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sediments of South Hartley Farm pool Whitley Bay
Northumberland*

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A new investigation of the Alga flora of the
littoral sediments of South Hartley Farm Pool
Whitley Bay, Northumberland

by

Winifred Slee, B.Sc. (Dunelm).

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The object of the Investigation

The object of the following investigation is to determine the condition of the algal flora inhabiting the littoral sediments of a small pool where the water level varies considerably throughout the year, and alternately exposes the littoral sediments to desiccation and re-irrigation.

There are the following possibilities regarding the state of the alga flora when the water level recedes:

- (a) the algae may retreat from their original position in the sediments, and follow the receding water line, afterwards returning with the advancing water level.
- (b) the algae may remain in the desiccated sediments when the water retreats. They may (i) persist entirely, and the re-appearance of the defunct species will ^{then} be most probably due to re-invasion ^{from the sediments}, which have remained unexposed by the retreat of the water; or (ii) they may enter into a resting condition of some kind, such as a cyst, or aplanospore or other protected body; or (iii) they may persist in their original condition to all appearances, and resume their vegetative activity on re-irrigation. Fritsch has shown that certain algae can withstand periods of desiccation without injury (Ref. Fritsch)

It will be shown that the algae of the sediments of this particular

pool exhibit all the above possibilities. This will be shown particularly by the members of the Bacillares, and Cyanophyceae, but the species of the Chlorophyceae in general showed a tendency to retreat with the water, though not invariably so.

The question of survival under conditions of desiccation is of considerable importance in connection with the distribution of algae. Animals coming to drink at the pool, or insects coming to seek for food in the mud, must necessarily carry away on their feet appreciable quantities of sediment which, if it contains algae capable of surviving the temporary desiccation, would inseminate the next pool, which was visited by them.

SECTION I

bank. This ~~water~~ pipe is in the bank about eighteen inches above water level. Any overflow is carried away by a drain situated in the extreme South East corner of the pool (Plate I outflow).

The pool is used for watering cattle which have free access to it. Owing to its shape they only use the North and South ends where the slope is gradual

SECTION 2

The Position of Stations and the Character of the Sediments

Of the Stations

Observations were taken at four stations which were named I, II, III and IV. Station I was situated in the extreme North East corner of the pool. Station II was situated on the North bank of the pool, twenty five feet East of the West bank of the pool. This station was marked with a large red stone. Station III was in the South West corner of the pool. Station IV was near the South East corner of the pool, at a point on the ^{South} bank, four feet ^{to the} West of the Eastern bank. This was because the outlet of the pool was in the extreme South - East corner. (Plate I. The map of the pool). Each station was taken at Maximum water-level

Samples of sediment were generally taken from positions in the pool, one foot in front of the water line at each station. These positions varied with the water level of the pool, and were therefore situated on lines, passing through the stations, and roughly parallel to the East and West banks of the pool.

Another station, named IIIA was occasionally used for the taking of observations. This station was on the South side of the pool, sixty feet in, from the West bank, (see Plate I Map) and ten feet in, from the Maximum level water line of the South bank. Samples of sediment were always taken from the same place at this station. It was situated in a small depression which was separated.

from the rest of the pool (when the water level was at its minimum) by a low bank of sediment which protruded from the East bank of the pool, half way across the South end. This bank was roughly parallel to the South bank. (Plate I Map and Section II)

The comparative, chemical, analysis of the sediments showed that they varied little in general composition. In all cases the sediments were mainly composed of sand, No clay was present in any of them.

The sediments of Station I contained more sand than those of the other stations, (88 parts per 100) (Plate VI). They contained average amounts of Carbonate of lime and (3.7 parts per 100) of Carbonaceous matter. Station I was sheltered to some extent from the North and East winds by the bank which forms the East shore of the pool and by the centenary wall (Sect I). It is exposed to the South and West winds, which are the prevailing winds in this district. These affect the water, which in turn affects the sediment, causing some of the organic matter to be washed out from it, The sediment at this station is generally lighter in colour after a West wind has been blowing.

The sediments of Station II contained least organic matter. Station II is situated on a comparatively exposed part of the North side of the pool, and not in a

Sheltered corner, hence the sediments were more exposed to movements of the water. The sediments of this station had only a poor alga-flora.

The sediments of Station III contained a larger proportion of Carbonaceous matter, and Carbonate of lime, than those of Stations I and II. This was because Station III is commonly used by cattle as a drinking place. It was sheltered by the stone wall ^{on the West}, and by a portion of the South bank (Plate I Map) which protrudes into the pool on the East. The water here was generally calm, and the sediments were not so affected by its movement. This station's ^{sediment} contained a large number of Euglena, and had a luxuriant Alga-flora.

Station IV was more exposed than Station III. The sediments of this station contained more organic matter than the sediments of the other three stations. This was because the current which flowed from the "Inlet" to the "Outlet" of the pool, tended to carry organic matter with it. The general level of the sediment at Station IV was higher than the level of the sediment at the other stations (probably due to the influence of the current) and when the water retreated this sediment was always the first to be invaded by the Macroflora, and as the water level advanced, it was always the last to be re-irrigated

(Plate I Map and Section II)
(Plate II)

The Rainfall and Changes in Water Level.

The rainfall was obtained from the readings of a rain-gauge situated in an enclosed garden, about one mile from the pool. The rainfall there, would probably be slightly different from the actual rainfall at the pool which is situated in the open country, but in general the rainfall at the garden would be proportional to the rainfall at the pool. The readings of the rain-gauge were assessed monthly, and these results are expressed graphically on plates III, IV and V.

As the pool is fed by the drainage of the pasture field in which it is situated, the rainfall has a direct bearing on the water level of the pool. The level of the water in the pool was taken from a mark made on the stone wall which supports the West bank.

(see Plate I Map of pool). These readings were expressed graphically on Plates III, IV and V.

The rainfall of 1923 was heavy in August and the latter part of November, and was comparatively low in June and September. (The level of the pool was therefore high in August and the latter part of November and low in September. (see Plate III.)

The rainfall of 1924 was heavy and was evenly distributed throughout the year, excepting during March which had a low rainfall.

The water^{level} of the pool remained near its maximum level in consequence, except in March when the water level fell two inches below maximum water level.

In 1925 the rainfall was not evenly distributed. Very little rain fell in June and in consequence the level of the pool fell to ^{its} minimum. The rainfall increased until September and the water in the pool gradually rose. The rainfall was low in October and the level of the pool again fell, but the level increased again until in December the pool was near to its maximum (Plate V)

The maximum level of the pool is only three inches above minimum water level, but as the depth of the basin is small compared with its radius of curvature when the water falls to its minimum level a considerable expanse of sediment is exposed. This is indicated in the Plan of the pool (Plate I).

SECTION I.

The macroflora^{bulk} of the sediments and of the ground adjoining the pool with special ^{reference} to the colonization of the sediment exposed by the shrinkage of the water.

The pool is surrounded on its North, West and South sides by meadow land. ^(Plate II) The dominant plants of the meadow are chiefly:-

Circa caespitosa Linn.

Agrostis alba Linn

Lolium perenne Linn

Festuca^{ovina} rubra Linn

Ranunculus acris Linn.

Ranunculus repens Linn

Stellaria media Cyrill.

Trifolium repens Linn

Aceracum pilosella Linn

Taraxacum dens-leonis Desf.

Bellis perennis Linn.

Plantago major Linn. and Plantago lanceolata Linn

Rumex acetosa Linn

The east bank of the pool is formed by a low mound surmounted by a hedge of Crataegus oxyacantha Linn. The predominating plants present on this mound are the following:-

Rosa canina Linn.

Rubus fruticosus Linn

Stellaria Holostea Linn

Lamium album Linn

Potentilla anserina Linn

Plantago lanceolata Linn.

Rumex obtusifolius Linn

Dactylis glomerata

The East bank of the pool is steep and at the water's edge are found patches of Juncus conglomeratus. Scattered patches of Alisma plantago are found near the west bank of the pool (Plate II). The middle of the pool is occupied by a profuse growth of Zannichellia palustris. This is never seen above the level of the water and it rises to the surface of the water. It is often covered with an epiphytic growth of Characium gracile.

In June 1923 the water level of the pool was low (Plate III) and a considerable expanse of sediment was exposed. This sediment was at first covered by an algal film composed of Coelastrum tenue, Coelastrum limosa and Anabaena inaequalis. This film gradually became desiccated and disappeared (Section 8. P.), as the water content of the sediment became lower.

The exposed sediment at the South end of the pool was first invaded by Taraxacum dens-lewisii, Plantago lanceolata, Plantago major and Stellaria media.

It is probable that the sediment was inoculated with seeds of the above plants by the wind, or by birds coming to seek for food in the sediments of the pool. Shortly after this seedlings of grass (Festuca ovina^{virgata} and Lolium perenne) appeared. The flora of the surrounding meadow now invaded the edges of the exposed sediment.

The grasses encroached more quickly than the other plants. Ultimately the sediments were covered

with a growth of Macroflora composed chiefly of; Taraxacum - dens lewisii, Plantago - lanceolata, Plantago - major, Stellaria media, Ranunculus repens, Potentilla anserina, Rumex obtusifolius, Rumex acetosa, Lamium album, Dactylis glomerata.

Lamium album and Potentilla anserina were found.

chiefly near the hedge, which surmounts the East bank of the pool. These plants were not found in the meadow but only on the bank which forms its Eastern boundary.

The exposed ~~sediment~~ at the North end of the pool was only sparsely covered with macroflora which consisted chiefly of Plantago major, Plantago lanceolata, and Lolium perenne. Plantago major grows nearest to the water line.

In 1924, the sediment was exposed for three weeks in October, and very little macrophytic vegetation appeared except a small amount of Lolium perenne and Festuca ovina. These grasses were only found near the edge of the exposed sediment.

In 1925 the water of the pool ^{fell to its minimum} level from June to September. ^(Plate V) The exposed sediment at the South end of the pool was again invaded first by Stellaria media, Plantago major and Plantago lanceolata. Seedlings of Polygonum aviculare (Linn) were also present. The exposed sediment had at first been covered with the algal film consisting chiefly of Coccolathia tenuis, Coccolathia limosa, and Anabaena inaequalis. This film became desiccated and finally disintegrated. ^{exposed} Ultimately the sediment was covered with a growth of macroflora consisting chiefly of:-

Plantago major, Plantago lanceolata, Sellaria media,
Polygonum aviculare, Trifolium repens, Ranunculus
repens, Taraxacum dens-leonis, Bellis perennis,
Rumex acetosa, Lolium perenne, Dactylis glomerata
 and Festuca ovina.

The exposed sediments at the North end of the pool were again only sparsely covered with macrophytic vegetation, which consisted chiefly of Plantago major, Plantago lanceolata and Lolium perenne.

From the above observations it appears that the sediments exposed by the shrinkage of the pool are first invaded by plants, whose seeds have been carried there by wind or by animals. They are then invaded by other plants which grow in the surrounding meadows.

These spread inwards from the edge of the pool, the grasses spreading more quickly than the other plants.

As the water of the pool advances when the pool is rising, these plants are inundated. They become water logged and the grasses are generally covered with an epiphytic growth of Characium gracileps. They finally decay and disappear.

SECTION 5

Methods of Collection

The sediment was collected with a small tin cylinder about two inches in diameter which was fastened onto the end of a stick. Over the lower end of the cylinder was lashed a piece of muslin. The upper end was left open. The sediment was collected by scraping the surface mud of the pond with the cylinder. The surplus water escaped through the muslin. The sediment was then placed in a specimen tube.

Sediment was generally taken from points not more than one foot from the ^{waterline} shore at the various stations.

Methods of Preservation

The material was preserved by adding enough 40% formaldehyde to ensure that the sediment was in a 2% solution of formaldehyde.

Experimental Methods of Observation

The material in 3% formaldehyde was examined in the following manner. The tube containing the material was thoroughly shaken and a small quantity of the material was taken from the tubes by means of a pipette at intervals of one, two and three minutes after shaking. This was to allow for sedimentation. This material was placed upon slides and examined microscopically.

The following scale was used to classify the number of organisms present in a sample of material:-

xxx	- one organism present in a field at HP
xx	- two organisms " " " " " "
x	- three to five " " " " " "
m	- five to ten " " " " " "
mm	- ten to twenty " " " " " "
mmm	- more than twenty " " " " " "

These results of the investigations were tabulated and are expressed in the sheets accompanying this Thesis.

The measurements needed to identify the organisms occurring in the sediments were made by means of the "camera lucida".

When desiccated sediment was used, this was generally ~~examined~~ in water. When desiccated sediment was irrigated it was placed in a shallow dish and irrigated with distilled water. This dish was covered with a piece of muslin to prevent contamination.

SECTION 6.

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The general microflora of the Sediments of the Pool
Section

The microflora of the ^{Littoral.} Sediments can be divided into two groups.

I These organisms which survive in the desiccated sediment. These remain in the sediment through the any period and can be revived at any time by the addition of water to the desiccated sediment. This group can be subdivided into two divisions

(a) Organisms which occur in the desiccated sediment as cysts or aplanospores. chiefly:-

Amoebae sp.

Arcella vulgaris

Euglena sp.

Caulastoria tenuis Ag.

Caulastoria limosa Ag.

