No really, how sustainable are we?

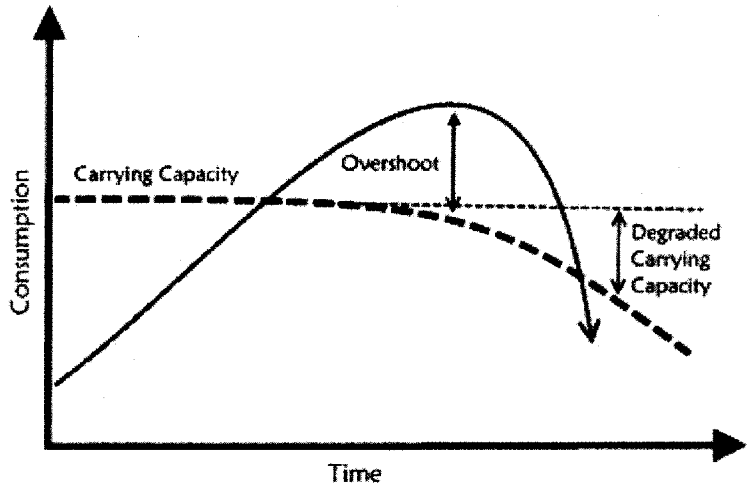
Ever since the writing of Thomas Malthus in the early 1800s, and especially since Paul Ehrlich's publication of "The Population Bomb" in 1968, there has been a lot of learned skull-scratching over what the sustainable human population of Planet Earth might "really" be over the long haul.

This question is intrinsically tied to the issue of ecological overshoot so ably described by William R. Catton Jr. in his 1980 book "Overshoot:The Ecological Basis of Revolutionary Change". How much have we already pushed our population and consumption levels above the long-term carrying capacity of the planet?

This article outlines my current thoughts on carrying capacity and overshoot, and presents six estimates for the size of a sustainable human population.

Carrying Capacity

"Carrying capacity" is a well-known ecological term that has an obvious and fairly intuitive meaning: *"The maximum population size of a species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment."*



Unfortunately that definition becomes more nebulous and controversial the closer you look at it, especially when we are talking about the planetary carrying capacity for human beings. Ecologists will claim that our numbers have already well surpassed the planet's carrying capacity, while others (notably economists and politicians...) claim we are nowhere near it yet!

This confusion may arise because we tend to confuse two very different understandings of the phrase "carrying capacity". For this discussion I will call these the "subjective" view and the "objective" views of carrying capacity.

The subjective view is carrying capacity as seen by a member of the species in question. Rather than coming from a rational, analytical assessment of the overall situation, it is an experiential judgment. As such it tends to be limited to the population of one's own species, as well as having a short time horizon – the current situation counts a lot more than some future possibility. The main thing that matters in this view is how many of one's own species will be able to survive to reproduce. As long as that number continues to rise, we assume all is well – that we have not yet reached the carrying capacity of our environment.

From this subjective point of view humanity has not even reached, let alone surpassed the Earth's overall carrying capacity – after all, our population is still growing. It's tempting to ascribe this view mainly to neoclassical economists and politicians, but truthfully most of us tend to see things this way. In fact, **all** species, including humans, have this orientation, whether it is conscious or not.

Species tend to keep growing until outside factors such as disease, predators, food or other resource scarcity – or climate change – intervene. These factors define the "objective" carrying capacity of the environment. This objective view of carrying capacity is the view of an observer who adopts a position outside the species in question.It's the typical viewpoint of an ecologist looking at the reindeer on St. Matthew Island, or at the impact of humanity on other species and its own resource base.

This is the view that is usually assumed by ecologists when they use the naked phrase "carrying capacity", and it is an assessment that can only be arrived at through analysis and deductive reasoning. It's the view I hold, and its implications for our future are anything but comforting.

When a species bumps up against the limits posed by the environment's objective carrying capacity,its population begins to decline. Humanity is now at the uncomfortable point when objective observers have detected our overshoot condition, but the population as a whole has not recognized it yet. As we push harder against the limits of the planet's objective carrying capacity, things are beginning to go wrong. More and more ordinary people are recognizing the problem as its symptoms become more obvious to casual onlookers.The problem is, of course, that we've already been above the planet's carrying capacity for quite a while.

One typical rejoinder to this line of argument is that humans have "expanded our carrying capacity" through technological innovation. "Look at the Green Revolution! Malthus was just plain wrong. There are no limits to human ingenuity!" When we say things like this, we are of course speaking from a subjective viewpoint. From this experiential, human-centric point of view, we have indeed made it possible for our environment to support ever more of us. This is the only view that matters at the biological, evolutionary level, so it is hardly surprising that most of our fellow species-members are content with it.

The problem with that view is that every objective indicator of overshoot is flashing red. From the climate change and ocean acidification that flows from our smokestacks and tailpipes, through the deforestation and desertification that accompany our expansion of human agriculture and living space, to the extinctions of non-human species happening in the natural world, the planet is urgently signaling an overload condition.

Humans have an underlying urge towards growth, an immense intellectual capacity for innovation, and a biological inability to step outside our chauvinistic, anthropocentric perspective. This combination has made it inevitable that we would land ourselves and the rest of the biosphere in the current insoluble global ecological predicament.

