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R.O. McLean

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THE TOLERANCE OF *STIGEOCLONIUM TENUE* KÜTZ. TO HEAVY METALS IN SOUTH WALES

By R. O. McLean*
Department of Botany, University College, Cardiff CF1 1XL

The distribution of *Stigeoclonium tenue* Kütz. and *Cladophora glomerata* Kütz. in relation to metal pollution by Cu, Pb, Fe, Zn and Mn was studied in 169 river stations in the spring months of 1972. Equal tolerance to Cu, Pb and Zn was demonstrated in both algae, but *Stigeoclonium* showed greater tolerance to Fe, even in conditions of poor nutrient status.

Numerous authors have suggested that *Stigeoclonium tenue* Kütz. demonstrates some tolerance to metal pollution. Thus Fjerdingstad (1965), in addition to classifying *Stigeoclonium* as a saprophilous organism, also describes it as a chemobiont being resistant to copper and other metallic poisons. Butcher (1955) found the alga within a five mile recovery zone below a copper waste effluent on the river Churnet. Palmer (1959) cited the alga in his list of species indicating copper and chromium pollution, whilst Whitton (1970), when comparing *S. tenue* with *Cladophora glomerata* Kütz., suggested that "well illuminated flowing water sites with abundant growths of *Stigeoclonium* but no *Cladophora* at all should be treated as suspect for metal pollution". This qualified Blum's (1957) reports of sensitivity to iron, chromium and copper by *Cladophora*.

The work described in this paper involves a study of *Stigeoclonium tenue* distribution in relation to metal pollution, and, if tolerance was apparent, whether it was connected with the alga's affinity for organically polluted conditions. The survey was performed in the spring months such that the full distributive capacity of the alga was expressed as described by McLean & Benson-Evans (1974).

MATERIALS AND METHODS

The rivers surveyed were chosen with reference to their pollution status in order to cover a wide range of conditions. Table I lists the rivers used with their classification according to a report by the Department of the Environment (1970). B.O.D., oxygen content, suspended solids and the presence of toxic substances were used as a basis of classification into Class I, rivers unpolluted or recovered from pollution; Class II, rivers of doubtful quality and needing improvement; Class III, rivers of poor quality requiring improvements as a matter of some urgency; and Class IV, grossly polluted rivers. Certain of the rivers used, e.g. the Ystwyth, Rheidol, Taf, Dafen, Kenfig, Afan and Pelena, were known to be polluted by metals.

169 stations were visited within a period of four weeks during April and May 1972. At each station the presence and relative abundance of both *S. tenue* and *C. glomerata* were recorded on the basis of a visual cover estimation which was represented numerically as: 3 = 10–100% cover, 2 = 1–10% cover, 1 = 0–1% cover, 0 = absent. A water sample was collected at each station and analysed for the total dissolved and undissolved copper, zinc, lead, iron and manganese using an EEL 140 atomic absorption spectrophotometer. Chemical analyses for pH, total hardness, percentage saturation of oxygen, biochemical oxygen demand, electrical conductivity, chloride, nitrate, nitrite, ammonia and suspended solids levels were obtained for each station for the period of survey from the River Authorities concerned.

* Present Address: The Department of Botany and Microbiology, University College of Wales, Aberystwyth SY23 3DA

TABLE I. Rivers covered in the survey including their pollution classification after the Department of the Environment

River number	River name	Pollution classification I, II, III or IV
1	Clarach	II, III
2	Rheidol	II, III
3	Ystwyth	I, II, III
4	W. Cleddau	I, II, III
5	E. Cleddau	I
6	Taf	I
7	Towy	I, II
8	Gwili	I
9	Cothi	I
10	Gwendraeth fach	I
11	Gwendraeth fawr	I, II, III
12	Dafen	IV
13	Pelena	III
14	Lloughor	I, IV
15	Amman	IV
16	Lliw	I, II
17	Tawe	I, II, III
18	Neath	I, II, III
19	Afan	I, II, III
20	Llynfi	I, II, IV
21	Ogmore	I, II
22	Ewenny	I, II
23	Kenfig	III
24	Ely	I, II, III
25	Taff	I, II, III, IV
26	Rhymney	I, II, III, IV
27	Sirhowy	II
28	Ebbw fach	I, II
29	Ebbw fawr	IV
30	Lwyd	I, II
31	Usk	I, II, III
32	Clydach	I, II, III

