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Ferns Naturalized in Hawaii¹

By W. H. WAGNER, JR.

INTRODUCTION

To analyze the phytogeography of Hawaiian ferns, it is necessary to establish their identity or relationship with the species of other regions. Such analysis is now complicated by adventive ferns that have appeared in the wild, some of which have become firmly established in certain localities, and often appear to be native. This is sometimes overlooked in surveys of phytogeographical relationships. For example, an ecological survey of Hawaiian "pteridophytes" which stresses distribution and endemism (MacCaughey, 19)² gives only one fern as having been introduced by man. Yet six other species listed, including one he calls "endemic," are really escapes from greenhouse, garden, or farm.

It may surprise botanists in temperate lands to learn that exotic ferns can arise as weeds and (or) become fixed in floras of warmer countries. However, in Hawaii, the approximate times of establishment of such exotics may be well known, and it is possible to judge the time a given plant took to spread through the island group. In order to throw more light on some of the examples, the patently unsolved questions are emphasized in the hope of elucidation by future study. I have probably overlooked some records, and I sincerely hope that the following review will stimulate their discovery and publication.

Ferns were collected with unusual thoroughness in Hawaii prior to 1888, the year Hillebrand's carefully prepared "Flora of the Hawaiian Islands" was published (17), for most Pacific botanists of the early nineteenth century explored Hawaii and the people of the islands were enthusiastic fern collectors. It is noteworthy that few new species

¹ Other plants traditionally termed "pteridophytes" will be included here in accordance with convention. Although it is now generally acknowledged that such plants as *Selaginella* and *Psilotum* are but distantly related to the ferns, or to each other, it is at present convenient to bring them together in floristic lists and in herbaria.

² Numbers in parentheses refer to Bibliography, page 120.

have been described since 1888 (Copeland, 7, p. 436). Even more noteworthy is the fact that all of these later-described novelties have been critical species with "difficult" distinctions. However, all of the ferns here interpreted as introduced appeared around or after 1888, and they are mostly sharply different morphological types. All are well known in other parts of the world, and are commonly used in horticulture. Like the introduced garden plant *Lantana camara*, a number of them are common or abundant in the Hawaiian flora today. It seems improbable that any such ferns now numerous in the islands could have been overlooked in pre-Hillebrand times had they grown wild here at all.

Exotic ferns which appeared during and after the period around 1888 were undoubtedly noticed by local collectors, but as Mr. Eugene Horner says in a letter, the fern intruders "were not often included in collections of Hawaiian ferns fifty or more years ago. Furthermore, there were but few exotic species in our islands at that time." On the other hand, there are native species, well known long before 1888, which behave as "weeds" or tend to grow in ruderal or disturbed habitats, including one of the rarest endemic genera. Examples are given in this paper.

To about 20 Hawaiian vascular plants of the pteridophyte level of life cycle attaches at least some suspicion of arrival through modern western world commerce—about one-eighth of the total number of local species. These will be discussed from the standpoints of first appearance, present occurrence and peculiarities, and additional evidence for recent introduction.

For much of the basic information in this paper and for criticism of the manuscript, I am especially grateful to E. B. Copeland, Lincoln Constance, H. L. Lyon, Eugene Horner, Harold St. John, Marie C. Neal, F. R. Fosberg, and C. V. Morton.

The following abbreviations for herbaria are used throughout the paper: BM, Bishop Museum; US, U. S. National Museum; NY, New York; UC, University of California; MIN, University of Minnesota.

WELL-ESTABLISHED SPECIES

ADIANTUM

One of the most common Hawaiian ferns in modern times is the New World maidenhair, *Adiantum cuneatum* Langsdorff and Fischer, indigenous to South America, but now evidently appearing in Ceylon,

India, Java, and elsewhere. Hillebrand's description of the maidenhair fern known to him (17, p. 634) is of the cosmopolitan *A. capillus-veneris* Linnaeus, originally indigenous to the islands. Since the first appearance of *A. cuneatum* in nature, probably originating from wind-blown spores from cultivated plants, there has been much confusion between the naturalized and the native species in Hawaii. H. L. Lyon writes (letter, November 8, 1949), "When I first came to Hawaii [1907], the cultivation of ferns in fern houses was as popular and common as the culture of orchids now. The most common forms in cultivation were *A. caudatum*, *A. trapeziforme*, *A. tenerum* var. *Farleyense*, and *A. cuneatum* in very many varieties, especial attention being given to crested varieties and those known as *gracillimum*. I found *A. cuneatum* in the wilds at that time and it has continued to spread until now it may be found in practically every locality that provides a suitable habitat."

C. V. Morton informs me that the earliest collection of *A. cuneatum* in the National Herbarium was made by Paul Bartsch in Hillebrand's Glen near Honolulu on October 30, 1907 (*Bartsch* 79). But Faurie was evidently the first to collect it as wild in the Hawaiian Islands: "in lateralibus aquaeductus, Kealia, Kauai, Jan. 1910, *Faurie* 154" (Copeland Herbarium). This was reported by Copeland in 1914 (7, p. 437) but was overlooked by Christensen in his enumeration published in 1925 (4). In 1937, Degener (8) wrote that *A. capillus-veneris* was the only *Adiantum* other than the naturalized *A. hispidulum* found growing wild here, but Skottsberg (27) shows that Degener's description is actually of a composite of *A. capillus-veneris* and *A. cuneatum*, plants sharply distinct from one another. Contrasts in the following key may clarify some of their features.

- | | |
|---|----------------------------------|
| <p>Rhizome surface usually irregular ("knobby"), bearing fronds very closely; scales deltoid-lanceolate or broader, with filiform tips, 0.5-1.5 mm. long, dark (cell walls appearing finely reticulate), their cells 40-80 microns \times 15-25 microns in dimensions; scales running 1.0-1.5 cm. up stipe base except in old fronds; stipes turning black late, therefore mostly maroon; pinnule texture membranaceous; veins in sterile pinnules ending in sinuses between crenations, if margin is not entire; sori reniform, the membranaceous "false indusium" 1.0-1.5 mm. long, attached at a point at the bottom of a deep notch.....</p> | <p><i>A. cuneatum</i></p> |
| <p>Rhizome surface usually smoother, fronds more distant; scales linear-lanceolate or narrower, 2-3 mm. long, pale (cell walls appearing coarsely netted), their cells 100-400 microns \times 30-70 microns in dimensions; scales only at base of stipe; stipes turning black early, therefore mostly</p> | |

very dark purple; pinnule texture chartaceous; veins in sterile pinnules ending at apices of sharp teeth, if margin is not entire; sori mostly oblong to oblong-lunate (very rarely individually reniform), the thicker "false indusium" 0.5-4.0 mm. long, attached mostly along a marginal line *A. capillus-veneris*

In the University of California Herbarium are 32 Hawaiian collections of these two entities: 18 of *A. cuneatum*, from Oahu, Kauai, east and west Maui, and Hawaii (Kilauea Crater); 13 of *A. capillus-veneris*, from Oahu, Kauai, Niihau, and east and west Maui. *A. cuneatum* shows crested forms growing wild on Oahu and Kauai, the finely dissected forms on west Maui. Both species grow on vertical damp rock surfaces, usually along streams or around springs in shady gulches up to at least 3,000 feet altitude. *A. cuneatum*, which often occurs in remote areas, is obviously the much more common now and *A. capillus-veneris* infrequent, though Hillebrand called *A. capillus-veneris* "common." Regarding his collections of *A. cuneatum*, Skottsberg (27, p. 110) is of the opinion that "the mode it occurred as naturalized did not suggest that this was an escape any more than *A. capillus-veneris*."

