

A STUDY OF THE BIOLOGY OF THE

JAMESON RESERVOIR

near

GRAHAMSTOWN, CAPE PROVINCE.

A dissertation submitted in fulfilment
of the requirements for the degree of

Master of Science

in the faculty of Science of Rhodes University

by

John F. Darbyshire.

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SUMMARY.

1. This thesis is an ecological study of a South African water storage reservoir and its tributary streams.
 2. A brief description of the reservoir, the surrounding vegetation, superficial geological strata, soils and early history of the reservoir is given in Chapter I.
 3. The surrounding vegetation is discussed in some detail in Chapter II. The zonation of the plants and the influence of water upon it are discussed.
 4. The results of the regular investigations of the physico-chemical environment are presented in Appendix 1 and the salient points noted in Chapter III.
 5. The species of algae collected are listed in Appendix 2 and in Chapter IV are discussed in relation to habitat and abundance.
 6. The animals are dealt with in a similar manner in Chapter V.
 7. Under 'Discussion and Conclusions' in Chapter VI an attempt is made to review the findings and discuss their significance.
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Mr. G. F. Walters did most of the photographic printing and

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Note: The Appendices, graphs, maps, diagrams and photographs are bound in a separate volume.

Chapter I

INTRODUCTION.

The Jameson reservoir forms part of the water storage supply for the Municipality of Grahamstown. It is situated about nine miles to the west of the city and lies in a valley of the Coldstream district on a small tributary of the New Year's river. At a lower level in the same valley is the Milner reservoir into which may run any water overflowing from the Jameson reservoir. The two reservoirs are referred to locally as the "Slaai Kraal" reservoirs. The Milner dam wall was built in 1899, while that of the Jameson reservoir was constructed in 1905.

The Jameson reservoir is approximately half a mile long and two hundred yards wide at its widest part. (See Map 1 and Photographs 1 and 2). The depth of the water may reach 36 feet close to the dam wall when the reservoir is full; but in other parts not more than 20 feet, decreasing gradually

towards the upper part of the valley to a few inches. An outlet pipe lies near the bottom of the deep part of the reservoir and through it water may be conducted first to the pump-house below the Milner reservoir, and later to the Municipal filtration plant on the outskirts of Grahamstown. The capacity of the Jameson reservoir is 130,000,000 gallons.

Two tributary streams flow into the reservoir. The one rising at Coldspring, referred to later as the 'top' stream, enters its upper eastern end, and the other, the 'oaks' stream, enters midway along the southern shore. The rainfall near the reservoirs averages 21.12 inches annually and is heaviest in the period September to March (See Table 8 in Appendix 1).

The combined catchment area of the two reservoirs is about $3\frac{1}{2}$ square miles. Most of the underlying rock of the area belongs to the Witteberg series. This is mostly a fine-grained quartzite, although there are extensive outcrops of micaceous shale and flagstones. The Witteberg quartzites, on weathering, generally give rise to a grey sandy soil which has been classified by Van der Merwe (1941) as belonging to the Eastern Province and Coastal Belt sub-group of the gley-like podsols. These are elluviated soils with a well leached A horizon and an accumulation of iron, and to a lesser extent, aluminium sesquioxides in the B horizon. There is very little organic matter or carbonate in these soils. The soil reaction is usually slightly acidic.

According to Du Toit (1928) the Witteberg quartzites yield water with a very low salt concentration, the average being about 100 parts per million. The Witteberg shales usually yield water with a higher concentration. Bond (1946) states that one of the main characteristics of water from the Witteberg shales and quartzites is the high relative concentration of the chloride and sulphate salts. The silica content is usually quite high, but there is a paucity

of bases and trace elements such as iron and manganese. Usually the water is slightly acidic with a pH value a little less than 7.

The slopes surrounding the reservoir are now covered by a sour grassland (See Photographs 3 and 4). The immediate borders of the reservoir and its two tributary streams are covered with a hydrophytic vegetation. At the head of the 'top' tributary stream at Coldspring there is a small acreage of cultivated land.

The nature of the vegetation near the site of the Jameson reservoir before the arrival of European settlers is not definitely known. It is likely that the introduction of European methods of farming soon caused some vegetational changes. Acocks (1953), referring to the conditions in the Albany Division during the fifteenth century suggested "...the vegetation of this area appears to have been a scrubby sort of mixed to sour grassveld wherever conditions were not suitable for forest or scrub-forest, and this grassveld would have replaced any forests that were destroyed...." Dyer (1937) states that "...before the advent of the white settlers most of the scrub and bush in the valleys was almost impenetrable but during the past hundred years considerable thinning has taken place by chopping out and grazing...." According to the Grahamstown Journal (1905a) all the vegetation was removed from the basins of the two reservoirs when they were built. During the course of this investigation in 1956 the hydrophytic vegetation along the south shore of Jameson reservoir was severely lopped; there was an extensive fire in part of the grassland on the surrounding slopes, and a herd of cattle was allowed to graze along the shores. Hence man and his animals still have an important influence on the adjacent vegetation.

The few trees and bushes at the eastern end of the reservoir which are characteristic of stream bank bush or low forest, e.g.

Rhus lucida and Rhus macowani, may be the surviving remnants of a larger plant community. Their presence in the valley supports a belief in recent vegetational changes.

The chapters which follow relate to data collected in the course of physical, chemical and biological studies of the water and surroundings of the Jameson reservoir, during the period February 1956 to February 1957.

Chapter II

THE VEGETATION IN THE VICINITY OF THE RESERVOIR.

Methods of Investigation. The description of the grassland slopes and the hydrophytic vegetation close to the reservoir is based on field notes and plant collections made on numerous occasions in 1956. The vegetation surrounding the entrance of the 'top' tributary stream into the reservoir was studied in greater detail. Map 2 shows the arrangement of the vegetation in this area. The plant zonation along the shores of the reservoir was studied with the aid of six line transects set at right angles to the shore-line. Diagram 1 shows the plants that were intercepted by these lines. Map 1 shows the position of these transects. Both these methods are described by McLean and Ivimey Cook (1943) .

The Grassland Surrounding the Reservoir. The dominant grasses on the upper slopes of the valley were Tristachya hispida, Alloteropsis semialata and Eragrostis capensis.

Other grasses present but only in small quantities were Cynodon dactylon, Ehrharta calycina, Heteropogon contortus and Themeda triandra.

Although grass plants predominated the number of grass species was a small fraction of the total number of plant species present. A number of low-growing bushes was found scattered throughout the grassland. The more common species were:-

Agyrolobium harveianum,
Aspalathus chortophylla,
A. setacea,
Erica glumaeflora,
Indigofera sp.,
Metalsia muricata and
Selago corymbosa.

There were a large number of herbs; of which the commonest were:-

Aristea sp.,
Helichrysum spp.,
Hypoxis spp.,
Lobelia tomentosa,
Tephrosia capensis and
Thesium spp.

The following grasses made their appearance on the lower moister slopes:-

Agrostis lachnantha,
Andropogon appendiculatus,
A. eucomus,
Aristida junciformis,
Briza minor,
Digitaria eriantha,
Eulalia villosa,
Panicum stapfianum,
Paspalum spp.,
Pentaschistis curvifolia,

Rhynchelytrum setifolium,
Setaria flabellata and
Sporobolus capensis.

Other plants found only on the lower slopes were:-

Albuca altissima,
Ficinia capillifolia,
Fimbristylis sp.,
Kyllinga melanosperma,
Lobelia spp.,
Oxalis sp.,
Pelargonium sp.,
Restio fruticosus,
Senecio sp.,
Senecio pterophorus,
Trifolium burchellianum,
Watsonia meriana, and members of the
Commelinaceae and
Orchidaceae.

The Hydrophytic Vegetation. The hydrophytic vegetation bordering the steeper north shores of the reservoir was noticeably more discontinuous than that on the south shore. (Compare Photographs 10, 11 and 12). Pearsall (1922) as a result of extensive observations in the English Lake District, stated that the zonation of vegetation is primarily dependent on the kind and degree of silting. He thought that variations in the same lake were due to the effects of different degrees of wave action and silting. Previously, Pearsall (1917) had also pointed out that there is a marked difference between the leeward and windward shores of Esthwaite Water. The former is more subject to wave action which cuts a sloping terrace, mainly below the water-line, continuous outwards into the lake through accumulation of material washed back by the undertow of the waves. This terrace, at first gently graded, ends in a steeper

slope. The coarseness of the detritus varies correspondingly from larger elements in the upper portions to finer ones carried down the slope and deposited farther out on the floor of the lake. Waves sweep, too, along the shore scouring the shallows and depositing silt in the more protected bays.

The prevailing winds at the Jameson reservoir were from the south-easterly and south-westerly directions, with westerly winds in July and August. The steep slope on the north shore sheltered the reservoir from northerly winds. Hence the north shore was subjected to more wave action than was the south shore. This applied particularly to the two headlands on the north shore. The cross-sectional views of the reservoir in Photograph 13 show only slight signs of the formation of a wave terrace, possibly because the wave action was neither sufficiently powerful nor of sufficient duration. However, certain steep sections of the more easterly headland on the north shore were undercut in 1956 and portions of it were seen to collapse into the water. These areas were unsuitable for colonisation by most Phanerogamic plants. On the leeward north shore there were two main stony zones situated on the headlands. There were no comparable areas on the windward south shore. Most of the silt accumulated in the wind-protected bays, and at the mouths of the tributary stream (See Photograph 5). Most Phanerogamic plants favoured the silty deposits; very little plant life was found among the stones (See Photographs 11 and 12).

The entrances of both streams into the reservoir were surrounded by deltas which remained damp after the fall of water level of the reservoir had left them exposed to the air. Reedswamp and marshy vegetation developed more freely in these moist areas (See Map 2). Similarly the relatively moister conditions which prevailed in the furrows draining the slopes of the grassland favoured the distribution of

such a hydrophytic grass as Eragrostis curvula along the lines of the furrows, and the increase in reedswamp and marshy vegetation near the entrance of the furrows into the reservoir.

These observations support Pearsall's view (1917) that the distribution of aquatic plants is determined mainly by the nature of the bottom deposit of the reservoir and streams.

A. (i) The hydrophytic vegetation surrounding the reservoir.

J. F. V. Phillips (1931) distinguished four groups of hydrophytic plants. These groups were:-

- a) the semi-aquatic plants
- b) the reedswamp plants
- c) the plants with floating leaves and
- d) the submerged or partly-submerged plants.

These four types of hydrophytic plants were found at the Jameson reservoir and Diagram 2 in Appendix 2 shows the typical zonation with the chief species in each zone. It was only at certain restricted localities that all the zones depicted in this diagram were coincident.

a) The semi-aquatic plants. Bews (1920) first used the term 'semi-aquatic' to include all light-demanding species which occur near to the margin of the free water surface. This includes representatives of the scrub forest and fynbos as well as many so-called marsh plants.

The few representatives of the scrub forest, probably relics of a more extensive growth, were confined to small clumps at the eastern end of the reservoir. A few trees reached a height of fifteen to twenty feet but the majority were low-growing bushes. The commonest were:-

- Cassine sp.,
- Carissa bispinosa,
- Euclea lanceolata,
- Gymnosporia buxifolia,
- Lycium campanulatum,

Melianthus comusus,
Myrica conifera, and
Rhus spp.

The fynbos plants were more numerous and widespread. Occasional bushes of Cliffortia spp. and Anthospermum spp. and small stands of Leptocarpus paniculatus and Tetraria cuspidata were found on the edge of the hydrophytic vegetation adjoining the reservoir (See Photograph 6). A few bushes of Indigofera sp., Podalaria burchellii and Rubus pinnatus were also present.

The following herbaceous plants were found amongst these bushes:-

Acalypha peduncularis,
Bulbine alooides,
Crassula spathulata,
Centella coriacea,
Commelina africana,
Geranium caffrum,
Gunnera perpensa,
Kniphofia uvaria,
Ranunculus multifidus, and
Zantedeschia aethiopica.

An unidentified moss and the ferns Blechnum australe, B. altenuatum, and Cheilanthes hirta were found in the deeply-shaded positions.

The grasses Eragrostis curvula, Pennisetum macrourum, Cymbopogon marginatus, and Danthonia cincta with Mariscus owani often formed a belt separating the representatives of the fynbos from the semi-aquatic marshy plants lining the immediate edge of the water. The members of the Cyperaceae and Juncaceae, found near the water's edge were:-

Carex zuluensis,
Cyperus tenellus,
Fuirenia hottentota,
Mariscus congestus,

Pycnus lanceus,
Scirpus cernuus,
Scirpus costatus,
Scirpus ludwigii,
Scirpus palludicola,
Scirpus prolifer,
Scirpus rivularis,
Juncus capensis,
Juncus dregeanus,
Juncus lematophyllus,
Juncus oxycarpus and
Prionium palmita.

