

An Overview of San Diego County's Ongoing Feral Pig Eradication Project

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ABSTRACT: Until 2006, San Diego County remained one of two counties in California that did not have a resident population of non-native wild pigs. Since that time, three or more introductions of pigs resulted in the establishment of several populations of wild pigs that grew and were believed to span the backcountry of San Diego County. Feral pigs have the potential to harm sensitive habitats, compete with native species, negatively impact drinking water quality, damage agriculture and rangelands, destroy archeological sites, and transmit diseases. They also pose a significant threat to the network of protected areas in San Diego County. In 2009, affected public land management agencies began working together to address San Diego's pig problem in an all-lands approach by forming an Intergovernmental Pig Group. The Group determined that eradicating pigs was feasible, especially given recent drought conditions, and should be the ultimate goal of the project. In the summer of 2014, USDA APHIS Wildlife Services began a large-scale effort to remove pigs across San Diego County. We provide an update on the status of the eradication effort and share information we have gathered on the San Diego pig population from remote cameras and samples collected from pigs taken during this effort. We also outline our strategy for the future to achieve eradication, including how an independent monitoring study will be used to certify that eradication has been, and remains, successful.

KEY WORDS: California, eradication, feral pigs, San Diego County, *Sus scrofa*, wild pigs

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INTRODUCTION

Until 2006, San Diego County remained one of two counties in California that did not have a resident population of non-native wild pigs (*Sus scrofa*). In 2005, there was a suspected release of pigs near El Capitan Reservoir, and between 2006 and 2008, infrequent reports of feral pigs in the vicinity of the San Diego River began increasing, suggesting a number of pigs had become established in the watershed and were expanding their range to adjacent watersheds and increasing in population size. San Diego County has dense urban populations that abut large tracts of protected lands with native habitats and rich biodiversity. Pigs pose a significant threat to these habitats and species. As a result, they also threaten the network of protected areas in the San Diego County. Over the last two decades, substantial investments have been made in San Diego County to preserve and protect species, habitats, and ecosystems. The establishment of a stable and self-perpetuating pig population puts those investments at risk. At least 28 habitat types, 136 special-status plants, ten rare natural communities, 26 mammals, 24 birds, six amphibians, 14 reptiles, four fish, and ten invertebrates are found within the range of documented occurrences of feral pigs within the County. The habitats of primary concern that are known to be particularly susceptible to damage by feral pigs include wetlands (e.g., meadows, riparian habitat), grasslands, and oak woodlands. These habitats are also home to a suite of threatened and endangered plant and animal species. Furthermore, pigs pose a threat to the quality of drinking water that serves the greater San Diego area and to the economically important agricultural sector that includes cattle ranching, nurseries, and crops such as avocados.

The initial population of pigs was restricted to the central San Diego River surrounding El Capitan Reservoir in the first years after the release. By late 2009 or early 2010, it was reported that pigs had dispersed more than 20 km north to suitable habitats just beyond the headwaters of the San Diego River (SDNHM 2010). By 2014, pigs had been detected in four different areas of the county (Figure 1). Through removal efforts, we have come to suspect that these four populations were in fact separate releases or escapes based on the locations of the populations, movement of known pigs, as well as behavior and observations of removed pigs (including individuals with ear tags and a castrated boar) that suggested some animals were domestic stock.

To respond to the growing threat of established feral pig populations in San Diego County, affected public land management agencies began working together to address San Diego's pig problem in a cooperative "all-lands" approach by forming a feral pig intergovernmental group. The group is made up of 11 state, local, federal, and tribal government agencies that manage lands and water in San Diego County. The feral pig removal effort was established based on consensus among the Feral Pig Intergovernmental Working Group (hereafter, "Working Group") that the pigs in San Diego County were an isolated and relatively new population, and therefore a county-wide eradication effort should be attempted to eliminate habitat degradation caused by feral pigs. The Working Group jointly agreed to an adaptive strategy to remove pigs with a goal of eradication, conducted necessary environmental compliance processes (under the National Environmental Policy Act [NEPA] and the California Environmental Quality Act [CEQA]), and