It will prove interesting for future observers to see whether *A. cuneatum* may not indeed be invading the original habitats of the native maidenhair fern.

The hairy maidenhair, *Adiantum hispidulum* Swartz, originally of the Old World tropics and of Polynesia exclusive of the Hawaiian Archipelago, was first discovered in the wild state by Topping in 1923, in Pauoa Valley, Oahu. In 1927, G. W. Russ found it in Waipio Gulch, Hawaii, at 1,500 feet altitude (Russ 6833, BM). Subsequent collections on Hawaii were made along the Hamakua Ditch trail (1932, Topping); in a wet pasture, Kukuihaele, at an altitude of 2,300 feet (1934, Ewart 339, BM); and at Kawela Paddock, Hamakua, Waimea, at an altitude of 2,600 feet (1938, Hosaka 2099). In 1939, Degener and others found it near a homestead in Olowalu Valley, west Maui. Now it is locally common in Maui in low wooded gulch bottoms, growing usually on rocks on vertical banks in dryer habitats than the other maidenheads. I have it from vertical rock faces in shaded woods along Wailua Stream, east Maui, altitude about 500 feet (5292)³; from rock banks about two miles from Wailuku in Iao Valley, west Maui (5298); with *Cyclosorus dentatus*, from along the ditch line in Waihee Valley (5301); from rocky banks above Kanaha Stream, north of

³ Field numbers cited without collector are mine, collected under the auspices of the University of California Herbarium.

Lahainaluna, altitude about 1,200 feet (5419); and from dry rocky gulches along the stream in Ukumehame Gulch, altitude 1,000 feet (5493). Wesley H. C. Wong, engineer of the Wailuku Sugar Company informed me in 1947 that this fern was common 20 years earlier in Iao and Waikapu Valleys, west Maui, so it probably first appeared there by at least 1925.

This species may now be regarded as completely established, at least on Maui and Hawaii. Its future spread should be of interest, because it appears to be very vigorous. Mrs. C. Ashley Giauque informs me that its reproduction is by obligate apogamy, usually a more rapid process than normal sexual reproduction. The variation in this plant is slight, by no means as great as that of *A. cuneatum*.

PTERIS

The only simply pinnate *Pteris* in Hawaii is *P. vittata* Linnaeus of the paleotropics. It was first reported in 1914 by Copeland as *P. longifolia* Linnaeus (of which *P. vittata* was then considered a synonym) on the basis of the following collection data: "Maui, in lateribus aqueductus, Wailuku, rara, 1909, *Faurie* 45" (Copeland Herbarium). Lyon informs me that when he first visited Maui he found it in abundance on rocky banks and walls adjacent to irrigation canals in the immediate vicinity of Wailuku. He notes that even though he later found it farther afield, it was not far removed from irrigation developments. In 1925, Christensen (4, p. 5) listed *P. longifolia* as "not hitherto recorded" on the basis of *Skottsberg* 552 from Kilauea Crater, Hawaii (1922); but it had been collected at that locality by J. F. Rock in July 1915 (BM). Degener first identified the plant as *P. vittata* in 1930.

P. vittata, with its characteristic tufted fronds bearing numerous undivided narrow pinnae and abundant pale scales at the stipe bases, is locally common in sunny places in various areas from sea level to about 4,000 feet. In the University of California Herbarium are specimens from taro patches at the mouth of Waihee Valley, Maui (5300); near Puu Anu, Maui (*Degener and Wiebke* 3118); and from exposed stream banks along the road in Punaluu Valley, Oahu (5767). Its first Oahu collection was in 1924 (*Judd* 1317, BM) on a rock pali at Maunaloa at 700 feet altitude. On Hawaii, Grether obtained it at the City of Refuge (*Grether* 4307) and at Kilauea Crater (*Grether* 4284), where it has been collected many times. It is to be expected that the

species has extended or will extend to the other large islands of the archipelago.

Whether *P. longifolia*, confined to the Antilles and South America, and *P. vittata* are maintained as distinct species or whether their nominal status is reduced to that of geographical subspecies, I have seen no material from Hawaii which corresponds closely with *P. longifolia*. Hieronymus (16), who redistinguished them in 1914, points out that *P. vittata* has non-articulate rather than articulate pinnae, that the short pinna stalks continue as decurrent and more or less discoloured ridges on the rachis, that the pinnae are oriented at an acute angle rather than perpendicularly, that the sterile margins are toothed rather than jagged, and that, upon falling, the scales do not leave rough protuberances on the stipe and rachis as in *P. longifolia*. While individually these features vary considerably, as a group they seem to hold; and the nature of the pinna bases is particularly helpful in making the distinction.

CERATOPTERIS

The peculiar dull-green, Old World, amphibious fern, *Ceratopteris thalictroides* (Linnaeus) Brongniart, so commonly grown with its New World relatives in mainland aquaria was apparently first reported by Neal in 1948 (22, p. 15). Lyon, however, contributes the following notes concerning this water-fern in Hawaii:

This is an oriental vegetable and was more common in Hawaii when I first came here than it is at the present time. It was undoubtedly brought here by the Chinese or else accompanied them, for it was grown or tolerated by them along the irrigation ditches leading to their rice fields on the borders of which it also occurred. Now, rice culture is practically abandoned on these islands and the present generation prefers other vegetables. I have no specimens of *Ceratopteris* in my herbarium but in times past transplanted plants to the borders of artificial ponds in Honolulu.

In 1947, members of the Botany Department of the University of Hawaii kindly showed me an interesting locality for this plant, a taro patch at Waiahole, Oahu, where it was locally common about three inches above the water line. Specimens (5060) were found there with fronds only 1.5 inches tall but fully fertile. On Kauai, in the same year, I found it in great abundance on wet ground and in several inches of water, associated with *Commelina* and grasses in wet meadows and taro patches along the road at the mouth of Wainiha

Valley (5607). Plants here ranged from 3 to 15 inches in height, but none were of statures comparable to the full-sized plants (over twice as tall) of the Philippines and New Guinea area. In the town of Hanalei, three miles to the east of Wainiha, sterile plants of this species were found under two to three feet of water at the bottom of a ditch along the main road (August 1947).

The earliest herbarium collection seems to be one made by Forbes on January 13, 1919 (*Forbes 2530.O*), in taro patches in Kalihi Valley, Oahu. Bishop Museum and the University of California also have collections made in similar situations in Manoa Valley (1930, 1934), Kahaluu Valley (1935), and at Waikane (1934).

Whether the diminutive naturalized *Ceratopteris* will persist in Hawaii remains to be seen.

