

The History of Human Impact on the Genus *Santalum* in Hawai'i¹

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Abstract: Adaptive radiation of *Santalum* in the Hawaiian archipelago has provided these remote islands with a number of endemic species and varieties. The prehistoric Polynesian inhabitants of Hawai'i utilized the sandalwood trees for many of the same traditional purposes as their South Pacific ancestors who had developed ethnobotanical relationships with *Santalum*. The ancient Hawaiians probably reduced the number and geographical distribution of sandalwood trees significantly through their extensive cutting and burning, especially in the dry forest regions. Nevertheless, vast numbers of the fragrant trees still existed in Hawai'i at the time of Western contact in 1778. Within a century after this contact, the extensive trade in sandalwood produced a massive decline in the Hawaiian species of *Santalum*. Although cultivation attempts during this century with both introduced and native sandalwood species have had limited success in Hawai'i, there is renewed interest in developing a sustainable forest industry based on the production of sandalwood for export trade. Biologists in general, however, have cautioned against large-scale harvesting of the remaining *Santalum* trees, suggesting that more research be undertaken first to determine the distribution and vigor of the remaining species.

The Hawaiian Archipelago is one of the most isolated group of islands in the world. Yet, this chain of remote islands has an extraordinarily diverse array of ecological conditions with vast tracts of fertile land. The discovery and colonization of this isolated archipelago was one of the most extraordinary achievements of our species. The people who originally found these islands brought with them plants, animals, and ideas that they utilized to colonize and build a Polynesian society beginning approximately 1,500 years ago (Kirch 1982, 1984). One set of ethnobotanical concepts that the early Polynesian immigrants brought with them involved the practical and ritual use of *Santalum* species. Their ancestors had developed these concepts over thousands of years of human experience in the tropical Pacific Islands of Melanesia and Polynesia. Much later, trade-motivated Westerners brought their ideas about commercial export to Hawai'i and soon identified the presence and marketable value of the native sandalwood trees.

A study of the history of human impact on the sandalwood plants in Hawai'i provides us with an excellent opportunity to examine the multifaceted relationship between *Homo sapiens* and a valuable group of endemic woody *Santalum* species that probably evolved from a single ancestral species through the process of adaptive radiation.

This paper surveys the interaction of social systems, cultural values, and useful plant resources in a variety of natural environments through a review of the exploitation and decline of the

genus *Santalum* in Hawai'i. Following a brief overview of the natural history of the genus in the archipelago, we examine the prehistoric use of sandalwood in Hawai'i and the human impact on the distribution of *Santalum* species in these islands. Subsequently, we describe the major economic, political, social, and ecological consequences of the early 19th century sandalwood trade between Hawai'i and China. Finally, we summarize a number of recent events involving a renewed interest and activity in the harvesting, marketing, cultivation, preservation, and scientific study of *Santalum* in the State of Hawai'i.

NATURAL HISTORY OF HAWAIIAN SANDALWOOD SPECIES

Worldwide, the family Santalaceae is represented by roughly 30 genera comprised of about 250 species which are mostly small tropical perennial herbs and shrubs (Press 1989:258). Two genera, *Santalum* and *Exocarpus*, are represented in Hawai'i (Imada and others 1989:78). *Santalum* was first proposed by Linnaeus in 1753 in his description of *S. album* (Stemmermann 1977:1). Specimens of the genus were initially collected for taxonomic study in Hawai'i by Gaudichaud during the voyage of the French ship *Uranie* in 1819. When this botanist published his findings in 1830, he described two species, *S. freycinetianum* and *S. ellipticum* (Stemmermann 1977:3).

Since Gaudichaud, a number of taxonomic studies of *Santalum* in Hawai'i have been undertaken. However, significant differences of opinion have arisen regarding interspecific and intraspecific classification. For example, St. John (1947:5) listed 19 species, while more recent revisions tend to group the taxa together into as few as four distinct species (Little and Skolmen 1989:112), with a number of varieties (Stemmermann 1977:114). The most recent classification by Wagner and others (1990) lists the following four species:

- S. ellipticum* (Coastal sandalwood) (fig. 1);
- S. freycinetianum* (Freycinet sandalwood) (fig. 2);
- S. haleakalae* (Haleakala sandalwood);
- S. paniculatum* (Hawai'i sandalwood).

These four endemic species made up the source of the early 19th century sandalwood trade (Little and Skolmen 1989:112; St. John 1947:5,18). More recently an alien *Santalum* species was introduced in Hawai'i. Earlier in this century, the Indian Sandalwood (*S. album*), traditionally the most important source of commercial sandalwood products, was purposefully brought into Hawai'i from India and planted in some areas for possible commercial production and marketing (Fletcher 1968:18).

The Hawaiian "coastal sandalwood" (*S. ellipticum*) generally grows as a shrub or small tree, rarely exceeding more than 18 feet in height (Stemmermann 1977:126). Individuals of this species that grow along or very near the coast are much lower in height; they were formerly classified as a separate variety (var. *littorale*). The other three species of *Santalum* in Hawai'i grow primarily as trees, with maximum heights of about 65 feet (Daehler 1989:2), though specimens of *S. freycinetianum* have been reported reaching heights over 80 feet (Little and Skolmen 1989:114). Trees of this height would have a diameter of nearly 3 feet (Daehler 1989:2; Little and Skolmen 1989:114).

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Figure 1—*Santalum ellipticum* Gaud. grows in dry forest at about 1000 ft elevation in the southern Wai'anae Mountains of O'ahu.

All members of the family Santalaceae are apparently hemiparasites (Stemmermann 1977:1). While these partially parasitic plants do produce their own photosynthates, they probably obtain some of their nutrition from a host plant(s). The genus *Santalum* utilizes sucker-like organs called haustoria which attach themselves to the roots of one or more host plants (fig. 3). Most haustoria are located within a few inches of the surface of the soil. Judd (1933:88) believed that Hawaiian sandalwoods are facultative, rather than obligate parasites, as evidenced by the occurrence of solitary sandalwood trees (Rock 1917:14). However, recent studies (e.g., Press 1989:258) indicate that many facultative parasites suffer reduced fecundity in the absence of a host. In the past, efforts to culture sandalwood seedlings have had higher success rates when the seedlings were planted alongside seedlings of other tree species (Judd 1936:83; also see other articles in this publication). Hawaiian sandalwoods utilize several species of native and introduced plants as suitable hosts (Judd 1935:19).

The original colonizing ancestor(s) of Hawai'i's sandalwood probably arrived from Southeast Asia by way of the intervening islands where *Santalum* can still be found today. The relatively large olive-like fruits of *Santalum* are eagerly sought by birds, and the seed(s) was most likely brought to the Hawaiian Islands in the gut of an avian species, as were nearly 40 percent of early colonizing plants in Hawai'i (Carlquist 1980:4-5). However,

Figure 2—*Santalum freycinetianum* Gaud. grows in seasonally dry forest at about 2000 ft elevation in the southern Wai'anae Mountains of O'ahu.



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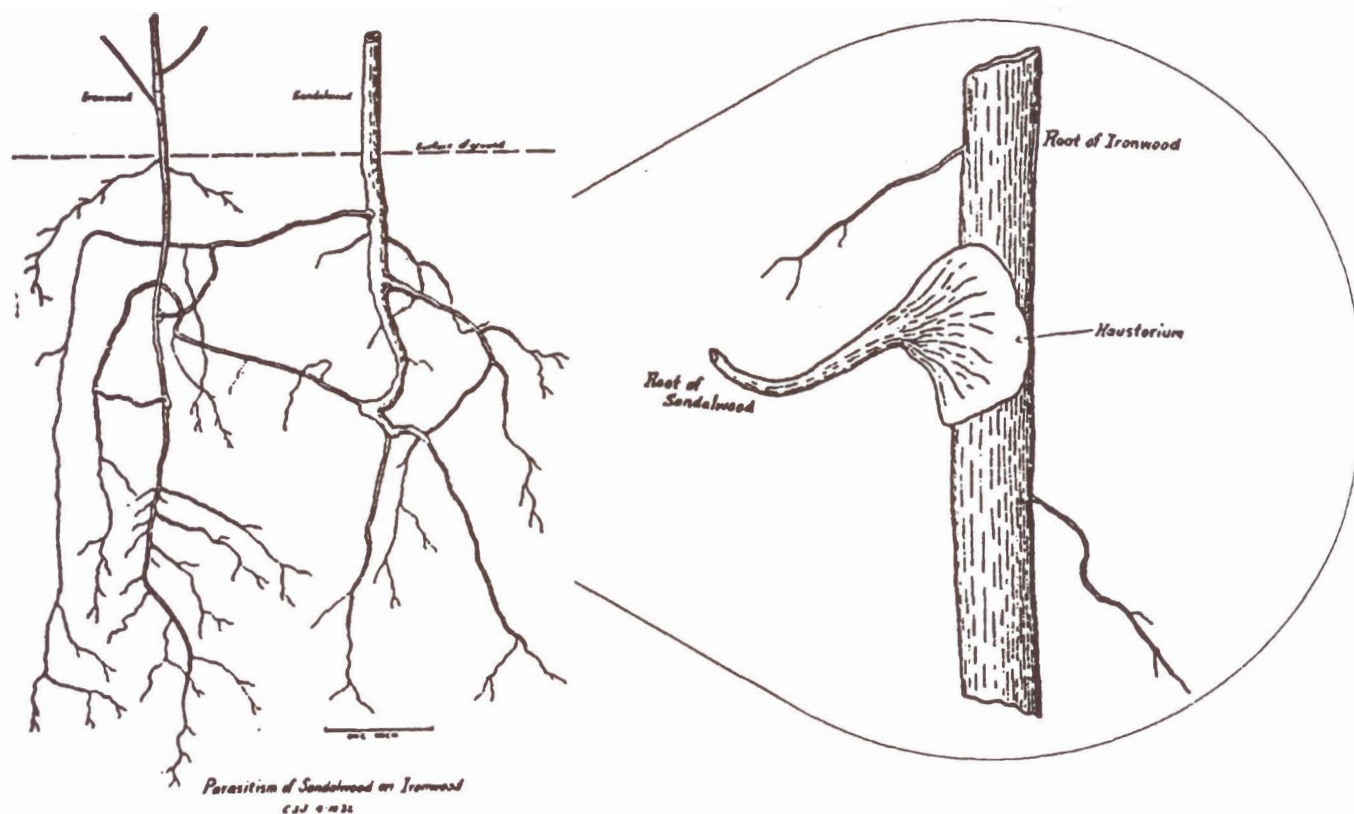


Figure 3—Haustoria of *Santalum* species is shown parasitizing ironwood tree (*Casuarina* sp.). Drawings by C.S. Judd, reproduced from: Cartwright (1935, p. 21).

the ancestral seed(s) carried by the fruit-eating bird may have been smaller than the present forms produced by the genus in Hawai'i. Large seed size is presumed by some to have evolved after arrival and establishment in the islands (Carlquist 1980:97).