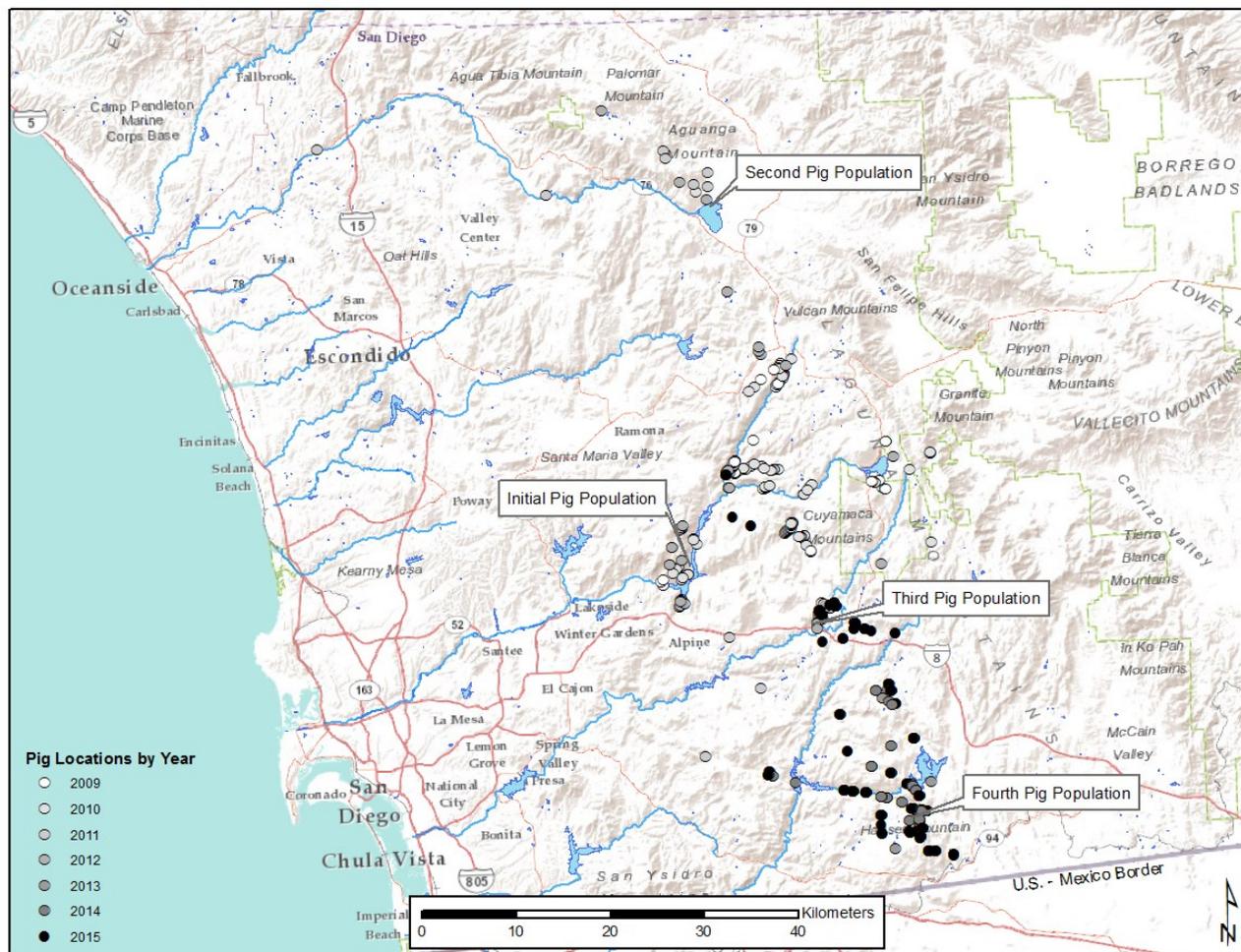


Figure 1. Map of the feral pig population in San Diego County, California. Points represent pig detections from track, sign, camera, or sighting and are coded by year. The locations of the initial pig population, first detected in 2005–2006, are identified, as well as subsequent populations are identified. The numbering follows the order in which the populations were detected.

