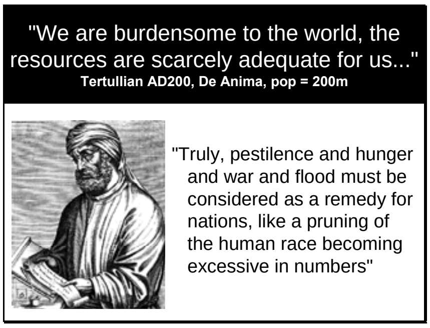
Slide 1

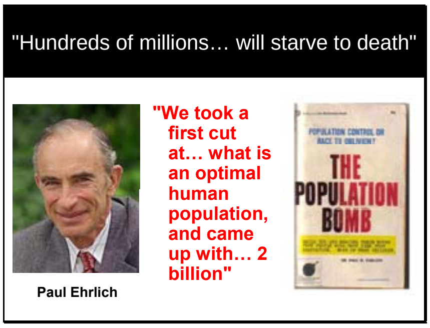
{Note: this lecture is based on many sources, some of which are quoted directly alongside the slides. Ask for specific sources if you need them: dyec@who.int.} It's been estimated that approximately 106 billion people (range 45-125 bn) have ever been born, so the population currently alive is roughly 6% of all people who have ever lived on planet Earth. The 6% is about 6 bn, and population clocks like this one show how the total population is increasing as the net result of additions by birth and losses by death. Many influential commentators have proposed that there are (or have been, or will be) too many people on the planet. Are they right, and if so why? Given the resources at our disposal, how many healthy people could there be?

Slide 2



The limits to population is a question bedevilled by personal opinion, often unsubstantiated by evidence. There is a long history of thinking that Homo sapiens has caused planetary overload. Here is Tertullian (160–220 AD), controversial early Christian author famous for coining the term "Trinity".

Slide 3



In The Population Bomb (1968), Paul Ehrlich forewarned of disaster for humanity due to overpopulation and the "population explosion". He predicted that "in the 1970s and 1980s hundreds of millions of people will starve to death", that nothing can be done to avoid mass famine greater than any in the history, and that radical action is needed to prevent overpopulation. Ehrlich was wrong; the mass starvations predicted for the 1970s and 1980s never occurred, apart from in selected parts of Africa, and that was more to do with politics than the depletion of resources.

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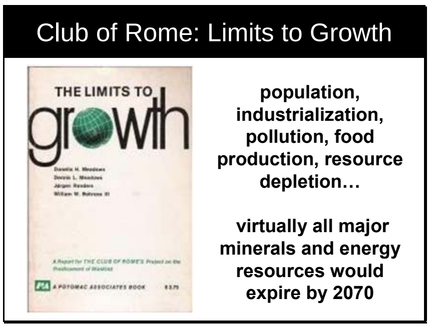
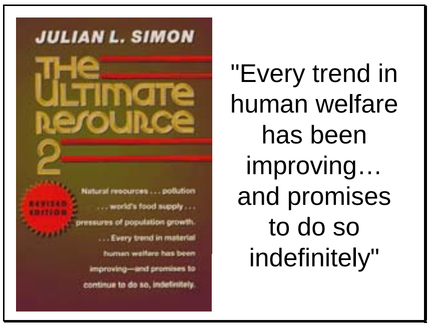


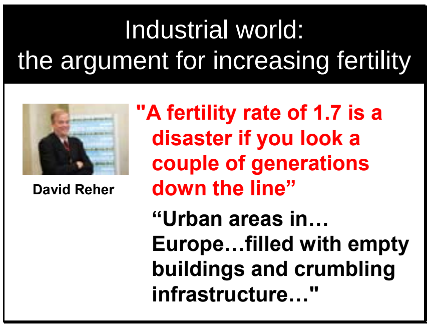
The Club of Rome talked about "population, industrialization, pollution, food production, resource depletion…" and predicted that "virtually all major minerals and energy resources would expire by 2070" (The Limits to Growth 1972).

Slide 5



Much more optimistically, Julian Simon and Herman Kahn's The Resourceful Earth (1984), emphasized mankind's ability to find or to invent substitutes for resources that were scarce and in danger of being exhausted.

Slide 6



On the question of fertility, low population, or the process of getting there, could also be a disaster. Mass mortality is clearly undesirable, but low fertility is problematic too, as we shall see.

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There now seem to be more pessimists than optimists; those who are worried about too many people. The view of Global Population Speak Out (http://gpso.wordpress.com/) is that overpopulation is threatening life as we know it on the planet. The end result will be apocalyptic, according to Gaia theorist James Lovelock. By the end of the century, the world's population will suffer calamitous declines until numbers are reduced to around 1 bn or less. By 2100, pestilence, war and famine will have dealt with the majority of humans". The UK government's chief scientific adviser said recently that the planet faces "a perfect storm" of food, energy and water shortages which could strike in less than 20 years. One in three people are already facing water shortages and by 2030 world water demand will increase by more than 30%; energy demands will increase by 50%. In Britain the debate is bound to the question of immigration. Britain's population will rise from its current level of 61 million to 72 million by 2050. The nation will then be the most populous in the European Union, outstripping Germany, whose population will fall from 82 million to 71 million people as immigration drops.

