Gregarious Grazers Eat Better

An ecological study of grazed grasslands shows significant nutritional benefits to animals in herds

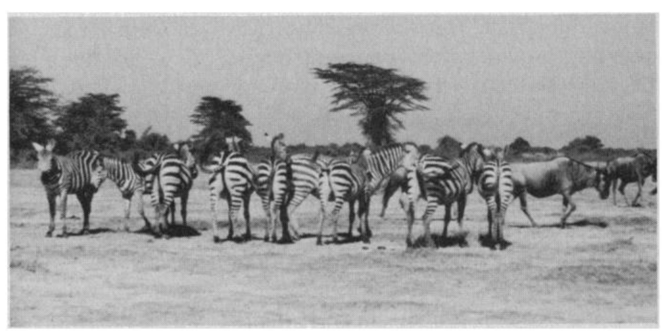
The great herds of wildebeest, buffalo, zebra, and the like of the East African plains are a stirring sight, and represent animal gregariousness writ large. Herding for these animals is often interpreted as a defense against predation, a factor that is important for many social species, including primates and birds. But, as Samuel J. McNaughton of Syracuse University points out, herding has significant energy consequences too. Systematic grazing of the grasslands enhances the concentration and quality of available food, albeit in a reduced vegetation stand. Foraging efficiency is therefore increased, which, suggests McNaughton, becomes a factor in the benefits of herd formation (*1*).

The passage of a grazing herd over a patch of grassland has the obvious immediate effect of reducing canopy height. An immediate response by the plant is enhanced lateral growth, which produces low, bushy foliage known as a grazing lawn. Continual grazing clearly presents a very strong selection pressure, and so this direct, short-term reaction is eventually translated to an evolutionary response, with a shift in the genetic and phenotypic characteristics of the surviving plants. There is, therefore, a coevolution between grazers and their "prey," says McNaughton: for the plants there is an effect on their morphology, and for the animals, an effect on behavior.

For those who have had the time and opportunity to observe the interaction between ungulates and the grasslands over which they roam, there has been an intuitive appreciation for some of the effects that McNaughton now documents so clearly in the *American Naturalist*. But, says Michael Coughenour of Colorado State University, the ecological community as a whole has remained pretty much unaware of the significance of the interaction. McNaughton's paper is extremely important, says Coughenour, because for the first time it formulates consequence of grazing, for both herb and herbivore and articulates them for an important academic audience.

A meadow left unmowed and ungrazed will quickly become dominated by a small number of species that can quickly grow tall. Graze the vegetation and there is an immediate selection for small species, with a consequent increase in species diversity. In some perceptive work in the mid-1970's the late T. H. Stobbs, an Australian agronomist, began to point to energy consequences too, showing that although grazing reduces the standing crop, biomass concentration increases (*2*). McNaughton came to the same conclusion in parallel (*3*). But until now no one had made the clear connection between vegetational response and herding behavior.

McNaughton chose as his study area the Serengeti, a vast plain of 25,000 square kilometers that straddles the border between Kenya and Tanzania. The area is famous for its large herds of ungulates, some 3 million of which, representing 25 species, occupy the grasslands at any one time. Some locations support species of tall grasses while others carry short or midheight grasses, with rainfall being an important factor. The tests included measurement of plant height and biomass concentration in these various areas, with a comparison of growth characteristics inside and outside exclosures in all cases.



Grazers in groups
Wildebeest and zebra often graze in mixed herds on the East African plains.

The results are striking. For instance, in short grasslands, which support large grazing herds, maximum height of the canopy in fenced, ungrazed areas was 39 centimeters compared with 3 centimeters in open locations. Biomass concentration was 1.13 milligrams per milliliter in fenced areas and more than twice this level, 2.57 milligrams per milliliter, in unfenced areas. Similar comparisons come from the less heavily grazed, midheight grasslands. The figures here for maximum height are 58 and 45 centimeters in fenced and unfenced sites; for biomass concentration they are 0.51 and 0.78 milligram per milliliter, respectively.

McNaughton was also able to compare the growth features at two locations of a single type of grassland, one of which (the Masai Mara Game Research) supports large grazing herds while the other (the Serengeti National Park) has comparatively few. Rainfall was essentially the same in the two sites, which were separated by just 45 kilometers. Mean canopy height in the Masai Mara (high animal density) was 15 and 9 centimeters for fenced and unfenced plots. For the Serengeti National Park (low animal density) the figures were 51 and 34 centimeters, respectively. The data for biomass concentration were again striking: 0.34 and 0.44 milligrams per milliliter inside and outside fences in the low animal density areas and 0.88 and 1.35 milligrams per milliliter, respectively, in the high animal density location.

The fact that the grass in the fenced plots in the Masai Mara grew to less than one-third the height of that in similar plots in the Serengeti National Park and had almost three times the biomass concentration, in spite of being free from grazing in both areas during the experimental period, indicates that intrinsic differences have developed between these two populations of the same species of grass. The intrinsic differences have presumably been the result of selective pressure by different grazing intensities, suggests McNaughton.

