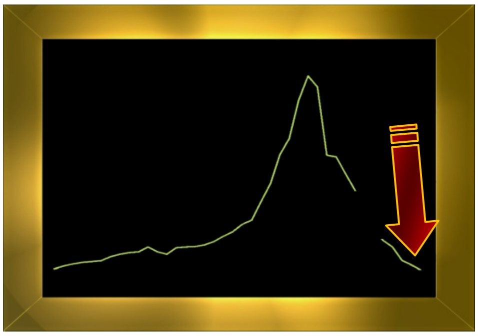
Open-space and Collapse

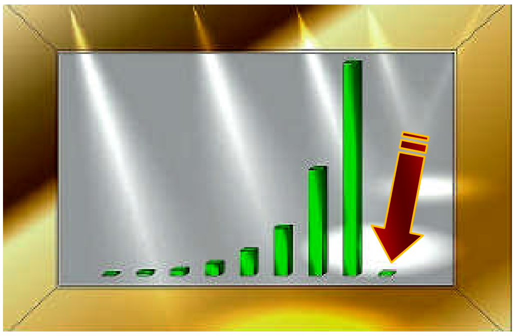
There is a widely-held MISPERCEPTION within our societies that human population growth and overpopulation cannot be truly serious so long as "*vast amounts of open space*" remain. Such "open-space" misperceptions are highly dangerous because they tempt us into complacency. In this respect, populations of real-world marine dinoflagellates such as *Karenia brevis* prove provocative and may have something to tell us about ourselves.

This PDF will assess these seductive, but deeply-erroneous, "open-space" suppositions mathematically – lest we permit them to distract us from the true degree of the dangers that our current trajectories invite. It may be, for example, that our species is closer in time to calamitous humanitarian, civilizational, and biospheric outcomes than we are to the Apollo moon missions and the Vietnam war.

The two graphs below summarize the results of two classic studies of reindeer herds (Scheffer, 1951; and Klein, 1968) discussed elsewhere in this collection. In each case, a period of exponential growth was followed by a catastrophic 99% die-off as each population collapsed.



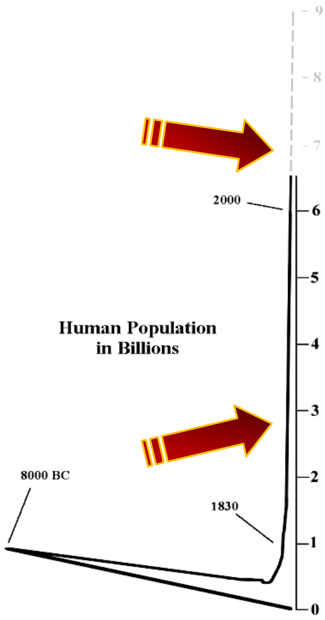
After Scheffer, 1951.



After Klein, 1968.

It should at least be provocative, if not disconcerting, that in each instance, the reindeer populations occupied *less than* ONE-TENTH OF ONE PERCENT *of the area* theoretically-available to them at the time of the collapse.

It is also sobering to notice that a graph of our own population growth over the past ten millennia is, if anything, far more pronounced and EVEN MORE EXTREME than that exhibited by either of the climb-and-collapse reindeer data sets depicted above.

