Control of Feral Sheep (*Ovis aries*) on Santa Cruz Island, California

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Abstract. - Overgrazing by feral sheep (Ovis aries) has contributed to soil erosion and reduction in native plant populations on Santa Cruz Island since sheep were introduced in the mid-1800's. After The Nature Conservancy acquired an interest in the western 90% of the island in 1978, contract research was undertaken leading to a sheep eradication program commencing in 1980. Partitioning of the island into 23 pastures by repairing existing fences followed by systematic hunting resulted in the near elimination of sheep on TNC property by 1989. Hunting in the boundary area will continue to prevent recolonization of sheep from the eastern portion of the island. Extensive vegetation and photo monitoring to document the recovery of the landscape was instituted in 1980.

Introduction

Islands, isolated by time and distance from neighboring landmasses, often support natural communities that exhibit unique characteristics. Island flora and fauna may evolve with considerably lessened selective pressures than face similar taxa on the mainland, making them particularly vulnerable to deliberate or accidental introductions of non-indigenous species (IUCN 1984). Insular ecosystems that have evolved without the presence of large herbivores may exhibit drastic reductions in populations of endemic plants when subjected to grazing (Carlquist 1974; Coblentz 1977). While the presence and impacts of goats (*Capra bircus*) and sheep (*Ovis aries*) on a number of the world's islands have been investigated during the past decade (Rudge 1970; Coblentz 1978), the documentation of control programs is minimal (Stone 1986).

Management of feral sheep on Santa Cruz Island, the largest of the eight California Channel Islands, has been of concern to landowners and biologists for many years. The feral sheep control program undertaken by The Nature Conservancy (TNC), provides an excellent opportunity to examine a successful management strategy and to document the elimination of an introduced herbivore.

Geographical Setting and History

Santa Cruz Island is located about 39 km south of Santa Barbara, California. Thirty-eight km long and ranging from 3-11 km wide, the island encompasses about 248 km². The island's large central valley is bordered on the north by a mountain range oriented on an east-west axis and has an average elevation of about 610 m and a maximum elevation of nearly 750 m. The north shore is rugged with steeply dissected ridges and slopes up to 30° while the south range with a maximum elevation of 464 m has gentler slopes and broader drainages.

The Mediterranean climate is characterized by hot, dry summers and mild, wet winters. Annual rainfall of about 51 cm falls mainly between November and April (Santa Cruz Island Ranch records 1977 *in* Brumbaugh 1980). Mean temperatures in the central valley range from 12-21° C (Brumbaugh 1980).

Of the estimated 625 plant species found on Santa Cruz Island, about 480 are assumed to be indigenous. Forty-three plant taxa are endemic

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to the California Islands and 10 of these are restricted to Santa Cruz Island (M. Carroll, pers. comm. 1987). Ten plant communities have been described for the island (Philbrick & Haller 1977). Grassland, chaparral, oak woodland and coastal sage scrub are the dominant communities, providing 89% of the vegetative cover (Minnich 1980). In the past, the coastal bluff association, presently restricted to inaccessible cliffs and marine terraces and particularly susceptible to intensive grazing, may have been more widespread (Philbrick & Haller 1977; Hochberg *et al.* 1980).

Sheep apparently were introduced to Santa Cruz Island in 1853 by James B. Shaw (U.S. District Court 1857). Genetic origin of the stock is uncertain but the recent sheep populations were likely a mixture of at least the Merino, Rambouillet and Churro breeds (Van Vuren 1981). Sheep were allowed to roam freely over the island, and were periodically rounded up for shearing (Towne &Wentworth 1945). Numbers increased rapidly. Between 1870 and 1885 an annual average of 20,000-30,000 were rounded up for shearing (Symmes & Associates 1922). In 1875, 12,000 sheep were slaughtered and in 1877, another 25,000 sheep were slaughtered due to a lack of feed (Thompson & West 1883). In 1890, 50,000 sheep were gathered in the roundup (Symmes & Associates 1922).

