Reprinted from

URBAN ECOLOGY

The Second European
Ecological Symposium
Berlin 8–12 September 1980

Edited by
R. BORNKAMM, J. A. LEE and
M. R. D. SEAWARD

Blackwell Scientific Publications
Oxford London Edinburgh
Boston Melbourne
1982

11. SPECIES SIZE DISTRIBUTIONS OF BIRDS AND SNAILS IN AN URBAN AREA

S. H. COUSINS
Energy Research Group,
The Open University, Walton Hall,
Milton Keynes MK7 6AA, Buckinghamshire, U.K.

SUMMARY

Urban ecosystems are hypothesized to present a gradient of declining 'green' patch size towards the urban centre. Small bird species are predicted to survive in urban centres for that reason. Analysis of a London bird atlas shows that average species size per 100 km^2 does decline towards central London. No such relationship is found for land snails and it is suggested that water relations may determine the snails' survival. Trophic structure based on the size of feeder and food 'packet' size is affected by any factor influencing organism size. Human food wastage creates a subsidy of large food 'packets' favouring some larger bird species.

INTRODUCTION

We can suppose that for most species the environment in cities becomes more dissected by human activities and artifacts as one passes from the outskirts to the centre. So although we may not know the dimensions of the patches or 'habitat islands' perceived by different species, we can conclude that for most species (but not all) the 'habitat islands' will become smaller and more isolated towards the city centre. A simple inequality of this type can be a powerful tool with which to analyse the complex problem of ecosystem patchiness.

Schoener (1968) has shown for birds that the territory or area inhabited by a species is positively correlated with its body size. So if we predict that on average green patch size decreases with urbanization, then for birds we should expect the size of species to decline on average also.

Whereas for bird species recolonization of suitable habitats is a relatively simple process, for snails it appears a major problem. Once extinction occurs locally, recolonization may take a long time. Thus for this group of relatively immobile species fecundity might be expected to play an important role in lessening the chances of extinction. Small species have shorter generation times and high rates of reproduction (Fenchel 1974), so small species might be favoured at the city centre. However, large species move more quickly than small ones and would recolonize more rapidly although the rate of colonization must also be a function of species abundance. I shall examine the hypothesis that it is not the speed of recolonization but the reproductive effort that ensures survival in habitat patches perceived by snails. These patches might be expected to become smaller and more isolated near the city centre. So again I predict that smaller species will be favoured in central urban areas.

BIRD SPECIES SIZE IN LONDON

Data are taken from Montier (1977). Species breeding records were collected for each 2 × 2 km grid square and then aggregated to presence or absence of breeding species in each of 24 10 × 10 km contiguous grid squares covering the whole of London. A 25th grid square is included at the centre of the city, also of area 100 km^2. It overlaps the four central contiguous squares. The accuracy of these data relies on the evenness of observation over London. Montier confirms that there may have been some under-collection of data in North-east London although it should also be noted that the failure of ornithologists to visit an area may mean that it is genuinely species-poor. Figure 11.1 shows both the location of the study area and gives an index of observer effort. Units of the index are absence of breeding records per 2 km square for the ubiquitous species Starling, *Sturnus vulgaris* (Linne), Blackbird, *Turdus merula* (Linne) and Songthrush, *T.philomelos* (Brehm). Data from square 4 (Fig. 11.1) were omitted from further analysis due to the low level of observer effort identified by this method.

Of all the bird species found breeding in London, only land birds are considered here. Different groups of land birds, such as resident species or migrants, are also compared. The single species distributions from Montier (1977) were used to produce composite maps showing the number of species present per 10 km square or some attribute of that collection such as average species weight. Note that average species weight applies to the mean of the weights of a collection of species, and does not reflect the abundance of those species other than their presence or absence. Weight data are from Cousins (1976). Figures 11.2–11.6 were obtained using the SYMAP programme (Dudnik 1972). SYMAP is an interpolative contour mapping programme and the values of the contours are given on each map. Habitat data used here are derived from the records of the London Natural History Society (Sandford 1972, 1975, 1977, 1979) for rainfall, built environment, soils and sulphur dioxide pollution, respectively. All correlations given are Spearman's rank coefficients.

