THE FERAL PIG IN HAWAII VOLCANOES NATIONAL PARK

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Abstract. The non-native feral pig in Hawaii and the Hawaii Volcanoes National Park is a major disruptive component of native rain forest and grassland habitats. The exotic pig was first introduced to Hawaii by early Polynesians more than 1,200 years ago.

European breeds of pigs were introduced to Hawaii in 1778 by Captain James Cook and during the nearly 200 years since that time, a large number of pigs of a wide variety of domesticated breeds have been brought to the islands.

The pig is an omnivore and a scavenger. In the rain forest and grassland communities of the park, it feeds on vegetation, insects, earthworms, ground nesting birds, eggs and rodents. It commonly scavenges on remains of dead cattle, goats and other pigs. In the rain forest, its chief diet is the starchy interior pulp of the tree fern.

The pig's habits of hollowing out interiors of tree ferns and making mud wallows creates micro-aquatic habitats for mosquitoes, other insects and various small crustacea. Because pigs create mosquito habitat in areas where these insects would not normally occur, the pig through spread of mosquito borne avian malaria and birdpox is an indirect threat to the extinction of native birds.

By the making of trails, mud wallows, mosquito habitat, and by its rooting activities, tusking of tree trunks and by its role in spreading weedy, non-native plant species, the exotic pig in Hawaii is also endangering native forest and grassland communities.

The arrival time of pigs (Sus sp.) in the Hawaiian Islands is unknown. It is believed, however, pigs probably arrived with the earliest migrations of Polynesian man in Hawaii about 1,200 years ago on voyages from the Society and Marquesas Islands. Polynesian peoples carried pigs, dogs and jungle fowl on exploratory voyages looking for new lands to settle. Pigs were domesticated and distributed by island people throughout all of the Pacific in Polynesia, Melanesia, Micronesia and Indonesia. The sources of the Pacific distributions of pigs were Eurasian wild boars, Sus scrofa, which inhabited Africa, Europe and Asia.

CAL-NEVA WILDLIFE TRANSACTIONS 1975

Domesticated pigs throughout the Pacific area served as important items of food as well as having important religious and other cultural significances. In the ancient Hawaiian taboo system pork could be eaten only by men and ownership of pigs and other valuables belonged only to chiefs. Populations of wild pigs throughout the Pacific were important sources of food for European explorers and settlers where pigs and goats were the only game meat available.

By the time the first Europeans arrived in Hawaii in 1778 under Captain James Cook, Polynesian pigs were widely distributed through all the major islands of the archipelago. Cook (1785) noted that pigs were common about the villages. He observed they were small in size, black in color and weighing about 50 to 60 pounds.

Cook introduced the first domesticated varieties of European pigs to Hawaii and in the nearly 200 years since large number of domesticated pigs have been introduced to upgrade the quality of pork raised in Hawaii. Boars of larger breeds were purposefully released into the wild to increase overall size of the much smaller Polynesian pigs (Judd, 1936; Tomich, 1969). From these releases, and from other domesticated pigs which escaped into the wild, such mixtures of European/Polynesian stock have occurred that the Polynesian pig in Hawaii is no longer recognizeable.

There can be little doubt--knowing the nature of pigs--that not long after the first introductions by Polynesian man some 1,200 years ago populations of feral pigs became established in the wild. Ellis (1917) observed in 1823 that Hawaiian people possessed small pigs which were sometimes found in the mountains. Today, it is well known that wild populations of feral pigs are distributed through forested areas of the six larger islands. Their greatest density is on the island of Hawaii and are abundant in the rain forest habitats of the Hawaii Volcanoes National Park.

On the island of Hawaii the feral pig, along with the feral goat and sheep, is a major game animal of economic importance to hunters. Pigs are hunted and trapped by many as sources of meat for the table. Despite the popularity of the pig as a game animal, however, free roaming wild pigs are considered pests in grassland, crop, forest and watershed areas. Their damages can be extensive through excessive rooting, the making of trails and wallows, and from inadvertent spread of weedy plants that follow in the wake of pig activities.

Along with other introduced predatory animals such as the domestic cat and dog, pigs are suspect in large part for extinction of native flightless birds and other ground nesting species. Moreover, the pig is presently a suspect in the spread of epizootic diseases among rare and endangered birds, by creation of mosquito habitats and a threat to localized, limited populations of certain rare plants. The pig is also a suspect in the spread of root rot fungi which may be a primary cause for the widespread loss of many native trees.