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So what is the truth? The title of this lecture paraphrases the title of an excellent book by Joel Cohen (1995), which summarizes and analyses the history of evidence and thinking on population growth. My view of population will be with oriented towards health; I acknowledge, but am not going to discuss in any detail, the consequences e.g. for preserving biodiversity in its own right.

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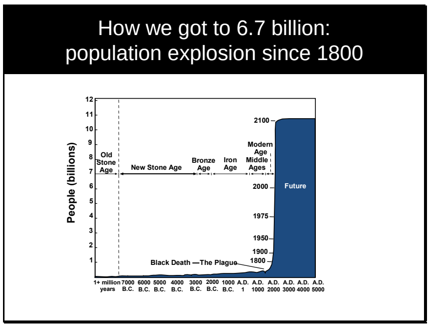
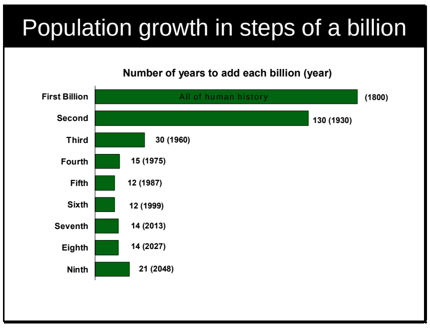


From 1m yr BC (when Raquel Welch and the dinosaurs roamed the earth; actually, neither is true, dinosaurs lived from 230-65m years ago). In terms of human population growth, everything has happened since we reached a population of 1 bn around 1800. The maximum of 10-11 bn in this picture is perhaps a little high.

Slide 10



This is how human population has grown, in steps of a billion. The 5th and 6th billions took the shortest time, just 12 years, but now the time step is lengthening again (Population Reference Bureau; UN World Population Prospects 2005).

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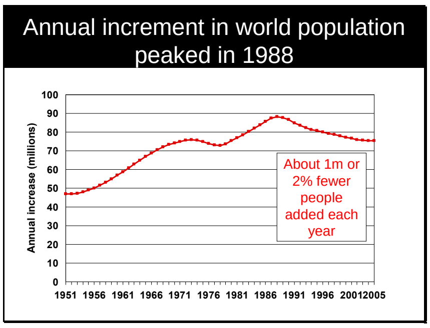

That is because population growth has peaked. When I was born I contributed to the addition of 50m people that year. The maximum increment was about 90m in 1988. The 20th century was, above all else, a century of population growth; the 21st century will be a century of aging. Is this the beginnings of a new era, or the beginning of the end? (UN World Population Prospects 2005).

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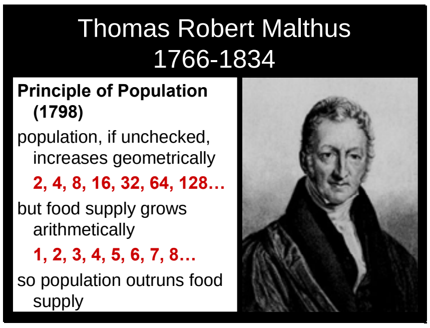

What are the factors that will stop population growth? The best-known exponent of regulation or negative feedback was Thomas Robert Malthus. At the end of the 18th century he suggested that human populations would be regulated by their food supply. The problem, as he proposed it, was that populations grow geometrically or multiplicatively (1,2,4,8,16 etc), but the food supply increases only arithmetically or additively (1,2,3,4 etc). So the population outruns the food supply. This is clearly a simplistic view, but there are numerous ways in which the basic idea of feedback could take effect.

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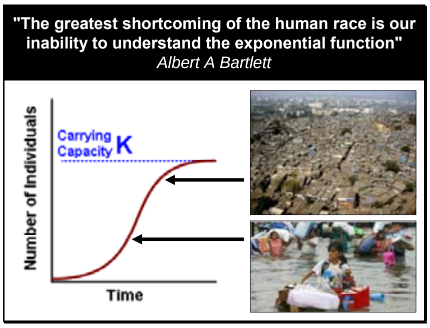

When we've understood exponential growth, we also need to understand why it stops. At some level of population, fertility must be reduced or mortality must increase, or both. How does the feedback really work in human populations? We now know the answer, and it is generally not as Malthus anticipated. We are not dying or producing fewer schildren because we have run out of food or any other resource, and yet human population is slowing down. To understand why we must understand the demographic transition.

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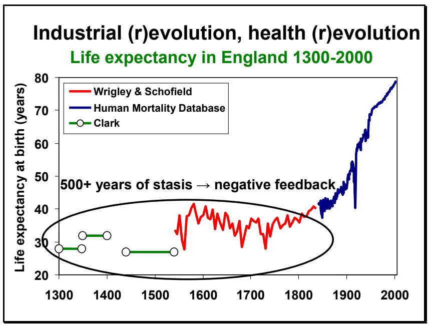

We can look at the data for England & Wales, as did Malthus (so far as he was able in the 18th century). Life expectancy was 30-40 years for about 500 years, in part because there was not enough food (frequent famines), and we had no idea how to control infectious diseases. Ironically, Malthus's regulatory process was in play when the population was relatively low; it is not currently the controlling factor at much higher population size.