arranged for additional permits such as depredation permits issued by the California Department of Fish and Wildlife (CDFW) for take of a managed game species. The group also worked together to identify and secure funding and elected to employ the services of USDA APHIS Wildlife Services (Wildlife Services) to lead the removal effort. This coordination and planning process took nearly five years to complete, but in July 2014 implementation of the coordinated eradication program finally began.

In addition to the removal program, the Working Group determined that an independent monitoring effort to complement the removal would increase the likelihood of successful eradication. The goal of this monitoring is to inform the strategy and actions of the eradication effort, particularly given the challenges of detection and tracking over a large area of contiguous habitat once population numbers are substantially reduced. To that end, CDFW contracted with researchers at the San Diego State University (SDSU) Institute for Ecological Monitoring and Management, in January 2015, to

develop a monitoring plan. The primary goals of the monitoring program are to: 1) confirm the current distribution of pigs in San Diego County, 2) track range expansions/contractions that may occur, and 3) determine the efficacy of the removal by helping to certify that areas that have been cleared remain pig-free. Monitoring involves detecting feral pigs and tracking their movements through the use of telemetry, track and sign detection, and the use of camera traps.

Here, we present the outcomes from the first 1.5 years of our removal and monitoring programs. We share lessons we have learned during the initial phases of our project, including gaps in knowledge that may hinder our understanding of the distribution and size of San Diego's feral pig population, and challenges in our assessment of the relative impact of our removal efforts on the population. We evaluate all potential sources of population reduction in the San Diego feral pig population, and we compare our removal estimates to the results of population growth models evaluated in previous research (CBI 2009). Finally, we will review the actions we are taking

to address our challenges and limitations and increase our likelihood of successfully eradicating pigs from San Diego County.

METHODS

Our eradication effort has been designed to make use of complementary datasets from our removal and monitoring programs. This approach capitalizes on the fact that the former is results-driven while the latter is data and observation-driven. We believe a combination of the two will provide the most robust information to direct our strategy. We are striving to not only collect positive survey data, which comes primarily from removal efforts (e.g., take of pigs, photographs of pigs), but are also using negative survey data collected through our monitoring to estimate the extent of the pigs' range over time and eventually, to confirm eradication. Both removal and monitoring efforts were focused on areas where pigs had been previously detected in San Diego County, California (Figure 1).

Removal Program

The removal program implemented by Wildlife Services has applied a range of methods including corral traps, cage traps, night-vision assisted shooting, snares, and working with dogs. Although aerial shooting was evaluated as a potential removal method during our NEPA and CEQA analyses, ultimately, employing an aerial platform is extremely difficult in this region and therefore unlikely to be used. The strategy for removal focused first on deploying baited remote cameras where pig sign was detected, or where previous observations had been reported, to determine if pigs were active in the area. Once pigs were detected in a location, more cameras were deployed to help identify the number of pigs in the area, as well as their activity patterns and movement habits. When feasible, camera trap photos were used to track individuals that had unique markings making individual identification possible. Removal efforts were then focused where pigs were detected. We deployed personnel and resources across the project area in locations with the most pig activity at the outset of the project. In particular, there was a concerted effort to document and remove pigs from the southern-most portion of the project area, which had and still has the largest and most active concentration of pigs in our study area. Concerns about pigs crossing the border and becoming established in Baja California Norte, Mexico, prompted support from project partners for a strategy focused on the southern pig population.

