The British Freshwater Phytoplankton, with Special Reference to the Desmid-plankton and the Distribution of British Desmids.

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I. Introduction.

Not until much work had been done at the phytoplankton of the freshwaters of Western Europe were investigations of a similar nature begun in the British lakes and rivers, and it is during the last ten years that almost all our knowledge of this branch of freshwater biology has been acquired.

We have ourselves conducted nearly all the British investigations, and we now think the work has progressed sufficiently to enable us to summarise the results, and to institute comparisons between the British phytoplankton and that of continental Europe and other regions.

Since 1900 we have collected plankton from a large number of lakes in the west of Scotland, from some of the lowland Scottish lochs, from practically all the lakes of the English Lake District and most of those in North Wales, from nearly all the lakes of the west and south-west of Ireland, from Lough Neagh and Lough Beg, from Malham Tarn in West Yorkshire, and from the Rivers Ouse, Lochay, and Bann. In the collection of material for these investigations we have been greatly assisted by four grants from the Government Grant Committee of the Royal Society and two from the Fauna and Flora Committee of the Royal Irish Academy.

From a biological standpoint the British lakes are of great interest, and since the publication of the first reports on their plankton, the diversity of the Algal constituents has been a revelation to the freshwater biologist. In the number and diversity of the species constituting this phytoplankton

the lakes of the western British areas stand ahead of any other lakes which have so far been investigated.

The numerous Scottish lakes are almost all of a montane character. They are situated in the vicinity of high mountains and in a northern latitude, and many of the higher plants occurring in these localities in abundance, at almost sea-level, are typical montane species.*

The lakes of the four principal areas examined, the North-west Scottish, the West and South-west Irish, the Welsh, and the English lakes, are situated in the most mountainous parts of the British Islands. As these areas contain the great majority of the British lakes, and are all geographically in the west or north-west, they can be spoken of as the *western and north-western lake-areas.* The mountains amongst which they are situated are composed almost entirely of old formations, and the lake-basins are for the most part drainage areas on outcrops of Older Palæozoic or of Precambrian rocks, often with associated intrusive Igneous masses.

Malham Tarn, West Yorkshire, and Lough Neagh are somewhat isolated lakes, and their phytoplankton is considered separately.

Wherever possible, boats were used for the collection of the plankton, and for one part of the investigation of Lough Neagh, the Lough Foyle and River Bann Fisheries Company kindly lent a steam launch. The smallest tow-net had a mouth-diameter of 6 inches and a length of 15 inches, the largest was 12 inches diameter and about 36 inches in length. The nets were usually towed after the boat at a speed of about $1\frac{1}{2}$ to 2 miles per hour, but on Lough Neagh the large nets were used up to a speed of 4 miles per hour. They were generally kept in the water from 20 to 30 minutes.

We have come to the conclusion that *the best fixing agent is 2 or 3 per cent. formalin, but it should always be replaced before the material is examined.*

Neither picric acid nor chromic acid should be used in plankton-work, as it is almost impossible to wash the material free from these reagents by ordinary methods, and *all the gelatinous colonies are broken up.* Alcohol is also to be avoided, as it causes too great a shrinkage and distortion of the more delicate plankton species.

During the past 18 years we have been acquiring a very extensive knowledge of the distribution of British freshwater Algæ, having made many thousands of collections in all parts of the British Islands. As the lake-areas are the richest parts of the country for freshwater Algæ, these districts

* Occurring in abundance around these lakes are :—*Festuca ovina*, var. *vivipara*, *Andreæa Rothii*, *A. petrophila*, *Bryum alpinum*, various species of *Rhacomitrium*, *Anthelia julacea*, *Platysma triste*, *Cladonia cervicornis*, *Stereocaulon coralloides*, *Sphærophoron coralloides*, *Lecidea geographica*, etc. The whole district is almost treeless.

have been worked very extensively, and as we did not begin plankton investigations until 1900, we have a much more complete knowledge of the general Algæ-flora of these areas—such as is found in the bogs, lake-margins, streams, on the wet rocks of the glens, etc.—than of the phytoplankton. In consequence of this previous detailed acquaintance with the Algæ of the lake-areas, we are enabled with a considerable degree of accuracy to state which species should be considered as *true constituents of the plankton* and which should not. The other constituents are *casual or adventitious,* and their sojourn in the plankton is both temporary and accidental.

The work has been entirely of a qualitative character. We have had neither the time nor the necessary funds to conduct quantitative investigations such as those carried out by Apstein,* Zacharias,† Lemmermann,‡ Volk,§ etc., in Germany, by Wesenberg-Lund‖ in Denmark, by Huitfeldt-Kaas¶ in Norway, and by others in Switzerland and the United States.**

We have also met with many difficulties in attempting to acquire a knowledge of the periodicity of the plankton of the British lake-areas. Neither academic duties nor funds have permitted the necessary number of visits to these areas which would be required in the course of a year in order to obtain an adequate idea of the periodicity of the plankton. At the very least, monthly visits would be imperative for reliable results to be obtained; and to collect material from a number of lakes, even in one district, would require several days, not to mention the difficulty, and in some cases the impossibility, of obtaining boats in the winter months. It is likewise no easy matter to find suitable men on the spot of sufficient intelligence to carry out detailed instructions at regular monthly intervals throughout the year.††

* Apstein, 'Das Süsswasserplankton, Methode und Resultate der quantitativ. Untersuchung.,' Kiel und Leipzig, 1896.

† Zacharias in 'Forschungsber. Biol. Stat. Plön,' vol. 3, 1895, etc.

‡ Lemmermann, "Das Plankton der Weser bei Bremen," 'Archiv für Hydrobiologie und Planktonkunde,' Bd. 2, 1907.

§ Volk, "Hamburgische Elbe-Untersuchung., I u. VIII," 'Mitteilungen aus dem Naturhist. Mus. Hamburg,' Bd. 19, 1903; Bd. 23, 1906.

‖ Wesenberg-Lund, 'Studier over de Danske Söers Plankton, Kjöbenhavn,' 1904.

¶ Huitfeldt-Kaas, 'Planktonundersögelser i Norske Vande,' Christiania, 1906.

** C. Dwight Marsh, in 'Wisconsin Geol. and Nat. Hist. Survey Bull.,' No. XII, 1903; Kofoid, in 'Bull. Illinois State Laboratory of Nat. Hist.,' vol. 8, 1908.

†† We are at present receiving regular periodic collections, with some necessary data, from several of the Scottish lochs and from some of the lakes of the English Lake District. We have been able to arrange for these collections by means of a further grant from the Royal Society. Periodic collections have also been made for a period of two years from one of the large pools of the Midlands. The details of all these collections will be published shortly.

II. Scottish Lakes.

Extensive collections of phytoplankton were made in various parts of Scotland, but especially in the west and north-west, in August, 1901, May and August, 1902, April, July, August, and September, 1903, and August, 1907. The areas comprised Perth, Inverness, Ross, Sutherland, and the Outer Hebrides. We have also examined a number of collections made by Mr. James Murray of the Scottish Lake Survey (Pullar Trust). In all, we have examined phytoplankton from 38 of the most important of the Scottish lochs. The results of these investigations have already been published,* the previous work being represented by a short report by Borge on some phytoplankton from the Island of Mull.† Mr. James Murray has also examined the plankton of a very large number of the Scottish lochs, and has at different times commented upon the occurrence and distribution of the phytoplankton.‡ Further remarks upon the Scottish phytoplankton have been made by Wesenberg-Lund in comparing it with the plankton of the Danish lakes,§ and still more recently a paper has appeared by Bachmann|| comparing the results of Scottish material with plankton from the Swiss lakes.

The Scottish phytoplankton is largely Chlorophyceous, and is conspicuous for the large number and great variety of its Desmids, among which the following are perhaps the most noteworthy: *Xanthidium subhastiferum*, *Staurastrum anatinum*, *St. Ophiura*, and *St. jaculiferum*. In some of the lochs, *Mesotœnium macrococcum* occurred as a normal constituent of the plankton. This is a most interesting adaptation of a colonial wet-rock species to a limnetic life, with an accompanying reduction in size of the colonies and their assumption of a spherical form. A similar adaptation of the mucous colonies of *Cosmocladium saxonicum* to a limnetic existence is also found in both the Scottish and the Irish lakes, but much less frequently.

In the smaller and more elevated lochs, *Microspora amœna* is a characteristic

* W. and G. S. West, in 'Linn. Soc. Journ. Bot.,' vol. 35, Nov., 1903; in 'Roy. Soc. Edin. Trans.,' vol. 41, part 3, 1905.

† Borge, 'Algol. Notis. 4, Süssw.-Plankton aus Insel Mull,' Botaniska Notiser, 1897.

‡ *Vide* James Murray, in 'Roy. Physical Soc. Edin. Proc.,' vol. 16, June, 1905; and in various reports, under the direction of Sir John Murray, on the Bathymetrical Survey of the Freshwater Lochs of Scotland in the 'Geograph. Journ.,' 1900—1908.

§ Wesenberg-Lund, in 'Roy. Soc. Edin. Proc.,' vol. 25, part 6, 1905; also in appendix to a subsequent paper, *ibid.*, part 12, 1906.

|| Bachmann, in 'Archiv für Hydrobiol. u. Planktonkunde,' vol. 3, 1907. It should be mentioned, however, that some of Bachmann's records are open to serious doubt. His identifications do not appear to be strictly accurate. We might ask, among many other questions, "What is *Cosmarium lunaria*?" He also copies Tanner-Fulleman's records, some of which appear to be equally doubtful.

constituent of the plankton, and sterile filaments of slender species of *Spirogyra*, *Zygnema*, and *Mougeotia* occur in abundance. The more slender species of *Mougeotia* are generally the most abundant of these filamentous Algæ, and in some instances they exhibit a coiling of the filaments such as is known to occur in certain of the plankton-forms of *Melosira*. (Consult fig. 1.)

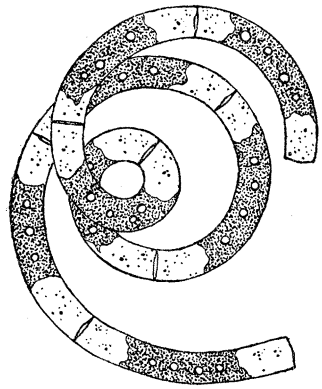

Fig. 1.—A Coiled Filament of one of the Sterile Species of *Mougeotia* from the Scottish Plankton. ×300.

The Protococcoideæ are not very abundant in the deeper Scottish lochs most of them having a decided preference for shallower and warmer water. The most frequent are *Botryococcus Braunii*, *Sphærocystis Schroeteri*, *Glœocystis gigas*, and *Ankistrodesmus falcatus*.

Diatoms are conspicuous, largely due to the occurrence in quantity of a few species. They occur throughout the spring and summer in large numbers in the deeper lochs, as the temperature of the water never becomes very high. Many of them are adventitious constituents washed into the plankton from the bogs and shores, but some have become established as true plankton-species. There are about 18 well-established species in the plankton, but only the three species of *Rhizosolenia* are of exclusive limnetic habit, all the remainder occurring in other situations.

The Myxophyceæ (Blue-green Algæ) are very poorly represented in the deeper lochs, and are by no means abundant in the smaller, shallower lakes. The phenomenon of "water-bloom" is very rarely met with, and discoloration of the water, even of the smaller lakes, does not occur either very often or with any great regularity as the result of the accumulation of large quantities of Blue-green Algæ.

The only periodic collections which have so far been reported upon were those made in Loch Ness and examined by Bachmann,* and our own

* Bachmann, *loc. cit.*, 1907, pp. 85—88.

observations relative to the periodicity of the Scottish phytoplankton are amply confirmed by Bachmann's brief report.

Desmids are the dominating constituents in the late summer and early autumn, and there is a preponderance of Diatoms in the colder months, but compared with the seasonal variations of the phytoplankton in some lakes, these differences are not very conspicuous.

Specimens of *Dinobryon* occur in quantity in the spring and summer, and the Peridinieæ are represented by 11 species, although in the larger lakes they are by no means numerous.

Of a total number of 354 species observed in the phytoplankton, 49·4 per cent. are Desmidiaceæ, 17·7 per cent. are Bacillarieæ, and 8·7 per cent. are Myxophyceæ.

III. Lakes of the Orkneys and Shetlands.

We have examined material from one freshwater loch in the Orkneys and from six in the Shetlands. The collections were made in August, 1903, and the results published in 1905.* Mr. James Murray has collected material from 34 lochs of the Orkneys and Shetlands, and has briefly noted a few species of the phytoplankton.†

Although containing a considerable number of species, the phytoplankton was not very rich. Most of the lochs were shallow, and contained quantities of *Asterionella formosa*. *Pediastrum Boryanum* and *Scenedesmus quadricauda* were both fairly common. Colonies of a *Crucigenia*, described by Wille from the Norwegian plankton as *C. irregularis*,‡ but most probably only irregularly developed forms of *C. rectangularis*, occurred in several lochs of the Shetlands.

Desmids were frequent, and in some cases numerous, but the species were mostly those of shallow lowland lakes. The characteristic western British types were absent, although further investigations in the Shetlands would no doubt bring some of them to light.

Peridinieæ were abundant, as is so frequently the case in shallow lakes, and the ubiquitous *Ceratium hirundinella* was much more generally abundant than in the larger Scottish lakes.

Out of 52 species of Algæ described by Börgesen and Ostenfeld§ as

* W. and G. S. West, in 'Bot. Soc. Edin. Trans.,' Nov., 1904 [1905], pp. 5—10.

† James Murray, in 'Roy. Soc. Edin. Proc.,' June, 1905, pp. 55, 56.

‡ Wille, in 'Nyt Magazin for Naturvidenskb.,' Bd. 38, Heft 1, 1900, p. 10, t. 1, f. 15. Consult also the remarks of G. S. West, 'Treatise Brit. Freshw. Alg.,' 1904, p. 217; and Ostenfeld in 'Hedwigia,' vol. 46, 1907, p. 383.

§ F. Börgesen and C. H. Ostenfeld, "Phytoplankton of Lakes in the Faeroes," 'Botany of the Faeroes,' Copenhagen, 1902.

occurring in the plankton of the Faeroese lakes, 28 were observed in the plankton of the Orkneys and Shetlands.

Of a total of 178 species observed in the phytoplankton, 47·4 per cent. were Desmidiaceæ, 20·9 per cent. were Bacillarieæ, and 9·6 per cent. were Myxophyceæ.