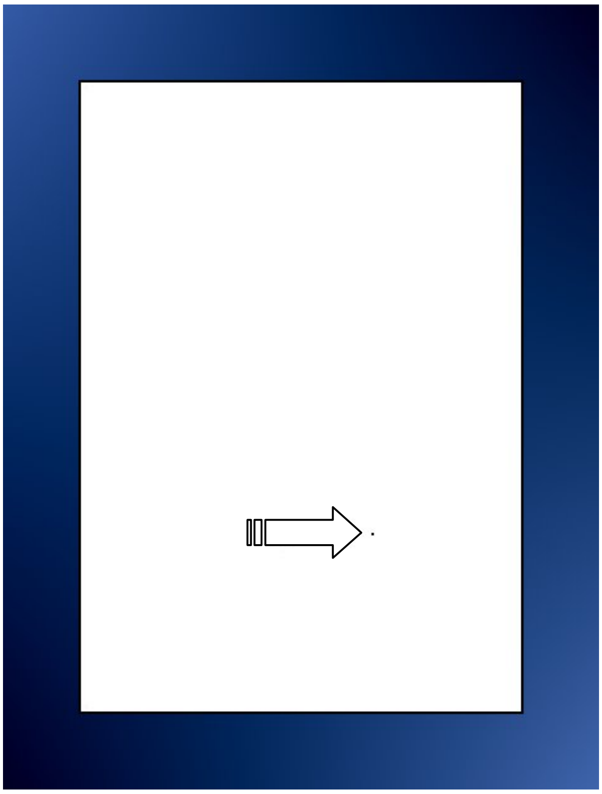


In the marine environment, real-world dinoflagellate populations such as *Karenia brevis* produce red-tides and their associated fish-kills when their populations reach concentrations of 100,000 to 1,000,000 or more *Karenia brevis* cells per liter. Because each cell releases, on an ongoing basis, small amounts of poisonous "brevetoxins," the accumulation of toxins reaches calamitous levels within the aqueous environment in which the population resides.

Thus, *Karenia brevis* and similar red-tide dinoflagellates constitute quintessential examples of population calamities that arise even while “vast amounts of open-space” remain theoretically-available in environments that appear to be ALMOST ENTIRELY EMPTY.

To illustrate this, we have prepared the following illustration.

The dot in this image denotes
two one-thousandths ***of one percent***



while the remaining 99.998 72% of the rectangle
represents an enormous quantity
of unoccupied "empty space"

While the dot in the image denotes just two one-thousandths of one percent, the remaining 99.99872% of the rectangle denotes the enormous quantity of unoccupied and seemingly-plentiful empty space. In the illustration, all one million *K. brevis* cells could physically-occupy the area denoted by dot while the remainder of the one-liter water sample (which equals a volume of 61.024 cubic inches) is proportionately depicted by the remainder of the empty rectangle in the illustration

Thus, in a one liter water sample from a red-tide, the population of *K. brevis* cells residing in that liter *physically occupy less than two one-thousandths of one percent* of the total volume that appears to remain theoretically-available to them. In a proportional way, the small dot in the illustration depicts the area needed to accommodate all one million *K. brevis* cells.

(For an outline of the supporting mathematics, see our attached appendices.)

In other words, despite an apparently enormous amount of open space, and despite the fact that the *Karenia brevis* population occupies a VOLUMETRICALLY-INSIGNIFICANT portion of the area or volume that appears to remain available, they have, by their combined overpopulation and their production of harmful wastes, managed to calamitously-damage the environment in which they reside

(*a set of conditions which would seem to be worth noting since our own species exhibits an extraordinarily similar pattern of behavior*).

Notice then, that in all three of our population growth/population collapse examples (two reindeer herds and dinoflagellate red-tides), real-world population disasters have taken place even when enormous quantities (99.9% plus) of area or volume still remain.

Why should we imagine that our own species is invulnerable?

We have thus seen that volumetrically-insignificant numbers of individual dinoflagellates, surrounded on all sides by "vast amounts of open space," routinely manage to calamitously-alter the aqueous environment in which they live. And specifically, that, in a one-liter sample of water from a red-tide, the dinoflagellate cells themselves occupy a total area equivalent to (or less than) the area that is proportionally represented by the dot shown in our illustration.

This, of course, is not to necessarily suggest a direct applicability of dinoflagellate impacts and trajectories to humanity's own global trajectories and impacts today.

However, it is at least provocative to consider that today our own species, surrounded by a seemingly enormous atmosphere and seemingly "vast amounts of open space" also appears to be well on its way, via an ongoing release of an assortment of industrial and societal wastes, *to a significant alteration of the entire gaseous environment in which we live* (not to mention the catastrophic physical damage that we inflict everywhere else).

Given the current demographic corner into which we seem to have painted ourselves, and with our 7th, 8th, and 9th billions on-track to arrive between now and mid-century, one would hope that we are collectively *smarter* than a mindless population of one-celled dinoflagellates that repeatedly cascade themselves toward calamity even while occupying less than 2/1000ths of 1% of the total volume in which a sampling resides.

Invoking sobriety, however, we may actually be following a trajectory that is provocatively similar to that of the dinoflagellates, because our own species, like the red-tide dinoflagellates of marine habitats, releases chemical wastes and toxins into our surroundings.

Worse still, from at least one point of view, we may actually be on a trajectory **that is considerably worse** *than that of the dinoflagellates*

(**and multiple orders of magnitude worse, at that**)

for dinoflagellate populations release only their metabolic, cellular, and biological_wastes into their surroundings. In our own case, however, we release not only our biological and metabolic wastes, but also a daily avalanche of unprecedented societal and industrial wastes that are being ever-amplified with our growing numbers and increasing industrialization.

