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KĪPAHULU VALLEY

FERAL PIG PROPOSAL

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PROPOSAL TO STUDY FERAL PIGS

IN KĪPAHULU VALLEY

HALEAKALA NATIONAL PARK

September 1977

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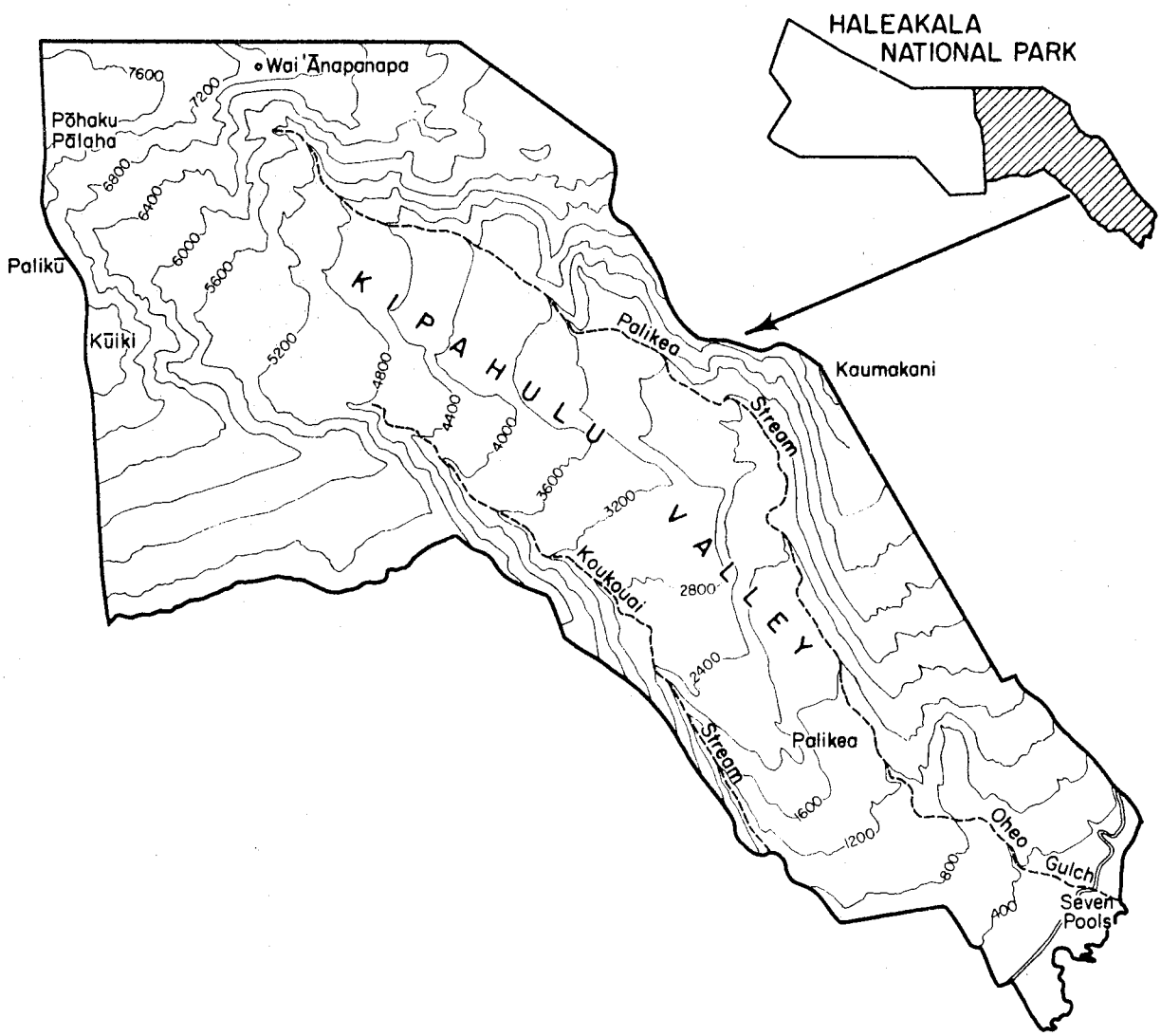

Frontispiece: Map showing the geography of Kīpahulu Valley, Haleakala National Park, Maui.

PREFACE

This proposal is written in response to Haleakala National Park Project Number HALE-N-6 (Kīpahulu Pig Study). As outlined in their Project Statement the research is to provide information in the following areas:

1. Population grouping, distribution and racial types.
2. Specific points of access into Kīpahulu Valley by outside populations of pigs.
3. The role of pigs in the introduction and spread of exotic plants into Kīpahulu Valley.
4. The role of pigs in the direct destruction of native plants.
5. The probable long range effect on Kīpahulu Valley if no control measures are taken.
6. If control measures are recommended, then a study is to be made of the cost, effectiveness and potential damage to the native habitat of:
   a. hunting,
   b. trapping,
   c. fencing,
   d. sterilants,
   e. any other feasible methods.

One problem which has been identified in the 1976 Kīpahulu Valley Report and the Resources Management Plan for Haleakala National Park (HALE) is the study of the

impact of feral pigs in the valley ecosystem. A program for research has been proposed and a budget estimated.

This program is in two parts. Part one describes a program to evaluate the impact of these animals on the valley ecosystem. Part two identifies the research program to study the feral pigs in Kīpahulu Valley. These two sub-programs are part of an integrated research program, whose main objective is to quantitatively describe the feral pig populations, their biology and behavior within Kīpahulu Valley. This information is then used to evaluate the impact of the feral pig on the plant communities in the valley. The vegetation analysis program will also assess the impact of the strawberry guava, (*Psidium cattleianum*), and other weeds in the valley ecosystem, and the role that the pigs have in establishing and dispersing these plants.

