GOAT MANAGEMENT PROBLEMS IN HAWAII VOLCANOES NATIONAL PARK

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Goat Management Problems in Hawaii Volcanoes National Park

A History, Analysis, and Management Plan

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A visitor who climbs a volcano in Hawaii ought to see mamane trees and silver-swords, not goats.

A. S. Leopold et al.

This could take one to several decades.

Second, during the period of peak population growth, excessive numbers of animals force individuals to browse, graze, peel off bark, devour parts of plants, or eat plants that would normally have been ignored. This could go on indefinitely until the population begins to grow emaciated or suffer malnutrition and other biological stresses, such as nonproductivity associated with overpopulation, as food supplies become limited.

In geologically young islands, as in Hawaii, erosion problems become manifest at this time due to the overgrazing, excessive trampling, and stripping away of groundcover species. Once soil is blown or washed away, exposing rocky substrates, restoration of the native vegetation becomes dependent upon the formation of soils; primary succession must be "reenacted" and this requires many decades or centuries.

Third, the population begins to decline and to come into balance with the severely modified carrying capacity of the habitat. The animal-plant-soil interrelationships adjust to a new degree of stability. The ecosystem may become healthy and self-sufficient again under new sets of balanced influences and conditions, but by that time it will be greatly modified.

Native plants that cannot withstand selective browsing pressures are replaced gradually by herbaceous and woody species that are less palatable, more browse resistant, or both. Therefore, the carrying capacity for introduced herbivores has become much less than it was before the initial population peak of the introduced herbivores. In the new adjustments to habitat stability, less browse-resistant plants may become extinct as parent plants are killed out and as all seedling reproduction is devoured. Other species that may become endangered are able to survive only because they may grow on inaccessible parts of the islands out of reach of goats. Only the hardier and more adaptable plants survive to maintain some semblance of the former flora.

There is, therefore, a relatively rapid change from the original biota to a new flora and fauna that are still composed of hardy native species but without many of the more fragile plants. There is, in addition, a mixed flora of flourishing, less palatable exotic species usually introduced by man but which spread rapidly because of the browsing activities of nonnative mammals. The spread of exotics in the wake of herbivore destruction drastically alters the original scheme of a pristine community.

Alterations of island ecosystems by goats in the western Pacific began with the voyages of Captain Cook in the 1770s. In 1773, Cook released goats on Queen Charlotte Sound and other areas around the coast of New Zealand. The reasons for such liberations, not only by Captain Cook but by sailors of other nations, were to provide emergency food for any future explorations when fresh meat might be needed. On 2 February 1778, Captain Cook landed "a ram goat and two ewes" on the Hawaiian island of Niihau, and other goats of unknown number on the island of Hawaii. Prior to 1793, Captain George Vancouver brought in more goats and by 1850, just 57 years later, the original introductions had proliferated to such an abundance that a skin export trade began with the collection and export of 26,154 skins to the United States. Marques (1906:48-55) wrote:

> . . . these animals of which the natives in the beginning took the greatest care, multiplied so rapidly that they soon took to the savage state, settling into the deep gulches and inaccessible mountains of the central ridges, in each of the seven islands of the archipelago wherever the tropical vegetation afforded them a ready subsistence. Soon after their release, they began to encroach on the cultivable lands, while to their depredations was also attributed in part the destruction of forests, including especially the young sandalwood so rare nowadays. So it was found necessary to kill them and the natives were not slow to realize the advantage to save their skins, in view of adding them to the commerce already started in hides and sheep skins. And since then, goats have constituted one of the regular articles of exportation to the United States.

C. S. Judd (1922), Superintendent of Forestry, wrote:

> . . . wild goats seem imperceptibly to have gotten ahead of the ranchers and today constitute a real and serious menace, of which only a few are fully aware. Not only are thousands of acres robbed of valuable forage grasses which should properly go to the cattle for the meat supply of the Territory but the undergrowth of bushes, ferns, and herbaceous plants which form valuable ground cover is being entirely consumed or destroyed by goats. The trees which form the complement in the scheme of water conservation are being barked and killed by this voracious pest.

Yocum (1964), in his studies and report on goat management needs to the National Park Service, stated:

> . . . it seems unwise to assume that feral goats could remain in the National Parks without doing much damage to native plants. My studies indicate that goats must be eliminated from National Park lands if these areas are to be reserved for the future peoples of the world to see native Hawaiian vegetation under as natural conditions as man can maintain.

Yocum summed up his recommendations by saying, "I conclude that the only solution to the very difficult problem . . . is to eliminate all goats . . . and not one feral goat should be allowed to remain on National Park lands."

Tomich (1969) stated that goats have presented great "problems of control . . . within the National Parks where exotics are undesirable in any numbers" and it should be a "firm purpose of the parks system to encourage and preserve only the native fauna and flora."

Goats in Hawaii have, therefore, been long recognized at the state and federal levels as significant factors in vegetation and species destruction. In less than 200 years, goats chewed their way from the seashore to the tops of island peaks and back down again, by which time they numbered in the tens of thousands, had eaten some species into extinction, and threatened the existence of many more. Moreover, the resultant forest destruction has been one of the major causes for declines in populations of native, endemic, nectar-feeding birds of the remarkable and unique family, Drepanididae, and perhaps birds of other families as well. Some of these endangered birds, the Hawaiian hawk, nene, creeper, akepa, akiapolaau, and ou, are very rare but important indigenous species of park habitats. When extinct elsewhere in Hawaii, some of these

species may survive only because of suitable habitat which can be preserved under the protection of Hawaii Volcanoes National Park, providing that the goats can be controlled.

In the eyes of the forester, the biologist, and the conservationist, the feral goat in Hawaii, and in the national parks, is a destructive, nonnative, inharmonious element. It has caused and still causes severe modifications to the community structures of indigenous biota. Goats, however, are not the only resource problem within the park. To lesser degrees, feral pigs, nonnative rats, introduced mongooses, and exotic birds are most assuredly creating problems, however subtle, that affect native species and habitat in many ways not yet determined. Small numbers of feral cattle still roam the park, and localized populations of feral house cats are to be found in and around housing areas within and adjacent to park boundaries.

Exotic plant species are numerous and at times can be very abundant and aggressive competitors with native species. Probably second only to goats, nonnative plant invaders create the park's most pressing management problems, and exotic plants may well remain problems long after wildlife dilemmas have been resolved.

The resources management problems of Hawaii Volcanoes National Park are many, varied, and complexly interrelated. Some have no answers yet, and for others solutions may never be found, but it is currently recognized that the goat is the most serious menace at present, that solutions are available, and that control of the goat deserves a high priority in all management plans and needs. The initial step forward on the long, arduous road back towards environmental recovery of the park must start somewhere, and the first step must be with the goat.

It is ironic that while the goat has been recognized in the past to be the most troublesome and most pressing of the park's many problems, it may now be the most easily solved.

Figure 1 shows the major vegetation types that occur within the park.

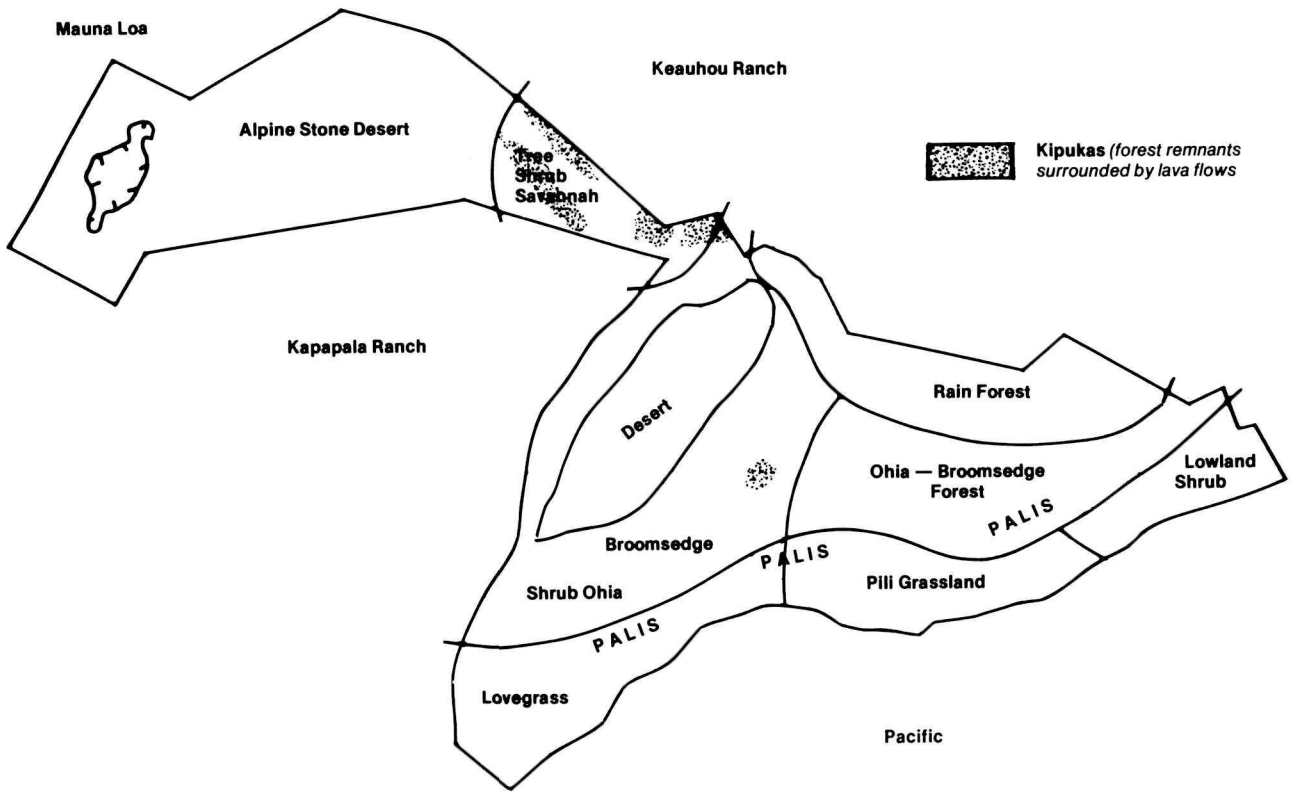


Fig. 1. Existing major vegetation types–lovegrass, broomsedge, and most lowland shrubs are exotic.

