

# Will Malthus Continue to Be Wrong

In 1798, a 32-year-old curate at a small parish church in Albury, England, published a sobering pamphlet entitled *An Essay on the Principle of Population*. As a grim rebuttal of the utopian philosophers of his day, Thomas Malthus argued that human populations will always tend to grow and, eventually, they will always be checked—either by foresight, such as birth control, or as a result of famine, war, or disease. Those speculations have inspired many a dire warning from environmentalists.

Since Malthus's time, world population has risen sixfold to more than 6 billion. Yet happily, apocalyptic collapses have mostly been prevented by the advent of cheap energy, the rise of science and technology, and the green revolution. Most demographers predict that by 2100, global population will level off at about 10 billion.

The urgent question is whether current standards of living can be sustained while improving the plight of those in need. Consumption of resources—not just food but also water, fossil fuels, timber, and other essentials—has grown enormously in the developed world. In addition, humans have compounded the direct threats to those resources in many ways, including by changing climate (see p. 100), polluting land and water, and spreading invasive species.

How can humans live sustainably on the planet and do so in a way that manages to preserve some biodiversity? Tackling that question involves a broad range of research for natural and social scientists. It's abundantly clear, for example, that humans are degrading many ecosystems and hindering their ability to provide clean water and other “goods and services” (*Science*, 1 April, p. 41). But exactly



**Out of balance.** Sustaining a growing world population is threatened by inefficient consumption of resources—and by poverty.

how bad is the situation? Researchers need better information on the status and trends of wetlands, forests, and other areas. To set priorities, they'd also like a better understanding of what makes ecosystems more resistant or vulnerable and whether stressed ecosystems, such as marine fisheries, have a threshold at which they won't recover.

Agronomists face the task of feeding 4 billion more mouths. Yields may be maxing out in the developed world, but much can still be done in the developing world, particularly sub-Saharan Africa, which desperately needs more nitrogen. Although

agricultural biotechnology clearly has potential to boost yields and lessen the environmental impact of farming, it has its own risks, and winning over skeptics has proven difficult.

There's no shortage of work for social scientists either. Perverse subsidies that encourage overuse of resources—tax loopholes for luxury Hummers and other inefficient vehicles, for example—remain a chronic problem. A new area of activity is the attempt to place values on ecosystems' services, so that the price of clear-cut lumber, for instance, covers the loss of a forest's ability to provide clean water. Incorporating those “externalities” into pricing is a daunting challenge that demands much more knowledge of ecosystems. In addition, economic decisions often consider only net present value and discount the future value of resources—soil erosion, slash-and-burn agriculture, and the mining of groundwater for cities and farming are prime examples. All this complicates the process of transforming industries so that they provide jobs, goods, and services while damaging the environment less.

Researchers must also grapple with the changing demographics of housing and how it will impact human well-being: In the next 35 to 50 years, the number of people living in cities will double. Much of the growth will likely happen in the developing world in cities that currently have 30,000 to 3 million residents. Coping with that huge urban influx will require everything from energy-efficient ways to make concrete to simple ways to purify drinking water.

And in an age of global television and relentless advertising, what will happen to patterns of consumption? The world clearly can't support 10 billion people living like Americans do today. Whether science—both the natural and social sciences—and technology can crank up efficiency and solve the problems we've created is perhaps the most critical question the world faces. Mustering the political will to make hard choices is, however, likely to be an even bigger challenge. —ERIK STOKSTAD

## Will mathematicians unleash the power of the Navier-Stokes equations?

First written down in the 1840s, the equations hold the keys to understanding both smooth and turbulent flow. To harness them, though, theorists must find out exactly when they work and under what conditions they break down.

## Does Poincaré's test identify spheres in four-dimensional space?

You can tie a string around a doughnut, but it will slide right off a sphere. The mathematical principle behind that observation can reliably spot every spherelike object in 3D space. Henri Poincaré conjectured that it should also work in the next dimension up, but no one has proved it yet.

## Do mathematically interesting zero-value solutions of the Riemann zeta function all have the form $a + bi$ ?

Don't sweat the details. Since the mid-19th century, the “Riemann hypothesis” has been the monster catfish in mathematicians' pond. If true, it will give them a wealth of information about the distribution of prime numbers and other long-standing mysteries.

## Does the Standard Model of particle physics rest on solid mathematical foundations?

For almost 50 years, the model has rested on “quantum Yang-Mills theory,” which links the behavior of particles to structures found in geometry. The theory is breathtakingly elegant and useful—but no one has proved that it's sound.