Challenges to the ‘new’ rangeland science

Science on many fronts advances by revolutions.1 During this process, concepts and theories – the core knowledge of a discipline – are tossed aside as alternative hypotheses, substantiated by empirical and theoretical studies that are published in the peer-reviewed literature, rapidly gain acceptance. Over the past decade, there has been a ‘revolution’ in the way semiarid grazing systems are viewed, resulting in the emergence of a ‘new’ paradigm for rangeland science.2–6 My reserve in hailing these developments as a genuine scientific revolution stems from the fact that very little of this ‘new’ science has appeared in the primary literature. Nonetheless, the tenets of this paradigm (Box 1) have been proposed as the scientific basis for rangeland policy in some southern African countries. However, three new6–8 have now successfully challenged the conceptual, theoretical and empirical basis of the new science.

In a thoughtful review, Illius and O’Connor7 challenge the nonequilibrial conception of African semiarid rangeland systems (Box 1) and falsify many of its precepts. They argue that animal numbers are regulated in a density-dependant manner by the limited forage available for use in the dry season, with numbers being virtually uncoupled from resources elsewhere in the system. The strength of the forces tending to equilibrium vary spatially and temporally, these diminish during the wet season (when water is widely available), and with increasing distance from dry-season range and water points. The presence of ‘key’ dry-season ranges – chiefly in areas along perennial rivers or serviced by artificial water points – enables heavier use of wet-season ranges than if these key resources were absent. A consequence of this is that animal numbers and range production tend to become uncoupled, especially during droughts. This carries the risk of ecological change, reduced productivity, and reduced flow of goods and services to pastoralists.

Illius and O’Connor7 developed their model further by using simulations to test the hypothesis that climatic variation in semiarid African rangelands reduces animal numbers below the level at which they would negatively impact vegetation and soils, and that spatial heterogeneity in resource availability buffers herbivores against climatic variation.5 The results confirm the key role of dry-season range as an equilibrial system in which regulation of animal numbers occurs over the dry season. By contrast, the area of outlying wet-season range has virtually no effect on animal numbers; therefore, it could be viewed as nonequilibrial, in the sense that herbivore dynamics are not coupled to wet-season resources. Interestingly, the results suggest that bouts of intense defoliation – a consequence of climatic variability – probably make these rangelands more, not less, prone to ecological damage (c.f. Ref. 3).

A key tenet of the new rangeland science, predicated on the nonequilibrium conception of rangeland dynamics, is that pastoralists should not adhere to a single conservative stocking rate, but should rather adopt an opportunistic strategy allowing animal numbers to fluctuate widely in response to climatic variation2 (Box 1). It is further argued that opportunistic strategies yield higher economic returns compared with strategies based on conservative stocking rates5. Campbell et al.6 tested these assertions by exhaustively comparing the economics of four cattle management scenarios in miombo savanna landscape in southern Africa. The analysis is based on a simulation model of the fluctuations over time of rainfall, animal numbers, outputs and prices, using data from field surveys and the literature.

The results suggest that strategies based on conservative stocking rates, as advocated by the ‘old’ rangeland science, would have higher economic returns than strategies based on opportunistic stocking rates. Previous analyses have failed to account for animal losses as a result of drought and the costs of capital tied up in livestock, and have tended to compare commercial with communal production, rather than considering different kinds of smallholder production methods (e.g. Ref. 9). However, to receive the full benefits of destocking, a decision to destock has to be made at the village level because the benefits of improved outputs per animal can only be achieved if the stocking rates of communal grazing lands are reduced. Making collective decisions about managing numbers is a process with considerable transaction costs and, thus, the likelihood of new institutions emerging is lessened. Campbell et al.6 find it surprising that a tight tracking scenario (where cattle numbers are maintained in equilibrium with the available food resources by purchasing and selling stock) is being recommended in the most recent policy literature (e.g. Ref. 5). Their results suggest that such a system would incur considerable economic losses. The costs of a current programme to reclaim small dams illustrate the environmental costs of the opportunistic scenario. A tight tracking policy is likely to further increase environmental degradation5 and its associated costs. The new science does not consider the likelihood of degradation and, hence, its economic costs.

