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Classification models and water resource planning

K R BULL
Institute of Terrestrial Ecology, Monks Wood Experimental Station, Huntingdon

1 Introduction

The first question to be answered in the process of environmental planning is — what is there now (Bunce & Heal 1984)? We need an environmental description to provide a baseline or reference scale upon which measurements or judgements may be made. There is seldom a clear answer to any environmental question, and often there are conflicting interests to confuse the situation further. It is very important, therefore, to make the description as objective as possible. We have chosen water catchment areas as our units of description as the first step in this process.

River and lake catchments are frequently used as convenient units, both for scientific studies and for managing water resources. They ideally represent separate hydrological systems fed by identifiable sources (eg rainwater, springs) with identifiable sinks (eg the lake or river, evaporation, underground aquifers). Catchment areas can also be quantified using contour maps.

Rivers (and lakes) may differ considerably from one another in their hydrology, chemistry and biology; such differences may alter seasonally or even from day to day or hour to hour, as a consequence of a multitude of environmental factors. How, then, can we assess a set of catchments and obtain a meaningful baseline?

Total environment sampling of all catchments at all points in time is a practical impossibility, and even large numbers of on-site investigations, including chemical and biological sampling, are costly and wasteful of resources. *Random sampling*, although a valid statistical exercise, can only provide answers based on the whole population of water catchments. We may end up with a lot of information about the 'average catchment', which is of little use when answering specific questions. *Selective sampling* is an option frequently chosen, basing the selection upon 'expert choice or judgements'. Such samples are difficult to relate to the wider population, are open to criticisms of judgement, and may overlook important factors or relevant catchments. A *stratified sampling* approach is the only really effective way to answer the problem. This method creates a series of catchment 'strata', analogous to the social strata which have been employed so effectively for opinion polls and in consumer research. By this means, individual groups or strata can be assessed, either totally or by subsampling, without the need to sample the whole population in detail; however, any catchments assessed are done so in the context of a defined framework of catchment strata and environment parameters.

2 The classification

The methods have been developed from those used extensively by ITE for land use surveys, in Cumbria (Bunce & Smith 1978), Scotland (Bunce & Last 1981) and Great Britain (Bunce & Heal 1984).

The classification so far has focused upon nearly 90 river catchments which have been, or are being, sampled by the North West Water Authority as part of its investigations into the effects of acid precipitation on fresh waters (Crawshaw 1984; Prigg 1983). Although these catchments had the disadvantage that they had been chosen selectively, the availability of chemical and biological data was an important factor for this initial investigation.

The data base for the classification was confined to maps which give uniform coverage throughout England and Wales. Ordnance Survey maps (1:25 000) provided most of the topographic information, and British Geological Survey solid geology maps (1:250 000) and Soil Survey of England and Wales soil maps (1:250 000) were used for catchment geologies and soils. Meteorological Office rainfall maps provided rainfall data.

Our data base yielded a total of 105 descriptive attributes for our catchments. These attributes were assigned to each catchment in turn, and the resulting sets subjected to Indicator Species Analysis (ISA) (Hill *et al.* 1975). Further computations using Reciprocal Averaging Analysis (Hill 1973) gave additional information for comparison with the ISA results,and have been used to help verify ISA results in previous studies (Jones & Bunce 1985; Charter 1984).

The available chemical and biological data were used to verify the ISA classification, and the chemical data were also used as the basis for a separate ISA classification, both on their own, and also together with the other 105 attributes.

3 Catchments in Eskdale and Dunnerdale

The Rivers Esk and Duddon have been studied extensively in recent years owing to the concern over poor fish stocks and occasional fish kills (Crawshaw 1985). Chemical and biological information exists for 40 tributaries which drain about 70% of the total catchments of the 2 rivers. These tributaries formed the data set for our first ISA.

The ISA divided the catchments into 2 sets on the basis of 'upland' and 'lowland' character. Although apparently an obvious separation in hindsight, it has been achieved without subjective judgements, and it is particularly important as it reflects the chemical and biological differences of the 2 stream types. For example, all 10 tributaries with low mean Ca concentration (<2 mg l^{-1}) are found in the 'upland' catchments; and, whilst 75% of 'lowland' catchments have stone fly larvae present, only 12.5% of the 'upland' ones have records of this species.

An important observation from the analysis is the difference in character between the Esk and Duddon tributaries: there are more Esk tributaries in the 'lowland' class, whilst Esk streams are greatly outnumbered in the 'upland' class.

