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THE HUMAN ENVIRONMENT: PENULTIMATE PROBLEMS OF SURVIVAL

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Fourteen years are crowded with events, work, and people. The ideas expressed herein are my own, but never really my own, as they are constantly exchanged, absorbed, reverberated, and tested with friends and family. For this paper in particular, I have had advice and counsel from Jesse Ausubel, Dennis Chinoy, Jeanne X. Kasperson, and, as a group, my friends and colleagues at Clark University; manuscript preparation assistance from Jim Blair, the Clark University Cartographic Laboratory, and Joan McGrath; shared thinking and research with Len Barry, Ian Burton, Chris Hohenemser, Roger Kasperson, and Gilbert White; and received research support from the National Science Foundation, the Rockefeller Foundation, and the Woodrow Wilson International Center for Scholars.

REUBEN G. GUSTAVSON MEMORIAL LECTURES

The Reuben G. Gustavson Memorial Lectures were established in 1975 in recognition of Dr. Gustavson's contributions to education and research. Sponsored by Resources for the Future, Inc., of Washington, D.C., and four universities he served, the lectures will be given annually for fifteen years at the University of Arizona, the University of Chicago, the University of Colorado, and the University of Nebraska. Contributions to the lecture fund were made by Resources for the Future, Laurance S. Rockefeller, William S. Paley, and by former students and colleagues at each of the sponsoring institutions. The lectures deal with Science and Society, with emphasis on questions related to resources and the environment.

Robert Kates' lecture, the seventh of the series, was delivered at the University of Colorado on January 27, 1983.

INTRODUCTION

> The ultimate problems of human existence are problems of mystery; the penultimate problems are of survival. The ultimate problems—the origin, meaning, and purpose of a human existence that contains the certainty of death—now seem to transcend formal human organization dedicated to their study and solution. Once the sole charge of priest and philosopher, investigation of the mystery of life and death is widely shared with science and ordinary men. The penultimate problems—the epoch-specific, overriding questions of our time—seemingly require greater formal human organization (Kates, 1969, p. 1).

I wrote that at the end of 1969, newly returned from Africa to a country swept up in the turmoil of foreign war and social change, having resolved to more systematically address my scientific and political efforts to the penultimate questions of my field, which studies the resources and hazards of the human environment. In so doing I was but one of many. John Platt (1969) had just published in *Science* his agenda of penultimate problems ordered by a scale of crisis intensity (Table 1).

Fourteen years later, now in the midst of his "5 to 20 years time to crisis," his list of major crises leading to "annihilation, great destruction, or change" still appears relevant. *Nuclear or radiological, chemical, biological warfare escalates*. Around the world men and women take to the streets and the ballot box to urge a halt to nuclear arms escalation. A major *famine* affected some 10-15 million people in the Sahel between 1969 and 1973. The end of the oceans did not occur in 1979, as predicted in the cautionary tale of eco-catastrophe by Paul Ehrlich (1970); nonetheless, major issues concerning *ecological balance* persist: the interaction of biogeochemical cycles, the future of renewable resources, and the acceleration of species extinction. The 1970s found the *development* hopes of millions set back in the face of worldwide economic decline. *Local wars* underway or initiated since 1969 (killing 1,000 or more) have involved 58 nations and claimed at least 8.3 million lives (Sivard, 1982). The *gap between rich and poor* nations

Crisis Intensity (No. Affected)	**Estimated Time to Crisis (Years)**	
	1-5	**5-20**
Total Annihilation (10^{10})	Nuclear or RCBW Escalation	Nuclear or RCBW Escalation
Great Destruction or Change (10^{9})	(Too Soon)	Famines Ecological Balance Development Failures Local Wars Rich-Poor Gap
Widespread Almost Unbearable Tension (10^{8})	Administrative Management Need for Participation Group and Racial Conflict Poverty, Rising Expectations Environmental Degradation	Poverty Pollution Racial Wars Political Rigidity Strong Dictatorships
Large-Scale Distress (10^{7})	Transportation Diseases Loss of Old Cultures	Housing Education Independence of Big Powers Communications Gap

Table 1. Platt's 1969 Classification of Major Problems and Crises (abridged from Platt, 1969, p. 1119)

has increased absolutely if not relatively from a difference in per capita income of $2300 in 1969, to $7700 in 1980 (Sivard, 1982).

That the agenda of penultimate problems persists is less striking than the omissions from the list. Platt, writing today, would surely include energy issues and the combination of global economic stagnation, inflation, and unemployment as major continuing crises that were absent from his original list. My own unpublished list of penultimate problems prepared that same year is shorter, more environmentally oriented, and focuses on cause. It contains three closely linked problems:

1) The Malthusian dilemma, the resurgent concern with the adequacy of resources and environment in the context of current and future rates of population growth, and the greater growth rates of technology and consumption.

2) The growing, separate, global concentration of wealth and poverty at a time of continued rising expectations, with the prospect of worldwide social unrest and conflict increasingly along racial, national, and continental lines.

3) The exceptional disparity between the greatly advanced technological capability for change, including that of destruction, and the primitive character of the human behaviors and institutions providing for control of this new capability (Kates, 1969, pp. 3–4).

In the remainder of this lecture I want to address briefly each of these issues in turn, using the hindsight of the last 14 years, some research that my colleagues at Clark University and I have undertaken on each of the problems, and the remarkable set of institutions, research, and documentation that developed during that period. A word first about these latter developments.

NEW INSTITUTIONS, RESEARCH METHODS, AND DOCUMENTATION

When John Platt foresaw multiple crises that pose the "gravest danger of destroying our society, our world, and ourselves in any of a number of different ways well before the end of this century," he called for ". . . action. Who will commit himself to this . . . search for more ingenious and fundamental solutions? Who will begin to assemble the research teams and funds? Who will begin to create those full-time interdisciplinary centers that will be necessary for testing detailed designs and turning them into effective application?" (1969, p. 1121).

Fourteen years later a host of interdisciplinary centers abound, the most recent being the World Resources Institute. Internationally, many of these institutes are part of the IFIAS (International Federation of Institutes of Advanced Studies) network. Another, based near Vienna, IIASA (the International Institute for Applied Systems Analysis) is funded by 17 countries. The world's natural scientific disciplines have come together under the aegis of the International Council of Scientific Unions and its Scientific

Committee on Problems of the Environment (SCOPE), while the world's nations work through the United Nations Environment Program (UNEP) begun in Stockholm in 1972. New sources of funding have emerged—such as the Club of Rome in the early '70s and the MacArthur Foundation in the '80s. Reuben Gustavson, who played such a key role in the development of Resources for the Future, would have been pleased by these developments.

In the wake of this creation of institutions has come a wave of research, documentation, and methodology. The development of global simulation models has triggered a new growth controversy that has yet to abate, and a dozen emulative or competitive models—seven of which were recently reviewed together (Meadows, Richardson, and Bruckmann, 1982)—have been constructed. The energy crisis encouraged new accounting systems using BTUs or joules instead of dollars to document energy flows or transactions. Progress was also made in documenting flows of the global cycles of carbon, nitrogen, sulphur, and phosphorus in addition to water, and in monitoring the stratosphere, oceans, and the terrestrial biomass. Major international studies and reviews have looked back at the year 1972 (Garcia, 1981), over the 10 years since the Stockholm Conference on the Environment (Holdgate, Kassas, and White, 1982), and forward on the next 20 years (U.S. Council on Environmental Quality, 1980), 50 years (Ridker and Watson, 1980), 75 years (Freeman and Jahoda, 1978), and 200 years (Kahn, Brown, and Martel, 1976).

Despite this outpouring of institutions, research, and documentation, a major caveat is in order. In the words of the UNEP World Environment report, "... the data base is of very variable quality . . . there are startling gaps and a special lack of reliable quantitative information on the developing world. This must be remembered when projections of the future state of the world environment are examined: many are based on only the scantiest of evidence about what, in fact, has been happening" (Holdgate, Kassas, and White, 1982, p. 622).