PITYROGRAMMA

Neotropical gold and silver ferns of the genus *Pityrogramma* were extremely popular in horticulture during the nineteenth century and, as could be expected, the genus was introduced into the Hawaiian flora. It has likewise appeared practically everywhere in the Old World tropics, but mostly as the traditional "silver fern," *P. calomelanos* (Linnaeus) Link (*Ceropteris*, Underwood). With the probable exception of Oahu, the commoner fern in the wilds of the larger islands of the Hawaiian Archipelago is now a gold fern which has usually been reported as *P. ochracea* (Presl) Domin (*Ceropteris*, Hieronymus). But the original *P. ochracea*, according to Domin (9, p. 8), is not farinose beneath, but is, rather, ferruginous-lanuginose. Identities of cultivated gold ferns are difficult to ascertain because, in part at least, of an apparently remarkable ability in the genus to form hybrids. The commonest and oldest of these is *P. calomelanos* \times *chrysophylla*, *P. hybrida* (Martens) Domin, which is distributed in many forms in culture as well as in nature (Domin, 10, p. 53). It was, for the most part, this plant to which the horticultural name "*Gymnogramme ochracea*" was applied.

The Hawaiian gold ferns undoubtedly derived from cultivated plants. True *P. chrysophylla* (Linnaeus) Link differs from *P. calomelanos* in having obtuse rather than acute pinnae and in its golden color (Domin, 9, p. 6). However, Domin (10, p. 20) says that *P. chrysophylla* "is the most common one in cultivation and shows an astonishing variety of garden forms, which in part resemble some hybrids so closely

that in some cases it is hardly possible to draw a line between the pure forms of this species and its hybrids with *P. calomelanos* and with other species."

Some authors, however, prefer to make *P. chrysophylla* merely a variety of *P. calomelanos*; and still others (see Posthumus, 23, p. 95) simply believe naturally occurring *P. calomelanos* includes both gold and silver forms. Though the local silver varieties seem to be thinner in texture than the gold and to have more dissected and sharply pointed pinnae and shorter scales, there is no clear way of separating them. In view of the divergence of opinion and the lack of usable anatomical characters, it seems wisest at present to regard the whole Hawaiian population as garden varieties of *P. calomelanos* in the broad sense. However, individual specimens from nature in Hawaii may be keyed out to varieties of *P. calomelanos*, *P. chrysophylla*, *P. hybridum*, and to *P. austroamericana* Domin. The possibility should be entertained that the Hawaiian plants could be derivative recombinations of original *P. hybridum* stocks, even if the ultimate parents do come to be interpreted as mere forms or varieties and the hybrids as intraspecific ones.

Domin (10, p. 55), in discussing *P. hybrida* f. *ochracea* (Hortorum), wrote that "under the name of *G. monstrosa* Hortorum there are in the gardens different forms of *P. chrysophylla* or *P. hybrida* with irregular, partly rudimentary, or abnormally shaped pinnules." Such a form is apparently not common in Hawaii; but in 1949, Horner showed me a large plant of this variety growing in a weedy field at Kilauea, Hawaii (5834). The pinnae of all fronds were narrow and remarkably asymmetrical, but the normally cut variety grew nearby (5832).

Pityrogramma calomelanos s. l. is frequent to abundant throughout the islands, particularly on banks and along roads in weedy gulches at lower elevations. Fosberg (letter) notes that "it is often the first plant to appear on bare subsoil of road cuts, becoming abundant, then growing less so as it is crowded out by more luxuriant later stages in vegetational succession." I found it on Kauai, Oahu, Maui, Molokai, and Hawaii; and it has been recorded from Niihau. On the islands I visited, the golden variety seems to me to be the much more common one at present, although Forbes in 1912 (in Robinson 24, vol. 39, no. 12, p. 588) said, "I find [*Ceropteris ochracea*]" to be widely spread over the whole group, especially irrigation ditches. The golden variety is

much less common than the silver." Lyon writes me that "on Oahu, at least, the silver fern is now, and for many years has been, quite as common if not more common than the gold fern. It has invaded and established itself in my back yard in Honolulu, but the gold fern has never made its appearance there." Fagerlund (11, p. 21) writes "Both types are frequent in the Kau desert [in Hawaii National Park] from Cone Peaks to Hilina Pali, especially along dry washes."

In one collection of small sterile plants from Punaluu, Oahu (5768), only a couple of fronds show a trace of wax. Normally, however, even very young plants, an inch or less tall, show the silvery or golden wax on the dorsal frond surfaces and stipes. The highest altitude recorded (5271) is 7,000 feet, where a single extremely robust plant was taken July 13, 1947, one mile north-northwest of Oili Puu in Haleakala Crater, Maui. This collection illustrates to what a distance from settlements plants of introduced ferns may spread. The earliest specimen from the islands at hand seems to be a gold fern collected by A. Brodie, Waiawa water tunnel, Kauai, September 13, 1903 (*vide* Lyon). Shortly afterward, Copeland took specimens in Nuuanu Valley, Oahu, at an altitude of 800 feet, November 17, 1903. The earliest dates in Bishop Museum and University of California Herbaria are Hawaii (Kilauea), 1908; Molokai (Kamalo), 1928; Maui (Lahaina), 1938; and Niihau, 1912.

PELLAEA

A native of Africa, *Pellaea viridis* (Forskål) Prantl, differs from the native *P. ternifolia* in its much larger and broader fronds with flat laminae and rounded pinnules and in its bright green, rather than dull gray-green, color. *P. viridis* was first collected growing wild in Hawaii by Lyon in 1928, on Pacific Heights ridge, Oahu, but he had seen it there previously (Degener, 8). Neal writes (October 24, 1949) that she has also "seen this fern in a garden on Pacific Heights, presumably as a volunteer." It has apparently spread across the island to the Waianae Mountains, where it was first collected by "Potter, Bush, and Topping" near Puu Kaua in 1935. Grether found it between Puu Kaua and Puu Kanehoa to the north in 1946 (*Grether 4236*); and I found it to the south, growing in large numbers on dry, rocky, grassy slopes above the trail at Pohakea Pass in 1949. It has undoubtedly become fully naturalized in these places on Oahu.

NEPHROLEPIS

The most bizarre of the introduced ferns is *Nephrolepis biserrata* (Swartz) Schott var. *furcans* Hortorum, the aptly named fishtail fern. It is a mutant sword fern with erect, pale-green, once-pinnate fronds a meter tall, the pinnae of which are once- (or more) forked. Neal writes that it is commonly grown in Hawaiian gardens, and I have seen it used very effectively as a border plant in the garden of the Molokai Seaside Inn, Kaunakakai. This odd plant has become a member of the flora, growing gregariously in various places in the islands, and will probably continue to spread. The only comparable situation known to me involves another horticultural "freak," *N. cordifolia* (Linnaeus) Presl var. *Duffii*, an aberrant form with pinnae reduced to a couple of small rounded segments, which I found in the rain forests of El Yunque, in eastern Puerto Rico. Of *N. biserrata* var. *furcans*, there is a specimen in the Paris Herbarium labeled "Fougères des Isles Hawai, collection L. Vossion, 1898," but the label does not state whether the habitat was horticultural or not.

