Earthquake Light

I enjoyed Deborah Shapley's account "Chinese earthquakes, The Maoist approach to seismology" (News and Comment, 20 Aug., p. 656), but I am bemused by her report that a trained (Chinese) seismologist gave the Americans a "convincing" account of an "earthquake light" which illuminated the night sky during one quake. I also have some epistemological difficulties with C. Barry Raleigh's reported explanation that "the electrical discharge represented by an earthquake light may build up before the quake."

Perhaps, under these circumstances, we should reexamine the communication (*1*) directed to the president of the Royal Society by William Stukeley on 26 March 1750. In it he points out that

> In an age when electricity has been so much our entertainment, and our amazement; when we are become so well acquainted with its stupendous powers and properties, its velocity, and instantaneous operation through any given distance; when we see, upon a touch, or an approach, between a non-electric and an electrified body, what a wonderful vibration is produced! what a snap it gives! how an innocuous flame breaks forth! how violent a shock! Is it to be wonder'd at, that hither we turn our thoughts, for the solution of the prodigious appearance of an earthquake?

And again,

> We had lately read at the Royal Society, a very curious discourse, from Mr. Franklin of Philadelphia, concerning thundergusts, lightning, the northern lights, and like meteors. All which he rightly solves from the doctrine of electricity. . . . From the same principle I infer, that, if a non-electric cloud discharges its contents upon any part of the earth, when in a high electrified state, an earthquake must necessarily ensue. The snap made upon the contact of many miles compass of solid earth, is that horrible uncouth noise, which we hear upon an earthquake; and the shock is the earthquake itself.

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Ion Beam Analysis

The article by Arthur L. Robinson "Nuclear science: X-ray evidence for superheavy elements" (Research News, 16 July, p. 219) gives a misleading impression of one aspect of analysis using ion beams. This involves the statement that "the researchers had to focus the ion beam on the inclusions, which have diameters of 50 to 100 micrometers, for long periods of time (an hour), a never-before-achieved accomplishment in itself."

In fact, beams of protons and other ions focused to spots of less than 4 μm in diameter have been in use in this laboratory for about 7 years. Positional stability to a few micrometers is normally possible for periods of several hours. A description of the system was first published in 1972 (*1*), and much analytical work using the system has since been reported (*2*). Several copies of the system have been built in other laboratories, although not always successfully.

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Cookson is indeed correct. In fact, because of the long-term stability of the accelerator beam there, researchers who were involved in the superheavy element discovery will soon be journeying to Harwell to repeat their experiment. The lower beam energy available from the English accelerator will mean that it may take six or seven times as long to accumulate a given amount of data as with the Florida State University machine, thus requiring a length of time which will severely test the former's stability. Nonetheless, Neil Fletcher at Florida State University believes the experiment will be an important one in increasing the credibility of the x-ray evidence for the existence of superheavy elements.

—A.L.R.

Food, Energy, and Population

The studies on agriculture and energy by David Pimentel's team at Cornell provide a great deal of useful information on this important relationship, especially as it applies to American practice. But conclusions based on their extrapolations to a worldwide scale can be seriously misleading. That was the case with the much-quoted article of 1973 (2 Nov., p. 443) and is also true of the sequel (21 Nov. 1975, p. 754).

In the 1973 article, Pimentel *et al.* estimated "the fuel energy needs to feed 4 billion humans," extrapolating from energy inputs for corn in the United States (roughly 1 gallon of gasoline per bushel of corn). Nitrogen fertilizer accounted for one-third of that total, applied at 112 pounds per acre. But total U.S. nitrogen fertilizer consumption in 1970 was 7.46 million short tons (*1*), an average of only 45 pounds per acre of cropland. Pimentel's calculation therefore overstated this part of the energy budget by 2.5 times. Moreover, in attributing energy use on a U.S. scale to "green revolution agriculture," Pimentel *et al.* did not distinguish between energy required for high yields per acre and energy which merely replaces high-cost human labor—not a necessary aspect of the green revolution. Almost half of the total energy budget for corn falls in the latter category. Finally, the authors compared energy used in all forms with estimated reserves of petroleum alone, an inherently misleading comparison.