London conforms to the general model of an urban environment, set up by Erz (1966), of concentric rings of habitat; the outermost ring is semi-natural

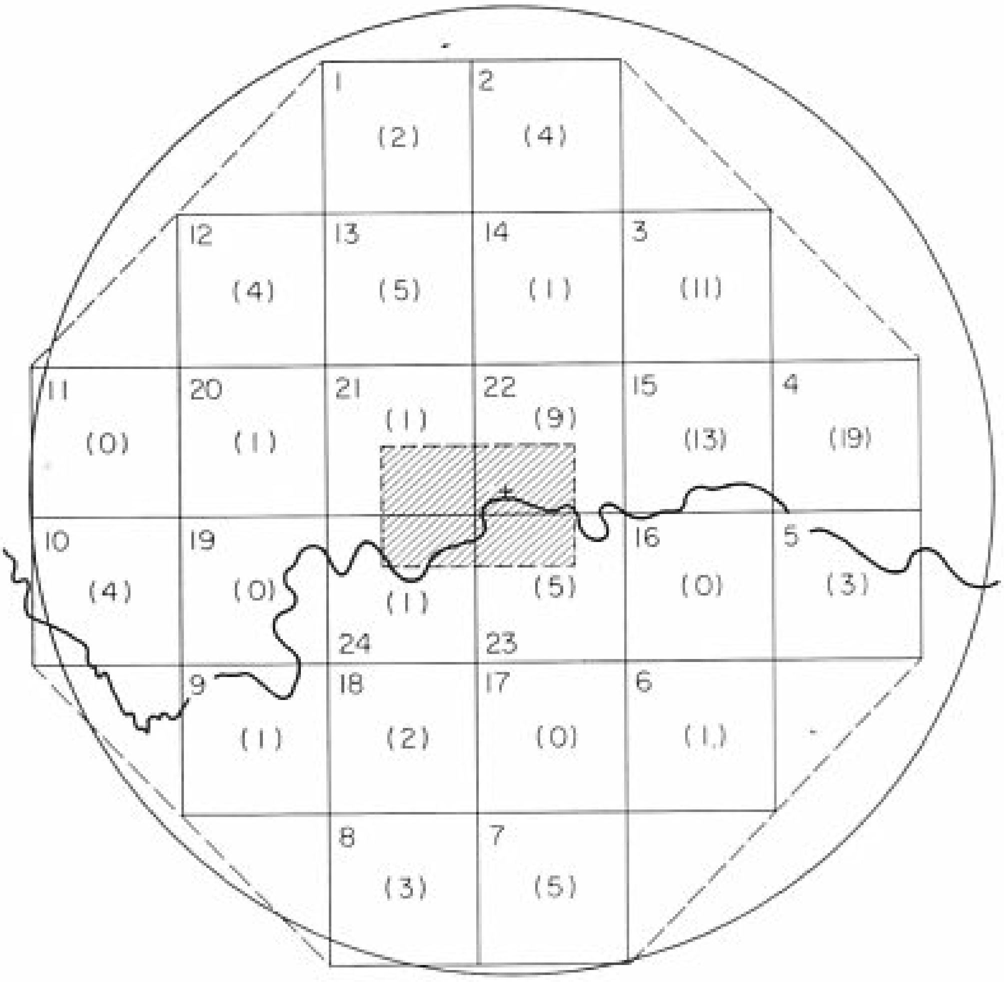

FIG. 11.1. The study zone of 24 10 × 10 km grid squares and central rectangle is shown within a radius of 32.5 km (20 miles) of St Paul's Cathedral marked by cross. In Figures 11.2–11.6 data are interpolated to the hatched lines. The river Thames is shown. Figures in brackets are an index of observer effort and indicate the number of absent records of three common breeding bird species in 25 4 km^2 plots of each 100 km^2.

with a predominance of vegetation leading through dwelling areas to the city centre itself with high-rise close standing buildings and little plant life. Figure 11.2 shows the roughly concentric distribution of an index of London's built environment. For this index Sandford's (1975) land-use classification of each 2 km square was adopted and scored 1.5 for 'settlements without gardens', 1.0 for 'settlements with gardens', and 0.0 if settlements were not the predominant land use. These values were summed for each 10 km square.

The concentric distribution of land bird species density, Figure 11.3, can be seen clearly. The maximum species density of 77 breeding species per 10 km square in outer London was compared to 43 species in the central 10 km square. Species density was negatively correlated with the built environment index at −0.90 significant at $P = 0.001$.