MENTAL MODELS OF THE FUTURE

Yet, questionable data appears to me a lesser issue than other problems that may perplex the reader of these environmental diagnoses and prognoses. A more important issue relates to the very different mental models authors hold as to the future, differences that can be crudely summarized along three dimensions: trend, cause, and certainty.

Most people who have thought about the penultimate problems have a mental image of the future that is convertible to a trend projection. Consider, for example, this incomplete diagram of 1,000 years of past and future world population (Figure 1). Take a moment and see if you can mentally extend it to the year 2050, when my granddaughter Sara will be 70, or if you are really brave and foolhardy, to 2200.

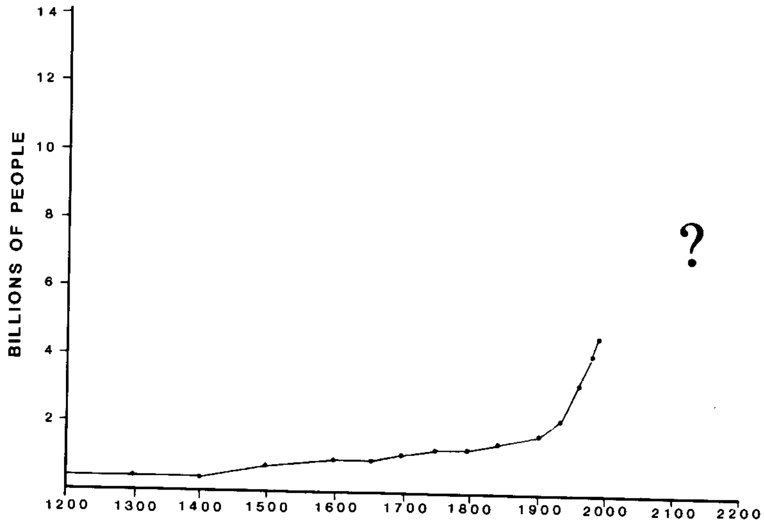


Figure 1. World Population, 1200–2200 A.D.: Do-It-Yourself Projection

Figure 2 shows the curves my students draw. These curves reflect well the basic divisions in trend. Curve A is the cornucopian vision of continued exponential growth, at least within Sara's lifetime; Curve B represents one of many variants of reaching a steady-state, zero-population-growth world; and Curve C is the Malthusian vision of overshoot and collapse (Meadows et al., 1972). All of the analyses since 1969 are strongly influenced by their authors' vision of the potential for either growth, steady state, or collapse.

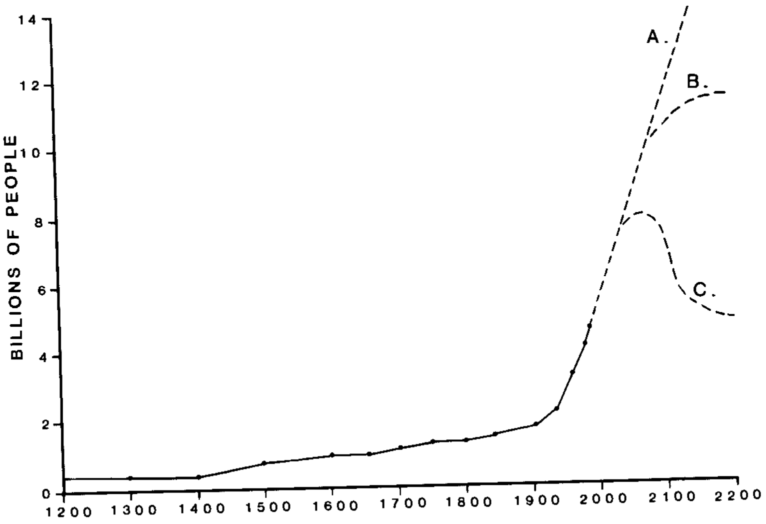


Figure 2. World Population, 1200–2200 A.D.: Alternative Projections

Beliefs as to the cause of such trends also differ widely. Some see physical limits or the behavior of natural systems as prime movers; others find cause in society (social or economic organization) or culture; still others highlight the autonomous role of technology; and still others, combinations thereof. Sometimes the distinctions are subtle, the causation must be inferred; sometimes it's blatant, as in *Nature Pleads Not Guilty*, Garcia's indictment of society for the worldwide trouble of 1972.

Finally, the degree of certainty one attaches to a diagnosis or prognosis is a mixture of both belief and style. Scientists differ in the strength of their own belief in their analyses, while others, regardless of belief, may speak either softly or loudly. A recurring problem for scientists who wish to influence or even to inform is to penetrate the cacophony of modern communication, to secure a place on the agendas of the media, the public, the decision makers. Thus, some opt to speak loudly either from belief or from necessity or both.

To overstate your case has become commonplace because to understate it may mean it will never be considered.

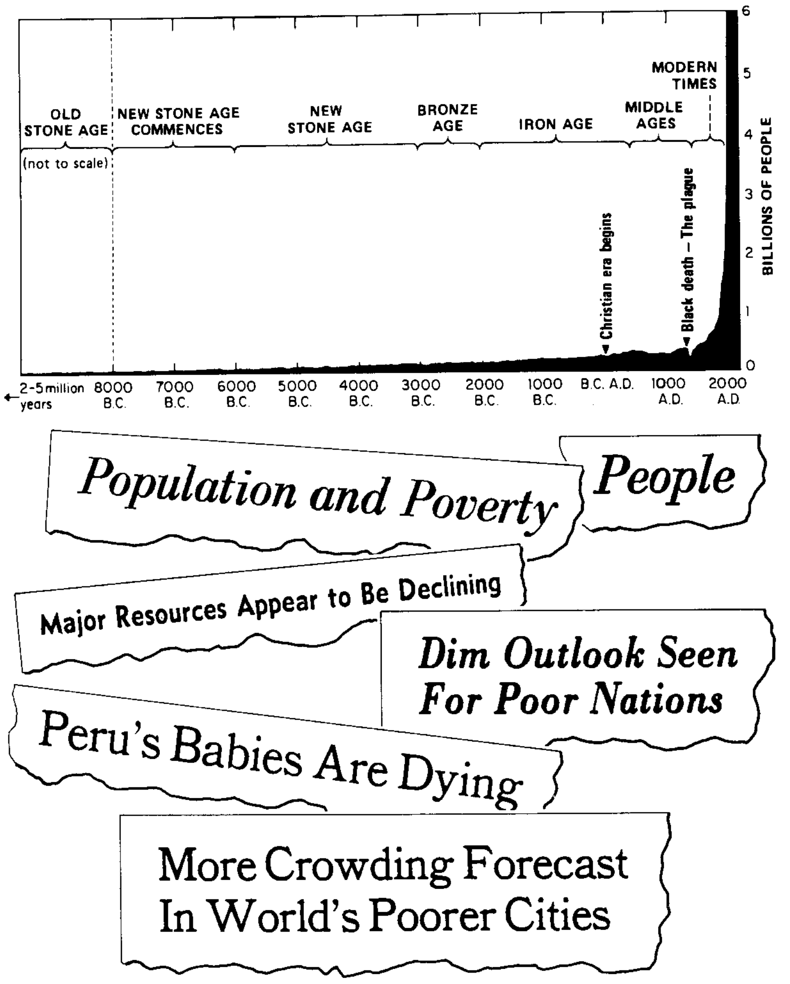
These three dimensions—the trends forseen, their causes, and the certainty with which they are proclaimed—are themselves simplifications, but in combination they transcend the usual dichotomous separation between neo-Malthusians and anti-Malthusians, growth or no-growth advocates, prophets of boom or prophets of gloom, cornucopians or catastrophists, or any of the other neat dualisms that are current these days. That the positions are more varied, however, does not seem to diminish the rancor evident in the debate and controversy.

