Public health

Population, environment, disease, and survival: past patterns, uncertain futures

Anthony J McMichael

Societies are exploring what sustainable development means for development choices. Increasingly, we recognise that human population health is not just an input to socioeconomic development, but is an essential outcome, and, over time, a marker of sustainability. There has been recent attention to how stocks of social and human capital precondition gains in population health. However, recognition of how environmental change can limit health and survival has been slower. Over many millennia, disease and longevity profiles in populations have reflected changes in environmental conditions and, often, excedances of carrying capacity. Today, population growth and the aggregated pressures of consumption and emissions are beginning to impair various global environmental systems. The research tasks in detecting, attributing, and projecting the resultant health effects are complex. Have recent health gains, in part, depended on depleting natural environmental capital? Population health sciences have a crucial contribution to make to the sustainability project.

Changes in patterns of health, disease, and survival within populations over time indicate the interplay between human biology, culture, and environmental conditions. However, most epidemiological research, done within a particular population, focuses on identification of individual-level risk factors that operate in the foreground and with some immediacy. We pay rather scant attention to larger-scale factors that affect health at the population level and, often, over a longer time-frame.[1,2]

This more macroscopic perspective has increasing relevance for three inter-related reasons. First, we face rapid social and economic changes as the processes of globalisation and urbanisation occur.[3,4] Second, we have begun to induce unprecedented large-scale environmental changes, including changes in the world's atmosphere and climate, stocks of biodiversity, freshwater supplies, and food-producing ecosystems.[5,6] Third, the international discourse on sustainable development is gathering momentum,[7] and an understanding of the likely consequences for human wellbeing and health should be central to this debate about the attainment of an ecologically sustainable future.[8,9]

There has been a succession of profound transitions in human ecology over the centuries, especially in food production, social structures, urban living, reproductive behaviour, and demographic profile. The career of *Homo sapiens* has now reached an important juncture, at a global scale, that obliges us to assess the likely health effects for a population of today's large-scale transformations in the conditions of living. Meanwhile, of course, variations in personal behaviours and exposures—in cigarette smoking, oral contraceptive use, dietary habits, workplace conditions, and so on—remain important determinants of health differences between categories of individuals within a population. But such differences, which arise at the individual level, comprise only one part—albeit an immediate and intuitively persuasive part—of a much larger story.

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National Centre for Epidemiology and Population Health, Australian National University, Canberra ACT 0200, Australia
(Prof A J McMichael PhD)
(e-mail: tony.mcmichael@anu.edu.au)

That individual-level focus, nevertheless, will be reinforced by the advent of postgenome biomedical research, with its promise of personalised modulation of genetically-based disease risks. Yet, clearly, genes cannot account for the interdecadal rise and fall of disease rates in populations. The doubling of the prevalence of obesity in European populations during the past 2 decades, for example, does not indicate genetic change but social and environmental changes, especially in the patterns of physical activity and socially-patterned diets.[10]

Human ecology: survival and disease patterns

Human ecology, comprising a society's culture, habitat, and its relation with the wider environment, is the prime determinant of the population's health profile. Changes in human ecology over many centuries have, therefore, resulted in various shifts in the patterns of population disease.

A central example, throughout the past 10 000 years since human societies first began farming, has been the nutritional effect of traditional staple-based, often monotonous, agrarian diets. Before the second agricultural revolution in Europe in the 19th century, most agrarian societies had widespread malnutrition and recurring famines.[11] The geographic spread of human populations has often compounded this nutritional deficiency problem. For example, the extension of agrarian societies into highlands and arid regions has exposed many populations to dietary iodine deficiency, leading to various iodine deficiency disorders.[12] Nevertheless, because of the great increase in environmental carrying capacity conferred by agricultural production and trade, farming populations—notwithstanding their nutritional deficits and recurring famines—have generally outnumbered and replaced smaller hunter-gatherer populations.

This widespread malnutrition and food insecurity in traditional agrarian societies shows the discordance between biological need and environmental supply that has often arisen as a result of changes in human ecology. Differences between populations in the extent of such biology-environment discordance, extending over millennia, could explain why the obesity-associated risk of non-insulin dependent diabetes, for instance, varies between European, east Asian, south Asian, and Pima Indian populations.[13]

Other diseases that characterise modern industrialised

society also indicate a discordance between our evolution-based biological needs and our way of living.[14,15] For example, the radical transformation of our modern food supply, entailing huge shifts in amounts of consumption of saturated fats, simple sugars, salt, and dietary fibre, has contributed to many of the non-communicable diseases that characterise longer-living populations in developed countries.[16] Urban crowding and migration have facilitated the local and long-distance spread of infectious diseases, respectively. Physical inactivity in the modern mechanised environment has predisposed to today's worldwide surge of urban obesity.