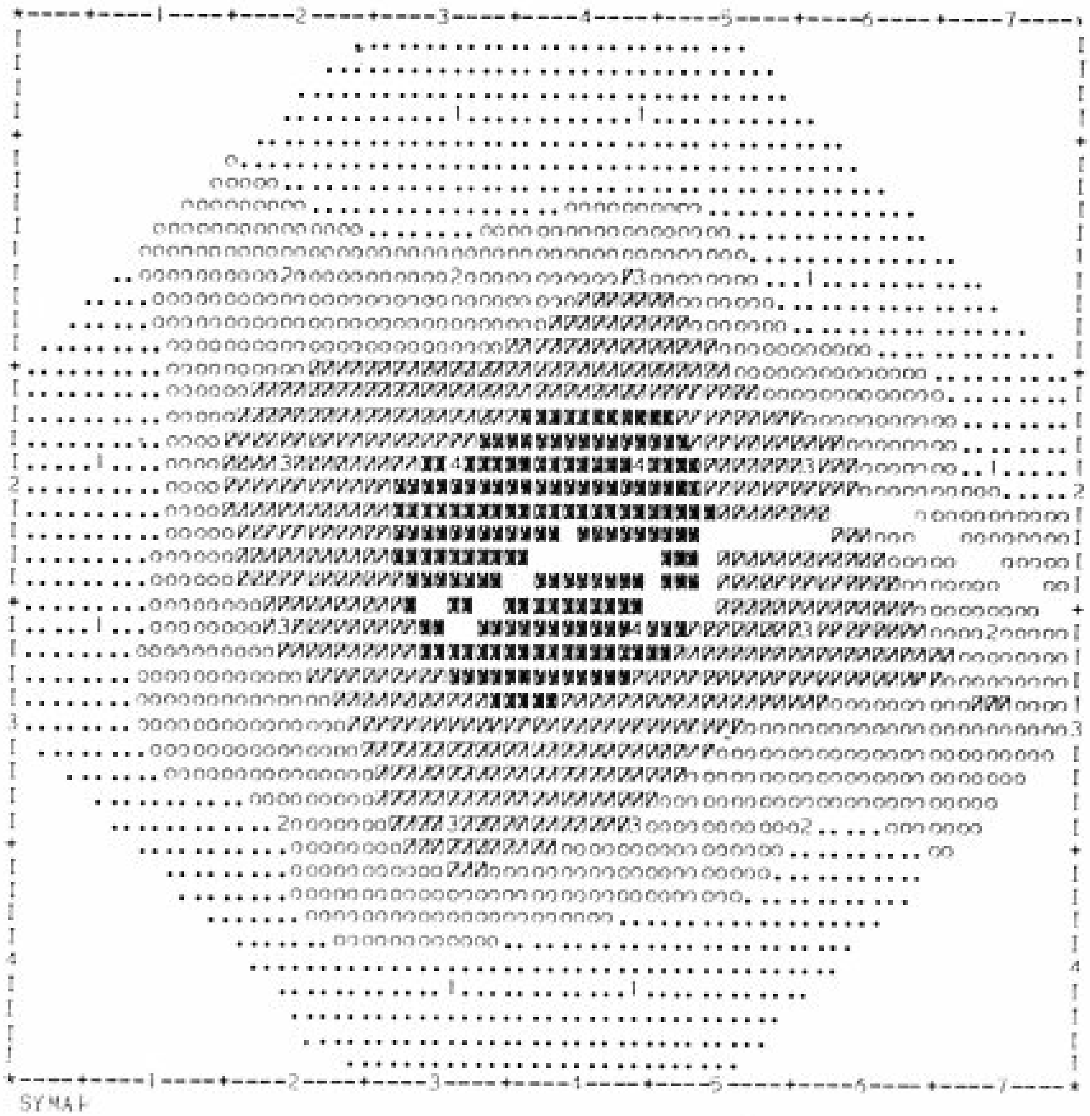

FIG. 11.2. Built environment index of settlements in London. Contours 1–4 (light to dark) respectively, 3–10.9 points, 11–18.9 points, 19–26.9 points, 27–35 points. For *units definition see text.*

The large parks situated to the west of central London raise the species density of that area, thus 60 and 64 species are recorded as breeding compared with 43, 49 and 53 species in the central and east central regions. The corresponding values for the built environment index are 27.5, 28.5, 35, 30 and 28.5.

