Duffy upon hearing of the experiment. Indeed, Duffy has good reason for saying that—he and Wurtz have an unpublished study with results similar to Bradley's.

To prove that these heading-sensitive neurons in the MST really are helping the brain compute heading, researchers in the field would like to see evidence that artificially changing the neurons' responses changes a monkey's perception of heading. They may soon get their wish. In recent unpublished experiments, UC Davis neurophysiologist Ken Britten put monkeys through tasks in which the animals had to discriminate between two simulated headings that were similar enough to make the animals very uncertain about the answer. Under those conditions, Britten's group found they could bias the monkeys' answers toward a particular heading choice by stimulating the MST neurons known to prefer that heading. That is "pretty good evidence," says Warren, that MST neurons "play a functional role in that type of judgment."

How these neurons get their information about eye movements is still unclear, however. It might come in the form of a copy of the neural signal that tells the eyes to move, or alternately the signal could arise from neural sensors activated by the muscle contractions that actually move the eyes. And then there is the question of whether the MST neurons can compensate for the head movements that normally accompany eye movements, a question that the teams of Andersen and Banks plan to address next.

But while not all the questions have been answered, the experiment has shown unequivocally, Andersen says, that the heading neurons "definitely use an eye movement signal to perform the computation." And that, says Warren, is a very satisfying result: "We have evidence [from the human experiments] that extraretinal information helps solve the problem, and they have now come up with a potential physiological basis for that." And therein may lie the answer to how you can enjoy the scenery without driving off the road.

–Marcia Barinaga

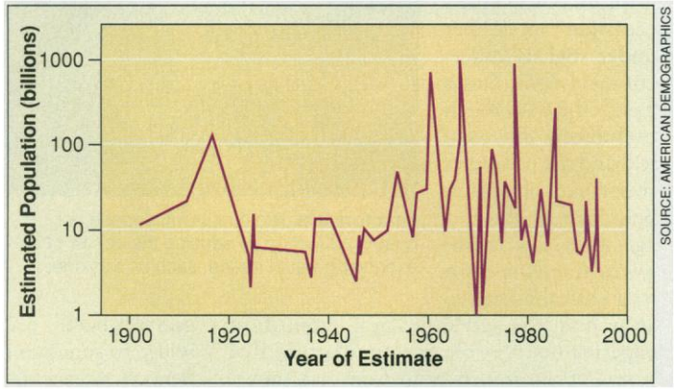
POPULATION

Ecologists Look at the Big Picture

How many people can the Earth support? The answer depends in part on how much land, water, and energy are available, so ecologists have often sought a solution using the same tools they apply to natural systems: looking at current patterns of food production and resource use, then extrapolating. But estimates have ranged from 1.5 billion to as many as 1 trillion people, depending on standard of living, new technologies, and so on.

At a crowded session on human population at the recent ecology meetings,* several speakers noted that resolution may come from a broader approach that includes social and economic dimensions. The bottom line, they say, is that human beings can choose to consume less and so boost Earth's carrying capacity. Such analyses are expected to yield a more realistic outlook and a bleak view of the choices ahead, suggesting, for example, that long-term prospects for maintaining the American lifestyle—or extending it to the nearly 6 billion people now on Earth—are grim.

This may seem all too obvious to some, but it is a novel idea when applied to this question, for most models of carrying capacity have assumed level or increased consumption, notes Cornell University agricultural scientist David Pimentel. The new analyses, he says, "are the first to consider reduced consumption as a realistic option for the future." And while previous models chiefly dealt with a defined set of ecological resources, the new studies wrestle with a dizzying array of variables, from modes of transport to amount of waste generated. "The natural sciences are valuable," says population biologist Joel Cohen of Rockefeller University in New York City. "But they can't stand alone." Yet for all the touted virtues of interdisciplinary work, this new style of analysis has yet to yield hard estimates of just how many people can live on Earth.



Crowd capacity. Estimates of how many humans can live on Earth have fluctuated from 1 billion to 1 trillion and show little sign of stabilizing.

Scientists anxiously watching population shoot up have been trying to calculate Earth's carrying capacity for centuries. But as Cohen noted in his talk, the resulting numbers haven't converged over time. For example, Stanford University biologists Paul Ehrlich, Anne Ehrlich, and Gretchen Daily recently estimated optimal population at about 1.5 billion, while in 1994 Paul Waggoner of the Connecticut Agricultural Experiment Station estimated that Earth could support 1 trillion people, assuming improved agriculture.

Cohen argues that many analyses have come up with wildly different figures because they rely on simple biological parameters, such as the amount of arable land per capita, then extrapolate. That ignores the human choices that influence these parameters at least as much as natural constraints, he says. A billion beef-eaters require much more land than a billion vegetarians, for example, and people may change their preferences as resources become scarce. "Ecological limits appear not as ceilings but as trade-offs," says Cohen, who is now assessing the consequences of such trade-offs. For example, cotton clothes use fewer resources than wool, which requires land for raising sheep.

Similarly, population biologist William Rees of the University of British Columbia presented another type of model that takes into account how a society's choices may affect its "ecological footprint"—the area of productive land needed to support it. His analysis suggests that each American leaves at least a 5.0-hectare footprint, each Canadian 4.3 hectares, and most Europeans 3.5 hectares. To bring the developing world up to the living standard of Canada, assuming available technology, would require two more planet Earths, says Rees.

This approach, marrying natural constraints with human economic choices, gets high marks from some. "Mr. Cohen's reasoned resolution of the issues points the way to a reconciliation" of diverse estimates, says Harvard University sociologist Nathan Keyfitz.

But Cohen is so convinced that estimates of carrying capacity are elastic, depending on standard of living, that he won't give a numerical estimate—a position that draws scorn from other scientists. It's "not helpful in the policy arena," says Ehrlich, who claims that his own work also incorporates social variables, although not in the same detail. "Science draws conclusions, and he draws none," Ehrlich says. But there is at least one point on which Cohen and his critics can agree: There are some serious limits to sustaining the lifestyles common in the developed world.

–Anne Simon Moffat

* Meeting of the Ecological Society of America, 11–14 August, Providence, RI.