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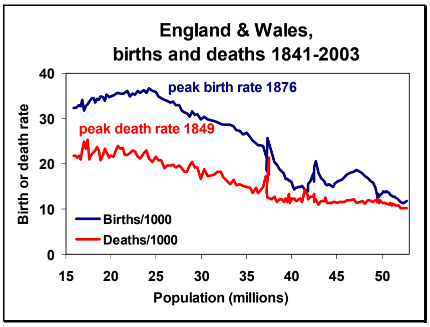

Human populations have not been regulated like animal populations; that is, births falling and deaths rising with population increasing faster than resources. On the contrary, the death rate has fallen as population has increased, and it continues to fall. Fertility has not dropped because resources are insufficient to conceive and feed children. Rather parents have chosen to stop having children when they know they will survive, and when they need fewer of them. So these data from England & Wales are typical, the death rate falls before the birth rate, though this process has happened much later, and is still underway, in other countries.

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The poorest countries with least resources have maintained high birth rates, and they have high population growth rates despite high child mortality. There are few places where population growth is slowed by poverty; rather, poverty encourages high population growth.

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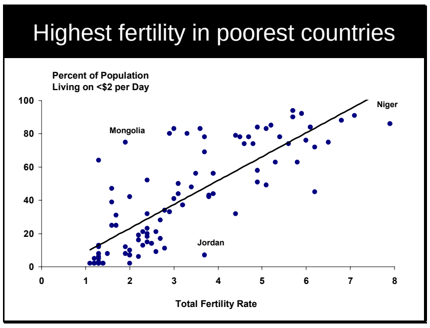

Countries with a higher percentage of people living in poverty typically have higher fertility rates. Poverty does not limit reproduction, or population growth (Population Reference Bureau, Population & Economic Development Linkages 2007 Data Sheet).

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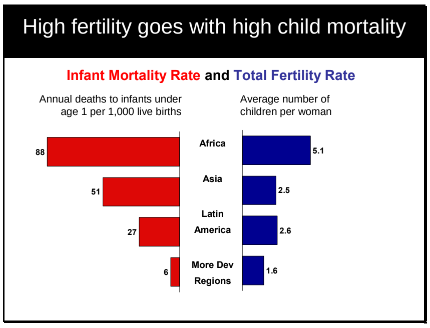

High infant mortality is strongly associated with high fertility; infant mortality may be both a cause and an effect of high levels of childbearing. In Africa, where infant mortality is high (88 infants die per 1000 live births), on average women have over 5 children each. By contrast, in more developed regions, where infant mortality is low (6 infants die per 1000 live births), women have fewer than two children on average (Population Reference Bureau, 2005 World Population Data Sheet).

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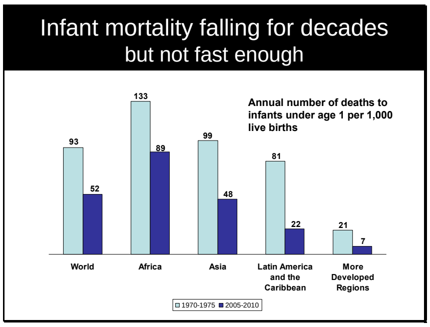

In the last 3 decades, the worldwide rate of infant deaths has in fact dropped, by nearly one-half: from 93 deaths per 1000 live births in the early 1970s to 52 deaths at the beginning of the new century. Although, in Africa, the infant mortality rate is 12 times higher than the rate for more developed regions (89 compared with 7), the fall in mortality is one force encouraging families to have fewer children (UN World Population Prospects: The 2004 Revision).

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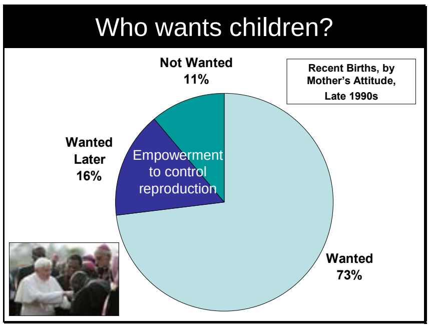

Healthy lifespan is just one measure of satisfaction; having children (fertility) is a key measure of satisfaction too; not too many, but not too few (Population Reference Bureau, Family Planning Worldwide 2002 Data Sheet).

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And condoms stop HIV transmission, which prevents the premature death of young adults. As Jacob Zuma is elected this week as South Africa's next president, millions of people are hoping that, despite his earlier transgressions, he will move his country on from the failures of Thabo Mbeki's era.

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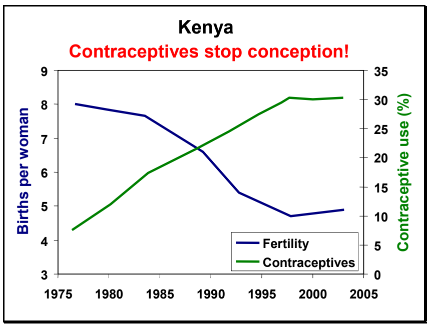

Contraceptives work, as shown in Kenya: there is a striking inverse relationship between contraceptive use and the number of children born to each Kenyan woman. Higher levels of family planning use are associated with lower levels of childbearing. In Africa, where a small proportion of married women of childbearing age practice family planning (21%), on average women have more than 5 children each. In contrast, in more developed regions, where a much greater percentage of married women of childbearing age practice family planning (58%), women have fewer than 2 children on average (Population Reference Bureau, 2005 World Population Data Sheet).

