Exploring the realized niche: simulated ecological mapping with a microcomputer

J. W. Kent

Introduction

The majority of educational programs for A-level Biology that are currently available rely mainly upon monochrome displays with little use of graphics other than to produce graphs, histograms, or maybe diagrams of organisms. Now that the Research Machines 480-Z has been joined by the BBC Micro and the Sinclair Spectrum in the DoI scheme for Micros in Schools (Kewney, G., 1982), the availability of such machines that allow the production of user-defined graphics characters displayed simultaneously in a variety of colours presents the opportunity to represent more of the complexity of biological situations than was previously possible. This facility, together with the ability to reduce considerably the duration of an experiment and to explore situations that might otherwise be hazardous to experimenter, apparatus, or live material makes computer simulation much more valuable as a teaching aid.

Field background

The field observations at Gore Point, Somerset, upon which this simulation is based, are described and discussed in a previous paper (Wilson, Crothers, and Oldham, 1983). The essential feature is that the usual zonation patterns of certain species on the shore are disrupted by the flow of fresh water down the beach from a small Exmoor stream. The matrices of values obtained using a series of parallel horizontal transects can be plotted as maps to reveal a relationship between salinity and species distribution (figures 3 to 6 in Wilson *et al.*; figure 1). In particular, low salinity at low water appears to prevent successful predation of mussels by dogwhelks, and grazing of a green alga (*Enteromorpha* sp.) by herbivores (topshells). This leads to the development of patches of green alga and mussels in and around the stream at the top of the shore. Away from the stream and high water mark, predation occurs and these two species are unable to become successfully established. The distribution pattern of the red alga *Corallina* reflects that of saline rock pools away from the influence of the stream. This is typical of those species which have poor tolerance of both high insolation or desiccation and further reduction in salinity of the estuarine water.

The conventional pattern on the shore is for most species to occur in wider or narrower bands parallel to mean sea level. The precise location of each band between high water mark and low water mark is largely dependent upon exposure of the organisms to rough weather (Ballantine, 1961; Jones, 1959; and Lewis, 1964). Changes in exposure are reflected by movement of the bands up or down the beach, with displacement of one species by another under extreme conditions.

In very general terms, the effect of any stream on littoral zonation may depend upon its width, the bank height, the speed and volume of fresh water flow, and the presence of suspended matter. These in turn will influence other factors such as salinity, turbidity, density, desiccation, temperature, and the supply of organic matter, which are of varying importance to the survival of different organisms on the shore. At Gore Point, however, the stream is narrow with no banks and has only a moderate rate of flow.

Some further important factors, such as rainfall, insolation, latitude, and temperature and tidal ranges, are independent of flow and exposure. However, it was not found possible to investigate more than the five species and two main factors mentioned above, as little more than 2.5 k of RAM is available in the four colour mode (Mode 5) of the BBC model A computer.

Abstract

A microcomputer program based upon field observations of littoral zonation modified by a small stream (Wilson, Crothers, and Oldham, 1983) is described which employs user-defined graphics characters in colour to display simulated ecological maps representing the patterning of organisms in response to local values of niche limiting factors. Interaction between predator and prey, trophic levels, and randomness in distribution are all clearly shown. An alternative display gives the distribution pattern of any one species superimposed on a matrix of local values for any of the environmental factors involved. The maps and plots produced represent possible real situations that could develop and hence suggest biologically significant implications without the tedium of data collection and manipulation, and also allow speculation.