Within the boundaries of Hawaii Volcanoes, pigs are distributed from sea level to 7,000 feet on the slopes of Mauna Loa, the upper limits of suitable cover and feeding habitat. Throughout this altitudinal distribution, pigs are adaptable to various terrains affording sufficient food and cover. A preferred habitat in the middle elevations, is the rain forest because of an abundance of fern food, moisture, and dense understory cover.

At elevations above the rain forest, pigs utilize mountain parkland forests and grassland-savannahs, but pigs found in open grassy areas are generally not far from nearby tree cover.

In the rain forest the diet of pigs is principally hapu, or tree fern (Cibotium sp.). Analyses of stomach contents show hapu may be the only food

present, but on an average, hapu and other species of ferns comprise about 80 to 85 percent of the diet. Pigs feed upon all age classes of hapu but, because they prefer the interior starchy pulp of tree fern trunks, they utilize the larger size classes. Trunks of standing ferns are difficult to feed upon so pigs feed largely on trunks that have toppled over from natural causes. There are no observations or other indications that pigs deliberately uproot larger ferns but they do push against and topple smaller ferns.

Pigs feed upon the interior pulp of hapu trunks by biting away the hard, bark-like, outer tissues; scraping away the fleshy pulp by use of scoop-shaped lower incisor teeth. A large trunk up to 12 inches in diameter and several feet in length will feed one to several pigs for several days. In time the interior of the trunk is completely hollowed suggestive somewhat of a hollowed dugout canoe. From feeding on the trunk the ground around becomes heavily trampled and fresh trails are established in the forest by movements of pigs to and from the trunk. Discovery of new trails in the rain forest often lead to a fallen hapu.

Other items of diet in the rain forest are grasses and sedges, comprising about 5 to 10 percent of the diet; insects and earthworms comprising about 3 percent; mud and soil litter from rooting for insects and earthworms, about 5 percent; and unidentified matter about 2 percent. It appears that feral pigs in the rain forest can subsist almost entirely upon ferns and grasses. Moreover, it becomes obvious that since most of the diet is fern and grass, taken above ground level, excessive damage by pigs uprooting substrates is done searching for earthworms. While earthworms are a relatively minor part of the diet, volume-wise, they are a highly desired delicacy and are found in about 50 percent of all stomachs analyzed.

Earthworms are searched for in grassy spots where investigations reveal they are often found right at ground level just beneath the grass mat. Pigs will uproot and roll back grass, much like one would roll back a rug, while searching for earthworms. One pig stomach analyzed after a period of excessive rooting in grass revealed the masticated remains of approximately 50 earthworms, but little grass. Grubs, pupae and adult insects are eaten whenever found.

In grassland regions of the park, grasses comprise as much as 50 percent of the pig's diet and where fruits and berries are locally abundant, pigs feed extensively upon guavas, passion fruits and other non-native weedy species. The spread of these noxious plants around Hawaii is due in part to the feeding activities of pigs.

Being predatory, as well as being scavengers, stomach analyses sometimes reveal remains of rats, birds and crunched up bones and flesh of goat, pig and cattle carcasses. Where hunters discard pig and goat remains pigs devour what is left in a short period of a week to 10 days. Observations on carcass feeding reveal that pigs do not prefer the remains until they are in an advanced stage of decomposition; teeming with fly maggots. It is, perhaps, the presence of fly maggots that attract pigs most since observations elsewhere show grubs, caterpillars and earthworms are readily consumed.

Aside from feeding, it is a well known habit of pigs to wallow in mud. They lie down and squirm around in mud until they are almost buried. Pigs wallow in mud for three probable reasons: (1) mud soothes and softens rough, dry skin; (2) mud cools in hot weather; and (3) mud helps rid skin of lice and the itching of lice. Probably the primary reason is the latter.

All pigs observed in the courses of these studies have had moderate to heavy infestations of hog lice, Haematopinus adventicus, the largest of all lice. They occur principally on the softer, underskin of pigs. Pigs are often

infected with mites causing sarcoptic mange which in many cases is quite severe. Severe cases no doubt lead to eventual death through a lowering of resistance to death from other causes. Such infestations by lice and mites cause considerable itching and observations of wild pigs soon reveal that scratching and rubbing against tree trunks and rocks is done many times a day for several minutes at a time.

Wallowing in mud as protection against lice appears to do two things: (1) it temporarily stops lice from further crawling and probably retards itching; and (2) dried mud encrusts lice so that some of them can be removed by the habit of rubbing against trees and rocks. Around each mud wallow and through the forest rubbing trees can be found smeared with pig mud. In time, bark on good rubbing trees is worn away from years of repeated use.