HISTORY AND ANALYSIS OF FERAL GOAT PROBLEMS IN HAWAII

In the region of what was to eventually become Hawaii Volcanoes National Park, local ranchers and the Territorial Government of Hawaii had long conducted goat control programs. In fact, the Territorial Government continued to eradicate goats within the park during the years from 1927 through 1931, some years after the park was established in 1916. In this single 5-year period of control efforts, the Territorial Government destroyed 17,389 goats, an average of 3478 goats per year (Fig. 2). The success of the Territorial Government relative to much of the later efforts by other groups can be attributed in large part to the specific allocation of management funds for goat reduction and to the fact that goats were hunted in team efforts with purpose and determination.

After termination of the Territorial Government's help to control park goats, goat control under National Park Service supervision went into a period of virtual neglect until 1937. This can be attributed to the fulltime needs of the park staff during those years to develop, operate, and maintain new park facilities. There was too little time, money, or manpower for effective goat control programs; and this same predicament, the crux of the problem, has haunted National Park Service goat control efforts throughout the entire history of the park.

Realizing that outside help was necessary, the park was opened to private hunters on an individual basis by special permit from 1932 through 1934. The program proved inefficient, however, because too few goats were killed and there were hints of favoritism being shown to "friends of friends" in the issuance of permits. The program was abolished in November 1934, by the Director's Office Order No. 288, which stated, "All operations having to do with the control of birds and animals must be performed by regular staff members of the National Park Service. . . ."

On 26 April 1935, the superintendent at Hawaii Volcanoes National Park requested special consideration for use of outside help and a legal opinion as to what would constitute outside help, because within the park there were "too few men and they cannot spare the time often enough to make any impression on rapidly multiplying goats."

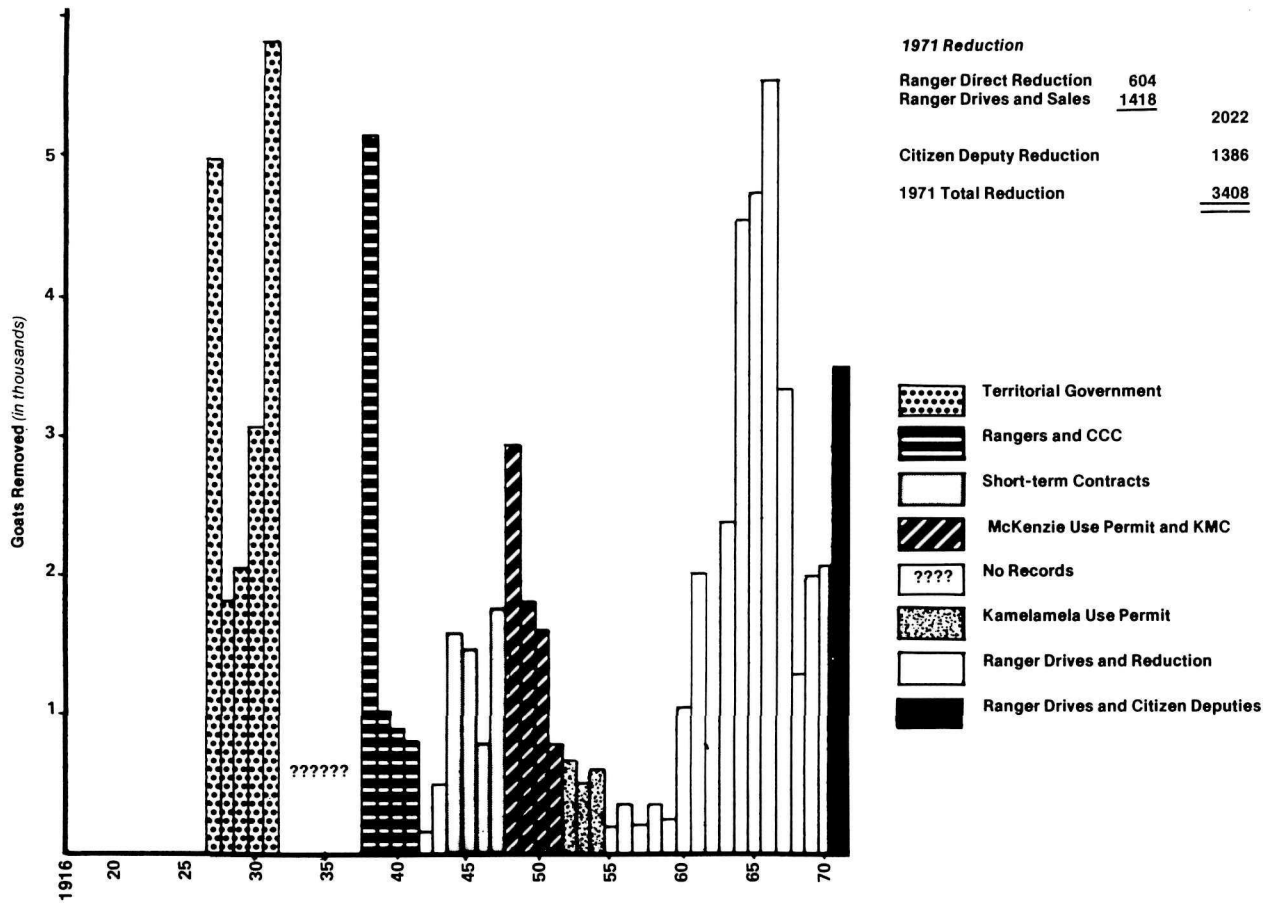


Fig. 2. Numbers of goats removed annually from Hawaii Volcanoes National Park.

On 8 June 1935, the Director replied:

> If the hunter be in a private capacity, and in the furtherance of his private purpose, then such hunting is prohibited even though, incidentally, detrimental animals and only detrimental animals be destroyed. If the hunter be in a public capacity, such as a Park Ranger, or a paid hunter acting under the direction and control of the National Park Service, then such hunting is for public purpose sanctioned by the statutes, and is not prohibited.

The park superintendent replied:

> . . . exotic animals must be controlled in the park. This we do not have the force to do. Therefore, it will be necessary to modify Office Order No. 288 or permit the employment of a sufficiently large force of permanent rangers to effectively control the goats.

A modification soon followed: "When the regular park personnel is insufficient to do the work, assistance of outside persons may be secured by a construction or modification of Office Order No. 288."

From 1935 through 1937, however, there was no followup on the modification. Control measures for those years, if any, went unrecorded and it can be assumed that goats were left to multiply relatively unmolested. The first outside assistance under the director's modification came from use of Civilian Conservation Corps (CCC) personnel from 1938 through 1941, during which time 7649 goats were removed through the highly efficient technique of organized drives. It was also through the CCC program that much of the extant boundary fences and internal drift fences were constructed to aid in goat control programs. But World War II stopped the CCC programs and the National Park Service lapsed into another period of virtual neglect. Only 583 goats were destroyed through 1943.

From 1944 through 1955, a new method of goat control was tried by issuing contracts to private individuals forming "goat control companies" to round-up goats for removal from the park to be sold for private profit. At first, short-term, 90-day contracts were let and then longer term contracts of 1-year duration. The issuance of contracts, however, did not result in sufficient numbers of goats being removed. Contract methods, therefore, were stopped in 1955 when the superintendent instructed that all goat control would henceforth be done "only by park employees."

The contract method had proved inefficient to the needs of the Service simply because "goat control companies" were in the business of harvesting goats for profit. It is understandable that contractees did not wish to flood the retail market nor did they wish to skim off any more than the biological surpluses of goats in order to insure a perpetual, sustained annual yield.

From 1955 through September 1970, employee control was the sole means of management. More than 30,000 goats were removed during this time; an annual average of 1900. Records reveal that the most successful NPS techniques were organized hunts and drives; the latter could net several hundred goats in a single day. However, because there was a continuing lack of funds and manpower, drives came too few and too far between to keep ahead of the reproductive rate.

