APPLICATION TO ENVIRONMENTAL ETHICS

According to Wilson, environmental issues figure in this equation. Wilson argues that humans have evolved in a symbiotic relationship with the rest of living nature. Simply and literally put, people cannot live without plants and other animals. Beyond the simple utilitarian factors, Wilson argues, people must take into account the human need of biodiversity. That need speaks to deep social and aesthetic needs within everyone—liking landscapes is a part of human biology—and of course pays major dividends in the search for new drugs and the like. In other words, Wilson argues that evolutionary biology shows that people need a new moral imperative: "Preserve and cherish nature and above all maintain biodiversity." This is not something that runs counter to traditional ethics, like the love commandment, although it certainly runs counter to the human urge to look for quick and easy solutions. Wilson argues that with the development of the human brain, people have reached a new level of evolution that requires them to think about the long-term future and eschew the immediate and comfortable for the distant and important. In short, to understand and counter the environmental crisis, people's first duty is to learn some evolutionary biology.

SEE ALSO *Biodiversity; Darwin, Charles; Evolution; Wilson, Edward O.*

BIBLIOGRAPHY

Ruse, Michael. 1986. *Taking Darwin Seriously: A Naturalistic Approach to Philosophy.* New York: Blackwell.

Wilson, Edward O. 1975. *Sociobiology: The New Synthesis.* Cambridge, MA: Harvard University Press.

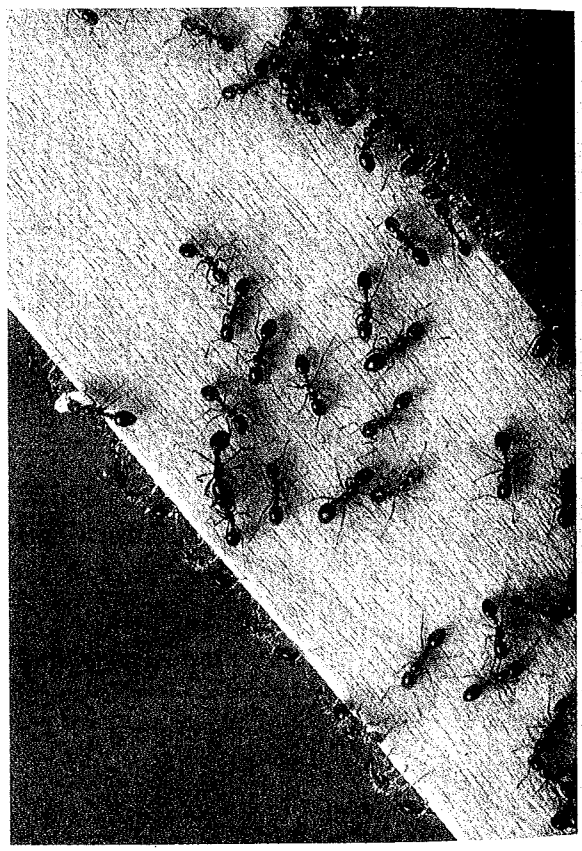
Wilson, Edward O. 1978. *On Human Nature.* Cambridge, MA: Harvard University Press.

Wilson, Edward O. 2002. *The Future of Life.* New York: Alfred A. Knopf.