Spyrogyra crassa, Kütz. Eunotia pectinalis Kütz.

(b) Organisms which occur in the desiccated sediments in an apparently unchanged condition or by thickening or mucilage generation of the cell wall. chiefly:-

Nitzschia sigmoides, Ehrenb.

Navicula sphaerophora (Kütz.)

Navicula platystoma (Ehrenb.)

Navicula exilis (Kütz.)

Loxonema lanceolata (Ehrenberg)

Characum gracileps (Lambert)

Gyrosigma acuminatum var. curta (Grünow)

Scyllatoria tenuis Ag.

Linabana inequalis Kütz

II These organisms which are found in the submerged sediment but do not survive in the desiccated sediment. This group can be subdivided into two divisions

(a) organisms which remain in the desiccated sediment only as dead and empty cells, namely:

Scenedesmus quadricauda (Turp) Bréb.

Ustinuin acerosum (Skrank) Ehrenb.

Fragilaria capucina Desmazieres

(b) organisms not found in the desiccated sediment and which apparently retreat with the water namely:-

Lyngbya ceruginea-coelura (Kütz) Gom.

Pteronias angulosa (Carter) Lemm.

Scenedesmus obliquus (Turp) Kütz

Scenedesmus hyugatus Kütz

Ankinstrodesmus falcatus (Loraa) Raup.

Largenheimia Wratislaviensis Schröder

Loelastrium splenicum (Näg)

Actinostrom Hantzschii (Lagerh)

Trachelemonas hispida

Tabellaria flocculosa Kützting

SECTION 7.

Characteristics of the Flora of the Desiccated Sediment.

The material used for observation was samples of sediment that had been exposed to the atmosphere for varying lengths of time, by the sinking in level of the water of the pool, and thus had become desiccated.

The samples of sediment were collected at Stations I, II, III and IV on the following dates.

September 25th 1923,

November 14th 1923.

June 9th 1924.

September 20th 1925.

On the first three occasions samples were taken at approximately three feet behind the water line at the four stations. On the last occasion samples were taken at four feet behind the water line and six feet behind it, as the moisture contents of the two sediments differed greatly. The sediment taken from four feet behind the water line at station I contained 8.6% of water, while that at six feet behind the water line contained 2.4% of moisture.

The desiccated sediment was mounted in sterile water and examined and the following

observations on organisms persisting in the desiccated sediment were made.

Amoebae sp. were found in all instances in the desiccated sediment and were fairly numerous. These were in an encysted condition and were surrounded by a very thick, roose wall, which was brown in colour. The protoplast was shrunken and withdrawn from the cell wall.

On one occasion only, and that on September 20th 1925 has Amoeba, ^{vulgaris} been found in the desiccated sediment. It did not appear to diverge in any way from the normal organism found in the submerged sediment of the pool.

Resting stages of Euglena sp. were found on November 17th 1923, and on September 20th 1925. The Euglena sp. were generally rounded and the cell wall was thickened. The cell contents were green and in some cases were filled with small granules. The sediment of Station I, on November 17th, 1923. contained more moisture than the sediment of the other three Stations, because a South-west wind had caused the water of the pool to irrigate the sediment at this station. Euglena sp. were present in the sediment at this station in their

normal condition.

It appears that the organisms in the above section, during a period of desiccation tend to surround themselves with a thick wall and the cell contents tend to concentrate and shrink from the cell wall, but are in contact with it at certain points. The cell contents also tend to become granular in the case of *Euglena*. These results agree with those of Fritsch. (Ref. II P. 18).

BACILLAREAE

The Bacillareae are represented in the desiccated sediment by Nitzschia sigmoides, Navicula sphaerophora, Navicula platystoma, Navicula exilis, Coconema lanceolata, Fragilaria capucina, Gyrosigma acuminatum, and Eunotia spectinalis Kütz.

Nitzschia sigmoides was found in the desiccated sediment of September 25th 1923, and occurrence there was comparatively rare. The protoplasts of the diatoms present were green in colour and were frequently moniliform in shape. The walls of the diatom appeared to be thickened with a mucilaginous exudation, yellow in colour, which was covered with adherent particles of sediment.

Navicula sphaerophora was found to be present in nearly all the material examined. The two platform chloroplasts showed the following variations in the diatoms observed:-

- 1) They retained their normal shape and brown colour and in this case oil globules were generally observed to be present.
- 2) They retained their brown colour but appeared as two irregular masses, or were fused together to form one irregular mass. In many cases this mass was moniliform in shape.
- 3) They were green in colour and had assumed

The shapes referred to in the previous paragraph.

At the same time the cell wall appeared to be thickened with a yellow mucilaginous exudation which adhered in irregular masses to the wall of the diatom. To the mucilage itself adhered particles of sediment. In several cases, on September 20th 1925, the chloroplast was observed to be breaking up into brown, irregular granular fragments. (Plate VII Figs 2+3)

On March 15th 1925, several *Navicula sphaerophora* were observed with small, colourless, needle-shaped crystals adhering to the walls of the diatom.

Navicula platystoma occurs frequently in the desiccated sediments. The chloroplasts behave in the manner as those of *Navicula sphaerophora*. The ~~walls~~ walls of the diatoms observed on September 20th 1925 were slightly thickened by a yellow mucilaginous exudation. No particles of sediment were observed adhering to the walls of the diatom. (Plate VII Figs. I)

Navicula exilis occurs frequently in the desiccated sediment. When examined they did not appear to differ from those found in the submerged sediments except that the chloroplast had changed from brown to green in colour, and oil globules were frequently observed.

Cocconeis lanceolata was present in

→ all desiccated sediments except those of September 20th 1923. The chloroplast was generally brown in colour but occasionally (as on Sept 20th 1925) was green. The chloroplast was either in two irregular masses in the cell or in one irregular mass which sometimes assumed a moniliform shape. Oil globules occurred frequently. In most cases the wall was thickened with irregular masses of mucilage, which adhered to it. Particles of sediment, ^{in turn} adhered to the mucilage.

Eunotia pectinalis appeared only in the desiccated ^{Sediment} of September 20th 1923. The diatom contained a number of yellowish-brown, round spherulike bodies. The walls appeared to have a mucous investment. The appearance was isolated and did not permit further investigation (Plate VI Figs 596) (Ref 6. P. 111)

c Gyrosigma acuminatum was found in the material of September 20th 1925. The chloroplasts were green in colour and the green colour had diffused throughout the contents of the diatom. No noticeable thickening of the cell wall was observed.

Fragilaria capucina was present in the desiccated sediment of November 17th 1923, and September 20th 1925 when alive (death was assumed when the diatom was devoid of contents), it did not appear to diverge from the normal diatoms found in the submerged sediment.

From the above observations it appears that some members of the Bacillariae prepare for a period of desiccation by thickening the wall of the diatom with an irregular layer of mucilaginous matter to which particles of sediment adhere. This may be a device to conserve the water supply in the diatoms and to absorb from the surrounding sediment what moisture is present.

The chloroplasts may retain their original colour and shape in which case oil globules are generally present. Often the chloroplasts change in colour, from brown to green and they may assume various shapes of which the starlike form appears ^{to be} the commonest.

CYANOPHYCEAE.

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The Cyanophyceae are represented in the desiccated sediment by Coelastrum limosa, Coelastrum tenuis, and Anabaena inaequalis.

Coelastrum tenuis was observed in the desiccated sediment of November 17th 1923, July 9th 1924 and September 20th 1925. Coelastrum tenuis occurs in the desiccated sediment, and also in the submerged sediment, more frequently, and in greater profusion than either Coelastrum limosa and Anabaena inaequalis.

Coelastrum limosa was found in the desiccated sediment of September 25th 1923, and September 20th 1925. Single resting spores were found in the desiccated sediments of November 17th 1923.

Anabaena inaequalis was found in the desiccated sediments of November 17th 1923, and September 20th 1925.

Coelastrum tenuis and Coelastrum limosa ~~are~~ are found in the desiccated sediment in two forms:-

- 1) The outer walls of the filament are coated with an irregular layer of mucilage. The protoplasts ~~are~~ have changed in colour from blue-green to a brownish-green. When supplied with

Sufficient moisture the filament apparently resumes its normal condition after twenty-four hours.

2) Each cell in the filament enters into a resting condition. The cell contents change from a blue-green to a brown-green colour and the cell walls are considerably thickened. It is probable that some of the specially adapted cells break away from the filament. In samples of desiccated sediment taken at Stations I and III on September 20th 1925 filaments of *Basillaria tenuis*, about twenty cells in length were observed, and four or five adjoining cells in each filament were empty. The transverse septa were absent but parts of the outer walls remained. The cells adjoining the absent cells, were rounded and protruded into the spaces once occupied by the contents of the empty ^{In one case because cells between the septa were seen} cells. The cells in the remainder of the filament had brownish green contents and the cell walls were considerably thickened (Plate VII fig 4). (Ref. P41)

It is probable that these resting cells when supplied with sufficient moisture, germinate, and grow into short filaments about six cells in length. In most cases when desiccated sediment had been resubmerged for about

three days, many short filaments of both Coellatoria tenuis and Coellatoria limosa were observed. These filaments were generally six to eight cells in length.

When desiccated sediment was placed in water under experimental conditions on November 17th 1923 and September 20th 1925 many ~~short~~ filaments of Coellatoria tenuis and Coellatoria limosa were observed, after the sediment had been immersed for three days. These filaments were about six cells in length and are probably hermaphrodites as described by Crow (Ref. Pico).

It is probable that resting cells of Coellatoria tenuis and Coellatoria limosa had germinated and grown into these short filaments.

Linabaena inequalis was found in the ~~dry~~ desiccated sediment. It did not appear to differ from the normal filaments found in the submerged filaments.

CHLOROPHYCEAE

31

Senedesmus quadricauda was found in the desiccated sediment of September 20th 1925. The cells present contained a number of brown granules, in addition to the protoplast which was generally much shrunken. The protoplast generally remained in contact with the cell wall at some point. In some cases, the protoplast appeared to be in a state of division:

Spyrogyra crassa was not found in the filamentous condition in the desiccated sediment except on September 25th 1923, at Station II, when a short filament of six cells in length was found. The contents of the cells had broken up into small fragments, and were probably in the process of disintegration. Zygospores of Spyrogyra crassa have been found in the desiccated sediment. When samples of desiccated sediment were placed in water on November 17th 1923, a germinating zygospore was observed after three days had elapsed. A germinating zygospore was observed in sediment taken from three feet behind the water line at Station IV on September 20th 1925. This sediment was moist.

SECTION 8

Variations in water level and the condition of organisms

in the sediment as the water recedes.

The variation in level is only about three inches, but as the depth of the basin is small compared with its radius of curvature, a considerable expanse of sediment is exposed when the water falls to its minimum level. This expanse of sediment is indicated on the "Plan of the pool" (Plate I).

In June and September 1923 the pool was very low and the water fell 2.5 inches below the maximum level point. (see Plate III)

In 1924, the rainfall was heavier than in 1923 and was more evenly distributed throughout the year. As a result the pool showed very little variation in water level except towards the end of September when it fell 0.75" below maximum water level. (Plate IV)

In 1925 the rainfall was much less than in the two preceding years. In ~~May~~^{June} the pool sank to its minimum level and varied little from that level until September when it began to fill and the maximum water level was reached in January 1926. (Plate V)

As the water of the pool was subsiding, samples of sediment were taken from the following places:-

- (a) points in the pool. six feet from the water edge. at Stations I, II, III and IV.
- (b) positions at the water edge at Stations I, II, III and IV.
- (c) positions one foot behind the water edge. at Stations I, II, III and IV.

Samples were taken on three occasions, June 9th 1923, Sept 18th 1923, and May 20th 1925.

In the sediments taken from the positions in the pool six feet from the water edge, the following organisms were found to be common to the sets of sediments examined.

Amoebae. sp

Euglena. sp

Nitzschia sigmoidea

Aphera ovalis (var. pediculus) on Nitzschia sigmoidea

Navicula sphaeroptera.

Navicula exilis

Tabellaria flocculosa.

Lochneria lanceolata
Gyrosigma acuminatum. v. curta.

Characium gracileps

Loxallatona tenuis

Loxallatona limosa

Scenedesmus quadricauda

Scenedesmus byugatus

Scenedesmus obliquus

Largenbeimia wratislaviensis

Loxostomum sphaericum

Actinostomum Hantzschii

Spyrogyra crassa

Cladocidium acerosum

In the sediments taken from the water edge the following organisms were found to be common to all:-

Amoebae

Navicula sphaerophora

Nitzschia sigmoides

Navicula exilis

Tabellaria flocculosa

Gyrosigma acuminatum v. curta

Scenedesmus quadricauda (rare)

Scenedesmus byugatus (rare)

Bacillaria limosa

Bacillaria tenuis

In the sediments one foot behind the water line the following organisms were common to all:-

Amoebae (in an encysted condition)

Milyschia signoides

Navicula sphaerophora

Navicula exilis

Loxonema lanceolata

Gyrosigma acuminatum

Scyllatoria limosa

Scyllatoria tenuis

} In the resting stages described
in Section 7.

Two Scenedesmus quadricauda were found on September 20th 1926 in the desiccated sediment. One of the organisms was empty and therefore assumed to be dead. The protoplast of the other had broken up into brown irregular granular fragments, as if about to disintegrate.

