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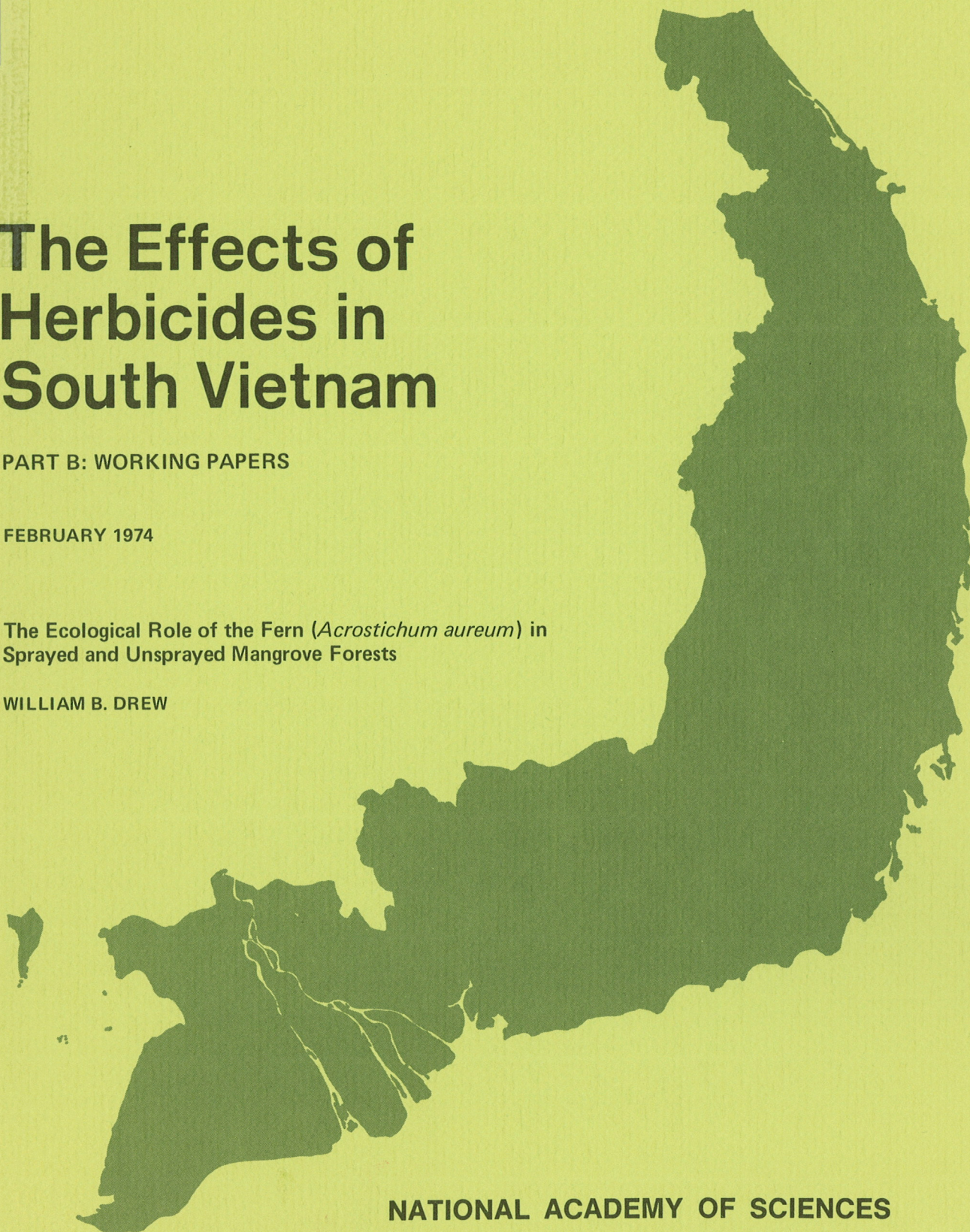
The Effects of Herbicides in South Vietnam

PART B: WORKING PAPERS

FEBRUARY 1974

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Sprayed and Unsprayed Mangrove Forests

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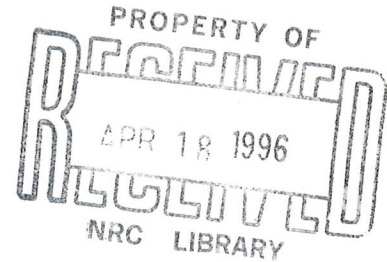
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NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL

WASHINGTON, D.C. 20418

The Ecological Role of the Fern (Acrostichum aureum) in
Sprayed and Unsprayed Mangrove Forests

WILLIAM B. DREW^a

It has been found in the past by French and Vietnamese foresters that if a mangrove forest is destroyed, as by clear-cutting, there may occur a relatively rapid colonization of the cutover area by Acrostichum aureum L., a large fern commonly found in this kind of habitat. With the widespread destruction of mangrove forest by herbicides applied for military purposes in South Vietnam (SVN), it became important to determine if the fern could rapidly and aggressively invade mangrove communities that had wholly or in part been killed by spraying.

The specific objectives were twofold: (1) to estimate within mangrove forests the area which has been taken over by this fern following the spraying of herbicides, and (2) to study the biological and ecological factors affecting the rate of spread of the fern.

GENERAL INFORMATION CONCERNING THE NATURE AND GEOGRAPHY OF THE FERN

Throughout much of the tropical and sometimes subtropical^b zones of the world, Acrostichum aureum is widely distributed in marshy, brackish habitats, usually associated with mangroves (Chapman 1970). This fern may attain a total height of 10-12 ft under favorable conditions, and has large pinnate leaves that arise from a short, erect or ascending

^aProfessor Drew, a member of the Committee on the Effects of Herbicides in Vietnam, is affiliated with the Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan 48824.

^bAs in southern Florida.

woody stem (diam. 3-4 in.), bearing thick, fleshy roots (see Figure 1). A very closely related fern, Acrostichum speciosum Willd., has been noted as a distinct additional species in similar habitats in Malaysia and eastern Australia (Watson 1928, Macnae 1966), but it is not recognized as a species taxonomically separable from A. aureum in the most recent flora of SVN (Ho 1970).

In SVN, Acrostichum aureum grows in association with the mangroves along the southern coasts and inland in estuarine habitats. The mangroves cover approximately 700,000 acres (250,000 ha according to Moquillon 1949?), including the delta formed by the Saigon and Dong-Nai Rivers along the shipping channels south of Saigon (Gia-Dinh or Rung-Sat Special Zone), a few localities northward along the coast, and especially the Ca-Mau Peninsula at the extreme southern portion of the country. For many years prior to 1941, the mangroves--especially in the Ca-Mau--were managed for the production of wood for charcoal. This forest also furnished poles, posts, tannin from the bark, and other minor products such as edible greens from the young shoots of Acrostichum.

RELATIONSHIP OF Acrostichum TO DESTRUCTION OF MANGROVES

As noted elsewhere in the Committee's report,^a mangroves can be killed by herbicides applied at rates used for military purposes in SVN. Concern has therefore been expressed (Meselson et al. 1970) that where the mangroves have been largely destroyed by repeated application of herbicides there may have possibly followed overgrowth of such species

^aSee Section IV C, Part A of the Report on the Effects of Herbicides in South Vietnam.

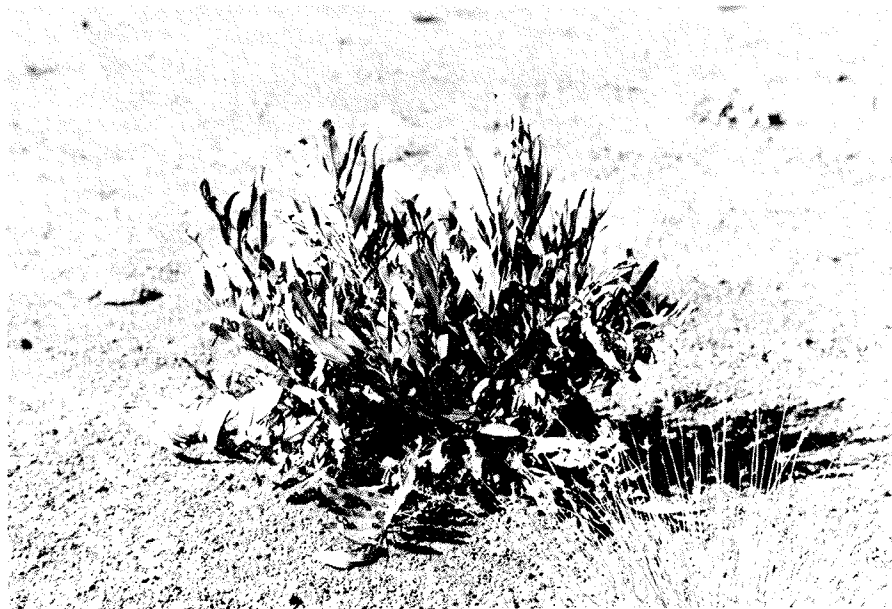


FIG. 1. Acrostichum aureum growing in
the denuded mangrove forest of the Rung-Sat.