Although these members of the Cyperaceae and Juncaceae were mainly responsible for the characteristic appearance of this zone Monerma cylindrica, Panicum repens, Polygonum tomentosum, Ilysanthes dubia, Limosella spp., Grammatotheca erinoides and Wahlenbergia procumbens were common. A few of the herbs which were found amongst the fynbos representatives were also present here.

b) The reedswamp plants. The reedswamp plants were usually found growing with the lower part of their stems immersed in shallow water but with their leaves and inflorescences borne well above it. Although the reedswamp plants were usually taller it is sometimes difficult to separate them from the semi-aquatics. The reedswamp plants were found growing on the moist soil at the water's edge, and the semi-aquatic plants often colonised the shallow water.

The reedswamp plants present were:-

Typha capensis,
Phragmites communis,
Cyperus fastigiatus,
C. textilis, and
Eleocharis limosa.

Deposits of organic detritus formed from the leaves and stems of these plants raised the soil surface immediately around them. As the water receded they were seen standing on slight hummocks.

c) The plants with floating leaves. These plants were rooted in the mud of the shallow waters but the leaves floated on the water surface. The species present were Aponogeton kraussianum and Limnanthemum thunbergianum. Usually they were found in close association with and in front of the reedswamp plants in the bays sheltered from the wind, and sometimes they intermingled with the looser outer part of the reedswamp vegetation.

Both species were amphibious in the sense that they continued to exist whether the sub-stratum was submerged or not. Their land forms had much shorter stems and smaller laminae than the water forms. In the drought period these plants were left above water on small hummocks similar in form to those of the reedswamp.

Limnanthemum thunbergianum* can also form adventitious roots usually an inch or so below the floating leaves. The power of producing a large number of adventitious roots must facilitate the colonisation of new areas by this species. No adventitious roots were observed on the petioles of Aponogeton kraussianum.

d) The submerged or partially submerged plants. The only representative of this group was one algal species Nitella mucronata (See Photograph 39). It was normally found close to the edge of the reservoir in shallow water.

Noteworthy was the absence of Angiosperms especially any species of Potamogeton, from this group.

* As an experiment a few of the Limnanthemum leaves were suspended in the top stream with all trace of the stem removed. By the tenth day numerous small roots had formed along the whole of the cut surface of the leaf. One leaf with the stem removed which was suspended in the same place for a fortnight was found to have a minute young plant growing attached to the leaf tissue. There appears to be no previous record of such a phenomenon in Limnanthemum thunbergianum.

(ii) The hydrophytic vegetation bordering the tributary streams.

Conditions in the 'top' stream are described here.

Those in the other tributary were similar. The four groups of hydrophytic plants distinguished by J. F. V. Phillips (1931) were present in the riparian vegetation.

Cliffortia spp. bushes lined most of the stream bank in the upper reaches, whilst Cyperus fastigiatus was the commonest species on the edge of the banks in the lower reaches. Common under the Cliffortia bushes were one unidentified species of moss, the liverworts Fossombronia zeyheri, and Anthoceros natalensis, a terrestrial species of Utricularia, which is a carnivorous member of the Lentibulariaceae and Arum lilies Zantedeschia aethiopica. A tall conspicuous grass between the bushes was Danthonia cineta. In the upper reaches the semi-aquatic marshy and reed-swamp plants were rare, but the submerged algae Nitella mucronata, Batrachospermum dillenii and Sirodotia huillensis formed extensive mats in the water. Batrachospermum and Sirodotia were confined to the fast flowing rivulet portions of the streams. Nitella was common in both fast flowing and stagnant water.

Aponogeton kraussianum was the commonest species of the plants with floating leaves in the upper region.

In the lower part of the stream there was a large increase in the amount of reedswamp and marshy semi-aquatic vegetation. For example Juncus lomatoxyllus, Scirpus costatus, and the reedswamp plants Typha capensis, and Phragmites communis, can form dense stands in the lower more silted regions of the stream. Most of the water surface in this region was covered by either Limnanthemum thunbergianum, Scirpus globiceps*, or Aponogeton kraussianum. The submerged alga Nitella mucronata was common in the lower reaches but

Batrachospermum dillenii and Sirodotia huillensis were rare.

* Scirpus globiceps produced both land and water forms. The water form had long internodes and long narrow leaves whilst the land form had shorter leaves and internodes. Adventitious roots were often found on submerged nodes of small detached pieces floating in the stream.

Vegetational Changes Related to the Fluctuations
in the Water Level of the Reservoir. Examination of

Table 10 in Appendix 1 showing the annual variation in the depth of the water in the reservoir, in conjunction with Photograph 13, discloses that large areas of the littoral zone became uncovered by water for variable periods, thereby subjecting plant life in these areas to consequent environmental changes. The plants in this zone may be divided into three groups:

- a) those which grow actively when the bottom deposit is still well covered by water,
- b) those that grow actively when there is little free water or the bottom deposit is only moist,
and
- c) those which grow actively when the bottom deposit is in a dry state.

When the water level was high Aponogeton kraussianum and Limnanthemum thunbergianum occupied the deeper water of the littoral zone, and to their landward side were colonies of reedswamp and semi-aquatics (See Diagram 2). As the water level fell plants of the landward zones appeared in the Aponogeton-Limnanthemum zone.

In 1956 most of the encroachment was by the small semi-aquatic plants, but it is probable that the longer marshy and reedswamp plants would be equally concerned when the fluctuations in water level were very slow.

First new shoots of Juncus dregeanus, Juncus oxycarpus, and Scirpus palludicola emerged from the original Aponogeton-Limnanthemum zone. They were followed later by the smaller semi-aquatics. Limosella aquatica was commonly the first of the latter to colonise the very shallow water, and wet mud, by runners (See Photographs 35 and 36). Scirpus cernuus occasionally formed an extensive mat-like growth on the moister parts of the shore. Here, also, appeared Cyperus tenellus, Scirpus ludwigii, Scirpus prolifer, and Scirpus rivularis, but they were not common. On the drier mud first Wahlenbergia procumbens and Gnaphalium repens, later Helichrysum declinatum and Ilysanthes dubia and finally Senecio pterophorus and Cotula heterocarpa appeared in what was originally the Aponogeton-Limnanthemum zone. Eventually as the water receded, this pattern of advance proceeded beyond the original zone of Aponogeton-Limnanthemum. The Aponogeton-Limnanthemum plants did not disappear immediately: they became transformed into the land forms with shorter stems and leaves, and in still drier conditions the aerial parts withered. Many of the marshy plants in the original semi-aquatic zone also withered. During 1956 these changes were accelerated by wintry conditions in addition to drought.

At the low water stage large reddish-brown patches on the mud close to the water's edge were common. On microscopic examination these were found to contain many diatoms (See Chapter IV).

The stage when the water level was low is that depicted by the six line transects of the shores of the reservoir in Diagram 1.

When the water level rose after the heavy rains in the spring, the plants that had colonised the dry mud were submerged and soon began to decay. At the same time, the aquatic plants began to grow rapidly and the zonation depicted

in Diagram 2 was soon restored. The rise in water level and the resulting decay of terrestrial vegetation were associated with increases in microscopic organisms; a matter referred to in Chapter VI.

Chapter III

THE PHYSICO - CHEMICAL ENVIRONMENT

The collecting sites chosen for physical measurements and collection of water samples are shown in Map 1. Views of some of the sites are shown in Photographs 18 to 25. Sites A, B and C were in the open water of the reservoir; site D was at the mouth of the 'top' tributary stream; site E was in the shallow water just above D (See Photograph 18); sites F, H, J, K and L were the lowermost pools in the 'top' stream; sites G, I, M, N, O and P were in adjacent shallower regions.

Physical methods. Figures for monthly rainfall in the area of the reservoir and depth of the reservoir on the first of every month during the investigation were taken from records compiled by the Engineer's Department of the Grahamstown Municipality (See Tables 8, 9 and 10 in Appendix 1).

Air and water temperatures were measured by the use of self-recording thermographs or a maximum and minimum thermometer, calibrated before use. (See Graph 1 and Table 1 in Appendix 1). The thermographs were housed in a screen with louvred sides mounted on a raft constructed of angle iron and wood. Two forty-four gallon drums were enclosed in the framework to provide the necessary buoyancy. Diagram 6 shows the dimensions of the raft and Photograph 20 shows it moored and in use at site F. For sheltered positions, like site F, the apparatus was quite satisfactory but in exposed positions like the centre of the reservoir the raft would have to be securely anchored. The raft was bolted together by steel bolts so that it could be easily dismantled for transport and re-assembled at the new site. The thermograph used to measure the water temperatures was Model T/362, made by Nagretti and Zambra. This model is a two pen mercury in steel temperature recorder. The mercury tube used to measure the surface water temperature in the centre of the pool at site F was supported by a wooden float so that the bulb lay horizontally three inches below the surface. The other mercury tube was weighted so that its bulb lay on the bottom of the pool and recorded the temperature there. The air temperatures at site F were measured by a thermograph, the part sensitive to temperature changes was a rolled bi-metallic strip of brass and invar steel. This instrument (Chart No. 38) was manufactured by the Cambridge Instrument Company. The clock mechanisms in both thermographs ran for seven days without attention.

A Secchi disc was used to measure the turbidity of the water. This is a circular disc, 20 cms. in diameter, the surface of which is divided into equal quadrants, painted so that two quadrants directly opposite each other are

black, and the intervening ones white. In use the disc is lowered into the water by means of a graduated line, the painted surface being uppermost. To the other, lower, surface a sinker is attached. When lowered into the water the painted surface, viewed from above, becomes finally indistinguishable at a depth depending on the turbidity of the water above it. Tests to determine turbidity in this way were made, usually in the afternoons. Notes were made of weather conditions prevailing at the time. (See Table 11 in Appendix 1).

The pH values of the water samples were determined by use of a Beckman pH meter either in the field or on return to the laboratory. The instrument was calibrated against a standard and readings corrected for temperatures (See Tables 3 and 4 in Appendix 1).

The cross-sectional views of the reservoir were constructed from five series of depth soundings, made from a boat at intervals along lines of stout string supported by cork and stretched across the reservoir between definite survey points.

Chemical methods.

(i) Collection of samples. One litre samples for chemical analysis were collected from the surface water by dipping clean polythene bottles just below the surface. For samples from deep zones a Kemmerer sampler as described by Welch (1948) was used (See Photograph 15 and Diagram 4 for its dimensions). In use this apparatus is attached to a graduated wire cable and by it lowered to the desired depth in the water with the rubber bungs in the open position and pinch clip closed. A slight jerk on the cable causes the copper cylinder to slide downwards and become stoppered by the lower bung. The metal messenger is allowed to slide

down the cable and to collide with the upper bung which closes the upper opening of the cylinder. One litre of water from the selected depth so enclosed in the cylinder, can be drawn to the surface and drained into a five-litre collecting bottle. Four litres were usually collected at each sampling in this way.

The samples for oxygen and carbon dioxide estimation were collected by the Kemerer sampler. On return to the surface the tube at the bottom of the sampler was connected to a 200 ml. bottle as shown in Diagram 5. The pinch clips were opened and the water was allowed to flow through the sample bottle until 500 ml. had overflowed. The pinch clips on the sample bottles were then firmly closed and the sampler was detached. By this procedure an uncontaminated sample should be obtained. The temperatures of water samples were noted at time of collection.

The mud samples for chemical analysis were collected at six sampling sites in the reservoir and 'top' stream (See Map 1) by means of a small Hiller peat borer (Erdtman 1943), which can furnish an uncontaminated core of mud up to 1 foot in length, even when the sampling is carried out through nineteen feet of water. Each core was divided into four equal sections, put into corked tubes and stored in a refrigerator at 6°C to await chemical analysis.

(ii) Chemical analysis of water. Except where it is stated otherwise the procedures used were those described in the widely used reference book 'Standard Methods for the Examination of Water, Sewage and Industrial Wastes' published by the American Public Health Association (1955).

The dissolved oxygen content was determined by the Winkler method. The principle behind this method is the combination of dissolved oxygen with manganous hydroxide to form manganic hydroxide in a highly alkaline solution. Upon acidification in the presence of an iodide, the

manganic hydroxide decomposes and iodine is liberated in an amount equivalent to the oxygen originally dissolved in the sample. The iodine is titrated with standard sodium thiosulphate using starch for the final stage of the titration. The manganous sulphate and the alkaline potassium iodide solutions were added to the water sample immediately after it was collected. The acidification and subsequent titration were performed in the laboratory. It was not found necessary to use any of the published modifications of this method to prevent any interference with the liberation of free iodine.

The dissolved carbon dioxide content was determined by titrating 100 m.l. of the sample against a 0.01 N sodium carbonate solution using phenolphthalein as the indicator, immediately after the sample was collected. This is the method described by Taylor (1949).

Gravimetric estimates of the total solids, i.e. the total amount of dissolved and colloidal matter present in a known volume of water after the sample had been passed through one sheet of filter paper (Greens 795), were made by evaporating 50 m.l. samples in weighed beakers first to dryness on a hot plate and later overnight in an electric oven set at 103° to 105° . In the morning the beakers were cooled in a desiccator, reweighed and the weight of the total solids in a litre of water calculated.