Overshoot

When a population surpasses its carrying capacity it enters a condition known as *overshoot*. Because the carrying capacity is defined as the maximum population that an environment can maintain *indefinitely*, overshoot must by definition be temporary. Populations *always* decline to (or below) the carrying capacity. How long they stay in overshoot depends on how many stored resources there are to support their inflated numbers. Resources may be food, but they may also be any resource that helps maintain their numbers. For humans one of the primary resources is energy, whether it is tapped as *flows* (sunlight, wind, biomass) or *stocks* (coal, oil, gas, uranium etc.). A species usually enters overshoot when it taps a particularly rich but exhaustible stock of a resource. Like fossil fuels, for instance...

Population growth in the animal kingdom tends to follow a *logistic* curve. This is an S-shaped curve that starts off low when the species is first introduced to an ecosystem, at some later point rises very fast as the population becomes established, and then finally levels off as the population saturates its niche.

Humans have been pushing the envelope of our logistic curve for much of our history. Our population rose very slowly over the last couple of hundred thousand years, as we gradually developed the skills we needed in order to deal with our varied and changeable environment,particularly language, writing and arithmetic. As we developed and disseminated those skills our ability to modify our environment grew, and so did our growth rate.

If we had not discovered the stored energy stocks of fossil fuels, our logistic growth curve would probably have flattened out some time ago, and we would be well on our way to achieving a balance with the energy flows in the world around us, much like all other species do. Our numbers would have settled down to oscillate around a much lower level than today, similar to what they probably did with hunter-gatherer populations tens of thousands of years ago.

Unfortunately, our discovery of the energy potential of coal created what mathematicians and systems theorists call a "bifurcation point" or what is better known in some cases as a tipping point. This is a point at which a system diverges from one path onto another because of some influence on events. The unfortunate fact of the matter is that bifurcation points are generally irreversible. Once past such a point, the system can't go back to a point before it.

Given the impact that fossil fuels had on the development of world civilization, their discovery was clearly such a fork in the road. Rather than flattening out politely as other species' growth curves tend to do, ours kept on rising. And rising, and rising.

What is a sustainable population level?

Now we come to the heart of the matter. Okay, we all accept that the human race is in overshoot. But how deep into overshoot are we? What *is* the carrying capacity of our planet? The answers to these questions,after all, define a *sustainable* population.

Not surprisingly, the answers are quite hard to tease out. Various numbers have been put forward, each with its set of stated and unstated assumptions –not the least of which is the assumed standard of living (or consumption profile) of the average person. For those familiar with Ehrlich and Holdren's **I=PAT** equation, if "**I**" represents the environmental impact of a sustainable population, then for any population value "**P**" there is a corresponding value for "**AT**", the level of Activity and Technology that can be sustained for that population level. In other words, the higher our standard of living climbs, the lower our population level must fall in order to be sustainable. This is discussed further in an earlier article on *Thermodynamic Footprints*.

To get some feel for the enormous range of uncertainty in sustainability estimates we'll look at six assessments, each of which leads to a very different outcome. We'll start with the most optimistic one, and work our way down the scale.

The Ecological Footprint Assessment

The concept of the Ecological Footprint was developed in 1992 by William Rees and Mathis Wackernagel at the University of British Columbia in Canada.

The ecological footprint is a measure of human demand on the Earth's ecosystems. It is a standardized measure of demand for natural capital that may be contrasted with the planet's ecological capacity to regenerate. It represents the amount of biologically productive land and sea area necessary to supply the resources a human population consumes, and to assimilate associated waste. As it is usually published, the value is an estimate of how many planet Earths it would take to support humanity with everyone following their current lifestyle.

