WATER AND MARSH PLANTS IN THE ARTIFICIAL BROKOPONDO LAKE (SURINAM, S. AMERICA) DURING THE FIRST THREE YEARS OF ITS EXISTENCE

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SUMMARY

The Brokopondo Lake in the interior of Surinam began to form when on 1 February 1964 the dam in the Surinam River near Afobaka was closed. The lake was intended to cover an area of about 150.000 ha and to have a maximal depth of about 47 m.

The basin, largely occupied by forest, was not cleared beforehand. During the initial stage the water in the flooded forest was characterised by a very high content of organic matter and the absence of oxygen. As the water level rose, differentiation between a hypolimnion and an epilimnion developed. The oxygen content of the epilimnion was high.

During the first three years of its existence the lake attained an area of about 84.000 ha and a maximal depth of 38 m.

Within this period eight aquatic plant species became numerous in the lake. Special attention was paid to *Eichhornia crassipes* and *Ceratopteris pteridoides*. In April 1966, when the lake covered about 78.000 ha, the former had colonized 53%, the latter 21% of this area. Since September 1966 both diminished greatly, *Eichhornia* as a result of artificial control, *Ceratopteris* for unknown reasons.

Floating pieces of decaying wood became overgrown by a variety of plant species, 27 of which were recorded.

Mixed vegetations of water and marsh plants developed, free-floating mats (*Eichhornia* being the matrix), patches attached to partly submerged tree tops, and belts along the shore. Twenty-two species were observed as constituents of these floating vegetations.

1. INTRODUCTION

On 1 February 1964, the dam built in the Surinam River near Afobaka was closed and the Brokopondo Lake began to form, afterwards named "Lake Prof. Dr. Ir. W. J. van Blommestein", after its projector.

Afobaka is situated 110 km south of the coast of Surinam and 90 km south of the capital Paramaribo.

The chief purpose of the lake was to provide water for hydro-electric power, required for the Surinam Aluminum Company (Suralco).

The lake was planned to cover an area of 150.000 ha, mainly consisting of forested land. Its greatest depth, just behind the dam, was calculated at approximately 47 m. The area would comprise a stretch of the Surinam River, from the Apresina Rapids NE of the village Pokigron up to Afobaka (a distance of 60 km), parts of the larger affluents Gran Creek (= Marowijne Creek) and Sara Creek, and many other smaller creeks and rivulets. The relatively large area of the lake is due to the width and the shallowness of the valley of the river and its tributaries in this region.

A team of biologists, changing in composition from time to time and consisting of four persons at a maximum, from November 1963 until June 1967 studied the biological implications of the process, in the lake as well as in its surroundings. This Brokopondo Research Project was set up by the Foundation for Scientific Research in Surinam and the Netherlands Antilles, financed by the Netherlands Foundation for the Advancement of Research in Surinam and the Netherlands Antilles (WOSUNA) from the outset through 1964, by the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) from 1965 onwards. More general information on the project is provided by SCHULZ (1954), LEENTVAAR (1966a, b) and VAN DER HEIDE (1966, 1967).

In the present paper the botanist of the team describes his observations on the vascular water and marsh plants in the lake, from January 1964 until December 1966. During this period the whole of the lake was crossed repeatedly by boat. Twice there was an opportunity to observe the area from an aeroplane, thanks to Dr. Weldon, Suralco's adviser on waterweed control.

At the end of December 1966 the lake had a depth of about 38 m near the dam, covering an area of about 84.000 ha.

2. THE EXPANDING LAKE AS A HABITAT FOR PLANT GROWTH

As a consequence of the relief of the area, the lake in its definite form will have a broad, shallow shore zone, a long, very irregular marginal line, and many islands. The expected fluctuation of the water surface implies that large stretches will alternately be inundated and fall dry.

The lake area, mainly covered with various types of forest, was not cleared before the dam was closed. The height of the trees in general was up to 20–30 m, in specimens of some species (*e.g. Ceiba pentandra* (L.) Gaertn.) up to 40 m and more. If 20 m is taken as the minimal height, it can be calculated that in about 70% of the completely filled reservoir the tops or even the greater parts of the trunks of the trees will remain above the water surface.

All this meant that the lake, though very large, would form from the onset a relatively quiet water body. This was of major importance for the development of plant growth.

