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Vegetation of Nauru and the Gilbert Islands: Case Studies of Poverty, Degradation, Disturbance, and Displacement[1]

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ABSTRACT: The indigenous floras of the raised phosphatic limestone island of Nauru and the atolls of the Gilbert Islands are among the poorest on earth. Long settlement, widespread destruction during World War II, monocultural expansion of coconut palms, and more than 75 yr of open-cast phosphate mining in the case of Nauru have led to serious vegetation degradation, disturbance, and displacement. The floras of Nauru and the Gilbert Islands consist of approximately 487 and 306 species, respectively, of which only 55 and 83 are possibly indigenous, but none of which are endemic. The balance is composed of ornamentals, weedy exotics, food plants, and a limited number of other useful cultigens. Although greatly outnumbered by exotics, indigenous species still dominate some of the most disturbed habitats, as well as constituting the most culturally utilitarian and ecologically important species. Because of the unique adaptability of indigenous Pacific island plants to the harsh conditions of coastal and small-island environments, and their cultural and ecological utility, it is argued that the protection and enhancement of the indigenous floras are crucial to the ecological integrity and cultural survival of small-island Pacific societies.

THIS PAPER FOCUSES ON the vegetation of Nauru and the Gilbert Islands (part of the Republic of Kiribati), with specific emphases on: (1) the nature of the existing floras and vegetation associations; (2) the importance of indigenous species relative to exotics in the vegetation associations; (3) the role of human disturbance and dispersal, particularly post-European-contact disturbance and dispersal in the impoverishment, modification, degradation, displacement, and enrichment of the indigenous floras and vegetation; and (4) an analysis of the cultural and ecological importance of the indigenous floras in the context of modern small-island development.

Previous Studies

Although collections were made on Nauru by Burgess in 1935; Fosberg in 1980; Scully in 1980; Thaman, Hassall, and Manner in 1980 and 1981; Thaman and Manner in 1987; and Swarbrick in 1988, little has been published. The only substantial publications are those of Manner, Thaman, and Hassall (1984, 1985); Thaman, Manner, and Hassall (1985); and Fosberg, Sachet, and Oliver (1979, 1982, 1987). These publications include most of the species cited and specimens examined before 1980.

The flora and vegetation of the Gilbert Islands and the Republic of Kiribati are better documented. The most detailed publications include those of Luomala (1953); Catala (1957); Moul (1957); Small (1972); Overy, Polunin, and Wimblett (1982); Thaman (1987*a*); and Fosberg and Sachet (1987). Other studies include those of Fosberg (1952), Christophersen (1927), and Wester (1985), which provide information on the plants of the atolls outside the main Gilberts group. Other

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accounts are those on Abemama (Watters and Banibati 1977), Butaritari (Sewell 1979), North Tabiteuea (Geddes 1975), and Tamana (Lawrence 1977). Thaman's studies (1987*b*, 1988*a*, 1990*a*) provide information on species found in houseyard gardens and agricultural areas. Useful general studies of atoll and small-island vegetation include Merrill (1945), Fosberg (1960, 1965), Wiens (1962), Alkire (1974), Soucie (1983), Guerin (1982), and Manner (1987).

Current Study

The current study is based on an in-depth analysis of the above sources; 5 weeks of fieldwork during three visits on Nauru in 1980, 1981, and 1987; a 10-day field study in the Gilbert Islands with I-Kiribati informants on Abemama and North and South Tarawa in Ausust 1984; and a 2-week reconnaissance survey on Tarawa in 1989. During these studies the Latin and Kiribati names of all plant species found in urban and rural areas were recorded, and the lists were cross-checked with names listed from previous studies. Two collections of herbarium specimens held by the Agricultural Division and the University of the South Pacific (USP) Atoll Research and Development Unit (ARDU) on Tarawa were also studied in 1984.

NAURU AND THE GILBERT ISLANDS

The Islands

The Republic of Nauru, a single uplifted limestone island, west of the Gilbert Islands, is located 142 km south of the equator at 166° 56′ E, some 2000 km east-northeast of Papua New Guinea, 4450 km south-southeast of the Philippines, and an equal distance southwest of Hawaii. The nearest island is Banaba (Ocean Island), 300 km due east.

The Republic of Kiribati, between 4° 43′ N and 11° 25′ S and 169° 32′ and 150° 14′ W (Douglas and Douglas 1989), consists of 33 islands in three main groups, the Gilbert Islands proper (formerly part of the British Gilbert and Ellice Islands Colony, known locally as Tungaru), the Phoenix Islands, and the Northern and Southern Line Islands, plus the isolated island of Banaba. These islands have a combined land area of only 811 km^2 in an ocean area of some 13 million km^2.

The main Gilbert Islands, the focus of this paper, consist of 16 small atolls or reef islets extending 640 km from north to south. They are 700 km east of Nauru, 400 km east of Banaba, and about 250 km north and south, respectively, of the atoll nations of Tuvalu (formerly the Ellice Islands) and the Republic of the Marshall Islands. Both Nauru and the Gilbert Islands are at considerable distances from the Philippines, Indo-Malaya, Australia, and Melanesia, the source regions or centers of dispersal of most Pacific island floras (Merrill 1945, Manner 1987).

Nauru, with an area of only 22 km^2, consists of a narrow coastal plain, ranging from 50 to 300 m wide, encircling a limestone escarpment rising some 30 m to the central plateau (Figure 1). The escarpment ranges in gradient from vertical cliffs to gradually sloping areas of colluvial soil interspersed with limestone outcrops and pinnacles. The plateau, with a maximum elevation of 70 m, consists of a matrix of limestone pinnacles and outcrops, between which lie extensive deposits of soil and high-grade tricalcic phosphate rock (Tyrer 1963, Viviani 1970). Buada Lagoon, about 12 ha in size, located in the low-lying southwest central portion of the island, is a landlocked brackish lake, with an associated fertile depression.

The Gilbert Islands (Figure 2) are for the most part atolls with central lagoons and encircling islets of various sizes and shapes. Kuria, Tamana, and Arorae are slightly raised limestone islands without lagoons. The total land area is estimated at 294 km^2, and the islands range in size from Tamana and Makin (5.2 and 7.2 km^2, respectively) to Maiana, Abaiang, and Tabiteuea (28.1, 28.5, and 49 km^2, respectively). Tarawa, where the capital is located, is the most populous island, with 21,393 people in 1985. It has islets with an estimated area of 19.9 km^2 and extends

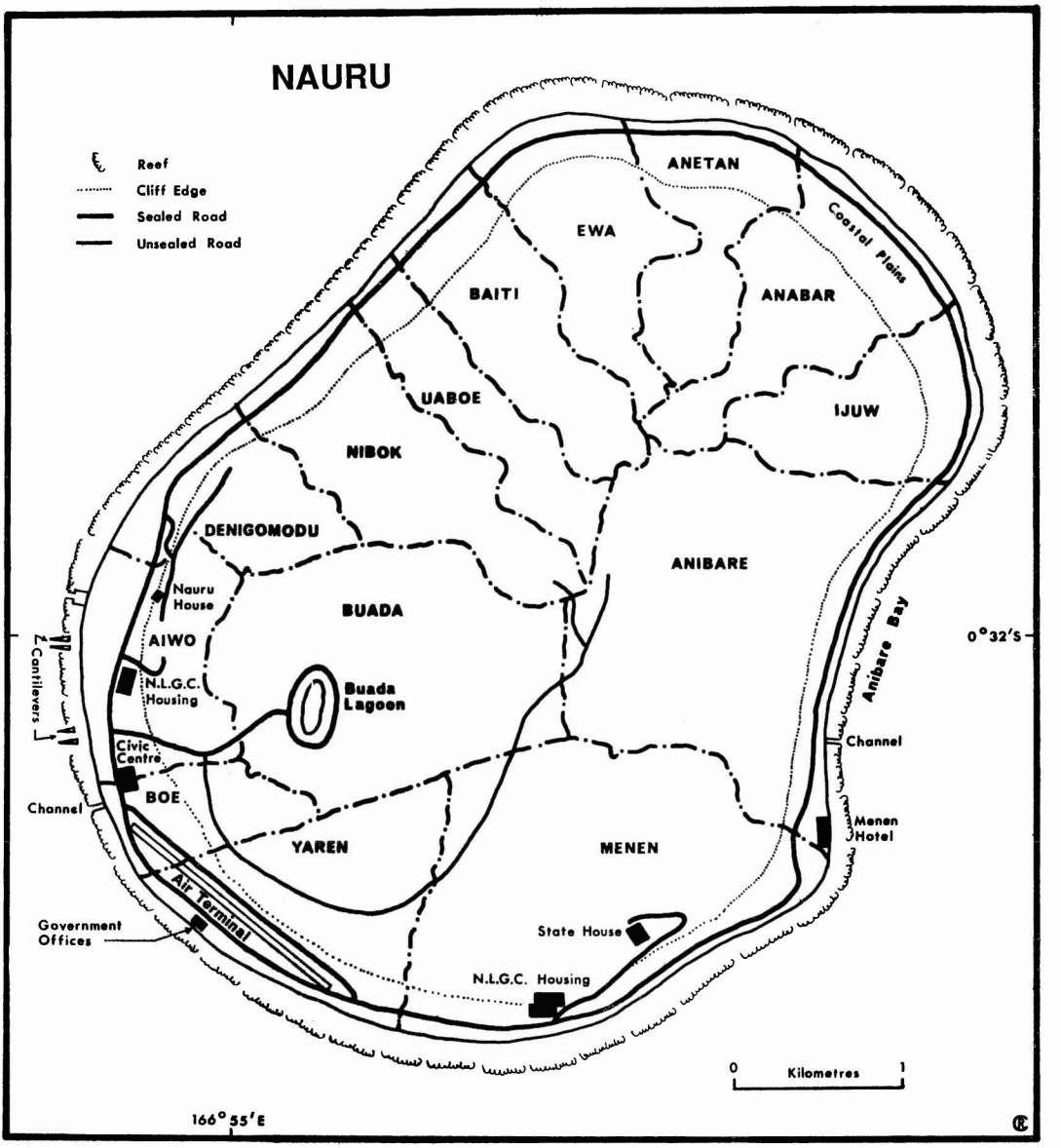

FIGURE 1. Map of Nauru.

over 64 km from north to south (Catala 1957).

On a typical islet there is usually an uplifted fringing reef in the wave zone of the ocean side. The reef may be covered by a sandy beach, which becomes a raised rampart or shingle ridge of coral boulders and fragments deposited during storms. This rampart is commonly the highest point on the islet, no more than 4 m above mean sea level. Lagoonward of the rampart, and extending to the lagoon itself, is an area of windblown sand. Toward the lagoon shore, increasingly fine deposits are of lagoonal origin. Limestone outcrops

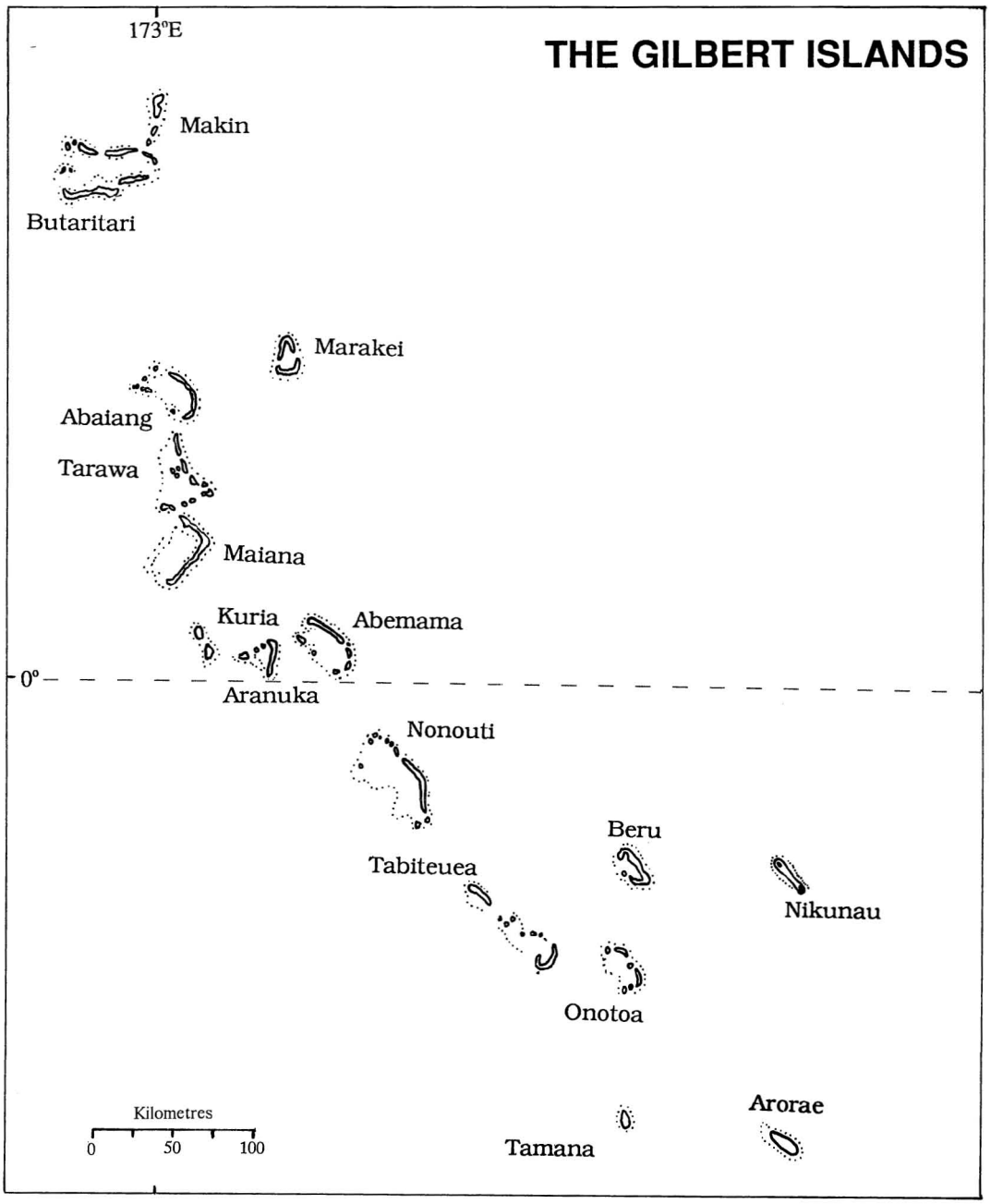

FIGURE 2. Map of the Gilbert Islands.

with little or no soil and low-lying swampy areas are often found as well.

