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FORUM

The 'emergent property' of Anand and Li is a mathematical artefact. Emergent properties do not exist

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Evidence of emergent properties is so sparse in ecology that any claim demands attention. Anand and Li (2001) examined the spatial pattern of individuals of two species, *Bouteloua eripoda* and *B. gracilis*, in a desert in New Mexico. They found that the variance in the number of plants per quadrat increased as quadrat size increased (Fig. 1a). They described this is an 'emergent property'.

Variance/mean

With any such claim, it is necessary to compare the evidence with that expected under a null model. I simulated a transect with 400 quadrats, each 10 x 10 cm (like theirs), and scattered plants at random over them[1]. I combined quadrats into blocks of increasing size (as they did). The resulting variance-blocksize relation (Fig. 1b) is very like Anand and Li's field result (Fig. 1a vs 1b). Thus, the increase in variance with blocksize, on which Anand and Li base their claim of an emergent property, occurs equally in the random data, perhaps a little more steeply. The basis for their claim of an emergent property is what would be expected on a random basis.

Anand and Li's error is in their statement: "… how variance between quadrats changed with increasing quadrat size. This has been traditionally used in plant ecology for the detection of critical scales and/or patch size in vegetation (cf. Greig-Smith 1979, 1983)". In fact, the traditional analysis for the number of individuals, which Anand and Li use, is not variance but rather variance/mean[2]. Null-model expectation in such a situation is that the individuals are scattered at random among the quadrats, which gives a Poisson distribution of the number of individuals per quadrat. When "the sampling unit is increased by pooling of contiguous quadrats along the transect" (as Anand and Li did) the mean increases, and since the variance of a Poisson distribution is equal to the mean, it increases too. This is the reason for the increasing variance with random data (Fig. 1b), and at least the major reason for the increase with Anand and Li's desert data (Fig. 1a). It is a well-known mathematical artefact. If they plotted log(variance/mean) instead of log(variance) they might see something of the pattern of the species, and their artefact would disappear.

The habitat examined by Anand and Li was not uniform, but a gradient. However, on a gradient one also obtains the same result (Fig. 1c).

Emergent properties

By definition, an 'emergent property' is a property of a system that cannot be predicted from the properties of its component parts. However, if we know all the properties of the components, and thus the processes operating, we can always predict the behaviour of a system[3]. An

1 For each plant there was an equal chance of its landing in any of the 400 quadrats (i.e., a 1/400 chance of landing in each one), independent of the other plants.

2 With other variates, such as frequency, cover and environmental factors, the argument no longer applies, and the change in variance is much more difficult, or impossible, to predict (Greig-Smith 1983).

3 Except in the case of the unpredictability of the Resurrection of Our Lord and Saviour.

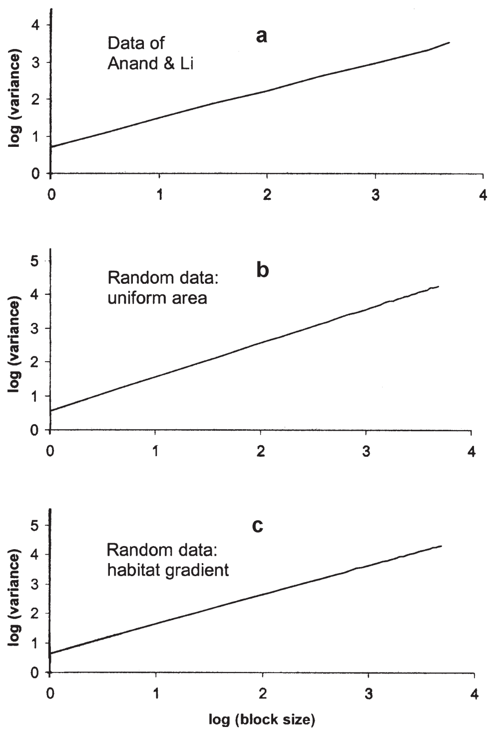

Figure 1. The relation between variance and block size (log-log scale). **a:** As reported by Anand and Li for individuals of *Boutoulea gracilis* in a New Mexico desert (this graph is typical of many, for two species and 10 years). **b:** Mean for random data simulating a uniform environment (individuals scattered at random over 400 quadrats at a density of 1.6 individuals per 10 x 10 cm quadrat). **c:** Random data, as in 'b', but with the probability of occurrence varying from 0.0 at one end of the transect to 1.0 at the other (i.e., along a habitat gradient).

'emergent property' occurs when we are ignorant of the properties of the components.

Suppose we have never seen a *Felis catus* (= *Felix domesticus*) before. We observe one snoozing in the sun, and conclude that they are like cushions, but expand and contract slightly each few seconds. We also observe a beef-steak sitting, and not moving, in a butcher's window (a door separates the *F. catus* from the beef-steak). We conclude the beef-steak will continue to sit there. Then someone opens the door, and an event occurs after which the beef-steak is no longer visible. We had not predicted this; it is an emergent property of the system, but only because of our ignorance about cats.

This is true of all emergent properties; they are emergent only to the extent that we are ignorant.

References

Anand, M. and Li, B.L. 2001. Spatiotemporal dynamics in a transition zone: patchiness, scale, and an emergent property. *Community Ecol.* 2: 161-169.

Greig-Smith, P. 1983. *Quantitative Plant Ecology,* 3rd edn. Blackwell, Oxford.