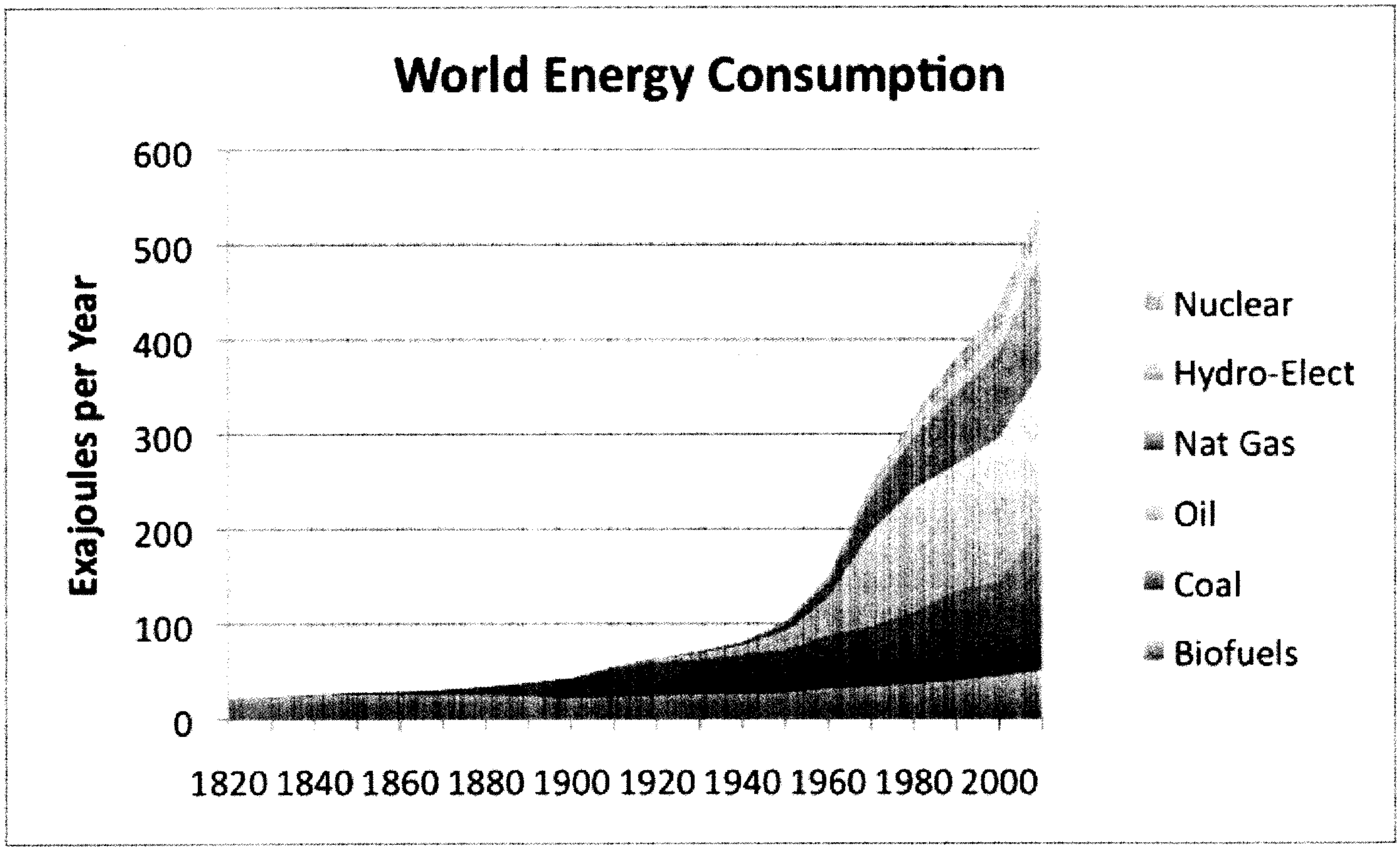
It has a number of fairly glaring flaws that cause it to be hyper-optimistic. The "ecological footprint" is basically for renewable resources only. It includes a theoretical but underestimated factor for non-renewable resources. It does not take into account the unfolding effects of climate change, ocean acidification or biodiversity loss (i.e. species extinctions). It is intuitively clear that no number of "extra planets" would compensate for such degradation.

Still, the estimate as of the end of 2012 is that our overall ecological footprint is about "1.7 planets". In other words, there is at least 1.7 times too much human activity for the long-term health of this single, lonely planet. To put it yet another way, we are 70% into overshoot.

It would probably be fair to say that by this accounting method the sustainable population would be (7 / 1.7) or about **four billion** people at our current average level of affluence. As you will see, other assessments make this estimate seem like a happy fantasy.

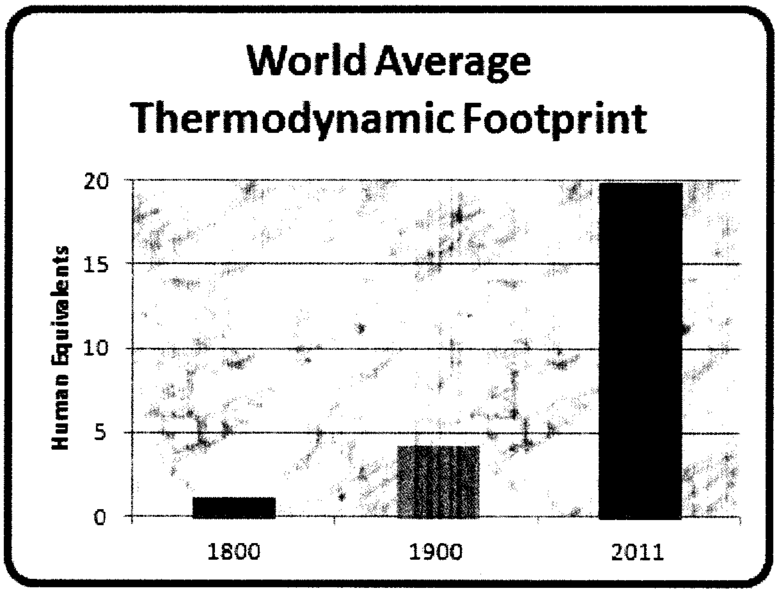
The Fossil Fuel Assessment

The main accelerator of human activity over the last 150 to 200 years has been our exploitation of the planet's stocks of fossil fuel. Before 1800 there was very little fossil fuel in general use, with most energy being derived from the flows represented by wood, wind, water, animal and human power. The following graph demonstrates the precipitous rise in fossil fuel use since then, and especially since 1950.