Having cautioned you to take the analyses of others with a grain of three-dimensional salt requires that I locate myself along these dimensions. As to *trend*, I think we are at a key turning point away from exponential growth towards a global steady state, but both exponential growth or overshoot and collapse can still characterize regional development. As to *cause*, I am an interactionist—nature, society, and technology all contribute to our penultimate problems, but may vary in importance by problem or setting. As to *certainty*, I am cautious—often skeptical—about evidence, but strongminded as to desired values, while always despairing of being able to separate fact from value.

Let's return to the penultimate problems. In my remaining time, I will address each of the problems in turn, first summarizing the major trends of the last 14 years, then presenting some thoughts as to the dynamics or causal process that underlies the trends, and then concluding with some personal concerns for the future.

THE MALTHUSIAN DILEMMA

In 1969, the population problem, some called it a bomb, appeared as such in its usual exponential form (Figure 3). Here in the early years of the '80s, this penultimate problem appears to have changed profoundly. It is now possible to visualize the ultimate population of the earth, ultimate at least for our lives, our children's, and their children. All major demographers agree that we are at the point of inflection where an exponential growth curve begins to be the S-shaped curve of the logistic. Current estimates (shown in Figure 4) differ only in timing and ultimate population, but are bracketed between 8 and 11 billion people with a



Human numbers took two to five million years to reach their first billion, about 1800 A.D. By 1975, 175 years later, the figure was up to four billion. Adding the next two billion could take only 25 years, according to current projections. Today's population explosion is putting tremendous pressures on Earth's resources, environment, and social fabric.

Figure 3. World Population Growth Through History (van der Tak, Haub, and Murphy, 1979, p. 2. Courtesy of the Population Reference Bureau, Inc.)

global steady state beginning as early as 2050. There are exceptions. Lester Brown (1981) tells us we can have a sustainable world of 6 billion people if we have the will and foresight, and Herman Kahn (1976) a quadcentennial (2176) population of 15 billion, give or take a factor of two.

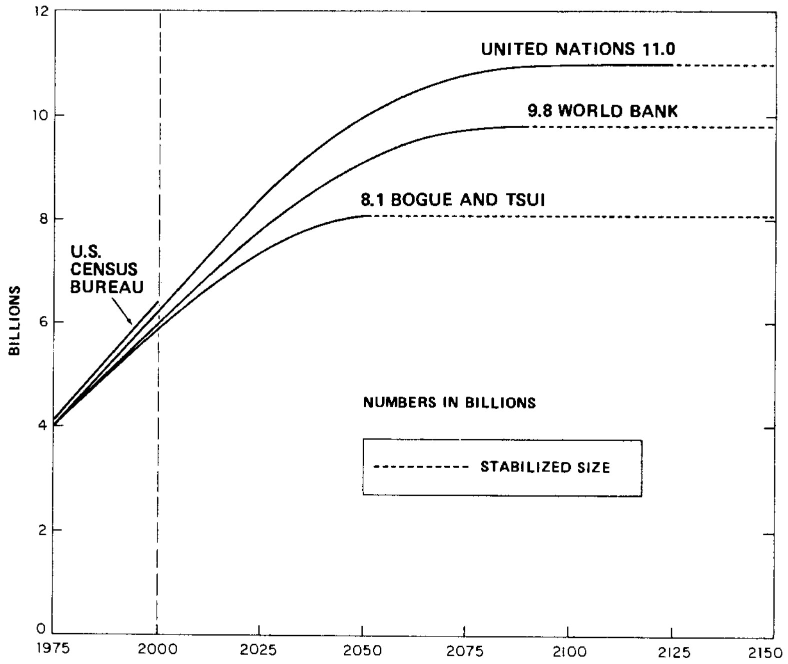


Figure 4. Projections of World Population in 2000 and Ultimate Stabilized Size (van der Tak, Haub, and Murphy, 1979, p. 38. Courtesy of the Population Reference Bureau, Inc.)

NOTES: Primary sources referred to in this graph include: U.S. Bureau of the Census, 1979; World Bank, 1979; United Nations, 1979; Bogue and Tsui, 1979.

The U.S. Census Bureau has not published projections beyond 2000. The World Bank publishes only one series. The other projections shown are medium series (between high and low variants).

If, as I think, we are at the point of inflection, and rates of population growth are decreasing, not only in the rich industrialized world but in many countries in the Third World, then there is some cause for elation. The task of providing a better life for the world's peoples will be reduced because the declining population signals some improvement in living standards and life expectancy, and reduces the burden of providing housing, schooling, and jobs for the new millions. The decline in birthrate that was evidenced in some countries during the '70s puts to rest one of the deep conflicts in responding to this overriding issue—whether a decline in the rate of population increase must precede or follow economic improvement and reduction in child mortality. This decline provides limited support for all of the three major theories of the demographic transition: economic development, birth control, and national culture. The largest reductions were in nations with high rates of development, with strong population control policies and actions, and primarily in the culture zone of East and Southeast Asia. But population decline occurred in lesser degree where only one or two of the three factors were present. We learned that population control could precede economic development, albeit at a slower rate, at least in cultures that prove receptive to it—much as we recently learned that French people regulated their population, for reasons that are not clear, a century ahead of the other nations of Western Europe, beginning prior to the industrial revolution. For 100 years, as shown in Figure 5, French mothers had a third fewer children than mothers in the rest of Western Europe.

While the transition to a steady-state world is in sight, it will be uneven—varying from Europe and North America, where 26 nations have essentially achieved zero population growth, to Africa, where population will increase tenfold over the next 75 years. African demographic exceptionalism is particularly evident in projected growth rates for the year 2,000, at which time it is expected that 75% of Asian populations will be growing at very fast rates (2.1% or higher), compared with only 30% of Latin American and 10% of Asian populations (Tsui and Bogue, 1978).

If we stabilize at 10 billion people, there will be cause for satisfaction, but quiet at best; the world of 2050 will be a world with 2 1/2 times the current population—with 2 1/2

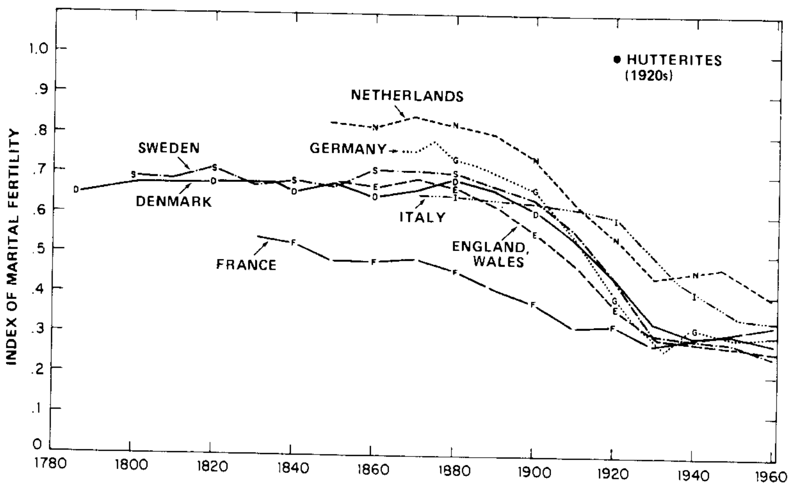


Figure 5. Index of Marital Fertility: Selected European Countries, 1787–1960 (van de Walle and Knodel, 1980, p. 17. Courtesy of the Population Reference Bureau, Inc.)

times the human needs to satisfy. Nor will that task be evenly distributed. In such a world, Nigeria will have more people that the United States or the Soviet Union. This map (Figure 6), in which the continents are proportional to their population, shows the change in demographic power by continental region between 1800, 1980 and after 2050. In

