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Cladophora glomerata and accompanying algae in the Skawa river

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CONTENTS

Introduction

The work is an attempt at describing the seasonal alterations in the appearance and structure of the thalli of *Cladophora glomerata* (L.) Kütz., as well as in the species composition and the development of the accompanying algae, especially of epiphytes.

Data from literature concerning the seasonal variability of *C. glomerata* thalli are limited and not very recent. The first papers on this subject are restricted to a graphic presentation of *Cladophora* thalli (Kützing 1853—1854) differing in shape, or to the description of biological regularities of the growth (the law of evection, Brand, Nordhausen, after Heering 1921). The only detailed mention is found in the work of Brand (Heering 1921). The author determines shapes of the thallus of *C. glomerata*, which differ from each other in their development, by means of states (e.g. *status hiemalis, status redivivus,* and others) or forms of this species (*forma rivularis, forma simplicior,* etc). Brand did not try to find a causal relation between these observations as to the alterations in the morphology of the thallus and the biological or physical and chemical properties of the reservoir in which he cultured thalli of the *Cladophora;* he ascribed to them a rather secondary role. It is difficult, therefore, to draw any more general conclusions from this work when determining, for example, the regularities which direct the seasonal alterations in the development of thalli of this species. In later years the variability of the *Cladophora* thallus was not investigated.

A good deal of attention has for a long time been paid to the algae accompanying the *Cladophora*. N a u m a n n (1926) considers the species of the section *Aegagrophila* of the genus *Cladophora* as best known association of an epipythmenic formation in lakes. Owing to the large dimensions of the thalli and of the mass appearance, which sometimes takes place, of the *Cladophora glomerata* in rivers of almost the entire northern hemisphere, it is considered as a species which distinguishes a separate association, the *Cladophoretum glomeratae* (S a u e r 1937, M a r g a l e f 1949, S y m o e n s 1951, B o h r 1962).

The present work is also a contribution to the cognition of the flora of algae in the Skawa river, which has as yet been only fragmentarily investigated in this respect (G u t w i ń s k i 1893, 1897, 1898, 1901).

I wish to express my most sincere thanks to all those who helped me in the execution of the present work. I am especially grateful to Professor K a r o l S t a r m a c h for his counsel and many suggestions, for his kind patronage and for providing me with a place to work in spite of the somewhat cramped conditions in his Department of Hydrobiology of the Jagiellonian University. I also wish to thank Dr K. W a s y l i k who confirmed the determination of a series of species of diatoms and blue-green algae and who determined some species of desmids, and Dr T. M r o z i ń s k a - W e b b and Dr C. S z k l a r c z y k - G a z d o w a for bibliographical indications concerning the periphyton.

Description of the locality

The Skawa river flows out at a height of 780 m. above sea level, from the north-western slopes of the Łysa Góra in the Beskid Wysoki (High Beskid). It collects water from a fairly large area (an area of $F = 1188$ km^2) situated between the Babia Góra range in the south and the Vistula (Wisła) river in the north. Flowing with a mean gradient of 5.6 pro mille mostly in a NNW direction, it falls into the Vistula in the locality of Podolsze, at 218 m. above sea level. Its length is 100 km.

The investigated sector of the river, 130 m. long and about 80 m. wide, is situated in its central course in the town of Sucha, about 250 m. below the railway bridge on the Skawa river, at 338 m. above sea level (fig. 1). The river is not regulated in this place, its bed has a slightly depressed level and the main current flows near the left bank. The rock material of which the bottom is formed is Magura sandstone (S z a f l a r s k i 1931, K s i ą ż k i e w i c z 1939, 1948, 1958), greyish or light grey in colour or, when weathered, yellow or greyish-green. The sandstone pebbles are mostly well polished, with a diameter of 5—15 cm. Some of them are larger, attaining 35 cm and even up to 50 cm in diameter. They are embedded in fine or coarse grained sand, sometimes slightly slimy. At the slightest rise in the water level these loose stones are continually moved from place to place.

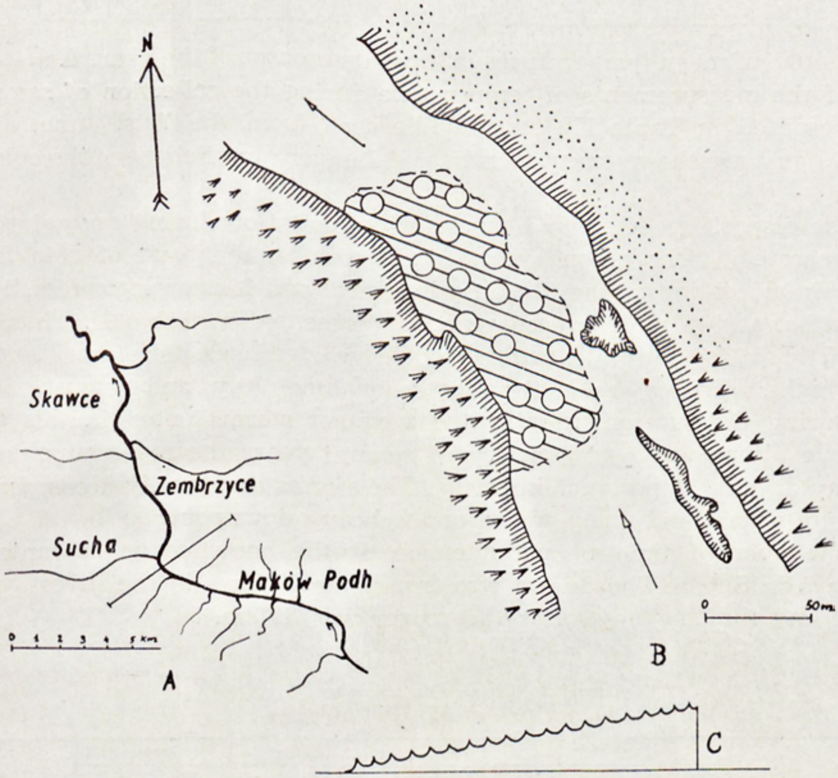


Fig. 1. A. Situation; B. Place of collecting samples and plan of disposition of *Cladophora glomerata*; C. Longitudinal profile of the river in the place of investigation.

The steep left bank of the river is about 2 m. high above the average surface of the water, and is overgrown by alder (*Alnetum incanae;* Zarzycki 1956, H. Chudyba 1958). The flat right bank has a large lag gravel bank; it is covered with scarce weedy vegetation and clumps of willows, with cultivated fields towards the end (lag gravel bank and a lower meadow terrace).

An analysis of thermal conditions was carried out on the basis of data obtained from the nearest station of the State Hydrological and Meteorological Institute at Maków Podhalański, and on that of measurements of air and water temperature carried out each time during the collecting of samples of water in the Skawa. Table I gives information as to the

Table I

Mean temperatures (in °C) in the years 1954–1959
for Maków Podhalański (350 m. above sea level)

Spring			Summer			Autumn			Winter			Whole year
Mar.	Ap.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
0.8	5.0	11.7	15	17.4	16	12.4	7.8	2.3	0.6	–4.0	–4.0	7.4

disposition of mean temperatures in separate months of the year. A detailed list of the measurements of temperature during the collection of samples is presented in Table IV. As may be seen from the lists, June, July, and August are the warmest months and January and February the coldest ones.

The disposition of mean figures for precipitation during several years in separate months of one year, carried out on the basis of data from the rainfall station of the State Hydrological and Meteorological Institute in Sucha, at 345 m. above sea level, is presented in Table II. Thus the mean figure for rainfall during a whole year reaches therefore 957 mm. The highest figures are in the months of June, July, and August.

During the summer months the frequent storms noted in this area deserve attention. Over a period of several years the mean number of stormy days is 11 per year in Sucha. The storms are usually accompanied here by strong and gusty winds and a heavy downpour.

The average time of maintenance of the snow cover amounts to 79 days in Sucha. The Skawa was frozen for 49 days in the investigated place and the thickness of the ice cover was 31 cm.

Table II

Mean rainfall (in mm^3) in the years 1954–1960
in Sucha (345 m. above sea level)

Period	Spring			Summer			Autumn			Winter			Total
	Mar.	Ap.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1954–1960	52.6	75.6	69	165	180.5	108	61	55	50	57	42.6	41	957.3
1959–1960	21	97	67	213	185	78	13	19	37	84	63	26	908

The course of mean figures of monthly water levels in the Skawa over a period of several years (measurements were carried out, according to data of the State Hydrological and Meteorological Institute about 100 m. above the place of investigation — the Skawa bridge on the road) is presented in Table III.

Such a disposition of water level is closely connected with the precipitation. Tributaries of the Skawa (mainly the Skawica and Bystre) have an influence on the high water level during summer (Keller 1899); maximum water level was noted as many as 61 times — most often in July — 32 per cent, 17 per cent in June, and 12 per cent in August. The absolute maximum for the Skawa occurred in June, 1903, and amounted to 665 cm., i.e. 443 cm. above the mean level.

Three kinds of flood, depending on the season of the year, may be distinguished here:

a) spring floods are closely connected with thaws in the upper sector of the Skawa, but they happen seldom. They are only dangerous when the flow of ice occurs at a high water level.

b) Summer floods are the most frequent and the most dangerous.

c) Autumn floods are caused by protracted rains. Culminating water levels during this period are, however, considerably lower than those of the summer or spring.

Floods do not last long: for the last 25 years a high water level was maintained only during 19 days, and only twice was the flood water maintained for more than 2 days. When the water level is high the water of the Skawa is of a yellowish-brown, café-au-lait colour, with uprooted or broken off trees, bushes, weeds or their fragments, seeds, grass sods etc. floating on the surface. The displacement of stone fragments during this period is greater. The water of the Skawa carries away everything that it can tear from the substratum and all that is introduced from neighbouring terrains or washed out from bends and backwaters.

This explains why the *Cladophora* thalli are then deprived of their lateral branches or even entirely torn away from the substratum.

The colour and transparency of the water are very variable during the year and depend on the level of water and the amount of emulsions brought from the upper course of the river, and also on the numerous small streams and on sewage. The water is generally clean, the depth variable, amounting usually to 30—70 cm. in the investigated place. Accurate data for the depth of the water at the moment of collecting samples are listed in Table IV, together with the results of the investigation of physical and chemical properties of the water. The velocity of the water current was medial or strong in spring, during summer very strong on the average, medial in autumn, and slow in winter.

Methods

Material was collected from April 19, 1959 till March 26, 1960, on the average every two weeks but in the winter months (December-February) only every four weeks. The regularity of the collecting trips depended on the current water levels of the Skawa. In a period of high water levels the trip was postponed to a later date. Altogether, 19 collecting trips were undertaken; the exact dates are given in Table IV.

For investigation 4—9 stones as large (30—40 cm. in diameter) and as typical as possible, disposed on the terrain of the whole locality, were selected. From each of them on the side which was sheltered from the

Table III

Mean figures of monthly water level in Sucha
in the years 1954-1960

Period	Spring			Summer			Autumn			Winter			Mean
	Mar.	Ap.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	
1954-1960	156	166	152	156	162	152	141	120	138	152	152	155	150
1959-1960													
mean	138	144	134	153	151	144	127	124	126	130	151	150	
maximum	160	180	138	200	276	194	130	126	130	160	226	176	
minimum	130	132	130	135	132	132	124	123	123	120	132	136	

Table IV

Some ecological factors in the Skawa river

Year	1959															1960		
Season	Spring			Summer					Autumn					Winter			Spring		
Date	Apr. 18	May 4	May 24	June 6	July 5	July 25	Aug. 11	Aug. 31	Sept. 10	Oct. 9	Oct. 29	Nov. 13	Nov. 24	Dec. 9	Jan. 2	Feb. 4	Mar. 5	Mar. 19	Mar. 26
Air temperature in °C	20	14	19	26	24	31	28	19	25	16	10	8	12	8	6	-6	10	14	19
Water temperature in °C	11	9	15	20	19	18	19	15	19	11	9	6	2	5	4	3	7	10	16
Depth in place of collecting samples in cm.	30	80	40	70	100	120	50	90	35	25	30	40	40	30	90	25	35	110	50
Current velocity in cm./sec.	25	90	35	65	120	150	65	100	35	30	35	40	45	30	110	25	30	140	60
pH of the water	-	7.2	-	-	7.4	-	-	7.2	-	-	7.2	-	-	7.0	-	6.7	-	-	6.8
Hardness of water in German degrees	-	4.6	-	-	5.0	-	-	4.8	-	-	5.0	-	-	6.0	-	9.8	-	-	5.2
Water alkalinity in mv.	-	1.3	-	-	1.6	-	-	1.4	-	-	1.4	-	-	2.0	-	2.2	-	-	2.1

current, about 2 cm of the *Cladophora glomerata* thallus was cut off at the base with a sharp scalpel (fig. 2 A).

The material collected from a determined surface of each stone was placed in a separate test tube or, if necessary, into several test tubes marked with appropriate ordinal numbers. The majority of the test tubes were preserved on the spot in a fluid composed of 1 part of 40 per cent

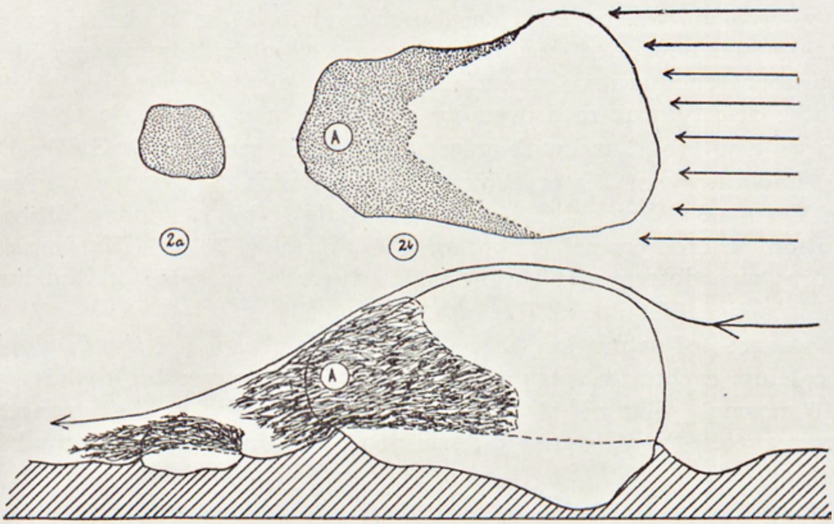


Fig. 2. Stones from the locality, with marked disposition of *Cladophora glomerata* thalli; A. Place of collecting samples. Arrows indicate direction of current. In the upper figure stones seen from above, in the lower one the stones in profile. Surface of stone „a" about 2 dcm^2, of stone „b" about 14 dcm^2.

formalin and 3 parts of 96 per cent ethanol. Some test tubes (2—3) which had not been fixed were taken to the laboratory in Cracow, where the algae were investigated in a live state. The aim of this investigation was to determine the degree of vitality at least of the specially characteristic species and to record such features as may undergo considerable alterations owing to the fixative. After investigation of the samples and noting the results, this material was also fixed.

