ECOLOGICAL STUDIES ON RIVER POLLUTION CONTROL

VOL II

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SYNOPSIS -THE ECOLOGY OF RIVER POLLUTION AND BIOLOGICAL SURVEILLANCE

Although in mainland Europe biological methods of assessing river pollution had been used since early in the century (The Saprobic System), there was considerable resistance to their use in Britain, reliance being placed on chemical and physical parameters both regionally and nationally. One regional exception was the Trent Fishery Board where Dr Butcher, a Biologist seconded from MAF, demonstrated the use of biological methods using benthic algae and invertebrates.

Effluents from the Birmingham Tame and Rea District Drainage Board's several sewage works discharged to tributaries of the River Trent. As the sole biologist I was encouraged to investigate the possible use of biological methods in monitoring the effect of their effluents on local streams and rivers. The results of several surveys on Midland streams over the period 1949 - 1960 established the effects of domestic and industrial discharges on riffle benthic communities (publications 1 & 2).

The effects of changing pollutional conditions, due to housing developments and the construction of a new trunk sewer, were clearly indicated by changes in the benthic communities (2). Encouraged by the results of these early studies I became an advocate of biological methods to complement physical and chemical ones in monitoring river water quality.

With the awakening of environmental awareness, several papers for conferences and symposia and chapters for books resulted from requests to write them. These presented a biological viewpoint on river pollution and water quality issues and publicised biological monitoring methods. As examples of these papers, seven (3, 6, 13, 16, 17, 18 and 19) are included in appropriate places, reflecting the development in biological monitoring methods over a period of some 30 years.

After moving to university, in co-operation with research students, more intensive quantitative studies were carried out on other rivers (4). Besides providing more detailed information on the response of invertebrates to different types of pollution at species level, these studies revealed the importance of the diel fluctuations in dissolved oxygen in affecting invertebrates in organically polluted streams. They also showed the seasonal differences in response to organic pollution (5).

To enhance the indicator value of specific invertebrates, laboratory apparatus was developed to determine their tolerance to different environmental factors involved in organic pollution, such as dissolved oxygen depletion, carbon dioxide and ammonia concentrations (6). By modifying the apparatus the effect of the diel fluctuations in dissolved oxygen was confirmed (7 & 8).

To investigate the effects of different dilutions of sewage effluent in river water on the population dynamics of snails, as an indication of sub-lethal effects, experimental streams, originally constructed on a sewage works to carry out similar investigations on fish, were used (9). In association with these investigations and biological surveys on lowland rivers laboratory toxicity tests, using a continuous flow system, were carried

out (10). These investigations confirmed that *Potamopyrgus jenkinsi* could be used as a valuable indicator of copper and ammonia toxicity.

Surveillance of polluted rivers had shown that where sewage treatment works had been upgraded to improve their effluent quality, associated with the decreased organic and ammonia content, there was an increase in the nitrate and phosphate. This resulted in sewage fungus growths in the river being replaced by troublesome growths of the alga *Cladophora* (blanket weed) symptomatic of eutrophication. Field surveys and laboratory culture studies showed phosphorus to be the key nutrient involved (11). In subsequent laboratory studies, using a continuous-flow technique, temperature, light intensity and duration were shown to be important natural factors affecting growth. Its sensitivity to ammonia and the heavy metals copper and zinc would probably account for its absence from some polluted streams (12).

The National Rivers Pollution Survey of 1970 included, for the first time, a biological classification. Unfortunately the results were considered "disappointing" when compared with the chemical classification. As a result the Biological Monitoring Working Party (BMWP) was set up to produce a biological method applicable to all river types. As a member and chairman of a sub-group which designated the scores, I was able to use the results of these researches in my contributions to the development of the method. Examination of the survey report showed that the probable reason was the failure of the biological method used to take into account the natural ecological differences of the benthic conditions in different types of river (13). Slow-flowing lowland rivers with a depositing substratum were not only more difficult to sample, but did not support a benthic fauna containing pollutional sensitive species, the presence of which was necessary to establish a good quality classification. In an attempt to solve this problem research was carried out for the DoE. To provide a substratum with hard solid surfaces in the absence of a natural hard substratum, an artificial substratum (colonisation sampler) - the S.Auf.U (Standard Aufwuch Unit) - was developed (14).

