DOCUMENT RESUME

ED 091 187 SE 017 711

AUTHOR	Holdren, John P.
TITLE	Population and the American Predicament: The Case Against Complacency.
INSTITUTION	California Inst. of Tech., Pasadena.
PUB DATE	73
NOTE	17p.; Occasional Papers Series 1 Number 4; For related documents, see SE 017 708 - 710
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	*Environmental Education; Life Style; *Living Standards; *Natural Resources; Physical Environment; *Population Education; *Population Growth; Population Trends; Public Health
IDENTIFIERS	United States

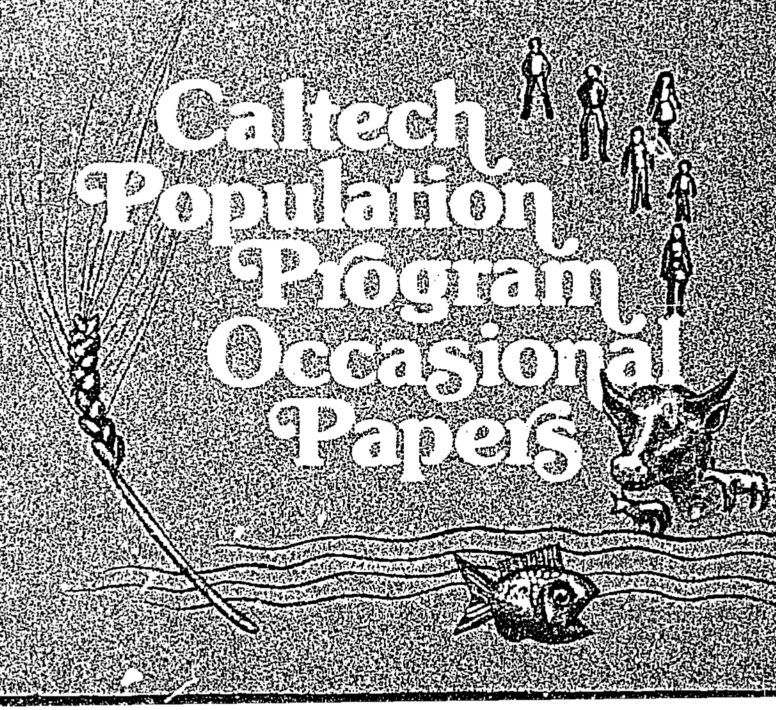
ABSTRACT

The goals of the Caltech Population Program are to increase understanding of the interrelationships between population growth and socioeconomic and cultural patterns throughout the world and to communicate this understanding. This series of occasional papers is one step in the process of communicating research results. The papers deal primarily with problems of population growth and the interaction of population change with such variables as resources, food supply, environment, urbanization, employment, economic development, and social and cultural values. This fourth paper in the series concentrates on the consequences of population growth in the United States. The author presents the position that the American population should be stabilized or even reduced. Reasons for this belief, as well as possible methods and their liabilities, are discussed. (LS)

Series 1 Number 4

POPULATION AND THE AMERICAN PREDICAMENT: THE CASE AGAINST COMPLACENCY

John P. Holdren



Caltech Population Program

The Caltech Population Program was founded in 1970 to study the factors influencing population growth and movement. Its goal is to increase our understanding of the interrelationships between population growth and socioeconomic and cultural patterns throughout the world, and to communicate this understanding to scholars and policy makers.

This series of Occasional Papers, which is published at irregular intervals and distributed to interested scholars, is intended as one link in the process of communicating the research results more broadly. The Papers deal primarily with problems of population growth, including perceptions and policies influencing it, and the interaction of population change with other variables such as resources, food supply, environment, urbanization, employment, economic development, and shifting social and cultural values.

The views expressed in this monograph are those of the author, and do not necessarily represent those of CIT or the Caltech Population Program, its directors, or staff.

