

so that only a single channel is conducting (12, 13), the researchers can detect small changes in the electrostatic environment. Hence, when an antiparallel spin-qubit pair tunnels into the right dot, the quantum wire can detect its presence there.

The remarkable recent experimental realizations involving the control, manipulation, and detection of spins in quantum dots (14–18) are breathtaking; they definitely pave the way to an actual implementation of the spin-parity meter of Loss and Engel. A successful realization of spin-based quantum computing depends on a detailed experimental investigation of the decoherence of the spin qubits (that is, the loss of their quantum mechanical integrity

due to interactions with the environment). With a spin-parity meter in hand (together with spin-qubit rotations, perhaps via pulsed magnetic fields) and with decoherence under control, spin-based quantum computation may be closer at hand.

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ECOLOGY

Population Dynamics: Growing to Extremes

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We have all heard about the hypothetical pair of houseflies that could cover the Earth with their offspring in a matter of months if all of their descendants survived to reproduce. This hasn't happened yet because as populations grow, their numbers become limited by a lack of resources or by increases in predators and parasites. But how quickly do such limiting factors come into play and how do they affect dynamics of different species? Ecologists have been obsessed with these questions and cracking the underlying mechanisms that explain them because the answers go to the heart of understanding ecology. On page 607 of this issue, Sibly *et al.* (1) undertake the most ambitious analyses yet of this problem by examining growth rates of 1780 populations of birds, mammals, bony fishes, and insects. They uncover some interesting patterns, which could contribute fundamentally to our understanding of population dynamics.

The data analyzed by Sibly *et al.* (1) were derived from the Global Population Dynamics Database (2), which contains nearly 5000 time series of population estimates for a wide variety of plant and animal species. This is an important repository for

data that often remain concealed in obscure journals and reports but, if carefully screened, can support powerful statistical analyses to search for broad patterns. After excluding data that covered short time periods or were unsuitable in other ways, the authors were left with 1780 time series for 674 species.

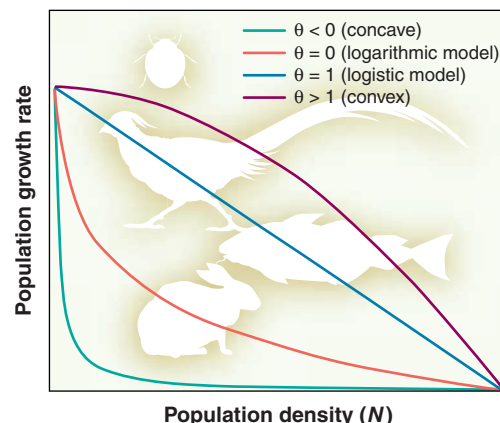
It may seem straightforward to simply plot population growth rates against population size and then assess the relationship by asking whether the shape of the curve is concave, linear, or convex (see the figure). But a large amount of statistical gymnastics is required to fit an appropriate mathematical model to measure the shape. Consider the logistic model, which is arguably the best-known model in ecology,

Different shapes for the relationship between population growth rate and density.

The shapes of the curves reflect the way a population changes with time, as described in the text. The growth rate–density relationship can be modeled by the θ -logistic equation $pgr = r_1[1 - (N/K)^\theta]$; r_1 is the rate of population growth at density 1 [$r_1 = r_0/(1 - K^{-\theta})$, where r_0 is the maximal rate of population growth from low density]; K is the carrying capacity of the environment, or equilibrium; θ controls the shape of the relationship and depends on the ways that members of a population interact at different densities. Sibly *et al.* (1) find that mammals, birds, fish, and insects do not generally grow exponentially to carrying capacity, as had been widely thought. Instead, population growth decelerates well before carrying capacity is achieved, as illustrated by the concave curve.

used in hundreds of modeling and statistical studies. This model has only two parameters: r , the maximal rate of population increase from low density, and K , the carrying capacity of the given environment (also called equilibrium). This model makes the restrictive assumption that the relationship between population growth rate and density is linear. But it doesn't have to be, and indeed, that is what the authors were trying to find out. So they used a modified logistic model that contains an extra parameter, θ , which allows the shape of the relationship to be convex ($\theta > 1$), linear ($\theta = 1$), or concave ($\theta < 1$).

Different values of θ may reflect fundamental differences in the nature of density dependence among populations. The linear logistic model ($\theta = 1$) assumes that the absolute negative effect of each additional individual on population growth is the same. This implies scramble competition, whereby each individual requires a fixed amount of resource to survive and reproduce (3). A convex ($\theta > 1$) relationship implies that a population can grow almost unchecked until it approaches equilibrium,



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when it stops abruptly as it suddenly runs out of resources or is halted by disease or predators. A weakly concave relationship, where θ is between 0 and 1, implies that the net reduction in population growth per individual is greater at low densities than at high densities; this effect becomes especially pronounced when θ is less than zero.

