

Carrying Capacity:

What Is It? How Have We Misunderstood It? And Why Is It Important?

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The *carrying capacity* concept has become essential for understanding what is now happening to human societies, and consequences to follow later. To begin with, here is a preliminary definition that would be familiar to livestock owners or range managers::

An environment's carrying capacity is the number of organisms of a given species it can support indefinitely.

Elements of the definition explained

The final word, indefinitely, is often neglected -- and even sometimes omitted in textbook definitions. Its neglect or omission lets the fact that an overload *can* be supported (but only temporarily) seem to show the carrying capacity concept is either vague or arbitrary. Duration matters. In time an overload damages an environment, thereby reducing its carrying capacity. Definitions of carrying capacity that neglect the time element are misleading. They distort the concept and obscure its relevance to biological reality.

The phrase "of a given species" recognizes the fact that a sheep or a cow eats more than a rabbit, so an environment of a given size could presumably support a greater number of rabbits and a smaller number of sheep or cattle, before the life-supporting characteristics began to diminish from overuse.

To appreciate the relevance of carrying capacity to human lives and humanity's future, we need to acknowledge some neglected (but obvious) facts.

- (I.) Human beings are organisms.
- (II.) Every organism, whether plant or animal or whatever -- as a bounded bundle of living substance -- is distinct from its surroundings. But life's processes involve interaction of that bounded bundle with those surroundings. *To live*, an organism has to *use* its environment in three ways.
- (1) To maintain its life, any organism must take in substances (and energy) from outside its body.
 - (2) Living bodies, as physical entities, occupy space; their lives depend on having sufficient room for their existence and normal activities.
 - (3) The organism's biochemical processes necessarily transform the substances taken in from the environment. The transformed products of such metabolism differ not only from the original environmental components but some also differ to some extent from the tissues of the organism. Being harmful (toxic) if retained within the organism, these products have to go somewhere. So they are excreted -- returned to an environment (as eventually also the dead remains of the organism will be returned).

In short, any living thing requires an environment *from which* to obtain sustenance materials, including energy, *in which* to exist and do whatever it does, and *into which* to discard stuff. A novel but useful way to express this is to note that organisms inevitably use their surroundings in three kinds of ways: All living beings do some "from-whiching," some "in-whiching," and some "into-whiching."

How and why we cause change in carrying capacity

So, by living, organisms necessarily produce environmental change. As time passes, cumulative from-whiching and into-whiching tend to diminish the abundance of some environmental characteristics and raise some others. *If not offset in some way*, this

environmental change can reduce the suitability of a given environment for supporting a given species of user.

How long can given rates of from-whiching and into-whiching by humans continue without loss of environmental habitability? Natural replacement rates of significant resources, together with rates by which effluents can be neutralized or recycled by nature must be invoked to reckon an answer

The term carrying capacity simply means, therefore, the maximum amount or intensity of a given kind of use, or the maximum use-load, an environment can endure while retaining its future suitability for that use. Clearly, different categories of users of an environment impose different *per capita* loads. Traditionally, the carrying capacity of an environment for a particular category of users has been expressed (by ranchers or range-managers) as a maximum *sustainable* species population of, say, cattle or sheep, caribou or bison, cougars or deer. Not “how many members of species X can be supported” (with no consideration of duration) but “how many . . . can be supported indefinitely? How many cattle continually grazing on a given tract of pastureland could it support without damage from overuse (both as sustenance source and as disposal site)?