From the results of these two interrelated research proposals it should be possible to answer the following questions.

1. How much are pigs a negative influence within the Valley? Is an active management program necessary?
2. Which of the following would be the most effective method of control?
    a. Fencing strategic areas
    b. Fencing the whole valley
    c. Trapping
    d. Hunting

e. Poisoning

f. Other (poisons, sterilants, combinations of above, etc.)

3. How much are strawberry guava and other weeds a serious threat to the valley's native ecosystem? If so, are they a threat at all elevations? Are pigs the principal dispersing agent? Should attempts be made to eradicate the species? If so, how?

4. Will the control of pigs in the valley allow the native ecosystem to reestablish itself naturally?

PROBLEM ANALYSIS:

Kīpahulu Valley, a unique area

Lamoureux (*in* Warner 1967) reported the occurrence of 197 species of native and 23 species of introduced higher plants in the undisturbed area between two and six thousand feet. Exotics were most commonly recorded from habitats which had been disturbed by pigs. The valley has at least 74 species of native ferns and related plants and a dozen species of rare Lobeliads. The large number of endemic plants and the diverse plant communities, ranging from tropical rainforest to subalpine vegetation, make the native biota in the valley almost unique. The complex forest ecosystem in this nearly impenetrable valley has remained relatively undisturbed by man though exotic animals and plants are invading certain areas. Consequently

the valley provides a unique natural laboratory for the study of endemics, evolutionary genetics, pedogenesis, and the complexities of pristine ecological systems.

Banko (*in* Warner 1967) found that the pristine ecological communities in the valley are a sanctuary for many rare and endangered birds, some thought to have been extinct. The extinction of certain species of native birds has been attributed among others to (1) the destruction of habitats by feral goats and pigs, and (2) diseases such as avian malaria and avian pox which are spread by the *Culex pipiens* mosquito (Warner 1967; Haleakala National Park 1976).

The Park realizes that the feral pig is an animal that needs to be controlled and managed in order to preserve the native biota and physical environment within the valley in as natural a condition as possible. The 1967 Expedition identified the feral pig as the primary destroyer of native ecosystems. Various factors may be aggravating the pig damage to the forest and at the same time making control measures more difficult. Pigs in the valley are inadvertently protected because of restricted access by hunters and the public. Being the only large mammal reported to date to occur in the valley, the pig has no predators or inter-specific competition for either food resources or habitat use. With the increase in numbers and density per unit area, the above factors would prove very favorable for the pigs to extend their home range, move into new areas in

the forest, and establish new home ranges, thereby increasing the possibility for further degradation of the forest.

Ecosystems in Hawai'i have evolved naturally in the absence of any large herbivores--the Hawaiian monk seal *Monachus schauinslandi*, and the bat, *Lasiurus cinereus*, being the only endemic mammals in Hawai'i. Native plants have evolved no defenses against grazing or browsing animals. The roots of some plants are very susceptible to trampling. The hydrandept soil type found with the valley dehydrates irreversibly forming fine pebble-like aggregates (USDA Soil Conservation Service, 1972). The loss of plant cover would dramatically increase the likelihood that such soil changes would occur which would result in a significant change in the ecosystem. Pig activity, therefore, has the potential to produce devastating effects and subject the ecosystem to chronic ecological stress.

While the National Park Service is giving consideration to control measures, studies by various scientists here and elsewhere have shown conclusively the irreparable damage that pigs cause to forest ecosystems. Of late, pig control has become quite an emotion-charged issue. Many feel that there should be more impetus and urgency in the control program. Others, like many hunters, feel that the pigs should be hunted as a perpetuating resource or else left alone. Some hunters have even suggested the release of domestic blood in feral populations in order to increase the

carcass value of game animals for hunting. Regardless of present Park pig management philosophies and the concerns of hunters and others, the following reasons should justify the establishment of a full-scale Pig Research Program in Kīpahulu Valley.

Introduction of exotic plants by pigs

Pigs open up new areas in the forest floor by trailing, rooting and wallowing. Such exposed areas apparently serve as habitats for the colonization and establishment of exotic plants which are often better competitiors than native species in such situations (Becking 1970). Pigs are suspected of dispersing the seeds of certain species on the bodies or in their feces. Many exotic species dominate the wallows and trails. Grasses, such as *Paspalum conjugatum* are dispersed along pig trails (Lamoureux and Stemmermann 1976). The spread of strawberry guava (*Psidium cattleianum*) into Kīpahulu was also thought to be correlated with feral pig activity. This exotic species was reported to be much more common between 2,000 and 3,000 feet than it was in 1967. Spatz and Mueller-Dombois (1975) reported that the increase of introduced species in pig-disturbed areas was substantial. Their studies showed that in grassland communities on Mauna Loa, Hawai'i, pig digging greatly increases the numbers of exotic species in communities with a former high percentage of native species. Ongoing exclosure studies by Jacobi (1976) have not only shown the invasion of weedy exotic

species in pig-disturbed areas, but also that certain exotics outcompete the endemics at least initially. On Hawai'i, Warshauer (1976) reported that pigs are responsible for the dispersal of seeds of *Psidium*, *Rubus*, and *Passiflora* all of which are noxious weeds. Though pigs have often been implicated as a dispersing agent of weedy species, more data needs to be assembled to substantiate the role pigs play in the spread of exotic species.