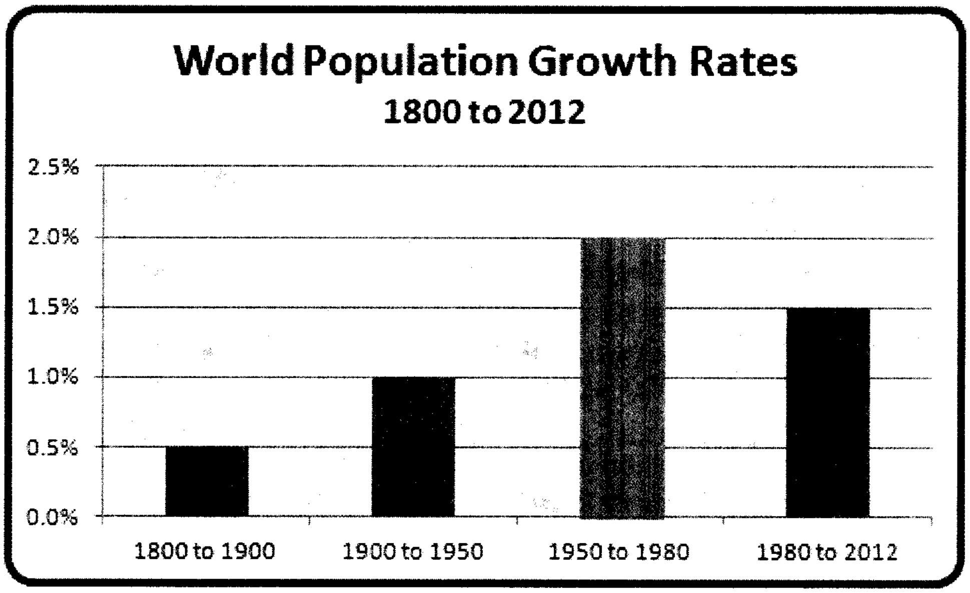
Graphic by Gail Tverberg

This information was the basis for my earlier Thermodynamic Footprint analysis. That article investigated the influence of technological energy (87% of which comes from fossil fuel stocks) on human planetary impact, in terms of how much it multiplies the effect of each "naked ape". The following graph illustrates the multiplier at different points in history:



Fossil fuels have powered the increase in all aspects of civilization, including population growth. The "Green Revolution" in agriculture that was kicked off by Nobel laureate Norman Borlaug in the late 1940s was largely a fossil fuel phenomenon, relying on mechanization,powered irrigation and synthetic fertilizers derived from fossil fuels. This enormous increase in food production supported a swift rise in population numbers, in a classic ecological feedback loop: more food (supply) => more people (demand) => more food => more people etc...

Over the core decades of the Green Revolution from 1950 to 1980 the world population almost doubled, from fewer than 2.5 billion to over 4.5 billion. The average population growth over those three decades was 2% per year. Compare that to 0.5% from 1800 to 1900; 1.00% from 1900 to 1950; and 1.5% from 1980 until now:



This analysis makes it tempting to conclude that a sustainable population might look similar to the situation in 1800, before the Green Revolution, and before the global adoption of fossil fuels: about **1 billion people living** on about 5% of today's global average energy consumption, all of it derived from renewable energy flows.

It's tempting (largely because it seems vaguely achievable), but unfortunately that number may still be too high. Even in 1800 the signs of human overshoot were clear, if not well recognized: there was already widespread deforestation through Europe and the Middle East; and desertification had set into the previously lush agricultural zones of North Africa and the Middle East.

Not to mention that if we did start over with "just" one billion people, an annual growth rate of a mere 0.5% would put the population back over seven billion in just 400 years. Unless the growth rate can be kept down very close to zero, such a situation is decidedly unsustainable.

<u>The Population Density Assessment</u>

There is another way to approach the question. If we assume that the human species *was* sustainable at some point in the past, what point might we choose and what conditions contributed to our apparent sustainability at that time?

I use a very strict definition of sustainability. It reads something like this: *"Sustainability is the ability of a species to survive **in perpetuity** without damaging the planetary ecosystem in the process."* This principle applies only to a species' own actions, rather than uncontrollable external forces like Milankovitch cycles, asteroid impacts, plate tectonics, etc.

In order to find a population that I was fairly confident met my definition of sustainability, I had to look well back in history - in fact back into Paleolithic times. The sustainability conditions I chose were: a very low population density and very low energy use, with both maintained over multiple thousands of years. I also assumed the populace would each use about as much energy as a typical hunter-gatherer: about twice the daily amount of energy a person obtains from the food they eat.

There are about 150 million square kilometers, or 60 million square miles of land on Planet Earth. However, two thirds of that area is covered by snow, mountains or deserts, or has little or no topsoil. This leaves about **50 million square kilometers** (20 million square miles) that is habitable by humans without high levels of technology.

A typical population density for a non-energy-assisted society of hunter-forager-gardeners is between 1 person per square mile and 1 person per square kilometer. Because humans living this way had settled the entire planet by the time agriculture was invented 10,000 years ago, this number pegs a reasonable *upper* boundary for a sustainable world population in the range of *20 to 50 million* people.