The distribution of species size (Fig. 11.4) is correlated with the built environment index at −0.66 and −0.63 for average species weight, and median species weight, respectively, with both significant at $P = 0.001$. Median species weight is fairly stable at 20–22 g but with 22 g at the outskirts and 20 g at the centre. Average species weight ranges from 122 g on the outskirts to 90 g at the centre.

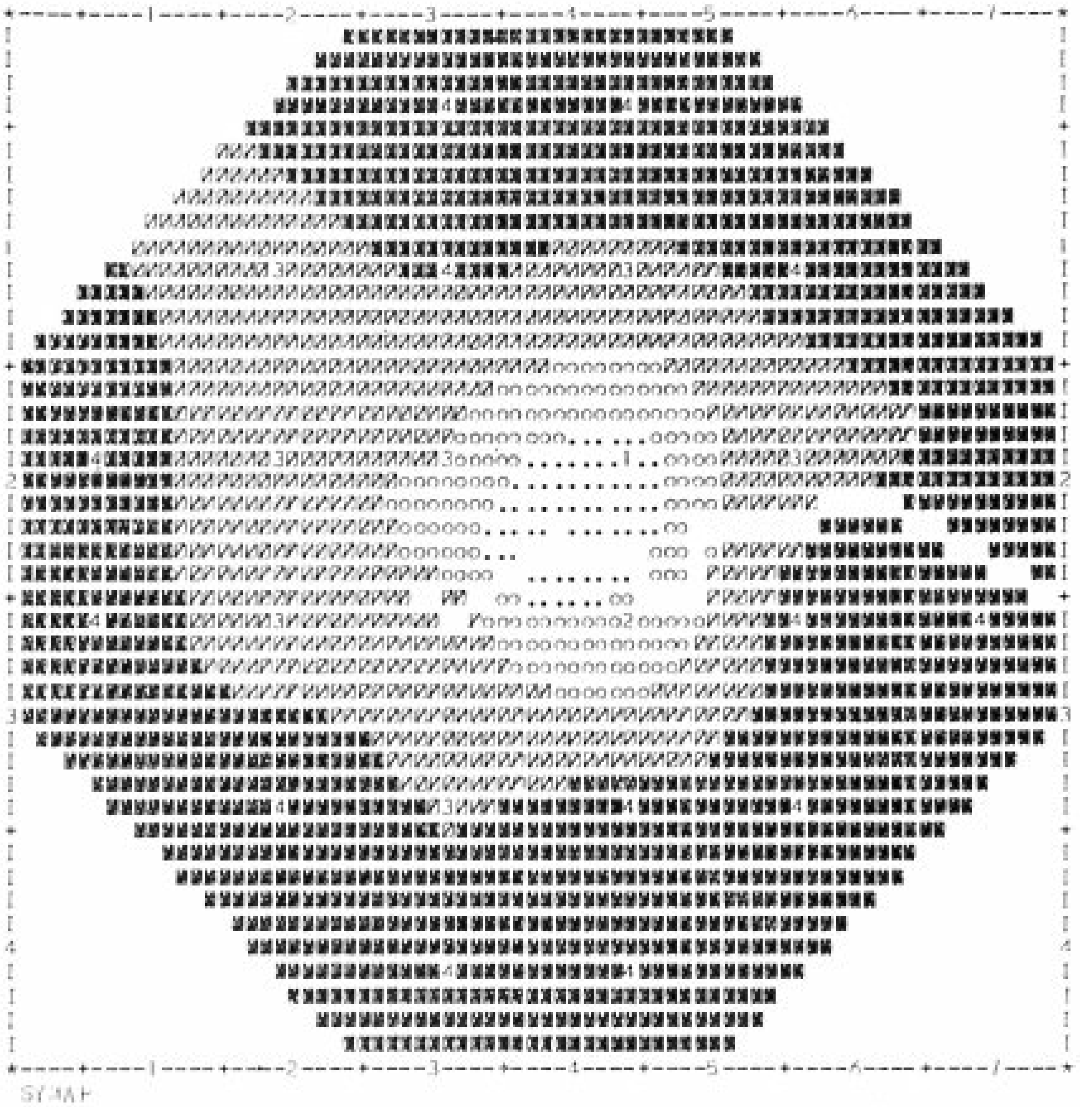

FIG. 11.3. Land bird species density/100 km^2. Contours 1–4 (light to dark), 43–51 species, 52–60 species, 61–68 species, 69–77 species.

