Introduction and Spread of Mangroves in the Hawaiian Islands

LYNDON WESTER*

THE TERRESTRIAL FLORA of Hawaii was derived from a small number of ancestral species as a result of the archipelago's remote location. Great expanses of open ocean separate Hawaii from continents and other islands, and thus water has acted as an effective barrier even to many widespread drift species whose propagules can float and withstand long immersion in seawater. The intertidal zone in Hawaii lacked vascular plants entirely despite the availability of habitats suitable for many of them (Guppy 1906, Egler 1942). The introduction and subsequent naturalization of mangroves and other exotic species has produced significant changes in the coastal environments.

Mangroves are opportunist trees that colonize the tidal zone of tropical coasts. The most extensive stands occur on aggrading shores which receive sediments from large drainage systems, but small colonies also can be found on limestone coasts, coral atolls, sand beaches, and lagoons, suggesting that protection from wave action, rather than the presence of fine sediments, is a prerequisite for seedlings to take root (Sauer 1976).

*Dr. Wester is an associate professor, Department of Geography, University of Hawaii, Honolulu, HI 96822.

About 50 mangrove species, belonging in some 12 families, include remarkable cases of possible convergent evolution. Seedlings of all mangrove species are well adapted for dispersal over oceans but, under natural conditions, none were successful in colonizing the islands of the central Pacific (Hawaii, Society, Marquesas, etc.). The taxa of the so-called eastern mangroves of Indo-Malaysia are, with one exception, made up of different species from the western mangroves of tropical America and West Africa. Only *Rhizophora mangle* L., the most common tropical American species, is also found in the eastern mangrove region, notably in Fiji, Tonga, and New Caledonia (Salvoza 1936, p. 199; Hou 1960).

The Introduction of Mangroves into Hawaii

The history of the introduction of exotic organisms is usually incomplete. The record of mangroves in Hawaii has been especially confused. Of the seven introduced taxa, only two are currently maintaining themselves (Table 1). *Rhizophora mangle* is the most common species in Hawaii, and the majority of mangrove communities are dominated by it. The American Sugar Company (Molokai Ranch Co.) first introduced the species in 1902 and planted it on Molokai in the belief that it would retain sediment from the eroded southern slopes of the island and supplement the honey flora (MacCaughy 1917, Degener 1940). Seedlings were intentionally transplanted from Molokai to Oahu (for reasons unknown) and have since volunteered elsewhere, including places on the islands of Hawaii, Maui, Lanai, and Kauai (Fig. 1).

The Hawaiian Sugar Planter's Association made two attempts to introduce Old World species from the Philippines. The first, in 1908,

Table 1. Mangrove species in the Hawaiian Islands[1]

Species	Date	Origin	Comment
Rhizophora mangle	1902	Florida	Abundant
R. mucronata	1922	Philippines	Last recorded 1928
Bruguiera gymnorhiza	1922	Philippines	Established
B. parviflora	1922	Philippines	Last recorded 1948
Ceriops tagal	1922	Philippines	Last recorded 1922
Conocarpus erectus	Before 1910	Florida?	Cultivated
C. erectus var. *sericeus*	1946	Bahamas	Cultivated

[1]Dates of introduction and last record were obtained from MacCaughy (*op. cit.*), accession records of the Hawaiian Sugar Planter's Association, and herbarium records.