I settled on the average of these two numbers, **35 million people**. That was because it matches known hunter-forager population densities, and because those densities were maintained with virtually zero population growth (less than 0.01% per year)during the 67,000 years from the time of the Toba super-volcano eruption in 75,000 BC until 8,000 BC (Agriculture Day on Planet Earth).

If we were to spread our current population of 7 billion evenly over 50 million square kilometers, we would have an average density of 150 per square kilometer. Based just on that number, and without even considering our modern energy-driven activities, our current population is at least 250 times too big to be sustainable. To put it another way, we are now **25,000%**into overshoot based on our raw population numbers alone.

As I said above, we also need to take the population's standard of living into account. Our use of technological energy gives each of us the average planetary impact of about 20 hunter-foragers. What would the sustainable population be if each person kept their current lifestyle, which is given as an average current Thermodynamic Footprint (TF) of 20?

We can find the sustainable world population number for **any** level of human activity by using the **I = PAT** equation mentioned above.

- We decided above that the maximum hunter-forager population we could accept as sustainable would be 35 million people, each with a Thermodynamic Footprint of 1.
- First, we set I (the allowable total impact for our sustainable population) to 35, representing those 35 million hunter-foragers.
- Next, we set AT to be the TF representing the desired average lifestyle for our population. In this case that number is 20.
- We can now solve the equation for P. Using simple algebra, we know that I = P x AT is equivalent to P = I / AT. Using that form of the equation we substitute in our values, and we find that P = 35 / 20. In this case P = 1.75.

This number tells us that if we want to keep the average level of per-capita consumption we enjoy in in today's world, we would enter an overshoot situation above a global population of about 1.75 million people. By this measure our current population of 7 billion is about 4,000 times too big and active for long-term sustainability. In other words, by this measure we are we are now **400,000% into overshoot**.

Using the same technique we can calculate that achieving a sustainable population with an American lifestyle (TF = 78) would permit a world population of only **650,000** people – clearly not enough to sustain a modern global civilization.

For the sake of comparison, it is estimated that the historical world population just after the dawn of agriculture in 8,000 BC was about five million, and in Year 1 was about 200 million. We crossed the upper threshold of planetary sustainability in about 2000 BC, and have been in deepening overshoot for the last 4,000 years.

The Ecological Assessments

As a species, human beings share much in common with other large mammals. We breathe, eat, move around to find food and mates, socialize, reproduce and die like all other mammalian species. Our intellect and culture, those qualities that make us uniquely human, are recent additions to our essential primate nature, at least in evolutionary terms.

Consequently it makes sense to compare our species' performance to that of other, similar species – species that we know for sure are sustainable. I was fortunate to find the work of American marine biologist Dr. Charles W. Fowler, who has a deep interest in sustainability and the ecological conundrum posed by human beings. The following three assessments are drawn from Dr. Fowler's work.

First assessment

In 2003, Dr. Fowler and Larry Hobbs co-wrote a paper titled, *"Is humanity sustainable?"* that was published by the Royal Society. In it, they compared a variety of ecological measures across 31 species including humans. The measures included biomass consumption, energy consumption, CO_2 production, geographical range size, and population size.

It should come as no great surprise that in most of the comparisons humans had far greater impact than other species, even to a 99% confidence level. When it came to population size, Fowler and Hobbs found that there are over two orders of magnitude more humans than one would expect based on a comparison to other species – 190 times more, in fact. Similarly, our CO_2 emissions outdid other species by a factor of 215.

Based on this research, Dr. Fowler concluded that there are about 200 times too many humans on the planet. This brings up an estimate for a sustainable population of **35 million people**.

This is the same as the upper bound established above by examining hunter-gatherer population densities. The similarity of the results is not too surprising, since the hunter-gatherers of 50,000 years ago were about as close to "naked apes" as humans have been in recent history.

Second assessment

In 2008, five years after the publication cited above, Dr. Fowler wrote another paper entitled *"Maximizing biodiversity, information and sustainability."* In this paper he examined the sustainability question from the point of view of maximizing biodiversity. In other words, what is the largest human population that would not reduce planetary biodiversity?

This is, of course, a very stringent test, and one that we probably failed early in our history by extirpating mega-fauna in the wake of our migrations across a number of continents.

In this paper, Dr. Fowler compared *96* different species, and again analyzed them in terms of population, CO_2 emissions and consumption patterns.

This time, when the strict test of biodiversity retention was applied, the results were truly shocking, even to me. According to this measure, humans have overpopulated the Earth by almost **700 times**. In order to preserve maximum biodiversity on Earth, the human population may be no more than **10 million people** – each with the consumption of a Paleolithic hunter-forager.

