Live capture and removal of feral sheep from eastern Santa Cruz Island, California

K. R. Faulkner[1] and C. C. Kessler[2]

[1]Channel Islands National Park, 1901 Spinnaker Drive, Ventura, CA 93001, USA. <kate_faulkner@nps.gov>.
[2]US Fish and Wildlife Service, 300 Ala Moana Blvd. Honolulu, HI 96850, USA.

Abstract Sheep (*Ovis aries*) were brought to Santa Cruz Island, one of the eight California Channel Islands, in the mid-1800s. The islands were ranched throughout the 19th and most of the 20th century. Hunting of feral sheep occurred during the late 20th century. The Nature Conservancy (TNC) purchased the western 90% of the island in 1979 and eliminated sheep from their property by 1989. Feral sheep remained on the eastern 10% of Santa Cruz Island (ESCI) and supported a private sport hunting operation. The National Park Service (NPS) completed acquisition of ESCI in 1997. The sheep, private property of the former landowners, had to be either purchased or relocated. NPS opted to live capture and move the sheep to the mainland. It was thought there were approximately 2300 sheep at the time. Capture operations began in May 1997 using herding and corral traps with bait. As sheep capture became more difficult additional techniques were tested. Herding into corral traps in strategic locations was the most efficient technique. As numbers declined, sheep were individually pursued and captured. Transport of animals from the island involved loading sheep into stock trailers and driving the trailers onto a landing craft. The project was declared complete in December 1999 with over 9200 sheep captured. However, remnant sheep were found several times and the last sheep was removed in February 2001. Each of the California Channel Islands had sheep for some time during the ranching era of the 19th and 20th centuries. This project ended this chapter in the history of the Channel Islands.

Keywords: *Ovis aries*, California Channel Islands, eradication, island restoration.

INTRODUCTION

Santa Cruz Island, 25,000 ha (Fig. 1), is the largest of the five islands in Channel Island National Park off the coast of southern California The island has rugged terrain that reaches 747 m, steep canyons, extreme slopes and perennial and ephemeral streams. Climate is Mediterranean with plant communities predominantly grassland, island chaparral, island and southern coastal oak woodlands, bishop pine forest, and coastal-sage scrub (Minnich 1980; Junak *et al.* 1995).

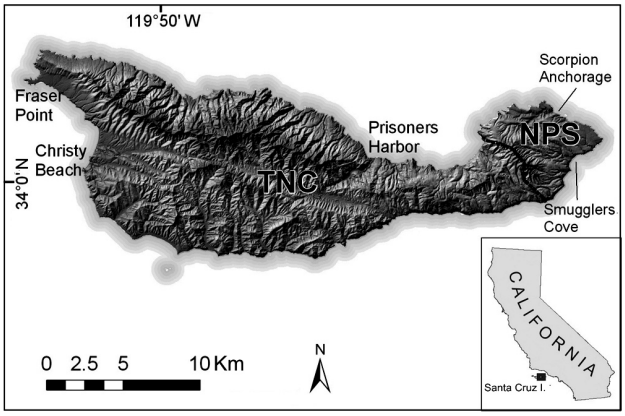

Fig. 1 Santa Cruz Island; the largest of the eight California Channel Islands.

Santa Cruz Island wss a Mexican land grant, which in the mid 1800s was transferred to private owners who shortly afterwards introduced sheep (*Ovis aries*) for wool and meat (US District Court 1857; Brumbaugh 1980). Periodic roundups of these Merino-Rambouillet-Churro sheep (Oklahoma State Univ. 1998; Van Vuren 1981) captured at least 50,000 (Towne and Wentworth 1945) (Fig. 2), which probably accounted for no more than half the population at any one time (Symmes and Associates 1922). Various fence lines and fenced pastures were constructed to facilitate the round-up. By the 1920s, sheep were essentially feral over extensive areas. In 1925, ownership was partitioned among descendants of the former landowner into two separate parcels. One parcel, forming the western 90% of the island (WSCI), was purchased by The Nature Conservancy (TNC) in 1979. The eastern 10% (ESCI) was purchased by the National Park Service (NPS) in 1997 through a "legislative

Fig. 2 Sheep round-up circa 1920 on Santa Cruz Island, California, USA.

taking" authorised by the U. S. Congress (Public Law 104-333; Sec. 817). Formal sheep ranching ended in the mid-1960s on WSCI and in 1984 on ESCI. By 1997, ESCI was primarily bare ground and overgrazed grassland, almost devoid of trees and severely eroded.