Given the well-known heat island effect of urban areas (Chandler 1965) it is interesting to investigate the species size distributions of resident and migratory birds, separately. Kendeigh *et al* (1977) have calculated the relative energy costs of migration or overwintering for birds of different weights and show that small birds profit more by migration than do large birds. Overall, migrants and residents show the same basic features as their composite distributions, although the decline in species density from 21 to 10 migrant species is steeper than that for resident species from 56 to 33. Similarly, the decline in mean species weight is steeper for migrants at 43 g to 18 g compared to 150 g to 113 g for residents. The species density of residents was correlated with the built environment index at -0.90, $P = 0.001$ compared to migrants at

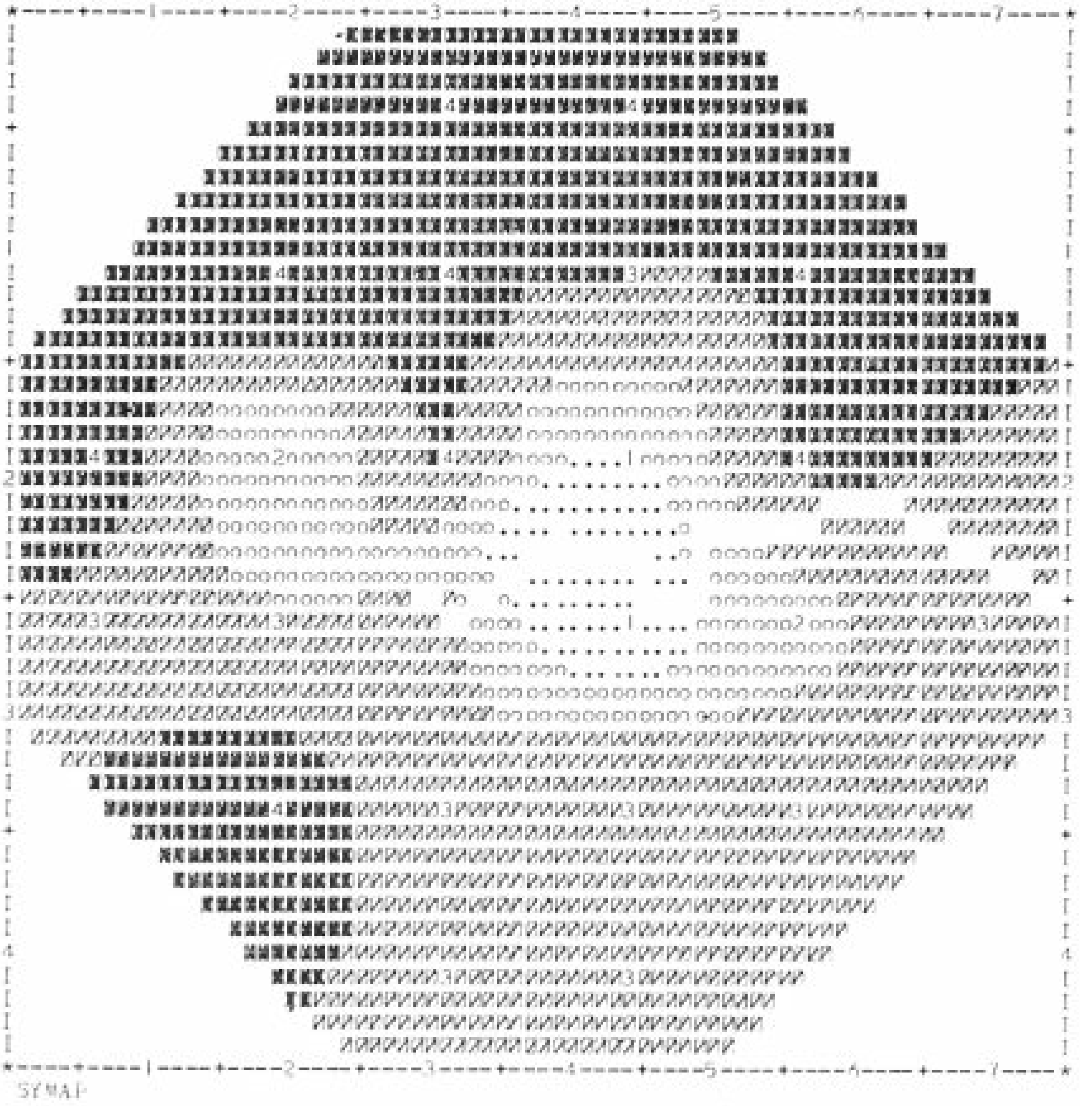

FIG. 11.4. Land bird average species weight/100 km². Contours 1–4 (light to dark), 90.5–98.5 g, 98.6–106.5 g, 106.6–114.5 g, 114.6–122.5 g.

-0.74, $P=0.001$. Average species weight of residents was correlated with the built environment index at -0.60, $P=0.001$ compared to migrants at -0.47, $P=0.011$. Median species weight was significantly correlated with the built environment index at -0.66, $P=0.001$ for resident species but was not significant for migrant species.

SNAIL SPECIES SIZE IN LONDON

The size of snail species was estimated from the scale drawings in Cameron and Redfern (1976) by taking the external shell dimensions and approximating the shells to cones or cylinders. Species density and size distribution maps were constructed in the same way as for land birds.

The presence or absence of land snail species in each of the 24 contiguous 10 km grid squares of London was taken from Kerney (1976). An analysis of the number of species in each square showed the species size (volume) distributions were skewed to the left (Kurtosis values −0.68 to −1.9) except for square 3 (Fig. 11.1) which skewed to the right (Kurtosis value 2.6). Data from that square was omitted from Figures 11.5 and 11.6 and the correlations, assuming there to have been under collection that area.

The species density of London's land snails decreases rapidly towards the city centre (see Fig. 11.5). Data extremes are 42 species at the city edge in the North-West and South, and nine species in the North-east square of central

