



Limnological Research in Suriname (1979 – 1986)

2026

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InfoBridge Foundation Occasional Paper 1

Introduction

In the Occasional Paper 1 of InfoBridge Foundation (Nijmegen, the Netherlands) two reports of limnological research in Suriname in the period 1979-1986 have been published. The two research reports were never published but are interesting enough to be published.

This first report presents limnological research of the Corantijn River system in the period 1979-1981. A manuscript of this paper was submitted to the WLA (Waterloopkundige Afdeling of Department of Public Works and Traffic of Suriname) in 1983 but never published as a WLA Report. A report on the first year of the research, carried out by Ruud Crul and Leo Reyrink, was published as a Hydraulic Research Division report (WLA) in Dutch (Crul and Reyrink, 1980).

A second report presents the results of a limnological sampling program on the Brokopondo Reservoir by the WLA in the period 1981 - 1986, also never published. A manuscript of this report was submitted to the WLA by the author in 1986.

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LIMNOLOGY OF SOME RIVERS AND CREEKS OF THE CORANTIJN RIVER SYSTEM, SURINAME (1979-1981)

1983

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Abstract

In this paper water quality and plankton composition of some rivers and creeks of the Corantijn River system in Suriname are described.

Sampling from May 1979 till January 1981 on a two-monthly basis revealed seasonal fluctuation. Both the water quality measurements and the plankton composition indicate oligotrophy of the investigated streams.

The discharge of the streams closely follows the rainfall in the catchment area and governs the plankton composition. In the long rainy season plankton is almost completely washed out. In the period of low discharge plankton develops, but only a few species may occur in relatively large numbers. Primary productivity of the plankton is low all year round.

Resumo

Neste artigo são descritas a qualidade da água e a composição do plâncton de alguns rios e ribeiros do sistema de rios Corantijn existente no Suriname.

Amostras retiradas durante dois anos numa base bimensal revelaram oscilações sazonais.

Quer as medições da qualidade da água, quer a composição do plâncton, indicam oligotrofia nos cursos de à suas analisados.

A descarga dos rios, estritamente ligada à queda da chuva na bacia hidrográfica, determina a composição do plâncton. Nas estações longas e chuvosas o plâncton quase que desaparece disperso pela ação das águas. No período de baixa descarga o plâncton desenvolve-se, mas só algumas espécies podem ocorrer em quantidades relativamente importantes. A produtividade primária do plâncton é baixa durante todo o ano.

1. INTRODUCTION

This paper presents the results of a limnological study of the Corantijn River system in Suriname carried out from May 1979 till January 1981. The study was initiated by the multidisciplinary 'Working Group Kabalebo Project' formed to study possible effects of the planned Kabalebo Project on the environment and on health conditions. The Kabalebo Project in West Suriname implied the construction of a man-made lake of approximately 1,500 km² to generate hydroelectric energy. A dam with a power station was planned in the Kabalebo River, one of the main tributaries of the Corantijn River (Fig. 1). Details of the Kabalebo Project were published in 1979 (NIEKOOP, 1979). A draft version of this report was submitted to the Hydraulic Research Division (WLA - Amatopo Afdeling) in 1983.

A report (in Dutch) on the first year of the study (May 1979 – April 1980) was published by the Waterloopkundige Afdeling (WLA) in Suriname (CRUL and REYRINK, 1980). Before that publication there was only one limnological study on the Corantijn River system (van der HEIDE, 1966). Research on other rivers in Suriname was carried out by GEIJSKES (1942) in the Marowijne River system and on the Suriname River system in the period 1963-1967 by LEENTVAAR (1975, 1979) and van der HEIDE (1976, 1982), mainly in connection with the construction of the Brokopondo lake. In the early 80s limnological data were collected for the lower Suriname River, the Saramacca River and some of their tributaries (MOHADIN, 1980; PANDAY-VERHEUVEL, 1983).

The present study was carried out with the following objectives:

- to obtain a base for comparing the undisturbed water quality with the disturbed situation resulting from the construction of the lake;
- to allow for making predictions about the water quality in the future especially about the self-purification capacity;
- to provide physical and chemical data for the fish ecological study which was carried out at the same time (VARI, 1982).

Several water quality parameters were measured, the plankton composition was determined, and the plankton productivity measured. Sampling was carried out on a two-monthly base to detect seasonal fluctuations.

2. RESEARCH AREA: GEOLOGY, SOILS AND CLIMATE

The Corantijn River system lies between lat. 6° -3° N and 58° - 57° W in West Suriname (Fig. 1). The river basin of the Corantijn River covers an area of about 68,000 km². The drainage area is located north of the Aracai mountains (forming the international border with Brazil) and west of the Eilerts de Haan mountains. The catchment area of the Kabalebo River is about 6,900 km². The subsoil of the Corantijn River basin belongs to the crystalline basal complex of the Guyana shield which mainly consists of granites. Only in the lower 100 to 150 km these precambrian formations are overlapped by younger deposits of loose sediments which extend seaward in the continental shelf.

The coastal plain consists of loose sediments: sandy and clayey formations and bio-sediments. The transition zone between the two totally different formations is formed by erosion products originating

from the upper part of the basin. Most of these materials are rather coarse and contain only a limited percentage of clay. The sandy material consists of almost pure (99%) quartzite.

The river enters the coastal plain at Cow Falls. Tidal fluctuations of the water level are detectable as far as Cow Falls and the saltwater intrusion as far as Mc Clemen (Figure 1). The river south of Cow Falls is characterized by falls and rapids ("soelas"). South of the Wonotobo Falls and along the Kabalebo River there are no permanent settlements or villages, so streams in these areas are not polluted. Only at the mouth where the Nickerie River enters the Corantijn River pollution by pesticides used in the large rice production areas of the District Nickerie is expected.

The research area of the present study was confined to the part of the Corantijn River system which will be affected by the Kabalebo Project: i.e., the Corantijn River from the Anora Falls to the mouth at Nickerie, the Kabalebo River, the Lucie River and eight larger creeks (Figure 1).

Suriname has a tropical climate which depends on the position of the Inter Tropical Convergence Zone. Differences between the seasons concern mainly cloudiness and precipitation. Four seasons can be distinguished: a short and long dry season and a short and long rainy season. The transitions of the seasons are gradual, and seasons vary in length. In some years the short rainy and dry seasons are hardly distinguishable. The monthly distribution of the rainfall for the Kabalebo area, the Sipaliwini area and Brokopondo reservoir area is shown in Figure 2. The discharge of the rivers in Suriname depends on the amount of rainfall in their catchment areas. Observations of the discharge of the Corantijn River at Mataway (see Figure 1) were made by the WLA of the Department of Public Works and Traffic of Suriname. The discharge at Mataway for the period January 1979 - March 1981 is shown in Figure 3. Mean monthly discharges of the Corantijn River and the Kabalebo River (averaged over the period 1952-1978) are given in Table 1 together with the monthly discharges of the Corantijn River at Mataway for the research period.

The data show roughly a period of high discharge from April till October (corresponding with the long rainy season) and a period of low discharge from October till April. Yearly means for 1979 and 1980 were 1,417 and 1,013 m³/sec. for the Corantijn River at Mataway, whereas the average yearly mean of the period 1952-1978 was 1,266 m³/sec. In the research period the lowest discharge of the Corantijn River at Mataway was less than 100 m³/sec. on March 18th, 1980, and the highest was 5,440 m³/sec. on June 19th, 1979.

3. RESEARCH

Ten sampling trips were carried out during the research period. Twenty eight sampling points were chosen in the research area (Figure 1), sixteen in the Corantijn River from Anora Falls to the mouth, two in the Kabalebo River, one in the Lucie River, seven in the main tributaries ("creeks") of the Corantijn River and two in a main creek of the Kabalebo River.

The Corantijn River can be divided in three parts (Figure 1):

- the estuarine part of the river (Cor.I) with two sampling points (1-2);
- the lower Corantijn River which contains only fresh water (Cor.II) with five sampling points (3-7);

- the middle Corantijn River (Cor.III) characterized by falls and rapids with nine sampling points (8 -16). The Kabalebo River has two sampling points (24-25) and the Lucie River one (28). The creeks are presented together and are only mentioned individually in special cases. For additional measurements (see par. 5.5) the Corantijn River was visited in February 1980 at Camp Mataway between the sampling points Cow Falls and Alligator Island (Figure 1). Some sampling points could not be visited during the first four trips due to logistical problems.

4. METHODS

4.1 Physical and chemical measurements

In Table 2 parameters, pre-treatment, analyses and trip numbers during which parameters were sampled, are described. As the field laboratory first started to function in October 1979, most of the parameters could not be analysed in the field during the first four trips.

4.2 Plankton collection and examination, and productivity measurements

The following program was carried out at each sampling point during the first six trips:

- sampling one litre of surface water in a PVC bottle;
- sieving 50 litres of surface water through a 30 µm plankton net using a 10 litre bucket;
- taking a haul sample with a 100 µm plankton net.

Only litre samples were taken on the last four trips in 1980.

For the qualitative and quantitative elaboration of the samples a Reichert Inverted Microscope and van Heusden Counting Chambers with a volume of 4 ml were used (van HEUSDEN, 1972). The litre samples were concentrated to less than 100 ml by decantation after sedimentation. The residue was put into a sedimentation chamber resting on a counting chamber (together 100 ml) to settle for a period of 24 hours.

Primary productivity of the phytoplankton was measured with the light and dark bottle oxygen method. Wheaton bottles of 300 ml were used. Water samples from the surface, 1 m and 3 m depth were transferred to paired light and dark bottles. The bottles were tied to a string and lowered to the depth of origin of their contents. In this way a chain was produced having a pair of light and dark bottles at each depth. The bottles were exposed 4 to 6 hours to the day light between 09.00 and 15.00 hours at the point of sampling. After the measurement each sample was immediately treated with Winkler's reagents to fix the final oxygen. The initial oxygen was fixed immediately after sampling in a third bottle. Oxygen was measured according to the Na-azide modification of the Winkler method (Standard methods, 1976).

4.3 Plankton identification

The plankton samples taken during the sampling trips 1-6 were examined in Suriname in 1979 and 1980 (CRUL and REYRINK, 1980) and were verified by the author in the Netherlands in 1980-1981.

Samples of trips 7 and 8 were examined by Mrs. Drs. M. PANDAY-VERHEUVEL in Suriname and the samples of trip 9 and 10 by the author in the Netherlands (only the most abundant species of the samples of trip 7-10 were counted).

For identification the following keys were available in Suriname: HUBER-PESTALOZZI (1941-1961), EDMONDSON (1959), PRESCOTT (1962), KUDO (1963), VOIGT (1957), HUSTEDT (1939), DESIKACHARY (1959), GRÖNBLAD (1945), SCOTT and GRÖNBLAD (1957), SCOTT et al. (1965), LEENTVAAR (1975, 1979), van der HEIDE (1976) and some papers of the Brazilian journal "Botanical" of the University of Paraná, Brazil. In the Netherlands other keys were consulted: BOURELLY (1966, 1968, 1970), GERMAIN (1981), van HEURCK (1896), HUSTEDT (1959-1966), PATRICK and REIMER (1966, 1975) and KOSTE (1978).

5. RESULTS

5.1 The physical and chemical measurements

The ranges of the measured parameters are given in Table 3. Results of measurements of the sampling trips 1-6 were published earlier (CRUL and REYRINK, 1980). The measured parameters will be compared with data of other rivers and creeks in Suriname below.

Dissolved oxygen (DO)

The DO content of the Corantijn River varied between 4.4 and 9.6 mg/l (57-127 % sat.) The estuarine part of the river (Cor. I) had records between 4.4 and 7.3 mg/l, the lower and middle Corantijn respectively between 4.5 and 8.1 mg/l and 5.3 and 9.6 mg/l. The two other rivers, the Kabalebo and Lucie River, had DO records respectively between 5.3 and 7.0 mg/l (67 — 93 % sat.) and 5.7 and 8.1 mg/l (70 — 106 % sat.). The creeks had a DO content which varied between 0.7 and 8.0 mg/l (9 — 98 % sat.). All these measurements corresponded with records given for other rivers in Suriname (LEENTVAAR, 1975; van der HEIDE, 1976,1982).