Nevertheless, our cultural and technical advances over the past two centuries have brought greatly reduced mortality, especially in early life, with resultant gains in life expectancy. These improvements have been followed by a reduction in birth rates. The gains in survival indicate, in the first instance, the receding of infectious diseases. This composite process, the demographic transition, continues to transform life expectancies and patterns of disease in less-developed countries.

Today's prospects for population health, however, entail some new uncertainties. Understanding how, over our long history, shifts in human ecology have affected the pattern of population health and disease is especially relevant today in assessment of the health effects of humankind's increasing disruption of the conditions of life on Earth. The evolutionary and historical experiences of the human species can assist that understanding.

The human diaspora: into new environments

Over many millennia, since the diaspora of the modern human species out of Africa from around 75 000 years ago, our ancestors have entered new environments, reshaped them, exploited them, depleted them, and, more recently, paved over them. In the course of becoming farmers, settled human communities came into much closer contact with the infectious microbes present in their herded animals and in pest animals that proliferated around the settlements. From these animal sources early agrarians acquired the range of infectious diseases that we now think of as naturally human—eg, tuberculosis, leprosy, cholera, smallpox, measles, influenza, the common cold, syphilis, &c.[17] That particular aspect of the story continues today, with the recent emergence from animal sources of HIV-1 and AIDS, Ebola virus, and the bovine spongiform encephalopathy (BSE) prion protein that causes variant Creutzfeldt-Jakob disease in human beings.

As mentioned above, the advent of farming, while boosting population size, typically resulted in chronic nutritional deficiencies. Only within the past century or so, in rich nations, has the dietary diversity of our hunter-gatherer ancestors been regained. This diversity has largely arisen as one of the benefits, as yet unevenly shared, of extended, globalised trading.[18]

Overall, then, the great historical scourges of human health—infectious diseases, malnutrition, starvation, and warfare—have had their roots in human cultural evolution, environmental exploitation, and territorial aspirations. These changes in human ecology have altered the relations of human societies with the physical environment, with diverse other species, and with other communities, tribes, and populations. A clear illustration of how the increasing scale and intensity of contacts between populations, via conquest, trade, and travel, has shaped the epidemiology of disease is afforded by the succession of phases of infectious diseases.

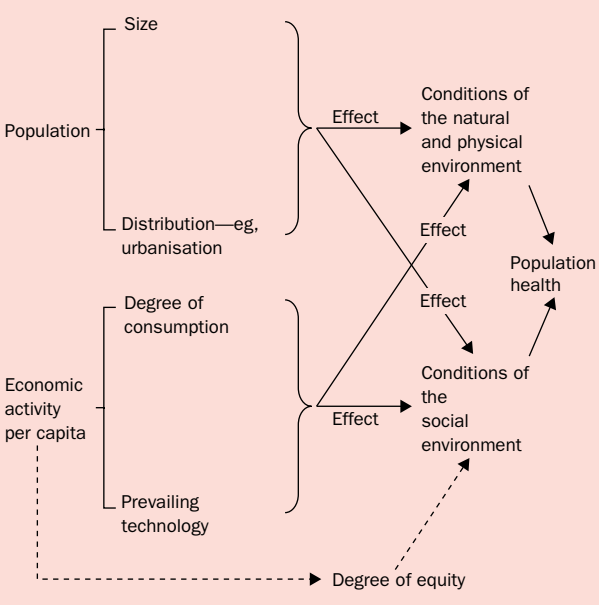
There have been four great historical transitions, as infectious diseases have equilibrated between interacting populations.[17,19] First, from around 5000 years ago as ancient civilisations around the eastern Mediterranean and South Asia made contact, the trademark epidemic infections of those localised civilisations were exchanged. There are archaeological, biblical, and other accounts, but no ready identification of specific diseases. Second, via the great powers of the Roman Empire and China around 2000 years ago, epidemic infections such as smallpox and bubonic plague were exchanged between the European and Asian ends of the Eurasian super continent. Third, as Europe began to explore and conquer across the oceans, from around 500 years ago, disease equilibration occurred between Europe and the Americas, and between Europe and the Pacific and Australasian regions. Most of these transoceanic exchanges entailed the devastating introduction of European infections into susceptible indigenous populations.[17,20] This process included smallpox, measles, typhus, influenza, and, via the trans-Atlantic slave trade, the introduction of malaria and yellow fever into Central and South America.

We are now apparently experiencing a fourth great transition as various infectious diseases equilibrate at a global level.[19] Examples include the unusually persistent seventh pandemic of cholera, the recent pandemic of HIV/AIDS, the wide spread of multidrug-resistant tuberculosis, and the resurgence of mosquito-borne malaria and dengue fever in tropical and subtropical regions. Similar processes seem to be happening within livestock. The international spread of BSE, of foot-and-mouth disease, and of various strains of salmonella all indicate the increasing connectedness of animal populations worldwide.