The first report of definite establishment of the fishtail fern in Hawaii is by Fosberg (13, p. 386), on a "considerable colony around the abandoned settlement at the mouth of Wailau Valley, Molokai, Dec. 28, 1936, Fosberg 13453." I have since found it locally abundant in grassy *Aleurites-Psidium* woods along the Wainiha Valley ditch-line trail, 700-800 feet (5604) and in rocky wet woods along an eastern tributary of Hanakapiai Stream, one mile from its mouth, at an altitude of about 500 feet (5610), both on Kauai. Also, it is found in abundance in several places in low damp woods along the road between Hana and Kaupo in east Maui (July 15, 1947).

The future behavior of such a horticultural monster should be observed.

BLECHNUM

Blechnum occidentale Linnaeus of the New World tropics is a striking example of the wide and rapid spread of a recent introduction. In only about 30 years it has become one of the most abundant ferns in the Hawaiian Islands, growing mainly in lower gulches but up to 2,000 or more feet altitude. On the large islands it is usually found along stream banks or on steep, shaded hillsides. The long narrow runners, covered with chestnut scales, enable it to form large colonies, or clones,

of hundreds of plants. Christensen (4, p. 15) first reported it as "introduced into gardens in the Hawaiian Islands and therefrom escaped."

The first collection cited in literature was from Makaleha Valley in the Waianae Mountains, Oahu, August 30, 1922, *Skottsberg 400*; but Lyon collected it in Makaleha Valley earlier, on May 19, 1918. However, he noted at about the same time that it occurred in great abundance in certain localities on Maui and Kauai. Degener (8) wrote in 1932 that "this fern is spreading rapidly along dry, partly shaded embankments" and cited new localities on Oahu, Maui, and Molokai. By 1944 to 1949 it was common in suitable places everywhere that I collected on those islands, as well as on Kauai; and it probably also occurs on Hawaii and other islands, though I have seen no specimens. On Kauai, it was frequent to abundant along streams in soil and on rocks at 1,000 to 2,500 feet altitude on the leeward "plateau" to the west (August 5 to 14, 1947), in gulches in the windward Hanalei area to the north (August 20 to 24), and along the Wahiawa Stream to the south (August 25). It often accompanies two other blechnoids, the indigenous species, *Doodia Kunthiana* Gaudichaud and *D. Lyoni* Degener.

Blechnum occidentale in Hawaii seems to be remarkably lacking in variability, unlike many of the ferns here both native and naturalized.

CYRTOMIUM⁴

Horner recently sent me material of *Cyrtomium falcatum* (Linnaeus f.) Presl from the Hualalai side of Puuwaawaa, Kona District. He collected them on December 27, 1949 from a group of several plants near the base of the hill, where *C. caryotideum* was also plentiful in the same area. Horner's record is apparently the second from the island of Hawaii, its first being a collection by Meebold on Hualalai in 1935 (Degener, 8, 1936).

C. falcatum, or the holly fern—a native of southern Japan, Korea, Formosa, and eastern China—is one of the most important of horticultural and florists' ferns and has been introduced here and there in the mainland United States. Copeland writes, "In 1942, a collector brings *C. falcatum* in from an isolated California station, and is hard to convince that it is not native." Its first report as naturalized in the islands (Christensen, 5) was based on a collection (*Degener and Wiebke 3217*) made in 1928 in gulches overlooking Kalaupapa, Molokai

⁴ Copeland recently reduced this genus to *Phanerophlebia*.

(US). Hawaiian specimens were reported earlier, but with no indication as to whether they came from gardens or from nature.

C. falcatum grows two or three feet tall and has dark-green, very thick-textured, shiny pinnae; these are numerous, up to 12 or more in number, and become progressively smaller toward the frond tip. The margins are leathery and smooth. In appearance it is very different from the native *C. caryotideum* (Wallich) Presl, the *kaapeape*, which occurs in similar habitats, usually rather arid wooded hillsides, throughout the islands. *C. caryotideum* is usually a lower plant with more spreading fronds. Its fronds are pale gray-green, much thinner in texture, and dull; and the pinnae usually number three to five, rarely up to nine and are much broader than those of *C. falcatum*, the end pinna being usually larger and broader than the others. The margins are always toothed with fine points. Although *C. caryotideum* also ranges widely in Asia, being known from the Himalayas to southern India and Formosa, there is no evidence that it has not always been in Hawaii.

LASTREA

Lastrea Torresiana (Gaudichaud) Moore—also called *Dryopteris uliginosa* (Kunze) C. Christensen and often, incorrectly, *D. setigera* (Blume) Kuntze—has now appeared as an introduction here, as it has in tropical lands everywhere. Maxon (21, p. 171) first reported it from the Hawaiian Islands, in 1923, on the basis of *Hapeman 6*, Tantalus, Oahu, May 11, 1908. He did not, however, specifically describe it as being introduced. Skottsberg (27, p. 47) recorded it again, based on his collection made along the Hilo-Kilauea road in a forest, 23 miles from Hilo, 1938 (*Skottsberg 3230*), and quoted the following note by Christensen: "Asiatic sp. everywhere cultivated and escaped from cultivation in many tropical countries." But it was apparently taken first on Hawaii at Kaumana Cave, Hilo, May 20, 1915 (*Forbes 606.H*, BM). Horner has written what is probably the earliest unpublished record of *L. Torresiana* (letter, February 14, 1950): "I recall taking two species of ferns to Prof. A. B. Lyons for identification shortly after starting my collection. They were growing sparsely in upper Manoa Valley, in what was then pasture land. This was, as near as I can estimate, the year 1892. He informed me that they were introduced, that others had reported they were growing there, but he had not yet seen them." The two species referred to by Mr. Horner were *Cyclosorus*

dentatus and *L. Torresiana*. The earliest date for this species to be noted growing as a naturalized fern, therefore, is considered to be about 1892. According to a note on a Bishop Museum specimen taken by G. O. Fagerlund and A. L. Mitchell at Hilina Pali, Hawaii National Park, "This fern is often found in lava tube cave-ins 0-3,100 ft. alt."

The University of California Herbarium has the following specimens: From near Onomea Natural Bridge, Hawaii, 1946, *Grether* 4269; from Hawaii National Park, Kilauea, Hawaii, growing on abandoned farm land with *Pteris vittata* and *Pityrogramma*, 1948, *Horner*.

I found *L. Torresiana*, in 1947, to be common on rocks and in alluvium along the stream at Ukumehame Gulch, west Maui, at 1,000 feet altitude (5445); locally common in company with *Nephrolepis*, *Sadleria*, and *Cibotium*, in rocky woods along a stream, 25 miles west of Hana by road, east Maui; and frequent in rich, shaded places in a rocky wooded gulch along Wailua Stream, at 300-500 feet, east Maui. Neal informs me that the earliest Maui collection was at Nuanualoa Gulch, December 5, 1919 (*Forbes* 1759.M). *Forbes* also collected it on Kauai in the Haupū range, near Nawiliwili Bay, October 31, 1916 (*Forbes* 701.K). There is no doubt now that this species is well-established in certain places, and that it will probably spread throughout the forested islands.

