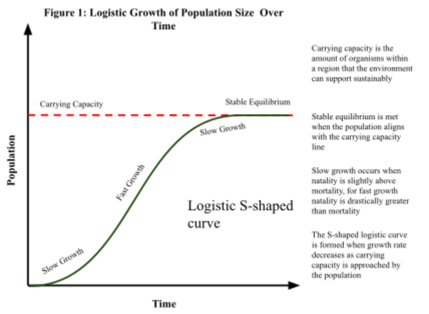
WIKIPEDIA

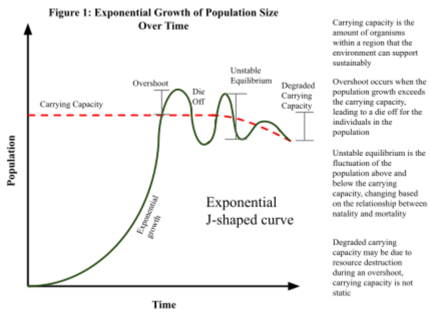
Carrying capacity

The **carrying capacity** of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water, and other necessities available in the environment. In population biology, carrying capacity is defined as the environment's maximal load,[1] which is different from the concept of population equilibrium. Its effect on population dynamics may be approximated in a logistic model, although this simplification ignores the possibility of overshoot which real systems may exhibit.

Carrying capacity was originally used to determine the number of animals that could graze on a segment of land without destroying it. Later, the idea was expanded to more complex populations, like humans.[2] For the human population, more complex variables such as sanitation and medical care are sometimes considered as part of the necessary establishment. As population density increases, birth rate often increases and death rate typically decreases. The difference between the birth rate and the death rate is the "natural increase". The carrying capacity could support a positive natural increase or could require a negative natural increase. Thus, the carrying capacity is the number of individuals an environment can support without significant negative impacts to the given organism and its environment. Below carrying capacity, populations typically increase, while above, they typically decrease. A factor that keeps population size at equilibrium is known as a regulating factor. Population size decreases above carrying capacity due to a range of factors depending on the species concerned, but can include insufficient space, food supply, or sunlight. The carrying capacity of an environment may vary for different species and may change over time due to a variety of factors including: food availability, water supply, environmental conditions and living space. The origins of the term "carrying capacity" are uncertain, with researchers variously stating that it was used "in the context of international shipping"[3] or that it was first used during 19th-century laboratory experiments with micro-organisms.[4] A recent review finds the first use of the term in an 1845 report by the US Secretary of State to the US Senate.[3]



Reaching carrying capacity through a logistic growth curve



Reaching carrying capacity through exponential growth, followed by die off and carrying capacity degradation

Contents

Humans

Several estimates of the carrying capacity have been made with a wide range of population numbers. A 2001 UN report said that two-thirds of the estimates fall in the range of 4 billion to 16 billion with unspecified standard errors, with a median of about 10 billion.[5] More recent estimates are much lower, particularly if non-renewable resource depletion and increased consumption are considered.[6][7] Changes in habitat quality or human behavior at any time might increase or reduce carrying capacity. Research conducted by the Australian National University and Stockholm Resilience Centre mentioned that there is a risk for the planet to cross the planetary thresholds and reach “Hothouse Earth” conditions.[8]. In this case, the Earth would see its carrying capacity severely reduced.[9]

In the view of Paul and Anne Ehrlich, "for earth as a whole (including those parts of it we call Australia and the United States), human beings are far above carrying capacity today."[10]

The application of the concept of carrying capacity for the human population has been criticized for not successfully capturing the multi-layered processes between humans and the environment, which have a nature of fluidity and non-equilibrium.[11]