River and creek water was mostly undersaturated. In the period of high discharge (long rainy season) DO saturation deficits generally were larger. In the creeks these deficits could increase to 91 % saturation. In the period of low discharge marked supersaturation occurred in the middle Corantijn (with a maximum of 127 % sat. at sampling point Tiger Falls I in January 1980). Vertical gradients were not observed (CRUL and REYRINK, 1980).

Biological Oxygen Demand (BOD)

The BOD of the rivers was generally low with a maximum of 4.4 mg/l O₂. The creeks showed markedly higher BOD levels (up to 11.3 mg/l O₂), especially when the water stagnated during low discharge. Allochthonous organic matter from the forest caused the higher BOD values in the creeks. When the water stagnated in the creeks, plankton blooms contributed to a high BOD value.

Temperature

The water temperature of the rivers varied between 25.5 °C in the long rainy season and 31.5 °C in the long dry season. A similar fluctuation was found in the Suriname River (van der HEIDE, 1982).

Seasonal changes in sunshine, rainfall and discharge were responsible for the variation of the river water temperature. The temperatures in the creeks were lower than those in the rivers all year round. The lowest record was 23.3°C in January 1980 in the Matapi Creek and in the Toeboeroe Creek. The highest temperature was 31°C in the Kapoeri Creek in October 1979 due to the inflow of Corantijn water into the creek. Similar differences between rivers and creeks were found by GEYSKES (1942) in the head waters of the Marowijne River and by van der HEIDE (1982) in the Sara Creek and Gran Creek in the Suriname River system, and in the Kabalebo River and one of its tributaries.

Secchi disc visibility, Turbidity and Color

Secchi disc readings in the Corantijn River included both the lowest (0.05 m) and the highest (2.8 m) of recorded values. Ranges in the estuarine part, the lower and middle Corantijn were 0.05 - 0.85 m, 0.25-2.5 m and 0.6-2.8 m respectively. The Lucie River and Kabalebo River had ranges of 0.6-2.4 m and 0.5-1.9 m respectively. The creeks had Secchi disc values between 0.35 and 1.75 m. The low values in the estuarine part of the Corantijn River were due to the inflow of turbid water of the Atlantic Ocean penetrating as far as Oreala (3) in the lower Corantijn. Low values in the upstream part of the river system were caused by the high silt load of the runoff water in the rainy seasons. Here transparency was related inversely with the discharge. The same relation was found by van der HEIDE (1982) in the Suriname River at Pokigron. In the creeks the Secchi disc readings in the period of low discharge were limited by the water depth. The transparency of the river water was generally greater than that of the creeks.

In accordance with the Secchi disc readings turbidity values were high in the estuarine part of the Corantijn River and at Oreala in the Corantijn River. Values ranged between 13 and 2,200 NTU in this part of the Corantijn River dependent on the discharge of the river. The middle Corantijn, the Kabalebo River, the Lucie River and the creeks had turbidity values between 0 and 62 NTU.

Color values were uniform for the rivers (20-130 mg/l Pt) and in general lower than those of the creeks (25-260 mg/l Pt). Simultaneously with the decrease of transparency in the long rainy season color values increased in this period due to the increased input of humic acids.

Conductivity (EC_{20}), pH, Alkalinity, Co content and Hardness

Electrical conductivity of river and creek water varied between 15.5 and 67 μ S. Only the samples in the estuarine part of the Corantijn River had high EC-readings. Measurements in the Suriname River system gave values between 19 and 85 μ S (van der HEIDE, 1982). The values are low which is normal for rivers in the Guyana shield. The scarcity of electrolytes is due to the nature of the soil which consists of an old, weathered layer on top of poor alkaline rocks of the crystalline basement and there is no (human-induced) pollution.

The Corantijn, Kabalebo and Lucie River had pH ranges of 6.2-7.8, 6.4-6.9 and 6.6-7.3 respectively. The creeks had a lower pH range: 4.8-7.6. These values are significantly higher than those recorded in the Suriname River system (van der HEIDE, 1982). The reasons for these differences are not clear.

Alkalinity of the rivers and creeks was low (respectively 0.15-0.49 meq/l and 0.13-0.69 meq/l), except at the sampling point Nickerie in the estuarine part of the Corantijn River which had higher records up to 1.35 meq/l due to the inflow of seawater. CO_2 content of the rivers varied between 1.7 and 6.5 mg/l and that of the creeks between 1.9 and 22.5 mg/l. High values of CO_2 were found in the Kapoeri Creek, as it carried water from a humic swamp. The water of the rivers and creeks is extremely soft (max. hardness 19.5 mg/l $CaCO_3$) due to the low content of lime in the bottom of the catchment area.

Mineral composition

The estuarine part of the Corantijn River had a significant higher salinity than the upstream part due to the inflow of the seawater (Table 3). In the water of the rivers and creeks low amounts of Na^+ , K^+ and Ca^{2+} were found respectively with maxima of 11.2 mg/l, 3.5 mg/l and 2.2 mg/l. Mg^{2+} was not measured, but is usually lower than the Ca^{2+} content. The water in the rivers contained soluble Fe up to 1.8 mg/l and up to 3.0 mg/l in the creeks. Low concentrations of soluble Mn were measured with a maximum of 0.2 mg/l for the rivers and 0.5 mg/l in the creeks. Cl^- content was low with a maximum of 15 mg/l for rivers and

creeks. Similarly, SO_4^{2-} content was low with maxima of 6 mg/l in the rivers and 4 mg/l in the creeks. The silica content was relatively high as compared with the other minerals. Concentrations up to 25 mg/l in the rivers and 45 mg/l in the creeks were measured.

Concentrations of $\text{NO}_3\text{-N}$, $\text{NO}_2\text{-N}$ and $\text{NH}_4\text{-N}$ were low. The nitrate concentration in the Corantijn River was 635 g/l at maximum. Maximum nitrate concentrations in the Kabalebo River, Lucie River and the creeks were respectively 580, 515 and 880 $\mu\text{g/l}$. The nitrite concentration was always lower than 10 $\mu\text{g/l}$ in the rivers and lower than 20 $\mu\text{g/l}$ in the creeks. Maximum ammonium concentrations for the Corantijn, Kabalebo, and Lucie River were respectively 730, 240 and 155 $\mu\text{g/l}$ and for the creeks 850 $\mu\text{g/l}$.

$\text{PO}_4\text{-P}$ had a maximum concentration of 390 $\mu\text{g/l}$ in the Corantijn River. Maximum orthophosphate concentrations in the Kabalebo River, Lucie River and the creeks were respectively 100, 57 and 160 $\mu\text{g/l}$. Normally orthophosphate was present in very low concentrations or absent. Therefore, phosphate could be the limiting factor with respect to algae dynamics in the Corantijn River system.

5.2 Plankton observations

A list of species - identified as far as possible - is given in Table 4. Tables of phyto- and zooplankton taxa and their abundance for each of the first six sampling trips were published earlier (CRUL and REYRINK, 1980). More than 200 taxa were distinguished of which 75% was phytoplankton and 25% zooplankton.

The phytoplankton

Most of the phytoplankton species (86%) belonged to the groups of diatoms (45%), Chlorophyceae (22%), desmids (19%). Species of other algae groups were found less often (14%) of which Euglenophyceae were found most often (7%). Other species found were Cyanophyceae (1%), Chrysophyceae (1%) and Dinophyceae (1%). Most of the diatoms were benthic representatives washed up from the streambed. Several species of *Surirella*, *Pinnularia* and *Eunotia* common for acid streams (ROUND, 1964) were found. The phytoplankton of the freshwater part of the Corantijn River was characterized by a dominance of *Melosira granulata*. In the middle Corantijn a representative of the Dinophyceae was dominant in the period of low discharge of 1980/1981: cf. *Gymnodinium* sp. In the period of low discharge species as *Eunotia asterionelloides*, *Dictyosphaerium pulchellum*, *Eudorina elegans*, *Pediastrum duplex*, *Bacillaria paradoxa* and *Fragilaria* cf. *capucina* were present in relatively large numbers. Desmids as *Closterium kuetzingii*, *Cosmarium* spp. and *Staurastrum* spp. were found regularly (CRUL and REYRINK, 1980). The estuarine part of the Corantijn River was characterized by a dominance of several marine central diatoms as *Coscinodiscus*, *Cyclotella* and *Biddulphia*.

In the Kabalebo and Lucie River almost the same species were found, but in other ratios. In the Kabalebo River *Eunotia asterionelloides* and *Melosira granulata* were dominant in the phytoplankton and in the period of low discharge *Golenkinia* sp. and *Pediastrum duplex* were present in fair numbers.

In the Lucie River *Fragilaria* cf. *capucina*, *Scenedesmus quadricauda*, *Scenedesmus obliquus*, *Melosira granulata* and *Eunotia asterionelloides* were occasionally dominant.

The creeks contained very little phytoplankton. The Kapoeri creek was dominated by desmids due to the fact that it received water from a humic swamp. At the end of the long dry season of 1979 the discharge of two creeks, the Sisa Creek and the Dalbana Creek was so low in the upstream parts that only stagnant pools remained. In the pools of the Sisa Creek blooms of *Chlamydomonas* sp., *Trachelomonas* sp., *Phacus* sp., *Gonium pectorale*, *Pediastrum tetras*, *Scenedesmus obliquus* and *Crucigenia quadrata* occurred. In the stagnant pools of the Dalbana Creek occurred blooms of *Merismopedia glauca* and *Phacus* sp.

The zooplankton

Most of the zooplankton species belonged to the groups of Rotifera and Rhizopoda. Some Cladocera and Copepoda were found. Ciliophora, Nemata, Oligochaeta, spicules of Porifera and insect larvae were found occasionally in the samples, but they were not further identified. The Corantijn River was poor in zooplankton. Only the Rhizopoda *Arcella* spp. and *Euglypha* spp. and the *Heliozoa Actinospaerium* sp. were observed regularly. In the period of low discharge rotifers and Cladocera were present in the plankton of the Corantijn river. In the Kabalebo River Rhizopoda were dominant in the zooplankton except for the end of the period of low discharge, when the rotifers *Polyarthra vulgaris* and *Trichocerca* sp. were found in relatively large numbers. In the Lucie River Rhizopoda were also present all year round. Rotifers and Cladocera were scarce. Only at the end of the period of low discharge the rotifers *Testudinella* sp. and *Trichocerca* sp. were present in fair numbers.

The creeks contained more zooplankton than the rivers, but the densities were very low. Only at the end of the period of low discharge some rotifers increased in number: *Keratella americana* reached fair numbers in the Kapoeri Creek, *Polyarthra vulgaris* and *Brachionus* sp. in the stagnant pools of the Sisa Creek, *Trichocerca* sp., *Polyarthra vulgaris* and *Filinia limnetica* in the stagnant pools of the Dalbana Creek and *Asplanchna* sp. in the Matappi Creek and Mataway Creek.

Seasonal fluctuations of the plankton

In the period of low discharge species diversity was greatest (CRUL and REYRINK, 1980), but only a few species were present in relatively high densities. Species occurring in large numbers were *Melosira granulata* (with a maximum of 280,000/l at sampling point Alligator Island in the Corantijn River in January 1980), cf. *Gymnodinium* sp. (with a maximum of 110,000/l at Amatopo in the Corantijn River in October 1980), *Eunotia asterionelloides* (with a maximum of 45,000/l in the Kabalebo River in January 1981) and *Chlamydomonas* sp. (with a maximum of 60,000/l in the stagnant pools of the Sisa Creek in March 1980). In the period of high discharge (long rainy season) the great inflow of rainwater had a diluting effect which resulted in a decreasing plankton density.

During the period of high discharge the water contained bottom diatoms, some Rhizopoda, mosquito larvae and sponge spicules, all in very low densities. They probably originated from small rivulets and water outside the riverbed (HYNES, 1972) This corresponds with the fact that Rhizopoda formed a greater proportion of the plankton during the rains than during the dry season in the Sokoto River in Africa (HOLDEN and GREEN, 1960). All of our observations correspond with those in other rivers in Suriname (LEENTVAAR, 1975; van der HEIDE, 1976, 1982; Mohadin, 1980).

As the flow velocity of a stream is a key factor for the development of the plankton (ROUND, 1977), the flow velocities of the Corantijn River and the Kabalebo River during the sampling trips are given in Table 5. Flow velocities of the Lucie River and the creeks were not available. In the period of high discharge flow velocity was high. The plankton had little opportunity to reproduce because of the short residence time and the plankton density was low (Table 6). After the long rainy season the discharge and therefore the flow velocity decreased. True plankters which probably originated from quiet parts and side arms of the rivers (HYNES, 1972), could develop when the residence time became long enough.