Water Resources

Apart from Buada Lagoon on Nauru, there are no significant surface freshwater resources on Nauru or the Gilbert Islands. The only permanent freshwater resource is groundwater in the form of a lens of often slightly brackish fresh water, hydrostatically floating on higher density salt water beneath it. The height of the freshwater lens above sea level and the level of salinity vary in relation to the elevation, geology, texture, shape, and width of islets, and with the amount of water use and rainfall. Replenishment or recharge of the lens is dependent on rainfall. Pools are sometimes found, during excessively wet periods, in areas where the lens is close to the surface, especially during high tides. The location and degree of development of the groundwater resource influences the nature of the vegetation, as well as the location of village wells and cultivation pits (Catala 1957, Small 1972, Lawrence 1977).

Climate

Climatically, both Nauru and the Gilbert Islands are located in the dry belt of the equatorial oceanic climate zone, with mean daily temperatures ranging from 26 to 32°C. Annual rainfall is extremely variable in both groups. Nauru averages 1500 mm per year with a range of 300 to 4572 mm. In the Gilberts, rainfall varies both annually and between islands, with annual averages of about 1000 mm for the drier islands such as Arorae and Tamana in the south, to 3000 mm for the wetter islands such as Butaritari in the north, and 1550 at Tarawa. Severe prolonged droughts, with as little as 200 mm of rain per year, are common, particularly in the central and southern Gilberts (Carter 1984). These droughts, such as those that prevailed over the group from 1987 to early 1989, place severe stress on even the most hardy coastal strand species, lead to the death of noncoastal exotics (such as breadfruit), and severely restrict the production of even coconut palms (Catala 1957).

Soils

The coastal soils of Nauru and the soils of the Gilbert Islands are among the poorest in the world. They are shallow, alkaline, coarse-textured, and have carbonatic mineralogy. Both are composed of a variable layer of organic matter, coral sand, and fragments, which overlays a limestone platform. On Nauru coastal soils are generally drier, only about 25 cm deep, and contain more coral gravel than sand in the lower horizons. The Gilbert Islands soils tend to be deeper, from 25 cm to 1 m or more deep, and are wetter, with some accumulation of clays, and with H_2S near the center of islets near the water table. Potassium levels are often extremely low, and pH values of up to 8.2 to 8.9 and high $CaCO_3$ levels make scarce trace elements, particularly iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn), unavailable to plants. Fertility is, therefore, dependent on organic matter for the concentration and recycling of plant nutrients, lowering soil pH, and for soil water retention in the excessively well-drained soils. Although levels of organic matter can be relatively high in undisturbed soils under natural vegetation, they can decrease dramatically as a result of clearance by fire or replacement by coconuts and other introduced plants (Catala 1957, Small 1972, Morrison 1987; also R. J. Morrison, 1987, comments on the soils of Nauru, Commission of Inquiry into Rehabilitation of Worked-out Phosphate Lands in Nauru, Institute of Natural Resources, Univ. of the So. Pac., Suva, unpubl. ms.).

The plateau soils of Nauru vary from shallow soils, composed primarily of organic material and sand or dolomite, with little phosphate, on the tops of limestone pinnacles, to deep phosphatic soils and sandy phosphatic rock, up to over 2 m deep between the pinnacles. Topsoils range from 10 to 25 or 30 cm in depth, overlaying a deeper material that is frequently reddish yellow and between 25 and 75 cm deep, changing to pinkish gray at greater depth. Undisturbed plateau soils have

a high level of organic material and are generally fertile.

Calcium dominates the exchange complex and exchangeable magnesium is also high. Exchangeable potassium is low, while extractable phosphate values are generally high and sulphate moderate. Levels of the trace elements manganese, copper, cobalt, and molybdenum are low, and these, plus iron and zinc, are rendered unavailable to plants under pH values >6.5 (Morrison 1987, unpubl. ms.). There are also scattered areas of phosphate soils and deposits in the Gilbert Islands. They seem to have originated from guano deposits accumulated over long periods of time under groves of *Pisonia grandis*, a favored seabird rookery species (Sachet 1983). These soils are often more acidic and darker than the surrounding soils.

Around Buada Lagoon and in some poorly drained swampy areas near the base of the escarpment on Nauru, and in some low-lying areas on the islets of the Gilberts, there are poorly developed, but relatively fertile, wet soils.

The People

The indigenous peoples of both Nauru and the Gilbert Islands are Micronesians, who have probably inhabited the islands for 3000 years or more. On Nauru, there is some evidence of Melanesian, and possibly Polynesian, influence (Viviani 1970); in the Gilberts there has been long contact with Polynesia, particularly with Tuvalu (the Ellice Islands) to the south (Bellwood 1978).

The estimated population of Nauru in 1983 was 8042, of whom 4964 were Nauruan, with the balance composed mainly of I-Kiribati, Tuvaluan, Chinese, Filipino, or Solomon Island contract workers in the phosphate industry. There are also European, Indian, and Pacific Island expatriates working mainly for the Nauruan Government. The Nauruans live on the coastal strip and around Buada Lagoon, the phosphate workers in the Nauru Phosphate Company dormitory accomodation at Location near the phosphate loading cantilevers, and the expatriate civil servants in residential areas on the escarpment. The town center is located between the airport and Location near the cantilevers (Figure 1), with most government offices near the airport.

In 1985 the population of the Republic of Kiribati was 63,883, of which 61,419 were I-Kiribati. Over one-third (21,393) lived in urban Tarawa, the capital and commercial center, with the balance living in villages in rural North Tarawa and other islands. At a projected growth rate of 4.3%, by 1993 the population of the urbanized area of South Tarawa would increase to 34,066, a population density of 4705 per km^2 (Douglas and Douglas 1989).

Development History

The early post-European-contact histories of both Nauru and the Gilbert Islands are similar (Viviani 1970, Carter 1984). After the first recorded European sightings of the islands in 1606 and 1798, respectively, the earliest significant contacts with Europeans were between 1820 and 1870. In that period, British and American whalers made regular stops for water and food, and beachcombers arrived. The next phase of contact was with traders, including slave and labor traders (in the case of the Gilberts) and missionaries in the mid- to late nineteenth century. Coconut oil was the main commodity until copra replaced it in the late 1870s, although sporadic copra trade from Nauru was not established until the 1890s.

Nauru was incorporated into Germany's Marshall Islands Protectorate in 1888; the Gilbert Islands were made a British protectorate in 1892. Along with Banaba and Tuvalu, they became part of the Gilbert and Ellice Islands Colony in 1916. In 1919, after World War I, Nauru became a League of Nations mandate of Great Britain, Australia, and New Zealand, administered by Australia. Nauru became independent in 1968 and the Republic of Kiribati was established in 1979.

The strategic and economic importance of both groups increased dramatically with the discovery, at the turn of the century, of high-grade phosphate rock on both Nauru and Banaba. Mining of phosphate began in

1907 and 1906, respectively, without the approval of the indigenous inhabitants. Caroline Islanders and Chinese contract laborers were recruited to mine the deposits on Nauru and Gilbert Islanders on Banaba. The deposits on Nauru have been mined continuously since 1907, except for disruptions during the two world wars. Mining ceased on Banaba in 1979. The deposits on Nauru are expected to be depleted by the turn of the century.

Through the late nineteenth century and early years of the twentieth century the populations of both the Gilbert Islands and Nauru were negatively impacted by the inroads of European influence and suffered extensively from introduced diseases to which they were not immune. The population of Nauru especially declined dramatically between the mid-nineteenth century and the first decades of the twentieth century: there were 1400 Nauruans in 1840 and 1250 in 1910 (Viviani 1970). The most disruptive period for both Nauru and the Gilbert Islands was, however, during World War II, when the islands were occupied by Japan, suffered continuous bombing by Japanese and American planes, were settled by thousands of Japanese marines, Japanese, and Korean laborers, and when some 700 Banabans were relocated to Nauru and indigenous populations of both Nauru and Banaba were decimated by deportation. There followed severe food shortages, malnutrition, and dysentery. As argued by Viviani (1970): "The Japanese had destroyed the Nauruan's homes, schools, and churches, placed them on a semi-starvation level and destroyed much of what was left of their old way of life. The deportation of two-thirds of the Nauruans and the death of nearly 500, mostly the old and the young, left the society after the war with a gap in generations and a disruption of family life. Again the Nauruan population had fallen well below the 1,500 level which the Nauruans themselves regarded as a minimum for survival."

Contemporary Economy

Nauru's sole export continues to be phosphate; the sporadic export of copra ceased in the 1950s. Phosphate earnings have made Nauru among the wealthiest nations in the world in terms of per-capita income, although the distribution of wealth is uneven because of the unequal land rights to phosphate deposits. Nauru is considered totally urbanized and Nauruans have almost completely abandoned subsistence production, except for the harvest of coconuts and pandanus fruit for consumption and pandanus leaves for plaited ware; the acquisition of fish and other seafoods; and the hunting of noddy birds, a traditional pastime. Most of the limited subsistence agricultural production is in the hands of immigrant communities. The establishment of its own heavily subsidized international airline, Air Nauru, in 1970, and the extension of the runway over the reef, have accelerated the processes of urbanization and an increasing dependence on imported products.

Since the cessation of phosphate mining on Banaba in 1979, copra has remained the only significant source of income in rural Kiribati. Exports of tuna and maricultural production of tuna baitfish and milkfish for export to Nauru and Hawaii, and the recent production of the seaweed *Eucheuma* for export now surpass copra as the main sources of export income. The subsistence economy in rural Kiribati remains strong, with a high dependence on traditional staple food crops—coconut, breadfruit, pandanus, the native fig (*Ficus tinctoria*) and giant swamp taro (*Cyrtosperma chamissonis*), pigs, chickens, and marine foods. Although Kiribati is increasingly urbanized, with over one-third of all I-Kiribati now living in urban South Tarawa, there remains a considerable dependency on subsistence production, even in urban areas. There is, however, rapidly increasing dependence on rice, flour, and other imported foods, even in rural areas. Improved road networks and the construction of airfields on all of the islands of the Gilbert group and on Kiritimati (Christmas Island) in the Line Islands have also accelerated the process of urbanization.

Because of the environmental factors described above—extreme isolation from major

plant source regions, small island size, extremely poor soils, and climatic and physiological drought—the indigenous floras of Nauru and the atolls of the Gilbert Islands are among the poorest and most restricted on earth. Moreover, the long settlement history, widespread destruction during World War II, monocultural expansion of coconut palms as the sole cash crop, increasing urbanization and contact with the outside world, and over 75 years of open-cast phosphate mining (on Nauru and Banaba) have all played a role in the serious degradation, disturbance, and displacement of the indigenous floras and vegetation.

VEGETATION TYPES

Coastal Strand Vegetation

The coastal strand vegetation of Nauru and the Gilbert Islands has been severely modified as a result of: (1) thousands of years of human habitation and selective removal of indigenous species for construction, boatbuilding, firewood, and other purposes; (2) the expansion of monocultural coconut groves for export production of coconut oil and copra; (3) the expansion of coastal settlements, which in Nauru and in urban South Tarawa occupy most of the coastline; and, (4) the widespread practice of allowing pigs to forage freely along beach flats (Viviani 1970).