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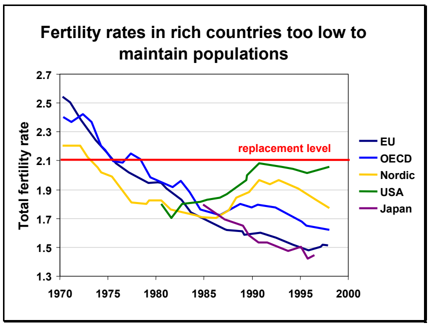

Low mortality and fertility will eventually stop population growth. But there are consequences of, and dangers in, cutting the birth rate too much. Some high-income countries now have very low levels of fertility.

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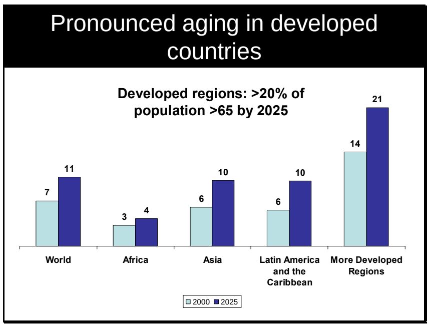

The first consequence is aging; old people are reliant on the young. By 2025, over 20% of the population in more developed regions, and 10% of all people, will be aged 65 and older. In Asia, the proportion of elderly people will nearly double, from about 6% in 2000 to 10% in 2025, an increase in 25 years from about 216m to about 480m older people. The speed of ageing is likely to increase over the coming decades, and to decelerate in most regions by midcentury. After mid-century, lower rates of population growth are likely to coincide with slower rates of ageing (United Nations, World Population Prospects: The 2004 Revision; Lutz Nature 2008).

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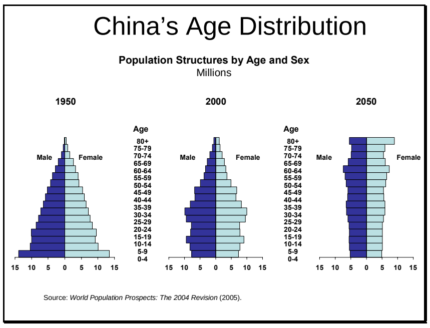

China is an extreme case. Dramatic fertility decline, due to the impact of the one-child policy, and improved longevity over the past two decades are causing China's population to age very quickly. China faces the prospect of having too few children to support its rapidly aging population. Meeting the health and long-term care needs of this growing elderly population will result in soaring health care costs and fewer working-age people to share the burden.

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And looking after one precious child, in an environment where high-energy diets are becoming the norm, can have undesirable consequences. This 8-month old baby from Jilin weighs 19 kg.

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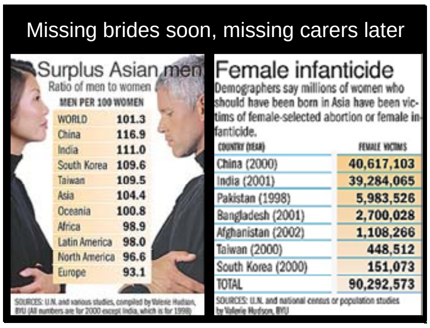

Forcing low fertility contributes to a skewed sex ratio – a loss of girls. Conservative estimates are that 90m women are missing in Asia because parents select sons over daughters through female infanticide and female fetus abortion. Surplus men are known as "bare branches" in China because they will never find marriage partners. Projections to 2020 suggest that China will have about 30m unmarried men between the ages of 15 and 35 (V Hudson 2003).

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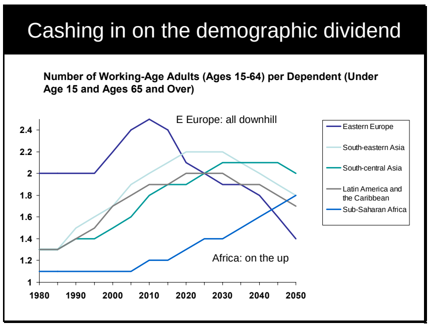

The demographic dividend is the economic payoff from having a large working population compared with the number of dependants, either young children or the elderly. Asia and Latin America are still in a relatively strong position; Eastern Europe is over the hill, and Africa's advantage is yet to come (UN World Population Prospects: The 2004 Revision).

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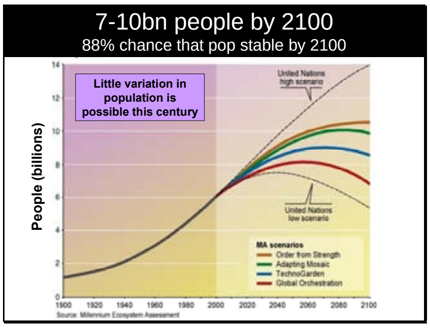

What are the consequences of these changes in birth and death rates for population size in the 21st century? It is highly likely (estimated to be 88% certain) that population growth will end during this century (Lutz Nature 2008). But this picture reveals another key fact: there is little variation among these population projections: whatever we do with respect to fertility, there are going to be 6-10 bn people in 2010. We can aim for the lower limit, but the critical factor will be how the average person generates and uses resources.