The genus *Santalum* was probably introduced to the Hawaiian Islands through the colonization of a single ancestral species. The four (or more) species and their varieties are one of many interesting examples of a process that has commonly occurred in insular environments and is referred to among biologists as adaptive radiation. According to this process, several taxa may evolve from a single ancestor, each adapting to a variety of different environmental conditions. In Hawai'i, Zimmerman (1972:528) suggested that the adaptive radiation was "...given much freedom for operation in a sort of 'biological vacuum,'" and noted that in Hawai'i such a "condition resulted in an astonishing proliferation of species, species diversification, adaptive morphology, and habitat utilization."

Santalum established itself throughout the main high volcanic islands. One species, *S. ellipticum*, was even extant on tiny Laysan in the Northwest Hawaiian Islands until it was extirpated by feral rabbits earlier in this century. This species also may have become extinct recently on Kahoolawe due to grazing pressure and soil erosion. Although they are not common in most areas today, some sandalwood plants can still be found in various habitats from sea level to well over 8,000 feet (Stemmermann 1977; Little and Skolmen 1989). Where *Santalum* occurs in the

dry forest, it grows as individual trees or in small clumps mixed in with other species (Rock 1916; St. John 1947; for a detailed discussion of the distribution of *Santalum* in Hawai'i, see Stemmermann in these proceedings).

PREHISTORIC ALTERATION OF THE HAWAIIAN ECOSYSTEMS

The original human colonists who settled in Hawai'i arrived by sailing canoes well over a thousand years ago. The early voyagers brought with them a number of species. Most were carried along on purpose, while others were probably introduced accidentally. As many as 25 alien plant species, including more than a dozen crop plants, were brought in consciously, while five or more plant species were unwittingly transported to Hawai'i. Pigs, dogs, and chickens were intentionally introduced, whereas other animals, such as rats, geckos, and skinks were most likely stowaways. The prehistoric Hawaiian immigrants also brought with them concepts about their natural environment and how it should be manipulated. Many of their traditional ideas about nature and resource management had been inherited from their South Pacific ancestors. This "transported landscape" of alien biota and cultural concepts concerning how they should alter the environment included various schemes for changing the landscape to facilitate the needs of a growing population. For example, the prehistoric Hawaiians cut and burned vegetation to

clear the lower forest land for agriculture, and they diverted streams to irrigate artificially constructed pond fields where they cultivated their staple taro crop, *Colocasia esculenta* (Kirch 1982).

Although it is a "difficult task" to ascertain the "shared and practiced" values of the prehistoric Hawaiians, the early inhabitants developed some environmental concepts involving regulated resource use; these ecologically-oriented ideas may have been motivated by an understanding of the significance of conservation (e.g., Burrows 1989). In some cases their values and practices seem to have been developed to sustain resource availability. Such principles of environmental concern or stewardship (*malama*) or resource use regulations (*kapu*) may have functioned primarily for the protection of species that had utilization value at the time.

As the prehistoric Hawaiians extended their influence inland from their early nucleated coastal settlements in windward areas, as well as expanding into drier leeward areas, they had an increasing impact on the areas where sandalwood occurred. Fire was used widely to remove lowland forests, perhaps primarily—but not necessarily only—to produce anthropogenic grassland or savannah where the Hawaiians could cultivate dryland crops such as sweet potatoes (*Ipomoea batatas*) and yams (*Dioscorea* spp.). Well before the first Europeans had arrived in the Hawaiian Islands, large areas of the lower forests were converted into semi-natural grasslands or degraded savannah. According to Kirch (1982), by A.D. 1600, probably 80 percent of all the land below 1,500 feet had been altered by extensive burning. Vancouver (1798, vol. 1:170) described the island of Kauai as having "...a space comprehending at least one half of the island, appeared to produce nothing but a coarse spiny grass [probably pili grass, *Heteropogon contortus*] from an argillaceous soil, which had the appearance of having undergone the action of fire" (quoted in Kirch 1984:142). A number of archaeological studies in Hawai'i (e.g., on Makaha, O'ahu; Halawa, Moloka'i; and Kaho'olawe Island) have documented the destruction of lowland forest due to conflagrations set off in the prehistoric period (Kirch 1984: 142-143). The use of fire for clearing land was probably the first major impact on the lowland *Santalum* populations, especially those of *S. ellipticum*, which reach down to the littoral fringe, and of *S. freycinetianum*, which can be found as low 800 feet above sea level.

Alteration of these low dry forest habitats also had a severe impact on native bird populations, which in turn may have affected the sexual reproduction of a number of native plants, including the sandalwood species. Fossil records from the Ewa Plain of O'ahu, coastal areas on Moloka'i, and elsewhere in Hawai'i, have revealed numerous species of birds (including geese, perching birds, and crows) that became extinct during the precontact period (Olson and James 1982).

The reduction and, in many cases, the elimination of native bird populations may have affected the sandalwood populations in two ways. First, native birds are important pollinators of native plants in Hawai'i. A recent survey of *S. haleakalae* estimated a remaining population on Maui of about 400 individuals, but only one seedling could be found. Among the thousands of flowers produced every year by the Haleakala sandalwoods, only a tiny percentage presently form seeds. One reason for this

may be the lack of sandalwood pollinators (Kepler 1985:11). Secondly, as noted earlier, birds are important agents of dispersal for sandalwood seeds. A reduction in native seed-eating bird populations (e.g., the extinct finch bill passerines and the extant, but extremely rare, endemic crow) may have resulted in a severe decline in the local populations of their food plants (Fern Duvall, Personal Communication, 1990). Although the population problems associated today with *S. haleakalae* probably involve more recently introduced alien organisms, the pattern of disruption may apply to the earlier demise of lowland sandalwood habitat in the prehistoric period.

Introduced lizards and rodents may have also had an early impact on sandalwood. Geckos and skinks are primarily insectivores. They might have contributed to a reduction in pollinating insects. Rats and mice, including the Pacific rat (*Rattus exulans*), which was an aboriginal introduction, are known to have a great affinity for the sandalwood seeds and will dig up the fleshy hypocotyls of germinating seeds (Judd 1933:85,88; Kepler 1985:11).

Although lowland sandalwood populations were greatly reduced during the prehistoric period, vast numbers of *Santalum* trees remained in the higher forest areas (i.e., above 1,500 feet elevation). Sometimes considered to be an economically self-sufficient unit, the radial land divisions of ancient Hawai'i, the *ahupua'a*, were probably developed to take advantage of the ecological diversity of the high volcanic islands. This system of land division usually consisted of an elongated strip of land which extended from beyond the reef to the top of the mountain range, thus acknowledging the "dependence upon the forests for wood and certain other plant materials" (Judd 1926:1). The traditional resource-oriented *ahupua'a* included native upland forests where a variety of trees, including sandalwood, were harvested. These forests were used as "supply forests" subjected to selective cutting. Judd (1926:2-3) believed that this type of harvesting resulted in limited degradation of the upper forest regions. He reported that native trails were found mainly along the ridgetops, and that large logs (e.g., *koa* canoe logs) were dragged down from the mountains along specified routes. Desirable parts of sandalwood trees were also removed from these forests during the prehistoric period.

TRADITIONAL USE OF SANDALWOOD IN HAWAII

In the Hawaiian language the sandalwood plants themselves are called *'iliahi*, which refers to the reddish color of new leaves, or the trees in general when they are in full bloom. The latter condition would certainly apply to *S. freycinetianum* and *S. haleakalae* when they produce their profuse blossoms of reddish flowers. The fragrant heartwood of sandalwood is known in Hawaiian as *'la'au 'ala*, literally "sweet wood" or "fragrant wood." Hillebrand (1965:389) suggested that the linguistic "root" for the Hawaiian name of the plant, *'iliahi*, could be found "...in the Tahitian *Eai* and probably also in the Vitian [Fijian] *Yasi*."

Although it has been suggested that the Hawaiians did not use sandalwood extensively (Stemmermann 1977), products derived from the genus had a number of traditional uses in Hawai'i,

and their source trees may have been highly esteemed. A list of traditional Hawaiian uses of sandalwood is presented below.

A. Medicinal applications (Krauss 1972:199):

1. Curing dandruff (shampoo with infusion of leaf);
2. Eliminating head lice (shampoo with infusion of leaf);
3. Curing diseases of both male and female sex organs (drink made from finely ground powder, mixed with other plants, followed by laxative);
4. Treatment of sores of long duration (infusion of powdered wood, mixed with other plant parts, used as drink, followed by laxative).

B. Perfume (Krauss 1972:199; Kepler 1985:10):

1. The heartwood was pounded into a fine powder, and this, or fine chips, was pounded into new tapa cloth (which had an objectionable smell, especially just after its manufacture).
2. The heartwood powder was also added to coconut oil and used to make a waterproof, perfumed tapa.