The changing of the physical and chemical properties of the water, which started when the flowing river was dammed up, and was gradually converted into a stagnant lake, have been studied by Messrs. Leentvaar and Van der Heide, and Mrs. Nijssen, hydrobiologist of the team. The processes involved are mentioned by the first (1966a, b) and the second (1966, 1967). Here a brief description by VAN DER HEIDE (1967) may suffice:

"After closure of the dam on 1 February, 1964, the level of the water above the dam at first rose quickly, and every day the inundated area became considerably larger. According as the artificial lake spread, this process went more slowly.

From the ecological point of view this had major consequences for the aquatic milieu. It had been found that the flowing river and its tributary creeks were well stocked with fish and well aerated. This oxygen supply is probably mainly a physical one (especially in waterfalls and rapids) and does not come via the green plankton, for the density of the latter is very small in the rivers, especially in the rainy seasons.

In the rapidly spreading water in the reservoir a complete consumption of the oxygen occurred as a result of the high oxygen requirement of the inundated rotting litter of the forest floor. Currents and turbulence in the still shallow water ensured total participation of the body of water in this process. In this period many dead fish were found floating on the surface, and for a time the reservoir was practically empty of fish, at least the larger specimens. The *Desmidiaceae* and *Diatomaceae* plankton of the somewhat acid, oligotrophic river water, were replaced by *Flagellatae* and *Crustacea* plankton in the reservoir water, indicating eutrophication by the products of decomposition. Only locally in the water nearest the surface was the oxygen production of the green plankton able to exceed consumption to such an extent that some oxygen was detectable in the water. Extensive fields of filamentous algae, in which the oxygen content could reach a high level and animal plankton was able to maintain itself, developed locally. ..."

"As the reservoir became fuller a differentiation occurred between a peripheral zone in which the above processes continued to take place and a central area in which the body of water had become still and which as a result began to acquire the characteristics of a true lake. In this connection it must always be borne in mind that there is open water only in the channels of the former river and creeks, and that the rest of the meanwhile quite considerable area consists of half-drowned forest.

As is normal for still water, horizontal stratification occurred in the central part, this being based on the fact that the surface layers acquire a higher temperature through the radiant heat of the sun, and thus a lower density, than the deeper ones. The resultant division of the body of water into a epilimnion and a hypolimnion, which can be very permanent in the tropics (the difference in density hinders mixing of the two milieus), meant the restoration of conditions favouring life of animal organisms in the uppermost strata. In the calm water the larger rotting organic particles could settle out, the dissolved inorganic products of decomposition of the drowned forest could, as a source of nutrition, foster the development of vegetable plankton, especially colonizing green algae, and as a result the oxygen content of the epilimnion could climb to the vicinity of saturation point. Animal plankton and also various species of fish, especially the "pireng' (*Serrasalmo*, related to the piranha), populated the reservoir again...."

"As the boundary between the epilimnion and the hypolimnion is highly dependent on the effect of the wind on the water, and since the latter is usually not very pronounced in Surinam and is additionally checked here by the treetops, the depth of the epilimnion was very slight, at first only a few metres. Moreover, in the rainy season the increased supply of water with stronger currents and greater turbulence sometimes eliminated the separation between the epilimnion and hypolimnion temporarily and locally, the result being a reduction in the supply of oxygen and fish mortality. Towards the end of 1966 the oxygen-containing stratum had reached a depth of 8–10 metres."

3. GENERAL REVIEW OF THE SPECIES INVOLVED

Within the short time available only an incomplete investigation of the presence of water and marsh plants before the beginning of the formation of the lake was possible. In some instances it appeared justified to construct a hypothetical picture of the original situation on the basis of data collected later or elsewhere.

Undoubtedly before the damming in several localities of the lake area water and marsh plants were present in small pools, small swamps, and along the banks of the river and its tributaries.

The species that were not adapted to the new circumstances disappeared, others being greatly favoured by the developing of other conditions, at least temporarily.

It is possible that some of the species mentioned hereafter settled in the lake after being introduced by birds. However, before the damming up of the river already a number of aquatic birds lived in the basin area, like herons, anhingas, kingfishers and fish-hawks. After the inundation only incidentally some other were observed, like cormorants and ducks. There was nothing resembling an invasion of water birds.

