	73 (70.9)	1450 (92.6)
Ground	65 (8.1)	41 (7.1)	57 (3.1)	9 (8.7)	89 (5.7)
Total dispatches	798	579	1844	103	1566
% of total population	15.8	11.5	36.6	2.0	31.1
Zone acreage	11430	11215	17180	6250	14709
Pig density/acre	0.07	0.05	0.11	0.02	0.11

In just 15 months of hunting, 4890 were dispatched with 1362 trap nights, 1192 Effective Hunter Days (EHD's), and approximately 1600 hours of helicopter flight time, Table 3. An additional 66 pigs were dispatched using miscellaneous techniques and during the monitoring phase of the

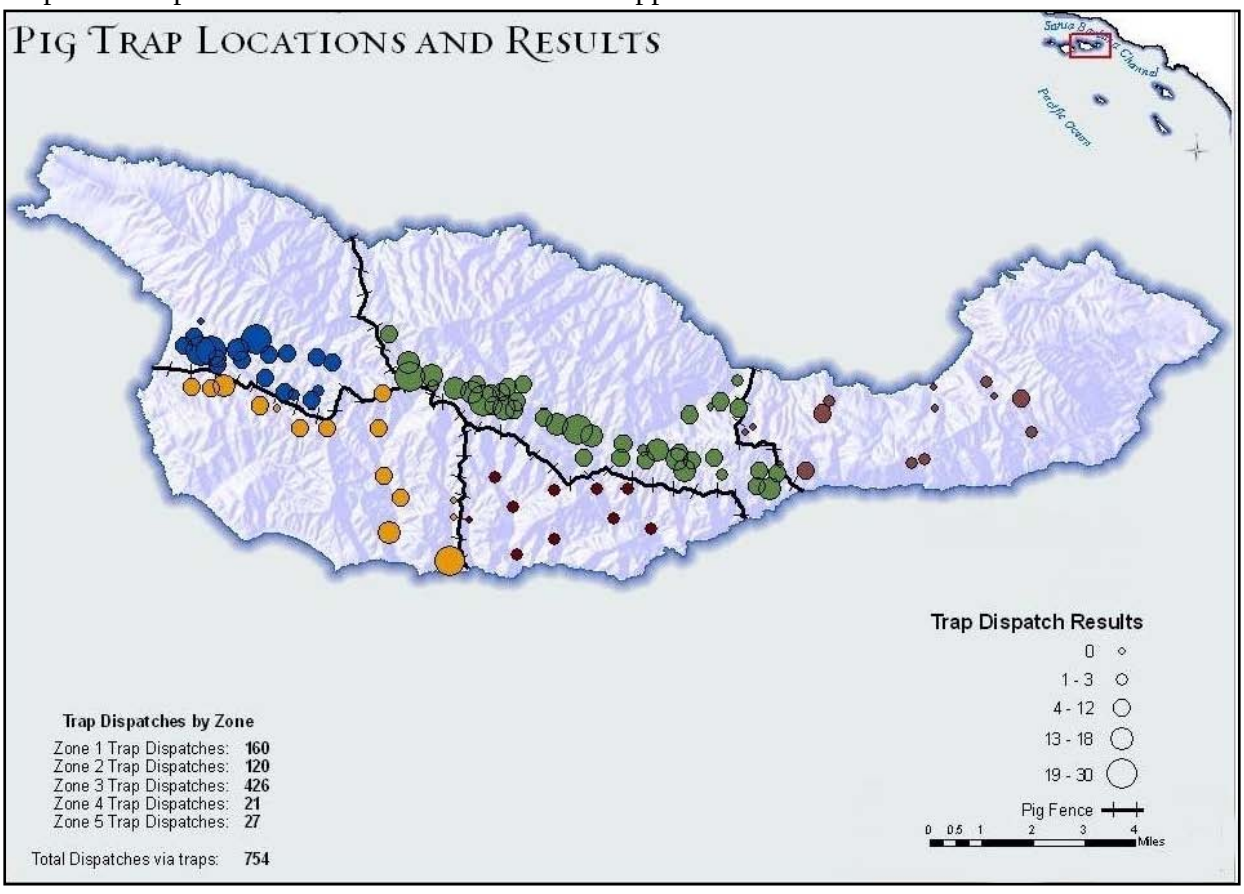
project we dispatched the final 80 pigs. Of those, 79 were Sentinel pigs and one was an unmarked pig captured with a net gun in Zone 5.

Table 3. Trapping and hunting effort and resulting dispatches by zone.

Zone	Acres	No. of Traps	Total trap nights	Trap dispatches	Aerial dispatches	Ground hunt effort (EHD)	Ground dispatches
1	11430	20	*	160	573	245	65
2	11215	15	205	120	418	251	41
3	17180	44	785	426	1361	248	57
4	6250	10	277	21	73	145	9
5	14709	14	95	27	1450	303	89
Total	60784	103	1362	754	3875	1192	261

*Trap night data were not collected in Zone 1.

Our hunting effort by method was very close to our original estimate. Effort differed between zones due to variations in zone size, pig populations, topography, vegetation, and weather conditions. Aerial hunting removed the greatest number of pigs in the two largest zones, Table 3. Trap success varied depending on each trap location, the surrounding area's pig density, and the length of time trapping was conducted prior to aerial hunting, Map 3. However, as expected, the greatest number of pigs were trapped where effort (trap nights) was highest, in Zone 3. Trap dispatches reported in Table 3 do not include trapped animals that were collared and released as



Map 3. Pig trap locations and associated dispatches.

Judas or Sentinel pigs. Thus, trapping success in each zone was actually higher than reported by dispatches alone.

Ground hunting required a team of hunters and dogs to conduct two full sweeps through a zone and return for hot-spotting. Average dispatches for effective hunter days (EHD) varied by zone from 0.14 pigs per EHD in Zone 4 to 0.40 in Zones 1 and 5, Table 4. The average number of acres each hunter covered per day also varied by zone from 86 in Zone 2 to 141 in Zone 3. Because of the large variations between topography and pig densities in each zone, and their impact on hunting, we have included detailed hunt descriptions for each zone in Appendix 2.

Ground hunters on SCI

5.2.4 Hunting Approach Success

Peaks in dispatches in each zone (Figure 2) represent aerial hunting, which removed a large portion of the population (over 70% of all dispatches), compared to the other hunting methods. This does not suggest, however, that relying solely on aerial hunting would have accomplished eradication faster or at all. The key was applying each of the eradication techniques in the optimum sequence during the eradication so that:

- it was the most cost effective technique to detect and dispatch animals at that particular population density and
- it minimized the chance of animals escaping any lethal encounter at that particular population density.

For example, trapping was the least invasive of all the eradication techniques employed during the project, and once the traps were constructed they required the use of minimal resources to be effective. The trapping program effectively removed a lot of the resident dominant boars and large family groups (sows and piglets) prior to aerial hunting. This meant that during the aerial hunting phase the

Pigs inside and outside a corral trap

helicopter crew was left to deal with group sizes that were small enough to minimize the chance of pigs escaping.

In turn, by the end of the aerial hunting phase pig numbers in each zone were so dramatically reduced that ground hunters had large areas where there were no pigs at all and when they were encountered, it was usually individuals. Using our team hunting method to systematically cover each zone, the hunters had a high chance of detecting remaining pigs. These pigs were still naive to hunters and dogs, and once they were detected, it was unlikely they would evade hunters.

By the time Judas pigs were employed to locate remaining pigs and the ground hunt was complete, nearly all non-Judas pigs had already been removed. Our hunting approach succeeded in never educating pigs to hunters, efficiently and swiftly decreasing the population, and completing the eradication humanely and effectively.

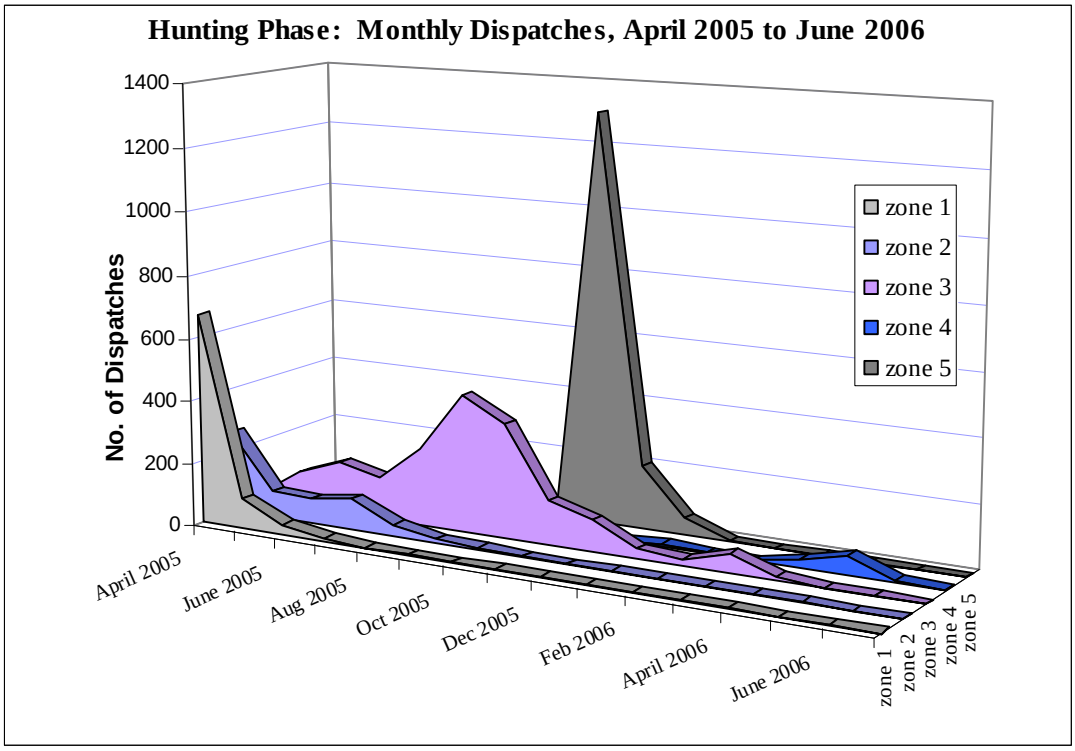


Figure 2. Peaks in pig dispatches, April 2005 to June 2006.

Table 4. Ground hunting effort (sweeps and hot spotting) and dispatches.