Although this only partly solved the problem of sampling lowland river, they were recognised as an official BMWP method for use where other sampling methods were not possible. Data generated in these investigations were used in determining the BMWP family scores. Later trials with the S.Auf.U. showed that data generated by the colonisation samplers were best interpreted by other means (15).

In 1978 NWC issued their review of discharge consent conditions "River water quality - the next stage". At a Society of Chemical Industry symposium to discuss the proposals, I was invited to present a biological viewpoint. The resultant paper (16) advocates and justifies biological surveillance in monitoring river water-quality. The appropriateness of biological monitoring of rivers for fisheries management was the theme of a paper presented at a British Freshwater Fisheries Conference (17). At a one-day symposium organised by IWPC on River Water Quality a paper reviewing biological surveillance methods used in Britain was presented (18). At a symposium held as part of the Council of Europe's "Freshwater Europe" Action Programme to encourage a common pan-European approach to river water quality monitoring and control, a paper outlining the principles and practices of biological surveillance methods and reviewing methods used in European countries, was presented in collaboration with a Belgian biologist, Dr N. De Pauw (19).

In retirement my interest in biological monitoring has continued, and being concerned about the way the BMWP Score was being applied, I welcomed being able to participate in the activities of a research team, under the leadership of W. J. Walley, working on the application of A.I. (Artificial Intelligence) to water quality assessment. In the development of an expert system - BERT - (Benthic Ecology Response Translator) I was used as the "expert" (20). In an alternative approach, a neural network, I supplied the knowledge base (21).

In developing the Score System, the Biological Monitoring Working Party had allocated values to invertebrate families according to their perceived sensitivity to organic pollution. These values were used in the 1980 and subsequent national surveys. Using the data from the 1990 survey, W.J. Walley carried out a computer-based re-appraisal of scores values allocated. As part of the exercise I contributed a biological explanation of the results which revealed the mis-scoring of some families (22) and demonstrated the effect of taking into account site type and abundance rating (23). In connection with this work a "Technical Note" was prepared describing the origin and development of the BMWP Score System (24).

Chapters in books. These were all written on the request of authors and editors.

"Biological aspects of river pollution" In "River Pollution 2, Causes and Effects", L.Klein, (1962). This chapter was first written for an earlier text by L.Klein - "Aspects of River Pollution" (1957). The book was subsequently re-written as three volumes for one of which the chapter was updated, doubling in size, such were the numbers of papers on the subject published at the time. These volumes became standard texts on river pollution for many years. The chapter reviewed literature on the subject up to that time and included my experiences of biological monitoring and my views on future developments.

"Invertebrates as indicators of water quality" In "Biological Indicators of Water Quality", Eds. L.M. Evison and A. James, (1970). This chapter resulted from a paper dealing with the advantages and limitations of using invertebrates as indicators of river water quality presented as a symposium on biological indicators of water quality. It was subsequently published as a chapter in a book.

"Zonation and classification of rivers" In "River Ecology" Ed. B. Whitton, (1975), is a review of European and American papers on the subject. Apart from early work by Carpenter on Welsh rivers, the subject appeared to be neglected by British workers. This probably accounted for the disregard of zonation and bio-typology in developing biological monitoring systems in Britain. The chapter concludes that in determining river management policies, recognition must be given to the existence of the different river zones.

"Eutrophication of rivers - Effects, Causes and Control" In "Treatment of Industrial Effluents", Eds. A.G. Gallely, C.F. Forster, D.A. Stafford (1977). Although much had, at the time, been written on eutrophication of lakes and reservoirs, information on the problem in rivers had not been collected together. Preparing the chapter was linked with the research on *Cladophora* (11 & 12).