C. Firewood (Wagner 1986:150).

D. Musical Instruments (Buck 1964:388):

1. *Iliahi* was sometimes used in the manufacture of the musical bow, or *ukeke*, a Hawaiian type of stringed instrument.

Knowledge of most of the uses listed above was probably brought to the Hawaiian Islands by the migrating Polynesians who arrived from their previous homelands in the South Pacific. The ethnographic record provides ample evidence that the heartwood and oil of *Santalum* were widely used among various other Polynesian and Melanesian Island peoples for a variety of practical, esthetic, and ritualistic purposes (Kirch 1984). For example, elsewhere in Polynesia the use of powdered sandalwood heartwood for scenting tapa, as well as mixing the sweet smelling powder with coconut oil for perfume, has been documented. Kirch (1984) points out that Tongan chiefs traded with Fijians for a number of goods and local sandalwood products, the latter prepared for the valuable exchange that occurred during the prehistoric period.

ARRIVAL OF WESTERN CULTURE AND THE EARLY HISTORIC SANDALWOOD TRADE

During the latter part of the 18th century and early part of the 19th century, a series of events occurred in the Hawaiian Islands that had profound effects on both the natural environment and human social conditions. The third Pacific expedition of Captain James Cook arrived in Hawai'i in 1778, ushering in the historic period for the archipelago. Alien species, new materials, and novel ideas entered the remote islands and precipitated significant changes in many realms of activity, including politics and human ecology. Kamehameha the Great rose to power and progressively consolidated his rule over the islands. By 1810 he had successfully unified all the main Hawaiian Islands, a feat never previously accomplished. During this same period the commercial value of Hawaiian sandalwood as an export item became known to various foreign traders and native chiefs.

Following the death of Captain Cook at Kealahou Bay of the Island of Hawai'i in 1779, his expedition continued on to the Pacific Northwest. While there, they purchased sea otter furs to keep themselves warm. Later, when they reached China, they

were astonished to find Chinese merchants offering them up to \$120 for pelts which they had bought for pennies (Kittelson 1982). Word of this new market spread quickly. In 1785 and 1786, Captain James Hanna led the first two trade voyages whose specific purpose was to purchase sea otter and seal furs in the Pacific Northwest and then resell them in Canton, China, for a large profit. In 1787, American ships began to take part in this trade (Tan 1951). The Hawaiian Islands were a convenient place for these ships to rest and restock supplies of water, firewood, and fresh vegetables.

At least three different sea captains have been credited with the original "discovery" of sandalwood in Hawai'i in the late 18th century. According to Tan (1951), this discovery can be attributed either to Captain William Douglass or Captain James Kendrick, while Wagner (1986) argues that it was Captain Simon Metcalf. How the valuable wood was first noticed in Hawai'i by foreigners is also uncertain. Possibly a load of firewood taken aboard a ship included logs or sticks of sandalwood. One of the traders, or possibly a Chinese cook, identified the characteristic, fragrant scent when the wood was burned (Daehler 1989; Wagner 1986). Once the presence of sandalwood in Hawai'i was identified by outsiders, its potential as a trade item on the Canton market was quickly recognized.

In China, the fragrant heartwood of sandalwood trees has long been used to manufacture ornate cabinets and chests, incense, perfumes, and medicines. It was also used as fuel for funeral pyres in religious observances in the Orient (St. John 1947).

Before the introduction of Hawaiian sandalwood onto the Canton market, most of the wood sold in China was "white sandalwood" (*Santalum album*), which was imported from India and the East Indies. Around the end of the 18th century the supply of this Asian white sandalwood was becoming insufficient to meet market demands in China. This shortage resulted in an increasing market value of acceptable sandalwood from a variety of source areas, including the Hawaiian Islands. As the islands emerged as a major source of raw material the remote archipelago soon became known in China as "Tahn Heung Sahn" or "the Sandalwood Mountains" (Kepler 1983). Sandalwood was sold in China by the "picul," a unit equal to 133 1/3 pounds, the amount that a typical man could carry. The average price per picul in China during the major Hawaiian sandalwood era in the early 19th century was \$8 to \$10, though the price fell in the late 1820's as a result of poor quality.

Tan (1951) states that the first shipment of marketable sandalwood could not have arrived in China from Hawai'i before 1792; however, there is an account of a shipment arriving earlier. Amasa Delano wrote in 1801: "As long ago as the year 1790, I saw more than thirty tons of what was called sandal wood brought from these islands to Canton in one vessel: but it was of an inferior kind, and the Chinese would not give anything for it" (Delano 1818:399). The source of this wood may have been *naio*, the "false sandalwood" (*Myoporum sandwicense*), which is also a native Hawaiian tree found in dry forest environments (fig. 4).

This aborted start apparently did little to deter the efforts of the traders, and the Hawaiian sandalwood trade developed rapidly. In 1791, after leaving Kaua'i, Captain Kendrick put three men

ashore on Ni'ihau with instructions to return to Kaua'i and begin collecting sandalwood (Tan 1951). During Delano's visit to Hawai'i in 1801, he also reported that some American traders had recognized the sandalwood trade to be profitable export business during the previous 7 or 8 years (Delano 1818:399). Chinese imports aboard American ships in 1804-1805 was 900 piculs. By 1811-1812 this amount had risen to over 19,000 piculs, and prices rose to the relatively high value of \$8 to \$10 per picul noted above (Tan 1951).

In the very early years of the sandalwood trade, the American entrepreneurs dealt with the chiefs as well as Kamehameha the Great himself; however, Kamehameha eventually provided himself with an exclusive monopoly over the sandalwood trade. The sudden wealth and availability of many new material goods seem to have overwhelmed the paramount authority of Hawai'i in these frenetic years of Hawaiian sandalwood exploitation. Kamehameha accumulated large amounts of luxury goods. The early Russian explorer, Kotzebue (1830:191) tells us that Kamehameha I pledged large amounts of sandalwood in advance for goods and ships, often paying greatly inflated prices for these items (Tan 1951). For example, Kamehameha is said

to have paid \$800 for a mirror, and \$10,000 for a brass cannon (Judd 1926).

Among the ships that Kamehameha purchased with promises of sandalwood payments was a brig which he named the *Kaahumanu*, after his favorite wife. Kamehameha used this vessel in an attempt to enter the China sandalwood trade himself. In February of 1817, under the direction of a foreigner, Captain Alexander Adams, the *Kaahumanu* set sail for Canton. As a result of heavy port charges and brokerage fees in the Chinese harbor, the voyage failed to make a profit. Indeed it incurred a loss of \$3,000 (Tan 1951), and returned "...with only a partial cargo of China goods and liquor" (Thrum 1905:5 1). As a result of the voyage, Kamehameha came to recognize the value of charging pilot and port fees, which he then established in Honolulu for his gain. According to Kotzebue (1830:192-3), "When Tameamea [Kamehameha] first sent a ship to Canton with sandalwood, he was obliged to pay a considerable duty for anchorage; whereupon he argued, that what was exacted from himself, he might with a safe conscience demand from others; and every ship is now required to pay forty Spanish dollars for anchorage in the outer, and eighty in the inner harbour of Hanaruro [Honolulu]".

HARVESTING SANDALWOOD IN HISTORIC HAWAII

The great burden of harvesting the sandalwood necessary to pay for the debts Kamehameha I had incurred was principally laid upon the common Hawaiian people. The King "...ordered men to go out in the mountains..to cut sandalwood," and then to transport this heavy harvest "...to the landings" (Kuykendall 1938:8). Judd (1926:3) tells us that because of the lack of roads and vehicles the wood "...was carried down in the form of logs, 3 to 6 feet long, and from 2 to 18 inches in diameter, after the bark and sap[wood] had been chipped off with adzes."

Large numbers of people were involved in the harvesting and handling of the sandalwood (fig. 5). In the 1820's, the Reverend



Figure 4—Naio (*Myoporum sandwicense* A. Gray) is called "Bastard" or "False Sandalwood." Source: Krauss ([n.d.] p. 202).



Figure 5—Hawaiians carried out sandalwood from mountain harvesting areas to coastal transport sites during the early 1800's. Drawing by J. Chong, reproduced with permission from: Edwards (1951, p. 1).

William Ellis (1969:397) witnessed a most impressive sight involving the massive transport of harvested sandalwood out of the uplands and far down slope to the South Kohala coast of the Island of Hawai'i: "Before daylight on the 22d, we were roused by vast multitudes of people passing through the district from Waimea with sandal-wood, which had been cut in the adjacent mountains for Karaimoke, by the people of Waimea, and which the people of Kohala, as far as the north point, had been ordered to bring down to his storehouse on the beach, for the purpose of its being shipped to Oah'u. There were between two and three thousand men, carrying each from one to six pieces of sandalwood, according to their size and weight. It was generally tied on their backs by bands made of ti leaves, passed over the shoulders and under the arms, and fastened across their breast. When they had deposited the wood at the storehouse, they departed to their respective homes." Frequent transport of heavy loads of sandalwood often produced callused areas (*leho*) on the shoulders of male bearers. Men with these marks were called *kua-leho* or "callous backs" (Lydgate 1916:52). According to Thrum (1905), on at least one occasion "About 500 canoes were employed..." in the transfer of sandalwood from shore to a waiting ship!

On the central plain of O'ahu (and perhaps elsewhere), large areas of grassland and dry forest were burned to make the standing or fallen sandalwood easier to find (St. John 1947:18). This was most likely fatal to seedlings, and may have severely

affected any live trees left standing after the fire because of the damage to the haustoria found close to the surface (Judd 1933:88).