By the 1920's the sheep had become feral and it was estimated that no more than half of the population was gathered during the roundups (Symmes & Associates 1922). In 1938, Edwin Stanton, who had purchased the western 90% of the island the year before, introduced 10,000 mainland sheep in hopes of domesticating the island sheep (Hochberg *et al.* 1980; Van Vuren 1981). The attempt was unsuccessful, and since that time reduction of the sheep population by fencing, trapping and hunting has been carried out by the Santa Cruz Island Company. Between 1955 and 1962 at least 27,950 sheep were rounded up and shipped to market on the mainland, while between 1963 and 1977 at least 14,658 sheep were shot by the members of Los Cazadores Rifle and Pistol Club (Santa Cruz Island Company records *in* Van Vuren 1981).

In 1978, The Nature Conservancy, an international, private, non-profit organization, purchased an interest in the western 90% (22,241 ha) of Santa Cruz Island from the Santa Cruz Island Company. Ownership, easement and management responsibilities for both parties were outlined in a complex acquisition document (The Nature Conservancy 1978). Responsibility for both the island and the Company was assumed by the Conservancy in December of 1987 upon the death of Dr. Carey Stanton, president of the Santa Cruz Island Company. For the purposes of this report the term "Santa Cruz Island" refers to the western portion of the island, exclusive of the Gherini property on the eastern end (Fig. 1).

The control of feral sheep on the island, the Conservancy's number one management goal, was an issue of concern throughout the period of its partial interest in the management of the Santa Cruz Island. As expressed in the management objectives in the deed of conservation easement The Nature Conservancy believed it had the obligation and the right to remove the feral sheep:

To preserve and to protect in perpetuity and to enhance the natural ecosystems, the unique natural flora and fauna, the bydrologic features and the natural aesthetic values of the Island (The Nature Conservancy 1978).

The Santa Cruz Island Company agreed the sheep were a problem but thought that the ultimate responsibility for their removal lay with the Company. Negotiations over these rights and responsibilities continued during most of the control program.

In 1978, The Nature Conservancy began to address resource management issues on Santa Cruz Island. Although the stewardship efforts of the Santa Cruz Island Company had succeeded in reducing or eliminating sheep from many areas, the more inaccessible areas of the island still supported large populations of sheep. A need for directed research to develop a management strategy and to provide documentation of the situation was apparent; by the spring of 1979 contracted field research was underway (Brumbaugh 1980; Hochberg *et al.* 1980; Laughrin 1982; Van Vuren 1981).

Research and Planning

Research was initially directed towards answering two questions: 1) What was the basic ecology and present status of the feral sheep population on Santa Cruz Island? (Van Vuren 1981) and 2) What impacts were the sheep having upon the natural resources of the island? (Brumbaugh 1980; Hochberg *et al.* 1980; Laughrin 1982; Van Vuren 1981). Answers to the first question provided valuable information in designing a realistic and viable control program. Documentation of the impacts served two main purposes: 1) it provided a baseline to measure the effects of the control program and to quantitatively document the recovery of island ecosystems, and 2) it established justification and expert testimony to support the Conservancy's actions in the event of legal action by groups or persons endeavoring to halt the program.

Four studies were undertaken (Brumbaugh 1980; Hochberg et al. 1980; Laughrin 1982; Van Vuren 1981). Information on the dynamics of the sheep population, including distribution and numbers, reproductive and mortality factors, physical traits and behavioral characteristics was determined (Van Vuren 1981). Impacts by sheep on the island's flora and plant communities were documented by Hochberg & co-authors (1980) and Van Vuren (1981), while the impact on soils and erosion processes was documented by Brumbaugh (1980) and Van Vuren (1981). Impacts on the fauna were researched by Laughrin (1982) and Van Vuren (1981). Management recommendations were included in each study. Without exception, all studies called for the removal of sheep at the earliest possible date citing potentially irrevocable damage to the natural resources of the island (Brumbaugh 1980;



Figure 1. Map of Santa Cruz Island showing Nature Conservancy and Gherini property, hunted vs non-hunted areas, fenced pastures, and density and impact classifications. Information from field data, Santa Cruz Island Company Records and Van Vuren (1981).

Hochberg *et al.* 1980; Laughrin 1982; Van Vuren 1981). In 1980 the population of sheep was estimated to be 20,000 and increasing (Van Vuren 1981). The Santa Barbara Botanic Garden report (Hochberg *et al.* 1980) summed up the situation succinctly by saying "The sheep must be eliminated <u>now</u> in order to insure the survival of both rare plants and rare habitats."