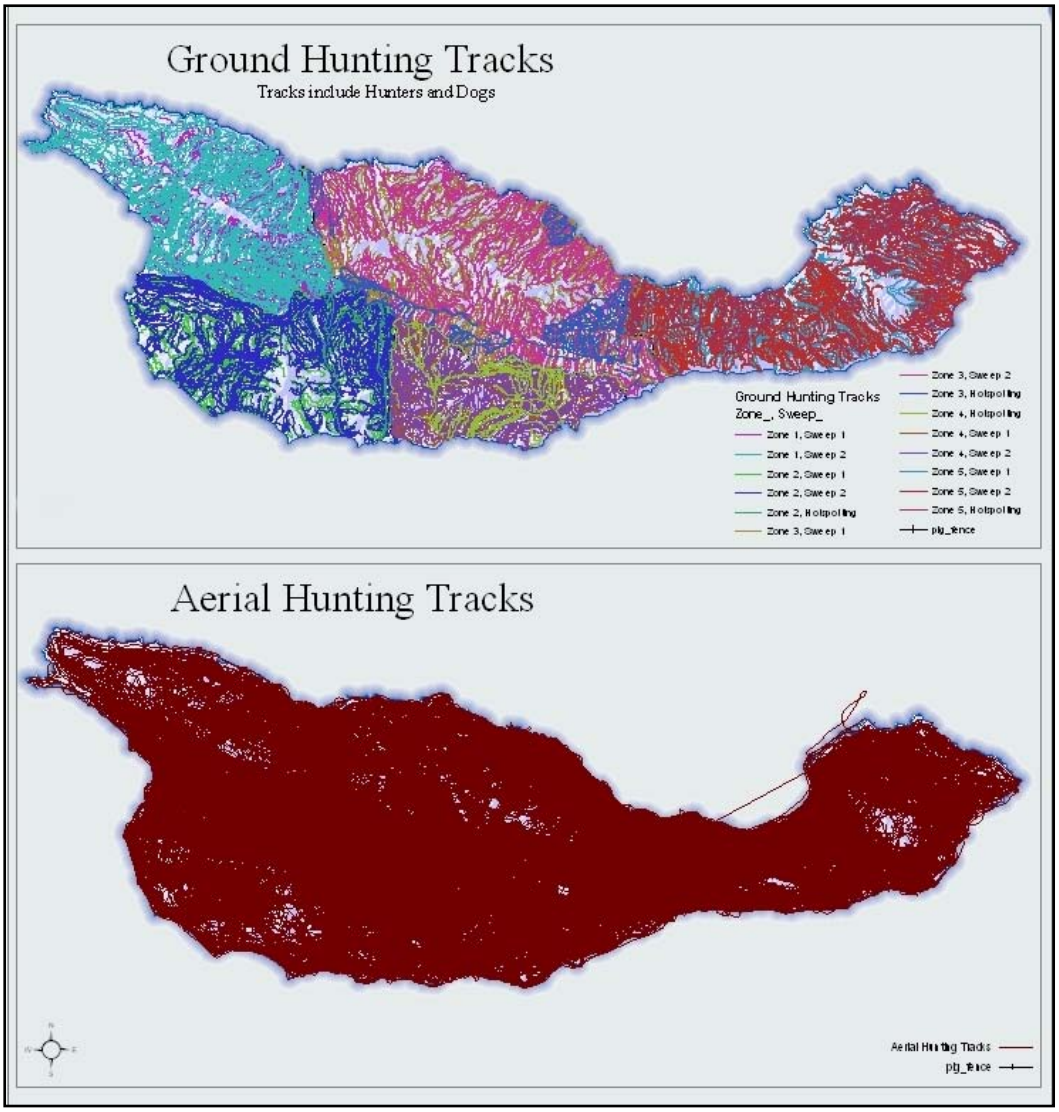
	1st Sweep	2nd Sweep	Hot-Spotting	Totals
Zone 1				
Acres covered per day	520	519	*	
Acres covered per hunter	106	98.3		
Dispatches / EHD	0.4	0.09		
Avg. Number of hunters	4.9	5.3		
Total number of days	24	24		48
Effective hunter days (EHD)	118	127		245
Number of dispatches	53	12		65
Zone 2				
Acres covered per day	534	488		
Acres covered per hunter	86	96		
Dispatches / EHD	0.22	0.09	0	
Avg. Number of hunters	6.23	5.1	3	
Total number of days	21	23	1	45
Effective hunter days (EHD)	131	117	3	251
Number of dispatches	29	12	0	41
Zone 3				
Acres covered per day	687	954		
Acres covered per hunter	141	184		
Dispatches / EHD	0.39	0.08	0.02	
Avg. Number of hunters	4.8	5.2	4.9	
Total number of days	25	18	7	50
Effective hunter days (EHD)	121	93	34	248
Number of dispatches	48	8	1	57
Zone 4				
Acres covered per day	481	481		
Acres covered per hunter	101	99		
Dispatches / EHD	0.14	0	0	
Avg. Number of hunters	4.77	4.85	6.67	
Total number of days	13	13	3	29
Effective hunter days (EHD)	62	63	20	145
Number of dispatches	9	0	0	9
Zone 5				
Acres covered per day	490	735		
Acres covered per hunter	91	124		
Dispatches / EHD	0.4	0.1	0.1	
Avg. Number of hunters	5.4	5.9	4	
Total number of days	30	20	6	56
Effective hunter days (EHD)	161	118	24	303
Number of dispatches	72	15	2	89

*Hot spotting was not conducted in Zone 1

5.2.5 Judas Pigs as a Hunting Tool

Judas pigs contributed substantially to project success. During the hunt in Zone 1 we first recognized the value of Judas pigs and relied on them more heavily in each subsequent zone. When densities were low, radio tracking Judas animals consistently improved unmarked pig detection. The number of Judas pigs used in each zone varied, as did the number of days that each was used as a Judas animal. Their benefit was evident by the additional dispatches resulting from their presence in Zones 1-4. The greatest benefit was in Zone 3, where 51 dispatches resulted from Judas pigs, followed by 20 dispatches in Zone 2, 17 in Zone 4, and 6 in Zone 1. The last pigs ever dispatched in Zone 1 and in Zone 3 were attributed to associations with Judas animals. In general, Judas animals were considered Sentinel pigs (used for monitoring rather than hunting) after sufficient time had passed when no other uncollared animals were associating with them.

All ground hunters and dogs carried GPS units whenever hunting. Map 4 demonstrates the intensive coverage that the SCI pig eradication project required. Aerial hunting (also recorded via GPS) was so thorough the entire map is shaded.



Map 4. Ground and aerial hunting tracks.

6.0 Monitoring

Monitoring each zone for additional pigs not detected during the hunting phase was a contract requirement and an essential element for project success. Monitoring could be considered a continuation of hunting (for possible remaining animals) and the transition from hunting to monitoring occurred when there appeared to be no more uncollared pigs associating with the Judas pigs in a zone. However, as uncollared animals associating with Judas pigs were dispatched, it was impossible to know which pig was the *last* pig without the passage of time. Consequently, the monitoring phase began in each zone when pigs were at a zero detectable density or when no uncollared pigs were associating with Judas pigs.

6.1 Methods

6.1.1 Forward Looking Infrared - FLIR

Initially, Forward Looking Infrared (FLIR) technology was planned for monitoring once pigs were at such low densities that they were no longer detectable. FLIR is a camera system containing infrared sensors that can be mounted on a helicopter. They detect heat and create an image based on the temperature of the objects present. In February 2006, a 3rd generation FLIR **(**LEO II – A3 Airborne Observation System) was tested on SCI to evaluate its effectiveness as a tool for monitoring and for final certification of the eradication. However, results demonstrated the FLIR could not detect heat (or therefore pigs) in dense Lemonade berry (*Rhus integrifolia)* bushes, which are commonly used as refuge by the pigs, nor under Eucalyptus *(Eucalyptus globulus)* trees. FLIR was therefore rejected as a monitoring tool for the project.

6.1.2 Sentinel Pigs as a Monitoring Tool

Cost effective and accurate monitoring was still needed to confirm each zone was clear of pigs following the hunting phase. Sentinel pig monitoring replaced FLIR as our primary monitoring tool. Sentinel pigs are Judas animals that are no longer finding or associating with other pigs in an area that is considered pig free. However, Sentinel pigs could still potentially detect the arrival of pigs from other areas in a zone that may be shifting their home-range. Sentinel pigs became an important component during monitoring and Judas and Sentinel pig movement data were used in the statistical analyses that ultimately led to certification. We placed Sentinels in zones at a density of no less than 1 per 1000 acres to detect other pigs that were not detected or dispatched during

The helicopter was an extremely efficient monitoring tool.

the hunting phase. In theory and overtime, remaining pigs might travel from other areas within the zone and associate with the Sentinel. The Sentinels, therefore, raised the probability that pigs were successfully eradicated from a zone when none were found with them.

We radio tracked all Sentinel pigs on a rotating schedule so that every individual was located every third day. Radio tracking via helicopter, we located each pig visually, recorded its location, and searched for others nearby. We collared 12 Sentinel pigs with GPS collars to collect more intensive movement data.

6.1.3 Notification of Pig Detection, Sightings, and Sign

Throughout the monitoring and certification phases of the project, we asked other island users who worked on SCI to report sightings of uncollared pigs or pig activity in zones we believed were pig free. We distributed sighting information datasheets to island users (Appendix 3) and followed up on all reported sightings and sign.

6.1.4 Monitoring Data Management

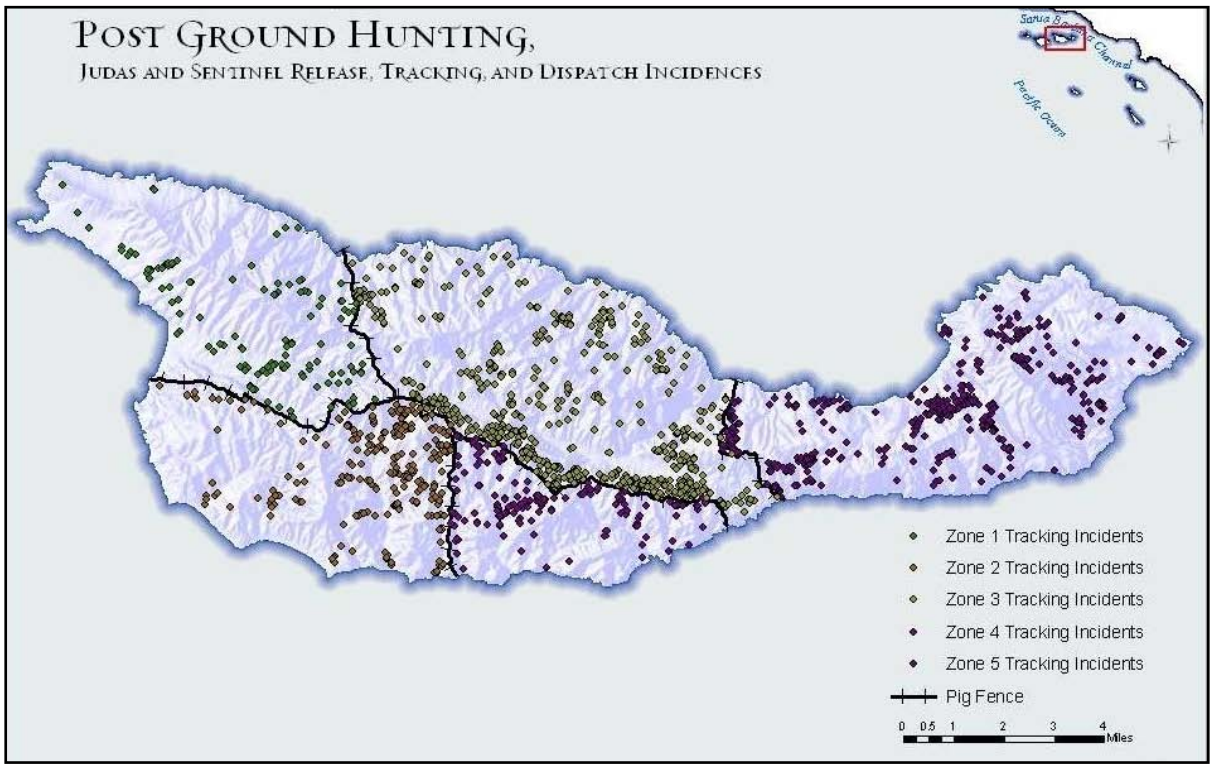
Throughout the monitoring phase we recorded all Judas and Sentinel pig locations and associations with other pigs (collared or not). All supplemental monitoring efforts by the ground or helicopter crew were recorded in the GIS as well.