On June 9th 1923, two ^{specimens of} Closterium acerosum were present in the desiccated sediment one foot behind the water line. The protoplast of one was much shrunken and was granular. The protoplast of the other had broken up into granular fragments, possibly a state in the process of disintegration.

From these observations the organisms ^{present} in the sediments one foot behind the water line, with the exception of Scenedesmus quadricauda and Closterium acerosum, remain in situ when the water recedes and then enter into some form of resting stage.

To withstand the period of desiccation

Other organisms are seldom found in very shallow water or in desiccated sediment. These include:-

Scenedesmus quadricauda

Scenedesmus obliquus

Scenedesmus ligulatus

Largenbeuma bratislavensis

Coelastrum sphaericum

Actinastrum Hantzschii

Closterium acerosum.

It appears probable that these organisms are unable to persist through a considerable period of desiccation. When left in situ in the desiccated sediment they disintegrate and perish. They occur more frequently in relatively deep water (from two to five inches in depth) than in shallow water (from one half to two inches in depth). Apparently they drift in some way from shallow water to deeper water as the level of the pool varies.

In this way they probably minimise the chance of exposure to desiccation.

The Cyanophyceae behave in a characteristic manner as the water in the pool subsides. As the water recedes, the newly exposed sediment becomes covered with a green film composed of Coelastrum tenuis, Coelastrum limosa and Anabaena inaequalis.

Coelastrum tenuis appears in much greater profusion than the other two algae.

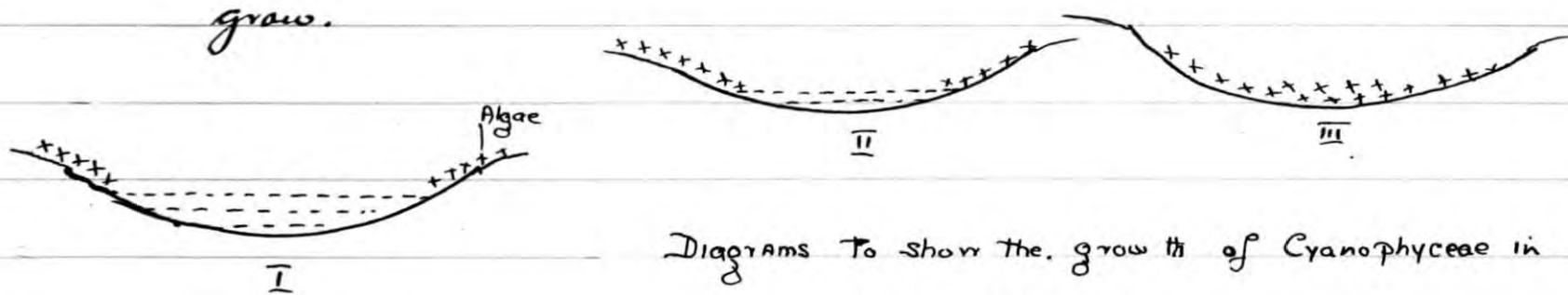
The floor of the pool is very uneven when seen through the shallow water near the shore owing to ripple marks. At the North and South ends it is still more uneven and contains numerous small depressions which are in most cases caused by the trampling of the feet of animals which come to drink at the pool.

The algae form a film over the whole of the sediment which is exposed to the atmosphere as the water recedes, but in the depressions, which contain water, algal growth is more luxuriant than elsewhere.

At first in each small depression, only the drying sides of the depression are covered with the algal film. Gradually, as the water evaporates, the exposed sediment is covered by the algae so that by the time the water level in the depression is very low, a thick green mat is formed at the bottom of the depression.

Should the water return at this stage (as it frequently did in 1924), the film generally floats on the surface of the water and is blown to one side of the pond. The film does not persist, but apparently disintegrates rapidly into individual filaments, and disappears from view.

Should the water not return for a long period, the film gradually dries, becomes brown and brittle and disappears. The algae enters into the resting stages described in Section I, the sediment dries and cracks and the macroflora begins to grow.



Diagrams to show the growth of Cyanophyceae in small depressions

In May 1925 at Stations I and II it was observed that several masses of *Spyrogyra crassa*, which had been blown to the edge of the pool by wind, entered into a state of conjugation and formed zygospores. These zygospores were probably left in 'retic' by the water as it receded, and germinated when the ground was resubmerged.

SECTION. qA.

Variations in water level and the behaviour of organisms

as the water advances. (a) Observational
The water in the pool sank to its minimum level several times during the years 1923-5. On three occasions namely, in September 1923, in November 1923 and in September 1925 the flora of the sediments, throughout the periods of inundation which followed the dry periods, was observed.

In each case organisms common to the sediments of the four stations were noted. Samples of sediments were taken at the four stations at the following times, and at the following positions, namely:-

- 1) Samples were taken at the water edge several days before the period of inundation
- (2) Samples were taken behind the water edge, at several days before the period of inundation.
- (3) Samples were taken at the water edge from three to five days after the beginning of the inundation period.
- (4) Samples were taken at the water edge, two weeks after the beginning of the period of inundation
- (5) Samples were taken at the water edge, three weeks after the beginning of the period of inundation

The results were arranged in the following tables.

Table of organisms common to sediments of the four stations Nov 3rd - Dec 5th 1923.

	1 yd. behind water edge.			
	Nov 3 rd	Nov 17 th <small>Water line</small>	Nov 17 th	Dec 5 th
<i>Amoeba</i> .	m	m R	m R	m R
<i>Euglena</i>	m	m R	r r r	-
<i>Nitzschia Sigmoides</i>	m	-	r r r	-
<i>Nitzschia Sigmoides</i> + <i>Amphora</i> bracts.	r	-	r	-
<i>Navicula Sphaeroptera</i> .	m	m R	r	m.
<i>Navicula exilis</i>	m	r R	m	m
<i>Cocconeis lanceolata</i>	r	r R	-	-
<i>Brachionia limosa</i>	-	m R	^m Short Length	^m Short Length
<i>Brachionia limosa</i>	-	-	^m Short length	^m Short length
<i>Scenedesmus quadricauda</i>	r	r	r	-
<i>Gyrodinium acuminatum</i>	m	=	r r R	=
<i>Characium gracile</i>	m	-	-	-
<i>Anabaena inaequalis</i>	-	r	-	^m Short Length

before
inundation

Period of inundation

R = Resting condition as described in Section 2

September 1925

42.

Organism	Sept 18 th	4' behind water line Sept 20 th	Alkali edge Sept 20 th	Sept 27 th	Oct 3 rd
<i>A. moebae</i>	r R.	r R.	r R.	-	-
<i>Eugenia</i>	m.	r R.	m	-	m.
<i>Trachetomena keopica</i>	rr.	rr.	-	-	m.
<i>Pityschia sigmoides</i>	-	rr R.	-	r	r
<i>Navicula splanoptera</i>	r	r R.	r	r	m.
<i>Navicula platystoma</i>	r	r R.	r	r	r
<i>Navicula exilis</i>	r	r R.	r	r	m.
<i>Loxomena lanceolata</i>	r	rr R.	r	r	m.
<i>Gyrosigma acuminatum</i>	r	r R.	r	-	m m.
<i>Coellasteria tenuis</i>	- r	rrr R.	Short m lengths r	Short m filament short	m.
<i>Coellasteria lunosa</i>	-	-	m	m filament	r
<i>Lyngbya</i>	-	-	r	r	-
<i>Unatama iniqualis</i>	r	-	r	Short m filament	-
<i>Scenedesmus quadricauda</i>	mm	-	m.	mm	mm.
<i>Scenedesmus obliquatus</i>	mm	-	m	mm	mm
<i>Scenedesmus obliquus</i>	-	r	r	m	-
<i>Plethomonas angulosa</i>	-	-	-	r	mm.
<i>Antenostrodium falcatus</i>	-	-	-	r	r
<i>Spyrogyra crassa</i>	-	R.	Germinaling zyogone.	-	-
<i>Characium gracileps</i>	-	-	-	m	mm
	Before inundation			Period of inundation	

R: Resting condition as described in Section 2

September 1925

#2

Organism	Sept 18 th	4' below waterline Sept 20 th	Algalia edge Sept 20 th	Sept 27 th	Oct 3 rd
<i>A. moebae</i>	r R	r R	r R	-	-
<i>Eugenia</i>	m	r R	m	-	m
<i>Trachetmenas kuspida</i>	rr	rr	-	-	m
<i>Mityschia sigmoides</i>	-	rr R	-	r	r
<i>Navicula Splanoptera</i>	r	r R	r	r	m
<i>Navicula platystima</i>	r	r R	r	r	r
<i>Navicula exilis</i>	r	r R	r	r	m
<i>Loxomena lanceolata</i>	r	rr R	r	r	m
<i>Gyrosigma acuminatum</i>	r	r R	r	-	m m
<i>Coellataria tenuis</i>	- r	rrr R	Short m lengths	Short m filaments	m
<i>Coellataria lunata</i>	-	-	r	Short m filaments	r
<i>Lyngbya</i>	-	-	r	r	-
<i>Arabana inaequalis</i>	r	-	r	Short m filaments	-
<i>Scenedesmus quadricauda</i>	mm	-	m	m m	mm
<i>Scenedesmus obliquatus</i>	mm	-	m	m m	m m
<i>Scenedesmus obliquus</i>	-	r	r	m	-
<i>Plectononas angulosa</i>	-	-	-	r	m m
<i>Antenostocidium falcatus</i>	-	-	-	r	r
<i>Spyrogyra crassa</i>	-	R	Germinaling zyogone	-	m m
<i>Characium gracileps</i>	-	-	-	m	m m
	Before inundation			Period of inundation	

R = Resting condition as described in Section 2

From the three Tables of results the following organisms are found to be present in the desiccated sediments behind the water line. They were all found in the nesting conditions described in Section 3

The organisms were chiefly:-

Limnospira sp

Euglena sp

Nitzschia signoides

Navicula sphaeroptera.

Navicula platystoma.

Navicula exilis

Loxoneura lanceolata

Gyrosigma acuminatum

Orsellaria tenuis

Orsellaria limosa

Limnospira inaequalis

Zygospores of Spyrogyra crassa.

As the water level rises and the water reinvades the desiccated sediment, the following organisms return with it:- Scenedesmus quadricauda.

Scenedesmus byugatus,

Scenedesmus obliquus

Coelastrum sphaericum

Pteromonas angulosa.

Characium gracile

These organisms continue to multiply rapidly and are very flourishing for a period. The organisms which have been present in the desiccated sediment take several days to recover their normal condition. At the end of five days the Amoebae are still encysted; The members of the Bacillariaceae present are recovering, but the chloroplasts have still not returned to their normal shapes; the resting ^{cells} ~~spores~~ of Coelastrum tenuis and Coelastrum limosa are germinating and many short filaments of both these algae are present. Germinating zygospores of Spyrogyra crassa were found on ground that had been inundated for three days.

The grass present on the newly inundated sediment either floated to the surface of the water, and was blown to the side of the pool where it was disintegrated or became covered with a profuse epiphytic growth of Characium gracile (Sect. 4 P. 114). This growth was particularly luxuriant at Station IV, and it is probable that this was because, ~~many~~ the current of the pool tended to run between the entry pipe in the west bank to the outlet-draw in the South-east corner.

The macroflora (Zanichella Palustris) which occupied the central portion of pool, was covered with the

epiphytic Characium gracileps. Any detached organisms of Characium gracileps would be carried towards Station IV and attach themselves to the grass there. The organisms which return with the water, continue to multiply rapidly for about two weeks after the ground has been inundated and then through the water of the pool. The floor of the pool was observed to become covered with a reddish-brown film. This was apparent first in the ^{bottom of the} small hollows, formed by the movement of the water. Gradually it spread until the whole of the floor of the pool was covered with the film. At this period the Bacillareae present increased in numbers rapidly, and it is probable that this film was composed of the members of the Bacillareae.

namely:- Navicula sphaeroptera

Navicula platystoma

Navicula exilis

Prasinema lanceolata

Gyrosigma acuminatum.

Navicula sphaeroptera appeared more frequently than the other members of the Bacillareae.

As the members of the Bacillareae increased the other organisms which return with the water declined in number until their occurrence was comparatively rare.

After three weeks the film changed from brown to green in colour, and disappeared.

As the film disappeared *Bacillaria limosa*, *Bacillaria limosa*, *Anabaena inaequalis*, and *Spyrogyra crassa* began to appear. These algae had been dormant during the period of luxuriant growth of the Bacillariae but they now showed luxuriant growth in their turn and then they in turn die off.

SECTION 9B

Experimental irrigation of the desiccated sediment.

On September 25th 1923, samples of desiccated sediments were taken at Stations I, II, III and IV. The samples were taken at approximately six feet behind the water line and the sediment contained very little moisture. The ground from which the sediment was taken was covered with a growth of macroflora at Stations I, III and IV.

On September 20th 1925 samples of surface desiccated sediment were taken at Stations I, II, III and IV. Two samples were taken at each station; the first at four feet behind the water line and the second six feet behind the water line. The sediments at III and IV, four feet behind the water line contained more moisture (8.6% compared with less than 2%) than those at six feet behind the water line. This was due to a North wind pushing the water towards ^{Station} III and IV on the previous week.