Direct reduction of individual plant populations by pigs

European workers have identified over 95 plant genera as hog foods. Bratton (1974*a*) observed that the decline in abundance of certain species of wild flowers in the Great Smoky Mountains National Park was due to their direct consumption by pigs. In Hawai'i, several people have noted that *Cibotium* starch comprised over 90% of the stomach contents of pigs in the 'Ōla'a Tract of Hawaii Volcanoes National Park. Selective predation on young *Cibotium* plants not only reduces the individual population, but also disrupts and fragments the frond canopy, favoring the establishment of exotics. In the Manawainui area on the island of Maui, Gon (1976) recorded the following native plants in the diets of pigs: *Marattia douglasii*, *Pteridium aquilinum*, *Cibotium splendens*, *Styphelia tameiameiae*, *Pteris excelsa*, *Athyrium* sp., and *Osteomeles anthyllidifolia*. The sparsity of many species of the Lobeliaceae family in pig-disturbed areas was noted by Warner (1967) and Becking (1970).

Reduction of individual plant populations in Kīpahulu Valley is probably a function of time and density of pigs per unit area.

Effects of pig damage on native birds

Giffin (unpub. data) did not find bird remains in any stomach contents examined. On the other hand, the scarcity of Lobeliaceae, probably due to pigs (Warner 1967), has also reduced this food source for many endemic birds in the valley. Pig wallows become breeding grounds for *Culex pipiens fatigens* (Baker 1977), suspected vectors for bird-pox, malaria, and other avifaunal diseases (Warner 1967; Haleakala National Park 1976). The decrease in drepaniids may therefore be indirectly due in some part to pigs.

Soil erosion

Rooting activity by pigs clears the forest floor of organic leaf litter and mixes up humus with the lower layers. Pig-ploughed areas may range from a square meter to several hundred square meters (Jacobi and Warshauer, unpub.). Lamoureux and Stemmermann (1976) noted dozens of such open areas, adding that the "entire ridge top from Basecamp 1 to Palikea has been transformed into an enormous pig wallow." Such exposed areas are constantly subjected to soil compaction, increased leaching, and sheet erosion. Kinzie and Ford (1977) reported that the increase in erosional sediments in Palikea Stream was thought to be the

result of pig disturbance on ground cover along the ridgetop bordering the stream.

Degeneration of forest

Observational records by various people tend to indicate that the near pristine rainforest in Kīpahulu Valley is being degraded by past and present pig activities. Pigs rooting for worms not only expose churned-up soil for invasion by exotics, but also directly disrupt decay and nutrient recycling. Pigs feeding on soil invertebrates like earthworms and larvae (which are their major food items in places like the Great Smoky Mountains National Park [Bratton, personal communication]) would inevitably disrupt the cycle of the breakdown of organic matter and its decomposition. In Hawai'i, hydrandept soils cannot be reversibly dehydrated (USDA Soil Conservation Service, 1972). The long term effects of pig digging on soil formation, dynamics, vegetational succession, and forest degradation have not been studied. The hapu'u (*Cibotium*), 'ōhi'a, and koa forests are being degraded with constant disturbance and damage to roots and seedlings. The forest cover is ultimately severely affected, and increased light penetration favors establishment of weedy species. Becking (1970) pointed out that regeneration of a koa and 'ōhi'a forest in pig-disturbed areas is extremely slow.

The National Park Service is keenly aware of the magnitude and severity of these pig management problems.

Efforts to preserve Kīpahula Valley as a truly natural pristine ecosystem probably will be difficult and perhaps futile if the pig problems are not fully evaluated.

In conclusion, it is very probable that if the National Park was to fail to implement some form of pig control program in the near future, several organizations and many people would soon become active in pushing for action. Such pressure should be resisted until a research program has been initiated. We have no information on the real impact of feral pigs or the most effective control methods in rainforest situations. Without this information good intentions could have a greater negative impact than the pigs.

PART 1. THE BIOLOGY OF THE FERAL PIG IN KĪPAHULU

INTRODUCTION

The feral pig, *Sus scrofa*, is today regarded as well established in the Hawaiian Islands. This destructive, non-native animal is highly adaptable in the rainforest ecosystems. It is presently distributed on six of the eight major islands in Hawai'i (Tomich 1969). Its absence on Lana'i and Kaho'olawe is probably due to the lack of a suitable forest habitat. Although the early Polynesians brought pigs with them to the islands as a food source, there is no recorded date of their introduction to Hawai'i. These pigs were of Asiatic origin and probably came from Tahiti (Titcomb, personal communication) less than 1,500 years ago. Cook ([1778] 1932) described these quadrupeds as "a small species of hogs, with long heads and small erect ears" and noted that they occurred in the mountains. Early pig introductions were highly successful and the animal was already well established and widespread when Cook arrived.

The landing of domesticated English pigs--a boar and a sow--on Ni'ihau by Cook in 1778 was the first of the many importations which followed. Some of the pigs escaped into the forest and became feral; others were deliberately released to improve the meat quality of the feral population. Crossbreeding between the original, small Hawaiian *Sus scrofa* and the larger, domestic breeds produced progenies

which today populate the forests on the Hawaiian Islands. Post-Cook feral pigs are therefore of various sizes and colors ranging from black through red to white (Kramer 1973). The feral pigs in Hawai'i are similar to those in Tennessee and Northern California where the present population has arisen from the interbreeding of the European wild boar *Sus scrofa* and domestic breeds. The proportion of the original Hawaiian pigs in the forest remains uncertain.

PAST AND ONGOING PIG RESEARCH IN THE UNITED STATES

In writing this research plan, past research on pigs on a global scale has been reviewed only to a limited extent. This was done to evaluate some of the techniques that had been used to research this animal in the very varied habitats in which it occurs. Though, extensive work has been done in Europe, Russia, New Zealand, this review has concentrated on research in the United States because

1. the pigs being studied in Hawai'i are similar in many respects to feral pigs in the continental U.S.
2. the research techniques and chemicals that would be considered for the control of pigs are readily available in the U.S.
3. much of the literature published in foreign journals is not immediately available.