In addition, we show elsewhere (see PDF 3 in this series) that the seeming immensity of earth's atmosphere and seas is also an illusion – another widely-held misperception that invites complacency.

Because three-quarters of the earth's surface is covered with lakes, rivers, oceans, seas, and ice, it is both easy and descriptive to picture our home as "a water planet" that could easily be known as "Planet Ocean" (IOF, 1978; Anson, 1991, 1996, 2007). On the other hand, if we consider earth's oceans and atmosphere as strictly surface features of our planet (again, see PDF 3 in this set), an entirely different assessment presents itself.

Recall, for example, that 99.94% of our planet consists of its crust, mantle, and molten interior, and the thin layer of water that we refer to as an ocean exists only as a thin and precarious surface film that is only six one-hundredths of one percent as thick as the earth itself (PDF 3).

To proportionally illustrate this depth to scale on a classroom globe, we would need a thin film of water just twelve one-thousandths of one inch deep to accurately convey the depth of the earth's oceans.

In a similar way, PDF 3 also shows that earth's seemingly-enormous atmosphere qualifies as a thin and precarious surface film which astronauts and cosmonauts have likened to "a single layer of skin on an onion."

No Other Animals Do This

Thus, although our own pollution is in some ways reminiscent of that produced by population explosions of dinoflagellates in a marine environment, there is a disturbing exceptionality to our own pollution because it consists of FAR MORE than our biological and metabolic wastes.

Consider, for example, an ordinary human being living in an industrialized country. One's daily body wastes are again present, of course, but humanity's collective biological wastes are natural products that have little impact on global systems. Next, however, envision this same person in an automobile, backed up in crowded traffic on a busy eight-lane highway, surrounded in every direction by hundreds of cars and trucks and buses, each spewing exhaust from an internal combustion engine.

This illustrates that we are *individually* contributing MUCH MORE than our body wastes to our surroundings. And the pollutants that we emit, of course (about a pound of CO_2 per mile), *are* NOT *rare or occasional wastes*, but are *daily, ongoing* wastes that we generate again and again through-out our lives.

We are the only animals on earth that do this and we repeat this behavior again and again, every day, in Los Angeles, Beijing, Mumbai, Tokyo, Karachi, Jakarta, Marseilles, New York City, Cairo, Rome, and Rio de Janiero, releasing multiple billions of tons of wastes relentlessly into the thin layer of air that makes up earth's atmosphere.

We are the only animals on earth that do this,
and these demands are not yet finished:

We now switch on our heating or air-conditioning systems, run our dishwashers and clothes dryers, operate lawnmowers and weed-trimmers, refrigerators and freezers, our street lights, fluorescent lights, toaster-ovens, microwaves, hair-dryers, steel mills, shopping malls, bowling lanes, televisions, and hot-water heaters.

And we *repeat* these and similar activities EVERY DAY, so that in serving us, our power plants release tons upon tons of additional wastes, *relentlessly and endlessly*, into the onion-skin-thin layer of air that comprises the atmosphere. We are the only animals that do this, or that have ever done this, and to these we have yet to add wastes generated by unwanted catalogue mailings, throw-away containers, and millions of items that have been shipped halfway around the world.

No other animals on earth SUPPLEMENT *their biological and metabolic wastes in this way.*

No other animals on earth have EVER *supplemented their biological and metabolic wastes in this way.*

And even dinoflagellates, in the worst of red tide outbreaks that have ever occurred, have never supplemented their cellular and metabolic wastes in this way. And our exceptionality in this behavior is not an incidental or minimal footnote to our biology – it is a pronounced and all-encompassing characteristic of our civilizations and our species.

How can we imagine that endless billions of us can endlessly behave in this way without calamitous repercussions?

If we intend to enjoy such extravagance,
our populations must be smaller.

Even if world population did not grow at all, these and similar impacts might be expected to double as the world's poorest nations industrialize and seek to emulate our own standard of living. Yet, even though the earth's atmosphere is not responding very well to our current assaults, we nevertheless appear intent upon adding at least our 7th, 8th, and 9th billions to our numbers between now and mid-century.