The 1975 article compounds some of these errors. One can heartily endorse the conclusion that population control in densely populated, low-income regions is of the highest priority without supporting that conclusion with dubious calculations based on the questionable assumption that "most people of the world desire to eat and live as we do in the United States." Taken literally, that assumption would require both global population-land ratios and global incomes at American levels. The first would be physically impossible without an enormous reduction of population elsewhere—in the case of South Asia, by 86 percent from present levels and even more from population levels in the future. Income equality might be physically possible at some time, but it is practically inconceivable for any visible future. Starting at 1972 nominal levels (*2*), if per capita output increased in India by 3 percent per year and in the United States by only 1 percent per year, it would take over 200 years to achieve equality.

Even if we assume that most people in the world would like a U.S.-style *diet*, Pimentel *et al.* incorrectly assume that this goal would require "the use of U.S. agricultural technology," which would be impossible because of insufficiencies of both land and energy. They neglect the fact that U.S. yields per hectare are far lower than European or Japanese yields, a natural result of differing constellations of availability and costs of land, labor, energy, and other inputs. For all cereal grains (*3*), U.S. yields in 1973 were 3680 kilograms per hectare; Japanese yields were 5755 kg; those of the Netherlands were 4649 kg, and the world average was 1898 kg. A purely academic calculation shows that if all land now planted in rice produced Japanese yields, all land planted in wheat, barley, rye, and oats produced Dutch yields, and all land planted in corn produced U.S. yields, the world output of cereals from existing cultivated land would be 3286 million metric tons—859 kg per capita or 95 percent of U.S. consumption. This is obviously not a realistic possibility, but it demonstrates the variety of "conclusions" that can be derived from the manipulation of coefficients.

As to possible expansion of cultivated land, Pimentel *et al.* cite the United Nations Food and Agriculture Organization (FAO) *Production Yearbook 1972* as evidence that nearly all the world's land presently suitable for cultivation is already in cultivation. Later, they refer to suggestions for the possible doubling of potential arable land. The 1974 World Food Conference in Rome, in which the FAO, the U.S. Department of Agriculture, and other expert bodies collaborated, stated in their assessment (*4*):

> While in some developing countries the practical ceiling on land development may have been reached, in a large part of the developing world there remain land resources which either are unutilized or are utilized in productive processes of very low returns. . . . All of these regions suffer from specific limitations, often connected with high rainfall and high temperatures, but modern technology is increasingly able to cope with the problems and one may expect some very major development programmes for cultivated land in these regions. . . . Altogether it should be possible to increase the arable area of the developing regions from the 737 million hectares of 1970 to nearly 900 million hectares by 1985.

Turning to energy, the authors extrapolate recent estimates of total per capita U.S. energy use for food production, processing, distribution, and preparation, and arrive at the figure of 5×10^{12} liters of fuel equivalent as what would be needed by "the use of the U.S. agricultural technology to feed a world population of 4 billion a high protein-calorie diet for one year. . . ." That is a grossly misleading calculation on two counts: (i) a high protein-calorie diet need not involve the amounts of meat consumed in the United States, nor the amounts of grain feed for whatever meat is consumed; and (ii) of the total energy used in the "food system," only one-quarter (*5*) is used on the farm and is relevant to "agricultural technology." A large fraction of the other three-quarters is used in processing, packaging, home refrigeration, and so forth—in other words, essentially to improve consumer convenience rather than levels of food production and consumption. In addition, as already suggested, it would be absurd to apply the labor-saving aspects of U.S. farm production to low-income (and therefore low labor cost) countries, even if they were seeking an American diet.

Having thus derived an enormously inflated figure for energy "requirements," the authors repeat the 1973 error of comparing them with known reserves of petroleum only, rather than with probable recoverable reserves of all fossil fuels including coal. Adding coal would expand the total by a factor of 5.

Similar comments can be made concerning the extrapolation of water requirements for corn or the energy requirements for fishing. Calculations are made based on possible sources of protein for a hypothetical population of 16 billion in the year 2135, as if no major technological changes in protein production or synthesis can be expected over the coming 160 years.