Control efforts by the NPS lagged farther and farther behind the goats' highly prolific reproductive ability. By late 1970 park censuses indicated a population of more than 14,000 goats, a total that was as great as at any recorded time in the past. After more than 40 years of goat control efforts, the park was no better off than when it had started—in fact probably worse off since goats had had 40 years more time in which to destroy the forests.

In 1970 the NPS again employed outside assistance to help with goat control. On 10 October, the first citizen participation goat management unit was opened on weekends and holidays to interested persons 21 (later reduced to 18) years of age or older possessing a state of Hawaii hunting license. The second unit began on 3 April 1971, and the present, or third, on 2 October. The combination of these three units contain approximately 13,500 of the estimated 15,000 goats within the park. Interest and number of goats reduced were highest during the early phases of each unit. However, as easily accessible goats were taken or forced into more remote portions of the unit, deputy interest and numbers of goats reduced per hunting day dwindled to practically nothing (Fig. 3).

Looking back over the long history of various goat control programs and up through analyses of current operations, it can be stated that the methods in order of most success and greatest efficiency are:

1. Organized hunts and drives.
2. The use of contracts for drives and removal of goats.
3. The use of private hunters (Deputy Rangers) on a one-man, individual goat hunting basis.

THE FENCING DILEMMAS

For over 40 years, no matter how good the various control efforts may have been, two factors have worked against an effective control program on a continual, 24-hour-a-day basis, year after year—inadequate boundary fencing to keep out goats and inadequate funds to keep existing fences in repair. Almost all of the existing 70 miles of boundary fence was inadequate from the time it was built, due to an improper size mesh in parts of the fence and in other parts no mesh at all—only smooth strand wire. Goats had relatively easy access into the park through all these years no matter how many were removed or otherwise discouraged.

The boundary fences are to date little more than rusted-out wire, rotten posts, and long sections of fallen fence (Figs. 4-6). The rainfall and lingering dampness and corrosive volcanic fumes have deteriorated the fences into

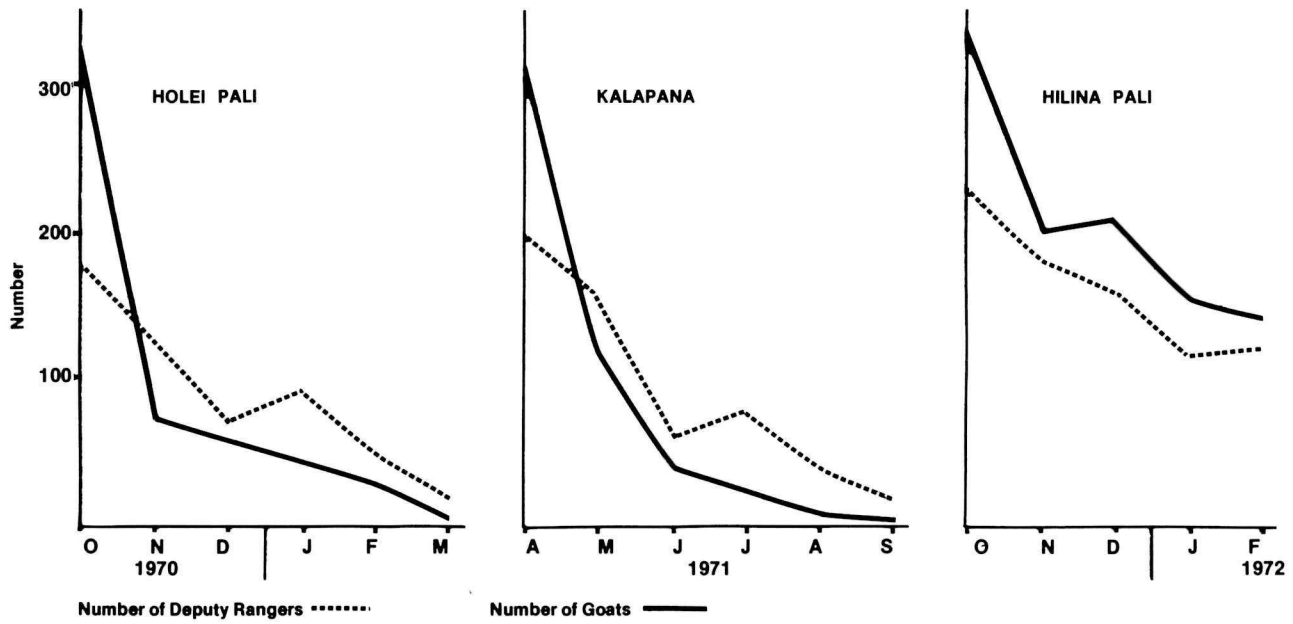


Fig. 3. Deputy Program Management Units. First unit started 10 October 1970, second unit started 3 April 1971, and third unit started 2 October 1971. The combination of these three units contains approximately 13,500 goats. Interest and numbers of goats reduced were highest during the early phases of each unit. However, as easily accessible goats were taken from each unit or forced into more remote areas, deputy interest and numbers of goats reduced per hunting day declined. In the above 16 months of operation, 665 deputy rangers removed 2158 goats–an average of 3.2 goats per deputy.

Fig. 4. Boundary fence between Hawaii Volcanoes and Keauhou Ranch.

Fig. 5. Boundary fence between Hawaii Volcanoes and Kapapala Ranch.

Fig. 6. Boundary fence between Hawaii Volcanoes and Ainahou Ranch.

virtual uselessness. It has been the almost complete lack of maintenance funds throughout the years that has been the worst of the dilemmas. The original fences, built in the 1930s by CCC labor, and other fences built since were not followed by programs of recurring annual maintenance that are so vitally necessary to keep fence materials in good repair.

Even new fences must have continual surveillance and inspection. The frequent winter windstorms blow trees across fencelines in the park's forested areas. Such occurrences create breaks or bridges into the park which provide goats an easy access to park lands (Fig. 7).

All too often in the past, breaks in fencelines were left to neighboring ranchers for repair, but rancher repairs, while good, were sufficient only to fence in cattle since a goat- or pig-proof fence was of little concern.

Fig. 7. Fallen trees from winter windstorms create a need to frequently check all fences in wooded areas. Goats will find and cross over such "bridges" in as few as 2 or 3 days.

ANALYSES OF GOAT IMPACT

Fences or not, goats had become an unnatural part of the natural scene, whatever else the National Park Service wished. Former NPS observers were able to gather much empirical data on the subject by witnessing goat-caused destruction throughout the years. The conclusions drawn were the same as those of state foresters prior to establishment of the park in 1916; goats constitute "a real and serious menace." This awareness provided additional justification for goat eradication efforts in addition to long-standing service policy on feral animals that justify removal of nonnative animals. This policy is based upon a desire to preserve the pristine wilderness quality of national parks where nonnative animals have no rightful places.

National Park Service observers also noticed that as native plants decreased there was a corresponding increase in numbers and abundances of exotic grasses and other plants that were opportunistic in the wake of goat destruction. Moreover, it seemed to some that exotic plants were spreading throughout the park regardless of the goat, and there has been a recurring, nagging theme to it all that seems to haunt the minds of those curious enough to think about it. Perhaps goats have already made such an impact upon the natural scene that by now the damage is irreversible. It seemed to some that goats had finally won out as necessary evils, to at last be retained for the potentiality of their ravenous appetites as biological controls over ever-worsening exotic plant invasions.

Indeed, it was the same reasoning that first permitted cattle to graze within the park. Early park administrators thought that cattle were necessary to control exotic grasses in order to lessen the dangers of wildfire upon unique park habitats and rare, endangered, endemic forest species. The grasses had been introduced along with cattle prior to the time the park was established, but it seemed at the time that cattle were necessary to keep grass cropped out to protect the forest. The strength of this belief resulted in early decisions to lease the park to ranchers even though cattle, as nonnative introductions, were incompatible with basic NPS policy. Cattle were permitted to remain within the park, to mow down grass, long after there was any reasonable doubt that cattle were swiftly killing out koa, mamani, pilo, mamaki, and other forest species. In fact, cattle were killing out the very things their presence was to have protected.

The cattle situation closely paralleled some of the thinking concerning goats. Park administrators at all levels had mixed feelings concerning goat-exotic plant relationships. Without any definite management plans and/or decisions on either of the two problems, the directions taken through years past varied from one park administration to another.

Darling and Eichhorn (1967) added further to the controversy, unwittingly, when they thought of the problem during their visit to the pali areas of the park and wrote:

> But what of the grass? In the absence of goats to eat it, the grass will grow long and wither and become a fire hazard to the forest above. Possibly, lacking any better animal (and God forbid the rabbit!) there is an optimum population of goats which would subsist by keeping down the grass without having to go up to the fringes of the forest. If an ecological study supported such a view, the goat in severely pruned numbers in this particular situation would not be an altogether harmful exotic.