The uncritical adoption of the new rangeland science as the foundation for land use and land-reform policies in several southern African countries5,10,11 is alarming.6,12 Moreover, Sandford13 strongly advocates the incorporation of the new thinking into academic curricula. The three papers discussed here, all of

Box 1. Tenets of the ‘new’ rangeland science

Over the past decade, a new rangeland science for semiarid areas has emerged2–4, founded on experience from development projects and pastoral studies (chiefly in tropical African savannas), as well as ‘theoretical rettooling’ (notably in scientific ecology)5. Proponents argue that as a result of high environmental variability, populations of plants and animals are governed by nonequilibrial processes; highly variable grass production and intermittent population crashes of herbivores during extended droughts keep animal densities below equilibrium. Under these conditions, livestock do not have a long-term negative effect on range resources.

Briefly stated, the tenets of the new rangeland science are as follows6:

- Rangeland systems do not have a single equilibrium point, but rather have multiequilibria, or are disequilibrial or nonequilibrial.
- The concept of carrying capacity is of minimal value.
- Pastoralists should not adhere to a single conservative stocking rate.
- Herbivores have a minimal impact on vegetation or production.
- Opportunistic strategies give the highest economic returns compared with other strategies.

The new approach represents a long overdue challenge to traditional rangeland science, especially the equilibrial conception of carrying capacity; the inappropriateness of fixed stocking rates; and the uncritical emphasis of the importance of grazing intensity on plant community composition and function, and on animal production. However, with the exception of the three papers reviewed here, its tenets have yet to be critically evaluated in the peer-reviewed literature.
which have been subjected to rigorous peer-review, successfully challenge the tenets of the new approach. Collectively, they represent a major advance in our understanding of the dynamics and economics of semiarid rangelands. Hopefully, these insights will be rapidly assimilated into policies for the sustainable management of these important ecosystems.

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Biological objects, units of selection and character decomposition

An increase in the use of quantitative methods and mathematical models is often considered to be the most promising road to a state where biology can finally meet the ultimate model science – physics – as an equal. Certain holists and antireductionists might invariably cry foul, but some vocal opposition is to be expected along the arduous way to salvation. However, the project appears to be in trouble even without such allegedly unenlightened enemies. The most sophisticated mathematical areas in biology, such as life history theory, population ecology and quantitative genetics, often seem to lack a certain rigor compared with their brethren in the physical sciences. However, in two new articles, Laubichler and Wagner and Laubichler now identify the source of that problem, suggest a solution and illustrate it with two examples from evolutionary biology: units of selection and character decomposition.

What are the objects of biological theories? The answer to this question seems obvious in most cases, but often is of no more than superficial use when a researcher is confronted with a concrete problem. Does the population-size variable refer to all the red-scale mites in an orchard or to the individuals on a single tree? Does a gene include the regulatory sequences, which might be far from the sequences that are transcribed into mRNA and thus might not be in the same linkage group? Most biological objects have multiple, overlapping definitions. Newton’s theory applies to objects that can be characterized by their mass, location in space and velocity, but most biological theories do not prescribe how to find the limits of the units to which they actually apply.

Laubichler uses semiotic theory to derive a definition of biological objects and functions. Semiotics is the study of signs and by using such a philosophical theory Laubichler takes a risky, but nevertheless worthwhile, path. In the terminology of the 19th-century American scientist and philosopher Charles Sanders Peirce, the structure of a sign and its relationships are triadic: there is the object, its representation as a sign and the context-specific interpretation of the sign. If one steers clear of a naïve theory of knowledge, then there is no direct access to the ‘pure’ object – the object is already a sign. Such object–signs are elements of scientific theories that aim to understand a specific aspect of reality by providing mechanistic explanations of certain phenomena. These functional relationships between object–signs are the real subjects of biological research. A specific, empirically motivated theoretical interest supplies the interpretative context, which, in turn, determines the formulation of the object–sign. Thus, biological object–signs are representations of a natural entity identified by a specific measurement and individualized by its functional role within a biological process.

If all this sounds far too theoretical, an example will help. A gene defined as a coding sequence for a protein requires a specific measurement procedure; that is, the identification of the mRNA. Describing DNA as a ‘code’ is motivated by wanting to understand processes, such as transcription and translation, at a cellular level. However, defining a gene as a unit of inheritance asks for a different measurement procedure, the identification of units that are passed on intact during sexual reproduction. Such a definition of the gene could be motivated by an interest in organism-level adaptations. Both definitions are legitimate within the context of their own research programme, but have a complicated relationship to each other. The semiotic perspective leads to a ‘recipe’ for finding biological objects: higher-level objects, cells or organisms, are found before their parts, which are subsequently defined by conceptual decomposition. This approach does not identify biological objects a priori or by definition, but derives them from the relevant biological processes.