POPULATION AND THE AMERICAN PREDICAMENT:

THE CASE AGAINST COMPLACENCY*

John P. Holdren

That the United States should and probably can achieve a condition of zero population growth at some time in the next hundred years is no longer a matter of much dispute. Most students of contemporary American problems seem to have agreed, at least, that the costs of long continued population growth would considerably outweigh the benefits; and the achievement in 1972 of a total fertility rate slightly below replacement has convinced many that a spontaneous and fortuitous approach to a stationary population is already underway. Since the factors that have led to the decline in fertility have not been disentangled, however, it is difficult to be sure yet whether the recent experience represents a fluctuation or a trend. Against this backdrop of loose consensus on the long-term desirability of ZPG (zero population growth) and uncertainty about the origins and persistence of recent levels of fertility, serious and controversial questions remain to be settled. Do the potential consequences of continued population growth in the United States justify systematic measures to hold fertility at replacement level, if it should show any tendency to rise again? Should such measures be used to push fertility well *below* replacement, if it does not drop that far without them, in order to bring the attainment of ZPG closer than seventy years hence and to render the intervening population increment smaller than some 70 million? Is even the present U.S. population of 210 million too large? Should there be zero economic growth as well as zero population growth?

Obviously, one's degree of concern about, say, a 30 percent increase in the U.S. population—the increase that would result if fertility remained at the replacement level in the absence of immigration—depends on the way one perceives two basic relations: the role of population size in contributing to existing problems, and the role of population growth in aggravating these

*This paper originally appeared in the Fall 1973 *Daedalus, The No-Growth Society*. Our thanks to the jorunal and to the American Academy of Arts and Sciences for permission to reprint it.

problems and impeding the success of attempted nondemographic remedies. I believe that those who are unconcerned by the prospect of 280 million Americans have seriously underestimated the importance of population in both roles. I will argue here that 210 million now is too many and 280 million in 2040 is likely to be much too many; that, accordingly, a continued decline in fertility to well below replacement should be encouraged, with the aim of achieving ZPG before the year 2000 and a gradually declining population for some time thereafter; and that redirecting economic growth and technological change (*not* stopping either) is an essential concomitant to but not a substitute for these demographic goals.

The Moderate Position

For the purposes of developing this argument, it is useful to begin with the more moderate position taken by the National Commission on Population Growth and the American Future. One can then focus on the specific issues that justify, I believe, a greater sense of urgency than the Commission's recommendations convey.

The Commission's March 1972 final report[1] concluded that "no substantial benefits would result from continued growth of the nation's population," and, more positively, recommended that "the nation welcome and plan for a stabilized population." Of the possible specific justifications for its recommendation, the Commission chose, perhaps wisely, to emphasize those that are relatively easily demonstrated and unlikely to be controversial: it said that coping with continued population growth would divert money, materials and talent from urgent domestic tasks; that, although solutions can be found to the problems of meeting the physical needs of an expanded population, these may include a good many measures we do not like; and that many policies desirable on their own merits (such as equality for women and universal access to contraceptives) will move us automatically in the direction of population stabilization.

With respect to the effects of American population growth on problems of resources and environment, the Commission's report held population stabilization to be desirable if not urgent. The report noted that population size, while far from being the sole cause of environmental damage, is a multiplier of other causes of such damage. Thus, argued the Commission, even in cases where reduction of emissions per person represents the easiest short-term approach to reducing environmental disruption, unabated population growth could wipe out the long-term gains from such a measure. As for mineral and energy resources, the Commission anticipated few problems of absolute supply in the next several decades that could not be alleviated by moderate increases in price. Such increases, the Commission concluded, would stimulate the use of lower grade domestic ores, or increased imports, or technological substitutes. Their basic verdict about resource adequacy held, even under the assumption of rather rapid population growth in the U.S. and substantially increased demands elsewhere. The most serious resource related difficulties facing this country in the next fifty years were deemed to be regional water shortages, increased pressure on scarce recreational land, and substantially higher food prices owing to shortage of good agricultural land.

The Commission's position, then, was hardly one of unrestrained optimism concerning the consequences of further population growth in the United States, but neither was it a flat statement that this country is overpopulated now or a clear call for early stabilization. What are the grounds for holding a stronger view? They emerge, I think, from a closer look at five sets of issues: the character of the environmental problems related to population, and their potential impact on well-being; the international ramifications of U.S. resource consumption; the specific mechanisms through which demographic variables contribute to problems of resources and environment; the liabilities and limitations of "direct," nondemographic attacks on problems with demographic components; and the meaning of "optimum" population size.