In some places in the uplands of the main Hawaiian Islands (e.g., the one next to the road to Waikolu Lookout on Moloka'i) you can still find large, man-made depressions that were dug to the same dimensions as the hulls of those ships that carried sandalwood from Hawai'i to China (*fig. 6*). These depressions known as *lua moku 'iliahi* were filled with sandalwood logs, which were later carried down to waiting ships. The amount needed to fill the depressions may have also been the quantity needed to trade for some types of ships (Stemmermann 1977:117,188).

Sandalwood harvesters were often gone for several days, sometimes for weeks, in the mountains collecting sandalwood. Many died of exposure and other misfortunes in the cold, often damp uplands. Kepler (1983:125-126) provides a graphic description of the obligate harvester: "It has been said that every piece of sandalwood cut during those boom years was stained with blood. Some villagers died in harness [carrying the ti leaf bound wood on the backs], crumbling motionless on the trails; others, less fortunate, turned into living skeletons, weak from the corroding effects of exhaustion, disease, malnutrition, and exposure to the chilly mountain winds without adequate clothing. To aggravate matters, much cutting was done at night with the aid of sandalwood torches."

The early historic period in Hawai'i brought increasing con-

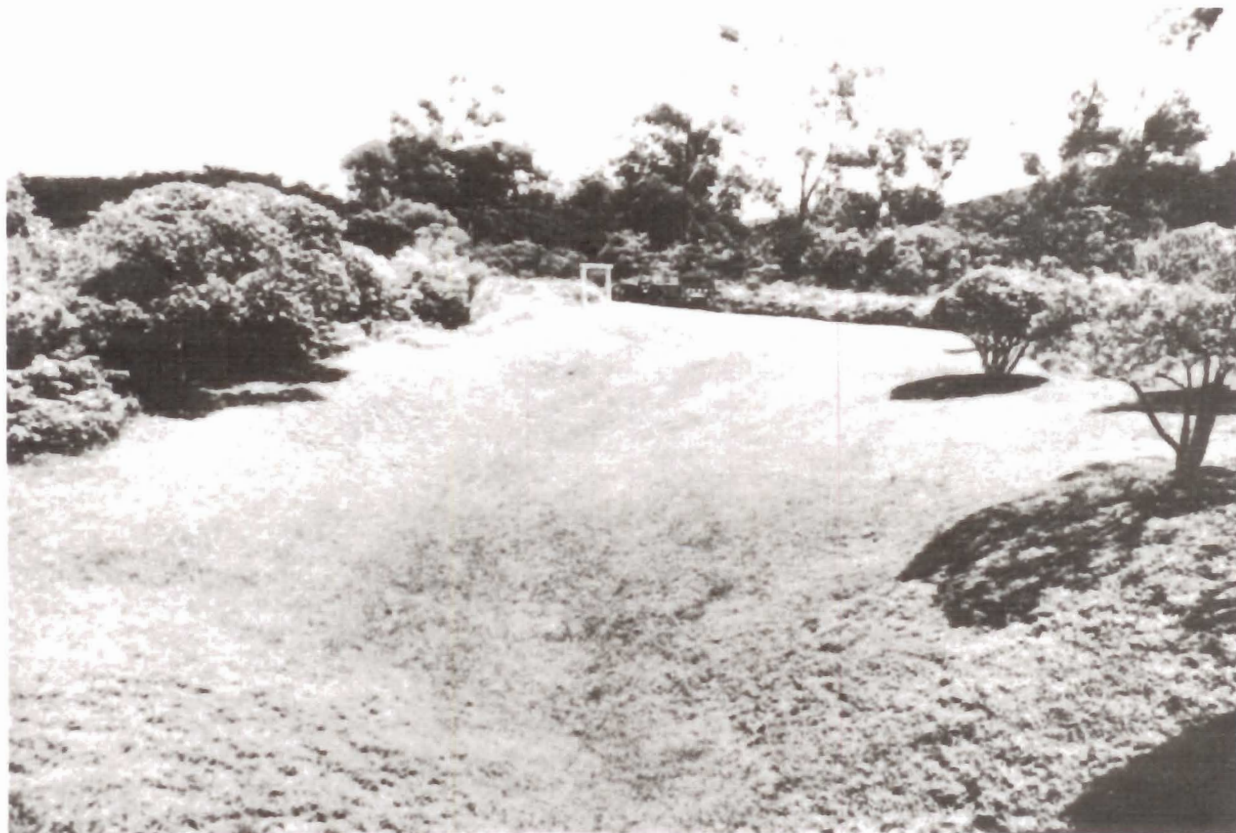


Figure 6—Sandalwood pits ("Lua Moku Iliahi") such as this one in the Moloka'i Forest Reserve were used for measuring the amount of logs that could fit in a ship's hold.

tact with foreign people and their debilitating alien illnesses. The combination of exposure to dangerous, often lethal, diseases and very strenuous sandalwood harvesting under harsh environmental conditions was calamitous for the forced laborers. Furthermore, with so many people busy collecting sandalwood for Kamehameha I (and later chiefs and native leaders), crops were neglected. According to the Hawaiian historian, Samuel Kamakau, "Because the chiefs and commoners in large numbers went out cutting and carrying sandalwood, famine was experienced from Hawai'i to Kaua'i.... The people were forced to eat herbs and fern trunks, because there was no food to be had. When Kamehameha saw that the country was in the grip of a severe famine, he ordered the chiefs and commoners not to devote all their time to cutting sandalwood" (quoted by Kuykendall 1938:88-89). Kamehameha I thus allowed the common people to return to their homes and placed a *kapu* (ban) on the cutting of young or small trees in an effort to conserve the resource.

HISTORIC SANDALWOOD TRADE AFTER KAMEHAMEHA THE GREAT

In 1819, Kamehameha I died, leaving the throne to his son Liholiho. Under the young, new ruler, Kamehameha II, the political system in Hawai'i underwent profound changes. The customary reapportionment of the land by the chiefly or royal heir was altered, resulting in the establishment of the principle of hereditary land holdings (Kelly 1970:7). Kamehameha II proceeded with actions that openly abolished the *kapu* system. He was also persuaded to give his chiefs a greater share in the thriving sandalwood trade (Daws 1968:6).

The early 1820's was a very active period in the Hawaiian sandalwood trade (table 1). From 1821 to 1823, American ships were selling an average of 21,000 piculs (1,400 tons) of Hawaiian sandalwood per year in Canton at \$8 per picul (Tan 1951:9-10). Kamehameha II and the chiefs bought ships and other expensive items from the American merchants on credit with

little regard to how much debt they were incurring. The brig *Neo*, which arrived in Honolulu in March 1819, was soon sold for the inflated price of \$51,750 to Kalanimoku, the Prime Minister of the Kingdom. "When word of this sale reached Boston, New England mercantile firms scoured shipyards and harbors of the Atlantic Coast anew for ships in good condition or bad. The only requirement was that they were able to reach the Hawaiian Islands" (Gast 1976:25).

Of all the ships purchased by the Hawaiian kings and chiefs, probably none is more famous than Cleopatra's Barge. This 83-foot-long ship was built in Massachusetts in 1816 for \$50,000. Four years later the large vessel was purchased by Liholiho and Kalanimoku for \$90,000. The purchase price was to be paid for in installments of sandalwood (Alexander 1906:24,29). This "notoriously unseaworthy" ship was wrecked on the coast of Kaua'i by "an incompetent captain" in April 1825 (Bradley 1968:64).

To obtain sandalwood for the China trade, American merchants were willing to extend enormous amounts of credit to Liholiho and the chiefs. In 1821, J.C. Jones, the American Trade Consul, reported that the native debt had risen to \$300,000 (Tan 1951:10).

Ward (1972:91-123), in his essay on early trade in the Pacific region, argued that sandalwood in Hawai'i, like the *beche-de-mer* of Fiji, was a locally available resource that had limited value to the islanders before contact with the Western traders. We suggest that the sandalwood in Hawai'i and elsewhere in the tropical Pacific had greater traditional value than may be generally recognized, especially as a powdered perfume to scent native bark cloth and mixed with coconut oil to adorn the human body in life and death. Nevertheless, once the Western traders started purchasing large amounts of sandalwood, the Hawaiian rulers found themselves with a trade item that was exchangeable for foreign goods. "Perhaps it is not to be wondered at that this easy money went to their heads; that it seemed to them an untold wealth with boundless limitations ... in the case of sandalwood there were no expenses absolutely. Nature produced it, the common people collected and delivered it and the king stood by to receive the money" (Lydgate 1916:54). The concept of purchasing goods with a mere promise to deliver sandalwood at some future time (buying on credit) may have been a strange idea, but was widely accepted by the powerful Hawaiian leaders. "King and Chiefs alike were so influenced by the luxuries that sandalwood could purchase and the ease they could obtain these items by merely signing promissory notes dealt disaster to the sandalwood resource as well as to the general welfare of the *maka'ainana* [common people]" (Daehler 1989:5).

In the Hawaiian society the "head of a family was a small farmer, raising just enough for the immediate needs of himself, and those dependent on him. Why should he raise more, since he couldn't sell it, and all he really owned was what he used (Lydgate 1916)."

By 1824, the easily accessible stands of sandalwood had been harvested, and much less wood was being cut. The chiefs were buying considerably fewer goods offered by the opportunistic foreign traders. The commercial trading skills of the Hawaiian rulers did improve somewhat over time as a result of experience

Table 1—American sandalwood imports at the Port of Canton, China, 1804-1805 to 1832-1833 (Gutzlaff 1834). The data presented below excludes imports of Hawaiian sandalwood from non-American ships. It also includes some sandalwood of non-Hawaiian origin. However, since Hawai'i was the major source of sandalwood imported into China during the early 19th century, the data can be used to gauge the vicissitudes of the sandalwood trade in Hawai'i during this period

Season	Piculs ¹	Season	Piculs	Season	Piculs
1804-1805	900	1815-1816	2,500	1824-1825	7,438
1805-1806	1,600	1816-1817	7,400	1825-1826	3,097
1806-1807	2,700	1817-1818	15,825	1826-1827	6,680
1807-1808	2,000	1818-1819	14,874	1827-1828	13,265
1808-1809	4,800	1819-1820	10,073	1828-1829	18,206
1809-1810	1,815	1820-1821	6,005	1829-1830	10,807
1810-1811	496	1821-1822	26,822	1830-1831	9,750
1811-1812	11,261	1822-1823	20,653	1831-1832	1,400
1812-1813	19,036	1823-1824	8,404	1832-1833	5,600
1813-1815 ²	1,100				

¹A picul is a Chinese measurement of weight equaling 133 1/3 lbs.