The dominant species in the outer coastal zone in Nauru include the herbaceous species *Lepturus repens*, *Cyperus javanicus*, *Ipomoea pes-caprae*, and *Vigna marina*; the woody species *Scaevola sericea*, *Tournefortia argentea*, and *Morinda citrifolia*, plus the aboriginal introduction, *Cocus nucifera*. Species common on rocky limestone sections of the coast include the same species plus *Polypodium scolopendria*, *Capparis cordifolia*, *Clerodendrum inerme*, *Terminalia catappa*, and *Calophyllum inophyllum*. Species present on nonrocky, somewhat disturbed inland coastal sites between the strand and the base of the escarpment include *Hibiscus tiliaceus*, *Cocus nucifera*, *Premna serratifolia*, *Calophyllum inophyllum*, *Pandanus tectorius*, *Morinda citrifolia*, *Terminalia catappa*, *Ochrosia elliptica*, and isolated specimens of *Barringtonia asiatica*, *Thespesia populnea*, and *Hernandia nymphaeaefolia*. Shrubby species include *Scaevola sericea*, *Colubrina asiatica*, *Abutilon indicum*, and *Phyllanthus societatis*; herbaceous species include *Cyperus javanicus*, *Digitaria setigera*, *Vigna marina*, *Ipomoea macrantha*, and the ferns *Polypodium scolopendria* and *Nephrolepis biserrata*. *Caesalpinia bonduc*, *Sida fallax*, and *Triumfetta procumbens* are scarce, but were probably more abundant in the past.

In the Gilberts the seaward rampart vegetation is dominated by *Scaevola sericea*, which commonly forms an almost unbroken belt in areas away from settlements. Other dominant species include *Tournefortia argentea*, *Pandanus tectorius*, and occasionally *Guettarda speciosa*, which are usually found as isolated specimens or in small groups, and the ubiquitous coconut. Herbaceous species include *Lepturus repens*, *Fimbristylis cymosa*, *Triumfetta procumbens*, *Euphorbia chamissonis*, and the parasitic *Cassytha filiformis*, often growing on *Scaevola*. Infrequently present are the naturalized aboriginal introductions *Tacca leontopetaloides* and *Eragrostis amabilis*. On the inner borders of the rampart vegetation, particularly on bare limestone or conglomerate areas, almost pure stands of *Pemphis acidula* are found, and *Sida fallax*, *Portulaca australis*, *P. lutea*, *Boerhavia repens*, and *B. tetrandra* occupy more open areas. Tree species, such as *Barringtonia asiatica*, *Cordia subcordata*, *Hernandia nymphaeaefolia*, *Premna serratifolia*, *Pisonia grandis*, and *Terminalia samoensis*, and the shrubs *Suriana maritima* and *Sophora tomentosa*, which are either localized or only rarely encountered, were probably much more abundant in the past before their widespread removal (Fosberg 1952, Catala 1957, Moul 1957, Geddes 1975).

Along the much more highly disturbed lagoon shores, vegetation includes *Tournefortia argentea*, *Scaevola sericea*, and *Guettarda speciosa*, bordered by coconuts, and the grass *Lepturus repens* and the sedge *Fimbristylis cymosa* in wetter sites. *Pemphis acidula* is also common inland from mangroves (Catala

1957, Moul 1957), and *Clerodendrum inerme* is present on some islands (Luomala 1953).

Mangroves and Coastal Marsh Vegetation

Shallow-water habitats with muddy bottoms and protected from strong wave action are almost nonexistent on Nauru, but are relatively widespread on the lagoon sides of islets in the Gilberts. Although reportedly present in the past around Buada Lagoon, Nauru's single mangrove species, *Bruguiera gymnorhiza*, is now restricted to a system of landlocked brackish ponds or small lagoons near the base of the escarpment in Meneng, Anabar, and Anetan Districts; the largest concentration is found around Araro Lake in Anetan. Fosberg (ca. 1972) also reported the occurrence of *B. gymnorhiza* in landlocked ponds, sinkholes, and small inland swamps in Palau. Other species commonly associated with mangroves and present in Nauru include *Derris trifolis*, encountered on limestone outcrops, and *Vitex negundo*, which is present in depressions on the coastal strip in Menen District.

In the Gilberts, monospecific *Rhizophora mucronata* stands are common on the lagoon sides, along channels between islets, and occasionally on the ocean coasts of the wetter larger islands of Butaritari, Abaiang, Tarawa, Abemama, Aranuka, Nonouti, Tabiteuea, and Onotoa. All these islands have areas of sheltered muddy lagoon flats, lagoon margins, and fishponds. Such areas are commonly bordered by extensive stands of *Pemphis acidula*, which commonly grows to just above the high water line (Luomala 1953, Catala 1957, Moul 1957, Fosberg ca. 1972). *Bruguiera gymnorhiza* is reportedly also present in mangrove associations on Butaritari, Abemama, and Tabiteuea (Fosberg and Sachet 1987). Other mangrove species present in the Gilberts include *Lumnitzera littorea*, which is found in salt swamps on Butaritari, and *Sonneratia alba*, which grows on the ocean side of Butaritari and is also reported from Marakei (Overy et al. 1982, Fosberg and Sachet 1987). A single mature *L. littorea*, possibly deliberately planted, was present in a roadside depression in Eita village, Tarawa, in 1989. No mangrove species have been reported from the lagoonless arid islands of the south, such as Tamana and Arorae (Lawrence 1977).

The swampy areas surrounding Buada Lagoon and near the base of the escarpment on Nauru are dominated by *Cyperus javanicus* and *C. compressus*, with one specimen of *Ludwigia octovalvis* collected from a coastal depression. In the Gilberts, where there are more extensive areas of inland swamps and man-made swampy depressions and *Cyrtosperma* pits, the dominant species are *C. javanicus*, *C. laevigatus*, and *C. compressus*, with *L. octovalvis* also very common in abandoned *Cyrtosperma* pits.

Relict Stands of Inland Forest

There are two distinct types of relict stands of primary inland forest on Nauru: (1) plateau forest, which probably covered up to 90% of the island before the onset of phosphate mining, and (2) escarpment forest, including forest on unmined limestone outcrops or pinnacles on the plateau. The former, four-fifths of which was removed during phosphate mining, is dominated almost entirely by 16-m-tall *Calophyllum inophyllum*. Infrequent canopy trees include *Guettarda speciosa*, *Premna serratifolia*, and *Terminalia catappa*, with the understory dominated by *Scaevola sericea*, *Morinda citrifolia*, and *Dodonea viscosa*, the parasite *Cassytha filiformis*, *Psilotum nudum*, and the ferns *Polypodium scolopendria* and *Nephrolepis biserrata*. Also occasional in open sites is *Phyllanthus societatis*. Exotic species dominant in disturbed sites include *Psidium guajava*, *Lantana camara*, and two herbaceous species, *Euphorbia hirta* and *Desmodium triflorum* (Manner et al. 1984, 1985).

In the Gilberts there is essentially no remaining primary forest; all of it, except for the rare relict stand or individual tree, has been replaced by coconut-dominated vegetation. There is evidence that the dominant inland forest species was probably *Pisonia grandis*, the typical woodland on many atolls (Fosberg 1952, Woodroffe 1985). Other elements include *Calophyllum inophyllum* and *Hernandia nymphaeaefolia* as the dominants; *Barringtonia asiatica*, *Macaranga carolinensis*, and *Terminalia samoensis*, which are uncommon today but were probably important components

previously; and *Guettarda speciosa*, *Pandanus tectorius*, *Scaevola sericea*, and *Premna serratifolia*, which are still common today and were undoubtedly important components (Catala 1957, Thaman 1990*a*). *Pipturus argenteus*, although possibly an aboriginal introduction, and *Acalypha amentacea* var. *grandis*, both reported present in the Gilberts and common on other atolls, could have also been a subcanopy component of the original forest. *Hibiscus tiliaceus* and *Terminalia catappa*, which are considered exotics on many atolls (Whistler 1980*a*, 1987) and which are still found in some areas in the Gilberts, could have been components in some forests. *Pisonia grandis*, which in some cases is protected as bird reserves, is found in relict stands on Onotoa (Moul 1957, Sachet 1983, Wester 1985, Woodroffe 1985).

Limestone Escarpment or Pinnacle Vegetation

The dominant species on the limestone cliffs of the escarpment and on emergent pinnacles on Nauru is *Ficus prolixa*, with *Terminalia catappa*, *Ochrosia elliptica*, and *Guettarda speciosa* constituting important second-stratum species (Manner et al. 1985). Isolated relict stands of *Barringtonia asiatica* and *Pisonia grandis* are also found along the crest of the escarpment above Anibare Bay. The ferns *Nephrolepis biserrata* and *Polypodium scolopendria* and the liana *Ipomoea micranthra* are locally abundant, and the herb *Laportea ruderalis* is found in moist shady habitats at the base of the escarpment. On the more gradual-sloping colluvial portions of the escarpment, almost impenetrable thickets of *Hibiscus tiliaceus* are found. Understory species include *Colubrina asiatica* and *Tacca leontopetaloides*. In Anetan District, in the north (Figure 1), *Clerodendrum inerme* festoons limestone outcrops and cliffs.

Coconut Palm–Dominated Agricultural Lands

Coconut groves are the major vegetation type in the Gilberts and, although far less important today than in the past, neglected plantations are found in a number of sites on Nauru's coastal strip. In the Gilberts they are found on both the major inhabited islands and on uninhabited islets. In most cases, particularly in Nauru, the plantations are composed of randomly scattered trees of various heights and ages. In the Gilberts dense stands with an almost continuous canopy are often found on limestone soils, both near the lagoon and along roads. More recent plantings, many of which were done under the Department of Agriculture's Grove Improvement and Replanting Programs, are more regularly spaced and of single age classes. These plantings now constitute a major proportion of the area under coconuts in the Gilberts (Sewell 1979).

In poorly maintained groves, coconut seedlings and fallen leaves and husks dominate the understory. In the more well-maintained groves, the soil surface has a sparse cover of grasses and herbs including *Thuarea involuta*, *Lepturus repens*, *Stenotaphrum micranthum*, *Fimbristylis cymosa*, *Euphorbia* spp., *Boerhavia* spp., *Sida fallax*, *Triumfetta procumbens*, and the exotic *Cenchrus echinatus*. Coconut stands near the seaward sides and toward the centers of islets are often more open. They contain a greater number of understory species including *Tournefortia*, *Guettarda*, *Pandanus*, and *Scaevola*, with young coconuts, and denser, almost continuous stands of the same grasses and herbs often present. *Cassytha filiformis* and *Laportea ruderalis* are occasional, while *Psilotum nudum* and *Polypodium scolopendria* are more often found in the shade and at the bases of coconut trees. *Dodonea viscosa* is sometimes found in dense stands or as isolated individuals (Catala 1957, Moul 1957), especially near sites of existing or former village settlements (Catala 1957, Overy et al. 1982). The density and composition of such vegetation varies, of course, depending on the maintenance and density of coconut plantings. *Scaevola sericea*, for example, covered over a third of the area under coconuts on Tabiteuea North in the early 1970s and forms a dense undergrowth, unless cleared (Geddes 1975).

Trees occasionally found as scattered individuals, but most certainly more numerous in the past, possibly as components of the dominant presettlement and pre-European-contact vegetation, include *Calophyllum inophyllum*,

Cordia subcordata, *Hernandia nymphaeaefolia*, *Pisonia grandis*, and *Premna serratifolia*. These species have been almost totally replaced in the drive, over the past 40 years, to extend coconut plantings (Catala 1957, Thaman 1990*a*). Instead, clearings or open areas in the coconut canopy are commonly occupied by thickets of *Scaevola* and *Guettarda*, or by planted *Pandanus* groves or individual pandanus or native fig (*Ficus tinctoria*) trees, both important staples, particularly in the drier southern islands.

Planted groves of edible *Pandanus tectorius* cultivars in forest clearings, both on the plateau and on the more gradually sloping areas of the escarpment, were also once a prominent feature of Nauru's agricultural vegetation. Today, they are restricted to a few relict groves, some of which were found to be present in the unmined areas of Anibar District in 1980.

Houseyard and Village Gardens

Houseyard and village gardens contain a greater proportion of aboriginal cultigens and recently introduced exotics, with greater diversity in Nauru mainly because of its greater urbanization and contact with overseas sources of nonquarantined planting materials.