Computer simulation

Initially it was hoped to produce a mathematical model which accurately reproduced individual species

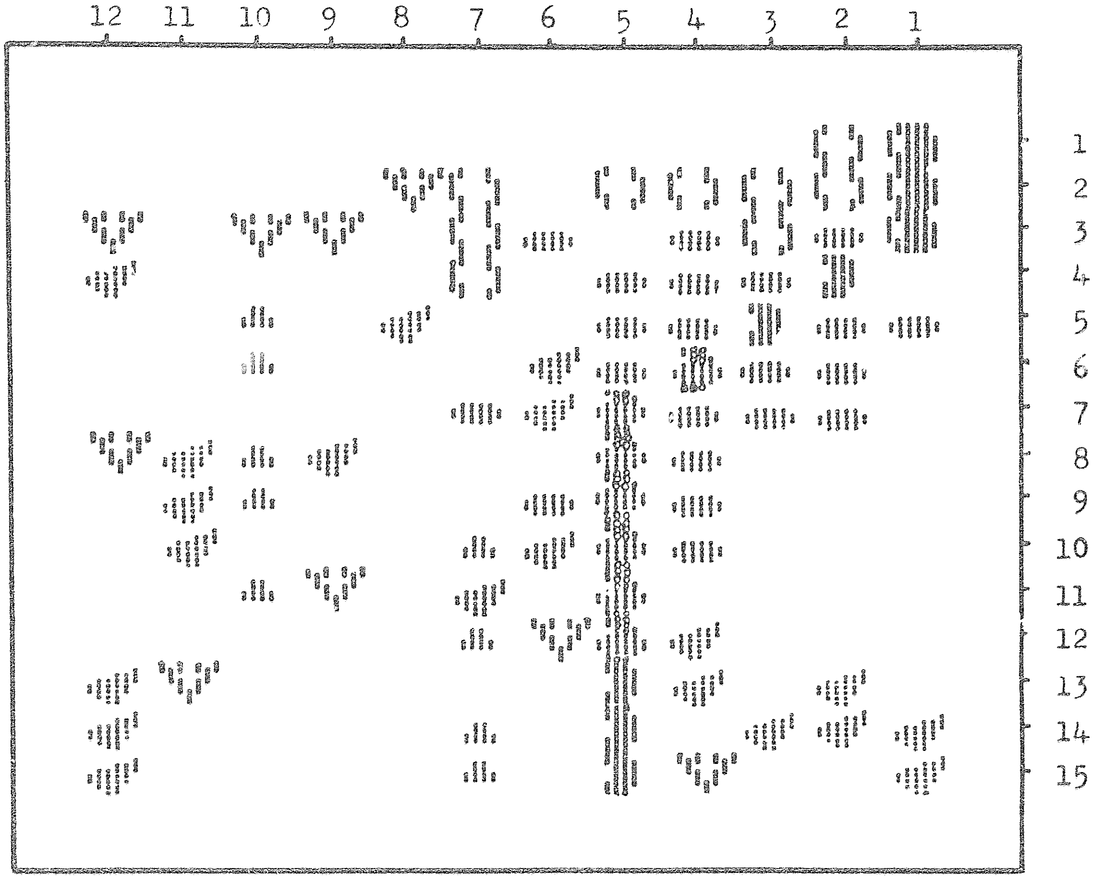

Figure 1 Map of species distribution at Gore Point derived from a typical set of students' observations. Figures indicate sample positions at 5 m intervals starting from the stream centre at High Water Mark. Symbols indicate the presence of a high density of individuals to avoid superimpositions; records of *Enteromorpha* have been omitted from points 2,3 and 3,4 for the same reason. See figure 2 for identities of symbols.

behaviour, but it soon became clear that the data available were insufficiently detailed to yield precise numerical relationships between the values for environmental factors and the responses of the various organisms. Instead, it was decided to develop a program that produced displays which were qualitatively compatible with the observed distribution patterns. The maximum and minimum for each factor were set at 9 and 0 (as used by Wilson *et al.* for conductivity), and the formulae were adjusted empirically to give an even spread of values. This simplification facilitated programming the comparison with the preset physiological limits and the presentation of the matrices for single factors, and also gave wider scope for subsequent interpretation in general terms. Any precise relationship between these scales and real field values could be established subsequently if required.

A screen display produced by the BBC computer operating in Mode 5 is 32 lines of 20 contiguous character fields with a maximum of four colours (including black) on the screen at once. This resolution is comparable to realistic ecological sampling rates and is also sufficient for the production of simulated schematic species distribution maps, such as might be produced from point quadrat data. To reduce the time required for each plotting run and to provide space for information and messages, the upper six lines of the display are used to represent the beach above HWM while the lowest line indicates LWM. Although the field data were collected only to the east of the stream, the display is symmetric with the stream in the centre to emphasize the local nature of the disruption of zonation.