During the first three years only aquatics floating freely on or just below the water surface came to the fore, *viz.* the well-known waterhyacinth *(Eichhornia crassipes)*, two floating ferns *(Ceratopteris pteridoides* and *C. deltoidea)*[1], two duckweeds *(Lemna valdiviana* and *Spirodela biperforata)*, two bladderworts *(Utricularia gibba* and *U. hydrocarpa)*, and *Jussiaea natans*.

This might be expected, because in the lake with its fluctuating and generally rising water level only plants that are independent of the water depth had a real chance. Other factors influencing the flourishing and expansion of these plants were the wind and the presence of the dying forest that offered at first shade, later only shelter. For some of the species a relation could be established between their behaviour and the processes in the water in the beginning of the lake formation.

Another group of species that got a chance to expand in the lake consisted of those able to thrive on decaying floating tree trunks and branches.

In several places the true aquatics formed mixed floating islands. Into these vegetations plants coming from the floating wood pieces might penetrate. In some cases it was seen that plants originally belonging to the forest flora in one or another way participated in the newly formed vegetation types.

As in other tropical countries, stagnant open freshwater bodies are scarce in

[1] LEENTVAAR (1966a) mentioned *Ceratopteris thalictroides* and published (1966b) a map of the lake showing the distribution of this supposed species at the end of 1964. This *Ceratopteris*, however, was not found in the lake; his data apply to *C. pteridoides*.

Surinam. Little is known about the pioneering stages of the hydroseres under these circumstances (see LINDEMAN 1953).

The process taking place in the Brokopondo Lake and described here cannot be observed elsewhere in the country.

4. EICHHORNIA CRASSIPES

4.1. General

Eichhornia crassipes Solms (Pontederiaceae), the waterhyacinth, is an aquatic plant, which floats by means of bulbous masses of air tissue in its pseudopetioles. As the older plants may continuously form offshoots, from which new plants sprout, the waterhyacinth may show a very rapid vegetative reproduction. Often the connections remain, resulting in the development of mats which in a short time may overgrow large areas of open water, provided the environment is suitable. This well-known process has been described from many localities, not only in tropical South America, where the species is indigenous, but also from other tropical and subtropical regions all over the world, where it was introduced. See *e.g.* PENFOUND & EARLE (1948) on the southern U.S.A., DE KIMPE (1957) on Congo-Kinshasa, VAAS & SCHUURMAN (1949) on Java and SPAFFORD (1939) on South Australia.

A favourable waterhyacinth environmenth is characterized in the first place by stagnant or only slowly running water and much light. Before the inundation this kind of environment was only to be found in a few places; consequently the waterhyacinth was scarce.

The inundation created a large body of water with favourable conditions for the waterhyacinth. The plant, therefore, showed an explosive reproduction after the closing of the dam, until an effective artificial control put an end to it.

4.2. Establishment and distribution

When the dam had been closed and the water in the Surinam River upstream of Afobaka began to rise, the waterhyacinth developed in the northern part of the lake (N of Gansee) from four already present nuclei. These were situated in two very small basins with stagnant water near the Aloesoebanja and Saidagoe Rapids, in a narrow and relatively quiet branch of the river flowing through the island Gran Prati ("Kapassie Island" on some maps), and in a small swamp along the railway west of Kabel.

Later new nuclei were formed, mainly by new plants transported from the south by the river. As in the lake basin itself before the closing of the dam, small groups of waterhyacinth could always be observed in a few places along the banks of the river upstream of the lake. However, in September 1964 rather large colonies were found in and near the outlet of the Sipari Creek near Aurora and in the Gran Rio and Pikin Rio near their confluence, where they merge into the Surinam River.

In the beginning the plants spread only along the banks of the river and along the inundated railroad. In July 1964 the total length of the zones thus formed was 35 to 40 km. By then only one small colony had been found in the retarded part of the Sara Creek.

From July 1964 onwards the potential distributional area increased considerably as more and more trees dropped their leaves and large parts of inundated forest became bare. In September 1964 the edge of the forest was covered with a fringe of waterhyacinth over a distance of 70 km, in some places the plants having penetrated some hundreds of metres into the bare forest.

The first mapping of the distribution of the waterhyacinth in two dimensions was carried out by Dr. Weldon and the author together, in November 1964. By then the newly formed lake covered an area of about 53.000 ha, of which the waterhyacinth had colonized about 5.000 ha (9%). The distributional pattern clearly reflected the prevailing direction of the wind which in the basin is east to southeast. See *fig. 1*.