IV. The Irish Lakes (West and South-west).

In 1906 we published an account of the plankton of some of the more important lakes of the West and South-west of Ireland,* from collections which we made in May, August, and September, 1904.

In the summer the phytoplankton is greatly in excess of the zooplankton, and the Entomostraca are only dominant in the early spring months. As in the Scottish lakes, the phytoplankton of the lakes of the west and south-west of Ireland is to a large extent Chlorophyceous, but the Bacillarieæ, the Peridinieæ and to some extent the Myxophyceæ, are also conspicuous. The latter are much more noticeable than in the Scottish plankton, especially species of *Anabœna, Oscillatoria, Gomphosphœria, Cœlosphœrium,* and *Chroococcus.*

The Desmids are numerous, and include many of the characteristic western types. There is a great abundance of *Spondylosium pulchrum,* var. *planum, Staurastrum anatinum, St. jaculiferum, St. Arctiscon, St. pseudopelagicum,* and *St. paradoxum,* var. *longipes,* but a curious absence of *St. Ophiura.* The latter is a feature of a large proportion of the Scottish phytoplankton, but we have not yet observed it in the Irish lakes. In the lakes examined, the Desmid-flora of the plankton was not quite so rich as that of some of the Scottish lakes, but we think that an investigation of many of the smaller lakes of Galway and Mayo would bring to light a phytoplankton not at all inferior to that of the western Scottish lochs.

Diatoms are very abundant, and form a relatively large part of the Irish phytoplankton. Centric Diatoms are more numerous than in the Scottish plankton, and are represented chiefly by species of *Melosira* and *Cyclotella. Tabellaria, Asterionella,* and the narrow forms of *Synedra* are very conspicuous in the Irish lakes.

The Peridinieæ are generally abundant, and are represented by 10 species. Much the most interesting of these is *Peridinium limbatum* (fig. 2), a characteristic horned species which occurred in some of the small lakes of Galway. It has only been found elsewhere in the United States.

* W. and G. S. West, "A Comparative Study of the Plankton of some Irish Lakes,' 'Roy. Irish Acad. Trans.,' vol. 33, sect. B, part 2, 1906.

Of a total of 246 species observed in the phytoplankton, 41·7 per cent. were Desmidiaceæ, 19 per cent. Bacillarieæ, and 13·3 per cent. Myxophyceæ.

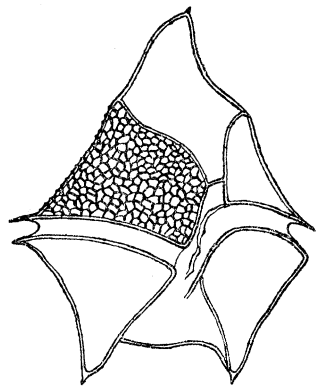

Fig. 2.—*Peridinium limbatum* (Stokes), Lemm., from the Plankton of a small Lake between Clifden and Roundstone, Galway. ×500. The reticulated surface markings of the cell-wall are only indicated on one of the plates.

V. Lough Neagh.

The first contribution to the plankton of the Irish lakes was an account of the plankton-Algæ of Lough Neagh and Lough Beg,* the material having been collected in May, 1900, and July, 1901. This material has since been subjected to a further examination. The lake is so isolated, and, moreover, so differently situated from the other Irish lakes examined, that we have kept the records in a separate column in the tabulated list of British phytoplankton. It is also of interest as being the largest lake in the British Islands; but although covering a large area it is very shallow, its average depth being only 45 feet, and the deepest sounding (made in the north-west corner), is only 96 feet.

The phytoplankton consists largely of Diatoms, Peridinieæ, and Chlorophyceæ. Of the latter, a few of the Desmids characteristic of shallow lakes are abundant, and *Staurastrum paradoxum*, var. *longipes*, occurs in prodigious quantity. *St. pelagicum* was first described from this lake, and has since been found in the lakes of Germany and Iceland. The Protococcoideæ are very well represented, species of *Cœlastrum*, *Pediastrum*, and *Oocystis* being especially noticeable. Of the Diatoms, *Tabellaria fenestrata*, var. *asterionelloides*, is the most conspicuous, but *Coscinodiscus lacustris*, *Cymatopleura elliptica*, and species of *Surirella* are also abundant. The Myxophyceæ are

* W. and G. S. West, "A Contrib. to the Freshw. Alg. of the North of Ireland," 'Roy. Irish Acad. Trans.,' vol. 32, sect. B, part 1, 1902.

well represented by species of *Anabæna* and *Oscillatoria*, the narrow limnetic species of *Lyngbya*, species of *Cœlosphærium*, *Gomphosphærium*, and *Aphanothece*; and *Chroococcus limneticus* is abundant. Three species of *Dinobryon* are fairly common, but we have no evidence to show whether they ever become dominant or not.

On the whole, the phytoplankton is a combination of that which occurs in shallow lakes with that of large pools and ponds. Out of a total of 128 species observed in it, 17·1 per cent. were Desmidiaceæ, 25·7 per cent. other Chlorophyceæ, 32 per cent. Bacillarieæ, and 16·4 per cent. Myxophyceæ.

VI. The Welsh Lake-area.

Plankton collections were made from 19 of the Welsh lakes, mostly those of Carnarvonshire, during June, 1905, August and September, 1906, and April, 1908.*

The phytoplankton of the spring and summer is essentially Chlorophyceous, and as in the case of the Scottish lakes, is especially noteworthy for the abundance of its Desmids. There is little bulk even in the summer plankton, and in general it has practically no effect on the colour of the water. *The Desmid-flora in certain of these lakes is equal to that found in the richest lakes of the north-west of Scotland, and in one case*—the Capel Curig Lakes—*is superior to that known from any other lake in the world which has been biologically investigated.*

Of a total of 162 species which we have observed in the phytoplankton of the Welsh lakes no fewer than 101 are species of Desmids.

The Protococcoideæ are relatively few, both in number of species and individuals, *Ankistrodesmus falcatus* and *Botryococcus Braunii* being the most frequent.

Diatoms are not conspicuous, and there are fewer species in the Welsh plankton than in either the Scottish or Irish lakes.

Apart from the spasmodic occurrence in fair quantity of one or two species of *Anabæna*, and the moderate abundance of *Oscillatoria Agardhii*, the blue-green element is distinctly scarce in the Welsh plankton.

Species of *Dinobryon* and various Peridinieæ occur abundantly in the Welsh lakes. *Ceratium cornutum* is more abundant than in any other part of the British Islands.

There is no great development of peat in this Welsh lake-area, and the water of the lakes is for the most part clear and limpid. The drainage is mostly down steep mountain sides, with occasional bogs and boggy pools.

* The details of these collections are being published separately.

The Capel Curig lakes merit special mention. The summer plankton is almost a pure Desmid-plankton, and consists largely of those rare and handsome species which are almost exclusively confined to the west-coast districts of the British Islands. The following species occur in great abundance :—*Micrasterias radiata, Staurastrum anatinum, St. aversum, St. Arctiscon, St. Cerastes, St. longispinum,* and a stout variety of *St. Ophiura.* It is interesting to note that *St. anatinum* is present in prodigious abundance, as it was from the littoral region of this lake, near the outlet, that it was originally described. *Micrasterias radiata* exists in myriads in the plankton of this lake, occurring in a profusion unknown in any other of its British localities.

Mixed with the Desmids are numbers of *Ceratium cornutum,* and a very few individuals of *Tabellaria fenestrata* and *T. flocculosa.*

Of a total of 162 species observed in the Welsh phytoplankton, 62·4 per cent. were Desmidiaceæ, 11·1 per cent. Bacillarieæ, and 7·4 per cent. Myxophyceæ.

VII. The English Lake-area.

Plankton collections were made from 18 of the English lakes in June, 1903, and September, 1906; and since then periodic collections have been commenced in Windermere, Ennerdale Water, and Wastwater.*

As in the Welsh lakes, the phytoplankton of the spring and summer is essentially Chlorophyceous, and contains numerous Desmids, but although most of the typical British plankton-Desmids occur, they are not represented by so many species as in the Scottish or Welsh lakes. The most frequent are the spiny species of *Staurastrum, St. lunatum,* var. *planctonicum, St. Arctiscon, Xanthidium antilopæum, Cosmarium subtumidum,* var. *Klebsii,* and *Spondylosium pulchrum,* var. *planum.* The presence of *Staurastrum Ophiura* in the plankton of Easdale Tarn is particularly interesting, as this Desmid is not known to occur in any of the bogs of the English lake-area.

The Protococcoideæ are somewhat scarce, *Glœocystis gigas* and *Sphærocystis Schroeteri* being the only generally distributed species, and these only in small quantity.

The Bacillarieæ and Myxophyceæ are represented by relatively few species, but in some of the lakes Diatoms are dominant constituents of the plankton. Particularly is this the case in Ullswater, in which *Asterionella formosa* was the dominant constituent of both the May and September plankton.

* As no work has previously been done at the plankton of the English lakes, only the list of species is given for comparison with those of the other British lake-areas. The details of the investigations are reserved for special publication.

Species of *Dinobryon* are common, especially in the early summer plankton. In the May and June plankton of Crummock Water and Derwent Water *Dinobryon cylindricum*, var. *divergens*, completely dominated all other constituents.

Comparison of precisely similar plankton-samples from the various lakes of the English Lake District shows clearly that the proximity of habitations has a distinct effect on the relative bulk of the plankton. *Those lakes which are contaminated by the presence of numerous dwellings and villages along or near the shores possess a relatively greater bulk of plankton than those free from contamination.* The explanation of this fact is most probably the increased amount of nitrates in the water of the contaminated lakes.

Out of 188 species observed in the phytoplankton, 51 per cent. were Desmidiaceæ, 21 per cent. were Bacillarieæ, and 9·5 per cent. Myxophyceæ.

VIII. Malham Tarn, West Yorkshire.

This lake is the largest natural sheet of water in Yorkshire and covers an area of 153 acres. It is situated on a limestone plateau at an altitude of 1250 feet, and there is an extensive peat-bog at its northern extremity.

The material was collected by boat on July 23, 1904.

Out of a total of 20 species observed in the phytoplankton nine were Desmids. *Sphærocystis Schroeteri* was very abundant and *Volvox aureus* rather common. Only one Diatom was observed, and four Blue-green Algæ. *Ceratium hirundinella* was very common.

The following is a complete list of the species observed:—*Mougeotia* sp. (sterile), *Gonatozygon monotœnium*, *Cosmarium Botrytis* and var. *depressum*, *C. depressum*, *Staurastrum Avicula*, var. *subarcuatum*, *St. brevispinum*, *St. furcigerum*, *St. Manfeldtii*, *St. paradoxum*, *St. teliferum*, *Volvox aureus*, *Pediastrum Boryanum*, *Sphærocystis Schroeteri*, *Surirella biseriata*, *Oscillatoria Agardhii*, *Microcystis æruginosa*, *Merismopedia elegans*, *Chroococcus limneticus*, *Ceratium hirundinella*, and *Peridinium* sp.

IX. The British River-plankton.

The first account of British river-plankton (*potamoplankton*) was the comparison of that found in the Upper River Bann with that of Lough Neagh,* and since then Fritsch† has published an account of the phytoplankton of the Rivers Thames, Trent, and Cam. We have also examined

* W. and G. S. West, in 'Roy. Irish Acad. Trans.,' vol. 32, sect. B, part 1, 1902.

† Fritsch, in 'Ann. Bot.,' vol. 16, Sept., 1902; *ibid.*, vol. 17, Sept., 1903; *ibid.*, vol. 19, Jan., 1905.

the plankton of the Rivers Ouse, Avon, and Cam in England, and the River Lochay in Scotland.

It would appear that some phytoplankton occurs all the year round in the British rivers, due mostly to the absence of severe winters, and that in the winter months the living constituents are mostly Diatoms. In fact, *Diatoms dominate throughout the entire year*, the most important genera being *Asterionella, Synedra, Melosira, Surirella,* and *Fragilaria.* Fritsch* summarises the phytoplankton of the Thames in the course of a year as follows :—

Mixed Plankton (with *Asterionella*-phase) → *Melosira* → *Synedra* → Mixed Plankton.

We find *Melosira varians* conspicuous in the spring-plankton of British rivers and persisting in quantity through the summer until the late autumn. *Synedra Acus* is one of the dominant summer species in the British rivers, although it is a spring or an autumn form in the Oder, the Danube, and the Illinois River. *Surirella biseriata* and *S. robusta,* var. *splendida,* are often conspicuous in the summer-plankton, the former being the more abundant, which is never the case in the lake-plankton.

Certain Protococcoideæ occur in the late summer, but never in great quantity. Species of *Pediastrum, Scenedesmus,* and a few other genera are the most frequent, and occasionally odd specimens of a *Cosmarium* or a *Closterium* may occur.

Flagellates and some of the Volvocaceæ occur mostly in the spring months and generally attain their greatest abundance before the maximum summer temperatures. *Endorina elegans* is most irregular in its occurrence, and is often found in quantity in midsummer or even in early autumn. We have never found the Volvocaceæ so numerous in river-plankton as they often become in the plankton of lakes and pools. *Pandorina morum* is the most frequent both in the rivers and small pools.

The backwaters of the rivers are largely the breeding-places of the plankton-organisms, and as pointed out by Kofoid, their contributory function to the plankton of the river is at its maximum during *the decline of the floods.* It is during such times that vast accumulations of plankton-units are carried into the main stream.

Melosira varians, Fragilaria capucina, and *Cyclotella Kützingiana* are perennial plankton-organisms in the rivers we have examined.

X. General Comparison of British Lake-areas.

In summarising our present knowledge of the phytoplankton of the British lakes, it has been one of our first duties to obtain a record of the

* Fritsch, *loc. cit.*, 1903, p. 637.

species which occur in the different areas. As these records have never previously been correlated, we have drawn up the following tabulated list of all the species observed in the phytoplankton of the British Islands.

In this list those Algæ, which, so far as is known, are *exclusively confined to the plankton* are marked "P"; those which are *exclusively plankton-varieties* of species which frequently occur in other situations are marked "Pv"; and those species which are *more abundant in the plankton than elsewhere* are marked "p."