Primary productivity of the plankton

Primary productivity measurements were carried out during the first six sampling trips at several points in the three rivers and at Mataway in the middle Corantijn on February 11th, 1980. However, the primary productivity of the plankton was so low that it was undetectable by the light and dark bottle oxygen method.

Periphyton was not studied in this research, but can represent a large percentage of the primary production, especially in shallow river parts with many rocks (WELCH, 1980). Because DO supersaturation occurred in the middle Corantijn and the Lucie River when plankton densities were low, periphyton may have contributed to the oxygen production in these river parts.

Annual and diurnal fluctuations of DO content and temperature

DO content and temperature fluctuations are shown in Figure 4 for three sampling points of the Corantijn River (representative of the different parts of the river), Kabalebo River, Lucie River and two creeks, Matappi Creek and Sisa Creek. For comparison the discharge off the Corantijn River at Mataway is also shown. DO saturations for these sampling points are given in Table 7. The sampling points of the rivers had a mean DO saturation above 80%, except for Nickerie in the estuarine part of the Corantijn River which had a mean DO saturation of 74.2%, probably due to the inflow of the seawater.

Amatopo in the middle Corantijn had the highest DO saturation. Both oxygen production by plankton and periphyton in the period of low discharge (indicated by supersaturation) and a good re-aeration by rapids and falls could be responsible for this. The low DO contents of May 1979 and May 1980 were caused by an increased oxygen demand for the decomposition of organic matter from the catchment area brought in by the heavy rains. The DO content of the creeks was generally lower than that of the rivers, especially in the period of high discharge, when oxygen consumption was higher because of the inflow of runoff water from the surrounding forest. A marked lower DO content was measured in the Sisa Creek in March 1980. At that time the creek had no discharge and in the stagnant water plankton blooms occurred which caused a high oxygen demand (BOD record of 5.6 mg/l O₂).

The readings of the temperature of the rivers were lowest in the long rainy season. An exception was sampling point Nickerie in the estuarine part of the Corantijn River, where inflow of seawater influenced the river water temperature (Figure 4). Highest temperature records were made in the long dry season due to the higher air temperature and solar radiation and the low water level. A similar fluctuation was found in the Suriname River (van der HEIDE, 1982). The temperature records of the creeks were generally lower than those of the rivers, as could be expected due to the shaded character of the creeks. The high temperature in the Sisa Creek in March 1980 was measured in stagnant water, because the creek had no discharge at that time. The temperature of the creeks did not show a uniform seasonal fluctuation pattern probably due to different local climatological conditions.

At Mataway in the Corantijn River diurnal observation series were carried out on February 11th and 12th, 1980. The parameters measured were DO content and temperature. The results are given in Table 8. The lowest record of DO was 6.5 mg/l in the early morning and the highest record was 7.0 mg/l in the afternoon. The range of the DO content was 0.5 mg/l. A similar small range was found by van der HEIDE (1982) in the Suriname River and the Kabalebo River. The lowest temperature was 28.0 °C at night and in the early morning and the highest 30.1 °C in the afternoon. The temperature range was 2.10 °C. Also in

the short dry season (March 2nd, 1965) van der HEIDE (1982) found a range of 1.1°C in the Suriname River, but only 0.50 °C in the long dry season in the Kabalebo River.

DO saturation increased during daytime which indicates that primary productivity exceeds respiration during the light period at that time.

6. CONCLUSIONS

The Corantijn River system has soft water with a low amount of electrolytes, as expressed by its low conductivity. It also indicates the absence of pollution. The water is slightly acid to neutral which is normal for the rivers of the Guyana shield. The discharge of the streams closely follows the rainfall in the catchment area with a delay of a few weeks. Transparency in the streams is related inversely with the discharge. Seasonal variations in sunshine and rainfall determine the temperature of the river water. Generally, the water temperature of the creeks was lower than that of the rivers due to the more shaded character of the creeks. The plankton composition was governed by the fluctuations of the discharge. The floods of the long rainy season removed almost all the plankton from the streams. After the long rainy season flow velocity decreased and a plankton population developed of mainly Chlorophyceae, desmids, diatoms, rotifers, and Rhizopoda. Only a few species could occur in great numbers such as *Melosira granulata* in the Corantijn River. The DO content of the streams generally showed a saturation deficit, probably because the oxygen demand of the forest litter was normally higher than the oxygen production by plankton and periphyton. Primary productivity of the plankton was low all year round, although DO supersaturation occurred in the middle Corantijn and Lucie River. Because this supersaturation also occurred with low densities of plankton, periphyton may have contributed to the oxygen production in these river parts. The water quality measurements and the plankton observations indicate oligotrophy of the water of the Corantijn River system.

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Table 1. Mean monthly discharges of the Corantijn River and the Kabalebo River (averaged for 1952-1978) and monthly discharges of the Corantijn River at Mataway during the re-search period

Discharge in m ³ /sec					
	Corantijn River				Kabalebo River
	1952/1978 (average)	1979	1980	1981	1952/1978 (average)
January	485	245	460	200	75
February	635	300	310	425	70
March	765	530	255	380	60
April	1,700	1,375	1,400		125
May	2,780	2,785	2,730		295
June	2,920	4,800	2,370		330
July	2,420	2,740	2,020		395
August	1,560	1,735	1,025		225
September	850	1,030	670		130
October	410	605	340		60
November	320	410	290		40
December	355	450	290		50
yearly mean	1,266	1,417	1,013		155
mean (Apr—Sep)	2,038	2,410	1,702		250
mean (Oct—Mar)	495	415	321		59

Table 2. Parameters, pretreatment, analyses and trip numbers of measurements in the field

Parameter	Filtration 0.45 um	Fixation/ transport	Analyses at/ in	Method	Trip nr.
Temperature	-	-	field	Mercury thermometer	1-10
Transparency	-	-	field	Secchi disc	1-10
DO	-	MnCl ₂ +NaOH	Field & Field lab ⁽¹⁾	Na-azide modification of the Winkler titration ⁽²⁾	1-10
Turbidity	-	* ⁽³⁾	Field lab ⁽¹⁾	Hellige turbidity meter ⁽²⁾	4-10
Colour	+ ⁽⁴⁾		Field lab	Hellige aquatester, Pt method	4-10
Conductivity	-	*	Field lab	Conductivity meter	4-10
pH	-	*	Field lab	pH meter	2-10
BOD ^{20 (5)}	-	*	Field lab	Oxygen meter	4-10
Alkalinity, CO ₂	-	*	Field lab	Titrimetric ⁽²⁾	2-10
Hardness	-	*	Field lab	Complexometric titration ⁽²⁾	2-10
SiO ₂	-	*	Field lab	Molybdo-silicate method ⁽²⁾	4-10
PO ₄ -P	-	*	Field lab	Stannous chloride method ⁽²⁾	4-10
SO ₄	-	*	Field lab	Turbidimetric method ⁽²⁾	4-10
NO ₃ -N	-	*	Field lab	Cd-Cu reduction method ⁽²⁾	4-10
NO ₂ -N	-	*	Field lab	Colorimetric method ⁽⁵⁾	4-10
NH ₃ -N	-	*	Field lab	Colorimetric method ⁽⁵⁾	4-10
Cl	-	*	Field lab	Argentometric ⁽²⁾	4-10
Fe	-	* + ⁽⁶⁾	Field lab	Colorimetric with KCNS	4-10
Na, K, Ca, Mn	-	-	Paramaribo	A.A.S.	4-10

Notes

⁽¹⁾ Field laboratory at 'Kamp Avanavero' near the Kabalebo River

⁽²⁾ Standard methods, 1976

⁽³⁾ * = cooled on ice, analyses within 24 hours

⁽⁴⁾ = filtration in the field laboratory

⁽⁵⁾ MACKERETH et al., 1978

⁽⁶⁾ Fixation with 2 ml conc. HCl/100 ml in the field.

Table 3. Ranges of measured physical and chemical parameters

	DO content (mg/l O₂)	% DO saturation	Temperature (°C)	BOD (mg/l O₂)
Corantijn I	4.4 - 7.3	57 - 98 ⁽¹⁾	26.0 - 30.5	0.1 - 4.1
Corantijn II	4.5 - 8.1	57 - 103	25.7 - 31.2	0.1 - 2.8
Corantijn III	5.3 - 9.6	65 - 127	25.8 - 31.5	0.1 - 3.4
Kabalebo R.	5.3 - 7.0	67 - 93	25.4 - 30.4	0.4 - 1.0
Lucie R.	5.7 - 8.1	70 - 106	25.5 - 30.0	0.3 - 4.4
Creeks	0.7 - 8.0	9 - 98	23.3 - 31.0	0.3 - 11.3
	Secchi (cm)	Turbidity (NTU)	Color (mg/l Pt)	Conductivity (µS)
Corantijn I	5 - 85	13 - 2,200	20 - 225	19.8 - 17.10 ³
Corantijn II	25 - 250	1 - 520	20 - 130	17.4 - 28
Corantijn III	60 - 280	0 - 30	20 - 120	15.5 - 42
Kabalebo R.	50 - 190	1 - 32	40 - 130	26.6 - 38
Lucie R.	60 - 240	0 - 62	25 - 110	24.5 - 67
Creeks	35 - 175 ⁽²⁾	0 - 45	25 - 260	18.0 - 42
	pH	Alkalinity (meq/l)	CO₂ (mg/l)	Hardness (mg/l CaCO₃)
Corantijn I	6.3 - 7.6	0.21 - 1.35	1.8 - 7.0	6 - 2094
Corantijn II	6.2 - 7.8	0.15 - 0.46	1.7 - 6.5	1 - 10.5
Corantijn III	6.2 - 7.3	0.18 - 0.45	1.8 - 3.9	1.5 - 13.3
Kabalebo R.	6.4 - 6.9	0.22 - 0.49	2.0 - 5.7	2.5 - 8.5
Lucie R.	6.6 - 7.3	0.26 - 0.36	2.0 - 3.2	3 - 7.2
Creeks	4.8 - 7.6	0.13 - 0.69	1.9 - 22.5	2 - 19.5
	Na (mg/l)	K (mg/l)	Ca (mg/l)	Fe (mg/l)
Corantijn I	1.6 - 3,040.0	1.0 - 145.0	0.2 - 440.0	0.07 - 1.8
Corantijn II	0.6 - 3.8	0.9 - 2.0	0.2 - 1.5	0.07 - 1.2
Corantijn III	0.5 - 2.8	1.0 - 1.6	0.2 - 1.4	0.1 - 0.9
Kabalebo R.	1.0 - 3.5	1.3 - 1.9	0.2 - 1.9	0.2 - 1.7
Lucie R.	1.1 - 8.7	1.3 - 2.2	0.1 - 1.6	0.2 - 1.6
Creeks	0.7 - 11.2	0.3 - 3.5	0.2 - 2.2	0.1 - 3.0
	Mn (mg/l)	Cl (mg/l)	SO₄ (mg/l)	SiO₂ (mg/l)
Corantijn I	0 - 0.6	3 - 5,845	0 - 850	4 - 25
Corantijn II	0 - 0.2	2 - 15	0 - 6.0	6 - 25
Corantijn III	0 - 0.2	0 - 11	0 - 3.0	7 - 20
Kabalebo R.	0 - 0.2	0 - 13	0 - 3.0	8 - 35
Lucie R.	0 - 0.2	0 - 15	0 - 2.3	10 - 25
Creeks	0 - 0.5	2 - 15	0 - 4.0	6 - 45
	PO₄-P (µg/l)	NO₃-N (µg/l)	NO₂-N (µg/l)	NH₄-N (µg/l)
Corantijn I	20 - 420	110 - 1,033	0 - 130	0 - 480
Corantijn II	0 - 120	20 - 635	0 - 10	0 - 480
Corantijn III	0 - 390	20 - 395	0 - 10	0 - 730
Kabalebo R.	0 - 100	10 - 580	0 - 10	0 - 240
Lucie R.	0 - 57	30 - 515	0 - 10	0 - 155
Creeks	0 - 160	0 - 880	0 - 20	0 - 850

Notes: ⁽¹⁾ with salinity correction. ⁽²⁾ or to the bottom, when water level was low

Table 4. Plankton - list of distinguished taxa

Cyanophyta

Anabaena
Aphanocapsa sp.
Coelosphaerium sp.
Gomphosphaeria sp.