In indigenous Nauruan houseyard gardens the dominance of recently introduced ornamental species is pronounced, with some 118 of 140 species classed as recent introductions. Indigenous species include *Abutilon indicum*, *Barringtonia asiatica*, *Calophyllum inophyllum*, *Cerbera manghas*, *Clerodendrum inerme*, *Cordia subcordata*, *Ficus prolixa*, *Guettarda speciosa*, *Morinda citrifolia*, *Ochrosia elliptica*, *Premna serratifolia*, and *Terminalia catappa*, which in some cases, such as with *Cerbera manghas* and *Cordia subcordata*, are only present today in Nauru in houseyard gardens. Common food plants include, in order of importance, coconut, breadfruit, bananas, pandanus, papaya, *Citrus* spp., and guava. Common ornamentals, found in at least four of 16 sample gardens, include *Acalypha amentacea*, *Bougainvillea* spp., *Caesalpinia pulcherrima*, *Caladium bicolor*, *Casuarina equisetifolia*, *Catharanthus roseus*, *Codiaeum variegatum*, *Cordyline fruticosa*, *Crinum* spp., *Delonix regia*, *Dieffenbachia* spp., *Hibiscus rosa-sinensis*, *Hosta plantaginea*, *Hymenocallis littoralis*, *Ixora* spp., *Jasminum sambac*, *Jatropha integerrima*, *Nerium oleander*, *Pentas* spp., *Plumeria* spp., *Polyscias* spp., *Pseuderanthemum caruthersii*, *Psidium guajava*, *Sanseviera trifasciata*, *Tabernaemontana divaricata*, *Tecoma stans*, and *Thunbergia erecta*.

The houseyard gardens of I-Kiribati, Tuvaluan, Chinese, and Filipino contract workers, and in the European and Indian expatriate communities of Nauru, are very different. Each reflects distinctive preferences in food and ornamental plants, and they are commonly dominated by food plants. I-Kiribati and Tuvaluan gardens at Location usually consist of a single banana, coconut, papaya, or breadfruit tree, or a few cassava, sweet potato, taro, tannia (*Xanthosoma sagittifolium*), pineapple, sugarcane, hibiscus spinach (*Hibiscus manihot*), or chili pepper (*Capsicum frutescens*) plants. All are often grown in boxed or fenced areas filled with imported soil or mulch. Chinese gardens at Location focus more on short-term vegetable plants, such as Chinese cabbages (*Brassica* spp.), onions and garlic (*Allium* spp.), amaranth spinach (*Amaranthus* spp.), coriander (*Coriandrum sativum*), long beans (*Vigna sesquipedalis*), and a range of cucurbits. Filipino workers plant *Dolichos lablab*, sweet potato, and *Moringa oleifera*. European expatriates plant tomatoes, lettuce, and parsley, whereas the expanding Indian expatriate community has planted eggplant (*Solanum melongena*), okra (*Hibiscus esculenta*), horseradish tree (*Moringa oleifera*), and *Averrhoa belimbi*. A similar range of food species is cultivated behind the work shops on Topside, although the number and areas under crops are greater, with some gardeners growing taro, tannia, and giant swamp taro, employing the traditional intensive mulching systems of the Gilberts and Tuvalu (Thaman 1987*b*, 1988*a*).

Although exotic ornamentals are common in areas immediately surrounding dwellings in the Gilberts, particularly in highly urbanized South Tarawa, the dominant plants are important tree crops: coconut palms (often planted for toddy production), pandanus, papaya, native fig (*Ficus tinctoria*), and

breadfruit (*Artocarpus altilis* and *A. mariannensis*). The latter two are found almost exclusively in villages around dwellings and bordering roads, with most families on the wetter islands such as Butaritari having at least one large breadfruit tree (Sewell 1979). On the drier southern islands, where breadfruit does not grow well, pandanus and *Ficus tinctoria* are dominant on the village periphery (Catala 1957). Other food plants found in village gardens include giant swamp taro (*Cyrtosperma chamissonis*), which is also cultivated in pits within villages. Less widely cultivated food plants include sweet potato, cassava, pumpkin (*Cucurbita pepo*), lime (*Citrus aurantiifolia*, the one citrus species that seems to do well in alkaline atoll soils), sugarcane, hibiscus spinach (*Hibiscus manihot*), and a range of short-term vegetables, such as cabbages (*Brassica* spp.), long beans (*Vigna sesquipedalis*), and cucurbits. The latter group has been promoted in hydroponic and mulching programs to increase supplies of nutritious vegetables.

Indigenous species commonly planted or protected in I-Kiribati houseyard gardens, villages, and urban areas include *Morinda citrifolia*; *Premna serratifolia*, *Scaevola sericea*, *Tournefortia argentea*, and *Clerodendrum inerme* (which is commonly planted as a hedge), and the ferns *Nephrolepis* spp. and *Polypodium scolopendria*. Less common are *Barringtonia asiatica*, *Calophyllum inophyllum*, *Cordia subcordata*, *Terminalia catappa*, and *T. samoensis*. Common exotic ornamentals include *Acacia farnesiana*, *Acalypha amentacea* vars., *Bougainvillea* spp., *Calotropis gigantea*, *Catharanthus roseus*, *Crinum asiaticum*, *Dracaena* spp., *Hibiscus rosa-sinensis*, *Hymenocallis littoralis*, *Ixora casei*, *Jasminum sambac*, *Lantana camara*, *Mirabilis jalapa*, *Nerium oleander*, *Ocimum* spp., *Plectranthus scutellarioides*, *Polyscias* spp., *Pseuderanthemum* spp., *Rhoeo spathacea*, *Russelia equisetiformis*, and *Tecoma stans*. The flowers or leaves of most of these plants are used for body ornamentation.

Ruderal Vegetation

Extensive areas of highly disturbed ruderal vegetation are found in both Nauru and the Gilberts. Major contributing factors include (1) long settlement; (2) destruction during World War II; (3) increasing urbanization and transportation network development (e.g., roads, causeways, and airfields); (4) total vegetation clearance and the use of heavy equipment, particularly in the case of the phosphate industry; and (5) the widespread practice of keeping villages and plantations clean by continuous burning, sweeping, and clearing of vegetation. These have created extensive areas of ruderal vegetation in settlements, waste places, along roadsides and airstrips, and in areas associated with pre-mining vegetation clearance in Nauru. The dominant species in most areas are grasses, annuals, and shrubby weedy species.

Species common in both Nauru and the Gilberts include (1) the grasses *Cenchrus echinatus*, *Chloris inflata*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Digitaria* spp., *Eleusine indica*, *Eragrostis amabilis*, and *Lepturus repens*; (2) the sedges *Cyperus javanicus*, *C. rotundus*, and *Fimbristylis cymosa* (which along with *Digitaria setigera* and *Lepturus repens* are probably indigenous); and (3) the herbaceous species *Amaranthus dubius*, *A. viridis*, *Bidens pilosa*, *Cassia occidentalis*, *Crotalaria spectabilis*, *Euphorbia* spp., *Passiflora foetida*, *Phyllanthus amarus*, *Physalis* spp., *Portulaca oleracea*, *Sida rhombifolia*, *Spermacoce assurgens*, *Stachytarpheta urticaefolia*, *Synedrella nodiflora*, *Tridax procumbens*, and *Vernonia cinerea*, plus the indigenous parasite, *Cassytha filiformis*.

Weedy species common only in Nauru include *Ageratum conyzoides*, *Alysicarpus vaginalis*, *Cleome rutidosperma*, *C. viscosa*, *Crotalaria goreensis*, *Desmodium tortuosum*, *Hedyotis corymbosa*, *Indigofera hirsuta*, *Malvastrum coromandelianum*, *Phyllanthus societatis*, and *Tricholena rosea*. Weedy species common in the Gilberts include *Cyperus polystachyos*, *Ludwigia octovalvis*, and the indigenous species *Boerhavia* spp., *Euphorbia chamissonis*, *Laportia ruderalis*, *Paspalum distichum*, *Sida fallax*, and *Triumfetta procumbens*. Of particular interest are the shrubby species *Pluchea indica* and *P. carolinensis*, and a hybrid of the two, all of which have become naturalized in ruderal habitats in the Gilberts; and the fact that whereas *Acacia farnesiana*

and *Lantana camara* are both naturalized and weedy in Nauru, they are only found cultivated in houseyard gardens in the Gilberts.

A few tree or treelike species have become naturalized in dense stands in Nauru. *Mangifera indica* is dominant in dense forests behind residences in the Buada Lagoon depression; *Annona muricata* and *A. squamosa* form dense stands on gradually sloping areas of the escarpment; *Adenanthera pavonina*, *Lantana camara* var. *aculeata*, *Leucaena leucocephala*, and *Psidium guajava* form dense stands or thickets between Buada Lagoon and the decalcination plant on the coastal strip in Aiwo District; and *Casuarina equisetifolia* and *Muntingia calabura* have colonized roadside areas and portions of the phosphate-mined area. Of particular interest is the almost monospecific colonization of the large topsoil stockpile on Topside by the cucurbit *Luffa acutangula*.

Giant Swamp Taro or Babei Pits

In the central areas of the main Gilbert Islands, and in and around villages, are extensive areas of pits for the cultivation of the ceremonial staple, giant swamp taro or *te babai* (*Cyrtosperma chamissonis*). These pits have been excavated to the level of the freshwater lens, through the limestone bedrock to depths of 1.5 to over 4 m. Because of increasing salinity and the declining importance of *te babai* relative to copra production, cash employment, and imported food, many of the pits on some islands have been abandoned. In some cases, such as on Onotoa, this occurred so long ago that the inhabitants have no recollection of their origin (Catala 1957, Moul 1957, Thaman 1990*a*). On Abemama, for example, a survey of 16 households revealed that whereas the mean number of pits in use was only 4.2, the mean number of empty pits per household was 23.4, with only 7.7 still containing sufficient water to produce *te babai*. Moreover, few of the productive pits were fully stocked, thus "reflecting more basically the changing food preference and habits of growing reliance on the cash component of a household's total income" (Watters and Banabati 1977). Pits ranged in size from 8 to 10 m long and 3 to 6 m wide. Weedy plants found in these pits include *Ludwigia octovalvis*, *Eleocharis geniculata*, and *Cyperus laevigatus*, the latter particularly common in abandoned pits. *Tournefortia argentea*, one of the main sources of leaf compost used in *te babai* cultivation, is also occasionally found near pits (Moul 1957).

On the wettest island, Butaritari, however, areas of *te babai* pits per household were much greater, with only limited or periodic evidence of neglect or serious underutilization, some households having over 2000 m^2 in productive pits (Sewell 1979).

Phosphate-mined Lands

As a result of almost 80 years of open-cast phosphate mining, some three-quarters of Nauru is under severely modified disclimax vegetation in various stages of succession. Before mining, the vegetation is removed by bulldozer and the topsoil removed to expose the phosphate deposits that lie between coral-limestone pinnacles. The extraction of phosphate then causes dramatic changes in local relief, which varies between 4 and 8 m from the top of the pinnacles to the pit bottoms, with about three to four pinnacles occurring within each 100 m^2. Because mining is only about 20% efficient, unconsolidated phosphate deposits remain in the pit bottoms and on the saddles and scree slopes between the pinnacles. These deposits (which might be mined at a later date) and the pinnacle surfaces constitute the main sites for recolonization (Manner et al. 1984, 1985).

Although there is widespread evidence that exotics commonly replace indigenous species in highly disturbed habitats, the Nauru study by Manner et al. (1984, 1985) supports the conclusion of Mueller-Dombois (1975) that indigenous (pioneer) species are often better adapted to edaphically harsh environments, given the cessation of human disturbance. The study by Manner et al. shows a very rapid colonization of mined areas by exotic herbs and ferns, followed by a fairly rapid replacement by native, primarily coastal strand, species.

Early pioneer species include the nonwoody

exotics *Alysicarpus vaginalis*, *Cleome rutidosperma*, *Crotalaria goreensis*, *Emilia sonchifolia*, *Eragrostis amabilis*, *Euphorbia cyathophora*, *E. hirta*, *E. prostrata*, *Hedyotis corymbosa*, *Syndrella nodiflora*, *Tricholena rosea*, *Tridax procumbens*, and *Vernonia cinerea*, plus the indigenous ferns *Nephrolepis biserrata* and *Polypodium scolopendria*. Of these, only the two fern species and *Euphorbia hirta*, *E. prostrata*, *Tricholena rosea*, *Tridax procumbens*, and *Vernonia cinerea* remain significant components of the flora in the later stages of succession, usually in open disturbed sites.

Species entering the succession early and remaining dominants in the 40- to 80-year-old sites include the trees *Calophyllum inophyllum*, *Dodonea viscosa*, *Ficus prolixa*, *Guettarda speciosa*, *Morinda citrifolia*, and *Premna serratifolia*; the shrubs *Phyllanthus societatis* and *Scaevola sericea*; the grasses and sedges *Lepturus repens*, *Fimbristylis cymosa*, and *Cyperus javanicus*; the parasite *Cassytha filiformis*; and the diminutive fern *Ophioglossum petiolatum*. All are indigenous. Larger exotics found in the later stages of succession in more open habitats include *Lantana camara*, *Psidium guajava*, and *Stachytarpheta urticaefolia*.

The study suggests that the potential natural disclimax vegetation of the open-cast mined plateau will probably be dominated by *Calophyllum inophyllum* and *Guettarda speciosa*, with the epiphytic *Ficus prolixa* dominating the more ecologically severe pinnacle habitats. *Morinda citrifolia*, *Premna serratifolia*, and the exotics *Lantana camara* and *Psidium guajava* could become important components of the subcanopy. The exotics *Casuarina equisetifolia* (which is native to limestone habitats on other Pacific islands) and *Muntingia calabura*, both now locally abundant in some mined areas, could enter into the succession as well.

