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Human Carrying Capacity: An Overview

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His latest book *How Many People Can the Earth Support?* (W. W. Norton, 1 995), from which the following selection is taken, has been called an "admirable tour de force on human population" by the distinguished paleontologist and curator of the American Museum of Natural History, Niles Eldredge. On the controversial question referred to in the book's title, Cohen takes the middle ground between the position of deep ecologists, such as David Foreman, who assert that the earth's population has already far exceeded its sustainable limit and optimistic economists who echo Julian Simon's view that the larger the population, the better. Cohen's readers will not find a definitive response to the dispute about the earth's carrying capacity, but they should become convinced that it is a highly complex and subjective issue. Cohen maintains that any analysis that results in definitive answers to questions about the relationships among population, resources, and the environment should be assessed with a highly critical eye. One must be careful when contemplating value-laden assumptions. Nevertheless, Cohen warns against passivity in the face of irrefutable evidence that uncontrolled population growth and environmentally inappropriate technological developments pose serious threats to the future of human civilization.

Key Concept: the earth's carrying capacity as a complex but vital issue

'J'he question of how many people the world can support is unanswerable in a finite sense. What do we want?
Are there global limits, absolute limits beyond which we cannot go without catastrophe or overwhelming costs? There are, most certainly.

—George Woodwell 1985

CASE STUDY: EASTER ISLAND

The constraints on the Earth's human carrying capacity are just as real as the wide range of choices within those boundaries. The history of Easter Island provides a case study of human choices and natural constraints in a small world. While exotic in location and culture, Easter Island is of general interest as one example of the many civilizations that undercut their own ecological foundations.

The island is one of the most isolated bits of land on the Earth. The inhabited land nearest to Easter Island is Pitcairn Island, 2,250 kilometers northwest; the nearest continental place, Concepción, Chile, is 3,747 kilometers southeast. The island is roughly triangular in plan, with sides of 16, 18 and 22 kilometers and an area of 166.2 square kilometers (a bit larger than Staten Island, a borough of the city of New York). About 2.5 million years old, the volcanic island rose from the sea floor 2,000 meters below sea level. A plateau occupies the middle of the island and a peak rises nearly 1,000 meters above sea level.

Radiocarbon dating suggests that people, almost certainly Polynesians, occupied the island by A.D. 690 at the latest; scattered earlier radiocarbon dates from the fourth and fifth centuries are uncertain. The first arrivals found an island covered by a rainforest of huge palms. The islanders were probably isolated from outside human contact until the island was spotted by Dutch sailors in 1722.

During this millennium or millennium and a half of isolation, a fantastic civilization arose. Its most striking material remains are 800 to 1,000 giant statues, or *moai,* two to ten meters high, carved in volcanic tuff and scattered over the island. Many are probably still buried by rubble and soil. The largest currently known is 20 meters (65 feet) long and weighs about 270 tonnes. It was left unfinished.

According to pollen cores recently taken from volcanic craters on the island, a tree used for rope was originally dominant on the island. At different times, depending on the site, between the eighth and the tenth centuries, forest pollen began to decline. Forest pollen reached its lowest level around A.D. 1400, suggesting that the last forests were destroyed by then. The deforestation coincided with soil erosion, visible in soil profiles. The Polynesian rat introduced for food by the original settlers consumed the seeds of forest trees, preventing regeneration. Freshwater supplies on the island diminished. In the 1400s or 1500s, large, stemmed obsidian flakes used as daggers and spearheads appeared for the first time; previously obsidian had been used only for tools.

While early visitors in 1722 and 1770 do not mention fallen *moaz,* Captain Cook in 1774 reported that many statues had fallen next to their platforms and that the statues were not being maintained. Something drastic, probably some variant of intergroup warfare, probably happened between 1722, when the Dutch thought the statue cult was still alive, and 1774, when Cook thought it finished. A visitor in 1786 observed that the island no longer had a chief.

The population history of the island is full of uncertainties. The prehistory is based on the dating of sites of agricultural and human occupation. The best current estimate is that the population began with a boatload of settlers in the first half millennium after Christ, perhaps around A.D. 400. The population remained low until about AD. 1100. Growth then accelerated and the population doubled every century until around 1400. Slower growth continued until at most 6,000 to 8,000 people occupied the island around 1600. The maximum population may have reached 10,000 people in A.D. 1680. A decline then set in. Jean François de Galaup, Comte de La Pérouse, who visited the island in 1786, estimated a population of 2,000, and this estimate is now accepted as roughly correct. Smallpox swept the island in the l860s, introduced by returning survivors among the islanders who had been enslaved and taken to Peru. The population numbered 111 by 1877. In 1888, the island was attached to Chile. Since then, Chileans have added to the population. The present population of 2,100 includes 800 children.