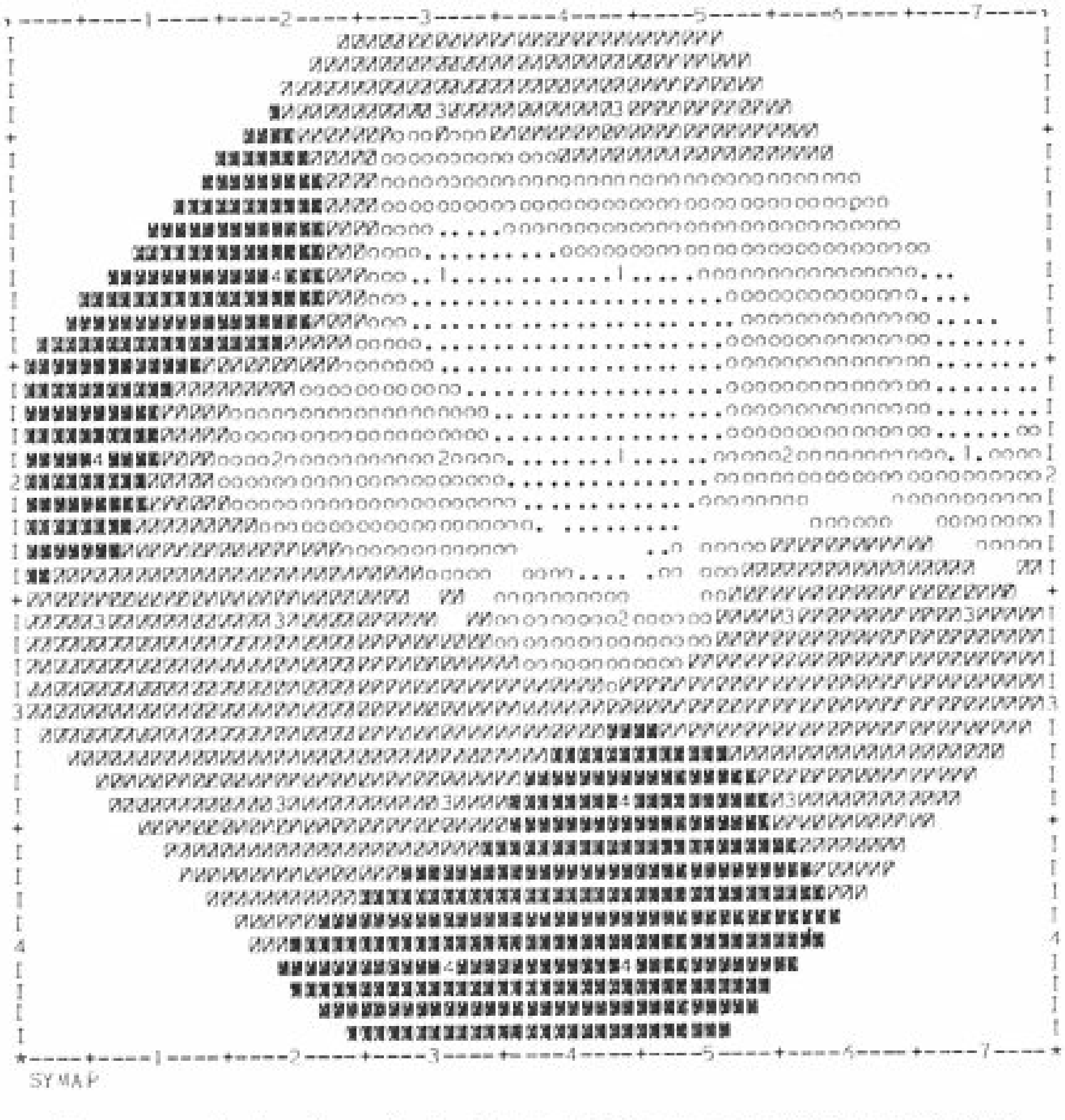

FIG. 11.5. Land snail species density/100 km². Contours 1–4 (light to dark) 9–17 species, 18–25 species, 26–33 species, 34–42 species.

Fig. 11.6. Land snail average species volume/100 km^2 (excepting *Helix pomatia*). Contours 1–4 (light to dark), 333–544 cc, 545–755 cc, 756–968 cc, 968–1179 cc.

London. Data are not available for the 25th grid square but only as part of the four central squares. The steepness of the decline in species density suggests that the analysis of snail distributions at a smaller scale than 10 km square would reveal quite large areas virtually without snail species. Perhaps there has been some under-recording where only nine species were found, although the large parks in the western areas of central London may have enabled more species to survive, accounting for the 19 to 28 species found there.

Boycott (1934) identified three main factors influencing snail distributions. These are human influence, the moisture conditions of the habitat and calcareous soils. Of these, calcareous soils can be considered a factor independent of ubanization. Urban environments are typically drier than their surroundings. Soils are often compacted which aids water run-off. Chandler (1965) notes the improvement in drainage in urban areas but also points to some added precipitation due to the particle burden of the urban atmosphere; relative humidity is markedly lower in the city centre, a factor he ascribes to the heat island effect.

Correlating the species density distributions with various environmental factors supports Boycott's conclusions. Species density is negatively correlated with the built environment index at −0.49 ($P < 0.01$), it is positively correlated with rainfall at 0.55 ($P < 0.01$), positively correlated with calcareous soils at 0.45 ($P < 0.05$) and negatively correlated with atmospheric sulphur dioxide levels at −0.77 ($P < 0.01$).

