Lag-Times, Delayed Feedbacks, and Overshoot

Stoplights and Twisting Mountain Roads

In their book BEYOND THE LIMITS, Meadows, Meadows, and Randers (1992) offered insights into the dynamics of delayed feedbacks, overshoot, and collapse. They point out, for example, that we are able to successfully navigate dangerous curves on a twisting mountain road, or negotiate a stoplight at a busy highway intersection because of feedbacks that allow us to respond to conditions as they change.

Suppose, for instance, that you are in an automobile that is traveling at a high rate of speed on a twisting mountain road. If you and/or your vehicle fail to make necessary adjustments in an ongoing and timely manner, the needed response will occur too late and a dangerous and deadly overshoot will result – perhaps sending your vehicle and its passengers off a precipice.

Or suppose that this same automobile is approaching a red stoplight in the near distance. Normally, a driver will take his or her foot off the accelerator and press on the brake pedal in a way that slows the vehicle to a safer speed, or which brings the vehicle to a gentle stop as it nears the red light.

Lag Times, Uncertainties, and Delayed Feedbacks

The BTL authors next ask us to imagine what happens if there are delayed feedbacks or lag times in such a system: What if your side of the window is fogged up so that a passenger must inform you about the stoplight's condition and its distance?

What if the passenger lies to you? What if the passenger tells you the truth, but you do not believe his or her report? What if the brakes, when touched, require two minutes before exerting their influence? What if the speed and mass of the vehicle produces so much momentum that hundreds of yards are needed to stop – as in the case of an aircraft carrier that must slow from its maximal speed?

Delays of these sorts can cause a driver to shoot past a stoplight or go off a cliff on a mountain road, destroying the vehicle and its passengers. In an automobile, feedback delays and lag times can prevent a driver from responding quickly and accurately enough to changing conditions, resulting in an overshoot and its accompanying disaster for the vehicle and its occupants.

In society, where our governments and social institutions are cumbersome and lumber along, *such delays are the* rule *rather than the exception*. And just like the passengers in our imaginary vehicle, inevitable lag times and delayed feedbacks can lead to disaster.

Certainties, Uncertainties, and Delayed Feedbacks

Imagine new data sets and information that are vitally important, but which include initial uncertainties. Early reports and papers concerning greenhouse gases and climate change both come to mind. Despite serious environmental implications, such information may also have significant economic consequences. Thus, the possibility of economic repercussions might prompt pleas for "more certainty" before taking action.

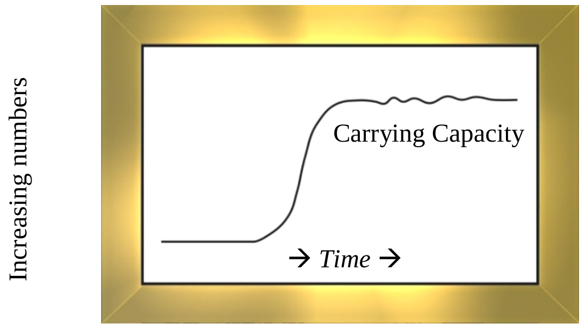
What if economic interests or a majority of government leaders do not want to believe the implications of early data? In society, extended lag times can result when officials, confronted by economic interests, elect to consign a problem to a backburner “until it can be studied more." In addition, when issues have high economic stakes, a classic conflict between private gain and issues of the public good can arise. Recent financial mismanagement, scandals, and bailouts remind us, painfully, that when money is involved, vested interests can dispense misleading or inaccurate information.

Those who stand to realize a financial gain from a given outcome may not always provide trustworthy information, thus raising the possibility of misinformation and/or disinformation. Assorted accounts, of course, could be completely accurate, but they could also be partially inaccurate, or might omit information that adversely impacts investment portfolios or desired business outcomes. Or, on the other hand, the information could be entirely disingenuous. Internationally, for example, it is common for intelligence agencies to occasionally dispense “disinformation” to put perceived enemies at a disadvantage. Unfortunately, the same strategy can be employed in policy debates, so that omission/disinformation issues are revisited again in a later chapter.

In the computer models tested by Meadows, et al. to assess trends in population and resource use, again and again the data produced projections of industrial collapse in the mid-21st century. In the refined data and updated programs reported in Beyond the Limits (1992) the authors offered the following sobering assessment: "...the model system, and by implication the 'real world' system, has a strong tendency to overshoot and collapse. In fact, in the thousands of model runs we have tried over the years, overshoot and collapse has been by far the most frequent outcome."

Certain "negative" feedbacks can help induce and maintain equilibrium

Sometimes "negative" feedbacks act as signals or bring about responses that allow a population to live in equilibrium with its environment, as illustrated by the graph depicted below.