²Total for two seasons combined (1813-1814 and 1814-1815).

and advice they received from the Christian missionaries who began arriving soon after the death of Kamehameha I. The king and the chiefs were also showing little inclination to payoff many of the debts they had incurred (Gast 1976:77).

In 1824, Kamehameha II died of a contagious disease that he contracted in London during a royal visit. In the next 2 years, the reduced amount of sandalwood on the Canton market resulted in a temporary increase in the market price in China. This, in turn, stimulated a renewed effort on the part of American merchants to collect the outstanding sandalwood debts of the Hawaiian chiefs. These events and the earlier (1821) report from the American consul, J.C. Jones, to his government were at least partially responsible for the visit of an American warship to the Hawaiian Islands. The U.S. schooner *Dolphin* arrived in Honolulu in January of 1826 under the command of Lt. Commander John Percival. As a result of Percival's "gunboat diplomacy," Kalanimoku (the prime minister) and his brother Boki (the acting Governor of O'ahu) signed a note for 5,481 piculs (365 tons) of sandalwood to cover the debts to be paid by the kingdom as soon as possible. Jones, who remained unsatisfied with the situation, sent a letter to Commodore Hull requesting that another American warship be sent to Hawai'i. "News of the impending visit of [another armed naval vessel] had preceded it to Honolulu, and for five months traders at that port had looked forward to its arrival with confidence that the presence of an American man-of-war would hasten the collection of the troublesome debts" (Bradley 1968:106). In October, the U.S. sloop *Peacock* arrived under the command of Captain Thomas Catesby Jones. In late December, Kamehameha III and the government of the Hawaiian Kingdom were forced to acknowledge and settle a reported debt of \$500,000 owed to the American traders (Tan 1951:10-11); however, the sum of money that the American claimants actually received was probably less than a third of this figure (Bradley 1968:109).

The pressures brought to bear upon the ruling class of Hawai'i by the American Naval forces resulted in the passage of the Kingdom's first written law—a sandalwood tax—issued in December 1826 (Gast 1976:82). The law stated that every man was required to deliver one half of a picul of sandalwood to the governor of the district to which he belonged, or to pay in lieu thereof four Spanish dollars, on or before September 1, 1827. Every woman 13 years and older was required to hand over a 12 by 6 foot handmade mat, or a quantity of tapa cloth of equal value. Special places were designated for depositing these payments, and all of the taxes collected were to be applied to the Kingdom's sandalwood debts (Tan 1951:11; Gast 1976:82).

By October of 1827, 20,000 piculs of sandalwood (1,333 tons) had been collected as a result of the tax. The search for, cutting, and transporting of this much sandalwood in less than 10 months caused a great amount of hardship for the common Hawaiian people. Food shortages again plagued the land (Tan 1951:12). The easily accessible sandalwood had already been harvested, making it more difficult to locate trees with adequate heartwood to meet the new tax requirements. "Unjust demands eventually caused the toiling Hawaiians to pull up young sandalwood trees so that their children would not also be compelled to fell and pack sandalwood logs" (Daehler 1989:5). According to Bradley

(1968:116), every native person who collected sandalwood for the government in 1827 "...was given the privilege of cutting a half a picul of wood for his own private speculation." Citing a letter written by Captain Jones on November 30, 1927, Bradley indicates that many Hawaiians partook of this offer and "that much of the wood cut during the preceding months was the property of commoners."

Once the pressure of the Kingdom's debt was somewhat relieved, Kamehameha III himself began to purchase ships and other luxury items, and subsequently, in 1828, another American warship arrived in Honolulu in response to the foreign traders' pleas for sufficient, timely debt repayment. Captain Finch, of the U.S. sloop *Vincennes*, held a conference with the King to discuss debts still owed the American merchants. These debts amounted to \$50,000. It was agreed that they would be paid off with 4,700 piculs of sandalwood (313 tons) within 9 months; "At the same time the chiefs signed a second note, agreeing to pay 2,165 piculs [144 tons] of wood, which represented the balance due from their purchase of a vessel in February 1828" (Bradley 1968:113). These debt repayments, with the accompanying 12 percent interest, were not completely settled until 15 years later in 1843 (Tan 1951:12; Gast 1976:85).

In 1829, Boki, who was saddled with both his own debts and those of his dead brother Kalanimoku, outfitted two ships for a planned voyage to collect sandalwood in the New Hebrides (Vanuatu). The boats sailed in December of that year. Unfortunately for Bold, the seamen, and their families, the ill-fated expedition was a total failure. Boki and his ship were lost at sea. The remaining vessel suffered from scurvy and a shortage of food. Of the 500 men sailed under Boki's command, only 20 returned alive to Hawai'i in August 1830 (Wagner 1986:58).

In the late 1820's the market value of sandalwood on the Canton market dropped steadily, from approximate \$13 per picul in 1827 to \$10 in early 1828, and then down to between \$6 and \$8 in 1829; in the next 2 years the price declined drastically, and by the end of 1831 the wood sold for only "a dollar and a half a picul" (Bradley 1968:117). The amount of sandalwood arriving for sale in Canton aboard American vessels in the 1831-1832 season amounted to only 1,400 piculs, less than 15 percent of the quantity arriving the previous year (table 1).

The Hawaiian sandalwood trade did rebound somewhat during the first half of the 1830's. In 1836, \$26,000 worth of the wood was sold on the Canton market at \$7 per picul. However, by 1838, the total season sales in China for sandalwood harvested in Hawai'i was down again to only \$6,000. In 1839, with nearly all accessible trees gone, the King placed a *kapu* on the remaining sandalwood; permission was required to cut it, and two-thirds of the harvest was reserved for Kamehameha III (Judd 1926:4). By 1840 the Hawaiian sandalwood trade had, for most practical purposes, come to a halt, primarily because of the low quality of the remaining sandalwood in the islands, competition from sandalwood sources in India and the East Indies, and falling sandalwood prices on the Canton market (St. John 1947:9; Tan 1951:13; Bradley 1968:117).

In the 1850's, sandalwood was still being accepted as payment for taxes in Hawai'i, but the amount submitted was small and of poor quality. An attempt was made to sell Hawaiian "false

sandalwood" (*naio*) in Canton, but it was rejected by the Chinese merchants (Judd 1926:4), as it probably was more than a half a century earlier (see above).

THE IMPACTS OF THE SANDALWOOD TRADE

According to Bradley (1968:119) "The sandalwood trade was a picturesque and passing incident," and aside from the "destruction of the sandalwood forests," it contributed little to the economic gain of the Hawaiian chiefs or common people, and had only minor social consequences. The reported famine and unhealthy work conditions associated with the trade certainly cannot be dismissed so easily. Although the locally accrued profits may not have brought significant general benefits to the Hawaiian people, the commercial sandalwood trade and several other, often interrelated, cultural developments in early historic period (e.g., the arrival and growing influence of the Western missionaries) undoubtedly precipitated important social changes.

For many years it was widely assumed that the sandalwood trees had become extinct due to the exploitative harvesting that had occurred for more than 50 years (e.g., Kuykendall and Gregory 1926; Mesick 1934; Cartwright 1935; Smith 1956). However, it has long been known by some botanists, foresters, and other naturalists—and more recently by the general public—that the sandalwood species can still be found in Hawai'i. Nevertheless, except for some higher mountain areas, such as uplands in the Kona District of Hawai'i Island, the quantity of trees is generally much smaller than it was before the foreign trade.

The ecological impacts of removing the great majority of the sandalwood plants from the Hawaiian forests are not at all clear. According to Judd (1926:3), the "...damage to the forest consequent to the trade...was insignificant in comparison with the damage to the native forest wrought by cattle." As noted above, under natural conditions, the sandalwood species of Hawai'i are found in a mixed association with a number of other species, primarily in the drier forest regions; and, while the selective removal of *Santalum* trees did not remove the forests themselves, the exploitative harvesting processes may very well have opened the way for an unknown number of alien species to become established. Certainly the impacts of human harvesting and the unprecedented grazing and trampling by newly introduced ungulates (e.g., goats and cattle), as well as the possible negative consequences of the introduced seed predators (rats and mice), did not provide ecological conditions conducive to the regeneration of the native vegetation. Cattle grazing still hinders the regeneration of *Santalum* in some upland Kona forests.

SANDALWOOD SINCE THE DECLINE OF THE 19TH CENTURY TRADE

Although Hawaiian sandalwood trees were still extant after the extensive trade, it is believed that in many regions only the most remote trees were left uncut. In the earlier part of this century, the botanist Joseph Rock estimated that as much as 90 percent of the *Santalum* trees were removed during course of the

sandalwood trade (Hirano 1977:11). Unfortunately, without complete data on the status of *Santalum* populations after the trade ended, it is very hard to gauge their rates of recovery. A survey of the more recent distribution and status of the genus, however, provides some insight.

In 1926 Kuykendall and Gregory (quoted in St. John 1947:9) referred to the devastating effects of the sandalwood harvest and the status of the trees at that time: "The reckless way in which the trees were cut destroyed the forests. Very little effort was made to preserve the young trees or to replace those which were cut down. In a few years sandalwood almost disappeared from the islands. Even today, a hundred years after the trade was at its height, only a few small groves are to be found."