Merismopedia glauca
Microcystis sp.
Oscillatoria spp.

Chlorophyceae

Ankistrodesmus falcatus
Ankistrodesmus sp.
Asterococcus sp.
Chlamydomonas sp.
Coelastrum cambricum
Coelastrum reticulatum
Crucigenia quadrata
Crucigenia tetrapedia
Cylindrocapsa sp.
Dictyosphaerium pulchellum
Errerella sp.
Gloeocystis planctonica
Golenkinia sp.
Gonium pectoral
Kirchneriella lunaris
Kirchneriella cf. *obesa*
Lagerheimia cf. *genevensis*
Micractinium pusillum

Mougeotia sp.
Oedogonium sp.
Oocystis sp.
Pediastrum duplex var. *gracillimum*
Pediastrum duplex var. *rotundatum*
Pandorina morum
Pediastrum tetras
Pediastrum sp.
Scenedesmus obliquus
Scenedesmus quadricauda
Scenedesmus spp.
Selenastrum cf. *westii*
Spirogira sp.
Tetraedron regulare
Tetraedron trigonum
Tetrastrum heteracanthum
Treubaria sp.
Ulothrix sp.
Volvox sp.

Desmidiaceae

Closterium kuetzingii
Closterium porrectum
Closterium spp.
Cosmarium cf. *amoenum*
Cosmarium cf. *baccatum*
Cosmarium cf. *dentatum*
Cosmarium floridanum

Cosmarium cf. *pseudoconnatum*
Cosmarium cf. *pyrimidatum*
Cosmarium spp.
Desmidium elegans
Desmidium grevillii
Desmidium laticeps
Euastrum subtrilobulatum

Desmidiaceae (continued)

Gonatozygon aculeatum
Hyalotheca indica var. *javanica*
Micrasterias borgei
Micrasterias cf. *pinnatifida*
Micrasterias siolii
Micrasterias sp.
Netrium sp.
Pleurotaenium cf. *minutum*
Spondylosium sp.

Staurastrum cf. *arachne*
Staurastrum leptocladum var. *cornutum*
Staurastrum cf. *mutabile*
Staurastrum cf. *sebaldi*
Staurastrum cf. *trifidum*
Staurastrum spp.
Staurodesmus spp.
Xanthidium trilobum

Diatomeae

Achnanthes cf. *lanceolata*
Achnanthes peragallii
Achnanthes spp.
Actinella mirabilis
Amphora sp.
Asterionella formosa
Asterionella japonica
Bacillaria paradoxa
Biddulphia mobiliensis
Biddulphia sinensis
Capartogramma cf. *crucicula*
Caloneis silicule
Chaetoceros sp.
Cocconeis placentula
Cocconeis spp.
Coscinodiscus asteromphalus
Coscinodiscus curvatulus
Coscinodiscus spp.
Cyclotella striata
Cyclotella spp.
Cymbella spp.
Diatoma anceps
Diploneis cf. *ovalis*
Ditylium spp.
Eunotia asterionelloides
Eunotia flexuosa
Eunotia formica

Eunotia cf. *naegelii*
Eunotia pectinalis
Eunotia serra var. *serra*
Eunotia zygodon var. *zygodon*
Eunotia spp.
Fragilaria cf. *capucina*
Frustulia rhomboides
Frustulia rhomboides var. *saxonica*
Gomphonema cf. *augur*
Gomphonema longiceps
Gomphonema subclavatum
Gomphonema spp.
Gyrosigma sp.
Melosira herzogii
Melosira granulata
Melosira granulata var. *muzzanensis*
Navicula bacillum
Navicula bacillum var. *gregoryana*
Navicula cf. *gracilis*
Navicula placentula
Navicula spp.
Nitzschia cf. *navicularis*
Nitzschia sigmoides
Pinnularia gentilis
Pinnularia gibba var. *subundulata*
Pinnularia gibba var. *linearis*
Pinnularia interrupta

Diatomeae (continued)

Pinnularia cf. latevittata
Pinnularia mador cf. pulchella
Pinnularia spp.
Rhizosolenia spp.
Skeletonema costatum
Stauroneis nobilis
Surirella bidentula
Surirella biseriate
Surirella biseriata var. bifrons
Surirella biseriata var. constricta
Surirella biseriata var. rostrata

Surirella didyma
Surirella elegans
Surirella linearis
Surirella linearis var. constricta
Surirella ovata
Surirella robusta
Surirella tenera
Surirella spp.
Synedra cf. pulchella
Synedra ulna
Tabellaria fenestrata

Chrysophyceae

Dinobryon sp.

cf. Mallomonas sp.

Euglenophyceae

Euglena spp.
Lepocinclis sp.
Phacus orbicularis
Phacus spp.
Strombomonas cf. napiformis
Trachelomonas cf. abrupta

Trachelomonas cf. armata
Trachelomonas cf. cylindrica
Trachelomonas cf. hispiada
Trachelomonas superba
Trachelomonas spp.

Dinophyceae

cf. Gymnodinium spp.

Porifera

sponge spicules

Rhizopoda

Arcella cf. discoides

Arcella cf. costata

Arcella spp.

Centropyxis aculeata

Centropyxis constricta

Diffugia spp

Euglypha acanthophora

Euglypha laevis

Euglypha cristata

Nebula barbata

Pareuglypha reticulata

Pontigulasia sp.

Quadrurella symmetrica

Sphenoderia lenta

Rotifera

Ascomorpha ecaudis

Asplanchna spp.

Brachionus falcatus zacharias

Brachionus zahniseri

Brachionus spp.

Colotheca sp.

Colurella sp.

Conochiloides cf. coenobasis

Euchlanis sp.

cf. Encentrum spp.

Filinia longiseta

Filinia sp.

Habrotrocha sp.

Keratella americana

Lecane spp.

Lepadella sp.

Macrochaetus sp.

Macrotrachela sp.

Manfredium sp.

Philodinia sp.

Platylabus leloupi latiscapularis

Platylabus quadricornis

Polyarthra vulgaris

Testudinella spp.

Trichocerca similis

Trichocerca spp.

Cladocera

Alona sp.

Bosmina sp

Bosminopsis cf. deitersi

Daphnia sp.

Diaphanosoma sp.

Moina sp.

Copepoda

Cyclops sp.

Daaptomus spp

nauplius larvae

Table 5. Flow velocities of the Corantijn River at Mataway and the Kabalebo River at Avanavero during the sampling trips (Source: Hydraulic Research Division).

Discharge in m ³ /sec - Flow Velocity in m/sec.				
	Corantijn River		Kabalebo River	
Sampling trip nr	Mean discharge	Mean Flow velocity	Mean discharge	Mean Flow velocity
1 - (May '79)	1,750	0.66	200	0.31
2 - (June/July '79)	4,000	0.85	600	0.82
3 - (Aug' 79)	1,600	0.64	360	0.62
4 - (Oct '79)	425	0.35	56	0.12
5 - (Jan '80)	325	0.31	48	0.11
6 - (Mar '80)	175	0.27	10	0.04
7 - (May 80)	2,600	0.74	550	0.78
8 - (Jul ' 80)	1,550	0.63	550	0.78
9 - (Oct '80)	300	0.30	40	0.10
10 - (Jan '81)	180	0.27	12	0.05

Table 6. Plankton densities (number/l) at Nickerie, Apoera and Amatopo (Corantijn River), Kabalebo River, Lucie River and Sisa creek during the research period

Sampling Trip nr	Nickerie sp 1	Apoera sp 4	Amotopo sp 16	Kabalebo R. Sp 24	Lucie R. sp 28	Sisa Cr. sp 22
1	3,000	1,000	700	300	100	---- ⁽¹⁾
2	3,000	500	300	200	100	50
3	5,500	7,000	3,000	200	1,000	150
4	6,000	7,000	1,500	400	1,300	150
5	3,000	200,000	80,000	400	2,500	700
6	1,000	15,000	5,000	2,600	2,000	120,000 ⁽²⁾
7	3,000	400	400	200	200	50
8	3,000	1,000	500	200	100	100
9	1,000	35,000	110,000	3,000	3,000	900
10	2,000	56,000	45,000	60,000	15,000	500

Notes : ⁽¹⁾ not sampled; ⁽²⁾ stagnant water

Table 7. DO saturation fluctuations in Corantijn river (for three sampling points: Nickerie, Apoera and Amotopo), Kabalebo river, Lucie River, Matapi Creek and Sisa Creek

	% DO saturation										
	Sampling trips										
	1	2	3	4	5	6	7	8	9	10	mean
Nickerie	60	72	77	69	90	85	66	71	71	81	74.2
Apoera	67	75	77	82	91	86	78	89	90	90	82.5
Amotopo	78	100	96	105	95	92	51	101	104	108	93.0
Kabalebo R.	67	76	82	85	79	85	87	88	93	87	82.9
Lucie R.	70	81	83	106	90	78	91	89	86	79	85.3
Matapi Cr	50	33	42	74	74	75	40	47	62	81	57.8
Sisa Cr.	--- ⁽¹⁾	71	76	97	77	35	78	74	70	54	70.0

Note: ⁽¹⁾ sampling point not sampled

Table 8. Diurnal observation series in the Corantijn river at Mataway on DO content and temperature
(Date: February 11, 1980, short dry season)

Time	Temp (°C)	DO (mg/l)	% Sat.
6.45	28.0	6.6 ⁽¹⁾	85
7.45	28.0	6.6	85
8.45	28.4	6.6	85
9.45	---	---	--- ⁽²⁾
10.45	29.4	6.8	90
11.45	29.8	6.8	90
12.45	29.9	6.9	92
13.45	29.9	6.9	92
14.45	30.1	7.0	93
15.45	29.8	6.9	91
16.45	29.9	6.8	90
17.45	29.9	6.7	89
18.45	29.3	6.9	91
19.45	29.0	6.8	89
20.45	28.7	6.6	86
21.45	28.1	6.7	87
22.45	28.1	6.8	88
23.45	28.0	6.6	85
0.45	28.0	6.8	88
1.45	28.0	6.7	86
2.45	28.0	6.7	86
3.45	28.0	6.7	86
4.45	28.0	6.6	85
5.45	28.0	6.6	85
6.45	28.0	6.5	83