The aim of each trip consisted in obtaining a collection of strata from a total surface of 1 dcm^2 of all investigated stones. Where 5 stones were taken into consideration the surface for collecting purposes on each of them was reduced in proportion. After the first few trips it was found that, on the basis of preliminary investigations, there is no perceptible difference in the material collected during a single trip. Therefore the term „habitat" defines in the present work the totality of places where samples were collected within the limits of the investigated sector of the river (the locality).

During the collection of samples, the surface of the stone from which the given sample was taken, the length of the *Cladophora* thalli, their colour and the manner in which they were disposed on the stones, as well as other observations concerning the disposition and morphology of the thallus were noted. Taking as a guide the colour of the algae, the area of the investigated sector of the river, overgrown by the *Cladophora* was roughly determined during the collection of samples. Some characteristic thalli were laid out on cloth cardboard and dried in a similar way as herbarium sheets. Collections of *Cladophora* dried in this manner formed an additional comparative material.

Water acidity was measured by means of a colorimetric acidimeter with a scale of 3 to 10 and with an accuracy of 0.2, made by Dr S. Wróbel in the Laboratory of Water Biology of the Polish Academy of Sciences, using Yamada's reagent for the pH scale 4 to 10, and additionally a solution of bromocresol green for the pH scale 3 to 5. Hardness and alkalinity was determined by methods generally accepted in the limnological practice (Klut 1927 et al.).

The degree of saturation of the cellular membranes of the *Cladophora* with calcium carbonate was determined visually by treating the alga with a 1/10 normal solution of HCl and, on the basis of the strength of effervescence, they were determined as: insignificant, moderate, considerable.

Altogether 117 samples were collected and studied. During 6 trips in spring 39 samples were collected, 34 samples in summer during 5 trips, 28 samples in autumn on 5 trips, and 16 samples in winter on 3 trips.

Photographs of *Cladophora* fragments with epiphytes were taken by means of a Zeiss NfpK microscope with a mounted „Mf" arrangement for microphotography. For diatom determination and an exact counting of striae or points on the frustules, photographs were made, according to Professor Starmach's method, directly on bromsilver paper by means of a PZO microscopic socket with a side eyepiece for setting up, with a linked 6,5 × 9 cm camera of the type MNF — 6,5 × 9. Photographs of whole thalli of the *Cladophora* were executed by means of a plate camera 9 × 12 placed upon the tripod of a special appliance with a bottom light. The figures were executed with the aid of a drawing ocular 10 × (MNR-1 a PZO production).

The collected material from each test tube was at first exploited for carrying out an analysis of the morphology of the *Cladophora*. Typical thalli were chosen, their length, the thickness of membranes, and length and breadth of cells were measured and the type of branchings and the manner of disposition of other algae upon them were determined. Characteristic thalli were stained by immersing them first into a 1 per cent solution of iron chloride and then into a 1 per cent solution of tannin, after which photographs were taken.

The species composition and numerical relations were determined on the basis of studying usually 5—6 aqueous preparations of a surface equal to that of a cover glass of 20 × 20 mm. In some cases, to prevent a too rapid evaporation of water, potassium acetate was used for the preparation (1 : 50) as it does not dry up and does not provoke plasmolysis of the delicate cells of the algae. It was always endeavoured to make preparations of material with an equal density and as equally transparent as possible, in which the separate threads of the algae should not lie one on the other. The material was suitably wetted with water when the necessity arose.

For making diatom preparations, half of the collected material was placed in a test tube and macerated in the following solution: 3 parts of saturated H_2SO_4, 1 part of a saturated solution of $K_2Cr_2O_7$. Then, after washing away dirt with 95 per cent alcohol and fixing the frustules from the diluted sediment in the ratio of 1 : 4, 3 permanent preparations were made in the pleurax, with a surface equal to that of a 20 × 20 mm cover glass. As 117 test tubes were collected, the total number of permanent preparations of diatoms amounted to 351.

From the qualitative point of view efforts were made to establish as accurately as possible the species composition and to determine in detail every species, even lower taxonomical units. When determination of the species was impossible, only the genus was determined. In the qualitative study small coloured flagellates, fungi, and some bacteria were not taken into consideration.

According to Starmach's recommendations (in manuscript 1961) for studying the sociology af algae, the following methods were used.

Quantity of the forms was determined by applying the scale:

+ — Very few. The given organism appears singly, not in every preparation. Altogether, 1—6 specimens in the investigated preparations.

1 — Single. The given organism is found in numbers of 1—6 individuals in a preparation. Altogether, 10 individuals in 100 fields of vision.

2 — Few. The given organism is found in numbers of 7—16 individuals in a preparation. Altogether, about 50 individuals in 100 fields of vision (or in 3 preparations).

3 — Medium. The given organism appears in numbers of 1—3 specimens in nearly all fields of vision. Altogether, about 100—150 specimens in 100 fields of vision.

4 — Many. The given organism is found in numbers of 4—5 individuals in nearly all fields of vision. Altogether, about 250 individuals in 100 fields of vision.

5 — Very many. The given organism dominates positively and is found in numbers of more than 5 individuals in each field of vision. Altogether, more than 250 individuals in each field of vision.

Quantitative estimation was carried out on identical surfaces of 20 mm² of each microscopic preparation. Preliminary trials showed that this surface is sufficiently large for estimating the number of all freshwater algae, with the exception of a few species with very large thalli (such as *Lemanea, Batrachospermum, Stigeoclonium,* and others). The few large algae were estimated in relation to a surface of 1 dcm², but when they appeared in a juvenile form, in the stage of spores or in a vestigial form, they were treated in the same manner as microscopic algae, i.e. they were counted in the preparations.

Table V

Estimation of the size of algae
(after Starmach 1961)

Coverage per cent after Braun-Blanquet	Mean figures	Value of the scale	Value in μ as accepted	Mean μ	Coefficient of calculation of size
75-100	87.5	5	300 and more	350	16
50- 75	62.5	4	200-300	250	11
25- 50	37.5	3	100-200	150	7
10- 25	17.5	2	40-100	70	3
1- 10	5.5	1	4- 40	22	1
0- 1	0.5	+	0- 4	2	0.1

The size of the investigated forms as well as the covering were estimated on the basis of a scale of 6 degrees (5 — 1 and +) the value of which, in relation to the per cent of coverage adopted from Braun-Blanquet's method and to the conventional scale in microns, is presented in Table V.

The evaluated size was a mean value for more than ten specimens found in several preparations.

Evaluation of the size of filamentous algae and of those which form colonies in the shape of tapes or threads (such as *Melosira, Fragilaria, Spirogyra* and others) was determined, considering that a filament with a diameter equal to the field of vision in the microscope corresponds:

with a breadth of 1— 5 μ in the scale to size 1
„ „ „ „ 5—20 μ „ „ „ „ „ 2
„ „ „ „ 20—40 μ „ „ „ „ „ 3
„ „ „ „ 40—60 μ „ „ „ „ „ 4
„ „ „ „ 60—80 μ „ „ „ „ „ 5

Filaments not longer than half the diameter of the field of vision in the microscope were shifted to the degree immediately lower.

The index of coverage was calculated by multiplying the number for the amount by the coefficient of calculation of size corresponding to the given degree of size. The number of the index thus obtained corresponds more or less to the conception of quantitativeness (Artmächtigkeit) in the sociology of higher plants. This number stresses more adequately the importance of the species in a community in relation to its associates and gives a certain notion as to the common mass of individuals of the same species present in a community.

Frequency and constancy were calculated from a joint table of records of the given season (spring, summer, autumn, and winter tables). These values were calculated from a fraction, the numerator of which states in how many records the given species is found, and the denominator gives the number of investigated records. Constancy was determined by the ordinal numbers I—V.

V —	Species	present	in	80—100%	of	the	records
IV —	,,	,,	,,	60— 80%	,,	,,	,,
III —	,,	,,	,,	40— 60%	,,	,,	,,
II —	,,	,,	,,	20— 40%	,,	,,	,,
I —	,,	,,	,,	1— 20%	,,	,,	,,

The number of records varied in individual seasons (but it was always more than 10) which explains why small inaccuracies arose in the calculation of the values mentioned above. The small differences which resulted thus are not so great as to prevent correct conclusions being drawn.

The index of dominancy and constancy (DKI = Dominanz-Konstanz-Index) was calculated from the sum of the indices of coverage of individual species multiplied by the number of constancy. It pictures the importance of individual species in the investigated community.

The coefficient of coverage (P) was calculated by means of the formula $P = \frac{s}{n} \times 100$, where s = the sum of indices of coverage of individual species in the table and n = the number of records in the table. The coefficient gives an idea of the sociological role of the given species in the community. Both the index (DKI) and the coefficient (P) were calculated from seasonal data for individual species (spring, summer, autumn, and winter tables).

Morphology of thalli

Cladophora glomerata is a settled benthonic alga, and only occasionally and accidentally can be seen in the form of freely floating small shrubs. It is a freshwater species, mostly inhabiting well aerated waters in all the rivers of the northern hemisphere. Its thallus is composed of threads abundantly branched dichotomously. It often forms long braids attached by means of rhizoidal cells to the substrate. The growth is, above all, apical being intercalary only in the older parts. Brand (Heering 1921) established certain regularities for the origin of appropriate types of branchings, which he described as the laws of evection and transvection (particular cases of the development of the stratum). It seems, however, that for the aims of taxonomy the genesis of evection or transvection is not important, but only their result, i.e. the presence of branches of an appropriate type.

The appearance of the thallus differs, in relation to age, season, and influence of external conditions (such as the velocity of the current, the depth in which they appear, mechanical factors, etc.). Brand (Heering 1921) determines them as the so-called states: *status frondescens* — the state of forming of branches; *status juvenilis* — juvenile state; *status detersus* — the state of a partial loss of branches, etc.

In the Skawa, *Cladophora* developed the most intensively in places through which the current flowed (fig. 1 B). The parts near the right bank with slowly flowing water were devoid of algae, or only sparsely overgrown with small shrubs. Thalli from lenitic places were coated with a greyish-brown, inorganic deposit and showed a very weak development throughout the whole period of investigation. Larger pebbles from lotic places were overgrown by *Cladophora* only on the side sheltered against the current (fig. 2 b). Only small stones (2 to 5 cm in diameter) lying as if in the shade of the larger ones, were covered by *Cladophora* on the whole surface protruding from the bottom (fig. 2 a).

Four periods of change in the structure and appearance of the thalli of *Cladophora glomerata* may be distinguished.

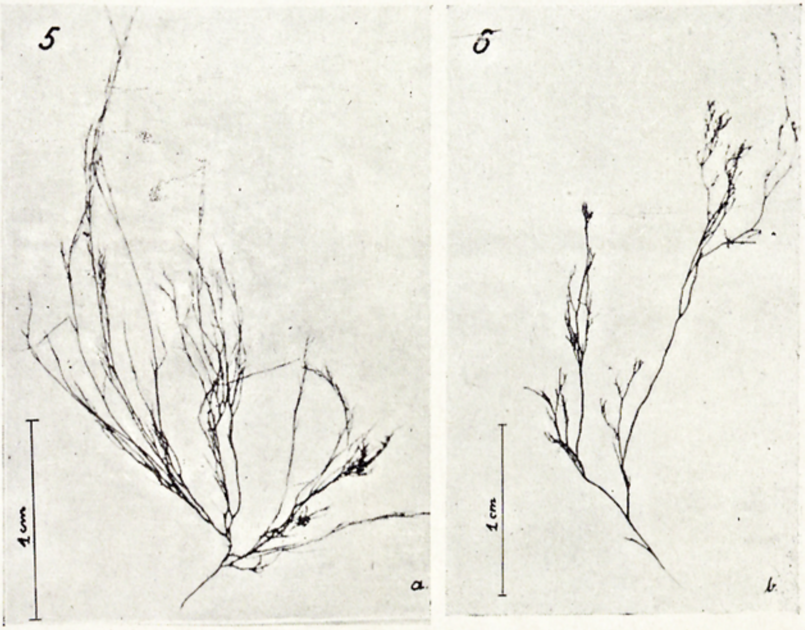
Spring period (March to May).

The first two weeks of March might be considered as a prolongation of the winter minimum development of thalli, or even their developmental stagnation. The average length of the thalli in this initial spring period amounts to 3—6 cm, and rarely attains 8 cm (other features of strata are given in Table VI). There is no uniform main axis, to which all lateral branches are related. The thallus is composed of numerous or less numerous uniformly developed lateral branches of the same order; sometimes one of these well-developed branches forms a seemingly main axis — the sympodium. The stratum resembles therefore ramifications of a cymose type. The cell-membranes were moderately impregnated with calcium carbonate. Individual more or less branched thalli form small and not numerous sods. They are yellowish-green, dirty greyish-green at the base, or brown, owing to the abundantly developing diatoms and the slime sediment.

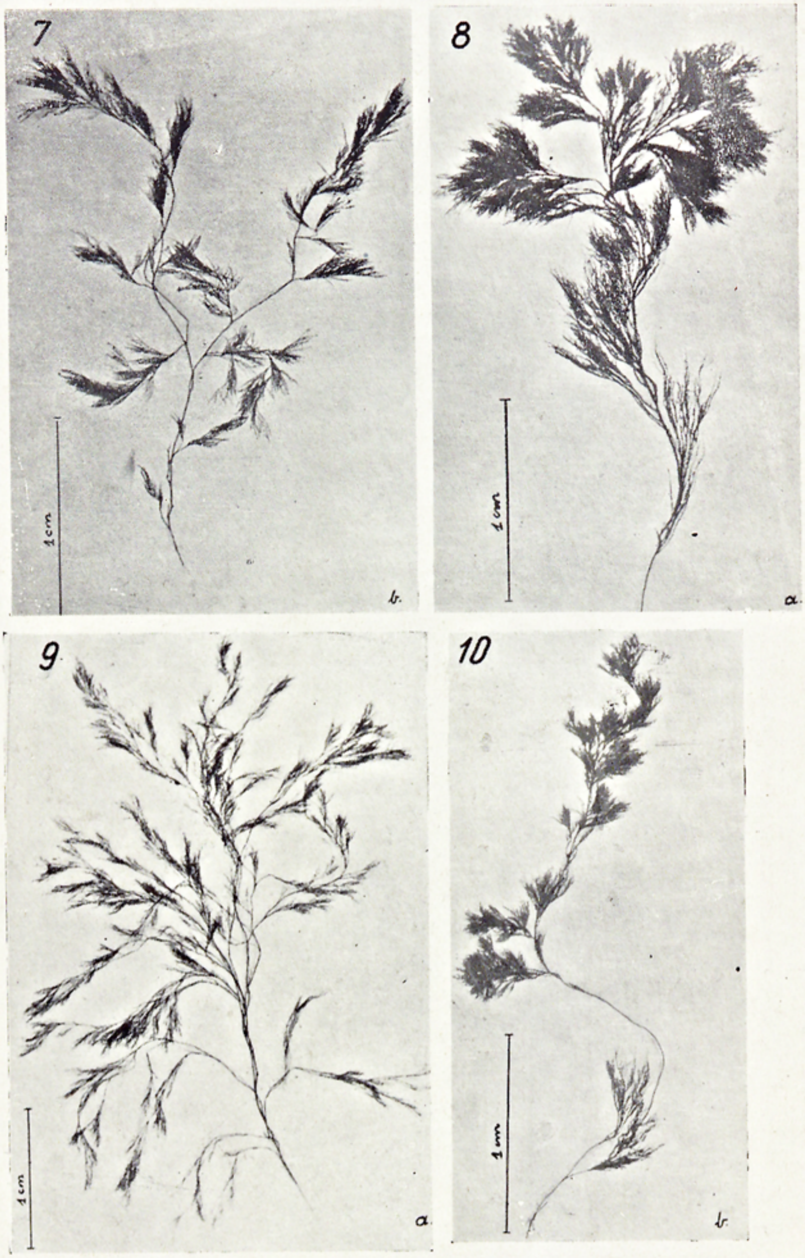
This period is related to the high spring water levels. The current of the river is strong, sometimes very strong, which affects both the formation of the substrate, overgrown by the *Cladophora*, and the appearance of its thalli. Only some few strong individuals, growing on larger stones or rocks, can survive this period of unfavourable conditions.

