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Why Is Human Niche Construction Transforming Planet Earth?

Rapid global changes in climate, the pollution of air, land, and sea, widespread species invasions and extinctions, and other massive environmental impacts are among the evidence that human societies are reshaping planet Earth. These changes are so transformative that many scientists are convinced humans have become a novel global force that has pushed Earth into a new period of geologic time: the Anthropocene. The question of when humans first became such a "great force of nature" is now widely debated. Yet the most important question is not when, but *why*. Why did humans and no other single species in Earth history gain the capacity to transform an entire planet? The key to answering this question lies in the unprecedented capacity of human societies to construct their ecological niche at increasing social and spatial scales, from the novel local ecological changes caused by mobile hunter-gatherers through hunting and the use of fire, to the global supply chains of the industrial world today.

Homo sapiens is not so distinctive biologically. We are just another species in the genus *Homo* with a few distinctive traits—and these do not even include stone tools or fire; other species of *Homo* wielded those hundreds of thousands of years before *H. sapiens* emerged among them in Africa. In my efforts to understand why behaviorally modern humans gained the extraordinary capacity to transform Earth, I discovered that it is necessary to go beyond biology—and even chemistry and physics—to examine and understand the many varied cultural forms and dynamic social changes in the human ecological niche over the past 50,000 years. To understand the emergence of humanity as a global force transforming Earth, we must view the human niche as a diverse and evolving sociocultural construct.

Like most ecologists whose work involves humans, I have tended to study the consequences of human activities rather than the causes. I've mapped the global ecological patterns produced by the different ways that humans use land—the anthropogenic biomes, or "anthromes"—which includes urban areas, villages, croplands, rangelands, and seminatural lands. In this research, I have depended primarily on empirical methods—direct analyses of data from remote sensing and agricultural and population censuses, among others. Yet the classic "natural" biome patterns of the Earth have long

been mapped based on their theoretical relationships with the global patterns of climate; for example, tropical woodlands form in warm and moist regions, while tundra forms in cold and dry regions. In this way, the global patterns of biomes can be predicted and mapped by biogeographers based on global climate patterns. When I first began my work mapping anthromes, I wanted a similar theoretical model capable of predicting such patterns; yet I found no simple theoretical analog of a "human climate system" that was shaping the terrestrial biosphere into anthromes. Moreover, it soon became clear that to develop such a model would be no small task. And so I hesitated.

In the fall of 2012, after I gave a talk on "Ecology in the Anthropocene," the editor of *Ecological Monographs* asked me: "How would ecological concepts and ideas have to change if we (re)focused our attention on anthromes, not biomes, as an underlying biogeographic organizing schema?" With this question and the offer of a paper of unlimited length, I decided it was time for me to focus on the ultimate causes of human transformation of the biosphere. It took more than a year of broad and intensive reading—from textbooks to journal articles—before I began to feel that I was gaining a general theoretical grasp of human sociality, social processes, and social change. It was also clear that my act of crossing disciplinary lines was pushing me far beyond my comfort zone, and I encountered multiple theoretical dead-ends. From the point of view of some disciplines, my questions were just asking for trouble. What is it about humans that distinguishes us from other species? Why do behaviorally modern humans—and their various societies—transform ecology so much more than any other species, and in so many different ways? The very act of bringing together social, ecological, and evolutionary explanations still seems seditious, as each discipline tends to demand a different way of understanding why and how humanity and ecology interact. Both cultural determinism and environmental determinism still have their adherents. In the end, it became clear that a new theoretical synthesis of social and ecological change would be necessary to explain the diverse and unprecedented ecological transformations human societies have produced.

Here, I present the product of my theoretical investigations: sociocultural niche construction. This new evolutionary theory explains *why* the ecological niche of behaviorally modern humans reshaped Earth, and why the human ecological niche continues to be both diverse and dynamic as the result of ongoing processes of sociocultural evolution. Not only does this theory have profound implications for ecological science

and conservation, it also challenges the classic environmentalist narrative that humans are environmental destroyers. Sociocultural niche construction requires a shift to a broader and deeper view of human societies as the shapers and stewards of the ecology of an increasingly used planet—a view that embraces Earth's ecological transformation over thousands of years through the actions of our ancestors.