Upon acquisition of WSCI, TNC determined that sheep were the main cause of habitat destruction and the greatest threat to the island's native biota (Brumbaugh 1980; Hochberg *et al*. 1980; Van Vuren 1981; Van Vuren and Coblentz 1987). Sheep also affected cultural and historic artifacts (Van Vuren 1982). TNC and volunteers began feral sheep eradication between 1981 and 1989 on most of WSCI and shot 37,717 sheep at a cost of US$240,000 (Schuyler 1987, 1993). TNC constructed a fence near their eastern boundary to restrict entry of sheep from ESCI, which left sheep on 3300 hectares of the island (this includes 800 ha of TNC property to the east of the sheep fence). The owners of ESCI at the time controlled the feral sheep (and feral pigs present throughout the island) with guided sport hunts for paying clients. This control ceased with the acquisition of ESCI by NPS.

The mandate of the NPS is to "Conserve the scenery, natural and historic objects and wild life therein and leave them unimpaired for future generations". Thus, the NPS decided to eliminate the remaining sheep from the island due to their ecological and archaeological impacts. Because

Pages 295-299 In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

the feral sheep were the property of the former landowners, the NPS had a legal responsibility to either purchase the animals or relocate them to the mainland. Animal rights organisations quickly announced that they would fight any project that involved killing the sheep. The NPS felt it would be possible to eliminate the sheep through live-capture and transport.

This paper outlines the methods developed over four years that enabled the eventual removal of all remaining sheep on ESCI through live capture and transport. We also describe some subsequent changes to the island ecosystems.

MATERIALS AND METHODS

Developmental phases

Upon acquisition of ESCI, the NPS immediately began developing an infrastructure that would support the removal of sheep including: 1) the rebuilding of corrals and fences, construction of walk-in traps; 2) purchase and modification of stock trailers; and 3) acquisition of baits, all terrain vehicles (ATVs), and sheep-holding containers for slinging under a helicopter. Fencing consisted of standard 1.2 metre high wire sheep fences hung on 1.8 metre metal T-posts. A veterinarian provided extensive advice and review of planned procedures for the holding and transporting of sheep.

The first year of the sheep capture and removal (Phase I; Table 1) was carried out by NPS personnel, including two Navajo sheep herders hired specifically for the project. The infrastructure to hold, feed, and transport the sheep was also developed during this period. NPS operations began by capturing sheep in the most accessible pastures by baiting into corrals using water, apple mash, molasses, hay, and sweet feed. One attempt was made to herd sheep using a line of 32 people and a helicopter.

In early 1998, the NPS solicited contractors with sheep herding experience to assist with the project. Phase II of the project began in June 1998 by contracting a sheep herding company with border collie dogs trained to work with large flocks of domestic sheep. However, this contractor worked for less than one month. Phase III involved the NPS continuing capture of sheep while searching for a new contractor with the necessary skills to capture the many feral sheep remaining on ESCI.

In Phase IV, over 70% of the sheep were captured with assistance from a contractor who specialised in the capture of livestock such as feral cattle, using dogs and people on horseback. Once it was thought that all sheep had been captured and removed, NPS staff on the island continued to monitor backcountry areas for sign of sheep.

Aerial surveys

Surveys using a Bell Jet Ranger helicopter flying along the contours of ESCI were conducted in the early morning of 12 and 13 November 1998 using three and two observers respectively. Each survey took approximately two hours to cover the approximately 3300 ha potentially occupied by sheep. More than 5000 sheep had already been removed and the primary purpose of the surveys was to estimate the number and distribution of sheep remaining.

Capture and transport

Most sheep were caught by herding them into large corral traps in strategic locations. The sheep were moved by a combination of personnel on foot, horses, and ATVs, and with the help of dogs and occasionally a helicopter. Passive baiting to attract sheep to corrals was used in Phase I of the programme when animals were particularly numerous and in need of food or water. Other methods attempted but less effective than herding were net gunning, drive-nets, boma fence, darting, pop-up traps, cannon nets, drop nets, night capture, plastic barriers, noise makers, plastic fencing, and telemetry. When sheep numbers were reduced, individual animals were pursued and captured.