6.2 Results and Discussion

The project's monitoring phase lasted from December 2005 to January 2007. The transition time from the hunting phase to the monitoring phase varied by zone but occurred on average about two months after Judas pigs were returned to zones following the ground hunt. After several months the Judas animals became Sentinels. Sentinel pigs were frequently located with other Sentinels (Table 5) during the extensive radio tracking we did throughout the monitoring phase. Monitoring ended after months (varying from 5 to 11 months per zone) had passed with Sentinel pigs discovering no unknown or uncollared pigs. At the completion of the monitoring phase, we dispatched Sentinel pigs. Throughout most of the monitoring phase there were at least 70 Sentinel pigs on the island being radio tracked. Because of variations in the monitoring effort between zones, a detailed zone by zone monitoring description is available in Appendix 4.

6.2.1 Sentinel Pig Monitoring

We collected hundreds of radio locations of Sentinels throughout the months of monitoring, Map 5. Although Sentinel pigs were only detecting and associating with other Sentinels, we recorded the association every time, Table 5. We continued to recapture Sentinel pigs every three months to administer hormone implants to sows, check radio-collar wear and fit, download GPS collar data, and replace collars that had old batteries.



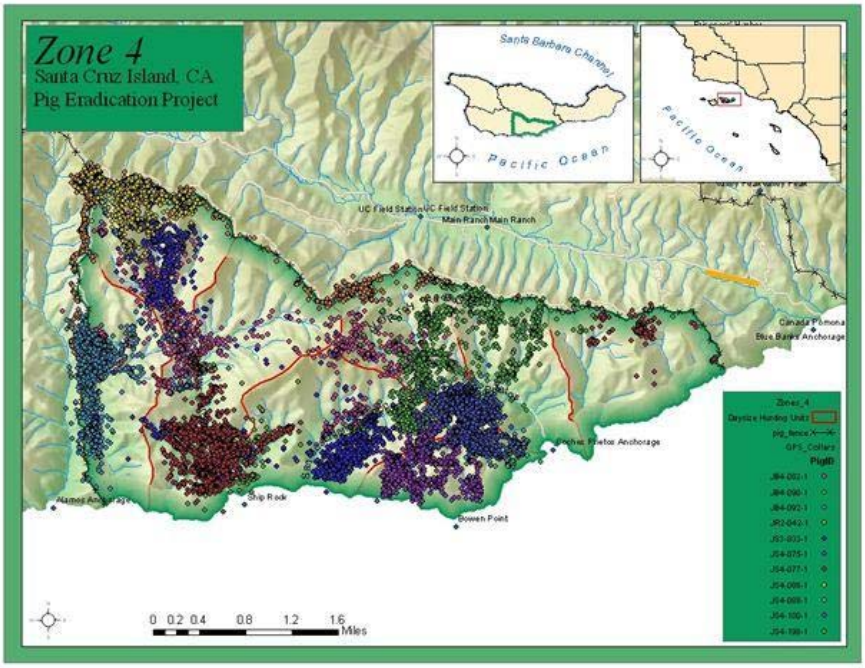
Map 5. Sample of Judas and Sentinel pig locations on SCI.

Table 5. Summary of Sentinel pig monitoring on SCI.

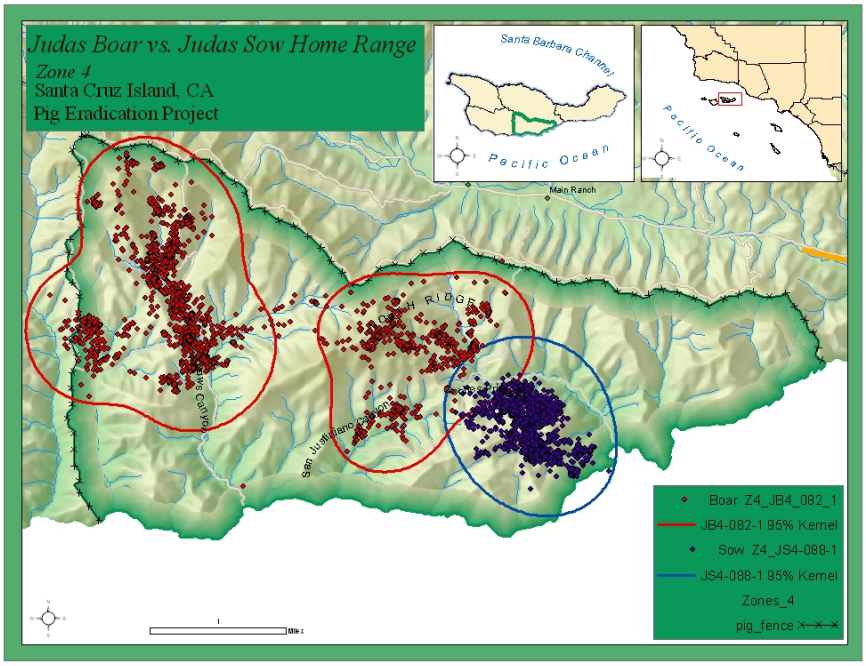
	Months Monitored	**No. of Locations**	**% Locations with Other Sentinels**	**Month Sentinels Removed**
Zone 1*	5	n/a	*	Jan 2006
Zone 2	11	619	28	Nov 2006
Zone 3	9	629	30	Jan 2007
Zone 4	5	253	47	Dec 2006
Zone 5	9	571	31	Dec 2006

*Data collection protocols were not defined at the time Zone 1 was monitored.

Our 12 GPS collared pigs collected pig association, movement, and home range data, Map 6. We used the home range data in Zone 4 to show variation between sow and boar home ranges, Map 7. Monitored pig data were also used to test the efficacy of supplemental monitoring techniques, such as remote cameras and visual sign stations during the certification phase. Monitored pigs could also assist in locating breaches in the zone fencing. Pig movement data from this project could be used to better understand Judas and Sentinel animal effectiveness for monitoring eradication projects.



Map 6. GPS collared pig locations in Zone 4 on SCI.



Map 7. Sample of boar and sow home ranges in Zone 4 on SCI.

6.2.2 Pig Sightings and Sign

We received a total of six sighting and sign reports from island visitors during the monitoring and certification phases of the project. These reports included pig tracks, rooting, scat, and vocalizations. Appendix 3 summarizes each report and resulting follow up outcome. In most cases, we were able to immediately respond to the reported sightings and in no case was the reported sign attributed to pigs. In general, skunks or foxes were responsible for soil disturbance which can look similar to pig sign to inexperienced people. Pig sighting reports were helpful because they demonstrated that island users were looking for sign and they increased our confidence that the island was in fact pig free.

7.0 Certification

The SCI feral pig project included a certification phase whereby TNC would use monitoring techniques to try to detect pigs in zones thought to be pig free. TNC contracted with Landcare Research, New Zealand to 1) define what degree of confidence was appropriate so that a lack of detectable pigs demonstrated a true absence of pigs and 2) provide recommendations and methods for field activities and data collection during the certification phase of the project that would increase confidence in eradication success (Ramsey 2007). In collaboration with Prohunt, Landcare developed a certification approach to reduce the likelihood that any undetected pigs remained. The certification phase would verify that the eradication had been achieved.

7.1 Methods

7.1.1 Statistical Analyses for Developing Certification Activities

Landcare used hunting data to 'design certification monitoring activities to determine the probability that pigs still persist on the island even though certain monitoring detects no pig presence,' (Ramsey 2007). To do this, Landcare first had to determine an appropriate level of confidence to represent that a lack of detection meant a zone was pig free and then assess the effectiveness of aerial hunting, ground hunting, and Judas animals at detecting pigs. From these analyses they recommended additional field activities to conduct that would increase confidence levels to a point where the island could be certified as pig free.

Landcare calculated the detection probability of the resident Sentinel pigs for each zone. They determined how effectively a Sentinel pig could discover an uncollared pig and whether or not there were any gaps in Sentinel pig coverage where an uncollared pig could have gone undetected. As a result, they determined the amount of additional monitoring that should be conducted for each zone to reach the certification threshold. They prescribed a combination of supplemental aerial hunting, ground monitoring, and continued Sentinel pig use to increase monitoring efforts in areas not well covered by Sentinel pigs at the time of their analysis. They provided Prohunt and TNC with maps and listed individual small hunting units that required these activities, Table 6.

Overall, there were three components to the certification phase. The first was the supplemental monitoring recommended by Landcare. The second component consisted of two low-level aerial surveys of the entire island for pig sign. The final certification requirement was a complete fence inspection to ensure it was intact and pig proof.

7.1.2 Supplemental Monitoring

Supplemental aerial monitoring was an aerial search of small hunting units from a helicopter with similar intensity as that applied during the hunting phase. Likewise, supplemental ground monitoring was done using hunters and dogs in a manner used during the active ground hunting phase. Part or all of the small hunting units that needed additional monitoring were subject to a single aerial search, followed by a single ground sweep. If terrain was unsuitable or unnecessary for ground sweeps (i.e. crags, cliff faces, or unvegetated terrain) then an additional aerial survey was substituted for a ground sweep. Following the completion of supplemental monitoring, all remaining Sentinel pigs, if any,

were dispatched. During this phase of certification, individual hunters also investigated areas that, based on their experience, deserved additional monitoring.

Table 6. Island small hunting units that required additional monitoring, Ramsey 2007.