Environment and Well-Being

The Population Commission divided environmental pollutants into two classes. The first class included most products of combustion and several conventional measures of water pollution. The apparent ease with which technological improvements could reduce emissions of these pollutants to levels below those posing acute threats to health formed the basis for the Commission's main conclusions concerning the environment. The second class of pollutants, including long-lived general poisons such as pesticides, radioisotopes and heavy metals, was not considered in detail, owing to the Commission's belief that insufficient information was available on these subjects. Neither were the effects on human well being of ecological disruption in forms other than direct poisoning of people considered in any depth, presumably also on grounds of insufficient evidence. And yet, ignoring for a moment the practical difficulties of implementing controls on even the common pollutants in the first class, it seems likely that the most serious environmental threats lie in precisely the categories that the Commission did not explore.

The long-term human consequences of chronic exposure to low levels of persistent environmental contaminants, for example, may be more serious—and the causes less amenable to removal—than those of acute pollution as it is perceived today. Much remains to be learned about this subject, including especially the potential for induction of cancer or genetic damage by contaminants present *at low concentrations and in combination*—pesticide and fertilizer residues, heavy metals, plasticizers, food additives, prescription and nonprescription drugs, and so on.

Still more threatening, in all probability, is civilization's interference in the smooth functioning of biological processes that provide us with services we do not know how to replace. Most potential crop pests are controlled by their natural enemies or by other environmental conditions, not by technology.[2] Similarly, many agents of human disease are controlled not principally by medical technology but by environmental conditions, and some carriers of such agents are controlled by a combination of environmental conditions and natural enemies.[3] The cycling of essential plant nutrients such as nitrogen, phosphorus and sulfur is contingent at various stages on biological processes, and these same cycles play an important role in the disposal of civilization's wastes. The environmental concentrations of ammonia, carbon monoxide, and hydrogen sulfide—all poisonous—are biologically controlled. The "public service" functions of the biological environment cannot be replaced by technology now or in the next century. This is so, not so much for lack of scientific knowledge or technical skill (although such limitations are important in many cases), but rather, for the most part, because the sheer size of the tasks simply dwarfs civiliztions's capacity to produce and deploy new technology.

The specific mechanisms by which civilization's activities are disrupting the performance of indispensable natural services have been described at length in the technical literature.[4] They include selective poisoning of vulnerable organisms and the corresponding disruption of terrestrial and oceanic food webs, alteration of chemical balances in the environment, overexploitation of commercial species, and the destruction of natural communities serving as ecological buffers and reservoirs of species diversity. Virtually all of the natural services are influenced in some degree by climate, especially those related to food production and the regulation of disease. Civilization's activities have the potential to disrupt climate in a variety of ways: the effects of carbon dioxide and particulate matter on the global radiation balance; large scale modification of the reflectivity and heat- and moisture-transfer properties of the earth's surface by agriculture, urbanization, and oil films on the ocean; the influence of the heat release that attends all use of energy by mankind.[5] Much uncertainty exists concerning the precise possibilities of inadvertent modification of climate by these various factors. Global warming or cooling is possible in principle, but a more complicated alteration of climatic patterns seems a more probable and more imminent consequence of the very unevenly distributed impacts of civilization.

This, then, is the central issue that is missed by those who view environmental concerns as a matter of nuisances, damage to scenery, and dirty air and water: with industrial nations in the forefront, mankind is systematically diminishing the capacity of the environment to perform its essential functions of pest control, nutrient cycling, waste management, and climate regulation, at the same time that growing population and rising consumption per person are creating ever larger demands for these services. Evidently, the inadequacy of present scientific knowledge to predict the time and character of the ultimate breakdown in this process is often taken to be grounds for complacency, but our ignorance here should be alarming, not reassuring.