The concentrations of nitrate, nitrite, and ammonium nitrogen were determined by the following colorimetric methods using an absorptiometer, the phenol-disulphonic acid method for nitrate, the alpha-naphthylamine sulphanilic acid method for nitrite and Nessler's method for ammonium. The basis of the phenoldisulphonic acid method is the formation of a yellow coloured alkaline salt of 6-nitro-1,2,4-phenoldisulphonic acid, which is formed when nitrate is added to 1,2,4-disulphonic acid. The basic principle of the nitrite method is the formation of a reddish purplish azo dye with diazotised

sulphanilic acid and alpha-naphthylamine hydrochloride. Nessler's reagent (a mixture of mercuric iodide, potassium iodide and sodium hydroxide) produces a yellow to reddish brown colour in reaction with ammonia. The sum of these three forms of nitrogen was termed the total inorganic nitrogen content.

The Kjeldahl method was used to determine the organic nitrogen content. The volume of water used for each determination was 500 m.l. Any ammonium nitrogen present in the water samples was removed by boiling before the digestion began. Boric acid was used to collect the ammonia that was evolved during the digestion.

The concentration of inorganic phosphate phosphorus was determined by the ammonium molybdate colorimetric method using stannous chloride as the reducing agent. A deep blue complex compound is formed when stannous chloride is added to a solution containing acidified ammonium molybdate solution and phosphate.

Sulphate sulphur was estimated by the ethylene diaminetetracetic acid (E.D.T.A.) method. The principle of this method is to precipitate the sulphate as barium sulphate by the addition of a slight excess of barium chloride. The residue of the barium chloride is then titrated with 0.2N E.D.T.A. using eriochrome black as an indicator. Since the concentrations of calcium and magnesium were determined by preliminary titrations with E.D.T.A., the sulphate sulphur content can be calculated from the following formula:

$$0.3206 \times \frac{1000}{\text{volume of aliquot taken}} (\text{Ca} + \text{Mg titre} + \text{m.l. of Ba added}) - (\text{Ca} + \text{Mg} + \text{Ba titre actually found}).$$

The electrometric method described by Piper (1950) was used for chloride estimations. The chloride solution is titrated with silver nitrate using a quinhydrone half cell and an agar potassium nitrate bridge.

The hydroxides, carbonates, and bicarbonates were

determined by the method described by Taylor (1949), except that bromophenol blue was found to be a more satisfactory indicator than methyl orange. Taylor (1949) said that the concentration of these radicles "... is determined by titration with a standard solution of a strong acid to certain hydrogen ion concentrations, using selected indicators which show definite colour changes at these points...."

The silicate concentration was estimated by the silico-molybdate colorimetric method. Ammonium molybdate combines with silica to form silicomolybdic acid which is yellow coloured.

The concentrations of calcium and magnesium were determined by titrating with E.D.T.A. using murexide and eriochrome black as the indicators. Both E.D.T.A. and these indicators are capable of forming complexes with calcium and magnesium, but E.D.T.A. is capable of extracting calcium and magnesium from the coloured indicator complexes with a resulting loss in colour of the solution.

An Eel flame photometer was used to estimate the potassium and sodium concentrations.

The concentration of iron was determined by the thioglycollic acid colorimetric method (British Drug Houses 1939). Thioglycollic acid reacts with either ferrous or ferric iron to form a purple coloured compound.

Dithizone forms a coloured compound with zinc and this is the basic reaction in the colorimetric determination of zinc.

The manganese concentration was determined by oxidising it to the coloured permanganate state by the addition of periodate and then determining the intensity of the colour with an Absorptiometer.

(iii) Chemical analysis of the mud. All the mud samples were weighed wet, dried for fifteen hours in an electric oven at 105°C, cooled in a dessicator, and re-weighed. The estimates of carbon and nitrogen were based on the dry weights of the samples.

The nitrogen content was estimated by using a micro-Kjeldahl apparatus. Mercurous sulphate was used as the catalyst and the ammonia released was distilled into boric acid.

The carbon content was determined according to the Walkley (1947) method, by oxidising a weighed piece of dry mud with excess potassium dichromate with sulphuric acid. The residual dichromate was back titrated against a solution of ferrous ammonium sulphate.

Both methods employed were those described in the pamphlet 'Plant and Soil Analysis' published by the Chemistry Department, Rhodes University.

I. C. Brown (1943) developed a method of estimating the total exchangeable acidic and basic ions in soils and mud, using a pH meter. A buffer solution is added to aliquots of a mud suspension and the pH of the mixture is determined by a Beckman pH meter. For exchangeable basic ions, an acetic acid buffer must be used; for the exchangeable acidic ions, an ammonium acetate buffer. The equivalents of exchangeable acidic and basic ions corresponding to a particular pH can be read from a standard curve given in Brown's paper.

Physical Investigations.

(i) Morphology. The profiles of the Jameson reservoir, drawn to scale, in Photograph 13, show that it is contained in a shallow basin, so that a small inflow of water causes a comparatively large increase in its superficial area. The significance of this fact in relation to animals and plants is referred to in other chapters.

The two tributary streams have similar morphological characteristics. In the highest reaches they are narrow and shallow with little bottom silt, and the water was seen to be fairly swift running, except in time of drought. In the lower reaches they widen and deepen and the water movement becomes less rapid, and as they near the reservoir they come to consist of a series of alternating shallow regions and deep pools of varying sizes. During the more severe conditions of the drought in 1956 the pools became isolated except for thin trickles flowing over the intervening connecting shallow sections.

At the mouths of both streams were delta-like accumulations of mud and plant debris, only completely covered by water when the reservoir was well filled.

(ii) Rainfall. Table 8 in Appendix 1 shows figures for average rainfall month by month, calculated from the data of the previous 11 years, and Table 9 in Appendix 1 shows those for 1956, the year of this investigation. A comparison of these two tables shows rainfall in 1956 was above average for the area. However, the main precipitation occurred during September and October. For the months previous to September it was below average and the area suffered a serious drought, which led to a depletion of supplies in all the municipal reservoirs. The Jameson reservoir was held as a final reserve. However, from June onwards this reserve had to be drawn upon. Table 10 in Appendix 1 shows the depths of the water in the reservoir at the dam wall, on the first of every month during 1956, and for comparison averages for the previous eleven year period.

Heavy rains fell on the 19th September and the drought was broken. In the right-hand column of Table 9 in Appendix 1 are the number of days in a particular month on which a recordable amount of rain fell in 1956.

In September and November a large volume of rain fell in a few short, violent storms; on the other hand the rain in April and May fell as 'light' rain. It is probable that during the heavy downpours a much greater proportion of the rainwater ran off the soil than in the light showers, and correspondingly larger quantities of silt and organic matter would be washed into the reservoir. This would explain the increase in the turbidity of the water during November and December as shown by the Secchi disc readings shown in Table 11 of Appendix 1.

(iii) Temperature. Temperature changes in air and water were traced by means of the thermographs. Graph 1 shows temperatures of air, surface water and bottom water of the pool at Site F in respect of the periods of widest ranges during the investigation. The period 10th to 16th June covered the occasions of lowest air and water temperatures, and that for 22nd to 28th January those of the highest air and water temperatures. Unfortunately, because of a mechanical failure in the thermograph during the January period, only small sections of the air temperature were recorded for this month.

In June the pool was 6ft. deep and in January 9ft.

The results of the data obtained may be summarised as follows:

1. The fluctuation of the surface water temperature follows fairly closely that of the air but less markedly and rapidly.
2. The highest temperature of the surface water, 30°C , occurred at 3 p.m. on the 22nd January. The greatest difference between the surface and bottom water temperature 7.6°C occurred also on that date.
3. The temperature at the bottom of the pool was only slightly affected by the sudden fluctuation in air temperature, and changes which occurred

were slow to develop. The temperature of the water at the bottom never fell below 4°C , the temperature at which water attains its greatest density.

On the 25th April a series of readings of temperatures were made in the reservoir and at various sites in the 'top' tributary stream (See Table 1 in Appendix 1). The surface water temperatures in the shaded uppermost parts of the stream (e.g. 13.3°C above site M at 3.15 p.m.) were lower than in the pools (e.g. 17.2°C at site F at 2.15 p.m.) and shallow parts of the lower reaches in the reservoir (e.g. 20.0°C at site D at 3.40 p.m.). Both in the stream and reservoir the deeper waters were a few degrees colder than the surface but there was no sign of a thermocline. The highest water temperatures were obtained in the shallow bays of the reservoir.

Table 1 in Appendix 1 also shows the water temperature on the night of the 1st December at three depths, viz. at the surface, at 6 ft. below, and at 15ft.3ins. below - i.e. on the bottom. The measurements were made at site B. As in the pool at site F, the surface water temperature remains above the air temperature in the middle of the night. The reading at 9.30 a.m. (20.0°C) would seem to indicate an intermediate belt of warmer water between the surface and bottom waters (both 18.9°C).

Chemical Investigations.

(i) Water. The results of the chemical analyses of the water in the reservoir and the 'top' tributary stream are shown in Table 3 of Appendix 1.

The data for the content of dissolved oxygen (See Tables 6 and 7 in Appendix 1) indicate that the deeper waters of the reservoir and the pools of the tributary stream were well aerated (e.g. 6.73 mg/litre of dissolved oxygen from the bottom water, site B, at 2. p.m. on 9.5.56 and 6.89

mg/litre of dissolved oxygen from the bottom water of the pool at site F at 2.20 p.m. on 16.5.56).

During the night of the 1st December regular analyses were made of the dissolved oxygen and carbon dioxide contents at site B and site F (See Table 6 of Appendix 1). There were only small variations in the gaseous content of the water with times at site B (between 6.47 and 7.79 mg/litre for dissolved O₂ and 3.0 and 5.5 mg/litre for dissolved CO₂); but there seems to be a significant difference between the values from the surface waters at site F, where there is an abundance of aquatic plants, (range between 4.08 and 5.64 mg/litre dissolved O₂ and 21.6 and 42.2 mg/litre dissolved CO₂) and the corresponding ones at site B in the open, plant-free water of the reservoir. The corresponding water temperatures for site B are shown in the temperature data in the Appendix 1.

A few measurements of the pH of these samples collected on the night of the 1st December are shown in Table 6 of Appendix 1. The values for site F (e.g. 5.92) were lower than for site B (e.g. 7.00 at same time of day).

The highest pH value measured was 7.46 obtained from surface water from site A on the 11th August (See Table 3 of Appendix 1). In the upper reaches of the 'top' tributary stream at site P on the same day the pH of the surface water was 5.70. Only a short period elapsed between the collection of these two samples. Throughout the investigation the highest pH values were usually obtained in the reservoir and the lowest in the uppermost part of the 'top' tributary stream. The lowest recorded pH was 5.55, obtained from the surface waters at site F at 11 p.m. on the 1st December, 1956.

The waters of the Jameson, Milner, Howieson's Poort and

Grey reservoirs were all characterised by small quantities of dissolved matter (See Tables 3 and 4 of Appendix 1). Sodium and chlorine were the ions most abundantly present, particularly so in Grey reservoir (65.9 and 107.6 mg/litre respectively).

(ii) Mud. According to the Grahamstown Journal (1905b), whilst the reservoir was under construction the site was cleared of all vegetation. It is probable that most of the soil in the basin was removed with the vegetation. In 1956, apart from rocky outcrops along the North shore, the bottom of the reservoir was covered with a layer of black organic sediment. At the three sampling sites in the reservoir it proved impossible to collect a core of a length of more than one foot. At the mouth and in the pools of the 'top' tributary there was a greater depth of sediment. Although no clear distinction can be made between planktogenic and other forms of detritus, it seems likely from the paucity of the plankton, that most of the sediment on the bottom of the reservoir had a terrestrial origin. In many lakes, such as the English Lakes, with well-timbered shores and large littoral regions a large quantity of the bottom deposit is derived from the shore-line vegetation. Moreover the tributary streams, especially when in flood, wash down large amounts of dead organic matter into the lakes. Pearsall (1920) found a well-defined zone of dead leaves and twigs outside tributary stream mouths in the English Lake district. Earlier in this chapter it was mentioned that small accumulations of mud and plant debris were found at the mouths of both tributary streams. Branches and twigs were found on the bottom in the centre of the reservoir.

Table 2 in Appendix 1 summarises the results of the

chemical analysis of mud. The moisture content of the mud samples was highest in the topmost three inches of the core (e.g. 54.9 % water in the top three inches compared with 24.3% water in lowermost three inches of the mud core at site A). With the exception of the surface sample at site F, the highest percentage of nitrogen and carbon lies in the topmost three inches of the mud core (e.g. .194% N and 3.39% C for the surface three inches at site A compared with .186% N and 3.22% C, .126% N and 2.04% C, and .090% N and 1.38% C for successively lower layers at the same site). These results quoted above also show a narrowing of the C/N ratio with increase in depth below the surface. The results from most of the other sampling sites show a similar tendency.