Measuring carrying capacity is not easy

But such a head-count measure very poorly expresses load magnitude for *human* uses of an environment, since humans vary culturally quite enormously in their from-whiching, and their into-whiching. All *Homo sapiens* are one species biologically, but cultural differences make us different quasi-species. Drive past a large junkyard or waste dump and be reminded that whereas human into-whiching that once involved disposing of just worn out clothing, broken furniture, and worn out or broken small tools and equipment, it now includes disposing of wrecked or “obsolete” trucks, automobiles, and discarded large machinery, as well as many bottles and boxes. We now also dispose of vast quantities of industrial chemicals, etc. So when Joel Cohen (1995) asked “How many people can the earth support?” in a book that was praised by Harvard’s Edward O. Wilson as “the definitive work on the global population problem,” he could not

conclude with a specific numerical answer. He could not justifiably say 100 million humans, or 1 billion, or 10 billion. His seemingly indecisive exploration of abundant treatments of the topic thus enabled a reviewer with a flagrant political bias (Madar 1996) to be scornful not only of Cohen's book, but of the book by Malthus two centuries before, and of modern Malthusians. The reviewer also expressed disgust for the notion that some parts of the world could be considered "overpopulated," and scorned the carrying capacity concept as well.

Instead of the Cohen book's time-ignoring and therefore misleading title, the question that mattered would have been: "Is the human user-load today below or above Earth's carrying capacity?" Or the real question could have been: "Do we still have a carrying capacity surplus, or are we now facing a carrying capacity deficit -- not a dollar deficit in the government budget, a carrying capacity deficit in a planetary ecosystem?"

For cattle in a pasture, carrying capacity has not been exceeded if the grass can re-grow as fast as the grazing herd consumes it, and sufficient potable water in a nearby stream continues flowing, uncontaminated by deposits of cow-manure. For modern humans, having accepted cultural developments that make us rely on abundantly consuming a number of *non-renewable* resources (that do not grow like grass), it should have begun to dawn on us by now that we have thrown away the criterion of sustainability of supply. We resent and resist any curtailment of our accustomed from-whiching. Having already surpassed seven billion as the number of living humans, our into-whiching has overtaken our abilities to adjust to living in a somewhat fouled nest. Sane minds appraising our situation must infer that we have indeed passed any reasonable measure of Earth's carrying capacity.

We must learn to recognize a carrying capacity deficit

Even a supposedly very adaptable human population lives in an environment that is finite, and its carrying capacity (for a given way of life) is finite, however difficult carrying capacity may be to measure. That is to say, a given environment can supply only limited quantities of the substances needed by a user population. It affords finite space in which their

accustomed interactions can occur. And likewise, its capacity for absorbing (and neutralizing or recycling) the transformed materials that a particular user population must dispose of is limited. Regardless how inadequately measured may be these environmental limits, they are real. And they are what is meant by the phrase “carrying capacity.”

On the resource front it is sometimes recognized that Liebig’s “law of the minimum” applies. That law says the *least* abundant necessary resource is what limits the sustainable load’s magnitude (Liebig 1840). We can express this principle more broadly by saying that ultimately carrying capacity may be limited by whichever of the three broad environmental functions is least adequately met. A shortage of disposal space, or of living space, may be as limiting as scarcity of some vital resource (e.g., food or fuel).

Now consider the predator-prey relationship: one species population -- as a component of the environing ecosystem -- is used as a “resource” by another species population. This relationship applies no less to herbivores, or to people who are vegetarians (for whom plants are their prey) than to carnivores or omnivores. It also applies to autotrophic plants for which abiotic materials -- e.g., soil nutrients, water, etc. -- are their “prey.” Implications of the exploitation of prey species was illuminated by one of the most vital scientific discoveries of all time -- the recognition by Thomas Robert Malthus (1798) of the vast significance of the fact that the human species was capable of reproducing in excess of the level required in usual circumstances for replacement of each mortal generation.

For too long, too many people, upon hearing reference to Malthus, have imagined his theory about population has been refuted. This simply means they have misread him. Here are the two best known sentences from his famous 1798 *Essay on the Principle of Population* (and I emphasize two essential words that are customarily neglected). He wrote:

“Population, *when unchecked*, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio.

