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Scaling problems almost everywhere; an introduction

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Abstract: This introductory essay-review tries to show the overall importance of scaling problems in general ecology; it tries to detect why have ecologists been so slow to recognize a number of these problems; it tries to outline some perspectives for the agenda of the future.

1. Praeambulum generale

1.1. Primordia

Scaling problems are perhaps as old as mankind (or, in a sense, if we consider the wonderful "scaling capacity" of birds or other animals, they are much older.) The primary *scientific* problems have been due to the early progress of *astronomy, geography* etc. (linked strongly with such practical needs as, for instance, the development of prudent navigation, choice of optimal commercial routes and of the most efficient means of communication). Needless to say, a long and difficult way can be traced from the primitive maps of Strabon through Mercator-scaling up till the various satellite-techniques of our age.

1.2. Singulae

Biological scaling, in general, has a long and a fairly intricate story as well. A few historical milestones may illustrate this.

1. Following the rich Greek tradition, some exceptionally clever masters of the renaissance (like Leonardo or Dürer) have tried to establish the so-called *canonical ratios* of the human body (incl. the differences between sexes and age-groups). The best sources are still the fantastic volumes of Dürer (1525-1528).

2. The famous (but for a long period: neglected or forgotten) papers of Verhulst (1838-1845) have introduced such relevant scaling concepts as the three ranges of a " *logistic curve*". A deep historical analysis and an abundant bibliography is given by the first chapter of the masterly book of G. E. Hutchinson (1978).

3. According to the Weber-Fechner law (1846-1860), noticeably different stimuli follow each other in an exponential way, and therefore *stimuli - response relations* can be used for scaling sensations. A thorough discussion of the psycho-physiological scaling can be found in Luce (1959) and Luce & Galanter (1963).

4. The marvellous book of D'Arcy Thomson (1917) has been just a treasury of very different scaling problems; one of them is

5. *allometry* which subject (the study area of "relative growth") became slowly popular after the publication of J. Huxley's introductory text (1932).

6. The pioneers of *numerical taxonomy* and *syntaxonomy* (e.g., Sokal & Sneath 1963, Orlóci 1975) have recognized the role of different scaling (say, the difference between *nominal* and *ordinal* scaling) and faced the problem of how different scaling procedures can be related to *resemblance* of various kinds. It is to be noted that a long and tedious way can be traced from geometric similarity (of Greek origin) towards a better appreciation of biological resemblance.

7. The last decade, promoted by a number of valuable books (e.g., Haken 1978, Arnold 1983, Mandelbrot 1983, Stewart 1989) has witnessed a growing interest in different research areas such as *synergetics, fractal geometry, catastrophe theory, chaos theory*, etc.; all full of different and difficult scaling problems. Some studies on non-linear dynamics and strange attractors (like May 1981, Farkas 1984, Schaffer 1985, etc.) have emphasized - inter alia - the essential difference between *linear* and *non-linear scalings*.

1.3. Referentia

Unfortunately enough, there is no comprehensive and up to date textbook on spatio-temporal scaling written for the biologist. Besides a number of semi-classical texts (e.g., Karsten 1925, Schmid 1954, etc), the best introduction is still provided by the excellent book of Batschelet (1971). The valuable volumes of Schmidt-Nielsen (1984) and Calder III (1984) contain many case studies, analyses and speculations useful in ecological context (or otherwise).

2. Interambulum speciale

2.1. Relevantia

The overall importance of scaling problems in general ecology or in vegetation science is shown clearly by the opening wording of Wiens's review (1989):

> "Acts in what Hutchinson (1965) has called the 'ecological theatre' are played out on various scales of space and time. To understand the drama, we must view it on appropriate scale."

We may add that for the sake of a better understanding many times *very many approriate scales* of different contexts should be conidered *simultanenously,* because the grandiose but sometimes fairly fuzzy plays of evolution or succession have too many components ("dramatis personae") who act according to their own strange (and partly unknown) *dramaturgiae*.

2.2. Contrastes; questiones molestae

Despite the clear-cut relevance if its inherent scaling problems, the history of ecology is full of surprising delays even in elementary recognition. The main question of Wiens's review is: "*Why* have ecologists been so slow to recognize scaling?" In order of seeking for some tentative answers, a possible way is to concentrate on a few "historical contrasts" and then on some explanatory moments.