This is a showy, medium- to large-sized, woodland fern with finely dissected, pale-hairy, thin-textured fronds. It is up to 1.5 meters tall, with pale, shiny stipes and rachises. However, one plant dwarfed by environment, its five fronds all less than 7.5 inches long but bearing numerous sori, was found growing on an exposed rock face near plants of the above description in the more shady places at the Ukumehame Gulch locality (5445C).

CYCLOSORUS

One of the chief taxonomic problems among Hawaiian ferns introduced in modern times involves two species long confused in the literature: *Cyclosorus parasiticus* (Linnaeus) Farwell (*Dryopteris*, O. Kuntze), and *C. dentatus* (Forskål) Ching (*Dryopteris*, C. Christensen). These species are amply distinct, though like many pairs of critical fern species, they are superficially similar. They were, however, identified and reported in Hawaii under the single specific name, *C. parasiticus* until 1942, when Skottsberg (27, pp. 46-47) revealed

the differences in the two species and reported that all the Hawaiian specimens he had seen were *C. dentatus*. Both species now occur in Hawaii and both are undoubtedly escapes. Apparently, it was not until 1937 that any author indicated that either might have been introduced (Hosaka, 18, p. 217).

In view of the long-standing confusion, it is desirable to discuss some of the distinguishing morphological features of these plants. Christensen (3, pp. 26-28) distinguished *C. parasiticus* from what is now known as *C. dentatus* (*Polypodium molle* Jacquin) on the basis of two characters: the blade never descrescent below, and the pinnae didymosorous, that is, with sori in pairs, one on each of the lowest veins of each lobe. Ching (2, p. 208) added differences of venation, indument, and glandulosity. My field observation of living specimens in Hawaii in 1947 showed other differences not so apparent in most herbarium specimens. Living plants of *C. parasiticus* are paler and duller green than those of *C. dentatus*, and the relatively narrower and more approximate pinnae of *C. parasiticus* give the frond a characteristic aspect. Most important, however, is the fact that in *C. parasiticus* the fronds are not dimorphic; there is no sharp break in morphology between the sterile and fertile fronds. Most fronds bear the characteristic paired sori, but the most fully developed fronds are entirely soriferous, showing 3-7 pairs of sori per lobe. In *C. dentatus*, by contrast, there is a sharp dimorphism in the sterile and fertile fronds. The sterile fronds are broader, shorter, and more spreading than the others, and are generally entirely without sori. The fertile fronds, on the other hand, are narrower, much taller, with very long stipes, and erect. Their pinnae are not only much more remote, but are often oriented or twisted at the base into a horizontal plane. The two species grow in similar habitats, usually in weedy woods and gulches or along roads and paths, and they are often found together, in which case the differences are conspicuous. To study these plants properly in the herbarium it is necessary to collect whole plants, including rhizome, and dry them whole or in labeled parts.

Key

Fronds dimorphic, the fertile ones narrower, with more remote pinnae, sharply distinct from and standing high above the more spreading sterile fronds; lamina darker green, usually chartaceous in texture, more or less short-hairy, without glands below; basal pinnae, 1-5 pairs, reduced in size often to mere auricles and becoming distant; all pinnae relatively broad, cut usually less than half-way down; anterior basal segments or

lobes of lower pinnae not extended or but little extended and not overlapping adjacent pinnae; excurrent veinlet below sinus joined by basal pair of veinlets plus one or two more distal veinlets; indusium sparsely short-hairy

C. dentatus

Fronds uniform, the fertile fronds of nearly the same shape as the sterile ones, but many fronds incompletely fertile, the sori in these paired at the bases of the segments; lamina pale green, membranaceous, densely long-hairy, often with dark-orange glands below; basal pinnae of the same size as those above or only slightly smaller; pinnae all narrower, and cut usually half-way down; anterior basal segments of lower pinnae extended, often overlapping the rachis or the lowest segments of the adjacent pinnae; excurrent veinlet joined only by basal pair of veinlets, the next pair ending above the sinus; indusium densely long-hairy.....

C. parasiticus

There is considerable variation in *C. dentatus*. Very large specimens growing in shaded, rich, damp woods and reaching 1.5 meters in height may be practically glabrous, with the sori medial, and may somewhat resemble the local representative of *C. truncatus* (Poirot) Farwell (*Nephrodium Hudsonianum* Brackenridge). The following specimens from Oahu illustrate this form: *Topping 3215*, Opaepa, July 19, 1925; *Wagner 5037*, rich, rocky woods near a stream, 3.5 miles from Waimano Home, Koolau Range, altitude 1,200 feet, June 27, 1947; *Wagner 5124*, along trail in wet valley bottom, Kawaiiki ditch trail, Koolau Range, altitude 1,000-1,080 feet, June 30, 1947; *Wagner 5454*, shaded bottom lands, *kukui* woods, Kaala Gulch, east of Kaupakuhale, altitude 1,000 feet, August 3, 1947. At the opposite extreme are hairy, small plants down to a foot or less in height, but fully fertile, which are found in exposed places; for example: *G. T. Hastings*, Tantalus, Oahu, May 6, 1931 (NY); *Grether 4277*, Kilauea Crater, Hawaii, April 14-16, 1946; *Alice King*, no data; and *Wagner 5296*, from exposed rock surfaces, 11 miles by road west of Hana, Maui, July 16, 1947. One might almost think of these and others of the forms of this plant as potentially distinct taxonomic entities, were it not for the numerous intermediates. There is, in addition, a strong tendency in *C. dentatus* for the stipes and rachises, particularly of the tall fertile fronds, to be pale chocolate-colored. A rather remarkable condition of asymmetrical development of certain pinnae on some fronds is commonly observed, also: one or several pinnae in these cases, often only on one side, are much larger than the others, and the segments become elongated and entirely separated as sessile pinnules. A few examples of this tendency are shown by the collections of Baldwin "Standard Species" (UC

74384); *Bartsch* 54, Mount Konahuanui, Oahu, October 28, 1907 (US); W. J. Robinson, Hawaiian Islands (NY); and *Wagner* 5304C, specimens "abundant and often freakish," Waihee Gulch, west Maui, July 18, 1947. Forked or crested fronds are often found also; *Wagner* 5304A and 5304B, for instance. Such variation was not observed in any of the hundreds of plants of *C. parasiticus* seen by me.

Seventy herbarium sheets of *C. dentatus* from Hawaii have now been examined, but only 18 of the less numerous *C. parasiticus*. However, *C. dentatus* arrived much earlier in the islands. It was apparently common after 1900; and it was first reported from Hawaii by Heller in 1897 (15, p. 780) as "*Dryopteris parasitica*," which was "common on Oahu in open places, valleys, and slopes, barely reaching to the lower limits of the lower forest." Of the several collections made before 1898, the earliest seems to be from ridges near Honolulu, collected December 20, 1887 (*W. E. Safford* 870, US).