A little more than 40 years ago, St. John (1947:20) described the distribution of *Santalum* on O'ahu at that time, indicating that sandalwood was still "...common and widespread at its former upper limit, now the lower forest line on the lee side of the Ko'olau Range and on both sides of the Wai'anae Mountains." St. John also pointed out that some areas of the island had been affected more severely than others. He noted the absence of native sandalwood in the vicinity of Honolulu, which apparently was an area of extremely intense harvesting during the trade era. For example, Nu'uuanu Valley may have been totally cleared of sandalwood as early as 1825 (St. John 1947:15).

In 1951, sandalwood trees were found growing on the island of Hawai'i in the Hawai'i Volcanoes National Park below the Chain of Craters Road (Fletcher 1968:18). In 1955, it was reported that a large number of sandalwood trees had been discovered in Kona (Anon. 1955: A1). Although the trees were reported to number in the thousands, they were found on cattle grazing lands; and it was observed that "Seldom do we see a seedling or small tree" (Anon. 1955:3,1).

More recently for the island of Moloka'i, Stemmermann (1980:44-45) reported the location of several populations of *S. freycinetianum* in the mountains between 2,100 and 3,750 feet elevation.

Kaho'olawe, a much smaller island (45 mi²), probably supported populations of coastal sandalwood, *S. ellipticum*, in the lowland and inland higher regions (Skottsberg 1926; Lamoureux 1970); but the species is now presumed to be extinct on that island (Stemmermann 1977:126; 1980:42).

Maui has populations of at least three species of sandalwood (Stemmermann 1980:42). The Haleakala sandalwood, *S. haleakalae*, is endemic to the higher region of East Maui and one of the most endangered Hawaiian sandalwoods. There are probably only a few hundred individuals of this species left, with very few seedlings to be found (Kepler 1985). This species needs special, immediate protection from alien organisms.

Besides the coastal sandalwood, the island of Lana'i has an endemic variety of the Freycinet sandalwood, *S. freycinetianum* var. *lanaiense*, known as the "Lana'i sandalwood." According to the U.S. Fish & Wildlife Service, only 39 individuals are known to exist, making the Lana'i sandalwood one of Hawai'i's most endangered taxa; only one sapling has recently been observed (U.S. Fish & Wildlife Service 1985:9086-9).

PROPAGATION AND FORESTRY EFFORTS

The earliest recorded attempt to grow Hawaiian sandalwood was undertaken by Dr. William Hillebrand, an avid botanist and horticulturist, sometime between 1851 and 1871 (Hirano 1977). Although numerous species of trees and shrubs which he planted on his Honolulu homestead can still be seen at the site—now known as the Foster Botanic Gardens (part of the Honolulu Botanic Gardens)—Hillebrand was not successful in his efforts with sandalwood; he attributed the problem to the parasitic nature of the species and indicated that "...all attempts to cultivate them in [his] garden have failed" (Hillebrand 1965).

In 1903, the Territorial Division of Forestry was formed. Under the direction of this agency, the first modern forest reserve system was established in the Hawaiian Islands. A major objective was to improve watershed conditions by removing alien ungulates and replanting large areas of uplands that had been degraded by cutting, burning and overgrazing activities, including those associated with the earlier sandalwood trade. The Division of Forestry also began the development of commercial forestry and some native plant propagation and protection (Daehler 1989:7). As a result of fire suppression and the removal of introduced grazing animals, some populations of native sandalwood on these protected lands made small comebacks in the first three decades of this century (Judd 1936b:82).

In the early 1930's, Indian sandalwood was selling for as much as \$500 a ton in New York. With this information in mind, Judd (1936a:83) argued that "...pound for pound [sandalwood] is, therefore, the most valuable wood in the world;" Judd also indicated that the Territorial Forest Service was trying "...to determine the best methods of increasing the number of growing trees" of *S. album* in Hawai'i. The Forest Service had begun importation of *S. album* seeds from India in 1930 and 1931 (Fletcher 1968:18); however, the trees proved to be difficult to raise. Nevertheless, by 1935, an experimental grove of over 1,500 plants was growing on the ridge 750 feet above sea level on Wa'ahila ridge near Honolulu. This early success in cultivation was attributed to the attention paid to sandalwood's need for a host plant, without which the seedling perished before reaching the end of its first year. The Wa'ahila grove was planted with two kinds of host plants, *Acacia koa* and *Casuarina equisetifolia*, 6 months before the Indian sandalwood seedlings were placed there. Subsequently it was learned that these hosts could be raised alongside newly sprouted sandalwood plants while they were still in the nursery, and then transplanted together. According to the chief of the Forest Service, C.S. Judd (1936a:83), "Planting by this method has attained 100 per cent success." This early success led Judd (1936b) to pen an article in the Honolulu Star Bulletin titled "Sandalwood, Once the Gold Mine of Hawai'i, is Coming Back." Seeds of the native sandalwood, *S. freycinetianum*, were also tried, but they would not germinate. Judd (1935; 1936b:83) blamed this failure on a fungus which apparently altered the viability of the seeds in fly-damaged fruits.

The economic potential of cultivating sandalwood continued to be a topic of discussion for many years. At least as late as 1949, about 500 Indian sandalwood trees were being planted per

year (Anon. 1946:9; Anon. 1949:6).

Unfortunately, the early success of Indian sandalwood propagation did not lead to a new source for the fragrant wood. The trees were found to be very slow growing, not reaching reproductive maturity until they were 40 to 60 years old. Furthermore, nearly all trees died with 10 to 15 years after germination and the few trees that did survive attained trunk diameters of less than 6 inches after 24 years of growth; these survivors would have yielded only a small amount of the valuable heartwood. This planting experiment with the alien *Santalum* did little in Hawai'i to encourage further forestry efforts involving cultivation of sandalwood for commercial purposes (Daehler 1989:1,8).

After these early attempts at Indian sandalwood propagation, most of the *Santalum* planting efforts in Hawai'i have been mainly the result of interest in Hawaiian history and native plants (Daehler 1989:8). In 1961, the Foster Botanic Gardens participated in an effort to plant native sandalwoods in windward O'ahu parks (Anon. 1961:A3). In the mid-1970's, the Lyon Arboretum of the University of Hawai'i at Manoa undertook research involving the propagation of three species of sandalwood species: the alien *S. album*, and two endemic species, *S. haleakalae* and *S. paniculatum*. This research focused on seedling germination and growth (Hirano 1977).

More recently, the bicentennial celebration of the arrival of the first Chinese immigrants to Hawai'i has stimulated renewed interest in planting sandalwoods. Frank Y.F. Lee, president of the Lee Family Association of Hawai'i, in cooperation with Herbert Kikukawa of the State Forestry and Wildlife Division, collected sandalwood seeds on Oahu in 1988. These were distributed to horticulturists at Foster Botanic Garden, Lyon Arboretum, and Waimea Arboretum (Taylor 1989:B1). On Kaua'i, the Kaua'i County Chinese In Chinese Bicentennial Committee conducted a preplanting project for sandalwood at Iliu Nature Loop in the Pu'u Ka Pele Forest Reserve during January 1989 (Daehler 1989:1).

RECENT SANDALWOOD HARVESTING AND COMMERCIAL TRADE

In fall 1988, native sandalwood made another appearance in the local media. In upland areas of the Kona District standing trees and fallen trunks of *S. paniculatum* were being harvested for shipment to a Hong Kong market. Advocates and detractors of the sandalwood logging and sale soon began debating the impact of this commercial activity. The controversy centered around the Hokukano Ranch (formerly the W.C. Greenwell Ranch) on the slopes of Mauna Loa above Kealahou on the island of Hawai'i. It was reported that since the ranch had changed ownership in July 1987, as many as 1,700 logs of native sandalwood trees may have been harvested; and an estimated 300 tons of the wood was shipped to China at a reported price of \$2 per pound (TenBruggencate 1988b:A4). At this price and poundage, the harvest could have grossed over \$1,000,000! However, Thomas Pace, the manager of Hokukano Ranch, later claimed that they made only \$40,000 from their sandalwood sales (TenBruggencate 1988a:A6).

In a critical response to the recent sandalwood harvesting,

environmentalist Deborah Ward (1988:4) of the Sierra Club's Hawai'i Island Chapter published a "Viewpoint" article in the Hawai'i Tribune-Herald headlined "The tragic logging of isle sandalwood trees." A number of the statements in her article, such as those describing the relationship between the sandalwood trees and rainfall, length of sandalwood logs, and value of individual harvested trees, were later pointed out to be exaggerations or outright errors. In addition, the land from which the Kona trees were recently harvested is private property, apparently used to graze cattle for many decades (Harada-Stone 1988). This contradicts Ward's allegation that the sandalwood harvesting was taking place in "virgin forests of sandalwood" (Ward 1988). Regardless of the inaccuracies in her article, Ward probably expressed an attitude of serious concern that many residents in the islands have regarding the possible environmental and cultural impact of a renewed, ongoing sandalwood trade.

At a legislative hearing in Kailua, Kona, on September 29, 1988, logger Albert Remmy claimed that young sandalwood plants were growing "all over the place" in the vicinity of the logging operations (Harada-Stone 1988:10). But if the areas referred to are still used as pasture lands, it is unlikely that Remmy was correct. As noted above, however, the manager of Hokukano Ranch has indicated that the cattle and other alien ungulates have been fenced out in the area where the logging took place. In any case, cattle can quickly destroy sandalwood seedlings, either as a result of their grazing or trampling activities.