Addendum: Third assessment

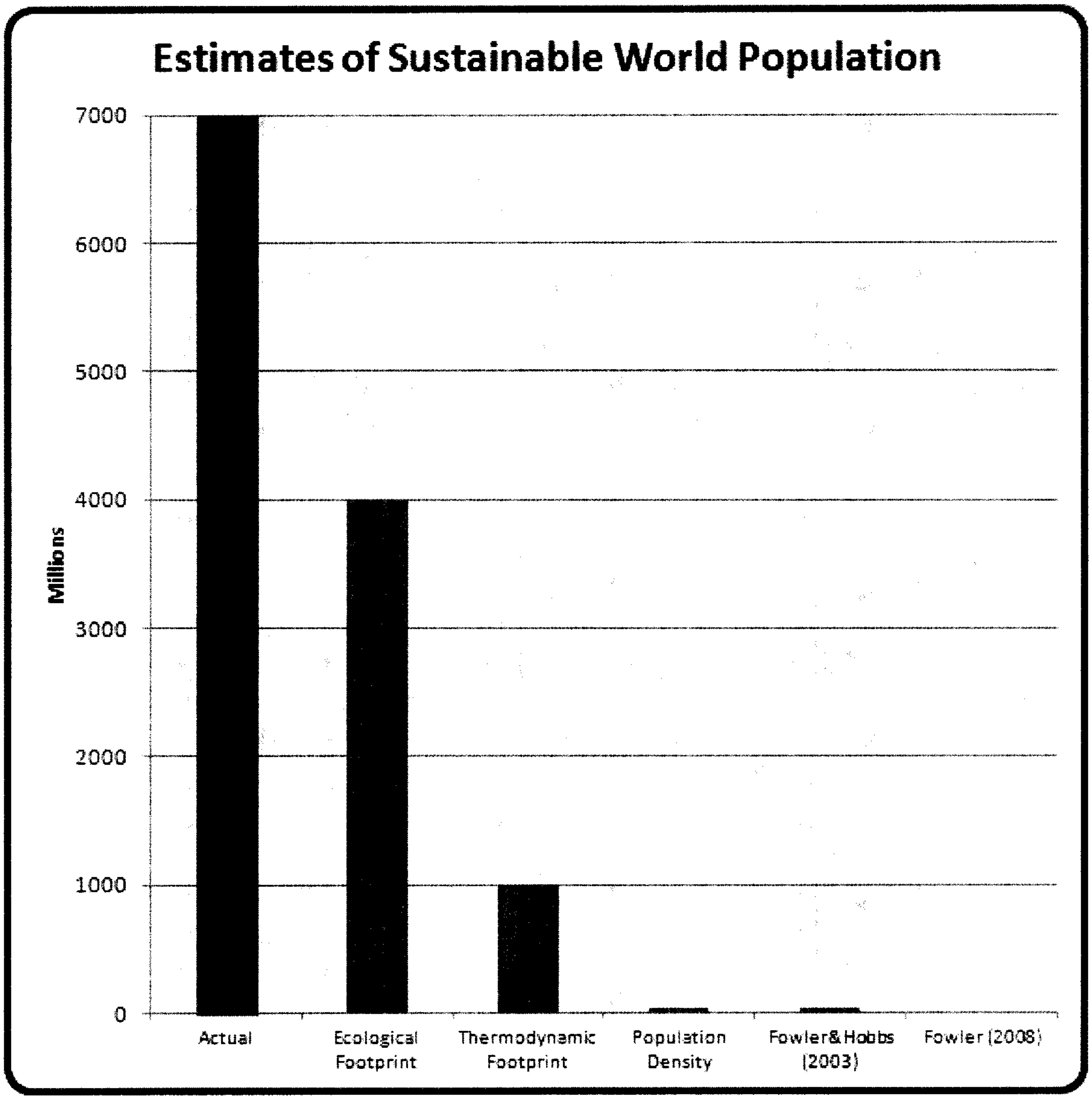
After this article was initially written, Dr. Fowler forwarded me a copy of an appendix to his 2009 book, *"Systemic Management: Sustainable Human Interactions with Ecosystems and the Biosphere"*, published by Oxford University Press. In it he describes yet one more technique for comparing humans with other mammalian species, this time in terms of observed population densities, total population sizes and ranges.

After carefully comparing us to various species of both herbivores and carnivores of similar body size, he draws this devastating conclusion: the human population is about 1000 times larger than expected. This is in line with the second assessment above, though about 50% more pessimistic. It puts a sustainable human population at about **7 million**.

Urk!

Conclusions

As you can see, the estimates for a sustainable human population vary widely – by a factor of 500 from the highest to the lowest.



The *Ecological Footprint* doesn't really seem intended as a measure of sustainability. Its main value is to give people with no exposure to ecology some sense that we are indeed over-exploiting our planet. (It also has the psychological advantage of feeling achievable with just a little work.) As a measure of sustainability, it is not helpful.

As I said above, the number suggested by the *Thermodynamic Footprint* or Fossil Fuel analysis isn't very helpful either – even a population of one billion people without fossil fuels had already gone into overshoot.

That leaves us with four estimates: two at 35 million, one of 10 million, and one of 7 million.

The central number of **35 million people** is confirmed by two analyses using different data and assumptions. My conclusion is that this is probably the absolutely largest human population that could be considered sustainable. The realistic but similarly unachievable number is probably more in line with the bottom two estimates, somewhere below 10 million.