For instance, some populations initially increase in numbers quite quickly, but then their rate of growth *gradually and increasingly slows down* until it eventually flattens out and stabilizes (see graph above) around the carrying capacity of the environment. When graphed, such data result in an S-shaped or sigmoid curve as depicted above.

Notice the fast growth initially, followed by slower and slower rates of increase, until finally, births and deaths are approximately equal and the population reaches a stable equilibrium with the environment in which it lives.

In these cases, as a population becomes ***more crowded***, various "negative" pressures or feedbacks begin to develop and increasingly-exert themselves in ways that oppose, diminish, or undermine further growth.

Thus, as a population becomes more and more ***crowded***, the "negative" factors that exert pressures opposing further growth *also become amplified*, causing the rate of growth to slow down more and more.

Examples of such **density-dependent feedbacks** include pollution, disease, environmental degradation, aggression, hunger, and infant mortality. As population density (crowding) in a given enviroment becomes greater, the negative pressures exerted by disease, hunger, pollution, and aggression also become *correspondingly intense*.

In many cases, these negative pressures eventually become strong enough to effectively offset, counterbalance, or cancel-out the forces of growth, resulting in a stable population that does not increase or decrease in numbers over long periods of time.

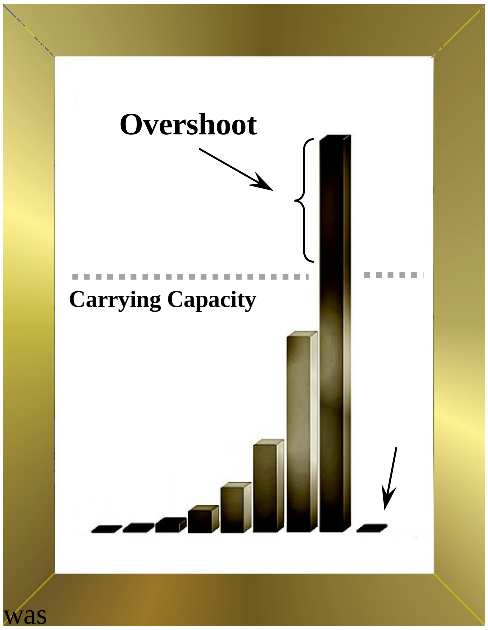
Sometimes, however, if a population is freed from competition, pathogens, and predators, for example, these and other normal restraints on population growth may disappear for a time, resulting in a population explosion called ECOLOGICAL RELEASE (addressed further in our pdf twelve).

In the absence of such restraints, the unhindered growth that results commonly results in the population OVERSHOOTING *the carrying capacity of its environment*

which is our topic below.

OVERSHOOT: CLIMB-AND-COLLAPSE

Often populations do not slow and stabilize, but continue to grow rapidly, <u>even as their numbers rocket past the long-term carrying capacity of their environment</u>.



In these instances, the population "overshoots" the carrying capacity of its environment. As overshoot occurs, consumption and environmental damage occur at unsustainable rates, ending in a comparatively large and rapid die-off called a COLLAPSE.

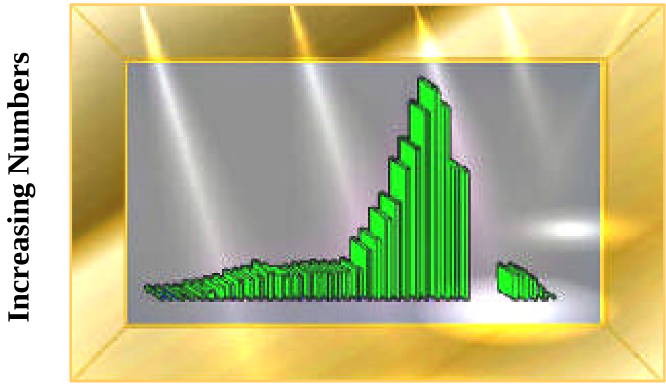
In a study reported by Klein (1968), a reindeer herd living on St. Matthew Island, Alaska grew exponentially at first, but within a few years they overshot the carrying capacity of their environment and **99%** *of the herd perished* in the catastrophic die-off that followed.

For anyone who has been hurt by or angered by the recent Wall Street, banking, and financial bubble, the graphs depicted here should be more than a little unsettling. <u>When the reindeer population bubbles cited here finally burst</u>, *there were no bailouts*, and it was not the death of an economic system, but the death of virtually all of the reindeer residing in the system, along with the destruction of the environmental systems that once supported them. As physicist Albert Bartlett has observed, "every increment of added population and every added increment of affluence invariably destroy increments of the remaining environment."