International Ramifications

In its examination of the impact of the U.S. population on resources, as in its treatment of environmental problems, the Commission on Population Growth and the American Future may have left the most important stones unturned. For the Commission assumed, in concluding that the resource needs of an expanding U.S. population can be met without great difficulty, that we would continue to have access to rich foreign deposits of fuels and minerals. Whether this actually will (or even should) be so hinges on deep and unresolved questions. How serious will the tensions be between the U.S. and increasingly prosperous but resource-poor Japan and Europe, as we compete for the world's remaining rich ores? Will the U.S. balance of payments be able to bear the bill? Does the rate at which the U.S. extracts high grade raw materials from less developed countries today compromise the ability of those countries to develop tomorrow, when only low grade ores remain? Can the prosperity gap between the rich and poor nations of the world be narrowed at a meaningful rate without drastic modification of present patterns of resource consumption?

It is well known that the United States accounts for roughly one third of the world's annual consumption of energy, and a similar fraction of the consumption of most industrial metals. The combination of the U.S., the Soviet Union, Europe, Japan and Australia accounts for 85 percent or more of the world's consumption of energy, steel, and tin.[6] The U.S. in 1970 was importing 100 percent of its chromium, 94 percent of its manganese, almost 70 percent of its nickel and tin, and 22 percent of its petroleum.[7] It has also been calculated, as a measure of the prosperity gap, that to supply the present world population with the average per capita "standing crop" of industrial metals characteristic of the ten richest nations would require more than sixty years' world production of these metals at the 1970 rate.[8] (Of course, the world population is growing, and, under existing patterns, the vast bulk of the extracted materials will go not to establish the underpinnings of prosperity in the poor countries but to support wasteful practices and further industrial growth in the rich ones.) Such figures need little elaboration. They suggest that even moderate population growth in rich countries exerts a disproportionate pressure on global resource flows, all else being equal, and that rapid progress toward developing the poor countries may be possible only if resource consumption is stabilized in the rich ones. Stabilized consumption, of course, is unlikely unless population size has also been stabilized.

That the United States is in for a period of relative resource scarcity and balance-of-payments problems is hard to doubt, regardless of how one views the likelihood of a major diversion of resource comsumption from rich countries to poor ones. The present (and worsening) petroleum situation is illustrating this problem all too vividly. So far, it is also leaving room for question as to whether the price mechansim can handle such difficulties smoothly (although, in fairness, it may be argued that mismanagement and inept regulation have not given the price mechanism a chance). In any case, the growing "energy crisis" has led to a predictable clamor for relaxation of environmental standards that have impeded development of new supplies. Curiously, the role that continued population growth will play in pushing up demand in an already precarious situation has not received as much attention.

The Role of Population

The reason for the widespread neglect of the population factor in the energy situation—and most other problems related to resources and environment—is that many observers regard such problems as primarily the result of faulty technologies and of high rates of growth of consumption per capita rather than of population size or growth rate.[9] This view can only arise from a failure to comprehend the implications of the multiplicative relationships that actually prevail. (Essentially, total consumption equals population times consumption per capita) total pollution equals total consumption times pollution per unit of consumption.) Perhaps the most basic point is that it is not meaningful to try to divide the "responsibility" for a given *level* of total consumption (or pollution) between population size and consumption (or pollution) per person. Such a procedure is analogous to trying to apportion the responsibility for the area of a rectangle between the lengths of the two sides. The property of interest, whether geometric area or population pressure, resides inextricably in the combined action of the contributing factors.

One can, on the other hand, distinguish among the relative contributions made by the *rates of change* of the various contributing factors to the rate of change of the total. Even in this strictly arithmetical exercise, however, it is easy to be misled, particularly when percentages are used. Consider the true statement, "Total energy consumption in the United States increased 1100 percent (12-fold) between 1880 and 1966, while population increased 300 percent (4-fold)."[10] On a quick reading, one might infer from this statement that population growth was not the major contributing factor. Actually, the increase in energy consumption per capita in this period was only 200 percent (3-fold); the 12-fold increase in total energy use is the product, not the sum, of the 4-fold increase in population and the 3-fold increase in use per person.

That simultaneously growing multiplicative factors yield a disproportionately growing product leads to even more startling numbers when three factors are considered rather than two. For example, an observed increase of 415 percent in emissions of automotive lead in the U.S. between 1946 and 1967 proves to have been generated by a 41 percent increase in population, a 100 percent increase in vehicle-miles per person, and an 83 percent increase in emissions per vehicle mile ($1.41 \times 2.00 \times 1.83 = 5.15$).[11] The dramatic increase in total impact arose from rather moderate but simultaneous increases in the contributing factors: no factor was unimportnat. Performing the same kinds of calculations on a variety of statistics shows, for the post-World War II period in the United States, that in strictly numerical terms the role of population growth in contributing to pressures on resources and environment has been substantial but not dominant.[12] Neither, however, has either of the other major contributors to these pressures—rising affluence and technological change—been consistently dominant.