A chronological list of past and ongoing pig research in the continental United States is shown in Table 1. The vast amount of well-documented resource materials and

TABLE 1. Feral pig research in the continental U.S.

Year	Investigator	Area of Feral Pig Research
1938	Stegerman, L.C.	distribution and natural history
1958	Hanson, R.P., and L. Karstad	distribution and natural history
1962	Matschke, G.H.	trapping methods
1963	Matschke, G.H.	eye lens nutrition studies
1965	Lewis, J.C.	behavior
	Matschke, G.H.	predation on ground nesting birds
1966	Henry, V.G.	reproductive biology
	McFee, A.F., M.W. Banner, and J.M. Rary	chromosome variation
1967	Matschke, G.H.	aging by dentition
	Matschke, G.H., and J.P. Hardister	movement of transplanted boars
	Matschke, G.H.	influence of oak mast on reproduction
1968	Rary, J.M., V.G. Henry, G.M. Matschke, and R.L. Murphy	cytogenetics
	Henry, V.G.	oestrous cycle and gestation
	Henry, V.G.	fetal development
	Henry, V.G., and G.H. Matschke	immobilization techniques
1969	Matschke, G.H., and V.G. Henry	immobilization with Cap-Chur-Barb
	Henry, V.G.	estimating whole weights

TABLE 1. (continued.)

Year	Investigator	Area of Feral Pig Research
1969	Henry, V.G.	predation on ground-nesting birds
	Pine, D., and G. Gerdes	general biology
1970	Barrett, R.H.	management on private lands
	Henry, V.G.	weights and body measurements
1971	Barrett, R.H.	ecology
1972	Henry, V.G., and R.H. Conley	fall foods
	Belden, R.C.	rooting and wallowing
	Fox, J.R.	control techniques
	Kurz, J.C., and R.L. Marchinton	movements; radiotelemetric studies
1974	Scott, C.D.	seasonal food habits
	Bratton, S.P.	ecological approach to management
	Bratton, S.P.	effects on high elevation vernal flora
1975	Bratton, S.P.	effects on gray beech forest
	Hensen, T.M.	age determination and age structure
	Scott, C.D., and M.R. Pelton	seasonal food habits
1976	Williamson, M.J., and M.R. Pelton	hematological parameters
	Frankenberger, W.B., and R.C. Belden	distribution, abundance, and management
	Wood, G.W., and T.E. Lynn, Jr.	distribution and population studies

TABLE 1. (continued.)

Year	Investigator	Area of Feral Pig Research
1976	Wood, G.W., E.E. Johnson, and R.E. Brenneman	immobilization with succinylcholine chloride
	Wood, G.W.	brucellosis
1977	Frankenberger, R.C., W.B. Frankenberger	management
	Brisbin, I.L., Jr. et al.	morphological characterizations
	Brisbin, I.L., M.W. Smith, and M.H. Smith	ecology, contaminant cycling and distribution; problem goals
	Wood, G.W.	ongoing: ecology and radiotelemetric studies
	Belden, R.C.	ongoing: farrowing peaks and radiotelemetric studies
	Singer, F.J.	ongoing: ecology and radiotelemetric studies
	Conley, R.H.	ongoing: radiotelemetric studies
	Brisbin, I.L.	ongoing: population genetics, ecology, and radiotelemetric studies

techniques available, and the accelerated tempo of some of the ongoing research projects should demonstrate the feasibility of a pig research program in Kīpahulu.

In Hawai'i, little research has been conducted on the feral pigs in rainforest habitats. The animal is still the most abundant and hunted game mammal though goats are also frequently hunted (DLNR, unpublished information). It was not surprising, therefore, for naturalists to record lurid accounts of the hunters and the rigors of pig hunting (Towers 1926, Vitousek 1941, Tillet 1957). Bryan (1957) reviewed the history and status of the pigs in Hawai'i. It was not until 1961 that the State of Hawai'i, Division of Fish and Game, initiated a study on feral pigs. Nichols (1963) researched the reproductive biology and movements of pigs on Hawai'i from 1961 to 1964. His work was done in mountain pasture habitats during a period of extreme drought conditions. Giffin (1968) continued the research when Nichols left the employ of the Division of Fish and Game. Giffin's unpublished work, "The Feral Pig on the Island of Hawaii," is the most up-to-date piece of information on population studies, behavior, and disease-carrying aspects of feral pigs. Although he did sample pigs from low to high elevations, the habitats he studied were fairly "open" and deliberately selected to be close to the road. Hence, the work by these two researchers may not be representative of dense, relatively undisturbed forests like that in Kīpahulu Valley.

RESEARCH ON CONTROL METHODS

Trapping

This is an effective method in decimating pig populations in some situations (Diong 1973). However, in the Great Smoky Mountains National Park, for example, trapping success for pigs is rather low because of the difficulty of designing a pig-specific trap; other land mammals such as raccoons, bears, and deer often being found in such traps. There is no such problem in Kīpahulu. Trapping success, however, would depend more on the trappers' familiarity with the movements of pigs and trap design than on the baits used. Admittedly corral-type traps, especially those designed for multiple captures, could disturb small areas of the forest floor vegetation. Much common sense is therefore needed for trap placement.

Problems for effective pig trapping do exist in a subtropical rainforest. Most of them are associated with maintaining the structure so that it does not rot, assuming wood is used in its construction. Corral-type traps also have to be firmly placed to prevent the pigs digging out under the trap in the soft soil. Logistic problems also exist when traps are being constructed or moved in the forest ecosystem. These problems are not insurmountable but the cost-effectiveness of all the facets of a trapping program must be fully evaluated. Indeed, Fox (personal communication) feels that trapping is not effective as a

short-term measure in reducing pig numbers in localized areas where they are plentiful.