In addition, potential consequences of the removal of sheep from the island were discussed. Among these were a likely increase in the feral pig (*Sus scrofa*) population due to improved cover and food supply (Van Vuren 1981), a higher risk of fire as a result of increased plant biomass, and an increased production of weeds (Hochberg *et al.* 1980).

This information, coupled with that from consultations with feral animal control experts and review of the literature on the successes and failures of other control programs resulted in a series of management recommendations (Van Vuren 1981). A combination of fencing, trapping and hunting was proposed as the means to eliminate sheep from Santa Cruz Island (Van Vuren 1981).

The Conservancy prepared its own feral sheep management plan in the spring of 1981 incorporating many of Van Vuren's (1981) recommendations as well as legal and public response considerations. A budget of \$240,000 along with the equivalent of two full-time staff positions was allocated to the project.

positions was anotated to the project. The reactions of the general public and the Conservancy's own membership were monitored throughout the program and alternative strategies were developed to be used if the situation warranted.

The plan drawn up by the Conservancy was considered experimental and subject to modification after testing based on the philosophy of "adaptive management" (Holling 1978). The plan called for repair of existing fences to partition the island into smaller units (pastures), followed by trapping in areas of high density and systematic hunting until each pasture was cleared of sheep. Three components: fencing, trapping, and hunting

were chosen because the Santa Cruz Island Company had shown them to be effective in previous control efforts, and the estimated costs of a combined program were projected to be within allocated financial resources.

Fencing was considered an integral part of both a trapping or a hunting program. Repair of the fences provided smaller more manageable size units and insurance that if the program were halted or delayed, any areas previously cleared of sheep would remain so.

Trapping, a potentially lengthy and expensive proposition, was considered for several reasons. In prior years the Santa Cruz Island Company had efficiently trapped large numbers of animals from accessible pastures and shipped the animals to market (Santa Cruz Island Company records *in* Van Vuren 1981). Impacts on non-target species, such as the endemic Santa Cruz Island fox (*Urocyon littoralis santacruzae*) were expected to be low. Successful trapping in areas with high densities of sheep promised to yield a good return for the amount of money and labor expended.

Systematic hunting of the fenced pastures was an integral part of an elimination program. Complete eradication of sheep could only be achieved by a group of hand-picked hunters. Like trapping, hunting would have minimal impacts on non-target species. Safety concerns and issues as well as potential public relations problems caused by a large scale hunting program (e.g., noise, carcass waste; Van Vuren 1981) were considered while planning the hunting phase.

Other control alternatives presented by Van Vuren (1981) were not incorporated in the plan as each appeared to have at least one serious drawback that would result in implementation difficulties.

Program Implementation

Construction and acquisition of facilities and equipment necessary to implement the program began in 1980. By 1982, a selfsufficient cabin facility, capable of housing nine people, was completed on the island and a 30 ft power boat to transport supplies and personnel to and from the mainland was operable. Vehicles, equipment, fencing and hunting supplies, and field communication capabilities had been acquired by 1982.

Repair of existing fences to divide the island into separate pastures commenced in 1981 and continued on a regular but intermittent basis until 1983. Drawing from a pool of several hundred volunteer workers who worked long hours under rugged conditions for only a small food stipend and their own personal satisfaction, over 100 miles of sheep-proof fence was repaired.

Trapping, originally to be used in areas of high sheep density, was never undertaken. Initially, two options were considered: The Nature Conservancy would conduct its own trapping program or the trapping effort would be contracted out. After many inquiries and much correspondence, it became apparent that: 1) wool from captured animals would not be marketable due to its poor quality; 2) a market that could handle the expected volume of meat and was within a reasonable transport distance, could not be located; 3) survival of transported sheep might be low due to lack of exposure to mainland diseases and the stress of transport; 4) topography in the areas of high sheep density made these locations quite inaccessible and 5) the costs of transport and handling were higher than first anticipated (Van Vuren pers. comm.)