Note: ⁽¹⁾ DO content measured in triplo with Winkler titration; ⁽²⁾ not measured

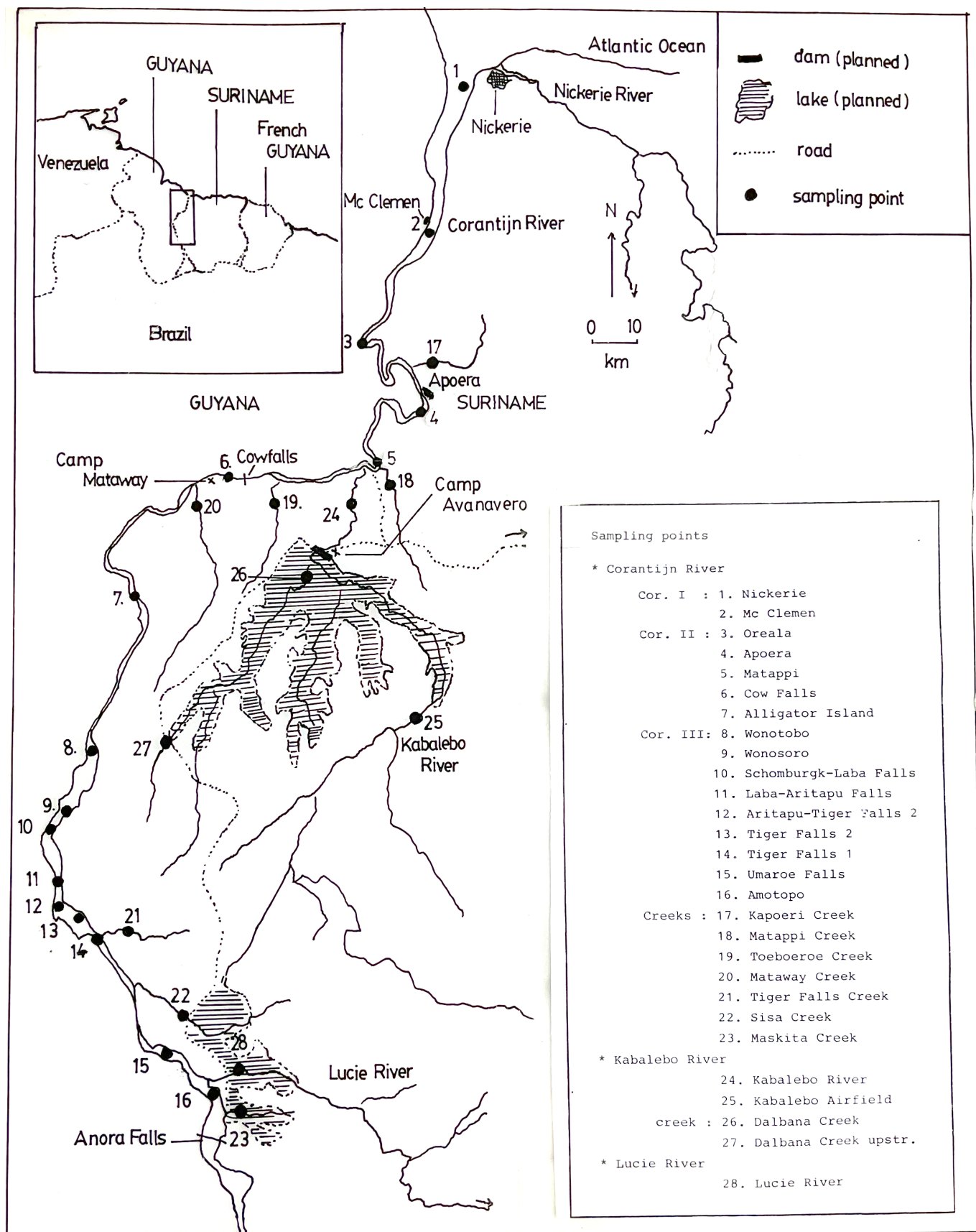
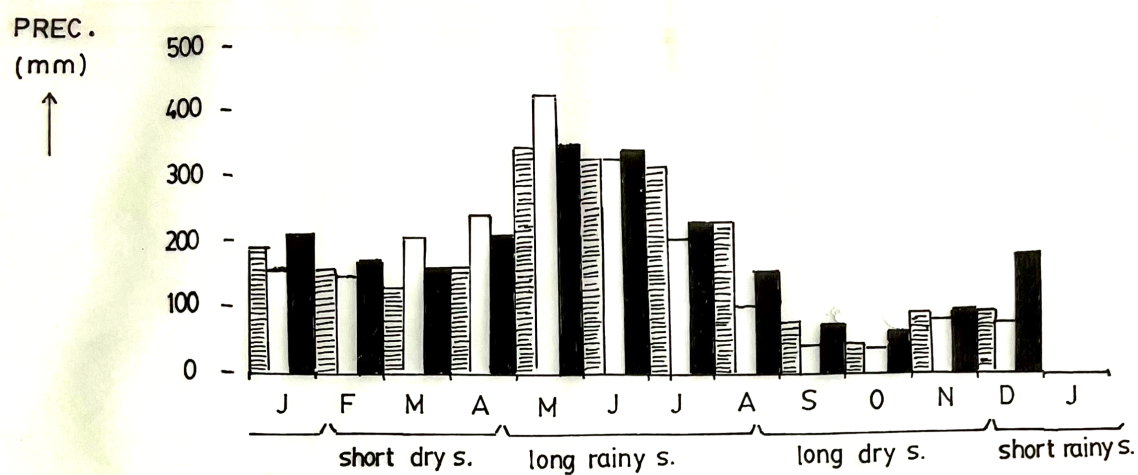


Figure 1. Map of research area with location of sampling points.



Suriname



- | | |
|-------------------------------|---------------------|
| 1 - Kabalebo area (W. Sur.) | yearly mean 2193 mm |
| 2 - Sipaliwini area (S. Sur.) | yearly mean 2053 mm |
| 3 - Lake Brokopondo (E. Sur.) | yearly mean 2204 mm |

Figure 2. Rainfall (monthly averages 1961-1970) for Kabalebo area, Sipaliwini area and Lake Brokopondo area (Source: Hydraulic Research Division).

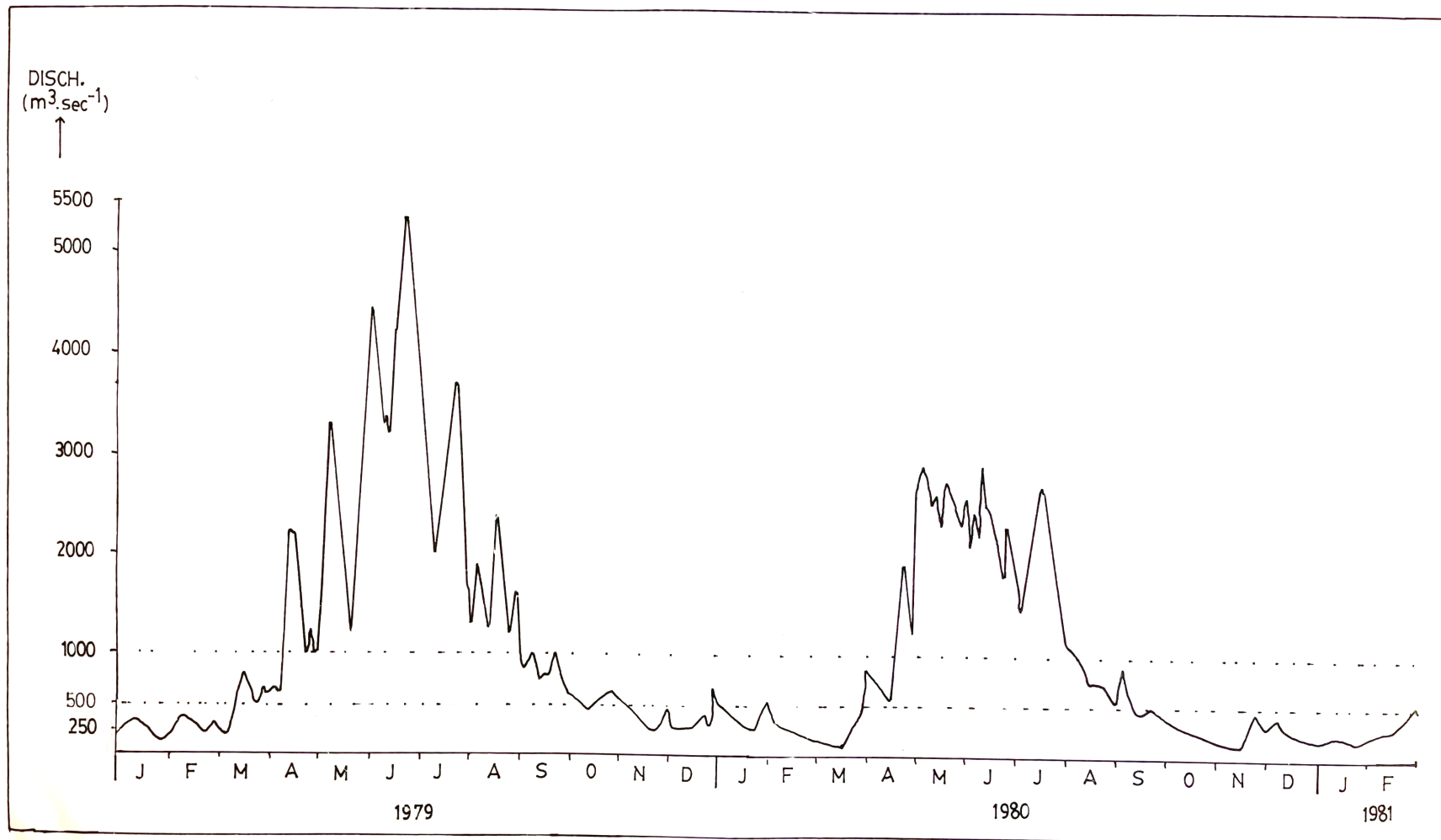


Figure 3. Discharge of the Corantijn River at Mataway during the research period.

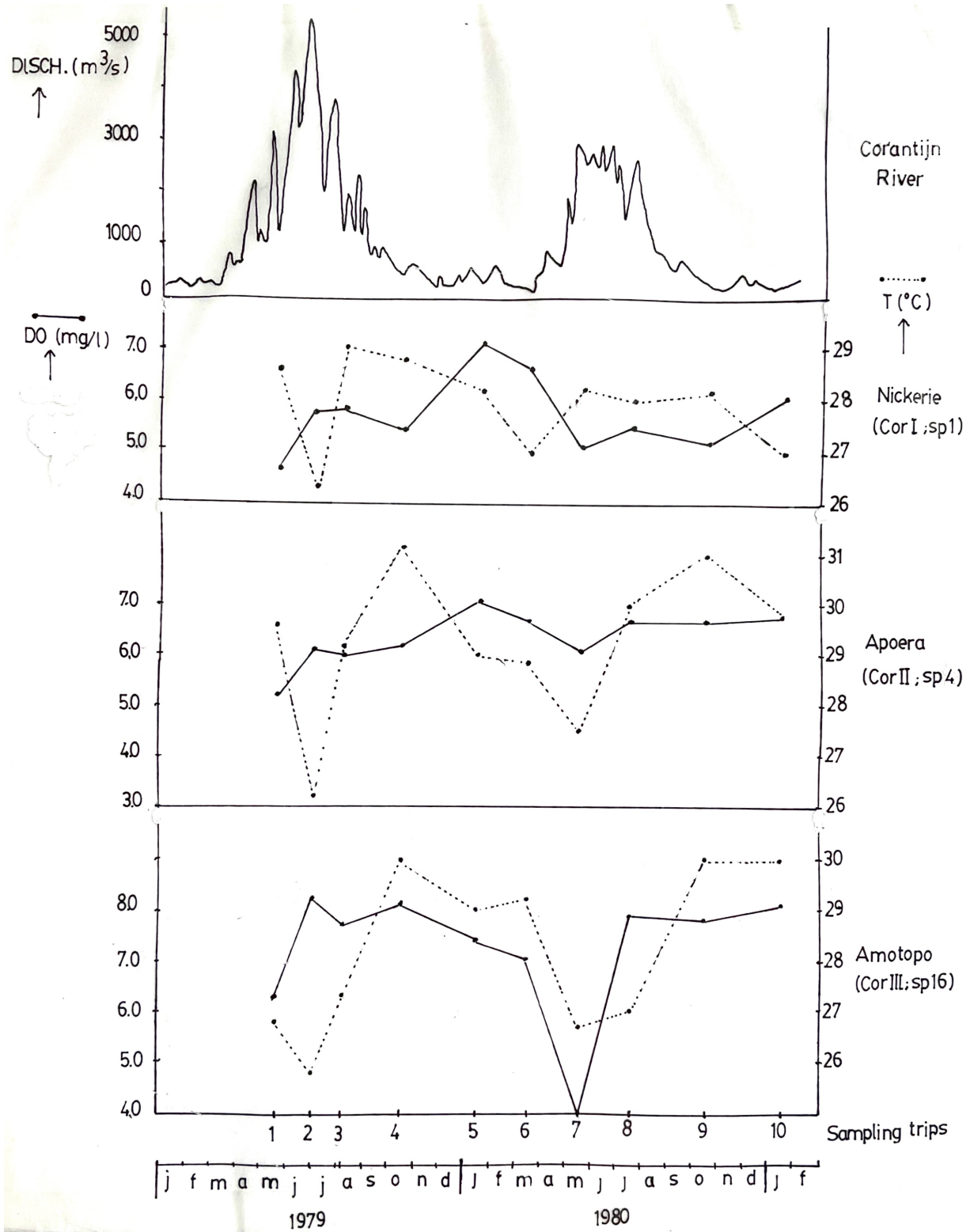
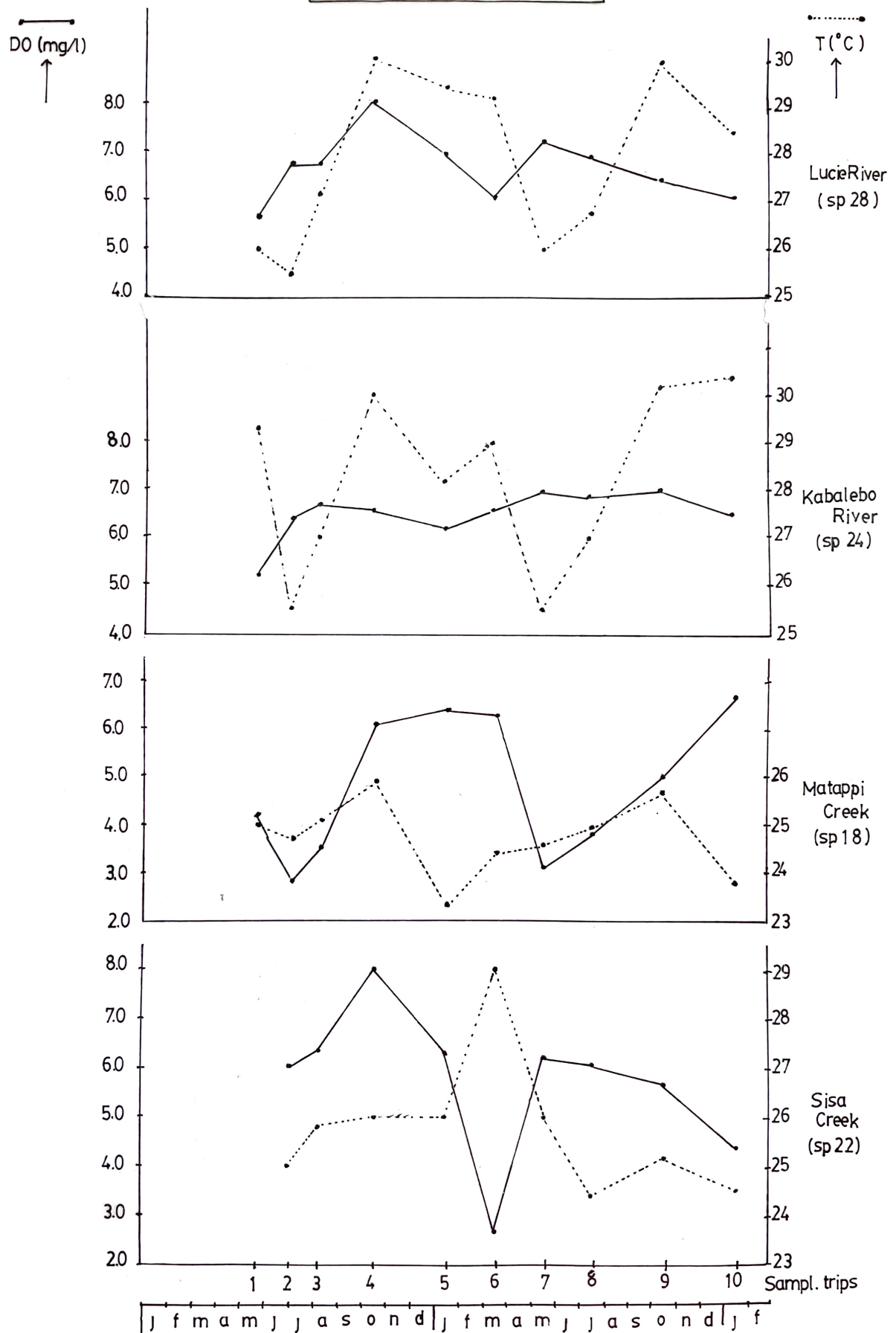