To expand our understanding of the feral pig population in San Diego County, all pigs that were removed were sampled for disease and genetic testing. To date, samples for genetic analysis have been banked, and it is expected that genotyping and analysis will begin in 2016. The National Wildlife Research Center (NWRC) Feral Swine Genetic Archive will be used to assess historical and recent gene flow and movement of pigs. It will also be used to assess population level information, including movements of pigs and relatedness among individuals, on a landscape level. NWRC has also been conducting disease screenings as samples are

received.

In addition to our own removal efforts, Wildlife Services has also led coordination to gather additional information and support pig removal on private and tribal lands. Although local tribes were engaged in the Working Group, they elected to organize and conduct pig trapping and shooting on tribal lands themselves rather than to contract with Wildlife Services. To assist with those efforts, we provided advice to tribal trappers on methodology, equipment, and approaches for successful removal of pigs on tribal lands. Wildlife Services has also continued to monitor for pigs on private lands when performing other services for landowners who are part of the normal program of activities in the region. Finally, we have also established a relationship with U.S. Customs and Border Protection (CBP) staff to gather additional information about pig populations near the U.S.-Mexico border. CBP has an extensive camera and sensor network, conducts regular helicopter scouting, and has dozens of agents on the ground in the region that may detect pigs near the border. We have asked for their assistance in reporting observations to support our efforts.

Monitoring Program

To track pig range and distribution, SDSU designed a monitoring network across the suspected range of feral pigs in San Diego County. The data collected from this monitoring will be analyzed to estimate home range sizes and occupancy rates across the study area, determine habitat preferences and movement patterns, and to understand seasonal changes in San Diego's feral pig population.

Permanent Camera Stations

The cornerstone of the monitoring program is the installation of camera stations. The goal of these stations is to cover the extent of the affected area, and slightly beyond, with monitoring stations that will remain in fixed locations through the duration of the feral pig eradication effort. These stations will allow for consistent data collection through all phases of the project, to inform strategic planning and to provide a basis upon which we can determine if the eradication effort has been successful.

Camera station locations were identified across the entire study area using a combination of a Geographic Information System (GIS) and field-based information. We began by generating a grid of 10×10-km cells over all known pig locations in San Diego County, surrounded by a 10-km buffer, to ensure an even distribution of effort across the project area. Based on mapping, we chose one to two camera locations within each cell along movement corridors, funnels, and pinch points to increase our chances of detecting pigs. These locations were cross-referenced with a habitat suitability model developed during a previous assessment of the potential impacts of pigs in San Diego County (CBI 2009). Exact camera placement varied based on site conditions, but cameras were generally installed within approximately 100 m of the mapped location. On-site placement was determined based on the location of wildlife trails, suitable mounting locations for the cameras, and options for camouflaging

the cameras from the public to limit vandalism and theft. As with Wildlife Services camera stations, SDSU cameras were baited with a fermented corn mixture to improve detection rates if pigs were in the general vicinity of the monitoring station. These camera stations will remain in place for two to four years after we believe eradication has been achieved.

Collaring and Tracking

We also included the use of radio-collared “Judas” or “Sentinel” pigs as a component of the monitoring and eradication program. This involves capturing and collaring pigs with VHF/GPS transmitters and releasing them. Subsequently, tagged individuals are expected to reintegrate with social groups, enabling us to locate other feral pig congregations. If after a period of time, the animal does not “find” any other feral pigs with which to group, it can be located with the telemetry signal and removed.

The collaring of feral pigs has been led by CDFW in coordination with Wildlife Services tracking and trapping efforts. On September 17, 2015, the first feral pig was collared with a Telonics CMM-340 VHF collar (Telonics Inc., Mesa, AZ). Telemetry tracking via triangulation was attempted one to two times per week, and we also recorded all locations of the collared pig from detection on cameras.

RESULTS

Removal Program

Although the implementation of the feral pig eradication program officially began in July 2014, several groups of feral pigs were removed from private lands prior to that time, totaling 65 individuals between 2010 and 2014. Since the beginning of the coordinated eradication program, an additional 49 individuals have been killed, for a total of 114 individuals (Figure 2). Of the 35 pigs that have been tested by NWRC for a suite of diseases, 14 were positive for leptospirosis and one was positive for swine influenza. Approximately half of the individuals taken were female. Many more juveniles and piglets have been taken than adults, as sounders have been the easiest groups to capture in corral traps. Corral and cage traps have been the most successful removal methods to date (Table 1).