A provocative perspective recently appeared in HOT, FLAT, AND CROWDED (Friedman, 2008). Author Friedman cites California Institute of Technology chemist Nate Lewis as follows:

"Imagine you are driving your car and every mile you drive you throw a pound of trash out your window. And everyone else on the freeway in their cars and trucks are doing the exact same thing, and people driving Hummers are throwing two bags out at a time – one out the driver-side window and one out the passenger-side window. Well, that is exactly what we are doing; you just can't see it. Only what we are throwing out is a pound of CO_2 – that's what goes into the atmosphere, on average, every mile we drive."

Multiple Orders of Magnitude

To summarize, it is provocative that calamitous red tides like those produced by *Karenia brevis* (which constitute a quintessential example of explosive population growth associated with poisonous wastes) routinely trigger catastrophic consequences in the environment in which they reside.

Today, in a similar way, mankind's release of environmental wastes and toxins characterizes our own population explosion. Unfortunately, however, we are not releasing only our biological, cellular, and metabolic wastes into our surroundings. Instead, we are supplementing our biological wastes, in a way that is UNPRECEDENTED in the history of life on earth, with tons upon tons of societal and industrial wastes so that we may be embarked on a trajectory that is even worse than that of red-tide dinoflagellates -

and multiple orders of magnitude worse, at that.

Thus, the widely-held supposition that the existence of "vast amounts of open space" somehow exempts us from population calamity is nothing more than an illusion – a dangerously-erroneous open-space delusion.

Footnote

In his 2005 best-seller COLLAPSE, Jared Diamond recounts the collapse of the original human population living on Easter Island. And just as it proves provocative to calculate the open-space insights offered by population explosions of red-tide dinoflagellates, it is also interesting to make a similar assessment of the peak numbers of humans living on Easter Island at the onset of the collapse.

Therefore, elsewhere in an appendix to this PDF we analyze Easter Island's total area (open space) at the onset of the collapse of its human population. The mathematics hints that the island's human residents and their environment both underwent collapse even while **99.999 97%** of the island's total area remained unoccupied and "vast amounts of open-space" still remained theoretically-available.

It is interesting to note that the results (2/1000ths of 1%) of the dinoflagellate analysis show such an unexpected similarity to a similar analysis applied to the historical human population living on Easter Island (less than 3/1000ths of 1%).

A major difference, of course, is that *dinoflagellate impacts arise from* **wastes** released into their surroundings, while the impacts of the *human* population on Easter Island (at a pre-industrial stage of development) arose from **physical damage** to their surroundings involving deforestation and over-exploitation of island birds, seabirds, and vegetation.

Today, however, our highly-industrialized populations have: (a) greatly-amplified physical impacts (think of chain saws, logging concessions, asphalt paving, and industrialized fishing fleets, for example), and (b) our impacts are global.

And thirdly, as we have become industrialized, we have now joined (*and enormously surpassed*) dinoflagellate populations as a species that produces and releases wastes into our environment.

Thus, in addition to our greatly-amplified physical damage and an enormous world population that will see us add our 7th, 8th, and 9th billions between now and mid-century, we must now add our unprecedented production of industrial and societal wastes.

Therefore, not only do we release the normal cellular and biological wastes to which natural systems are generally adapted, but *our species alone* supplements its biological wastes with an ongoing, ever-increasing, and unparalleled avalanche of industrial and societal wastes which is:

(a) unique among all animals on earth,

(b) unique among all animal species that have ever lived, and

(c) is multiple orders of magnitude worse than any catastrophic outbreak of dinoflagellate red-tide in the history of the earth.

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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Supporting mathematics

This item outlines the supporting mathematics for this critique of the deeply-erroneous "open-space" hypothesis. Since marine biologists routinely sample one-liter samples of red-tide out-breaks, the following data constitute a starting point for the mathematical portrait which we will derive below: First, severe and deadly red-tide conditions are common when *Karenia brevis* populations reach concentrations ranging between 100,000 to 1,000,000 or more cells per liter. Secondly, a one-liter sample of water equals approximately 61.024 cubic inches. And thirdly, we begin with the approximate dimensions of a typical *K. brevis* cell as set forth immediately below.

Background values:

(1) A volume of 1 liter = 61.024 cubic inches
(2) The approximate dimensions of a single cell of *K. brevis* are:

L: ~30 um (= 0.03 mm) = ~ 0.0012 inches **
W: ~ 0.0014 inches ("a little wider than it is long") *
D: ~ 10 – 15 um deep (10 um = .0004; 15 um = .0006), so average
= ~ .0005 inches

** Nierenberg, personal communication, 2008
* Floridamarine.org, 2008

The above values permit the following calculations:

Volume of a typical cell of *K. brevis* = (L) x (W) x (D) = (.0012) x (.0014) x (.0005) = ~ .000 000 000 840 cubic inches.