Hunting was started by The Nature Conservancy in pastures with repaired fences. Few feral animal control projects of this magnitude had been tried anywhere in the world, thus few precedents were available. Hunts started with three to four carefully selected hunters testing equipment and field procedures for several days. Evaluation of the success of the hunts was based on the number of animals taken per day, crew size and hunt duration.

Hunting on the island was strictly regulated. All hunts and Conservancy personnel were under the direct supervision of the Preserve Manager. Maintaining all TNC equipment and facilities on the island was also the manager's responsibility. Overall coordination for the program, including mainland logistical support and public relations, was handled by the Project Director and office staff in Santa Barbara.

Selection of hunting crews was of particular importance. Teamwork was a key component in the success of the program. Hunting experience was not as important as dedication, physical stamina and having the self-confidence to work in rugged, isolated conditions. Eighty five people, primarily Nature Conservancy staff, participated as hunters. Ten of these individuals comprised a long-term core group, accumulating over 50% of the nearly 10,500 person-hours spent hunting on the island.

Safe, reliable, functional equipment was a necessity. In addition to .243 caliber rifles with scopes, hand-held UHF radios proved invaluable. Constant maintenance of equipment and an adequate supply of replacement parts on the island kept delays due to equipment failure to a minimum. Ammunition was initially purchased in small lots and was reloaded. The amount of time required to reload proved prohibitive, so one large shipment of 30,000 rounds was purchased to cover the rest of the program.

Development of hunting procedures and techniques was a experimental process. The optimal arrangement proved to be a group of seven to nine hunters, equipped with radios and enough supplies for an entire day of hunting. Positioning of hunters on adjacent ridges to surround a group of sheep, to act as spotters, and to block the escape routes of sheep proved to be highly effective. Often the hunter nearest a group of sheep had a limited view due to topographical features while someone located a distance away could spot animals and direct the operation by radio. The ability to communicate amongst hunters was a key factor in the success of the control program. Working with several hunters to

remove a single group of animals resulted in returns far exceeding the capabilities of individual hunters. Knowing the home range, bedding grounds and preferred escape routes of a group of sheep greatly improved the hunter's effectiveness.

Response of the sheep to hunting was highly variable. At times, small groups would run together to form one large herd while at other times groups would split and run in several directions. Animals appeared to have no preference as to running uphill or downhill. Group leaders could be either ewes or rams. Shooting the leaders first resulted in momentary confusion, allowing the hunters more time to remain within accurate shooting range.

Weather played a role in the effectiveness of hunts. During the cool parts of the day (early morning and late afternoon) or the year (late fall through spring) sheep often grazed in the open and were easy to spot. During hot weather, animals sought shade under shrubs or trees and were extremely difficult to find, although initially, in areas of high sheep density almost every spot of cover would contain sheep. To take advantage of the cooler hours of the day, especially in summer, hunters typically left the cabin facility at daybreak and returned well after sunset spending up to 16 hr in the field.

Water and cache boxes, containing food, ammunition, extra equipment and safety supplies were placed at strategic locations by helicopter. These supply drops, located throughout the remote areas, were noted on water-proofed topographic maps issued to all hunters. To maximize the hunters' efficiency, each hunting crew also included a cook whose sole responsibility was providing meals.

No wounded animals were left in an area. Although extra time and effort were involved, wounded animals were tracked down and shot. Meat was taken whenever possible, but carcasses were generally left where they fell. Lack of a market and the economic and logistical constraints of removing the meat from the island in a sanitary fashion made large scale use of the meat impractical. Carcasses in running or standing water were removed and, if practical, moved 50 m away. Scavengers, such as ravens (*Corvus corax*) or feral pigs generally cleaned up the remains quickly and almost no evidence of the hunting program remained in 1989. Documentation of the impacts of carcass build-up in island ecosystems was not undertaken, although short-lived population booms of blow flies (Calliphoridae) and increased numbers of young pigs were noted.

Given the rugged conditions, potential problems and the length of the program, safety considerations and contingency plans received high priority. All hunts were conducted with safety of crews, island personnel and the general public as the primary concern. A thorough review of hunting procedures, contingency plans and an equipment checkout was conducted before every hunt for every hunter. Particularly stressed was the need to know the final point of impact for every bullet and for intra-group radio communication to account for all hunting and non-hunting personnel. To protect the general boating public, signs warning of the hunting program and of unpotable stream water were posted in popular anchorages.