There are number of potential negative impacts associated with the removal of the large sandalwood trees from upland pasture lands in Kona. The mature, living trees are a needed source of seeds for seedling regeneration of the sandalwood (rather than that which can occur by coppicing or root sucker development). The seeds of *Santalum* are also a food source for native birds and other animals. The remaining, relatively large numbers of standing sandalwoods in the upland ranch lands are unique, but depleted due to many years of cattle grazing. Large numbers of fallen trunks and limbs lie on the ground; many are rotting. Remmy noted from his own logging experience that "...there isn't a good stand of sandalwood anywhere on the island." (Harada-Stone 1988:10). However, even the harvesting of fallen, dead or dying trees could have a negative ecological impact on native organisms, especially insects. For example, they serve as habitat for endemic long-horned beetles. Furthermore, James Juvik, Professor of Geography, has pointed out that forest vegetation provides essential watershed protection necessary for sustainable lowland development (Harada-Stone 1988).

THREATS TO THE SURVIVAL OF THE SANDALWOOD SPECIES

Diverse contemporary dangers threaten the survival of the native sandalwood species in Hawai'i. Some of these present or potential threats have plagued *Santalum* during both the prehistoric and historic periods. All of the threats described below can be either directly or indirectly associated with human activities.

Harvesting

Harvesting of sandalwood undoubtedly began during the prehistoric human period as early Polynesians cut sandalwood to obtain the fragrant, medicinal, and ritualistic materials the woody plants provided. Although the huge volume of logging that occurred during the early 19th Century sandalwood is evidence of the vast numbers of trees that still existed at the time of western contact, it has been suggested that the prehistoric human impact on *Santalum* was significant and widespread in Hawai'i, especially in the drier lowland areas. In addition to the rapacious early historic harvesting, we have also referred to the very recent logging on the island of Hawai'i that has occurred within perhaps the only groves of substantially large and numerous sandalwood trees. Also, along with the actual cutting and removal of the logs, damage results from the movements of vehicles and machinery needed to harvest and transport the wood.

Fire

Selective cutting of sandalwood during the prehistoric human period (lasting approximately 1,500 years) probably had less impact on the distribution and quantities of the *Santalum* species than the use of fire. As noted earlier, prehistoric use of fire converted extensive dry forest areas into anthropogenic grasslands. This process probably resulted in a large loss of sandalwood trees, along with the destruction of numerous other native woody species. Man-made fires have also affected Hawaiian forest areas during the historic period. At least some of the common Hawaiian people reportedly used fire in their obligate search for acceptable sandalwood during the early 19th century (St. John 1947). Increase in the human population intensifies the possibility of intentionally or accidentally set fires which might further reduce the number of sandalwood trees in some areas. A recent fire in the North Kona area near Pu'uwa'awa'a probably resulted in the destruction of some *Santalum*.

Conversion of Forest Lands to Agricultural Areas

Clearing of forest to grow crops has been a major threat to sandalwood at low elevations ever since the first humans arrived in the Hawaiian Islands. Over the past two centuries, the development and expansion of commercial agriculture and ranching has eliminated many areas where sandalwood was part of the former forest. On the island of Lana'i, for example, approximately 90 percent of the native vegetation has been destroyed by direct and indirect human activities, and the native dry forest has been removed almost entirely—much of it cleared to make way for pineapple cultivation (U.S. Fish & Wildlife Service 1985).

Alien Ungulates

Cattle, goats, and deer all readily eat sandalwood foliage. Cattle also damage the plants by trampling the ground over their shallow root systems (Judd 1933). The impact of cattle and other

mammalian herbivores in the remaining sandalwood groves (e.g., the upland Kona forests) must be curtailed if regeneration of *Santalum* is to continue in these important refugia. Recent observations of areas containing *S. paniculatum* in the uplands of Kona by foresters with extensive field experience involving sandalwood ecology are encouraging. Where fencing has been put in place and the alien ungulates have been excluded from areas with sandalwood, regeneration in the form of seedlings, coppicing, and root suckers, proceeds effectively (Grahame Applegate, Research Officer, Queensland Forest Service, personal communication, 1990).

Alien Rodents

Rats and mice are voracious consumers of sandalwood seeds. In the case of both the Lana'i sandalwood (*S. freycinetianum* var. *lanaiense*) and the Haleakala sandalwood (*S. haleakalae*), introduced rats and mice have virtually eliminated reproduction of new trees (U.S. Fish & Wildlife Service 1985; Kepler 1985).

Diseases

Sandalwood is apparently plagued by several diseases in Hawai'i. Judd (1936a) referred to a fungus affecting the viability of sandalwood seeds; he also called attention to a "spike disease" which did considerable damage to *S. album* in India and may have been introduced to Hawaii. A newspaper account of the Hokukano Ranch manager regarding diseased sandalwood trees on property between 4,500 and 6,500 feet above sea level: "Many trees, standing and down, displayed a severe heart rot from the base into the upper parts of the tree" (TenBruggencate 1988a).

Banana Poka

The alien weed banana poka is a very aggressive passion fruit vine (*Passiflora mollissima*) that climbs over most other plants in the forest areas it invades. Its dense growth eventually covers whole sections of the forest, shutting out sunlight and thus greatly affecting the lives of other species. It already infests approximately 350 acres on Maui, 12,000 acres on Kaua'i, and 85,000 acres on the island of Hawai'i! A recently proposed control measure involves the use of cattle to help remove the weedy vines. This would probably do a considerable amount of further damage to the sandalwood in the affected forests since the bovines are especially fond of *Santalum* seedlings (TenBruggencate 1990).

Poor Germination Rates

Several possible causes for the low viability of sandalwood seeds have been offered, including the loss of native pollinators - both birds and insects (Kepler 1985) and disease (Judd 1936a).

Off-road Vehicles

Use of off-road vehicles have had a negative impact on many of the native Hawaiian coastal plants. For example, until recently Ka'ena Point, O'ahu, was heavily used by off-road vehicles which severely damaged the native plants there, including the low lying *Santalum ellipticum*.

CURRENT AND PROPOSED CONSERVATION MEASURES

Several suggestions have been offered concerning the conservation and resource management of Hawaiian sandalwood species, including the following:

1. *Moratorium on the Cutting of Sandalwood Trees*: A moratorium was proposed in September 1988 by State Representative Virginia Isbell to provide the State of Hawai'i with sufficient time to inventory the quantity of healthy sandalwood trees (Hosek 1988).

2. *Changes in Zoning and Tax Incentives*: A change in the zoning designation of those private lands containing populations of sandalwood from "agriculture" to "conservation" would give the State of Hawai'i power to regulate the removal of trees. This could offer a means of protection for the Kona stands of *Santalum*. Tax incentives might motivate ranchers to separate cattle (and other alien ungulates) from the sandalwood plants. Proper fencing and trapping could help natural regeneration of the woody plants.

3. *Private Preserves*: Private preserves could be set up and managed by the land owners themselves, or they could be developed and administered by other organizations such as the Nature Conservancy or other private groups. Motivated by the Kona logging controversy of 1988, the Hokukano Ranch decided to set aside the upper 3,000 acres of the ranch (between 4,500 and 6,500 feet elevation) as a natural area under its own supervision. Probably the most beneficial conservation measure involved in this action is the exclusion of cattle from the area through use of fences. The ranch management has also paid hired help to collect sandalwood seeds. These seeds have been cultivated in "a nursery for eventual planting back in the sandalwood forest;" germination rates are reportedly about 30 percent (TenBruggencate 1988a).

4. *Purchase and/or Management of Natural Areas*: Castle and Cooke recently gave the Nature Conservancy a perpetual conservation easement over a 500-acre site in Kanepu'u, the last remaining native dry forest area on the island of Lana'i. One of the two last stands of Sandalwood (*S. freycinetianum* var. *lanaiense*) is located within the Kanepu'u area, which has a relatively large number of endemic species.

5. *Use of the Endangered Species Act of 1973*: Official listing of species under the federal Endangered Species Act of 1973 provides protection for species in serious danger of becoming extinct. Presently only one taxon of Hawaiian sandalwood has even been proposed for official listing under the Act. In 1985, the U.S. Fish & Wildlife Service filed to have the Lana'i sandalwood listed as an endangered species (see above, U.S. Fish & Wildlife Service 1985). In the future, appropriate taxa of

Hawaiian *Santalum* may be proposed for this special kind of protection.

SUMMARY

For many centuries the heartwood of the Hawaiian sandalwoods has been a valuable natural product. It was used for a variety of purposes in the traditional Hawaiian culture. However, huge numbers of the trees probably perished in the prehistoric period due to cutting and burning. Extensive alteration of some natural ecosystems in Hawai'i began long before Western contact in the late 18th century. The sandalwood populations below 1,500 feet elevation must have declined drastically as a result of the wide-ranging development of agricultural systems in both the wet and dry lowland areas. Nevertheless, early written descriptions of Hawai'i indicate that vast forests still existed in the uplands of the main islands when the first Europeans arrived. The international trade of the early 19th century was not just "a picturesque and passing incident" in the history of Hawai'i as Bradley (1968) has suggested. It was the first major phase in the transformation of the Hawaiian economy from subsistence to commercial orientation. It brought much superficial wealth to the ruling class of native peoples, but inflicted considerable hardship upon the more populous common people.

From an ecological point of view, the sandalwood trade was disastrous, for many native organisms including the *Santalum* species it meant severe declines in actual number or habitat. Although the impact of alien hoofed mammals was almost certainly more harmful to the upland native forests of Hawai'i, we should not overlook the environmental changes that were directly produced by human interference associated with the sandalwood trade. Literally thousands of Hawaiian people went into the various forests to search for and destroy sandalwood trees to deliver their quotas of the fragrant heartwood.

The *Santalum* genus in Hawaii did not become extinct as a result of the intense and far reaching harvest of the early 19th century as has been widely believed; but drastic reductions in the sizes of the species populations and significant declines in the quality of the trees most definitely did occur in most areas. Since the cessation of the 19th century, sandalwood trade the species of *Santalum* have recovered to some degree and can be commonly found in a few areas. One species *S. paniculatum* can still be found in relative abundance in some upland areas of Kona on the island of Hawai'i. These remaining "groves" have recently become the focus of a renewed and controversial economic activity.

