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ABSTRACT: Feral goats (*Capra hircus*) and feral sheep (*Ovis aries*) occur on numerous islands throughout the world and cause severe damage to island resources. Damage includes large-scale alteration of plant communities, negative impacts on insular endemic species of plants and animals, and damage to soils and cultural resources. Complete eradication is the best solution to the problem. Proposed control techniques include poisons, predators, diseases, sterilization, trapping, and shooting from the air, but experience shows that shooting from the ground, combined with the use of dogs, Judas goats, and perhaps fencing, is the best approach in most cases. Successful control programs have recently been completed, or are nearly completed, on the islands of Hawaii, San Clemente, and Santa Cruz.

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INTRODUCTION

A feral animal is a formerly domesticated species that has reverted to a wild state. Feral populations become established by a variety of means. Early mariners, particularly Captain Cook, intentionally released goats and sheep onto islands so that a supply of meat would be available on the next voyage. Some populations resulted from ranching operations that failed and were abandoned. Many populations were established for no apparent reason.

As of 1982 feral goats or sheep occurred on 100 or more islands (Rudge 1984) and were causing severe damage to island ecosystems, in some cases for hundreds of years. When Charles Darwin visited the island of St. Helena in 1836, he noted that feral goats had caused the destruction of an entire forest there (Darwin 1962:486). Though populations of feral livestock occur on the mainland, damage to resources on islands is particularly severe for two reasons. First, plants species on islands may lack defenses against herbivory, because they evolved in the absence of large mammalian herbivores (Thorne 1969). Second, islands are often rich in insular endemic species that constitute a biological resource of considerable value.

Though we have known since Darwin's time or even before that feral goats and sheep can cause damage to resources, until a few decades ago serious efforts to control numbers had been infrequent, and most attempts at eradication had been unsuccessful. Over the past 10 or 15 years, there has been a remarkable series of successes at eradicating feral goats and sheep from islands, and a great deal has been learned. My purpose is to establish the imperative for eradicating feral goats and sheep by describing the damage they cause on islands, review the various approaches and techniques that have been tried in control programs, and describe some recent successes.

DAMAGE TO ISLAND RESOURCES

Feral goats and sheep have two types of effects on island resources (Van Vuren and Coblentz 1987). Their principal impact is damage to vegetation. But, the resultant alteration of plant communities can have important secondary effects, such as soil erosion and impacts on animals that depend on unaltered plant communities for habitat.

Both feral goats and sheep have catholic diets (Coblentz 1977, Van Vuren and Coblentz 1987) and may show a particular preference for insular endemic plants (Baker and Reeser 1972, Parkes 1984, Van Vuren and Coblentz 1987). Persistent defoliation has led to large-scale changes in plant communities on many islands, including Galapagos (Hamann 1975), Santa Cruz (Brumbaugh 1980), Hawaii (Scowcroft and Giffin 1983), St. Helena (Wodzicki 1950), and Campbell (Meurk 1982) islands. In some cases, overgrazing has resulted in the extinction or near-extinction of insular endemic plant species (Turbott 1963, Thorne 1967, Baker and Reeser 1972, Parkes 1984, Cronk 1986).

Probably the most dramatic evidence of the destruction caused by feral goats and sheep is the remarkable recovery of vegetation that occurs after control, exclusion, or eradication (Turbott 1963, Baker and Reeser 1972, Dilks and Wilson 1979, Hamann 1979, Mueller-Dombois 1979, Meurk 1982, Park and Walls 1984, Parkes 1984, Scowcroft and Hobdy 1987). Plant species thought to be extinct reappeared after control programs on Hawaii (Baker and Reeser 1972), Raoul (Parkes 1984), and Santa Cruz (R.C. Hansen, pers. comm.) islands.

Alteration of plant communities by feral goats and sheep may affect biologically important vertebrates that depend upon these plant communities for suitable habitat. Insular endemic birds (Turbott 1963, Leathwick et al. 1983, Scowcroft and Giffin 1983, Van Vuren and Coblentz 1987), mammals (Coblentz 1978), and reptiles (Coblentz 1978, Coblentz and Van Vuren 1987) may suffer from such habitat destruction.