Upon capture, sheep were transported by herding, vehicle, or helicopter, held in corrals near Scorpion Harbor, and shipped to the mainland. The holding pens, along with lanes and gates, were built in a sheltered area to separate sheep and facilitate loading operations. Food and water were provided as some sheep were kept in the pen for a week or more. Sheep were generally held until numbers reached approximately 200 animals, which justified running a landing craft.

Sheep about to be shipped were loaded into 6.7 m stock trailers modified with a centre platform to create a top and bottom that could be sectioned into four compartments. Each trailer could carry 75 sheep and was pulled by a ¾ ton pickup truck. Up to three trailers were loaded onto the park's 24 m landing craft for the 35 km trip across the channel to the Port of Hueneme on the California mainland. Tractors and forklifts were used to tow trailers onto and off the landing craft. The trailers were offloaded at the mainland and driven 145 km north to a stockyard in Buellton, California to be transferred to their owners.

Monitoring

Post-project monitoring was informal and carried out primarily by park and TNC personnel in the course of their other duties on the island. Staff carried out regular surveys by foot or vehicle throughout ESCI. Efforts concentrated on preferred habitats, such as water sources and canyons.

RESULTS

Size of sheep population

It is unknown how many sheep were on ESCI at the time of acquisition by NPS. Densities on highly impacted areas on WSCI were estimated at approximately 2 sheep/ha (Van Vuren 1981; Van Vuren and Coblentz 1987; Schuyler 1993). A similar density on ESCI (including the additional 800 ha of TNC property to the east of the sheep boundary fence) would indicate approximately 6600 sheep. However, in the seven months prior to NPS acquisition, the landowners had shot approximately 3000 sheep as part of their sport hunting operation. The hunt operators estimated that 2300 sheep were on ESCI at the time of the land purchase and the NPS began the project believing this to be a good estimate of numbers.

Table 1 Capture of sheep.

Period	Phase	Number of sheep captured
May 1997 – May 1998	I. NPS Initial Operations	1999
June 1998	II. Contractor #1	328
June 1998 – Sept. 1998	III. NPS Operations	273
August 1998 – December 1999	IV. Contractor #2 (Lausten) and NPS Operations	6653 (3822 of these following the Nov. 1998 aerial count)
January 2000 – February 2001	V. Monitoring and removal of remnant sheep	6
TOTAL		9259

Another estimate can be made by back-calculating from the number of sheep captured and using the following assumptions about feral sheep: 1) female to male ratio is 1:1, and 2) the productivity of females is almost 100% (Van Vuren 1981; Van Vuren and Coblentz 1987; Griffin 1976). This suggests annual recruitment of between 40%-50% of the total population. While lambs were found at any time of the year, most reproduction was during winter (Van Vuren and Coblentz 1987). Assuming 45% annual recruitment to the total population, this amounted to a monthly increase of 3.8%. Monthly capture rates were calculated by dividing the total captures for a period by the months of that period. This resulted in an estimation of roughly 5000 sheep present on ESCI at the beginning of the project; more than double the belief of the former hunting guides.

Aerial counts

The aerial counts in November 1998 tallied 1889 and 1712 sheep, respectively. Observers estimated they had likely missed approximately 15% of the animals and therefore thought the number of sheep was likely approximately 2100 animals. Most aerial counts have been shown to be underestimates (Caughley 1974; Cook and Jacobson 1979; Caughely and Grice 1982; Gasaway *et al.*1986; Pollock and Kendall 1987), and the proportion that escapes detection can be up to 50% of the animals (Stoll *et al.* 1991).

In the year following the count (between December 1998 and December 1999) 3822 sheep were removed. Assuming an annual increase of 45 %, and that lambing was shortly after the count, the population during the survey would have been 2,635 animals; an under-estimation by the aerial count of up to 35%. However, since ESCI was relatively barren of trees and with woody vegetation cover of appeared to be less than 10%, a 35% undercount is much higher than estimated by observers. Sheep may have been able to hide in ravines and on cliff-faces. Furthermore, the earlier use of the helicopter for herding may have increased aversion behaviour by the sheep

Capture of sheep

In the first year of operation, NPS staff used the various herding methods to capture and relocate nearly 2000 sheep from the island. Initially, the extremely poor condition of habitats due to an unsustainable number of sheep resulted in large numbers of animals voluntarily entering corrals in search of water. As sheep numbers declined and food became more available, capture operations shifted to herding or pursuing individual animals. Herding was useful for removing sheep, but not at a rate that could keep up with recruitment through births.