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
CHLOROPHYCEÆ.						
Œdogonium spp. (sterile)	×	×	×	×	×	×
,, *punctato-striatum*, De Bary	×					
Ulothrix zonata (Web. and Mohr), Kütz.	×	—	—	—	×	
,, *subtilis*, Kütz.	—	—	—	—	—	×
,, ,, var. *variabilis* (Kütz.), Kirchn.	×	×	×	×	×	
,, *moniliformis*, Kütz.	×	×				
Geminella interrupta, Turp.	×	—	×			
Myxonema subsecundum (Kütz.), Hazen.	—	—	×			
,, *tenue* (Ag.), Rabenh.	—	—	—	—	—	×
Microspora amœna (Kütz.), Lagerh.	×	—	×	×	×	
,, ,, var. *irregularis*, W. and G. S. West	—	—	×			
,, *abbreviata*, Rabenh.	—	—	—	×	×	
Mougeotia spp. (sterile)	×	×	×	×	×	×
,, *elegantula*, Wittr.	×	—	—	—	×	
Zygnema spp. (sterile)	×	—	×	×	×	
,, *ericetorum* (Kütz.), Hansg.	×					
Spirogyra spp. (sterile)	×	—	×	×	×	
Debarya glyptosperma (De Bary), Wittr.	—	×				
Gonatozygon monotænium, De Bary	×	×	×	×	×	
,, ,, var. *pilosellum*, Nordst.	×	—	×	×	×	
,, *Brébissonii*, De Bary	—	—	—	×		
,, *Kinahani* (Arch.), Rabenh.	×	×	×	×		
,, *aculeatum*, Hastings	×					
Genicularia elegans, W. and G. S. West (P)	×					
Spirotænia condensata, Bréb.	—	—	—	×		
Mesotænium macrococcum (Kütz.), Roy and Biss.	×	—	×			
Cylindrocystis diplospora, Lund.	×					
,, ,, var. *major*, West	—	—	—	—	×	
Netrium Digitus (Ehrenb.), Itzigs. and Rothe	×	×	×	×	×	
Penium Libellula (Focke), Nordst.	×	—	×			
,, ,, var. *interruptum*, W. and G. S. West	—	—	—	×		
,, *minutum* (Ralfs), Cleve.	×	×	×	—	×	
,, *margaritaceum* (Ehrenb.), Bréb., var. *irregularius*, W. and G. S. West	—	×				
,, *truncatum*, Bréb.	—	—	—	—	×	
Closterium abruptum, West	—	×				
,, *acutum*, Bréb.	×	—	—	—	×	×
,, *aciculare*, T. West, var. *subpronum*, W. and G. S. West (p)	×	—	×	—	—	×
,, *acerosum* (Schrank), Ehrenb.	—	×				
,, ,, var. *minus*, Hantzsch	×	—	×			

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Closterium Ceratium, Perty	—	—	—	—	—	×
,, *Cornu*, Ehrenb.	—	×				
,, *Cynthia*, De Not.	—	×				
,, ,, var. *curvatissimum*, W. and G. S. West	×					
,, *decorum*, Bréb.	—	—	×			
,, *Dianæ*, Ehrenb.	×	—	—	—	×	
,, *Ehrenbergii*, Menegh.	×					
,, *incurvum*, Bréb.	—	×				
,, *Jenneri*, Ralfs	×					
,, *juncidum*, Ralfs	—	—	—	×		
,, *Kützingii*, Bréb.	×	—	×	—	×	
,, ,, var. *onychosporum*, W. and G. S. West (Pv)	×	—	×			
,, *Leibleinii*, Kütz.	—	×	×			
,, *lineatum*, Ehrenb.	×					
,, *Lunula* (Müll.), Nitzsch.	—	×				
,, *macilentum*, Bréb.	×	×	—	×		
,, *moniliferum* (Bory), Ehrenb.	×					
,, *parvulum*, Näg.	×	—	×	—	×	
,, *pronum*, Bréb.	×	—	×			
,, *Pseudodianæ*, Roy	×	—	×			
,, *rostratum*, Ehrenb.	×					
,, *setaceum*, Ehrenb.	×	—	—	×	×	
,, ,, var. *elongatum*, W. and G. S. West (Pv)	×	—	—	—	—	×
,, *striolatum*, Ehrenb.	×					
,, *toxon*, West	×					
,, *tumidum*, Johnson	—	—	—	—	×	
,, *turgidum*, Ehrenb., forma *glabra*, Gutw.	×					
,, *Ulna*, Focke	×					
,, *Venus*, Kütz.	×					
Docidium Baculum, Bréb.	—	—	—	×		
Pleurotænium coronatum, Bréb.	×	—	—	×		
,, ,, var. *fluctuatum*, West	×					
,, *Ehrenbergii* (Ralfs), De Bary	×	—	×	×	×	
,, *nodosum* (Bail.), Lund.	—	—	—	×		
Tetmemorus Brébissonii (Menegh.), Ralfs	×					
,, *granulatus* (Bréb.), Ralfs	×	×	×	×	×	
,, *lævis* (Kütz.), Ralfs	—	×				
Euastrum affine, Ralfs	—	—	—	×		
,, *ampullaceum*, Ralfs	×					
,, *ansatum*, Raifs	×	×	×	×	×	
,, *bidentatum*, Näg.	×	×	×	×	×	
,, *binale* (Turp.), Ehrenb.	×					
,, *crassum* (Bréb.), Kütz.	×	—	—	×		
,, *denticulatum* (Kirchn.), Gay	×	×	×			
,, *Didelta* (Turp.), Ralfs	—	—	—	×		
,, *elegans* (Bréb.), Kütz.	×	×	×	×	×	
,, *gemmatum*, Ralfs	×	×				
,, *montanum*, W. and G. S. West	—	—	—	—	×	
,, *oblongum* (Grev.), Ralfs	×	×				
,, *pectinatum*, Bréb.	—	—	—	—	×	
,, ,, var. *inevolutum*, W. and G. S. West	×	×				
,, *pinnatum*, Ralfs	×					
,, *sinuosum*, Lenorm.	—	×				
,, *verrucosum*, Ehrenb.	×					

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Euastrum verrucosum, var. *reductum*, Nordst. (p)	×	×	×	×	×	
„ „ var. *planctonicum*, W. and G. S. West (Pv)	×					
Micrasterias Americana, Ehrenb.	×					
„ *apiculata*, Menegh., var. *fimbriata*, Ralfs	×					
„ „ var. *brachyptera* (Lund.), Nordst.	×					
„ *conferta*, Lund.	×					
„ *denticulata*, Bréb.	×	×	×	×	×	
„ *Jenneri*, Ralfs	×					
„ *Mahabuleshwarensis*, Hobson, var. *Wallichii* (Grun.), W. and G. S. West	×	×	—	—	×	
„ *Murrayi*, W. and G. S. West (P)	×					
„ „ var. *triquetra*, W. and G. S. West (P)	×					
„ *papillifera*, Bréb.	×	×	×	×	×	
„ „ var. *glabra*, Nordst.	—	—	—	×		
„ *pinnatifida* (Kütz.), Ralfs	×	—	—	×	×	
„ *radiata*, Hass. [= *M. furcata*, Ralfs] (p)	×	—	×	×	×	
„ *rotata* (Grev.), Ralfs	×	—	—	×		
„ *Sol* (Ehrenb.), Kütz. [= *M. radiosa*, Ralfs] (p)	×	×	×	×	×	
„ *truncata* (Corda), Bréb.	×	—	×	×	×	
Cosmarium abbreviatum, Racib.	×	×				
„ „ var. *planctonicum*, W. and G. S. West (Pv)	×	—	×	×	×	
„ *angulosum*, Bréb., var. *concinnum* (Rabenh.), W. and G. S. West	—	×				
„ *bioculatum*, Bréb.	×	×	×	×	×	
„ *Blyttii*, Wille	×	—	—	—	×	
„ *Boeckii*, Wille	—	×				
„ *Botrytis*, Menegh.	×	×	×	×	×	×
„ „ var. *tumidum*, Wolle	×					
„ „ var. *depressum*, W. and G. S. West (Pv)	×	—	×			
„ *Brébissonii*, Menegh.	×	—	×			
„ *capitulum*, Roy and Biss., var. *grœnlandicum*, Börges. (p)	×	—	×	—	×	
„ *cælatum*, Ralfs	×					
„ *connatum*, Bréb.	×	—	×	—	×	
„ *contractum*, Kirchn.	×	—	×	×		
„ „ var. *ellipsoideum* (Elfv.), W. and G. S. West	×	×	×	×	×	
„ *controversum*, West	×	—	—	—	×	
„ *Corribense*, W. and G. S. West (P)	—	—	×	×		
„ *costatum*, Nordst.	—	—	—	×	×	
„ *depressum* (Näg.), Lund. [= *C. Scenedesmus*, Delp.] (p)	×	×	×	×	×	
„ *depressum*, var. *achondrum* (Boldt), W. and G. S. West (p)	×	—	—	—	×	
„ *difficile*, Lütkem	×					
„ „ var. *sublæve*, Lütkem	×	×	×	—	×	
„ *exiguum*, Arch.	—	—	—	×		
„ *formosulum*, Hoff.	×	×	—	—	×	
„ *globosum*, Buln.	—	—	—	×		
„ *granatum*, Bréb.	×	—	×			
„ „ var. *subgranatum*, Nordst.	—	×	—	—	—	×
„ *humile*, Gay	×	×	×	×	—	×
„ *impressulum*, Elfv.	×					

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Cosmarium Kjellmanni, Wille, var. *grande*, Wille	×					
,, *Lundellii*, Delp., var. *æthiopicum*, W. and G. S. West	×					
,, *læve*, Rabenh., var. *septentrionale*, Wille	×					
,, ,, forma *octangularis* (Wille) nob.	×	×	×			
,, *Logiense*, Bissett	—	—	—	—	×	
,, *margaritatum*, Roy and Bissett	×	—	—	×		
,, *margaritiferum* (Turp.), Menegh.	×	×	×	×	×	
,, *Meneghinii*, Bréb.	—	×				
,, *moniliforme* (Turp.), Ralfs	×	—	×	×		
,, *ornatum*, Ralfs	×	—	×	×	×	
,, *orthostichum*, Lund.	—	—	—	×		
,, *ovale*, Ralfs	×	—	×			
,, *Phaseolus*, Bréb.	—	×				
,, *pseudopyramidatum*, Lund.	—	—	—	×		
,, *punctulatum*, Bréb.	×	×	×	—	×	
,, ,, var. *subpunctulatum* (Nordst.), Börges.	—	×	—	×		
,, *pyramidatum*, Bréb.	—	×	—	×		
,, *quadratum*, Ralfs, forma *Willei*, W. and G. S. West	—	—	—	—	×	
,, *Ralfsii*, Bréb.	×	—	—	×		
,, *reniforme* (Ralfs), Arch.	×	×	×	×	×	
,, *speciosum*, Lund.	—	×				
,, *subaversum*, Borge	×					
,, *subarctoum* (Lagerh.), Racib.	×	—	×	—	×	
,, ,, forma *punctata*, W. and G. S. West	—	×				
,, *subcostatum*, Nordst.	×	×				
,, *subcrenatum*, Hantzsch.	×	×	—	—	×	
,, *subcontractum*, W. and G. S. West (P)	×					
,, *subprotumidum*, Nordst.	—	×				
,, *subtumidum*, Nordst., var. *Klebsii* (Gutw.) W. and G. S. West (p)	×	×	×	×	×	×
,, *subundulatum*, Wille	—	—	—	×		
,, *subspeciosum*, Nordst.	—	×				
,, *Turpinii*, Bréb. (p)	—	×	×	—	×	×
,, *tetraophthalmum* (Kütz.), Menegh.	×	×	×			
Cosmocladium saxonicum, De Bary	—	—	×	×		
Xanthidium antilopæum (Bréb.), Kütz.	×	—	×	×	×	×
,, ,, var. *depauperatum*, W. and G. S. West (Pv)	×	×	×	×	×	
,, ,, var. *Hebridarum*, W. and G. S. West (Pv)	×	—	×			
,, ,, var. *læve*, Schmidle	×					
,, ,, var. *polymazum*, Nordst.	×					
,, ,, var. *triquetrum*, Lund. (p)	—	—	—	—	×	
,, *armatum* (Bréb.), Rabenh.	×	—	×	×	×	
,, ,, var. *cervicorne*, W. and G. S. West	×	—	—	×		
,, *cristatum*, Bréb.	×	—	×			
,, ,, var. *uncinatum*, Bréb.	—	—	—	—	×	
,, *fasciculatum*, Ehrenb.	×					
,, *subhastiferum*, West (p)	×	—	×			
,, ,, var. *Murrayi*, W. and G. S. West (Pv)	×	—	—	—	×	
,, *controversum*, W. and G. S. West, var. *planctonicum*, W. and G. S. West (Pv)	×					

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Xanthidium tetracentrotum, Wolle, forma, W. and G. S. West	×					
Arthrodesmus convergens, Ehrenb.	×	—	—	×	×	
„ *crassus*, W. and G. S. West (P)	×	—	×	—	×	
„ *Incus* (Bréb.), Hass.	×	—	×	×	×	
„ „ var. *longispinum*, W. and G. S. West (Pv)	×					
„ „ var. *Ralfsii*, W. and G. S. West, forma	×	—	—	×	×	
„ *octocornis*, Ehrenb.	×	—	—	×		
„ *quiriferus*, W. and G. S. West (P)	×					
„ *subulatus*, Kütz.	×					
„ *triangularis*, Lagerh.	×	×	—	×	×	
„ „ var. *subtriangularis* (Borge), W. and G. S. West (Pv)	×	×	×	—	×	
Staurastrum aculeatum (Ehrenb.), Menegh.	—	—	—	×		
„ *affine*, W. and G. S. West (P)	—	×				
„ *alternans*, Bréb.	—	×				
„ *anatinum*, Cooke and Wills (p)	×	×	×	×	×	×
„ „ var. *grande*, W. and G. S. West (p)	×	—	—	×		
„ „ var. *Lagerheimii* (Schmidle), nob. (p)	—	—	—	—	×	
„ „ var. *longibrachiatum*, W. and G. S. West (Pv)	×					
„ „ var. *pelagicum*, W. and G. S. West (Pv)	×	—	—	—	—	×
„ „ var. *truncatum*, West (p)	×	—	×	—	—	×
„ *angulatum*, West, var. *planctonicum*, W. and G. S. West (Pv)	×					
„ *apiculatum*, Bréb.	—	—	×	—	—	×
„ *Arachne*, Ralfs	×	—	×	×		
„ „ var. *curvatum*, W. and G. S. West (Pv)	×					
„ *Arctiscon* (Ehrenb.), Lund. (p)	×	—	×	×	×	
„ *aristiferum*, Ralfs	—	—	—	×		
„ „ var. *protuberans*, W. and G. S. West (Pv)	×					
„ *asperum*, Bréb.	×					
„ *Avicula*, Bréb.	×					
„ „ var. *subarcuatum* (Wolle), West	×	—	×	×		
„ *aversum*, Lund. (p)	×	—	×	×		
„ *Bienianum*, Rabenh.	×	—	×			
„ *boreale*, W. and G. S. West (P)	—	×				
„ *brachiatum*, Ralfs	×	×	×	×	×	
„ *Brasiliense*, Nordst., var. *Lundellii*, W. and G. S. West (p)	×	—	×	×	×	
„ *brevispinum*, Bréb. (p)	×	×	×	×	×	×
„ „ var. *altum*, W. and G. S. West (Pv)	×	—	×			
„ „ var. *obversum*, W. and G. S. West (Pv)	×					
„ *Cerastes*, Lund.	—	—	—	×		
„ *Clevei* (Wittr.), Roy and Bissett	×					
„ *conspicuum*, W. and G. S. West (P)	×					
„ *curvatum*, West (p)	×	×	×	×	×	
„ *cuspidatum*, Bréb.	—	—	—	—	—	×
„ „ var. *maximum*, W. and G. S. West (p)	×	×	×	×	×	×