The possibility of constructing a self-maintaining pig trap (one in which a pig is trapped, dies and attracts other pigs) will be researched. However, before any practical work is begun, legalities may have to be reviewed by a government lawyer to ensure that no regulation is being violated. Even if there is no legal problem, the ethics of such a program would have to be discussed with Park officials and the general public so that no adverse reaction would be engendered which may have a dampening effect on other feral pig control programs.

Shooting

This is a good short-term measure to remove pigs constantly harassing or frequenting a relatively open area. The cost-effectiveness of this program is low. However, the feasibility of shooting pigs in a rainforest has never been realistically evaluated. Most local hunters use dogs in such situations to track down the pig and hold it at bay until the hunter can arrive and make the kill. People and dogs trekking through the area generally result in environmental damage. Gun shots may also disturb birdlife to an unacceptable level (Federal law prohibits the use of silencers on rifles). Long-term control measures with shooting alone would probably be too expensive and impractical

in the rainforest because of poor visibility and rugged terrain. However, it may be the most effective method to reduce the population rapidly before implementing other control measures.

Once the population levels are known within the valley the time spent looking for and shooting pigs can be correlated with the population density, forest type, the type of terrain, movements, etc., to produce realistic figures on cost effectiveness, man-hours needed to kill one pig under various conditions, etc. It is assumed that the Park Service would use this information to justify various control programs.

Poisoning and the use of chemicals

Poisoning is probably the most effective control measure but it is fraught with potential political and environmental problems. It would be very difficult to develop a mammal-specific poison or bait. Poisoning is a potentially powerful resource management technique that will require much research because of the potential environmental hazard. Non-specific poisons might enter the food chain of ground-living biota, birds, and even the stream biota. According to the U. S. Presidential Executive Order 11917 of May 28, 1976, the "use of sodium cyanide is prohibited in (1) areas where endangered or threatened animal species might be adversely affected; (2) areas of the National Park System;..." However, feral pigs have been

drastically reduced in certain areas with a control program based on poisoning with sodium monofluoroacetate (1080) so a poisoning program may be extremely attractive to resource managers. Though quite extensively used, this technique has not been approved for federal agencies. However, poisoning *per se* is not the only method of reducing the number of pigs. Animals could be immobilized with drugged food after being baited to feed in a particular area.

This approach has several advantages over trapping.

1. It does not require cumbersome equipment in the rainforest.
2. The animals are not killed outright, maimed, or starved to death.
3. They could be transferred elsewhere.

However, a disadvantage is that during the period between ingestion and immobilization the animals could wander away from the treatment site.

Baker (personal communication) has indicated that locally pigs are readily attracted to coconut. The initial year's experimentation will test the use of coconut and other food sources as baits. When suitable baits have been found experimentation with immobilizing substances will be carried out. On completion of the population studies in Kīpahulu, the above experiments will be transferred to the valley to test their effectiveness in various densities of the pig population. Again, the idea is to provide the

resource managers with reliable estimates of effectiveness and the suitability of this technique under different densities of pig activity. The translation of this information into budget estimates is outside the scope or competence of this research proposal.

Hunting with dogs

This is one of the most successful local methods of control in small areas, but could be expensive in terms of time and manpower (Barrett 1970, 1971). Hunters have been very reluctant to operate in areas where the terrain is difficult or where they may lose their dogs. However, hunter-caused impacts upon the fragile ecosystem would be undesirable. Also, dogs lost during expeditions could have a serious negative impact on the nēnē population.

The suggestion that the lower portion of the valley be hunted is not recommended because the pigs would probably move higher up the valley to escape the hunters (Lamoureux and Stemmermann, 1976). This movement would subject previously unimpacted areas to pig activity.

Chemical sterilants

This option has potential but considerably more research is needed. Sterilants have so far worked "well" only on controlled populations of mammals but not free ranging animals.

The effectiveness of chemical sterilants in field situations will be reviewed since this approach is ostensibly a very humane way of dealing with the problem. However, the impact of these chemicals on all life-forms would need to be assessed because the substances could be released into the streams and ground-water systems in the Valley. Since the State of Hawaii still retains certain water rights within the valley, the impact of such a control program on their rights would also have to be evaluated.

Fencing

A fencing program to isolate the valley, once the pigs have been removed or reduced, in order to prevent a re-invasion of the cleared area may be feasible. This approach would be most cost effective if a few critical access points are discovered. To fence off the whole valley would be excessively expensive both in material and labor as much of the terrain is difficult to extremely difficult to maneuver in because of the density of the vegetation and the water-logged condition of the soil.

A cost analysis of a fencing program is outside the scope of this research proposal. However, the strategic areas for fencing and the quantity and types of terrain that would be covered by a fence could be assessed.

"No action" alternative

The "no action" approach by Park management would only, for reasons already mentioned, encourage further damage and degradation to the forest. It is quite plausible to project that ineffective management or the "no action" alternative would eventually alter species composition and drastically reduce both the numbers and species diversity of the native biota in the valley. Studies in Europe, for example, have shown that the rooting activity of pigs over hundreds of years actually altered the species composition and dominance in many European forests in favor of beech (Bjerke 1957, cited Bratton 1974*b*). In the continental U.S., there are already noticeable signs of changes in species composition with an increase in beech root sprouts on pig-disturbed areas in the high elevations of the Great Smoky Mountains (Bratton 1974*a*).

Additional knowledge of recent historical trends would also be obtained, where possible, by personal interviews with local residents. However, some of this information may be more easily obtained by local residents who are also NPS employees since there is a considerable reluctance among many local people to respond to researchers.

RESOURCE MANAGEMENT QUESTIONS

Three resource management questions have to be answered.

1. Should the pigs be controlled?
2. If yes, can they be controlled?
3. If yes, how can they be controlled?
4. What is the best method(s), and why?