as the fern Acrostichum aureum, which are less readily killed and are difficult to eradicate once established.

That this fern can indeed invade cleared mangrove forest land under certain ecological conditions has been noted by French foresters working in the Ca-Mau Peninsula (Moquillon 1949?). They found that in depressions amounting to over 18,000 acres in the Ca-Mau, the fern frequently invaded immense areas. In order to obtain a stand of useful mangrove species, the fern was cut, allowed to dry, and then burned. Burning the masses of fern destroyed the spongy layer of humus that retained large quantities of rain water. The Acrostichum was considered by the French foresters indispensable to any reforestation of such depressions simply because of the role the dried leaves played in furnishing fuel to burn off the layer of humus.

Holdridge (1940) has also noted that Acrostichum aureum occurs sparsely in uncut mangrove forests in Puerto Rico, but he found that when the canopy is opened up through heavy cutting of the forest this fern may overrun the whole opening. To reestablish mangrove seedlings in such dense stands of fern, a combination of fire to burn the accumulation of dead fronds and subsequent cutting by hand of the stout fern rhizomes was required.

OCCURRENCE OF Acrostichum IN UNSPRAYED MANGROVES

In his intensive monograph on the mangroves of Gia-Dinh, Vu-Van-Cuong (1964) found that Acrostichum was generally present in the mangrove forests at a low density. He found that the population of this fern tended to increase on sites 10-12 ft above sea level where the habitat is somewhat drier.

At the cleared plot in the mangrove forest near Vung-Tau, members of the Committee censused two transects (each 50 x 2 m) on either side of the area to determine the density of the fern in a relatively undisturbed stand. In the entire 100 m² of the first strip investigated, a total of 1154 stems of all species were counted, but only one fern plant was found. No ferns at all were found in the second transect, in which a total of 410 stems were counted. The density, expressed in percent, was thus 0.08/200 m². It should be noted that while the first transect was made on a site with a sandy soil profile located farthest from an estuarine channel, the second strip was run on a site closer to the channel, somewhat lower in elevation with heavy clay soil and probably subject to more frequent tidal inundation. In view of Vu-Van-Cuong's (1964) observations on higher, drier sites supporting stands of the fern, one would expect to find few if any plants of Acrostichum in heavy, wet, clay soils, such as were represented in the second transect.

In a similar mangrove forest near Klung in southeastern Thailand (comparable to that of the Ca-Mau), 6 transects (each 100 x 2 m) in relatively undisturbed mangroves were made in April 1972, by technicians of the Royal Forest Department. A condensed summary of the results that pertain to the occurrence of Acrostichum aureum is as follows:

<u>Plot no.</u>	<u>Total stems of <u>A. aureum</u></u>	<u>Total no. of stems of all species</u>
1	0	202
2	1	272
3	0	302
4	0	345
5	5	471
6	0	262
Totals	6	1854

A percent density of 0.32 for the 1200 m² in the transects indicates that in a mature mangrove stand that has not been aerially sprayed with a herbicide the occurrence of Acrostichum aureum is at best sporadic with relatively few plants.

Members of the Committee visiting this site in Thailand briefly, observed that partial cutting (shelterwood) of the forest appears to lead to an increase in the fern population. In an area of approximately 0.5 acres, 12 young ferns were counted growing on the stumps of recently felled mangroves, or on the bases of a few living trees. Mature ferns in the same locality were estimated at six plants, but about 300 yd away there was a large stand of the fern which could possibly have furnished spores borne on the diurnal tidal flow.

Here the young ferns were covered daily by high tides to a depth of as much as 1 ft or more, and the mature parent plants were frequently submersed with only the tips (6-12 in.) of the leaves above water. On somewhat higher and drier sites with shallower flooding from high tides, the size of the fern was considerably larger than in the lower areas.