During the first 1.5 years of our coordinated eradication program, Wildlife Services invested over 13,000 labor hours, 2,668 trap nights, 54,078 camera nights, and 56 dog hours. A substantial number of trap nights and person-hours were lost due to vandalism and theft of cameras and traps over a period of several weeks. We relied on the assistance of law enforcement officials to stop the illegal activity and recover stolen equipment. We ran cameras at 315 different locations with 125 to 150 cameras active at any given time. Although many of the methods we have applied require a substantial investment of person-hours, we found that it has been necessary to apply all the methods at our disposal, particularly when it comes to removing solitary adult boars that have large home ranges and are wary of traps and humans.

In addition to tracking the number of pigs lethally removed through the efforts of Wildlife Services, we

have also attempted to document the fate of other pigs within the study area. We examined annual pig harvest reports produced by CDFW, but reporting to CDFW is not required of pig tag holders, so these records are likely an underestimate of pigs taken by recreational hunters. Between 2005 and 2015, CDFW received reports of 35 pigs taken from San Diego County (Figure 2). In addition to hunting, we have also received a report of at least one pig that was struck and killed by a vehicle. Finally, we suspect there has also been some reduction in our local pig population by predation. It is most likely that mountain lions (*Puma concolor*) opportunistically prey on pigs (Hopkins 1989), but coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) may also prey on pigs to some extent, particularly the smaller juveniles and sows (Maehr and Brady 1989, White et al. 1995, Baker et al. 2001, Young et al. 2006).

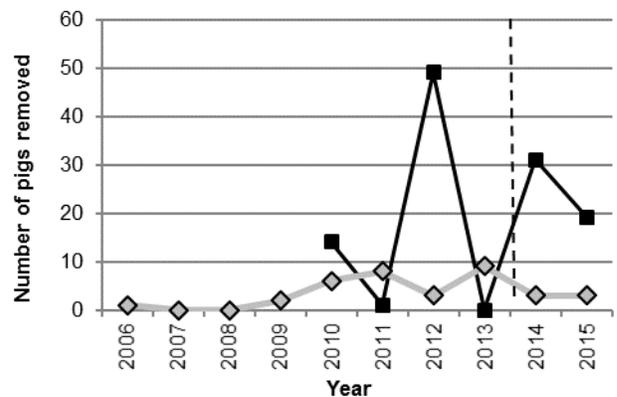


Figure 2. Number of feral pigs documented as removed from the population in San Diego County, California since the initial release in 2006. The dark line represents pigs removed by Wildlife Services, and the gray line shows harvest records reported to CDFW by recreational hunters between 2006 and 2015. Dotted vertical line represents the beginning of the coordinated eradication program led by Wildlife Services.

Method	January 2010 - July 2014	July 2014 - December 2015
Cage trap		6
Corral trap	51	28
Dogs		2
Foot snare		2
Night vision		4
Shooting	14	7
Grand Total	65	49

Table 1. Feral pig take in San Diego County, California, reported by method. All pig removals tracked here were those taken in efforts led by Wildlife Services. The number of animals removed is split into the time frame prior to the start of the coordinated eradication program in July 2014, and after implementation began.

Monitoring Program

Permanent Camera Monitoring Stations

We have established 67 camera stations that are being run by SDSU ($n = 25$) and project partners ($n = 42$), with another ten planned, as permanent monitoring stations across the project area. To date, our SDSU cameras have collected data during >3,000 camera nights, gathering over 250,000 photos. We have processed all camera data through December 2015 and we have not detected pigs in any locations beyond the extent of the range documented at the beginning of the project. We are in the process of gathering and processing photos from our partners' cameras over the last year.