Feature variability of Cladophora glomerata thalli during a year

Season	Date of collecting samples	Average length of thalli	Colour of thalli	Disposition of accompanying algae	Average length of apical cells of branches in μ	Average breadth of apical cells of branches in μ	Average length of cells of the main thread in μ	Average breadth of cells of the main thread in μ	Average breadth of cell-membranes of the main thread in μ	Degree of impregnation of cell-membranes with calcium carbonate	Presence of zoosporangiae	Presence of stolons	Development of branchings	Abundance of branchings	Content of inorganic sediments (sand, slime) on thalli and sods	Status, after Brand	Forma, after Brand
Spring 1959	Apr. 18	3- 5 (10)	yellowish-green	on whole thalli	150-250	30-40	300-500	50- 80	10-15	negligible insignificant	-	-	in clusters, apical	average	average	detersus redivivus	-
	May 4	1- 4 (6)	dull green	on whole thalli	-	-	200-350	60- 70	10-12	-	-	-	in clusters	negligible	very large	detersus stagnalis	-
	May 24	15- 30 (45)	bright green	in apical and basic parts	200-370	30-40	200-300	60- 70	8-10	-	small amount	present	in clusters, dychotomic, apical	very large	average	-	genuina fasciculata
Summer 1959	June 6	3- 5 (8)	dull green	in basic and median parts		-	250-400	60- 80	15-20	-	-	-	apical	negligible	large	detersus	-
	July	2- 5 (10)	greenish-yellow, greyish-yellow at base	on whole thalli	130-250	30-45	250-600	60-100	15-20	-	-	-	in clusters, dichotomic	average	large	detersus	callicoma
	July 25	3- 4 (8)	greyish-yellow, brown at base	on whole thalli	60-250	30-50	300-650	100-180	15-22	-	-	-	in clusters apical	small	very large	detersus	-
	Aug. 11	6- 7 (10)	dull green	in basic and median parts	80-250	40-50	300-600	80-150	15-22	-	present	present in small amount	in clusters, dichotomic	average	average	detersus redivivus	-
	Aug. 31	5- 7 (10)	greyish-green	in basic and apical parts	100-300	40-60	300-600	80-150	15-26	-	-	-	in clusters	small	large	detersus	-
Autumn 1959	Sept.10	20- 40 (55)	dull green, yellow at base	on whole thalli	300-530	10-12	250-650	60-120	20-30	-	small amount	-	in clusters	small	small	detersus redivivus	genuina
	Oct. 9	100-150 (200)	bright green, yellow at base	on whole thalli	130-300	40-60	300-600	60-100	10-15	-	present	-	in clusters, apical, dychotomic	very large	small	-	genuina simplicior callicoma
	Oct. 29	5- 16 (30)	greenish-yellow, brown at base	in basic and median parts	200-500	30-65	350-600	100-130	10-15	-	-	-	in clusters, dychotomic	large	small	-	genuina
	Nov. 13	6- 7 (20)	dull green, brown at base	in basic and median parts	250-600	40-70	350-600	100-130	12-15	-	-	-	in clusters, apical	average	average	-	rivularis
	Nov. 24	5- 6 (15)	dull green, brown at base	in basic and apical parts	130-300	35-60	400-800	100-120	12-15	-	-	-	in clusters, apical	average	small	-	rivularis
Winter 1959	Dec. 19	4- 5 (8)	bright green, yellow at base	in basic and apical parts	200-350	50-70	400-600	50- 90	15-20	average	-	-	in clusters, apical	small	small	ramosus incrustans hiemalis	-
	Jan. 2	0,5- 1	dull green, brown at base	on whole thalli	200-400	60-80	450-600	60-100	15-25	average	-	-	apical, in clusters	small	average	hiemalis incrustans	-
	Feb. 4	2- 3 (8)	dull green, brown at base	on whole thalli	150-350	35-60	250-400	50-100	10-18	average	-	-	in clusters	average	small	refrondescens redivivus incrustans	-
Spring 1960	Mar. 5	3- 6 (8)	yellowish-green, brown at base	in basic parts	130-350	30-50	250-400	60- 80	6-12	average	-	-	apical	small	average	incrustans	-
	Mar. 19	0,5- 1 (8)	yellowish-brown	in basic parts	-	-	250-450	70-120	12-15	average	-	-	apical	low	low	incrustans detersus	-
	Mar: 26	2- 4 (5)	yellowish-brown	on whole thalli	200-350	40-60	250-400	120-160	15-25	large	-	present in small amount	in clusters	average	average	incrustans stoloniferus	-



Figs. 3, 4. Thalli collected on March 26, 1960.
Fig. 5, 6. Thalli collected on July 25, 1959 after a storm.



Figs. 7, 8. Thalli collected on May 24, 1959.
Figs. 9, 10. Thalli collected on October 9, 1959.

The remainder of the thalli is torn away by the strong current or buried in stone rubble.

From the end of March till May long, winding offshoots (stolons), formed by some of the branches, may be observed. They give the impression of faded vegetative thalli and were easily noticeable, as their chlorophyll content was usually smaller and the length of their cells often relatively large (66—700 μ). Initially the threads were unbranched, later on producing rhizoids which attached themselves to the substrate and formed news plants.

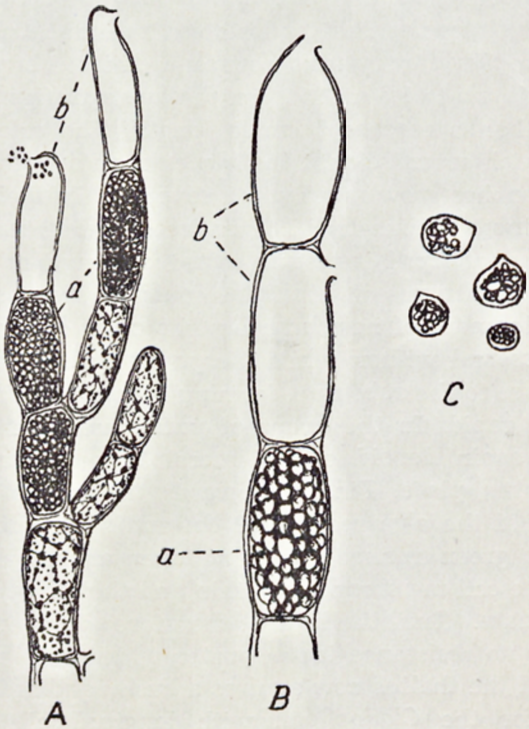
At the beginning of April, with the external conditions still unfavorable (the mechanical action of flowing water) most of the lateral branches are torn off. As a result of this, the single and true main axis of the thallus, the monopodium can now be conveniently seen. The shape of the thallus has now the form of clustered branches. In the old parts of the main thread the cell content, as well as some transversal cell walls, nearly always vanish. The cell membranes become considerably thicker (some up to 25 μ) and a distinct stratification can be seen upon them. The degree of saturation with potassium carbonate increases. Sometimes the incrustation was so great that the thalli became brittle.

Favourable ecological alterations in the water (higher temperature, lower water level) in the first and second half of April provoke a slow growth of *Cladophora*. Very numerous and delicate branches are formed on the main axis, up to 1,5 cm long on the average (figs. 3, 4). The growth of the whole thallus reaches 5 cm in length. The colour of the thallus becomes yellowish-green so that the places they overgrow become easily visible. The branches grow rapidly and cover up the main axis which was previously distinctly delineated. The entire shape of the thalli is altered. Towards the end of April it resembles the clustered or cymose branches and sometimes both types of branching could be seen on a single thallus. After the development of new branches the older ones usually fall down upon the thallus and wither, while the young ones produce rhizoids and attach themselves to the substrate, forming new plants. In May the growth is rather more rapid. In the event of unfavourable external conditions the thallus is again devoid of all lateral branches, after which their regeneration takes place. Finally, towards the end of the month, the average length of the alga reaches 30 cm and sometimes even 45 cm. It forms a bright green runner spreading over almost the entire bottom of the river. The cell membranes are thin and they are not saturated with calcium carbonate. The thalli are therefore very elastic and bend easily, offering no resistance to the water which carries them along.

The shape of the thallus now aquires a bushy and sod-like appearance, characteristic for the *Cladophora*, with longitudinally very numerous brushlike ramifications in its upper part (figs. 7, 8). The average length and breadth of cells of the main thread or of the lateral branches does not alter to any greater degree. The sods are very compact and of a bright green colour.

As a result of the rather rapid growth of the main thread or of its separate lateral branches, somewhat complicated branchings are formed. Thus, if the growth tends towards an elongation of the upper part of the main thread, the main trunk of the thallus is maintained and it has a monopodic shape. It might also be observed that the main branch and one (or several) of the lateral branches were elongated simultaneously as a result of which branchings of a sympodic type arose. In the cases mentioned above it frequently occurs that near the apical cell in the subapical part a lateral bud develops and produces, when growing, dichotomous branches. All three types of these branchings can be very often found in a single thallus.

From the end of May until October zoosporangia could be seen in the apical parts of the branches (above all in the young, sometimes also in the old ones, but never in the cells of the main thread). Their appearance is very diverse and it is sometimes difficult to distinguish them from vegetative cells. They were usually swollen and more or less elongated. The outlet aperture is in the lateral wall of the cell or in its apex. The



Figs. 11. A, B. Fragment of apical branchings of the thallus; a — cells (zoosporangia) in which the plasma disintegrated into zoospores; b — cells (zoosporangia) from which zoospores flowed out; C — zoospores.

zoospores are of a piriform shape and have a colourless beak-like extremity on which flagellae are situated (their number was not counted). Chromatophores are placed almost exclusively in their central part. The rounded posterior extremity is also colourless. Zoospores are 14 to 19 μ long and 9 to 11 μ broad (fig. 10). When the empty sporangia are detached only the main threads remain besides the branches that did not participate in the formation of spores. The places from which the sporangia were detached become rounded and after a certain time new offshoots, very slender at first, are formed upon them. It was sometimes observed, however, that the threads from which sporangia had been detached become thicker. Their cells do not produce any new offshoots and show no increase in thickness; their cell membrane becomes thicker and, owing to a slight tumefaction near the lateral walls, they acquire a knotted appearance (fig. 11).

Summer period (June to August).

The strongly developed and abundantly branched *Cladophora* seen in the second half of May, become stripped of nearly all lateral branches in June. This must be ascribed to bad external conditions alone. The summer period abounds in floods, which often occur at this time and are very dangerous. Loosely connected sods of thalli are found only here and there on the investigated area. The branchings of threads is insignificant and the shape of the thallus is of a clustered, sometimes cymose type (figs. 5, 6).

In July and August the shape of the thalli does not differ, in most cases, from the one described above in relation to the summer period. Only the length of cells in the main thread increases, attaining 650 μ, while their breadth reaches 180 μ.

In the period between successive floods or during a rise in the water level, the thalli regenerate rapidly. They sometimes reach a very typical appearance with bushy, brush-like branchings, fimbriated in the upper parts. After the next flood, or high water level, however, the thallus is again deprived of its lateral branches and the process of regeneration begins anew.

This process of destruction and renewal of the branches is repeated throughout the whole summer season.

Autumn period (September till November).

After the summer period, unfavourable for the development of thalli, September and the first two weeks of October seem to be the second advantageous period for the growth of the *Cladophora*. The protracted duration of low water levels, the relatively high temperature of the water, and a slow or moderate current create conditions propitious for the development of thalli. The alga begins to reproduce itself rapidly and starts growing so that at the beginning of October it attains a maximal length of 2 m. The sods, loose at first, become dense owing to the growth of the thalli and the development of young individuals, often taking place in new localities. A slow „merging" together of individual sods into a uniform underwater lawn, slightly undulating in the current, takes place.

The morphology of individual *Cladophora* thalli was very diverse at that time. Forms with a strongly developed main axis and numerous lateral branchings with brush-like extremities were preponderant. Often the main axis of some thalli ramifies slightly above its base, or at the base itself, forming a few, or, more rarely, several, equal, strongly developed and abundantly branched lateral trunks. Separate long threads, tangled together by the incessant movement of the water, form long, fimbriated stringy ropes. The shape of the thalli during the first weeks of autumn seems to be typical for *Cladophora* and resembles closely that of thalli towards the end of May (figs. 7, 8).

The strongly developed *Cladophora* thalli produce very convenient ecological conditions for the development of accompanying algae, mostly diatoms, blue-green and green algae.

Some species of these algae first settle mainly in the nether parts of the strata, later gradually occupying the central parts and, finally, the whole thalli are covered by epiphytes. In the tangled *Cladophora* threads various free-living organisms develop, separately or in colonies. A mass overgrowth of epiphytes and other algae upon the *Cladophora* thalli was observed in the second half of October (figs. 9, 10).

The thalli then developed very slightly and only in the upper parts which were still of a dull greenish colour. When the apical branches become covered by epiphytes, an entire inhibition of the growth of the thalli takes place. Their colouring becomes similar to that of the epiphytes which cover them — from a yellow to a rusty-grey hue at the base and in the central parts. The walls of the membrane cells of the main thread and of its branches become thicker (up to 70 μ), and the lateral and apical branches are very brittle, no longer able to withstand the strength of the current, which, however, does not increase at this time but rather diminishes. A mass shedding of all apical branches and nearly all the lateral ones takes place, so that towards the end of October only thalli 5 to 16 cm long, which retain only their main branches, can be found. Their appearance resembles that of thalli seen in July or August, after a period of high water levels. It is possible that in this case the shedding of branches is caused by a too large amount of overgrowing epiphytes and of particles of slime settled among them. This probably provides considerable obstacles for metabolism, leading finally to the dying off of individual branches which then fall away from the remainder of the thallus.

This mass shedding of all, or nearly all, branches can be observed also during other seasons of the year in the strata that remain temporarily, as a result of a fall in the water level, above the surface of the water and are only humected from time to time.

Only a very slow regeneration takes place in November, mostly in the apical parts. The apical branches sprouting then are no longer as brush--like and abundant as in May or September.

The length of entire thalli does not increase but diminishes as a result of rather frequent high water levels. The sods of the algae no longer form a green bed in the river, appearing only here and there. A large number of previously overgrown stones are carried away or covered with stone rubble displaced by the water during a high water level.

The average thickness of cells in the main thread increases at this time (to 70 μ), and some of the transversal cell membranes are disrupted. Epiphytes continue to develop, mostly in parts near the base where, together with inorganic parts, they give a greyish-brown hue to the thalli. The apical parts of the algae are of a dull green colour.