To a large degree, the future of *Santalum* in Hawai'i depends upon a combination of factors. These include the vicissitudes of the sandalwood markets (especially abroad), public acceptability of further cutting and export of the native wood, and government decisions concerning conservation of the species for a number of potential economic and non-economic benefits—such as their inherent right to exist and role as habitat and food source for other native species.

The history of human impact on the Hawaiian sandalwoods has not yet come to an end. The native Hawaiian biota is unique

and renowned for its remarkable endemism. As one of the greatest "living museums" of evolutionary biology, the Hawaiian native ecosystems and their special flora and fauna are worth our serious consideration. Any further economic development within those Hawaiian environments containing the less common, rare, threatened, or endangered species should be done with great care and the fullest possible understanding of what the ecological consequences will be.

REFERENCES

- Alexander, W.D. 1906. The story of Cleopatra's barge. Hawaiian Historical Society Paper. No. 13.25-31.
- Anon. 1961. Drive to plant trees in Windward parks. Honolulu Advertiser. March 22. A3, 1.
- Anon. 1955. Sandalwood discovery on Big Island told. Honolulu Advertiser. February 18, A1, 3.
- Anon. 1949. Sandalwood has failed to make a comeback. Honolulu Advertiser. November 13, 6.
- Anon. 1946. New era for sandalwood. Honolulu Star-Bulletin. April 18, 6.
- Bradley, H.W. 1968. The American frontier in Hawaii: The Pioneers 1789-1843. Gloucester, Mass.: Peter Smith.
- Buck, P. 1964. Arts and crafts of Hawaii - Sec. 9: Musical Instruments. Honolulu: Bishop Museum Publication 45.
- Burrows, C. 1989. Hawaiian conservation values and practices. In: Stone, C.P. & D.B. Stone (Editors) Conservation biology in Hawaii; 203-213. University of Hawaii Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, Honolulu, Hawaii.
- Carlquist, S. 1980. Hawaii: A natural history. Kaua'i, Hawaii: Pacific Tropical Botanical Garden.
- Cartwright, Bruce. 1935. Extinction of trees soon followed the sandalwood rush—Hawaii's unhappy first export trade. Honolulu: Paradise of the Pacific; 21-23.
- Daehler, R.E. 1989. Tahn Heong Sahn - The sandalwood mountains. Forest Management Note, Kaua'i, No. 89-1. Hawaii DLNR, Division of Forestry and Wildlife.
- Daws, G. 1968. Shoal of time: A history of the Hawaiian islands. Honolulu: University of Hawaii Press.
- Delano, A. 1818. A narrative of voyages and travels. Boston, Mass.: E.G. House.
- Edwards, Webley. 1951 September 9. The Fragrant Wood of Hawaii. Honolulu Advertiser, Weekly Magazine Section 7.
- Ellis, W. 1969 (orig. 1842). Polynesian researches, Hawaii. Rutland, Vermont: Charles E. Tuttle Co.
- Fletcher, W.B. 1968. New hope for the sandalwood. National Parks Magazine. 42(255):16-18.
- Gast, R.H. 1976. Contentious consul: A biography of John Coffin Jones. Dawson's Book Shop. Los Angeles.
- Gutzlaff, C. 1834. A sketch of Chinese history, ancient and modern. Vol. II. London: Smith, Elder, and Co.
- Harada-Stone, D. 1988. Sandalwood logging defended, ripped at special Kona hearing. Hawaii Tribune-Herald, September 30, 1, 10.
- Hillebrand, W. F. 1965. (orig. 1888). Flora of the Hawaiian islands. New York: Hafner Publishing Co.
- Hirano, R.T. 1977. Propagation of *Santalum*. Sandalwood Tree Plant Propagator 23(2):11-14.
- Hosek, L. 1988. Sandalwood forests mystify scientists. Honolulu Star-Bulletin, September 29, A4.
- Imada, C.T.; Wagner, W.L.; Herbst, D.R. 1989. Checklist of Native and Naturalized Flowering Plants of Hawaii. Honolulu: Bishop Museum Occasional Papers. Vol. 29.
- Judd, C.A. 1926. The natural resources of the Hawaiian forest regions and their conservation. Territorial Division of Forestry. Unpublished manuscript. 8 p.
- Judd, C.A. 1933. The Parasitic Habit of the Sandalwood Tree. Thrum's Hawaiian Annual; 81-88.

- Judd, C.S. 1935. Reviving the Sandalwood Industry. *Paradise of the Pacific* 47(4): 2.
- Judd, C.S. 1936a. Growing Sandalwood in the Territory of Hawaii. *Journal of Forestry* 34(1): 82-83.
- Judd, C.S. 1936b. Sandalwood, once the goldmine of Hawaii, is coming back. *Honolulu Star-Bulletin*, February 8, sec. 3, 1.
- Kelly, M. 1970. Some aspects of land alienation in Hawaii. *Hawaii Pono Journal* 1(1): 6-12.
- Kepler, A.K. 1983. *Hawaiian Heritage Plants*. Honolulu: Oriental Publishing Company.
- Kepler, A.K. 1985. Sandalwood: Hawaii's precious 'iliahi. *Mauian*. 2(6): 6-11.
- Kirch, P.V. 1982. Transported Landscapes. *Natural History* 91(12): 32-35.
- Kirch, P.V. 1984. *The evolution of the Polynesian chiefdoms*. Cambridge: Cambridge University Press.
- Kittelson, D. 1982. Role of Hawaiians in the fur trade. *Honolulu Advertiser*, January 20, B1.
- Kotzebue, O. 1830. *New voyage round the world*. London: Colburn & Bentley Publishers. Vol. 2.
- Krauss, Beatrice H. [n.d.]. *Ethnobotany of Hawaii*. Honolulu: University of Hawaii, Department of Botany; 246 p. Unpublished manuscript.
- Kuykendall, R.S. 1938. *Hawaiian kingdom, 1778-1854*. Honolulu: University of Hawaii Press.
- Kuykendall, R.S.; Gregory, H.E. 1926. *A history of Hawaii*. New York: Macmillan.
- Lamoureux, C.H. 1970. Plants recorded from Kahoolawe. *Hawaiian Botanical Society Newsletter* 9:6-11.
- Little, E.L.; Skolmen, R.G. 1989. *Common Forest Trees of Hawaii (Native and Introduced)*. U.S. Dept. of Agriculture & Forest Service, Agri. Handbook No. 679.
- Lydgate, J.M. 1916. Sandalwood days. *Thrum's Hawaiian Annual*.
- Mesick, L.S. 1934. *The kingdom of Hawaii*. Honolulu: Porter.
- Olson, S.L.; James, H.F. 1982. Fossil birds from the Hawaiian islands: evidence for wholesale extinction by man before Western contact. *Science* 217:633-635.
- Press, M.C. 1989. Autotrophy and heterotrophy in root hemiparasites. *Tree* 4(9): 258-60.
- Rock, J.F. 1916. The sandalwoods of Hawaii. *Hawaii Territorial Board of Agriculture and Forestry, Botanical Bulletin* 3:9-43.
- Skottsberg, C. 1926. Hawaiian vascular plants I. *Acta Horti Gothob.* 5:135-145.
- Smith, J.G. 1956. Sandalwood and whales. *Honolulu Advertiser*, May 13, A4.
- Stemmermann, R.L. 1980. Observations of the Genus *Santalum* (Santalaceae) in Hawaii. *Pacific Science* 34(1): 41-54.
- Stemmermann, R.L. 1977. Studies of the vegetative anatomy of the Hawaiian representative of *Santalum* (Santalaceae), and observations of the genus *Santalum* in Hawaii. Unpublished Master's thesis for Botany Department, University of Hawaii.
- St. John, H. 1947. The history, present distribution, and abundance of sandalwood on Oahu, Hawaiian Islands: *Hawaiian Plant Studies* 14. *Pacific Science* 1(1): 5-20.
- Tan, P. 1951. A historical survey of Sino-Hawaiian trade. Masters Thesis. University of Hawaii.
- Taylor, L. 1989. Sandalwood's return timed for Chinese bicentennial. *Honolulu Star-Bulletin*, January 9, B 1.
- TenBruggencate, J. 1990. Wild cattle might be used to stem banana poka. *Honolulu Star-Bulletin/Advertiser*, February 25, D4.
- TenBruggencate, J. 1988a. Salvaging Mauna Loa's historical sandalwood crop. *Honolulu Star-Bulletin/Advertiser*, October 2, A3, 6.
- TenBruggencate, J. 1988b. Private sandalwood logging has state upset. *Honolulu Star-Bulletin/Advertiser*, September 27, A3.
- Thrum, T.G. 1905. The sandalwood trade of early Hawaii as told by pioneer traders, voyagers, and others. *Thrum's Hawaiian Annual*.
- U.S. Fish & Wildlife Service 1985. Endangered and threatened wildlife and plants: proposed endangered status for *Santalum freycinetianum* Guad. var. *lanaiense* Rock (Lanai sandalwood or 'iliahi). *Fed. Reg.* 50(44): 9086-9089.
- Wagner, J.P. 1986. The rape of the fragrant trees. *Honolulu Magazine*, November, 97 ff.
- Wagner and others. 1990. *Manual of Flowering Plants of Hawaii*, Vol I and II. Honolulu: Bishop Museum Press.
- Ward, D. 1988. Viewpoint: The tragic logging of isle sandalwood trees. *Hawaii Tribune-Herald*. September 25, 4.
- Ward, R.G. (Ed). 1972. *Man in the Pacific islands: essays on geographical change in the Pacific islands*. London: Oxford University Press.
- Zimmerman, E.C. 1972. Adaptive radiation in Hawaii with special reference to insects. In Kay, E.A. (ed.) *A Natural History of the Hawaiian Islands*. Honolulu: University of Hawaii Press, 528-535.