There can be little doubt that feral goats eat considerable quantities of exotic plant material in the pali regions, but how much and of what benefit to the survival of competing native vegetation? As recently as 1971, arguments for this logic were reflected in various NPS correspondence:

> . . . besides the feral goat and pig, there are hundreds of exotic plant species in Hawaii. Many of these plants appear to be well established, and would probably be impossible to eradicate from the national parks. And is it conceivable, that some of them may be held in a state of equilibrium by the pressure of the exotic goat?
>
> In the case at hand, we must be concerned not only with the obvious destructive effect feral goats have on native vegetation, but also with the influence goats have on the distribution and abundance of exotic plants. A management plan designed without a clear understanding of the interrelationships between the goats and exotic plants would run the risk of creating plant pests that may have more serious consequences to the survival of native flora than that attributed to goats. On-going biological studies of this and other aspects of the goat problem will provide this Service with a sound base for the development of feral goat management strategy.

To help answer these problems, studies were started in 1969 to try to shed light upon goat-exotic plant interrelationships and to document the impact of feral goats upon native vegetation. Such data was to support, refute, or balance out suppositions and conclusions that had been made from previously obtained empirical observations.

A long-term study was initiated by biologist David K. Morris in 1969 which was continued through the summer of 1970. The study was resumed later in the year by James K. Baker who added investigations into goat and pig control measures to the studies.

As part of the long-term study, several exclosures, each 1000 m^2, were constructed to record the recovery potential of native plants in the absence of goats. In this way the ability of exotic plants to out-compete native species when goats are excluded could be determined. Would the resulting flora be largely exotic or largely native? In addition, a 1000 m^2 enclosure was built to record the exact sequences of events in which a native forest is disturbed and to determine the changes from native flora to exotic flora under the influence of goats, and then back again after the goats are removed.

To help determine what the original flora may have been, Donald W. Reeser has studied the current status and distribution of the park's rare and endangered flora to originate ideas on what the composition of the early flora was prior to the presence of goats and how they were distributed. His search for seed sources and supervision of a greenhouse propagation program is important groundwork preliminary to future successful reforestation projects to reestablish native flora as much as practical once goats are under control. Many of the experimental plantings in park habitats have already been destroyed by goats, pointing up the importance of added goat control.

Analyses of goat stomach contents have been made to determine amounts and kinds of foods taken and to ascertain any preferences shown for native over nonnative species; preliminary work in this regard was done by Morris (1969) (Figs. 8, 9). Short-term returns on all of the above long-term studies have already verified or answered much of what was needed to be known in order to disassociate any need for perpetuation of goats as control agents on exotic plants and to justify a management program that calls for complete control of all goats to levels compatible with the ability of native plants to recover.

Of the several goat exclosures, the Kukalauula exclosure has been the most dramatic to date (Figs. 10-12). The exclosure is situated in the pali area of the park where the heaviest goat concentrations are found. At the time of its construction in 1969 not a single native plant was recorded within the 1000 m^2. The flora was composed principally of two exotic grasses both of which were so overgrazed that the ground cover resembled a closely mowed lawn. After 2 years of recovery, several native species reappeared and they now comprise more than half the ground cover within the exclosure. While there is at present a higher number (by one) of exotic species, it appears evident that the vigorously growing native plants are capable of crowding out and replacing the once dominant exotics.

Of special interest and surprise was the appearance of a heretofore undescribed legume, *Canavalia kauensis* St. John, sp. nov. It is of further interest to note that, so far as is known, the entire world distribution of this interesting new species is found only within the exclosure; a patch approximately 150 x 30 ft. However, an examination of the ground outside the exclosure reveals that *Canavalia* seeds are lying dormant in the soil, but how long have they been there?

It is currently theorized that the legume was an "ice cream" plant for goats a long time ago, early in the 150-year-goat-history in that region of the island where the plant was formerly distributed. It was probably one of the first plants to go, and with subsequent destruction of the remaining ground cover the relatively barren substrate in this semiarid, windswept region has been almost continuously subjected to rapid desiccation after intermittent rainfall. Recent tests seem to indicate that the hardened seedcoat requires prolonged dampness prior to successful germination. It seems reasonable to assume that soil moisture was largely insufficient to permit *Canavalia* seeds to sprout and probably few ever reached maturity before goats devoured them again.

When construction of the exclosure allowed dense growths of native piligrass (*Heteropogon contortus*) and nonnative *Eragrostis* and *Cynodon* to reappear, wind desiccation of the soil was retarded sufficiently to give *Canavalia* time to germinate and opportunity to reach maturity. Subsequently, the vigorously growing legume has crowded out the exotic pioneers within the exclosure—a form of natural retribution perhaps.

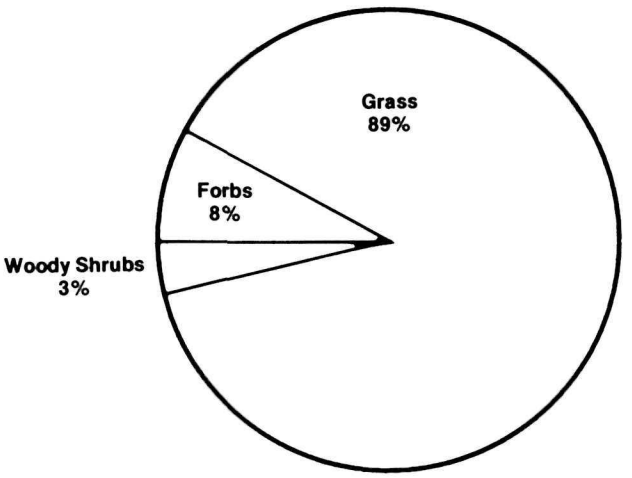
Analyses of goat stomach contents show clearly that goats prefer native browse whenever available. This probably is due to the fact that native species are generally less browse resistant and more palatable. The phenomenon easily explains why there is a relatively rapid disappearance of native plants, in the presence of goats, while less palatable nonnatives flourish and spread.

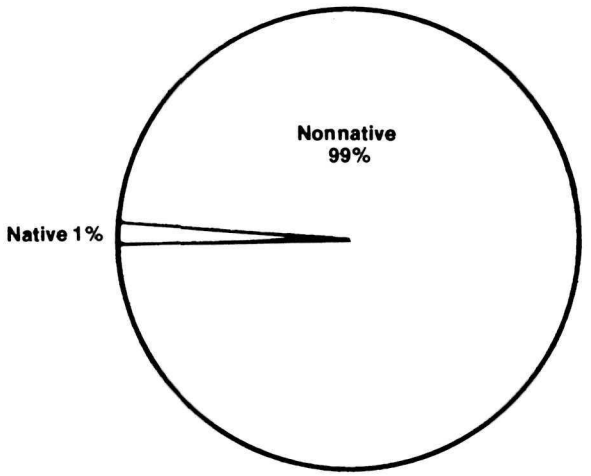
Morris (1969a) determined that on a volumetric basis grasses comprised 89% of the food taken in the pali regions with only 8% being forbs and 3% being woody shrubs. On a species basis, 99% of the vegetation eaten was nonnative while 1% was native (Figs. 8, 9). This analysis is easily attributable to the almost complete absence of vegetation other than grass along the palis (Fig. 1) and to the fact (as revealed in the Kukalauula exclosure analysis) that native species are almost nonexistent. This supports the hypothesis that, under continual and heavy goat pressures, native plants disappear, to be steadily replaced by exotics and maintained in that unnatural balance. Importantly, however, the results of the Kukalauula exclosure show that once goats are removed, natives reappear and can, in time, crowd out the exotics to a point where more natural conditions are reattained.

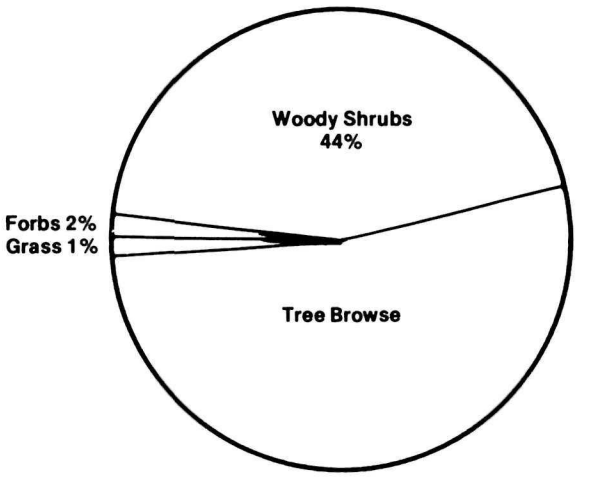
Morris (1969a) found an almost complete reversal in the northern, higher elevation areas of the park where increased rainfall supports a mountain parkland ecosystem of koa (*Acacia koa*)—grassland savannahs with occasional closed kipuka forests of mixed communities (Fig. 1). In this region of the park, the area called the "Mauna Loa Strip," only 10% of the park's goats are to be found and native vegetation is dominant, despite the destruction of the strip by cattle grazing early in the history of the park. Analyses of the stomach contents of goats of the strip showed that 53% of the food was tree browse, 44% was woody shrubs, 2% was forbs, and only 1% of the food was grass (grass was 89% in the palis). Moreover, 98% of the food was native while only 2% was exotic, even though exotic food is abundantly available. The conclusions to be drawn are that, when available, goats prefer native browse and ignore less palatable exotic species. We may assume, then, that as native vegetation is devoured and decimated, exotic species have opportunity to flourish and spread.