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Staurastrum cuspidatum, var. *divergens*, Nordst.	×					
,, *cyrtocerum*, Bréb.	×					
,, ,, var. *compactum*, W. and G. S. West (Pv)	—	×				
,, *dejectum*, Bréb. (p)	×	×	×	×	×	×
,, ,, var. *inflatum*, West (p)	×	×	×	×	—	×
,, *denticulatum* (Näg.), Arch. (p)	—	—	×	×	×	
,, *Dickiei*, Ralfs	×	—	×			
,, *dilatatum*, Ehrenb., var. *obtusilobum*, De Not.	×	×	×			
,, *dorsidentiferum*, W. and G. S. West (P)	—	—	×			
,, *erasum*, Bréb. (p)	×	×	—	×	×	
,, *forficulatum*, Lund.	×					
,, *furcatum* (Ehrenb.), Bréb.	×	—	—	×		
,, *furcigerum*, Bréb. (p)	×	—	×	×	×	×
,, ,, forma *eustephana* (Ehrenb.)	—	—	—	×	×	
,, ,, forma *armigera* (Bréb.)	×					
,, ,, var. *reductum*, W. and G. S. West (Pv)	—	—	×			
,, *gracile*, Ralfs	×	×	×	×	×	×
,, ,, var. *nanum*, Wille	×	—	—	—	×	
,, ,, var. *cyathiforme*, W. and G. S. West, forma	×	—	×			
,, *grande*, Bulnh.	×	—	×	—	×	
,, *granulosum*, Ralfs	—	—	×	—	—	×
,, ,, var. *acutum* (Bréb.), W. and G. S. West	×					
,, *hexacerum* (Ehrenb.), Wittr.	—	×	×	×	×	
,, *hirsutum*, Bréb.	×					
,, *inflexum*, Bréb.	—	—	—	—	×	
,, *inelegans*, W. and G. S. West (P)	×					
,, *irregulare*, W. and G. S. West	—	—	—	—	×	
,, *jaculiferum*, West (biradiate vertical view) (p)	×	—	—	×	×	
,, ,, (triradiate vertical view) (p)	×	×	×	—	×	
,, ,, var. *excavatum*, W. and G. S. West (Pv)	×	—	×			
,, ,, var. *subexcavatum*, W. and G. S. West (Pv)	×					
,, *lævispinum*, Biss.	×					
,, *longispinum* (Bail.), Arch. (p)	×	—	×	×	×	
,, ,, var. *bidentatum* (Wittr.), W. and G. S. West (p)	×	—	—	×	×	
,, *lunatum*, Ralfs, var. *planctonicum*, W. and G. S. West (Pv)	×	×	×	×	×	
,, *Maamense*, Arch.	—	—	×			
,, *Manfeldtii*, Delp. (p)	—	×	×	—	×	
,, *megacanthum*, Lund. (p)	×	—	×	×	×	
,, ,, var. *Scoticum*, W. and G. S. West (Pv)	×					
,, *monticulosum*, Bréb., var. *bifarium*, Nordst.	×					
,, *mucronatum*, Ralfs, var. *subtriangulare*, W. and G. S. West (Pv)	×	—	—	×	×	
,, *muticum*, Bréb.	—	—	—	×	—	×
,, *Ophiura*, Lund. (p)	×	—	—	—	×	
,, ,, var. *cambricum*, W. and G. S. West	—	—	—	×		
,, *orbiculare*, Ralfs	×					
,, ,, var. *depressum*, Roy and Bissett	—	×				

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Staurastrum paradoxum, Meyen	×	×	×	×	×	×
„ „ var. *cingulum*, W. and G. S. West (Pv)	×	×	×	×	×	
„ „ var. *longipes*, Nordst. (p)	×	×	×	×	×	×
„ *pelagicum*, W. and G. S. West (P)	—	×	×	—	—	×
„ *pilosum*, Näg.	—	×				
„ *polymorphum*, Bréb.	×	—	—	—	×	
„ *polytrichum*, Perty	×					
„ *pseudopelagicum*, W. and G. S. West (P)	×	×	×	×	×	
„ *punctulatum*, Bréb.	×	×	—	—	×	
„ *Saxonicum*, Buln.	—	×				
„ *Sebaldi*, Reinsch., var. *productum*, W. and G. S. West (Pv)	×	—	×			
„ „ var. *ornatum*, Nordst.	—	—	×	×	—	×
„ *sexangulare* (Buln.), Rabenh. (p)	×	—	×	×	×	
„ „ var. *supernumerarium*, W. and G. S. West (Pv)	×					
„ *sibiricum*, Borge	×					
„ *sublævispinum*, W. and G. S. West	×					
„ *subnudibrachiatum*, W. and G. S. West (P)	×					
„ *subgracillimum*, W. and G. S. West	×					
„ *subpygmæum*, West	×	—	×			
„ *teliferum*, Ralfs	×	×	—	×	×	
„ *tetracerum*, Ralfs	×	×	—	×		
„ *Tohopekaligense*, Wolle, var. *trifurcatum*, W. and G. S. West	×	—	×			
„ *tumidum*, Bréb.	×	—	—	×		
„ *verticillatum*, Arch.	×					
„ *vestitum*, Ralfs	—	—	—	—	×	
Spondylosium pulchrum (Bail.), Arch., var. *planum*, Wolle (p)	×	—	×	—	×	
Sphærozosma granulatum, Roy and Bissett	×	×	—	—	×	
„ *Aubertianum*, West	—	—	×			
„ „ var. *Archerii* (Gutw.), W. and G. S. West (p)	×	—	—	×	×	
„ *excavatum*, Ralfs	—	—	×			
„ *vertebratum*, Ralfs	×	—	×	×	×	
Desmidium aptogonum, Bréb.	×	—	—	×	×	
„ *coarctatum*, Nordst., var. *cambricum*, West (p)	×	—	—	×		
„ *graciliceps* (Nordst.), Lagerh.	×					
„ *occidentale*, W. and G. S. West (P)	×					
„ *Pseudostreptonema*, W. and G. S. West (p)	—	—	×			
„ *Swartzii*, Ag.	×	—	—	×	×	
Gymnozyga moniliformis, Ehrenb.	×	—	×	×	×	
„ „ var. *gracilescens*, Nordst.	×					
Hyalotheca dissiliens (Sm.), Bréb.	×	—	×	×	×	
„ „ forma *tridentula*, Nordst.	×					
„ *Indica*, Turn. (p)	×	—	×	—	×	
„ *mucosa*, Ehrenb.	×	×	×	×	×	
„ *neglecta*, Racib. (p)	×	—	×	×	×	
„ *undulata*, Nordst.	—	—	×	×		
Volvox aureus, Ehrenb.	—	—	—	×	—	×
Pleodorina californica, Shaw	×					
Eudorina elegans, Ehrenb.	×	×	×	×	×	×
Gonium pectorale, Müll.	×	—	—	×		
Pandorina Morum (Müll.), Bory.	×	×				
Chlamydomonas pulvisculus, Ehrenb.	—	—	—	—	—	×

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Urococcus insignis, Kütz.	—	×				
Pediastrum Boryanum (Turp.), Menegh.	×	×	×	×	×	×
,, ,, var. *brevicorne*, A. Br.	—	—	—	—	—	×
,, ,, var. *granulatum*, Ralfs	—	×	×	—	—	×
,, ,, var. *longicorne*, Reinsch.	—	—	—	—	—	×
,, *duplex*, Meyen.	×	×	×	—	—	×
,, ,, var. *asperum*, A. Br.	—	—	×	—	—	×
,, ,, var. *clathratum*, A. Br. (p)	—	—	—	—	—	×
,, *glanduliferum*, Benn.	—	×	—	—	×	
,, *integrum*, Näg.	—	×				
,, *simplex*, Meyen.	×					
,, *Tetras* (Ehrenb.) Ralfs	×	—	—	—	—	×
Sorastrum Americanum (Bohlin), Schmidle	×					
,, *spinulosum*, Näg.	×					
Cœlastrum cambricum, Arch. (p)	×	—	×	—	—	×
,, *microporum*, Näg.	—	—	—	×	—	×
,, *Morus*, W. and G. S. West	×					
,, *reticulatum* (Dang.), Senn. (p)	—	—	×	—	—	×
,, *sphæricum*, Näg.	×	×	×			
Crucigenia quadrata, Morren	—	—	—	—	—	×
,, *rectangularis* (Näg.), Gay	×	—	×	—	×	
,, ,, forma *irregulare* (Wille)	×	×				
,, *Tetrapedia* (Kirchn.), W. and G. S. West (P)	—	—	—	—	—	×
Scenedesmus acutiformis, Schröder, var. *Brasiliensis* (Bohlin), W. and G. S. West	—	×				
,, *bijugatus* (Turp.), Kütz.	×	×	×	×		
,, ,, forma *arcuatus* (Lemm.), W. and G. S. West (p)	—	—	×			
,, *denticulatus*, Lagerh., var. *linearis*, Hansg.	×	×				
,, *obliquus*, Kütz.	×	—	—	—	—	×
,, *Hystrix*, Lagerh.	×					
,, *quadricauda* (Turp.), Bréb.	×	×	×	×	—	×
,, ,, var. *abundans*, Kirchn.	×	×	—	×	—	×
,, ,, var. *horridus*, Kirchn.	—	—	—	—	—	×
Dimorphococcus lunatus, A. Br.	×					
Dictyocystis Hitchcockii, Lagerh.	×					
Elakatothrix gelatinosa, Wille	—	—	—	—	×	
Ankistrodesmus biplex (Reinsch.), G. S. West	—	—	×			
,, *falcatus* (Corda), Ralls	×	×	×	×	×	×
,, ,, var. *acicularis* (A. Br.), G. S. West	×	×	×	—	×	×
,, ,, var. *mirabilis*, G. S. West	—	×	—	—	—	×
,, ,, var. *spiralis* (Turn.), G. S. West (p)	—	×	—	—	—	×
,, ,, var. *spirilliformis*, G. S. West	×	—	—	×	×	
,, *Pfitzeri* (Schröder), G. S. West (P)	×	×	×	—	×	
Closteriopsis longissima, Lemm. (p)	—	—	×	—	—	×
,, ,, var. *tropicum*, W. and G. S. West	—	×				
Characium Debaryanum (Reinsch), De Toni	—	—	×			
Selenastrum gracile, Reinsch.	—	—	—	—	—	×
Kirchneriella lunaris (Kirchn.), Möb.	×					
,, *obesa*, W. and G. S. West (p)	×	×	×	—	—	×
Oocystis apiculata, West	—	×				
,, *crassa* (Wittr.)	×	×				
,, *lacustris*, Chodat (P)	—	—	×	—	×	
,, *Marssonii*, Lemm. (P)	—	—	×	—	—	×

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Oocystis parva, W. and G. S. West (p)	×	×	—	—	×	×
„ *solitaria*, Wittr.	×	—	×	—	—	×
Nephrocytium Agardhianum, Näg.	×	×	×	×	—	×
„ *lunatum*, West (p)	×	—	×	—	×	
Tetraëdron minimum, Hansg.	—	×	—	—	—	×
„ *cruciatum* (Wolle), W. and G. S. West	×					
„ *enorme* (Ralfs), Hansg.	—	—	×			
„ *limneticum*, Borge (P)	×					
„ *regulare*, Kütz.	×					
Dictyosphærium pulchellum, Wood (p)	×	—	×	×	×	×
„ *Ehrenbergianum*, Näg.	×	×				
Botryococcus Braunii, Kütz. [inclus. *Ineffigiata neglecta*] (p)	×	×	×	×	×	×
„ *proluberans*, W. and G. S. West (P)	×					
„ *sudeticus*, Lemm.	×					
„ „ var. *planctonicus*, Lemm.	×					
Syhærocystis Schröteri, Chodat (P)	×	×	×	×	×	×
Tetraspora lacustris, Lemm. (P)	—	—	—	—	×	
Glœocystis gigas (Kütz.), Lagerh.	×	×	×	×	×	×
„ „ var. *planctonicum*, W. and G. S. West (Pv)	—	—	×			
„ *infusionum* (Schrank), W. and G. S. West	×	—	×			
„ *vesiculosa*, Näg.	×	—	×			
Golenkinia paucispinosa, W. and G. S. West (P)	—	—	—	—	—	×
Richteriella botryoides (Schmidle), Lemm., forma *quadrata* (Lemm.), Chodat (P)	—	—	×	—	—	×
HETEROKONTÆ.						
Ophiocytium cochleare, A. Br.	×					
„ *bicuspidatum*, Lemm.	×					
„ *capitatum*, Wolle	×					
Tribonema affine (Kütz.), G. S. West	×					
Askenasyella conferta, W. and G. S. West (P)	×	—	×	—	—	×
Oodesmus Dœderleinii, Schmidle (P)	—	—	—	—	—	×
Chlorobotrys regularis (West), Bohlin	—	—	×	—	—	×
BACILLARIEÆ.						
Melosira crenulata, Kütz.	—	—	×	—	—	×
„ „ var. *tenuis* (Kütz.), Grun.	—	—	—	—	—	×
„ *arenaria*, Moore	—	—	×	—	—	×
„ *granulata* (Ehrenb.), Ralfs (p)	×	×	×	×	×	×
„ *varians*, Ag.	—	—	×	—	—	×
Cyclotella compta, Kütz. (p)	×	×	×	—	×	×
„ „ var. *affinis*, Grun.	×	×	×	×	×	×
„ *Kützingiana*, Chauvin	—	—	—	—	—	×
„ *Meneghiniana*, Kütz.	×	—	×			
„ *operculata*, Kütz.	×	—	×			
„ *Schröteri*, Lemm. (P)	—	—	×			
Coscinodiscus lacustris, Grun. (p)	—	—	—	—	—	×
Stephanodiscus Astræa (Ehrenb.), Grun. (P)	—	—	—	—	—	×
Rhizosolenia eriensis, H. L. Sm. (P)	×					
„ *longiseta*, Zach. (P)	×	—	×			
„ „ var. *stagnalis*, Zach.	×					
„ *morsa*, W. and G. S. West (P)	×	—	×	—	×	
Tetracyclus lacustris, Ralfs	×	—	—	—	—	×