It would be more helpful in illuminating the relationships among food, energy, and population to focus on the coefficients in key food-deficit areas, based on technology relevant to those areas, and then to determine the difference alternative paths of population growth (for example, for South Asia, fertility rates of 40 or of 25 per 1000) would make to production and consumption potential. Such studies would, in all likelihood, demonstrate dramatic differences resulting from higher or lower rates of population growth. But simple extrapolations of irrelevant coefficients distract attention from the real problems of the real world.

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2. The *World Bank Atlas* (Washington, D.C., 1974) shows gross national product per capita for the United States in 1972 as $5590 and for India as $110. The apparent ratio of 51 : 1 undoubtedly overstates the "gap" in real terms.
3. Calculations on areas, yields, and production are based on data in FAO, *Production Yearbook 1973* (FAO, Rome, 1974).
4. United Nations, World Food Conference, *Assessment of the World Food Situation: Present and Future* (FAO, Rome, November 1974), p. 113.
5. J. S. Steinhart and C. E. Steinhart, *Science* **184**, 307 (1974).

The article by Pimentel *et al.* is a major step toward understanding relations among food supplies and population. Their references to fisheries, however, may leave the reader with several wrong impressions.

Pimentel *et al.* imply that the 1972–73 decline in world fish catches was due principally to general overfishing. The 1972–73 decline was caused almost solely by a precipitous decrease in catches of Peruvian anchovies, from over 13 million metric tons in 1970 to 2 million metric tons in 1973. Examination of world marine fish and shellfish catches—excluding those of the Peruvian anchovy—since 1955 shows that there has been a reasonably uniform increase of about 4 percent per year, about twice the rate for the human population. While what happens to the Peruvian anchovy is by no means trivial in the world food picture, general statements about world fisheries must weight this special case appropriately.

The authors suggest that present overfishing is prejudicial to increases in fisheries catches. The exact opposite may be the case. A good working definition of overfishing is fishing at a level which stresses the stock to a point where it produces less than the maximum. The stock can recover with appropriate management to produce the maximum. It is quite possible that the present overfished state of many stocks could mean that in the future they will produce *more* than they do now.

Pimentel *et al.* state that an estimate that fish yield from the oceans might be increased to 100 million metric tons is probably overoptimistic. The estimate they refer to was published in 1972, but the assessment made for the United Nations World Food Conference in late 1974 (*1*) says:

> The [Indicative World Plan] estimated that the annual potential yield of conventional marine species . . . was of the order of 118 million tons, and subsequent assessments have confirmed this figure of well over 100 million tons. . . .

A much larger total yield may be possible by harvesting less familiar marine species. Harvesting and marketing of these species on a large scale presents serious technological problems, but some experts have estimated that the total sustainable harvest of all species might be at least 300 million tons.

There are other ways in which the production of food from the sea could be increased. One is the diversion to the food market of large amounts of fish used for meal; the authors suggest this alternative. Total useful fish production could be increased by millions of tons by elimination of waste. A great deal of fish is thrown back into the sea because of lack of markets or other reasons. Other large amounts are lost by improper handling, preservation, and storage. Elimination of waste in processing can also increase yields substantially. While serious technological and economic problems make it difficult to predict the future for aquaculture, the possibility of significant increases by the year 2000 (or later) cannot be discounted.

In other words, a 200-million-ton catch appears quite possible by the year 2000; it could provide at least 28 million tons of protein. A 300-million-ton catch could provide at least 42 million tons of protein, about equal to the amount projected for livestock in 2000.

A last thought relates to the fossil energy needs for catching fish. Estimates given by Pimentel *et al.* are at odds with Steinhart and Steinhart's estimates (*2*) that coastal fishing breaks even on calories expended versus the calorie yield, and that even relatively inefficient distant water fishing consumes less than 20 calories for each calorie of yield; they also conflict with Hirst's conclusion (*3*) that fish is one of the most efficient of several major food groups in terms of the ratio of primary energy use to protein content.

In sum, Pimentel *et al.* have probably seriously underestimated the contribution that aquatic foods can make to the world food supply.