Therefore, one million *Karenia brevis* cells occupy approximately (1,000,000) x (.000 000 000 840), or an actual physical volume of approximately 0.000 84 cubic inches.

Since one liter equals 61.024 cubic inches, subtracting 00.000 84 cubic inches occupied leaves (61.024) – (00.000 84) or approximately 61.023 16 cubic inches *still unoccupied.*

In other words, the dinoflagellate cells in this one-liter sample still have approximately 61.023 16 cubic inches of unoccupied volume (or of apparently" empty space") still appearing to remain theoretically-available.

Percentage Unoccupied

The percentage unoccupied therefore equals (61.023 16) divided by (61.024 00) = ~ .999 987 2 or ~ 99.998 72 % *unoccupied volume remaining*.

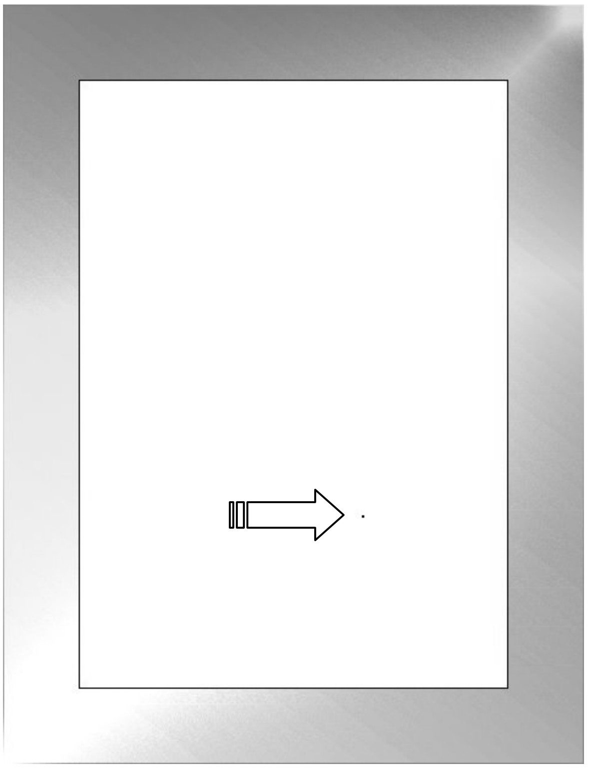
This means that the above *K. brevis* population manages to routinely visit calamity upon itself and the aqueous environment in which it resides, even when the *K. brevis* cells themselves physically-occupy less than two one-thousandths of one percent of the total volume that seems to remain theoretically-available to them.

In other words, (100%) – (99.998 72%) equals .001 28 % , or less than *two one-thousandths* of one percent of the volume that seems to remain theoretically-available.

This demonstrates that, despite an apparently enormous amount of "open space," and despite the fact that the *K. brevis* cells themselves occupy a VOLUMETRICALLY-INSIGNIFICANT portion of the "open-space" that seems to remain available, they have, by their combined over-population and each cell's production of invisible and calamitous wastes, catastrophically-altered and damaged the aqueous surroundings in which they live.

PART TWO

The illustration below depicts the physical amount of space that constitutes *two one-thousandths* of *one percent*. Note that the dot in the image denotes two one-thousandths of one percent of the colorless rectangle.



Preparing the Illustration

Red-tides produced by algal blooms of dinoflagellates such as *Karenia brevis* occur even as the dinoflagellate cells themselves physically occupy **l**ess than 2/1000^{ths} *of* 1% of the total volume of the water sample in which they reside.

(And the above 2/1000th calculation assumes *K. brevis* concentrations of ***one million or more*** cells per liter. Some *K. brevis* red-tides occur at much smaller concentrations of as little as 50,000 to 100,000 cells per liter.)

The step-by-step mathematics outlined below allows one to prepare a two-dimensional illustration like the one shown on the previous page that visually depicts the proportional amount of area occupied by two one-thousandths of one percent.