In December 1997, a major rainstorm and subsequent flood damage halted capture of sheep and diverted approximately six months of work to repairing of housing, fences, and facilities. The rains also created ideal conditions for vegetation regrowth and likely resulted in substantial recovery of the sheep population.

In June 1998, the first of two contractors began the planned use of eight sheep herding dogs (border collies) and four personnel to herd sheep into corral traps. Hundreds of sheep were moved into traps but their pace of entry outstripped the staff, the trap gate was not closed in time, and all sheep escaped. Having experienced this trap, no sheep would re-enter it. Although morale shattering for those involved, there were lessons learned: 1) a method of rapidly closing the gate was needed, and 2) sheep will learn to avoid traps. Camouflaging someone near the gate was tried, but the sheep could detect their close proximity through scent and would become skittish and suspicious. The border collies worked well at first, but the sheep learned that they could bolt past the dogs by exploiting the extreme terrain and their overwhelming numbers. The contractor left after two weeks having captured 328 sheep.

A single attempt to drive sheep with a line of people and a helicopter resulted in the capture of only one sheep. This sheep drive initially moved many hundreds of sheep. However, all but one of the animals eventually ran around or through the line.

These problems were resolved by engaging a "cowboy" livestock company, Ralph Lausten, Inc., experienced with horses and cattle dogs, which coordinated with NPS personnel. People on foot, horseback, and ATVs herded the sheep into traps, exploiting the terrain and using people on horses to quickly close a distant corral gate. Traps and fence lines were then inserted into each section of the island that constituted a flock's home range. The sheep's inability to easily migrate into a new area was exploited by clearing sections as rapidly as possible. This allowed sheep to be cleared from a section without educating the adjoining flocks. Stragglers were left to be dealt with later.

In this way, the island was divided into sections that were quickly cleared of most sheep. By December 1999, all sheep had been captured except for a few isolated individuals, which were removed by the park personnel when discovered. The last sheep was found hiding in a heavily vegetated area on TNC property to the west of the sheep boundary fence.

Between 1997 and 2001, 9259 sheep were removed from Santa Cruz Island (Table 1). One animal died in transport between the island and the sheep yard in Buellton, California. It is not known how many animals died or were injured during capture or holding on the island. After 9253 sheep had been captured park staff and the contractor believed that all sheep had been eliminated by December 1999. However, in November 2000, TNC reported sheep on their property. Over the following two months, six sheep were located and removed. The last of the sheep was found in February 2001. The total cost for capture and relocation of the sheep to the mainland was approximately US$2,000,000 (J. Fitzgerald, Channel Islands National Park; pers. comm.).

DISCUSSION

Population size and monitoring

Santa Cruz Island is now free of sheep after 150 years of their effects on landscapes and native vegetation. This was only achieved after some hard lessons were learned. The first of these was that estimations of the size of animal populations vary greatly when "gut feelings" are used rather than structured surveys. Additionally, the estimated near doubling of sheep numbers, from 5000 to 9259 animals during the three years of the project, illustrates the substantially increased productivity as food resources improved. This highlights the need for sufficient resources to complete removal projects as quickly as possible. For this well-funded project, vague estimates of population sizes did not alter the outcome. However, large underestimates of the number of animals could be the difference between success and failure for many projects unable to sustain necessary funding or management support.

Over a year was required to detect and remove the last sheep, which demonstrates the necessity of monitoring after such a project. Monitoring can be the most expensive aspect of a project with little to show for the funds expended. However, it must be planned for and resources set aside in order to properly conduct searches for the last animals. We recommend that projects to remove feral animals commit much greater resources to monitoring than was done in this case.

Unexpected problem with sheep behaviour

In addition to difficulties with herding sheep using dogs, flocking behaviour by sheep was initially a hindrance, but one that became an advantage. Staff initially attempted but failed to herd sheep out of their home range and into corrals in another area. Boyd (1981) remarked that feral sheep on St. Kilda "…formed a close flock when disturbed, running to the limits of their home range before doubling back". This describes our experiences regarding sheep behaviour. On Santa Cruz Island, sheep had home ranges from 20 to 300 ha. Rams covered a greater area then ewes. The sheep expanded their home range in the fall and winter when vegetation was scarcest (Van Vuren 1981). Our initial lack of understanding of sheep home range resulted in expenditure of time and resources for no gain. Once this aspect of behaviour was understood, it was exploited and used to section the project area into management units. Corrals were then built in each home range unit and we did not attempt to move sheep out of their range.