Winter period (December to February).

A weak growth of thalli, mostly in the apical parts, can be observed at the beginning of December which ceases completely towards the end of the month, this state being maintained until the end of February. The winter period is marked by a standstill in the growth of the *Cladophora*. Besides no changes occur during winter in its morphology. The type of clustered and cymose branchings prevails. There are few lateral branches and they are hardly ever branched at the apex. The length of the thalli diminishes, as a result of higher water levels which frequently occur, being on the average 0.5 to 3 cm. The sods formed by the alga are very loose and grow on a small quantity of stones.

A list of characteristic features of *Cladophora glomerata* is contained in Table VI. They were obtained on the basis measurements and observations of 10 different thalli from each test tube.

The results of investigation and observation of the development and morphology of *C. glomerata* in the Skawa river during one year (fig. 12) may be summarised in the following manner:

I. In the annual development of the thalli the following can be discerned:

1. A typical annual cycle, conditioned by inherited and stabilised properties of growth and reproduction. Favourable external conditions liberate these possibilities. The period of maximum development begins in May and continues through the consecutive months until October. From November till April the growth is stationary and the possibility of a small increase in the size can only arise in very favourable external conditions

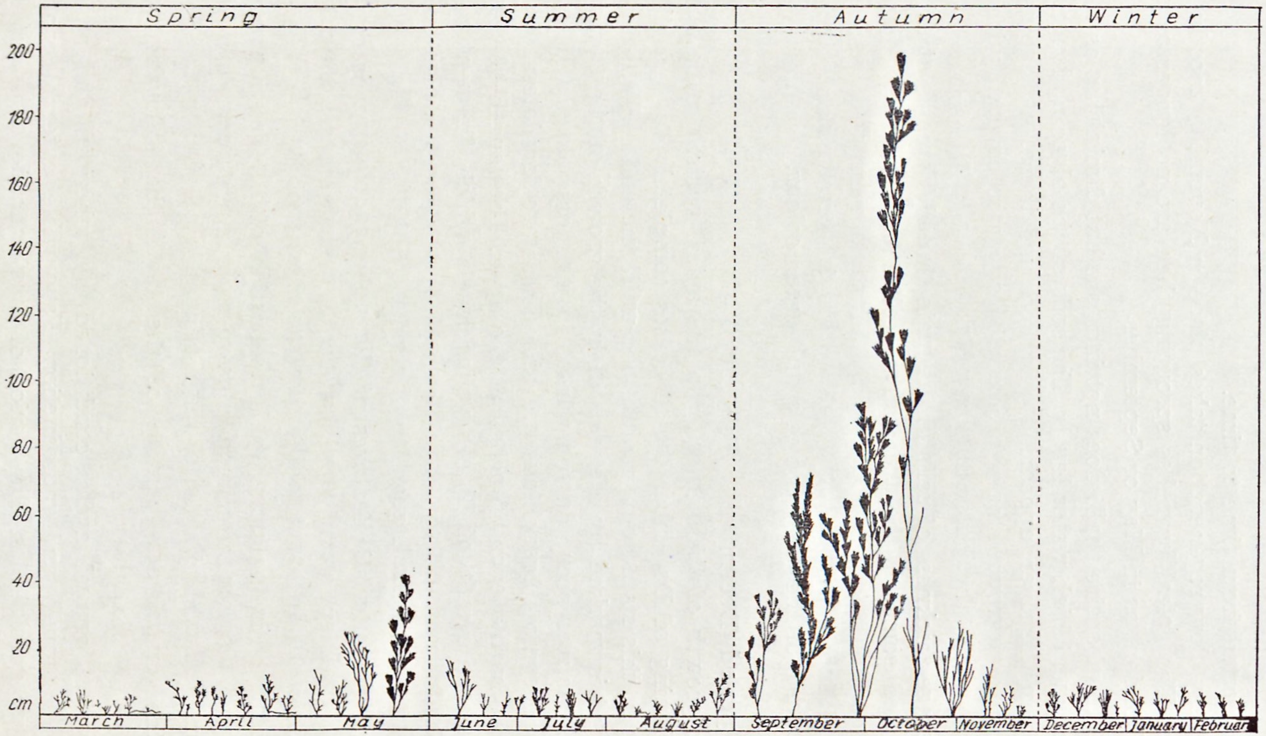


Fig. 12. Diagram of the seasonal development cycle of the Cladophora glomerata thalli in the Skawa river

which sometimes take place in the initial and terminal months of this period.

2. The seasonal cycle (untypical), repeated several times in the year (summer), during the maximum development, consists in a alternate succession of abundantly branched thalli and of thalli deprived of branchings. It is conditioned, in the first place, by external conditions, such as low high water levels, velocity of the current, water temperature, epiphytes etc.

II. In connection with the ecological conditions of the Skawa river, two distinct periods of maximum growth can be discerned on the development of thalli, i.e. towards the end of May and in September.

III. The development of thalli varies in the course of the year. Forms with a developed main axis, from which issue lateral branches of the first and of the following ranks, mainly prevail. They all ramify the most abundantly in the apical parts, forming dichotomous brush-like branches. The main axis ramifies frequently at a certain distance from the base or in its vicinity, forming a few, seldom more than ten, similarly developed lateral trunks. There is then no main axis. Each of these branches may have a different aspect depending on the regular growth and ramification of the lateral branches of the same rank or on the development of only one of these branches. In the branches thus formed no regularity was observed. The formation of a suitable type of branches of the strata mostly depends on external factors, sometimes accidental, as mentioned previously. Therefore, in not uncommon cases, thalli with bizarre branchings, whose appurtenance to suitable types of clustered, cymose or dichotomous branchings is difficult to ascertain, are found. All three types of branchings could frequently be stated in the thallus.

Accompanying algae

The strongly developed *Cladophora* thallus with a smooth surface deprived of mucilage fosters the development of an enormous number of epiphytic and free living algae of various systematic groups.

Epiphytic algae of the genera *Chamaesiphon, Meridion, Diatoma, Synedra, Cocconeis, Amphora, Epithemia, Eunotia,* and others adhere closely to the cell membranes, while others, from the genera *Rhoicosphenia, Cymbella, Gomphonema,* are attached by means of mucilage-stalks.

Free-living algae are represented by unicellular organisms from the genera *Closterium, Cosmarium, Staurastrum, Euastrum, Navicula,* and others or by colonial organisms forming threads or long tapes of the *Melosira, Tabellaria, Diatoma, Fragilaria, Spirogyra, Zygnema* and other genera.

They take advantage of the environment formed by the *Cladophora* by means of the tangled filaments of its thalli. It appears that a purely mechanical factor plays here the principal role. Well developed and often compact *Cladophora* thalli forming aerdense net of tangled filaments facilitate the maintenance of the cells of free-living algae which are not washed out by the movement of the water. When a certain combination of species in the components of a community becomes established, the probable existence of physiological and biological connections between particular species of algae cannot be overlooked (B o h r 1962). Neither the investigations that were carried out nor the data from literature permit a final conclusion as to whether the species composition of algae accompanying the *Cladophora* in the Skawa river should be considered as strictly connected with these thalli and, in general, with the ecological properties of this environment.

It is true that the communities determined as *Cladophoretum glomeratae* associations and described by S a u e r (1937), M a r g a l e f (1949), S y-m o e n s (1950), and partly by B o h r (1962), have many similar features and even a certain number of species in common. Differences in the floristic composition and in the degree of constancy of individual common species exist, however. B o h r (1962) even admits that *Clodophora glomerata* is a species common for several associations of algae appearing in running and stagnant fresh waters. It should therefore be considered as a species characteristic for a higher phystosociological systematic unit rather than an association, for example for an alliance of associations of *Cladophora glomerata.*

Essential difficulties arise for finding common criteria when comparing the results of the present paper with those of the above mentioned authors.

The distinction of the *Cladophoretum glomeratae* association was based hitherto upon different premisses and the authors used various methods of investigation. In the majority of the mentioned papers, related to the differentiation of the *Cladophoretum glomeratae* association, there were no tables with sociological records. All the difficulties mentioned suggest that the problem of a sociological study of algae accompanying *Cladophora glomerata* is a real one, but that it should be conducted with similar methods.

Qualitative composition of accompanying algae

Under the name of „accompanying algae" all plant organisms growing upon the *Cladophora* thalli or developing in the dense net of its tangled filaments are considered in the present paper. Plant organisms developing directly on the substrate on which the *Cladophora* grows were not taken into consideration.

During a year long investigations of algae accompanying *Cladophora glomerata* in the Skawa river, 226 species of plants belonging to 53 genera

(Table VII) were found. This number concerns only those that were identifield without any doubt whatsoever. It seems that the number of forms is not yet a complete although an approximate one.

In some cases, owing to a lack of distinct morphological features, identification of the species was very difficult or even impossible; this was true mainly for species such as the *Phormidium, Chamaesiphon,*

Table VII.

Floristic spectrum of the accompanying algae

Taxonomical group	Spring		Summer		Autumn		Winter		Total	
	No of species	No of genus	No of species	No of genus	No of species	No of genus	No of species	No of genus	No of species	No of genus
Schizomycetes	1	1	1	1	1	1	1	1	1	1
Cyanophyta	16	10	19	11	19	11	9	7	19	11
Chrysophyceae	1	1	–	–	1	1	1	1	1	1
Bacillariophyceae	168	25	134	24	154	26	128	23	176	26
Xanthophyceae	1	1	1	1	1	1	–	–	1	1
Chlorophyta	27	12	27	12	26	11	18	8	27	12
Rhodophyta	1	1	1	1	1	1	1	1	1	1
Total	215	51	183	50	203	52	158	41	226	53

Achnanthes, Nitzschia, bacteria, and very small algae of the flagellates group. In these cases only the name of the genus was given, the species were not defined at all.

Diatoms are the most numerous: 176 species from 26 genera. There are 27 species from 12 genera of green algae, 19 species of blue-green algae from 11 genera, and a small number of representatives of other groups.

An extensive list of the species found, containing their index of dominance and of constancy (DKI), coefficients of coverage (P) and the degree of constancy during the different seasons of the year, is presented in Table VIII. It can be seen that some species appear constantly throughout the year, only demonstrating greater or smaller quantitative variations in particular seasons. 134 species of this kind were found, of which there were: *Schizomycetes* 1, *Cyanophyta* 9, *Bacillariophyceae* 105, *Chlorophyta* 18, *Rhodophyta* 1. An absolute predominance of diatoms in the species present in the course of the year appears here. They are followed by green algae, blue-green algae and, at the very end, by a small number of red algae and bacteria species. Only *Sphaerotilus natans* which covered, sometimes very abundantly, the *Cladophora* thalli was identified here; it was easily recognised owing to its morphological features.

The species appearing constantly should be divided into two groups:

1) Especially characteristic species or dominants, with a IV and V class of constancy (listed in Table IX).

2) Accompanying species (subdominants) with a II and III class of

constancy, and accidental or accessory species (adominants) with a I class of constancy.

Among species dominating in particular seasons only a small number constitute dominants throughout the year and these seem to be most characteristic for the community. The remaining number of seasonal dominants might rather form a basis for determining facies, subfacies, sociations etc. The dominating species repeatedly appearing in particular

Table VIII

Coefficient of coverage (P) of especially characteristic species (dominants) accompanying the Cladophora glomerata thalli

Species / Season	Spring	Summer	Autumn	Winter	Mean yearly
1. Diatoma elongatum var. tenuis	816	600	1019	1012	862
2. Synedra ulna	649	888	652	745	733
3. Fragilaria capucina	1023	209	353	1050	659
4. Gomphonema olivaceum	692	582	632	600	626
5. Diatoma vulgare var. productum	485	821	590	376	568
6. Diatoma vulgare var. ehrenbergii	481	134	876	136	407
7. Gomphonema olivaceum var. calcareum	348	311	451	463	393
8. Diatoma vulgare	1015	292	82	138	382
9. Cocconeis placentula var. euglypta	336	318	343	387	346
10. Diatoma vulgare var. capitulatum	516	285	334	7	285
11. Nitzschia linearis	263	127	332	227	237
12. Cymbella affinis	233	207	311	190	235
13. Cocconeis placentula	210	243	165	319	234
14. Diatoma vulgare var. ovale	324	59	185	155	181
15. Nitzschia dissipata	124	110	211	244	172
16. Amphora ovalis	146	58	100	340	161
17. Cymbella ventricosa	233	105	120	145	151
18. Chamaesiphon incrustans	138	66	147	203	138
19. Navicula tuscula	131	89	128	106	113
20. Synedra vaucheriae	223	15	124	78	110
21. Gompohonema angustatum	52	171	123	78	106
22. Achnanthes minutissima	132	60	154	52	99
23. Rhoicosphenia curvata	135	76	16	106	83
24. Gomphonema intricatum var. pumillum	38	90	99	52	69
25. Navicula cryptocephala var. veneta	49	58	42	78	57
26. Navicula pupula var. rostrata	61	42	61	52	54
27. Gomphonema longiceps var. subclavatum	39	54	92	26	53
28. Gomphonema parvulum	60	28	56	59	51
29. Tabellaria flocculosa	119	59	6	9	48

seasons of the year as dominants are listed in Table IX, after a diminishing mean coverage coefficient for a year (P). Of them, only the two first, *Diatoma elongatum* var. *tenuis* and *Synedra ulna*, might have the greatest diagnostic value for the determination of an association. They are, as can be seen, species with a coefficient of coverage above 700.

Of species constantly appearing during the year, but classed in the groups of subdominants and adominants, 105 were found, belonging to the following systematic groups: *Schizomycetes* 1, *Cyanophyta* 8, *Bacillariophyceae* 77, *Chlorophyta* 18, *Rhodophyta* 1. Diatoms are here in prevailing number, while the number of plants of other groups is relatively low.