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Tabellaria fenestrata (Lyngb.), Kütz.	×	×	×	×	×	
,, ,, var. *asterionelloides*, Grun. (Pv)	×	×	×	×	×	×
,, *flocculosa* (Roth.), Kütz.	×	×	×	×	×	
Denticula tenuis, Kütz.	×	—	×	—	—	×
Meridion circulare, Ag.	—	—	—	—	—	×
Diatoma elongatum, Ag.	×	×	×	—	×	×
,, ,, var. *tenuis* (Ag.), V. H.	—	—	—	—	—	×
Fragilaria capucina, Desmaz.	—	—	—	—	×	×
,, *construens*, Grun.	×	—	—	—	—	×
,, *Crotonensis* (A. M. Edw.), Kitton (p)	×	×	×	—	×	×
,, ,, var. *contorta*, W. and G. West (Pv)	×					
,, *mutabilis* (W. Sm.), Grun.	×	×	×			
Amphipleura pellucida, Kütz.	×	×	×			
Synedra Acus (Kütz.), Grun.	×	×	—	×	×	×
,, ,, var. *angustissima*, Grun.	—	—	×			
,, ,, var. *delicatissima* (W. Sm.), V. H. (p)	—	—	—	—	—	×
,, *Lemmermanni*, W. and G. S. West (P)	—	—	×			
,, *pulchella*, Kütz.	×	×	×	—	×	
,, *radians* (Kütz.), Grun.	—	—	—	×	×	×
,, *Revaliensis*, Lemm.	—	—	×			
,, *Ulna* (Nitzsch), Ehrenb.	×	—	×	×	×	×
,, ,, var. *longissima* (W. Sm.), Grun.	—	—	—	—	—	×
,, ,, var. *splendens* (Kütz.), Grun.	—	—	—	—	—	×
Asterionella formosa, Hass. (p)	×	×	×	×	×	×
,, *gracillima*, Heib. (p)	×	—	×	—	×	×
Ceratoneis Arcus (Ehrenb.), Kütz., var. *Amphioxys* (Rabenh.), De Toni	×	—	—	—	×	
Eunotia biceps, (W. Sm.), G. S. West	×	—	—	—	×	
,, *Diadema*, Ehrenb.	×					
,, *gracilis* (Ehrenb.), Rabenh.	×	—	—	—	×	
,, *lunaris* (Ehrenb.), Grun.	×	—	×	×	×	
,, *major* (W. Sm.), Rabenh.	×	—	—	—	×	
,, *pectinalis* (Kütz.), Rabenh.	×	—	×	×	×	
,, ,, var. *bidens*, Grun.	×					
,, ,, var. *undulata*, Ralfs	×					
,, *tetraodon*, Ehrenb.	×					
Achnanthes coarctata, Bréb.	—	×				
,, *exilis*, Kütz.	×					
,, *flexella* (Kütz.), Bréb.	×	—	—	—	—	×
Stauroneis anceps, Ehrenb.	×					
,, *Phœnicenteron*, Ehrenb.	—	×	—	—	×	
Gomphonema acuminatum, Ehrenb.	×	—	—	×		
,, *constrictum*, Ehrenb.	×	—	—	—	×	
,, *geminatum*, Ag.	×	—	×	—	×	
,, *intricatum*, Kütz.	—	—	×	—	×	
,, ,, var. *Vibrio* (Ehrenb.), V. H.	—	×				
,, *olivaceum* (Lyngb.), Kütz.	—	×	—	—	×	
Cocconeis Pediculus, Ehrenb.	—	—	—	—	—	×
,, *Placentula*, Ehrenb.	×	—	—	—	—	×
Gyrosigma attenuatum (Kütz.), Rabenh.	—	×	×	—	—	×
,, *Spencerii* (Quek.), O. K.	—	—	—	—	—	×
Navicula alpina (W. Sm.), Ralfs	×	×				
,, *Brébissonii*, Kütz.	—	×				
,, *divergens*, Ralfs	×					
,, *elliptica*, Kütz.	×	×				
,, ,, var. *minima*, V. H.	×					

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Navicula gibba, Kütz.	×	—	—	—	×	
„ *Iridis*, Ehrenb., var. *affinis* (Ehrenb.), V. H.	—	×				
„ *major*, Kütz.	×	×	×	×	×	
„ *nobilis* (Ehrenb.), Kütz.	×					
„ „ var. *Dactylus* (Ehrenb.), V. H.	×					
„ *pusilla*, W. Sm.	—	×				
„ *radiosa*, Kütz.	—	×	×	×	×	
„ *viridis*, Kütz.	—	×	—	—	×	×
Vanheurckia rhomboides, Bréb.	×					
„ „ var. *Saxonica*, W. and G. S. West	×	×	×	×	×	
Cocconema cæspitosum (Kütz.), G. S. West	—	—	×			
„ *cuspidatum* (Kütz.), G. S. West	×					
„ *Cistula*, Ehrenb., var. *maculata*, Kütz.	×					
„ *cymbiforme*, Ehrenb.	×	×	×	—	×	
„ *Ehrenbergii* (Kütz.), G. S. West	×					
„ *gastroides* (Kütz.), nob.	×					
„ *gracile* (Raben.), nob.	—	—	—	×	×	
„ *lanceolatum*, Ehrenb.	×	×	×	—	×	
„ *ventricosum* (Ag.), nob.	×	—	—	—	×	
Amphora ovalis, Kütz.	×	×	×	—	×	×
Epithemia turgida (Ehrenb.), Kütz.	×	×	×	—	×	×
Rhopalodia gibba (Kütz.), O. Müll.	×	×	—	—	—	×
Nitzschia acicularis, W. Sm.	—	—	×	—	—	×
„ *dissipata* (Kütz.), Grun., var. *acuta* V. H.	—	×				
„ *linearis* (Ag.), W. Sm.	×	×	×			
„ *Palea* (Kütz.), W. Sm.	×	×	×	—	×	×
„ *Sigma* (Kütz.), W. Sm.	—	—	—	×	×	
„ *sigmoidea* (Ehrenb.), W. Sm.	×	—	×	—	—	×
Cymatopleura elliptica (Bréb.), W. Sm.	—	×	×	—	—	×
„ „ var. *Hibernica* (W. Sm.) V. H.	—	—	—	—	—	×
„ „ var. *rhomboides*, Grun.	—	—	×			
„ *Solea*, W. Sm.	×	—	×	—	—	×
Surirella biseriata, Bréb. (p)	×	—	×	×	×	×
„ *linearis*, W. Sm.	×	×	—	—	×	
„ *ovalis*, Bréb.	×	—	—	—	—	×
„ „ var. *pinnata* (W. Sm.) V. H.	×					
„ „ var. *angusta* (Kütz.) V. H.	×					
„ „ var. *ovata* (Kütz.) V. H.	—	—	—	—	—	×
„ *robusta*, Ehrenb. (p)	×	×	×	×	×	
„ „ var. *splendida* (Ehrenb.) V. H. (p)	×	×	×	×	×	×
„ *spiralis*, Kütz.	×	—	—	—	—	×
„ *turgida*, W. Sm.	—	—	×	—	—	×
Campylodiscus Hibernicus, Ehrenb.	×	×	×	—	—	×
MYXOPHYCEÆ.						
Hapalosiphon Hibernicus, W. and G. S. West	×					
Stigonema minutum, Hass.	×	—	×			
Nostoc microscopicum, Carm.	×					
Anabæna circinalis (Kütz.), Hansg. (p)	×	×				
„ *Hassallii* (Kütz.), Wittr.	—	—	×			
„ „ var. *tenuis* (W. and G. S. West), Lemm.	—	—	×			
„ *Flos-aquæ* (Lyngb.), Bréb. (p)	×	—	×	×	×	×
„ *Lemmermanni*, P. Richter (P)	×	—	×	×	×	×
Lyngbya bipunctata, Lemm. (P)	—	—	—	—	×	

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
Lyngbya contorta, Lemm. (P)	×					
„ *Kützingii*, Schmidle, var. *distincta* (Nordst.), Lemm.	—	—	—	—	—	×
„ *limnetica*, Lemm. (P)	×	—	×	—	—	×
„ *Martensiana*, Menegh.	—	—	×			
„ *versicolor*, Gomont	×					
Oscillatoria tenuis, Ag.	×	×	×	×	×	×
„ *limosa*, Ag.	—	—	×	—	—	×
„ *Agardhii*, Gomont (p)	—	—	×	×	×	
„ *irrigua*, Kütz.	—	—	—	—	×	
„ *rubescens*, D. C. (P)	×	—	—	—	×	
Phormidium tenue (Menegh.), Gomont	—	—	×	—	—	×
Glœotrichia echinulata (Eng. Bot.), P. Richter (p)	×					
Glœothece linearis, Näg.	×	—	×			
Synechococcus major, Schroet.	×					
Merismopedia glauca (Ehrenb.), Näg.	×	×	×	×	×	
„ *æruginea*, Bréb. (p)	×	×	×	—	×	
„ *elegans*, A. Br.	—	×				
„ *punctata*, Meyen	×					
Merismopedia tenuissima, Lemm. (P)	—	—	×	×	—	×
Cœlosphærium Kützingianum, Näg. (p)	×	×	×	—	×	×
„ *minutissimum*, Lemm. (P)	×	—	×	×	—	×
„ *Nägelianum*, Unger.* (P)	×	×	×	×	—	×
„ *natans*, Lemm. (P.)	—	—	×			
Gomphosphæra aponina, Kütz.	—	—	×	—	—	×
„ *lacustris*, Chodat (P)	×	—	×	×	×	×
Aphanocapsa pulchra (Kütz.), Rabenh.	—	×				
Aphanothece saxicola, Näg.	—	—	×			
„ *clathrata*, W. and G. S. West (P)	—	—	×	—	—	×
Dactylococcopsis rhaphidioides, Hansg. (P)	—	—	×	—	—	×
Microcystis æruginosa, Kütz. (p)	—	—	×	—	×	×
„ *elabens* (Bréb.), Kütz.	×	×				
„ *icthyoblabe*, Kütz.	—	—	—	×		
„ *incerta*, Lemm. (p)	×	—	×	×	×	
„ *marginata*, Menegh.	×					
„ *Flos-aquæ* (Wittr.), Kirchn.	×	×				
„ *prasina* (Wittr.), Lemm. (p)	—	×	×	—	—	×
„ *pulverea* (Wood), Migula	—	—	—	—	×	
„ *roseo-persicina*, Kütz.	—	—	—	—	—	×
„ *stagnalis*, Lemm. (p)	×	×	×	—	×	×
Chroococcus cohærens, Näg.	×	×	×			
„ *helveticus*, Näg.	—	—	×			
„ *limneticus*, Lemm. (P)	×	×	×	×	—	×
„ „ var. *subsalsus*, Lemm. (P)	—	—	×			
„ *minimus* (v. Keissler), Lemm.	×	×	—	—	×	×
„ *pallidus*, Näg.	×	×				
„ *turgidus* (Kütz.), Näg.	×	×	×	—	×	
PHÆOPHYCEÆ.						
Stichoglœa olivacea, Chodat (P)	×					
Phæococcus planctonicus, W. and G. S. West (P)	×	—	×			

* It seems probable that this "species" is merely a form of *C. Kützingianum*, Näg.

Species.	Scottish lakes.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh lakes.	English lakes.	Lough Neagh (and L. Beg).
FLAGELLATA.						
Dinobryon bavaricum, Imhof. (p)	×	—	×			
„ *cylindricum*, Imhof. (p.)	—	—	×	×	×	
„ „ var. *pediforme*, Lemm.	×	—	—	×		
„ „ var. *palustre*, Lemm.	×	—	×			
„ „ var. *angulatum*, Lemm. (p)	×					
„ „ var. *divergens* (Imhof.), Lemm. (p)	×	×	×	×	×	×
„ „ var. *Schauinslandii*, Lemm. (p)	×	—	×			
„ *elongatum*, Imhof. (p)	×	—	×	×	×	
„ „ var. *undulatum*, Lemm. (p)	×	×	×	×	×	
„ *protuberans*, Lemm. (p)	×	—	—	×	—	×
„ *Sertularia*, Ehrenb.	×					
„ „ var. *thyrsoideum* (Chodat), Lemm. (p)	—	—	×	—	—	×
„ *sociale*, Ehrenb.	—	—	×			
„ *utriculus* (Ehrenb.), Klebs.	×					
Halobryon Lauterbornii, Lemm. (p)	×					
Synura uvella, Ehrenb.	—	—	—	—	×	
Mallomonas acaroides, Perty (p)	×	×	×			
„ *caudata*, Iwanoff	×	—	×			
„ *producta*, Iwanoff	—	—	×			
„ *longiseta*, Lemm. (P)	×	—	—	—	×	
Diplosigopsis frequentissima, Lemm. (p)	×	—	×	×		
Bicœca lacustris, J. Cl., var. *longipes*, Zach. (p)	—	—	×	×		
Cryptomonas erosa, Ehrenb.	—	—	×			
Lepocinclis ovum (Ehrenb.), Lemm., var. *punctato-striatum*, Lemm.	—	—	×			
Euglena viridis, Ehrenb.	×	×	×	×		
PERIDINIEÆ.						
Gymnodinium, sp.	—	—	×			
„ *paradoxum*, Schilling (p)	×	—	—	—	×	
„ „ var. *major*, Lemm. (Pv)	—	—	×			
Glenodinium pulvisculus (Ehrenb.), Stein (p)	×	—	×	—	—	×
Ceratium cornutum (Ehrenb.), Clap. and Lachm. (p)	×	×	×	×	×	
„ *curvirostre*, Huitf.-Kaas. (P)	×					
„ *hirundinella*, O. F. Müller (P)	×	×	×	×	×	×
Peridinium bipes, Stein	—	—	×			
„ *cinctum*, Ehrenb. (p)	—	—	×	—	—	×
„ *inconspicuum*, Lemm.	×	—	—	×	×	
„ *limbatum* (Stokes), Lemm. (p)	—	—	×			
„ *pusillum*, Schilling (p)	×					
„ *tabulatum* (Ehrenb.), Clap. and Lachm.	×	×	×	×	×	×
„ *umbonatum*, Stein	×					
„ *Westii*, Lemm. (P)	×					
„ *Willei*, Huitf.-Kaas. (P)	×	×	×	×	×	×

The above list includes the species of the lake-plankton only, and the Flagellata are very incompletely recorded.

