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Periodicity of Freshwater Algae

Studies on the Occurrence and Reproduction of British Freshwater Algae. iii. A Four Years' Observation of a Freshwater Pond. by F. E. Fritsch; Florence Rich

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the point of view adopted by him as regards soil problems, and to make special mention of the points more likely to be of interest to ecologists. Although of course much of it is controversial matter, especially that part of it dealing with the toxic action of plant excreta, yet it should not fail to help and stimulate plant ecologists in facing the soil problems which are of such importance to their subject.

WALTER STILES.

PERIODICITY OF FRESHWATER ALGAE

Fritsch, F. E., and Rich, Florence. "Studies on the occurrence and reproduction of British freshwater Algae. iii. A four years' observation of a freshwater pond." *Ann. de Biologie lacustre*, **6**, 1913, 83 pages.

This paper is based on the examination of algae collected fortnightly during four years from a small pond near Harpenden, Hertfordshire. The pond investigated is small and roughly rectangular in outline, about 30 m. long and 12 m. in greatest width, and the depth does not normally exceed 1 m. There are frequent changes in water level, related to rainfall and temperature; in summer the pond sometimes dries up completely for a time, in winter it is usually frozen over for a short period. The two long sides of the pond are bordered with rushes, and abundant aquatic and marsh vegetation develops in it during the mild period of the year and must not only shade the algal vegetation but possibly enter into competition with it, besides furnishing a substratum for a rich epiphytic flora.

The phanerogamic vegetation which occupies a large part of the pond from early April to the end of October shews the following phases: (1) spring—*Ranunculus aquatilis* dominant; (2) early summer, *Lemna*- and *Bidens*-seedlings; (3) summer—*Glyceria fluitans* dominant, *Juncus* spp., *Bidens*; (4) late summer—*Bidens cernua* dominant; (5) autumn—*Lemna*, *Ranunculus aquatilis*, *Callitriche verna*; (6) winter—*Ranunculus*, *Callitriche*.

A list is given of the dominant Algae—those which at certain times form a really conspicuous feature of the flora—shewing that the general aspect of the algal flora is largely determined by filamentous Conjugatae, *Oedogonium* spp., *Microspora* and *Conferva*, with large quantities of *Eunotia Arcus* in the winter months; at one time or another the three Flagellates present (*Trachelomonas volvocina*, *T. hispida*, *Euglena viridis*), *Ophiocytium cochleare*, *Sphaerocystis Schroeteri* and *Ineffigata neglecta*, play a more or less important part; while *Synedra radians* and *Eunotia lunaris* are important as epiphytes at certain periods of the year. The absence of *Cladophora* is attributed to the unsuitability of the conditions in this pond for the growth of such a coarse form—the almost complete stagnation and the liability to complete desiccation in summer.

The annual cycle is varied and complex, probably owing to the shallow nature of the pond and its exposed position, which bring with them a rapid and frequent change of water level. There are four main phases corresponding largely to the four seasons and also to the phases shewn by the phanerogamic vegetation. The winter phase with its *Microspora* and Diatoms corresponds to the period with *Ranunculus* and *Callitriche*; the spring phase with its Conjugatae, *Oedogonium* and *Conferva*, to that with *Ranunculus* dominant; the summer phase with *Euglena*, Desmids and *Anabaena* dominant, to that in which *Lemna*, *Glyceria* and *Bidens* are successively dominant; while the autumn phase, which is only distinguished in its algal flora by the presence of such forms as *Lyngbya* and *Trachelomonas*, is equally little characterised by its phanerogamic flora. The four main phases differ not only in the quality but also in the quantity of algal growth present: there is a great increase in the amount of Algae with the approach of the spring phase, both as to number of individuals and number of species; on the advent of summer in a normal year there is again a decrease, often sudden and very marked, and the number of species may for a time be restricted; in the autumn phase there is a revival in numbers of species and individuals; there is often no very marked decrease in the amount of Algae with the arrival of the winter phase, but the number of species generally shews an appreciable decrease as compared with the autumn phase.

Evidently the variations in number of species in the different seasons of the year depend on changes of temperature and light intensity, on changes in the bulk of water and consequent alterations of concentration, and on changes in the air content of the water, which take place more or less regularly at these times. The authors point out that for the determination of the relation between frequency of freshwater Algae and external conditions, small pieces of water are alone suitable. In large water areas, especially in lakes, the changes produced by meteorological influences are brought about so slowly that greater annual uniformity is attained, and the effects could only be satisfactorily studied over a long period of years; while the difficulties of obtaining representative samples are almost insuperable. This does not apply to the typical plankton, which owing to its ubiquity in a piece of water is readily collected and which tends to shew pronounced and uniform annual periodicity.

The authors classify the factors governing freshwater algal growth into three groups—(1) seasonal, (2) irregular, (3) correlated. Seasonal factors, probably the chief determinants in larger water areas, are rather masked by the irregular factors in a small piece of water, but are responsible for the general trend of the annual cycle. Irregular factors—abnormal drought or rainfall, abnormal sunshine, abnormal temperatures—throw most light on the conditions determining the existence of the diverse members of the algal flora. The observations made are summarised as follows. I. Rainfall (i.e. degree of concentration of water): (1) favoured by relatively dilute water—Desmids, *Oedogonium*, *Chaetophora*, *Pandorina*, *Sphaerocystis*, *Peridinium tabulatum*; (2) favoured by relatively concentrated water—Zygnemaceae, *Eudorina*, *Gloeocystis*. II. Sunshine: (1) favourably affected by sunshine—Zygnemaceae, Desmids, *Oedogonium*, Protococcales; (2) adversely affected by sunshine—Confervales, *Anabaena*. III. Temperature: (1) favoured by low temperature (probably mainly affecting amount of dissolved gases)—*Microspora*, *Eunotia*, *Synedra radians*; (2) favoured by relatively low temperatures—Zygnemaceae, *Oedogonium*, *Chaetophora*; (3) favoured by higher temperatures—Desmids, Protococcales, *Anabaena*, *Peridinium tabulatum*.

Several correlated factors have been recognised in studying the periodicity of algae in this pond: (1) forms dependent on enrichment of water by decay of other members of the flora—*Euglena*, *Navicula*; (2) forms influenced in their development by competition with others—*Conferva*, *Microspora*, *Oedogonium*; (3) forms influenced in their development by the presence of a suitable substratum—*Eunotia lunaris*, *Synedra radians*, and no doubt other epiphytes.

The principle of limiting factors, which has been established for various physiological phenomena, is strikingly illustrated by the authors' observations of cases in which, for instance, the extent of development of Zygnemaceae was limited by exceptional dilution of the water, that of the Desmids by unusual concentration of the water; in the case of *Oedogonium* sunshine is apparently the limiting factor—no maximum is obtained until the necessary amount of sunshine has been realised; in *Chaetophora* and the Protococcales the limiting factor is concentration of the water, in *Euglena* the amount of organic substance dissolved in the water. While in most cases there is only one limiting factor in Nature, the others being apparently always realised, the case of *Oedogonium* is especially interesting because there is evidence of the existence of two limiting factors—the amount of sunshine and the concentration of the water; in *Conferva* and *Microspora*, where the main limiting factors are amount of sunshine and temperature respectively, competition on the substratum is probably a second limiting factor.