Does the conclusion that population is a significant factor in the United States still hold in the 1970s, with population growing at 1 percent per year while per capita consumption of many kinds grows at 4 percent? In a word, yes. It should be obvious that the impact of rapid growth in consumption per capita is greater in a large population than in a small one, and, correspondingly, that the *absolute* impact of an increment in population is increased by rapid growth in the per capita consumption factor that the population multiplies.[13] (That the *relative* importance of population growth compared to growth of per capita consumption decreases in this situation is small consolation.) It is equally clear that the absolute significance of a fixed percentage increment of population goes up with the size of the base to which that increment is added—one percent of the U.S. population now is 2.1 million people; in 1933 it was 1.25 million.

The foregoing observations on the role of population have been strictly arithmetical ones, with no attention to the possible cause-and-effect relations between population and the other factors contributing to pressures on resources and environment, and the society to successive increments of impact. It is in these possibilities, however, that the greatest potential for harm in further population growth resides. Consider some of the ways in which changes in demographic variables can cause changes in consumption per capita and in pollution per unit of consumption. The present spatial pattern of population growth—suburbanization—leads to increased use of the automobile (more vehicle miles per person). This effect, together with that of population density itself, leads in turn to increased traffic congestion, hence more gallons of gasoline and harmful emissions per vehicle mile, and longer periods that the drivers are exposed to elevated concentrations of pollutants. The demand of each new increment of population for food is met by means of disproportionate increases in the use of fertilizer and pesticides on existing land;[14] a 1 percent increase in output now requires increases in inputs much greater than 1 percent—an example of diminishing returns. Growing demand for materials and fuels—the combined result of population growth and rising affluence—accelerates the application of more energy-intensive and environmentally disruptive techniques needed to exploit lower grade ores. In all these cases, population growth is generating pressures, directly and indirectly, that grow faster than the population itself.

A further 30 percent increase in the population of the United States, then, is likely to cause an increase in pressure on resources and environment that considerably exceeds 30 percent. The threat is compounded by the fact that the response of any system, environmental or social, may change dramatically with rather small changes in pressure as its capacity is approached. That is, the next 5 percent may cause a very different response than the previous 5 percent. Such thresholds are not uncommon in everyday experience—the difference between a freeway carrying a capacity load at 60 miles per hour and a massive traffic jam is a few extra cars; and they are not uncommon in nature—fish that tolerate a ten degree rise in temperature without difficulty may turn belly up when the temperature goes up five degrees more. Neither the thresholds of the environmental systems discussed earlier nor those of our social systems have yet been identified, but symptoms of stress in both areas are abundant enough that it seems imprudent, to say the least, to regard *any* further increase in population-related pressures with complacency.

Liabilities of "Direct" Approaches

No one has seriously suggested that stabilizing or reducing the size of the American population would, by itself, solve the problems of environment, physical resources, poverty, and urban deterioration that threaten us or that already exist. Attacks on the symptons of these problems and on their causes other than population should be imaginatively formulated and vigorously pursued. There is evidence that the growth of energy consumption per person can be significantly slowed, by reducing waste and inefficiency, without adverse effects on the economy.[15] Economic growth itself can be channeled into sectors in which resource consumption and environmental impact per dollar of GNP are minimized.[16] Practical mechanisms to alleviate the maldistribution of prosperity must be devised and put to use. But those who advocate the pursuit of these "direct" approaches to the *exclusion* of population limitation are opting for a handicap they should not want and cannot afford.