Figure 4. Annual fluctuations of DO content and temperature at three sampling points of the Corantijn River (representative of the different parts of the river), in the Kabalebo River, Lucie River and two creeks, Matappi Creek and Sisa Creek.

Figure 4. (continued)





TEMPERATURE AND OXYGEN STRATIFICATION IN THE LACUSTRINE ZONE of LAKE BROKOPONDO, SURINAME

1986

R.C.M. Crul

Abstract

Temperature and oxygen profiles - spanning a 5 year period - have been analysed to provide more information about the stratification pattern in the lacustrine zone of Lake Brokopondo.

The lake with a surface area of 1,500 km² and a mean depth of 13.6 m is warm monomictic. Annual turnover takes places in the period January-March and the rest of the year the lake is stratified. During the stratification period a distinct arrangement of the water column into epi-, meta- and hypolimnion is not visible in the profiles. The pattern of stratification below the level of daily warming and cooling is a more or less gradually decreasing temperature gradient.

The oxygen distribution in the water column is closely connected with the temperature stratification. During the circulation period the oxygen distribution is uniform in the water column and during the stratification period a strong clinograde oxygen profile develops with the temperature gradient and dissolved oxygen disappears rapidly in the deeper layers.

Spatial distribution of temperature and dissolved oxygen is fairly uniform in the lacustrine zone of the lake.

INTRODUCTION

Thermal stratification is prevalent in all but the shallower lakes in the tropics. LEWIS (1973, 1983) argued on basis of his studies on Lake Lanao (Philippines) and Lake Valencia (Venezuela) that most of the lakes in the tropics deep enough to stratify would prove to be monomictic. For Lake Brokopondo stratification during the filling phase (1964-1967) has been discussed thoroughly by VAN DER HEIDE (1976, 1978^a, 1978^b and 1982). In the lacustrine zone of the lake stratification developed and complete mixing did not occur during that period, probably due to the restraining effect of the drowned vegetation (VAN DER HEIDE, 1978^b). Present evidence indicates that Lake Brokopondo has an annual turnover in the period January-March (PANDAY—VERHEUVEL, 1983).

In this paper temperature and oxygen profiles of three sampling stations in the lake have been analysed to provide more information about the stratification pattern.

The data were collected monthly spanning a 5-year period from May 1981 till February 1986 by the Hydraulic Research Division (HRD) of the Ministry of Public Works, Telecommunication and Housing of Suriname.

STUDY AREA

Lake Brokopondo with a surface of approximately 1,500 km and a maximum depth of 48 m lies in the tropical rainforest region of Suriname at 4° - 5° NL and 54° - 55° WL (Fig. 1) .

By damming the Suriname River at Afobaka in 1964 a large man-made was formed due to the low - lying terrain of the catchment area of the Suriname River. The lake contains more than 1,000 islands which form almost 10% of the lake surface.

General and morphometric characteristics of Lake Brokopondo are given by VAN DER HEIDE (1982) together with data of other large man-made lakes in the tropics. The most important are listed in Table 1.

Suriname has a tropical climate which depends on the position of the Inter Tropical Convergence Zone. Differences between the seasons concern mainly cloudiness and precipitation. Four seasons can be distinguished: a short rainy season (December-February) , a short dry season (February-April), a long rainy season (April-August) and a long dry season (August-November). No climatological data were available for the research period.

Therefore climatological data from the period 1960—1970 given by VAN DER HEIDE (1982) for the Lake Brokopondo area are used as an indication (Figure 2). Lowest air temperatures and highest windspeed occur in the short rainy and dry season. Rainfall is highest in the long rainy season and insolation is highest in the long dry season.

Lake Brokopondo is mainly fed by the Suriname River and to a lesser extent by tributaries ("creeks") of which the Gran Creek and the Sara Creek are the most important and by direct precipitation on the lake. Most of the years the maximum level of the lake (48.2 m at the dam) was not reached. The spillways were used only twice since the closure of the dam (PANDAY-VERHEUVEL, 1983) . The mean water level for the period 1970—1980 was 45 m near the dam (HRD, Suriname) .

MATERIALS AND METHODS

In May 1981 the HRD started a new limnological sampling program on the lake. This program included sampling of three stations in the lacustrine zone of the lake: Afobaka, Kabel and Bedoti (Figure 1) . The stations were visited monthly during a two-days trip using a canoe with an outboard motor.

Water samples were taken between 7.00 and 17.00 hr with a 2-litre Ruttner bottle from surface to bottom with an interval of 5 metres. Unfortunately no uniform time schedule was used. Bottom depth ranged between 25 and 36.5 m, 24 and 36 m and 24 and 31.5 m for Afobaka, Kabel and Bedoti respectively.

Bottom depth variations were not only caused by water level fluctuations. Trees of the inundated forest are still present in the lake and obstruct sampling. Each month a location had to be found where sampling was possible to the bottom.

Temperature was read from the thermometer built in the Ruttner bottle.

From the Ruttner bottle Wheaton bottles of 250 ml were filled for the determination of dissolved oxygen (DO) content. These bottles were treated according the Azide Modification of the Winkler Titration.

Several temperature depth profiles and time-depth diagrams were selected to illustrate the stratification pattern. In the temperature depth profiles the observed temperatures are connected with straight lines. Seasonal variations are illustrated in diagrams of isotherms and of observations at standard sampling depths. Isotherm depths were calculated by linear interpolation between standard sampling depths and connected by straight lines. Broken lines were used when the isotherm depth could not be calculated from the observations. The same procedure was used for the DO observations.

RESULTS AND DISCUSSION

Temperature

Figure 3 shows the monthly recorded water temperatures at Afobaka at 6 depths during the research period.

The lake becomes isothermal in January and remains so in February and March. Dependant on the weather conditions in these months the water column may cool or warm isothermally.

The water temperature of the upper layers begins to rise in April following the air temperature (Figure 2) and thermal stratification becomes visible.

The highest fluctuations in temperatures recorded at Afobaka occurred in the surface layer (0 m) with a minimum of 27.4 °C and a maximum of 32 °C. The other two stations showed similar temperature fluctuations in the surface layer indicating uniform weather conditions in the lake area.

Temperatures of the deeper layers fluctuated more or less simultaneously, but the amplitudes of the fluctuations diminished. This indicates the existence of vertical heat exchange to the deeper layers despite of the temperature gradients.

In the water layers near the bottom temperature decreased during the long rainy season in contrast with the increasing surface temperature. This must have been caused by the cold flood water of the Suriname River.

After October surface temperature decreases due to lower air temperatures until the water column becomes isothermal.

The thermal structure of the water column is shown by the temperature profiles of 1984 of the station Afobaka in Figure 4. The water column showed no structure or a transitory one in the January-March profiles and mixing was to the bottom. The genesis of stratification is evident in the April profile and till January the profiles are showing a temperature gradient. Due to this gradient mixing has been limited to the upper part of the water column in this period.

The pattern of stratification below the level of daily warming and cooling was a more or less gradually decreasing temperature gradient. The terminology relating stratification was originally proposed for lakes in temperate climates and cannot be used without some qualification for lakes in the tropics (BEADLE, 1974) .

The classical pattern of stratification - a well-mixed epilimnion a metalimnion with a steep temperature gradient and a hypolimnion with an uniform temperature - did not exist in Lake Brokopondo. A similar situation is reported by LEWIS (1983) for Lake Valencia (Venezuela). LEWIS (1973, 1983) argued that the upper water column of Lake Lanao (Philippines) and the water column of Lake Valencia (Venezuela) consisted of an upper mixed layer which varied in thickness followed by alternating thick layers of positive and negligible density layers and that the number of the layers changed through time.

No distinct temperature layers could be detected in Lake Brokopondo due to the use of 5 m intervals in the profiles.

A temperature profile with a 1 m interval carried out at Afobaka in July 1986 suggests that a similar pattern may also exist in Lake Brokopondo (Figure 5).

Similar stair step-like temperature profiles have been recorded by SCHMIDT (1973) during the high-water phase in Lago do Castanho (Brazil) .

In Lake Valencia the thickness of the upper-mixed layer changed greatly during the stratification period under influence of non-seasonal weather events (LEWIS, 1983). The boundary of this layer was defined as the depth at which the temperature gradient was $0.1^{\circ}\text{C}/\text{m}$ or more.

The 5 m interval was too big to identify the upper-mixed layer in Lake Brokopondo. Non-seasonal weather events may also be important in Lake Brokopondo. The observed fluctuations of the surface temperature in the different year cycles are an indication for their importance. It is evident that sampling once a month is not frequent enough to reveal these non-seasonal variations. Seasonal variations in water temperature distribution at the three stations are illustrated in time depth diagrams in Figure 6. General trends noticed in the temperature profiles at Afobaka (Figure 4) are also apparent in these diagrams.

Water temperatures were lowest during the circulation period. After March the water column is warming which is reflected by the decline of the isotherms. Inflow of cold flood water during the long rainy season is reflected by the rise of the isotherms in the deep layers in the period May-August. After

October the rise of the isotherms indicates cooling of the water column and in January the water column becomes isothermal. Most of the year the temperature of the water is above 28 °C. Temperatures below 28 °C occur in the circulation period due to isothermal cooling and in the stratification period due to the inflow of the cold flood water. REISS (1977) also suggested that inflowing streams are sources of deep cold water layers in Amazonian lakes.