Cyclosorus dentatus occurs well into the rain forests now, and I have specimens of it and of *C. parasiticus* from the Makawao Forest Preserve, east Maui, along the road at 4,200 feet (5138 and 5139 respectively). It tends, however, to occur in disturbed places and, usually, rudrally; hence I believe MacCaughey's description (19) of it as "hygrophytic, between 4500-5000 ft." to be misleading. *Cyclosorus dentatus* is also a common weedy volunteer around gardens and yards and along roadside ditches, and St. John and Hosaka (28, p. 23) called it a weed in pineapple fields. I do not know of *C. parasiticus* in such situations, but it is to be expected.

Cyclosorus parasiticus seems to have been first collected in the Hawaiian Islands by Topping, along the Waikane-Waiahole Trail, Oahu, on a sunny bank at 500 feet, on January 3, 1926 (*Topping* 3274, NY, MIN, US). At present it can be considered only frequent in the islands as a whole; I have it from Oahu, Maui, and Kauai, although it probably occurs on other islands. It is almost always in company with or near *C. dentatus*.

MICROSORIUM

Microsorium Scolopendria (Burmamn) Copeland (*Polypodium Phymatodes* Linnaeus), the Hawaiian name of which is *laua'e*, is an important and conspicuous plant in understory vegetation in low areas on all the islands, especially windward, and usually well below 2,000 feet altitude. Christensen (4, p. 19) reported Skottsberg's collection

(801), one of the first ones made here, in 1922 at Keanae village, Maui. Degener took it the same year in Makiki Valley, Oahu (*Degener 1531*, US). Christensen (4, p. 5) questions that it had escaped from gardens as "it is the commonest fern in nearly all Polynesian Islands and may possibly be indigenous in Hawaii also." Only four years prior to the 1922 collections, however, MacCaughey had stated (19, p. 212), "this species does not occur in the Hawaiian Archipelago, but it is very common at Palmyra Island," roughly 1,000 miles to the south. Lyon writes me that "strange to say, it was a very common plant on the isolated island group of Palmyra before that group had been visited by many Europeans." (Excellent illustrations and a good description of its occurrence there are found in Rock, 25.) It seems possible that Palmyra represents the edge of its original natural range in the Pacific.

As no author before MacCaughey even mentioned this plant in Hawaii, it must have begun to appear in the wild sometime around 1920. After 1922, the species became increasingly common, and it is now numerous practically everywhere at low altitudes in wet secondary woods, terrestrially and sometimes epiphytically. But it is rare, if not absent, from the natural high rain forest. Its rise in abundance parallels that of *Blechnum occidentale*. Frequently it is seen in gardens and in hanging pots. Lyon writes: "It has long been cultivated here and spreads rapidly in gardens where it is sometimes a nuisance." I have records in the field from various places on Kauai, Oahu, Maui, Molokai, and Hawaii. Fagerlund (11, p. 21) writes that at Hawaii National Park it is found "near steaming cracks in Kilauea Caldera and in the hot area near Kokoolau Crater where it is rather frequent."

Microsorium Scolopendria is quite variable in the Hawaiian Islands, as it is elsewhere. On Tantalus, Oahu, a small, coriaceous, epiphytic form with deeply pigmented axes was found; in the damp, shaded rocky woods along Wailua Stream on east Maui, was found a very large terrestrial form over 4 feet tall, the primary lobes of which are again lobed (5284); and on exposed weed banks along nearby roads, occurs a form with simple but fully fertile fronds 6 to 10 inches long and 1 to 2 inches broad (5288). This fern, often grown in greenhouses in the mainland United States, is unique in the Hawaiian flora, in its leathery, shiny, bright-green, coarsely lobed, long-stiped fronds, up to a meter or more tall, arising from a long-creeping, dark-green rhizome a centimeter in diameter. The sori are large and deeply immersed, reflecting "warts" on the upper frond surface. Its closest

relative in Hawaii is the odd endemic *Microsorium spectrum* (Kaulfuss) Copeland—with broadly triangular simple or shallowly 3- to 5-lobed fronds and numerous minute sori—which is much less common than the introduced species. If the Hawaiians once utilized *Microsorium* to impart a pleasing odor to tapa cloth, as reported by Fosberg (12, p. 22), it is probable that the native species was the fragrant fern used.

PHLEBODIUM

A fern similar to the *laua'e*, which was introduced about a decade earlier but which has spread far less exuberantly, is the golden polypody, *Phlebodium aureum* (Linnaeus) J. Smith (*Polypodium*, L.) of Florida and tropical America. It was reported first by Robinson in 1913 (24, vol. 40, no. 5, p. 202, pl. 9) from a Forbes collection of 1909 in the Wahiawa mountains, Kauai (*Forbes 308*). The pinnae are narrower and more numerous than those of the *laua'e*, the frond is somewhat thinner and dull whitish or blue-green, and the rhizome is invested by dense, long, golden scales. Lyon writes me of his impression that "*Phlebodium aureum*, like the mynah bird, prefers to hang around human habitations." While it has apparently not spread far, I have found it near Kaukaopua, Hanalei Valley, in the crotch of a mango tree and on exposed *Pandanus* prop-roots (5627); on the mossy cross beam of a front-porch roof in the town of Hanalei, in company with *Microsorium Scolopendria* and the indigenous *Pleopeltis Thunbergiana* Kaulfuss (5631); and in the garden of the McBryde Power House, Wainiha Valley (5633). These stations were all within 100 feet of sea level, but I have recorded it in notes (August 23, 1947) from the Kalihikai ridge, Kauai, at an altitude of 1,200 feet. It was found even higher on Oahu, on the bough of a large woodland tree on Tantalus, at 2,000 feet altitude (3213), in October 1944. That year I saw it also as a volunteer with *Nephrolepis* sp. on a Canary Islands date palm (*Phoenix canariensis* Hortorum) in a yard near Bishop Museum in Honolulu. Miss Neal informs me that it is commonly grown in Honolulu gardens. The fact of its introduction here seems extremely convincing, although Robinson was doubtful, reasoning that "the remoteness of the locality where [Forbes' specimen] was collected makes its origin from a cultivated plant improbable" (24, vol. 40, no. 5, p. 202). However, the remote occurrence of other naturalized ferns reported here, weakens her argument somewhat.

AZOLLA

The floating, heterosporous, New World fern, *Azolla filiculoides* Lamarck, is abundant in various taro patches on Oahu and Maui. In still water, it forms a dense, dull-green carpet of tiny gregarious "un-fernlike" plants, with a life-habit like that of duckweed.

Christensen did not include the genus in his enumeration of 1925, although Robinson had noted in 1912 (24, vol. 39, no. 5, p. 232) that an "*Azolla* sp." had been introduced to prevent the breeding of mosquitoes in the ditches along the rice fields. This early introduction must have been unsuccessful, but now the plant should be reckoned with as a member of the Hawaiian fern flora. In 1943 (13, p. 387), Fosberg wrote that it "appeared in the taro patches and irrigation ditches of Oahu about 1934, and so became extremely abundant. In 1926, H. L. Lyon introduced *Azolla caroliniana* into the islands at the request of the mosquito abatement committee. The latter plant did not become established." Elsewhere (12, pp. 18-19), Fosberg states that "It has spread with great rapidity and grows with amazing luxuriance in the taro patches which are kept flooded with water." He notes also that some taro growers regard it as beneficial because it prevents weed growth, whereas others believe it increases taro diseases. It is also much favored as a plant for small aquaria (Lyon, in letter).