THE OCCURRENCE OF MANGROVES IN THE HAWAIIAN ISLANDS

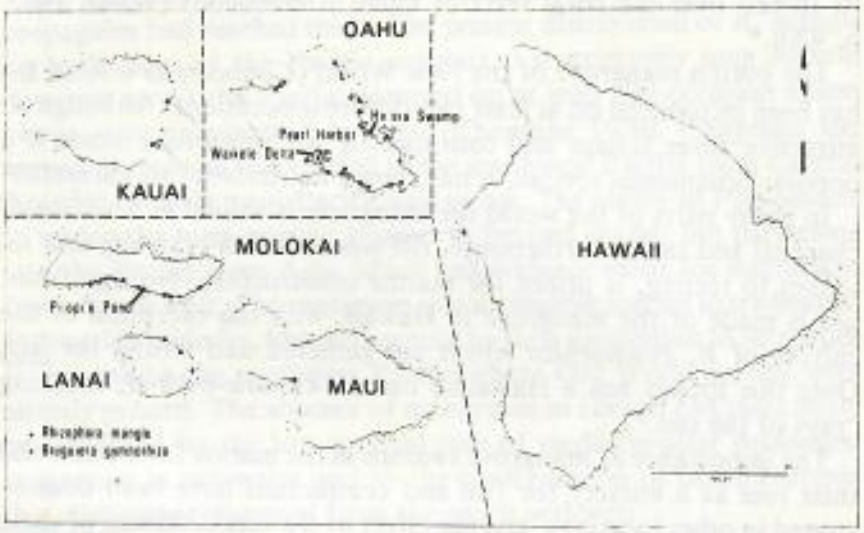

Figure 1. The occurrence of mangroves in the Hawaiian Islands. Locations indicated are based on herbarium specimens, direct observation, or air photo interpretation.

was unsuccessful, but in 1922 the association obtained material of four species [*R. mucronata* Lam., *Bruguiera gymnorhiza* (L.) Lam; *B. parviflora* (Roxb.) Wight & Arn. ex Griff., and *Ceriops tagal* (Perr.) C. B. Rob], which were planted on mud flats around Oahu in the hope of reclaiming them (Degener 1945). Of these species, only *B. gymnorhiza* has become established and is found in several localities around Oahu (Fig. 1). Although the species is generally regarded as an extreme pioneer, in Hawaii it produces relatively few seeds that do not spread far from the parent plant, so it is far less effective than *R. mangle* in the colonist role (Fosberg 1948). *Bruguiera parviflora* was observed and collected from He'eia Swamp on a number of occasions until 1948 but is no longer present. Apparently *R. mucronata* germinated successfully and persisted at least until 1928, when it was last collected (Salvoza 1936, p. 217), but has since disappeared. The introduction of the fourth species, *Ceriops tagal,* was a complete failure since no trace of it has been found since the seed accession record.

The reported introduction of *Sonneratia caseolaris* (L.) Engl. and its spread over the coral reefs of Oahu is erroneous (Walsh 1967, p. 420).*

The button mangrove of the New World (*Conocarpus erectus* L.) has been introduced on at least two different occasions. Although its attractive silver foliage and tolerance to salt spray have made it a popular ornamental species, it has shown no tendency to naturalize.

In many parts of the world the mangrove is valued as a source of charcoal and tanin; furthermore, the wood, which is strong and resistant to rotting, is prized for marine construction. No significant use is made of the mangrove in Hawaii, with the exception of the calyces of *B. gymnorhiza* which are gathered and strung for leis. Only this species has a Hawaiian name—*kukuna-o-ka-lā*, meaning "rays of the sun."

The importance of mangrove swamps in the marine food chain and their role as a nursery for fish and crustaceans have been demonstrated in other locations, and the effect of the establishment of these swamps on the marine ecosystems of Hawaii is worthy of attention (Walsh et al. 1975).

Mangrove Habitats

The porous basaltic lavas that form the high islands of the Central Pacific allow rapid infiltration of precipitation, so there is little surface runoff especially when the natural vegetation cover remains undisturbed. Wave action is sufficient to remove most of the sediments that are washed into the ocean, allowing few opportunities for the development of shallow mud flats or extensive estuarine mangrove swamps. However, the Hawaiian Islands possess a variety of sites able to support small mangrove stands. These include shores well protected by reefs, embayments, lagoons, and anchialine pools near the shoreline and subject to tidal influence. Although no section of the coast has escaped human modification, suitable habitats undoubtedly existed before the human discovery of the islands.

*The statement regarding *Sonneratia* arose from a misunderstanding of a verbal statement by M. Doty, Department of Botany, University of Hawaii (personal correspondence).