Michael Ruse

EXOTIC SPECIES

The fire ant (*Solenopsis invicta* Buren) in the southern United States, the zebra mussel (*Dreissena polymorpha*) in lakes and waterways of the midwestern United States, and the seaweed *Caulerpa taxifolia* in Mediterranean waters are commonly cited examples of exotic species. What makes them exotic is a shared property: Each species inhabits but is not considered native within the region listed. In the United States, for instance, *Solenopsis* was first discovered in the late 1920s in Mobile, Alabama, likely introduced accidentally in ships transporting agricultural products from South America (Williams et al. 2001); shipping also carried it to Brisbane, Australia, around 2000 (McCubbin and Weiner 2002). Similarly, shipping was responsible for the zebra mussel's arrival in North American Great Lakes around 1986 (Ram and McMahon 1996). *Caulerpa*, a common aquarium plant, was first detected in Mediterranean coastal waters adjacent to the Oceanographic Museum of Monaco near Nice, France (Francour et al. 1995). Although these species were almost certainly introduced by humans to these areas, this circumstance is not what defines their exotic status (cf. Noss and Cooperrider 1994). If nonhuman processes had introduced them, they would be equally exotic. *Solenopsis* is deemed native rather than exotic in Argentina, Brazil, Paraguay, and Uruguay, and



Red Imported Fire Ants. *The red fire ant (*Solenopsis invicta*) is an insect species native to South America, but found on several continents. The ant was accidentally introduced to the southern United States in the 1930s, traveling in soil on a ship that docked at the Mobile, Alabama port. The ants are a nuisance to humans, pets, and livestock, and cause extensive medical and agricultural damage every year.* PHOTO COURTESY OF SCOTT BAUER, USDA AGRICULTURAL RESEARCH SERVICE, BUGWOOD.ORG.

neither the zebra mussel nor *Caulerpa* is regarded as exotic in the Black and Caspian seas or Indian Ocean, respectively.

DEFINING *NATIVE* AND *EXOTIC* SPECIES

As the foregoing examples illustrate, a species is appropriately labeled "exotic" only with respect to regions in which it is not considered native. These regions may change, of course, as migration and extinction change the flora and fauna of regions, so a clear criterion for nativeness is needed. Without an explicit criterion, *exotic* and *native* are problematically imprecise concepts and are, consequently, often used inconsistently by ecologists and conservation biologists (Shrader-Frechette 2001; Colautti and MacIsaac 2004). Unfortunately, no such criterion has emerged. It is often unclear, for instance, what temporal reference is being (and should be) considered the standard for nativeness. Cattle, for instance, are arguably a staple of contemporary U.S. biocultural identity and could be judged native on that basis, yet they are exotic as judged against a U.S. precolonial ecological reference state. Similarly, horses were native in North America during the Pleistocene but were presumably exotic when Europeans reintroduced them after they had been locally extinct for more than 10,000 years.

Analogous reference problems confront restoration efforts that seek to determine what past ecological state of a degraded area should be its restoration target (see Callicott 2002). These problems do not, however, show that *native* and *exotic* are entirely useless concepts within conservation biology or that the distinction between them is baseless. It seems undeniable, for example, that the recent introduction of *Caulerpa* and the zebra mussel into areas in which they are classified as exotic justifies the label.

DISTINGUISHING *EXOTIC* AND *INVASIVE* SPECIES

The fire ant, zebra mussel, and *Caulerpa* are labeled *invasive* more often than *exotic*. How this concept should be defined is controversial (see Richardson et al. 2000), but these species are called invasive in regions in which they are considered nonnative because they have had a significant adverse effect on ecosystems, primarily through high fecundity, high density, rapidly expanding distributions, and competitive advantages over native species. Describing these species as exotic does not, however, imply that their impact must be adverse. In fact, some studies suggest less than one-quarter of exotic species negatively affect ecosystems (Williamson and Fitter 1996). *Exotic* and *invasive* are, therefore, distinct concepts and should not be conflated. This does not mean, however, they are unrelated. Being exotic is necessary for a species to be invasive: Native species obviously cannot invade regions they already inhabit.