Were the species of the helioplankton of large ponds, pools, and ditches also included, many of the Protococcaceæ (or Autosporaceæ) would have to

be added, such as sundry species of *Chodatella, Lagerheimia, Golenkinia,* and other genera.

The following summary is instructive:—

	Species only.						Totals. Species and varieties of each group.	
	Scottish.	Orkneys and Shetlands.	W. and S.W. Ireland.	Welsh.	English lakes.	Lough Neagh (and L. Beg).	Species.	Varieties.
Chlorophyceæ (except Desmidiaceæ)	54	31	37	20	24	33	81	18
Desmidiaceæ	176	85	103	101	96	22	236	68
Heterokontæ	5	—	2	—	—	3	7	0
Bacillarieæ	63	37	47	18	41	41	94	22
Myxophyceæ	31	17	33	12	17	21	53	2
Phæophyceæ	2	—	1	—	—	—	2	0
Flagellata (except Peridinieæ)	12	4	13	6	4	3	18	7
Peridinieæ	11	4	10	5	6	5	15	1
Totals of species for each area, and grand total of both species and varieties for entire British phytoplankton	354	178	246	162	188	128	506	118
							Grand total.	

The grand total of 506 species and 118 varieties is sufficient evidence in itself that the British phytoplankton is exceedingly rich, and of this total 46 per cent. are species of the Desmidiaceæ.

Many of these constituents are, of course, adventitious or casual, consisting of littoral or bog species which are carried into the plankton by the rains and exist there only a short time before perishing. There are, however, many constituents which are exclusively limnetic in habit, and also others which are much more abundant in the plankton than in other situations. These have been discriminated in the foregoing list.

XI. General Summary and Discussion on the Dominance of Desmids.

The tabulated list gives a very adequate idea of the Algal constituents of the British freshwater plankton, and also shows that many of these constituents are common to the four British lake-areas.

The British lakes combine to some extent the characteristic features of the Central European and Northern European lakes, but are on the whole more

nearly akin to the latter. In addition they have peculiarities which tend to mark them off from either of those groups; for instance, the relatively high winter temperatures. Very many of these lakes never freeze, and most of the others only rarely become covered with ice, and then for comparatively brief periods. The summer temperatures are also comparatively low. The highest temperature we have recorded in Windermere in the course of twelve months' observations (including one of our warmest summers) was 14°·4 C. (58° F.), in Wastwater 17°·2 C. (63° F.), and in Ennerdale Water 15°·5 C. (60° F.). The highest temperatures we have obtained in the Welsh lakes were 17°·5 C. (63°·5 F.) in Llyn Ogwen and 18° C. (64°·5 F.) in Llyn Llydaw. The small sheet of water known as Llyn Elsie attained a summer (August) temperature of 19°·7 C. (67°·5 F.). The summer temperature of the Irish lakes rarely exceeds 18°·3 C. (65° F.). The average range of temperature in the Scottish lochs is from about 5° C. to 13° C., and the highest we have ourselves measured was 16°·6 C. (62° F.) in Loch Earn.

In all the four British lake-areas the water is soft, with only small quantities of dissolved lime, a peculiarity which accounts for the rarity of snails at the lake margins.

The phytoplankton is never of very great bulk, and it is quite exceptional for it to colour the water to any appreciable extent.

The periodicity of the phytoplankton is very variable in the different lakes. In some it is conspicuous, but in others it is not very well marked. Investigations at present in progress indicate that it is most conspicuous in the shallower lakes, and particularly in those at considerable altitudes, but at present our data are not nearly sufficient for generalisations to be made.

The Myxophyceæ play quite a secondary part in the plankton of the British lakes as compared with the Central European lakes. They are more abundant in some of the Irish lakes than in any of the others, and sometimes the phenomenon of "water-bloom" makes its appearance. This phenomenon, which is due to sudden and simultaneous maxima of a few of the limnetic species of Blue-green Algæ, is of very irregular occurrence in the British lakes, and is practically confined to sporadic appearances in some of the shallower-lakes.*

Oscillatoria tenuis is general but never abundant, and *Anabæna Lemmermanni* should be specially mentioned, as its spores form deep blue-green floating clusters, which sometimes give a decided colour to the surface water.

* The phenomenon of "water-bloom" is better seen in some of the large pools and meres of the lowland parts of Britain than in any of the lake-areas. A good description of the "breaking of the meres" has been given by Phillips in 'Trans. Shropshire Archæol. and Nat. Hist. Soc.,' 1883, and earlier records were by Greville, Dickie, and Drummond.

Of the colonial unicells, *Cœlosphœrium Kützingianum* (and the form of it known as *C. Nägelianum*), *Gomphosphœria lacustris*, and *Chroococcus limneticus* are the most important. *Microcystis* (*Clathrocystis*) *œruginosa* occurs more particularly in pools and small, shallow lakes, where the temperature of the surface water becomes relatively high in the summer.

In the Scottish and the Welsh lakes the Blue-green Algæ are decidedly scarce. This scarcity is to be attributed to the Alpine character of so many of these lakes, in which the maximum temperature of the surface water is relatively low.

The FLAGELLATA are well represented by various Peridinieæ, by *Mallomonas*, and by several species of *Dinobryon*. In many of the larger British lakes *Dinobryon* completely dominates the spring plankton, and a few colonies generally persist through the summer and the early part of the autumn. The most abundant species is *D. cylindricum*, and its var. *divergens* is equally common. In the smaller lakes *Dinobryon* is fairly general, but does not attain such great maxima as in the larger lakes. *Mallomonas acaroides* sometimes occurs in prodigious abundance, but lasts only a few weeks.

Of the Peridinieæ, *Ceratium hirundinella* is general, but it only occurs in large maxima in the smaller lakes. The variations in this organism have been well described and figured,* but there is one form in the lakes of the Outer Hebrides and the west of Ireland† which is apparently unknown in the plankton of the rest of Europe. In this curious form the first antapical horn is very much deflected to one side (*vide* fig. 3). Species of *Peridinium* often occur in very large quantity in the smaller lakes, and in the shallower of the large lakes. *P. tabulatum* is frequent, but *P. Willei* is general throughout the Scottish, Irish, and English lakes.‡ It occurs most abundantly in the small upland lakes (up to 1800 feet) with an Alpine character. *P. Westii* is exclusively confined to the Scottish lakes, where it appears to be frequent.

The BACILLARIEÆ are abundant in the British phytoplankton, but they rarely occur in such great quantities as in the Central European lakes, and scarcely ever form the vast maxima which periodically appear in so many of those lakes. Diatoms are fewest in the plankton of the Welsh lakes,

* Lemmermann, in 'Archiv för Bot. utgifv. af K. Sv. Vet.-Akad.,' Bd. 2, 1904, No. 2, t. 2, f. 1—49; W. and G. S. West, in 'Roy. Soc. Edin. Trans.,' vol. 41, 1905, p. 494 (*c.* fig.); 'Roy. Irish Acad. Trans.,' vol. 33, sect. B, part 2, 1906, pp. 93, 94 (*c.* figs. 1—9); Bachmann in 'Archiv für Hydrobiologie und Planktonkunde,' Bd. 3, 1907, pp. 55—58, figs. I, I*a*, II.

† W. and G. S. West, in 'Roy. Irish Acad. Trans.,' *loc. cit.*, 1906, p. 94, f. 9.

‡ The distribution of *Peridinium Willei*, Huitf.-Kaas, extends from N. Italy, Ireland, England, and Scotland to Norway, Finland, the Faeroes, and Iceland.

forming only an average of 11 per cent. of the entire phytoplankton. This low percentage is probably due to the small numbers of adventitious species washed into the lakes from the mountain sides, and is possibly accentuated by the stony character of the lake margins and lake bottoms. They occur in the greatest variety in the Scottish and Irish lakes, probably owing to the large number of adventitious species washed into the lakes by the rains. The Pennate Diatoms are much the most numerous and conspicuous.

Among the commonest forms are *Asterionella* (with a range of form and size which embraces both *A. formosa* and *A. gracillima*) and the two species

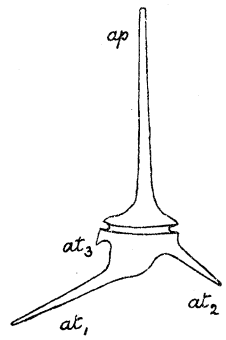

FIG. 3.—Peculiar Form of *Ceratium hirundinella*, O. F. M., in which the first antapical horn (at_1) is greatly deflected to one side. × 200.

of *Tabellaria*. *T. fenestrata* is much more abundant than *T. flocculosa*, except in the English lakes, where the reverse obtains. The chain-forms of *T. fenestrata* are the most frequently observed, but the star-dispositions (var. *asterionelloides*) are common except in the Welsh lakes. *T. fenestrata*, var. *asterionelloides*, is one of the dominating features of the late spring, the summer, and the early autumn plankton of many British lakes, and it exhibits great variability in the relative strength and breadth of the girdle view of the cells.* That these differences are of no varietal importance is proved by the occurrence of all intermediate stages.

We have not observed any star-dispositions of *T. flocculosa* in any of the British lakes, although such have been observed by Holmboe in Norway and by Wesenberg-Lund in Denmark (*T. flocculosa*, var. *pelagica*, Holmboe).

The numerous plankton-forms of *Asterionella* almost convince one that *A. formosa* and *A. gracillima* are merely states of the same species. No chains of *Asterionella* were observed in any of the lakes.

The genus *Fragilaria* is somewhat rare, and of the species which occur *F. capucina* is the commonest. *F. crotonensis* is very general in Scotland

* *Cf.* W. and G. S. West, in 'Roy. Soc. Edin. Trans.,' vol. 41, 1905, Plate 2, figs. 1—3.

and Ireland, but is always scarce. We have not observed it in the English* or Welsh lakes. A variety of it—var. *contorta*—occurs in Loch Ruar, Sutherland, which is unique in the curious twisting of its exceedingly short filaments. This variety is not known from elsewhere.

Throughout all the British lake-areas, but more especially in the west of Scotland and the west of Ireland, species of the genus *Surirella* form a considerable and conspicuous part of the phytoplankton. The most frequent is *Surirella robusta*, var. *splendida*, which sometimes occurs in great abundance,† but *S. biseriata* and *S. linearis* are both general. In this respect the British lakes compare with the lakes of Central Africa, in which several plankton-species of *Surirella* are abundant.‡ In the Yan Yean Reservoir, Victoria, *S. robusta*, var. *splendida*, is also a constituent of the plankton.§ Wesenberg-Lund‖ states that various species of the genera *Surirella* and *Cymatopleura* occur in the plankton of principally alpine or shallow lakes in level country, and that they have been carried out by rivers and waves into the pelagic region, where they vegetate but for a short period and then perish. We find that in the British lakes, and also in those of Central Africa, the genus *Surirella* is frequently a true plankton-genus, and the various species which have been recorded both vegetate and multiply in the plankton to an extent we have rarely noticed in other situations.

Several of the Naviculaceæ occur with considerable regularity.

Centric Diatoms are relatively few and insignificant in the British lakes. *Melosira* is represented chiefly by *M. granulata* and *M. varians*. The latter is perennial in the plankton of British rivers. Species of *Cyclotella* are not abundant, and only in Lough Corrib, Galway, have we observed the curious gelatinous colonies which occur so frequently in some of the Central European lakes.

The genus *Rhizosolenia* is represented by two (and if the record of *R. eriensis* be correct, by three) species. *R. longiseta* is very rare, but *R. morsa* occurs in some of the lakes of all the British lake-areas. We have observed the resting-spores of this species in the June plankton of Thirlmere in the English Lake District.

No species of *Attheya* has yet been observed in any of the British lakes.

The CHLOROPHYCEÆ are well represented in the British lakes, more

* This species occurs both in the plankton (helioplankton) and the benthos of the large pools in the Midlands of England.

† Consult W. and G. S. West, *loc. cit.*, Plate 1, figs. 1—4, and Plate 2, fig. 6 (photos).

‡ G. S. West, in 'Linn. Soc. Bot. Journ.,' vol. 38, 1907, p. 85.

§ G. S. West, in 'Linn. Soc. Bot. Journ.,' vol. 39, 1909, p. 17.

‖ Wesenberg-Lund, 'Plankton Investigations of the Danish Lakes,' Copenhagen, 1908, p. 42.

especially by the Desmidiaceæ. Apart from the latter, *Botryococcus Braunii* and *Sphærocystis Schroeteri* are the most general and abundant. Species of *Oocystis* are frequent, but never occur in quantity. *Dictyosphærium pulchellum* often occurs abundantly, but it also at times occurs in equal abundance in bogs.

Eudorina elegans is fairly general, even in large lakes such as Lough Corrib, although it reaches its maximum abundance in small lakes.

Pediastrum Boryanum and *P. duplex* are frequent in the plankton of the shallower lakes, but *P. simplex* is very rare. Several species of *Cœlastrum*, *Scenedesmus*, and *Crucigenia* occur in many of the lakes, but never in quantity.

Species of *Zygnema*, *Spirogyra*, and *Mougeotia* occur in the plankton of most of the lakes, principally in the late spring and summer. They are usually the slender species of these genera, and are almost invariably sterile. In the smaller alpine lakes *Mougeotia* is often abundant, and forms no small part of the phytoplankton.* The curious coiled *Mougeotia*-filaments of some of the Scottish lochs have already been referred to. It would appear that the coiling is a limnetic character,† developed to augment the floating-capacity of the filament, and the fact of its presence is direct evidence that some of these solitary filaments of *Mougeotia* are adapting themselves to a life in the plankton.