To add to the localities given by Fosberg, I have the following: abundant but sterile, in taro patches at the mouth of Waihee Valley, west Maui (5299); sterile, from the bank of a ditch at Waiahole, Oahu (5061); and in a swamp just northwest of the intersection of Kapiolani Boulevard and Kalakaua Avenue, Honolulu (5040). Only the last collection had sporocarps. The glochidia of these were non-septate, indicating that this collection belongs to *A. filiculoides*, as do those of Fosberg.

RELATIVELY RARE SPECIES

Other ferns recorded during recent years as new to the Hawaiian flora have evidently not attained the extensive ranges of the foregoing and cannot yet be classed with them. I have seen only one of these less successful invaders in the field. The wide-ranging, Old World, climbing fern, *Lygodium japonicum* Swartz, which was reported by Fosberg (13, p. 387) as "semi-established around an old garden at Puueo, Hilo," on the island of Hawaii is one of these. Lyon has recently written me that this fern "has established itself in hedges and

along walls in the vicinity of human habitations but I have never come upon a plant very far afield." Copeland (7, p. 435) reports another, *Athyrium esculentum* (Retzius) Copeland, on the basis of *Faurie 154*, Kealia, Kauai, 1910. (This fern, throughout its natural range from tropical Asia to southern Polynesia, is the most widely eaten of all ferns.) I did not find it on Kauai; but I saw it in gardens at Hana, Maui, in company with a large *Blechnum* species [possibly *B. capense* (Linnaeus) Schlechtendal]. MacCaughey erroneously lists *Athyrium esculentum* as "endemic" (19, p. 215).

The familiar dwarf club-moss of greenhouses, *Selaginella Kraussiana* (Kunze) A. Braun is becoming common at the edges of wet woods, along roadsides, and in gardens and lawns in the Kilauea area of Hawaii National Park (reported by Fagerlund, 11, p. 21). The earliest Bishop Museum collection from that area was taken from lawns of the park residence on December 17, 1938, by G. E. Olson (Neal, letter, October 21, 1949). Eugene Horner pointed out the vigorous carpets of dwarf club-moss being formed around his home at the Olaa House Lots in August 1949. Lyon informs me that "this plant has been slowly spreading in several localities for many years but it cannot take advantage of wind-currents to make long hops because of its heterosporous habit."

Probably any of the numerous ferns not noted here but listed and treated in Neal's "In gardens of Hawaii" (22) should be regarded as potentially capable of escape into the flora. The Bishop Museum herbarium contains several collections, made during the years 1933 to 1938, of the pantropical, coastal swamp leather-fern: *Acrostichum aureum* Linnaeus. According to the data of T. C. Zschokke on the earliest collection, the plants grew 10 feet tall at the pumping station at Kamehameha School Farm, Hahaione Valley, Maunaloa, Oahu, and were introduced in April 1926 from the Philippines. This is another potential escape which should be interesting to watch; it may spread into other low swampy areas.

DUBIOUS AND PROBABLE INTRODUCTIONS

Several other ferns said to have been introduced into the flora may only appear to have been introduced, *Marattia Douglasii* Baker, for instance. It is discussed by Selling (26, p. 127) as follows: "MacCaughey once said of the latter (1919 [20], p. 2) that it is 'not at all unlikely that the pala was deliberately introduced, by the natives, dur-

ing this epoch. Its present distribution in the islands is in no way incompatible with this hypothesis.' Its spores have been found, however, in the strata of Period I." Some of the sword ferns, *Nephrolepis* (page 104), are especially problematical from this standpoint. However, it should be noted that in interpreting *Nephrolepis*, as in many other critical fern genera, preliminary field observations are often infinitely preferable to studies of fragmentary specimens in herbaria, particularly in view of the resemblance individual fronds may bear to specimens of other species in marginal characters, soral position, and indument. Clearly, there are at least four entities in Hawaii: *Nephrolepis exaltata* (Linnaeus) Schott, the *okupukupu* or *pamoho*, which is the commonest; *N. hirsutula* (Forster) Presl; *N. cordifolia* (Linnaeus) Presl; and the aforementioned *N. biserrata* (Swartz) Schott var. *furcans* Hortorum, which seems to be an obvious naturalization.

Of *N. cordifolia*, Fosberg (13, p. 386) has written: "... although this species has commonly been regarded by previous writers as introduced in the Hawaiian Islands, its frequent occurrence as a part of the undisturbed cloud forests of the mountain ranges, and its absence from the lowlands indicates that it is in all probability native." (It was first reported by Bailey in 1883.) I agree with Fosberg that *N. cordifolia* should henceforth be considered indigenous and base my belief on the following evidence. First, Hillebrand (17, p. 579) said of what he interpreted as the native *N. exaltata*, "I have two forms: one small and narrow, with fibrillose rachis and oblong obtuse pinnae, the lowest gradually dwarfing; the other larger and broader, with naked rachis, the frond almost truncate at the base, or only slightly narrowing, the pinnae falcate, acute. A few very short paleaceous surculi, similar to those which occur in *N. tuberosa*, but without buds or tubers, are to be seen in a specimen of the smaller sort." Hillebrand's "smaller" form must have been the Hawaiian representative of this pantropical *N. cordifolia*. Second, Heller (15, p. 782) got two entities, writing that "... while *N. acuta* [which according to his specimens was actually *N. exaltata*] is confined to low altitudes, this species [his "*N. exaltata*," but according to his specimens *N. cordifolia*] replaces it at high altitudes." Third, on a sheet loaned to me by the Gray Herbarium and bearing three fronds of *Nephrolepis* collected by Brackenridge during the United States South Pacific Exploring Expedition in the years 1838-1842, two fronds are *N. exaltata* and one is *N. cordifolia*.

Other specimens collected before 1900 may be found to be mixed in herbaria. It is quite possible that garden plants of *N. cordifolia* from other parts of the world have also been introduced, but these may well be found away from the original rain forest. I saw an individual large plant with abundant "tubers" along the dirt road in a *Eucalyptus* association in relatively dry country between Makawao and Olinda, east Maui, at an altitude of about 2,500 feet (where it had been seen earlier by Hannah Lou Bonsey); this individual may well have been an escape. In 1947 and in 1949, I found the presumably native form to be common in wet highlands on Hawaii, Maui, Molokai, Oahu, and Kauai; and Fosberg reports it from Lanai. The "tubers" which Hillebrand notes as being absent seem to be uncommon in the local population, and only one of my specimens (Alakai Swamp, Kauai, 5501) shows one of any size (1.5×0.9 cm.).