For the trouble is that the "direct" approaches are imperfect and incomplete. They are usually expensive and slow, and often they move the problem rather than removing it. How quickly and at what cost can mass transit relieve the congestion in our cities? Redesigning the entire urban community is a possibility, of course, but is even slower. If substantially more economical cars are designed, how fast will their share of the market grow, and how much of the gain will be wiped out by an increased total number of cars? If residences and commercial buildings that use energy more efficiently are developed, how long will it be until the tens of millions of inefficient buildings that now exist have been replaced? Fossil-fueled power plants can, in time, be replaced by nuclear reactors—trading the burden of noxious routine emissions of the former for the uncertain risks of serious accident, sabotage, nuclear terrorism, and management in perpetuity of radioactive wastes. We could back away from energy-intensive and nonbiodegradable nylon and rayon and plastics in favor of a return to cotton and wool and wood, thereby increasing the use of pesticides, the rate of erosion due to overgrazing and overlogging, and the fraction of our land under intensive exploitation. It is evident, in short, that there are difficult trade-offs to be made, and that fast and comfortable solutions are in short supply.

It has sometimes been suggested that such population-related pressures as exist in the United States are due mainly to spatial maldistribution of people, and that, accordingly, the "direct" solution is redistribution rather than halting or reversing growth. It is true that congestion and some forms of acute pollution of air and water could be relieved by redistributing people. But many of the most serious pressures on resources and environment—for example, those associated with energy production, agriculture, and ocean fisheries—depend mainly on how many people there are and what they consume, not on how they are distributed. Some problems, of course, would be aggravated rather than alleviated by redistribution: providing services and physical necessities to a highly dispersed population would in many instances be economically and ecologically more costly then doing the same for a concentrated population. In the end, though, the redistribution question may be largely an academic one. People live where they do for relatively sound reasons of economics, topography and tastes. Moving them in great numbers is difficult. Therefore, even those kinds of population pressure that might in principle be alleviated by redistribution are likely in practice to remain closely linked to overall size.

I point out these shortcomings of "direct" approaches not to suggest that intelligent choices are impossible or that pathways through the pitfalls cannot be found, but rather to emphasize that the problems would be tough enough even without population growth. Why, then, should we compound our plight by allowing population growth to continue? Is it logical to disparage the importance of population growth, which is a significant contributor to a wide variety of predicaments, only because it is not the sole cause of any of them?

How Much Is Too Much?

Those who advocate the early attainment of zero population growth, or a return to a smaller population by way of a period of negative growth, are often challenged to name an "optimum" population figure and defend it. What, after all, is the point of stopping or turning around if we don't know what the optimum is? Perhaps it is actually larger than the present population. The question of the optimum is not an easy one, but I think one can make some sensible observations about it.

First, we can probably agree that the optimum and the maximum are not the same thing. The maximum population, or carrying capacity, is determined by such factors as usable land area, fertility of soils, availability of mineral resources and water, and the ability of biological systems to absorb civilization's wastes without breakdowns that deprive us of essential services. No one knows just what the maximum is or which limiting factor will determine it,[17] and in any case, the answer will almost certainly vary with time (as technology changes). But in no event is a population size that is at or near the maximum likely to be optimum: if availability of resources defines the the limit, the maximum implies bare subsistence for all; if environmental constraints define it, the maximum is likely to represent a precariously unstable situation. By the same token, it is easy to imagine a population size smaller than the optimum—one, for example, too small to enjoy the benefits of specialization, economies of scale, and cultural diversity.

A general, and perhaps innocent, definition of the optimum population size is the size that permits the maximum average well-being per person. It is the definition of "well-being" that gets us into trouble, for this term clearly must include physical necessities such as food, water, shelter, and a livable environment; social essentials such as employment and economic security, education, and means for conflict resolution and the administration of justice; and amenities such as recreation and cultural pursuits. Not all of these values can be adequately reflected in the economic marketplace, and there are considerable differences in the relative importance that different groups and individuals would assign to the various ingredients. What is important to me—say, proximity to a great museum—may be unimportant to you compared to some other value—say, proximity to wilderness. Yet without consensus on what well-being consists of, how can we say anything useful about optimum population?