Supporters of the concept argue that the idea of a limited carrying capacity is just as valid applied to humans as when applied to any other species. Animal population size, living standards, and resource depletion vary, but the concept of carrying capacity still applies. The number of people is not the only factor in the carrying capacity of Earth. Waste and over-consumption, especially by wealthy and near-wealthy people and nations, are also putting significant strain on the environment together with human overpopulation. Population and consumption together appear to be at the core of many human problems.[12][10] Some of these issues have been studied by computer simulation models such as World3. When scientists talk of global change today, they are usually referring to human-caused changes in the environment of sufficient magnitude eventually to *reduce* the carrying capacity of much of Earth (as opposed to local or regional areas) to support organisms, especially *Homo sapiens*.[13]

Factors that govern carrying capacity

Some aspects of a system's carrying capacity may involve matters such as available supplies of food, water, raw materials, and/or other similar resources. In addition, there are other factors that govern carrying capacity which may be less instinctive or less intuitive in nature, such as ever-increasing and/or ever-accumulating levels of wastes, damage, and/or eradication of essential components of any complex functioning system. Eradication of, for example, large or critical portions of any complex system (envision a space vehicle, for instance, or an airplane, or an automobile, or computer code, or the body components of a living vertebrate) can interrupt essential processes and dynamics in ways that induce systems failures or unexpected collapse. (As an example of these latter factors, the "carrying capacity" of a complex system such an airplane is more than a matter of available food, or water, or available seating, but also reflects total weight carried and presumes that its passengers do not damage, destroy, or eradicate parts, doors, windows, wings, engine parts, fuel, and oil, and so forth.) Thus, on a global scale, food and similar resources may affect planetary carrying capacity to some extent so long as Earth's human passengers do not dismantle, eradicate, or otherwise destroy critical biospheric life-support capacities for essential processes of self-maintenance, self-perpetuation, and self-repair.

Thus, carrying capacity interpretations that focus solely on resource limitations alone (such as food) may neglect wider functional factors. If the humans neither gain nor lose weight in the long-term, the calculation is fairly accurate. If the quantity of food is invariably equal to the "Y" amount, carrying capacity has been reached. Humans, with the need to enhance their reproductive success (see Richard

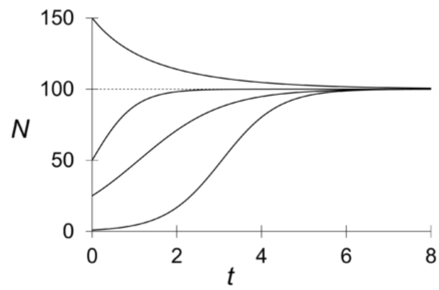
Dawkins' *The Selfish Gene*), understand that food supply can vary and also that other factors in the environment can alter humans' need for food. A house, for example, might mean that one does not need to eat as much to stay warm as one otherwise would. Over time, monetary transactions have replaced barter and local production, and consequently modified local human carrying capacity. However, purchases also impact regions thousands of miles away. For example, carbon dioxide from an automobile travels to the upper atmosphere. This led Paul R. Ehrlich to develop the I = PAT equation.[14]

$$I = P \cdot A \cdot T$$

where:

I is the impact on the environment resulting from consumption
P is the population number
A is the consumption per capita (affluence)
T is the technology factor

An important model related to carrying capacity (K), is the logistic, growth curve. The logistic growth curve depicts a more realistic version of how population growth rate, available resources, and the carrying capacity are inter-connected. As illustrated in the logistic growth curve model, when the population size is small and there are many resources available, population over-time increases and so does the growth rate. However, as population size nears the carrying capacity and resources become limited, the growth rate decreases and population starts to level out at K. This model is based on the assumption that carrying capacity does not change. One thing to keep in mind, however, is that carrying capacity of a population can increase or decrease and there are various factors that affect it. For instance, an increase in the population growth can lead to over-exploitation of necessary natural resources and therefore decrease the overall carrying capacity of that environment.[15]



This is a graph of the population due to the logistic curve model. When the population is above the carrying capacity it decreases, and when it is below the carrying capacity it increases.