<1> *"Classical" versus "modern" scalings.* Some early works in vegetation science, like the famous "Iter Lapponicum" of Linnaeus, or many essays of A. v. Humboldt contain a number of classical scaling problems. (see e.g., Drude 1890, Worster 1977). Our classics have recognized, for instance, the dependence of *vertical* zonality of vegetation types on the *horizontal* zonality of a study area. (That is, if we go to north, then the abbreviation of zonality ranges becomes noticeable; this relation can be represented by a suitable nomogram as well.) Although the new (sociological) lines of Scandinavian and Swiss pioneers have developed some sampling methods from the begenning of this century (see e.g., Goodall 1952), the importance of *sampling scaling* has been obscured for a surprisingly long period, for almost half a century. The break is partly due to the substantial paper and book of Peter Greig-Smith (1952, 1957); we can say safely that after these publucations at least the "scaling-conciousness" of field biologists has started to grow.

The vexing question is: *why this drastic delay?* How can one characterize this "spiritual canyon" between "classical" and "modern" scaling efforts? A primary answer may point out to the difference between observable (physiognomical) and nonobservable (non-physiognomical) phaenomena, or to the relevant trinity of *globality - regionality - locality;* stating that an explanatory contrast exists between the "global-physiogomical" and the "local - non-physiognomical" approaches. Secondly, this contrast can be made even sharper by showing a polarity between the Humboldtian *de-global* way of thinking and the *in-global* effort of coenologists; the former tries to relate everything - say, regionality - to a "global picture"; the latter wants to give a precise "local description" (and for the sake of this, does not care, at least at a start, of global relations). A third, more methodologically minded answer may stress the fact that coenologists have used most frequently only *one, single, arbitrary geometric size* of quadrat (or some other types of sampling units) for a long time; that is, they have represented only one, single point of a spatial process (see <3>). Note that the last remark is not true for some exceptional pioneers of vegetation science (like Kylin or Svedberg); it is shown clearly by the long story of such consepts as the *"minimi-area"*. Note also that the most striking novelty of Greig-Smith has been the application of a series of unit sizes. It is, however, still a debatable point whether the "Fisherian scenario" adapted by Greig-Smith is acceptable or not, because the use of variance-estimates involved pre-supposes some frequently non existing conditions of normality and linearity.

<2> *Scaling versus dynamics.* There exists a strange historical dilemma between 'static' and 'dynamic' approaches with relation to scaling. Taking an example out of the many, let us consider now some simple features of diversity reasoning. Since the early guesses of Margalef (1958) and since the activity of MacArthur's group (cf. MacArthur 1965), it is quite clear - even a scientific commonplace - that without proper scaling, without "patterning" (and, further, without processing) almost all diversity data are meaningless. But, surprisingly enough, this simple truth has not appeared in the literature of vegetation science for a fairly long time (cf. Juhász-Nagy 1984). One may ask: why is it so?

A primary explanation can show the contrast between *"sessility"* and *"mobility"*; it can show why scientists studying "mobile objects" have been forced to appreciate at least some aspects of scaling much earlier than their seemingly more fortunate colleagues. (In this respect, terrestrial plant communities, the classical objects of vegetation science, have many deceiving advantages and disadvantages, simultaneously.) A secondary explanatory moment is the chronic *lack of reliable comparisons*. Leaving alone animal or micro-communities at the moment, it would be highly desirable to have much better comparisons between scaling properties (say, considering the tempos of change of terrestrial and limnic plant communities, see Reynolds 1984, 1988). It is to be noted that the talk of Judit Padisák shall present us some good comparisons in this symposium. A tertiary, rather complicated explanation is due to the long history of our subdisciplines. Note that while such reasearch areas as population biology, demography, etc. have been *eo ipso* "dynamically minded" from their start (and sensitive enough to some problems of temporal scaling), whereas biogeography, phytocoenology etc., having had a fairly long "static tradition", needed a series of troublesome *"re-dynamization"*. The unfortunate consequences are shown clearly by the drastic delay of plant demography (alias: "harperology"), or, by many features of modern succession theory (see Fekete 1975).

<3> *Temporal versus spatial scaling.* It is fairly easy to state that evolution, succession, etc. should always be regarded as spatio-temporal processes; it is, however, extremely difficult to realize the conditions of such an operative study (with special reference to scaling of both ways). These difficulties, again, need some explanation.