When ecologists talk about the niche of a species, we are usually referring to its environmental requirements and tolerances, and the ways in which it is able to use resources. Rainforest species require moist environments, for example, and some species thrive based on their ability to harvest insects by poking a hole in the bark of a tree. Considered from a conventional evolutionary point of view, the niche of a species is the product of inherited genetic adaptations to environmental pressures over which the species has no control, such as the adaptations needed to thrive in a specific climate. Through processes of natural selection, species become adapted for life within their ecological niche, and when species are within their niche, their adaptive fitness is at its highest.

Recently, this "one-way" understanding of the ecological niche has been challenged by the observation that many species are not only adapted to environmental constraints beyond their control, but also actively engage in altering their environments profoundly—by building dams (beavers) and nests (some birds and insects, among other taxa), for example, or by releasing toxic chemicals that inhibit the growth of competitors (plants, microbes). Clearly, the relationship between organisms and their environments can also be a two-way street. These environment-altering species are known as "ecosystem engineers" by ecologists. When ecosystem engineers alter environments to such a degree that it affects their ability to thrive and to reproduce (their adaptive fitness)—or that of other species sharing their environments—this alteration is considered an evolutionary process in itself. The result: the production of an "ecological inheritance," and the basis for the new evolutionary theory of niche construction.

Niche construction theory is fundamental to explaining both why humans gained the capacity to transform Earth's ecology, and why different human societies have changed ecology in such varied ways over the long term. By combining niche construction theory with a theoretical understanding of humans' exceptional social and cultural capacities and their evolution, we have the basis for the theory of sociocultural niche construction.

Figure 1: Manuring and preparing soils for wheat planting, Xueyan, Jiangsu, China (courtesy of the author).

While many species are social (consider honeybees, for example), the extraordinary sociality of behaviorally modern humans marks us as Earth's first "ultrasocial" species. Humans have unrivaled capacities for learning from others and for transmitting this social learning—as cultural inheritances—both within and across generations. This makes it possible for human cultural inheritances to accumulate and evolve over time. Moreover, the very nature of human social life is itself structured largely by social learning, often requiring socially learned relationships with non-kin individuals for survival. This dependence on social learning means that the behaviors of human individuals, groups, and entire societies are incredibly variable—with different strategies for ecosystem engineering and exchange of food and other resources, different forms of social organization, and even different modes of social learning and cultural transmission, from languages, arts, and religion to other symbolic behaviors. The core behaviors needed to survive and to reproduce within behaviorally modern human societies are not determined by human biology—they must be learned.

In behaviorally modern human societies, direct interactions with the environment to procure food and other necessities—by foraging, farming, or even shopping at the supermarket—may be optional. Sustenance and other necessities can be gained through complex social relationships among unrelated individuals and even strangers, by sharing, bartering, or even ordering online using a credit card. The human ecological niche—how humans live in, utilize, and transform environments to survive and reproduce—is thus largely sociocultural, constructed and enacted within, across, and by individuals, social groups, and societies based on socially learned behaviors. Long-term changes in the construction of the human niche—the structure and func-

tioning of human societies and their transformation and use of environments—are the product of evolution by natural selection acting on the individual and social modes of sociocultural niche construction. As with "human nature," the "human niche" is not determined by human biology but by sociocultural traits and their evolution at the individual, group, and societal levels. It might even be said that there is no "human niche"—that there are only sociocultural niches, and these are defined by the cultural traits of the society within which specific individuals have learned to live.

Cultural traits can evolve far more rapidly than biologically determined traits—one reason why human societies have evolved so many diverse and complex cultural forms, and why these have changed so much in the more than 50,000 years since humans first spread across the Earth out of Africa. Major bursts of sustained evolutionary change in the human niche, known as sociocultural regime shifts, have also been driven by processes of runaway sociocultural niche construction, as can be seen in the rise of agriculture. Cultivating soils can lead to a loss of nutrients; sustaining their productivity thus requires cultural adaptations such as the harvesting and use of manures to maintain soil fertility. This is a good example of how a specific suite of cultural and ecological inheritances, like cultivation, can lead to social and environmental changes so great that we must adapt to them by adopting ever more transformative cultural and ecological inheritances. These runaway processes of evolutionary change tend to lock societies into long-term cycles of adaptation in their sociocultural niche, as they work harder to sustain ever more demanding societies.