RESULTS

The raw data collected are listed in McLean (1972). The total range covered for each environmental factor and the range within which each alga occurred are given in Table II. *Stigeoclonium* was found throughout the whole range of iron and manganese recorded, but only in the lower ranges of copper, lead and zinc up to 0·02, 0·20 and 0·55 mg l^{-1} respectively. Observations of the first 21 stations surveyed, which included the metal-polluted Clarach, Ystwyth and Rheidol rivers, showed that zinc and lead were found throughout these stations, with copper at station 11 and iron in stations 11–21. No detectable B.O.D. values and low levels of nitrogen and phosphorus occurred at these stations which had iron present (Fig. 1). The pH levels in these stations were uniform and generally below pH 7·0. Stations with the highest content of lead and zinc in the survey, e.g. No. 39, Zn = 25 mg l^{-1} and No. 5, Pb = 0·6 mg l^{-1}, had undetectable B.O.D. values and were not colonised with *Stigeoclonium. Cladophora* was found in similar ranges of manganese, lead, zinc and copper to *Stigeoclonium* but showed absence from areas with high levels of iron. *S. tenue* was generally found in wide ranges of most of the other environmental factors recorded; *Cladophora* tolerated only a slightly narrower range of nutrient concentrations, although this alga did not exist in the high B.O.D. and nitrite levels tolerated by *Stigeoclonium*.

TABLE II. The total range covered for each factor in the survey together with ranges for occurrence of *Stigeoclonium* and *Cladophora*

Factor	Total range of survey	Range tolerated by *Stigeoclonium*	Range tolerated by *Cladophora*
Fe	0·00– 9·98 mg l^{-1}	0·00– 9·98	0·00– 0·45
Cu	0·00– 0·04 mg l^{-1}	0·00– 0·02	0·00– 0·02
Pb	0·00– 0·67 mg l^{-1}	0·00– 0·20	0·00– 0·22
Kn	0·00– 0·99 mg l^{-1}	0·00– 0·99	0·00– 0·85
Zn	0·00– 3·25 mg l^{-1}	0·00– 0·53	0·00– 0·42
pH	4·6 – 9·7	5·5 – 9·7	7·1 – 9·7
Total hardness	5·3 – 999·8 mg l^{-1}	5·3 –490·0	36·0 –370·0
% Satn 0_2	38·9 – 140·9 mg l^{-1}	38·0 –116·4	38·0 –120·0
B.O.D.	0·0 – 14·4 mg l^{-1}	0·0 – 14·4	9·5 – 6·3
Elect. cond.	24·0 –4500 mhos	24 –800	83 –700
Cl	2·0 –2000 mg l^{-1}	2·0 – 60·0	7·0 –120·0
NO_3	0·0 – 2·8 mg l^{-1}	0·0 – 2·6	0·05– 2·3
NO_2	0·0 – 0·16 mg l^{-1}	0·0 – 0·16	0·0 – 0·035
NH_3	0·0 – 9·25 mg l^{-1}	0·0 – 1·96	0·0 – 2·52
Susp. Sols	0·0 – 726·0 mg l^{-1}	0·0 –726·0	0·0 –528·0

DISCUSSION

The Mersey River Board's Standards for Trade Effluent (1960) suggested that levels of zinc, copper, lead and iron should in each case not exceed 1·0 mg l^{-1} for total dissolved and undissolved metal. Field data demonstrated that *Stigeoclonium* is tolerant to iron at levels far above this standard, whereas copper, lead and zinc are less tolerated; thus both *S. tenue* as well as *C. glomerata* existed only in the lower ranges recorded for these three metals. This seems to contradict the suggestions of Butcher (1955), Palmer (1959) and Fjerdingstad (1965) that *Stigeoclonium* is tolerant to metal pollutants with special reference to copper. Additionally, Whitton's (1970, 1972) suggestions that *Stigeoclonium* seems more resistant to metals than *Cladophora* was not supported for any metal except iron. In fact, it is possible that river sites with *Stigeoclonium* present and *Cladophora* absent were not clear of the latter because of metal pollution, but because the organic load was beyond *Cladophora*'s tolerance and still optimum for *Stigeoclonium*. The former's greater sensitivity to organic load was demonstrated by the lower maxima of B.O.D. and nitrite conditions tolerated by *Cladophora* in this survey as compared with *Stigeoclonium* (Table II).