These habitats could have been colonized by mangrove if viable propagules had reached them. The present distribution of *R. mangle* on both sides of the Pacific suggests that extremely long natural dispersal across the Pacific occurred on at least one occasion unless plants were transported by man (Chapman 1970). Chapman has argued *R. mangle* was carried to the southwest Pacific from Central America by early trans-Pacific navigators. The ability of Polynesians to undertake long oceanic voyages is beyond doubt, but they came into the Pacific from Asia. Much less evidence exists for migrations from east to west. The mangrove was a valuable species in traditional Polynesian societies, but there would be little motivation to introduce *R. mangle* to the southwest Pacific where Old World species were already present. The absence of mangroves in Hawaii can most likely be explained by the low survival rate of seedlings after prolonged immersion in salt water and by the configuration of ocean currents that discourage dispersal from the south and west.

The Mangrove Community

He'eia Swamp, occupying 35 acres on the windward coast of Oahu, has a diversified and persistent mangrove community that has been the subject of several biological studies (de Ausen 1966, Walsh 1967, Lee 1971). Runoff from the Koolau Mountains is channeled through He'eia Stream into a grassy freshwater marsh once used for taro cultivation and later as a rice paddy. Salt water penetrates up the stream mouth and through openings in a fish pond wall which flanks the landward side (Fig. 2). Two belt transects were constructed across accessible parts of the swamp, one at right angles to the stream and one to the shore. All species in each square meter were noted.

Rhizophora mangle predominates along stream edges, where it grows tallest (up to 12 meters) and forms a dense canopy without understory. With increasing distance from the ocean shore or stream-side, trees become progressively smaller, the canopy more open, and *Bruguiera gymnorhiza* takes a dominant role in association with occasional *Pluchia indica* (L.) Less, *Batis maritima* L., *Acrostichum aureum* L., and *Thespesia populnea* (L.) Soland. ex Correa. On berms and elevated margins of the swamp subject to less frequent inundation *T. populnea*, *Hibiscus tiliaceus* L., *Schinus terebinthifolius*