After defining the shapes and colours (algae: primary producer—green; topshells and mussels: herbivore—magenta; dogwhelks: carnivore—red) of the species (figure 2), upper beach (red), and central stream (green), the current values of flow and exposure are supplied from the keyboard. It was intended that these factors should be expressed on arbitrary non-linear 10 point integer scales (0–9) for convenience but it was subsequently found that any non-negative decimal value is accepted. These can then be used to calculate the rate of spread of fresh water as the stream flows down the shore, and the effect of exposure in wetting the upper shore with spray. The interval between ebb and flood tides (uncover) is estimated separately with no allowance for spring or neap tides. Note that the exposure scale follows that of Jones (0 = calm) rather than that of Ballantine.

As the map area is scanned, the above calculations are made for each of the 25 rows and the results are used to estimate the local exposure to salinity for each of the 20 cells in each row. The local values for exposure, uncover, and salinity are compared with preset upper and lower physiological limits for each species. If any of the three values fall outside the tolerance range, then that species cannot occur in that cell. The possible occurrence of a predator also precludes the presence of prey there, since dogwhelks can migrate, albeit rather slowly (Crothers, personal communication) and attack all the sedentary mussels unless prevented by low salinity. Similarly, the form of the *Enteromorpha* pattern reflects the limitation imposed on topshell activity by low salinity and becomes patchy away from HWM.

