BEHAVIOR

The Ultimate Ecosystem Engineers

How did human societies initially domesticate plants and animals, and what were the keys to success?

Bruce D. Smith

"Evolution helps those who help themselves" is the basic idea behind the concept of niche construction or ecosystem engineering (*1*). Many animal species attempt to enhance their environments, and humans have been trying to make the world a better place—for themselves—for tens of thousands of years, often with unforeseen consequences. We have long been the ultimate niche constructors in terms of our rich repertoire of ecosystem skills and the magnitude of their impact. Today, as our efforts at ecosystem engineering are beginning to attempt to reduce and reverse human modification of environments, interest is also growing across diverse fields (including archaeology, biology, climatology, genetics, and geography) in the origins of human dominance of Earth's ecosystems. The general concept of niche construction provides an important new window of understanding about how our distant ancestors, through their initial domestication of plants and animals, first gained the ability to significantly alter the world's environments.

Currently, research on domestication is carried out on two largely disconnected scales—at the level of individual plant and animal species to document the "what, when, and where" of domestication worldwide (*2*), and at a regional or larger scale, to identify causal "macro" variables (such as climate change and population growth) that may account for "why" human societies first domesticated target species (*3*). The theory of niche construction provides a link between research at these two different scales of analysis by offering insights into the intervening "how" of domestication—the general human behavioral context within which macroevolutionary factors forged new human-plant/animal relationships of domestication.

Niche construction or ecosystem engineering activities have been documented in a broad range of different animal species. Beavers, for example, through their tree-cutting, dam building, and pond-creating efforts, generate new landscapes for themselves and many other species. Such efforts at environmental modification are proposed to play an important if underappreciated role in shaping biotic communities and evolutionary processes (*1*).

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Early strategists. Human niche construction, including controlled burning, may date back to as early as 55,000 yr B.P. Shown is an Australian aborigine.

Studies of human niche construction have usually concentrated on either a particular form of environmental modification, such as controlled burning of vegetation, or on human intervention in the life cycle of a particular target species. Only recently have regional-scale studies offered a fuller appreciation of the extent to which traditional resource-management strategies involve the coherent and integrated manipulation of a broad range of plants and animals and their habitats (*4*).

Documenting the overall niche construction strategies of past human societies, however, remains a difficult challenge. Archaeological evidence for the management of wild plants (sowing, burning, weeding, irrigation, transplanting, and mulching) provides widely scattered clues to the developmental history of integrated systems of human environmental management. Controlled burning of vegetation to maintain a preferred ecosystem state, for example, is documented throughout the Holocene (the last ~10,000 years) in numerous temperate and tropical environments, and may have been present as early as 55,000 years ago in southern Africa (*5*). Yet in many world regions, the appearance of domesticated plants and animals in the archaeological record provides the strongest evidence for integrated strategies of ecosystem engineering.

A number of different aspects of our current understanding of the initial, worldwide domestication of plants and animals points to domestication taking place within a broader behavioral context of niche construction strategies. The development of such human–target species relationships was not a unique event, limited to a particular time or place. Eight to 10 environmentally and culturally diverse world regions have been identified as likely independent centers of domestication and agricultural origin (*2*). Each exhibits a distinct sequence of domestication of different species over millennia. Human societies thus domesticated a diverse array of species at different times and in developmental isolation across a broad range of ecosystems.

In addition, recent research indicates that the initial domestication of plants and animals in these independent centers encompasses a remarkable diversity of species-specific relationships reflecting a wide range of different forms of human intervention. In Asia, for example, the domestication of two utilitarian species—the dog (for hunting) and the bottle gourd (for containers)—by ~12,000 years before the present (yr B.P.), did not so much involve deliberate human intervention as it did allow dogs and bottle gourds to colonize the human niche. In contrast, the initial cultivation of tree crops (such as fig by 11,400 yr B.P. in the Near East and banana by ~10,000 yr B.P. in Southeast Asia) involved the intentional cutting and transplanting of branches, indicating a recognition of the long-term benefits to be gained by a commitment to sustained management.