What makes species invasive is not well understood (Williamson 1996), but high fecundity and absence of predators, parasites, and competitors that negatively affect a species in its native distribution is clearly an important part of the explanation (Sax and Brown 2000). Invasive *Solenopsis* in the United States, for example, normally outcompetes native ants to the point of competitive replacement (Porter et al. 1988). In the presence of even relatively low densities of parasitoid Phorid flies that parasitize them in their native range, however, invasive *Solenopsis* consume less, grow to smaller size, and are less competitive against native ants (Mehdiabadi and Gilbert 2002, Mehdiabadi et al. 2004). Being introduced into new areas frees exotics from these types of ecological pressures. Nevertheless, native species can sometimes escape these pressures as well. For example, white- and black-tailed tail deer in some parts of the United States (especially areas with severe hunting restrictions) share many of the negative attributes of invasive species because humans have eradicated their native predators. Similarly, natural biological changes like mutation can produce selectively favorable physiological or behavioral properties that provide the same advantages, thereby causing a low-density native species to reproduce and spread more effectively, potentially to the detriment of ecosystems containing it. Both natives and exotics can thus be noxious.

ECOLOGICAL IMPLICATIONS AND ETHICAL EVALUATION OF EXOTIC SPECIES

Despite this possibility, the more significant threat comes from exotic rather than rogue native species given that exotics escape negative ecological pressures more completely and with greater frequency than natives. Highly destructive and invasive species, such as the examples discussed above, are usually exotic rather than native. Even though only a small minority of exotics becomes invasive, the threat they pose to native species, agriculture, and industry is growing as humans become better vectors for exotics through increasing travel and trade (Vitousek et al. 1997). At any instant, for example, the zebra mussel is only one of approximately 3,000 to 7,000 species carried globally in ballast (Carlton 1999). As global trade increases, the number of exotics introduced through shipping increases, and one of the few reliable generalizations to emerge within invasion biology is that more exotics will become established and thus potentially invasive as the number of introductions increases (Lonsdale 1999). This significant and escalating threat justifies

an ethical imperative to prevent and reduce introductions of exotics. *Solenopsis* alone has been implicated in the extinction of several native species in the southeastern United States (Forys et al. 2001).

Ethical evaluation of exotics becomes more complicated once they have established self-sustaining populations in new areas and when it is reasonably clear that they will not become invasive. Even if reference state problems with the native-exotic distinction are ultimately resolvable, it is unclear that a simple preference for native over exotic species is ethically defensible (Sagoff 2003). In one of the founding texts of invasion biology, for example, Elton (1958) appealed to people's aesthetic appreciation and intellectual interest in an area's flora and fauna as one reason for excluding and eradicating exotics. But this rationale cuts both ways. The introduced mute swan and many exotic garden ornamentals, for example, are aesthetically pleasing for much of the U.S. populace, as well as interesting intellectual subjects for relevant research communities. Exotics, even invasives, can also benefit ecosystems to which they are introduced. For example, the substantial economic costs imposed by the zebra mussel clogging intake ports of boats, power plants, and infrastructure waterways are responsible for its label as a noxious pest. As a filter feeder, however, the zebra mussel has cleared much of the excess nutrients and algae caused by sewage and industrial pollution in the Great Lakes, to the benefit of many native invertebrates and fish (Strayer et al. 2004). Absent an unequivocal threat to native species or economic interests, the cultural opposition to exotic species may be nothing more than an indefensible prejudice (Chew and Laubichler 2003).

SEE ALSO *Biodiversity; Conservation Biology; Ecological Restoration; Extinction; Invasive Species; Species.*

BIBLIOGRAPHY

Callicott, J. Baird. 2002. "Choosing Appropriate Temporal and Spatial Scales for Ecological Restoration." *Journal of Biosciences* 27: 409–420.

Carlton, J. T. 1999. "The Scale and Ecological Consequences of Biological Invasions in the World's Oceans." In *Invasive Species and Biodiversity Management*, ed. O. T. Sandlund, P. J. Schei, and A. Viken. New York: Kluwer.

Chew, Matt K., and Manfred D. Laubichler. 2003. "Natural Enemies: Metaphor or Misconception?" *Science* 301: 52–53.