No species of the *Schizomycetes*, an absolute majority of the *Cyano-*

Table IX

Species dominating in different seasons of the year, with several sociological indications

	Spring (39 samples)			Summer (34 samples)			Autumn (28 samples)			Winter (16 samples)		
	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index
Achnanthes lanceolata	–	–	–	–	–	–	151	1,5	1.5	7	0.6	0,1
- - var. capitata	–	–	–	–	–	–	40	0.7	0.5	46	0.7	0,6
- - var. elliptica	–	–	–	–	–	–	79	1.2	1.2	42	0.7	0.5
- - var. rostrata	–	–	–	–	–	–	72	1.2	1.0	–	–	–
- linearis	–	–	–	–	–	–	67	1.1	1.0	7	0.5	0.1
- minutissima	132	1.7	1.7	60	1.0	0.8	154	1.7	1.7	52	0.8	0.7
Amphora ovalis	146	1.0	2.7	58	0.6	0.8	100	0.7	1.5	340	1.5	4.5
- - gracilis	45	0.9	0.7	–	–	–	–	–	–	6	0.5	0.1
- - var. pediculus	–	–	–	–	–	–	26	0.5	0.4	36	0.8	0.5
Caloneis bacillum	–	–	–	–	–	–	16	0.6	0.2	24	0.6	0.3
- liber	–	–	–	–	–	–	16	0.6	0.3	–	–	–
- silicula	–	–	–	–	–	–	7	0.5	0.1	8	0.5	0.1
Ceratoneis arcus	400	1.8	5.3	–	–	–	122	0.8	1.7	117	0.7	1.4
- - var. amphioxys	585	2.7	8.1	–	–	–	–	–	–	43	0.9	0.6
- - var. linearis	194	1.3	3.7	–	–	–	–	–	–	–	–	–
Chamaesiphon incrustans	138	2.1	2.0	66	1.4	1.3	147	2.0	2.0	203	1.8	1.7
- polonicus	–	–	–	–	–	–	–	–	–	102	1.2	1.3
Cocconeis pediculus	27	0.7	0.4	–	–	–	140	1.2	1.2	87	1.4	1.4
- placentula	210	2.0	2.0	243	3.0	3.0	165	1.8	1.8	319	3.3	3.3
- - var. euglypta	336	3.5	3.5	318	3.6	3.6	343	3.7	3.7	387	3.9	3.9
Cyclotella meneghiniana	–	–	–	92	0.7	1.5	333	1.2	3.3	–	–	–
Cymatopleura solea	–	–	–	–	–	–	354	0.9	5.0	136	0.6	2.0
- - var. apiculata	–	–	–	130	0.9	1.9	121	0.7	1.7	–	–	–
- - var. vulgaris	–	–	–	–	–	–	107	0.6	1.3	–	–	–
Cymbella affinis	233	2.8	2.8	207	2.2	2.2	311	3.2	3.2	190	2.1	2.1
- helvetica var. balatonis	–	–	–	7	0.5	0.1	247	1.3	3.7	290	4.5	4.5
- - var. curta	76	1.3	1.2	–	–	–	73	1.1	1.0	58	0.9	0.8
- laevis	44	0.8	0.5	–	–	–	57	0.8	0.6	6	0.5	0.1
- prostrata	–	–	–	–	–	–	100	0.8	1.8	380	2.0	6.0
- sinuata	–	–	–	–	–	–	109	1.7	1.6	54	1.0	0.7
- - f. ovata	–	–	–	–	–	–	50	0.8	0.7	–	–	–
- ventricosa	233	2.6	2.6	105	1.2	1.1	120	1.5	1.4	145	1.7	1.7
Diatoma elongatum var. tenuis	816	3.2	9.4	600	1.7	5.0	1019	3.6	10.8	1012	4.0	11.5
- vulgare	1015	1.9	10.7	292	0.7	3.3	82	0.6	1.0	138	0.6	1.6
- - var. capitulatum	516	2.3	6.9	285	1.5	3.8	334	1.6	4.0	7	0.5	0.1
- - var. breve	–	–	–	–	–	–	–	–	–	152	0.8	[illegible].0
- - var. ehrenbergii	481	1.6	10.6	134	0.8	4.5	876	1.6	10.6	136	0.6	2.0
- - var. lineare	–	–	–	–	–	–	206	1.1	3.0	79	0.7	1.2
- - var. ovale	324	1.3	3.7	59	0.6	0.7	185	0.8	2.0	155	0.9	1.8
- - var. productum	485	2.1	6.3	821	3.0	9.0	590	2.5	7.5	376	1.4	4.1
Epithemia zebra	–	–	–	–	–	–	17	0.6	0.2	–	–	–
Eunotia arcus	59	0.6	0.9	–	–	–	336	1.5	4.2	80	0.6	1.0
- lunaris var. subarcuata	44	0.9	0.7	–	–	–	–	–	–	–	–	–
- subarcuata	–	–	–	–	–	–	18	0.5	0.2	–	–	–
Eucocconeis flexella	–	–	–	–	–	–	7	0.5	0.1	–	–	–
Fragilaria capucina	1023	2.0	14.2	209	0.8	4.0	353	0.9	5.0	1050	2.4	16.0
- - var. mesolepta	–	–	–	–	–	–	452	1.0	6.3	744	1.5	11.6
- construens	–	–	–	–	–	–	–	–	–	154	0.7	1.7
- - var. binodis	61	1.0	0.9	–	–	–	–	–	–	82	1.3	1.3
- crotonensis	203	0.6	2.6	–	–	–	–	–	–	–	–	–
- intermedia	225	1.3	3.5	–	–	–	227	1.2	3.3	245	1.2	3.2
- - var. capitellata	247	1.3	3.7	–	–	–	–	–	–	244	3.9	3.9
- - var. dubia	–	–	–	–	–	–	70	0.6	0.9	–	–	–
- pinnata	54	0.9	0.8	–	–	–	7	0.5	0.1	119	1.9	1.9
- - var. lancettula	59	0.9	0.8	–	–	–	91	1.4	1.3	112	1.4	1.4
- virescens var. mesolepta	155	0.6	4.3	108	0.6	1.5	478	0.8	5.0	–	–	–
Gomphonema acuminatum	–	–	–	–	–	–	49	0.8	0.7	–	–	–
- angustatum	52	0.8	0.6	171	2.0	1.8	123	1.3	1.3	78	1.0	0.9
- gracile	73	0.9	0.7	–	–	–	98	1.2	1.1	97	1.1	1.0
- intricatum var. pumilum	38	0.7	0.5	90	1.2	1.1	99	1.2	1.1	52	0.8	0.7
- longiceps	–	–	–	–	–	–	31	0.6	0.3	71	0.9	0.8
- - var. subclavatum	39	0.7	0.5	54	0.9	0.6	92	1.1	1.0	26	0.6	0.2
Gomphonema olivaceum	692	2.8	8.4	582	2.2	6.6	632	2.3	7.0	600	2.0	6.4
- - var. calcareum	348	1.4	4.1	311	1.2	3.4	451	1.7	5.2	463	1.5	4.6
- parvulum	60	1.0	0.9	28	0.6	0.4	56	1.0	0.9	59	1.1	0.9

Table IX cont.

	Spring (39 samples)			Summer (34. samples)			Autumn (28 samples)			Winter (16 samples)		
	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index	Coefficient of coverage (P)	Mean numerosity	Mean coverage index
Gyrosigma attennatum	–	–	–	334	0.9	4.3	–	–	–	490	1.0	5.2
- scalproides	–	–	–	25	0.6	0.4	–	–	–	–	–	–
Hantzschia amphioxys	–	–	–	49	0.6	0.7	–	–	–	–	–	–
Homoeothrix fusca f. elongata	–	–	–	82	1.3	1.1	–	–	–	–	–	–
Meridion circulare	1186	1.5	16.0	102	0.6	1.6	–	–	–	286	3.7	3.4
Navicula anglica	–	–	–	–	–	–	38	0.8	0.7	–	–	–
- bacillum	–	–	–	–	–	–	121	0.8	1.7	–	–	–
- cryptocephala	105	1.5	1.5	–	–	–	104	1.6	1.5	106	1.3	1.3
- - var. exilis	43	0.7	0.5	–	–	–	45	0.8	0.7	–	–	–
- - var. veneta	49	0.9	0.8	58	0.9	0.8	42	0.8	0.6	78	1.1	0.9
- - var. intermedia	–	–	–	–	–	–	36	0.7	0.5	–	–	–
- dicephala	22	0.6	0.3	–	–	–	20	0.6	0.3	–	–	–
- exigua	–	–	–	104	1.1	1.0	–	–	–	–	–	–
- gracilis	209	1.0	2.9	–	–	–	311	1.5	4.3	79	0.7	1.4
- minuscula	11	0.5	0.2	–	–	–	–	–	–	–	–	–
- pupula	88	1.4	1.4	–	–	–	97	1.4	1.4	70	1.2	1.1
- - var. mutata	37	0.7	0.5	–	–	–	52	0.8	0.6	–	–	–
- - var. rostrata	61	0.8	0.7	42	0.7	0.6	61	1.0	0.8	52	0.8	0.7
- radiosa	239	1.2	3.6	41	0.5	0.6	–	–	–	7	0.5	0.1
- - var. tenella	324	1.5	4.3	–	–	–	–	–	–	7	0.5	0.1
- reinhardtii	44	0.6	0.6	–	–	–	–	–	–	247	2.8	2.6
- rotaeana	41	0.8	0.6	–	–	–	47	0.9	0.7	–	–	–
- tuscula	132	1.8	1.7	89	1.3	1.3	128	1.7	1.7	106	1.7	1.7
- viridula	29	0.5	0.4	–	–	–	–	–	–	7	0.5	0.1
Nitzschia acicularis	29	0.6	0.4	–	–	–	90	0.7	1.2	–	–	–
- angustata f. antiqua	–	–	–	–	–	–	21	0.6	0.2	–	–	–
- - var. curta	28	0.6	0.4	–	–	–	46	0.8	0.6	–	–	–
- dissipata	124	1.5	1.4	110	1.5	1.4	211	2.1	2.1	244	1.8	1.8
- - var. media	–	–	–	–	–	–	45	0.8	0.6	–	–	–
- dubia	–	–	–	–	–	–	91	0.7	1.1	79	0.7	1.2
- gracilis	–	–	–	–	–	–	52	0.8	0.6	–	–	–
- heufleriana var. elongata	–	–	–	–	–	–	101	0.7	1.6	79	0.7	1.2
- kützingiana	–	–	–	–	–	–	77	1.1	1.0	47	0.8	0.6
- linearis	263	1.3	3.8	127	0.8	1.8	332	1.6	4.6	227	1.0	2.7
- sigmoidea	–	–	–	231	0.7	3.1	379	0.9	5.0	571	1.1	0.7
- stagnorum	29	0.6	0.4	–	–	–	–	–	–	85	1.1	1.0
- thermalis	–	–	–	49	0.6	0.6	–	–	–	–	–	–
- vermicularis	434	1.2	6.8	27	0.5	0.4	–	–	–	–	–	–
Rhoicosphenia curvata	135	2.0	1.8	76	1.2	1.1	16	0.6	0.2	106	1.3	1.3
Stauroneis phoenicenteron	59	0.6	0.8	–	–	–	–	–	–	–	–	–
- smithii	7	0.5	0.1	–	–	–	–	–	–	6	0.5	0.1
Stigeoclonium flagelliferum	–	–	–	–	–	–	–	–	–	97	1.8	1.5
- tenue	–	–	–	–	–	–	–	–	–	47	0.9	0.7
Surirella angustata	–	–	–	–	–	–	–	–	–	7	0.5	0.1
- - var. elongata	–	–	–	–	–	–	47	0.8	0.5	–	–	–
- ovata	59	0.9	0.8	–	–	–	40	0.8	0.6	–	–	–
- - var. pinnata	–	–	–	26	0.6	0.3	40	0.9	0.7	7	0.5	0.1
- - var. salina	–	–	–	–	–	–	–	–	–	19	0.6	0.2
Synedra acus	218	1.1	3.0	390	1.6	4.7	–	–	–	97	0.7	1.5
- - var. radians	–	–	–	–	–	–	387	1.6	4.5	246	1.2	3.2
- amphicephala	18	0.6	0.3	–	–	–	–	–	–	–	–	–
- capitata	–	–	–	–	–	–	358	0.7	5.0	–	–	–
- parasitica	–	–	–	55	1.0	0.9	–	–	–	–	–	–
- rumpens	69	1.0	0.9	–	–	–	21	0.6	0.2	43	0.7	0.5
- - var. familiaris	24	0.5	0.3	–	–	–	19	0.6	0.3	–	–	–
- - var. fragilarioides	–	–	–	–	–	–	40	0.8	0.6	–	–	–
- ulna	649	1.1	7.0	888	1.5	9.7	652	1.2	7.8	745	1.1	7.4
- - var. amphirhynchus	–	–	–	1113	2.3	15.7	976	2.1	14.5	308	5.0	4.9
- - var. oxyrhynchus	–	–	–	1175	2.1	16.0	626	1.4	9.7	483	1.0	7.0
- vaucheriae	223	2.0	2.0	15	0.5	0.2	124	1.3	1.2	78	1.1	0.9
- - var. capitellata	108	1.7	1.7	–	–	–	101	1.4	1.3	–	–	–
Tabellaria fenestrata	201	0.7	3.1	–	–	–	–	–	–	–	–	–
- flocculosa	119	0.7	1.5	59	0.6	0.7	6	0.5	0.1	9	0.5	0.1
Ulothrix zonata	297	1.6	4.2	–	–	–	–	–	–	209	1.1	3.0

phyta, and none of the *Chlorophyta* or *Rhodophyta*, although belonging to species which accompany the *Cladophora* throughout the whole year, ever attain the IV and V class of constancy. Therefore individual species of the above mentioned groups, with the exception of some blue-green algae, never play a more important role in a community, being subdominants or adominants. This classification of algae accompanying the *Cladophora* seems to be in accordance with the generally accepted postulate, that two groups of species form a plant association as to quality: a small number of dominating species and a large group of species appearing in small numbers (B o h r 1962).

Of species which do not appear constantly, i.e., not in all months of the year, 92 were found. Individual systematic groups are represented in the following manner: *Cyanophyta* 10, *Chrysophyceae* 1, *Bacillariophyceae* 71, *Xanthophyceae* 1, *Chlorophyta* 9. In this group of „seasonal organisms" diatoms also appeared in the greatest numbers. It seems that diatoms are organisms capable of living in all seasons of the year.

Species appearing only in certain seasons can also be divided into two groups:

1) Species which are dominants during a given season
2) The remaining species — subdominants and adominants.

Species which are not constantly present and dominate only during certain seasons of the year are represented by the following systematic groups:

	spring	summer	autumn	winter
Cyanophyta	—	1	—	—
Chrysophyceae	—	—	—	—
Bacillariophyceae	10	5	16	10
Xanthophyceae	—	—	—	—
Chlorophyta	—	—	—	—
Total	10	6	16	10

All species dominating in particular seasons and therefore also those which „do not appear constantly" are listed in Table VIII. The species dominating in particular seasons, and especially their coefficients of coverage, are somewhat varied. The possibility of discerning the seasonal aspects of an association therefore exists.

In this case also, out of species dominating in particular seasons, only those were considered as having the highest diagnostic value for the determination of seasonal aspects that had coefficients of coverage (P) higher than 700.

They are therefore the following for the spring period: *Meridion circulare*, *Fragilaria capucina*, *Diatoma vulgare* and *D. elongatum* var. *tenuis*.

For the summer period: *Synedra ulna* var. *oxyrhynchus, S. ulna* var. *amphirhynchus, S. ulna,* and *Diatoma vulgare* var. *productum.*

For the autumn period: *Diatoma elongatum* var. *tenuis, Synedra ulna* var. *amphirhynchus,* and *Diatoma vulgare* var. *ehrenbergii.*

For the summer period: *Synedra ulna* var. *oxyrhynchus, S. ulna* var. *tenuis, Synedra ulna,* and *Fragilaria capucina* var. *mesolepta.*

These lists demonstrate that only diatoms might have the greatest diagnostic value, not only for establishing the name of the association but also its seasonal aspects.