Other observed features have also been incorpo-

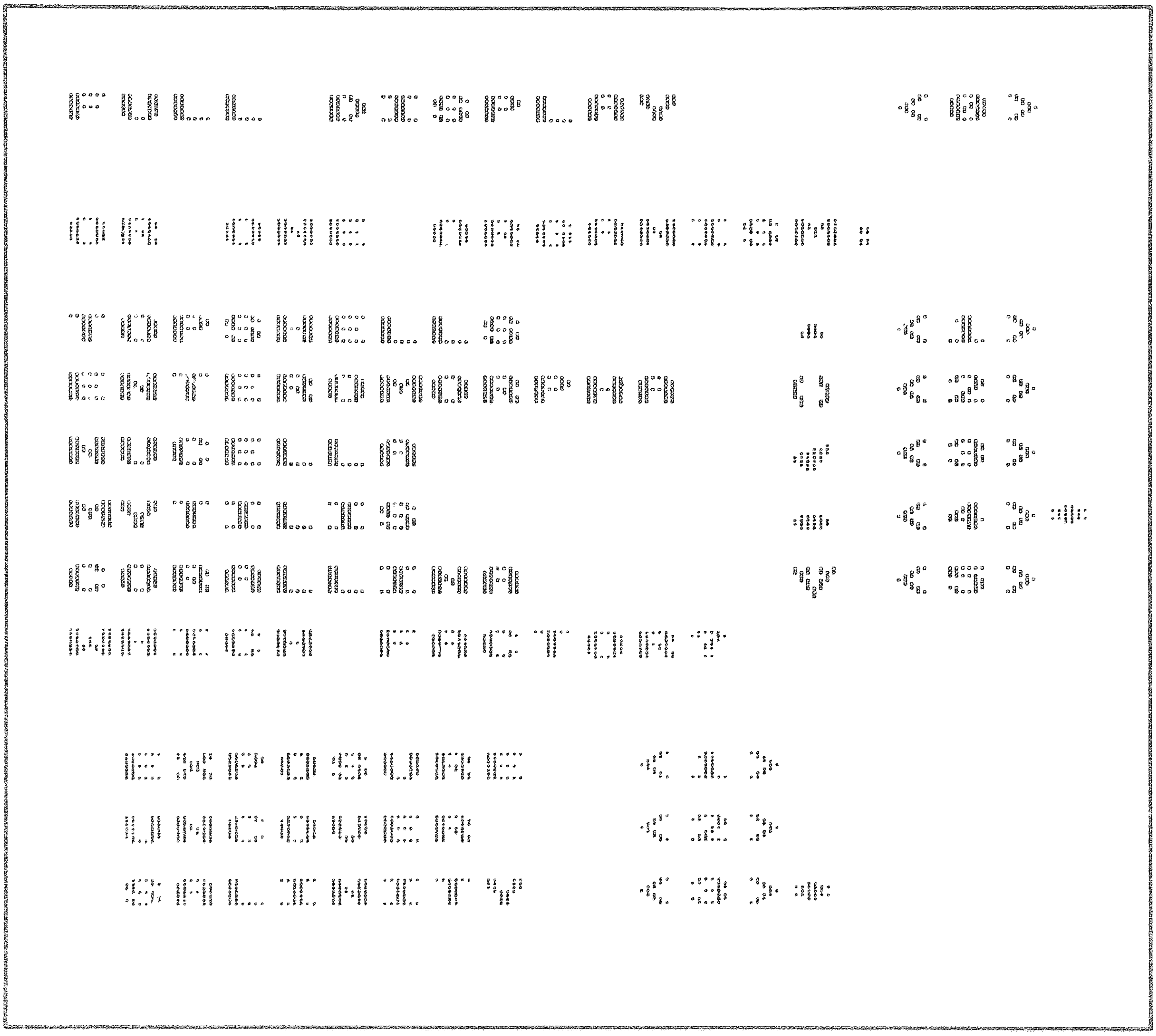

Figure 2 Print of screen display: initial options available. On the screen the options and symbols for *Enteromorpha* and *Corallina* would be in green, the dogwhelk (*Nucella*) symbol would be red, and the remainder would be magenta. Asterisks indicate that a display of *Mytilis* (*mussel*) over salinity matrix has been selected. See figure 4.

rated. Topshells are more common at the top of the shore, *Corallina* is more common in midshore rock pools, while dogwhelks are more common near LWM. The density of these is such that none is found at every sample point, so their patterns are generated using random functions. These have the useful effect of producing different but compatible distributions each time the display for the same values of flow and exposure is produced. Conversely, the longevity and sedentary nature of mussels means that they are found wherever the three environmental factors and potential presence of dogwhelks do not prevent it. Finally, since superimposition of symbols can lead to a confusing picture, the only combinations allowed are mussels or dogwhelks over *Enteromorpha*, and in deciding which animal to plot in any cell, the rarer predator (topshell) is considered first and the commoner prey (mussel) last. Figure 3 shows a typical display resembling the observed pattern at Gore Point.

At the beginning of the program, the user is given the choice of seeing a full display, as described above, or a single species displayed over a background of local values for one of the three controlling factors (figure 4). In this case each cell contains an integer representing the local value for the factor selected plotted in a contrasting colour to the chosen species which is then superimposed if the factors and probability allow. The figure may be read in the 30 or so milliseconds before the species symbol is added, and the value can still be discerned after superimposition when comparison is made with adjacent cells lacking an organism as each factor has a characteristic pattern.

During the mapping phase, the user may skip to the end of the display from any line and then has the choice of repeating the display, setting new conditions, or leaving the program. Repetition is useful because the random patterns and numbers of individuals are