The first question appears to have been answered by many people, e.g. Becking 1970; Lamoureux and Stemmermann 1976. However, within the local community there is a sizable lobby of hunters who may demand factual evidence of the damage done by pigs. Several questions that are as yet unanswered are

a. Are the pigs solely responsible for the damage in Kīpahulu Valley?
b. Is the damage significant or will the pig population become stabilized within the valley and have minimal impact in years to come?
c. Will the pigs move higher up the valley and damage other areas, as yet undisturbed?
d. Why is the pig damage only a problem within the last decade?

If the answer to the first resource management question has not been predetermined by the resources managers and administrators of Haleakala National Park from previous reports, it is important to realize that the scientific evidence establishing this assumption factually will only be available at the end of the three year research program. The objective determination of sole responsibility and the

significance of pig damage has yet to be made, particularly in a rainforest ecosystem. *An outcome of the research proposed in this program would be an objective assessment of the impact of feral pigs in a rainforest ecosystem.*

The above statement is somewhat moot because all the subjective assessments of feral pig activity in Hawaiian rainforests are that pigs do considerable, and frequently irreparable, damage. However, the objective assessment is the one that would carry the most weight in any tribunal. It is also the only way that items 4 and 5 of the HALE Project Number N-6 can be answered.

An answer to the second resource management question (Can the pigs be controlled?) should be available approximately one year after the population studies are begun. At this time a working draft-map of the pig population and their movements would be available as well as an assessment of the extent of pig activity within the valley (HALE N-6. Items 1 & 2). Critical questions are

1. Are the pigs moving into and out of the valley laterally?
2. Are they moving up and/or down the valley to and from the *Deschampsia* grasslands and the Hāna Rainforest?
3. What is the normal life-span of a pig in the valley?
4. What is the reproductive rate of these pigs?

5. How many litters and how many piglets per litter survive on an annual basis?

With answers to these questions it should be possible to decide whether or not the pigs can be controlled. At the same time, it should be possible to evaluate and test various methods of controlling these animals. If it is determined that control is not feasible the National Park Service may need to review the entire research proposal in terms of redefining program objectives.

As mentioned earlier each method of pig control has its problems. Though it will probably not be possible to totally eliminate feral pigs from Kīpahulu Valley, a mixture of control techniques could be devised that would keep the population sufficiently low enough to have a minimal impact in the area.

The control techniques are critically dependent on information of the reproductive biology of the pig in Kīpahulu Valley (HALE N-6 Item 6). For example, a strategic fencing program would be useless if the pigs were allowed to reproduce for long periods within the valley proper. On the other hand, a culling program which took place after every other cycle of reproduction would be much less successful and probably more expensive than if the culling was carried out after every cycle.

Which control techniques should be used can only be guessed at this point. Apart from the purely scientific

aspects of this question, political, humanitarian and economic problems must also be considered. The final program, if any, would have to be decided upon by the NPS administration.

PROPOSED RESEARCH METHODOLOGY

The impact of feral pigs on Hawaiian ecosystems is detrimental and the management problems have been discussed. This applied research is directed towards collecting data for the pig control program in Kīpahulu Valley.

Preliminary Investigation of Control Methods

Year 1.

A major part of this developmental work would be carried out at Haleakala National Park on Kaumakani Ridge and in the Hāna Rain Forest. The object of this developmental study would be to experiment, modify, and develop suitable techniques for the research proper in Kīpahulu Valley beginning January 1978. Kaumakani Ridge would be the initial site where resources management techniques would be studied. As they are perfected they will be transferred to the Hana Rain Forest for field testing in rainforest conditions. In this way the resources management techniques can be developed without interfering with the population dynamic studies in Kīpahulu.

The following procedures would be carried out during the developmental period:

1. Baiting
   a. with food.
   b. urine, chemical attractant
   c. sound recordings of grunting, squealing; audial stimuli as attractant
2. Immobilization

   The following chemicals* would be used:
   a. Cap-Chur-Barb (pentobarbitol-scopolamine)
   b. M99 Etorphine and M 50-50 Diprenorphine
   c. Succinylcholine chloride and phenyclidine hydrochloride.
3. Trapping

   with box traps, and "arena" corral-type, swing-door traps
4. Instrumentation techniques with transmitters, radiotelemetric equipment, etc.
5. Shooting. Records would be kept of shooting programs in the various ecosystems.
6. Snaring. The feasibility of snaring pigs will be evaluated.

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*These chemicals may need official clearance and a permit for use from the Department of Interior.

Field research proper--Movement-ethnology, home range, activity, and distribution:
January 1978 through December 1979.

Past records on pig movements in the valley seem to suggest that there is both a shift in pig activity as well as an extension of range. Hjort (1945) noted that pig tracks were not seen below 4,500 ft. The 1967 Expedition noted the occurrence of pigs throughout the valley. Vaughan (1970) observed that pig trails, dens, and rooting areas were common up to 4,000 ft, but were infrequent from 4,000 to 5,000 ft. Recently, Lamoureux and Stemmermann (1976) and Kinzie and Ford (1977) have independently reported a considerable increase in pig activity in the lower portions of the valley. Reconnaissance studies made earlier this year seem to support this observation. The disparity in the observations may be due to different observers with different backgrounds.

To date, over ten species of American mammals have been studied with radiotelemetry. Kurz and Marchinton (1972) were the first people to study pig movements using radiotelemetry. Since then, radio tagging has been extensively used to study feral pigs in South Carolina and more recently in Florida, West Virginia, Denver, and Tennessee (Singer, personal communication). Radio telemetry is the preferred method for this area because of the limited visibility and the necessity to leave the area as undisturbed as possible.