THE MOST INTERESTING FEATURE OF THE BRITISH FRESHWATER PHYTOPLANKTON IS THE DOMINANCE OF DESMIDS. In 1903, and again in 1905, we showed that in contrast to any previously known plankton that of the Scottish lakes was unique in the abundance of its Desmids. Since then we have found that this dominance of Desmids is not confined to the lochs of the Scottish Highlands, but is a feature of the plankton of the four lake-areas of the British Islands, and that *the plankton of the western British lake-areas differs markedly from all other European plankton in the abundance of its Desmids.*‡

* In the alpine lakes of the Pike's Peak Region, Colorado, Shantz states that species of *Spirogyra* and *Œdogonium* form a large part of the summer plankton (*vide* 'Amer. Microscop. Soc. Trans.,' March, 1907). Fragmentary filaments of various species of *Œdogonium* are also very frequent in the summer plankton of the British lakes.

† Consult G. S. West in 'Linn. Soc. Bot. Journ.,' vol. 38, 1907, pp. 85 and 86.

‡ Among European lakes, only those of Norway and certain parts of Sweden approach the British lakes in the possession of a conspicuous Desmid-flora in the plankton (consult Huitfeldt-Kaas, *loc. cit.*, 1906; and Lemmermann, in 'Archiv för Bot. utgiv. af K. Sv. Vet.-Akad.,' Bd. 2, 1904), and it should be mentioned that many of these plankton Desmids are identical with the British ones. Tanner-Fullemann has recorded the occurrence of a number of Desmids in the plankton of the Schoenenbodensee (*vide* 'Bull. de l'Herb. Boissier, 2me sér., t. 7, 1907), but the species which he records, when it is

In discussing this phenomenon of the rich Desmid-flora of the British freshwater plankton, it is necessary, in the first place, to briefly outline the general distribution of the Desmidiaceæ in the British Islands, *quite irrespective of the freshwater plankton.* We have studied the distribution of British Desmids in detail during the past 16 years, and the obvious fact, patent to anyone who chooses to collect these plants over extensive areas, is the *much greater richness of the Desmid-flora in the western areas of the country.* The eastern districts of England are exceedingly poor, but on passing from the newer Tertiary formations to the Older Palæozoic and Precambrian formations the Desmid-flora gradually increases in richness, attaining its maximum diversity in certain of the Precambrian areas.

The richest areas of all are the little boggy pools and smaller lakes of the Lewisian Gneiss of North-west Scotland and the Outer Hebrides, and similar areas on the Precambrian formations of Donegal, Mayo, and Galway. There are also several very rich localities in the English Lake District and North Wales, all on the Silurian and Ordovician with sundry Igneous intrusions. There are, in addition, two rich localities in the south of England, one on the Lower Greensand of Surrey (Thursley Common), and the other on the Middle Eocene of Hampshire (the New Forest). In both these localities there are deep, spongy bogs, with a fairly rich Desmid-flora, but at the same time it is a flora which falls far short of the much richer Desmid-floras of the Precambrian areas. We may add that these are not statements based upon a few casual observations, but upon a detailed examination of many thousands of collections made in all parts of the country, from the Shetland to the Scilly Islands, and from the east of England to the west of Ireland. It is also necessary to give some explanation of what is meant by a "rich" area. We do not apply the term "rich" to a mere abundance of Desmids, or even to the occurrence of a great quantity of 30 or 40 species, but only to those areas in which 150 to 200 (or even 300) species can be found in more or less abundance, including many of the rare species with a restricted distribution.

We have, therefore, as a foundation on which to base this discussion of

possible to be certain of his identifications, are those of shallow alpine and subalpine lakes, and not in any way comparable to the characteristic plankton species of the western British areas. Neither do we regard his records as constituting a "rich" Desmid-flora.

Among extra-European lakes, Victoria Nyanza has a conspicuous Desmid-flora in the plankton, and the Yan Yean Reservoir, Victoria, possesses a very rich Desmid-plankton, quite equal to the best of the British lakes, although with an entirely different association of species. In the latter case the drainage water is mostly from Silurian and Granitic outcrops, but it is not yet possible to make a definite statement concerning the drainage into Victoria Nyanza.

the dominance of Desmids in the plankton of the British lakes, a fairly complete and necessary knowledge of the general distribution of Desmids in the bogs, pools, etc., throughout the whole of the British Islands. The first point of importance is that the great majority of the British lakes (those constituting the western and north-western lake-areas) are all situated in the richest Desmid-areas in these Islands, or for that matter in Europe. It is, therefore, not in the least surprising that the plankton of these lakes should on the whole contain an abundance of Desmids. That the Desmids of the plankton should differ considerably from those of the bogs of the drainage areas—a matter discussed in a later part of this paper—does not affect the main question, *viz., that the phytoplankton of these lakes possesses in many instances such an abundance of Desmids that it can be correctly described as a Desmid-plankton.*

Those facts which explain the abundance of Desmids in the bogs and bog-pools, among the mosses of the dripping rocks, and among the leaves of the submerged plants of the lake-margins, will likewise furnish the explanation of the abundance of Desmids in the plankton, as the plankton-Desmids have certainly originated from bog and swamp species, and others are being constantly recruited from the same sources. In endeavouring to discover the relationship between the conditions of environment and the richness of the Desmid-flora, two facts stand out very clearly :—

1. The rich Desmid-areas correspond very accurately with the areas of the old geological formations. They are mostly mountainous districts, with considerable outcrops of Igneous rocks.

2. These areas also correspond, but with less accuracy, to the areas of greatest rainfall.*

It is now necessary to enquire more closely into the relationships between the geological nature of the drainage-area, the rainfall, and the richness of the Desmid-flora.

We will first consider the *rainfall* of the areas in question. This is relatively heavy, varying from about 45 to upwards of 100 inches, and is due to two causes: first, to the fact that these areas are almost all near the west coast, being districts in which large mountains are situated in close proximity to the sea; and secondly, to the prevailing westerly and south-westerly winds. Such conditions naturally result in wet, mossy hill-sides, with numerous bogs. There is consequently much peaty water, rich in humic and other organic acids, in which submerged plants, such as *Utricularia minor*, *Sphagnum cuspidatum*, *S. subsecundum*, and other

* Mr. James Murray (in 'Roy. Phys. Soc. Edin. Proc.,' vol. 16, 1905, p. 58) also points out that Sir John Murray had indicated this fact to him.

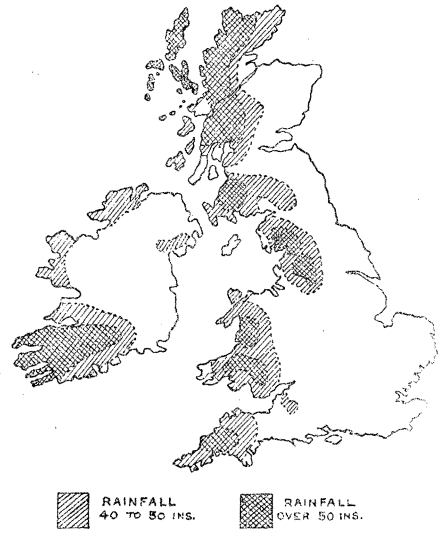

Fig. 4.

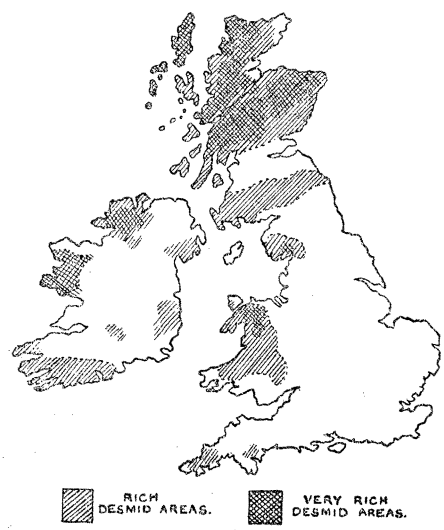

Fig. 5.

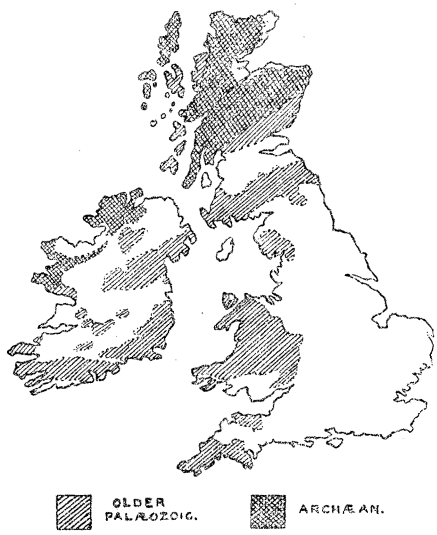

Fig. 6.

Maps of British Islands, to show (fig. 4) areas with Rainfall over 40 inches; fig. 5, distribution of rich and very rich Desmid-areas, characterised by the western types mentioned (pp. 201 and 202); fig. 6, distribution of Older Palæozoic and Archæan rocks.

Note.—The Desmid-flora of the central and south-eastern counties of Ireland is very imperfectly known. Notice the falling off in the Desmid-flora of Skye in fig. 5, corresponding with the absence of Archæan rocks indicated in fig. 6.

aquatics thrive, and furnish all the requirements for the prolific growth of Desmids.

This seems a natural explanation of the occurrence of a rich Desmid-flora, and one which is accepted by Wesenberg-Lund* as the main cause of the phenomenon.

A detailed study of the distribution of Desmids has shown us, however, that the mere presence of suitable habitats is insufficient to account for the great richness of the Desmidiaceæ in certain areas of these Islands. Among the mountains of the Pennine Chain are some of the finest peat-bogs in the British Islands—in all outward appearances ideal spots for the occurrence of a rich Desmid-flora. Such are Cocket Moss, Austwick Moss, and others less well known. Again, on Thursley Common in Surrey, and in the New Forest, are bogs which are unsurpassed in Britain as habitats for the Desmidiaceæ. In all these localities the bogs are deep and dangerous, fed mostly by bottom springs, and furnish an ideal home for quantities of submerged *Sphagnum* and *Utricularia minor*. Desmids occur in countless millions among the larger aquatics; in fact, collections made in these localities would be regarded as "rich" or "very rich" by those who had no experience of the western areas. *Utricularia minor*, which harbours some of the best of British Desmids among its leaves, flowers profusely in the localities mentioned, and no finer specimens can be obtained even in Mayo and Galway. Yet the Desmid-flora which occurs among the *Utricularia* in the above-mentioned localities is not to be compared with that which occurs in precisely the same environment in the western British areas, and, moreover, it contains none of the real British rarities.

How is it that an ideal locality such as Cocket Moss, which would be described as "rich in Desmids," contains practically none of those species which are both dominant and characteristic of the western areas? The conditions are almost identical with those obtaining in the western bogs, and the rainfall is from 50 to 60 inches.

From a consideration of the above remarks it is obvious that some factor, other than mere abundance of rainfall and presence of ideal habitats, has a profound influence on the distribution of Desmids. This at once causes us to enquire into the statement that we have previously made,† viz., that *the rich Desmid-areas correspond geographically with the Precambrian and Older Palæozoic outcrops* (*together with the intrusive Igneous material*). (Consult figs. 5 and 6.)

* Wesenberg-Lund, 'Plankton Investigations of the Danish Lakes,' Copenhagen, 1908 p. 281.

† *Vide* p. 197 of the present paper.

In the first place, it has been recently pointed out* that the association of the rich Desmid-areas with the older strata is (in the British Islands) most probably due in part to the antiquity and consequent hardness of the rocks. The mountainous regions which have resulted from those changes in the earth's surface which have produced folding and contortion, and from the resistance of these old, compressed rocks to subaerial denudation, are not only directly responsible for the rainfall owing to their geographical position, but are themselves most suitable for the formation of peat-bogs. In these areas Desmids flourish, and therefore, so far as the British Islands are concerned, the richness of the Desmid-flora bears a distinct relationship to the antiquity of the geological formations of any area under consideration. It seems probable that the determining factor is a chemical one. It is certainly something more than mere suitability of habitat, otherwise how is the relative poorness of the extensive bogs of the more recent formations to be explained ?†

It is very probable that the chemical composition of the water plays an important part in determining this distribution. That the chemical factors are quite apart from the occurrence of brown, peaty water, is evident from the poorness of the Desmid-flora of so many peat-bogs, and also from the fact that the best and richest Desmid-floras only occur in clear water with no obvious peaty characters. Wesenberg-Lund is incorrect when he states that Desmids *chiefly* thrive in "brown water rich in humic acids."‡ Some of them certainly do, and often profusely, but these are generally the common, ubiquitous species which have almost a world-wide distribution. The great majority, including most of the western British types, prefer clear water with little peat. An excess of the brown peaty material is distinctly unfavourable. The plankton-Desmids also occur much more abundantly in the clear lakes than in the brown peaty ones.

Although it appears so probable that chemical factors determine the distribution of many Desmids, no definite information on this point has yet been obtained. The drainage water which has percolated through the old formations (rocks and soil) may possibly contain minute quantities of something in solution which greatly favours the development of certain types of Desmids, and may be directly responsible for their restricted distribution.§

* G. S. West, in 'Linn. Soc. Bot. Journ.,' 1909, vol. 39, p. 10.

† How is it, also, that the peaty bogs and ditches of the fens of the east of England, such as are left of them, are poorer in the Desmidiaceæ than any other part of the British Islands ?

‡ Wesenberg-Lund, *loc. cit.*, 1908, pp. 280 and 281.

§ There would be nothing remarkable in this, as diatoms thrive and build up their siliceous cell-walls in water containing silica in such minute quantities that ordinary chemical analysis reveals no trace of it.