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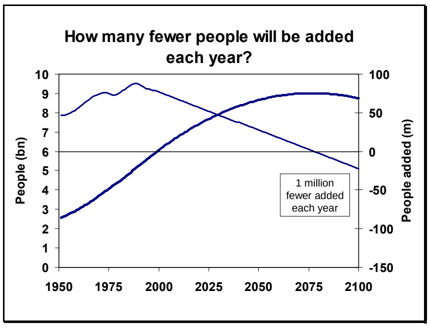

It is easy to explain why there can be little variation. Over the past 20 years there have been 1m fewer people added to the world population each year. If that continues, there will still be 8-9 bn people in 2100.

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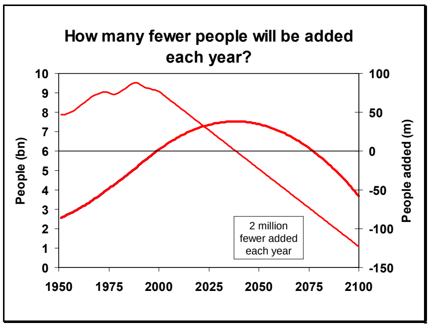

If we add 2m fewer people each year, this gets us to about 4bn by 2100. This is an extreme and unlikely scenario: as the population falls, more people are removed each year, an increasing proportion of those that remain. A population of 1-2 bn by the end of this century is impossible without disastrously low fertility or disastrously high mortality.

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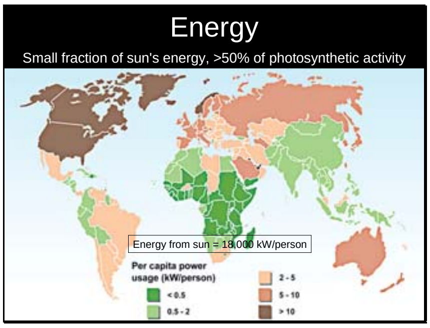

While we can work to reduce fertility to lower levels (what are the optimum lower levels?), we must also either (a) generate more resources, (b) demand fewer, (c) use current resources more efficiently. What follows is a brief look at 4 key resources: energy, water, food and space, before I take a more systematic view. On energy, we may at first be reassured by the fact that we use a tiny fraction of the sun's energy. However, we already use over half of the earth's photosynthetic activity (energy converted by green plants).

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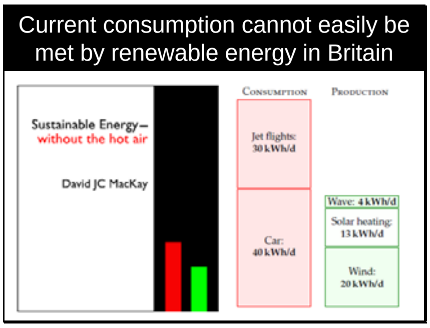

Could Britain survive on renewable energy? Here are comparisons of selected energy-consuming activities with conceivable renewable energy production from three UK sources. On the left, driving 50 km per day consumes 40 kWh per day, and taking an annual long-range flight by jet uses 30 kWh per day (averaged over the year). On the right, covering the windiest 10% of Britain with onshore wind farms would yield 20 kWh per day per person; covering every south-facing roof with solar water-heating panels would capture 13 kWh per day per person; and wave machines intercepting Atlantic waves over 500 km of coastline would provide 4 kWh per day per person. Mackay draws 2 conclusions. First, for any renewable facility to make an appreciable contribution – a contribution at all comparable to our current consumption – it has to be country-sized. To provide ¼ of our current energy consumption by growing energy crops, e.g. would require 75% of Britain to be covered with biomass plantations. Second, if economic constraints and public objections are set aside (a very big if), it would be possible for the average European energy consumption of 125 kWh/d per person to be provided from these country-sized renewable sources (Mackay 2008).

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Low quality drinking water evidently does not stop population growth, but it certainly contributes to high mortality, especially of children. Scenes like this one in Mexico are frequent. Water management is a key factor in distribution. The failure to provide clean water is not excusable in terms of its total availability.

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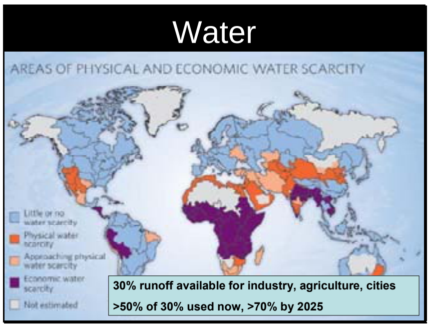

Water is scarce in some places because rainfall is low. But it is also scarce because it is badly managed. We are using a large and growing proportion of the Earth's renewable water supply. 30% of all the runoff from land to sea each year is accessible for use in irrigated agriculture, industries and cities. The rest is flood water not captured by dams, or water too remote geographically to be of use. Human activities already make use of more than half of this accessible supply. Human water use tripled in the years from 1950 to 1990, and this escalating water use is running up against limits. Projections of population size and water use per person suggest that humans could be using at least 70% of accessible runoff in 2025, and possibly all of it (Postel Science 1996).