The core at site F was taken from a deposit of coarse silt which had been deposited at the entrance to that pool during the recent rains. The other cores were taken from rich organic mud. This difference in origin may explain the aberration of the chemical analysis of the site F sample.

Table 2 shows also that the highest concentration of exchangeable ions was found in the surface layers of the mud. (e.g. the total concentration of exchangeable ions at site A was 11.3 milliequivalents per 100 gms. of mud and values for successively lower layers at the same site were 9.2, 9.1 and 5.8).

Chapter IV

THE ALGAE

Methods. It was aimed to investigate the characteristics of the algal population of the reservoir and its tributary streams, i.e. to identify species and to estimate their distribution in relation to habitat, to seasonal and daily periods, and to observe the development of communities. An attempt was made to culture some species.

The algae were collected in a systematic manner. The period between collection and examination of algal collections was kept at a minimum. The attached algae in the shallow waters were collected by hand. These algae were either scraped from the substrata in the field or transported to the laboratory still attached to stones or organic matter. In all cases the attached algae were transported from the field to the laboratory (about 9 miles away) in wide-necked

glass bottles partially filled with water from the situation of sampling. Attached algae were collected from such different substrata as:-

1. Stones submerged in shallow water,
2. organic debris either moist or in shallow water,
3. aquatic plants, and
4. mud.

Algal collections were made in situations likely to provide different microhabitats, for example from the swift flowing shallow rivulets and the tranquil conditions found in 'pools' of the tributary streams. A series of collections of attached algae was made every three months.

Samples from the floor at deeper parts of the reservoir were obtained on two occasions in December 1956. The mud scoop used for this purpose is illustrated in Diagram 3 of Appendix 1.

As regards free floating algae, water samples were collected at fortnightly intervals at sites shown on Map 1.

A surface water sample was obtained by dipping the neck of a five litre collecting bottle just below the water surface and allowing a little more than 4 litres of water to run slowly into the bottle.

Deeper water samples were drawn by one of two methods. At the outset the apparatus shown in Photograph 14 was used. However, the need for a method of sampling speedily and frequently led to the use of the modified Kemmerer water sampler shown in Photograph 16 and referred to in Chapter III.

The laboratory examination of the water sample comprised two stages: (a) filtration and (b) examination of the filtrate by microscopy.

For filtration the Sedgwick-Rafter method was used. Whipple (1927) described the stages in this method in the following manner:

"... the filtration of a measured quantity of the sample through a layer of sand which retains the organisms, the separation of the organisms from the sand by washing it with a small measured quantity of filtered or distilled water, and decanting; the microscopic examination of a portion of the decanted fluid; the enumeration of the organisms found therein; and the calculation of the number of organisms in the sample of water examined...."

Photograph 16 illustrates the filtering apparatus used. It consisted of an oil lamp chimney-glass fixed vertically, narrow end downwards, containing, from above downwards, a sand layer one inch thick, a thin wad of glass wool a quarter of an inch thick, a fine thin silk cloth cover over a rubber stopper, which closed the end of the glass tube. The stopper was perforated by a short, hollow glass tube, connected by tubing to a water-tap suction pump.

The quality and size of the sand grains used in the filter is important. The American Public Health Association (1955), in their 'Standard Methods for the Examination of Water and Sewage' state that "...white sand is required as a filtering medium. This may be Berkshire or Ottawa sand, ground quartz, or white beach sand. It should be washed and screened, that portion being used which passes N.S. Series No. 60 screen and is retained on a No. 120 screen."

Welch (1948) said that "...such sand is satisfactory for ordinary samples. However, if it is necessary that very minute organisms be retained, a smaller size of sand grain must be used as for example 60 to 140 sand...."

The sand used in the filter was river sand that had been washed in acid to remove the organic debris and then rewashed in distilled water. Sand grains that were passed by a Standard 60 sieve and retained by a 140 sieve were used. The sand layer was kept constantly at one inch thick.

Whipple (1927) recommends that to free the sand filter of entrapped air a small quantity of distilled water should be added to the filter and the funnel should be tilted from side to side to allow the air to escape. This procedure was adopted.

During filtration of a sample the sand was kept covered by water. The water suction pump was used to maintain steady, gentle suction until most of the sample had passed through the filter. The remainder was allowed to pass by gravity. At this point the rubber stopper was withdrawn, the sand allowed to fall into a clean beaker, and the inside of the funnel washed down with 5 ml. distilled water, the washings falling into the beaker. The sand was gently agitated by shaking the latter and then allowed to settle until the supernatant liquid could be decanted into a 10 ml. measuring cylinder. The washing of the sand was repeated until the washings bulked to 10 ml. which were transferred to an appropriately labelled sample vial. The sample was then ready for microscopic examination.

A Rafter microscopic counting cell of 1 ml. volume was used. The floor of the cell was divided into ten equal squares.

The cell, having been carefully filled and covered with a cover slip, examined under a binocular microscope, using 1/6in. objective and magnification x 10 eyepiece. The examination followed a routine pattern, i.e. a preliminary survey, noting the general distribution of organisms and rarer types, then their identification, counting and measurement.

In respect of each sample a permanent Styrax mount of diatoms was made for use in identification.

According to Whipple (1927) the results obtained by the Sedgwick-Rafter method are accurate to within 10%. Others claim a probable error of less than 5%. The American

Public Health Association (1955) recommends ten standard fields using a 16 m.m. objective with x75 eyepiece, when the sample is adequately concentrated, i.e. when there are at least five organisms per field and preferably ten.

The organisms were identified and counted in five fields from each of the ten squares. In each square one field was taken near the centre and the other four were each near one of the respective corners. The linear dimensions of the algae were measured using eyepiece micrometer. Each cell of a colonial species was regarded as equivalent to a unicellular organism. The counts were later expressed in cell units per litre of the original unconcentrated water sample.

On the occasions when it was found inconvenient to examine samples within a short period from time of collection the organisms were concentrated in 10 ml. of 3% formalin buffered with hexamin instead of 10 ml. of distilled water. Otherwise procedure was the same.

The colonisation of aquatic leaves was studied by suspending detached leaves of Limnanthemum thunbergianum and Aponogeton kraussianum in the surface layers of the tributary stream at sites F and L. These leaves were carefully cleansed before immersion in the water and remained in position for periods varying from three to thirty-seven days, then recovered and returned to the laboratory for examination. The rate and nature of algal colonisation of bare areas was studied. For this purpose glass photographic plates (full plate) and stones which averaged four inches in diameter were used. Before use the photographic plates and stones were cleaned and sterilized. The glass plates and stones were placed in the surface waters and on the bottom deposit at site C in the reservoir, and at sites F and L in the 'top' tributary stream. The plates were immersed for periods from one to

five weeks beginning in late January 1957. The stones remained under water for five weeks, during January and February. After the period of immersion and on return to the laboratory the glass plates were examined under a microscope using a 1/6in. objective. All the algae in ten random fields on the upper surface of the glass were counted and identified as far as possible. Each cell of a colonial species was counted and regarded as equivalent to a unicellular alga.

The effect of raising the level of nitrogen and phosphorus concentration in the reservoir water to the level recommended by Chu (1942) in his culture medium No. 10 for the growth of many algae was studied by growing algal cultures in the laboratory. Four glass tanks of 4½ litres capacity were used for this purpose. Each tank was filled with 4 litres of water from the surface of the reservoir collected at site B on the 11th December 1956. The water in each tank was agitated daily early morning and evening by passing a slow stream of air bubbles through it for two hours.

To the water of the first tank were added 0.16 gms. calcium nitrate and .040 gms. potassium hydrogen phosphate; to the second 0.16 gms. of calcium nitrate; to the third .040 gms. of potassium hydrogen phosphate; but no addition was made to the fourth.

The rate of growth of the algal populations in the water of each tank was estimated by siphoning off a litre sample from it, at weekly intervals, separating off the organisms on a column of sand and estimating the population density by the Sedgwick-Rafter method. After filtering through the sand the water was returned to its original culture tank.

Any drop in the water level of a tank due to evaporation was corrected by the addition of re-distilled water. The

tanks were exposed to daylight but screened from bright sunlight during the whole period of the investigation.

The aufwuchs. Ruttner (1953) said "...By the term 'aufwuchs' we mean all those organisms that are firmly attached to a substrate but do not penetrate it.....In addition to attached species there belong to the aufwuchs biocoenosis a large number of free living forms, which crawl upon the substrate, swim about in the dense confusion of the sessile species, or even undertake larger temporary excursions into the open water. These are members of the most diverse branches of plant and animal kingdoms occurring in fresh water...."

Welch (1952) defined the term 'periphyton' which is the most similar term in English as "...that miscellaneous assemblage of organisms growing upon free surfaces of objects submerged in water...." Welch thought entrapped organisms should be regarded as extraneous. In the present investigation since many algae occurred most abundantly amongst, but, unattached to, sessile algae, the term 'aufwuchs' as defined above has been chosen to describe this community rather than the English term 'periphyton.'

Most of the algal species found in the reservoir and its streams were usually associated with an aufwuchs community.

Ruttner (1953) distinguished between the aufwuchs on a persisting non-living substratum and that on a transitory, usually living, substratum. Decaying organic matter was regarded as living because of the saprophytes permeating it. In the reservoir some species were found in both situations, although often preferring one to the other. These preferences will be referred to later.

(i) The aufwuchs associated with organic matter. Most of the plant material floating or immersed in the water occurred

in the littoral regions of the reservoir, and along the banks of the tributary streams. The majority of the algae usually associated with organic matter was to be found in the same regions. Except for a lack of algal colonisation on Polygonum tomentosum, there was little difference in the compositions of the aufwuchs communities associated with different Angiosperms. Also no difference between the colonisation of different morphological parts could be detected, although decayed material carried the more luxuriant algal growths. Few algae were associated with an actively growing plant organ. More algae were to be found growing on the lower surfaces of plant material than on the upper ones.

Occasionally a plant organ or a portion of one with its associated algae became detached from the parent plant and swept away by wave or current action. Some of this material sank into deeper layers of water and eventually came to lie on the bottom deposit. By this time the relative proportions of the associated species of algae had changed, although most of the species present were the same as those found in the aufwuchs associated with floating plant organs.

The aufwuchs communities associated with plants in the series of pools formed at the lower end of the 'top' tributary and in the littoral zone of reservoir were similar. In this environment the early colonists of aquatic plant material were firmly attached to the leaf surface, chiefly the under surface. The commonest forms were four species of Oedogonium and less common Bulbochaete varians var. subsimplex. Circular colonies of Coleochaete pulvinata, C. scutata and Chaetophera sp. were common. Where the material was well agitated by current or wave action small colonies of Stigeoclonium falklandicum and Stigeoclonium sp. were found on young plant material in the

summer. Between these colonial forms were many species of diatoms. These species of Eunotia were often present, E. alpina, E. lunaris and E. tenella. The last species was the commonest often present in long chains of cells attached together along their valves. Other common diatoms were:

Achnanthes minutissima

A. oblongella

Gomphonema acuminatum

G. clevei

G. gracile

G. parvulum

Synedra ulna

S. rumpens

and varieties of the last two species.

Fan-shaped colonies of Synedra ulna were often found with only their apices attached to the plant (See Photograph 44).

Less frequently individuals of

Amphora coffeaeformis

Diploneis ovalis

D. subovalis, many small species of

Cosmarium and

Chaetosphaeridium globosum were noted, and

Nitzschia palea.

It was quite common to see short filaments of Bulbochaete varians var. subsimplax growing on the older Oedogonium filaments.

The commonest species closely associated with but unattached to plant material were two species of Spirogyra, two species of Zygnema and Mougeotia sp. Other filamentous species common in spring and early summer were

Tribonema bombycinum

Microspora sp. c.f. quadrata and

Ulothrix sp.

The latter was usually found in well-shaded water.

Within the algal network were a large number of unattached algae and animals (the animals found in the aufwuchs are discussed in chapter V).

Navicula cryptocephala var. intermedia

N. radiosa

2 Navicula species

Pinnularia gibba

P. lata

P. subcapitata

Frustulia rhomboides

Gyrosigma sp.

Mastogloia smithii

Cymbella amphicephala

C. ventricosa

chains of cells of Tabellaria fenestrata

Tabellaria flocculosa and

Melosira sp.

Cyclotella comensis

Fragilaria sp.

and two Suirella species were the commonest diatoms found within this algal network. Among the desmids the commonest were many species of Cosmarium and Closterium, four species of Staurastrum, Micrasterias crux-melitensis, and one species each of Euastrum, Pleurotaenium, and Sphaerososma (See Photograph 42).

The more active algal forms present were:

Chlamydomonas ovalis

Trachelomonas volvocina

two species of Euglena and

one species each of Phacus

Peridinium and

Gymnodinium.

The colonial forms were a distinct group. Chief among these were:

Ankistrodesmus falcatus

Aphanocapsa grevillei

Asterococcus sp.