There is an important caveat in using this analytical approach. The time series use estimates rather than exact counts of populations, and they therefore contain measurement errors. Such errors can substantially bias estimates of the strength of density dependence and make density-independent time series appear as if they were generated from a density-dependent model (4). From simulations, Sibly *et al.* claim that the effects of measurement error should not bias estimates of θ toward particularly large positive or negative values. A pure error model, in which all meaningful variation in population size is swamped by measurement error, should yield a value of $\theta = 0$. However, it is not yet clear what happens to estimates of θ in the presence of measurement error if density dependence is weak or absent, and how this may be distinguished from true density dependence.

This caveat notwithstanding, the analyses have turned up a major surprise. The values of θ tend to be negative more often than not, which means that plots of population growth rate against population size are concave. This implies that populations experience strong density dependence early in their growth, with a weaker effect as they approach and exceed their carrying capacity. Why might this be the case? One possibility is that the logistic model ignores the age, size, and developmental-stage dependence of population structure. For example, density dependence may act most strongly at just one particular stage such as during the period of juvenile survival. Population growth rate usually includes all individuals in the population, not just those affected most strongly by density dependence. If the whole population exceeds its carrying capacity, there will be an immediate reduction in the recruitment of juveniles due to density dependence. However, as adults are better competitors, their numbers might respond only slowly, or not at all. Therefore, at high densities the population would not reduce rapidly to equilibrium. Conversely, at low densities, juvenile recruitment will be high, and they will grow rapidly into the adult class and swell the population's number. The net effect of this differential behavior above and below equilibrium is to generate a concave density response. However, this is pure speculation and the issue clearly requires a great deal more thought.

The findings of Sibly *et al.* have some general implications. First, their finding that values of θ tend to be much less than 1 violates a key assumption of the classical logistic equation, whereby growth rate should reduce linearly with density. Although this may not be news to most ecologists, the logistic model is still widely used by theoreticians and is a staple of textbooks. Second, the authors comment that as a consequence of concave density responses, many populations appear to live at densities above the carrying capacity of their environments. Another way of putting this is that rates of population decline will be slower than rates of return, perhaps for the reasons suggested above. It might therefore appear that we can reduce populations substantially before impairing their productivity. However, it would be very risky to manage populations on this basis, for example, when attempting to obtain sustainable yields in hunting or fishing.

That is because parameters of the population growth curve will change as populations are exploited. This may change the shapes of the density responses. Furthermore, we still have much to learn about how measurement error affects parameter estimates in such models, and hence the shapes of these relationships. Research on these fronts should prove rewarding for further understanding the ways in which populations change with time and for facilitating better wildlife management and conservation.

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NEUROSCIENCE

Similar Is Different in Hippocampal Networks

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When driving your car to work on two alternate but familiar routes, different combinations of neurons in the hippocampal region of the brain assist you in the navigation process. This is because ensembles of hippocampal “place cells” form a map-like representation of the environment (1). In addition to spatial cues such as shopping malls and other salient landmarks, hippocampal neurons respond to other features during the drive, including speed changes and local information (such as the type of transmission and the shape and size of the car's interior). So how will the hippocampal map representation be affected if you are driving your spouse's Jaguar instead of your two-seater Lotus on the same routes? According to Leutgeb *et al.* on page 619 of this issue (2), local information regarding each car as well as either route you may choose to take will be faithfully encoded in the hippocampus and there will be no interference between the two types of representations.

Instead of cars, routes, and human drivers, Leutgeb *et al.* studied rats under two sets of conditions and monitored the firing

patterns, or activity, of their hippocampal neurons. In one condition, the rats were tested in each of two different recording chambers (differing in shape) but the chambers were always in the same part of the same room. In the second condition, recordings were made from rats that were placed in each of two different rooms but in the same recording chamber located in the same part of each room. Collection of data began after the rats had at least 1 week of experience in either scenario. In the second condition, both the spatial positions of activated place cells (representing “place fields” in the chambers) and their discharge rates were statistically independent (a phenomenon known as “remapping”), as expected from previous studies. However, in the first condition, virtually all the activated hippocampal neurons remained anchored to the same Cartesian coordinates, even though the firing rate of the individual neurons varied more than an order of magnitude in the different chambers. This finding led the authors to conclude that local information is coded by rate, independently of the ensemble-coded place.

The most basic functions attributed to neuronal networks are the segregation and integration of patterns of activity. Such function is most pertinent in the hippocampus, often con-

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