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2. J. S. Steinhart and C. E. Steinhart, *Science* **184**, 307 (1974).
3. E. Hirst, *ibid.*, p. 134.

The projection by Schoning of a total annual fish yield of 200 million metric tons for the year 2000 is about double that of other projections (*1*). We hope Schoning's projection is correct.

Schoning questions the 20 calories energy input per calorie of fish-protein output. In spite of "Hirst's conclusion," Hirst (*2*) reported an input of 27 calories energy input per calorie of fish-protein output. Hirst's estimate is actually higher than the estimate we quoted (*3*) of 20 calories input per fish-protein calorie and the estimate of Edwardson (*4*) of about 21 calories input per fish-protein calorie. A recent analysis by Rochereau and Pimentel (*5*) concerning the Northeast fisheries of the United States suggests that Northeast fisheries are far more efficient than other fisheries. For the Northeast fisheries which use small fishing vessels, we calculated 5 calories input per calorie of fish-protein produced or at least ¼ the energy expenditure of the other fisheries mentioned.

Gordon and Pryor are concerned about our extrapolations. We emphasized in our 1975 article that extrapolations which involve the interdependencies of food, population, energy, land, water, and other environmental resources are fraught with many difficulties. This is especially so when no one set of acceptable assumptions exists for any of the factors. Our assumptions were stated and the resulting extrapolations were made to provide some perspective about energy and land constraints as they relate to feeding a rapidly growing world population. Based on our selected set of assumptions, we projected that "*If* petroleum were the only source of energy for food production and *if* we used all the petroleum reserves solely to feed the world population [4 billion], the 66,053 billion liter reserve would last a mere 13 years."

With another set of assumptions or coefficients, the 13 years might have been doubled to 26 years. Extending the supply of a resource from 13 years to 26 years might be consoling to our generation, but neither projection is consoling for future generations. As we stated in our articles, "Numerous estimates . . . are possible with the use of various combinations of population size, dietary standards, and production technology," but the one selected sufficed "as an *example* of the limitations" that face mankind.

We fully recognized the fact in both our articles that about half of the energy budget for corn replaces labor, and the other half is for productivity (see also *6*). This is documented and was the reason we focused much of our attention on labor inputs and alternatives.

Petroleum and natural gas are the two important energy resources utilized by agriculture. The reserves of both of these resources are in short supply. Petroleum was often used because it is a convenient, familiar measure. Coal, if used for agriculture in the future, will compete with agriculture for a vital agricultural resource—land (*6*).

Gordon and Pryor question our using corn as an average crop for an energy input-output analysis and extrapolation. They base their argument strictly on the fact that corn requires 2.5 times more nitrogen than the average of other crops. They apparently did not examine any of the data in our table 1 of our 1975 article. If they had, Gordon and Pryor would have found that corn requires "roughly 1 gallon of gasoline per bushel of corn"; oats, 0.6; wheat, 1.2; and soybeans, 1.6 gallons per bushel. More crops could be mentioned, but the point is that when *all* the inputs are taken into consideration and not just nitrogen, corn is a good average crop.

Gordon and Pryor attribute to us the conclusion that "population control in densely populated, low-income regions is of the highest priority." This is *not* our conclusion. We stated that overpopulation is a problem for the world as a whole including the developed regions.

Then turning to energy used in the U.S. food system, Gordon and Pryor claim that only "one-quarter" of the energy in the "food system" is used in agricultural production. They give as their source an estimate that was published in 1974 (*7*), but this estimate is based on no better data than our estimate of "one-third." In addition, the U.S. Senate Committee on Agriculture and Forestry (*8*) reported that food production is more energy-intensive than either food processing or food distribution based on the percentage of energy costs compared with total costs of the activity.

Our extrapolations, although "simple," were based on "realistic coefficients" that were selected to call attention to the fact that high energy-intensive U.S. agricultural technology is generally inappropriate for "green revolution agriculture." We hope that others will examine the relationships that exist among food, energy, and population, using the "numerous estimates" or coefficients that are available. Unfortunately, no matter how the coefficients are manipulated either by Gordon and Pryor, by us, or by others, the "real problems of the real world" will not disappear.

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