Coelastrum sp.

Kirchneriella ~~sp.~~ sp.

Nephrocytium sp.

two species of Pediastrum

Selenastrum westii

Sphaerocystis schroeteri.

As the plant material reached an advanced stage of decay and began to sink, filamentous colonies of Hapalosiphon stuhlmannii became common over most of its surface. Other blue-green colonial algae were two species of Oscillitoria, two species of Anabaena and Nodularia spumigenia. These algae remained the commonest algae when the organic debris lay on the bottom.

In the shallow rivulet portions and the extreme borders of the pools in the lower regions of the tributary streams very few filaments of the attached filamentous algae such as species of Oedogonium and Bulbochaete were found. In these regions, most of the plant material was covered with sessile diatoms and unattached filamentous algae. The same algal species were present as in the stream pools.

Local growth of algae in these shallow regions was extremely rapid during the spring and early summer (See Photographs 37 and 38). Their disappearance was equally rapid. On some occasions a large number of gas bubbles were seen entrapped within the algal masses.

The aufwuchs associated with plant material in the well-shaded shallow upper parts of the tributary stream was dominated by sessile diatoms of which Synedra ulna and Eunotia alpina and E. tenella were the commonest.

Filamentous algae were rarely seen associated with organic matter in this region.

Observations were made of the development of aufwuchs communities on fresh leaves of Limnanthemum and Aponogeton immersed in water at sites F and L. The observations were qualitative and few in number.

Algae growing on aquatic leaves after immersion in the surface layer of water, at site F, for 17 days from 24.11.56 to 11.12.56.

Limnanthemum leaves	Aponogeton leaves
Achnanthes sp.	Closterium sp.
Coleochate sp.	Coelastrum sp.
Cymbella sp.	Eunotia sp.
Eunotia tenella	Gomphonema sp.
Eunotia spp. (2)	Oedogonium sp.
Gomphonema sp.	Staurostrum sp.
Nitzschia sp.	Synedra sp.
Oedogonium sp.	A few unidentified flagellates.

The leaves of Aponogeton were in a more advanced stage of decay than those of Limnanthemum at the end of the period. There was a greater number of protozoa associated with the leaves of Aponogeton than with those of Limnanthemum.

Algae growing after immersion in the surface layers of water on different Limnanthemum leaves for periods:-

From 13.1.57 To 16.1.57 3 days	From 13.1.57 To 30.1.57 17 days
At site F	
Achnanthes minutissima	Achnanthes minutissima
Diploneis sp.	Amphora sp.
Eunotia tenella	Cosmarium sp.

At Site F
(Contd.)

Eunotia tenella	Cyclotella sp.
Gomphonema sp.	Eunotia tenella
Mougeotia sp.	Eunotia sp.
Tabellaria fenestrata	Gomphonema sp.
Unidentified diatom	Melosira sp.
	Navicula sp.
	Pediastrum sp.
	Tabellaria fenestrata

At site L

Coleochaete sp.	Cosmarium sp.
Eunotia tenella	Eunotia tenella
Eunotia sp.	Eunotia sp.
Synedra ulna	Frustulia sp.
A septate fungus	Navicula sp.
Unidentified diatom	Oedogonium sp.
	Stigeoclonium sp.
	Synedra ulna
	Synedra sp.
	Trachelomonas sp.

There appeared to be a greater number of diatoms at site F than at L. A similar difference was noted in the cases of well-developed aufwuchs communities attached to plants.

Algae on the upper surface of the leaves were observed only on those collected from site L on 30th January. These included a few diatoms of Synedra ulna and Synedra sp. and at site F, Achnanthes minutissima, Eunotia tenella, Gomphonema sp. Melosira sp. and Tabellaria fenestrata.

Only a few filamentous algae and no epiphytes were found on these leaves from sites F and L and it would appear that the sessile diatoms were the pioneers in colonization.

From the observations made at sites F and L and those of collections of mature aufwuchs communities it is reasonable to conclude that the leaves were colonized in this order -

1. Sessile diatoms,
2. attached filamentous forms and other attached colonial forms,
3. epiphytes on the algae,
4. free living forms within the meshwork of filamentous algae.

(ii) The aufwuchs associated with inanimate objects.

The aufwuchs communities found on stones in water of less than three feet depth in the reservoir and lower part of the 'top' tributary stream show little variation with different localities. Many of the stones were covered with macroscopic colonies of Calothrix sp. and Phormidium sp. Calothrix formed globular colonies which protruded well clear of the surface of the substratum, those of Phormidium were closely adpressed to the rock surface.

Another common alga forming macroscopic colonies on stones was a species of Chaetophora. This species was not found in the most stagnant parts of the stream (See Photograph 43). Stigeoclonium sp. was present and seemed to be more sensitive to stagnant conditions than Chaetophora, as it was only found in small colonies in the turbulent parts of the stream and littoral region of the reservoir. The most numerous diatoms attached to the stones were:

Achnanthes minutissima

A. oblongella

Cymbella ventricosa

Eunotia flexuosa

Eunotia sp.

Gomphonema acuminatum
Navicula cocconeiformis
N. cryptocephala
Rhopalodia gibberula
Rhopalodia sp.
Synedra ulna
Synedra sp.

The commonest diatoms that were closely associated with but unattached to the stones were:-

Fragilaria sp.
Pinnularia obscura
Pinnularia subcapitata
Pinnularia sp.
Nitzschia clausii
N. perminuta
N. tryblionella var. levidensis

In general the diatoms predominated on the stones in water of a depth of a few inches whereas the colonial algae mentioned above, especially the blue-green, were more abundant on stones in the deeper waters. One reason for this distribution suggested by the studies on algal colonisation on glass plates described later, is that diatoms were quicker to colonise bare areas than colonial forms. As the level of the reservoir fluctuated considerably during the year many stones were alternately immersed in water and exposed to air within a short time. These stones were likely to provide a regular supply of bare areas for colonisation. Alternatively the diatoms may tend to survive short periods of dessication better than do colonial forms.

Stones in the littoral zone of the reservoir in more than three feet of water were covered with a fresh water sponge containing a symbiotic unicellular blue-green species (See Photograph 28).

In the swift running upper reaches of the tributary stream

Batrachospermum dillenii and Sirodotia huillensis form pure growths on some rocks. Both species were rare in the more stagnant lower reaches and absent from the littoral region of the reservoir. They showed enhanced growth in shady positions, and the upright portions reached their maximum size in spring. The colonial algae found attached to stones in the shallow parts of the littoral zone of the reservoir extend into these upper reaches. The commonest diatoms here were Synedra, Eunotia and Navicula species. Many rocks on the edges of the stream in this region were covered with liverworts and mosses. Only a few mosses were found on the edge of the reservoir.

Sessile filaments of Hapalosiphon sp., Oedogonium sp. and Bulbochaete varians var subsimplex occurred infrequently on stones. Similarly filaments of Ulothrix sp., Mougeotia sp., Spirogyra sp. and Oscillatoria sp. appeared but never so abundantly as when associated with organic material.

The most noticeable difference between the algal communities associated with inanimate and animate substrata was the greater quantity of blue-green algae in the former. These differences may be the result of differences in the micro-environments usually associated with stones and organic matter as well as differences in their suitability as substrata for colonisation. The most luxuriant growth of aquatic Angiosperms was in the more sheltered areas of the tributary stream and reservoir. Plant material that originated in areas where wave or stream current was strong, eventually was swept into calmer more stagnant waters where the final stages of decay occurred. In areas where aquatic vegetation was most developed a thick layer of organic detritus from the decay of the surrounding vegetation covered the bottom, thus most of the exposed stones available for algal colonisation were found on the bottom in shallow turbulent waters. In contrast most of the living and partially decomposed organic matter was in the stagnant

waters.

An attempt was made to discover the influence of the differences of habitat associated with animate and inanimate matter by observing growths on clean glass plates and stones placed for certain periods in surface waters and on the bottom deposit of sheltered areas.

Although the data obtained from the glass plates were quantitative and comparative they were not necessarily comparable with those which might be obtained if it were possible to estimate growths on natural substrata. Certain algae present on natural substrata may not appear on glass plates. But the glass plate method is unlikely to include dead algae from another habitat, as only algae with protoplasmic contents were counted.

All the glass slides suspended in the surface water at sites C, F and L were removed by unknown persons and no results were possible. The counts obtained were in respect of plates on the bottom deposit at sites C, F and L.

Tables 6, 7, 8, 9 and 10 in Appendix 2 show the numbers of algae expressed as cell units counted under the microscope in ten fields taken at random.

At all three sites diatoms seem to be in the majority. At site C the only non-diatom was Trachelomonas. Growths at site C were sparser than at sites F and L for the same periods. At site F the commonest algae were:-

Achnanthes minutissima

A. oblongella

Eunotia tenella

Melosira sp.

Navicula cocconeiformis

N. cryptocephala

Navicula sp.

and Trachelomonas volvocina.

At site L the commonest algae were:-

Achnanthes minutissima

A. oblongella

Eunotia tenella

and Synedra ulna.

These species at site L show an increase in population size the longer the glass plate was immersed. The other species do not show this feature clearly. There was no obvious difference in the degree of colonisation occurring after a week's immersion at different times in January and February. The glass plate immersed for 36 days had colonial algae attached. This does suggest that colonial algae would colonise the glass plates after the diatoms were well established.

At site F Eunotia tenella was the only alga showing an increase in the degree of colonisation with the length of immersion. Again there was little difference in the degree of colonisation after a week's immersion in January or February.

A few glass plates, left out at the edge of the south shore for a week in February became covered with an almost pure growth of Achnanthes spp. No estimate was made of the size of the population.

To determine whether rough surfaces were more easily colonised than smooth, half the area of some glass plates were roughened by carborundum. No difference could be detected between growths on the two types of surface after exposure.

Clean sterilised stones were placed on the bottom of sites F and L on the 7th January and removed after 5 weeks. After this period the stone at the shallow shaded site L was covered with a brown mucilage in which were many individuals of Synedra ulna and Synedra sp. Other diatoms present but in fewer numbers were:-

Diploneis ovalis

Eunotia alpina

Eunotia tenella

Frustulia rhomboides

Navicula sp.

two species of Pinnularia

and Tabellaria fenestrata.

Two desmids, one species each of Closterium and Cosmarium, Trachelomonas volvocina and Asterococcus sp. were also present. The most abundant filamentous alga present was Batrachospermum dillenii. Two small colonies of this species were found on the sides of one stone, sheltered from the full force of the stream current. There were a few filaments of Mougeotia and two Oedogonium species on the stones placed at site L.

The stones placed on the bottom in the centre of the stream pool at site F had a sparse covering of diatoms. No other algae were present. The diatoms present were:-

Achnanthes minutissima

Eunotia tenella

Gomphonema sp.

two species of Navicula

Melosira granulata

and Pinnularia sp.

Algae associated with the bottom deposit. Many of the algae found in the aufwuchs associated with aquatic plants were also found on organic matter on the bottom deposit in the shallow parts of the tributary streams and the littoral regions of the reservoir. Filamentous algae and diatoms usually associated with floating organic matter were often left behind on the wet mud after a rapid fall in water level. The conspicuous red-brown patches often found there consisted mainly of diatoms more commonly found in the aufwuchs. The commonest species were Achnanthes minutissima,

two species of Nitzschia and Synedra rumpens. Less common were:-

Cyclotella comensis
Fragilaria virescens
Cymbella ventricosa
Frustulia rhomboides
Gomphonema acuminatum
Navicula sp.
Pinnularia gibba
Pinnularia sp. (section Maiores)

two species of Nitzschia and
three species of Suirella ~~sp.~~

One species of Euglena was common in these patches

The commonest filamentous algae stranded on the mud were:-

Anabaena (2 species)
Oscillatoria (2 ")
Mougeotia (1 ")
Spirogyra (3 ")
Tribonema (1 ")
Ulothrix (1 ")
and Zygnema (2 ")

Algae, other than those characteristic of the aufwuchs occurred in the shallow water of stream and reservoir, such as Nitella mucronata, also a species of Vaucheria. The latter was found only in the very shallow water and on the wet mud of the lowest part of the tributary stream and not on the shores of the reservoir. This species appeared to produce reproductive bodies only when immersed in one or two inches of water. Moist depressions such as made by the hoofs of cattle close to the water's edge contained compact communities of algae. Besides Vaucheria, the common colonial forms were three species of Nostoc and Botrydium sp.

Occasionally there were filaments of two species each of Oscillatoria and Anabaena. The diatoms were less abundant; the commonest species were:-

Achnanthes minutissima
Anomoeneis zellensis
Amphora sp.
Cyclotella comensis
Cymbella sp.
Eunotia sp.
Eunotia tenella
Frustulia sp.
Gomphonema sp.
Gyrosigma sp.
Melosira sp.
Navicula sp.
Pinnularia sp.
Stauroneis sp.
Suirella sp.
Synedra rumpens
and Tabellaria fenestrata.