In reference to the above remarks, James Murray* has stated that "another theory is that the lochs which are richest in Desmids are only found in the older geological formations, but this does not accord with facts, as I find that such lochs occur in all the formations from the Lewisian to the Tertiary, at least; and it will, I think, be found that some of these lochs lie entirely in glacial deposits." It should be pointed out that if glacial drift is excluded none of the lake-areas are even near the British Tertiary formations. Many of the lakes have doubtless been formed in Tertiary times, and if they are spoken of as "Tertiary lakes" it must be distinctly understood that *they are situated in drainage-basins on the old formations.* Those lakes which Murray has termed "Tertiary lakes" are certain of the Scottish lochs which are surrounded by and rest upon more or less extensive sheets of glacial drift. It must be distinctly borne in mind that most of this glacial drift has been derived from the old rocks, and what is very much more important, that the drainage into such lakes consists mostly of water which has partly traversed the exposed outcrops of the old rocks of the surrounding hills and mountains, and partly percolated through them. Therefore, any peculiarities which may be characteristic of the drainage water from the old formations, are also equally characteristic of the water of such lakes.

The point of primary importance is that the greater part of the drainage water of such a lake has traversed the older rocks, and possesses those peculiarities which so far as we can see account for the Desmid-flora not only of its plankton, but of its littoral region and also of the surrounding bogs. It is immaterial *when* the lake was formed, or whether its bed be one of glacial drift or of old rocks.

IN THE BRITISH ISLANDS THE REALLY RICH DESMID-FLORAS, CONTAINING MANY OF THE WESTERN BRITISH TYPES, ARE ONLY FOUND IN THOSE AREAS WHICH COMBINE THE MOST SUITABLE HABITATS (*such as are found on boggy hill-sides with an abundant rainfall*) WITH A DRAINAGE-WATER DERIVED FROM GEOLOGICAL FORMATIONS OLDER THAN THE CARBONIFEROUS.

We would suggest a very exact chemical investigation of the water of bogs and lakes in different areas as a possible means of throwing further light upon this question. It has been suggested that the absence of lime is the determining factor in the abundance of Desmids, and it may possibly have much to do with the restricted distribution of the western British types.

There are a large number of western types of British Desmids, of which the most important are included in the following list:—

Gonatozygon aculeatum, Hastings; *Spirotænia trabeculata*, A. Br.; *Penium*

* James Murray, *loc. cit.*, 1905, p. 58.

adelochondrum, Elfv.; *P. Clevei*, Lund.; *Tetmemorus Brébissonii* (Menegh.), Ralfs, var. *minor* De Bary.

Micrasterias radiata, Hass.; *M. conferta*, Lund.; *M. pinnatifida* (Kütz.), Ralfs; *M. apiculata* (Ehrenb.), Menegh., and var. *brachyptera* (Lund.), W. and G. S. West.

Euastrum pictum, Börges. forma; *E. Turneri*, West; *E. aboense*, Elfv.; *E. intermedium*, Cleve; *E. pingue*, Elfv.; *E. validum*, W. and G. S. West.

Docidium undulatum, Bail.; *Pleurotænium eugeneum* (Turn.), W. and G. S. West.

Cosmarium bipunctatum, Börges.; *C. capitulum*, Roy and Biss., var. *grœnlandicum*, Börges.; *C. Corribense*, W. and G. S. West; *C. commissurale*, Bréb., var. *crassum*, Nordst., *C. distichum*, Nordst.; *C. didymoprotupsum*, W. and G. S. West; *C. entochondrum*, W. and G. S. West; *C. monomazum*, Lund., var. *polymazum*, Nordst.; *C. obsoletum* (Hantzsch), Reinsch; *C. perforatum*, Lund.; *C. pseudexiguum*, Racib.; *C. pseudopyramidatum*, Lund., var. *stenonotum*, Nordst.; *C. quadridentatum*, W. and G. S. West; *C. quadrifarium*, Lund.; *C. retusum* (Perty), Rabenh.; *C. retusiforme* (Wille), Gutw.; *C. Smolandicum*, Lund., var. *angustatum*, West; *C. sexnotatum*, Gutw., var. *tristriatum* (Lütkem.), Schmidle; *C. subquadrans*, W. and G. S. West; *C. subretusiforme*, W. and G. S. West; *C. synthlibomenum*, West; *C. taxichondriforme*, Eichl. and Gutw.; *C. tenue*, Arch.; *C. tumidum*, Lund.; *C. venustum*, Bréb., var. *hypohexagonum*, West; *C. viride* (Corda), Josh.; *C. zonatum*, Lund.

Staurastrum Arctiscon (Ehrenb.), Lund.; *St. aversum*, Lund.; *St. bacillare*, Bréb.; *St. Brébissonii*, Arch.; *St. Brasiliense*, Nordst., var. *Lundellii*, W. and G. S. West; *St. Cerastes*, Lund.; *St. Clevei* (Wittr.), Roy and Biss.; *St. conspicuum*, W. and G. S. West; *St. corniculatum*, Lund.; *St. curvatum*, West; *St. dorsidentiferum*, W. and G. S. West; *St. elongatum*, Barker; *St. erasum* Bréb.; *St. forficulatum*, Lund.; *St. grande*, Bulnh.; *St. lævispinum*, Biss.; *St. longispinum* (Bail.), Arch.; *St. maamense*, Arch.; *St. megalonotum*, Nordst.; *St. natator*, West; *St. Ophiura*, Lund.; *St. Picum*, W. and G. S. West; *St. quadrangulare*, Bréb.; *St. setigerum*, Cleve; *St. sexangulare* (Bulnh.), Rabenh.; *St. spiniferum*, West; *St. subgracillimum*, W. and G. S. West; *St. cosmospinosum* (Börges.), W. and G. S. West; *St. Duacense*, W. and G. S. West; *St. Hibernicum*, West; *St. jaculiferum*, West; *St. cornutum*, Arch.

In addition to the above, there are a number of species which are extremely rare in a few of the richest localities outside the western areas, whereas in the latter they are generally distributed and many of them prodigiously abundant. Such are:—

Spirotænia acuta, Hilse; *Netrium oblongum* (De Bary), Lütkem., var.

cylindricum, W. and G. S. West; *Penium exiguum*, West; *Closterium Ulna*, Focke; *Tetmemorus minutus*, De Bary; *Micrasterias Sol*, Ehrenb.

Euastrum crassum (Bréb.), Kütz., var. *scrobiculatum*, Lund.; *E. crispulum* (Nordst.), W. and G. S. West; *E. inerme*, Lund.; *E. pinnatum*, Ralfs; *E. pulchellum*, Bréb.; *E. sublobatum*, Bréb.; *E. ventricosum*, Lund.

Cosmarium connatum, Bréb.; *C. Debaryi*, Arch.; *C. decedens*, Reinsch; *C. elegantissimum*, Lund.; *C. annulatum* (Näg.), Arch., var. *elegans*, Nordst.; *C. Hammeri*, Reinsch; *C. isthmium*, West; *C. Nymannianum*, Grun.; *C. ovale*, Ralfs; *C. parvulum*, Bréb.; *C. pseudamœnum*, Wille; *C. pseudopyramidatum*, Lund.; *C. pseudoconnatum*, Nordst.; *C. sphæroideum*, West; *C. subundulatum*, Wille; *C. variolatum*, Lund.

Staurastrum aculeatum, Ehrenb.; *St. anatinum*, Cooke and Wills; *St. Arnellii*, Boldt; *St. furcatum*, Ehrenb.; *St. inconspicuum*, Nordst.; *St. arachne*, Ralfs; *St. lanceolatum*, Arch.; *St. oxyacanthum*, Arch.; *St. pungens*, Bréb.; *St. scabrum*, Bréb.; *St. aristiferum*, Ralfs; *St. pileolatum*, Bréb.; *St. pterosporum*, Lund.; *St. subscabrum*, Nordst.

Having discussed the most important facts concerning the general distribution of Desmids in the British Islands, we can now return to the abundance of the Desmids in the British freshwater phytoplankton.

We have shown which areas of these Islands possess the rich Desmid-floras, and when one considers that the British lakes are almost all situated in these western areas, it is not very surprising that they possess a plankton containing numerous Desmids. Neither is it surprising that many of these should be the western types, provided that these western types are capable of withstanding the conditions of a limnetic life.

THEREFORE WE CONSIDER THAT THE DESMIDS OF THE BRITISH FRESHWATER PHYTOPLANKTON ARE DUE LARGELY, AND THE WESTERN TYPES ENTIRELY, TO THE SITUATION OF THE LAKES IN THE RICH DESMID-AREAS OF THE OLD FORMATIONS.

The antiquity of the geological formations is not a special factor in the occurrence of the numerous *plankton Desmids*, but in the occurrence of *Desmids as a whole*. The presence of numerous Desmids in the plankton of the lakes follows as a matter of course.

One does not expect an abundance of Desmids in the plankton of the large Swiss lakes. They are situated in poor Desmid-areas, and in North Switzerland the geological formations are for the most part too recent.

Most of the Central European lakes are situated in areas relatively poor in Desmidiaceæ. In Denmark the formations are Cretaceous and Jurassic, largely overlain by drift, and similarly the lakes of Northern Germany are situated on immense areas of drift, overlying comparatively

recent formations. Hence the dearth of Desmids in the lakes. On the other hand, the Scandinavian lakes are situated on the old formations, and contain an abundance of Desmids, many of which are identical with those of the British lake-areas.

The Desmids of the plankton have without doubt originated from the Desmid-community of the surrounding area, although in most cases there is little resemblance between the plankton-community and that which can be observed in the surrounding drainage-basin. There is an almost complete absence from the surrounding peat-bogs and dripping rocks of those species which are most conspicuous and abundant in the plankton. The common Desmids of the bogs are only found in the limnetic region of the lakes as casual or adventitious constituents, and therefore the great majority of the Desmids brought by the rains into this limnetic region, with its new conditions of life, find it impossible to maintain their further existence, and rapidly perish. The plankton-community as a whole, as shown by Wesenberg-Lund, is a very ancient one, and this is further confirmed in the case of the British lakes by the existence of this distinct community of plankton-Desmids. We have already stated* that many of the plankton-Desmids "have existed under these pelagic conditions for a long time, as there is every indication of this in the modifications some of them have undergone, and in the species and varieties which are at present only known to occur in the plankton."

During the vast period in which Desmids have been washed by the rains from their bog habitats into the lakes, a specific selection has taken place, certain species having adapted themselves, with or without slight morphological changes, to a limnetic existence. Only those have survived which were able to withstand the new conditions.

One of the principal conditions necessary for existence in the new life would be the ability to float in the surface waters. In some species, more especially in the discoid species of *Micrasterias*, this necessity has brought about no morphological alteration; and in others, amongst which are certain species of *Cosmarium* and *Staurastrum*, there is again no change of external form, but a copious development of surrounding mucilage. In many others morphological changes have occurred, mostly in the further development of those characters which have proved of most avail in the struggle against sinking. It is thus that spines and processes have been greatly increased in length, so that many of the plankton-forms are the longest-spined forms known.† Certain species of *Staurastrum* and *Arthrodesmus* best exhibit this

* W. and G. S. West, in 'Roy. Soc. Edin. Trans.,' vol. 41, 1905, p. 512.

† In the ordinary habitats of Desmids, and in the former habitats of plankton-species spines are commonly found well developed. This armature has probably two functions,

great development of spines. The species of *Closterium* found in the British lake-plankton are mostly adventitious constituents, and are never abundant.

Nearly all the plankton-Desmids are summer and autumn constituents, and the majority of them attain their maximum abundance in September and October, during the slight fall after the maximum summer temperature.

Neither plankton-Desmids nor those which occur in other situations undergo any seasonal form-variations. This we have conclusively proved by the examination of large numbers of periodic collections of these plants. This is merely what one would expect, as environmental form-changes in Desmids occupy long periods of time. As regards the plankton, the variations in the conditions of buoyancy during the year in the surface waters of a lake are not so great as the environmental differences between the habitats in which the same species of Desmid will thrive.

Large numbers of both the plankton and bog species survive the winter in the vegetative condition, and the formation of zygospores appears to be very rare.

In Diatoms it is known that the seasonal form-variation, when it occurs, is in the colony and not in the individual, but colonial Desmids are much fewer and much less abundant than colonial Diatoms.

Lastly, we would comment upon the *cosmopolitanism of the freshwater plankton-community.* This is generally true except for the Desmids. Wesenberg-Lund* states that the numerous plankton researches in the Central European lakes have been unable to demonstrate any special, geographically localised plankton-communities. He remarks† that the "freshwater plankton-communities, in contrast to all other communities on land or water, everywhere contain the same types, nearly everywhere the same species." As regards the Desmid-flora, however, these statements do not hold good. *Wherever there are lakes with a rich Desmid-flora in the plankton, there one also gets a more or less definitely localised plankton-community.* It has been stated‡ that the Desmidiaceæ show more decided geographical peculiarities than any other group of Freshwater Algæ, notwithstanding the fact that a large number of them are cosmopolitan and ubiquitous all the world over. These geographical peculiarities occur

one of anchoring the individual to its environment, and the other to serve as a protection against Desmid-eating animals. Whether the more elongated spines of the plankton-species likewise serve a similar function of protection against the depredations of the plankton Rotifers and Entomostraca is a point which requires further investigation.

* Wesenberg-Lund, *loc. cit.*, 1908, p. 293.

† *Loc. cit.*, p. 313.

‡ G. S. West, in 'Linn. Soc. Bot. Journ.,' vol. 38, 1907, p. 82; W. and G. S. West, in 'Ann. Roy. Bot. Gard., Calcutta,' vol. 6, part 2, 1908, p. 176.

in the Desmid-community of the plankton quite as much as in the general Desmid-community of the surrounding country. In fact, they appear to be well marked.*

Even with the meagreness of our present knowledge we can recognise three distinct plankton-communities of Desmids, which can at once be distinguished from each other, and which form a most interesting comparison. These are (1) the Desmids of the British (and to a certain extent of the Scandinavian) plankton, (2) the Desmids of the plankton of Victoria Nyanza, and (3) the Desmids of the Victorian plankton (as exemplified by the Yan Yean Reservoir). There are doubtless several other distinct plankton-communities of Desmids, notably in the South American and the Indo-Malayan regions. There are marked geographical peculiarities in the general Desmid-community of these regions, and should any of the lakes be found on investigation to possess a Desmid-plankton, it is highly probable that many of the species will possess their proper geographical character.

* In considering this question it should be borne in mind that Desmids in the vegetative condition cannot be blown about by the wind, as even partial desiccation is almost invariably fatal. Also, that in most species zygospores are very rarely formed, and that no zygospore has yet been observed of any of the typical plankton-species. The only Desmids which appear to survive a partial desiccation are certain species of *Cylindrocystis* and *Penium*, and possibly of *Mesotænium*.