In each case a note was made of the organisms found in the desiccated sediments after examination. The sediment was placed in a shallow dish and irrigated with sterile water.

This dish was covered with a piece of muslin to exclude any foreign matter.

The irrigated sediments of September 20th 1925 were examined:-

(a) After ~~four~~^{one} hour's immersion in water.

(b) After three hours' immersion in water.

(c) After three days' immersion in water.

The sediment of September 25th 1923 was examined after three days' immersion in water.

The sediments of Stations I, II, III and IV taken six feet behind the water-line on September 20th 1925 yielded the following:-

Amoebae sp in an encysted condition

Trachelemonas hispida

Euglena sp in an encysted condition

Navicula sphaerophora

Navicula platystroa

Navicula exilis

Loxonema lanceolata

} These organisms were in the resting stages described in Section 7.

Oscillatoria tenuis

Oscillatoria limosa

} These algae were in the resting stages described in Section 2

Free resting spores were also observed.

Anabaena inaequalis - showing hormogones.

Zygospores of Spyrogira crassa.

Scenedesmus quadricauda - two specimens were observed.

one was devoid of contents and the contents of the other were very much broken up into irregular-shaped granules.

After immersion in water for one hour practically no change was observed in the organisms.

After three hours immersion in water very little change was observed in the organisms, except that the Navicula exilis showed movement. The other members of the Bacillanaceae were shedding the particles of sediment that adhered to the mucilaginous exudation covering them.

In sediment that had been immersed for three days in water the Amoebae had not altered but the Euglena had regained their normal appearance and showed movement.

Navicula sphaerophora, Navicula platystoma and Loxocoma lanceolata had lost all traces of the ^{adherent} particles of sediment and the irregular covering of mucilage present in the desiccated sediment.

The chloroplasts however had not assumed their normal platform shapes but still retained

the shapes they had assumed when exposed to desiccation

This material yielded a profusion of short filaments of Oscillatoria tenuis and Oscillatoria limosa. These filaments were about five to six cells in length and the terminal cells of each filament were rounded. No none of the single resting cells of these Algae, which were present in the desiccated sediment, appeared to be present after three days immersion in water, it is probable that these resting cells germinated and formed these new filaments.

Many short filaments of Anabaena inaequalis about twelve cells in length were observed.

Two germinating zygospores of Spyrogyra crassa were present and in each case the filament issuing from the zygospore was two cells in length.

The samples of sediment taken from four feet behind the water line on September 20th 1925 at Station I and II were very dry, and the flora of the sediments was very similar to the flora present in sediment six feet behind the water line.

The sediments taken from four feet behind the water line at ^{Stations} III and IV contained more moisture than the sediments at Stations I and II

The amoebae were in an encysted condition and Trachelemonas lespida was in a normal condition Euglena sp were not in an encysted condition but were in their normal state

Navicula sphaerophora, Navicula platystoma, Navicula exilis and Loxocoma lanceolata were not covered with irregular masses of mucilage, but were normal in appearance except that the chloroplasts had not assumed their normal shapes.

Many short filaments of Coelastrum tenue and Coelastrum levis were present. These filaments were generally about eight cells in length. Short filaments of Anabana inaequalis were also present.

When samples of sediments from four feet behind the water line were irrigated, the diatoms present showed movement almost immediately.

The desiccated sediments taken on September 25th 1923 from six feet behind the water line contained the following organisms:-

Navicula sphaerophora.

Navicula platystoma

Navicula exilis

Nitzschia sigmoides

Gyrodinium aureolum

These were all in resting stages as described in Section 7.

After the sediment had been immersed in sterile water for three days, the diatoms had assumed their normal appearance. except that the chloroplasts had not re-assumed their usual shapes.

Many short filaments of Coellatoria tenuis and Coellatoria limesa were present and a geminoblastic zygospore of Spyrogyra crassa was observed.

From these observations, apparently the Amoebae do not easily and quickly leave their encysted condition and resume their normal form after a period of desiccation. Euglena sp however quickly returns to its normal condition when the available water supply is increased.

When an increased amount of water is available, the diatoms which had been present in the desiccated soil return to their normal condition. The smallest diatom present, Navicula exilis, shows the first signs of recovery. Probably the irregular mucilaginous exudation to which particles of sediment adhere, helps to conserve the water supply of the diatoms and also aids in the absorption of water from the surrounding sediment. The chloroplasts however, take a longer ^{eventually} time to linger

time to ~~essentially~~ recover their normal shape and colour.

The resting cells of the Cyanophyceae require only a small quantity of moisture before they germinate and produce the short filaments which are found, and apparently take about three days to form these filaments.

The zygospores of Spyrogyra crassa take longer to germinate and require more moisture to germinate than the Cyanophyceae.

Scenedesmus quadricauda does not survive the period of desiccation but persists and finally disintegrates.

SUMMARY

Summary

The chief conclusions drawn from these observations ~~made on~~ the flora of the sediments of South. Hartley. Farm Pool, may be summarised as follows:

1/ Certain of the organisms which form the microflora of the sediments of the pool, (Amoebae sp., Euglena sp., Trachelemonas hispida, Sprogyra crassa) remain in situ as the water recedes, and these persist in the desiccated sediments as cysts or aplanospores until the water level rises and the sediments are resubmerged. They then resume their vegetative life but take a considerable period varying from three days to several weeks to do so. In Euglena the cell contents contract, become granular but remain in contact with the cell wall. This agrees with the statements made by Fritch (Ref 3. P 18).

2/ Members of the Cyanophyceae also remain in situ as the water recedes and develop resting cells. As the water recedes, the newly exposed sediment is covered with a film composed mainly of Bacillaria tenuis, B. limosa, and Anabaena inaequalis. This film becomes desiccated, ^{brittle} separates into filaments. Bacillaria tenuis and Bacillaria limosa develop thick walled resting cells in their trichomes. ^{These persist in the desiccated sediment.} When the ground is resubmerged, either

85

by the rising in water level. or by experimental means numbers of short hormogones, six to eight cells in length appear. while the resting cells disappear. Hence it is probable that the resting cells have germinated and formed these hormogones

3) Other organisms, which do not enter into any definite resting stage are also capable of persisting in 'situ' throughout the period of desiccation. This applies chiefly to the Bacillanaceae (Naucula sphaeroptera, Naucula platystoma, Naucula exilis, Gyrosigma acuminatum and Loccosema lanceolata). These secrete an irregular layer of mucilage upon their cell walls, and to this adhere particles of sediment. This device is probably to conserve the moisture in the diatom and also to help in the rapid absorption of any moisture in the surrounding sediments. The chloroplasts change in colour from brown to green and assume various irregular shapes of which the meniform one is the commonest. On re-irrigation the smallest diatom Naucula exilis recovers its normal state. First.

4) Other organisms belonging chiefly to the Chlorophyceae (Scenedesmus quadricauda, Scenedesmus hyugalis, Scenedesmus obliquus, Pleuromonas angulosa, Actinastrium Kuntzei, Cyclastrum sphaericum, Protoschödoemus falcatus) are ^{apparently} incapable of withstanding

dessication and in some manner not actually observed, they advance and retreat with the water line.

Any organisms left in "situ" by the retreating water, perish
 b) As the water in the pool rises and the dessicated sediment is resubmerged, the organisms which invade the sediment with the advancing water, at first are dominant. These then show luxuriant growth.

and then gradually decrease in numbers and are replaced by those organisms which have persisted in situ in the dessicated sediment. These in turn have a period of maximum growth and then decrease numerically and are replaced by other organisms. This process is subject to constant repetition.

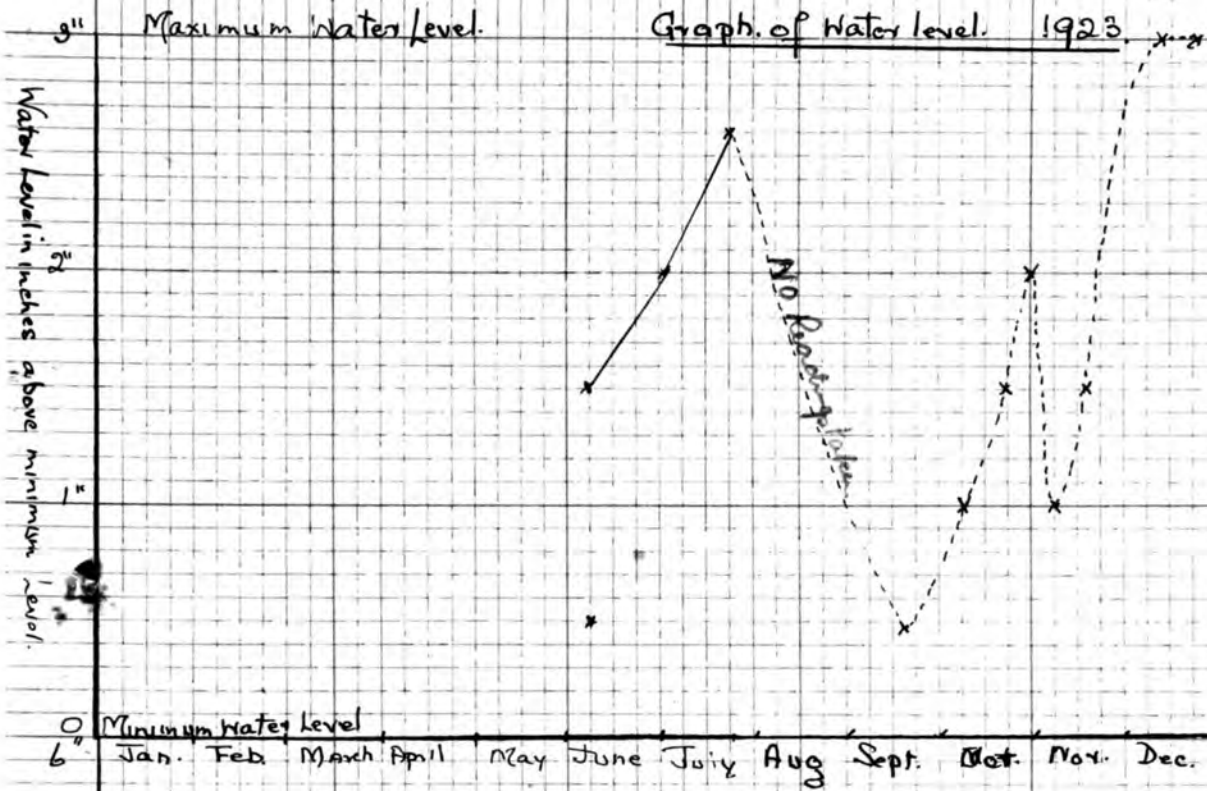
b) The sediment exposed by the shrinkage of the water of the pool was first covered by an algal film composed of members of the Cyanophyceae. This film became dessicated and brittle and disappeared. The sediment was then invaded by the Macroflora. It was first invaded by plants whose seeds had been carried there by the wind or by animals or birds. It was then invaded by plants ^{growing} on the surrounding grounds ^{which encroach inwards}. The rhizomatous plants (grasses) encroach more quickly than the other plants.

It thus appears that many of the algae, namely the Bacillareae, Cyanophyceae and a few species of the Chlorophyceae are well equipped to withstand a considerable period of desiccation. These algae apparently will be capable of surviving in the sediments of pools which completely dry up at some period of the year. They ^{also} will be able to survive a period of desiccation during the transmission of sediment from one pool to another, by birds and animals. This will be of considerable importance to their distribution.