The initial domestication of goats in the Near East by 10,000 yr B.P., and the subsequent domestication of other livestock species, also called for considerable sustained human intervention, but of a very different kind. Human preemption of herd dominance hierarchies, resulting in human control of animal reproduction, allowed the selective culling of immature males, producing an age and sex profile (that is, a majority of adult females and a few adult males) that is the hallmark of managed domesticated herds. In contrast, the initial domestication of seed-bearing plants (such as wheat, rice, maize, millet, and sunflower), including two species of squash that were domesticated in South America and Mexico by 10,000 yr B.P. (*2*), involved yet another form of human intervention in the life cycle of target species—the sustained planting of stored seed stock in prepared planting areas. Plants with starch-rich underground organs (including manioc, arrowroot, and leren), on the other hand, were brought under domestication in South America by ~9000 to 8000 yr B.P. by replanting fragments of parent plants, paired with sustained selection for desired attributes (larger tubers and preferred starch types, for example) (*2*).

Evidence is also growing for early attempts at domestication that eventually proved unsuccessful. In both the Near East and the Americas, initial efforts at plant management and manipulation were often abandoned, for as yet unknown reasons, and the crops in question were not successfully domesticated until several thousand years later (*6*).

Whatever the exact mixture of macroevolutionary forces that were in play, humans identified potential domesticates within the broader context of niche construction strategies through endless auditioning and experimentation with a long list of possibilities. Domesticates would not have been different, necessarily, from the many other managed species in either requiring a greater investment of labor, or constituting a greater intellectual challenge. What set humans apart was their recognized potential for open-ended expansion and ever-increasing returns.

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ASTRONOMY

A Closer Look at a Gamma-Ray Burst

A study of gamma rays produced when stars collapse or collide reveals details of the explosion mechanism, particularly the role of magnetic fields.

Stefano Covino

Gamma-ray bursts are among the most intriguing astrophysical events. Although short-lived, these explosions are the most luminous objects in the universe. However, the detailed mechanisms driving these bursts are still partly unknown. On page 1822 of this issue, the observations reported by Mundell *et al*. (*1*) will allow us to better understand the physical processes that power these celestial sources. By measuring the polarization of the electromagnetic radiation emitted immediately after a burst, Mundell *et al.* can help us unravel the role of magnetic fields in controlling the outflows produced by these explosions.

These burst events were first detected in the 1960s as intense and brief pulses of high-energy photons. They are now observed at photon energies across the whole electromagnetic spectrum and have been located at cosmological distances (that is, more than 10 billion light-years from Earth). They are also possible sources of gravitational waves, ultrahigh-energy cosmic rays, and neutrinos. The most successful description of these events involves a very energetic outflow from an inner engine, either a massive star undergoing core-collapse or the merger of two compact objects (see the figure). Inhomogeneities in the outflow generate a prompt high-energy emission of gamma rays, whereas the later interaction of the outflow with the matter surrounding the progenitor object generates a fainter and softer long-lasting emission, called the afterglow. One of the hottest open topics is to understand what drives the outflow, its composition, and its dynamics. This is where the observations performed by Mundell *et al*. make an important contribution.

Gamma-ray burst outflows are extreme events. Initially they are ultrarelativistic, that is, the flow must have a velocity greater than 99.99% of the speed of light. This allows high-energy photons to escape from the very compact region where they are generated. The hypothesis accepted by most researchers assumes that the outflow is initially hot, with the expansion driven by its internal energy (*2*–*4*). This is known as the matter-dominated scenario, and serves as the reference model for outflows. The most popular alternative scenario requires that the outflow is driven by electromagnetic energy, which is called the Poynting flux–dominated scenario (*5*–*7*). (The Poynting flux is the flux of energy car-

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