Two fixed receiving locations would be established, one on Koukouai Ridge and another on Palikea Ridge. These sites presently appear to be the best areas for radio monitoring. Other areas on Kaumakani Ridge will continue to be investigated but no suitable sites in this area have been located.

A total of 30 pigs, from the lower, middle, and upper valley, would be collared with transmitters each with a different frequency. Pig movement would be monitored over 12 months. Direct tracking using a portable antenna would also be attempted. With the two fixed points, the movements of pigs relative to them could be used to determine the exact location of all collared specimens. Radio-location and tracking methods suggested by Cochran (1967) would be tested and used. Computer programs prepared by Siniff and Tester (1955) and Tester and Siniff (1965) would be used to analyze all radio-tracked pigs. This study aims to produce maps on the home range in relation to the center of activity, activity radius, movement patterns in general, and points of entry or exit in the valley. Such a study would determine if the valley is a "migration sink" for pigs from adjacent forest reserves. Location of entry or exit points, if any, in the valley would be of strategic significance for developing pig control measures in the valley. Studies on the home range and its associated parameters would provide useful data on habitat use and

predictability on the presence of the animal in the forests.

Transplantation of pigs outside their "home range" would also be done. If successful, the movements of transplanted pigs would provide useful information on homing instinct as well as their ability to establish a new home range. This might help predict their general movement patterns and their behavior when their home range is constantly harassed or disturbed by hunters, dogs, trappers, or Park employees, and/or if public opposition demanded live trapping and transfer of captured pigs.

Population estimate and modelling

Both direct and indirect methods would be used to estimate the number of pigs in the valley. Telemetric studies on their movements would reveal the nature of such movements as well as whether the population is closed or open. These results will then help to determine which of the following censusing methods would be most effective: King strip census, flushing/drive counts, Lincoln index, territory mapping method, track counts, and/or multiple recapture.

Census data would provide information on the reproductive potential of the pigs. The data would be used to construct population models for prediction of population growth under different situations.

Habitat relations

The pigs would be distributed as little as possible during the entire period of radio-tracking. However, the following field work would be done:

1. Continuous recording of climatological data--precipitation, temperature, cloud cover, light penetration, lunar cycle, and humidity.
2. Studies and measurements of wallows and rooted areas at different elevations.
3. Phenology of plants significant in the biology of the pig--continuously recording biological phenomenon such as flowering and fruiting. Phenological records and multi-variate analyses of other environmental factors such as precipitation, relative humidity, temperature, etc., would be used to determine the pig movement, and reproduction.

Resource utilization and feeding behavior

Whole stomachs would be collected, food items examined macro- and microscopically, and quantitative proportions of various food items determined. Records of freshly damaged vegetation around wallows and pig-rooted areas would be made.

Racial compositions

The phenotype of all pigs shot or immobilized at different elevations would be evaluated. In addition, hair, tissue and blood samples would be collected for

serological testing, electrophoretic studies, and chromosome count.

General

Ectoparasites as well as defecated and undefecated feces would also be collected from all pigs examined. Fecal analysis together with stomach contents analysis would provide useful data on types and proportions of undigested and undamaged ingesta which leave the pig, to help determine the role pigs play in dispersing exotics.

PART 2. THE IMPACT OF THE FERAL PIG ON THE KĪPAHULU ECOSYSTEM

It is proposed that while the mammalian biologist is studying the biology of the feral pigs in Kīpahulu Valley, that a plant biologist accompany him with four specific objectives in mind:

1. to assist the mammalogist in the identification of plants which the pig has ingested or damaged in some other way (e.g. uprooted, debarked, etc.);
2. to establish a number of exclosures within the Valley in order to follow the recovery of the vegetation after the impact of feral pigs has been removed;
3. to study the distribution and biology of weeds, in particular *Psidium cattleianum*, the strawberry guava; and
4. to analyze the impact of pig disturbance on the various plant communities within the Valley.

All four objectives are directly pertinent to HALE N-6 Items 3 & 4.

Objective 1--Plant identification

Analysis of feces and stomach contents are part of the proposed activity of the mammalian biologist. It is particularly important that the diet of the pigs in the Kīpahulu Valley ecosystem be reliably identified. Such

diets will probably include seeds and vegetable matter. A competent botanist will assist in the analysis of fecal and stomach contents in a manner that will minimize the mammalian biologist's involvement in this activity.

As will be identified in Objective 3, it will also be necessary to grow seeds and other material collected from fecal material. The identification of seedlings from propagules is a subject that requires a certain expertise. A botanist would be more suitably trained in such matters which would reduce the mammalian biologist's participation in that activity and allow him to be more profitably concerned in other matters.

Objective 2--The establishment of exclosures and the study of their consequent revegetation

At least three 10 by 100 meter exclosures at approximately 3,000 feet elevation would be constructed within the study area.

1. Open 'ōhi'a-'ōlapa (*Metrosideros-Cheirodendron*) forest with scattered *Acacia koa* and ground fern.
2. Mixed *Acacia koa* forest.
3. Koa-hapu'u (*Acacia-Cibotium*) forest with 'ie'ie (*Freycinetia*) liana and scattered 'ōhi'a and 'ōlapa.

This elevation is presently the most heavily impacted area in Kīpahulu Valley. A fourth exclosure at a higher

elevation in an 'ōhi'a forest should be established if a suitably disturbed and readily accessible site can be found.

The objective of this particular study would be to quantitatively document the changes in the vegetation of these exclosures after feral pig activity within the exclosure had been removed. The samplings would probably have to be carried out at very frequent intervals initially, perhaps every month. It is anticipated that in this region, the weeds in particular would revegetate the area within a very short period of time. The quantitative information on the lower strata would be gathered using the point-frequency technique. The upper story of vegetation would be sampled separately from the ground flora, using a modified point-frequency technique.