The temperature distribution at the three sampling stations suggests that spatial distribution of temperature is fairly uniform in the lacustrine zone of the lake.

Dissolved oxygen

The available data show that the surface water of the lake is most of the time (slightly) undersaturated.

Mean DO saturations at Afobaka, Kabel and Bedoti for the research period were respectively 79, 88 and 85%. Minimum DO saturations of the surface water were observed at the end of the stratification period and the start of the circulation period (December-February) . The saturation deficit could increase to 78% at Afobaka and 42% at Kabel and Bedoti. Maximum DO saturations were observed during the stratification period with occasional supersaturation up to 115% at Afobaka, 113% at Kabel and 103% at Bedoti. Supersaturation was occasionally observed at Kabel and Bedoti at 5 m and 10 m depth. The distribution of DO in the water column is shown by DO profiles Of 1984 of the station Afobaka (Figure 4).

At the start of the circulation period (January) the DO content of the surface water decreases because mixing takes place of the well-oxygenated surface water with less-oxygenated or anaerobic water from deeper layers. The oxygen distribution becomes more or less uniform with DO levels between 2 and 3 mg/l dependant of the oxygen demand of the water of the deeper layers. Later in the circulation period (February-March) DO content increases to 4 - 6 mg/l in the whole water column, because re-aeration and photosynthesis exceeds the decreasing oxygen demand of the water.

As thermal stratification establishes itself and the temperature gradient increase (June), oxygen depletion progresses in the deeper layers as result of the oxygen demand. As stratification intensifies (September), deoxygenation occurs below 15 m (in 1984 even below 10 m).

During the stratification period the DO content of the upper layers is highest due to the effective isolation from the deeper oxygen consuming layers and because oxygen production by algae contributes to higher oxygen levels. At the end of the stratification period (December) the temperature gradient decreases and vertical exchange increases. The DO content of the surface water decreases and the water of deeper layers becomes oxygenated again.

The DO profiles of Kabel and Bedoti show the same pattern in the stratification period. In the circulation period DO content in the surface water at Kabel and Bedoti decreases less severe than that of Afobaka. The lowest DO values recorded at the surface at Kabel and Bedoti were 4.5 mg/l. The lower DO content at Afobaka is probably caused by a higher oxygen deficit of the water column due to the greater depth and consequently thicker anaerobic layer. The temporal DO distribution of the three stations is shown in time-depth diagrams in Figure 7.

The three stations showed more or less the same fluctuations in DO content in the water column which indicates that the spatial DO distribution was fairly uniform in the lacustrine zone of the lake. The diagrams show that the DO distribution is strongly determined by the stratification. Only the upper

water layers are saturated with oxygen most of the year. Fluctuations of the DO content during the stratification period must have been caused by variations in primary production of the phytoplankton and by fluctuations of the mixing depth due to non-seasonal weather events. The deeper layers are oxygenated in the circulation period and short before and after this period. During the stratification period the deeper water layers become deoxygenated.

At the station Bedoti which is nearest to the point where the Suriname River enters the lake (see Figure 1) the influence of the flood water of the long rainy season is clearly visible in the DO diagram. During the stratification period the deeper water layers close to the bottom become oxygenated again for a short period in the long rainy season due to the underflow of oxygen-containing flood water from the Suriname River.

CONCLUSIONS

The monthly temperature and oxygen observations confirm that Lake Brokopondo is warm monomictic. Annual turnover takes place in the period January-March and the rest of the year the lake is stratified.

BEADLE (1974) stated that prolonged and frequent sampling is necessary for a good understanding of stratification in tropical lakes. VAN DER HEIDE (1982) and LEWIS (1983) observed great fluctuations of the weekly data in their researches.

It is clear that the sampling frequency - once a month - in the present research legitimates only general conclusions. Furthermore, the use of the 5 m interval in the profiles prohibits the identification of temperature layers as LEWIS (1983) found in Lake Valencia. A standardised sampling program is recommended to investigate whether complex layering as found in Lake Valencia (LEWIS, 1983) also exists in Lake Brokopondo.

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Table 1. Some general and morphometric data of Lake Brokopondo

(Source: van der Heide, 1982; Table X)

<u>General characteristics</u>		<u>Unit</u>
Latitude	4°26' - 5°00' N	-
Longitude	54°45' - 55°21' W	-
Altitude	50	m AMSL
Catchment area above dam	12,550	km ²
Ratio of annual outflow to volume	1 : 1.6	-
Direction of the main axis	NE - SW	-
Direction of predominant winds	NE - SE	-
Number of islands	1,166	-
<u>Morphometry</u>		
Length	56	km
Surface, total (islands included)	1,776	km ²
Surface, open water	1,579	km ²
Surface, islands	197	km ²
Mean breadth	31.7	km
Volume	24.2	km ³
Maximum depth	48.2	m
Mean depth	13.6	m
Mean depth, islands excluded	15.3	m
Shore line, total	3,666	km
Shore line, islands	1,899	km
* m AMSL= metres above mean sea level		

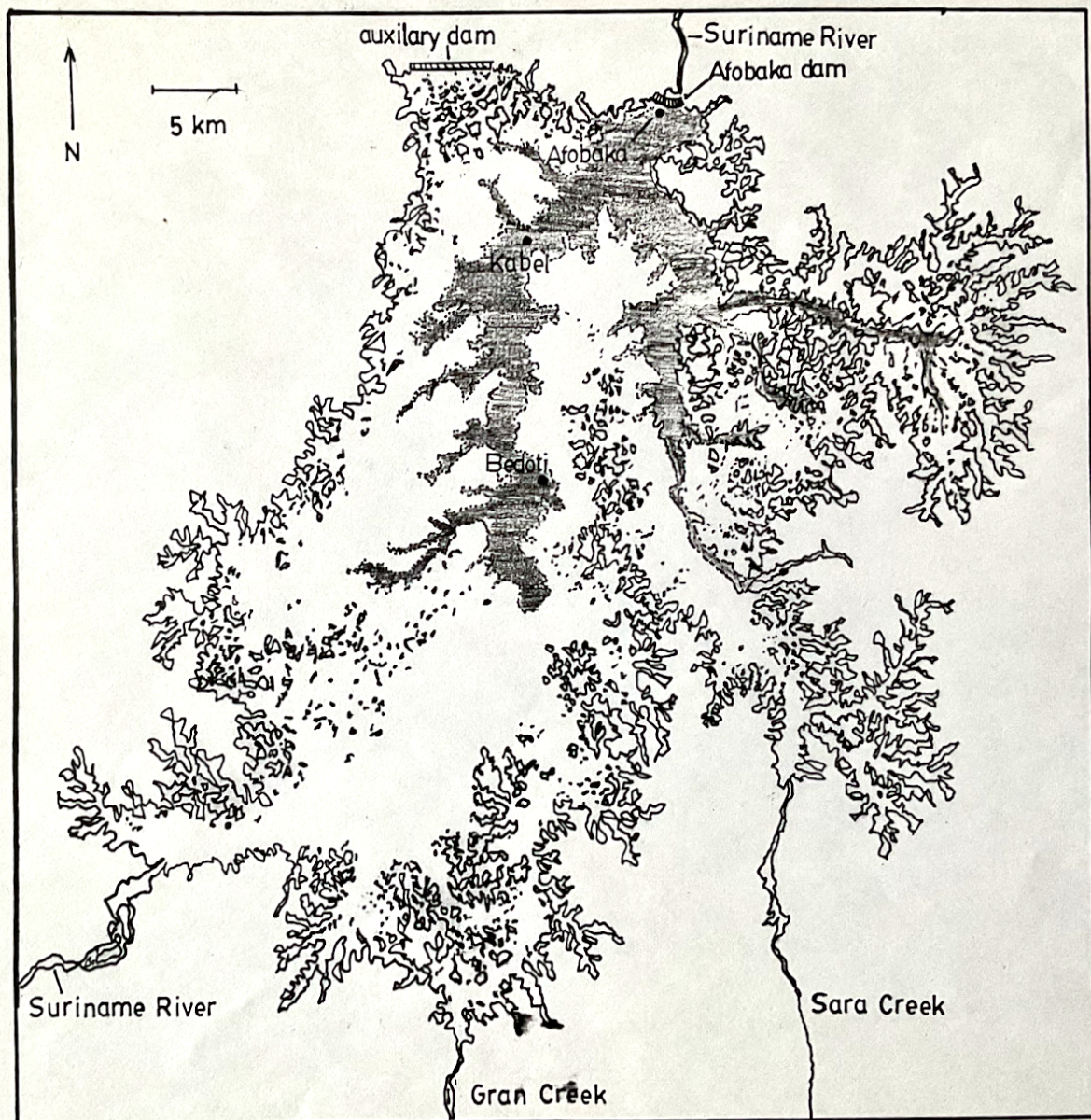


Figure 1. Lake Brokopondo, showing the shoreline and the islands at maximum level.

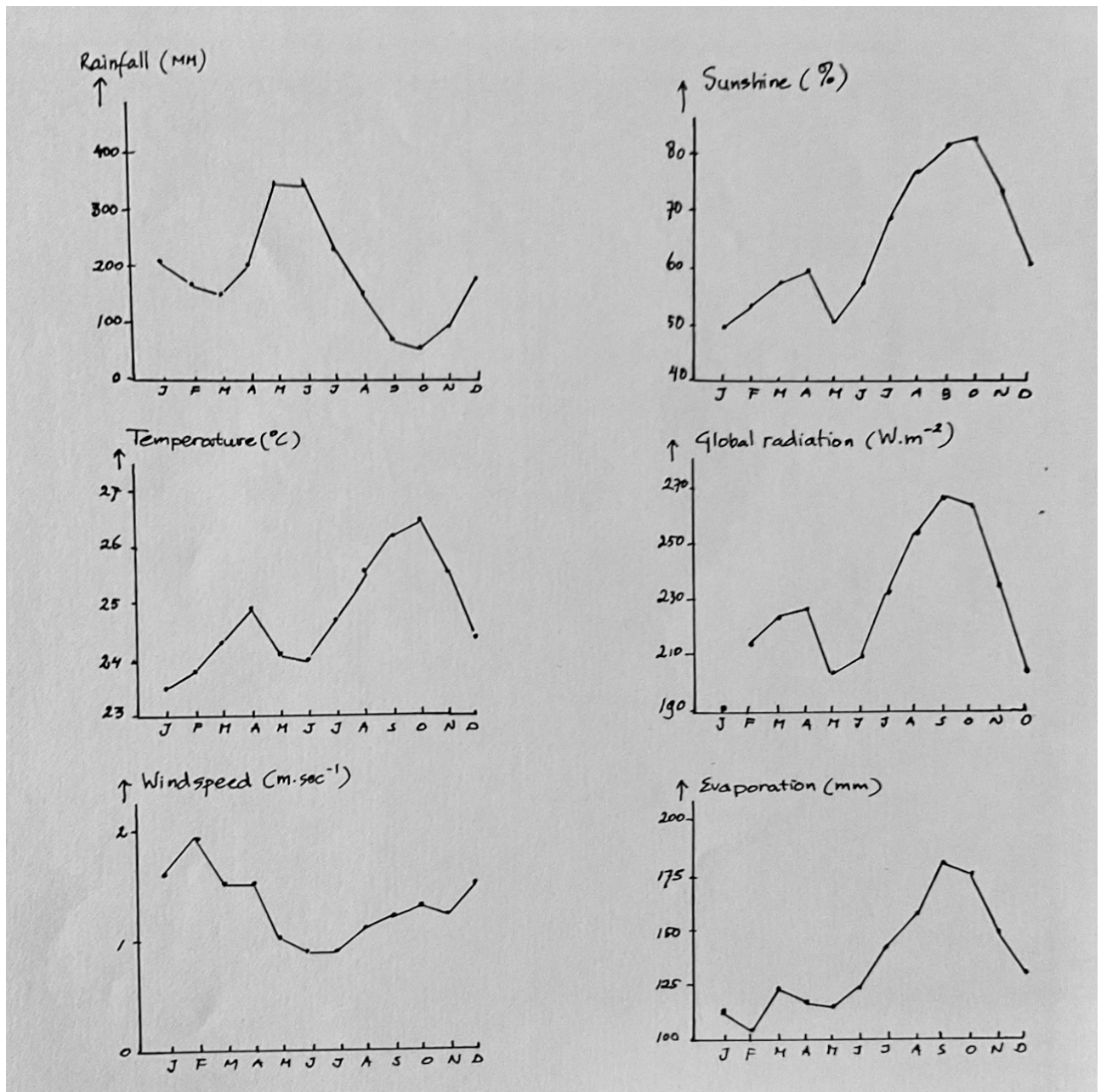


Figure 2. Various climatological data form the period 19690-1070 for the Lake Brokopondo area.