Further, trampling by feral goats and sheep may destroy vegetation (Coblentz 1978, Van Vuren and Coblentz 1987), cause soil compaction (Brumbaugh 1980), and damage cultural resources (Van Vuren 1982).

CONTROL ALTERNATIVES

Three control strategies are available (Van Vuren 1981, Coblentz et al. 1990, Parkes 1990a,b). First, do nothing. Islands often are remote, and control of feral herbivores may be economically and logistically difficult. In some cases, no control has been attempted because no damage was perceived (Gould and Swingland 1980). However, inability to detect damage does not mean it is not occurring (Coblentz and Van Vuren 1987).

The result of doing nothing, however, often is severe damage to island resources. Feral sheep (Van Vuren and Coblentz 1987), and perhaps feral goats as well, have the ability to maintain high densities on severely damaged ranges, thereby promoting further damage.

Second, densities may be reduced through an ongoing control program that does not result in eradication, or distribution may be altered by fencing followed by local eradication.

Such control programs have been implemented on many islands (Baker and Reeser 1972, Dilks and Wilson 1979, Rudge 1983, Scowcroft and Giffin 1983, Parkes 1990b) because complete eradication was infeasible or because the feral goats or sheep themselves were deemed a valuable potential resource to be preserved (Warner 1960, Rudge 1983). Some relief from damage often results, but there are several problems with partial reductions or local eradications. Management, either density reductions or fence maintenance, must continue indefinitely. This is risky because of logistical difficulties (many islands are remote) and because it requires an annual expenditure of funds. Further, if control is suspended even for a short time, populations will quickly recover. Both feral goats and sheep have high reproductive rates; four years after an 80% reduction in numbers, both species can return to about 90% of pre-control levels (Rudge and Smit 1970, Van Vuren 1981). Finally, once an ecosystem is damaged, even low densities of feral herbivores may prevent recovery.

Third, the feral populations may be totally eradicated. The cause of the damage is completely removed, and, because water is an effective barrier to dispersal of goats and sheep, eradication only has to be done once. Eradication on islands, however, usually is expensive and logistically difficult; islands often are remote, every last animal has to be removed, and it is the last few sheep or goats that can be extremely difficult to find.

CONTROL TECHNIQUES

Several control techniques have been attempted or proposed over the years (Baker and Reeser 1972, Van Vuren 1981, Daly and Goriup 1987, Coblentz et al. 1990, Parkes 1990b). Some have proven problematic; others have demonstrated efficacy in reducing or eradicating feral goats and sheep.

Poisons

Poisons, particularly Compound 1080, can be very effective (Parkes 1983), but have several disadvantages. One is legal restrictions on use; these restrictions depend on the toxicant and the locality. A suitable bait must be found that is widely accepted (Eason and Batcheler 1991). On arid islands, a daily requirement for water might be exploited by placing baits in or near scare water sources, but feral goats have the option of drinking sea water (Burke 1990). The most important problem with the use of toxicants is effects on non-target species; islands often support insular endemic animals of great biological importance that may be affected.

Predators

Introduction of predators has been suggested, but to my knowledge never tried. For example, there was interest in introducing mountain lions (*Felis concolor*) to control sheep on Santa Cruz Island. Predators could reduce numbers, but might not be effective enough to cause eradication. And, the problem of effects on non-target species may be a concern.

Diseases

Diseases have been proposed but apparently never used for control of feral goats or sheep. It has, however, been tried with feral pigs (*Sus scrofa*) on Santa Rosa Island; hog cholera was introduced several decades ago and resulted in an estimated 80% reduction in pig numbers (Nettles et al. 1989). The principal problem with disease as a control technique is that of finding a pathogen that is sufficiently virulent, legal to introduce, and harmless to valued non-target species. Further, for continental islands there may be a serious liability problem if the disease somehow infected mainland domestic animals.