Even though the population of goats is relatively low throughout the strip, by comparison with the palis, the availability of native browse suggests that as far as impact upon native species is concerned, goats are doing most damage at present in the strip area. Even an untrained eye cannot fail to notice large numbers of dead and dying trees throughout the kipukas that is caused by the goat habit of peeling away bark, leaving bright, yellow-colored wood of freshly stripped pilo (*Coprosma*) trees exposed, glistening with sap and glaring almost like neon signs.

In the kipukas (forest remnants surrounded by lava flows) goats are rapidly killing out the pilo and mamaki (*Pipturus*) understory and are preventing the growth of koa and mamani (*Sophora*) by devouring all seedlings. Moreover, the killing of older mamani occurs by the same bark-peeling habit. Goats, therefore, are responsible for vast







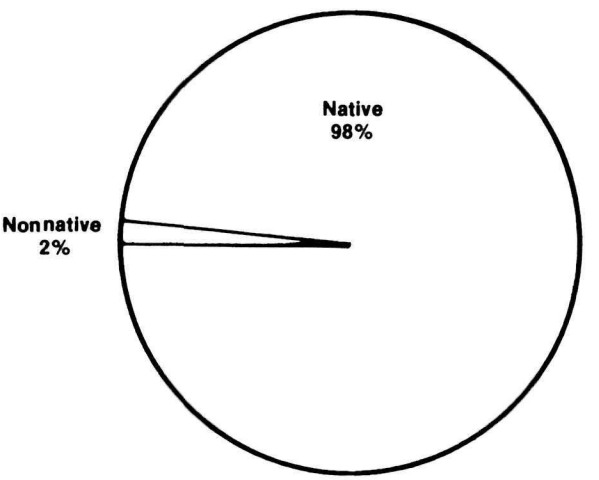


Fig. 8. Summer food of goats from pali areas of Hawaii Volcanoes National Park. Percentages of grass, forbs, and woody browse, and native vs nonnative materials consumed in summer months, 1969. (From David K. Morris. *Summer food habits of feral goats in Hawaii Volcanoes National Park, 1969.*)

Fig. 9. Summer food of goats from Mauna Loa strip area of Hawaii Volcanoes. Percentages of grass, forbs, and woody browse, and native vs nonnative materials consumed in summer months, 1969. (After David K. Morris. *Summer food habits of feral goats in Hawaii Volcanoes National Park, 1969.*)

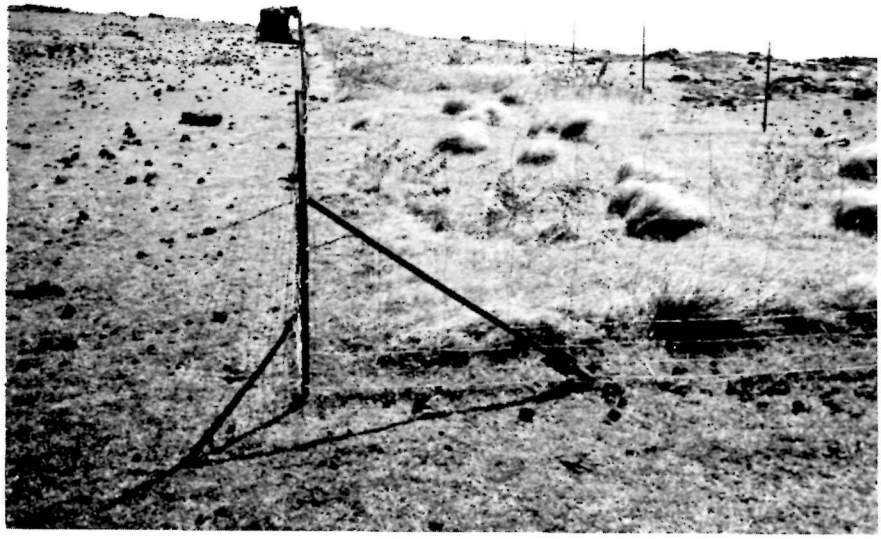


Fig. 10. The Kukalauula goat exclosure is located in the coastal pali area of the park where most goats are found. The close-cropped vegetation outside the fence is nonnative grass. The bunch grass inside the exclosure is a native pili grass; one of several native plants now recovering after only 2 years protection from goats.

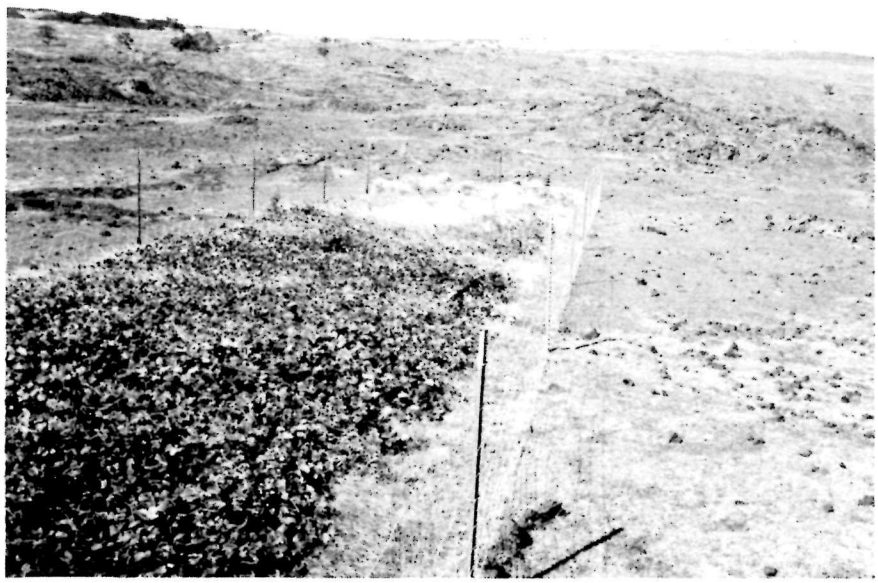
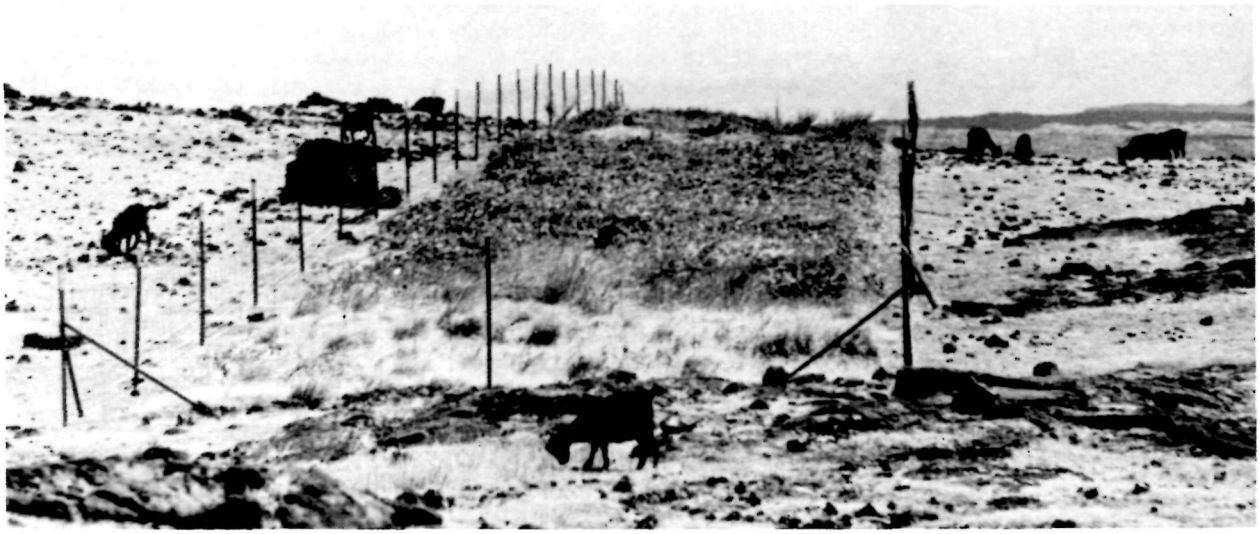


Fig. 11. The palis around the Kukalauula goat exclosure are almost devoid of vegetation other than close-cropped nonnative grass. Scattered trees higher up on the slopes are all that remain of a native ohia woodland after 150 years of goats in this region. The densely growing legume inside the exclosure is a new *Canavalia* species unknown before construction of the fence. The rapid recovery potential of native vegetation being demonstrated within the exclosure is a probable indication of what most of the goat-barren palis would resemble in a short time once goats are eliminated.



Species	% Cover Outside Exclosure	% Cover Inside Exclosure
Plants native to Hawaii		
Awikiwiki, *Canavalia kauensis*	None	45.0
Crabgrass, *Digitaria pruriens*	0.4	23.2
Pili Grass, *Heteropogon contortus*	None	1.2
Wild Portulaca, *Portulaca cyanosperma*	None	Trace
Total ground cover by natives	0.4%	69.4%
Exotic plants		
Lovegrass, *Eragrostis tenella*	20.0	0.6
Bermuda Grass, *Cynodon dactylon*	17.2	18.8
Sedge, *Cyperus compressus*	4.4	None
Molasses Grass, *Melinis minutiflora*	1.6	None
Sedge, *Bulbostylis capillaris*	1.6	None
Spanish Clover, *Desmodium triflorum*	0.4	1.2
Alaalapuloa, *Waltheria indica*	None	2.4
Cassia, *Cassia leschenaultiana*	None	2.4
Total ground cover by exotics	45.2%	25.4%
Bare soil and rock	38.0%	None
Litter	14.4%	None

Fig. 12. Kukalauula goat exclosure. Data collected December 1971, 2 years after exclosure was constructed. Information derived from Mueller-Dombois and Spatz (1972).

ecological changes taking place in kipuka ecosystems.