Leaving out those two words -- “when unchecked” (which need emphasis) -- turns Malthus’s meaning upside down. That is why people can imagine subsequent history has refuted him. Although his language today seems archaic, he was correctly noting that populations tend when possible to over-reproduce and thus have the potential to grow exponentially. His Essay was not

so much about predicting population growth, or demonstrating the inevitability of famines, but about what in fact held populations back from maximum potential increase. Had checks such as he discerned not been operating, the 950 million human population on the planet in 1798 would have doubled in a quarter century. (European settlers in the New World, essentially not limited at the time and with a fresh continent to exploit, had indeed doubled in a quarter century.) Anyone should be able to do the further arithmetic: another doubling of world population by each subsequent generation would in two centuries have loaded the world by 1998 with about 242 billion people. That didn't happen, and the more or less thriving fraction of that number living today enables people to suppose we can disregard his message. But what prevented doubling of total population each generation from happening was Earth's carrying capacity being not that huge. So even our "explosive" growth from two billion to seven billion within my lifetime was checked enough to validate Malthus's theory about population checks.

However, population numbers alone are inadequate for assessing carrying capacity. A density of population that makes difficult the spatial segregation of the three kinds of use of environment would imply an approach of a carrying capacity deficit. In general, these three uses of environment by any living thing need to be kept apart to avoid mutual interference. But this becomes increasingly problematic when added population density on a finite planet, or within any finite portion of it, interferes with insulating from each other specific parts of the environment devoted exclusively to just one of the three use types.

Further, the proportion of "the" environment devoted to one or another of these three kinds of uses will differ as organisms evolve, either genetically or culturally. So let us focus on today's humans, who have become much different from their ancestors. As *Homo sapiens* made enormous cultural advancement in recent decades, many of us became almost a new species, which I call *Homo colossus*. We made ourselves more and more dependent upon obtaining from somewhere on our planetary environment "sustenance" materials *to feed our machinery* as well as to feed our flesh-and-blood bodies. Once we had turned an evolutionary corner by beginning to use fossil fuels, various mineral ores, and other non-renewable resources, our per capita resource appetites and our per capita environmental impacts grew more and more gigantic. Both our "from-whiching" and our "into-whiching" escalated hugely, even as the

number of us was also growing. A trend of escalating withdrawals of resources from environments entailed a comparably burgeoning need for environments into which we could dispose of enormously increased amounts of “waste,” some of it with unprecedented toxicity. In fact, Earth’s atmosphere and oceans have been used as global sinks for some of the end-products of modern human life. The fact that rising CO₂ levels in the planet’s atmosphere have begun inducing serious climate change should be recognized as a major indicator of the human load having exceeded carrying capacity. The present human user load is damaging the environment on which our lives depend.

Two human quasi-species

As a vital aid to understanding where we stand and what is happening around us, it helps to regard today’s human population as comprising what seems tantamount to a pair of distinct species. I will call them two *quasi-species*. First, there are ordinary humans, designated *Homo sapiens*. Humans are a species whose lives are shaped and can change not just as genes evolve but as culture evolves. For a substantial portion of humanity non-genetic changes have greatly altered our ecological relationship to other life and to non-living components of the environment. All humans differ from non-human animals by the fact that a portion of the energy involved in human ways of living comes from controlled use of fire -- burning fuels outside our bodies, in addition to the energy released by metabolic processes within human bodies. No other species controls and uses fire as we do. Fire use is thus a part of what we mean when we speak of “human nature.” At first energy from humanly controlled burning of fuels served only to warm us or cook our food. But when people learned to make machines that could take the heat energy from burning fuels and turn it into mechanical energy to turn wheels and accomplish many new types of task, this breakthrough enabled people so-equipped to do many more things, accomplish larger goals, and become ecologically a different kind of creature. So I call this modern quasi-species *Homo colossus*. We have committed ourselves by our technological achievements to from-whiching on an enormously more ravenous scale, taking greater amounts and a larger variety of resources from the environment -- and we rely on continuing to be able to do so. Of

course this increased from-whiching had to result in comparably more extensive into-whiching, so by both our withdrawals from and our additions to the world around us, we significantly change environments upon whose pre-existing characteristics our lives depend.