Technology can play a role in the dynamics of carrying capacity and while this can sometimes be positive,[16] in other cases its influence can be problematic. For example, it has been suggested that in the past that the Neolithic revolution increased the carrying capacity of the world relative to humans through the invention of agriculture. In a similar way, viewed from the perspective of foods, the use of fossil fuels has been alleged to artificially increase the carrying capacity of the world by the use of stored sunlight, even though that food production does not guarantee the capacity of the Earth's climatic and biospheric life-support systems to withstand the damage and wastes arising from such fossil fuels. However, such interpretations presume the continued and uninterrupted functioning of all other critical components of the global system. It has also been suggested that other technological advances that have increased the carrying capacity of the world relative to humans are: polders, fertilizer, composting, greenhouses, land reclamation, and fish farming. In an adverse way, however, many technologies enable economic entities and individual humans to inflict far more damage and eradication, far more quickly and efficiently on a wider-scale than ever. Examples include machine guns, chainsaws, earth-movers, and the capacity of industrialized fishing fleets to capture and harvest targeted fish species faster than the fish themselves can reproduce are examples of such problematic outcomes of technology.

Agricultural capability on Earth expanded in the last quarter of the 20th century. But now there are many projections of a continuation of the decline in world agricultural capability (and hence carrying capacity) which began in the 1990s. Most conspicuously, China's food production is forecast to decline by 37% by the last half of the 21st century, placing a strain on the entire carrying capacity of the world, as China's population could expand to about 1.5 billion people by the year 2050.[17] This reduction in

China's agricultural capability (as in other world regions) is largely due to the world water crisis and especially due to mining groundwater beyond sustainable yield, which has been happening in China since the mid-20th century.[18]

Lester Brown of the Earth Policy Institute, has said, based on ecological footprint accounting discussed below: "It would take 1.5 Earths to sustain our present level of consumption. Environmentally, the world is in an overshoot mode."[19]

Ecological footprint

One way to estimate human demand compared to ecosystem's carrying capacity is "ecological footprint" accounting. Rather than speculating about future possibilities and limitations imposed by carrying capacity constraints, Ecological Footprint accounting provides empirical, non-speculative assessments of the past. It compares historic regeneration rates, biocapacity, against historical human demand, ecological footprint, in the same year.[20][21] Most recent results from Global Footprint Network's data platform (http://data.footprintnetwork.org) show that humanity's footprint exceeded the planet's biological capacity in 2016 by over 70% (a 2002 publication reported overshoot for 1999 at >20%[20]). However, this measurement does not take into account the depletion of the actual fossil fuels, "which would result in a carbon Footprint many hundreds of times higher than the current calculation."[22]

There is also concern of the ability of countries around the globe to decrease and maintain their ecological footprints. Holden and Linnerud, scholars working to provide a better framework that adequately judge sustainability development and maintenance in policy making, have generated a diagram that measures the global position of different countries around the world, which shows a linear relation between GDP PPP and ecological footprint in 2007. According to the Figure 1 diagram, the United States had the largest ecological footprint per capita along with Norway, Sweden, and Austria, in comparison to Cuba, Bangladesh, and Korea. [23]

See also

- Tourism carrying capacity
- Arable land
- Ecological economics
- Effects of global warming
- Environmental space
- List of countries by fertility rate
- Inflection point
- Optimum population
- Overpopulation in wild animals
- Overshoot (ecology)
- Population
- Population ecology
- Population growth
- Principles of Intelligent Urbanism
- r/K selection theory
- Simon–Ehrlich wager
- Thomas Malthus
- Toxic capacity
- Aftermath (2010 TV series)#Population Overload

Footnotes

1. Hui, C (2006). "Carrying capacity, population equilibrium, and environment's maximal load". *Ecological Modelling*. **192** (1–2): 317–320. doi:10.1016/j.ecolmodel.2005.07.001 (https://doi.org/10.1016%2Fj.ecolmodel.2005.07.001).
2. "Carrying Capacity" (http://www.sustainablescale.org/ConceptualFramework/UnderstandingScale/MeasuringScale/CarryingCapacity.aspx). *The Sustainable Scale Project*. Retrieved 16 February 2017.
3. Sayre, N. F. (2008). "The Genesis, History, and Limits of Carrying Capacity". *Annals of the Association of American Geographers*. **98**: 120–134. doi:10.1080/00045600701734356 (https://doi.org/10.1080%2F00045600701734356).