Cost

The NPS spent approximately US$2,000,000 to live capture and transport 9259 sheep to the mainland; a cost of US$216/sheep. By comparison, TNC spent approximately US$240,000 to eliminate 37,717 sheep on their property between 1981 and 1989 (Schuyler 1987). To compare the cost/sheep between the NPS and TNC projects, we used 1985 as a midpoint for the TNC project and adjusted for inflation. The estimated cost of the NPS project in 1999 was US$371,000; or about US$10/sheep. In addition, the NPS would have had to pay the sheep owners an unknown fair market value for their animals.

Island projects tend to have higher costs than similar mainland projects because of the need to transport people, equipment, and supplies by boat or air to the island. Since both projects were done on the same island, there are many similarities in the logistical and environmental challenges and costs. Part of the explanation of cost difference is that TNC used volunteers extensively for their project, while all of the workers on the NPS project were paid staff or contractors. However, the primary explanation for the cost difference is that live capture and transport of the sheep is inherently more expensive than direct reduction. Of the US$216/sheep cost, approximately US$60/sheep was spent to transport animals from the island to the Buellton stockyard. This cost did not vary much through the project. However, the cost to capture each sheep increased greatly as the project progressed and more expensive methods were used. In the last year of the project a helicopter was used extensively for locating remnant sheep and for transporting sheep in a cage slung from the helicopter.

Additional costs included the construction and maintenance of temporary infrastructure (fencelines, traps, corrals), acquisition of support equipment (sheep trailers), and the care and feeding of sheep. Finally, the extended duration of the project, resulted in the handling of greatly increased numbers of sheep.

Recovery of island ecosystem

The primary reason for removing sheep from Santa Cruz Island was to protect and restore the unique island ecosystem. The island, never connected to mainland California, provides habitat for over 600 species of vascular plants including at least 8 endemic taxa (Junak *et al.* 1995), one species of endemic snake, and four species of endemic mammals (Schoenherr *et al.* 1999). There is also an endemic species of bird, the island scrub jay (*Aphelocoma insularis*). Island scrub jays, which prefer oak woodland and chaparral habitat, are currently uncommon on ESCI.

The removal of feral sheep from the TNC property in the late 1980s resulted in dramatic and rapid changes in the soils and vegetation. As vegetation began recovering on TNC property, differences in vegetative cover between the western and eastern portions of the island developed. The boundary fence between the properties delimited recovering vegetation and bare ground that was visible (Fig. 3). The demarcation was even visible in satellite photos. As the vegetation recovery on ESCI progresses, the line has become less dramatic.

The difference in timing for sheep removal from TNC and NPS property provided an opportunity to assess the impact of sheep on frequency of landslides. Widespread slope failures were highly correlated with the presence of sheep. In the 1970s, slope failures were common over the entire island (Pinter and Vestal 2005). By the late 1990s, 80% of slides were on the 10% of the island with sheep (Pinter and Vestal 2005). Within four years of the removal of sheep from ESCI, vegetation recovery there was sufficient to substantially reduce slope failures in spite of heavy rains during the winter of 2004-2005 (Pinter and Vestal 2005).

The removal of grazers is allowing the expression of some aggressive non-native plants that have the potential to dominate vegetation communities. NPS staff are controlling high priority plant species. Olive (*Olea europaea*) seedlings, originating from planted groves on ESCI, virtually exploded throughout the project area; between 2005 and 2009, park staff removed more than 11,000 plants (P. Power, Channel Islands National Park; pers comm.). If not controlled, feral olives threaten the recovering native plant communities and have the potential to transform the native shrub and grassland communities to non-native woodland.

There has been a substantial increased in vegetation cover over the whole island but most of the vegetative on ESCI continues to of be non-native species (Klinger *et al*. 2002; Morrison 2007). Although ESCI lags behind the TNC property in the recovery of trees, shrubs, and other native plants, it is beginning to show decreased cover of bare ground, increasing herbaceous cover, and growth of native woody plants. NPS and TNC are continuing to monitor and assess invasive plant species and prioritise control activities.