The prediction that smaller species would be selected in central urban areas has been refuted by the data. Average species size was not significantly correlated with the built environment index. However, one very large species, *Helix pomatia*, has a disproportionate effect on the data. If this calciphile species is omitted from the correlation then species size is positively correlated with the built environment index at 0.53, $P < 0.01$. The distribution of average species size is shown in Figure 11.6. Similarly, there was a positive correlation of species size (omitting *H.pomatia*) with SO_2 levels at 0.58, $P < 0.01$. Median species size is significantly correlated with rainfall at −0.34, $P < 0.01$ but not with the built environment index.

DISCUSSION

Both birds and snails show a decline in species density with increasing urbanization. For snails, the effects of urbanization appear greatly intensified by slow speed and poor powers of dispersal. In birds, smaller species tend to survive towards the city centre, unlike snails where the effect of species size is less clear. Earlier it was observed that desiccation of the environment was part of the phenomenon of urbanization (in temperate zones at least). Because snails depend upon the production of mucous as a surface on which to move, they are much affected by the moisture conditions of their habitat. Calow (1976) has pointed to the surface to volume relationship in which water content is proportional to the snail's volume while water loss is a function of its surface area. Because of the declining ratio of surface to volume with increasing size, large snails can be at an advantage under dry conditions. The preceding section may provide at least part of the explanation of snail species size distributions in urban areas.