Species which do not appear in all months of the year, belonging to the group of subdominants and adominants, are represented in the following systematic groups:

	spring	summer	autumn	winter
Cyanophyta	7	9	10	—
Chrysophyceae	1	—	1	1
Bacillariophyceae	53	24	33	13
Xanthophyceae	1	1	1	—
Chlorophyta	9	9	8	—
Total	71	43	53	14

As to the developmental possibilities of these species or the role which they may play in the determination of seasonal aspects of the association, no positive opinion can be formulated. They appear as separate specimens or in greater numbers, especially after a period of higher water levels. Their vitality is somewhat diminished and the presence of dead cells (empty diatom shells) was also noticed among them. It is probable that they are mostly frustules of specimes brought in with rock material during a greater rise in the water level from other localities or habitats, situated in the upper course of the river or of its affluents, or washed out into the water during heavy rainfall.

Periodicity

When studying the periodicity in the appearance of algae species of various systematic groups accompanying the *Cladophora glomerata* in the Skawa, the following features were taken into consideration:

the seasonal spatial index,
the seasonal index of dominance and constancy (DKI),
the seasonal coefficient of coverage (P),
the floristic composition in a given season,
the thermic and hydrographical data for the studied sector of the river.

As results from these data, in the investigated community of algae the following periods of development for particular systematic groups can be observed (Table X).

The time from March till May is the spring season for diatoms and green algae. Water temperature during the collecting of samples was 7, 10, 16°C in March, 11° in April, 9°, 15° in May; the mean water level was 138, 144, 134 cm; current velocity in the places where samples were collected was 30, 140, 60 cm/sec. in April and 90, 35 cm/sec. in May; pH of the water was maintained within the limits from 6.8 in March to 7.2 in May.

The diatoms are the most numerous, both in the amount of species (168 out of the total number of 176) and in the spatial index and the coefficient of coverage for separate species (fig. 13).

Diatoms attain their maximum development mostly in March, April, and the beginning of May. *Meridion circulare, Diatoma vulgare, D. elonga-*

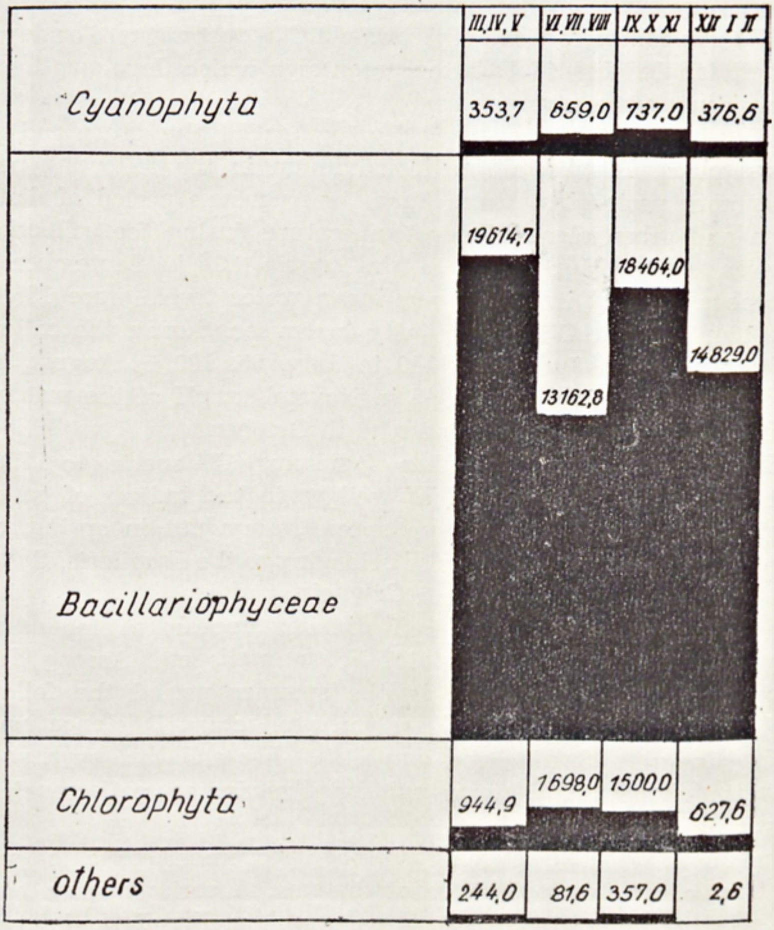


Fig. 13. Sums of the coefficient of coverage (P) of different groups of algae in particular seasons of the year in the investigated period.

tum var. *tenuis, Fragilaria capucina, Synedra ulna, Gomphonema olivaceum*, and slightly less *Diatoma vulgare* var. *productum* and var. *ehrenbergii* and var. *capitulatum, Ceratoneis arcus, C. arcus* var. *amphioxys, Navicula radiosa* var. *tenella, Cymbella affinis, C. ventricosa, Nitzschia linearis*, and others have a mass development.

A series of „seasonal" diatoms appear, reaching maximum development in spring, such as, for example *Synedra ulna* var. *biceps*, and var. *impressa, Eunotia valida, Stauroneis phoenicentron, Navicula viridula, Cymbella helvetica, C. aspera*, and others.

A certain number of dead diatoms with entirely empty shells were found. They covered, together with slimy parts of the soil, the *Cladophora* thalli, mostly from the *Cyclotella, Pinnularia, Caloneis, Gyrosigma, Cymbella, Epithemia, Hantzschia, Nitzschia, Cymatopleura, Surirella* genera and a small number from others. These species usually have low constancy classes and very small spatial indices or coefficients of coverage.

The *Ulothrix zonata*, which overgrows old *Cladophora* thalli or develops among their tangled filaments is the green alga which develops the most abundantly during the spring period.

Towards the end of May a strong development of blue-green and green algae takes place. They attain their maximum in the following period.

The summer period lasts from June till August, a period of diatoms, blue-green and green algae. Water temperature during the collecting of samples was 20°C in June, 19°, 18° in August, 19° in September, 11°, 9° in October, and 2° in November. Mean water levels were 135, 151, 144, 127, 124, 126 cm. Current velocity in cm/sec. during the collecting of samples was 65 in June, 120, 150 in July, 65, 100 in August, 35 in September, 30, 35 in October, 40, 45 in November; pH of the water was in the range of 7.4 to 7.2 in July and 7.2 in October.

A gradual decrease in the number of diatoms (134 species to 175) was observed in the summer months, as well as in the indices of coverage for individual species. Many diatom species, abundant in spring, could not be found in summer, mainly those belonging to the *Fragilaria, Synedra, Eunotia, Stauroneis, Pinnularia*, and *Caloneis*.

New summer seasonal species of diatoms appear, as for example *Navicula exigua, Nitzschia angustata, N. thermalis* etc. Among diatom species with a mass appearance in the summer period the following should be mentioned: *Diatoma vulgare* var. *productum, D. elongatum* var. *tenuis, Synedra ulna, S. ulna* var. *amphirhynchus* and var. *oxyrhynchus, Gomphonema olivaceum, Diatoma vulgare, Synedra acus, Cocconeis placentula* var. *euglypta*, and others.

The autumn months (September, October, November) form the second period of an abundant appearance of diatoms. A series of new species can be found, such as the *Achnanthes lanceolata, Fragilaria intermedia* var. *dubia, Nitzschia kützingiana*, etc. The total number of autumn species

Table X

List of algae collected in the Skawa river together with Cladophora glomerata

	Spring (39 samples)			Summer (34 samples)			Autumn (28 samples)			Winter (16 samples)		
	Constancy	DKI	P	Constancy	DKI	P	Constancy	DKI.	P	Constancy	DKI	P
Cyanophyta												
Merismopedia glauca Näg.	II	7	9	I	0.7	2	I	0.6	2	II	3	9
- punctata Meyen.	II	11	15	II	19	28	II	26	47	-	-	-
Microcystis aeruginosa (Kütz.) Elenk.	I	4	11	II	6	8	II	4	6	-	-	-
Aphanothece clathrata W. et G.S.West.	I	0.7	2	II	9	13	III	29	34	II	5	15
Gloeocapsa kützingiana Näg.	I	3	9	III	39	38	I	3	11	-	-	-
Chamaesiphon polonicus Hansg.	II	4	5	III	53	52	III	27	56	IV	66	102
- incrustans Grun.	IV	15	138	IV	67	66	IV	165	147	V	162	203
Lyngbya circumcreta C.S.West	I	1	4	I	1	4	II	3	6	-	-	-
- kryloviana Popova et Degter	-	-	-	I	1	4	II	3	6	-	-	-
- kützingii Schmidle.	-	-	-	II	2	2	II	3	6	-	-	-
Phormidium subfuscum Kütz.	II	18	2	III	35	35	I	2	8	-	-	-
- autumnale Gom.	II	27	35	III	29	29	II	17	30	-	-	-
- ambiguum Gom.	I	4	9	II	73	108	III	164	195	I	0.2	1
- favosum Gom.	III	98	81	III	51	50	III	47	56	III	14	29
Oscillatoria formosa Bory.	II	9	12	II	21	31	II	11	20	I	0.1	0.6
Spirulina okensis (C.Meyer.) Geitl.	I	3	7	III	30	30	I	3	12	II	3	8
Calothrix kossinskajae Poljansky	-	-	-	II	3	5	III	67	80	-	-	-
Homoeothrix varians Geitler.	II	11	14	III	73	72	III	12	14	II	3	9
- fusca Starm. f. elongata Starm.	I	0.3	0.7	IV	111	82	II	11	19	-	-	-
Chrysophyta												
a.) Chrysophyceae												
Hydrurus foetidus Kirchn.	II	34	43	-		-	I	48	172	II	0.6	2
b.) Bacillariophyceae												
Melosira varians Ag.	III	147	126	III	49	48	III	137	163	III	64	134
Cyclotella meneghiniana Kütz.	I	0.4	1	IV	125	92	V	467	333	II	0.8	2
- kützingiana Thwait.	-	-	-	I	0.2	0.6	III	92	109	-	-	-
Tabellaria fenestrata (Lyngb.) Kütz	IV	313	201	I	0.2	0.6	-	-	-	II	0.8	2
- flocculosa (Roth.) Kütz.	IV	186	119	IV	80	59	IV	7	6	V	7	9
Meridion circulare Ag.	IV	1848	1186	IV	139	102	III	103	123	IV	179	286
Diatoma vulgare Bory	IV	1584	1015	V	497	292	IV	91	82	V	110	138
- - var. ovale (Fricke) Hust.	V	633	324	IV	80	59	V	259	185	V	124	155
- - var. breve Grun.	III	192	164	II	36	54	III	56	67	IV	97	152
- - var. productum Grun.	IV	756	485	V	1395	821	IV	661	590	V	301	376
- - var. lineare Grun.	III	75	64	III	136	134	IV	231	206	IV	50	79
- - var. ehrenbergii (Kütz.) Grun.	IV	750	481	IV	195	143	V	1227	876	IV	87	136
- - var. capitulatum Grun.	IV	805	516	IV	338	285	IV	374	334	IV	4	7
- elongatum (Lyngb) Ag. var. tenuis (Ag.) V.H.	V	1592	816	V	1210	600	V	1425	1019	V	810	1012
Fragilaria crotonensis Kitt.	IV	317	203	II	331	486	III	102	121	-	-	-
- capucina Desm.	IV	1596	1023	IV	285	209	IV	395	353	IV	672	1050
- - var. mesolepta Rabenh.	III	211	180	III	171	168	IV	507	452	IV	476	744
- intermedia Grun.	IV	351	225	III	67	66	IV	254	227	IV	157	245
- - var. capitellata A. Cl.	IV	386	247	III	58	57	III	39	47	IV	156	244
- - var. dubia Grun.	II	26	33	-	-	-	IV	78	70	-	-	-
- virescens Ralfs.	III	151	129	II	2	3	I	0.4	1	-	-	-
- - var. mesolepta Schönf.	IV	242	155	IV	147	108	V	669	478	III	2	5
- leptostauron (Ehr.) Hust.	III	93	79	-	-	-	I	0.5	2	II	1	3
- - var. dubia Grun.	III	5	4	-	-	-	I	0.3	1	II	1	3
- construens (Ehr.) Grun.	I	12	31	-	-	-	-	-	-	V	123	154
- - var. binodis (Ehr.) Grun.	IV	95	61	III	16	16	III	4	5	IV	52	82
- pinnata Ehr.	IV	84	54	I	0.2	0.6	IV	8	7	IV	76	119
- - var. lancettula (Schum.) Hust.	IV	92	59	III	11	11	IV	101	91	IV	52	82
- brevistriata Grun.	III	42	36	II	78	115	III	4	5	II	24	76
- capitellata (Grun.) Boye P.	III	7	6	I	4	12	II	2	4	II	1	3
Ceratoneis arcus (Ehr.) Kütz.	IV	624	400	III	84	83	IV	137	122	IV	75	117
- - var. linearis Holmboe	IV	303	194	III	55	54	III	100	120	II	12	39
- - var. amphioxys (Rabenh.) Brun.	IV	912	585	III	128	125	III	49	58	IV	28	43
Synedra vaucheriae Kütz.	V	435	223	IV	20	15	V	173	124	IV	50	78
- - var. capitellata Grun.	IV	169	108	III	30	30	IV	113	101	II	7	22
- ulna (Nitzsch) Ehr.	V	1265	649	V	1509	888	V	913	652	V	960	745
- - var. biceps (Kütz.) Grun.	III	108	86	-	-	-	-	-	-	-	-	-
- - var. amphirhynchus (Ehr.) Grun.	III	163	140	IV	1513	1113	IV	1093	976	IV	197	308
- - var. oxyrhynchus (Kütz.) V.H.	III	434	371	IV	1599	1175	IV	701	626	IV	309	483
- - var. impressa Hust.	II	72	92	II	71	104	-	-	-	-	-	-
- capitata Ehr.	II	353	452	-	-	-	IV	401	358	II	0.8	2
- amphicephala Kütz.	IV	28	18	III	48	47	III	5	6	III	3	6
- acus Kütz.	IV	340	218	V	664	390	III	352	419	IV	62	97
- - var. radians (Kütz.) Hust.	II	67	86	-	-	-	V	542	387	IV	157	246
- parasitica (W.Sm.) Hust.	II	3	4	IV	75	55	II	4	7	II	0.8	2
- rumpens (Kütz.) Carlson	IV	108	69	III	22	22	IV	23	21	V	38	48
- - var. capitulata	II	2	3	I	0.5	1	I	4	15	-	-	-
- - var. familiaris (Kütz.) Grun.	IV	38	24	I	0.3	0.8	IV	22	19	I	0.3	2
- - var. fragilarioides Grun.	III	39	34	III	31	30	IV	45	40	II	8	26
- minuscula Grun.	II	3	4	-	-	-	-	-	-	-	-	-
- tabulata (Ag.) Kütz. var. parva (Kütz) Grun.	III	14	12	-	-	-	I	4	15	III	16	34
- bicurvata Biene	II	7	9	-	-	-	-	-	-	III	2	4
Eunotia lunaris (Ehr.) Grun.	II	14	18	-	-	-	-	-	-	II	0.8	2
- - var. subarcuata (Näg.) Grun.	IV	73	44	III	5	5	V	25	18	III	16	34

Table X cont.