(1) Use imaging software to open a rectangle 500 pixels tall
by 350 pixels wide = 175,000 square pixels

(2) One percent of this area = (175,000) x (.01) = 1750 square pixels

(3) 1/1000^{ths} of one percent = (1750) x (.001) = 1.750 square pixels

(4) 2/1000^{ths} of one percent = (1750) x (.002) = 3.5 square pixels

(5) Calculate the square root of 3.5 square pixels = 1.87 pixels, so
that a square of (1.87 pixels) x (1.87 pixels) = 3.5 square pixels

Thus given a starting rectangle of 500 x 350 pixels, a small square of 1.87 pixels by 1.87 pixels (length x width) would visually depict a physical region of two one-thousandths of one percent.

This example underscores quite clearly that sheer physical amounts of "open space" available to a population constitute a fallacious criterion by which to judge overpopulation.

It is at least interesting and perhaps worth noting that the original human population of **Easter Island** (see following item) underwent collapse following an estimated peak population of ~15,000. In that case, as the calculations outlined below show, the collapse of that population, its environment, and its society occurred even as the humans themselves physically occupied ***less than*** **3/1000^{ths}** ***of one percent*** of the "open-space" that remained theoretically available to them - a number that is in provocative agreement with the 2/1000ths of one percent that characterizes calamity in an outbreak of dinoflagellate red-tide.

APPENDIX 4 – Open-space remaining at the time of the collapse of Easter Island's original human population

A recent survey of ancient and contemporary societies (Diamond, 2005) whose original ascendancy was followed by collapse includes a chapter devoted to Easter Island with its land area of 66 sq. miles and an estimated peak population (depending on the study surveyed) of between 6,000 and 30,000 people. Taking a mid-range estimate of ~ 15,000, the following mathematics obtains: Assume that each person, while standing, is, on average, approximately two feet width at shoulders and 1.5 feet front to back, so that each individual physically occupies (2) x (1.5) = ~ 3 sq. feet of space.

Thus, 15,000 people x 3 sq. feet each would occupy approximately ~ 45,000 sq. feet.

Since one square mile = 27,878,400 sq. feet, the island's total "empty space" amounts to 66 square miles times 27,878,400 for a total island area of ~ 1,839,974,400 sq. feet.

Since a total of approximately 45,000 sq. feet is physically occupied by the 15,000 residents, 45,000 sq feet divided by 1,839,974,400 sq. feet (the total existing area) equals:
2.44568×10^{-5} = .000 02446
= 2.45 / 1000ths of 1%

(a) 1% of 1,839,974,400 = .01 x 1,839,974,400 = 18,399,744 sq. feet
(b) 1/10th of 1%: .001 x 1,839,974,400 = 1,839,974 sq. feet
(c) 1/100th of 1%: .000 1 x 1,839,974,400 = 183,997 sq. feet
(d) 1/1000th of 1%: .000 01 x 1,839,974,400 = 18,399 sq. feet (e) 3/1000ths of 1%: .000 03 x 1,839,974,400 = 55,199 sq. feet

Thus, at its peak, the human population of Easter Island probably occupied less than 3/1000ths of 1% of the island's available area.

In addition, since 100% minus 3/1000ths of 1% = 99.999 97 %, *the total percentage of unoccupied "open space" at the time of collapse was approximately* 99.999 97 %.

Thus, Easter Island's human population, its environment, and its society *underwent catastrophic collapse* even when 99.999 97 % of the island remained unoccupied. In other words, collapse occurred even as "*vast amounts of open-space*" remained theoretically-available.

In other words, we see still another "natural experiment" that ended in collapse, this time involving a human society confined to an island with limited resources. In addition, the above collapse occurred even as "*vast amounts of open-space*" remained theoretically-available to the island's human occupants.

Footnote 1: Just like Easter Island, our planet itself is, after all, also an island (in space), and though earth is many times larger in size than Easter Island, so is the size of our population.

Footnote 2: The similarity of our situation and that of the peak population of Easter Island is not perfect, however. The humans on Easter Island constituted a *pre-industrial* society that could deforest their environment, kill all of its birds and most of its seabirds, and overexploit its resources.

Unlike us, however, the pre-industrial residents of Easter Island could not generate billions of tons of CO_2 and industrial wastes and plunder resources from all parts of the planet. In addition, they had no industrial wastes, automobile exhausts, oxidized fossil fuels, chlorofluorocarbons, logging concessions, investment portfolios, mercury wastes, and mechanized fishing fleets with which to assault their environment.

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 Consequences
- 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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