For every tree killed, there is less food available for endemic nectar-feeding birds and less insect food for other bird species. With the death of a tree there is less living substrate for the growth of symbiotic and parasitic plants and animals; and there is less opportunity for related forest members to survive because, as canopy layers are opened, sunlight wilts those species that are shade-adapted and the direct sunlight causes soils to dry out rapidly. The herb, fern, moss, fungus, and grass communities present in the forest disappear as heat and dryness increase and they are also trampled into extinction by the hooves of herds of goats. Erosion sets in and soils wash away.

The pristine conditions of the kipukas have been disturbed to the point that closed forest communities are slowly deteriorating into open woodlands (Figs. 13-16). If goat pressures continue, forests within the kipukas will eventually resemble the grasslands and savannahs of adjacent ranches, where cattle have speeded up the process, and would in time take on appearances of the barren grassland pali areas. Such happenings cannot be disputed. The deterioration of a climax forest into a goat-dominated grassland or savannah happens, and sometimes in less than a century. It is happening now in Hawaii Volcanoes National Park.

Wodzicki (1950) gives a graphic example of goat-induced grassland dominance from an original montane rain forest in New Zealand which is an exact parallel to situations in Hawaii, not only within the park but elsewhere in the islands:

> The replacement of a forest formation by a grassland association . . . upon the progressive action of introduced animals was described by Moore and Cranwell (1934). . . . The primitive montane forest consisted of a closed canopy provided by tall trees and epiphytes, of middle layers by shorter trees and shrubs, with saplings and ferns, and the floor covered by mosses, liverworts and filmy ferns. Grass elements such as *Microlaena* occurred only very sparingly. . . .
>
> Wild cattle were reported in 1888, but in the early thirties only pigs and goats were present. After their liberation this forest degenerated on certain ridges into a 'comparatively stable indigenous induced community dominated by the tall tussocky grass *Microlaena avenacea*.' This occurred in three gradual stages. . . . In the first stage the main damage was in the baring of the forest floor due to the effect of trampling or browsing on seedlings, small plants and trees. The rooting of pigs led to a further disturbance of the leaf cover and tended to alter its relationship with surface water which now

Fig. 13. A fenced portion of native forest which is goat-free in Hawaii Volcanoes National Park. The canopy is koa and ohia. The naturally dense understory is pilo and mamaki which provide the damp, shady microhabitats for fern-, herb-, fungi-. moss-, and grass-related associations. The pilo is a succulent, soft-barked tree that is perferred goat browse.

Fig. 14. An unfenced portion fo the same forest only 300 ft from the scene in Fig. 13. The composition and density of trees is approximately the same. However, goats have killed out the entire understory of native pilo. mamaki, and other plants. Such continued destruction by goats rapidly deteriorates a closed forest community into a woodland sere and ultimately into a grassland savannah. Continual browsing by only a few goats will prevent any possible seedling growth and recovery of the forest.

flowed freely, carrying with it the leaves, and soon stripping the thin humus below. The action of wind has to be added and the continuity of the canopy was impaired by the drying of many trees either through ring-barking or damaged roots. In the second stage the ferns grew apart and the fronds of many were attacked by goats while the trunks of some of them were knocked and ripped longitudinally by pigs. In the third stage of complete dominance of *Microlaena* the inroads of pigs and goats continued, destroying the fern population of which some plants had a considerable economic importance in holding ridges and slopes.

This change from a primitive montane forest into a stable native grass community took place in a relatively short period of little over 50 years.

The results of the various goat exclosures, as well as support data from other studies within the park, indicate the following:

- Goats are selective and choose native species over nonnative species whenever available;
- Goats help to perpetuate the growth and spread of less palatable exotic species;
- Goats can, in time, deteriorate a native forest into a grassland-savannah;
- Goats are the likely cause of extinction, or near extinction, of several species of soft-barked native trees and shrubs;
- Goats denude areas of their vegetative cover to a point that causes shallow topsoils to erode, exposing rocky substrates; and
- If goats can be removed from the scene, native plants will reappear, flourish, and in some cases out-compete invading exotics.

Based upon these findings, no further consideration should be given to the perpetuation of goats for the purpose of controlling exotic plants. Goats will largely ignore exotics so long as native species are available. It is evident that reappearing native species have inherent abilities of their own for natural recovery. This is not to imply that native recovery will act as a biological control on exotics; such is not the case. There will always be exotics but it is evident that under favorable circumstances (the absence of goats) natives can recover and become important parts of the community again, however altered and modified it currently may be by exotic plant invaders. Moreover, native plants have far better opportunity for survival in the face of competing exotics than they have in face of both exotic plants and feral goats, because goats give exotics an overwhelming advantage.

It is suggested, therefore, that proper management of Hawaii Volcanoes National Park can begin only with control of the goat. That is the necessary first step. With removal of the goat, rare and endangered plants and other less-threatened vegetation have at least some natural chance for recovery, even without the aid of man. But an aid in that recovery would be to continue and increase greatly the greenhouse and reforestation projects within the park. In addition, there must be developed a greatly expanded program of operations to physically remove large numbers of various aggressive, invading, nonnative plants.

Fig. 15. A goat-protected area in Kipuka Puaulu (Bird Park) in Hawaii Volcanoes National Park. The understory trees are a naturally dense stand of pilo.

Fig. 16. An unprotected area of the same forest only 30 ft away from the scene in Fig. 15. The density of pilo trees is the same but goats have killed out 100% of the trees by the habit of stripping bark from soft-barked species. Such trees evolved in the absence of herbivorous ungulates and they cannot now survive in the presence of only a few goats as occasional stragglers will continue to devour seedlings as quickly as they appear.

OTHER GOAT CONTROL TECHNIQUES

Management in New Zealand

The difficulties in controlling goats have been attributed largely to the inadequacies of boundary fencing, funding, and manpower which have continually plagued even the very best of NPS intentions, efforts, and long-time policies to dispose of feral animal problems. But more than that, even under optimum endeavors and conditions, traditional drives and organized hunts were never entirely satisfactory in removing the maximum number of goats desired. For every goat captured in a drive, another one or more broke away. For every goat shot in a hunt, a dozen or more escaped. For every goat seen in the park, hundreds went unseen.

Perhaps, therefore, it would be useful to explore the use of new or different techniques. It is known that goat control has been successful in certain other parts of the world. What of their methods? How were they successful? It was with this purpose in mind that Baker visited New Zealand in September 1971 to study the noxious animal control work of that country which has had exotic plant and animal problems so very similar to those of Hawaii.

Goats were introduced into New Zealand in 1773, only 5 years before the same Captain Cook introduced them into Hawaii in 1778. With each succeeding visit, Cook carried in seeds and other animals to help make New Zealand more "suitable" for human occupation. Whalers and other sailors who followed Cook brought in more animals, and when the regular settlement of New Zealand began in 1840, importation of animals both wild and domestic became a major concern.

A total of 207 species of introduced vertebrates including fish, amphibia, birds, and mammals were brought in and released. Ninety-one became permanently established, including 32 mammals of which many became problems. Attitudes toward introduced animals began to change as damages to forests and croplands as well as native plant and animal extinctions were noticed. By 1907, a law was passed which prohibited any more importations of wildlife except by special permit. In 1956 the *Noxious Animals Act* was passed which permitted wholesale control upon those animals covered by the Act, and the control of noxious

animals came under the direction of the New Zealand Forest Service in that same year.

Through the troublesome years, New Zealanders had developed a wide variety of control techniques applicable to such diverse groups of animals as rabbits, opossums, deer, chamois, thar, goats, pigs, and others. Not all of the animals have been easy to control, but of the several ungulates, New Zealanders now consider the goat the easiest to eradicate and goats have been virtually eliminated from several large areas of the country.

New Zealand's determination to control the goat has resulted in more than one million being destroyed through 1970—as many as 73,000 in a single year. In a single area, more than 17,000 were killed in 3 months by nine men with rifles and several dogs.

Through one or more of the following techniques, New Zealand has come to grips with its own goat dilemmas:

Dogs: Trained goat dogs, the same kinds used for sheep herding, have been exceptionally effective for use in tracking and herding goats and to ferret-out isolated individuals from hiding places. Above all other methods, the dog has been New Zealand's answer to effective goat control. In mop-up operations, dogs are used to good advantage when the last remaining goats are difficult to clean out, and they are especially useful in mountainous, forested terrain where goats might go undetected by hunters or could easily escape if seen. By either voice or whistle commands, goat dogs can be instructed to move out behind the goats, round them up, and either hold them at bay or move them back to the hunter. Goats at bay are more afraid of the dogs than they are of the hunter and man can move among the goats so long as dogs hold them together.