Note, first, that the study of *temporal* processes has a rich tradition of several hundred years, whereas a more or less consistent theory of *spatial* processes can look back only to a meagre decade (cf. Cliff & Ord 1981, Ripley 1981, 1988, Podani 1984). Secondly, note that the early hopes of a spatio-temporal coupling by means of diffusion modelling (see Okubo 1980, Britton 1986) is followed now by some feelings of frustation, because the apparatus involved (systems of partial diferental equations) is very difficult to handle. Thirdly, even if some diffusional processes can be studied sucessfully by means of simulation (e.g. Czárán, this volume), the miniature Inferno of a mental confusion is still open, since many problems of spatio-temporal scaling simply cannot be avoided.

2.3. Nucleus prosper

Fortunately enough, there is an approach, called *"pattern and process" approach*, which makes possible an acceptable interconnection of space and time. The historical merit is due to the fine, classical paper of Alex Watt (1947); later on several scientists have tried to apply a number of versions of this approach in several contexts (e.g., Miller 1967, Stanley 1979, White 1979, Cacraft 1981, Schoener 1985).

3. Postambulum provisorium

3.1. Discussio brevis

The essence of any version of a "pattern and process" approach is to study first *pattern transformation* of some kind, and then to make *inference*, say, scaling inferences, from the properties of such a transformation.

Depending on the basic definitions and on several methodological postulates, there exist a number of possible scenarios as, for instance, (a) *point processes* (e.g., Diggle 1985), (b) *patch processes* (e.g., Pickett & White 1985), (c) *biotic-floristical processes* (e.g., Juhász-Nagy 1976-84, Juhász-Nagy & Podani 1983). In concreto, (a) is repre-sented in this symposium by the excellent lecture of Norm Kenkel. The approach of Jan Leps and

Frantisek Krahulec is close to (b); (c) is going to be developed further here by the talks of Sándor Bartha and Sergio Camiz.

Without going into some doubtful propaganda of my own methodological block, permit me to say a few words about its main properties (expecting some corrosive comments of yours later on).

First of all, the (c)-type of processes are all *binary* processes, and the *Boolean* character of modelling makes possible to use of the so-called Σ - conditions of Khinchin (1957), that is, within a theoretical envelope all additivity and subadditivity conditions are satisfied. (This property permits to subdivide any diversity envelope into regions of association and dissociation.) Secondly, a complex envelope can be studied successfully "in motion" (either in space, or in time, or in a spatio-temporal referential system). Thirdly, using inequalities of well-known properties, *a max-min scaling* is always possible (gaining contrast between maximal and minimal areas, or, gaining a number of points, intervals, orderings within the framework of a *characteristic scaling*).

3.2. Agenda selecta

Speculating on the very many unsolved problems of scaling, it would be rather ridiculous or even idiotic to have some feelings of self-complacency. Just a few "zum Beispiel" examples may illustrate something of our urgent agenda. Quoting the subtitle of Schmidt-Nielsen's book ("Why is animal size so important?"), we may think of a similar task of vegetation science; namely, of detecting scaling relations between strategies (see Grime 1979) and size-classes (from the *Sequoia*-range to tiny ephemers). Such a detection may imply a more careful study of the route "allometry → synallometry"; it may imply a better understanding of the self-thinning rule (see e.g., White 1981, Westoby 1984). The difficult problems of environmental heterogeneity are all full of scaling rebuses; such a relation is shown by the contrast between *"fine-grained"* and *"coarse-grained"* environment (see Wiens 1989). But our knowledge so far is very much limited of the meaning of a "grain"; we cannot interpret many times the meaning of "being fine" or "being coarse"; in particular, the screening-scaling capacity of coalitions (group of populations) are to be studied.

3.3. Prospectus

How can vegetation science progress in a better approximation of these and other problems with a solid hope of success? By quoting (without any political allusion) the watch-word of the late Austro-Hungarian Monarchy, I think that *"viribus unitis"*. (The latin noun, *vis,* means force, virtue, talent, effect, etc.) *Viribus unitis,* in this context, means not only a good international and inter-disciplinary co-operation; it does mean a better equilibrium between specialists and generalists; it does mean a closer, a more intensive attention to the activities of others (incl. zoologists, microbiologists, geographers, mathematicians, etc.).

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