I believe that from these fundamental differences in human values an operationally useful conclusion does emerge: the concept of the optimum population hinges on the need for social, cultural and environmental diversity, for only thus can a wide variety of preferences be satisfied. At very low population sizes, the raw material for sufficient cultural and social diversity does not exist; near the physical maximum, on the other hand, diversity must be sacrificed in order to maximize efficiency.[18] From the individual's perspective, of course, diversity in the social and physical environments is related to personal options—access to a variety of employment possibilities, living accommodations, educational and recreational opportunities, degrees of privacy, and so forth. With respect to this criterion, then, one can say that the optimum population size is that beyond which further growth closes more options than it opens. The reader may wish to ponder what this definition implies in the case of the United States. For myself, I am unable to think of many options that are being opened by further population growth (greater variety in airline schedules?), but it is easy to think of a good many that are being closed (the opportunity to escape congestion, to survive without an automobile, to live anywhere but in a city).

Of course the optimum population size and the maximum size are dynamic quantities, not static ones. "Optimum" should mean "optimum under existing social and technological conditions." To argue that a region is not overpopulated by pointing out that certain technical and social changes could, in time, relieve the population-related pressures there is to miss the point. Technological innovation and cultural evolution will no doubt lead to changes in the population size regarded as optimum, and perhaps will push up the maximum. But a prudent society will let its actual population conform to such changes as they occur, rather than hope blindly, as most do today, that technology and social change will render acceptable whatever degree of population growth happens to materialize.

My own suspicion is that the United States, with about 210 million people, has considerably exceeded the optimum population size under existing conditions. It seems clear to me that we have already paid a high price in diversity to achieve our present size, and that our ability to elevate the average per capita level of well-being would be substantially greater if the population were smaller. I am also uneasy about the possibility that 280 million Americans, under conditions likely to include per capita consumption of energy and materials substantially higher than today's, will prove to be beyond the environmentally sustainable maximum population size.

That many people will disagree with these conclusions should not be surprising, given the value judgments and uncertainties that are involved. In a practical sense, however, disagreements at this point about the hypothetical optimum and maximum population sizes are relatively unimportant. What is surprising, and more important, is that there is not more agreement concerning what the rate of change of population size should be. For given the uncertain (but possibly grave) risks associated with substantially increasing our impact on the environment, and given that population growth aggravates or impedes the solution of a wide variety of other problems (including the land-use predicament, pressure on water and energy resources, and the imbalance of international resource flows), it should be obvious that the optimum *rate* of population growth is zero or negative until such time as the uncertainties have been removed and the problems solved.

It is obvious that this "optimum" condition cannot be achieved instantly. Unfortunately, the importance of achieving it sooner rather than later has been widely underestimated. In this connection, the recent rapid decline of fertility in the United States is cause for gratitude but not for complacency. Efforts to understand the origins and mechanisms of the decline should be continued and intensified, so that the trend can be reinforced with policy if it falters.

Notes

1. *Population and the American Future,* Report of the Commission on Population Growth and the American Future (Washington, D.C.: U.S. Government Printing Office, 1972).
2. *Man's Impact on the Global Environment,* Report of the Study of Critical Environmental Problems (Cambridge, Mass.: M.I.T. Press, 1970).
3. Jacques M. May, "Influence of Environmental Transformation in Changing the Map of Disease," *The Careless Technology*, ed. M. Taghi Farvar and John P. Milton (Garden City, N.Y.: The Natural History Press, 1972).
4. For synopses and extensive bibliographies, see, for example, *Man in the Living Environment,* Report of the Workshop on Global Ecological Problems (Madison, Wisconsin: University of Wisconsin Press, 1972); and *Man's Impact on the Global Environment.*
5. *Inadvertent Climate Modification,* Report of the Study of Man's Impact on Climate (Cambridge, Mass.: M.I.T. Press, 1971).
6. United Nations, *Statistical Yearbook, 1972* (New York: United Nations Publications Office, 1973).
7. National Commission on Materials Policy, "Towards a National Materials Policy: Basic Data and Issues, An Interim Report" (Washington, D.C.: U.S. Government Printing Office, April 1972).
8. Harrison Brown, "Human Materials Production as a Process in the Biosphere," *Scientific American* (September 1970).
9. For an exposition of this viewpoint, see, for example, Ansley Coale, "Man and His Environment," *Science* (October 1970), 132-136.
10. U.S. Bureau of the Census, *Historical Statistics of the United States: Colonial Times to 1957* (Washington, D.C.: U.S. Government Printing Office, 1960); *Statistical Abstract of the United States, 1972* (Washington, D.C.: U.S. Government Printing Office, 1972).
11. Barry Commoner, "The Environmental Cost of Economic Growth," *Population, Resources, and the Environment,* Research Reports of the Commission on Population Growth and the American Future, 3, ed. Ronald G. Ridker (Washington, D.C.: U.S. Government Printing Office, 1972), p. 343.
12. Paul R. Ehrlich and John P. Holdren, "Impact of Population Growth," *Population, Resources, and the Environment,* p. 365; Paul R. Ehrlich, Anne H. Ehrlich and John P. Holdren, *Human Ecology: Problems and Solutions* (San Francisco: W. H. Freeman and Co., 1973), Ch. 7.
13. As an example, consider the potential affect of population growth on total energy consumption. Most forecasts show energy consumption per capita increasing at 3 percent per year in the United States during the remainder of this century. Although I think this estimate is too high for a