Zone 1			Zone 2			Zone 3			Zone 4			Zone 5		
Small Hunting Unit	Action	Ground Hunt N/A	Small Hunting Unit	Action	Ground Hunt N/A	Small Hunting Unit	Action	Ground Hunt N/A	Small Hunting Unit	Action	Ground Hunt N/A	Small Hunting Unit	Action	Ground Hunt N/A
1	x	n/a	23	(x)		58	(x)		78	(x)		44	(x)	
2	x	n/a	24	(x)	n/a	59	(x)		80	(x)		46	(x)	
3	x	n/a	25	(x)		60	(x)		81	(x)		47	(x)	
4	(x)	n/a	27	x		62	(x)		82	(x)		49	(x)	n/a
5	x	n/a	28	x		63	(x)	n/a	84	(x)		50	(x)	n/a
6	x		29	(x)		64	(x)		85	(x)		51	(x)	n/a
7	(x)		31	(x)		65	(x)		86	(x)	n/a	52	(x)	
8	x		32	(x)	n/a	69	(x)					54	(x)	
10	x		34	(x)		70	(x)					55	(x)	
11	(x)		35	x		72	(x)					56	(x)	
12	(x)		40	(x)	n/a	73	(x)							
13	(x)	n/a				77	(x)							
14	(x)													
15	(x)													
16	(x)	n/a												
22	(x)													
% of Zone to be Monitored = **48%**			% of Zone to be Monitored = **31%**			% of Zone to be Monitored = **34%**			% of Zone to be Monitored = **35%**			% of Zone to be Monitored = **36%**		

Key: x = full unit survey required, (x) = partial unit survey required, n/a = a unit deemed unsuitable for ground monitoring and was only aerially monitored.

7.1.3 Spring Low-level Aerial Surveys

We planned two low-level flights to search for pig sign in the spring of 2007. Aerial surveys present a better view for searching for pigs or pig sign than surveying from the ground. All Sentinel pigs were dispatched prior to conducting the surveys. The first survey was in early spring following the first rain and the second was in late spring. By conducting the first survey in early spring (early in the rainy season) the pilot and passenger could look for fresh pig sign or rooting before vegetation grew thick. They could establish base level observations for the second aerial survey when the vegetation had grown. Any remaining pigs would be detected in the second survey where there was lush growth and moist soil conditions.

7.1.4 Fence Inspection

The third part of certification was an inspection of the pig fence to ensure it was pig proof. This was done by the crew walking the entire fence line in all five zones. In the unlikely case that a pig remained on the island, it would be contained in one zone by the fence.

7.1.5 Data Management

Throughout the certification phase we recorded tracks for all supplemental monitoring (hunting) efforts by the ground and aerial hunting crews in the GIS. In addition, we recorded our spring aerial survey tracks and all other supplemental data collected.

7.2 Results and Discussion

7.2.1 Supplemental Monitoring

Between October 2006 and February 2007, hunters, dogs, and the helicopter covered the small hunting units in each zone with the same intensity they used during the initial ground and aerial hunting effort. The ground monitoring focused mostly on deep canyons, where water and dense scrub would provide habitat to pigs within the intended hunting unit. Certain areas (with open grass or steep cliffs) were unsuitable for supplemental ground monitoring and were instead monitored via helicopter a second time.

Kelvin Walker (left, foreground) discusses the hunt with his crew.

Prohunt found the recommendations for supplemental monitoring in areas *not* sufficiently covered by Sentinel pigs counter intuitive because these were probably areas with substandard pig habitat. Our Sentinel pig movement data showed that once population densities were low (throughout the monitoring phase) the remaining pigs occupied the best habitat. When Sentinel pigs were released into a zone they travelled to these ideal habitats.

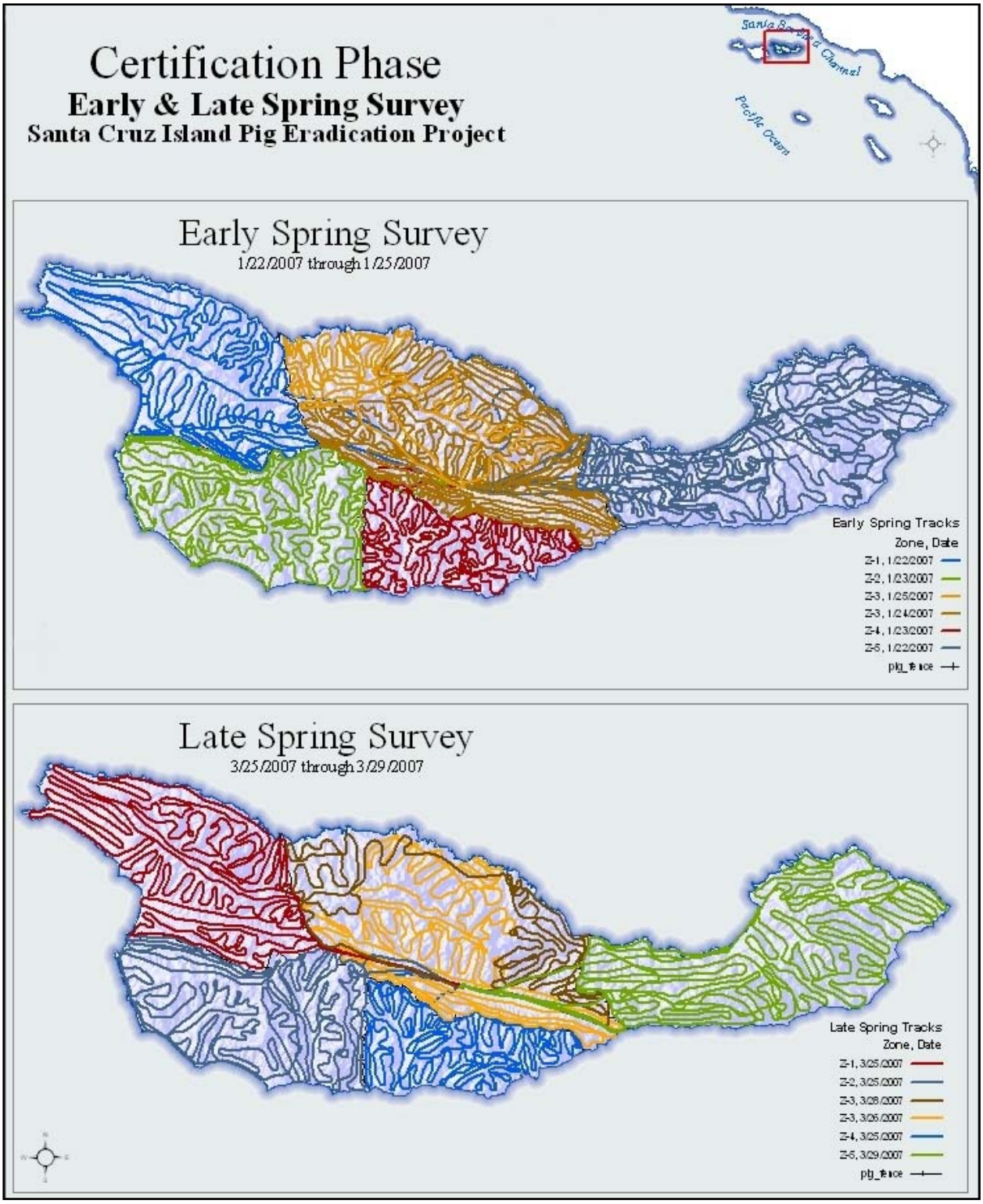
Although the recommended monitoring addressed the possibility of pigs living in lower quality habitat, away from Sentinels, we wanted to monitor areas with good pig habitat too. Therefore, in addition to the monitoring recommended by Landcare, ground hunters investigated areas where a pig could have gone undetected based on their hunting experience and knowledge of pig behaviour. These areas had previously high pig densities or were places where the dogs had demonstrated interest during the initial ground hunt but found no pigs. No pigs or sign were discovered during any supplemental monitoring or during this additional focused effort.

Well-timed supplemental monitoring of both types could potentially decrease the monitoring phase of a project. Rather than relying on tracking Sentinel pigs repeatedly as the only means to increase

confidence in eradication success, supplemental monitoring could be employed simultaneously but in different zones, speeding the process further.

7.2.2 Aerial Surveys

The first aerial survey took place over a four day period in January 2007 and the second over a five day period in March 2007, Map 8. Each survey systematically covered every zone using methods similar to those used during the initial aerial hunt (starting at one end of a zone and methodically searching each gully and ridge line without skipping any terrain). Prior to the first survey, the island received little rain and was not yet fully green. The survey crew noticed old pig trails and rooting in zones that had recently been occupied by pigs, but they did not observe any fresh sign. By March the rainy season was ending and the island had fresh vegetation. Although the rainy season only produced about 8 inches, the majority came in spring rather than winter, which allowed for vegetative growth and the detection of pigs. Much of the old rooting previously observed was covered with grass or other vegetation and many pig trails had become overgrown. However, the survey crew did observe some fresh trails which were investigated and attributed to humans. Both island-wide, low level aerial surveys resulted in the detection of no fresh pig sign, trails, or rooting.



Map 8. Low-level aerial surveys for project certification.

7.2.3 Fence Check

Throughout the project, the entire fence line was checked after every major rain event since most breaches in the fence occurred during large rainstorms when water eroded gullies under the bottom barbed wire. We made repairs as needed throughout the project. As part of the certification, we did a final fence inspection in May 2007. Each fence was walked and checked for holes, damage, or gaps that could have been created by rain run off. We found no holes or damage in the fences.

8.0 Supplemental Trials

During the project's certification phase, TNC and NPS were faced with one of the biggest challenges for managers: when to dismantle an eradication project. Ending prematurely is risky because if there are any remaining animals they will require the greatest skill to detect and dispatch. However, given the scarcity of conservation resource dollars and the expense of maintaining eradication teams, sustaining effort to hunt animals that do not exist wastes limited funds (Morrison 2007). If a pig was present following presumed eradication, the pig density would be so low that it would be virtually impossible to detect without a verified and calibrated monitoring technique.

Sentinel pig feeding at baited camera station

Throughout the eradication project we worked closely with TNC and NPS to help alleviate risks associated with the project. During the certification phase specifically, we collaborated with Landcare Research and TNC to develop methods that could address the following questions:

- How can we be certain there are no pigs remaining on the island? Is there an effective way to detect pigs at low density without employing an expensive professional monitoring team?

- If a pig is discovered in the future, following Prohunt's demobilization, is it a native pig missed by Prohunt or a pig introduced from the mainland to sabotage the project?

To address these questions we conducted trials to calibrate the detection probability of pigs at low density using two different survey methods in areas with GPS collared Sentinel pigs. We also collected genetic samples from island pigs to archive for future use if needed.

8.1 Camera Trials

Adaptive management was as much a part of the certification phase as the hunting and monitoring phases. Before Landcare established that supplemental monitoring could achieve certification, they requested Prohunt trial other pig detection methods. Landcare recommended Prohunt conduct sand track trials to measure the detectability of pigs at low density using pigs with known movements (via GPS collars). The first trial was in Zone 2 in September 2006. We established ten $2m^2$ plots on suitable soil within the collective home range of the GPS collared pigs. We monitored plots for 10 days and then randomly relocated them to new locations for another 10 days. The likelihood of a pig encountering a particular plot was naturally dependent on whether the plot was in a high or low use area within the home range. During each inspection (every 10 days) we recorded the presence or absence of pig sign.