	Spring (39 samples)			Summer (34 samples)			Autumn (28 samples)			Winter (16 samples)		
	Constancy	DKI	P	Constancy	DKI	P	Constancy	DKI	P	Constancy	DKI	P
Eunotia valida Hust.	III	121	103	-	-	-	-	-	-	-	-	-
- arcus Ehr.	IV	92	59	III	48	47	V	512	366	IV	51	80
Cocconeis pediculus Ehr.	IV	42	27	III	14	14	IV	156	140	IV	56	87
- placentula Ehr.	V	410	210	V	413	243	V	231	165	V	255	319
- - var. euglypta (Ehr.) Cl.	V	655	336	V	540	318	V	480	343	V	130	387
Eucocconeis flexella Kütz.	-	-	-	-	-	-	IV	8	7	II	0.8	2
Achnanthes minutissima Kütz.	IV	206	132	IV	81	60	V	216	154	IV	33	52
- - var. cryptocephala Grun.	II	9	12	II	2	3	III	15	18	-	-	-
- linearis (W.Sm.) Grun.	III	92	78	II	11	16	IV	77	67	IV	4	7
- lanceolata (Bréb.) Grun.	III	39	33	-	-	-	V	212	151	IV	5	7
- - var. capitata O.Müll.	III	51	43	II	17	24	IV	44	40	IV	26	46
- - var. rostrata (Östr.) Hust.	III	35	30	II	14	20	IV	81	72	III	10	22
- - var. elliptica Cl.	III	16	14	II	8	12	IV	89	79	IV	27	42
- amphicephala Hust.	III	88	75	III	16	16	III	46	55	III	13	28
Rhoicosphenia curvata (Kütz.) Grun.	IV	211	135	IV	104	76	IV	18	16	IV	64	106
Stauroneis phoenicenteron Ehr.	IV	92	59	-	-	-	-	-	-	-	-	-
- anceps Ehr.	II	3	3	-	-	-	-	-	-	-	-	-
- smithii Grun.	IV	10	7	-	-	-	III	5	6	IV	4	6
Navicula binodis Ehr.	II	2	2	-	-	-	III	5	6	-	-	-
- rotaeana (Rabenh.) Grun.	IV	64	41	II	13	18	IV	52	47	II	0.8	2
- bacillum Ehr.	III	129	110	III	21	21	IV	136	121	III	2	4
- pupula Kütz.	IV	137	88	III	25	24	IV	109	97	IV	45	70
- - var. rostrata Hust.	V	119	61	IV	57	42	IV	68	61	IV	33	52
- - var. mutata (Krasske) Hust.	IV	58	37	II	11	16	IV	59	52	II	6	20
- minuscula Grun.	IV	17	11	-	-	-	III	5	6	-	-	-
- cryptocephala Kütz.	IV	164	105	III	36	35	IV	116	104	IV	64	106
- - var. intermedia Grun.	II	29	37	III	35	35	IV	40	36	III	2	5
- - var. veneta (Kütz.) Grun.	IV	77	49	IV	79	58	IV	47	42	IV	50	78
- - var. exilis (Kütz.) Grun.	IV	67	43	II	3	5	IV	50	45	II	8	26
- rhynchocephala Kütz.	-	-	-	III	5	5	I	0.4	1	-	-	-
- viridula Kütz.	IV	46	29	-	-	-	III	4	4	IV	5	7
- hungarica Grun. var. capitata Cl.	III	6	5	I	0.3	0.8	III	15	18	II	0.8	2
- radiosa Kütz.	IV	273	239	IV	56	41	I	0.6	2	IV	4	7
- - var. tenella (Breb.) Grun.	IV	506	324	III	15	14	I	0.5	2	IV	4	7
- gracilis Ehr.	IV	326	209	III	30	30	IV	349	311	IV	50	79
- tuscula (Ehr.) Grun.	IV	204	131	IV	121	89	IV	144	128	IV	68	106
- reinhardtii (Grun.) Cl.	IV	69	44	-	-	-	III	66	78	V	198	247
- dicephala (Ehr.) W.Sm.	IV	35	22	I	0.1	0.3	IV	22	20	-	-	-
- anglica Ralfs.	III	20	17	-	-	-	V	53	38	II	0.8	2
- exigua (Greg.) O.Müll.	-	-	-	V	177	104	III	4	5	-	-	-
- - var. elliptica Hust.	III	16	14	I	0.5	1	III	4	4	-	-	-
- graciloides A.Mayer	-	-	-	-	-	-	III	4	4	II	0.8	2
- cuspidata Kütz. var. ambigua (Ehr.) Grun.	-	-	-	I	0.3	0.8	III	39	47	-	-	-
Pinnularia mesolepta (Ehr.) W.Sm.	II	2	2	I	0.4	1	II	2	3	-	-	-
- viridis (Nitzsch.)	II	2	3	I	0.5	1	I	0.6	2	-	-	-
- - var. sudetica (Hilse) Hust.	III	5	5	I	0.6	2	II	2	3	-	-	-
- - var. intermedia Cl.	III	6	5	-	-	-	-	-	-	-	-	-
- microstauron (Ehr.) Cl.	II	2	2	-	-	-	-	-	-	-	-	-
- borealis Ehr.	II	3	3	-	-	-	-	-	-	-	-	-
- biglobosa Schum. f. semiinterrupta A.Cl.	II	3	3	I	0.6	2	-	-	-	-	-	-
- - Schum.	II	2	2	-	-	-	-	-	-	-	-	-
Caloneis bacillum (Grun.) Mer.	II	10	12	III	41	40	IV	18	16	IV	16	24
- silicula (Ehr.) Cl.	III	8	7	-	-	-	IV	8	7	IV	5	8
- - var. ventricosa (Ehr.) Donk.	III	3	4	-	-	-	III	5	6	-	-	-
- amphisbaena (Bory) Cl.	II	2	2	-	-	-	-	-	-	III	3	6
- liber (W. SM.) Cl.	II	13	17	I	0.5	1	IV	18	16	-	-	-
Gyrosigma acuminatum (Kütz.) Rabenh.	II	2	2	I	0.6	2	III	4	4	III	2	4
- attenuatum (Kütz.) Rabenh.	II	3	4	IV	455	334	II	2	4	V	389	490
- scalproides (Rabenh.) Cl.	III	22	18	IV	34	25	II	2	3	-	-	-
Amphora Ehr. sp.	I	0.6	2	I	0.4	1	-	-	-	-	-	-
- ovalis Kütz.	IV	228	146	IV	80	58	IV	112	100	IV	217	340
- - var. pediculus Kütz.	III	92	79	III	17	17	IV	28	26	IV	23	36
- - var. gracilis Ehr.	IV	71	45	III	4	4	III	8	9	IV	4	6
- veneta Kütz.	II	2	2	I	0.4	1	II	2	3	II	2	5
Cymbella laevis Näg.	IV	68	44	-	-	-	V	80	57	IV	4	6
- naviculiformis Auersw.	I	0.4	1	III	5	5	-	-	-	-	-	-
- prostrata (Berkeley.) Cl.	III	334	285	III	120	117	IV	112	100	IV	240	380
- sinuata Greg.	III	64	55	III	16	16	IV	122	109	IV	34	54
- - f. ovata Hust.	III	47	50	II	2	2	IV	56	50	II	18	57
- affinis Kütz.	V	455	233	V	351	207	V	435	311	V	150	190
- lanceolata (Ehr.) V.H.	III	5	5	I	0.4	1	II	2	4	II	1	4
- helvetica Kütz.	II	8	11	-	-	-	-	-	-	-	-	-
- - var. curta Cl.	IV	118	76	III	5	5	IV	82	73	IV	37	58
- aspera (Ehr.) Cl.	III	14	12	-	-	-	II	1	2	-	-	-
- helvetica var. balatonis (Grun.) Cl.	III	245	210	IV	9	7	IV	277	247	IV	180	290
- ventricosa Kütz.	V	455	233	V	178	105	V	167	120	V	116	145
Gomphonema acuminatum Ehr.	III	9	8	I	0.4	1	IV	55	49	II	1	3

Table X cont.

	Spring (39 samples)			Summer (34 samples)			Autumn (28 samples)			Winter (16 samples)		
	Constancy	DKI	P	Constancy	DKI	P	Constancy	DKI	P	Constancy	DKI	P
Gomphonema parvulum (Kütz.) Grun.	IV	94	60	IV	39	28	IV	63	56	IV	38	59
- angustatum (Kütz.) Rabenh.	V	102	52	V	290	171	V	172	123	V	62	78
- longiceps Ehr.	III	34	29	-	-	-	V	43	31	V	57	71
- - var. subclavatum Grun.	IV	60	39	IV	73	54	V	129	92	V	20	26
- intricatum Kütz. var. pumilum Grun.	IV	59	38	V	154	90	V	138	99	IV	34	52
- gracile Ehr.	V	141	73	III	45	44	V	138	98	V	77	97
Gomphonema Ag. sp.	IV	155	99	V	238	140	V	58	42	IV	20	31
- olivaceum (Lyngb.) Kütz.	IV	1080	692	V	990	582	V	885	632	V	480	600
- - var. calcareum Cl.	V	678	348	V	529	311	V	631	451	V	370	463
Epithemia zebra (Ehr.) Kütz.	I	0.2	0.5	I	0.5	1	IV	20	17	-	-	-
- turgida (Ehr.) Kütz.	I	0.2	0.5	I	0.7	2	III	4	4	-	-	-
Hantzschia Grun. sp.	I	0.6	2	-	-	-	-	-	-	-	-	-
- amphioxys (Ehr.) Grun.	I	0.3	0.8	IV	67	49	I	0.5	2	-	-	-
Nitzschia Hass. sp.	-	-	-	-	-	-	I	0.5	2	-	-	-
-angustata (W.Sm.) Grun.	I	0.4	1	III	83	82	III	128	153	-	-	-
- - var. curta Grun.	IV	44	28	III	13	13	IV	52	46	-	-	-
- - f. antiqua (Schum.) A.Cleve	II	10	13	I	2	3	IV	23	21	II	1	3
- thermalis Kütz.	I	3	8	IV	67	49	I	15	54	-	-	-
- stagnorum Rabenh.	IV	45	29	III	4	4	III	15	18	V	68	85
- sinuata (W.Sm.) Grun. var. tabellaria Grun.	I	0.2	0.5	I	0.1	0.3	III	4	4	-	-	-
- linearis W.Sm.	IV	483	263	IV	173	127	IV	372	332	IV	145	227
- dissipata (Kütz.) Grun.	V	242	124	IV	150	110	V	295	211	V	195	244
- - f. media (Htz.) Grun.	III	50	43	III	29	28	IV	58	45	II	8	26
- heufleriana Grun. var. elongata Pant.	II	3	3	III	40	39	V	142	101	IV	50	79
- palea (Kütz.) W.Sm.	III	57	48	II	44	64	III	14	17	I	0.3	2
- paleacea Grun.	III	18	15	III	19	19	III	14	17	III	5	10
- gracilis Hantzsch.	II	3	4	III	19	18	V	73	52	III	15	28
- - var. capitata Wisł. et Poretzky	I	3	7	I	4	12	III	13	13	III	2	4
- sigmoidea (Ehr.) W.Sm.	III	360	307	IV	314	231	IV	424	379	IV	265	571
- vermicularis (Kütz.) Grun.	IV	676	434	IV	36	27	III	4	5	III	3	6
- acicularis W. Sm.	IV	45	29	II	2	2	IV	101	90	II	0.8	2
- kützingiana Hilse.	III	73	62	-	-	-	IV	86	77	IV	30	47
- dubia W.Sm.	II	12	16	I	0.6	2	IV	102	91	IV	50	79
- denticulata Grun.	II	11	14	-	-	-	I	3	11	III	2	5
Cymatopleura solea (Breb.) W.Sm.	II	72	92	III	109	107	IV	396	354	IV	87	136
- - var. vulgaris Meist.	II	31	39	II	57	83	IV	119	107	III	3	6
- - var. apiculata (W.Sm.) Ralfs.	-	-	-	IV	177	130	IV	135	121	II	0.8	2
- elliptica (Breb.) W.Sm.	I	0.1	0.2	-	-	-	III	4	5	-	-	-
Surirella angustata Kütz.	III	15	13	III	34	33	III	23	28	IV	4	7
- - var. hankensis Skv.	III	5	4	-	-	-	-	-	-	-	-	-
- - var. elongata Skv.	II	3	4	III	16	15	V	66	47	-	-	-
- tenera Greg.	I	0.1	0.2	-	-	-	II	2	3	-	-	-
- ovata Kütz.	IV	92	59	II	21	31	V	56	40	I	0.3	2
- - var. salina (W.Sm.) Hust.	III	75	64	III	10	12	II	6	10	IV	16	19
- - - pinnata (W.Sm.) Hust.	III	28	24	IV	36	26	IV	55	40	IV	4	7
- linearis W.Sm. var. helvetica (Brun) Meist.	III	6	5	-	-	-	-	-	-	-	-	-
Xanthophyceae												
Tribonema subtilissimum Pascher.	II	6	7	I	0.2	0.6	II	1	2	-	-	-
Chlorophyta												
Scenedesmus quadricauda Breb.	II	7	9	II	13	20	II	8	14	I	0.3	2
Ulothrix zonata Kütz.	IV	464	297	III	136	133	III	164	196	IV	134	209
- tenuissima Kütz.	II	14	18	II	14	20	III	21	25	II	13	40
- variabilis Kütz.	II	2	2	II	31	46	II	14	24	II	1	3
- oscillarina Kütz.	II	8	10	II	13	20	II	2	4	II	25	77
Microspora amoena (Kütz.) Rabenh.	II	13	17	II	31	45	-	-	-	-	-	-
Draparnaldia glomerata (Vauch.) Agardh.	I	0.1	0.2	II	13	19	I	1	5	I	0.3	2
Stigeoclonium tenue Kütz.	I	0.2	0.5	II	11	16	II	7	14	IV	30	47
- flagelliferum Kütz.	III	48	41	III	200	196	II	2	4	IV	62	97
Gongrosira trentepohliopsis Schmidle	II	109	140	III	57	56	II	1	2	III	64	134
Spirogyra Link. sp.	I	0.2	0.5	II	127	187	II	226	476	-	-	-
Zygnema Agardh. sp.	I	35	91	III	275	269	II	169	301	-	-	-
Closterium rostratum Ehrenb.	I	15	37	III	108	106	I	0.6	2	II	1	3
- parvulum Näg.	I	6	17	III	66	65	I	0.5	2	-	-	-
- ehrenbergii Menegh.	I	0.4	1	II	3	5	I	0.4	1	II	1	2
- moniliferum (Ehrenb.) Bory.	I	28	73	II	57	84	I	0.6	2	I	0.2	1
- cornu Ehrbg.	I	6	16	II	32	46	II	31	55	-	-	-
- acerosum (Schr.) Ehrenb.	II	65	84	II	34	51	II	2	3	I	0.3	2
- leiblenii Kütz.	I	0.2	0.5	II	2	3	III	108	129	-	-	-
Cosmarium impressulum Elfr.	I	8	21	III	58	57	I	0.6	2	I	0.1	0.6
- formosulum Hoff.	II	11	15	II	23	34	II	11	20	I	0.2	1
- obtusatum Schmidle	I	0.3	0.7	III	110	108	II	43	77	I	0.2	1
- cucurbita Breb.	II	14	17	III	50	49	III	29	35	I	0.3	2
- coelatum Ralfs.	I	6	16	II	8	12	I	0.4	1	-	-	-
Staurastrum punctulatum Breb.	I	2	4	III	43	42	II	15	27	II	1	4
- muricatum Breb.	I	6	16	II	2	3	II	43	77	-	-	-
Euastrum elegans (Breb.) Kütz.	I	0.2	0.5	II	4	6	I	0.5	2	-	-	-
Rhodophyta												
Chantransia pygmaea Kütz.	III	227	194	II	55	81	III	154	183	I	0.1	0.6

was 154. *Cyclotella meneghiniana, Diatoma vulgare* var. *ehrenbergii, D. elongatum* var. *tenuis, Fragilaria capucina* var. *mesolepta, F. virescens* var. *mesolepta, Synedra ulna, S. ulna* var. *amphirhynchus, S. acus* var. *radians, Eunotia arcus, Cymbella affinis, Gomphonema alivaceum* var. *calcareum, G. olivaceum* and others develop especially abundantly in this season.