From foraging to farming -- and back to foraging

Let us consider finally some fundamental implications of important “revolutions” in human history. Our ancestors in the last 10,000 years or so became farmers by learning (in what we know as the horticultural revolution) to live by managing local ecosystems to ensure reasonably steady supplies of food and fiber resources. This revolution was seen as a big step forward; *their* ancestors had been hunter-gatherers. Human life for those earlier tribes had depended on *foraging* for sustenance materials drawn from an environment in which the location and availability of useful stuff was due to processes of nature *not* under human control.

We have paid far too little attention to the essential character of the shift that was involved when former foragers advanced to farming, though we called it a “revolution” to reflect recognition that it was a truly transformative (and we assumed, beneficial) change. But not fully understanding just *how or why* the origin of farming had worked for human benefit, we then totally missed recognizing that the supposed further advance from ordinary *Homo sapiens* status to the mechanized *Homo colossus* way of life (the Industrial Revolution we called it) amounted to a retrograde development -- *reversion to foraging*, now on a gigantic scale, for initially abundant stocks of *resources that do not re-grow*. Formed and put in place by geological (not biological) processes, these resources, as they are depleted do not replenish themselves, at least not on a humanly meaningful time scale.

As long as we mistook as the equivalent of re-growth each mere discovery of a previously long-existing but not yet humanly known deposit somewhere of the ore or the fuel we had come to need, we based the continuing livelihood of our new quasi-species on a vast Ponzi scheme. Ponzi -- and after him men like Bernie Madoff -- deluded, stole from, and ruined investors by paying falsely labeled “profits” to earlier investors, using revenue not obtained from any productive industrial activity they were ostensibly financing but from later rounds of

investments by new contributor-victims (Henriques 2011). We let it become customary to annex to the known resource base newly discovered but not newly formed “increments” of life-supporting substances. They were just as exhaustible as what we were already using up. Extraction was misnamed “production.” Depletion was made to seem harmless because discovery was mistaken for renewal. These misconceptions were passed off as respectable economic thoughtways enabling maintenance of carrying capacity. When P. T. Barnum asserted that “There’s a sucker born every minute” he was grossly understating reality. Not just a few abnormally gullible people but most members of today’s quasi-species *Homo colossus* (living in “developed” nations) have unwittingly inverted the reality of our difference from less-privileged *Homo sapiens*. Because we basked in abundance and could have and do many things our ancestors could scarcely dream of having and doing, we naively fancied ourselves superior to or more advanced than the earlier or less-privileged, ordinary *Homo sapiens* (people living in “underdeveloped” -- or more euphemistically, in “developing”) nations.

Too late. As we have begun to recognize the nature of carrying capacity and how it must depend on *real* resupply processes, we are beginning to discover which quasi-species is condemned to endure the consequences of flagrantly excessive from-whiching and into-whiching. As such knowledge soaks in, we are discovering that, if we measure carrying capacity in head-count terms -- how many human users can the world durably support -- the long-term is going to include many fewer generations of *Homo colossus* than *Homo sapiens*.

We have already greatly exceeded our planet’s human carrying capacity.

Of hubris and unanticipated repercussions

This has occurred as the natural result of too many of us doing too much, using too much, expecting too much -- usually in accord with generally accepted standards of normal behavior and respectable thoughtways, by decent, law-abiding *Homo colossus* who have imagined ourselves to be just “normal human beings.” Most of us could not realistically be accused of intending or desiring to bring about a carrying capacity deficit, but it came about by our collective “innocent” being and acting. The intensified misery and competition for dwindling

supplies the carrying capacity deficit will entail is likely to encourage a kind of paranoid imputation of culpability. “Others” will be villified and blamed; overt conflict on various scales will be likely, contributing to a period of population reduction, unplanned, merciless, deplored, self-reinforcing. Societies will fall into disarray. Historians will discover clues that “should have been recognized” but were not. Only ecologists, some of them, will truly understand the rise and decline of human carrying capacity and the rise to dominance and fall therefrom by *Homo colossus*.

Source cited:

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