Sterilization

Fertility inhibition is another technique that has been proposed but never used successfully for feral sheep and goats, though the approach has been the subject of considerable attention as a means for controlling feral horses (Kirkpatrick et al. 1990). Sterilizing males is not effective because of the polygamous mating system of goats and sheep; females that fail to conceive with a sterilized male simply cycle again and breed with another male. I know of no sterilization technique for females that does not require capture; and, if the female is in hand, it seems that the most effective sterilization technique is to remove her from the island.

Trapping

Trapping has successfully removed tens of thousands of feral goats and sheep from islands. For example, 30,000 goats were trapped on the island of Hawaii (Baker and Reeser 1972), and 28,000 sheep were trapped on Santa Cruz Island (Van Vuren 1981). But, trapping can be logistically difficult. Several problems have been encountered. First, if the trapping operation is done for profit, then only the easiest and most convenient animals will be captured and removed, leaving those that are difficult to capture (Baker and Reeser 1972). Second, trapping cannot lead to eradication, since many goats or sheep always will elude capture, no matter how intensive efforts are. Finally, disposition of captured animals is a problem. During the planning for the control of feral sheep on Santa Cruz Island, I was unable to locate a market for captured sheep.

Shooting From the Air

Shooting from helicopters is an extremely effective and fast way of control, and has been used successfully in New Zealand (Baker and Reeser 1972). Drawbacks are that it is extremely expensive, it is impractical for outlying islands, and goats, in particular, may quickly learn to recognize the sound of an approaching helicopter and hide (J.K. Baker, pers. comm.).

Shooting From the Ground

Shooting by hunters on foot, in most cases, has proven to be the most effective technique. Working in teams, hunters equipped with small caliber rifles can kill large numbers of feral goats and sheep quickly and economically (Calvopina 1985, Coblentz et al. 1990, Parkes 1990b, Rice 1991, Schuyler 1992). Most successful eradications have been achieved by shooting from the ground.

Detecting Remnant Survivors

The biggest problem in an eradication program is not in removing large numbers of sheep or goats; rather, it is finding and eliminating the last animals. Dogs have been used in New Zealand to discover survivors when densities become low (Parkes 1990b). A recently developed technique is the "Judas goat," which has proven effective in locating remnant

populations. Because goats and sheep are social (Shackleton and Shank 19984), a radio-collared animal released into an area subject to intensive control efforts will locate and associate with remnant survivors (Taylor and Katahira 1988).

Fencing

An important component of several control programs has been the use of fencing. Fencing is very expensive and requires maintenance, but it may be important in two ways. First, it may be used to restrict the range of goats or sheep that are not scheduled for eradication. The problem here is the cost of permanent maintenance. Second, it may be used to partition a large island into small partitions to facilitate eradication. Segments can be cleared sequentially; should the control program suffer a temporary delay, maintained fencing will prevent recolonization.

Island size is an important factor in eradication success. In New Zealand, 16 islands from which feral goats were eradicated averaged 442 ha, whereas 7 islands that still supported goats averaged 12,296 ha (Parkes 1990a). Fencing to partition larger islands (> 10,000 ha) into smaller segments has been used in successful control programs on the islands of Hawaii (Baker and Reeser 1972), Campbell (Dilks and Wilson 1979), and Santa Cruz (Schuyler 1992).

SOME RECENT SUCCESSES

Many attempts at eradication have been unsuccessful (Daly and Goriup 1987). Three recent successes, however, illustrate some of the problems that might be encountered and how they can be surmounted.

Hawaii

Feral sheep have been present in large number on Mauna Kea for about 150 years; damage has been severe (Scowcroft and Giffin 1983). In particular, sheep have destroyed mamane (*Sophora chrysophylla*) forests, which constitute the habitat of the endangered bird, the palila (*Psittirostra baileui*). During the 1940's a concerted effort was made to control sheep numbers; about 40,000 were shot, and only 200 remained (Warner 1990). But, there was a change in administration and a change in goals. Because feral sheep were valued by sport hunters, the last 200 sheep were spared, to be managed on a sustained yield basis for sport hunting (Warner 1960). Hunters were unable to control numbers, and the feral sheep population increased to <5,000. Because sheep were destroying the critical habitat of the palila, a lawsuit was filed requesting that sheep be removed from palila habitat. In 1979, a federal judge ordered the State of Hawaii to eradicate all feral sheep from the upper slopes of Mauna Kea. This was accomplished in 1981.