Helicopters: In recent years the helicopter has been a major tool in effective control work on goats, deer, thar, and chamois. When used in conjunction with men and dogs working simultaneously on the ground, New Zealanders are able to clean out animal-infested areas in minimum time with the greatest cost efficiency. If animal control work is to be done with the quickest, surest, and least expensive methods overall, in difficult terrain, the helicopter is a most practical consideration.

Poison: The New Zealand Forest Service has developed techniques for using poison on leaves of preferred browse species in areas of high deer and goat concentrations. The method is used best in areas where well-defined browse lines are established and little other food is available. Under such conditions, out-of-reach limbs are broken off or pulled down and tied in place below the browse line. Poison is applied to the undersides of randomly selected leaves and only one or two leaves need to be eaten to administer a fatal dose. Advantages to this technique are that deer or goats need never be seen to be eradicated and poisoned leaves work 24 hours a day when other techniques cannot.

Since New Zealand, like Hawaii, has no native mammals other than bats, almost any carnivore or scavenger mammal that might be secondarily poisoned is only another pest that needs eradication. Tests show that the poison is too diluted in the meat of an animal to secondarily kill humans. It is, therefore, a safe and usable technique.

No matter what combinations of the above techniques are used, a basic philosophy considered by New Zealanders stresses the importance of over-control rather than risk irreparable damage by return of the same old problems through practicing under-control. Emphasis on total eradication is based upon a fundamental principle that success is not measured in numbers of animals killed but in how few, if any, are left to start over again.

The success with goats in New Zealand is largely a result of determined perseverance on the part of New Zealand resource managers to pursue a management objective through to completion. This is done in retrospect of problems and experiences in the past and apprehension for the future should noxious goat control go unattended.

The lessons to be learned from New Zealand are: (1) that goat control must be pursued relentlessly and with determination; (2) dogs are essential; and (3) it is wise not to risk under-control unless one expects the problems to be perpetually recurring.

The lessons to be learned from our own misadventures are: (1) there must be a plan; (2) it must receive uninterrupted review and implementation; and (3) it must be programmed for sufficient funds and manpower to achieve its objectives.

THE BREEDING AND RECOVERY POTENTIAL AS A FACTOR IN GOAT MANAGEMENT

As already mentioned, a fundamental principle of animal control work is that the success of a program depends entirely upon how many animals are left behind, not upon how many are destroyed. That is, success or failure of the program hinges upon the reproductive potential of any remaining animals, keeping in mind another biological principle that when a population is low, by comparison to the normal carrying capacity of its habitat, biotic potential for reproduction is greatly increased.

Rudge and Smit (1970) were able to determine the breeding potential of a herd of feral goats in New Zealand and they concluded that if a goat population is reduced by 80% it will bounce back again at a very rapid rate. The goats are able to rebound to within 90% of their original level in only 4 years. In so doing, the original survivors could more than double in just the first 2 years on the road back to recovery (Fig. 17).

This reproductive phenomenon and lack of an understanding of its full significance by park officials has plagued the control efforts of Hawaii Volcanoes from the start. Yearly average reduction has done little more than skim off the tops of biological surpluses of a highly reproductive animal–surpluses that would have died out anyway as the population exceeded the carrying capacity of the habitat. In some of the more remote and seldom hunted pali areas, the goat populations are probably being kept in check by their own mortality rates caused by density-dependent factors which operate naturally to maintain stable population levels.

National Park Service efforts to control goats have accomplished little more than to play the roles of predators, which in actuality maintain ungulate herds in good health, vigor, and reproductive trim (Fig. 18). Hawaii Volcanoes' goat eradication efforts have unwittingly achieved the same objectives of every good game farm.

Ironically, it is the basic human desire for success that works against meaningful goat eradication, because employees who direct and participate in drives and hunts naturally want to see as many goats taken as possible. Drives and hunts are, therefore, usually conducted when and where maximum numbers can be taken.

Emphasis upon goat reduction within the same area quite naturally does not continue long because of the greater "success" potential that can be achieved elsewhere. But in actuality, the best success can be obtained only when reduction parties can concentrate their efforts upon a small portion of goat range to eventually chalk up zero goats repeatedly. Then and only then can the operation be termed successful even though the goat:cost ratio suggests that nothing is being accomplished except to waste time and taxpayers' money.

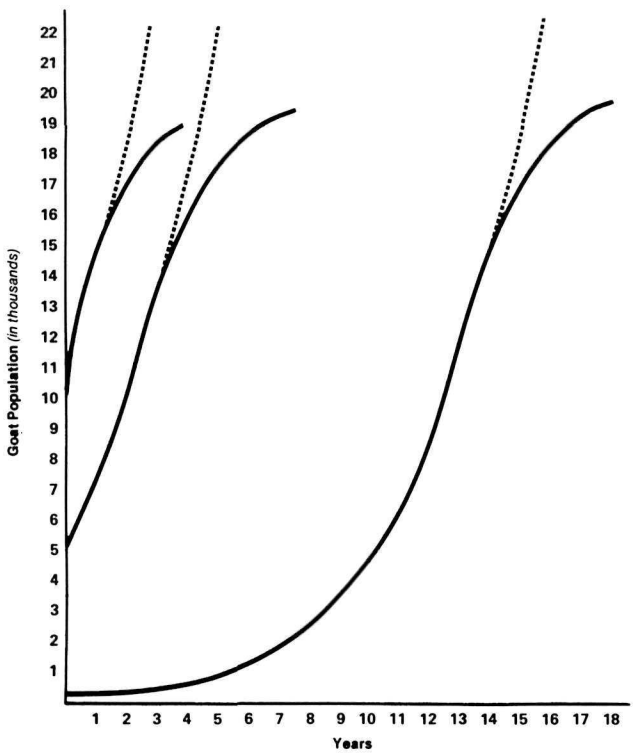


Fig. 17. Breeding potential of feral goats. This graph for the Hawaii Volcanoes goat population is based upon data derived by Rudge and Smit (1970) who determined the population growth rate of a feral herd over a 3.5-year period. Goats will increase at a predictable rate until ecological limits of food and space are attained. It is surmised that in Hawaii Volcanoes this point is probably between 15,000 and 20,000 goats.

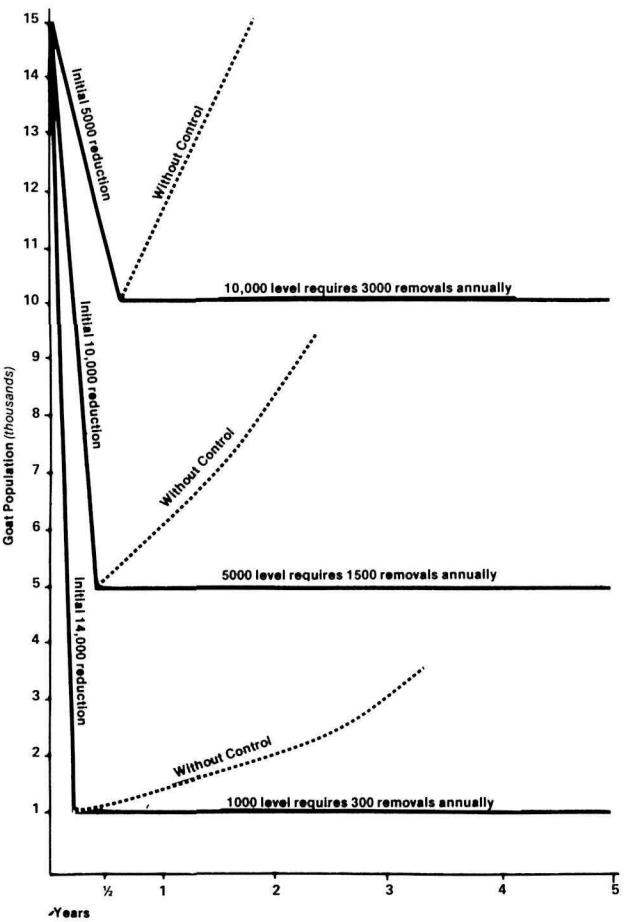


Fig. 18. Goat control vs breeding potential. Based on breeding potential (Fig. 17) and assuming an unconfined population of 15,000, this graph shows needed reduction efforts to maintain hypothetical levels. As populations lower, control becomes progressively harder; to remove 300 annually from 1000 goats is more difficult than to remove 3000 annually from 10,000 goats. (In only 3 years has reduction within the park exceeded 5000 goats, and the annual average is less than 2000. Thus, NPS efforts only skim biological surpluses.)

Nevertheless, due to the immensity of Hawaii Volcanoes National Park and the extensive distribution of its goats, it has seemed until now to be impractical to concentrate upon a zero goat/small area basis when there are large areas of the park that are receiving no attention. The zero goat/small area system has been practical only to clear out isolated trouble spots in certain small areas of the forest, and only as a temporary measure–for, in short time, the immigration potential of goats creates the same problem all over again.

However, if small, workable management units could be boxed off, a zero goat/small area technique would be practical. Fenced-off management units of a few thousand acres each would be feasible to handle, and once a unit became goat free, the perimeter fence would keep it goat free and permit reduction parties to turn their attentions to other management units. In this manner a unit-by-unit program would clear out the majority of goats in relatively short time–a goal that has not only been impractical in the past, but seemingly absolutely unobtainable.