Distributions of wallows in the park are confined to rain forest habitats where patches of swampy ground clear of trees can be used for wallows. To be suitable, boggy soils must be deep enough to form a body sized depression and be swampy enough to hold water and stay muddy for long periods of time. Otherwise, the mud may dry quickly and once hard a mud wallow is useless. Well used wallows stay muddy for several weeks at a time during the summer dry season and are perpetually muddy through the winter rainy months. In areas outside the rain forest long standing wallows are non-existent because of usually shallow, porous lava soils.

A well established wallow may be used almost daily year after year by a number of pigs. Home ranges of pigs may contain several wallows as indicated by permanent trails connecting one wallow with another. Trails may lead into wallows from all directions much like spokes on a wheel. In studies of trail systems through the forest the only trails which can be considered permanent lead between wallows and some are several hundred yards in length. Older trails are as much as a foot wide and in places may be three or four inches deep.

In the making of wallows and tree fern hollows, rain catchment basins are formed which become habitats for mosquito larvae and other aquatic organisms. In places pig created aquatic habitats are abundant. In one two-acre study area 35 tree fern hollows were found to contain mosquito larvae and in a 50 acre plot five mud wallows contained larvae.

Larvae of four other families of Diptera are known from wallows and hollows as well as numerous species of nematodes, copepods, ostracods, cladocera and microscopic protozoa.

Most species are exotic--that is they are non-native--though there are some which are endemic, but endemic organisms which are aquatic in the forests are a rarity. It is interesting to think about this because there would be almost no standing water in the Hawaiian rain forests were it not for the pig. Furthermore, it is interesting to think about the ecological subtleties of how abundances of these aquatic animals, now provided for by the pig, could be upsetting natural balances. It was because of such a lack of standing water in the rain forests that such adaptive phenomena occurred in Hawaii as the evolution of non-aquatic damselfly larvae. Now everywhere else in the world damselfly larvae are aquatic--but not in Hawaii. Damselflies were able to occupy a niche in pondless rain forests by evolution of terrestrial larvae living in damp soils and leaf litter.

In the several genera of exotic Diptera utilizing pig created water holes are representatives that no doubt compete with native flies. Is utilization of common habitat and food sources significant to the detriment of native forms, however subtle the utilization may be? And what of the native insects which naturally occur in the forest but which populations now literally explode in numbers because of considerably more habitat? Surely this

must upset natural balances however subtle it may be.

In considering the presence of exotics one is reminded of a basic problem in Hawaii which has been extinction on a massive scale caused from introductions of exotic species tripping balances in disfavor of natives.

Since food and habitat availability are limiting factors even among native populations the same become even more limiting with introductions of competitive exotics. We have to wonder about the directions being taken by native species in competition, survival, extinctions, or start of new evolutionary adaptation in the face of new biological pressures brought about by the feral pig. We can, perhaps, get some insight into what is happening by looking at pig/mosquito and pig/pilo tree, Coprosma sp., relationships.

It is important to know there were no mosquitoes in Hawaii before 1826. In that year a merchant ship en route to Hawaii took on water from a Mexican port contaminated with larvae of the night flying mosquito, (Culex quinquefaciatus). After the ship arrived in Hawaii a watering party drained out the contaminated water into a fresh water stream to take on new water. In a relatively short period of time mosquitoes spread throughout the lowland and middle elevations of all major islands.

The potential for epizootic diseases among forest birds in Hawaii always existed because of vagrant birds from mainland areas which arrived on occasion in Hawaii and because some of the resident birds are migratory to and from mainland areas where bird diseases are commonplace. However, in the absence in Hawaii of a suitable vector, such as the mosquito, diseases such as bird malaria and bird pox could not be spread among non-migratory forest birds.

Warner (1968) showed evidence that many of the native, non-migratory birds in Hawaii never developed immunities to avian diseases and he attributes extinction of so many Hawaiian bird species to spizootics spread by mosquitoes, along with man caused changes in habitat and other disturbances. Hawaiian birds are for the most part rare and endangered for the same reasons, and birds in lowland and middle elevation habitats are threatened still with extinction from mosquitoes spreading diseases. In time, some birds may survive in habitats above present elevational limits of Culex until, of course, a high elevation Culex arrives in Hawaii or, unless, immunities are developed.