San Clemente Island

Located 100 km west of San Diego, California, San Clemente has supported tens of thousands of feral goats for many decades. In 1972 the U.S. Navy, owner of the island, decided to eradicate the >20,000 goats on the island because they were deemed a direct threat to several federally-listed species of plants and animals endemic to the island. A program of trapping and shooting removed about 16,000 goats, but several thousands eluded these efforts. In the late 1970's, the Navy decided to kill the remaining goats by shooting them from helicopters, but they were sued by Give Our Animals Time (GOAT). The result was that the Navy was directed to begin intensive trapping, with the goal of eradication by non-lethal means. Another 3,000-4,000 goats were removed, but many still remained. Highly intensive trapping had failed to achieve eradication.

In 1983, the Navy resumed shooting, but a series of lawsuits and directives from the U.S. Secretary of Defense repeatedly halted these efforts. A few goats were trapped, but in the meantime the survivors were reproducing. Eventually, shooting resumed, and numbers were reduced to very low levels. Judas goats were employed to discover the survivors, and at present only a few goats remain; prospects for complete eradication are high (B.E. Coblentz, pers. comm.).

Santa Cruz Island

In 1978, The Nature Conservancy (TNC) bought the western 90% of Santa Cruz Island. Severe damage by feral sheep was obvious, and TNC decided on a program of complete eradication. But their first step was unusual; they knew that a control program could be halted by a lawsuit or by political changes, as had happened on San Clemente Island and elsewhere (Warner 1960, Rice 1991), so TNC funded several studies that described, quantitatively, the damage that sheep were causing. Their second step also was unusual. Because Santa Cruz Island is large (24,900 ha), and the 22,000 ha owned by TNC supported an estimated 21,000 sheep (Van Vuren and Coblentz 1989), the decision was made to partition the island into segments. About 160 km of fencing were repaired or constructed, resulting in segments that ranged 137-4,517 ha (Schuyler 1992).

Eradication began December 1981 (Schuyler 1992). Sheep were shot by teams of hunters on foot, using small-caliber, high-velocity rifles, and coordinated with hand-held radios. Eradication proceeded sequentially, one segment at a time. As expected, a lawsuit was filed (Schuyler 1992), but because TNC already had the data in hand that demonstrated the imperative for eradication, the suit was dismissed. Further, because the island had been partitioned with fencing, segments already cleared of sheep were not recolonized during the delay. By 1987, 36,551 sheep had been shot and only 40 remained (Schuyler 1992). By 1989, the last sheep on TNC lands had been discovered and shot. Some feral sheep remain on 3,016 ha at the extreme east end of the island, but these are excluded by a fence that is maintained and patrolled regularly. The National Park Service currently is negotiating to buy the remainder of Santa Cruz Island not owned by TNC; eradication from the entire island will be completed soon thereafter.

CONCLUSION

Until about 15 years ago, almost all studies of the damage caused by feral goats and sheep on islands was descriptive, and attitudes about destruction of resources that apparently was occurring were surprisingly apathetic (Coblentz 1978). Indeed, feral goats had their defenders (Dunbar 1984). Since then, however, an impressive body of quantitative data documenting impacts has accumulated, and many populations have been eradicated. Recovery of island ecosystems has been dramatic, further underscoring the need for eradication.

Despite the availability of an array of control techniques, shooting from the ground, with the assistance of dogs or

Judas goats and perhaps fencing, remains the most economical and effective method. Some large islands may never be free of feral goats and sheep because of logistics and cost; but for most islands, the spectacular recovery of vegetation where eradication has been successful, along with recent successes such as Hawaii, San Clemente Island, and Santa Cruz Island, demonstrates that compete eradication should be the only goal.