Also present were:-

Trachelomonas hispida
T. volvocina
Euglena sp.
Phacus sp.
Closterium diana
C. parvulum
Cosmarium granatum
C. hammeri var. africanum
C. laeve
C. subcrenatum
C. sulcatum
Selenastrum westii

and an unidentified motile alga. Many of these algae



mentioned above occurred in the aufwuchs associated with organic matter.

On the mud taken from the deeper parts of the reservoir the commonest algae were Trachelomonas volucina, Phacus sp. two unidentified flagellates, filaments of Anabaena sp. and two Oscillatoria species. Few diatoms were found in this region.

The free-floating algae. Estimation of the sizes of populations of free-floating algae deduced from examinations made of samples drawn at different stations are given in Table 1 in Appendix 2. They are expressed as cell units per litre of water.

Variations occur according to period of the year and from station to station. Different species of algae were concerned in the increases at different times, e.g. the high total occurring on the 18th April at site D was due mainly to an increase in the relative numbers of Sphaeroszoma sp. whereas on the 11th December at the same site Melosira granulata was the commonest species. The largest algal populations were found to occur during March to April. A scarcity showed itself in June to August. A marked fall in population in the tributary stream and reservoir happened at the beginning of November. At this time heavy rains fell and the stream was in flood. Algae were probably swept downstream into deeper water. Estimates of phytoplankton in the reservoir for the 8th November showed a concentration of algae at five feet below the water surface.

Most of the free-floating population belonged both in cell totals and in species totals to the Chlorophyta or to the Chrysophyta. Two groups of algae prominent in these divisions were the diatoms and the desmids. Table 2 in Appendix 2 indicates the fluctuations in the totals of diatoms and desmids. In the reservoir the peak for desmids

occurred on the 24th March; for diatoms on the 9th January. During May to October totals of both were small. Figures for the tributary stream show a similar trend.

The commonest algae found floating in the reservoir were Staurastum manfeldtii, Sphaerosma sp., Trachelomonas spp., (T. hispida and T. volvucina), and Melosira granulata. During March and April Botryococcus braunii was abundant but is omitted from Table 3 as no reliable numerical estimate was possible. The two Trachelomonas species were the only algae present constantly throughout the year although less numerous in winter.

The peak period for Melosira seemed to occur during December - January, whereas Staurastrum and Sphaerosma were more abundant in March (See Table 3 in Appendix 2).

There was no phytoplankton specifically characteristic of the populations of the tributary stream. The algae collected in the water samples were of the same species occurring, but in greater abundance, in the nearby aufwuchs communities, and presumably originate from the latter (See Tables 4 and 5 in Appendix 2).

The estimates of populations of free-floating algae made from different depths at site B on the night of the 1st December showed no changes during the period 6 p.m. to 9 a.m. on the following day.

The culture experiment. The estimates of the total algal populations in the four nutrient media of the culture experiment are shown in Table 14. It can be seen that the addition of extra nitrate or phosphate has increased the size of the algal population. It would appear that the addition of phosphate and nitrate delays the peak population although it is eventually the largest population. The total number of diatoms per litre of each culture solution are shown in Table 15 of Appendix 2. Here again the addition of nitrate and phosphate produced the largest population.

Unfortunately this experiment was not so successful as it appears from the results shown in Tables 14 and 15, because the majority of the populations belonged to species of algae which were only of a minor importance in the original natural populations or as contaminants introduced during the experiment. So it would be unwise to draw any conclusions from these populations as to the effect on the algal population in the reservoir of an increase in the level of nitrate or phosphate. But this experiment does illustrate that the culture of algae in the laboratory is difficult. Probably pure or simple mixed cultures in larger containers would have produced more reliable results.

Chapter V

THE ANIMALS

The investigation conducted under this heading followed generally the lines of that concerning algae, i.e. it sought to identify species, to note their distribution, to assess the size and any variations of the populations; also to note feeding habits.

The animals are discussed under three headings:

- 1) zooplankton,
- 2) other invertebrates and
- 3) vertebrates.

Methods of Collection.

(i) zooplankton. Collections of samples were made from the main waters of the reservoir. They were obtained at regular monthly intervals between June 1956 and February 1957, usually at 3 p.m. The method used was to tow a conical net

astern a boat at an even and moderate speed through the surface water. The net was made of bolting silk with 120 meshes to the square inch. It was 14 inches in diameter at the open end and four feet in length. The open end was attached at its circumference to a metal ring of the same size, which in turn was attached by a rope 12 yards long secured to the stern of the boat. At the apex of the net a small glass bottle was so fixed that entrapped material was swept into it.

The tow was made always along a course shown on Map 1 from the deeper end of the reservoir, near the dam wall, direct to the shallow end.

At the finish of a tow the glass sample bottle was detached and the contents preserved until examination at the laboratory by addition of a small quantity of 20% formalin buffered with hexamine.

(ii) Other invertebrates. These were collected by hand from stones, mud and organic matter along the shore of the reservoir and the bank of the 'top' tributary stream. A coarse linen net attached to a long handle was also used to collect invertebrates from the shallow waters in the same regions. The invertebrates living on the mud in the deeper waters were collected by means of the mud scoop described in Chapter IV. These non-planktonic invertebrates were kept moist and transported in glass bottles from field to laboratory. Collections were usually made at the same time as were the algal collections from the same situations.

(iii) Vertebrates were observed in the field. Occasionally specimens were collected.

Methods of Examination. The zooplankton samples were examined under a binocular microscope using a $1\frac{1}{2}$ ins. objective and a x 10 eyepiece. The volume of each zooplankton sample was made up to 200 milli-litres with distilled water, then well shaken and a 1 milli-litre aliquot

was withdrawn and placed in the Rafter counting cell. After a preliminary survey for rare specimens, the animals were counted along two traverses of the length of the cell. This procedure was repeated on two further millilitres and the average of the six counts was taken as a basis for the estimation of the zooplankton population.

The non-planktonic invertebrates were examined under a low power microscope; no precise methods were used to estimate the size of their populations.

Dead specimens of the crab, Potamonantes sidneyi, and the water tortoise, Pelomedusa subrufa, were identified in the laboratory. The other vertebrates were identified by the use of field keys. Field glasses when necessary were used to observe the reptiles, birds and the otter, Aonyx capensis. Notes were made in the field of observations.

The zooplankton. The commonest animals collected in the tow-net were Diaptomus sp., two species of Daphnia, the larvae and pupae of Chaoborus sp. and Keratella cochlearis. Occasionally other animals, more characteristic of the littoral regions, were found.

The totals of the zooplanktonic organisms are shown in Table 11 in appendix 2. On the 2nd. November and the 24th. December the numbers of organisms caught are noticeably smaller. During these months there were heavy rain storms which would cause a sudden dilution of the planktonic population. If these heavy rains had not occurred it is a matter for conjecture whether or not the population of Entomostraca would have reached a higher peak than it did, and probably during December or January. The figures for the tow-netting on the 15th. February suggest the beginning of a fall in the size of

the zooplankton population.

The species of *Diaptomus* seems to have two maxima, one in July and the other in January. This is in contrast with findings in temperate Europe and North America where species of *Diaptomidae* usually have one summer maximum. The Cladoceran population fluctuated more rapidly than the Copepods. The lowest numbers of *Daphnia* spp. were found either at the time the largest number of *Chaoborus* larvae were present or a little later. The reduction of the *Daphnia* population might have been caused by the *Chaoborus* larvae feeding on them. Ostracods were rarely found in the plankton; they were most abundant among the littoral vegetation.

The *Chaoborus* larvae had a maximum in January. The small number of pupae found in the samples suggest that the *Chaoborus* larvae migrate from the surface layers of the reservoir to pupate. Wood (1956) discovered a definite adlittoral migration of *Chaoborus* sp. pupae in a lake in Ontario, Canada, but no pupae were noticed in the littoral regions of the Jameson reservoir.

Keratella cochlearis showed a sudden increase in December but for most of the year, this rotifer was not abundant.

On two occasions tow-nettings were made at intervals throughout the night, to obtain material for the study of any diurnal vertical movements of zooplankton. The results are shown in Tables 12 and 13 in Appendix 2. These figures indicate what species have left or entered the surface since the previous tow-netting. The night of the 21st June was a normal winter's night with full moon, and that of the 1st December a normal summer's night with no moon. In the middle of the night in June

the numbers of Diaptomus were low but in December there seemed to be a small peak at such a time. In regard to the two Daphnia species the reverse was the case, a large number occurred in June at 1 a.m. and a lesser number in December at 12.30 p.m. It is noteworthy that in June the movement of the Chaoborus larvae was similar to that of the Daphnia species. The rotifer Keratella cochlearis showed no appreciable movement on either occasion.

Other Invertebrates. Many small invertebrates were found in the littoral zone of the reservoir, and in the tributary stream. Some were found moving freely about the wet mud or shallow water, others were closely associated with living plants and others lay beneath or near to stones.

Staphylinids were the commonest beetles to be found on the mud near the water's edge. Gyrinid beetles and Hygrometrid water-skaters were common, moving rapidly over the water's surface in the sheltered parts of the reservoir and in the tributary stream. Below the water's surface in the same regions amongst the aquatic plants were adult insects belonging to the families Corixidae, Hydrophilidae, and Dytiscidae and immature stages of Zygoptera, Anisoptera, Tricoptera, Ephemeroptera, Hemiptera and Culicidae. All these insects were more abundant in the summer than in the winter.

Several animals were found amongst the tangle of algae growing around aquatic plants and stones.

Protozoa and Nematodes were the commonest but a few water-mites, Chaetognatha, leeches, and a few unidentified insect larvae were also present. These animals were most abundant during the spring and summer

when the aufwuchs was fully developed. A small ^{mollusc}/Ancylus caffer, was occasionally found attached to plant stems, but more often to stones, in the littoral zone of the reservoir.

Common underneath the stones in the littoral zone of the reservoir were several species of Triclad turbellaria and Annelid worms. The stones in the deeper parts of this region, that is between three and six feet, when the reservoir was full, were usually encrusted with a Spongillid sponge, bright green in colour from the symbiotic blue-green algae it contained. In the mud of the same region, as well as in the deeper waters, Chironomid larvae were common in the spring and summer months.

The only large invertebrate was the crab Potomonautes sidneyii which was often seen moving over the mud in the reservoir and tributary streams. These crabs seem to act as scavengers and feed on dead animal and plant material. They dig burrows into the bank of the stream and shores of the reservoir, into which they quickly disappear when alarmed.

The Vertebrates. According to the records of the Albany Angling Society the reservoir was stocked in 1938 with 22 largemouth black bass - Huro salmoides. In 1950, 35 mosquito fish, Gambusia affinis affinis, were introduced to serve as 'forage fish' for the bass. The records state that the last bass was seen in December 1954. During 1956 the present writer observed only one black bass and a few gambusia fish in the shallow waters near the mouth of the 'top' tributary stream.

It is understood that for a few years after 1938 fish in the reservoir were plentiful. After a bad drought in 1946 there was a decline in the size and numbers of bass caught. The decline continued in the following years, and in consequence, in 1954, the reservoir was closed to fishing.

Black bass lay their eggs in a nest made of a variety of materials such as stones, gravel, among fibrous roots, or on a hard bottom deposit. In all cases the nest is carefully fanned free from silt and mud. A bottom of soft deep mud is unsuitable for nesting and under these conditions the fish do not spawn, or if they do the eggs are not viable. In the Jameson reservoir a suitable area for nesting would be the shallow littoral region where the bottom deposit is hard. Other deeper parts of the reservoir bottom are not so suitable. As the water level in the reservoir fluctuates irregularly, it is probable in any year that some of the eggs were destroyed by exposure. Also the young fry would lose the protection of rooted aquatic plants. This fluctuation of the water level and a lack of planktonic food were probably the most important factors limiting the size of the bass population rather than the presence of too many predators or some unfavourable chemical factor in the water. The gambusia mosquito fish are viviparous and so fluctuations in water level would not interfere with their propagation.

The amphibia were represented by several species of Rana. These insectivores were plentiful near the mouth of the 'top' tributary stream where they were noted actively moving in the water or resting amongst the floating vegetation.

Two reptiles were seen near the reservoir; the water leguan Varanus niloticus, and the water tortoise Pelomedusa subrufa. According to the "Guide to the Vertebrate Fauna of the Eastern Cape Province" published by the Albany Museum (1937) Varanus niloticus "...occurs in all the rivers of our region. Large ones sometimes travel far from water, visiting fowl-houses, etc. Is carnivorous and egg-eating, fond of crabs, snails such as the large Achatina, frogs and toads, especially Breviceps and Bufo, the prey being swallowed whole,

also takes rats, mice and birds ...lays its soft-shelled eggs ...deep down in living termite heaps near rivers or reservoirs but sometimes high above the water...."

The water leguans were observed on many visits to the reservoir. Often they were seen scraping away mud and soil at the foot of the stream bank, possibly searching for the crab Potomonautes sidneyii in their burrows. Such burrowing by the crabs and leguans must weaken the solidarity of the stream bank, which added to the effects of water erosion and also of the movements of cattle is likely to lead to the collapse into the stream of portions of the bank. Such an occurrence is likely to have an important effect on the organisms living in the stream.