As argued by Manner et al. (1985), given no deliberate human intervention, the succession to a disclimax vegetation association capable of sustaining human life will probably take "many thousands of years." It is stressed that it is ironic that Nauru's central plateau, from which Nauruans formerly obtained some of the necessities of life, will be a "topographic jungle" stripped of its natural vegetation, before the next century, to provide the phosphate needed to revive phosphate-poor soils to fuel the development of Australia and New Zealand.

THE FLORAS

Like the extremely limited, degraded, and displaced vegetation types, the indigenous terrestrial floras of Nauru and the Gilbert Islands exhibit extreme poverty and current numerical domination by exotics. Of a total of 487 and 306 species present on Nauru and the Gilberts, respectively, only 55 (11.3%) and 83 (27.1%), respectively, are possibly indigenous (Table 1). There are *no* reported endemics, reflecting the lack of habitat diversity and the predominance of ubiquitous, easily dispersed pantropical or paleotropical coastal species. The greater diversity in the Gilberts is probably the result of greater total land area, greater coastal habitat diversity, and less coastal habitat degradation over time. The high number of recent introductions in Nauru reflects its greater contact with the outside world, increasing urbanization, and the total absence of quarantine regulations there.

Nature of Indigenous Species

Of the indigenous species (Table 1), eight are widespread pantropical or paleotropical pteridophytes, including *Psilotum nudum*, *Polypodium scolopendria*, and *Ophioglossum*, *Pteris*, and *Nephrolepis* spp., with *Pyrrosia adnascens*, a common epiphyte found on Nauru. There are no indigenous gymnosperms, although the widespread *Cycas circinalis* is found in cultivation. Indigenous monocotyledons are restricted to *Pandanus tectorius*, some cultivars of which are undoubtedly aboriginal introductions, and a range of sedges and grasses (Cyperaceae and Poaceae), some of which could be aboriginal or recent introductions. The coconut palm (*Cocos nucifera*) is classified as an aboriginal introduction.

The dicotyledons are composed almost exclusively of salt-tolerant, widely dispersed, pantropical coastal species. A large proportion of these species (28 of 55 for Nauru and

TABLE 1

SPECIES THAT ARE INDIGENOUS OR POSSIBLY INDIGENOUS TO NAURU AND KIRIBATI

SPECIES	NAURU	KIRIBATI
Pteridophytes		
Asplenium nidus	+e?	+e
Nephrolepis biserrata	+	+
Nephrolepis hirsutula	+	+
Ophioglossum nudicaulis	−	+
Ophioglossum petiolatum	+	−
Polypodium scolopendria	+	+
Psilotum nudum	+	+
Pteris ensiformis	+e	+e
Pteris tripartita	+	+
Pyrrosia adnascens	+e	−
Herbs		
Achyranthes canescens	E?	+e
Adenostema lanceolatum	−	+e
Boerhavia albiflora	−	+e
Boerhavia repens	−	+
Boerhavia tetrandra	−	+
Hedyotis biflora	−	+e
Hedyotis verticillata	−	+
Laportea ruderalis	+e	+
Portulaca australis	−	+
Portulaca lutea	−	+e
Sesuvium portalucastrum	−	+e
Tribulus cistoides	−	+e
Triumfetta procumbens	+	+
Wollastonia biflora	−	+e
Grasses and Sedges		
Cyperus iria	+e	−
Cyperus javanicus	+?	+
Cyperus laevigatus	−	+?
Cyperus polystachyos	−	+
Digitaria pacifica	−	+e
Digitaria setigera	+?	+?
Eragrostis whitneyi	−	+e
Fimbristylis cymosa	+	+
Fimbristylis dichotoma	−	+e
Lepturus pilgerianus	−	+
Lepturus repens	+	+
Paspalum distichum	−	+
Stenotaphrum micranthum	−	+
Thuarea involuta	−	+e
Vines and Lianas		
Canavalia cathartica	+e	+e
Canavalia rosea	+e	−
Capparis quiniflora	+e	−
Cassytha filiformis	+	+
Derris trifoliata	+e	−
Ipomoea littoralis	+e	+e
Ipomoea macrantha	+	+
Ipomoea pes-caprae	+	+
Vigna marina	+	+

TABLE 1 (continued)

SPECIES	NAURU	KIRIBATI
Shrubs		
Abutilon asiaticum var. *albescens*	+e	+e
Abutilon indicum	−	+e?
Allophylus timoriensis	−	+e
Caesalpinia bonduc	+e	+e
Capparis cordifolia	+	−
Clerodendrum inerme	+	+
Colubrina asiatica	+	−
Dodonaea viscosa	+	+
Euphorbia chamissonis	+e	+e
Pemphis acidula	−	+
Phyllanthus societatis	+	−
Polyscias grandifolia	−	+e
Scaevola sericea	+	+
Sida fallax	+e	+
Sophora tomentosa	−	+e
Suriana maritima	+e	+
Trees		
Aidia cochinchinensis	+e	+e
Barringtonia asiatica	+e	+e
Bruguiera gymnorhiza	+e	+
Calophyllum inophyllum	+	+
Cerbera manghas	+e	+e
Cordia subcordata	+e	+
Erythrina variegata	+e	−
Fagraea berteriana	E?	+e?
Ficus prolixa	+	+e?
Ficus tinctoria	−	+
Guettarda speciosa	+	+
Hernandia nymphaeaefolia	+e	+e
Hibiscus tiliaceus	+	+
Inocarpus fagifer	−	+e?
Lumnitzera littorea	−	+e
Macaranga carolinensis	−	+e
Morinda citrifolia	+	+
Neisosperma oppositifolia	−	+e
Ochrosia elliptica	+e	−
Pandanus tectorius	+	+
Pipturus argenteus	−	+e
Pisonia grandis	+e	+
Premna serratifolia	+	+
Rhizophora mucronata	−	+
Sonneratia alba	−	+e
Terminalia catappa	+?	+?
Terminalia samoensis	−	+e
Thespesia populnea	+	+e
Tournefortia argentea	+	+
Vitex negundo	+e	+e
Vitex trifolia	−	+e
Total species	55	83

NOTE: ? = status uncertain, possibly an aboriginal or recent introduction; E = possibly extinct; e = endangered.

SOURCES: An extensive review of the available literature and personal records and observations by the author; see in particular Thaman 1989*a*, 1990*b*.

40 of 83 for the Gilberts) are severely restricted in distribution, endangered, or possibly extinct, because of removal and severe habitat modification or limitation (Table 1). Many species still found in the Gilberts were probably present in the past in Nauru, but are now extinct. Species such as *Abutilon asiaticum*, *Caesalpinia bonduc*, *Euphorbia chamissonis*, *Sida fallax*, *Suriana maritima*, *Aidia cochinchinensis*, *Barringtonia asiatica*, *Cerbera manghas*, *Hernandia nymphaeaefolia*, *Pisonia grandis*, *Thespesia populnea*, and *Vitex negundo* are represented by only a few remaining individuals, often in houseyard gardens, or by localized relict communities. Moreover, some of the plants reported present in Kiribati may not actually be present as indigenous species in the main Gilbert group, but, rather, as deliberate introductions, or citations from Banaba that have been included in "Kiribati" lists. For example, *Wollastonia biflora* and *Abutilon* spp., which are reported from Tarawa (Fosberg and Sachet 1987) but not seen by recent collectors, are known locally as *te kaura ni Banaba*, the "*Sida fallax* from Banaba" (Overy et al. 1982, Thaman 1987*a*). Similarly, *Ochrosia elliptica*, which is present today on Nauru, has also been reported present on Banaba, but not in the Gilbert group. Before widespread disturbance in both areas, Nauru and the Gilberts would have undoubtedly had more species in common.

Comparison with Other Island Floras

The extreme poverty of the indigenous floras of Nauru and the Gilbert Islands becomes more obvious when compared with estimates of the indigenous floras of island groups that are larger or closer to the plant source regions, such as Malaya (ca. 20,000), the Philippines (10,000), Bismarck Archipelago (700), Vanuatu (750), Fiji (more than 1100), Tonga (257), Samoa (548), and French Polynesia (600). Only extremely isolated small islands such as Easter Island and the three small atolls of Tokelau, with indigenous floras of 32 and 33 species, respectively, have poorer floras (Good 1947 in Manner 1987, Parham 1971). When taken individually, the floras of Pacific atolls range from as few as three to perhaps 150 indigenous species, compared to some Indian Ocean atolls, nearer to continental areas, which have close to 300 indigenous species (Fosberg 1952).

The floristic poverty of Nauru and the Gilberts becomes even more pronounced based on a comparison of the occurrence of 142 widespread coastal species in 11 Pacific island groups (Table 2). All of these species have the ability to cope successfully in environments characterized by loose shifting sands, wave action, soil-less limestone and volcanic terraces and rock outcrops, high salinity, strong sunlight, strong winds, sea spray and associated physiological drought (Fosberg 1952, 1960), and, in some cases, periodic inundation and waterlogging, all conditions common in Nauru and the Gilberts.

The island groups range from large, geographically older high island groups such as Fiji, composed of over 300 islands with a total area of 18,376 km^2, to the three small isolated atolls of Tokelau with a total land area of only 12.2 km^2. Also included are high island groups with diverse habitats, such as Guam, a volcanic island with extensive areas of limestone and an area of 549 km^2; Samoa and Hawaii, recent basaltic volcanic island groups, with little or no limestone; Palau, a group of some 340 volcanic and uplifted limestone islands, including an atoll, Kayangel, and the raised phosphate island of Angaur, located only 850 km to the east of the Philippines; Tonga, a group of about 150 uplifted limestone and some volcanic islands, with a total area of 697 km^2; Niue, an isolated uplifted limestone island, like Nauru, but with an area of 258 km^2 and few beaches; and Makatea, an uplifted phosphatic island about the same area as Nauru and without protective barrier reefs or lagoons.

Although these comparisons are strongly biased by size and geologic age, their distance from plant source areas, and the availability of information on other islands such as Banaba, the poverty of the coastal floras of the two small phosphate islands of Nauru and Makatea and the atolls of the Gilbert and Tokelau islands is clearly apparent: only 58

TABLE 2

NATURE AND GEOGRAPHICAL OCCURRENCE IN SELECTED ISLAND GROUPS OF WIDESPREAD COASTAL PLANT SPECIES OF THE TROPICAL PACIFIC OCEAN

SPECIES	FIJI	TONGA	SAMOA	GUAM	HAWAII	NIUE	PALAU	MAKATEA	TOKELAU	NAURU	KIRIBATI	TOTAL
Ferns												
Acrostichum aureum	+	+	+	+	*	+	+	–	–	–	–	6(1)
Asplenium nidus	+	+	+	+	+	+	+	+	+	*?	+	10(1)
Davillia solida	+	+	+	+	*	+	+	+	+	–	–	8(1)
Nephrolepis spp.	+	+	+	+	+	+	+	+	+	+	+	11
Polypodium scolopendria	+	+	+	+	+	+	+	+	+	+	+	11
Pteris spp.	+	+	+	+	+	+	+	–	–	+	+	9
Pyrrosia adnascens	+	+	+	+	–	–	–	–	–	+	–	5
Stenochlaena palustris	+	+	–	–	–	–	+	–	–	–	–	3
Tectaria spp.	+	+	+	+	–	+	+	–	–	–	–	6
Thelypteris spp.	+	+	+	+	+	+	+	–	–	–	–	7
Total present (x/10)	10	10	9	9	7	8	9	4	4	5	4	
Herbs												
Achyranthes spp.	*	*	*	+	*	*	+	*	*	+?	+	4(7)
Boerhavia spp.	+	+	+	+	+	+	+	+	+	–	+	10
Crinum asiaticum	*	*	*	*	*	*	*	*	*	*	*	–(11)
Dendrobium spp.	+	+	+	+	–	–	+	–	–	–	–	5
Hedyotis spp.	+	+	+	+	+	+	+	–	+	–	+	9
Heliotropium spp.	–	–	–	+	+	+	+	+	–	+	–	6
Hymenocallis littoralis	*	*	*	*	*	*	*	–	–	*	*	–(9)
Laportea (*Fleurya*) spp.	+	+	+	+	*?	*?	+	+	+	+	+	9(2)
Lepidium bidentatum	–	–	–	–	+	–	–	+	–	–	–	3
Peperomia spp.	+	+	+	+	+	+	+	+	–	–	–	8
Portulaca lutea	+	+	+	+	+	+	–	+	–	–	+	8
Portulaca pilosa	+?	+	+	+	+	+	+	–	+	–	+	9
Procris pedunculata	+	+	+	+	–	+	+	+	+	–	–	8
Sesuvium portalucastrum	+	+	–	+	+	+	–	–	–	–	+	6
Tacca leontopetaloides	*	*	*	*	*	*	*	*	*	*	*	–(11)
Taeniophyllum fasticola	+	+	+	+	–	+	+	+	–	–	–	7
Triumfetta procumbens	+	+	+	+	+	+	+	+	+	+	+	11
Total present (x/17)	15	15	14	16	14	15	14	12	9	6	11	
Grasses/Sedges												
Cyperus javanicus	+	+	+	+	*	*	+	+	–	*	*	5(4)
Cyperus laevigatus	+	+	+	–	+	+	–	–	–	–	+	6
Cyperus polystachyos	+	+	+	*	+	–	*	–	–	–	+	5(2)
Digitaria setigera	+	+	+	+	*	*	+	+	+	+	+	9(2)