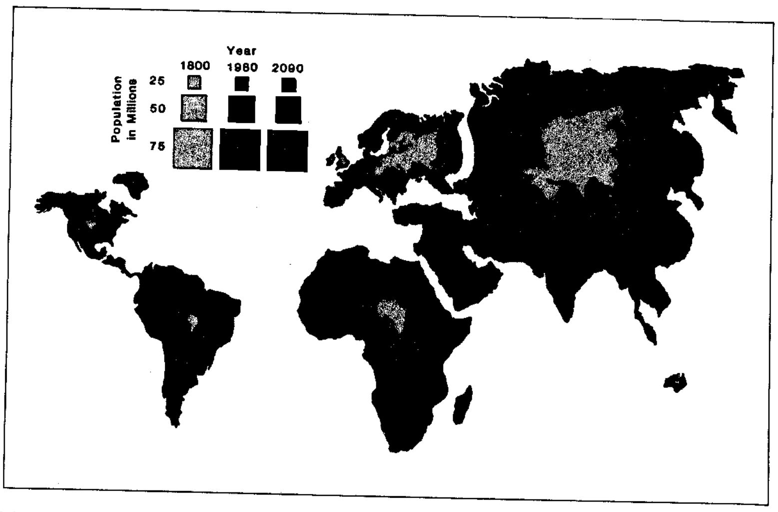


Figure 6. Changing World Population.

1800, 1 in 5 persons was a European, 1 in 14 and African. In the years following 2050, the figures will be reversed, with profound effects on issues of power, migration, and race.

Nor will the steady state be necessarily a happy state—western values are rooted in accumulation, achievement, and growth. The hierarchy of social organization permitted by upward mobility will need to change in a world of more limited demands and opportunities. What to replace it with will be a major challenge.

That the turning point in global population was revealed in the 1970s does not, of course, signal an end to the Malthusian dilemma, or a reduction in the controversies between anti-Malthusian and neo-Malthusian thought. The remarkable thing about Malthus' *Essay on Population* is not that it fits the cynical definition of a classic given by Petersen (1979): "a work that everyone cites but no one reads," but that, despite its repeated refutation, both in theory and observation, it arises anew in each successive intellectual generation by successive expansion of the numerator of resources and the denominator of population (Figure 7).

In 1798, the numerator of the Malthusian equation was solely food and agricultural land, not because Malthus was ignorant of other natural resource needs, but because food requirements so dominated other needs. By the 1850s, however, the food requirements were expanded to other energy and material resources, marked by the classic volume of Jevons (1865) in Britain on the coal question, at the same time as national censuses made possible expansion of the denominator as well. In the United States, the counterpart development might have been the plea of the American Association for the Advancement of Science (AAAS) in 1873 and 1890 (1890) for forest conservation. Food, however, does not disappear; it persists as a concern but on a wider population scale.

The postwar United States would mark a new turning point with the Paley Commission report (President's Materials Policy Commission, 1952), discounting fears as to resource scarcity and laying the groundwork for a new definition of the Malthusian numerator involving amenity

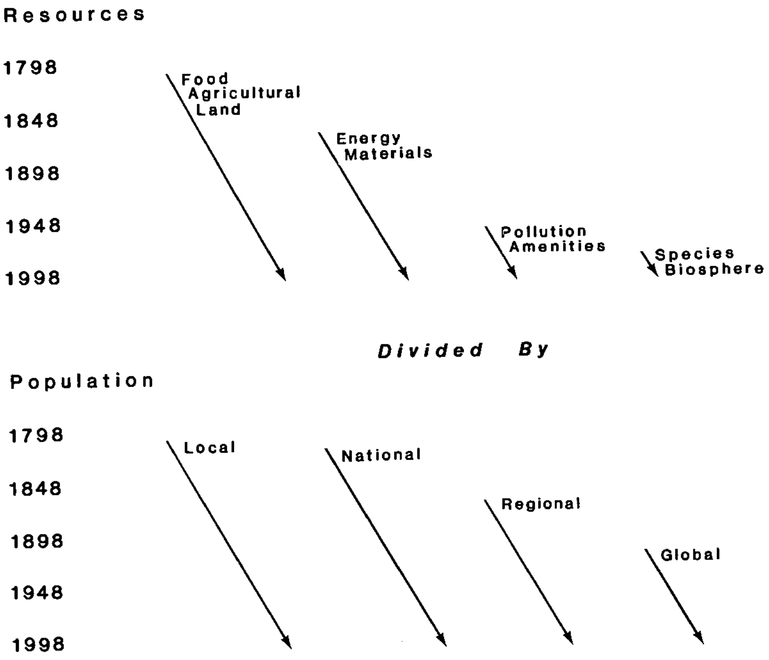


Figure 7. Expanding the Malthusian Equation: Resources Divided by Population.

resources and the pollution-absorbing capacity of the environment. The Stockholm Conference on the Environment in 1972 would enlarge these concerns to a global scale centered on the biosphere and the basic life-support system of biogeochemical cycles. The final extension is the current concern with extinction (Regenstein, 1975; Myers, 1979; Ehrlich and Ehrlich, 1981), and predictions of massive species destruction over the next several decades.

But the earlier definitions by no means disappear; they persist. In the 1970s the concern with food adequacy gets new life in the context of the Sahelian drought. The concern with energy and material resource adequacy is revived by the massive increase in commodity prices during that decade and the recognition of the limitations of oil reserves. As with the earlier Malthusian predictions, the neo-Malthusian predictions also fail. A classic case, of course, is Jevons (1865) on the coal question. An extrapolation of the growth in coal use from the time he wrote his book is shown in Figure 8A along with the actual course of British coal production. These figures bear a striking similarity to those represented in Figure 8B, a recent projection concerning oil use taken from the *Global 2,000* reports extrapolating 1950–75 oil growth with Hubbert's projection of expected U.S. oil production.

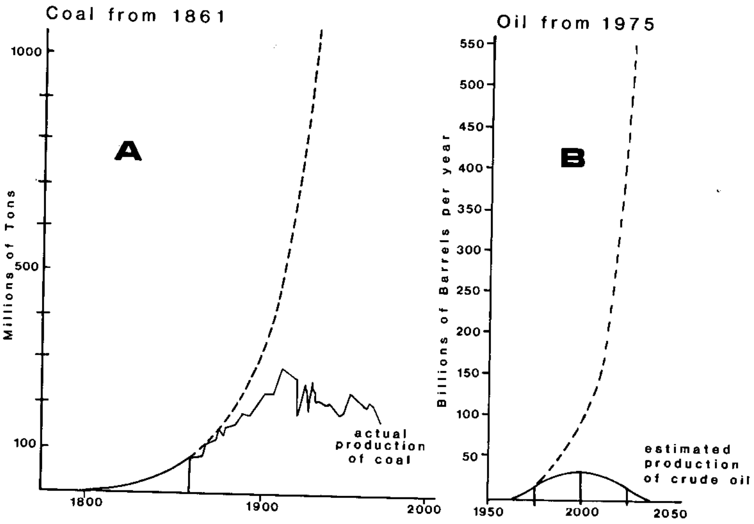


Figure 8. Extrapolating Coal Use from 1861, Oil Use from 1975 (Jevons, 1865; U.S. Council on Environmental Quality, 1980)

Nonetheless, it is safe to predict that neo-Malthusian debate will persist, and along these particular lines: food adequacy will be of most serious concern in Africa; energy adequacy in terms of alternatives for industrialized countries and in terms of fuel wood and high import prices in developing countries; pollution in the megacities of the developing world; species in the tropical rain forest; and the biosphere in the context of the increasing human modification of the atmosphere.

To sum up the Malthusian dilemma, the last 14 years have seen a declining rate of population growth everwhere but in Africa, with future projections of a global steady-state population of from 8-11 billion occurring as early as 2050. Support is found for all the major theories of the demographic transition debated in the early years of the '70s. At the same time, the numerator of concern in the Malthusian equation continues to expand and the Malthusian equation is constantly redefined anew, providing plenty of concerns for the future.