It is possible that in order for *Stigeoclonium* to demonstrate its full tolerance to metal pollution, as described by previous authors, suitable organic conditions providing optimum nitrogen and phosphorus levels should prevail. In such conditions where optimum growth could occur, greater tolerance to zinc, lead and copper would exist. In respect of zinc and lead, those stations in this survey which were rich in these metals were generally poor in basic nutrients. Thus even though the alga could exist in such low nutrient levels in spring, as demonstrated by the ranges of occurrence (Table II), when zinc or lead was present, its tolerance to these metals could not be expressed and the alga would be absent. Additionally, the absence of chelation of these metals in such a situation would render them to be in the free ionic form and to be more toxic to the alga. A tolerance to iron, however, could still be expressed in conditions of low B.O.D. and nutrient levels. In comparison, at stations high in copper, e.g. No. 67, Cu = 0·04 mg l^{-1}, low B.O.D. values did not exist and the absence of the alga was probably due to a direct toxic effect of the metal.

The metal tolerance of *Stigeoclonium* is thus possibly associated with its tolerance and affinity for organic pollution. In the absence of such conditions,

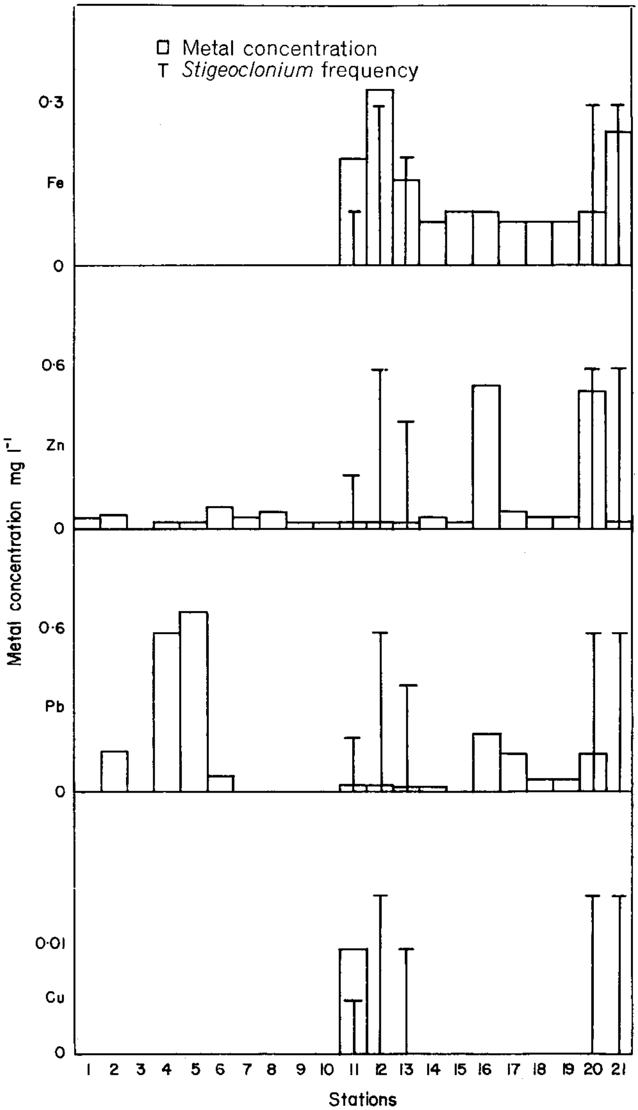

FIG 1. Concentrations of Zn, Cu, Pb and Fe and abundance of *Stigeoclonium tenue* in stations 1–21.

lead and zinc would not be tolerated, but iron would not be toxic. The large tolerance to most environmental factors by *Stigeoclonium* in the spring which was suggested by McLean & Benson–Evans (1974) was reaffirmed as far as most parameters were concerned but was not extended to heavy metals except possibly in the case of iron.

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