In 1994, nine endemic plant species were federally listed as threatened or endangered on Santa Cruz Island. Habitat alteration and soil loss were identified as threats to recovery of all of the listed species (US Fish and Wildlife Service 2000). The last known location of *Malacothrix squalida*, an endangered annual plant, had been on ESCI in the 1960s (S. Junak, Santa Barbara Botanic Garden; *pers. comm.*). However, since the removal of the sheep, it is being seen again on ESCI.

Fig. 3 Sheep fence clearly showing the effects of sheep on the right contrasted with no sheep for approximately 15 years on the left. Santa Cruz Island, California, USA.

Native animals are also expected to respond positively to the removal of feral sheep. Drost *et al*. (2009) found that Santa Cruz Island deer mouse (*Peromyscus maniculatus santacruzae*), and Santa Cruz Island harvest mouse (*Reithrodontomys megalotis santacruzae*) have increased in numbers and the harvest mouse has increased in distribution. It is likely that the improved food and cover resulting from sheep removal is supporting increases in mouse populations.

Feral pigs (*Sus scrofa*) were also present on Santa Cruz Island and impacted soils and vegetation. Pigs were the last species of non-native mammals on the island, and were eliminated between 2005 and 2006 under a programme carried out jointly by NPS, TNC, and contractor Prohunt, Inc (Parkes *et al.* 2010). The elimination of the feral pigs closed the approximately 150 year chapter of the island's ranching history. The inclusion of Santa Cruz Island into Channel Islands National Park in 1980 and the acquisition of the island by TNC and NPS represented a major shift in the purposes for which the island is valued by the public. We are now in a period of ecological restoration. The island ecosystem will continue to face many threats. However, it is hoped that a more intact and resilient ecosystem will allow the many unique taxa and ecosystem processes to persist long into the future.

ACKNOWLEDGEMENTS

We thank all the staff of Channel Islands National Park who were critical to support of the diverse aspects of the removal of sheep and to the continuing efforts to protect and restore the native biota of Santa Cruz Island. In particular, K. Bullard and J. Fitzgerald who managed numerous aspects of the sheep removal project from beginning to end. Boat captains D. Willey, D. Brooks, J. Provo, and K. Duran provided safe transportation for crews and sheep. K. Bullard and S. Morrison provided very helpful comments on early drafts of this paper. S. Junak, Santa Barbara Botanic Garden, provided information on location of endemic plants on ESCI. The greatest accolades for completion of the removal of sheep belong to Ralph Lausten and his staff for their knowledge and dedication to completing the job. Former landowners, Tom Gherini and John Gherini supported the National Park Service in all aspects of this project.

REFERENCES

Brumbaugh, R.W. 1980. Recent geomorphic and vegetal dynamics on Santa Cruz Island, California. In: Powers, D.M. (ed.). The California Islands: Proceedings of a multidisciplinary Symposium, pp 139-158. Santa Barbara, California. Santa Barbara Museum of Natural History.

Boyd, J.M. 1981. The Boreray sheep of St. Kilda, Outer Hebrides, Scotland: The natural history of a feral population. *Biological Conservation 20*: 215-227

Caughley, G. 1974. Bias in aerial survey. *Journal of Wildlife Management 38*: 921-933.

Caughely, G. and Grice, D. 1982. A correction factor for counting emus from the air and its application to counts in Western Australia. *Australian Wildlife Research 9*: 253-259.

Cook, R.D. and Jacobson, J.O. 1979. A design for estimating visibility bias in aerial surveys. *Biometrics 35*: 735-742.

Drost, C. A.; Gelczis, L. and Power, P. 2009. Distribution and abundance of harvest mice and deer mice on Santa Cruz Island in relation to feral animal removal. In: C. Damiani and D.K. Garcelon (eds.). Proceedings of the Seventh California Islands Symposium, Oxnard, California, February 5-8, 2008, pp. 349-361. Institute for Wildlife Studies, Arcata, California.

Gasaway, W.C.; DuBois, S.D.; Reed, D.J. and Harbo, S.J. 1986. Estimating moose population parameters from aerial surveys. Biological Papers of the University of Alaska Number 22. 108pp.

Giffin, J. 1976. Ecology of the feral sheep on Mauna Kea, Hawaii. Final report for Pittman-Robertson. Project No. W-15-5, Study No.XI. Dept Lands and Natural Resources, Hawaii.