Eleocharis spp.	+	+	+	+	+	–	+	–	–	–	–	5
Fimbristylis cymosa	+	+	+	+	+	+	+	–	+	+	+	10
Ischaemum spp.	+	+	+	+	+	+	+	–	–	–	–	7
Lepturus repens	+	+	+	+	+	+	+	+	+	+	+	11
Paspalum distichum	+	+	+	+	*	+	+	–	–	–	+	8(1)
Sporobolus spp.	+	–	–	+	+	–	+	+	–	*	*	5(2)
Stenotaphrum spp.	+	+	+	–	–	+	+	–	–	–	+	6
Thuarea involuta	+	+	+	+	–	–	+	–	–	–	+	6
Total present (*x*/12)	12	11	11	10	10	8	11	4	3	5	10	
Vines/Lianas												
Abrus precatorius	+	+	+	+	*	+	+	+	–	–	–	7(1)
Canavalia cathartica	+	+	+	+	*	–	+	–	–	+	+	7(1)
Canavalia rosea	+	+	+	+	*	+	+	–	–	+	–	7(1)
Canavalia sericea	+	+	+	–	+	+	–	–	–	–	–	5
Cassytha filiformis	+	+	+	+	+	+	+	+	+	+	+	11
Derris trifoliata	+	+	+	+	*	–	+	–	–	+	–	6(1)
Entada phaseoloides	+	+	+	+	*	–	+	–	–	–	–	5(1)
Epipremnum pinnatum	+	+	+	–	*	–	–	–	–	–	–	3(1)
Hoya australis	+	+	+	–	*	–	–	–	–	–	–	3(1)
Ipomoea littoralis	+	+	+	+	+	+	+	+	–	+	+	10
Ipomoea macrantha	+	+	+	+	*	+	+	–	+	+	+	9(1)
Ipomoea pes-caprae	+	+	+	+	+	–	+	–	–	+	+	8
Mucuna gigantea	+	+	+	+	+	+	+	–	–	–	–	7
Vigna marina	+	+	+	+	+	+	+	–	–	+	+	9
Total present (x/14)	14	14	14	11	14	8	11	3	2	8	6	
Shrubs												
Abutilon spp.	+	–	–	*	+	+	–	–	–	+	+	4(2)
Acanthus ebracteatus	–	–	–	–	–	–	+	–	–	–	–	1
Allophylus timoriensis	+	+	+	+	–	+	+	+	–	–	+	8
Bikkia tetrandra	+	+	–	+	–	–	+	–	–	–	–	4
Caesalpinia spp.	+	+	+	+	+	+	+	–	–	+	+	9
Canthium spp.	+	+	+	+	+	–	+	+	–	–	–	7
Capparis spp.	+	+	+	+	+	+	+	+	–	+	–	9
Clerodendrum inerme	+	+	+	+	*	+	+	–	–	+	+	8(1)
Colubrina asiatica	+	+	+	+	+	+	+	+	–	+	–	9
Dalbergia candenatensis	+	+	–	+	–	–	+	–	–	–	–	4
Desmodium umbellatum	+	+	+	+	–	+	+	–	–	–	–	6
Dodonea viscosa	+	+	+	+	+	+	+	+	–	+	+	10
Eugenia reinwardtiana	+	+	+	+	+	+	+	–	–	–	–	7
Euphorbia chamissonis	+	+	+	+	–	+	+	–	–	+	+	8
Gardenia taitensis	+	+	+	–	*	+	–	*	+	*	*	5(4)
Geniostoma spp.	+	+	+	+	–	+	+	–	–	–	–	6

TABLE 2 (continued)

SPECIES	FIJI	TONGA	SAMOA	GUAM	HAWAII	NIUE	PALAU	MAKATEA	TOKELAU	NAURU	KIRIBATI	TOTAL
Nypa fruticans	–	–	–	*	*	–	+	–	–	–	–	1(2)
Pemphis acidula	+	+	+	+	*	+	+	+	+	–	+	9(1)
Scaevola sericea	+	+	+	+	+	+	+	+	+	+	+	11
Sida spp.	+	+	+	*	+	+	–	–	–	+	+	6(1)
Sophora tomentosa	+	+	+	+	–	–	+	–	–	–	+	6
Suriana maritima	+	+	–	+	–	–	+	+	–	+	+	7
Tephrosia purpurea	+	+	+	+	*	+	–	–	–	–	–	5(1)
Timonius spp.	+	+	+	+	–	+	+	+	–	+	–	8
Wollastonia biflora	+	+	+	+	–	+	+	–	–	–	+	7
Wikstroemia spp.	+	+	+	+	+	–	+	–	–	–	–	6
Ximenia americana	+	+	+	+	–	–	+	–	–	–	–	5
Total present (x/27)	25	24	21	24	15	19	24	11	3	11	13	
Trees												
Acacia simplex	+	+	+	–	–	–	–	–	–	–	–	3
Aidia cochinchinensis	+	+	+	+	–	–	+	–	–	+	+	7
Avicennia alba	–	–	–	+	–	–	–	–	–	–	–	2
Barringtonia asiatica	+	+	+	+	*	+	+	+	+	+	+	10(11)
Barringtonia racemosa	+	–	+	+	*	+	+	–	–	–	–	5(6)
Bruguiera gymnorhiza	+	+	+	+	*	–	+	–	–	+	+	7(8)
Calophyllum inophyllum	+	+	+	+	+	+	+	+	+	+	+	11
Casuarina equisetifolia	+	+	+	+	*	*	+	*	*	*	*	5(11)
Cerbera manghas	+	+	+	–	*	–	+	–	–	+	+	6(7)
Ceriops tagal	–	–	–	–	–	–	+	–	–	–	–	1
Cocos nucifera	*	*	*	*	*	*	*	*	*	*	*	(11)
Cordia subcordata	+	+	+	+	*	+	+	+	+	+	+	10(11)
Cycas circinalis	+	+	+	+	*	*	+	–	–	*	*	5(9)
Cynometra spp.	+	–	–	+	*	–	+	–	–	–	–	3(4)
Diospyros ferrea	+	+	+	–	+	+	+	–	–	–	–	6
Dolichadrone spathacea	–	–	–	–	*	–	+	–	–	–	–	1(2)
Erythrina fusca	+	+	+	–	*	–	*	–	–	–	–	3(5)
Erythrina variegata	+	+	+	+	*	+	+	–	–	+	–	8(9)
Excoecaria agallocha	+	+	+	+	–	+	+	–	–	–	–	6
Ficus obliqua	+	+	+	–	–	+	–	–	–	–	–	4
Ficus prolixa	+	+	+	+	–	+	+	+	–	+	+	9
Ficus scabra	+	+	+	–	–	+	–	–	–	–	–	4
Ficus storkii	+	+	+	–	–	+	–	–	–	–	–	4
Ficus tinctoria	+	+	+	+	–	+	+	–	+	*	+	8(9)
Glochidion spp.	+	+	+	+	–	+	+	+	–	–	–	7
Grewia crenata	+	+	+	+	–	+	–	–	–	–	–	5

Guettarda speciosa	+	+	+	+	*	+	+	+	+	+	+	10(11)
Gyrocarpus americanus	+	+	+	−	−	−	−	−	−	−	−	3
Heritiera littoralis	+	+	−	+	*	+	+	−	−	−	−	5(6)
Hernandia nymphaeaefolia	+	+	+	+	*	+	+	+	+	+	+	10(11)
Hibiscus tiliaceus	+	+	+	+	+	+	+	+	−	+	+	10
Inocarpus fagifer	+	+	+	*	*	*	*	−	−	−	*	3(8)
Intsia bijuga	+	+	+	+	*	−	+	−	−	−	−	5(6)
Leucaena insularum	+	+	−	+	−	+	+	−	−	−	−	5
Lumnitzera littorea	+	+	−	+	−	−	+	−	−	−	+	5
Mammea odorata	+	−	+	+	*	−	+	+	−	−	−	5(6)
Manilkara spp.	+	+	−	−	−	−	+	−	−	−	−	3
Metroxylon spp.	+	−	*	*	*	−	+?	−	−	−	−	2(5)
Morinda citrifolia	+	+	+	+	*	+	+	+	+	+	+	10(11)
Neisosperma oppositifolia	+	+	−	+	*	+	+	−	+	−	+	7(8)
Pandanus tectorius	+	+	+	+	+	+	+	+	+	+	+	11
Phaleria disperma (spp.)	+	+	+	−	*	*	+	−	−	−	−	4(6)
Pipturus argenteus (spp.)	+	+	+	+	+	+	+	+	*	−	+	8(9)
Pisonia grandis	+	+	+	+	−	+	+	−	+	+	+	9+
Pittosporum spp.	+	+	−	+	+	+	+	−	−	−	−	6
Planchonella costata (spp.)	+	+	+	+	−	+	+	+	−	−	−	7
Polyscias spp.	+	+	+	+	−	+	+	−	−	−	+	7
Pongamia pinnata	+	−	+	+	*	−	+	−	−	−	−	4(5)
Premna serratifolia	+	+	+	+	−	+	+	+	−	+	+	9
Rhizophora spp.	+	+	+	+	*	−	+	+	−	−	+	8
Santalum spp.	+	+	−	−	+	*	*	−	−	−	−	3(5)
Serianthes spp.	+	+	−	+	−	−	+	−	−	−	−	4
Sonneratia alba	−	−	−	−	−	−	+	−	−	−	+	2
Soulamea amara	−	−	−	−	−	−	+	−	−	−	−	1
Syzygium spp.	+	+	+	+	+	+	+	−	−	−	−	7
Terminalia catappa	+	+	+	+	*	+	+	+	+	+	+	10(11)
Terminalia samoensis	+	+	+	+	*	−	+	+	+	−	+	8(9)
Thespesia populnea	+	+	+	+	*	+	+	+	−	+	+	9(10)
Tournefortia argentea	+	+	+	+	*	+	+	+	+	+	+	10(11)
Vavaea amicorum	+	+	+	−	−	−	−	−	−	−	−	3
Vitex spp.	+	+	+	+	+	+	+	−	−	+	+	10
Xylocarpus spp.	+	+	+	+	−	−	+	−	−	−	−	5
Total present (x/62)	57	52	48	46	38	39	54	21	16	23	30	
Grand Total (x/142)	133	126	117	116	98	97	123	55	37	58	74	

NOTE: Under the island groups, + = presumably indigenous, * = presumably an exotic aboriginal or recent introduction, and ? = status uncertain; under total, the number outside the parentheses indicates the number of island groups where a given species was indigenous, whereas the number in parentheses indicates its occurrence as an exotic.

SOURCES: Fiji (J. W. Parham 1972); Tonga (Yuncker 1959); Samoa (B. E. V. Parham 1972, Whistler 1980*b*); Guam (Stone 1970); Hawaii (Neal 1965, St. John 1973); Niue (Sykes 1970); Palau (Fosberg et al. 1980); Makatea (Wilder 1934); Tokelau (Parham 1971, Whistler 1988); Nauru (Thaman et al. 1985); Kiribati (Luomala 1953, Catala 1957, Overy et al. 1982, Fosberg and Sachet 1987); general (Fosberg et al. 1979, 1982, 1987); personal records and observations by the author; see in particular Thaman 1989*a*, 1990*b*.

and 55 species, respectively, are recorded from Nauru and Makatea, and 74 and 34 species, respectively, from the Gilberts and Tokelau, of the 142 common coastal species. In all other island groups, including Hawaii and Niue, at least two-thirds of the 142 species are present as indigenous or long-established introductions.

The Gilberts and the Tokelaus have the fewest ferns, although Nauru has the fewest widespread coastal herbs. It may be assumed that the fern *Davallia solida* and widespread herbs such as *Boerhavia*, *Hedyotis*, *Portulaca* spp., and *Sesuvium portalucastrum* were all originally present on Nauru, but eliminated with the widespread destruction of coastal habitats. Nauru, the Tokelau atolls, and Makatea have the fewest species of coastal grasses and sedges, possibly due to the combination of widespread habitat destruction and a relative absence of marsh or wetland environments. The widespread destruction of the areas around Buada Lagoon for cultivation by the Japanese during World War II may have eliminated many natural wetland environments. In the case of the Gilberts, the widespread cultivation of *Cyrtosperma chamissonis* in pits excavated down to the freshwater lens has provided artificial wetland habitats. However, whether a given sedge species arrived naturally or was introduced deliberately because of its cultural utility is uncertain.