The plausibility of these numbers can be checked from the annual rates of population growth or decline that they imply. An increase from 50 people in A.D. 400 to 10,000 people in A.D. 1680 requires an annual increase of 0.41 percent. If the number of original settlers were 100 instead of 50, the implied population growth rate would be 0.36 percent; if 25 instead of 50, 0.47 percent. The long-term growth rate of around 0.4 percent per year is within the historical experience of developing countries before the post—World War II public health evolution. If the population declined from 10,000 in 1680 to 111 in 1877 (including removals by Peruvian slave traders), the annual rate of decline was 2.3 percent. If the population maximum in 1680 was only 6,000 instead of 10,000, then the annual rate of decline was 2.0 percent. A population decline from 10,000 in 1680 to the 2,000 reported by La Pérouse in 1786 requires an annual decline of 1.5 percent. In round numbers, Easter

Island's human population seems to have increased by about 0.4 percent per year for about 13 centuries, then to have declined by about 2 percent per year for about two centuries before resuming a rise in the twentieth century

Paul Bahn, a British archeologist and writer, and John Flenley, an ecologist and geographer in New Zealand, synthesized the archeological and historical data in an interpretive model.

> "Forest clearance for the growing of crops would have led to population increase, but also to soil erosion and decline of soil fertility. Progressively more land would have had to be cleared. Trees and shrubs would also be cut down for canoe building, firewood, house construction, and for the timbers and ropes needed in the movement and erection of statues. Palm fruits would be eaten, thus reducing regeneration of the palm. Rats, introduced for food, could have fed on the palm fruits, multiplied rapidly and completely prevented palm regeneration. The over-exploitation of prolific sea bird resources would have eliminated these from all but the offshore islets. Rats could have helped in this process by eating eggs. The abundant food provided by fishing, sea birds and rats would have encouraged rapid initial human population growth. Unrestrained human population increase would later put pressure on availability of land, leading to disputes and eventually warfare. Non-availability of timber and rope would make it pointless to carve further statues. A disillusionment with the efficacy of the statue religion in providing the wants of the people could lead to the abandonment of this cult. Inadequate canoes would restrict fishing to inshore waters, leading to further decline in protein supplies. The result could have been general famine, warfare and the collapse of the whole economy, leading to a marked population decline. Of course, most of this is hypothesis. Nevertheless, there is evidence, as we have seen, that many features of this model did in fact occur. There certainly was deforestation, famine, warfare, collapse of civilization and population decline".

Supposing you accept this summary of the island's history, would you accept the following conclusion of Bahn and Flenley? "We consider that Easter Island was a microcosm which provides a model for the whole planet." Easter Island shares important features with the whole planet and differs in others. Draw your own conclusion.

LIVING IN THE LAND OF LOST ILLUSIONS: HUMAN CARRYING CAPACITY AS AN INDICATOR

A number or range of numbers, presented as a constraint independent of human choices, is an inadequate answer to the question "How many people can the Earth support?" While trying to answer this question, I learned to question the question.

If an absolute numerical upper limit to human numbers on the Earth exists, it lies beyond the bounds that human beings would willingly tolerate. Human physical requirements for bare minimal subsistence are very modest, closer to the level of Auschwitz than to the modest comforts of the Arctic Inuit or the Kalahari bushmen. For most people of the world, expectations of well-being have risen so far beyond subsistence that human choices will prevent human numbers from coming anywhere near absolute upper limits. If human choices somehow failed to prevent population size from approaching absolute upper limits, then gradually worsening conditions for human and other life on the Earth would first prompt and eventually enforce human choices to stop such an approach. As different people have different expectations of well-being, some people would be moved to change their behavior sooner than others. Social scientists focus on the choices and minimize the constraints; natural scientists do the reverse. In reality, neither choices nor constraints can be neglected.