It is anticipated that within three years the trend of vegetation recovery would be evident. However, this does not mean that the area should not be monitored in subsequent years at annual or biennial intervals.

Apart from quantitative data, photographic records of the area would be kept as well, to document the revegetation of the exclosures.

Objective 3--The weed problem

Concern was expressed in the 1976 Kīpahulu Valley Expedition Report (Lamoureux and Stemmermann 1976) about the apparent distribution of the strawberry guava and other weeds within the Valley. It was stated that since 1967 the

strawberry guava had increased in numbers and had also become established higher up the Valley. This segment of the proposal would deal specifically with the strawberry guava problem.

The following information would be obtained:

1. the distribution of the guava and other weeds within the Valley,
2. the age-class structure of the guava populations at various altitudes within the Valley,
3. the reproductive strategy of the guava and other weeds in various parts of the Valley, and
4. the role of pigs in the dissemination and establishment of guava and other weeds.

It is important to know whether or not weed seeds pass through the pig digestive tract intact. If so, is their germination promoted by passage through the pig tract? Some simple experiments culturing pig feces and recording the growth of seedlings from the feces should suffice. Quantitative results could be obtained later if the preliminary experiments indicate that this mode of dissemination is effective.

Distribution map of guava and other weeds

The distribution of weeds within Kīpahulu Valley needs to be mapped for later possible correlation with pig activity. The map would also serve as a basis for resource managers, who may need to know the extent of the guava and

other weed infestations in order to implement an eradication program, if needed.

The method of analysis of distribution would be by following contour lines, perhaps at 400-500 foot intervals, and recording the presence or absence of guava, for example, at regular intervals along the contour lines using a modified Braun-Blanquet system. At the same time, the reproductive strategy of the weeds in various parts of the Valley could be evaluated. That is, the reproductive status of the trees at every given site would be recorded in terms of the number of seedlings, how many of them were flowering, whether they were fruiting, whether there were ripe fruits on the ground, and whether there was evidence of the pigs feeding on the fallen fruit. This information would be used to establish priorities for management action. Reproducing populations should receive immediate attention, non-reproducing populations could be left till later.

The map which would be produced would have semi-quantitative information of the weed distribution. This map could then be used as a basis for choosing two or three transects in the Valley which would be sampled quantitatively at specific intervals to measure the population structure of guava and other weeds in various areas of the Valley. This information is necessary because it will give some idea as to the success of establishment of the weeds in the various areas of the Valley--coupled with the information on

the reproductive status in the various areas, it should be possible to predict whether or not these weeds will pose a continuing threat to the Valley, and therefore need immediate management activity, or whether there is little threat of reproduction and further spread above specific elevations.

Finally, it must be clearly established that in fact the pig is or is not responsible for the spread of the guava or other weeds, either actively (via the digestive tract) or passively (establishment in wallows). The correlation of the distribution of weeds and pig activity will be a useful key in this respect. Coupled with studies on the germination of seeds from pig feces, the pig as the primary agent for the introduction and dissemination of weeds into the Valley could be evaluated. Were there a positive correlation between weeds and feral pig activity, it would be a substantive reason for implementing a pig management program.

This information should be available within one year of the implementation of the contract.

Objective 4--The impact of pigs in different plant communities

The impact of pig activity on different vegetation types will be evaluated as far as possible. It is hoped that it will be possible to ascertain whether or not the impact is the consequence of:

1. differences in the substratum, e.g., marshy ground compared with areas with good drainage;
2. continuous trampling in areas where favored foods grow;
3. preferred areas for wallowing, sleeping, etc.;
4. certain vegetation types being more fragile than others.

TIMETABLE OF REPORTING

At the conclusion of the first year, the distribution, reproductive status and population structure of the various weeds, and the visability of weed seeds under various circumstances--but particularly after passage through the gut of the pig--should be completed and available as a technical report.

At the conclusion of the second year, information should be available on specific plants damaged by the feral pigs and the mode of damage inflicted by the pigs--for example, whether the damage is conducted on a non-specific basis by general rooting activities or whether in actual fact specific plants are chosen as part of the diet. At this time, an interim technical report should also be available which will show the pattern of regeneration within the exclosures up to and including the 18-month study period.

Finally, after three years, a comprehensive review of the impact of pigs on both native and introduced plants would be available. Those species which would be discussed

would be those which were significantly affected, i.e., those depleted or promoted in number and/or vigor. At this time, an assessment would be made of the impact of feral pig activity on the various plant communities within Kīpahulu Valley and the specific effect of pig activity on individual species.

ENVIRONMENTAL IMPACT OF THIS RESEARCH PROPOSAL

There is no doubt that the activity of the research workers will have an impact on the valley ecosystem. However, every effort has been and will continue to be made to minimize the impact and several features have been built into the proposal to this end. In particular the experimentation with management techniques will be conducted in areas adjacent to the valley until their operation in rainforest conditions is perfected. The use of radioinstrumentation for tracking the pigs and monitoring their activity allows for this work to be carried out without any further entry into the area after the pigs are collared. The methodology for the analysis of the weed problem will provide the maximum information with a minimum amount of activity in the area.

However, in order that the necessary information can be gathered the researchers will have to work in the valley, perhaps entering a number of areas previously untouched. The most severe impact will be produced from trapping activities. The traps will have to be brought into the area and set up both of which may require that trees be felled. It may well be that the National Park Service will restrict trapping research to either the Kaumakani Ridge, and perhaps the Hana Rain Forest, so that the anticipated associated activities are not inflicted on the valley ecosystem. Trapping would then be a technique which would be used as a last resort by the resource managers after all other systems failed.

This proposal assumes that the National Park Service would allow the temporary construction of barbed-wire exclosures and base camp in the valley. These could be removed later after the research program was completed.

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