Hochberg, M.; Junak, S. and Philbrick, R. 1980. Botanical study of Santa Cruz Island for The Nature Conservancy. Vol. 1, Santa Barbara Botanical Gardens, Santa Barbara, California.

Junak, S.; Ayers, T.; Scott, R.; Wilken, D. and Young, D. 1995. *A flora of Santa Cruz Island.* California Native Plant Society. 397 pp.

Klinger, R.C.; Schuyler, P. and Sterner, J.D. 2002. The response of herbaceous vegetation and endemic plant species to the removal of feral sheep from Santa Cruz Island, California. In: Veitch, C.R. and Clout M.N. (eds.). *Turning the tide: the eradication of invasive species*, pp. 141-154. IUCN SSC Invasive Species Specialist Group. IUCN Gland, Switerland and Cambridge, UK.

Minnich, R.A. 1980. The vegetation of Santa Cruz and Santa Catalina Islands. In: Power D. (ed.). The California Islands, Proceedings of a Multidisciplinary Symposium, pp. 123-137. Santa Barbara Museum of Natural History, Santa Barbara, California.

Morrison, S. 2007. Reducing risk and enhancing efficiency in non-native vertebrate removal efforts on islands: A 25 year multi-taxa retrospective from Santa Cruz Island, California. In Witmer, G.W.; Pitt, W.C. and Fagerstone, K.A. (eds.). *Managing vertebrate invasive species: Proceedings of an international symposium*, pp. 398-409. USDA/APHIS/WS, National Wildlife Research Center, Fort Collins, Colorado.

Oklahoma State University. 1998 Breeds of livestock; Santa Cruz sheep. http://www.ansi.okstate.edu/breeds/sheep/santacruz/index.htm

Parkes, J.P.; Ramsey, D.; Macdonald, N.; Walker, K.; McKnight, S.; Cohen, B.; and Morrison, S. 2010. Rapid eradication of feral pigs (*Sus scrofa*) from Santa Cruz Island, California. *Biological Conservation 143*: 634-641.

Pinter, N. and Vestal, W.D. 2005. El Niño-driven landsliding and post grazing vegetative recovery, Santa Cruz Island, California. *Journal of Geophysical Research*, V. 110.

Pollock, K.H. and Kendall, W.L. 1987. Visibility bias in aerial surveys: a review of estimation procedures. *Journal of Wildlife Management 51*: 502-510.

Schoenherr, A.A.; Feldmeth, C.R. and Emerson, M.J. 1999. *Natural history of the islands of California*. University of California Press, Berkeley, California.

Schuyler, P. 1987. Control of feral sheep on Santa Cruz Island. Unpublished report for The Nature Conservancy.

Schuyler, P.T. 1993. Control of feral sheep on Santa Cruz Island, California. In Hochberg, F.G. (ed.). Advances in California Islands Research: Proceedings of the Third California Islands Symposium, pp. 443-452. Santa Barbara Museum of Natural History, Santa Barbara, California.

Stoll, R.J., Jr.; McClain, M.W.; Clem, J.C. and Plagman, T. 1991. Accuracy of helicopter counts of white-tailed deer in western Ohio farmland. *Wildlife Society Bulletin 19*: 309-314.

Symmes and Associates. 1922. Report on Santa Cruz Island, Santa Barbara County, California. Symmes and Associates: San Francisco, Ca., 93 pp.

Towne, C.W. and Wentworth, E.N. 1945. *Shepherd's Empire*. University of Oklahoma Press, Norman, Oklahoma.

Van Vuren, D. 1981. The feral sheep on Santa Cruz Island: Status and impacts. Unpublished report for The Nature Conservancy, Santa Barbara, California.

Van Vuren, D. 1982. Effects of feral sheep on the spatial distribution of artefacts on Santa Cruz Island. *Bulletin of the Southern California Academy of Sciences 81(3)*: 148-151.

Van Vuren, D. and Coblentz, B. 1987. Some ecological effects of feral sheep on Santa Cruz Island, California, USA. *Biological Conservation 41*: 269-278.

US District Court (San Francisco). 1857. Transcripts of the proceedings, case no.176. Petition of Andres Castillero for the island of Santa Cruz, No.340SD.

U.S. Fish and Wildlife Service. 2000. Thirteen plant taxa from the Northern Channel Islands Recovery Plan. Portland, Oregon, 94 pp.