According to the guide book quoted above the water tortoise Pelomedusa subrufa "...occurs plentifully in dams and reservoirs throughout our region and the same species is distributed throughout Africa, except the Rain Forest. They leave the water in winter, roughly from May to August and bury themselves in soft soil or under trees among the dead leaves remaining there until the warm weather comes. When the dams dry up they leave and bury themselves as in winter, but not in the bed of a dam. They are mainly carnivorous, feeding in the water. Any insect falling in the water is eaten, they will catch frogs and fish in pools when the water is drying up, and it is common knowledge that they will catch small ducklings and goslings. In summer they like to bask in the sunshine just at the edge of the water, retreating therein on the slightest alarm...."

It was confirmed that these water tortoises were quick to move into the water when alarmed. The veld fire that occurred towards the end of winter killed a number of these water tortoises hibernating near the edge of the reservoir.

The birds visiting the reservoir can be classified into three groups comprising feeders on:

1. fish,
2. soft vegetable matter and
3. insects, worms, etc.

The numbers and habits of the birds in these groups were quite different. The fish-eating birds were the common grey heron, Ardea cinerea, the South African darter Anhinga rufa levaillantii and the Malachite Kingfisher Corythornis cristata cristata. These birds were few in number and were often found in positions overlooking the water.

The ducks and geese fed on soft vegetable matter. They were more numerous in individuals and species than the fish-eating birds. They usually frequented the region near the mouth of the 'top' tributary streams where the greatest development of the hydrophytic vegetation occurs.

Those birds feeding mainly on insects and other small animals were ubiquitous and numerous.

The Cape clawless otter, Aonyx capensis, was seen on a few occasions. It is amphibious in habit and said to feed on fish and crabs.

The spoor of a small antelope was seen on two occasions at the water's edge near the mouth of the 'top' tributary stream.

Chapter VI

DISCUSSION AND CONCLUSIONS

Apart from the records of the extensive investigations of Hutchinson, Pickford and Schuurman between 1927 and 1929, published studies of South African standing waters have been mainly systematic in content. Natural waters have been studied more often than artificial lakes and reservoirs.

Against this background it seemed desirable that the present investigation should be wide in scope. The aim was to collect information on many aspects of one particular stretch of water, the Jameson reservoir, in order to obtain some understanding of the complete biocoenosis associated with it. A municipal reservoir was chosen rather than a natural pan because it was less likely to dry out.

One year's investigation by a single person is unlikely to produce an account that is sufficiently detailed in any single respect, and moreover conclusions drawn from data

for any one year may be exceptional in some feature.

To counteract the disadvantages of lack of time and assistance, the collecting methods chosen were simple; the field apparatus was compact and light for ease of transport. During any one visit to the field, specimens of animals or plants were collected, water samples drawn, and physical measurements made which tended to reduce the effect of variable factors.

Ricker (1937) pointed out that estimates of a plankton population made from total counts of individual samples are subject to sampling errors. These errors can be allowed for only if the distribution is known to be random or when the methods of collection are designed to overcome the lack of randomness. Langford (1953) concluded that "...a lack of randomness should be assumed in individual instances, until the opposite has been proven...." Variations in the abundance of plankton occur in both horizontal and vertical directions as well as with time. To overcome these variations fully, replicate vertical series of samples should be taken frequently at a number of stations in the open water throughout the season. Errors in sampling other communities of organisms and in measurements of physico-chemical features of the environment should be allowed for in a similar manner. In practice it was impossible to collect the adequate number of samples. As a result only major variations, that is consistent differences over a period or trends, will have much meaning.

A plankton net towed the length of the reservoir should eliminate irregularities in the horizontal distribution of plankton. No species were found in vertical tow-nets that did not occur in the surface samples. Thus qualitatively the surface samples were representative of the deeper waters of the reservoir. Unfortunately the smallest organisms, the

nannoplankton, pass through the finest meshes of bolting silk, and some other method of collecting these organisms is needed. The other important disadvantages in the use of plankton nets are their varying efficiency when different concentrations of plankton are sampled. The efficiency of plankton nets has been shown to change with age and accompanying shrinkage and fraying of the threads. Langford (1953) said that the more active organisms may be able to avoid being caught in the net.

The Sedgwick-Rafter method of enumeration was used in the present investigation for the nannoplankton since it did not require additional expensive equipment. Although the small amount of water collected by the Kemmerer water sampler makes it impossible to count the larger and rarer forms, it is suitable for the commonest species. With this method one can collect organisms of less than ten microns broad e.g. Cyclotella sp., but it is unknown what percentage of the smallest organisms are left entangled in the grains of the sand filter when the concentrated sample is decanted.

Quantitative estimates of the attached littoral and benthic forms were not attempted.

The vegetation surrounding the Jameson reservoir has been described in Chapter II. In general the findings are in agreement with those reported for other parts of South Africa and elsewhere.

The form of the reservoir has a great influence on the physico-chemical conditions and indirectly on the biota occurring there. Owing to the seasonal incidence of the rainfall the Jameson reservoir is an astatic water. Its basin is shallow, particularly at the eastern end, hence a fall from the high summer water level leads to the exposure of relatively large areas of shores during the winter months. Cattle and aquatic birds commonly deposited their excreta in

the shallow water or on the wet mud. Also many Phanerogamic plants colonised the mud when the water receded.

Hutchinson et al (1932) when referring to grass pans in South Africa said "...the bed of the pan when dry is frequented by domestic animals. When the pan fills the accumulated dry dung of these animals as well as the decaying terrestrial vegetation constitutes a rich source of organic matter a medium for bacteria and saprophytic flagellates.... It is probable that the richness of the fauna of many temporary waters is to be explained by such a sudden influx of nutritive matter as soon as the basin has filled"

Wright (1954) said that the zooplankton populations in Atwood Lake, U.S.A. in 1947 were greater in the shallow upper end where a large amount of vegetation was inundated by a rise in water level than in the deeper regions. The zooplankton population was not associated with a large phytoplankton population.

Soon after the water level rose in the Jameson reservoir following the heavy rains in the spring, there was a large increase in the quantity of microscopic animals and algae in the littoral regions particularly near dead organic matter. It is assumed that a similar increase in the number of saprophytes occurred in the Jameson reservoir as was described by Hutchinson.

Photographs 23 and 24 show the extent to which the water level may fluctuate at one site in the tributary streams. During the dry winter period the lower reaches consisted of a series of pools interconnected by shallow rivulets. After heavy rains the water level rose rapidly, the limits of the pools were lost, vegetative matter was torn free and swept down the streams to the quiet backwaters around their mouths. In spring and summer these masses of organic matter were colonised by many algae and animals, similar to those found

in decaying organic matter in the littoral region of the reservoir.

Another important feature associated with the shallowness of the basin was the uniformity in the physico-chemical conditions. For example the largest differences throughout the year in temperature, dissolved oxygen content and pH between the surface and the deep waters of the reservoir were 2.8°C, 3.52 milligrams per litre and 0.1 respectively. No consistent differences in the concentration of dissolved substances were correlated with a change in depth. The absence of a hypolimnion allows the water to be mixed by wind action. As a result there follows an even distribution of dissolved oxygen and the products of organic decay probably largely derived from the bottom deposit. It is unlikely this would have been the state of affairs had the reservoir been deep, as Ruttner (1953) said that "...the influence of sediments is greater the smaller the lake or the larger the surface area of its sediment with respect to the volume of water...."

The range of diurnal and nocturnal fluctuations in temperature, gaseous content, and pH of the water in the Jameson reservoir and 'top' tributary stream is shown in Graph 1 and Tables 1 and 6 of Appendix 1. The salient features have been mentioned in Chapter III.

Hutchinson et al (1932) said that "...taken as a whole the waters of South Africa differ from those of temperate Europe and North America more in their high winter than in their summer temperatures.....It seems probable that none of the localities investigated by us ever fall below 4°C, the temperature of maximum density of water...."

Nygaard (1932) said while discussing temperatures in the waters of the Transvaal that...." the shallow lakes and ponds (i.e. the pans) in winter nights may cool down to temperatures not much above freezing while in summer, they may reach day temperatures not far from 30°C. The deeper lakes of course,

afford a considerably smaller daily and annual oscillation.... In the month of July, when the temperature of the air is near its annual minimum, water temperatures of 17.5 to 20°C were observed, which shows that day temperatures of the bodies of water may be high even in winter. It is therefore evident that the plankton and more especially the algal flora are exposed to extraordinarily great daily and annual oscillations of temperature...."

The results obtained from the Jameson reservoir agree with the conclusions of these earlier workers.

The chemical analyses of the bottom deposit shown in Table 2 of Appendix 1 have been commented on in Chapter III. The carbon : nitrogen ratio has frequently been used to characterise a soil. Although a particular portion of organic matter may undergo a rapid decomposition there is in general an equilibrium between the various soil decomposition processes. It is assumed that this C/N ratio can be used to characterise a mud in a similar fashion. Misra (1938) said the C/N ratio of mud does not depend to any large extent upon the original chemical nature of the organic matter it receives. Issac (1935) while discussing the soils of the South Western Cape said "...Taken as a whole, it would seem that the narrowing of the C/N ratio with depth is to be regarded as a corollary to the general theorem that the C/N ratio tends to narrow with decreasing organic matter content in the soil...." The chemical analyses of the mud from the Jameson reservoir seem to indicate a similar narrowing of the C/N ratio with increasing depth below the surface. The C/N ratios shown for the reservoir are within the range found for the sediments of a number of lakes in Cumberland (Misra 1938

Pearsall and Pennington 1947).

The noticeable feature of the water was the small quantity of dissolved material. The elements estimated were present in ^{low} concentration except for sodium and chlorine. Even the maximum values for these two elements 108 milligrams per litre for chlorine and 52.9 milligrams per litre for sodium, were not large enough to warrant the water being termed brackish.

Other interesting features of the chemical analysis of the waters can be summarised as follows: The pH of the reservoir was always close to the neutral point and the water in the tributary stream was usually slightly acid; Milner reservoir and the Grey dam appeared to be slightly more acid whereas Howieson's Poort was slightly more alkaline than the Jameson reservoir. Except for the Grey dam, the elements sodium, potassium, calcium, and magnesium were in a slightly stronger concentration in the Jameson than in the other Grahamstown reservoirs. Often the concentrations were higher in the reservoir than in the tributary stream. The concentration of iron in the Jameson reservoir showed an increase during the months of August to December; Howieson's Poort and the Grey dam had only a small quantity of iron present. The silicon concentration in the Jameson reservoir was moderate and seemed to be slightly higher in the upper reaches of the stream. Milner had the highest concentration of silicon of all the reservoirs investigated. The phosphate content was always low in all the reservoirs. Sulphate sulphur reached a maximum in August, after which there was a large decrease in the Jameson; the Grey dam had only a trace of sulphate sulphur. Howieson's Poort had the lowest and the Grey dam the highest concentration of chlorine. In the Jameson reservoir the total inorganic nitrogen content showed the highest figures during August to December. The individual values for nitrate, nitrite and ammonium nitrogen followed the same trend, with most of the

nitrogen being in the ammonium form and the least being present as nitrite. The total inorganic nitrogen value for the Grey dam (1.087 millegrams per litre) was the highest recorded. It appeared from Tables 5 and 3 in Appendix 1 that organic nitrogen was more abundant than the inorganic nitrogen in the Jameson reservoir during November. Whether this applied to the whole year is unknown. The two trace elements investigated, zinc and manganese, were present in very small quantities.

The limnoplankton of the reservoir, i.e. forms characteristic of the open water consisted of a few species. The chief species in the zooplankton were two species of Daphnia, a species of Diaptomus and the larvae of one species of Chaoborus. The commonest algae were Melosira granulata, Staurostrum mannfeldtii, Trachelomonas spp. and Sphaerosoma sp. Individual species of many algae were found occasionally in the open water but most were more abundant attached to aquatic plants or stones in the littoral zone. Similarly the majority of algal species found floating in the tributary streams were more often found attached to the neighbouring plants or stones.

Schuurman (1932) found a nocturnal vertical migration of the zooplankton in Florida Lake near Johannesburg. She found the largest number of organisms in the surface waters one or two hours after ^{sunset.} It appears the zooplankton of the Jameson reservoir reach their maximum vertical movement later in the night than those in Florida Lake. Also Ruttner (1953) referring to European waters, said "...usually find the maximum of Crustacea in the surface waters at the beginning of evening twilight..." No vertical movement was detected in the phytoplankton of the Jameson reservoir. The small amount of nocturnal vertical movement of algae that Schuurman (1932) observed in Florida Lake, she attributed to involuntary

movements due to currents.