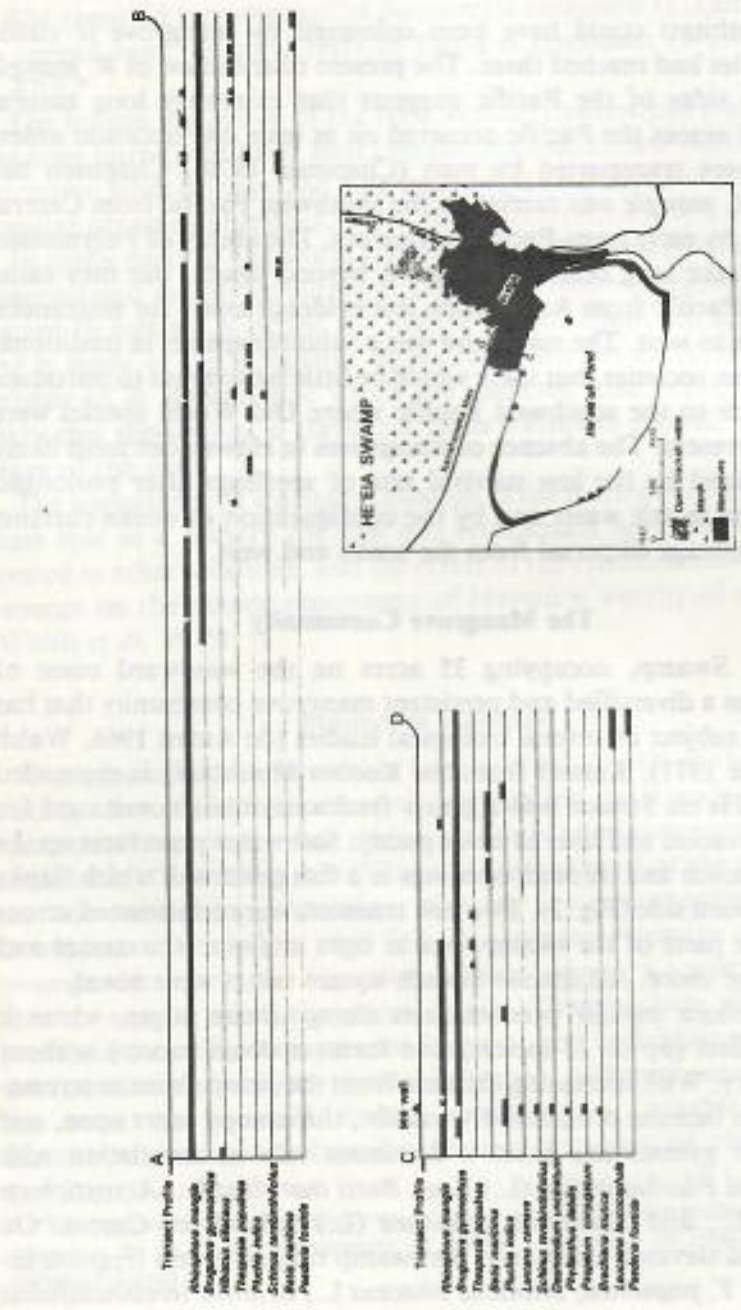

Figure 2. Composition of mangrove communities in the He'eia Swamp, Oahu. Species present in each square meter of belt transects A-B and C-D are indicated.

Raddi, *Lantana camara* L., and *Leucaena leucocephala* (Lam.) de Wit are found, with a few herbs and the vines *Paederia foetida* L. and *Ipomea alba* L.

Where tall trees are cut back from a bridge to prevent fouling, the lower growing *B. gymnorhiza*, *T. populnea*, and *H. tiliaceus* flourish. This would suggest that the success of *R. mangle* in areas frequently inundated by tidewater may be explained by competition for light, since the *Rhizophora* can grow taller and possibly more rapidly than its associates. Attenuated, mature specimens of *T. populnea* and *H. tiliaceus* are encountered occasionally under a mangrove canopy and may be remnants of an earlier littoral community that has been replaced in part by the spread of the mangrove.

Areas of unvegetated shallow water or mud flat have never been extensive in Hawaii, but they are important feeding grounds for water birds. Some of the coastal zone has been reclaimed for urban or industrial use, and the continuing invasion of the mangrove into the remaining areas further threatens bird species such as the rare and endangered stilt (*Himantopus himantopus knudseni*). It has already been necessary to remove mangroves from declared sanctuaries which are favored feeding grounds for birds, but reinvasion by seedlings is inevitable.

Human Factors Influencing Mangrove Distribution

Interference with shoreline processes has made suitable habitats for mangrove colonization by creating shelter from wave action and through altering patterns of sedimentation. Under natural conditions the gently shelving leeward coast of Molokai would have presented suitable sites for the development of a mangrove fringe, but disturbance of the natural vegetation by grazing has caused serious erosion and an enormous increase in sediment yield. The broad mud flats that have formed along many miles of coastline support a band of mangrove up to 400 meters wide, profoundly altering the former shore. Access to open water has been impeded but, because this is an area of slight economic value and low priority for recreational use, no efforts have been made to prevent the invasion.

Channels on Oahu, such as those of Ala Moana Park, the Honolulu International Airport, and the Ala Wai Canal of Waikiki,

that were dug to drain marshes or to direct surface runoff, have been invaded by *R. mangle*. Sometimes this invasion has had the beneficial effect of protecting banks from erosion, but in shallow channels the infestation is dense enough to impede drainage and removal becomes necessary.