Obviously this fern grows sporadically with low density as part of the unsprayed and uncut mangrove ecosystem, flourishing on higher, drier sites subject to shallow or infrequent tidal inundation. Partial removal of the trees by cutting and thinning the stand appears to favor reproduction of the fern, but firm conclusions could not be drawn on this point, since no comparative data between cut and uncut stands of mangroves at Klung were available.

OBSERVATIONS AND FIELD EXPERIMENTS IN GIA-DINH (RUNG-SAT SPECIAL ZONE)

For reasons of security it was not possible to carry out ground studies on Acrostichum in the Rung-Sat Special Zone except in a few selected sites. With the cooperation of the Vietnamese and U.S. Navies, two sites that had been preselected from aerial photographs were examined January 31, 1972. The sites were located on an island bounded on the east by the Song-Dua (river), and on the west by the Dan-Xay River. Because both sites were edged by high banks, the interior was subject only to occasional high tides. In both areas, the mangrove forest had been nearly eliminated by repeated applications of herbicides; however, since the cessation of spraying in 1970, there has been regrowth of some of the mangrove species along gullies and areas extending inland 100-200 or more yd from the river margin. Both areas supported substantial stands (2-3 acres) of fern, or fern mixed with the palm Phoenix paludosa Rosb. and saplings of such elements of the mangrove forest as Excoecaria agallocha L., Derris trifolia Lour., or Ceriops spp.

At both sites 10 plots, each about one yard square (1 m^2), were laid out along the margins of the stands of Acrostichum, on soil ranging from bare clays to others covered with organic debris. On each plot, spores from mature fertile leaves (fronds) of Acrostichum were sown by rubbing two fruiting fronds together until the plot was obviously well covered with both the brownish sporangia and spores.

Dr. Ho (Committee member from the University of Saigon) and his associates mapped the vegetation within strips 10 yd wide running from near the river's edge inland for approximately 150 yd. On August 11, 1972,

the sites were revisited to examine the experimentally "seeded" plots and the mapped strips (transects). In brief, not a single germinated spore (prothallus) or young fern plant (sporophyte) was found within the plots. Moreover, a careful search among the mature ferns revealed no young plants of recent (6 months or less) origin.

On the same date, Dr. Ho and his associates reexamined the transects laid out the preceding January. On Site 1, within an area of 598 yd² (500 m²), he found that there was a significant increase in the number of new seedlings of black mangrove (Avicennia officinalis L.--8 seedlings) and a woody legume (Derris trifolia Lour.--6 seedlings). On Site 2, the transect data for 299 yd² (250 m²) revealed similar increases in new seedlings, namely: Cerriops sp. (1.7 plants), black mangrove (6 plants), Bruguiera sp. (1 plant), Scyphiphora hydrophyllacea Gaertn. (1 plant), and Derris (7 plants). Of these plants, the single seedlings each of Bruguiera and Scyphiphora represent the first plants of either species found on either site. Bruguiera is especially significant since it is an important genus in the mature mangrove forest. Finally, there was no increase in the population of the fern, especially at Site 2, where the transect included Acrostichum in 60 percent of the transect area.

On December 16, 1972, both sites were visited again with Dr. Ho. The hand-sown spores of Acrostichum in the 1 yd² (1 m²) plots still showed no signs of having germinated. However, scattered around the periphery of the stand of fern at Site 2, 15 very young plants (sporophytes) were recorded that had not been found on previous trips, even though the area had been examined carefully. The factors favoring

establishment of these new ferns at Site 2 while no plants could be found at either Site 1 or in the hand-sown plots at both sites are not clear. All that can be concluded is that conditions must have become more favorable than at the other locations sampled.

Further information on successful germination of the fern spores was obtained from a third location along the banks of the Song-Dua (river) a short distance upstream from Site 1. Here along the high bank, a dense stand of a grass (Paspalum vaginatum Swartz) formed a meadow-like turf some 8-12 in. high, in contrast to the sprawling mats of the species usually encountered in sprayed mangrove areas. Scattered in the grass were mature plants of Acrostichum. When the area was examined closely, numerous sporophytes of the fern were observed beneath the stems of the grasses on the shaded soil.