We set infrared cameras at every plot location to determine which GPS collared pig left sign at a particular plot. Over the entire 20 day period, pig tracks and photos were recorded at the plots on five

separate occasions. There were 12 GPS collared pigs in Zone 2 at the time of the trial. We provided this data to Landcare Research for analysis.

The second trial was in Zone 4 during December 2006. This trial varied from the Zone 2 trial as we used 2kg of cracked corn as bait at each plot. Prohunt argued for this method to increase trial efficiency, since baited stations would increase pig visitation and pigs at low densities should be detected sooner using this method. In addition, we no longer employed sand plots because remote cameras were equally effective for presence/absence data and had the additional benefit of identifying individuals. Over the 20 day period, we recorded 13 collared pig visits at bait stations and in 10 cases the bait was taken. There were 11 collared pigs in Zone 4 at the time of the trial. The bait trial was more successful at detecting pig activity at low density than the unbaited trial in Zone 2, since the bait likely attracted pigs to the stations.

These supplemental trials quantitatively assessed a potential method for detecting pigs at low density. They could be used in the future if pig presence was ever suspected on SCI. They could also be applied to other areas where ungulates persist at very low densities and monitoring is required.

8.2 Genetic Information

To address the concern that someone could introduce a pig to SCI following the eradication, Prohunt collected blood and tissue samples from approximately 250 pigs during the course of the project. Samples were taken between July 2005 and December 2006, predominately from Zones 3 and 5. Sample collection was time-intensive and logistically challenging. When a group of pigs was dispatched in a trap we immediately transported them via helicopter to a team who collected the samples. If a pig is discovered on SCI in the future, its genetic information can be compared with the genetics of those dispatched during the eradication to determine whether it was reintroduced from the mainland.

9.0 Reducing Non-target Impacts and Protecting Sensitive Resources

Since the pig eradication project was part of a larger restoration program on SCI, if our efforts negatively impacted other sensitive island resources, the entire program would suffer. Throughout the project, we coordinated our work with other projects and had no negative impact on the island's cultural or natural resources, including threatened and endangered species. SCI is home to the endangered Santa Cruz Island Fox (*Urocyon littoralis santacruzae*) and protected bald eagles (*Haliaeetus leucocephalus*), as well as nine endangered plants and many other species endemic to the Channel Islands. In addition, there are over 3000 Native American archaeological sites on the island.

Santa Cruz Island Fox,
Photo: C. Cory

Because island foxes have not been exposed to diseases present on the mainland it was critical that hunting dogs undergo six weeks of strict quarantine before leaving New Zealand and receive treatment for parasites and vaccinations for: canine distemper, canine adenovirus, canine parainfluenza, leptospirosis, canine corona, rabies, and Bordetella viruses. When the dogs arrived on the island they were held in quarantine for an additional three weeks and were tested for Lyme disease. Once the dogs were released from quarantine they received fox aversion training. A hunter and shock-collared dog walked by a dummy fox or fox scent; if the dog showed interest the dog handler delivered a shock to the dog (Appendix 1). Dogs learned to associate fox sight or smell with the shock. Follow up training was repeated on a regular basis. The hunting dogs had been previously been exposed to aversion training in New Zealand to avoid Kiwi birds (*Apteryx sp.*) and the Lord Howe Island Woodhen (*Gallirallus sylvestris*). To further protect foxes in two captive breeding facilities on the island, we coordinated aerial and ground hunting timing with the Institute for Wildlife Studies and TNC biologists to minimize impact. This required altering our hunting schedule so that we were not in the areas during the fox breeding or whelping seasons.

In spring 2006, for the first time in 50 years, two pairs of bald eagles nested and successfully hatched chicks on SCI. A 500 meter buffer was established around the nests by biologists, and the helicopter and ground hunters were not allowed within the area for six months. The nest in Zone 2 created challenges during monitoring and the Zone 3 nest posed a conflict during the second sweep of ground hunting. We restructured the ground hunt and monitoring to avoid the areas until the chicks fledged.

In order to protect SCI cultural resources, we worked closely with the NPS archaeologist to inspect every potential trap site before trap construction. As the trapping program began in each zone, hunters would locate ideal spots for pig traps and the archaeologist would inspect each site for archaeological activity. If any was detected he suggested suitable alternate sites. To protect SCI's threatened and endangered plants, TNC provided us with locations, detailed descriptions, and photographs of the plants to avoid.

10.0 Adaptive Implementation

Adaptive project management was a major factor for the pig eradication project's success. Prohunt company founders have over 50 years combined experience in ungulate control and eradication. We designed the project based on that experience and yet recognized that all projects vary and methods must be adaptable to address unexpected conditions. Furthermore, there was no precedent for an eradication project of this intensity and size. We entered into the contract with TNC and NPS acknowledging the need for adaptive management.

Appendix 1 compares our proposed project implementation plan with the actual order that activities were completed across all five zones. Despite changes due to the adaptive approach taken on this project, Prohunt still accomplished the hunting, monitoring, and certification phases in line with our original estimates. This is rarely the case with large-scale projects that encounter challenges and require multi-agency collaboration mid-stream. It is also important to note that the proposed work schedule was considered very ambitious. It was not by chance that the eradication remained on schedule. Without Prohunt's commitment, years of field experience, and an open-minded adaptive approach, project challenges could have become project delays, which increase the chance of failure.

Several situations arose during the project that required discussion and modification of proposed methods. For example, upon arrival we immediately noted that the cattle guards constructed by the fence contractor would not limit pig movement between zones. This was the first need for modification and was immediately addressed by gating all cattle guards.

A more significant challenge was the need to alter our timeline so that NPS property (Zone 5) could be hunted during the season with fewest visitors and lowest fennel (*Foeniculum vulgare*) densities (from November to March). We had planned to hunt zones in order, as they were adjacent to one another, to reduce the chance of pig infiltration from neighboring zones. As each zone was cleared of pigs it became added protection in case of fence failure. Because Prohunt learned of the need to hunt Zone 5 after initiating trapping and hunting in Zone 3, it resulted in decreased hunting efficiency in Zone 3 and increased hunting intensity in Zone 5 to complete the hunt within only 5 months. Since we had such a limited time frame to conduct the hunt, the overall approach had to be altered; trapping time was reduced and aerial hunting accounted for a greater number of dispatches. Although eradication was accomplished, Zone 5 was the only zone with an unmarked pig that was never detected by Judas or Sentinel pigs during the ground hunt or during monitoring. We believe this was due to our forced deviation from our preferred hunting approach and the short time frame we had to hunt this zone.

Further changes to the project were needed when two proposed monitoring and certification methods were rejected during the course of the project. Extensive research and planning went into our proposal for Mark/Release pigs as a monitoring tool. However, it took little time in the field to recognize the inefficiency of capturing pigs to mark that would soon be dispatched. This was not the most effective use of collared pigs. The second rejected method was FLIR, planned for use during certification. Once field tested, Prohunt, TNC, and NPS recognized that it would be ineffective detecting pigs under dense foliage, their most commonly used refuge.

Rejection of these methods necessitated mid-project development of innovative techniques that could still meet project needs. The Judas and Sentinel pig protocols were developed in place of Mark/Release pigs and were highly successful. To replace FLIR, TNC contracted with Landcare Research to analyze monitoring data and recommend supplemental monitoring that would increase confidence levels that pigs had been successfully detected and eradicated in each zone.

The redesigning of monitoring and certification methods mid-project was the most challenging adaptive management needed for the project. The process was time consuming but necessary. We collaboratively developed methods that were statistically quantifiable, feasible to conduct in the field, and affordable to land managers. The result was a set of methods that may facilitate future eradication projects during monitoring and certification.

11.0 Lessons and Hindsight

Throughout this project Prohunt had opportunities to improve techniques for monitoring, GIS data base management, and certification for eradications of this scale. These improvements can be applied to future projects and adapted to fit various situations. As expected, additional opportunities arose for learning about methods that we would not recommended for future projects. Several were related to Judas and Sentinel pig monitoring techniques.

An important consideration for future projects is how long Judas and Sentinel pigs should be monitored. Monitoring over a long time period required that we refit radio-collars routinely because pigs gained or lost weight regularly. The GPS collars also required pig recaptures so data could be downloaded and batteries replaced. Every time a radio-collar is refitted or a new collar is used there is a chance (either by human error or collar failure) that the replacement collar will not function. It is not unusual for a percentage of collars to fail prior to the end of their battery life. Project staff and managers should realize that they may lose one of their Sentinel animals if it happens and that recapturing or dispatching a Sentinel pig with a faulty transmitter may be extremely challenging. Pigs that were captured and handled (the Judas and Sentinel pigs) were the most wary and hunter-educated of the population. Continuous radio tracking conditioned the pigs to hide rather than run from the helicopter, therefore requiring that a hunter be dropped off to obtain a visual of the animal. In future projects, monitoring data should be analyzed early in the project to help minimize the monitoring time period, the number of recaptures needed, and the chance of using a faulty collar. In addition, we suggest using additional VHF radio transmitter implants to mitigate the risk of failed VHF or GPS collars.

At the peak of the monitoring phase, we were tracking 70 Judas and Sentinel pigs, capturing and handling them regularly for collar refit and hormone implants, and transporting them between zones. Keeping records on each encounter with collared pigs became difficult. To assist with pig identification in the field and to streamline data management, we recommend using passive integrated transponder tags (PIT tags) with a unique serial ID for each monitored animal. Every time an animal is captured it can be scanned, the serial number recorded, and the capture and relocation data more easily managed.

Another challenge was being able to quickly identify whether a pig was collared from the air. When collars were new, they were easy to identify but after months of wear and accumulated dirt they were difficult to see. The use of brightly coloured large Allflex® cattle ear tags in both ears helped with this problem.

In hindsight we would recommend a stronger critique of quarantine protocols imposed on dogs on arrival to and departure from a new field site. Opinions of veterinarians in New Zealand differed from those in the U.S. who developed the protocols. U.S. veterinarians focussed on minimizing adverse affects on the endemic island fauna but failed to consider the need for a protocol during demobilization, even though the endemic island fox was known to carry a parasite not recorded elsewhere. This introduced a threat of infection to our dogs and the parasite could have been carried to other places had the issue not been managed successfully just prior to our departure from the island.

It is important that an eradication contract contains as many detailed components of the project as possible so contractors may bid accurately on the job. This requires having clearly defined field and data collection methods for hunting, monitoring, and certification. Even if the hunting approach is well designed the project may suffer if monitoring and certification techniques are developed late in the project. This situation occurred on the SCI feral pig project during the certification phase. TNC, based on Landcare's recommendations, requested that Prohunt conduct supplemental sand plot trials that were not a part of the original contract. Prohunt also wished to conduct the trials and did so, but at our own expense. On other projects contractors may refuse to conduct additional work not listed in a contract, or if they offer to do work not estimated in their cost they may run financial risks.