An ideal tool for estimating how many people the Earth can support would be a model, simple enough to be intelligible, complicated enough to be potentially realistic and empirically tested enough to be credible. The model would require users to specify choices concerning technology, domestic and international political institutions, domestic and international economic arrangements (including recycling), domestic and international demographic arrangements, physical, chemical and biological environments, fashions, tastes, moral values, a desired typical level of material well-being and a distribution of well-being among individuals and areas. Users would specify how much they wanted each characteristic to vary as time passes and what risk they would tolerate that each characteristic might go out of the desired range of variability Users would state how long they wanted their choices to remain in effect. They would specify the state of the world they wished to leave at the end of the specified period. The model would first check all these choices for internal consistency, detect any contradictions and ask users to resolve them or to specify a balance among contradictory choices. The model would then attempt to reconcile the choices with the constraints imposed by food, water, energy, land, soil, space, diseases, waste disposal, nonfuel minerals, forests, biological diversity, biologically accessible nitrogen, phosphorus, climatic change and other natural constraints. The model would generate a complete set of possibilities, including human population sizes, consistent with the choices and the constraints.

The speed registered on the speedometer of a car, the current total fertility rate of a population and the gross national or domestic product of an economy are, every one, indirect arid incomplete summaries of more complicated realities: they are summary indicators, approximate but useful. Likewise, estimates of the human carrying capacity of the Earth are indicators. They indicate the population that can be supported under various assumptions about the present or future. Estimates of the Earth's human carrying capacity are conditional on current choices and on natural constraints, all of which may change as time passes. This view of estimates of human carrying capacity as conditional and changing differs sharply from a common view that there is one right number (perhaps imperfectly known) for all time.

Human carrying capacity is more difficult to estimate than some of the standard demographic indicators, like expectation of life or the total fertility rate, because human carrying capacity depends on populations and activities around the world. The expectation of life of a country can be determined entirely from the mortality experienced by the people within the country. But that same country's human carrying capacity depends not only on its soils and natural resources and population and culture and economy, but also on the prices of its products in world markets and on the resources and products other countries can and are willing to trade. When the world consisted of largely autonomous localities, it may have made sense to think of the Earth's human carrying capacity as the sum of local human carrying capacities; but no longer.

BEYOND EQUILIBRIUM

Think of a man engaged in four activities: lying on his back on the floor with his arms and legs relaxed; standing erect but at ease; walking at a comfortable pace; and running. When lying on his back, the man is at a passive equilibrium. If you push him gently on one side, he may rock a bit but will roll back to his original position. If you push him hard enough, he may switch from a passive supine equilibrium to a passive prone equilibrium. Whether he is supine or prone, he can remain in his present equilibrium without effort.

Standing is a much more complicated matter. Opposing muscles are constantly adjusting their tension to maintain upright posture, under the guidance of the body's sensory and nervous systems for maintaining balance. The man may not appear to be working, but his oxygen consumption increases and he will fall to the floor if he relaxes completely. If pushed hard, he may not be able to stay standing. His apparent equilibrium is dynamically maintained by constant control.

Walking is controlled falling. The man's center of gravity moves forward from his area of support and he puts one foot forward with just the right timing and placement to catch himself. He then pivots over the forward foot and continues to fall forward with just-in-time support from alternating legs. Anyone who has watched a child learn to walk, or an adult learn to walk with crutches, appreciates the complex sequential coordination, muscular strength and balance required to walk. The equilibrium of walking is not a stationary state at all, but a sustained motion.

Finally, running is more than an acceleration of walking because the runner may have both legs off the ground at once. The effort required, the speed of the motion and the vulnerability to collapse increase compared to walking. On a rocky mountain ridge or a crowded city street, running is impossible; simplification and control of the environment are required to sustain the equilibrium of steady running.

The purpose of this foray into kinesiology is to find some old and new analogies for the situation of humans on the Earth. If the population size of the human species was ever in a passive equilibrium regulated by the environment, it must surely have been before people gained control of fire. By using fire, early peoples massively reshaped their environment to their own advantage, with the effect of increasing their own population size. For example, they periodically burned grasslands to encourage plants desirable to themselves and to the game they hunted. After the mastery of fire, people moved from a supine equilibrium to a controlled balance analogous to standing. With the invention of shifting cultivation some ten or so millennia ago, arid then settled cultivation, the human species initiated a form of controlled forward falling analogous to walking. Humans invented cities and farms and learned to coordinate them. Where agriculture failed, civilizations collapsed. In the last four centuries, surpluses of food released huge numbers of people from being tied to the land and enabled them to make machines and technologies that further loosened their ties to the land. Machines for handling energy, materials and information released people from old work, imposed new work and transformed much of the natural world. More than ever before, the land that still supported people became a partly human creation. For humans now, the notion of a static, passive equilibrium is inappropriate, useless. So is the notion of a static "human carrying capacity" imposed by the natural world on a passive human species. There is no choice but to try to control the direction, speed, risks, duration and purposes of our falling forward.