N. hirsutula, characterized by its chaffy rachises and lamina, was first reported from the Hawaiian Islands by Bailey (1, p. 48) as variety " β —*N. hirsutula*, Presl" of *N. exaltata*. He describes it, quoting from Hooker and Baker, as follows: ". . . rachis densely and both surfaces more or less coated with ferruginous down." Of *N. exaltata* and this variety, he writes: "Found in great variety of situations and altitudes, some of which effect a change in its coat probably, whence B." Whether Bailey actually had *N. hirsutula* is still open to question, for this fern is very localized in the islands and the first collection manifestly of this species seems to have been Topping's, 1923, along the Waiahole-Waikane Trail, Oahu. It has since been reported elsewhere on Oahu and in various places on Hawaii and Kauai. In addition to Oahu specimens from both of the mountain ranges, I have material taken in 1947 on Kauai from the Napali Coast (5621) and Hanalei Valley (5628). And it is commonly cultivated in gardens in the Hanalei area. Leo Koch found it growing in a rather odd situation, on the underside of a wooden trough at the Waipio Naval Base dock, Oahu, July 1944 (Koch 110). Like *N. cordifolia*, it may be easily confused with *N. exaltata* by a casual collector. Further evidence of early occurrence in Hawaii definitely seems desirable before this plant warrants interpretation as native.

Reports of true *N. biserrata* from Hawaii are apparently based upon misidentifications. Neal informs me (letter, November 21, 1949) that specimens cited in literature and thus filed in the Bishop Museum herbarium are actually *N. hirsutula*, and adds that this "leaves var.

furcans as the only representative of *N. biserrata* in our Hawaiian collection." Therefore, additional confirmation is needed before the typical form of this species is admitted into the flora.

The once-pinnate species of *Athyrium* in the Hawaiian Islands are an exceptionally difficult group for taxonomic interpretation, and their problems will not be discussed here. One of the most distinctive, *Athyrium japonicum* (Thunberg) Copeland (*Diplazium*, Beddome), has been reported only during the last 12 years. Skottsberg (27, pp. 108-109) first reported this plant from Hawaii in his 1938 collection, the Kohala Mountains along the upper Hamakua ditch trail, between Koiawe and Alakahi Valleys (*Skottsberg 3179*). Two collections which undoubtedly belong to this species were made by Horner in 1948 and 1949 along the upper Waipio ditch trail in rain forest at an altitude of 3,000 feet in the Kohala Mountains, Hawaii. Horner writes that in his opinion this species "is probably a late introduction—within the last ten or twelve years. I have made many trips on the upper Waipio ditch trail, but did not notice it until 1947. It probably appeared between my last visit before the war (approximately 1938) and my first visit after the war, in 1947. I have not noticed it growing elsewhere. . . . It is growing to a great extent on the trail and is spreading rapidly." Of the various species of once-pinnate *Athyrium*, I know of none which can be confused with *A. japonicum* upon close comparison, though they seem to be mutually closely related. Skottsberg notes differences in cutting and shape of segments, sporangia, spores, and scales (27, pp. 108-109) of *A. japonicum*.

I believe, on the basis of Horner's information, that *A. japonicum* has somehow been introduced into the Hawaiian flora in very recent times. Its localization to the Kohala Mountains in Hawaii and its rapid increase in numbers support this view. Copeland informs me that this is a fern which is sometimes grown in gardens and that it has turned up as an introduction even in South America. The original range of the species appears to have been from Japan through Okinawa and Formosa to China and tropical Asia. The behavior of *A. japonicum* should be watched through the coming years to see whether it spreads to other islands. It is here tentatively regarded as another of the naturalized ferns of the Hawaiian Islands, at present growing in weedy fashion in a limited area only.

The several native Hawaiian ferns which grow weedlike in disturbed places, might be suspiciously regarded as new advents. The

very rare and peculiar endemic genus, *Diellia*, by no means a weed, tends to occur in areas disturbed by rock slides, cattle, and trail-making, but others of the local ferns become abundant in such spots. An outstanding example in the wetter regions is *Sphenomeris chinensis* (Linnaeus) Maxon, the *pala'a* fern. Although it rarely produces extensive stands, both young and old plants cover dirt banks along some roads and trails in the higher forests and it nearly reaches sea level on the wetter, windward sides of the islands. It is reported by St. John and Hosaka as a pineapple weed, though not a serious one (28, p. 27). They also report (p. 25) that the native bracken, *Pteridium aquilinum* var. *decompositum* (Gaudichaud) Tryon, is a "somewhat troublesome weed" along the borders of pineapple fields near uncultivated thickets and must be plowed out. Another negative native plant is the often deplored *Dicranopteris linearis* (Burmenn) Underwood, the *uluhe*, which in damper areas locally may cover entire open hill-sides and form nearly impenetrable thickets, as it does throughout the Old World tropics. The common *Psilotum nudum* (Linnaeus) Grisebach is found on boles of coconut trees and rock walls, even in downtown Honolulu. Other native ferns, such as *Microlepia strigosa* (Thunberg) Presl and *Doodia Kunthiana* Gaudichaud, behave as weedy plants in disturbed woods of the lower and dryish gulches.

SUMMARY

To conclude, the evidence for or against introduction of the various species has been discussed. Ferns which in all likelihood were introduced by modern commerce into the Hawaiian Archipelago and which are now independently self-reproducing there should be excluded from statistics analyzing phytogeographical affinities. The following list shows the evidently naturalized plants, over twice as many brought from the Old World as from the New, and their first collection dates.

- Adiantum cuneatum*, 1907, now common, probably now on all islands.
- Adiantum hispidulum*, 1923, frequent, on three islands.
- Pteris vittata*, 1909, frequent, on three islands.
- Ceratopteris thalictroides*, 1919, local on two islands.
- Pityrogramma calomelanos* s. 1, 1903, common, probably on all islands.
- Pellaea viridis*, 1928, local on Oahu.
- Nephrolepis biserrata* var. *furcans*, 1936, frequent, on three islands.
- Blechnum occidentale*, 1918, abundant, probably on all islands.
- Cyrtomium falcatum*, 1928, local, Molokai and Hawaii.
- Lastrea Torresiana* (*Dryopteris uliginosa*), 1892, frequent, on four islands.

- Cyclosorus dentatus, 1887, abundant, on all islands.
Cyclosorus parasiticus, 1926, frequent, on three islands.
Microsorium Scolopendria (Polypodium Phymatodes), 1922, common, probably on all islands.
Phlebodium aureum, 1909, frequent, Oahu and Kauai.
Azolla filiculoides, about 1934 (as established), local, Oahu and Maui.

Less important are the following species, known at present from only one or two places: *Lygodium japonicum*, 1936, Hawaii; *Athyrium esculentum*, 1910, Kauai; and *Selaginella Kraussiana*, 1938, Hawaii.

Several other ferns may or may not be modern introductions; *Nephrolepis hirsutula* is one of these. For *Athyrium japonicum* there is more definite indication that it is a naturalized fern. *Nephrolepis cordifolia* of the high rain forest is apparently indigenous, although garden plants have probably gone wild, too.

The most striking examples of extraordinarily rapid spread are ferns probably introduced within the last 35 years: *Microsorium Scolopendria* and *Blechnum occidentale*. The most peculiar situation is the invasional success locally of a horticultural "freak," *Nephrolepis biserrata* var. *furcans*.

It is likely that none of the naturalized ferns existed as members of the flora until 60 or 70 years ago. Thus in ferns, as in other plants and in animals, Hawaii shows the impact of commerce and immigration on the biotic constitution of an originally isolated and highly endemic subtropical area.

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