Collaring and Tracking

After the first pig was collared on September 17, 2015, SDSU and Wildlife Services worked cooperatively to locate the pig one to two times per week, if possible. We confirmed via Wildlife Services camera monitoring stations that the collared pig rejoined her sounder shortly after capture and collaring. We gathered a total of 26 locations for the animal, including her initial capture. In early January 2016, it appeared that the collar signal was no longer moving, and on January 13, 2016 we recovered the collar with no sign of the pig in the vicinity. We suspect the collar may have been cut off by a hunter, but we cannot confirm this. To date, we have not detected the sow on cameras in the area since. Based on the sow's locations, we estimated a 100% minimum convex polygon home range of 30.9 km². Prior to November 2015, the female and the rest of the sounder were using a much smaller home range area of approximately 6.4 km². After difficulty in detecting the signal for several weeks in November, we found that the group had moved five km to the north. We received reports that a group of hunters had successfully killed the other adult sow in the collared pig's sounder. It is possible that the hunting pressure and removal of the other sow spurred the group's movement to the north.

DISCUSSION

Although unchecked population growth and the consequences of a rapidly expanding feral pig population were concerns for many land managers in the County, we believe that eradication is still a feasible project goal. Although we do not have reliable estimates of the maximum size the feral pig population had reached, several factors may have affected population size or growth rates since the releases. Unfavorable environmental conditions during the four-year drought California is experiencing, a low level of hunting and predation pressure on the feral pig population, and our concerted removal efforts appear to have either limited population growth or substantially reduced the population of feral pigs in San Diego County. There are eight known pigs remaining within our study area, and we estimate the population may be as low as 20 or fewer pigs. However, the biggest threat to the success of the project appears to be new releases of feral pigs in San Diego County. In addition to our current monitoring efforts, expanded post-removal monitoring may be warranted to detect new releases and address them immediately, before new populations have an opportunity to

grow and disperse.

We suspect that the pigs removed from San Diego County since 2010 may have been the result of at least three, and possibly four, separate releases or escapes, including the initial release in the San Diego River (Figure 1). One release to the north may have been completely contained in 2012 when Wildlife Services removed a group of 30 animals that exhibited domesticated behaviors and included ear-tagged animals. There was another group of pigs to the east of the initial 2005 release site, where a release was confirmed when ear-tagged animals and a castrated boar were removed. It is unclear whether the animals from the eastern site were able to traverse Interstate 8 to the south to reach the southeastern portion of our study area, or whether that population is yet another release or escape. There have been unconfirmed reports that a pig farm once operated near the town of Campo, CA and that pigs may have originated there, as the southeastern population of pigs is less than ten km from that area. The genetic testing described above may help us identify whether that is the case, thus providing a better understanding of how the release and spread of pigs in the county occurred over the last ten years.

Across the entire study area, trapping has been the most successful method of take thus far. However, as numbers dwindle and the remaining pigs become more educated and/or trap-shy, particularly wide-ranging boars, we will likely rely more heavily on shooting, night vision, tracking with dogs, and foot snares to target specific individuals. The use of remote cameras has helped to pattern movements of known pigs identifiable by unique markings, which has led to the successful removal of several of the large boars and sounders in our study area. The success of the project thus far suggests that continuing with a goal of eradication remains feasible. Research conducted by colleagues at NWRC (Amy J. Davis, USDA NWRC, pers. comm.) determined that, based on pig detections on remote cameras, occupancy rates have been reduced over time, particularly in the southern end of the project area where initial population size and density was the highest. Despite the original size of the population near the U.S.-Mexico border at the outset of our coordinated eradication program, to our knowledge no pigs have been detected at or south of the border. Pigs were active within five km of the border but were never detected south of State Route-94, a major highway that runs east-west along the southern part of San Diego County. Furthermore, there have been no detection of pigs along the border by Wildlife Services or CBP.