GLOBAL CONCENTRATIONS OF WEALTH AND POVERTY

In 1969, average per capita income for the developing countries was $204, compared with $2,460 for the industrialized countries, a ratio of 1 to 12. In 1980, the figures had risen to $820 and $8,505, respectively, a ratio of 1 to 10 (Sivard, 1982). In absolute terms the rich had grown much richer, but not in relative terms, although the poor were still very poor. The worldwide stagflation had taken its toll on the industrialized nations' growth, while it had penalized developing countries with an order of magnitude increase in oil prices, high interest rates, and low demand and prices for most export commodities.

The penultimate problem of poverty and wealth in 1969 anticipated social disorder and conflict, and there were plenty of both in the 1970s. Since 1969, 43 wars claimed at least 8.3 million lives (Sivard, 1982), primarily in the poor

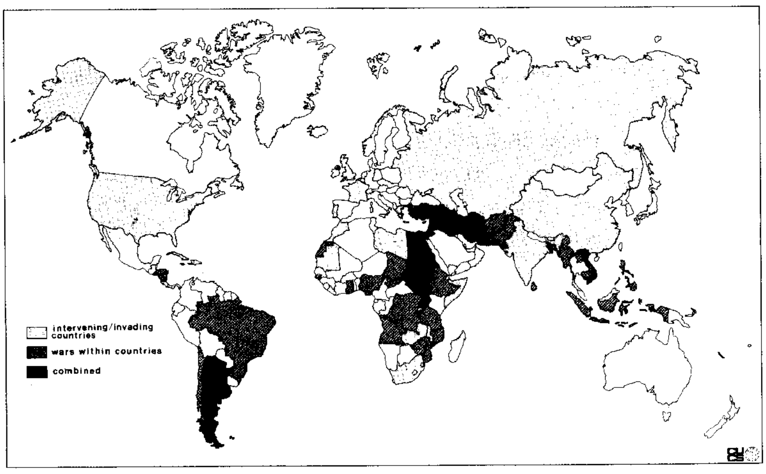


Figure 9. Wars, 1969–1981 (after Sivard, 1982)

parts of the world (Figure 9). Since 1968, there were 7,425 internationally related terrorist incidents (U.S. Department of State, 1982). Amnesty International kept records on some 4,952 prisoners of conscience in 1981 (Amnesty International, 1982) and urged action in behalf of prisoners in 67 countries. Major attempts to ameliorate North-South tension in the form of the Brandt report (1980), the new economic order, aid distribution, or trade concessions basically failed. Official development assistance was .34% of industrial nation gross national product (GNP) in 1970, and .35% in 1981 (Sivard, 1982). The U.S. proportion was second lowest among 17 industrial nations and a national disgrace.

The global concentration of wealth and poverty is foremost an issue of political economy, not of the human environment. Nevertheless, it is important to recognize that economy and environment interact in at least two important ways: on the one hand, economy may prevent the realization of feasible improvements in the human environment; on the other, within specific regional contexts, environment often exacerbates the disparity between nations.

By the end of the '70s, the sociopolitical, rather than the technical, obstacles of many environmental issues were clear. There was a consensus that, in the aggregate, food supplies were adequate to feed all the world's people—shortages were limited to region or class (Figure 10). Thirty percent of the population of low-income countries may be malnourished, but poverty rather than environment was the prime source.

Similarly, there is a growing consensus on other issues of health and mortality. Based on the experience since 1969, it now seems clear that communicable diseases that take the lives of 5 million children a year can be eradicated as was smallpox (Holdgate, Kassas, and White, 1982); that improved water and sanitation are in reach of the rural peoples of the world, as they have been provided for urban people (United Nations, 1980); that death from disaster can be reduced by at least half, using the best practices currently available in developing countries (Burton, Kates and White, 1978); and that pollution can be controlled for about

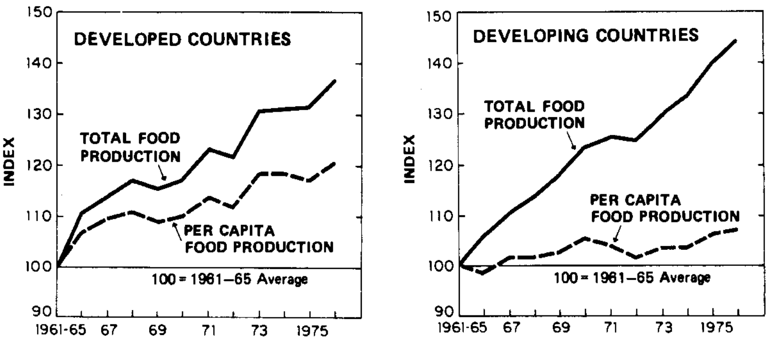


Figure 10. Total and Per Capita Food Production: Developed and Developing Countries, 1961–65 to 1976 (van der Tak, Haub, and Murphy, 1979, p. 25. Courtesy of the Population Reference Bureau, Inc.)

NOTE: Developed countries include all of Europe, U.S.S.R., Israel, Japan, South Africa, U.S., Canada, Australia, New Zealand. Developing countries include all others.

1-2% of GNP, as is being done in many industrialized nations (Holdgate, Kassas, and White, 1982). In each of these areas, there is more knowledge than is currently used; what is needed is a little wealth and much will.

Political economy and environment converge to produce a class of small, low-income nations that are the poorest-of-the-poor (Figure 11). Indeed, the gap between them and

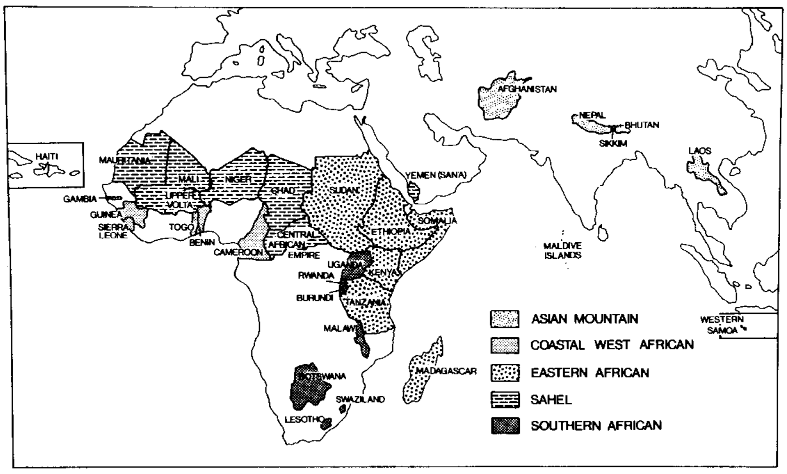


Figure 11. Least-Developed Nations (Clark University Program in International Development and Social Change, 1974)

other developing nations is growing rapidly, both absolutely and relatively. This is a map of the so-called "least-developed nations," a dubious accolade, whose criteria (per capita GNP, illiteracy, percent manufacturing) were defined when I was in the employ of one such nation. With the best of intentions, there was hope that identifying this group of nations would entitle them to special considerations of need in global aid distributions and in trade adjustments.

Five years after this designation, home in America, my colleagues and I were struck by the nonrandom location of these nations. Located mainly in Africa, they are peripheral not only to the core centers of world power, but within their own regions as well. Their small size, landlockedness, regional peripherality, and arid or mountain environments combine to enhance the effects of political-economic poverty. It is not environment that makes them poor, but it is environment that makes them the poorest-of-the-poor.