A striking example of induced mangrove invasion has occurred at the mouth of Waikele Stream as it flows into West Loch of Pearl Harbor, where mechanical harvesting of sugarcane has greatly increased the sediment load of the stream. This technique, developed at a time of labor shortage during World War II, requires cane to be

Figure 3a. Mangrove colony on the delta of Waikele Stream, West Loch, Pearl Harbor in 1951.

bulldozed into windrows for gathering by crane and grabline. In the process, quantities of soil and rock are collected, and these must be washed from the cane before the stalks are crushed. The sediment-laden water from the Oahu Sugar Company Mill was discharged into Waikele Stream and, in the absence of sufficient wave action to remove the solid material, a delta began to form. Although settling ponds were installed in about 1965, clearing of the upper watershed in preparation for housing developments has maintained a high sediment load in the stream and the delta has continued to expand. Mangroves have been present in Pearl Harbor at least since 1917, but

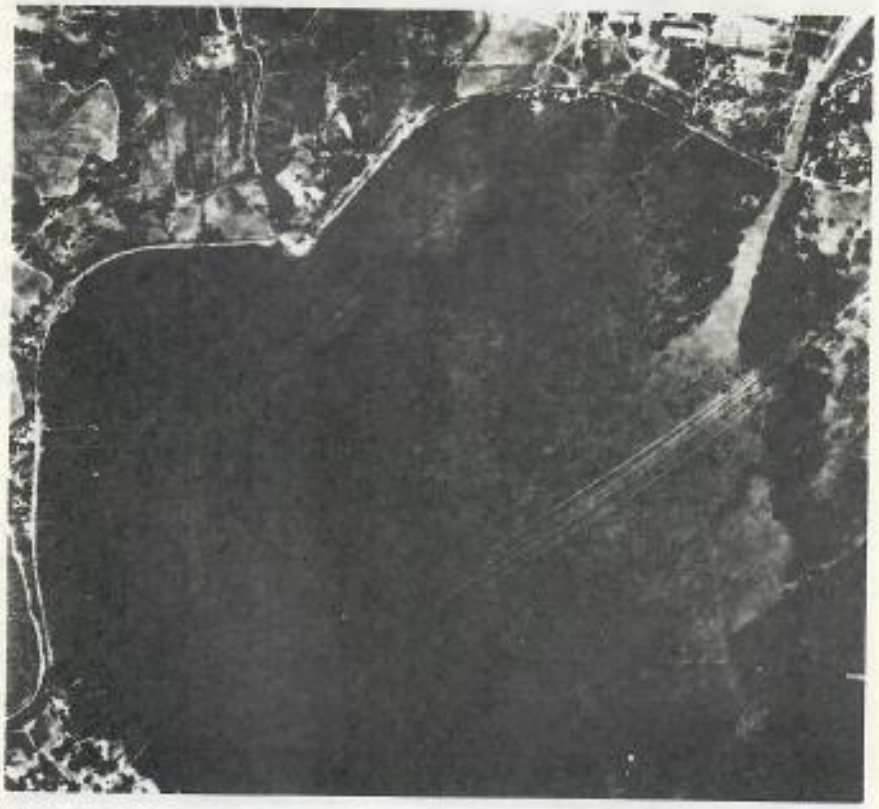

Figure 3b. Mangrove colony on the delta of Waikele Stream, West Loch, Pearl Harbor in 1965.

the abruptly sloping shore provided few suitable habitats. At first only a discontinuous fringe one tree deep formed, but by the 1950s trees began colonizing the newly created delta and a stand of 40 acres now exists (Fig. 3).

The mangrove has also invaded Hawaiian fishponds. These rock wall structures built by the Polynesians were more numerous and varied in Hawaii than anywhere else in Oceania. Although the ponds were probably not a major food source, their construction and maintenance appear to have been a symbol of power and status and were important in the development of the highly stratified Hawaiian

Figure 3c. Mangrove colony on the delta of Waikele Stream, West Loch, Pearl Harbor in 1975.

society (Kikuchi 1976). Few ponds are now commercial ventures. Most are abandoned and, in the absence of maintenance, are slowly filling with sediment. This provides an environment for mangroves, which take root in the walls and the shallow ponds (Apple and Kikuchi 1975, p. 73). The tangle of roots and stems reduces water circulation and increases the rate of silt deposition. Organic matter contributed by litter from the tree canopy futher accelerates the filling of ponds (Fig. 4). Seeds are able to become wedged between boulders long enough to develop root systems that can hold the plants in place against strong wave action; however, they may ultimately cause dismemberment of the walls. In Java, mangroves are purposely planted in dikes and banks to protect them (Hou 1958). However, their presence in Hawaiian fishpond walls alters their traditional character and, in the absence of all maintenance, will eventually result in deterioration.