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International trade and prices: (1) Food price inflation is being fuelled by surging demand from the middle classes of Asia and South America as people move from basic grain to protein-based diets, meaning higher consumption of meat, milk, fruit and vegetables, but with rice still a staple for both the affluent and urban and agricultural poor. As more people turn to a meat-based diet, additional grain is needed to feed bigger herds of cattle, further fuelling demand. (2) Population growth imposes extra strain on arable land, already being eroded by the extreme weather caused by global warming. (3) Against this backdrop, vast areas that could be used to grow food are being turned over to the production of ethanol and biodiesel, derived from corn, sugar, soya and palm oil, as the developed world, notably the US and EU, seek to reduce dependence on oil. Optimists: If today's high prices trickle down to the farm level in developing countries, they could have a very positive impact on food production and convert agriculture into an engine of growth and employment. We do not see famines in stable and peaceful democracies. Pessimists: How much extra land in Africa and eslewhere can sustainably be brought back into production? Where will the irrigation water come from (FAO, A Sen 2008)?

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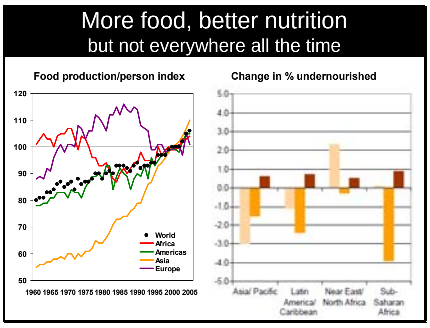

Although the credit crunch has lowered the price of food, a global recession now increases the risks of hunger for the most vulnerable. The stage is set for the next international food crisis (von Braun Nature 2008). If global economic annual growth falls by 2–3% below the recent years' figure of about 5%, and agricultural investment declines in parallel by 20% — a plausible scenario — this would put cereal prices 30% above what is expected without a recession by 2020. Globally, 16m more children would be malnourished. However, if spending on agricultural research and development (R&D) is maintained (assuming a modest 3% decline in investment growth) in the face of this recession, cereal prices would be about 15% lower than the non-recession baseline in 2020, and malnutrition would be about the same as in the baseline scenario. Investment in R&D is necessary to keep long-term food prices at tolerable levels. But to avoid price spikes, bubbles, action needs to be taken to improve market efficiency and food trade in crises.

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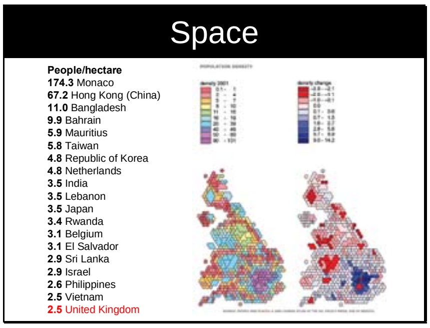

Is England too crowded? The first map, using data from the 2001 Census, shows people per hectare. London is clearly the most densely populated part of the UK while large areas remain very sparsely populated. The second map looks at how that density has changed since the previous census in 1991. Only London saw a significant increase in density with the East Midlands, North West of England and Glasgow becoming less crowded (M Easton 2008). People in the UK choose to live at higher density (that's the compromise they make), and our population density is lower than in many other countries. Density per se is unrelated to the standard of living.

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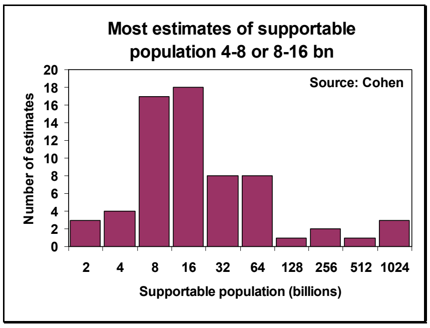

This has so far been a selective view of some key resources and whether they are limited. A more systematic treatment is needed. Joel Cohen reviewed all the studies that examined total possible human population size in terms of resources: 50% are below 12 bn, 75% are below 30 bn (Cohen 1995, p215).

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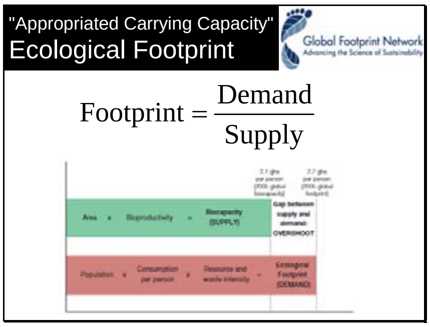

Cohen, Mackay and others have stressed the importance of good accounting. Going beyond Cohen, I'm going to examine just one contemporary approach to assessing the "carrying capacity" of the earth. Rees and Wackernagel (1990-1994) developed the idea of the Ecological Footprint. The EF measures the amount of biologically productive land and water area required to produce the resources an individual, population or activity consumes and to absorb the waste it generates, given prevailing technology and resource management. This area is expressed as global hectares, hectares with world-average biological productivity. EF is designed to address the question: How much of the biosphere's regenerative capacity is occupied by human activities? The method is limited in 3 ways: some aspects of sustainability are excluded; some aspects of demand are hard to quantify; and there are surely calculation errors. It takes, according to some calculations, 2.1 hectares of land and water to provide for one average human. The EF for the average US citizen is about 10 hectares. So if all humans lived at US standards, we'd need another four Earths. [Ecological Footprint = (annual demand in tonnes / national yield in annual tonnes per ha) x Yield Factor x Equivalence Factor Ecological Footprint of consumption = Ecological Footprint of Production + Ecological Footprint of Imports – Ecological Footprint of Exports].