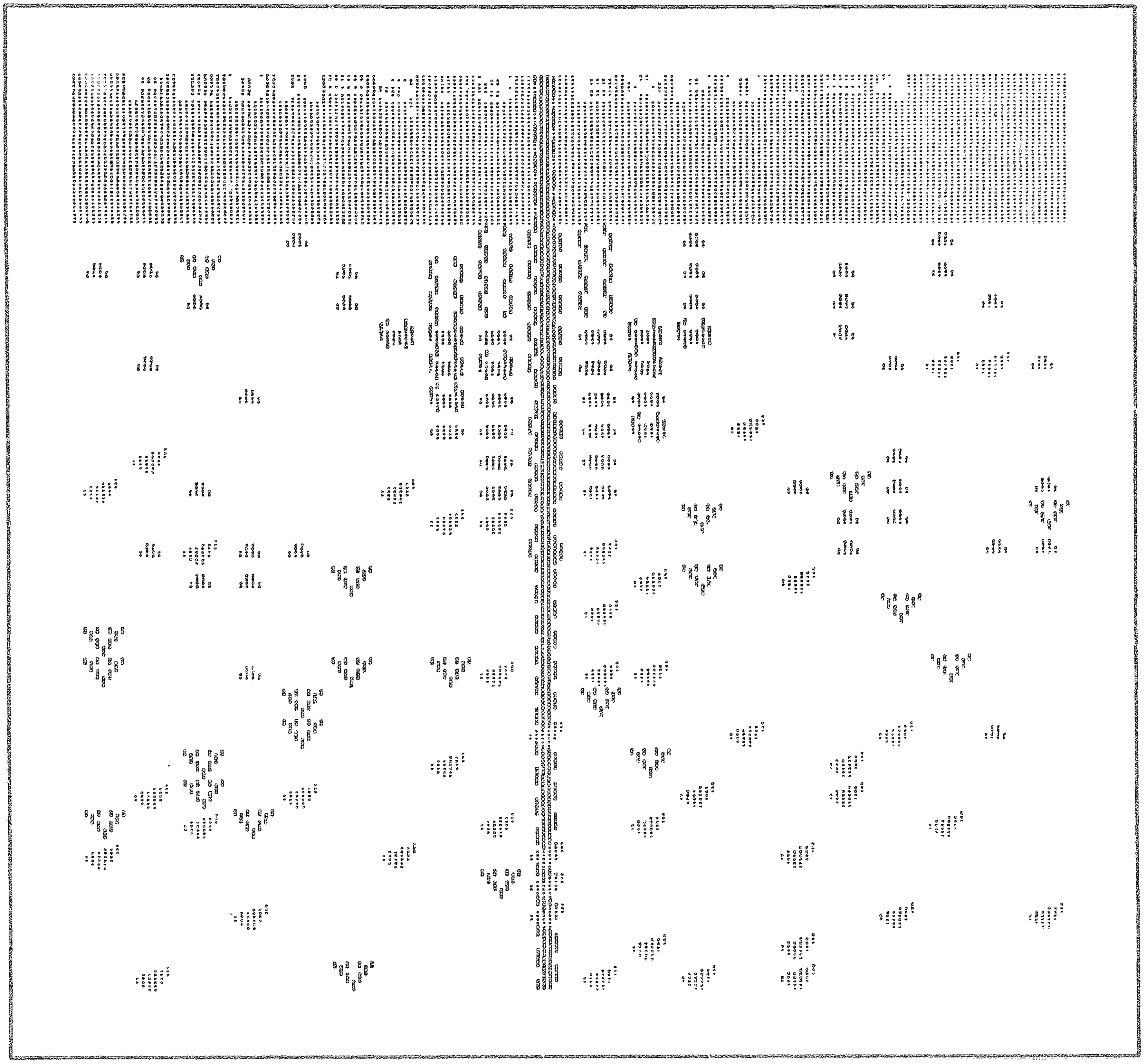

Figure 3 Print of screen display: full display of shore showing species distributions for a stream flow rate of 5.3 and an exposure of 4. On the screen, the upper beach would be red, the text black and the central stream green. Colours of other symbols would be as given for figure 2.

different each time, giving the illusion of repeated sampling in a stable environment, for example in successive years or by successive investigators.

Program notes

A segment of the program dealing with symbol display for every cell of shore is illustrated in figure 5. It should be noted that BBC Basic allows certain liberties to be taken that permit the packing of the program into a smaller space. In particular, LET and THEN may be omitted, the values of TRUE (−1) and FALSE (0) may be used in arithmetic expressions, line numbers are not required between the delimiters of the ON ... GO TO list if the variable never points to the missing positions, and NEXT need not be followed by the appropriate loop variable.