Although the adaptive approach to this project was critical to its success, it resulted in a lack of certain hunting data being collected early in the project. For example, since Zone 1 was hunted first it lacks traps success data and some Judas/Sentinel pig data because monitoring methods were still being developed. In hindsight, we recommend all eradication projects collect hunting (trapping, aerial, and ground) effort data, regardless of its predetermined use at the onset of a project. Early in a project it can be difficult to predict what data will later become essential. It is much more efficient to collect data and not need it, than not collect it and recognize its value later.

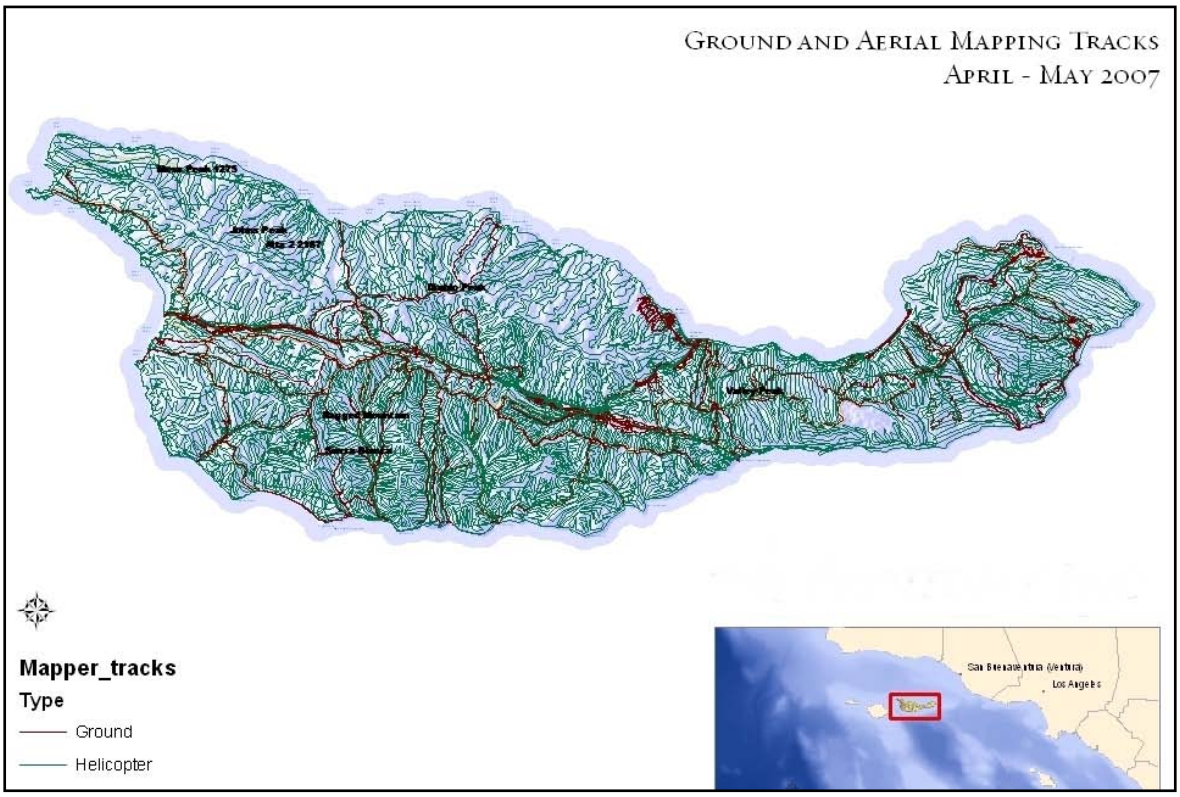
Whenever possible however, we recommend data collection protocols be defined in advance of project implementation. All hunting and monitoring efforts should be closely tracked and all data recorded in a consistent format. The number of days Judas pigs remained in a zone, how often they associated with collared or uncollared pigs, and the number of dispatches that result from their presence are all very valuable data that can be used to support an eradication project's final certification. Hunting and monitoring data can also be used to streamline future projects so that radio monitoring of Sentinels continues only as long as necessary. The estimated length of monitoring needed for various projects can be determined by analyzing hunting data statistically.

We recognize that every project will come with its lessons and hindsight and the need for adaptive management. Our goal is to learn from these lessons and make each project more efficient and streamlined than the last.

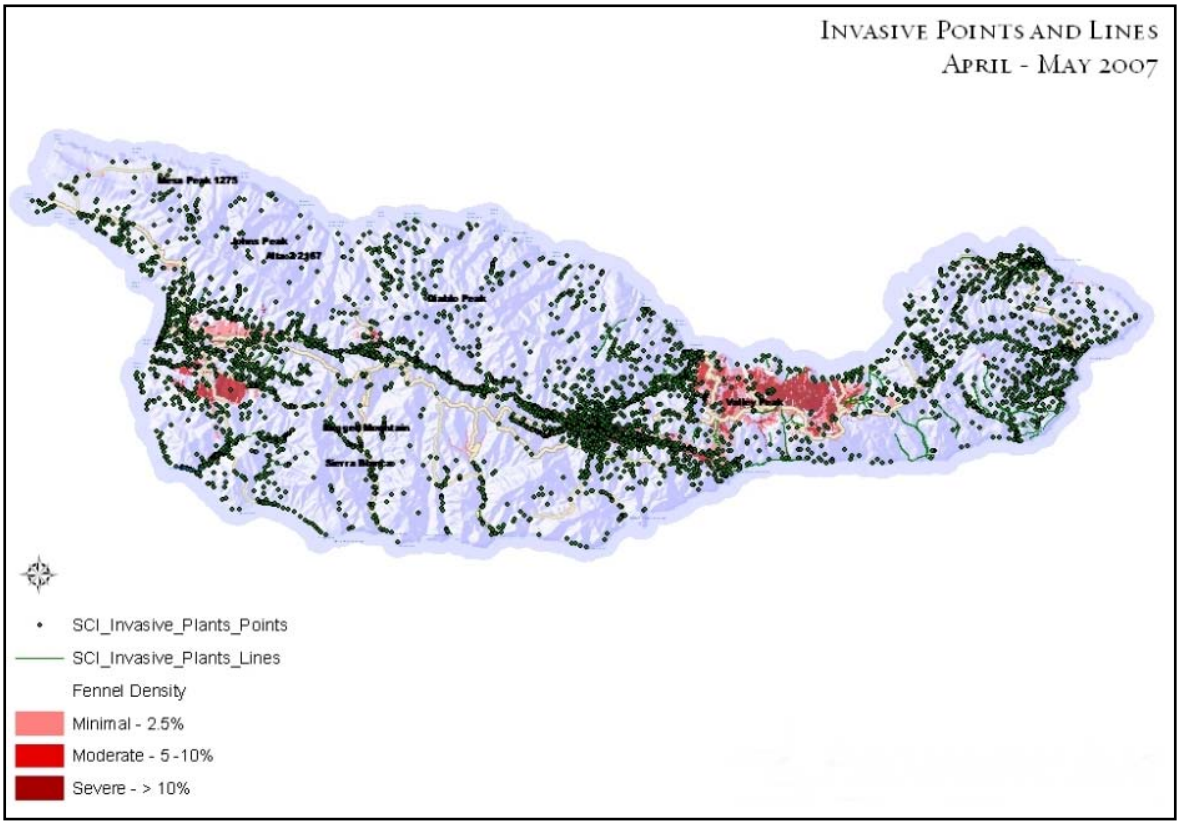
12.0 Partnership and Restoration Program Efficiency

One way land managers can reduce the risks involved in eradication projects is to keep the eradication team on site for as long as possible in case a previously undetected pig is discovered. Through commitment to project success and partnership, Prohunt worked with TNC to make this feasible. Prohunt offset the cost of keeping their hunters available for months after the hunting phase was completed by working on four additional TNC island restoration projects. We had the skills and infrastructure to conduct: island-wide golden eagle surveys and captures via net-gunning; feral turkey control and monitoring; invasive plant surveys, and ranch and island operations support by transporting heavy equipment to or from remote areas using the helicopter.

In April 2007 TNC contracted with Prohunt to conduct an aerial and ground survey of 55 high priority invasive weed species on the island. Because Prohunt was already on the island conducting the certification phase of the pig project, we could conduct the survey more cost effectively than mainland consultants. Our aerial survey method expedited the weed survey *and* reduced weed transmission that results from walking through weed populations to map them (Knapp et al. 2008). The island mapping project indirectly resulted in yet more survey coverage for any remaining pigs or fresh pig sign. Therefore, not only was weed mapping more cost effective and efficient, but TNC leveraged their investment in the pig eradication to conduct other restoration projects and received another pig sign survey free of charge. When costs are spread over a variety of projects by conducting several on a single island or multiple neighboring sites, natural resource management can become increasingly affordable (Morrison et al. 2007).



Map 9. SCI invasive plant survey tracks, April-May 2007



Map 10. Locations of 55 weed species surveyed by Prohunt, April–May 2007.

13.0 Conclusion

Like no other pig eradication to date, this project was completed in record time with quantified results, and a very high probability that there are no remaining pigs on Santa Cruz Island. Its successful completion demonstrated that large, topographically complex islands can be free of feral pigs if the project is planned and implemented strategically with technical expertise and commitment. Eradication projects are risky and this success represents a milestone in island conservation and eradication project strategy. It can be used elsewhere as a model to help increase the pace and scale of effective biodiversity conservation (Morrison 2007).

Essential to success was Prohunt's strategic eradication approach. Not educating animals while a population is being reduced is perhaps the most important means of limiting the risk of failure. This required consistent focus on how the last individual would be captured before the first was engaged. In contrast to animal control, eradications require that *every* engagement with an individual matters, because ultimately every individual will need to be removed. The efficiency of the feral pig eradication on Santa Cruz Island is a testament to the benefit of having this strategic approach from the start (Morrison et al. 2007).

In addition to Prohunt's hunting approach being a model for other projects, we demonstrated that data collected during an eradication can provide quantitative evidence of success. That same data (collected during the hunt) can help project staff plan their monitoring phase and any necessary supplemental monitoring or certification activities. This project's demonstrated use of hunting data to develop and meet certification criteria will help future eradication projects streamline their efforts and ultimately reduce project costs.

Prohunt's commitment to a successful eradication and collaboration with TNC and NPS was instrumental in the adaptive approach required by a project of this size. Our accomplishments on SCI demonstrate that not only can success be achieved, but that risks of eradication projects can be managed and reduced. This project was truly multi-agency and collaborative in nature and would not be the success it is without that foundation.

Prohunt's approach can be applied to future eradications on larger scales and within shorter time frames. Originally, TNC and NPS estimated six years would be required for the initial hunting phase and another five to complete hunting and monitoring to finish the SCI pig eradication. However, the island was certified as 'pig free' only 22 months following project implementation. This project is proof that, "accelerated implementation reduces investment risk in eradication. But perhaps most importantly, efficiency can help reduce the risk of extinction of native species on islands" (Morrison 2007).

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Santa Cruz Island Foxes, Photo: C. Cory

Appendix 1
Prohunt Inc. Non Target Aversion Policy

Prohunt Inc Non-target Aversion Policy

Objective

- To train dogs off non-target species.
- To ensure dogs are under the control of their handler(s) at all times.