Program Results

By 1983, the island was subdivided into 23 pastures, ranging in size from 137-4,517 ha (Fig. 1). The five largest pastures encompassed 14,544 ha or 66% of the total area. Hunting by The Nature Conservancy started 17 December 1981 and has continued to the present. By June 1989, a total of 31,871 sheep had been shot by the Conservancy and fewer than 5 sheep were known to remain on the 21,757 ha west of No Man's Land. The Santa Cruz Island Club, a sport hunting club active on the island until 1985, aided in the control efforts, particularly in the southern pastures, shooting an additional estimated 5,300 sheep between October 1981 and December 1985 (B. Huffman pers. comm.). The area east of the repaired boundary fence was not hunted and continues



Figure 2. Estimated pre-control density of sheep per 100 ha in each pasture on Santa Cruz Island: (density = number of sheep shot / size of pasture (ha) x 100). Information from field data and Van Vuren (1981).

to support high numbers of sheep (Fig. 1). Until all sheep are removed from the eastern portion of the island the adjacent pastures to the west are subject to recolonization by sheep. The success of an eradication program is measured not in how many animals were removed but in how few animals remain. The Nature Conservancy will continue hunting on its portion of the island until no sheep remain.

The density and number of sheep on the island prior to the control program, based on the number of animals subsequently shot in each pasture, is shown in Figure 2. Although reproduction in the sheep population occurred during the period of the program (1981-1989), the number of sheep recorded in each pasture provides a fairly accurate representation of pre-control densities. Intensive hunting was conducted in a pasture until 80-90% of the initial population was gone. Subsequent reproduction was kept to a minimum through continued periodic hunting until no animals were known to remain. Public reaction to the control effort was carefully monitored and evaluated throughout the program. Between December 1981 and August 1984, only a small number of people were aware of the program. Hunting had been taking place in areas of the island that were rarely visited by the general public and distant from popular anchorages. In July 1984, hunting activities commenced in the large North Shore pasture affecting both the boating public and the Santa Cruz Island Club bow hunters. The control program became widely known, and the story was written and sent out by the Associated Press news wire.

A suit against The Nature Conservancy by the California Wildlife Federation was filed in August 1984. It was argued that the finest recreational hunting opportunity in western North America was being ruined. The Federation asked for a temporary restraining order to halt the program. The Conservancy prepared a response consisting of legal depositions from staff, researchers and experts in the field of feral animal control. The aim of the response was to demonstrate that if a restraining order were served irreparable damage to the island's natural ecosystems would occur. The suit was dropped after an initial court rejection and no further legal action took place.

The Nature Conservancy was concerned with the response of the general public and its own membership. To coordinate communication with the media, all enquiries, interviews and responses were handled by the Santa Cruz Island Project Director. Fact sheets detailing the background of the problem, the necessity of a control program and alternative control options were prepared. By the Fall of 1984, the control efforts were no longer news and public reaction to the continuation of the program declined.

The removal of sheep from Santa Cruz Island offers an excellent opportunity to study the recovery of a large ecosystem. Documentation of the recovery of the flora, fauna and soils is a task which will continue for years. An

extensive photo-monitoring program has been maintained on a regular schedule since 1980. To quantitatively measure the vegetation changes, the following methods have been employed: 1) nested frequency method in the predominantly annual vegetation types (U.S. Forest Service 1983), 2) line intersect method in the shrub communities and 3) quadrants showing species composition, % canopy cover, diameter at breast height and seedling density in the woodland communities (Mueller-Dombois & Ellenberg 1974). Although insufficient time has transpired to establish long term trends, the early results appear encouraging. Increases in native species diversity and cover and a rise in number of endemic plant seedlings have occurred (Griggs & Schuyler 1985).