The conclusion from these multisite experiments—that the history of animal density is most significant in determining growth characteristics—was firmly supported by the results from the transplantation work. Information on the genetics of grasses suggests that morphologies associated with dwarfing under grazing pressure are under relatively simple genetic control, which can respond rapidly to directional selection.

The high biomass concentration in grazed, short grasses is the result of a more densely packed foliage within the canopy volume, which becomes ecologically significant for grazers. The most important property in their food source is energy intake per bite, not the amount of standing biomass. It is possible for a herbivore to starve in the midst of apparent plenty, if the quantity of food culled in each tongue-swing is of a low concentration.

Stobbs calculated that for a cow-size grazer, a bite size of about 0.3 gram of usable nutrients was necessary for survival, a figure that translates to 0.8 milligrams per milliliter biomass concentration. McNaughton's data from the Serengeti show that vegetation taller than 40 centimeters would be deficient in support of such an animal. An animal grazing on a 10-centimeter greensward would be reaping rich rewards in terms of available energy per bite. Moreover, plants cropped at this level are in a more juvenile state, and therefore offer higher protein content and greater digestibility.

An individual as part of a grazing herd therefore appears to have available to it food of high concentration and quality, which increases foraging efficiency. Is this a factor in the gregariousness of grazers? McNaughton believes so.

It is theoretically possible for a solitary grazer to maintain a grazing lawn on its own, and thus reap the benefits of enhanced food quality. But such an individual would be extremely vulnerable to predation. Defense against predation is reckoned by behavioral ecologists to be the key factor in the gregariousness of ungulates. What McNaughton is doing is to suggest that there is something of an interplay between the benefits of some protection against predation and enhanced food quality resulting from intensive grazing.

Tom Caraco of the University of New York at Albany concedes that enhanced foraging efficiency available on a grazing lawn can offset the potential costs of gregariousness that might arise through sharpened resource competition. Defense against predation remains the prime factor in herding behavior, he says, with the grazing effect being a secondary, facilitating influence.

—Roger Lewin

References

1. S. J. McNaughton, *Am. Nat.* **124**, 863 (1984).
2. T. H. Stobbs, *Aust. J. Agric. Res.* **24**, 821 (1973).
3. S. J. McNaughton, *Science* **191**, 92 (1976).

NSF Commits to Supercomputers

The four new centers are monuments to "experimental theory"— and to the dogged persistence of their champions

The National Science Foundation's (NSF's) recent announcement of four new supercomputer centers represents a major departure for the agency. Responding to widespread concerns about the poor state of academic computing, NSF is spending at least $200 million over the next 5 years to create a system of national research centers open to everyone in the scientific community—in effect, doing for supercomputers what NSF's national observatories do for telescopes. At the same time, NSF is responding to the proliferation of high-powered workstations on academic desktops. The supercomputer initiative includes, for the first time, a unified computer network that ultimately could connect every scientist in the country to every other scientist.

And perhaps most significant, the announcement dramatizes the fast-rising importance of what is sometimes called "experimental theory": the use of high-speed numeric processors not just for data reduction but for simulation, exploration, and discovery. Some enthusiasts even talk of a paradigm shift, a new mode of doing science. John W. D. Connolly, director of NSF's 1-year-old Office of Advanced Scientific Computing, caught that spirit when he announced the four centers on 25 February: "We are establishing today four Fermilabs for theorists!"

The concept of "supercomputer" is a moving target, since by definition it refers to the fastest number-cruncher available at any given time. One can, however, point to a definite beginning of the modern era: 1978, the year that Cray Research, Incorporated, of Chippewa Falls, Wisconsin, introduced its Cray 1. The first of the so-called "vector" machines, it was capable of some 20 million operations per second, roughly ten times faster than any machine previously on the market. ("Vector" refers to the machine's ability to process several streams of data simultaneously, rather like having eight checkout lines in a supermarket instead of one.) A similar machine, the Cyber 205 from Control Data Corporation (CDC) in Minneapolis, was introduced in 1981. Since then, Cray and CDC have dominated the market.

These devices, which are sometimes called "Class VI" machines according to categories of computational power devised by the Department of Energy, have allowed researchers to simulate systems whose complexity approaches that of the real world. In aerodynamics, for example, a new airfoil design can be "flown" in a supercomputer, modified, and flown again until it is optimized. The wings of both the Boeing 767 and the European Airbus 310 were designed this way because it was much more effective than testing a lot of models in a wind tunnel. In elementary particle theory, supercomputers have been used to extract testable predictions from quantum chromodynamics, the theory of the strong interactions. In astrophysics, they have opened up a whole new subfield of numerical relativity, allowing researchers to model what happens when, say, gas and dust spiral into a massive black hole.

Supercomputers have likewise been used in automobile design, in nuclear weapons design, in the exploitation of oil reservoirs, in understanding the propagation of cracks in metals, in advanced computer graphics, and in much more. Strikingly, however, relatively little of this work has been done by academic researchers. Part of the problem is simply the lack of access: at some $10 million to $20 million apiece, the new supercomputers went into oil companies and aerospace companies, or into national laboratories funded by mission-oriented agencies such as the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). The colleges and universities, meanwhile, were hard-pressed to maintain what computer facilities they had. In