Requirements

- All Prohunt Inc dogs must pass the initial non-target aversion program and the maintenance training program as required.

Training Requirements

Target Field

- An area where dogs are run every day to ensure there is nothing out of their normal routine.

Devices Used

- Dummy collar, electric collar, fox urine, fox bedding, taxidermy fox

Hunters

- Each hunter will train his dog(s) and the dog(s) he normally hunts with.
- Two dogs can be trained at once.
- Hunters will make sure their dogs have had dummy collars on for 5 days prior to test day. This will ensure the dogs are used to the weight of the collar when the electric collar is introduced.
- The vhf collars the dogs wear will substitute for the dummy collar.

Training Officer

- Trainer will set up an area with fox urine, bedding and the taxidermy fox.
- These will be laid in an area just visible to the hunter and trainer, approximately 70 meters away.

Introducing Dog to Aversion Training

- The trainer will stay back from the target area with the remote control for the electric collars.
- The hunter will put the electric collar(s) on his dog(s).
- The hunter will take his dog(s) past the area, if the dog(s) show a small amount of interest such as sniffing or looking and then backs off the hunter will acknowledge this as good behaviour.
- However, if the dog(s) keep moving toward the target the hunter will call the dogs in and growl at them.
- If the dog(s) don't respond to the hunter and keep moving in on the target the trainer will give the dog(s) a short shock with the electric collar. At the same time the hunter will growl at them.

Maintenance Training

- Any dog(s) that have shown an interest in the non-target species and have not responded to their handler will be required to repeat the training and not be used in the field until they prove to be conditioned.
- Dogs that have passed the training are required to repeat the training every 2 months.

Appendix 2
Detailed Hunting Discussion

Zone 1

Located in the far western portion of the island, this zone had extensive rolling grasslands but also encompassed part of the north ridge of the island. In April 2005 we began trapping in areas of dense vegetation cover and high pig density. We constructed 20 traps which resulted in 160 dispatches between April 6 and May 19. No traps were placed on the coastal side of the North Ridge because this area was open and ideal for aerial hunting. Aerial hunting in Zone 1 was very effective with the exception of vegetated boundaries around creeks. Between May 4 and July 9, 2005, one to two hours per day of aerial hunting resulted in 573 dispatches, or 71.8% of the total pigs dispatched in Zone 1.

Ground hunting (245 EHDs) was conducted from May 9 to July 25 with two complete sweeps through the zone and subsequent hot spotting. During that time hunters dispatched 65 pigs in Zone 1. There were several challenges to ground hunting Zone 1 in the summer months. First, the effective hunting day was limited to early morning hours due to the heat and limited scent detection by the dogs because pig scent from the night before would dissipate with mid morning heat. Pigs also remained hidden under vegetative cover during the heat. Dog health issues arose due to the lack of water, high temperatures, and numerous grass seeds that created infections in the dogs. Furthermore, heavy morning fog, more prevalent in Zone 1 than elsewhere, restricted helicopter use and required that we plan alternate hunting locations daily. During ground hunting in Zone 1 we found that the proposed Mark/Recapture program was not feasible. The pigs we collared prior to the ground hunt were instead used as Judas animals. Judas pigs in this zone resulted in six dispatches from the helicopter. The success of using this method for finding associated animals convinced us to use Judas animals as an aerial hunting tool in all zones.

Zone 2

Located in the southwest, Zone 2 was 11,215 acres and contained extensive canyons as well as steep ridges and mountains. Zone 2 was the second zone hunted but was trapped simultaneously with Zone 1. We constructed traps in April 2005 and pre-baited them on a regular basis between May and July. If bait was taken, the traps were set. We stopped trapping in late July when they were no longer productive. A total of 120 pigs were dispatched using 15 traps and 205 trap nights.

Aerial hunting in Zone 2 was more challenging than in Zone 1 because it was more heavily vegetated and provided more cover for pigs. Pigs attempted to evade the helicopter and aerial hunting became more time intensive. When the aerial hunting dispatch rate per unit effort dropped, we released Judas pigs (all females were hormone-implanted Super Sows) and radio tracked them via helicopter. We found the sows tended to remain stationary and boars travelled to find them. Almost all Judas pigs detected other pigs, but one implanted sow detected seven boars. Aerial hunting in Zone 2 removed 418 pigs, or 72.2% of all dispatched pigs. Five percent of these dispatches were the direct result of using Judas pigs while aerial hunting. Before ground hunting began the Judas pigs were recaptured and moved to another zone.

Ground hunting in Zone 2 lasted from July 27 to October 24, 2005. The two ground sweeps and subsequent hot spotting required 251 EHD and resulted in 41 dispatches. Helicopter access was, at times, limited by fog and high temperatures restricted the number of hours we could use dogs. We replaced spent dogs with others regularly to help manage potential heat stroke. Helicopter use resulted in saving dogs lives by swiftly bring those with heat stroke to water and cooling them down.

Zone 3

Zone 3 was the largest zone (17,180 acres), was in the central portion of the island, and had the most diverse terrain and vegetation. Geographic features, including the highest point on the island, bisected the zone into two parts: the remote north shore and the central valley and associated drainages. The hunting phase lasted from April 14, 2005 until June 12, 2006. The fact that Zone 3 required the greatest hunting effort is due in part to it being the largest zone but was also due to a change in schedule. After starting the hunt in Zone 3 in April, Prohunt was asked to complete the entire hunting phase in Zone 5 during the winter season. This required us to hunt in Zone 5 and 3 simultaneously.

A total of 44 traps were constructed in Zone 3 in two stages throughout the central valley. We set no traps on the north side of north ridge because it was ideal for aerial hunting and appeared to have low pig density. The first phase of trapping was from May 23 to August 26, 2005 and the second phase began on August 27, 2005. A total of 426 pigs were dispatched over 785 trap nights.

Aerial hunting in Zone 3 was conducted from April 16, 2005 and June 4, 2006, with the greatest effort from June 2005 through January 2006. Increased coordination between Prohunt and other island users was necessary in Zone 3 because it was heavily used by boaters, researchers based at the UC Field Station, and visitors and staff at TNC's Main Ranch. In order to minimize conflicts between visitor use and hunting, TNC temporarily closed beach access and Prohunt worked only in areas closed to visitors and with very limited researcher and staff access. Aerial hunting in Zone 3 started on the north side of north ridge. When trapping became less productive, we aerial hunted both sides of the north ridge to include the central valley. When the helicopter dispatch rate per unit effort dropped we introduced Judas pigs, which successfully detected others that could have been missed. Prior to ground hunting, Judas pigs were recaptured and moved to another zone. Aerial hunting resulted in 1361 pig dispatches (73.8% of the total number dispatched in Zone 3). Three percent of these dispatches were the direct result of using Judas pigs during aerial hunting.

We ground hunted Zone 3 from March 1 to May 24, 2006 with two sweeps and subsequent hot spotting. A total of 248 EHD's resulted in 57 dispatches. During the first ground hunting sweep an active bald eagle nest was discovered. TNC closed the area with a 500 meter buffer to all activities, including ground and helicopter hunting, until the nestlings were old enough to thermo-regulate if their parents were scared off the nest by hunters. Because of this closure, the second ground sweep was timed to avoid this area until later in the season.

Zone 4

Zone 4 (6,250 acres) was located in the south-central portion of the island and was dominated by steep ridges and canyons. Zone 4 was the smallest and last zone hunted on the island. We only constructed ten traps in Zone 4 and set them on January 30, 2006. During the trapping effort from late January to mid March, 57 pigs were captured and radio collared, to be used as Judas pigs. Following the trapping effort for Judas animals, we continued trapping periodically to dispatch any captured pigs (n=21).

Aerial hunting in this zone began in May 2006, after Judas pigs were moved temporarily into other zones. The aerial hunting effort removed 73 pigs, 70.9% of the total number of pigs dispatched in Zone 4. Seventeen of the 73 dispatches were a direct result of associations with Judas pigs after they had been returned to Zone 4.

Following aerial hunting, the ground hunt started at the eastern fence line on May 29, 2006. This sweep moved west through the zone and ended just 13 days later. The second sweep and three days of hot spotting were completed on July 20, 2006. The lag time between sweeps and hot spotting allowed the remaining pigs to resume normal movements and leave sign that ground hunters could use to help detect them. Ground hunting removed just 9 pigs in this small zone. In total, from March 10 to July 20, 2006, trapping, aerial hunting, and ground hunting dispatched a total of 103 pigs.

Zone 5

Zone 5 (14,709 acres) was on the east end of the island and is owned and managed by Channel Islands National Park. Geographic features included a steep, narrow isthmus, a large ridge (Montanon Ridge), and several large canyons. This zone was originally scheduled to be hunted following Zone 4 but was moved forward in schedule. Hunting here needed to coincide with winter months when the dense fennel (*Foeniculum vulgare*) dies, improving visibility, and when there was low park visitation, especially at the campgrounds. Moving the hunt ahead in schedule would affect fewer visitors since the park had to close during the hunt for public safety. NPS restricted all public access to Zone 5, except for weekend day trips, from November 1, 2005 through March 20, 2006 and we conducted all hunting activities during this closure. In addition to modifying our zone hunting sequence, we condensed the entire hunting phase within a short five month window. To do this, we compressed trapping and aerial hunting significantly to allow time for two ground hunting sweeps and hot spotting before the park re-opened in March.

On November 22, 2005 fourteen traps were constructed west of Montanon Ridge, no traps were constructed east of the Ridge. We pre-baited them and set them whenever bait was consumed, but only twenty-seven pigs were trapped. This number appears low because concerns that rainfall would accelerate fennel growth pushed us to move aerial hunting ahead of trapping. This was the only time we were forced to forego our preferred hunting strategy. In the other zones, traps were open for a long period of time prior to aerial hunting, whereas in Zone 5 aerial hunting began four days *before* traps were activated**.** Aerial hunting was so effective that traps had little impact on the pig population.

To ensure a successful hunt within a limited time frame, it was imperative that aerial hunting reduced the population density as much as possible *and* kept remaining pigs naive. However,

because of our limited time, we did not introduce Judas pigs into Zone 5 during the aerial hunt. Although we began aerial hunting prior to trapping, we continued even as the ground hunt commenced. Between November 2, 2005 and March 20, 2006, we dispatched 1450 pigs (92%) via aerial hunting. The first day of aerial hunting resulted in 232 dispatches, the highest number for any one day during the project.

We began ground hunting on November 27, 2005 after aerial hunting had reduced the pig population to a density where it would be most effective. The first sweep took 30 days and resulted in 72 dispatches and the second took just 20 days to complete with an additional 15 dispatches. The second sweep was shorter because as aerial hunting continued to reduce pig numbers, it shortened the time ground hunters spent detecting and dispatching pigs. Prior to hot spotting, the ground hunt was temporarily suspended to encourage the remaining pigs to leave cover and to increase the chance of sign (scat, tracks, or rooting) accumulating. Following rainfall that cleared away old sign, hunters surveyed for fresh sign and new soil disturbance via helicopter. Hot spotting took six days and resulted in an additional two dispatches. A total of 89 pigs were dispatched by the ground hunting team.