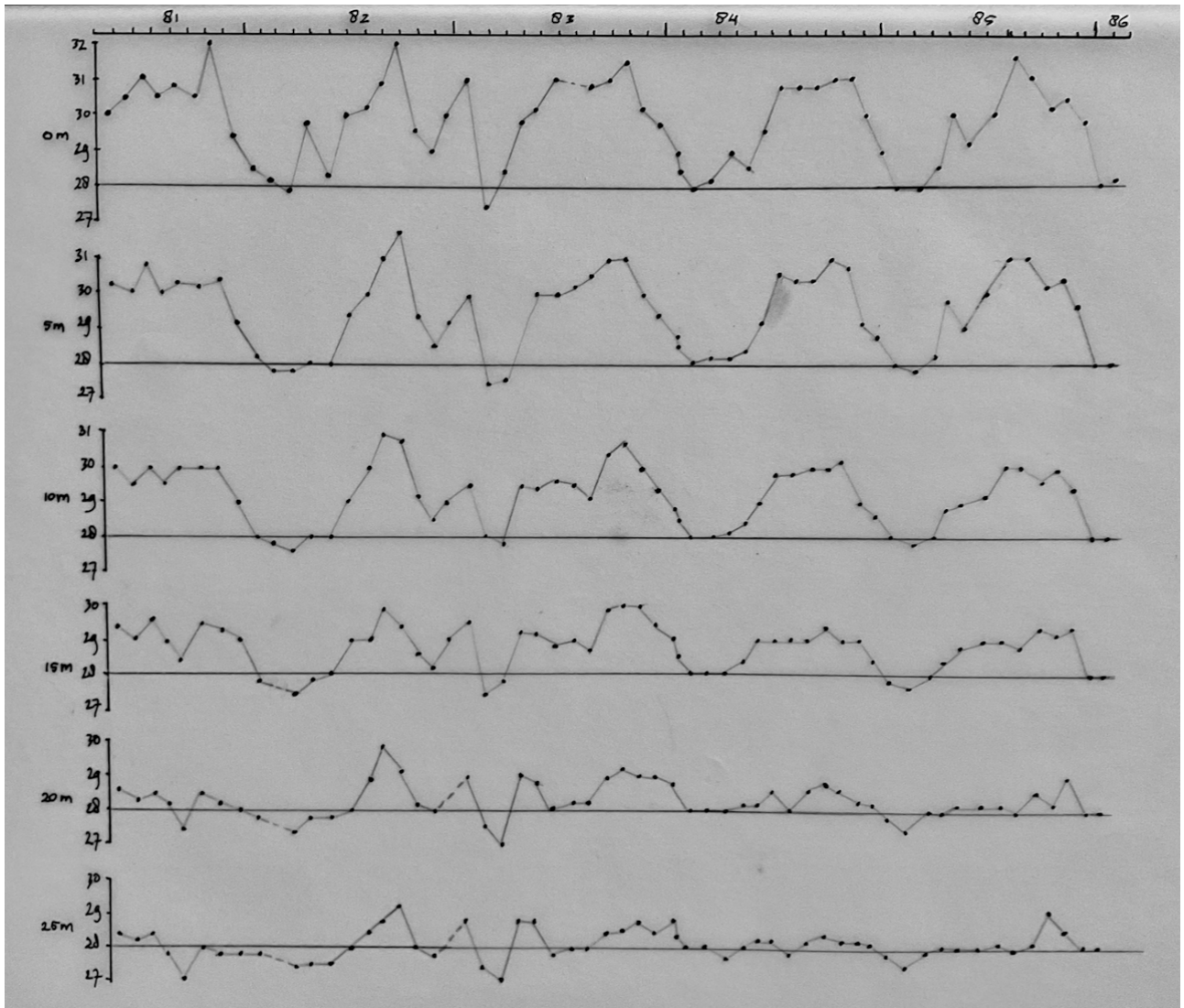


Figure 3. Mostly recorded water temperatures at Afobaka at 6 depths during the research period.

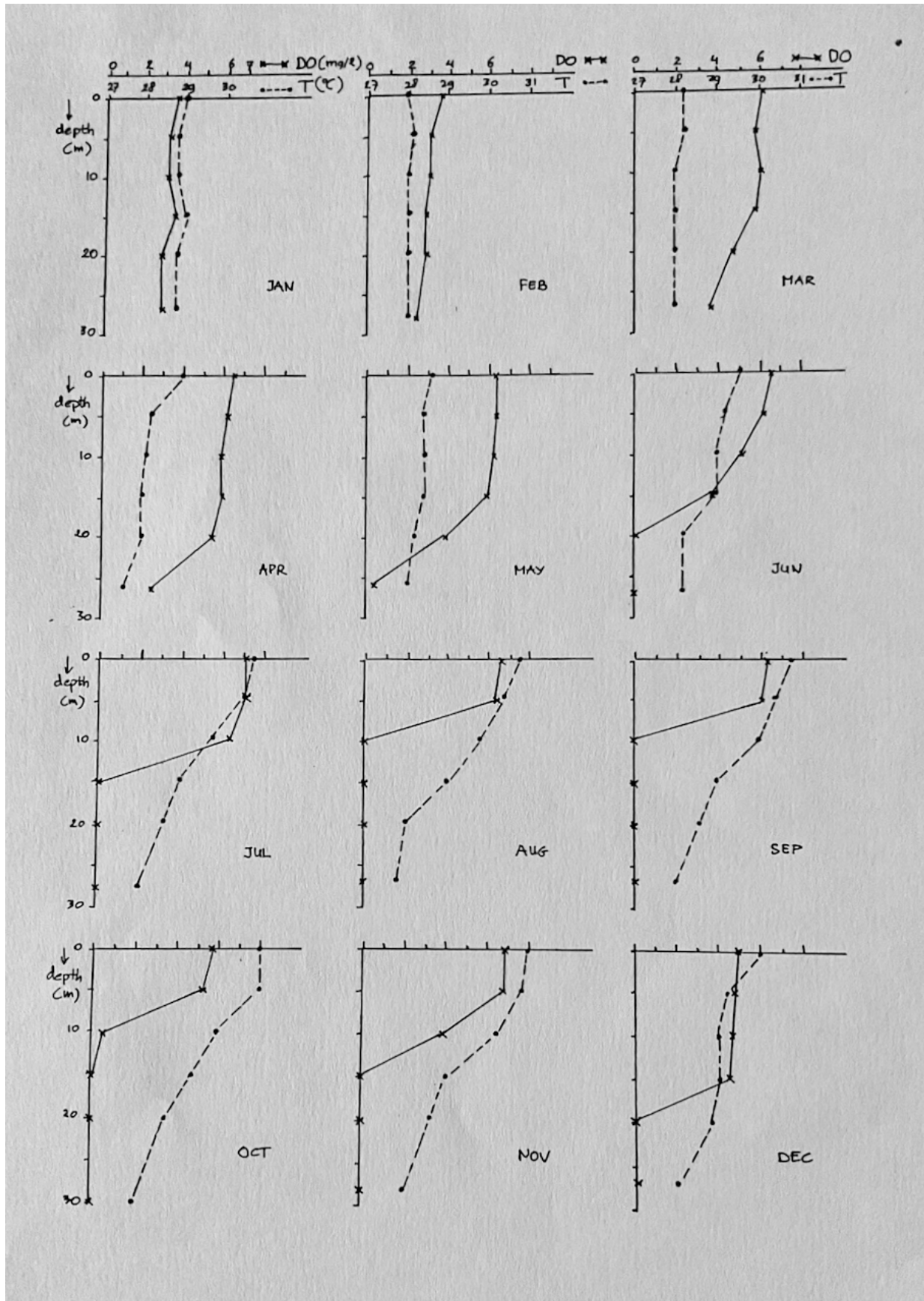


Figure 4. Temperature and Dissolved Oxygen profiles at Afobaka in 1984.

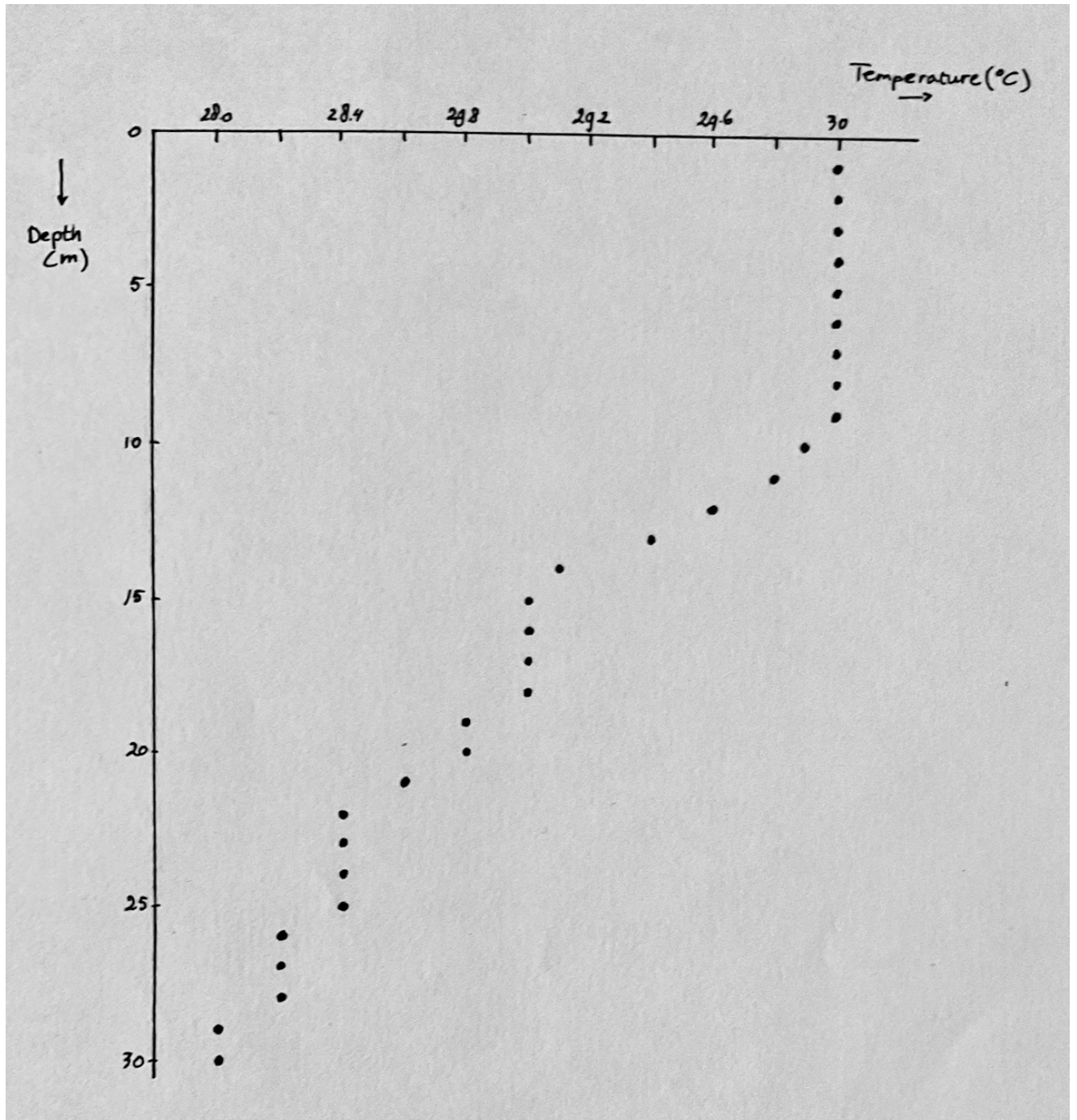


Figure 5. Temperature profile with a 1 m interval at Afobaka in July 1986.