This survey was followed by two more mapping campaigns in the expanding

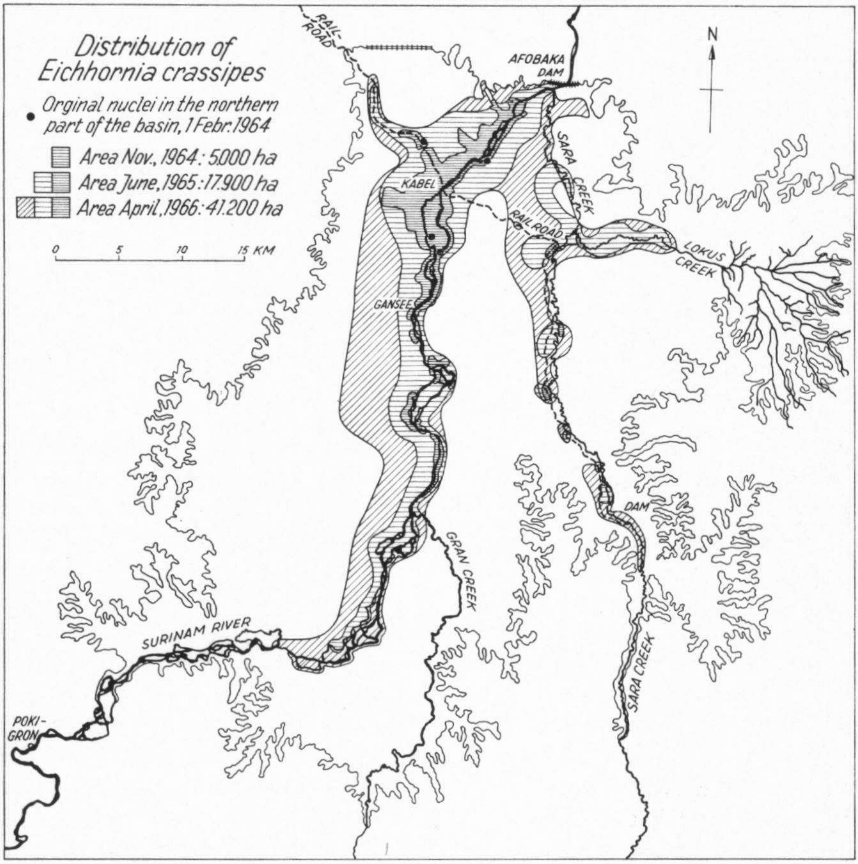

Fig. 1. The distribution of *Eichhornia crassipes* in the Brokopondo Lake. The ultimate shore-line is indicated, the islands are left out.

lake. In June 1965 and in April 1966, when the lake covered 70.000 ha and 78.000 ha respectively, the colonized area amounted to 17.900 ha (25%) and 41.200 ha (53%) respectively. At the time of the latter survey the area occupied covered the then whole length of the lake, that is from Mamadam to Afobaka, and in many places the plants reached what was then the shore.

It has to be stressed that the areas mentioned above were not completely overgrown by the waterhyacinth, but were areas in which the species was present, regardless of its density. In these areas the plants formed floating mats varying in size from only some leaves to one or several hectares. In general, the longer a locality was colonized, the more extensive were the mats and the smaller the distances between them. Therefore the increase of the total amount of waterhyacinth is very insufficiently expressed by the quotient of two successive area values. It should be clear that this increase was much higher.

The waterhyacinth flourished in more respects than only in a rapid increase of its numbers. In the older nuclei the leaves attained a height of nearly one metre and had laminas of 20 cm in diameter. There may have been some flowers nearly throughout the year, but the main flowering period was from August to October.

From the beginning there were some areas only thinly covered with plants, especially in the northernmost part of the lake. On the one hand this was a consequence of the disappearing of more and more tree tops and the appearence of large bodies of open and, because of the wind, turbulent water, from which the plants were blown away. On the other hand artificial control also became locally and temporarily successful.

Since the middle of September 1966 the amount of waterhyacinth was decreasing as a result of intensive and effective control. Plans to make a final survey in the beginning of December 1966 could not be carried out. By then the distributional pattern no longer depended on natural environmental factors but on the progress of the control campaign.