The definition of graphics characters and the control of colour display are generally computer specific, so will not be described here. The operations at each particular line number are:

260 keep tally of current cell position
275 calculate salinity
280 set uncover in stream delta
285 print current value if one factor display selected
290, 315, 410, 550 branch to next step according to display selected
295 skip topshell symbol print if algal display selected
300 set probability for topshell presence
305 set topshell probability flag
310 print topshell symbol if conditions and probability permit
320 branch according to whether topshell excluded, possible or printed

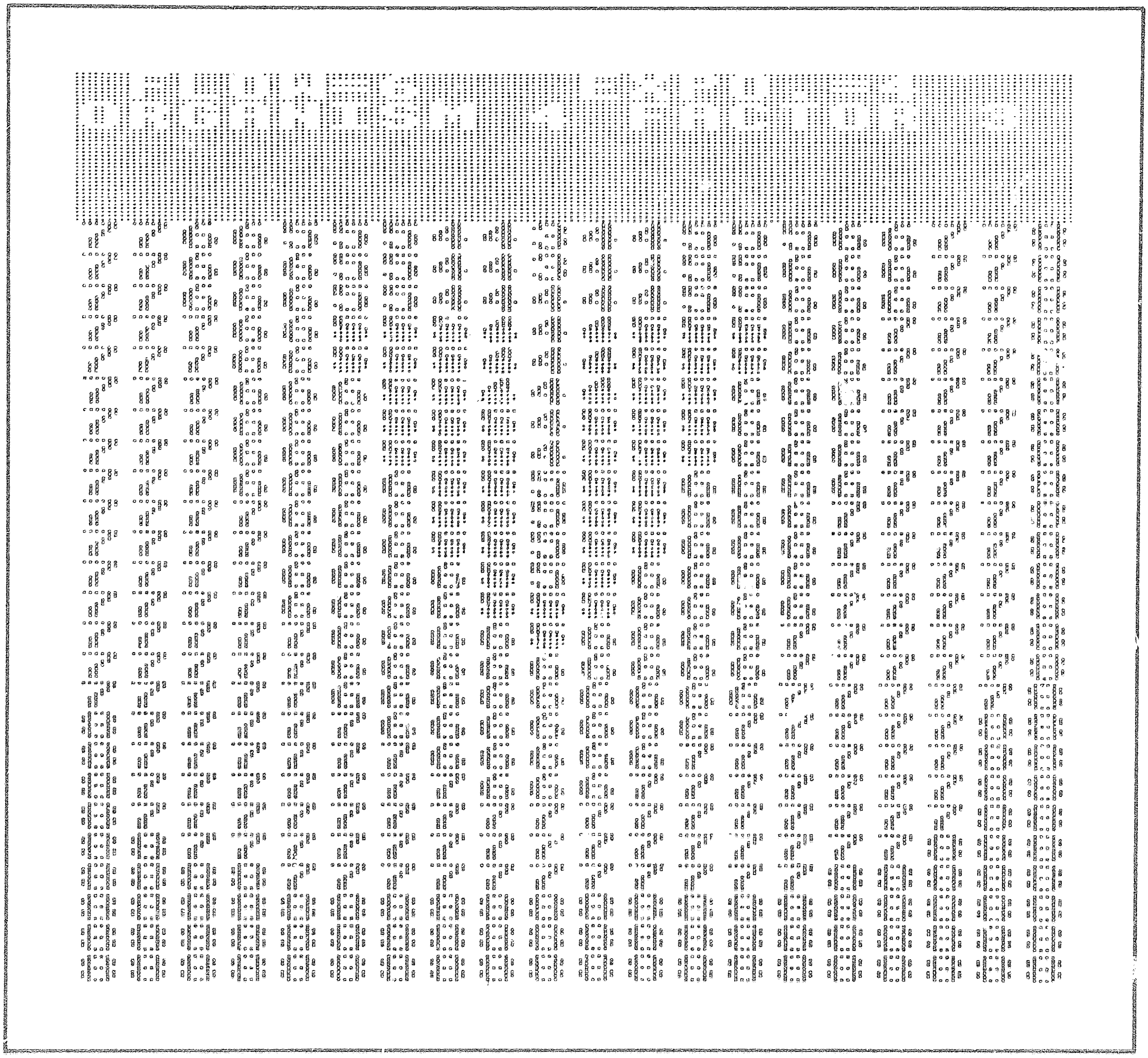

Figure 4 Print of screen display: distribution pattern of mussels with respect to salinity (organism 4 and factor 3—see figure 2) for a stream flow rate of 6 and an exposure of 4. The mussels appear as a horse-shoe shaped bed at salinity values 4 and 5. On the screen the colours of upper beach, text and mussels would be as given in figures 2 and 3, and the matrix numerals would be green.

400 print *Enteromorpha* symbol if conditions and probability permit
450 skip dogwhelk symbol print if mussel display selected
500 set probability for dogwhelk presence
510 print dogwhelk symbol if conditions and probability permit
600 skip mussel if dogwhelk possible
610 set upper shore limit for mussels in stream
620 print mussel symbol if conditions and probability permit
630 skip *Corallina* print if other species already present
640 print *Corallina* symbol if conditions and probability permit
650 move on to next cell

PROCSPOT is a procedure dealing with the colour, symbol, and probability that an organism will occur. It checks factor values against the preset limits, increments LIN if presence is possible, and prints the appropriate symbol if the probability permits.