Looking to the future, the most immediate response to the global inequalities of wealth will be an ever-accelerated pattern of national and international migration reproducing that which has already occurred in Europe (Table 2) and North America. The great disparity in numbers between Europe and Africa will result in massive African outmigration, with Africans occupying the migrant worker status of current-day Latins. This outmigration is already evident in France today (Table 3). In the Americas, the legal

		Receiving Countries				
Sending Countries	**Total**	**West Germany**	**France**	**Switzerland**	**Belgium**	**Netherlands**
Greece	250	240	*	*	*	*
Italy	500	230	100	150	12	*
Portugal	510	40	450	*	*	*
Spain	640	150	330	100	40	20
Yugoslavia	490	400	55	25	*	*
Total	2,390	1,060	940	280	70	40

Table 2. European Migration Balances, 1960–1970 (in thousands) (Bouvier, Shryock, and Henderson, 1977, p. 13. Courtesy of the Population Reference Bureau, Inc.)
*Less than 10,000.

Nationality	**Number (000s)**	**% of Foreign Population**
Algeria	884.3	21.1
Portugal	858.9	20.5
Italy	558.2	13.3
Spain	531.4	12.7
Morocco	322.1	7.7
Tunisia	167.5	4.0
Poland	86.4	2.1
Yugoslavia	77.8	1.8
Other	709.5	16.8
Total	4,196.1	100.0

Table 3. Foreign Nationals in France, 1976 (in thousands) (Bouvier, Shryock, and Henderson, 1977, p. 13. Courtesy of the Population Reference Bureau, Inc.)

and illegal migration across the permeable U.S. border will accelerate, illegal migration at the Mexican frontier having recently doubled in direct response to the devaluation of the peso. One recent projection (Davis, 1982) of a 1.5 million annual immigration to the United States, which is only a half again larger than current estimates of immigration (legal and illegal), sees an Hispanic-Black-Asian majority in the United States by the middle of the next century. These massive migrations will bring fresh energy, new culture, and old issues of power, exploitation, and racism to most of the wealthy world.

To sum up, the rich grow richer absolutely, less so relatively, as an ever more important gap appears among the poor countries, with the emergence of a persistent group of least-developed countries. In such a world, social disorder is commonplace, and unmet human needs mock the great potential for the betterment of human existence. The basic causes, rooted in political economy, are beyond my competence to analyze, but unmet human needs could be met with modest reallocation of resources and national leadership. The least-developed nations remain so, their problems exacerbated by environmental and spatial location. The gaps will be most evident between Africa and the rest of the world, and the accelerating migration from poor to rich countries will bring new problems and opportunities.

THE SOCIAL CONTROL OF TECHNOLOGY

There is a basic asymmetry between the benefits and risks of a technology. With the exception of those technologies the function of which is to kill or destroy (weapons, chain saws, pesticides, antibiotics), most technologies only create hazards incidental to their production and beneficial use. Thus the identification of a technological hazard and social efforts to control it inevitably lag behind a given technology's use. The vested interests of both technology sponsor and consumers further restrain social control.

In the 1970s, the lag between technology development and hazard control diminished considerably both for old and new technologies. This is shown for 6 hazards in Figure 12. In the United States, for example, much of the '70s was marked by the discovery of the "hazard-of-the-week"—

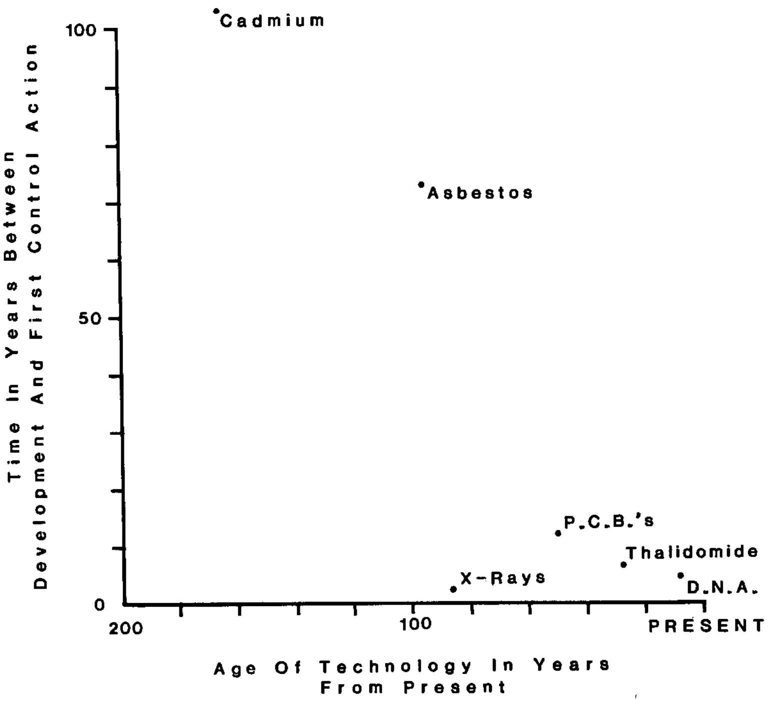


Figure 12. Technological Development and Hazard Control (based on estimates by M. Morrison, Clark University)

between 40-50 new or newly discovered hazards were featured in the media each year. This increase in hazard management arose from several sources.

Commoner (1971) argued that changes in technology since World War II have been fundamental and disjunctive, not simply the continuation of processes initiated by the industrial revolution. The most dramatic technological threat was the introduction of nuclear weapons in 1945. Less dramatic, but also significant, was the synthesis, large-scale production, and disposal of thousands of new chemicals, and the mobilization and concentration of fossil energy and naturally scattered materials.

While one may argue about whether World War II represents a technological watershed and that the spate of hazard identification is the delayed recognition of the perils of progress, there have also been major improvements in the ways in which hazards are identified and monitored. These include new screening techniques with low-cost tests; computer modeling of hazardous sources, pathways, and sinks; monitoring networks for major air, land, and water pollutants; and rapid growth in general scientific effort devoted to hazard research.

Along with the disjunctive change in technologies and improved means of hazard identification, the public, too, has become more sensitive to hazard. More than 78% of the public perceive *greater* risk today than in the last 20 years, contrary to the expectations of most experts (Harris, 1980). The source of this changing public perception is not wholly clear. Part of it lies in the actual and identified increase in hazardous technologies and in the attention provided to them by both scientists and the media. But there are also deeper roots: the concern with radiation and chemicals may be replacing older insecurities, enhanced by the periodic fluctuations of optimism and despair in public mood, and by the politics of liberalism and conservatism.

Whether public perception matches the reality of hazard, the burden of hazard on society is a large one. In the United States alone, the estimated social costs of hazards associated with the manufacture and use of technology—including property damage, losses of productivity from illness or death, and most but not all of the costs of control—amounted to between $179 and $283 billion in 1979 (Table 4), equivalent to 7.8%-12.4% of GNP (Tuller, forthcoming).

Cost To	**Cost of Control**	**Damage and Loss**
Private Sector	67.4-80.4	
Federal Government	21.7-34.8	
State and Local Government	11.0-17.3	Not Available
Public	31.7-52.1	
Total	99.1-132.5	79.8-150.2
Total Costs and Losses	178.9-282.7	

Table 4. Social Costs, Damages, and Losses from Technological Hazards, 1979 (in millions of dollars) (Tuller, forthcoming)

Similarly, from 15% to 25% of the annual mortality is associated with various technologies (Harriss, Hohenemser, and Kates, 1978). No similar analyses have been done elsewhere in the world, but there is every reason to believe that such patterns of damage and loss would be found equally in most industrialized countries and in urban areas of developing countries, where the damage estimates might even be greater.