LITERATURE CITED

BAKER, J.K., and D.W. REESER. 1972. Goat management problems in Hawaii Volcanoes National Park. U.S. Dept. Interior, Nat. Park Serv., Nat. Resour. Rep. No. 2, 22 pp.

BRUMBAUGH, R.W. 1980. Recent geomorphic and vegetal dynamics on Santa Cruz Island, California. Pages 139-158 In The California Islands: proceedings of a multidisciplinary symposium (D.M. Power, ed.), Santa Barbara Mus. Nat. Hist., Santa Barbara, Calif.

BURKE, M.G. 1990. Seawater consumption and water economy of tropical feral goats. Biotropica 22:416-419.

CALVOPINA, L. 1985. The impact and eradication of feral goats on the Galapagos Islands. Pages 157-158 In Conservation of island birds (P.J. Moors, ed.), Int. Council for Bird Preserv., Tech. Publ. No. 3.

COBLENTZ, B.E. 1977. Some range relationships of feral goats on Santa Catalina Island, California. J. Range Manage. 30:415-419.

COBLENTZ, B.E. 1978. The effects of feral goats (*Capra hircus*) on island ecosystems. Biol. Conserv. 13:279-286.

COBLENTZ, B.E., and D. VAN VUREN. 1987. Effects of feral goats (*Capra hircus*) on Aldabra Atoll. Atoll Res. Bull. 306:1-5.

COBLENTZ, B.E., D. VAN VUREN, and M.B. MAIN. 1990. Control of feral goats on Aldabra Atoll. Atoll Res. Bull. 337:1-13.

CRONK, Q.C.B. 1986. The decline of the St. Helena ebony *Trochetiopsis melanoxylon.* Biol. Conserv. 35:159-172.

DALY, K., and P. GORIUP. 1987. Eradication of feral goats from small islands. Int. Council for Bird Preserv., Study Rep. No. 17, 46 pp.

DARWIN, C. 1962. The voyage of the Beagle. Doubleday and Co., Garden City, NY, 524 pp.

DILKS, P.J., and P.R. WILSON. 1979. Feral sheep and cattle and royal albatrosses on Campbell Island; population trends and habitat changes. N.Z.J. Zool. 6:127-139.

DUNBAR, R. 1984. Scapegoat for a thousand deserts. New Sci. 104(1430):30-33.

EASON, C.T., and D. BATCHELER. 1991. Iophenoxic and iopanoic acid as bait markers for feral goats. Wildl. Res. 18:85-90.

GOULD, M.S. 1980. The tortoise and the goat: interactions on Aldabra Island. Biol. Conserv. 17:267-279.

HAMANN, 0.1975. Vegetational changes in the Galapagos Islands during the period 1966-1973. Biol Conserv. 7:37-59.

HAMANN, 0.1979. Regeneration of vegetation on Santa Fe and Pinta Islands, Galapagos, after the eradication of goats. Biol. Conserv. 15:215-236.

KIRKPATRICK, J.F., I.K.M. LIU, and J.W. TURNER, JR. 1990. Remotely-delivered immunocontraception in feral horses. Wildl. Soc. Bull. 18:326-330.

LEATHWICK, J.R., J.R. HAY, and A.E. FITZGERALD. 1983. The influence of browsing by introduced mammals on the decline of North Island kokako. N.Z.J. Ecol. 6:55-70.

MEURK, CD. 1982. Regeneration of subantarctic plants on Campbell Island following exclusion of sheep. N.Z.J. Ecol. 5:51-58.

MUELLER-DOMBOIS, D. 1979. Succession following goat removal in Hawaii Volcanoes National Park. Proc. Conf. Sci. Res. Nat. Parks 1:1149-1154.

NETTLES, V.F., J.L CORN, G.A. ERICKSON, and D.A. JESSUP. 1989. A survey of wild swine in the United States for evidence of hog cholera. J. Wildl. Dis. 25:61-65.