Further details of the simulation program may be obtained from the author, while a version of this and a related program for the BBC model B are published by Garland Computing, 35 Dean Hill, Plymouth.

Acknowledgements

Thanks are due to the staff at the Leonard Wills Field Centre for valuable discussions, to the Somerset College of Arts and Technology for the use of computing facilities, and to biology students there for consumer reaction.

```
260FOR J=0 TO 19
275E(2)=9-INT(F*UNC*(10-ABS(9-J))/90+.3*F):E(2)=E(2)*((E(2)<0)+1)
280IF ABS(J-9)<W E(1)=0 ELSE E(1)=UNC
285IF Q>1 GCOL0,2+(Q=3ORQ=6):PRINTTAB(J,I);INT(E(EF))CHR$8
290ON Q GOTO300,300,295,500,450,640
295P=2:GOTO305
300P=RND(I/1.5)
305IF P=1 LIN=2 ELSE LIN=1
310S=1:PROCSPOT(3,228,P)
315ON Q GOTO320,650,320
320ON LIN GOTO400,410,650
400S=4:PROCSPOT(2,229,1+INT(RND(I/5)+(I>9)))
410ON Q GOTO500,,650
450P=2:GOTO510
500P=RND(20-I/2.5)
510S=7:LIN=1:PROCSPOT(1,238,P)
550ON Q GOTO600,,,650,600
600IF LIN>1 GOTO630
610IF J=9 AND I-6<2*F E(1)=0 ELSE E(1)=UNC
620S=10:PROCSPOT(3,237,1)
630P=POINT(20+J*64,1001-I*32):IF P>0 GOTO650
640S=13:PROCSPOT(2,227,RND(3+ABS(I-20)/.25))
650NEXT
```

Figure 5 Segment of Gore Point simulation program that deals with the individual cell display. See text for details.

References

Ballantine, W. J. (1961) A biologically-defined exposure scale for the comparative description of rocky shores. *Field Studies*, **1** (3), 1–19.

Jones, W. E. (1959) The effects of exposure on the zonation of algae on Bardsey Island. *Rep. Bardsey Obs.* (Extract), 1–6.

Kewney, G. (1982) More micros for schools. *Personal Computer World*, **5** (9), 89–91.

Lewis, J. (1964) *The ecology of rocky shores*. English Universities Press.

Wilson, C. M., Crothers, J. H., and Oldham, J. H. (1983) Realized niche: the effects of a small stream on sea-shore distribution patterns. *Journal of Biological Education*, **17** (1), 51–58.

The author

J. W. Kent is a Lecturer in Biology in the Department of Humanities and Science, Somerset College of Arts and Technology, Taunton, Somerset TA1 5AX.