In 1886, E.L. Greene noted that Lotus argophyllus niveus Munz, a Santa Cruz Island endemic taxa, was found "on exposed rocky slopes, but nearly extinct" (Greene 1886). By December 1986, Nature Conservancy personnel were finding populations of Lotus on nearly every ridge of the north shore area, often with over 150 individuals per stand. Likewise, in the early 1940's very few seedlings of Quercus tomentella Engelm., Dendromecon rigida harfordii (Kell.) Raven or Lyonothamnus floribundus aspenifolius (Greene) Raven were to be seen (Dunkle 1950). Dunkle (1950) postulated that climatic factors rather than grazing by feral sheep might be the greater limiting factor for plant reproduction. However, in December 1986, four years after the removal of the majority of the sheep from the north shore pastures, seedlings of all three endemic taxa were noted on numerous occasions. The presence of Lyonothamnus seedlings is nearly the first time reproduction of this endemic genus has been recorded in recent years (S. Junak pers. comm.). Field staff continue to map new locations of rare plants whenever they are found. An aerial survey of the entire island, incorporating both infrared and black and white coverage, was flown in July 1985, providing a baseline from which to compare future observations.

Although progress is currently being made in monitoring, the following subjects need quantitative documentation: 1) changes in distribution and status of native and feral vertebrate populations, 2) the role of alien plants in the succession of vegetation communities, 3) changes in the hydrologic regime and 4) changes in soil formation and erosional processes as a result of the sheep removal program.

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Shark Attacks off the California Islands: Review and Update

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Abstract - Eight white shark attacks on divers are known to have occurred off San Miguel and the Farallon Islands. Details of all eight cases, compiled from personal interviews with victims, witnesses and/or attending physicians are presented. Island and mainland attacks are compared and the behavior of white sharks is discussed.

Introduction

The Farallon Islands off San Francisco and the northern Channel Islands off Santa Barbara have, for decades, provided excellent locales for divers to harvest, photograph, and observe marine organisms. However, this exploration has not been without risk for its participants. Usually errors in judgment or equipment malfunction have caused the few diving accidents reported from these locations. Although ever present, the threat of shark attack did not come to the forefront of public awareness until the mid-1970's when several shark "horror" films were released, inspite of four attacks having been reported from the Farallon Islands prior to that time.

Miller & Collier (1981) reported on 47 unprovoked cases of shark attacks on humans from the coasts of California and Oregon during the period 1926-1979. In their update, Lea & Miller (1985) described an additional 12 cases of shark attacks for the same geographical area. Diver incidents accounted for 34 (57%) of the 59 known shark attack cases which included six from California's islands. Specific details have been published for 16 of the 34 diver attacks, including three cases from the Farallon Islands (Fast 1955; Collier 1964, 1992; Baldridge, 1974; Follett 1974; Lea & Miller 1985). The white shark, *Carcharodon carcharias*, was positively identified or highly suspect in 30 (88%) of the diver attacks. Since the documentation by Lea & Miller (1985) white shark attacks on divers have occurred at San Miguel Island and Southeast Farallon Island.

Subsequent to the three published Farallon Island shark attack cases additional data has been compiled from personal interviews with victims, witnesses, and/or physicians. To date, eight shark attacks have occurred at the Farallon and northern Channel Islands. They are presented chronologically by location.

Farallon Islands

The Farallon Islands (Fig. 1) are 23 nautical miles west of San Francisco. The nearest mainland is Bolinas Point, Marin County, 17.8 nautical miles northeast of the islands. Southeast Farallon consists of two large islands separated by a narrow, impassable gorge. Middle Farallon is 2.3 nautical miles northwest of Southeast Farallon. North Farallon is 6.5 nautical miles northwest of Southeast Farallon and is comprised of two clusters of bare precipitous islets and rocks. Five species of pinnipeds are known to inhabit the islands: northern elephant seals (Mirounga angustirostris); California sea lions (Zalophus californianus); Steller's sea lions (Eumetopias jubatus); northern fur seals (Callorbinus ursinus) and harbor seals (Phoca vitulina).

Case 1 - Date: 14 January 1962. Victim: Floyd Pair, Jr. (male, 29 yr). Lat./Long.: 37°41.4'N, 122°55.6'W. Time of Attack: 1030 hours.

attacks, including three cases from the Farallon Over 100 divers, including Pair, chartered Islands (Fast 1955; Collier 1964, 1992; four boats to participate in the Midwater