Global environmental changes: increasing human effect on the biosphere

Over the past 2 centuries, three great changes in human ecology have happened: industrialisation, urbanisation, and, latterly, increased control over human fertility. The associated combination of receding infant-and-child mortality coupled with a downtrend in adult mortality, rapid population growth, and economic intensification, has resulted in human beings exerting enormous aggregate pressure on the natural environment, and the biosphere is showing the strain in several ways.[5,6] These include global climate change, stratospheric ozone depletion, accelerated loss of biodiversity, the spread of invasive species, land degradation, exhaustion of wild fisheries, depletion of freshwater supplies, and the long-distance dissemination and bioaccumulation of persistent organic chemicals. The distinctive aspect of these changes is their intercontinental, often global, character.

These global environmental changes, historically unprecedented, pose various hazards to the health of human beings.[3,6] Epidemiologists face difficulties in assessment of these environmentally-induced risks. First, most of these incipient environmental changes have not yet had detectable health effects; indeed, many of the anticipated effects are likely to emerge over coming decades.[21] Second, many of the causal pathways are of a complex and indirect kind—such as those that affect the transmission of vector-borne malaria and dengue fever, or the environmental diminution of regional agricultural yields and, hence, food insecurity. Third, the usual multivariate causality of disease precludes ready attribution to any particular environmental change.



Schematic diagram to show how characteristics of population and economy impinge on the natural, physical, and social environments, and how these then act as major determinants (facilitators and delimiters) for population health

Detection of the early health effects of global environmental changes will therefore be difficult.[21] Some clues, however, have begun to emerge—for instance, with the northerly spread of tick-borne encephalitis in Sweden in association with winter warming over the past 2 decades.[22] Some part of the recent spread of malaria and dengue fever might have been due to the climate change that has occurred over the past quarter-century, although there are other explanations.[21,23] The persistence of around 800 million people with malnutrition could partly indicate the regional degradation of agroecosystem resources, compounded by other adverse environmental effects on photosynthesis, plant physiology, and the occurrence of crop pests and diseases.[6,24] According to the Intergovernmental Panel on Climate Change,[25] the increased tempo of extreme weather events and their adverse effects on human beings over the past decade probably indicates climatic instability due to incipient global climate change.

The figure shows the main relation between demographic change, economic development, environmental effect, and population health. Note the central, integrating, role assigned here to population health. For policy purposes, health is not a sideshow; it is a key criterion of how well we are managing the natural and social environments.

A paradox?

Meanwhile, life expectancies continue to increase. Average life expectancy, worldwide, approximately doubled from around 35 to 70 years during the 20th century.[26] Notwithstanding persistent health inequalities, destructive wars, the disastrous HIV/AIDS pandemic, and the plunging life expectancy in post-communist Russia, human health was, overall, positively transformed during the 20th century.

Is it plausible, then, that our ongoing erosion of the biosphere's life-support systems will engender future health losses? Surely, argue the optimists, if we are seriously mismanaging the biosphere and eroding environmental capital, the damage should already be evident in humankind's health statistics.[27]

There are three possible explanations for this apparent paradox:

- Modern human societies, via technological, economic, and political achievements, have attained near-immunity to adverse external environmental circumstances.
- Adverse health effects are already occurring, but we have no null comparison data. That is, with no counterfactual global population living in an unstressed environment, we do not know if health gains would have been greater without environmental change. (However, since adverse health effects would arise unevenly around the world, it should be possible to make inter-region comparisons.)
- There is a lag period between the decline in environmental conditions and the occurrence of health effects. This notion lag reflects both complexity of process and the protective buffering afforded by human culture.

The first explanation discounts long human experience. Throughout history, great civilisations, as in Mesopotamia, Egypt (the Old Kingdom), the Indus Valley, Mesoamerica, Peru, and elsewhere, have crumbled in the wake of environmental infrastructural decline.[6] The first explanation also overlooks the crucial fact that the human economy is a wholly dependent (and ultimately accountable) subset of the natural economy.[28] To assume an immunity of modern human societies to adverse environmental conditions would therefore be imprudent, indeed naive. Most probably, the realistic explanation is a combination of the last two explanations.

Conclusion

A major contemporary challenge is to provide a satisfactory, healthy, and equitable standard of living for current and future generations. This aim must include sustained adequate food yields, clean water and energy, safe shelter, and functional ecosystems. Human-induced global environmental changes could impair our ability to meet this challenge.

Human population health should be a key criterion of sustainable development.[29] As shown in the figure, it is an indicator (albeit integrated over decadal time) of how well we are managing our natural and social environments. History has shown us, repeatedly, that changes in human ecology and, in particular, in humankind's relation to the natural environment, shape the patterns of population health and survival. Appreciation of this ecological perspective will be essential if we are to achieve a sustainable future.[30]

Conflict of interest statement
None declared.

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