4 Other catchments in north-west England

Extending the model further to include catchments outside the Esk and Duddon gives a different ISA separation. The initial separation is one of size, and it is clear that most Esk and Duddon tributaries drain 'small' catchments, in contrast to the streams sampled outside Eskdale and Dunnerdale, which are mainly 'large' catchments. The subsequent classification of the 'small' catchments is similar to the 'upland'/'lowland' separation described above, most of the Esk and Duddon tributaries being distributed between the 2 classes, as before.

Chemical and biological data indicate that 'large' catchment streams are generally similar to 'lowland' streams. It is not surprising, therefore, that the ISA classification of chemical data separates 'small upland' catchments from the rest, with low Ca and alkalinity levels and high acidities and aluminium concentrations. Combining chemical and physical attributes adds little to the main divisions of the analysis.

Further extending the model to include an additional 15 catchments, many of them with different geologies from the southern Pennines, resulted in a separate geological class in the large catchment group consisting almost entirely of the new catchments. This geological feature, sedimentary bedrock, in contrast to the mainly igneous geology of the previous 72 catchments, is therefore a 'strong' indicator in the analysis. It is also likely to be an important factor in the chemistry and biology of the streams draining these catchments.

5 Discussion

Our main aim in this work was to combine the practical usefulness of water catchments with the proven analytical models previously used for land classification studies.

The divisions often appear obvious and predictable but they have been derived without subjective judgements. Furthermore, whilst it is easy to recognize extremes within any set, individuals form a continuum across the range so that intermediate types are not easily characterized. A small set of catchments may provide a simple classification model, with little need for a computer, but larger data sets, with their widely differing characteristics, increase the necessity for a good computer model.

We believe that models such as ours have great potential for future applications in assessing current resources and in the subsequent planning and monitoring of change. Our models, to date, are relatively simple with few catchments from a very large population, but the model is flexible, and more catchments may be added, as we have done, or additional data bases used to include additional attributes. Conversely, particular data sets may be selected for separate analysis to answer specific questions.

The ISA classification has the advantage of identifying important attributes, which may be used to classify individual catchments not included in the analysis, and may provide pointers for future investigations. Once the classification framework has been identified, it is much easier to attempt comparisons between catchments (eg 'twinning') or to identify changes with time. Differences and changes can also be seen within the context of the entire model and related to the population being studied.

An important aspect of classification models is their sensitivity to changes in attributes. We know that increasing the range of catchments changes the classification, and our analysis shows that our model is sensitive to sedimentary geology. We also know that some attributes may be omitted with little effect on the classification. The opportunity for such alterations in the classifications may have great importance for planners, and provides a predictive capability which may be a valuable decision-making tool.

The great advantage of our method is that, once set up, the model can be used and amended without the need for a great deal of expert support. It can thus provide a convenient resource base for those needing to quantify the environmental description of water catchments in space and time.

6 References

Bunce, R.G.H. & Heal, O.W. 1984. Landscape evaluation and the impact of changing land-use on the rural environment: the problem and an approach. In: *Planning and ecology*, edited by R.D. Roberts & T.M. Roberts, 154-188. London: Chapman & Hall.

Bunce, R.G.H. & Last, F.T. 1981. How to characterize the habitats of Scotland. *Annu. Rep. Edinburgh Cent. Rural Econ. 1980/81,* 1-14.

Bunce, R.G.H. & Smith,R. S. 1978. *An ecological survey of Cumbria.* Kendal: Cumbria County Council and Lake District Special Planning Board.

Charter, E. 1984. *A survey, classification and evaluation of small open waters in Cumbria.* MSc thesis, University College, London.

Crawshaw, D.H. 1984. *The effect of acid run off on the chemistry of streams in Cumbria.* (Report no. TSN 84/3.) Warrington: North West Water Authority.

Hill, M.O. 1973. Reciprocal averaging: an eigenvector method of ordination. *J. Ecol.,* **61**, 237-249.

Hill, M.O., Bunce, R.G.H. & Shaw, M.W. 1975. Indicator species analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. *J. Ecol.,* **63**, 597-614.

Jones, H.E. & Bunce, R.G.H. 1985. A preliminary classification of the climate of Europe from temperature and precipitation records. *J. environ. Manage.,* **20**, 17-29.

Prigg, R.F. 1983. *Juvenile salmonid populations and biological quality of upland streams in Cumbria with particular reference to low pH effects.* (Report no. BN 77-2-83.) Carlisle: North West Water Authority.