4.3. Influence of insects

The leaves of the waterhyacinth in the lake are eaten by a kind of grasshopper and sucked by a kind of cicada. The gnawed leaves wither and die. A floating mat visited intensively by these insects may be ruined completely.

During his visit in September 1965 Dr. Weldon noted that in some places the waterhyacinth was affected by a species of beetle larva. He did not collect any material. In October this phenomenon was further investigated by the author. Many petioles of dying waterhyacinth appeared to be pierced by a larva which had eaten its way from below upwards. In some stems larvae or cocoons with a metamorphosing insect were found. With the help of Dr. Weldon material was sent to Dr. W. H. Anderson in Washington (Agricultural Research Service, Insect Identification and Parasite Introduction Branch), who identified it as an *Epipagus* spec., of the family *Pyraustidae*. Dr. Anderson found this or a closely related species in waterhyacinths in Uruguay (in litt.).

The occurrence of the above-mentioned insects locally had a noticeable influence on the amount of living waterhyacinth, but it led nowhere to wholesale mortality over large areas.

4.4. Control

The waterhyacinth control is carried out by Suralco. In July 1964 the Suralco surgeon in Afobaka started the campaign. He carried out a number of experiments with various chemical herbicides in experimental basins as well as in the lake.

In October 1964 a special service was set up. For special advise the assistance of Dr. L. W. Weldon from Fort Lauderdale, Fla. (Agronomic Research Service, Crops Research Division) was assured, who visited the lake in October/November 1964 and September 1965.

In the meantime the service staff grew considerably and in November/December 1966 consisted of 50 persons. There were 15 spraying crews with special boats, operating from four camps in the lake. In the beginning the waterhyacinth plants were scooped up as well as sprayed by means of hand and motor pumps. Later only motor pumps were used. The spraying compound, 2-4-D is an auxin that is particularly effective in dicotyledons.

In October 1965 and April 1966, during five and four days respectively, part of the waterhyacinth area was sprayed from an aeroplane. On September 18, 1966, an aeroplane started a long control campaign which had not yet been finished in December 1966 when the author left Surinam.

From the beginning of the campaign the crews managed to keep the water just above the dam nearly free from waterhyacinth. Apart from this the campaign proved ineffective for a long time. The crews covered only small parts of the lake and did not perform their tasks very well. Within a short time the areas of spraying were overgrown again. The increase by natural growth and supply from the south far exceeded the effects of control.

During the second half of 1966 the situation has changed. The control service discovered how to work most effectively and the effects to spraying from an aeroplane, since September, were tremendous.

According to Dr. Weldon it will be impossible to eradicate the waterhyacinth in the lake, but it can be controlled. This, however, will prove very costly.

5. CERATOPTERIS PTERIDOIDES

The floating waterfern *Ceratopteris pteridoides* (Hook.) Hieron. (Polypodiaceae) has important characteristics in common with the waterhyacinth. Its vegetative reproduction is very rapid, by the forming of young plants on the edge of full-grown floating leaves. These young plants are set free and consequently *Ceratopteris*, unlike *Eichhornia*, does not form distinct mats. As a result the plant is able to form a more or less continuous cover only in sheltered places with stagnant water. The species is widespread in tropical and subtropical America (DeVol 1957).

In April 1964 some *Ceratopteris* plants were observed for the first time in the lower stretch of the Sara Creek. Presently the plant multiplied rapidly in that place. The supposed origin of this nucleus is a dead course of the Soekroewatra Creek, that, 30 km to the south, flows into the Sara Creek. In July 1964 an apparently old population of this species was still present there (see also 8).

Large parts of the Sara Creek basin have been gradually colonized by this *Ceratopteris*. In some other places of the lake the species also turned up. Sometimes it disappeared again, sometimes it formed large masses. The success of *Ceratopteris* varied greatly and unpredictably, but in general it may be said that the populations were densest where the trees still had their leaves.