variety of reasons, it is instructive in the present context to explore the effect of two different scenarios for population growth on the assumption that the per capita energy forecast is correct. My "high" population possibility assumes a total fertility rate corresponding to replacement (2.1 children per family average) through the year 2000, with immigration remaining at 400,000 per year. This gives 265 million Americans in the year 2000. The "low" possibility assumes a fertility rate corresponding to 1.4 children per family through the year 2000, with the same immigration rate, which gives 238 million in 2000. The lower population scenario cuts *in half* the increase in total energy consumption between 1973 and 2000, assuming 3 percent per year growth in per capita energy consumption in each case. The savings in the year 2000 over the high population result amounts to 20 quadrillion BTU, which happens to be equal to *total* U.S. domestic petroleum production in 1971.

14. David Pimentel, L.E. Hurd, A.C. Bellotti, M.J. Forster, I.N. Oka, O.D. Sholes, and R.J. Whitman, "Corn, Food, and the Energy Crisis," *Report 73-1*, Department of Entomology and Section of Ecology and Systematics (Ithaca, N.Y.: Cornell University, March 1973).
15. Office of Emergency Preparedness, Executive Office of the President, *The Potential for Energy Conservation* (Washington, D.C.: U.S. Government Printing Office, October 1973).
16. It is not economic growth *per se* that puts pressure on resources and environment but rather the physical components of economic activity—specifically, flows of materials and energy. Stabilization of these flows, which is necessary, need not entail stabilization of the level of economic activity for a long time thereafter. What is needed, in part, is a major effort to devote the sort of technical skills and ingenuity that have been applied so enthusiastically to space and weapons to the task of increasing the economic good that can be extracted from each pound of metal and gallon of fuel.
17. It is clear, however, that the limit for the United States will not be land area. To argue that we have plenty of room is to be correct but irrelevant. The pressure of population in this country is not on land area as a whole, but on some specific kinds of land (coastlines, good farmland), on environment, on resources, on institutions, and on values.
18. The statement that diversity must be sacrificed if one wishes to maximize effficiency appears to be true of ecosystems as well as for human society, if by efficiency we mean high net production per unit of input of energy or other resources. The trade-off between diversity and efficiency may prove to be a fundamental dilemma for civilization; efficiency is essential in a world of limited resources and growing demands, but diversity is the best (perhaps the only) insurance against uncertainty about what the future will be like. The dilemma is already being experienced in global

agriculture: the need to increase production encourages reliance on a few high-yielding strains of wheat and rice, but the loss of diversity as the new grains replace traditional types increases the threat of widespread crop failure from pests or disease.

The Author

In 1972 and 1973 John P. Holdren was a Senior Research Fellow in the Caltech Population Program and the Environmental Quality Laboratory, California Institute of Technology. He is now Assistant Professor in the Energy and Resources Program, University of California, Berkeley. He holds B.S. and M.S. degrees in engineering from M.I.T. and Ph.D. in engineering and plasma physics from Stanford. In addition to publications in plasma theory and fusion fuels, Dr. Holdren has written widely on the interactions of population, technology, and environmental disruption, and on energy problems. His books include *Human Ecology* (with Paul and Anne Ehrlich) and *Energy* (with Philip Herrera).