There are very few vines and lianas on the atolls and Makatea. On Nauru and Niue, where there are virtually no beaches or coastal swamps, only eight of the 14 widespread species occur. *Abrus precatorius*, *Entada phasioloides*, and *Mucuna gigantea* are noticeably absent on Nauru and in the Gilberts.

With the exception of the Tokelau Islands (three species) Nauru, the Gilberts, and Makatea have the poorest shrub flora, with only 11, 13, and 11 species, respectively, of a possible 27 species. Similarly, there are only 16 of 62 common coastal tree species in the Tokelaus, and only 23, 30, and 21 species, respectively, on Nauru, the Gilberts, and Makatea. The shrubs *Allophylus timoriensis*, *Pemphis acidula*, *Sophora tomentosa*, and *Wollastonia biflora* and the trees *Ficus tinctoria*, *Neisosperma oppositifolia*, *Pipturus argenteus*, and *Terminalia samoensis*, most of which are present on the smaller elevated phosphate-rich island of Fais and the limestone island of Satawal in the Western Caroline Islands (Fosberg 1969, Fosberg and Evans 1969), are conspicuously absent on Nauru.

There are other widespread noncoastal species, which might have been present in the past on Nauru, that were present in 1932 on Makatea. These include the fern *Ohioglassum pendulum*; orchids, such as *Oberonia* and *Taeniophyllum* spp.; the herb *Procris pedunculata*; the vines *Abrus precatorius* and *Dioscorea bulbifera* (the latter the most widespread of all yam species and present from East Africa to Micronesia and eastern Polynesia) (Stone 1970); and the shrubs and trees *Alyxia* sp., *Canthium barbatum*, *Celtis paniculata*, *Glochidion ramiflorum*, *Ixora* sp., *Melochia odorata*, *Planchonella* (*Pouteria*) sp., *Tarenna sambucina*, and *Timonius* sp. (Wilder 1934). Makatea has one presumably endemic species, *Euprichardia vuylstekeana*, and it might be expected, given the diversity of pre-mining microhabitats and the isolation of Nauru, that there could have been endemic species there also. Interestingly, the one plant that was thought to be possibly endemic on Nauru turned out to be *Phyllanthus societatis*, "a common plant among coral rocks" on Makatea in 1933 (Wilder 1934).

A similar comparison with the relatively undisturbed flora of Henderson Island, a remote raised limestone island with a limestone plateau and pinnacle topography, provides further insight into some of the plant species that might have existed in the past on Nauru. Because it was unsuitable for permanent habitation and had no economic phosphate deposits, Henderson has survived successive Polynesian and European impacts, with only five known introduced plant species. Species of widespread genera found on Henderson, but not on Nauru include *Davillea solida*; *Boerhavia tetrandra*, *Euphorbia sparrmannii*, *Lepidium bidentatum*, *Peperomia hendersonensis*, *Portulaca lutea*, *Procris pedunculata*, and *Sesuvium portalucastrum*; the shrubs *Allophylus* sp., *Alyxia* sp., *Canthium barbatum*, *C. odoratum*, *Glochidion pitcairnense*, *Ixora fragrans*, *Jasminum didymum*, *Eugenia*

reinwardtiana (*Eugenia rariflora*), *Morinda umbellata* var. *forsteri*, *Pemphis acidula*, *Timonius polygamus*, and *Xylosma suaveolens* var. *haroldii*; and the trees *Celtis paniculata* var. *viridis*, *Geniostoma hendersonense*, *Mertya brachypoda*, *Pittosporum arborescens*, *Sesbania coccinea*, and *Santalum hendersonense*. Nine species or varieties are presently recognized as endemic, all of which are found in the interior. These are the very areas so devastated on Nauru. Not present on Henderson, but present on Nauru are *Calophyllum inophyllum* and *Barringtonia asiatica* (Fosberg et al. 1983, Fosberg et al. 1989, Paulay and Spencer 1989).

Based on species reported present in less-disturbed environments on other atolls, such as those of Tuvalu (Woodroffe 1985), the Line Islands (Wester 1985), Tuamotu Archipelago (Guerin 1982, Sachet 1983), and Bikini Atoll (Fosberg 1988), widespread species that might have been present in the Gilberts before habitat modification by humans include the herbs *Heliotropium* spp. and *Lepidium bidentatum*; the sedge *Scirpus* spp.; and the shrubs *Timonius polygamus* and *Ximenia americana*. (Note: A single mature specimen of *X. americana* was subsequently identified by the author on Buota Islet, North Tarawa, in 1991 after this paper was submitted.)

Nature of Exotic Species

Exotic species, which constitute 89 and 73% of the current floras of Nauru and the Gilberts, respectively, dominate the ruderal and houseyard vegetation in many areas. They include a wide range of ornamentals, weedy species, food plants, and a number of other useful species.

Ornamentals, which are normally confined to houseyard and village gardens, compose some 52 and 28% of the total species recorded from Nauru and the Gilberts, respectively. On Nauru, introductions by travelers from Australia, Fiji, and other areas with highly developed ornamental gardening traditions; the absence of quarantine restrictions; and the almost total breakdown in the subsistence economy, coupled with the more favorable soil conditions (compared to the Gilberts), seem to be the main reasons for the disproportionate importance of ornamental plants there.

The proportions of the floras composed of weedy species on Nauru and the Gilberts are 17 and 22%, respectively, an indication of both the poverty of the indigenous flora and the highly disturbed nature of the vegetation.

Although food plants represent 16 and 22% of the floras, respectively, because of the harsh environments and limited focus on food production in Nauru, many of these species are restricted in numbers or utility and are often represented by experimental attempts to diversify food production or by individual, often immature specimens of a given species. Food plants of particular importance on either Nauru or the Gilberts include the indigenous species native fig (*Ficus tinctoria*) and numerous edible pandanus cultivars (*Pandanus tectorius*), some of which are undoubtedly aboriginal introductions, and the aboriginal introductions coconut (*Cocus nucifera*) and giant swamp taro (*Cyrtosperma chamissonis*). Recent introductions of more localized importance, or of particular importance to contract worker communities on Nauru or in recent urban home food production programs in the Gilberts include the vegetables hibiscus spinach (*Hibiscus manihot*), a range of Chinese cabbage cultivars, long beans (*Vigna sesquipedalis*), amaranthus spinach (*Amaranthus* spp.), and pumpkin (*Cucurbita pepo*); the staple root crops taro (*Colocasia esculenta*), tannia (*Xanthosoma saggitifolium*), sweet potato (*Ipomoea batatas*), and cassava (*Manihot esculenta*); a range of banana and plantain cultivars (*Musa* cultivars); and the tree crops lime (*Citrus aurantiifolia*), fig (*Ficus carica*), guava (*Psidium guajava*), mango (*Mangifera indica*), soursop (*Annona muricata*), and the horseradish or drumstick tree (*Moringa oleifera*), all of which seem to do well in the harsh environments of either Nauru or the Gilberts. Important emergency or pig foods include Polynesian arrowroot (*Tacca leontopetaloides*) and purslanes (*Portulaca* spp.) and the leaves of *Morinda citrifolia*, *Pisonia grandis*, and *Polyscias* spp., which were eaten as part of a campaign in urban Kiribati to arrest night blindness induced by vitamin A deficiency among children.

Other useful plants found either on Nauru or in the Gilberts include kapok (*Ceiba pentandra*), cotton (*Gossypium barbadense*), tobacco (*Nicotiana tabacum*), and bamboo (*Bambusa* sp.?, which was reportedly more abundant in the past). As suggested above, some larger weedy exotics, such as *Adenanthera pavonina*, *Annona* spp., *Casuarina equisetifolia*, *Lantana camara*, *Leucaena leucocephala*, *Mangifera indica*, *Muntingia calabura*, and *Psidium guajava*, some which are classified as ornamentals, food plants, or other useful plants, have become naturalized and competitive with the indigenous species in some disturbed and relatively undisturbed sites on Nauru.

ECOLOGICAL AND CULTURAL UTILITY OF EXISTING FLORAS

Although highly disturbed, outnumbered, and, in some ways, "enriched" by introduced exotics, the vegetation and floras of Nauru and the Gilberts still constitute a critical ecological and cultural resource to both Nauru and Kiribati. This is particularly true for the indigenous species, virtually all of which had wide cultural utility within the subsistence economy.

Ecological Utility

The most important ecological attributes of coastal plant resources include the provision of shade and animal and plant habitats; protection from wind, erosion, flood, and salt water incursion; land stabilization; protection from the desiccating effects of salt spray; and soil improvement and mulching.

Shade is important to humans, plants, and animals, especially in highly reflective low-lying coral island and lagoonal environments, and in villages and urban areas. As populations increase, shade and the role that trees and other coastal plants play as habitats for other important animal and plant species will become more important. Of particular importance are mangrove ecosystems, which contribute either directly or indirectly, through primary and secondary productivity, to the nutritional requirements of a high proportion of marine food species (Watling 1985). In Fiji over 60% of commercially important species live in mangroves or depend on mangrove food webs at some stage in their life cycle (Lal et al. 1983); in eastern Australia and Florida, the figures are 67 and 80%, respectively (Watling 1985). Destruction and reclamation of mangroves have deleterious effects on fisheries yields: in the Malacca Straits mangrove reclamation for industrial expansion led to a substantial drop in catches per effort (Khoo 1976). Baines (1979) argued that mangrove removal can lead to declines of 50 to 80% in yield of offshore fisheries.

Mangrove and coastal strand forests stabilize tidal-zone soils and reduce the impact of storm surge and ocean salt spray, while damage from wind, erosion, and flood are increased when forests are removed. After Tropical Cyclone Isaac in Tonga in 1982, most indigenous plant species were little affected by hurricane-force winds and 2- to 3-m storm surge, whereas introduced noncoastal species suffered high mortality due to windfall and excessive salinity related to both storm surge and severe salt spray. Moreover, areas inland from where coastal and mangrove forests were intact suffered far less damage and mortality (Thaman 1982). Conversely, in Truk, where mangroves were completely removed by Japanese woodsmen, "the coast has been washed away rapidly and is lined with coconut trees in various stages of falling into the sea" (Fischer and Fischer 1970).

The role of coastal plants in soil stabilization is critical to the success of land reclamation and other low-cost coastal engineering works. Species already used for land reclamation in various areas of Asia and the Pacific include *Bruguiera gymnorhiza*, *Calophyllum inophyllum*, *Casuarina equisetifolia*, *Cocos nucifera*, *Hibiscus tiliaceus*, *Lumnitzera littorea*, *Rhizophora* spp., *Scaevola sericea*, *Sonneratia alba*, *Terminalia catappa*, and *Tournefortia argentea* (Yao 1986). Many of the coastal herbs, grasses, sedges, vines, and shrubs are also of considerable importance for coastal stabilization and land reclamation. In the Gilberts, species of particular importance for the stabilization of the extensive reclaimed

Temaiku milkfish ponds on Tarawa are *Scaevola sericea* and *Tournefortia argentea*.

One of the most important ecological roles played by coastal plants is the protection of inland agricultural areas, noncoastal vegetation and fauna, settlements, and water supplies from salt water spray and storm surge. Of particular value are plants with high tolerance to salt spray and saline soils. These include coconut, pandanus, *Tournefortia argentea*, *Scaevola sericea*, and *Guettarda speciosa*, followed in importance by *Cordia subcordata*, *Clerodendrum inerme*, *Terminalia samoensis*, *Premna serratifolia*, *Morinda citrifolia*, and *Calophyllum inophyllum* (Soucie 1983). Farmers throughout the Pacific purposely leave strand or mangrove forests intact seaside of their gardens, as they know that to remove these trees would make farming problematic. In the Gilberts, stands of *Pemphis acidula* are left seaward of agricultural areas to provide protection from salt spray, and *Casuarina equisetifolia* has been planted to protect newly planted coconuts (Thaman 1990*b*). Species commonly used for living fences or hedging include *Clerodendrum inerme*, *Cocos nucifera*, *Erythrina variegata*, *Ficus tinctoria*, *Hibiscus tiliaceus*, and *Premna serratifolia*. *Crinum asiaticum* is commonly used for garden borders. Low-growing *Hibiscus tiliaceus* cultivars are planted as windbreaks, and plant products such as woven coconut leaves or roots are used for sandscreens.

Soil improvement and the provision of organic material is also important to the success of agriculture in nutritionally poor and highly permeable coastal soils, particularly atoll soils, which are among the least fertile in the world. As stressed by Soucie (1983), organic material increases soil water-holding capacity and reduces soil pH to more favorable levels at which minerals become more available to plants. Organic matter also reduces runoff, water and wind erosion, and water loss to evaporation.