Hunter-gatherer (or small-scale) societies, some of which remain successful today despite the pressures of larger-scale agricultural and industrial societies, rely on remarkably complex sociocultural toolkits: these include social hunting, projectiles, resource sharing, niche broadening—expanding the range of utilized species when preferred species are driven to extinction—and even the propagation of favored species—the first stages of domestication. Agricultural societies built on these complex strategies by developing even more novel and transformative subsistence regimes, from domestication, tillage, and irrigation to manuring, taxation, and the marketplace. Social roles became more diverse and specialized in response to larger social groupings dependent on complex and unequal social organization. Societies also adopted more powerful and complex tools and technologies to increase productivity, resulting in greater alterations to the environment. While the use of fire for cooking and clearing land

represents the first substitution of nonhuman biomass energy for human biological energy—used in engineering ecosystems and to digest food—farmers learned to supplement the energy of human labor with domestic livestock, wind, and hydropower. Industrial societies scaled up further with populations growing rapidly, sustained by expanding trade in food and other resources across Earth. These societies increased their use of fossilized biomass (coal, oil, natural gas) and non-biomass forms of energy—such as nuclear and solar power—to supplement and ultimately eliminate human energy in engineering ecosystems, the social allocation of food and resources, and even in communicating with one another.

Figure 2: Water buffalo plowing in preparation for rice transplanting, Dianbai, Guangdong, China (courtesy of the author).

While evolutionary processes are never simply linear or progressive, there are some remarkable general trends in human social change over the past 50,000 years. The potential scale of individual human societies has increased from a few dozen individuals to a few hundred million. The potential productivity of a single square kilometer of land to sustain human populations has been amplified through cooperative ecosystem engineering from sustaining less than 10 individuals to sustaining thousands. Energy use per human individual has also grown by a factor of more than 20 times through the use of

non-biomass energy, now mostly from fossil fuels, while the flow of materials, energy, biota, and information across human societies has become essentially global and continuous. Quality of life has also generally improved: human individuals now live nearly twice as long on average as they did in the Paleolithic era. No doubt these long-term trends in human sociocultural niche construction have emerged in response to many different pressures—and even through random variations. But natural selection acting on human cultural and ecological inheritances has had the greatest impact on shaping how humans interact socially and ecologically, and is the ultimate cause of the unprecedented global changes human sociocultural niche construction has produced.

In recognizing the Anthropocene as a new epoch of geologic time, we are confronted with the reality that human societies are now a global force that is actively and continuously reshaping Earth. The dynamics of the human sociocultural niche—including its social organization, cooperative ecosystem engineering, exchange relationships, and energy systems—are now tightly coupled with long-term changes in the Earth that are altering the ecology of our planet profoundly and permanently. While it is possible that for most people times have never been better, the opposite is true for most other species—and there are strong indications that anthropogenic global changes in climate and biodiversity have the potential to derail the future of human societal development.

It should never be forgotten that, like biological evolution, sociocultural evolution is a process, not a destiny. Even the most successful large-scale societies of today could go the way of the dinosaurs. Indeed, with current trends, such an outcome seems increasingly plausible. Yet, we would also do well to remember that contemporary societies have managed to reduce and even eliminate pollutants; have protected and restored endangered species and their habitats; and that there is still considerable opportunity to implement the massive shift in energy systems needed to prevent catastrophic global climate change.

Societies are advancing in their ability to understand not just the consequences but the ultimate causes of human transformation of Earth. This knowledge has the potential to guide the development and implementation of more successful social strategies that might sustain both humans and nonhumans together more desirably on Earth. Humans have always been so much more than "destroyers of nature." In an increasingly anthropogenic biosphere it is essential to shift the paradigm. Humanity long ago emerged as a global sociocultural force capable of altering Earth for better and for worse. We humans

and all other species must now live together on a used planet reshaped by generations of our ancestors. It is time to go beyond the idea that we might somehow return to a "balance of nature" that would bring human societies back into a safe harbor in the "natural" world. It is time to embrace the sociocultural realities, strategies, and "cultures of nature" that might enable human societies to become better stewards of both humans and the rest of Earth's species in the Anthropocene.

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