4. Zimmerer, Karl S. (1994). "Human Geography and the "New Ecology": The Prospect and Promise of Integration" (http://dusk.geo.orst.edu/prosem/PDFs/human_geog.pdf) (PDF). *Annals of the Association of American Geographers*. **84**: 108–125. doi:10.1111/j.1467-8306.1994.tb01731.x (https://doi.org/10.1111%2Fj.1467-8306.1994.tb01731.x).
5. "UN World Population Report 2001" (https://www.un.org/esa/population/publications/wpm/wpm2001.pdf) (PDF). p. 31. Retrieved 16 December 2008.
6. Ryerson, W. F. (2010), "Population, The Multiplier of Everything Else", in McKibben, D (ed.), *The Post Carbon Reader: Managing the 21st Century Sustainability Crisis*, Watershed Media, ISBN 978-0-9709500-6-2
7. Brown, L. R. (2011). *World on the Edge*. Earth Policy Institute. Norton. ISBN 978-0-393-08029-2.
8. Steffen, Will; Rockström, Johan; Richardson, Katherine; Lenton, Timothy M.; Folke, Carl; Liverman, Diana; Summerhayes, Colin P.; Barnosky, Anthony D.; Cornell, Sarah E.; Crucifix, Michel; Donges, Jonathan F.; Fetzer, Ingo; Lade, Steven J.; Scheffer, Marten; Winkelmann, Ricarda; Schellnhuber, Hans Joachim (August 14, 2018). "Trajectories of the Earth System in the Anthropocene" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6099852). *Proceedings of the National Academy of Sciences*. **115** (33): 8252–8259. doi:10.1073/pnas.1810141115 (https://doi.org/10.1073%2Fpnas.1810141115). PMC 6099852 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6099852). PMID 30082409 (https://pubmed.ncbi.nlm.nih.gov/30082409).
9. "Planet at risk of heading towards irreversible "Hothouse Earth" state — PIK Research Portal" (https://www.pik-potsdam.de/news/press-releases/planet-at-risk-of-heading-towards-irreversible-201chothouse-earth201d-state). *www.pik-potsdam.de*.
10. Ehrlich, Paul R; Ehrlich, Anne H (2004), *One with Nineveh: Politics, Consumption, and the Human Future*, Island Press/Shearwater Books, pp. 137, 182, see also pages 76–236
11. Cliggett, Lisa (2001). "Carrying Capacity's New Guise: Folk Models for Public Debate and Longitudinal Study of Environmental Change". *Africa Today*. **48**: 3–19. doi:10.1353/at.2001.0003 (https://doi.org/10.1353%2Fat.2001.0003).
12. Fred Pearce (2009-04-13). "Consumption Dwarfs Population as Main Environmental Threat" (http://e360.yale.edu/feature/consumption_dwarfs_population_as_main_environmental_threat/2140/). Yale University. Retrieved 2012-11-12.
13. Ehrlich, Paul R; Ehrlich, Anne H (2008), *The Dominant Animal: Human Evolution and the Environment*, Island Press/Shearwater Books, pp. 235, see also pages 234–309
14. Ehrlich, Paul R.; Holdren, John P. (1971). "Impact of Population Growth". *Science*. **171** (3977): 1212–1217. Bibcode:1971Sci...171.1212E (https://ui.adsabs.harvard.edu/abs/1971Sci...171.1212E). doi:10.1126/science.171.3977.1212 (https://doi.org/10.1126%2Fscience.171.3977.1212). PMID 5545198 (https://pubmed.ncbi.nlm.nih.gov/5545198).
15. Swafford, Angela Lynn. "Logistic Population Growth: Equation, Definition & Graph." Study.com. N.p., 30 May 2015. Web. 21 May 2016. "Logistic Population Growth - Boundless Open Textbook." Boundless. N.p., n.d. Web. 21 May 2016.
16. Martire, Salvatore; Castellani, Valentina; Sala, Serenella (2015). "Carrying capacity assessment of forest resources: Enhancing environmental sustainability in energy production at local scale". *Resources, Conservation and Recycling*. **94**: 11–20. doi:10.1016/j.resconrec.2014.11.002 (https://doi.org/10.1016%2Fj.resconrec.2014.11.002).
17. Economy, E., *China vs. Earth*, The Nation, May 7, 2007 issue
18. Nielsen, R., *The Little Green Handbook*, Picador, (2006) ISBN 978-0-312-42581-4
19. Brown, L. R. (2011). *World on the Edge*. Earth Policy Institute. Norton. p. 7. ISBN 978-0-393-08029-2.
20. Wackernagel, M.; Schulz, N.B.; et al. (2002). " "Tracking the ecological overshoot of the human economy" (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC123129). *Proc. Natl. Acad. Sci. USA*. **99** (14): 9266–9271. Bibcode:2002PNAS...99.9266W (https://ui.adsabs.harvard.edu/abs/2002PNAS...99.9266W). doi:10.1073/pnas.142033699 (https://doi.org/10.1073%2Fpnas.142033699). PMC 123129 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC123129). PMID 12089326 (https://pubmed.ncbi.nlm.nih.gov/12089326).