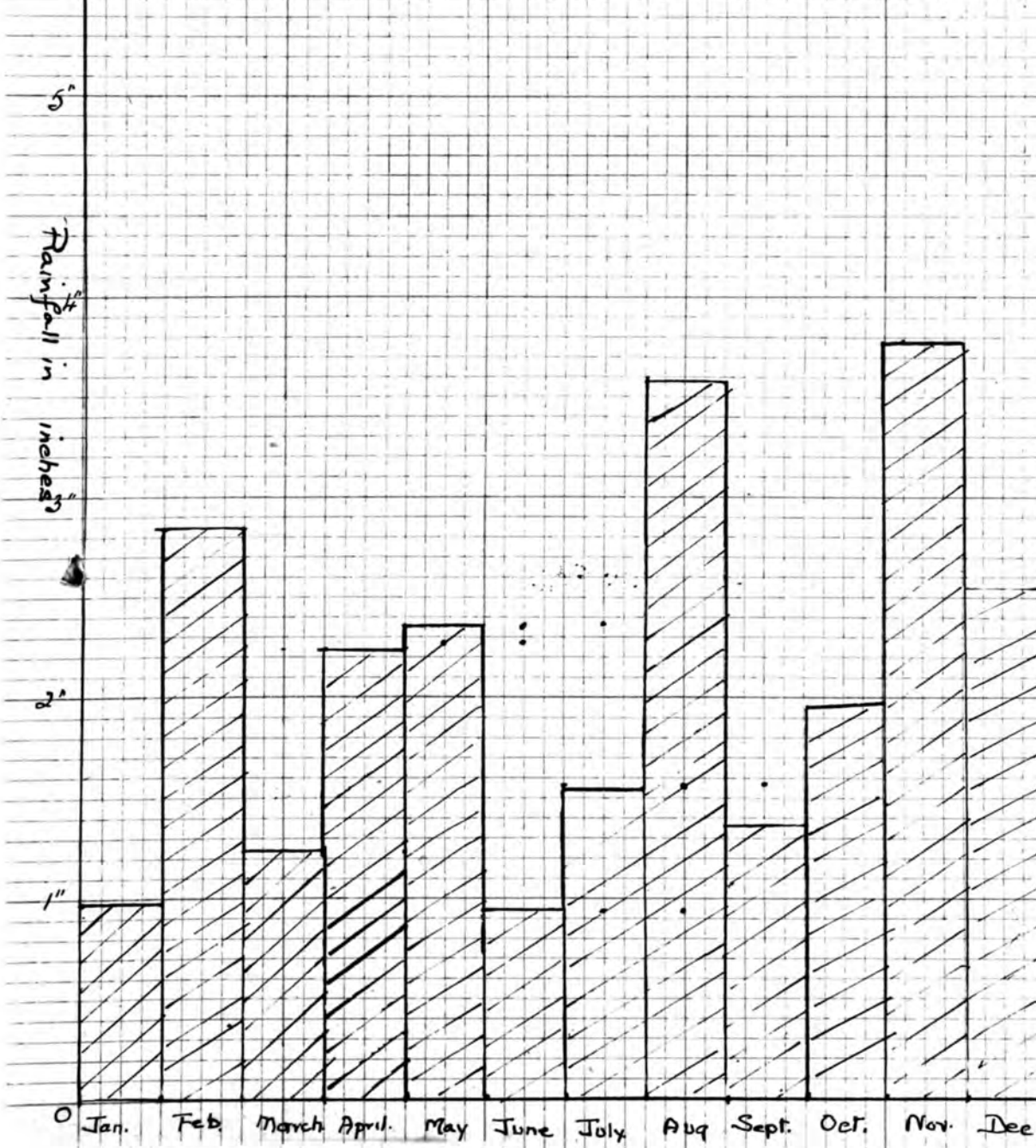
The majority of the members of the Chlorophyceae found in the sediments of the pool, show a tendency to advance and retreat with the water. They will ^{be} therefore at a considerable disadvantage in comparison to the other algae, and apparently will be unable to persist in sediments which are exposed to a considerable period of desiccation, as would be experienced by the sediments of a pool which dries up for long periods, or by sediment carried on the feet of animals and birds in going from one pool to another.

This investigation was suggested by Dr B. Millard Griffiths
Head of the University Department of Botany at
Durham, and the work has been carried
out under his advice and criticism.

Graph of Water level. 1923

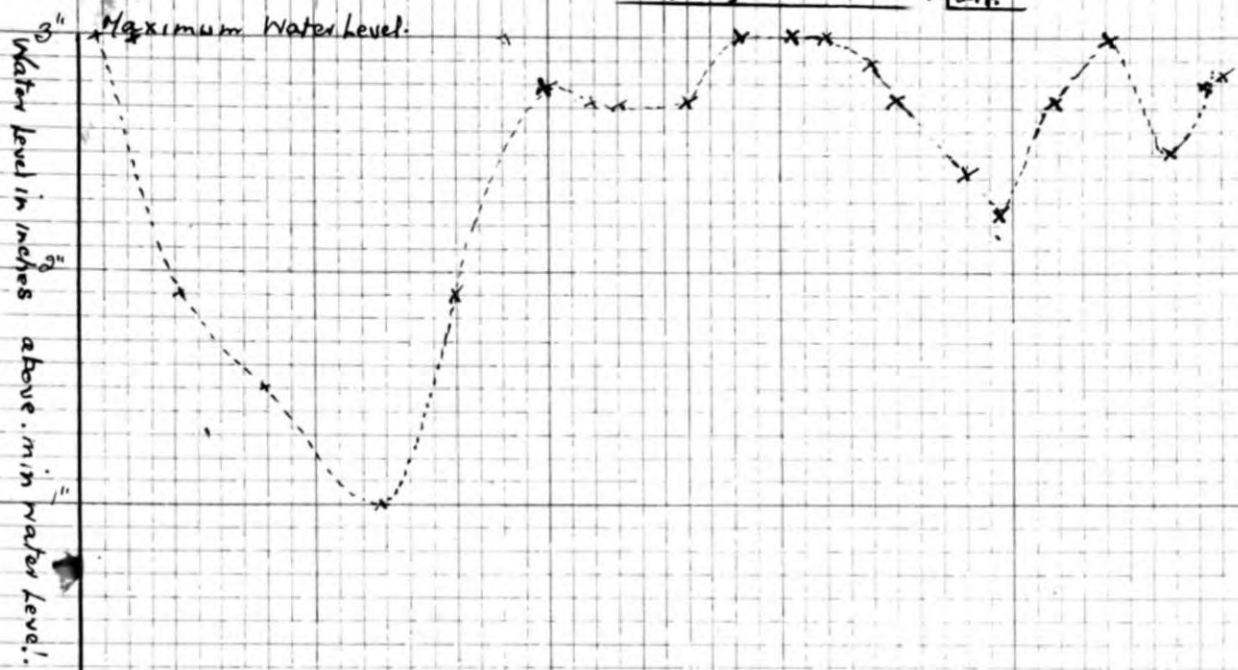


Graph of Rainfall 1923



Graph of Water Level 1924.

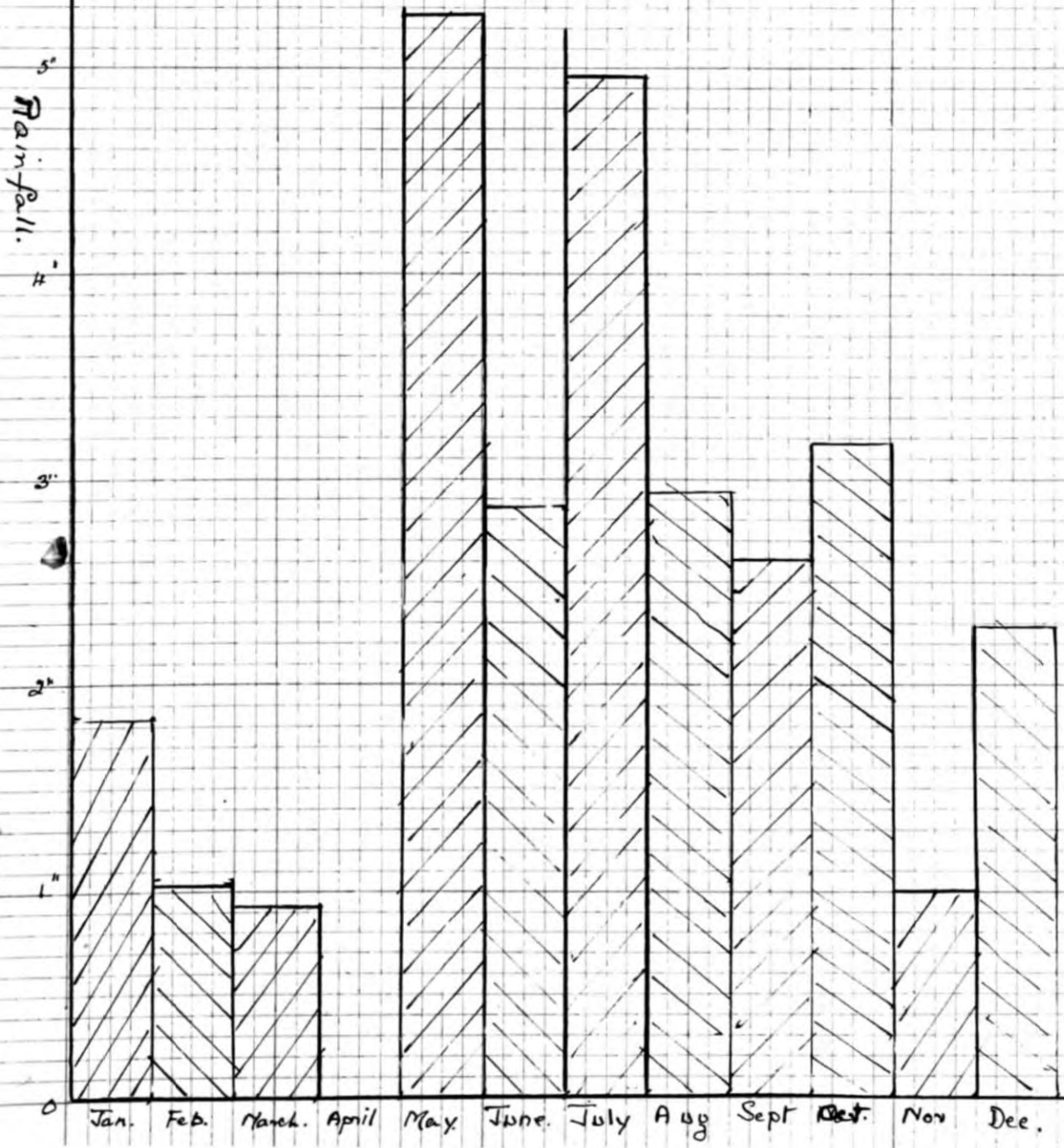
PLATE IV



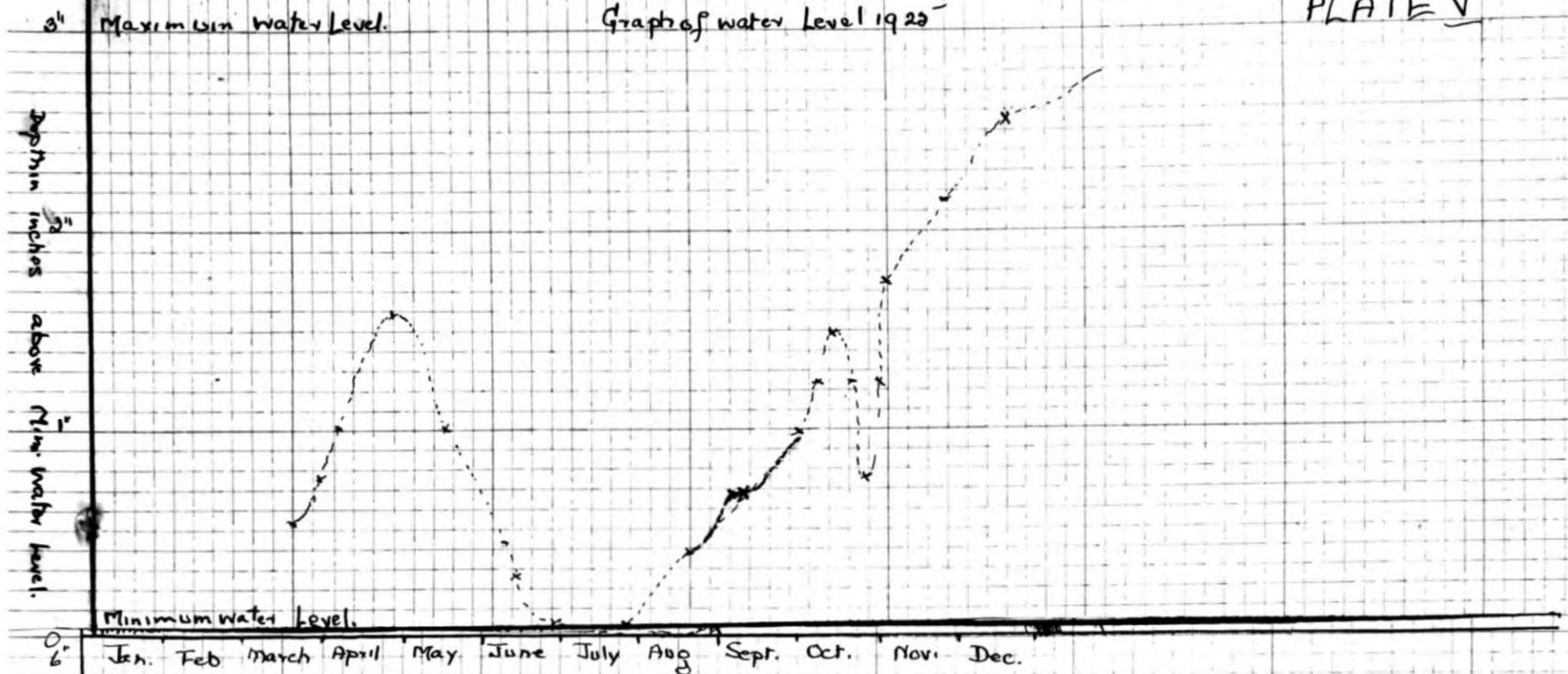
Minimum Water Level.

Jan. Feb. March April May June July Aug. Sept. Oct. Nov. Dec.