In the summer months as well as in the autumn ones the relatively most abundant appearance of blue-green and green algae can be observed. Blue-green algae are found in the greatest numbers in July and in the beginning of August and green algae in August.

Species like *Homoeothrix fusca* fo. *elongata, Chamaesiphon polonicus, Ch. incrustans, Phormidium ambiguum, Ulothrix zonata, Closterium rostratum,* and *C. leibleinii* develop especially abundantly during the entire period.

After flood periods, mostly in summer, a very intensive development of blue-green and green algae was observed. This might be connected with an increase of the amount of nutritive substances in the water.

A distinct fall in the amount of algae of all systematic groups takes place in the winter period, from December to February. The water temperature during the collecting of samples was 5 °C in December, 4° in January and 3° in February; the mean water level was 130, 151, 150 cm; current velocity in cm/sec. amounted to 30 in December, 110 in January and 25 in February; pH from 7.0 in December to 6.7 in February. Blue-green and green algae species disappear in the first place, and the very few remaining ones have very low coefficients of coverage. Only *Chamaesiphon incrustans* and *Ulothrix zonata* develop without any more important changes.

Diatoms, in spite of a decrease in their amount are, as before, the most commonly found. The species *Diatoma elongatum* var. *tenuis, Fragilaria capucina, Gomphonema olivaceum* etc. develop in greater numbers, while other seasonal species, *Hydrurus foetidus* and *Fragilaria construens,* reach their maximum in this period.

As can be seen, diatoms are the dominating group in the course of the whole year (fig. 13). Maximum amounts of cells appear twice in the spring months and for a second time in the autumn, while other algae, mostly green and blue-green, appear in greater numbers only once during the year, in the summer or autumn.

The remaining few species belonging to other systematic groups *(Schizomycetes, Chrysophyceae, Xanthophyceae* and *Rhodophyta)* do not play any important role in the investigated community owing to their very low coefficients of coverage. They do not need to be discussed in detail.

We may therefore consider that in the investigated community of algae two seasonal aspects may be distinguished: the autumn-winter-spring aspect and the summer aspect. The autumn-winter-spring aspect is characterised by a very abundant amount of diatoms and the summer aspect by a more numerous presence of green and blue-green algae.

The seasonal changes observed in the investigated community of algae were mostly of a numerical character. The floristic composition changed also, but within limits that allowed the general character of the community to maintain itself throughout the year.

The already mentioned seasonal aspects of the appearance of algae accompanying the *Cladophora* thalli might be connected with data illustrating ecological factors, such as water temperature current velocity and the length and abundance of *Cladophora* thalli.

The most abundant development of diatoms takes place at a temperature from 4 to 11 °C (thus in autumn, winter and spring) and a distinct decrease is seen at a temperature exceeding 18 °C (in summer). The winter decrease in the amount of diatoms may be put down to the weak development of *Cladophora* thalli.

The diminution of the number of diatoms in summer is accompanied by an increase in the amount of blue-green and green algae, undoubtedly under the influence of the rise in the temperature of the water.

The velocity of the current has a mechanical and negative influence upon the appearance of the *Cladophora* thalli and the degree of overgrowth by algae. It seems that a medium current (25—50 cm/sec.) is the most favourable for a strong development of accompanying algae (spring, autumn) as well as for an abundant development of *Cladophora glomerata* thalli (spring, autumn), which in turn create conditions favourable for the anchorage of other accompanying algae.

In many species a distinct periodicity of development was observed, this being in a certain measure in accordance with the appearance of the entire systematic group to which the given species belongs. The diagrams in figs. 14 and 15 illustrate numerical changes, expressed in percentages, of mean indices of coverage for the appearance during the year of some dominants and „seasonal" accompanying species of the *Cladophora glomerata* thalli in the Skawa.

Influence of high water levels

The stony bottom of the river in the place where samples were collected is shaped by the influence of the water current. With a rise in the water level the velocity of the current increases. The rising waters undermine the banks, transport rubble, and deposit it together with fine slimy particles. As the current velocity increases and becomes very great (more than 100 cm/sec.) distinctly negative conditions arise for organisms growing upon the stony bottom of the river — they are torn off, washed out, and carried downstream. These conditions have an unfavourable influence not only on the external appearance of the *Cladophora* thalli, as already

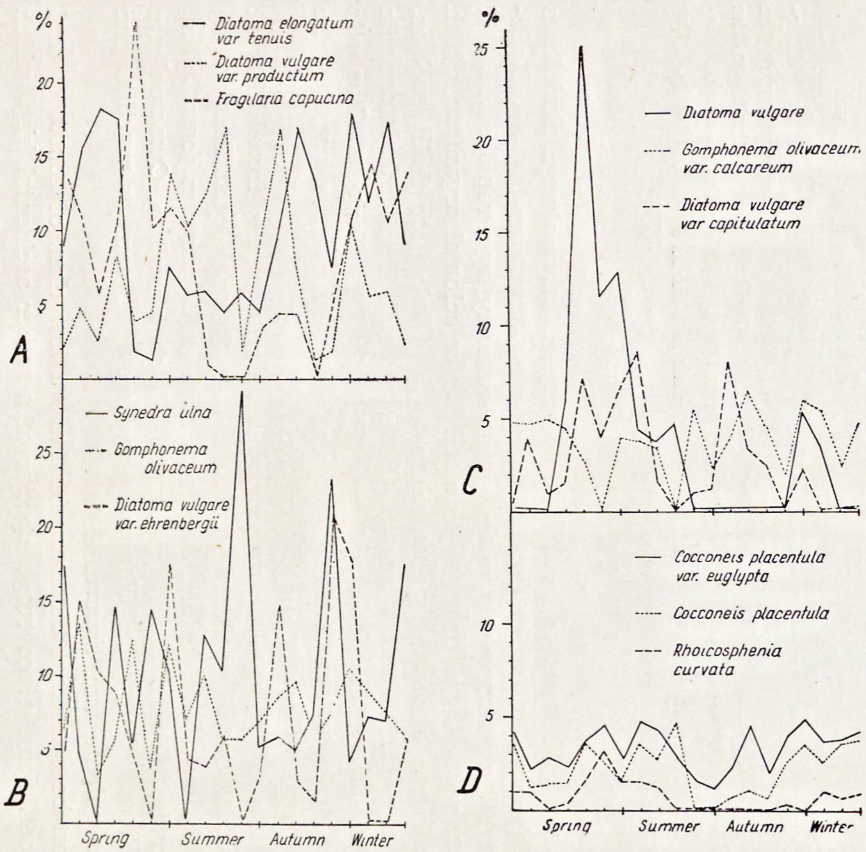


Fig. 14 A, B, C and D. Mean coefficient of coverage (in percentage) of some dominants accompanying the *Cladophora glomerata* thalli in Skawa river.

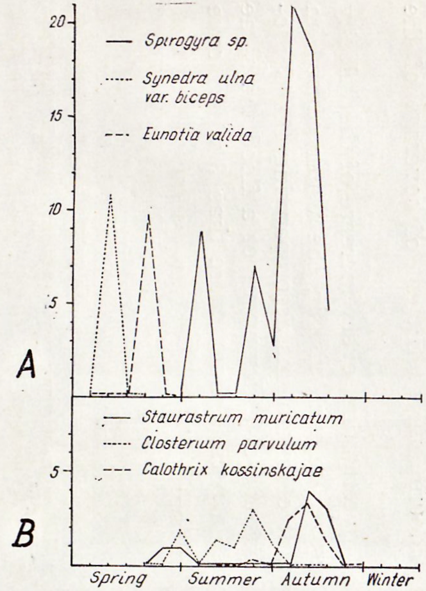


Fig. 15 A and B. Mean coefficient of coverage (in percentage) of some species of „seasonal" algae accompanying the *Cladophora glomerata* thalli in the Skawa river.

mentioned, but also on the amount and coefficient of coverage of the accompanying algae.

During the whole period of investigation, every increase of the velocity of the current above the average, or each rise in the water caused an immediate fall in of the amount of organisms accompanying the *Cladophora* (fig. 16). But after the passage of a downpour or a flood the algae again start to develop and after a period of not more than 3 weeks once more regain their previous number.

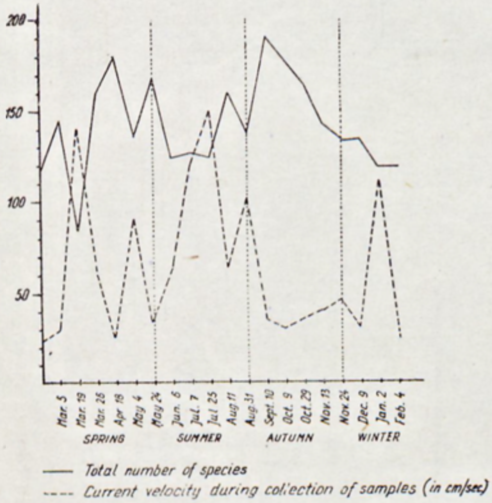


Fig. 16. Number of species of different algae groups accompanying the *Cladophora glomerata* thalli on the packground of hydrographical relations in particular periods of the year.

The index of coverage for individual species nearly always diminishes after higher water levels (fig. 17). Organisms accompanying the *Cladophora* thalli are very rarely entirely washed away by a rapid current. If this takes place they are usually unicellular or colonial organisms which have no means of attaching themselves to the *Cladophora* thalli, such as, for instance, *Closterium acerosum, C. ehrenbergii, Fragillaria intermedia* var. *capitellata, Nitzschia stagnorum, N. palea, N. dissipata, Cymbella prostrata, C. lanceolata, Caloneis bacillum, Gyrosigma acuminatum, Synedra amphicephala, Merismopedia glauca,* etc.

The river current also carries and settles organisms from different places which were not found, or found only in small quantities among the *Cladophora* thalli before the flood, such as *Cosmarium formosulum, C. cucurbita, Staurastrum punctulatum, Melosira varians, Cymatopleura solea, Pinnularia viridis, Navicula cryptocephala* var. *intermedia,* and *Diatoma vulgare* var. *lineare.*

It can be seen that these species have a low class of constancy and small coefficients of coverage, species of a rather accidental kind which

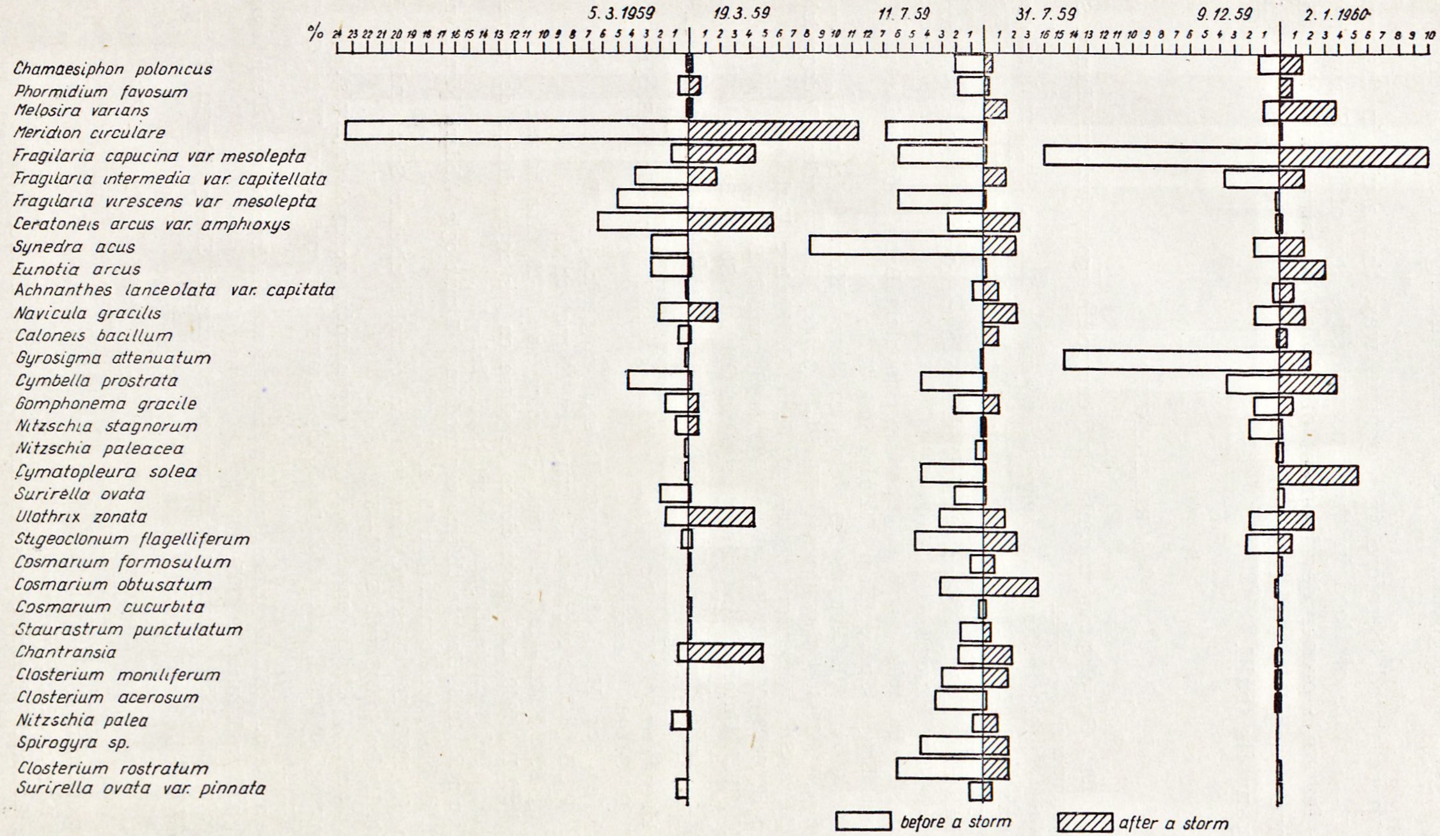


Fig. 17. Mean coefficient of coverage of some species of algae accompanying the *Cladophora glomerata* thalli in the Skawa river before and after a storm (in percentage).

have no greater diagnostic value for determining an association or its facies.

It can be stated therefore, in a general way, that a rise in the water level and a state of flood in the investigated sector of the Skawa river do not favour a proper development of *Cladophora* strata and that they also have a negative influence upon the development of the algae which accompany its thalli.

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