In Europe, the seasonal distribution of phytoplankton is bimodal, with minimal numbers in winter and mid-summer and maxima in spring and autumn. During the spring and autumn maxima, the diatoms and sometimes the Chrysophyceae are the most abundant algae. Next in numerical importance are the Cyanophyceae, which are usually most abundant in mid-summer when the diatoms are at a minimum. The Chlorophyceae are usually present in the summer also, but generally they form a small part of the total annual crop.

In the Jameson reservoir only a general summer maximum and a winter minimum could be discerned in the phytoplankton population. This is in agreement with Schuurman's (1932) investigation of Florida Lake near Johannesburg.

Pearsall (1932) found Melosira granulata occurred in abundance only in those lakes which have a considerable myxophycean element in their plankton. He suggested that "...the abundance of Melosira is conditioned by those factors which in summer bring about myxophycean maxima. Melosira granulata was not associated with a large myxophycean population in the Jameson reservoir.

Nygaard (1932) found that the semi-natural lakes and river dams in the Transvaal were dominated by the diatom Melosira. He found Melosira granulata var. augustissima reached a very great development in February and July. He suggested this was because the temperature in the larger waters of the Transvaal did not fall below the optimum temperature for the species. The majority of the planktonic diatoms are found in the cooler parts of the world. It may be that the higher annual mean water temperatures of South Africa exclude them from this region. Melosira seems to be the exception.

Both Nygaard (1932) and Huber-Pestalozzi (1928) found

Microcystis aeruginosa and Botryococcus braunii widely distributed in South African dams and vleis. Both species were found in the Jameson reservoir.

All the algae found in the open water of the Jameson reservoir were also found in the littoral regions. Godward (1937) found in Lake Windermere that many of the planktonic algae originated from the littoral region. Prowse (1955) said "...The tendency has been to regard samples of algae taken from open or free water as being the important part of the populationwith enclosed bodies of water a number of new factors operate and one would expect the presence of macrophytic vegetation or the nature of the bottom to exert some influence on the nature of the free floating population, especially in shallower waters....There seemed to be evidence that in some way the presence of the macrophytes stimulated the ratio of reproduction of the algae, and it is possible that they acted as generating cycles releasing the organisms to the open water. It may be argued that these forms should not be regarded as plankton, but it is evident that many of the organisms concerned were reproducing in the free-floating condition and showed no attached stage whatsoever...."

Nygaard (1932) said samples from Florida Lake and the Vaal River dam were the only Transvaal waters investigated by him that contained genuine plankton organisms "...such as make up the plankton of the larger bodies of water" Butcher (1932) concluded that small streams in the United Kingdom apparently lack a plankton distinctive from the benthic organisms. These opinions agree with the findings of the present investigation.

Godward (1937) found in general that the sessile littoral algal communities in Lake Windermere were dominated by diatoms in the spring, by green algae and blue-green algae in the summer, by diatoms and blue-green algae in the autumn and that

there was a small population of algae in the winter. She added that these generalisations were less true for littoral than for planktonic algae. Blum (1956), referring to benthic algae said "...as with planktonic algae, the seasonal variation may be summarised broadly as maximum development in warm months followed by minimum development in cold months, but many algae behave in quite different ways...." In the Jameson reservoir most of the algae were to be found in the littoral regions, often associated with organic matter in various stages of decay. There was a general increase in their numbers in the spring and summer at the time when most of the aquatic plants were actively growing and the water level had risen. A succession of dominant algae with change of season was not observed. The tables showing the population of free-floating algae show the peak populations in spring and summer. This may reflect the fact that there is a greater population of attached algae to supply detached free-floating cells in these months rather than that the conditions in summer in the open water were more suitable for algal growth than in the winter. The algal counts show an evenness in the distribution with depth. This compares with the uniformity of the physico-chemical environment of the reservoir.

Blum (1956) said "...the indications are that algal succession within a stream is less stereotyped and probably more intricate than certain well known successions of plants on land...." Butcher's methods (1932) for studying algal colonisation were modified and used in the present investigation. Although Reese (1935) produced some evidence to show that numerical results from slide counts were not comparable with those from the river bottom, she found the species present in both situations were similar. The results of the few studies of algal succession in the Jameson were presented in Chapter IV

and a few tentative conclusions were drawn.

The animals found in the littoral region were described in Chapter V.

The organisms characteristic of the bottom deposit exclusive of those associated with freshly deposited organic matter were few in number. In Europe, waters were classified in accordance with the species of Chironomid larvae present in the bottom deposit. At present there is insufficient data to test this classification on South African waters.

Ruttner (1953) defined the production of a community as "...the total amount of organic matter (representing the balance between assimilation and dissimilation) that is formed within a certain period of time from the raw materials supplied to the community...." In practice it is extremely difficult to calculate such a figure for an aquatic community and the usual indices of productivity are the standing crop of organisms present at any one instant or the concentration and the course of changes in dissolved materials which are thought to be due to biological activity. Present knowledge of the physiology and biochemistry of individual planktonic species and particularly of sedentary organisms is meagre. For these reasons inland waters are usually classified into a few large groups by the combination of these several methods of approach. The two main European types, the eutrophic and oligotrophic waters, can be regarded as the two extremes of a series which has a large number of intermediates. Hutchinson et al (1932) described the eutrophic type as "...one rich in the various inorganic materials necessary for plant growth and does not contain an excessive amount of brown humic material; eutrophic lakes are in general rich in both zoo- and phytoplankton, since such lakes are shallow and have bottom deposits rich in organic material, the stationary water below the thermocline is deficient in oxygen, so limiting the nature of the bottom fauna...." The same workers described an oligotrophic

type of water as one "....deficient in all dissolved materials and poor in plankton. Oligotrophic lakes are deep and have little littoral vegetation or organic matter in their bottom deposits; they do not therefore suffer from an oxygen deficiency in the hypolimnion...." It appears that the conditions found in the Jameson reservoir more closely simulate the European oligotrophic than eutrophic waters.

Ruttner (1953) referring to Lundquist's investigations on the sediments of Swedish lakes and the studies of Gams on the Lunzer lakes said "....These studies are in agreement in showing that many lakes have undergone a gradual development towards eutrophy from their original condition of oligotrophy, as a result of the growth of marginal vegetation, accumulation of sediments and increased supply of nutrients...." Deevey (1942) came to similar conclusions after a study of Linsley Pond, Connecticut. Blum (1956) said "...that left to itself it would appear that a stream through its own maturation processes should over a period of centuries increase in eutrophy in its lower course...."

It was mentioned in Chapter I that the Jameson reservoir was completed just over fifty years ago. In terms of biological change this is not a long period of time. Already the shore vegetation is reasonably well developed, but the plankton, especially the algal section, is poorly represented. The younger South Western Cape reservoirs described by Hutchinson and his co-workers (1932) are characterised by a lack of shore vegetation, little phytoplankton and a zooplankton consisting almost entirely of Crustacea. It appears that these reservoirs represent a stage in development earlier than that illustrated by the Jameson reservoir. The lower regions of the 'top' tributary stream seem to be more productive than the upper reaches, which agrees with Blum's views mentioned above.

The reasons for the seasonal periodicity and low productivity of the algae in the Jameson reservoir are probably numerous.

The high annual mean water temperature may adversely affect the annual crop but the small seasonal fluctuations are unlikely to be the significant factor controlling the changes in sizes of populations. Since no measurements of light intensity or day length were made no conclusions can be made of their importance. Various investigators (e.g. Lund 1954 and 1955) have said that a seasonal fluctuation in light intensity was an important factor influencing seasonal periodicity. The turbidity of the water in the Jameson reservoir was not great. Table 7 in Appendix 1 shows the seasonal variation in the concentration of dissolved oxygen in the water. Ruttner (1953) said that "...under normal conditions the oxygen content first exerts a distinct limiting action at relatively low values...." (i.e. 1 to 2 milligrams per litre). It is unlikely that either of these factors was limiting the annual production of algae.

Much attention has been paid to the role of mineral nutrients limiting productivity and seasonal periodicity of algae. It has been established that certain species have specific nutrient requirements (Chu 1943 and Rodhe 1948). In comparison with water analyses from other parts of South Africa and elsewhere, the general concentration of the mineral nutrients in the Jameson reservoir was low. As the underlying rock in the watershed of the Jameson reservoir consists largely of silica it is not surprising that the water should have such a small concentration of dissolved nutrients.

Nitrate nitrogen and phosphate phosphorous are most often cited as limiting factors for phytoplankton growth. Chu (1943) said that the upper limits of nitrogen and phosphorus for optimum growth of several common genera of phytoplankton never occurs in natural waters. The results from the culture experiment when nitrate nitrogen and or phosphate phosphorus was added to water from the reservoir, have been discussed in Chapter IV and difficulties of culture experiments pointed out.

West (1916) was probably the first to suggest that a rich desmid flora was correlated with waters poor in electrolytes. Pearsall (1921) after a study of the various lakes in Cumberland was able to classify them in order of development of vegetation and dissolved materials. The phytoplankton of his 'primitive' lake type with rocky shores, little silt, and clear soft waters with a paucity of calcium and magnesium and an abundance of potassium and sodium, was dominated by desmids. He was also able to observe the replacement of the desmids by diatoms and blue-green algae as the dominant algae in the more advanced lake types, with well developed shore vegetation, silty shores and larger concentration of dissolved materials. Hutchinson et al (1932) said that "...localities rich in desmids are rare in South Africa..." In their investigations the maximum concentration of chlorine was .0022 N in 'desmid waters'. In view of this finding, the chlorine ion content of the Jameson reservoir may be too large for an abundant desmid population although all the other nutrients are present in concentrations similar to those 'desmid' waters of Pearsall. Tiffany (1951) pointed out that Pearsall's hypothesis did not satisfactorily explain the rich desmid collections found in the eastern parts of the United States.

Holsinger's results (1955) from Sinhalese lakes agree with Pearsall's findings that the presence of nitrogenous organic matter is one of the factors determining myxophycean maxima in English lakes. The blue-green algae in the Jameson reservoir were most abundant when associated with decaying organic matter on the bottom deposit, they were rarely found in the open water. In accordance with the earlier investigations this distribution might be due to their high organic nitrogen requirements.

Pearsall (1923) said that silicon and calcium were the

main elements limiting the diatom populations of English lakes. He said substantial increases in the proportions of diatoms will not take place in those lakes where the silica and calcium carbonate contents are below 0.5 and 3 milligrams per litre respectively. Table 3 in Appendix 1 shows the silicon and calcium concentrations were well above these minima and so could not be the factors limiting diatom production in the Jameson reservoir.

Trace elements may be definitely toxic to some planktonic organisms in high concentration. It is probable that concentrations of both zinc and manganese in the Jameson reservoir (See Table 5 in Appendix 1) were not large enough to be toxic and were sufficiently great to avoid a deficiency of these elements.

Although Budde (1944) and Hustedt (1944) emphasise the importance of pH as a factor influencing both the composition and production of the algal flora, many investigators favour the view that pH in itself is often not the limiting factor, but some other chemical factor associated with pH is responsible.

Hutchinson (1944) said competition between species was an important factor determining the composition of a biocoenosis. Round (1955) noticed an interaction between Achnanthes species and Amphora with Navicula species. Lefevre et al (1950) suggested that the secretion of antibiotics by dominant algal species might be an important factor in bringing about almost unispecific composition frequently reported for water blooms.

Recent work has suggested that there are unknown factors associated with organic matter, possibly of direct nutritive importance (Saunders (1957)). However, Chandler and Weeks (1945) suggested that a combination of factors determines seasonal

periodicity. If this is correct, then many pure and simple mixed culture experiments, closely associated with field studies of the natural environment possibly at the micro level, will be needed before all the factors controlling the composition and periodicity of the algal flora in the Jameson reservoir are known.

The dynamics of animal populations are complex. Although food is only one of the factors controlling animal populations, a clear exposition of predator-prey relationships is important to appreciate the structure of the community associated with the reservoir. Unfortunately the biotic interrelationships between the various taxonomic groups are largely unknown. For example there is very little information available concerning the relative importance of living algae in the diet of zooplanktons under natural conditions. The fact that Entomostracan and algal populations show a peak in the summer does not necessarily mean that living algae form the major part of the diet of these animals in the Jameson reservoir: a careful study of the gut contents of these animals would be needed to verify this. Species belonging to the same genera are known to be detritus feeders. If the majority of the minute animals in the reservoir feed on decayed organic matter then the algae are of secondary importance in the food cycle since it appears that most of the organic matter is derived from phanerogamic plants.

The relationships of the larger animals which feed on microscopic matter or on one another are even more difficult to understand. The paucity of the plankton is one possible reason for the small fish population of the reservoir. Hutchinson et al (1932) noted an abundance of bird life associated with waters with luxuriant shore vegetation. Johnsgard (1956) was able to correlate changes in water level and vegetation with changes in bird populations near

a dam in the State of Washington U.S.A. A few observations have been made on the relationships between the bird fauna and the shore vegetation of Jameson reservoir in Chapter V. It is not maintained that a satisfactory food supply is the only environmental requirement controlling animal populations.

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