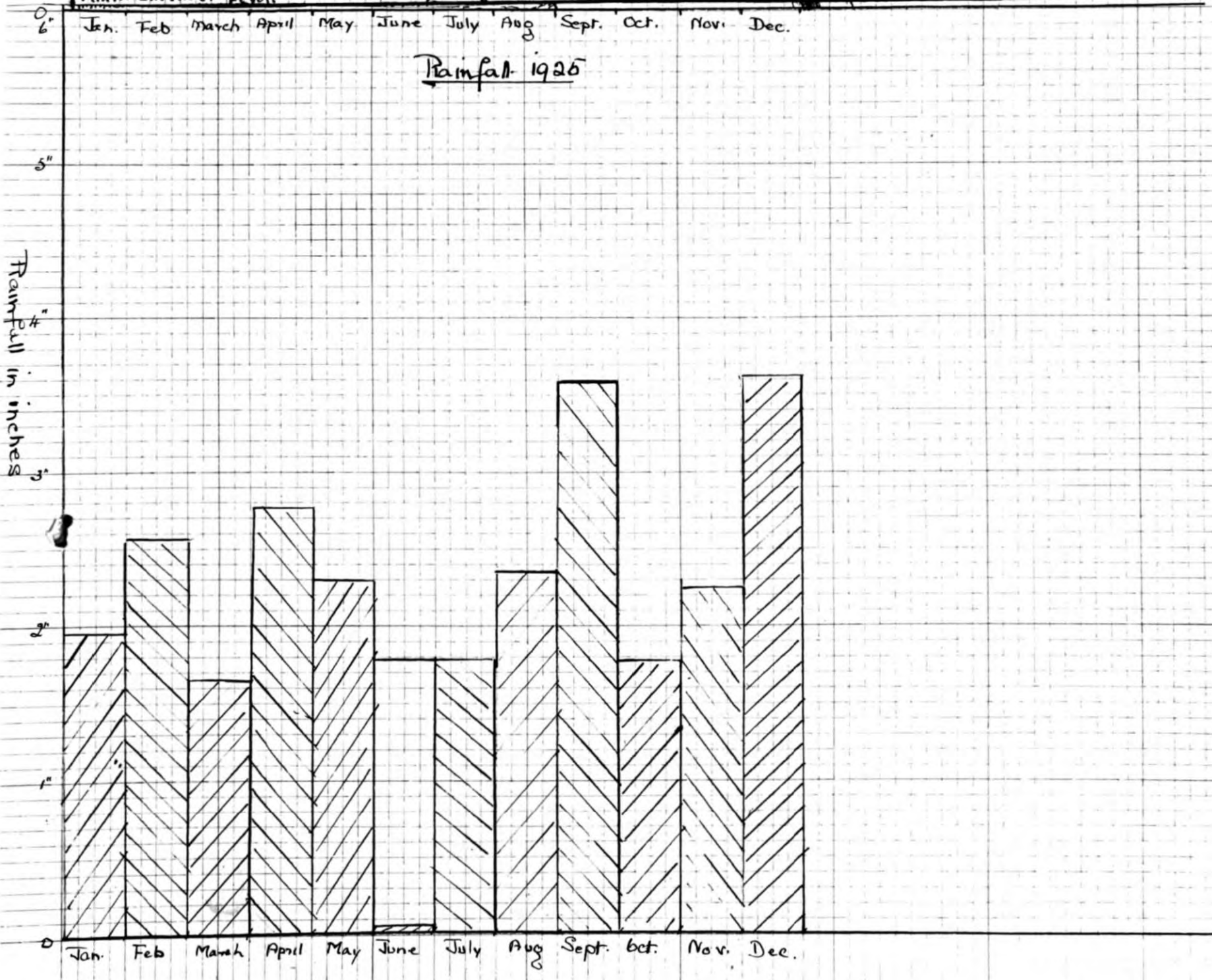
Graph of Rainfall 1924.



Graph of water level 1925



Rainfall 1925



Comparative
Rough Analysis of the sediments

	STATION 1	STATION 2	STATION 3	STATION 4
Sand.	88	84	82	82.
Carbonate of Lime	2 nd Most.	Least.	most.	3 rd Most
Iron hydrate.	Least.	most.	3 rd most	2 nd Most
Clay.	—	—	—	—
Carbonaceous matter.	3.7	3.4	4.0	6.0.

Water - 6 parts carbonaceous matter per 10,000.

Description of Plate 7

- 1) *Navicula platystoma*. Erenb. taken from desiccated (value view) sediment, showing adherent particles of sediment and mucilage x 1000.
- 2) *Brucellaria tenuis* Ag. taken from desiccated sediment, showing a gap from which resting cells have escaped.
- 3) *Navicula sphaerophora*. Kützling (value view) taken from desiccated sediment, showing adherent particles of sediment and mucilage. x 1000
- 4) *Navicula sphaerophora*. (circle view) of $\bar{3}$. x 1000
- 5) *Eunotia pectinalis*. Kütz. (circle view) taken from desiccated sediment, show twenty spore-like bodies.
- 6) *Eunotia pectinalis* Kütz (value view of same).
- 7) Germinating zygospore of *Spirogyra crassa*.

PLATE 7.

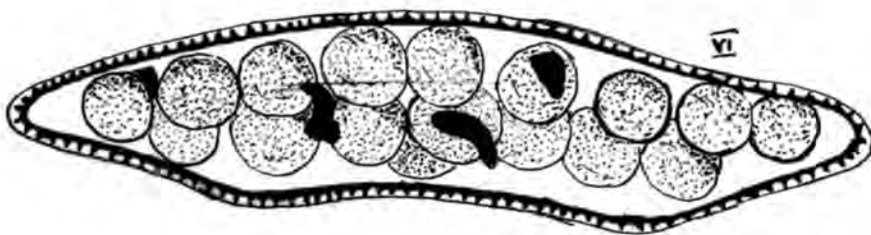
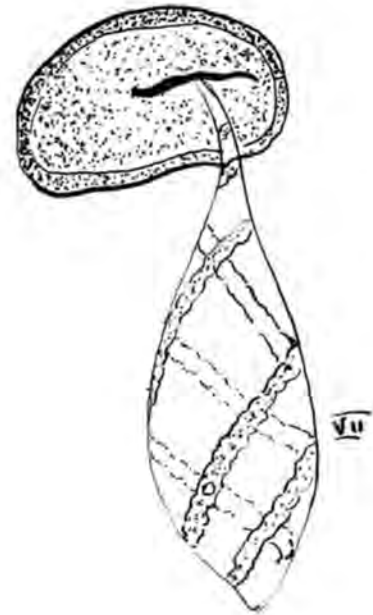
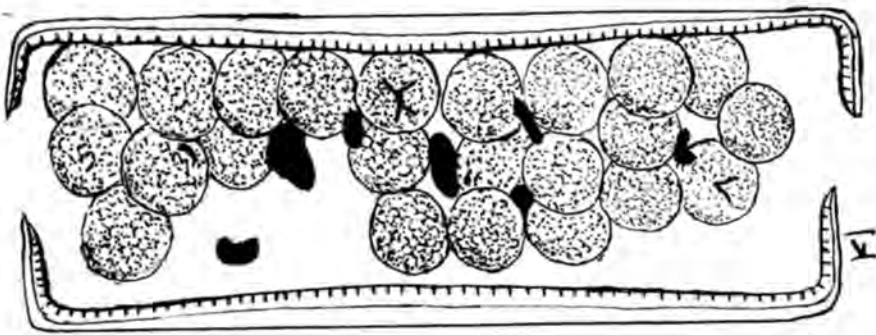
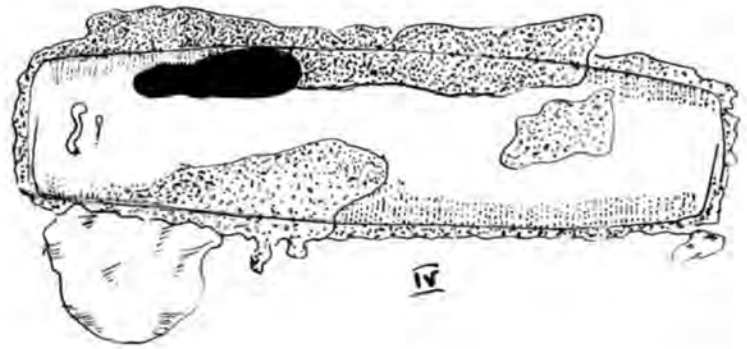
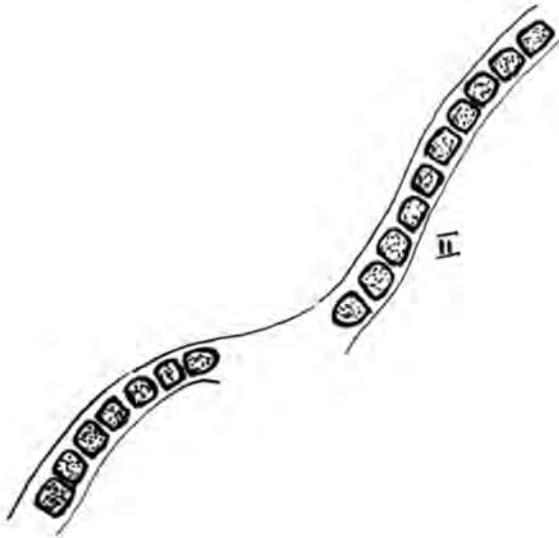
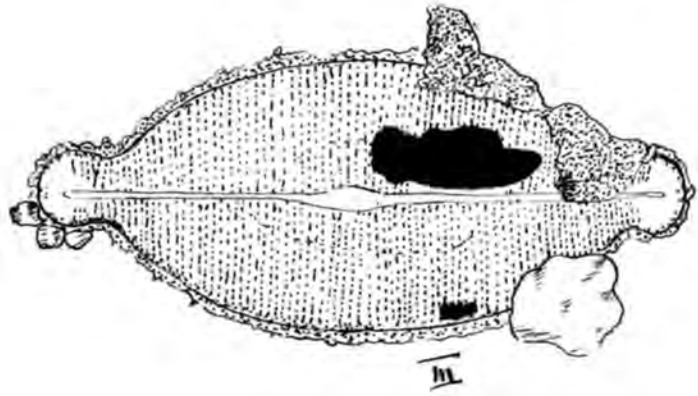
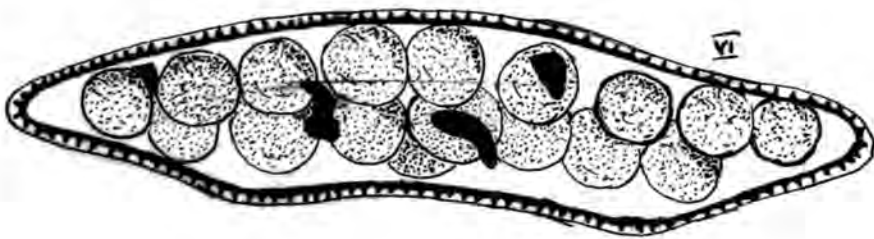
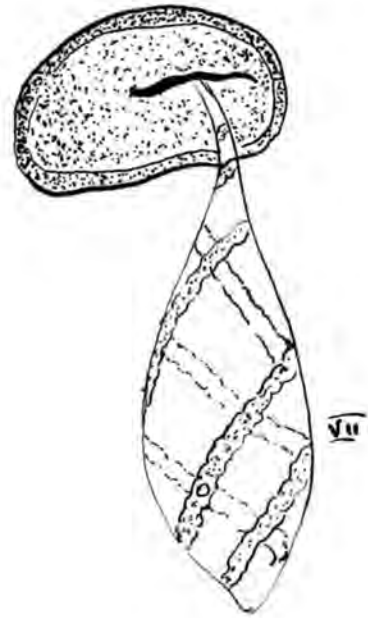
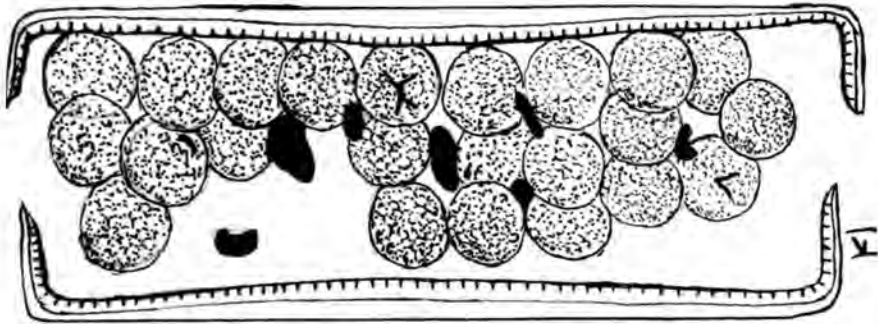
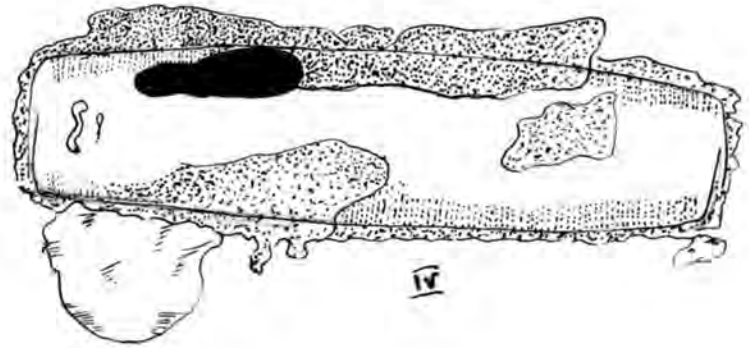
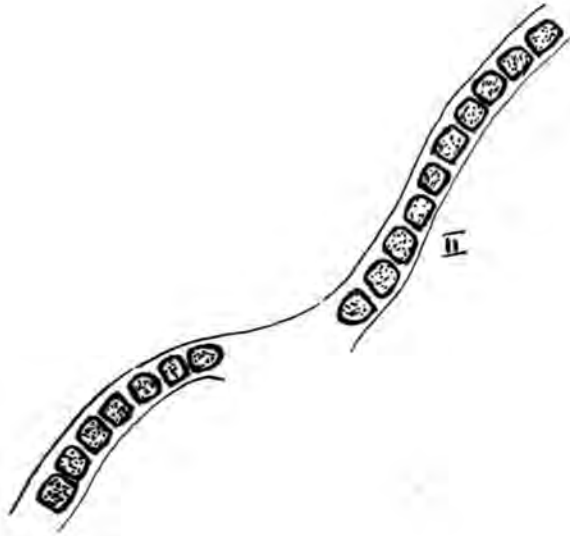
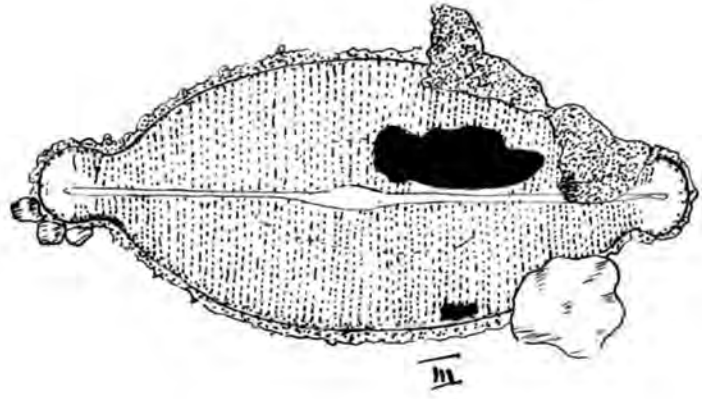


PLATE 7.