Despite this large toll, there are grounds for cautious optimism. Most acute effects (e.g., accidental injury) of technology have been on the decline or have held relatively constant. Cancer rates, with three exceptions (declining stomach and uterine, rising lung cancer), have been relatively constant, although studies claim a significant increase in the 1970-76 period in the United States, with later data still unavailable (Schneiderman, 1982). Significant progress in the United States has been made in reducing levels of 3 of the 5 major air pollutants (Conservation Foundation, 1982), and national surveys, while revealing epidemic proportions of deleterious blood-lead levels in children, demonstrate nevertheless a marked and gratifying decrease (Figure 13). The UNEP World Environment report finds that despite rising human impacts on natural

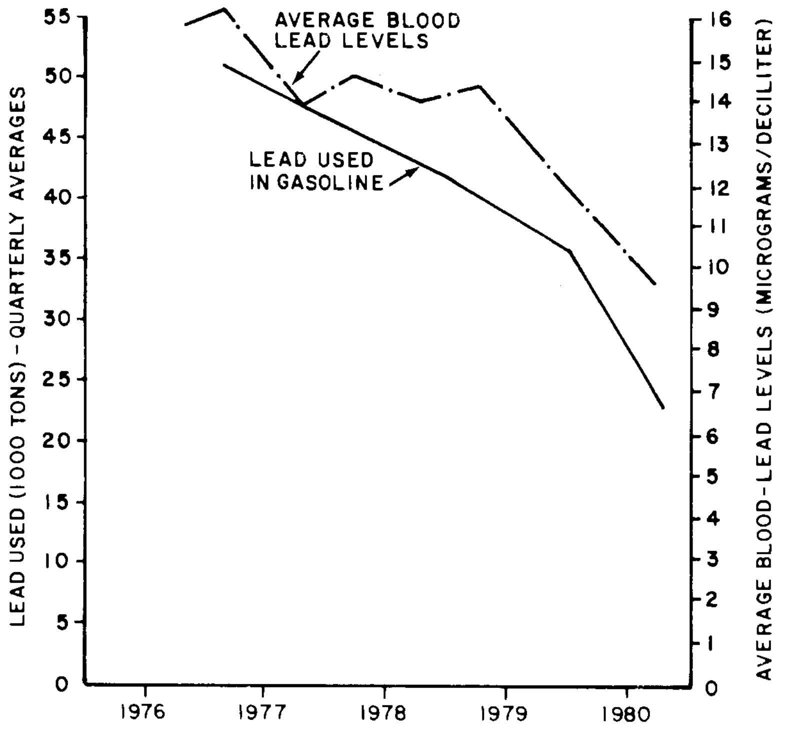


Figure 13. Lead Used in Gasoline Production and Average NHANES II Blood-Lead Levels, February 1976–February 1980 (U.S. Department of Health and Human Services, 1982, p. 134)

NOTE: NHANES II is the acronym for the Second National Health and Nutrition Examination Survey.

systems, the overall short-term productivity of soil, ocean, and forest has not been significantly impaired (Holdgate, Kassas, and White, 1982). Thus, for technologies whose consequences are immediate, whose sources are identifiable, and whose mechanisms are reasonably well understood, the problem of achieving a tolerable level of risk is expensive and challenging but acceptable, a concomitant to the widespread beneficial use of modern technology.

More difficult to deal with are acute hazards of a rare catastrophic nature, or slow and cumulative hazards of great persistence, spread, or toxicity. Our recent comparison of 93 technological hazards has identified 5 sets of extreme hazards, 4 of which represent difficult types to cope with (Table 5). These 4 are intentional biocides, the persistent, delayed teratogens, the rare catastrophes, and the diffuse global threats. The fifth group is composed of common killers, such as automobiles or black-lung disease.

Class	**Examples**
I. Hazards	Appliances, Aspirin, Bicycles, Saccharin, Skateboards
II. Extreme Hazards	
1. Intentional Biocides	Antibiotics, Chain Saws, Vaccines
2. Persistent Teratogens	Mercury, Uranium Mining
3. Rare Catastrophes	Aviation Crashes, LNG Explosions
4. Diffuse Global Threats	Fossil Fuel-CO_2, Ozone Depletion
5. Common Killers	Auto Crashes, Coal Mining
III. Multiple Extreme Hazards	Nuclear War, Pesticides, Recombinant DNA

Table 5. Taxonomy of Technological Hazards

The *intentional biocides* derive their lethality from the great toxicity involved in the design of technologies to hurt living organisms: humans in the case of weapons, insects with pesticides, vegetation with herbicides and chainsaws, and bacteria and viruses with drugs. Highly efficient, these technologies are usually narrowly targeted and access to them is restricted. But, if by error of decision or application or by intention, they drift off target, then they are enormously dangerous. Thus, in our time we have already seen nuclear war in Japan, massive pesticide poisoning in Pakistan, and worldwide penicillin-resistant strains of gonorrhea.

Persistent, delayed teratogens and mutagens comprise a class of hazards whose inherent danger arises from the potentiating combination of characteristics, each of which is threatening but manageable by itself. The combination of long life for the material, long delay until consequences appear, and transgenerational impact make them so hazardous. Metals such as cadmium, selenium, antimony, molybdenum, lead, and mercury have human-created fluxes of between 5 to 80 times those found in nature. All of these can accumulate slowly, and persist almost forever to cause serious disruption to living organisms, especially fetuses. Several are also mutagenic. Heavy metals and radiation have already caused numerous outbreaks and a few major epidemics such as mercury-caused Minamata disease in Japan and the seed-grain mass poisoning in Iraq.

For most of the *rare catastrophes* the mechanisms are well understood: a jumbo jet collision, collapse of a dam, a nuclear reactor accident, an LNG (liquefied natural gas) tank explosion, or the fall of a satellite. We have already had a number of major dam failures, only one jumbo jet collision, a single LNG tank explosion, and near misses with satellites and nuclear reactors. However, for some potential catastrophes such as the accidental creation of a virulent microorganism using recombinant DNA technology, the threat, while possible, is almost impossible to assess reliably or perhaps even to verify if it did occur.

Finally, there are the *diffuse global threats* caused by materials worldwide in their disbursement that slowly but steadily accumulate mainly in or through the atmosphere and threaten to change the climate, destroy the protective ozone layer, or increase the acidity of precipitation. The threats are identifiable, but much scientific uncertainty still remains regarding the speed at which they are evolving, the sources, the mechanisms, and the impacts. We do know that the annual release of CO_2 into the atmosphere is equal to about 10% of that used by plants; nitric oxides and nitrate products produced by human sources are about 50% of what the biosphere produces naturally, and more sulphur dioxide enters the atmosphere from human activities than is exchanged naturally (Holdgate, Kassas, and White, 1982).

This taxonomy of hazards lends itself to a priority list or to a hazard agenda (recall Table 5). A few hazards are extreme in more than one of the 5 dimensions—for example, the radiation effects of nuclear war, recombinant DNA, and some pesticides. Most hazards are not extreme in any dimension, for instance, saccharin, aspirin, household appliances, or skateboards. In between are examples of hazards that are extreme in one or another major group. This suggests a modified form of "triage": extraordinary attention to the multiple extreme hazards, distinctive effort appropriate to each of the groups of extreme hazards, and an ordered but routine response for the remainder.