Many Pacific societies have evolved sophisticated systems of fertilization and mulching using the leaves of coastal plants. In the Gilberts, where the practice has perhaps attained its greatest sophistication, the leaves of *Guettarda speciosa*, *Tournefortia argentea*, and *Sida fallax* are applied in pandanus baskets, along with other leaves and topsoil, as part of an elaborate mulching system for giant swamp taro (*Cyrtosperma chamissonis*), pandanus, and breadfruit. *Sida fallax*, in particular, is considered to be such a strong fertilizer that it is only occasionally added fresh to the soil in fear of injuring plants. Other species commonly used for mulching include *Abutilon* spp., *Boerhavia* spp., *Erythrina variegata*, *Hernandia nymphaeaefolia*, *Hibiscus tiliaceus*, *Morinda citrifolia*, *Scaevola sericea*, *Thespesia populnea*, *Triumfetta procumbens*, and *Wollastonia biflora*. Coconut and pandanus refuse, especially coconut husks, are commonly heaped around the bases of plants, often within small fences, to aid the mulching process (Small 1972, Lambert 1982, Soucie 1983, Thaman 1984).

Cultural Utility

Because island societies have been perhaps the most dominant factor in the ecology of the smaller Pacific islands, the cultural utility of plants continues to be a major factor in the propensity of small island societies to protect or degrade their vegetation. Ethnobotanical studies indicate that there are some 68 different uses in the Pacific islands for the 142 common coastal species listed in Table 2, with the total number of uses being 992 (Thaman 1989*a*, 1990*b*). This is an average of 7.0 uses per plant, ranging from no reported uses for only four species to as many as 121 for the coconut. Next in order of importance, all with more than 15 reported uses, are *Hibiscus tiliaceus*, *Pandanus tectorius*, *Calophyllum inophyllum*, *Cordia subcordata*, *Guettarda speciosa*, *Scaevola sericea*, *Thespesia populnea*, *Pemphis acidula*, *Rhizophora* spp., *Casuarina equisetifolia*, *Terminalia catappa*, *Premna serratifolia*, *Erythrina variegata*, *Inocarpus fagifer*, *Ficus prolixa*, *Tournefortia argentea*, *Morinda citrifolia*, *Lumnitzera littorea*, *Ficus tinctoria*, *Pisonia grandis*, and *Bruguiera gymnorhiza*. Other species with at least seven uses each include *Hernandia nymphaeaefolia*, *Barringtonia asiatica*, *Gardenia taitensis*, *Sida fallax*, *Vitex* spp., *Entada phaseoloides*, *Dodonaea viscosa*, *Cerbera*

manghas, *Tacca leontopetaloides*, *Clerodendrum inerme*, *Crinum asiaticum*, *Triumfetta procumbens*, *Cassytha filiformis*, *Polypodium scolopendria*, *Neisosperma oppositifolia*, and *Ipomoea pes-caprae* (Table 3). All of these species are found on Nauru and/or the Gilberts. Moreover, these totals do not include more strictly ecological functions of coastal plants, such as shade; protection from wind, sand, and salt spray; erosion and flood control; coastal reclamation; animal and plant habitats; and soil improvement (mentioned previously).

With specific reference to Nauru and the Gilberts, preliminary analyses of available data indicate 133 uses for 36 indigenous species and 118 uses for 41 exotic species on Nauru, and 170 uses for 29 indigenous species and 104 uses for 39 exotic species in the Gilberts. This gives totals of 251 and 274 uses for 77 and 68 species, respectively, for Nauru and the Gilberts, a clear indication of the cultural utility of both floras.

It must be stressed that the analyses are based on traditional uses, many of which have lapsed or are only employed in emergency, because modern technology has preempted them. Modern medicine, clothing, fishing lines, matches, crockery, plastic bags, soap, and emergency food rations (food aid) have, for example, replaced traditional plant-derived products. Moreover, many of the current generation, schooled in the modern educational system and living in the cash economy, often know few of the traditional uses of plants, let alone their vernacular names—a state that could be referred to as "devegetation of the mind"—and that has undoubtedly contributed to the degradation of the indigenous and long-established aboriginal vegetation of both Nauru and Kiribati.

Of particular note is the importance of traditional food and beverage crops, the abandonment of which, for highly processed and imported foods such as sugar, white rice and flour, cabin biscuits, noodles, canned fish, soft drinks, alcohol, and tea, has led to dangerous levels of food dependency and some of the highest, or most rapidly increasing, incidences in the world of vitamin and mineral deficiency and nutrition-related diseases. Dis-

TABLE 3

COASTAL PLANT SPECIES OF PARTICULAR CULTURAL UTILITY BASED ON A STUDY OF THE ETHNOBOTANY OF THE 142 COMMON COASTAL SPECIES IN TABLE 2

LATIN NAME	USES
Cocos nucifera	121
Hibiscus tiliaceus	56
Pandanus tectorius	48
Calophyllum inophyllum	42
Cordia subcordata	37
Guettarda speciosa	33
Scaevola sericea	30
Pemphis acidula	27
Thespesia populnea	26
Rhizophora spp.	24
Casuarina equisetifolia	22
Premna serratifolia	22
Morinda citrifolia	21
Ficus prolixa	20
Tournefortia argentea	20
Terminalia catappa	19
Erythrina variegata	19
Ficus tinctoria	19
Inocarpus fagifer	18
Pipturus argenteus	18
Lumnitzera littorea	17
Pisonia grandis	17
Bruguiera gymnorhiza	15
Hernandia nymphaeaefolia	15
Nypa fruticans	14
Barringtonia asiatica	13
Intsia bijuga	13
Cycas circinalis	13
Gardenia taitensis	11
Sida fallax	11
Santalum spp.	10
Mammea odorata	10
Vitex spp.	10
Entada phaseoloides	10
Dodonea viscosa	10
Cerbera manghas	10
Tacca leontopetaloides	9
Clerodendrum inerme	9
Crinum asiaticum	9
Triumfetta procumbens	9
Ficus obliqua	8
Cassytha filiformis	8
Polypodium scolopendria	8
Neisosperma oppositifolia	8
Metroxylon spp.	7
Ipomoea pes-caprae	7

SOURCES: Adapted from Thaman 1989*b*, 1990*b*.

eases such as iron-deficiency anemia, night blindness induced by vitamin A deficiency, diabetes, cardiovascular disease, hypertension and stroke, gout and hyperuricemia, some forms of cancer, and dental disease, which were rarely encountered in the past, are now serious causes of morbidity and mortality in Nauru, Kiribati, and among other atoll populations, such as Tokelauans, Marshall Islanders, and people from the atolls of the northern Cook Islands, who have adopted western diets and life styles (Zimmet et al. 1977, 1978, Speake et al. 1979, Thaman 1983, 1985, 1988*b*, Coyne 1984, Pargeter et al. 1984).

CONCLUSIONS

The vegetation types and floras of Nauru and the Gilbert Islands are among the most impoverished, degraded, disturbed, and displaced in the Pacific islands. Long habitation; almost a century of open-cast phosphate mining; continuous bombing, destruction, and displacement of the people during World War II; rapid urbanization; and the abandonment of agriculture and subsistence activities on Nauru have arguably produced one of the most severely modified natural and cultural floras on earth. In the Gilberts, limited land area and habitat diversity, a long settlement history, some destruction and plant introduction during the war, rapid urbanization (by the late 1990s South Tarawa will have population densities approaching those of Singapore; Carter 1984), and over a century of the monocultural expansion of coconut plantations onto almost all available land has also produced one of the most highly modified floras in the world. As argued by Catala (1957:79) about the Gilberts: "With the exception of *Pemphis* stands and, of course, of the mangrove proper, no primitive vegetation types can be recognized today. The original formations have been so thoroughly modified by man that there is no trace left of them, especially as all these islands are rather densely populated.... In many cases the primary components are now only represented by isolated specimens, which tend to disappear not only because of the growing prevalence of the coconut palm but also because the natives do not care to preserve or propagate them.... In some islands even valuable trees such as the pandanus may be disappearing, as they are considered of minor importance in comparison with the commercial value of copra."

The highly disturbed nature of inhabited atoll vegetation is further supported by Fosberg's (1988) study of Bikini Atoll, where he suggested that: "Nothing is known with certainty of the vegetation of Bikini prior to the coming of the Marshallese people." He argued that, as a result of both centuries of habitation by the Marshallese and the expansion of coconut plantations under German and Japanese occupation, most of the native vegetation, which was probably "part woody-forest or scrub, with grass on very poor or dry sites," has disappeared, "though all or most of the native plant species probably survived." I have stressed (1989*b*, 1990*b*) that "agrodeforestation" (i.e., the destruction of, or failure to replant or protect, a wide range of ecologically and culturally valuable indigenous and exotic trees in existing agricultural areas) has resulted from official overemphasis on the expansion of monocultural cash crops for export. The destruction of natural vegetation associations and culturally valuable plants in the Gilberts and elsewhere in the Pacific has been the result of this ongoing process. As Chambers (1983) argued, trees and tree planting as traditional components of agricultural systems have been ignored in institutionalized rural development because they "fall into the gaps" between the traditional sectoral responsibilities of "agriculture" and "forestry."

Although both the vegetation and limited indigenous floras of Nauru and the Gilberts have been severely degraded and outnumbered by exotic species, most of the native species are still present, commonly in an endangered state. The indigenous flora also still dominates most habitats, including the later stages of the phosphate-mined pit and pinnacle topography of Nauru. Even in ruderal habitats and in houseyard gardens and villages, where they are outnumbered by exotics, indigenous species constitute important components.

It is argued that, while floristic degradation

in both Nauru and the Gilbert Islands appears to be among the most severe in the Pacific, the current floras of both areas still constitute important ecological and cultural resources that must be protected. Unfortunately, despite the undeniable developmental importance of vegetation protection and reforestation and agroforestry to small island communities, few if any planners or national development plans have included such measures in their lists of priorities or strategies, although some countries do have legislation (often not enforced) protecting mangroves and coastal zones from indiscriminate exploitation.

The importance of indigenous and long-established vegetation and floras to sustainable island development, though often well understood by rural Pacific peoples, seems to be poorly understood by most planners and policymakers. The lack of quantitative data available to decisionmakers on the extent, nature, and cultural and ecological importance of coastal plant communities is a major problem. However, because of recent initiatives to promote sustainable development, increasing interest has been shown by some policymakers, city planners, and administrators in the protection of mangroves and coastal forests. This has taken the form of protective legislation and a number of studies stressing the importance of coastal ecosystems and plant communities in national development (e.g., Dahl 1980, Maragos et al. 1983, Hamilton and Snedaker 1984, Watling 1985). In Fiji, the establishment of a Mangrove Management Committee and a survey of mangrove resources have provided a basis for a proposed mangrove management plan. The increasing activity by the South Pacific Regional Environment Programme (SPREP), the South Pacific Action Committee for Human Ecology and Environment (SPACHEE), and an increasing number of environmentally conscious ministries and environmental management committees throughout the region augur well for the future.

To encourage vegetation protection, revegetation, and reforestation of small islands, there are at least ten action strategies that could be implemented *now* by governments, aid agencies, community organizations, and families and individuals themselves. These strategies, which could also address many of the commonly held development objectives of Pacific governments, include the following:

1. Establishment of protected areas on small offshore islands and in coastal areas that could serve as buffer zones to protect inland areas, renewable sources of products of both subsistence and commercial value, and gene pools of species for coastal revegetation and agroforestry.
2. Establishment of nurseries at national, island, and community levels to supply planting materials for revegetation programs and to protect currently endangered coastal species of particular ecological and cultural importance.
3. Import or reintroduce, from other analogous habitats, appropriate species that are absent or endangered (this assumes that the causes of endangerment will be addressed and corrected to ensure success of such programs).
4. Systematically protect and replant species of particular importance: (a) as animal habitats, fish breeding grounds, and as components in marine and terrestrial food chains; (b) in erosion, wind, flood, and salinity control; and (c) for soil improvement and mulching.
5. Initiate coastal reclamation programs using local materials, such as rock, sand, nontoxic domestic waste, and plant products (e.g., senile coconut palm stems) to build dikes, seawalls, and other engineering structures that could be stabilized by planting appropriate salt-tolerant coastal species.
6. Promote mangrove replanting and rotational utilization schemes, such as those currently fostered in Southeast Asia (Yao 1986, Chan 1987).
7. Encourage the protection or planting of buffer zones and salt-tolerant and wind-resistant living fences, hedging, and windbreaks in agricultural, residential, and urban areas, and along transportation

routes and causeways, which are often subject to erosion and damage during extreme events.

8. Encourage home gardeners; institutions such as schools, hospitals, prisons, police, and military institutions; government departments; private businesses; and community-based organizations to become actively involved in revegetation programs, both at the national and community levels.
9. Encourage aid agencies, particularly non-government organizations, to support national-level and community-based programs of coastal revegetation and tree planting because of their considerable developmental potential and ecological importance.
10. Make the consideration of the protection and/or replanting of salt- and wind-resistant coastal tree and plant species integral components of all coastal development projects, and a major item of focus in the process of environmental impact assessment (EIA).

Through such actions it should be possible to protect and enhance the vegetation and floras so crucial to the ecological integrity and cultural survival of small-island societies, such those of Nauru and the Gilbert Islands.

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