21. Rees, W.E. and Wackernagel, M., *Ecological Footprints and Appropriated Carrying Capacity: Measuring the Natural Capital Requirements of the Human Economy*, Jansson, A., Folke, C., Hammer, M. and Costanza R. (ed.), Island Press, (1994)
22. "FAQ - Global Footprint Network" (http://www.footprintnetwork.org/en/index.php/GFN/page/frequently_asked_technical_questions/). *footprintnetwork.org*. Retrieved 28 March 2018.
23. Holden, Erling; Linnerud, Kristin (May 2007). "The sustainable development area: satisfying basic needs and safeguarding ecological sustainability". *Sustainable Development*. **15** (3): 174–187. doi:10.1002/sd.313 (https://doi.org/10.1002%2Fsd.313).

References

- Gausset Q., M. Whyte and T. Birch-Thomsen (eds.) (2005). *Beyond territory and scarcity: Exploring conflicts over natural resource management.* Uppsala: Nordic Africa Institute ISBN 9171065407
- Tiffen, M; Mortimore, M; Gichuki, F. (1994). *More people, less erosion: Environmental recovery in Kenya*. London: Longman.
- Shelby, Bo and Thomas A. Heberlein (1986). *Carrying capacity in recreation settings*. Corvallis, OR: Oregon State University Press.
- Karl S. Zimmerer (1994). ”Human geography and the ’new ecology’: the prospect and promise of integration”. *Annals of the Association of American Geographers* **84**, p. xxx
- Martire, S.; Castellani, V.; Sala, S. (2015). "Carrying capacity assessment of forest resources: Enhancing environmental sustainability in energy production at local scale". *Resources, Conservation and Recycling*. **94**: 11–20. doi:10.1016/j.resconrec.2014.11.002 (https://doi.org/10.1016%2Fj.resconrec.2014.11.002).

External links

- Jared Diamond, Easter Island's End (http://www.hartford-hwp.com/archives/24/042.html)
- AAAS Atlas of Population and Environment (https://web.archive.org/web/20110928172852/http://atlas.aaas.org/index.php?part=1&sec=trends)

Retrieved from "https://en.wikipedia.org/w/index.php?title=Carrying_capacity&oldid=946340743"

This page was last edited on 19 March 2020, at 15:37 (UTC).