Now that the mosquito is established in Hawaii some would, and do, occur in natural tree cavities and leaf axils, despite the pig. But these small bodies of water are so few by comparison to bodies of water created by pigs that the pig must be considered a direct threat to continued survival of many species of rare and endangered birds.

In studies of the impact of pigs upon vegetation in mountain parkland habitats, an interesting cause and effect relationship was revealed between boars and the pilo tree (Coprosma rhynchocarpa). The pilo is a common, shade-tolerant understory species which has soft, succulent bark that pigs can damage easily by a habit of tusking on trunks of trees.

Boars slash the bark for two probable reasons: (1) to use it for food when the bark is completely removed from the trunk and/or (2) to mark the trunk with slashes as a method of marking territorial claims or a show of size superiority and male dominance. Slash marks are made as high up on a tree as a boar can reach and tusk marks out of reach of smaller boars probably indicate the presence of a larger boar. If all of the bark is removed, as is sometimes done, the tree eventually dies.

After boars slash pilo trees interesting changes may occur in pilo growth forms. The pilo is normally a slender, straight, single-trunked tree growing tall in shade in competition with other pilo trees for available sunlight. Multiple-trunked trees occur occasionally but pilo trees with more than one trunk usually grow less tall and natural selection favors the taller, single-trunked trees.

In the presence of non-native ungulates, such as the pig, single-trunked trees are at a disadvantage because pigs can tusk all sides of a trunk and thus kill a tree. Multiple-trunked trees become favored because two or more trunks growing close together provide protection to layers of bark between trunks.

A damaged pilo responds by sending up suckers from the base of a wound, usually near ground level. In time, these grow into additional trunks. Once pilo trees become multiple-trunked their chances for survival are enhanced against continued pressures of pigs and/or goats which also damage pilo trees.

Comparative studies of pilo trees in areas that are inhabited by pigs and goats show significantly higher percentages of multiple-trunked pilo than areas free of goats and pigs. Therefore, any mutations that might occur for multiple-trunked pilo would be favored in the presence of ungulates. Pigs, along with goats, could well be playing a subtle, or perhaps not so subtle role in adaptation of a native tree in face of new biological pressures.

Since the pig is a destructive intruder upon the natural scene, within a national park, National Park Service policy states that the pig should "be eliminated" if possible to do so "by approved methods which will preserve wilderness qualities."

Pig control in Hawaii will be a sensitive, moral and political issue, as it already is, since the pig has economic importance as a game animal and cultural significance to various groups of island people. Moreover, there is an argument that pigs should be considered "native" since primitive man brought pigs in with him. Another National Park Service principle states that parks should be administered as they were prior to the arrival of European man and as they would be today had European man never arrived upon the scene. Pigs arrived in Hawaii more than 1,000 years before Europeans and aboriginal people in Hawaii would with little doubt have maintained use of pigs right up through today.

But aside from these considerations pig control will be difficult to achieve. As we found with management problems with feral goats, control cannot be achieved with any hope for long lasting success until boundary fences can be constructed which keep out repeated reinvasions of additional animals. Goat fences presently constructed are good for goats but not for pigs and it is doubtful enough money could ever be appropriated to build boundary fences wholly pig proof.

About all the National Park Service can do at the moment is to come up with the best management plan possible, with the limited funding available, which will reduce numbers of pigs down to levels more acceptable in areas of critical impact.

Even this will not be easy since pig control is difficult in the often almost impenetrable rain forest terrain where most pigs are found. In some parts of the world poisons have been used with good success and while poison control is highly efficient cost-wise, use of many poisons on Federal lands in the United States is presently illegal. Other methods of control would be trapping and hunting but experience shows these methods remove relatively few pigs for the numbers of pigs involved and the time/man power requirements and expenses entailed. Yet, hunting and trapping are useful methods

in localized areas of high pig impact where particular dangers exist to rare and endangered species and/or ecosystems.

Biological control is not permissible if one is thinking in the classic sense of introducing predatory animals to prey on pigs. Introduction of pathogenic organisms to spread diseases among pigs, or introduction of disease, would be too big a gamble, even if legal, if diseases among park pigs spread outside onto neighboring farms and into huntable populations of pigs used for food.

Chemo-sterilant control has possibilities but no one yet has developed satisfactory techniques for chemical control of large numbers of free ranging animals over large areas of distribution.

These are examples of problems and considerations facing resource managers at Hawaii Volcanoes. Hopefully, these issues can be resolved to the mutual satisfaction of all concerned and in the best interests of native species and habitats suffering from feral pig activities.

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