Another classic study of the rise and fall of a reindeer herd

In two earlier chapters we have referenced V.B. Scheffer's classic study, *The Rise and Fall of a Reindeer Herd* (1951). Scheffer's study took place over a period of four decades between 1910 and 1950, generating a graph approximating the one depicted below.

The reindeer population in Scheffer's study underwent a population explosion followed by a catastrophic die-off, even with vast amounts of open space remaining. Within a few years, Klein conducted a similar study with the results addressed above (previous page; 1968).



The Scheffer study began in 1910 when scientists introduced a small herd of twenty-five reindeer to forty-one square mile St. Paul Island, Alaska. The island had no timber wolves or other predators, and no major competitors. Thus, at the outset, with the island all to itself, the reindeer population increased its numbers exponentially in a classical case of ecological release. The left side of the graph shows the reindeer numbers in the initial years of the study. By 1938, however, the herd's numbers peaked at more than two thousand individuals.

Notice that the data generated over the first 28 years of the study exhibit a classical **J-curve** as the herd underwent an *exponential* increase in numbers. Notice also, however, that on the right side of the graph, a precipitous die-off took place that, given our own trajectories, we might do well to contemplate.

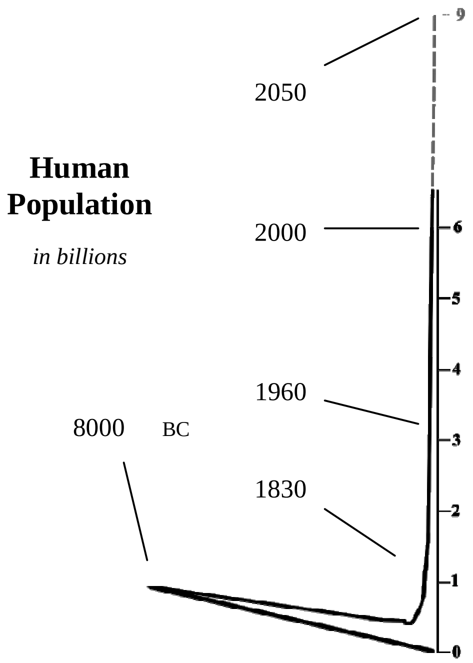
Notice that following the peak in 1938, reindeer numbers fell repeatedly and precipitously, *even though the animals themselves physically-occupied* **less than one tenth of one percent** *of the total "open space" that was theoretically available.*

During its collapse, the reindeer population was virtually wiped out with a loss of **99%** of its numbers. By the time the study ended in 1950, there were only eight reindeer still surviving on the island. (Note that the graph depicts no data for the years 1942-1945 when the chaos of World War II interrupted the study.) Like the study reported in by Klein (as addressed on our previous page) 99% of this population also *perished* during the collapse.

It might be wise to note, therefore, that mammalian populations *are not immune to overshoot and collapse*.

In the last one hundred years, our own species has been so successful (at least temporarily), at conquering pathogenic microbes and hunger that we have escaped the natural controls that once held our numbers in check.

With each new advance in medicine, our population has extended its temporary release. As a result, our worldwide numbers, which began rocketing sharply upward in the mid-1800s, have continued to soar (as shown in the graph below) and <u>we</u> are now in a calamitous condition of overshoot.



Notice that our graph is, if anything, FAR MORE EXTREME than those that preceded the collapse in each of the reindeer populations. We do not yet know the earth's precise carrying capacity for our species, but it would have been best to address this question many decades ago.

As it is, many, if not most, scientists surmise that we are *already* well beyond earth's carrying capacity for our species, in a classic case of overshoot.

A continuation of today's demographic tidal wave *may constitute the greatest single risk that our species has ever undertaken.*

Excerpted from
What Every Citizen Should Know About Our Planet
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Expanded implications of this excerpt are also addressed in additional PDFs in this collection:

- Razor-Thin Films - Earth's Atmosphere and Seas
- Numerics, Demographics, and a Billion Homework Questions
- Conservation planning - Why Brazil's 10% is Not Enough
- Eight Assumptions that Invite Calamity
- Climate - No Other Animals Do This
- Critique of Beyond Six Billion
- Delayed feedbacks, Limits, and Overshoot
- Thresholds, Tipping points, and Unintended consequencs
- Problematic Aspects of Geoengineering
- Carrying Capacity and Limiting Factors
- Humanity's Demographic Journey
- Ecosystem services and Ecological release
- J-curves and Exponential progressions
- One-hundred key Biospheric understandings

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