Appendix 3
Summary of Pig Sightings by Other Island Users and Pig Sign Form

Sighting #	1
Date	Early January, 2007
Observer	Biologist
Affiliation	TNC
Type of Sign Discovered	Possible rooting
Location	Pelican Trail, 10 minutes walk from the parking lot
Report Rcvd By	Rcvd by word of mouth same day as sighting
Action taken	After the report was given, a hunter was immediately flown to the area to check around the potential pig rooting for other sign such as tracks or scat. The next morning a team of two hunters and two dogs were sent to the same location.
Results of investigation	No pig sign (tracks or scat) was found. The "rooting" was skunk digging and the dogs discovered a skunk in the vicinity.

Sighting #	2
Date	1/17/2007, report rcvd 1/18/07
Observer	Island Visitor
Affiliation	Santa Cruz Island Foundation
Type of Sign Discovered	Tracks and rooting
Location	Chinese Harbour Road / China Pines
Report Rcvd By	Rcvd day after sighting
Action taken	A hunter and dogs went to Chinese Harbour the day of the report to investigate.
Results of investigation	There were no pig marks or pig rooting present anywhere. There was skunk digging covering the area. The reported rooting was dismissed as skunk sign.

Sighting #	3
Date	1/26/2007, 10:45am
Observer	Biologist
Affiliation	IWS Eagle Crew
Type of Sign Discovered	Pig vocalizations: observer heard a "pig grunt" while driving
Location	Prisoners Harbour, near gate going up to the Navy site after you cross the creek.
Report Rcvd By	Rcvd by Prohunt staff from biologist.
Action taken	Immediate response. Observer showed Prohunt the exact spot the noise came from. Prohunt responded with two hunters as well as dogs and the helicopter.
Results of investigation	After thoroughly checking the area, no pig scent was detected by the dogs. No pig sign was discovered by the hunters. A raven was heard in the area where the biologist had reported the pig grunting. The low chortling and clucking of the raven could have been mistaken for a pig grunt, especially over the noise of the engine of the observer's vehicle.

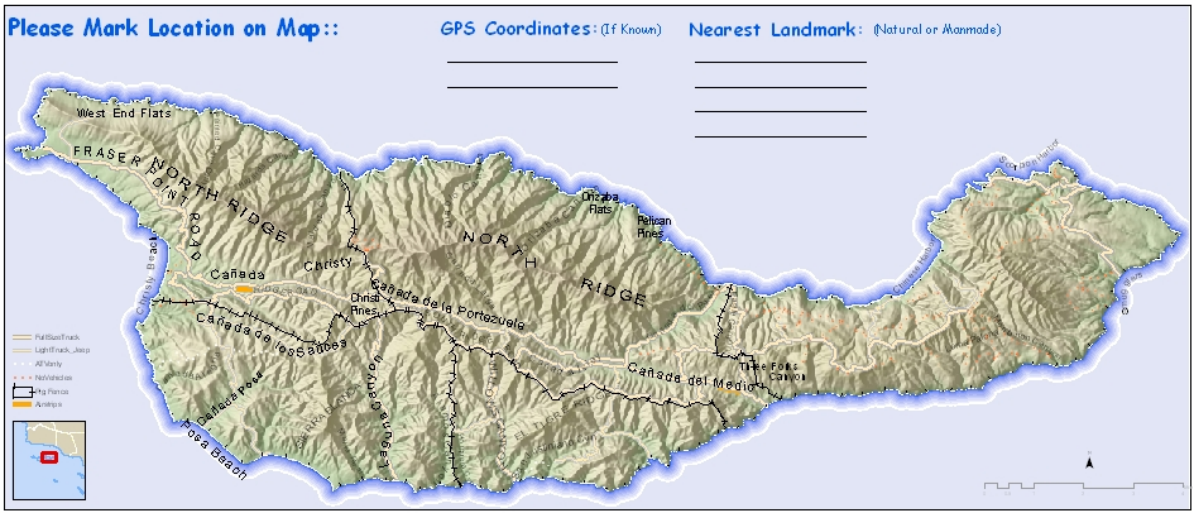
Sighting #	4
Date	12/4/2006, report rcvd 2/6/2007, nearly 2 months later
Observer	Botanist
Affiliation	USGS
Type of Sign Discovered	Rooting
Location	Near the south ridge road between Albert's Road and the Camino Real Road.
Report Rcvd By	Prohunt staff directly from observer
Action taken	Because the sighting was not reported until nearly 2 months after discovered, and because there were still known Judas pigs in the area, no one was sent to investigate the rooting.

Results of investigation	However, we reviewed the Judas tracking data for the time and the location of the sighting. Judas tracking data showed there were Judas pigs in the same area during the dates the rooting was observed.
Sighting #	5
Date	6/19/2007, report rcvd 6/22/2007
Observer	Student and teacher
Affiliation	Paso Robles High School
Type of Sign Discovered	Fresh pig scat and tracks "still wet", as well as tracks along the road.
Location	Scat located: Nad27UTM 3765191 235945. Posa Canyon on a bench above the road wash out. Tracks located along road on ridge between Sauces and Posa.
Report Rcvd By	Prohunt staff directly from student and teacher
Action taken	Hunters and 3 dogs hiked to the exact area of the "pig scat" the following morning (6/23/2007) and also investigated the area between there and the ridge where the tracks were supposedly seen. They were able to get to the exact location thanks to the coordinates provided.
Results of investigation	There was nothing found - no tracks and no scat at all. There were clumps of dry dirt, most likely dug up by skunks, that the student could have thought was pig scat. There were no pig tracks anywhere in the immediate area either.
Sighting #	6
Date	6/16/2007, report rcvd 7/8/2007
Observer	Boaters staying at Del Norte.
Affiliation	Island visitors
Type of Sign Discovered	Dead pig floating off shore
Location	Boat was anchored off Smugglers Cove and people saw a bloated dark mass with a seagull sitting on top floating from Yellow Banks toward the boat and out towards San Pedro Point. The boaters said it was "blackish, bloated, and had little legs." They did not go right up to it.
Report Rcvd By	Initially the report came second hand from TNC Facilities Manager who informed Prohunt immediately. A hunter tried to locate the boaters at Del Norte for more information, but could not.
Action taken	No action taken.
Results of investigation	Without further information and with such a lag time between the sighting and the report, we took no action. Without a better look, the bloated dark mass could have been a seal or sea lion with flippers that could look like legs.

Type of Sign Discovered or Number of Pigs Seen: _____ **(also fill in table below)**
Date_____ **Time**_____

Observer(s) _____ **Affiliation: (circle one)**
TNC NPS Field Station IWS Other _____
Enter Type of Sign Here: Enter Physical Pig Sighting Here:

Type of Pig Sign Discovered?		**or**	**Size**			**Sex**			**Color**		**Was the Pig Wearing a Collar?**		
			Piglet	Juvenile	Adult	Sow	Boar	Unknown	Spotted	Black			
Tracks											Yes	No	Not Sure
Scat											Yes	No	Not Sure
Rooting											Yes	No	Not Sure
Other											Yes	No	Not Sure



If you actually sighted a pig what was their action after sighting (e.g. which direction did they run) _____
_____
_____

Please submit to one of the following: (Mark which one) Prohunt: Office___ TNC : David Dewey ___ UCSB: Lyndal or Brian ___ Other: _____

Appendix 4
Detailed Monitoring Discussion

Zone 1

During a two month period following ground hunting in Zone 1, Judas pigs detected the three remaining pigs. Despite intensive and ongoing monitoring following those dispatches, and substantial Sentinel pig interaction, no additional uncollared pigs were ever detected. Five months after the last uncollared pig was dispatched, we moved the Sentinel pigs out of Zone 1. We kept Zone 1 completely pig free to check for evidence of remaining pigs or pig sign following rains that would remove any old sign. Although we found no fresh pig sign following rain, as a precaution fresh Sentinel pigs were introduced again and still no uncollared pigs associated with them. On January 3, 2006 the last Sentinel pig was captured and relocated to Zone 2.

Zone 2

After the ground hunting and hot spotting in Zone 2 were complete, we introduced approximately 30 Judas pigs into the zone in December 2005 to ensure sufficient coverage and to keep additional Sentinels that would be used in other zones as needed. Tracking 30 collared animals in one zone was time intensive, even via helicopter. Sentinel pig numbers were later reduced when some were transferred to Zone 5 for monitoring. We also dispatched Sentinel pigs that did not associate with other Sentinels but kept 15 in Zone 2 for the duration of the monitoring phase.

Over the 11 months when Sentinel pigs were in Zone 2, we recorded 619 monitored pig locations and Sentinel pigs were with other Sentinels 28% of the time they were located. They covered large distances within the zone, congregated with multiple other collared pigs, and did not detect or associate with any other uncollared pigs. This confirmed the effectiveness of the hunting phase.

Zone 3

Twenty-one Judas and Sentinel pigs were reintroduced to Zone 3 after the completion of the ground hunt. Of these, 10 were fitted with conventional collars and 11 had GPS collars. We collected 629 locations of monitored pigs and found that 30% of the time they were located with other collared animals. We detected and dispatched only one post ground hunt pig in dense vegetation through its association with a Judas pig. The Sentinel pigs remained in Zone 3 for a total of 9 months of monitoring after the ground hunt was completed. The last Sentinel pig was removed from Zone 3 on January 15, 2007. This was the final pig dispatched for the entire eradication project.

Zone 4

After the ground hunting and subsequent hot spotting was completed in Zone 4, we released 14 collared pigs in July 2006. The Sentinel pigs remained in the zone for six months, until December 24, 2006. During monitoring, we recorded 253 locations and no uncollared pigs were found. Sentinel pigs in Zone 4 were found with one or more other Sentinel pigs 47% of the time.

Zone 5

After the ground hunting and subsequent hot spotting was completed in Zone 5 we released 18 Sentinels in March 2006. A total of 571 locations were recorded between March 18 and December 6, 2006 (when the last Sentinel pig was removed). Despite months of tracking, no uncollared pigs were found, however, 31% of the time Sentinel pigs were located with other Sentinel pigs.

The last uncollared pig of the entire project was dispatched in Zone 5 during the monitoring phase, on June 23, 2006. This was the *only* dispatch of an uncollared pig during the monitoring phase of the project. The pig was discovered opportunistically during aerial surveys Prohunt was conducting for golden eagles. The helicopter crew captured the pig with a net gun and then dispatched it. The fact that Zone 5 was the only zone where Judas or Sentinel pigs did not detect an unknown pig may indicate that accelerating the hunting phase and modifying our hunting approach in this zone made the hunt less effective. The opportunistic nature of the final dispatch also emphasizes the benefits of having an eradication team work on multiple projects on the same study area.