In one small crevice of bare soil in the grass, prothallia of the fern were found along with tiny new sporophytes. Here, then, were microhabitats unusually favorable to the germination and growth of the spores. Such conditions did not seemingly exist at Sites 1 and 2, or at other locations visited in the Gia-Dinh (Rung-Sat), such as Loi-Giang and Thanh-An Island.

TESTS OF THE VIABILITY OF THE FERN SPORES UNDER ARTIFICIAL CONDITIONS

Collections of fruiting leaves (fronds) from many individual ferns were made on August 11 at both Sites 1 and 2 in the Gia-Dinh. This material was air-dried in SVN and returned to the United States for laboratory tests. The fronds were separated into two lots depending upon visual evidences of

maturity of the sporangia. Efforts were then made to sow the spores from each lot separately on two types of media containing nutrients according to Knudson's formula. One surface was of agar jelly, the other liquid. The glass petri plates were left on a laboratory bench at room temperature with ordinary fluorescent overhead lighting.

Both the liquid and agar media yielded excellent germination (+90%) of the spores from the younger fruiting fronds (Lot 1), whereas the material from the older fronds (Lot 2) proved not to have retained any significant number of spores. Apparently the spores had been mostly discharged from the sporangia before the fertile fronds were harvested.

By the first week of January, 11 weeks after the spores were sown, final counts of the plates of Lot 1 (the younger fruiting fronds) showed that 196 out of 200 spores were now growing prothallia on the agar base, whereas 190 out of 200 spores had successfully germinated in the liquid culture. The few spores present in the glass plates from the more mature fronds (Lot 2) had also germinated successfully.

THE AREA OF DEFOLIATED MANGROVE COVERED BY FERN IN SVN

By means of a comparison of aerial photography taken of Gia-Dinh (Rung-Sat Special Zone) before and after application of herbicides, it had been hoped to obtain a reasonable estimate of the area of defoliated mangrove forests invaded by Acrostichum aureum. However, the aerial photographs taken prior to the application of herbicides were not of sufficient quality to permit a meaningful comparison in the Rung-Sat Special Zone. Similarly, large-scale photography of the extensive mangrove

forests of the Ca-Mau Peninsula before and after the application of herbicides is not available, so that it is not possible to estimate the increase in area covered by the fern there following aerial spraying.

In the Gia-Dinh (Rung-Sat Special Zone), the fern populations are found growing primarily near the banks of the rivers and the subordinate channels, rather than in the centers of the sprayed areas. These stands may be predominantly Acrostichum, or a mixture with a variety of trees, shrubs, vines, and herbs. Again it should be noted that the fern populations were generally confined to a zone reaching from 100 to as much as 300 yd from the larger channels and inland in higher portions of defoliated areas, but were absent farther away where dead mangrove stumps had been removed for charcoal production, and there was little or no living vegetation.

In the Ca-Mau Peninsula, opportunity to make observations was limited due to very tight security problems. Trips by river patrol boats were made to areas where we could land (see Figure IV C-8, Part A of the Report on the Effects of Herbicides in South Vietnam). At none of these stops was there a significant population of Acrostichum; but in passing a former village site we observed a large stand of the fern. At this time, the Committee can neither state the total area of former mangrove forest that has been invaded by the fern in SVN, nor the increase in the fern population following destruction of the mangroves by herbicide.

SUMMARY

1. The large fern (Acrostichum aureum L.) occurs generally in unsprayed mangrove forests but the number of individuals per unit area is small.

2. Upon destruction of the mangrove forest by whatever means (cutting, spraying with herbicides), the fern tends to increase in numbers, but only where the site offers ecological conditions favorable to the successful germination of the fern spores.

3. The sample of fern spores tested under laboratory conditions was found to have a very high degree of germinability.

4. On the basis of limited ground observations in SVN, it does not appear that, under the ecological conditions now prevalent, this large fern will overgrow extensive areas of former mangrove forest mostly destroyed by herbicides.

5. In some areas, however, the extent of which is unknown, the ecological conditions favoring successful germination of the fern spores will exist so that some colonization by Acrostichum will occur. The data collected indicate that it will be a slow process.

6. Ultimately, as species of the former mangrove forest are reestablished, whether by natural revegetation or replanting by man, the increasing shade formed as the forest canopy closes may be expected gradually to eliminate much of the fern.

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