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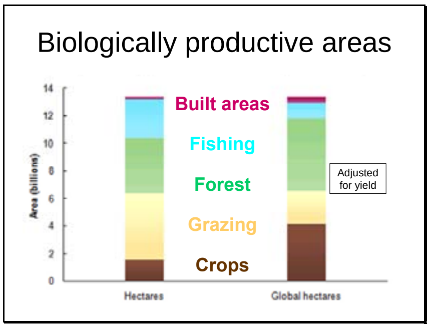

The relative area of land types worldwide in hectares and global hectares (adjusted for yield). In 2005, the world had 4.1 bn global hectares of cropland biocapacity as compared to 1.6 bn hectares of cropland area (Figure 1). This difference is due to the relatively high productivity of cropland compared to other land types. This is not surprising since agriculture typically uses the most suitable and productive land areas, unless they have been urbanized. The built-up land Footprint is calculated based on the area of land covered by human infrastructure — transportation, housing, industrial structures and reservoirs for hydropower.

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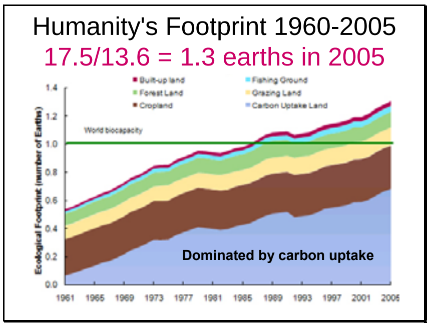

According to present analysis, human demand exceeds yield. In 2005, humanity's total EF was 17.5 bn gha; with world population at 6.5 billion people, the average person's Footprint was 2.7 gha. But there were only 13.6 bn gha of biocapacity available that year, or 2.1 gha per person (measured by satellite imaging). This overshoot of almost 30% means that in 2005 humanity used the equivalent of 1.3 Earths to support its consumption. Put another way, it took the Earth approximately a year and four months to regenerate the resources used by humanity in that year.

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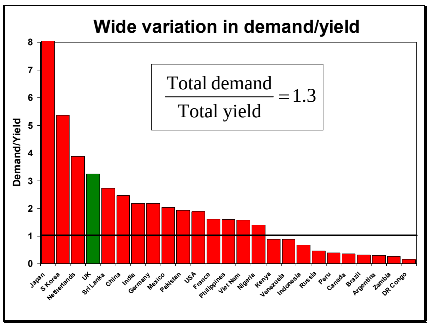
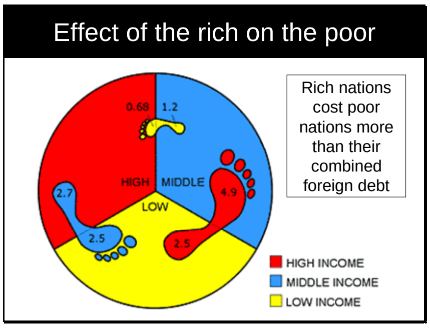


In the UK, our demand is about x3 our own yield, in the USA it is x2, while in unexploited, resource-rich countries like DR Congo it is much less than 1. The total demand/yield is estimated to be 1.3 and rising. While we can question the accuracy of the 1.3 estimate, it would be prudent to assume that not all countries could live like we do in the UK, where demand exceeds yield by a factor of more than 3. We must also account for variable resource use within countries. South Africa's ecological footprint is 2.1 hectares per person, the second-highest in Africa after Libya. If everyone lived like the average South African, we would need 1.4 planets. However, given the huge disparity in wealth (and therefore impact) of various population groups, a few are living with a footprint of >7 times what the earth can provide, whereas the majority have footprints that are far smaller.

Slide 44



The environmental damage caused by rich nations disproportionately affects poor nations and costs them more than their combined foreign debt, according to a first-ever global accounting of the dollar costs of countries' ecological footprints. Climate change and ozone depletion impacts predicted for low-income nations have been overwhelmingly driven by emissions from middle and high income nations, a pattern also observed for overfishing damages indirectly driven by the consumption of fishery products (Srinivasan PNAS 2008).