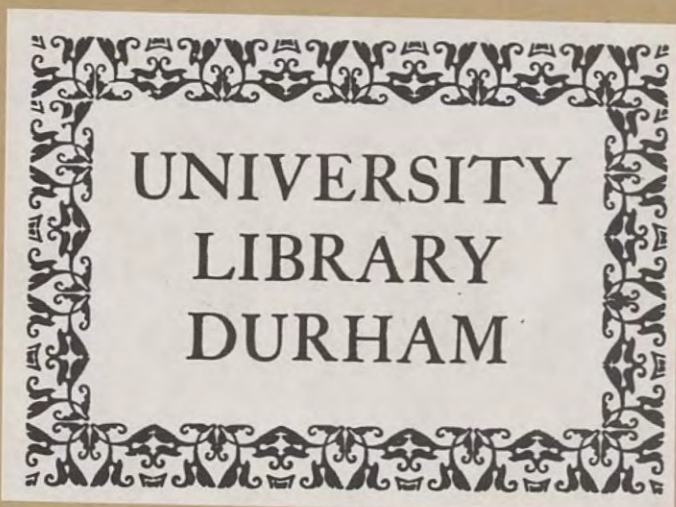


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P14



[L58]
+ M.Sc. 1

1923 - 1925

Detailed Records of the occurrence
of Species in the Sediments of -

South Hasley Farm Pool, in Whitley Bay

Northumberland

Hilifreda Sue B.Sc.



1925

STATION I 1925

	March 14	March 17	April 19	April 28	June 3 rd	June 26	Sept 13	Sept 20 1' in front of station water	Sept 20 1' in front of station water	Sept 20 1' in front of station water	Oct 3 rd	Oct 11	Oct 18	Oct 25 th	Nov 1 st
<i>Limnolae</i> sp.															
<i>Trachelomonas hispida</i>															
<i>Arcella vulgaris</i>				r	r							m			
<i>Euglena</i> sp.	r		m		mm	r			r	r			r		
<i>Gymnodinium</i> sp.															
<i>Nitzschia sigmoides</i>															
<i>Limnospira ovalis</i> v. <i>pediculus</i> on <i>Nitzschia sigmoides</i>															
<i>Navicula sphaerophera</i>	mm	m	m		mm	m		mm	r	r	r			r	
<i>Navicula platystoma</i>	mm	mm	mm		r	m		mm	mm	r	m		r		
<i>Navicula exilis</i>			r	r	r	r				mm	m				
<i>Characium gracile</i>	r	r	r	r	r	r				r	m				
<i>Loxoneis lanceolata</i>	mm	m	mm	m	r				m						
<i>Fragilaria capucina</i>	m	r	r		r										
<i>Tabellaria flocculosa</i>	m	r			r										
<i>Gyrodinium acuminatum</i>	m	r	m		r									r	
<i>Coelastrum tenue</i>		r					r	r	m						
<i>Coelastrum limosa</i>		mm													
<i>Lyngbya aeruginosa</i>	r	r													
<i>Limnospira irregularis</i>		r					r	r	m						
<i>Plectononcus angulosa</i>											m	mm	mm		
<i>Chlamydomonas</i> sp.			r								m	mm	mm		
<i>Scenedesmus quadricauda</i>	r					mm		r	mm	m	r	m	mm		
<i>Scenedesmus hyalinus</i>						mm		mm	r	r	m	mm			
<i>Scenedesmus obliquus</i>								r	r	r		r			
<i>Ankistrodesmus falcatus</i>															
<i>Actinastrum hantzschii</i>												m			
<i>Coelastrum sphaericum</i>															
<i>Langsdorffia ovalis laevis</i>															
<i>Spyrogyra crassa</i>								r	r						
<i>Cladocium acerosum</i>		r											r		

STATION 2 1925

	March 15 th	March 17 th	April 19 th	April 29 th	June 3 rd	June 26 th	Sept 13 th	Sept 20 th before 10:00 before 10:00 14' before 10:00 14' before 10:00 14' before 10:00 14' before 10:00	Sept 20 th 14' before 10:00 14' before 10:00 14' before 10:00	Sept 20 th 14' before 10:00 14' before 10:00 14' before 10:00	Sept 24 th	Oct 3 rd	Oct 11 th	Oct 18 th	Oct 23 rd	Nov 1 st
<i>Amoebae</i> sp																
<i>Trachelemonas hispida</i>						✓	✓		✓	✓						
<i>Arella vulgaris</i>	✓												✓			
<i>Euglena</i> sp						m	✓	mm	m	mm	✓	R	m	m		
<i>Gymnodinium</i> sp												✓	✓			
<i>Nitzschia sigmoides</i>							✓						✓			
<i>Ampetora ovalis</i> v <i>pediculus</i> on <i>Nitzschia sigmoides</i>						m										
<i>Navicula sphaerophora</i>	m	✓		✓	✓	✓	✓	R	✓				✓			
<i>Navicula platystoma</i>	m	✓	m		✓	✓								m		
<i>Navicula exilis</i>	✓			m										mm		
<i>Characum gracile</i>	mm	✓	✓	R	✓						m					
<i>Loxoneura hancicollata</i>	m	✓	✓	R	mm	✓	✓	✓	m			✓				
<i>Fragilaria capucina</i>			✓	✓	mm											
<i>Tabellaria fluctuosa</i>															✓	
<i>Gyrosigma acuminatum</i>	✓	✓	✓		✓			✓						mm		
<i>bracillata tenuis</i>	mm					✓	✓	✓								
<i>bracillata lunata</i>						✓					✓	mm				
<i>Lingulya ceruginea</i>	mm	mm						✓								
<i>Amalania inequalis</i>					✓	✓		✓		✓						
<i>Pterononas angulosa</i>													mm	mm		
<i>Chlamydomonas</i> sp													mm	m		
<i>Scenedesmus quadricauda</i>						✓	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
<i>Scenedesmus byugalis</i>							mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
<i>Scenedesmus obliquus</i>								mm	mm	mm	mm	mm	mm	mm	mm	mm
<i>Antennodiopsis falcatus</i>															✓	
<i>Actinastrum Hanbyckii</i>															mm	
<i>Lullulastrum sphaericum</i>																
<i>Lagenhemia tralatensis</i>																
<i>Spizogira crassa</i>						m							✓			
<i>Cladocum acerosum</i>													✓	m		

STATION 3 1925

	March 15 th	March 17 th	April 19 th	April 20 th	June 20 th June 26 th	Sept 13 th	Sept 20 th in water in pond	Sept 20 th 4' in water water line	Sept 20 th 1' in front of water line	Sept 24 th	Oct 3 rd	Oct 11 th	Oct 16 th	Oct 23 rd	Nov 15 th
<i>Limnoloba</i> sp.	✓	✓✓					✓ R								
<i>Trachelomonas hispida</i>						✓							✓		
<i>Arella vulgaris</i>		✓✓✓		✓✓✓ m											
<i>Euglena</i> sp.	✓✓			✓ ✓ ✓ ✓						✓	✓		✓		
<i>Gymnoclinium</i> sp.															
<i>Netzschia sigmoides</i>	✓✓														
<i>Limnoloba ovalis</i> v. <i>pedunculata</i> in <i>Netzschia</i> sp.						✓✓✓					✓✓				
<i>Navicula sphaeroptera</i>	mm.	mm.		mm mm			✓			✓✓	✓✓				
<i>Navicula platysterna</i>		✓		mm mm	mm	✓	✓	✓				✓✓✓			
<i>Navicula exilis</i>	✓✓✓	✓		m.	m			✓	✓			✓✓✓			
<i>Characium gracile</i>		✓		✓	m			✓	✓				m		
<i>Cocconeis lanceolata</i>	mm			✓ mm	✓✓		✓ R	✓		✓✓			mm		
<i>Fragillaria capucina</i>		✓✓		✓✓	✓✓			✓							
<i>Talellaria flocculosa</i>		✓			m			✓							
<i>Gyrodinium acuminatum</i>	mm	✓		✓ mm	✓✓			mm							
<i>Coelastrum tenue</i>							✓ R								
<i>Coelastrum limosa</i>		✓ R													
<i>Cynglya denigra</i>		mm		✓✓											
<i>Unabaena inequalis</i>		✓			mm		✓ R								
<i>Pleurosigma angulosa</i>						m.				m.	m	mm	mm	mm	
<i>Chlamydomonas</i> sp.		✓✓		✓ ✓										m.	
<i>Scenedesmus quadricauda</i>		✓✓		✓ ✓✓	mm mm		✓ D	mm	mm	mm	mm	mm	mm	mm	
<i>Scenedesmus hyugalis</i>		✓✓✓			mm		✓ D	mm	m	mm	mm	mm	mm	mm	
<i>Scenedesmus obliquus</i>								✓		mm	mm	✓			
<i>Achnanthes falcata</i>										✓		✓✓			
<i>Achnanthes Hantzschii</i>															
<i>Coelastrum sphaericum</i>															
<i>Longiclavula waikanaensis</i>															
<i>Spyrogira crassa</i>															
<i>Chlamydomonas acerum</i>					m								✓		

STATION IV, 1925

	March 15/25	March 17/25	April 19/25	April 29/25	June 3/25	June 26/25	Sept 15/25	Sept 20/25 11:00 AM 11:00 AM 11:00 AM	Sept 20/25 11:00 AM 11:00 AM 11:00 AM	Sept 20/25 11:00 AM 11:00 AM 11:00 AM	Sept 29/25	Oct 3/25	Oct 11/25	Oct 18/25	Oct 23/25	Nov 1/25
Amoebae Sp.	m	✓														
Amoebae { Trachelimonas fusca	✓✓	✓✓		✓			✓									
Amoebae { Arcella vulgaria		✓														
Flagellata Euglena Sp.				m		✓		r	m		✓	✓	m			
Peridinium Gymnodinium sp.																
Milneschia sigmoidea				✓✓	✓✓											
Cynophora ovalis v. pedunculata in Olitschia sig. mordax.													m			
Nauculea sphaerophora.	m m m			m m m	m	m m.		r	r	✓	r	m	m			
Nauculea platystoma	m m m	✓		m m m		m m.		m	✓	✓	✓	m	m			
Nauculea exilis	m	✓		r				m			✓	m	m			
Characium gracile	✓✓			✓		✓	✓✓				✓	✓	m	m m		
Loxonema lanceolata	m m m			m.	✓✓		✓	✓	✓				✓			
Fragilaria capucina				✓✓		✓										
Tabellaria flocculosa.		✓														
Gyrodinium acuminatum	m m m	m			✓											
Coellatoria tenuis		m m		✓✓	m.	m m.		✓	✓	m.	✓✓	✓	m			
Coellatoria limosa		m m.				✓										
Hynglyca viridula		✓				✓✓	✓✓			✓						
Amalthea inaequalis														✓		
Pteromonas angulosa.							m m					m m.	m m m	m		
Ichlamydomonas sp.	m			✓			m.							✓		
Scenedesmus quadricauda	✓✓					✓	m m		m m m	m.	m.	m m m	m m	m		
Scenedesmus byugatus.							m m.		m m			m m m	m m	m.		
Scenedesmus obliquus												✓	✓			
Ankistrodesmus falcatus.	✓✓															
Actinastrium Hantzschii												✓				
Coelastrum sphaericum.																
Lagodon watslawensis																
AKONTAE { Spyrogira crassa.																
AKONTAE { Closterium acerosum.		✓						✓						✓		

South Hartley Farm Pool.

Northumbria.

1923

STATION I 1923.