The continued use of Judas or sentinel pigs as a tool to facilitate removal is unlikely, but we may consider collaring on a case-by-case basis if new animals are detected. We anticipate that there will be limited opportunities for collaring in the future, as the numbers of pigs has declined significantly. Furthermore, the average size of the animals and removal methods are not conducive to capture, sedation, and collaring. Many of the pigs captured in corral or individual traps are juvenile pigs that are not suitable for collaring, due to weight limits and expected growth rates that make safe collar fitting difficult. In the event that we do have a situation where the

benefit of collaring would outweigh the risk of releasing a captured animal, we have secured a satellite collar to facilitate tracking and improve our ability to use the sentinel pig to locate other animals.

Between our removal efforts, harvest by successful hunters, and possible predation by native predators such as coyotes, bobcats, and mountain lions (Hopkins 1989), we have observed what appears to be a substantial decline in the population of pigs in San Diego County, as reflected in our detection of the species on camera traps and from tracks, scat, and rooting. Although Bieber and Ruf (2005) suggest that limited food resources would be indicative of poor environmental conditions for feral pigs, we posit that drought may be another indicator as water is a limiting factor for pigs, particularly in the arid southwest. Acorn masts, an important food resource for pigs (Barrett 1982, Waithman et al. 1999), are subject to boom and bust cycles, and the synergistic effects of limitations in both food and water resources may have limited pig population growth and range expansion in San Diego in the last decade.

Beyond these environmental conditions limiting the growth of San Diego's feral pigs, it appears that a number of pigs have been successfully removed through hunting. Recreational pig hunting in the county has increased since the initial pig population was introduced, and it may have also assisted to some degree with keeping the population small in the years after the initial release. It is difficult to know the exact impact as harvest reporting for pig hunters is optional, but if we consider the 35 pigs reported to CDFW to be an underestimate, it appears that even a low level of hunting pressure may have slowed population growth, particularly when coupled with targeted removals performed by Wildlife Services on private lands prior to the beginning of the coordinated eradication effort. Additionally, organized hunts took place on tribal lands that surround El Capitan Reservoir (USFS 2013) where the population of pigs was originally at its highest. The harvest from those efforts was not documented. Despite the uncertainty, if these estimates are combined with the recorded pig take by Wildlife Services, upwards of 200-250 pigs may have been removed from San Diego County between 2006 and 2015. If pig population estimates for San Diego County based on models under poor (e.g., extended drought), or even moderate environmental conditions (CBI 2009) are accurate, the removal of 200-250 pigs could have mitigated population growth from the initial release as well as the subsequent releases/escapes. Based on these numbers, our approximation of 20 animals remaining appears to be a reasonable estimate.

As many research efforts have documented (e.g., McCann and Garcelon 2008, Ramsey et al. 2009, Klinger 2011), once a population is reduced to extremely low numbers and densities, removal becomes more difficult. Moderate harvest rates (i.e., greater than the reproductive/growth rate of the population), even with low population densities, are necessary to successfully achieve eradication. To reach our eradication goal, we plan to focus efforts in the coming years on taking adult females where possible, because removing those individuals will have the greatest effect on the population (Bieber and Ruf 2005). We also plan to continue inten-

sively monitoring our study area with remote cameras. We will complement the detection/non-detection data gathered from remote cameras with ground survey data to document areas where sign (i.e., tracks, scat, rooting) has been observed and those areas where no pig activity has been documented. We are in the process of establishing protocols to better gather and track this non-detection data from across the project area, by developing a grid-based strategy to have SDSU and Wildlife Services staff visit areas within each grid cell across the study area on a monthly or bi-monthly basis to increase the probability of detecting new pig sign.

As we approach a pig population of zero, we will continue using camera monitoring combined with our information from removal efforts to determine our detection probability and our confidence in actual eradication (Ramsey et al. 2009). A long-term commitment to this monitoring will be critical both in confirming successful eradication as well as detecting additional releases that may threaten our project goals. Finally, in the future, the Working Group should consider focusing more effort on education and enforcement to prevent further releases or escapes that could threaten the long-term success of this project.

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