Apple and Kikuchi (1975) made a comprehensive survey of all ponds and determined a priority for conservation of those with distinctive character, cultural significance, or aesthetic value. Fifty-six ponds are believed worthy of listing on the National Register of Historic Places, and it is hoped that support may become available to ensure their preservation. Unfortunately, many hundreds of others are likely to disappear as a result of accelerated sedimentation and mangrove invasion.

Conclusions

Since the purposeful introduction of mangroves in Hawaii, two species have become naturalized. *Rhizophora mangle* is the more abundant and has spread to all major islands, whereas *Bruguiera gymnorhiza* is confined to Oahu. The most extensive swamps occur on sediment deposited as a result of human action. However, suitable habitats were available for mangrove under natural conditions, and their absence is attributed to difficulty of dispersal.

Mangrove colonization is causing some minor adjustments in littoral plant communities, but of greater concern is their encroachment upon feeding grounds of rare water birds. Some traditional cultural sites are also threatened by invasion, and control by continual clearing will be necessary.

Figure 4. Pi'olp'o Fishpond, Molokai, shows the extent to which mangroves have invaded walls and colonized the sediments accumulated in the pond in the absence of periodic cleaning.

The effect of the mangrove on marine food chains and the value of the swamp as a nursery for fish and crustaceans warrant further investigation.

Literature Cited

Apple, R. A., and W. K. Kikuchi. *Ancient Hawaii Shore Zone Fishponds: An Evaluation of Survivors for Historic Preservation*. Honolulu: National Park Service, 1975.

Chapman, V. J. "Mangrove Phytosociology," *Tropical Ecology*, 11(1970):1-19.

de Ausen, T. T. "Coastline Ecosystems in Oahu, Hawaii." M.Sc. thesis, University of Hawaii, 1966.

Degener, O. "*Rhizophora mangle* L.," *Flora Hawaiiensis*. Honolulu: privately published, Feb. 10, 1940.

Degener, O. "Tropical Plants of the World Around," *Journal New York Botanical Garden*, 46(1945):74-91.

Egler, F. E. "Indigene Versus Alien in the Development of Arid Hawaiian Vegetation," *Ecology*, 23(1942):14-23.

Fosberg, F. R. "Immigrant Plants of the Hawaiian Islands II," *University of Hawaii Occasional Papers*, 46(1948):3-17.

Guppy, H. B. *Observations of a Naturalist in the Pacific Between 1896 and 1899*. New York: Macmillan, 1906.

Hou, D. "Rhizophoraceae," *Flora Melesiana*, 5(1958):429-493.

Hou, D. "A Review of the Genus *Rhizophora* with Special Reference to the Pacific Species, *Blumea*," 10(1960):625-634.

Kikuchi, W. K. "Prehistoric Hawaiian Fishponds," *Science*, 193(1976):295-299.

Lee, B. K. H., "Ecological and Physiological Studies of Soil Microfungi in He'eia Mangrove Swamp, Oahu, Hawaii." Ph.D. dissertation, University of Hawaii, 1971.

MacCaughy, V. "The Mangrove in the Hawaiian Islands," *Hawaiian Forester and Agriculturalist*, 14(1917):361-365.

Salvoza, F. M. "*Rhizophora*," *University of the Philippines Natural and Applied Science Bulletin*, 5(1936):179-327.

Sauer, J. D. "Problems and Prospects of Vegetational Research in Coastal Environments," *Geoscience and Man*, 14(1976):1-16.

Walsh, G. E. "An Ecological Study of a Hawaiian Mangrove Swamp." In *Estuaries*, edited by G. H. Lauff. Washington, D.C.: American Association of the Advancement of Science Publication No. 83, 1967:420-431..

Walsh, G. E., S. C. Snedaker, and H. J. Teas, eds. *Proceedings, International Symposium on Biology and Management of Mangroves*. Gainesville, Florida: University of Florida, 1975.