PARK, G.N., and G. WALLS. 1984. The enclosure plots on Arawapa Island. Pages 20-26 In Biological and ecological values of Arawapa Island Scenic Reserve (P.R. Dingwall and M.R. Rudge, eds.), N. Z. Dep. Lands and Survey, Wellington, N.Z.

PARKES, J.P. 1983. Control of feral goats by poisoning with Compound 1080 on natural vegetation baits and by shooting. N. Z. J. For. Sci. 13:266-274.

PARKES, J.P. 1984. Feral goats on Raoul Island. II. Diet and notes on the flora. N. Z. J. Ecol. 7:95-101.

PARKES, J.P. 1990a. Eradication of feral goats on islands and habitat islands. J. Roy. Soc. N. Z. 20:297-304.

PARKES, J.P. 1990b. Feral goat control in New Zealand. Biol. Conserv. 54:335-348.

RICE, C.G. 1991. Goat removal from Aguijan Island: lessons for future efforts. Trans. West. Sec. Wildl. Soc. 27:4246.

RUDGE, M.R. 1983. A reserve for feral sheep on Pitt Island, Chatham group, New Zealand. N. Z. J. Zool. 10:349-363.

RUDGE, M.R. 1984. The occurrence and status of populations of feral goats and sheep throughout the world. Pages 55-84 In. Feral mammals—problems and potential (R.N. Munton, J. Clutton-Brock, and M.R. Rudge, eds.), Int. Union Conserv. Nat. and Nat. Resour., Gland, Switz.

RUDGE, M.R., and T.J. SMIT. 1970. Expected rate of increase of hunted populations of feral goats (*Capra hircus* L.) in New Zealand. N. Z. J. Sci. 13:256-259.

SCHUYLER, P. 1992. Control of feral sheep on Santa Cruz Island. In Recent advances in California Islands research: Proc. of the Third California Islands Symp (F.G. Hochberg, ed.), Santa Barbara Mus. Nat. Hist., Santa Barbara, Calif., (in press).

SCOWCROFT, P.G., and J.G. GIFFIN. 1983. Feral herbivores suppress mamane and other browse species on Mauna Kea, Hawaii. J. range Manage. 36:638-645.

SCOWCROFT, P.G., and R. HOBDY. 1987. Recovery of goat-damaged vegetation in an insular tropical montane forest. Biotropica 19:208-215.

SHACKLETON, D.M., and C.C. SHANK. 1984. A review of the social behavior of feral and wild sheep and goats. J. Anim. Sci. 58:500-509.

TAYLOR, D., and L. KATAHIRA. 1988. Radio telemetry as an aid in eradicating remnant feral goats. Wildl. Soc. Bull. 16:297-299.

THORNE, RP. 1969. The California Islands. Ann. Missouri Bot. Gard. 56:391-408.

TURBOTT, E.G. 1963. Three Kings Islands, New Zealand: a study in modification and regeneration. Pages 485-498 In Pacific Basin biogeography (J.L. Gresslitt, ed.), Bishop Museum Press, Honolulu, Hawaii.

VAN VUREN, D. 1981. The feral sheep on Santa Cruz Island: status, impacts, and management recommendations. The Nat. Conserv., Arlington, Virginia, 166 pp.
VAN VUREN, D. 1982. Effects of feral sheep on the spatial distribution of artifacts on Santa Cruz Island. Bull. S. Calif. Acad. Sci. 81:148-151.
VAN VUREN, D., and B.E. COBLENTZ. 1987. Some ecological effects of feral sheep on Santa Cruz Island, California, USA. Biol. Conserv. 41:253-268.
VAN VUREN, D., and B.E. COBLENTZ. 1989. Population characteristics of feral sheep on Santa Cruz Island. J. Wildl. Manage. 53:306-313.
WARNER, R.E. 1960. A forest dies on Mauna Kea. Pac. Discovery 13(2):6-14.
WODZICKI, K.A. 1950. Introduced mammals of New Zealand. N. Z. Dep. Sci. Ind. Res., Bull. No. 98., 255 pp.