I think the lowest two estimates (Fowler 2008, and Fowler 2009) are as unrealistically high as all the others in this case, primarily because human intelligence and problem-solving ability makes our destructive impact on biodiversity a foregone conclusion. After all, we drove other species to extinction 40,000 years ago, when our total population was estimated to be under 1 million.

So, what can we do with this information? It's obvious that we will not (and probably cannot) voluntarily reduce our population by 99.5% to 99.9%. Even an involuntary reduction of this magnitude would involve enormous suffering and a very uncertain outcome. It's close enough to zero that if Mother Nature blinked, we'd be gone.

In fact, the analysis suggests that Homo sapiens is an inherently unsustainable species. This outcome seems virtually guaranteed by our neocortex, by the very intelligence that has enabled our rise to unprecedented dominance over our planet's biosphere. Is intelligence an evolutionary blind alley? From the singular perspective of our own species, it quite probably is. If we are to find some greater meaning or deeper future for intelligence in the universe, we may be forced to look beyond ourselves and adopt a cosmic, rather than a human, perspective.

Discussion

How do we get out of this jam?

How might we get from where we are today to a sustainable world population of 35 million or so? We should probably discard the notion of "managing" such a population decline. If we can't even get our population to simply stop growing, an outright reduction of over 99% is simply not in the cards. People seem virtually incapable of taking these kinds of decisions in large social groups. We can decide to stop reproducing, but only as individuals or (perhaps) small groups. Without the essential broad social support, such personal choices will make precious little difference to the final outcome. Politicians will by and large not even propose an idea like "managed population decline" - not if they want to gain or remain in power, at any rate. China's brave experiment with one-child families notwithstanding, any global population decline will be purely involuntary.

Crash?

A world population decline would (will) be triggered and fed by our civilization's encounter with limits. These limits may show up in any area: accelerating climate change, weather extremes,shrinking food supplies, fresh water depletion, shrinking energy supplies,pandemic diseases, breakdowns in the social fabric due to excessive complexity,supply chain breakdowns, electrical grid failures, a breakdown of the international financial system, international hostilities - the list of candidates is endless, and their interactions are far too complex to predict.

In 2007, shortly after I grasped the concept and implications of Peak Oil, I wrote my first web article on population decline: Population: The Elephant in the Room. In it I sketched out the picture of a monolithic population collapse: a straight-line decline from today's seven billion people to just one billion by the end of this century.

As time has passed I've become less confident in this particular dystopian vision. It now seems to me that human beings may be just a bit tougher than that. We would fight like demons to stop the slide, though we would potentially do a lot more damage to the environment in the process. We would try with all our might to cling to civilization and rebuild our former glory. Different physical, environmental and social situations around the world would result in a great diversity in regional outcomes. To put it plainly, a simple "slide to oblivion" is not in the cards for any species that could recover from the giant Toba volcanic eruption in just 75,000 years.

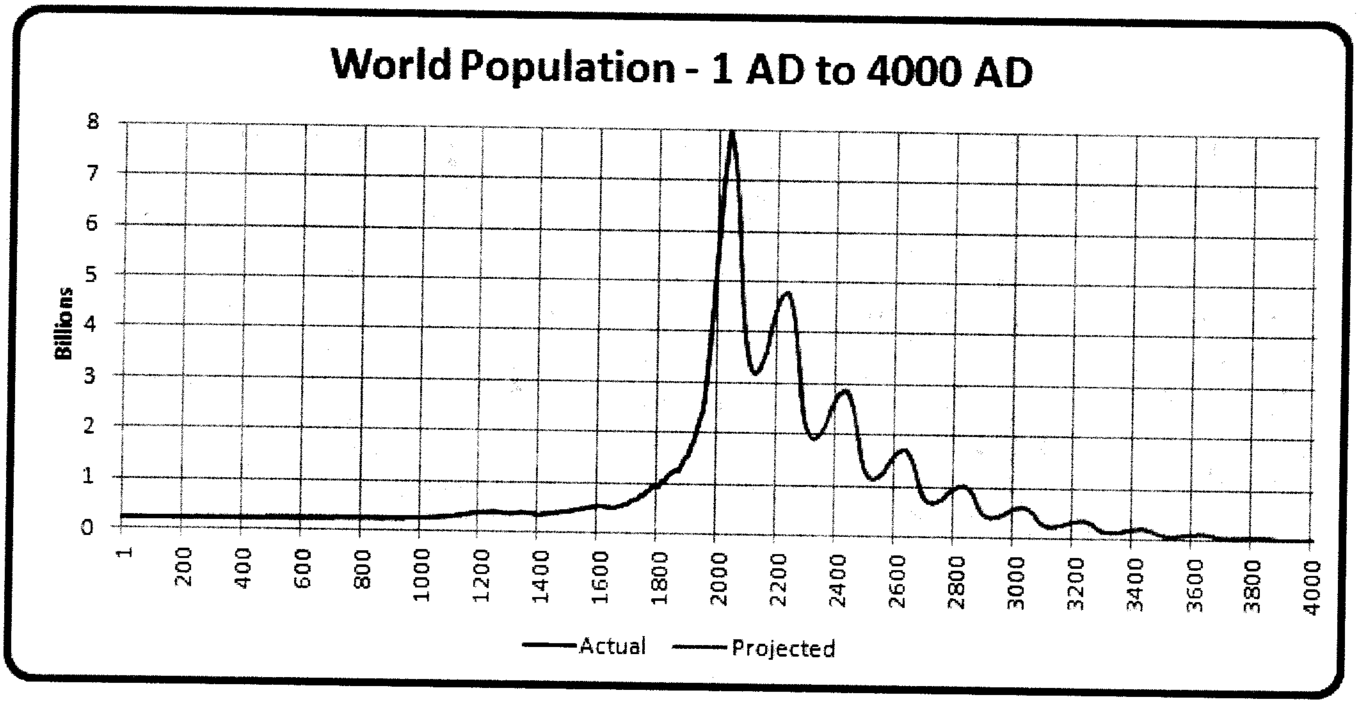
Or Tumble?