List of Publications by H A Hawkes on the Ecology of River Pollution and Biological Surveillance presented in the Thesis

1. Hawkes, H.A. 1955, The biological assessment of pollution in Birmingham streams, J.Inst.Munic.Engrs., 82, 452-63

2. Hawkes, H.A., 1963. Effects of domestic and industrial discharges on the ecology of riffles in Midland streams. Int.J.Air.Wat.Poll. 7, 565-83

3. Hawkes, H.A. 1964. An ecological basis for the biological assessment of river pollution. Chem, and Ind., 437-42

4. Hawkes, H.A. and Davies, L.J. 1971. Some effects of organic enrichment on benthic invertebrate communities in stream riffles. British Ecological Society. Int. Symposium, Norwich, 1970. The Scientific Management of Animal and Plant Communities for Conservation, Blackwell, 271-293.

5. Davies, L.J. and Hawkes, H.A., 1981. Some effects of organic pollution on the distribution and seasonal incidence of Chironomidae in riffles in the River Cole. Freshwater Biol. 11, 549-559.

6. Hawkes, H.A. 1978. River-bed Animal - tell-tales of pollution. In "Biological Surveillance of River Quality". Eds. H.A. Hawkes and J.G. Hughes. Proc.Sec. K., British Assoc. Adv. Sc., Aston 1977, 55-78

7. Grant, I.F. And Hawkes, H.A. 1977. Apparatus for creating controlled diel oxygen regimes for experiments with aquatic macroinvertebrates. Laboratory Practice, Vol.26, No.6, pp. 473-475

8. Grant, I.F. and Hawkes, H.A. 1982. The effects of diel oxygen fluctuations on the survival of the freshwater shrimp (*Gammarus pulex*), Environ.Pollut. (Series A). 28, 53-66.

9. Watton, A.J. and Hawkes, H.A. 1984. Studies on the effects of sewage effluent on gastropod populations in experimental streams. Wat. Res., 18, 1235-1247

10. Watton, A.J. and Hawkes, H.A. 1984. The acute toxicity of ammonia and copper to the gastropod *Potamopyrgus jenkinsi* (Smith). Environ. Pollut. (Series A), 36, 17-29

11. Pitcairn, Carole E.R. and Hawkes, H.A. 1973. The role of phosphorus in the growth of *Cladophora*. Wat.Res. 7, 159-171

12. Robinson, P.K. and Hawkes H.A., 1986. Studies on the growth of *Cladophora glomerata* in laboratory continuous flow culture. Br.phycol. J. 21, 437-444

13. Hawkes, H.A. 1974. Water Quality - biological considerations. Chem. and Ind., Dec., 990-1000

14. Girton, C. and Hawkes, H.A. 1979. The use of invertebrate colonisation samplers in the biological surveillance of river water quality. Paper presented to the 1979 Autumn Meetings of the Institute of Water Engineers and Scientists at London and Leeds 1-31.

15. Watton, A.J. and Hawkes, H.A. 1984. The performance of an invertebrate colonisation sampler (S.Auf.U.) in biological surveillance of lowland rivers. In "Freshwater Biological Monitoring" Eds., D. Pascoe and R.W. Edwards, Pergamon Press, Oxford, 15-24.

16. Hawkes, H.A. 1979. Water quality issues - an ecological reaction. Chem. and Ind. March, 201-204.

17. Hawkes, H.A. 1981. Biological surveillance of rivers in relation to fisheries - potential and limitations. Proc. 2nd Brit. Freshw.Conf. 1981, Liverpool.