	June 9 th Wet	June 9 th Dry	June 20 th	3 Sept 15 th	Sept 25 th 2' in pool	Sept 25 th Edge of & pool	Oct 6 th	Oct 18 th	Oct 20 th	Nov 3 rd	Nov 17 th Wet	Nov 17 th Wet 1' from limp post	Dec 15 th
<i>Amoebae</i>		r		3		3			m	m h			m R
<i>Trachelemonas lupida</i>		r										m	
<i>Amoeba vulgaris</i>					m			m					
<i>Euglena sp</i>					m	r r	m		r	r	r r r	m	
<i>Gymnodinium sp</i>													
<i>Nitzschia sigmoides</i>				r		r r r		r r m		m		Dead	r
<i>Amphora ovalis ripidulosa</i>		r		r				m r					
<i>in N. sigmoides</i>													
<i>Navicula sphaerophora</i>		r			r	r	r r r		m	m			
<i>Navicula platystoma</i>													
<i>Navicula exilis</i>		r			m	r							
<i>Characium gracile</i>	m m	r		m m	m	r				m			
<i>Wocorema lanceolata</i>	r						r						
<i>Fragillaria papuensis</i>	r												m
<i>Talassaria flocculosa</i>	r							m m					
<i>Gyrosigma acuminatum</i>	m m		r	m			m m	m R	m				
<i>Coelastrum tenue</i>	r					r r		m	m				
<i>Coelastrum limosa</i>													
<i>Hydrolybia aeruginosa</i>													m
<i>Anabaena inaequalis</i>													
<i>Plectononcus angulosus</i>													
<i>Chlamydomonas sp.</i>													
<i>Scenedesmus quadricauda</i>	r		m	m m	m m m	m m	m m	m m	m				
<i>Scenedesmus lyngbyalis</i>	r			r	m m	m m							
<i>Scenedesmus obliquus</i>	r				m				m				
<i>Actinostrodium falcatus</i>													
<i>Actinostrodium Hantzschii</i>	r			r	r								
<i>Coelastrum sphaericum</i>	r												
<i>Largeleimica hvalis laevis</i>													
<i>Spyrogyra crassa</i>				r	m m	m m				m m m			
<i>Chlorella aceratom</i>					r		r		m	r	r r		

STATION 2 1923

	June 9 th Wet	June 9 th Dry	June 29 th	Sept 18 th	Sept 25 th 2' in pool	Sept 25 th Edge of pool	Oct 6 th	Oct 18 th	Oct 20 th	Nov 3 rd	Nov 17 th Wet	Nov 17 th 1' further back	Dec 5 th
<i>Amoebae.</i>									r r	r R	r R	r R	r R
<i>Trachelononax lupida</i>											m		m
<i>Arcella vulgaris</i>													
<i>Euglena</i> sp.				mm					m	m	mm	m	
<i>Gymnodinium</i> sp.													
<i>Mitochondria signoides</i>		r											
<i>Amphora ovalis</i> v. <i>pediculus</i> or <i>N. signoides</i>										r r		r	m
<i>Nauicula sphaeroptera</i>													
<i>Nauicula platystoma</i>													
<i>Nauicula exilis</i>		r			r		m	m	m			r	
<i>Characium gracile</i>	r			mm	mm				r				
<i>Loxonema lanceolata</i>													
<i>Fragilaria capucina</i>	r												
<i>Tabellaria flocculosa</i>													
<i>Gyrodinium acuminatum</i>	r				m	r	r	r					
<i>Coelastrum tenue</i>							m	m					m
<i>Coelastrum lutescens</i>								m		r r r			
<i>Hydrocolea aeneoquies</i>													
<i>Anabaena inaequalis</i>													
<i>Pleurosigma angulosa</i>													
<i>Chlamydomonas</i>													
<i>Scenedesmus quadricauda</i>	r	r		mm	mm	mm		r r r	r r	r r	r r	r r	
<i>Scenedesmus hyalinus</i>	r												
<i>Scenedesmus obliquus</i>													
<i>Limnocalanus macrurus</i>													
<i>Actinostichum hantzschii</i>	r												
<i>Coelastrum sphaericum</i>													
<i>Longitarsus vladislavensis</i>													
<i>Spyrogyra crassa</i>				r r	mm	r r							
<i>Chlorella acerisum</i>				r	m		m	r	r				

STATION 3 1923

	June 9 th wet	June 9 th dry	June 29 th	Sept 18 th	Sept 25 th 2' in pool	Sept 28 th Edge of Pool	Oct 6 th	Oct 16 th	Oct 25 th	Nov 3 rd	Nov 17 th wet	Nov 17 th 1' from bar	Dec 5 th
<i>Limnobot</i>				r	m	m			m	r	r		m
<i>Trachelemonas liopida</i>								r					m
<i>Dracella vulgaris</i>													
<i>Euglena</i> sp.							mm	r		m	r	r	
<i>Gymnodinium</i> sp.													
<i>Nitzschia sigmoides</i>		rr			rr	d	r	m	r				
<i>Limptona ovalis</i>													
<i>N. sigmoides</i>				r		r			rrr		rrr		
<i>Navicula sphaerophora</i>	r	rrr										rr	
<i>Navicula platystoma</i>													
<i>Navicula exilis</i>			m		hm		m	r	r	m			
<i>Characium gracile</i>							rr						
<i>Loxoneura lanceolata</i>		rr			r	r				r	r		
<i>Tragularia lapuana</i>													
<i>Tabularia florulosa</i>	r											rr	
<i>Gyrodinium acuminatum</i>	r						mm			mx			
<i>Coellatoria tenuis</i>							r		rr				r
<i>Coellatoria limosa</i>								hm	hm	rrr	rrr	rr	rr
<i>Lyngbya cerisea</i>							m	m					
<i>Anabaena inaequalis</i>													
<i>Plectononcus angulosus</i>													m
<i>Rhynchonella</i> sp.													m
<i>Scenedesmus quadricauda</i>	r			mm	mm	m	mm	mm	m	rr			
<i>Scenedesmus byugalis</i>				m		m	r	r	m				
<i>Scenedesmus obliquus</i>								mm	m				
<i>Antennula trochiliformis falcatus</i>		rr											
<i>Actinostrium Hantzschii</i>	r												
<i>Coelastrum sphaericum</i>													
<i>Argenteum walsbyi</i>													
<i>Spyrogyra crassa</i>													
<i>Chlamydomonas</i> sp.							mm						

STATION 4. 1923.

	June 9 th Net	June 9 th Day	June 29 th	Sept 18 th	Sept 25 th 2 nd m pool	Sept 25 th 140 fathoms	Oct 6 th	Oct 18 th	Oct 25 th	Nov 3 rd	Nov 17 th net	Nov 17 th 1 fathoms	Dec 5 th
Amoebae													
Trachelomonas hispida							m						m
Amoeba vulgaris													
Euglena sp							mm						m
Gymnodinium sp													
Nitzschia Sigmoides													
Amphiteria oralis v pectuculus				r			r						
on N Sigmoides													
Navicula Sphaeroptera						r							
Navicula exilis					mm								m
Characium gracile						r		rr					
Laccinema lanceolata								r					
Fragillaria capurina						r							
Talassaria flocculosa													
Gyrogonia acuminatum						mm	mm	mm	rr				
Coscinotia tenuis													
Coscinotia limosa									r	rrr			
Lyngbya aesignea													
Limnospira inaequalis													
Plectonon angulosa													
Chlamydomonas sp?													
Scenedesmus quadricauda													
Scenedesmus byugatus		mm		mm		m	m						
Scenedesmus obliquus		m		m		m	m						
Antennulodermis falcatus								m					
Achnanthes Hantzschii													
Laelastrum sphaericum													
Largenhemia Bratislaviensis													
Spirogyra crassa													
Cladocium acerium							mm	mm					

Summary 1923.

	June 9 th wet	June 9 th Dry	June 29 th	Sept 18 th	Sept 25 th 2' in pool	Sept 25 th Edge of pool	Oct 6 th	Oct 18 th	Oct 26 th	Nov 3 rd	Nov 17 th wet	Nov 17 th further back	Dec 5 th
<i>Amoeba</i> sp	r		r	r	h			m	r	rR	rR	rR	
<i>Trachelomonas hispida</i>	rr						r	rr		rr			m
<i>Arcella vulgaris</i>													
<i>Euglena</i> sp				rr	rrr	rrrr	rrrr	rrr	r	r	rrr	r	r
<i>Gymnodinium</i>													
<i>Netzschia sigmoides</i>	rr		rrr	rrr	rrr	rrr	rrr	m	rr	rr	r	rrr	r
<i>Pimpfira ovalis</i> v. <i>pediculus</i> on <i>N. Sigmoides</i>	rrr		r	r	rrr			rrr	rr	rr	rrr		
<i>Navicula sphaerophora</i>	rr	rr		rr	rr	rrr		r	r			rr	r
<i>Navicula platystrophia</i>				r	m		m	r	m	m			m
<i>Navicula exilis</i>		rr											
<i>Characium gracile</i>	m	r	mm	rr	m			rrr	m	r			
<i>Loxonema lanceolata</i>	rr	rrr		rrr		rr		rr	rrr	rrr	rr	r	rr
<i>Tragillaria capucina</i>	r							rrr				rrr	
<i>Tabellaria fenestrata</i>	rr												
<i>Gyrosigma acuminatum</i>	m		rr	m	r	m	rrrr	m	r				
<i>Coelastrum lenticula</i>					rr	r	m		m	m	r	r	
<i>Coelastrum lenticula</i>	r						m	r	rrr	rrr			
<i>Dynghyia axiginea</i>								rr	rr		rr		
<i>Anabana inaequalis</i>													
<i>Pteromonas angulosa</i>													
<i>Chlamydomonas</i> sp										m			
<i>Scenedesmus quadricauda</i>	r	rrr	mm	m	mm	mm	mm	mm	mm	rrr	rr	rrr	rrr
<i>Scenedesmus hyemalis</i>	r		m	r	r	rr	r	r					
<i>Scenedesmus abliguus</i>	rr			r			rrr						
<i>Ankenstodesmus falcatus</i>		r											
<i>Actinastrium Hantzschii</i>	m	r		rr									rr
<i>Coelastrum sphaericum</i>	rr												
<i>Coelastrum Bratislavense</i>	rr												
<i>Spyrogyra erassae</i>				m	mm	mm	r	r	mm				
<i>Chlorella acerosa</i>			rr	r			mm	r	r	rr	rrr	rrr	-

1924

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Handwritten notes in the right margin, including the word "Lactuca" and other illegible text.

Handwritten notes in the right margin, including the word "Lactuca" and other illegible text.

STATION 3 1924

	May 26 th	June 3 rd	June 14 th	June 22 nd	June 27 th	July 8 th	Aug 31 st	Sept 6 th	Sept 20 th	Sept 27 th	Oct 4 th	Oct 11 th	Oct 19 th	Oct 26 th	Oct 29 th	Nov 2 nd	Nov 11 th	Nov 23 rd	Dec 6 th	Dec 14 th	Dec 22 nd	
<i>Amoeba</i>																						m.
<i>Trachelemonas hispida</i>		m.							mm	mm	mm			mm				m				
<i>Anella vulgaris</i>	m.					r																
<i>Euglena</i> sp.		m	r			mm	mm	mm	mm	mm	mm	mm	mm	m		m						mm
<i>Gymnodinium</i> sp.																						
<i>Mitschia sigmoides</i>													r									
<i>Limptera ovalis</i> v. <i>pediculus</i> or <i>N. Sigmoides</i>				r																		
<i>Navicula sphaeroptera</i>		m.	m.	mm		mm	mm	mm	mm	mm	mm	mm	mm	m.		mm	mm					mm
<i>Navicula platystoma</i>		m.		mm					mm	mm	mm	mm	mm	m		m						m.
<i>Navicula exilis</i>	m.	m.	m.						m	mm	mm	mm	mm	m.		mm	mm					
<i>Characium gracilipes</i>			r	r		mm	r	mm	mm	mm	mm	mm	mm				r	mm				
<i>Loxocoma lanceolata</i>		m.	r	r		mm	mm	mm	mm	mm	mm	mm	mm	m.			r	mm				
<i>Fragilaria capucina</i>											mm	r	r				r					r
<i>Tabellaria flocculosa</i>													mm									
<i>Gyrosigma acuminatum</i>		m.	r	r		r		r	m	mm	mm	mm	mm	m.			r	mm				mm
<i>Oscillatoria tenuis</i>	m.		mm			r	r	mm	mm								r	r				r
<i>Oscillatoria limosa</i>	m					r	r							r				r				
<i>Hydrocolea ceratium</i>			r																			
<i>Amoeba</i> <i>inequalis</i>						r	r						r				r					
<i>Pleuromonas angulosa</i>		m.																				
<i>Chlamydomonas</i> sp.		m.																				
<i>Scenedesmus quadricauda</i>		m.	r				r	r	m			r					r	r				
<i>Scenedesmus byugalis</i>																		r				
<i>Scenedesmus obliquus</i>														m.			r					r
<i>Antennulodiscus foliatus</i>																						
<i>Actinodinium Hangschii</i>																						
<i>Loxostoma sphaericum</i>							r															
<i>Langenhemia tralostanensis</i>																						
<i>Spyrogyra crassa</i>			mm	m.	r																	
<i>Closterium acerosum</i>			r				mm										r					r