The years ahead should bring a continuation of the helpful trends of the '70s despite some of the current retreat from caution. The public has been remarkably consistent in its desire for environmental protection and health safety (Figure 14). However, a diminution in the publicly recorded fears for the future will not occur until we understand the

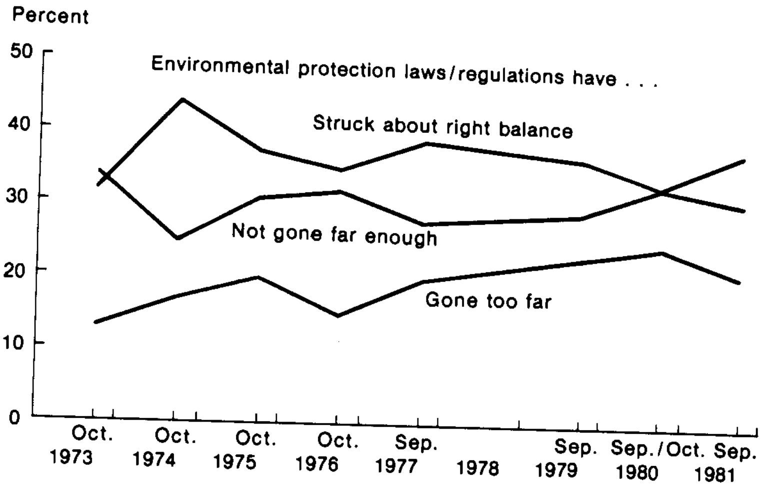


Figure 14. Public Perception of Environmental Laws and Regulations, 1973–1981 (Conservation Foundation, 1982a, p. 425. Courtesy of the Conservation Foundation and the American Enterprise Institute)

NOTE: The primary source of the information represented in the graph reproduced here is the Roper Organization Polls, 1973–1981. The question asked was: There are . . . differing opinions about how far we've gone with environmental protection laws and regulations. At the present time, do you think environmental protection laws and regulations have gone too far, or not far enough, or have struck about the right balance? "Don't know/no answer" responses (not plotted) ranged between 10% and 21%.

mechanisms of the major human diseases of industrial countries (cancer and atherosclerosis), determine the effects on the biosphere of human-induced changes in energy and materials flow, and learn to control the irrational insecurity of the arms race.

In the developing world the situation is more worrisome. Technologies that are tightly controlled in industrial countries, such as pesticides or antibiotics, are readily available in many developing countries. The great urban centers of the Third World display patterns of auto injury or pollution that exceed those of many wealthy cities, and at the same time they maintain an environment of infectious disease and malnutrition comparable to or exceeding those of rural areas. In the year 2000, there may be 61 such cities with populations exceeding 4 million, including Mexico City with 32 million people, São Paulo with 26 million, and 8 others with over 15 million people.

For the industrialized countries, I find particularly troubling the structural changes taking places in the roles of scientist, technologist, and entrepreneur and in the basic division of labor among scientific discovery of principles, technological development of devices or processes using them, and entrepreneurial production and distribution. There is an inevitable lag between hazard creation and hazard identification. Scientists, knowledgeable about the basic principles of a technology but uninvolved in its development, serve to provide early warning and identification of hazard. But in the three major technologies of the last 40 years, this has broken down: in the creation of the atom bomb, in computer and related information technologies, and in the emerging biotechnology. In the first case, the dual wartime role of the scientist and technologist that created the bomb ended for some scientists rather quickly. These then became "critical scientists,"to use Ravetz's term (1971), and many of them served and continue to serve to warn us of the dangers of the arms race.

In contrast, the subtle consequences, both good and bad, of the information revolution have not emerged yet. Indeed, we still know surprisingly little about television's effects after 20 years of intensive study (Graham and Kasperson, forthcoming). Fortunately, the first-order consequences of information technologies do not appear to affect health and environment directily (with the exception of radiation and certain chemicals).

Most troubling of all for me is the emergent biotechnology, but not because I possess expert knowledge of its hazards. What disturbs me is the structure of the technology, with scientific experiments, technological development, and entrepreneurial production collapsed into a continuous activity, and those most knowledgeable playing all three roles in a rush to early discovery, innovation of use, and profit. Theoretically, biotechnology is extremely powerful, and I worry that even the much-improved societal hazard management developed in the last decade cannot cope with its challenge in the face of the massive co-optation of the relevant scientific community.

To sum up, despite an expanding technology and growing hazard perception, there are encouraging signs of improving social control, albeit at a high cost of between 7-12% of equivalent GNP. The basic lag between benefit and hazard identification is diminishing even though the new hazards are more subtle and less evident, supported in part by the increased social sensitivity—some would argue hypersensitivity—to hazard. It is now possible to draw up an agenda of particularly hazardous types based on physical, biological, and social characteristics. Worrisome for the future is the consolidation of roles in technology development as exemplified in the emerging biotechnology and the ready diffusion of hazardous technology in the Third World without the institution of social control.

CONCLUSION

By profession I am a worrier, a scientific worrier in my chosen corner of the human environment. I try to measure, weigh, and anticipate what to take seriously, what to ignore, what to act upon, and what to study more. The penultimate problems of human existence are mega-worries, and tonight I have reported on their state over the 14 years since I began systematically to contemplate them.

By personality, I am an optimist, but I worry about the interaction of personality and profession—does my internal biology of hope (Tiger, 1979) distort my scientific judgment? Yet I must report hope, surely for at least two of the three penultimate problems. A historic turning point has been reached in world population numbers. There is a growing competence in the social control of technology in industrialized countries. Even the disparity between rich and poor has slowed, albeit in a surprising way by the humbling of the rich rather than the elevation of the poor. Yet there is still much cause for concern:

1) It is overwhelming to find that our leaders continue to engage in the endless overkill of the arms race.

2) It is frustrating to know the potential to eliminate death from hunger, disease, and disaster and how little that potential has been realized.

3) It is worrying that in the aggregate we still know so little about the impacts of the 3 great technological innovations of the last half century.

As a professional worrier, I recently had a surprising interchange with an old friend in the course of doing a videotape interview. She asked me: "As you look to the future, what is the thing you fear most and what is the thing you hope most?" I hemmed and hawed, thought frantically, mentally reviewed my current list of 17 natural and 93 technological hazards, and then spontaneously blurted out "The loss of hope, and the loss of idealism."

If we come to accept the inevitability of nuclear war, the persistence of hunger and disease, the mindless autonomy of technological change, then they surely will come to pass. It is only that curious mixture of faith and necessity that we call hope that can keep the penultimate problems in their place.

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ABOUT THE AUTHOR

Robert W. Kates, research professor, Center for Technology, Environment, and Development, Clark University, is recognized internationally for his contributions to risk assessment and management of hazards, climate impact assessment and theory of the human environment.

He was born in Brooklyn, New York, in 1929. He studied at New York University, Indiana University (Gary), and received M.A. and Ph.D. degrees in geography from the University of Chicago. He has been a member of the faculty of the Graduate School of Geography at Clark University since 1962, and was named research professor in 1981. He has been a visiting scholar at several institutions and participated in many collaborative research projects including the Collaborative Research on Natural Hazards project with the Universities of Chicago, Colorado and Toronto. He is co-author with Ian Burton and Gilbert F. White of *The Environment as Hazard* and author of many other monographs, reports and research publications.

His awards include the Association of American Geographers Honors Award, honorary membership in Phi Beta Kappa, and a MacArthur Prize Fellowship. He is a member of the National Academy of Sciences, American Academy of Arts and Sciences and other professional organizations. He is an active participant in the committees and panels of these organizations.

REUBEN GUSTAVSON

Reuben G. Gustavson, born in Denver on April 6, 1892, was the son of an immigrant carpenter. Because of a physical ailment caused by a boyhood accident, his father decided that Reuben could never make a living as a carpenter and insisted that he take the commercial course in high school. Reuben's job was as an office worker for a railroad. The likelihood of an academic career for him was extremely slight—particularly one that might lead to national and international repute.

Volunteer work in the research laboratory of a tuberculosis sanitorium fired Gustavson's desire to study for a scientific career. Lack of money (as usual) and admission (language) requirements seemed insurmountable obstacles. A perceptive admissions officer found a way around the language requirement by accepting an examination in Swedish (the language of the Gustavson home) in lieu of a high school language course. Had it not been for this wise judgment, our country might well have been deprived of Reuben Gustavson's enormous contribution to science and education.

He was to be a teacher of chemistry at Colorado State University (1917–20) and the University of Arizona (1959–67); teacher and researcher in chemistry and chairman of the department at the University of Denver (1920–37) and the University of Colorado (1942–43); vice president and dean of faculties at the University of Chicago (1945–46); president of the University of Colorado (1943–45), and chancellor of the University of Nebraska (1946–53). He became president of the Resources for the Future (RFF) foundation during its formative years (1953–59) and chairman of its board of directors (1961–71). He died in 1974.