Still, there *are* those physical limits I mentioned above. They are looming ever closer, and it seems a foregone conclusion that we will begin to encounter them for real within the next decade or two. In order to draw a slightly more realistic picture of what might happen at that point, I created the following thought experiment on involuntary population decline. It's based on the idea that our population will not simply crash, but will oscillate (tumble) down a series of stair-steps: first dropping as we puncture the limits to growth; then falling below them; then partially recovering; only to fall again; partially recover; fall; recover...

I started the scenario with a world population of 8 billion people in 2030. I assumed each full cycle of decline and partial recovery would take six generations, or 200 years. It would take three generations (100 years) to complete each decline and then three more in recovery, for a total cycle time of 200 years. I assumed each decline would take out 60% of the existing population over its hundred years, while each subsequent rise would add back only half of the lost population.

In ten full cycles - 2,000 years - we would be back to a sustainable population of about 40-50 million. The biggest drop would be in the first 100 years, from 2030 to 2130 when we would lose a net 53 million people per year. Even that is only a loss of 0.9% pa, compared to our net growth today of 1.1%, that's easily within the realm of the conceivable,and not necessarily catastrophic - at least to begin with.

As a scenario it seems a lot more likely than a single monolithic crash from here to under a billion people. Here's what it looks like:



It's important to remember that this scenario is **not a prediction**. It's an attempt to portray a potential path down the population hill that seems a bit more probable than a simple, *"Crash! Everybody dies."*

It's also important to remember that the decline will probably not happen anything like this, either. With climate change getting ready to push humanity down the stairs, and the strong possibility that the overall global temperature will rise by 5 or 6 degrees Celsius even before the end of that first decline cycle, our prospects do not look even this "good" from where I stand.

Rest assured, I'm not trying to present 35 million people as some kind of "population target". It's just part of my attempt to frame what we're doing to the planet, in terms of what some of us see as the planetary ecosphere's level of tolerance for our abuse.

The other potential implicit in this analysis is that if we did drop from 8 to under 1 billion, we could then enter a population free-fall. As a result, we might keep falling until we hit the bottom of Olduvai Gorge again. My numbers are an attempt to define how many people might stagger away from such a crash landing. Some people seem to believe that such an event could be manageable. I don't share that belief for a moment. These calculations are my way of getting that message out.

I figure if I'm going to draw a line in the sand, I'm going to do it on behalf of **all** life, not just our way of life.

What can we do?

To be absolutely clear, after ten years of investigating what I affectionately call "The Global Clusterfuck", I do not think it can be prevented, mitigated or managed **in any way**. If and when it happens, it will follow its own dynamic, and the force of events could easily make the Japanese and Andaman tsunamis seem like pleasant days at the beach.

The most effective preparations that we can make will all be done by individuals and small groups. It will be up to each of us to decide what our skills, resources and motivations call us to do. It will be different for each of us - even for people in the same neighborhood, let alone people on opposite sides of the world.

I've been saying for a couple of years that each of us will each do whatever we think is appropriate to the circumstances, in whatever part of the world we can influence. The outcome of our actions is ultimately unforeseeable, because it depends on how the efforts of all 7 billion of us converge, co-operate and compete. The end result will be quite different from place to place - climate change impacts will vary, resources vary, social structures vary, values and belief systems are different all over the world.The best we can do is to do our best.

Here is my advice:

- Stay awake to what's happening around us.
- Don't get hung up by other people's "shoulds and shouldn'ts".
- Occasionally re-examine our personal values. If they aren't in alignment with what we think the world needs, change them.
- Stop blaming people. Others are as much victims of the times as we are - even the CEOs and politicians.
- Blame, anger and outrage is pointless. It wastes precious energy that we will need for more useful work.
- Laugh a lot, at everything - including ourselves.
- Hold all the world's various beliefs and "isms" lightly, including our own.
- Forgive others. Forgive ourselves. For everything.
- Love everything just as deeply as you can.

That's what I think might be helpful. If we get all that personal stuff right, then doing the physical stuff about food, water, housing,transportation, energy, politics and the rest of it will come easy – or at least a bit easier. And we will have a lot more fun doing it.

I wish you all the best of luck!

Bodhi Paul Chefurka

May 16, 2013