Certain authors (Platt & Denman 1977; Cousins 1980) have argued that energy flows in ecosystems can be efficiently modelled by analysing food flows between size classes of animals. The size of an organism determines its food demand and the size of species it may eat. Each organism consumes 'packets' of food and is itself a 'packet' of food to other organisms. There are features of examining ecosystems in this way which have particular application to urban systems. Firstly, any cause of body size selection, be it the size of 'habitat islands', moisture conditions, reproductive strategy or heat island effect, will have implications for feeding interactions between species. Secondly, the waste food, resulting from human activity in towns, occurs at relatively large 'packet' sizes which is suitable for large species. This may offer an explanation of the paradox that whilst bird species are on average smaller in towns, the characteristic urban species, Feral Pigeon *Columbia livia* (Gmelin), Starling, Herring Gull *Larus argentatus* (Pontoppidan) are quite large. Examples of large 'packet' food supplies are grain spills, offal, food at rubbish dumps, household waste food and waste from take-away foodshops. It may also be worth noting that although the House Sparrow *Passer domesticus* (Linne) feeds on smaller food particles it, together with the above three 'urban' species, is a gregarious feeder that does not defend a feeding territory. These species can be compared to the majority of species in the study area which defend a feeding territory (Williamson 1967) and which may be more dependent on there being suitably large areas of habitat for their survival in towns (Schoener 1968).

In conclusion, the gradients of environment in urban areas and in particular the distribution of vegetated and non-vegetated space offers opportunities for research in the spatial ecology of single species or communities. Since so many functional attributes of an organism are associated with its size, the examination of the spatial distribution of organism size can help assess the importance of spatial phenomena in ecology.

REFERENCES

Boycott A.E. (1934) The habitats of land mollusca in Britain. *Journal of Ecology*, **22**, 1–38.

Calow P. (1976) Evolution, ecology and energetics: a study in metabolic adaption. In *Advances in Ecological Research*, **10**, 1–62, Academic Press, London.

Cameron R.A.D. & Redfern M. (1976) *British Land Snails*, Academic Press, London.

Chandler T.J. (1965) *The Climate of London*, Hutchinson, London.

Cousins S.H. (1976) A preliminary checklist of British breeding bird weights. Mimeograph, The Open University, Milton Keynes.

Cousins S.H. (1980) A trophic continuum derived from plant structure, animal size and a detritus cascade. *Journal of Theoretical Biology*, **82**, 607–618.

Dudnik E.E. (1972) *SYMAP Users Reference Manual*, Department of Architecture, University of Illinois, Evanston, Illinois, U.S.A.

Erz W. (1966) Ecological principles in the urbanization of birds. *Ostrich Supplement*, **6**, 357–363.

Fenchel T. (1974) Intrinsic rate of natural increase: the relationship with body size. *Oecologia* (Berlin), **14**, 317–326.

Kendeigh S.C., Dol'nik V.R. & Gavrilov V.M. (1977) Avian energetics. In *Grannivorous birds in ecosystems* (Ed. by Pinowski J. and Kendeigh S.C.), pp. 127–204. Cambridge University Press, Cambridge.

Kerney M.P. (1976) *Atlas of the non-marine mollusca of the British Isles.* Institute of Terrestrial Ecology, Cambridge.

Montier D.J. (1977) *Atlas of Breeding Birds of the London Area.* Batsford Ltd., London.

Platt T. & Denman K. (1977) The organisation of pelagic ecosystems. *Helgoländer wissenschaftliche Meeresuntersunchungen*, **30**, 575–581.

Sandford H.A. (1972) Recording maps and overlays. *London Naturalist*, **51**, 20–21.

Sandford H.A. (1975) Habitat overlay. *London Naturalist*, **54**, 72–73.

Sandford H.A. (1977) Regolith overlay. *London Naturalist*, **56**, 105–106.

Sandford H.A. (1979) Air pollution overlay. *London Naturalist*, **58**, 89–92.

Schoener T.W. (1968) The size of feeding territories among birds. *Ecology*, **49**, 123–141.

Williamson K. (1967) The bird community of farmland. *Bird Study*, **14**, 210–226.