Three times the colonized area was mapped. In November 1964 it measured 1.200 ha, in June 1965 11.700 ha and in April 1966 17.000 ha. The distributional pattern of this species appeared also to be greatly influenced by the prevailing wind directions. See *fig. 2.*

At the beginning of December 1966 the amount of *Ceratopteris* appeared to

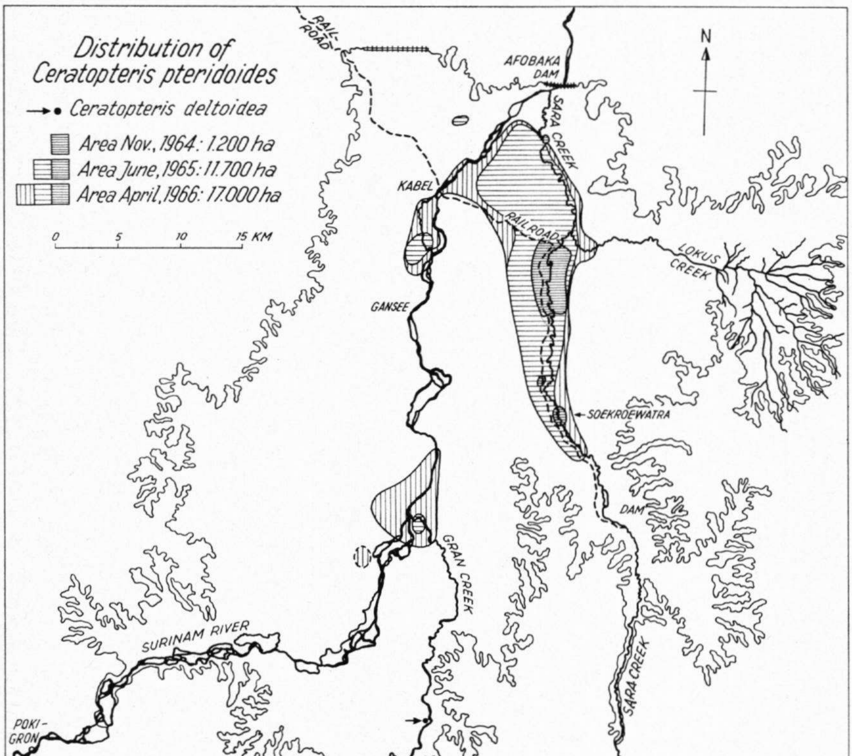

Fig. 2. The distribution of *Ceratopteris pteridoides* in the Brokopondo Lake. The ultimate shore-line is indicated, the islands are left out.

have been reduced considerably. Only scattered groups were observed in the occupied area. It is possible that the control of the waterhyacinth, which in many places offered shelter to *Ceratopteris*, also affected the latter indirectly. Another possibility is the increasing influence of the direct light.

Dr. Weldon advised Suralco to control *Ceratopteris* with the spraying compound diquat. No start had been made by the middle of December 1966.

6. OTHER AQUATIC PLANTS

Lemna valdiviana Philippi (Lemnaceae), a duckweed common all over tropical America, was observed for the first time on 22 February 1964 near the mouth of the Lokus Creek. On 3 March it was followed by *Spirodela biperforata* W. Koch, an equally widespread species (DAUBS 1965), in the same region. Most probably both species were present there already before the closing of the dam. Since then they spread rapidly over the Sara Creek area, where in July 1964 a closed field of both, 15 km in diameter, was measured. At first *Lemna* was the dominating species here, afterwards *Spirodela*. In the meantime both duckweeds turned up in many other localities of the lake. The ratio between the two species in mixed fields usually varied greatly. The cause of this was not studied.

There was a clear correlation between the optimal development of the duckweeds and the initial stage of the change in the properties of the water. It is quite feasible, that the duckweeds were favoured by the high content of organic compounds in the water. This is a generally known phenomenon, *e.g.* in the Netherlands and several other countries (see HILLMAN 1961). On the other hand the duckweeds obviously flourished best as long as the trees kept their leaves and provided some shade. In the full sun they turned completely red and diminished. As soon as the "lake milieu" had established itself, the duckweeds were found only in small numbers, mainly among the floating islands of the other aquatics.

Before the closing of the dam *Utricularia gibba* L. (Lentibulariaceae) probably was present in some small swamps along the railroad NW of Kabel. The species showed an enormous increase, more or less in connection with the stage of the lake forming mentioned above. It seemed, however, independent of the shade. In the beginning the species formed large suspended "clouds" in calm and rather shallow water and occurred frequently intermingled with filiform algae. Later, as the situation got stabilized and the "lake milieu" came into existence, it maintained itself only attached to dead branches and among the roots of waterhyacinth and *Ceratopteris* islands. Nevertheless, since the intensive control of the waterhyacinth started, it has become the most numerous and the most widespread waterplant in the lake. It flowered from October to February.