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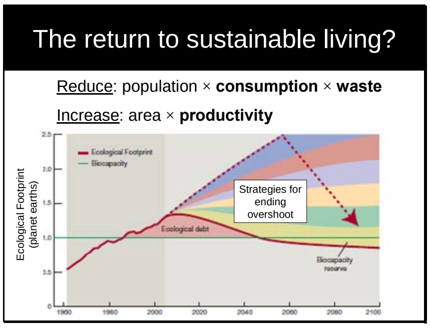

The Living Planet Report (2008) asks how we can return to sustainable use of the earth's resources. On the demand side, EF depends on population size, and on consumption per capita and waste. Reductions in all 3 components result in a smaller footprint. Supply depends on the amount of biologically productive area available, and the productivity of that area. However, increases in productivity may come at the expense of greater resource use or waste production. The wedges represent different ways to reverse the overshoot. Population cannot be reduced much below the present level. Three other variables that are perhaps more amenable to change are consumption, waste and productivity per capita. An energy policy (extending Mackay above) would include e.g. improving energy efficiency in industry, buildings, and transport; growth in the use of renewable energy such as wind, hydro, solar and thermal, and bio-energy; and the phasing out of remaining emissions from conventional fossil fuels used for power and industrial processes by an expansion of carbon capture and storage.

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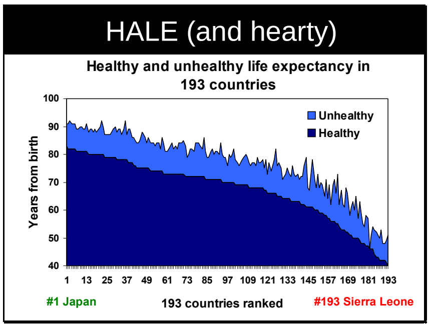

But how does health figure in all of this? We want to ensure that resources are used so that everyone everywhere leads a long and health life. One statistic that measures progress towards this need is HALE, or healthy life expectancy (= average number of years that a person can expect to live in "full health" by taking into account years lived in less than full health due to disease and/or injury).

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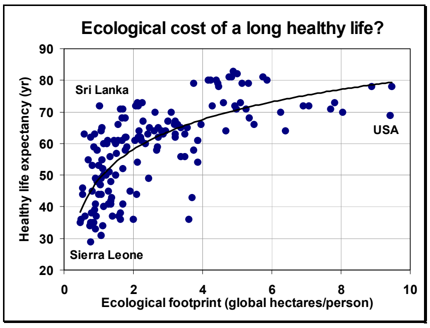
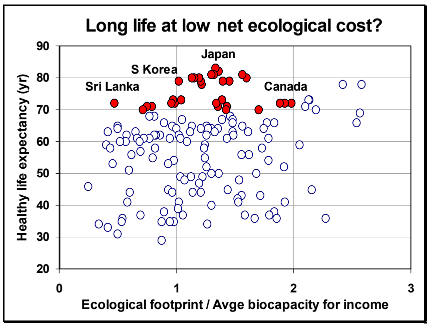


Here is the relation between EF and HALE across all countries. At first sight the graph shows that long healthy lives require a large ecological footprint. But countries like Sri Lanka suggest that good health can be bought at low ecological cost, for the time being at least .

Slide 48



We can also look at the relation between ecological demand, yield and EF, to draw the same conclusion. Some countries that have longest life expectancies have low demand/yield, at least for the time being. But is this sustainable?

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To draw some conclusions: Renowned ecologist EO Wilson accepts that population will be of the order of 8 bn, and that the main question is not about how many people we are, but how each of us contributes to demand, efficiency and productivity.

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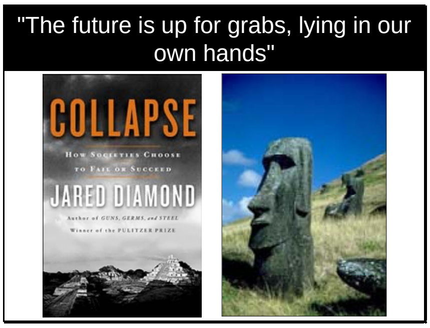

Diamond's subtitle is: how societies choose to fail or succeed. My cautiously hopeful view is that earth does have enough resources, but they will have to be very carefully managed. As Diamond puts it, reflecting on the demise of earlier civilisations (like that on Easter Island), "The future is up for grabs, lying in our own hands".

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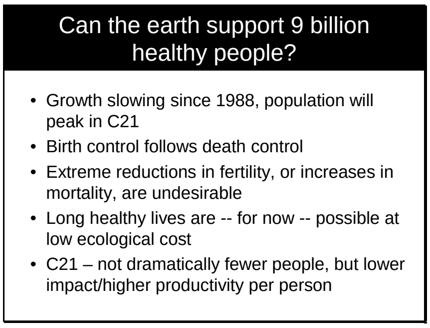
If they ever make the film – perhaps Diamond's 12 – the snapshots will look like this, illustrating the most serious problems, directly and indirectly linked to population and health.

Slide 52



To reiterate the facts. (1) Population growth has been slowing since 1988 and population will peak during the 21st century. (2) Human population are not regulated as Malthus supposed; rather birth control follows death control. (3) There will not be dramatically fewer people by the end of the 21st century without a minor (very low fertility) or major catastrophe (very high mortality). (4) Some countries have shown that long healthy life is -- for now at least -- possible at low ecological cost. The problem is that it is not consistent with our current rich-world life style. (5) The major challenge of the 21st century is for each of us to reduce consumption, and increase efficiency and productivity.