18. Hawkes, H.A. 1982. Biological surveillance of rivers. Wat.Pollut.Control. 81, 3 329-342

19. De Pauw, N. and Hawkes, H.A. 1993. Biological monitoring of river quality. Proceedings of the Freshwater Europe Symposium, Aston University, Birmingham. 87-111

20. Walley, W.J. Hawkes, H.A. and Boyd, M. 1992. Application of Bayesian inference to river water quality surveillance. Proceedings of the Seventh International Conference on the Application of Artificial Intelligence in Engineering, Waterloo, Canada. 1033- 1047, Elsevier

21. Ruck, B.M., Walley, W.J. and Hawkes, H.A. 1993. Biological classification of river water quality using neural networks. Proceedings of the Eighth International Conference of Artificial Intelligence in Engineering, Toulouse, France

22. Walley, W.J. and Hawkes, H.A. 1996. A computer-based reappraisal of the Biological Monitoring Working Party scores using data from the 1990 river quality survey of England and Wales. Wat.Res. 30, (9), 2086-2094

23. Walley, W.J. and Hawkes, H.A. 1997, A computer-based development of the Biological Monitoring Working Party score system incorporating abundance rating, site type and indicator value. Wat.Res. 31, (2), 201-210

24. Hawkes, H.A. 1998.Origin and development of the Biological Monitoring Working Party score system, Technical Note, Wat.Res. 32 (3), 964-968

CHAPTERS IN BOOKS

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STATEMENTS ON CONTRIBUTIONS TO JOINT PUBLICATIONS

The Ecology of River Pollution and Biological Surveillance

4 & 5 L.J. Davies was a NERC Research Student. He continued my work on stream riffles under my supervision. After initial training in sampling and identification he carried out the agreed programme of research. He was the first worker to use the "Aston Cylinder" quantitative sampler which I had constructed in the departmental workshop. My role was of supervisor steering him to investigations which whilst relevant to his work were also of interest to my longer term studies, e.g. the effects of the diel oxygen pattern on the distribution of invertebrate species. He obtained his PhD on this and other experimental work.

7 & 8 I.F. Grant was a University sponsored Research Student. I supervised him and encouraged him to look at the effect of diel oxygen fluctuations experimentally. The apparatus described in this paper was a modification of one I had developed with the earlier student Davies and described in Publication 6.

9 A.J.Watton was another Research Student supported on my DoE Research Contract. After initial guidance he carried out the laboratory toxicity studies on his own.

10. The experimental streams had been designed by me for earlier studies and I directed the student to make use of them for his population studies on gastropods which I was aware were present. He carried out the tedious work of sorting and measuring and of processing the results.

11 Carole, E.R. Pitcairn was a Research Fellow supported on a Nuffield Foundation Grant I had obtained to work on Eutrophication. The concept of the project was therefore mine, based on my earlier observations. Her PhD was in terrestrial plant ecology and I had to initiate her in the methods of freshwater ecology and aquatic culture techniques. After this however, as a Research Fellow, she carried out the agreed research programme of field and laboratory studies with minimum supervision from me. She prepared the paper and presented it.

12 P.K. Robinson was a Research Student in my Section whose supervisor took early retirement. I took over his supervision and redirected the project. The student responded and with the minimum of help he successfully developed the technique.

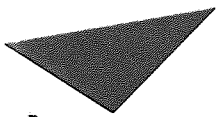
14. C.Girton was a research student supported on my DoE Research Contract. As Contract Supervisor I was involved in the day to day work with the student. After designing the programme and selecting river sites much of the routine sampling was carried out by the student assisted by the technician. The sorting and identification was carried out by the student and technician. I was involved in the processing of the data, interpretation and preparation of contract reports.

15 This was a continuation of the survey work started with Girton. The student processed the results statistically. Based on these results I wrote the paper for a conference.

19 As a member of the organising committee of the symposium, I was asked to write this paper when the original author withdrew at the last moment. Knowing that Prof. De Pauw was an authority on Biological Monitoring methods used in mainland Europe, I approached him for information on methods used in the different E.C. countries. As he contributed such a major contribution, we agreed on joint authorship. His contribution was The Experiences of the European Community p.97-103, I contributed the remainder including The British Experiences.

20 & 21 In the A.I. work, reported in these papers, I only acted as the "domain expert", providing information and interpreting data sets. I was more the investigated than an investigator!

22 & 23 In these two papers the mathematical processing of the data to reappraise and develop the BMWP Score was carried out by W.J. Walley. My contribution was to provide an ecological explanation of the differences in the scores and suggest possible modifications to be investigated.



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