The blue-flowered *Utricularia hydrocarpa* Vahl was found in the Sara Creek area near the village Dam in January 1966. At that time it covered already tens of square meters, occurring mainly in dense, pure vegetations, here and there together with *Utricularia gibba*. The species maintained itself locally, but later a part of its area was overgrown by the waterhyacinth. It was not observed elsewhere in the lake.

It is not known if the species was present in the lake before the inundation. However, it had been collected in 1949 in a small swamp some 30 km NW of the lake area.

Some specimens of *Ceratopteris deltoidea* Benedict (Polypodiaceae), another floating fern, were found in July 1965 in a dead branch of the Gran Creek, at that time already included in the lake (see *fig. 2*). It seems likely that the plants were present there already before the dam was closed.

Contrary to its close relative, *C. pteridoides*, vegetative reproduction is not very important in this species. The number of the plants increased only moderately, as they spread some kilometers to the north and the west.

Ceratopteris deltoidea has been reported from the southern USA, several of the Caribbean islands and the coastal area of Demerara (BENEDICT 1909; DEVOL 1956). In Surinam it had been collected only once before, *viz.* in a coastal swamp. Thus it seems likely that the present station is the southernmost so far known.

Jussiaea natans H. et B. (Onagraceae) turned up in the lake and was found for the first time in March 1966 on Gran Prati where it already occupied a considerable area. Since then the number of its localities in the lake has increased slightly. The plants suffered much from the spraying of the waterhyacinth at the end of 1966.

This collection was the second in Surinam. The species has a tropical South-American distribution; it has been found before only in the coastal part of the Nickerie district, in 1961, where it probably had established itself from the nearby Berbice district in Guyana.

A species that more or less behaved like a waterplant though not being a true one, was *Dichorisandra hexandra* (Aubl.) Standley (Commelinaceae). This species which occurs nearly throughout tropical America and has a very wide ecological range formed pure floating islands. The shoots might climb into the dead trees. It was frequent in particular in the Gran Creek area. Flowering was not observed.

Finally a *Lindernia* species (Scrophulariaceae) has to be mentioned. It was found attached to a dead branch in the northern part of the lake, in December 1966. Though flowers were present it could not be identified to species so far, but is certainly represents a new record for Surinam.

7. THE GROWTH ON FLOATING WOOD

Trunks of dead trees and large detached branches floating in the lake gradually were overgrown by various plants before they decayed completely. Most of the species involved are common species of open, humid or wet places, throughout Surinam and the neighbouring countries (see also 8, and LINDEMAN 1953). The number of species on one piece of decaying wood might amount to 13. Most frequent were *Cyperus ferax*, *Jussiaea leptocarpa*, and *Eclipta alba*.

In total 27 (identifiable) species of *Spermatophyta*, *Pteridophyta* and *Bryophyta* were counted:

Amaranth.: *Alternanthera sessilis* (L.) R.Br.; Comp.: *Eclipta alba* (L.) Hasskarl; Conv.: *Ipomoea tiliacea* (Willd.) Choisy, a twiner; Cyp.: *Cyperus densicaespitosus* Mattf. et Kük., *C. ferax* L. C. Rich, *C. ligularis* L., *Fimbristylis miliacea* Vahl; Gent.: *Coutoubea ramosa* Aubl. fo. *ramosa;* Gram.: *Andropogon bicornis* L., *Panicum laxum* Sw.; Malv.: *Hibiscus bifurcatus* Cav.; Melast.: *Aciotis purpurascens* (Aubl.) Triana; Mor.: *Cecropia surinamensis Miq.* (young trees), *Coussapoa latifolia* Aubl., an epiphyte; Onagr.: *Jussiaea affinis* DC., *J. leptocarpa* Nutt., *J. linifolia* Vahl; Pont.: *Eichhornia crassipes* Solms (mainly young plants); Sol.: *Solanum jamaicense* Miller; Zing.: *Costus* sp.; Polypod.: *Blechnum indicum* Burm.f., *Ceratopteris pteridoides* (Hook.) Hieron. (only young plants), *Pityrogramma calomelanos* (L.) Link., *Thelypteris gonggylodes* (Schkuhr) Small; Leucobr.: *Octoblepharum albidum* Hedw.; Semantoph.: *Trichostelen papillosum* (Hornsch.) Jaeg.