A GOAT MANAGEMENT PLAN

The following is an outline of the major elements that must be included in any plan designed for the effective and efficient control of feral goats in Hawaii Volcanoes National Park. The complete success of the program depends upon the faithful, unwavering adherence to each of these major elements.

- Rebuild existing boundary fences. Program annual fence inspection, fence repair and maintenance, and periodic aerial goat surveillance to prevent reinvasion.
- Cross-fence certain areas of the park into workable blocks or management units. The cross fences forming the management units, together with the park boundary fencing, will require approximately 116 miles of fencing.
- Fence materials will consist of galvanized 6-ft steel posts and 48-inch-high hog wire with 6-inch mesh. A single strand of barbed wire along boundary fences will add 1 ft to the height of the fence for added protection against cattle. Figure 19 is an outline map of the park with the suggested management units delineated.
- As fenced management units are completed, goats must be effectively controlled to levels compatible with the natural restoration of native vegetation. Control will be by organized hunts and drives, supplemented with dog and helicopter support.
- As each management unit is cleared of goats, monitor the recovery of native flora to determine need for exotic plant control and revegetation projects that will help to restore each unit to as near a pristine condition as possible.

Goats will still need to be controlled in some of the more accessible areas of the park, especially in the area of the palis. This can be accomplished by NPS personnel, supplemented as necessary by the deputy ranger program. This kind of control effort should continue until such time as the unit management techniques have succeeded.

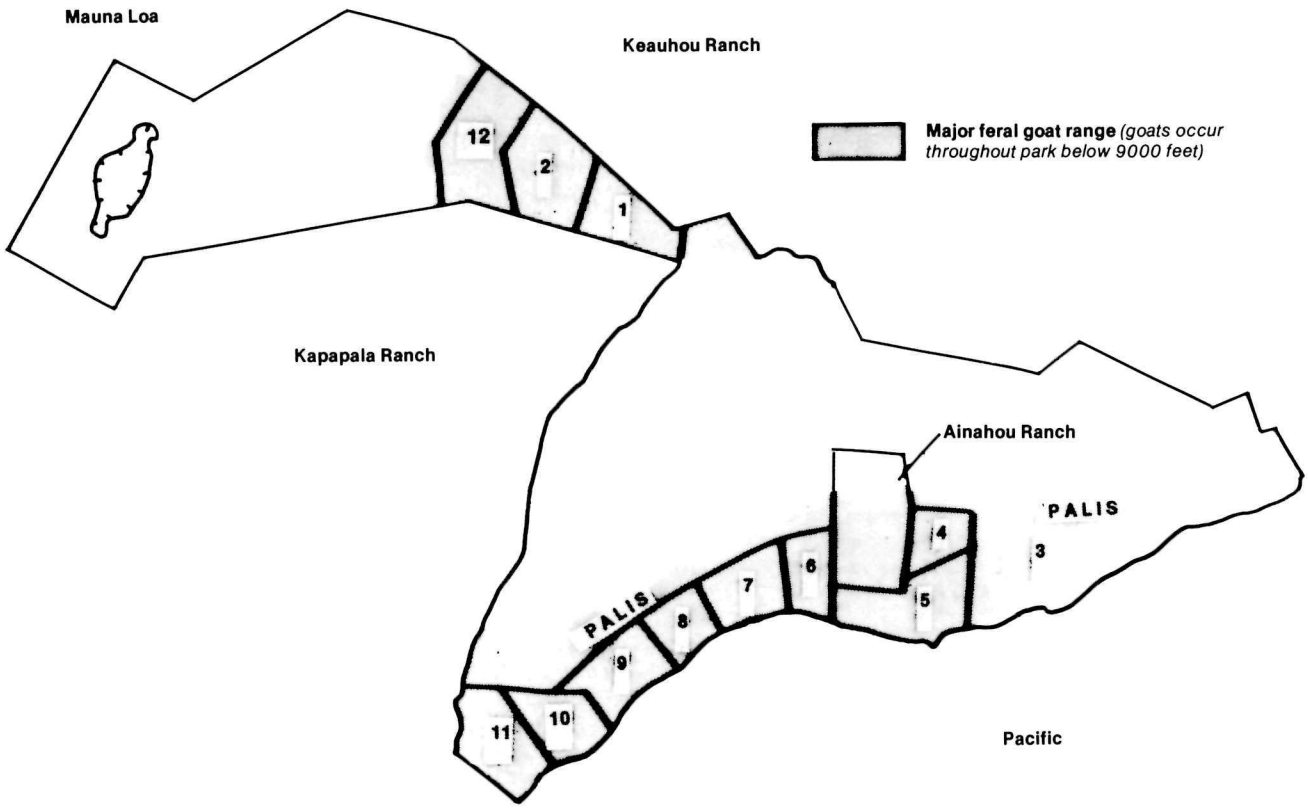


Fig. 19. Distribution of goats in the park and locations of proposed goat-control fences.

CONCLUSIONS

Feral goats are incompatible with Hawaii's unique biota, which evolved in the absence of herbivorous mammals on an isolated, volcanic archipelago. Goats are considered to be the major cause for a continuing destruction of natural communities in the park. Their continued presence, at least in such numbers as exist at present, defies any hopes for habitat and species restoration. Goats cannot be considered to be an effective control of exotic plants so long as native plant species are present. Goats are destroying native habitat on which several endangered birds depend. Their browsing habits have been a major contributor to the extinction of numerous endemic flowering plants, and by stripping away ground cover and pulverizing the soil, erosion sets in to expose lava substrates. Consequently, year after year the prospect for the restoration of native plants becomes less and less.

The various methods used to control goats have included: (1) large-scale drives by the Territory of Hawaii, Civilian Conservation Corps, and the National Park Service; (2) short-term and long-term contracts to "goat control companies"; and (3) hunts by NPS personnel and deputized rangers. These methods have certainly eliminated large numbers of goats—more than 70,000—but unfortunately, even in the best control years, they did little more than skim off biological surpluses which actually benefited the health and vigor of the goat population. Furthermore, the lack of adequate boundary fencing and internal drift fences precluded ever reaching the objective.

The results of exclosure studies and other investigations have shown conclusively that restoration of Hawaiian biota cannot occur except in the absence of the goat over a considerable period of time. Even if present goat reduction

methods are substantially augmented, achievement of this requirement cannot be guaranteed. Therefore, a plan is proposed that, it is believed, will solve the park's goat management problems. The major steps to this plan are few: (1) the construction of goat-proof boundary fences; (2) the construction of internal, fenced management units; (3) the continuation of organized drives and hunts but on a greatly expanded scale, and the use of dogs to effectively seek and herd the large number of goats—a technique new to Hawaii; and (4) monitoring the recovery of freed areas to determine needs for exotic plant control and future revegetation projects.

As objectives of the plan succeed, the NPS can proceed with much needed resource management projects of a positive nature, such as native tree reforestation, reestablishment of the endangered nene (Hawaiian goose) and, hopefully, other bird species. It is further anticipated that subsequent successional recovery of native ecosystems will encourage a natural establishment of other rare and endangered flora and fauna.

The National Park Service is the largest land and species conservation agency of the Federal Government in Hawaii. If and when rare and endangered plants and animals become extinct elsewhere in Hawaii, as some have already done, the sole surviving populations may well exist only within national park lands. This responsibility of the Service to protect rare, endemic biota that is found nowhere else in the world is second to none in the National Park System. It is biota that may number only in the few tens of remaining individuals and be found only in a single small area. These are treasures that belong not only to the people of Hawaii and the rest of the United States; they belong to all the world.

APPENDIX

Rare and Endangered Plants
Hawaii Volcanoes National Park

The following plants are known to occur within Hawaii Volcanoes National Park; some are known from nowhere else in the world but from within Hawaii Volcanoes. The rarity of the plants can be attributed in large part to a long history of browsing activities by feral cattle and goats, and in part to the rooting and browsing activities of wild pigs. Some of the plant species number only a few tens of individuals.

Awikiwiki	*Canavalia kauensis**
Ohai	*Sesbania tomentosa**
Hau-kuahiwi	*Hibiscadelphus Giffardianus**
Aiea	*Notocestrum breviflorum**
Aiea	*Notocestrum longifolium**
Ahakea	*Bobea timonioides**
Naupaka	*Scaevola kilaueae**
	*Stenogyne angustifolia***
Hame	*Antidesma pulvinatum*
Ohe makai	*Reynoldsia sandwicensis*
Halapepe	*Dracaena hawaiiensis*
Kauila	*Alphitonia ponderosa**
Ae	*Zanthoxylum dipetalum**
Kului	*Nototrichium sandwicense**
Ohe mauka	*Tetraplasandra hawaiiensis**
Papala	*Charpentiera obovata*
Holei	*Ochrosia sandwicensis*
Hoawa	*Pittosporum hosmeri*
Silversword	*Argyroxiphium sandwicense*

*Considered as endangered.

**May already be extinct.

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As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources." The Department works to assure the wisest choice in managing all our resources so that each will make its full contribution to a better United States—now and in the future.

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