8. MIXED VEGETATIONS OF WATER AND MARSH PLANTS

Ceratopteris pteridoides, found in a former riverbed of the Soekroewatra Creek (see 5), occurred there in the form of floating islands, together with some other marsh plants. The most common of the latter was a small, blue-flowered, so far unidentified, species with floating leaves (v.D. 1503). Another remarkable plant is a probably undescribed infraspecific taxon belonging to the grass species *Panicum repens* Berg, with long-ciliate instead of bare spikelets.

Other plants taking part in the floating islands were an unidentifiable *Nymphaea* sp., *Jussiaea affinis* DC., and *Lemna valdiviana* Philippi.

It was clear that this vegetation, found on 14 July 1964, was no more in its original position but had come up with the rising water. Accordingly the species normally rooting in the bottom disappeared shortly afterwards and were not found any more. Only *Ceratopteris* and *Lemna*, independent of the water depth, maintained themselves.

Where *Eichhornia* and *Ceratopteris pteridoides* occurred together they sometimes formed mixed mats; the latter species was then "built in" by the first.

In the waterhyacinth mats often some duckweeds (both species) and some *Utricularia gibba* might be found. *Jussiaea natans*, if present, usually occurred in a ring around a waterhyacinth island. In a few places it was observed that sterile shoots of a *Syngonium* sp. (Araceae), an epiphyte coming down from the dead trees, intermingled with the waterhyacinth in the water.

Older waterhyacinth vegetations might be richer in accompanying species, notably plants coming from floating wood (see 7).

Common species were *Eclipta alba* (L.) Hasskarl (Compositae), *Cyperus ferax* L. C. Rich. (Cyperaceae), and *Jussiaea affinis* DC. (Onagraceae). At the outset the most abundant species in the centre of the lake was *Phaseolus campestris* Mart. ex Benth. (Papilionaceae), a twiner, equally covering the dead tree tops and the floating vegetation mats connected with them. Afterwards it disappeared.

The mixed *Eichhornia* mats generally soon fell victim to control, as they formed parts of the densest vegetations that were first sprayed.

In the Gran Creek area of the lake, where the waterhyacinth has not penetrated during the period of observation, floating mats probably had been present from the beginning along the banks of the creek. In 1966 these vegetations were studied.

Here and there, in relatively sheltered places, a mat of marsh plants consisting of one dominating grass species developed along the shore, either *Hymenachne donacifolia* (Raddi) Chase or *Panicum mertensii* Roth. These grasses rooted in the mud on the land side but often floated freely in the deeper water more to the water side of the vegetations. The mats extended to one hectare at a maximum.

In many places in the area similar vegetations of smaller size were found among the dead branches of partly inundated shrubs and tree tops. In particular here a number of accompanying species might be mixed among the dominant grasses, up to ten together in one locality. Some of them were present as well on freely floating pieces of decaying wood (see 7). The total set of observed species (all *Spermatophyta*) consists of:

Amaranth.: *Alternanthera sessilis* (L.) R.Br.; Comm.: *Dichorisandra hexandra* (Aubl.) Standley, often in pure vegetations, never flowering; Comp.: *Eclipta alba* (L.) Hasskarl, *Struchium sparganophorum* (L.) O. Kuntze; Cyp.: *Cyperus ferax* L. C. Rich.; Gram.: *Hymenachne amplexicaulis* (Rudge) Nees, often codominant, *H. donacifolia* (Raddi) Chase, *Panicum mertensii* Roth, *P. milleflorum* Hitchc. et Chase; Malv.: *Hibiscus bifurcatus* Cav.; Mor.: *Cecropia surinamensis* Miq. (young trees); Onagr.: *Jussiaea affinis* DC. Papil.: *Phaseolus campestris* Mart. ex Benth.

The latter species often overgrew both the dead branches and the floating mats. This was always the case with two frequent lianas, both *Convolvulaceae*, *viz. Ipomoea tiliacea* (Willd.) Choisy and *Aniseia martinicensis* (Jacq.) Choisy.

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