Colautti, Robert I., and Hugh MacIsaac. 2004. "A Neutral Terminology to Define 'Invasive' Species." *Diversity and Distributions* 10: 135–141.

Elton, Charles. 1958. *The Ecology of Invasions by Animals and Plants*. London: Methuen.

Forys, E. A.; C. R. Allen; and D. P. Wojcik. 2001. "The Likely Cause of Extinction of the Tree Snail Orthalicus reses reses (say)." *Journal of Molluscan Studies* 67: 369–376.

Francour, P.; M. Harmelin-Vivien; J. G. Harmelin; and J. Duclerc. 1995. "Impact of Caulerpa Taxifolia Colonization on the Littoral Ichthofauna of North-Western Mediterranean Sea: Preliminary Results." *Hydrobiologia* 300/301: 354–353.

Lonsdale, W. M. 1999. "Global Patterns of Plant Invasions and the Concept of Invasibility." *Ecology* 80: 1522–1536.

McCubbin, Keith, and John Weiner. 2002. "Fire Ants in Australia: A New Medical and Ecological Hazard." *Medical Journal of Australia* 176: 518–519.

Mehdiabadi, Natasha J., and Larry E. Gilbert. 2002. "Colony-Level Impacts of Parasitoid Flies on Fire Ants." *Proceedings of the Royal Society of London* B 269: 1695–1699.

Mehdiabadi, Natasha J.; Elizabeth K. Kawazoe; and Larry E. Gilbert. 2004. "Phorid Fly Parasitoids of Invasive Fire Ants Indirectly Improve the Competitive Ability of a Native Ant." *Ecological Entomology* 29: 621–627.

Noss, Reed F., and Allen Y. Cooperrider. 1994. *Saving Nature's Legacy: Protecting and Restoring Biodiversity*. New York: Island Press.

Porter, Sanford D.; Bill Van Eimeren; and Larry E. Gilbert. 1988. "Invasion of Red Imported Fire Ants (Hymenoptera: Formicidae): Microgeography of Competitive Replacement." *Annals of the Entomological Society of America* 81: 913–918.

Ram, Jeffrey L., and Robert F. McMahon. 1996. "Introduction: The Biology, Ecology, and Physiology of Zebra Mussels." *American Zoologist* 36: 239–243.

Richardson, David M.; Petr Pysek; Marcel Rejmanek, et al. 2000. "Naturalization and Invasion of Alien Plants: Concepts and Definitions." *Diversity and Distributions* 6: 93–107.

Sagoff, Mark 2003. "Native to a Place, or What's Wrong with Exotic Species?" In *Values at Sea: Ethics for the Marine Environment*, ed. Dorinda Dallmeyer. Athens: University of Georgia Press.

Sax, Dov F., and James H. Brown. 2000. "The Paradox of Invasion." *Global Ecology and Biogeography* 9: 363–371.

Shrader-Frechette, Kristin 2001. "Non-Indigenous Species and Ecological Explanation." *Biology and Philosophy* 16: 507–519.

Strayer, David L.; Kathryn A. Hattala; and Andrew W. Kahnle. 2004. "Effects of an Invasive Bivalve (Dreissena polymorpha) on Fish in the Hudson River Estuary." *Canadian Journal of Fishery and Aquatic Science* 61: 924–943.

Vitousek, Peter M.; Carla M. D'Antonio; Lloyd L. Loope, et al. 1997. "Introduced Species: A Significant Component of Human-Caused Global Change." *New Zealand Journal of Ecology* 21: 1–16.

Williams, David F., Homer L. Collins, and David Oi. 2001. "The Red Imported Fire Ant (Hymenoptera: Formicidae): An Historical Perspective of Treatment Programs and the Development of Chemical Baits for Control." *American Entomologist* 47: 146–159.

Williamson, Mark 1996. *Biological Invasions*. London: Chapman and Hall.

Williamson, M., and Alaistair Fitter. 1996. "The Varying Success of Invaders." *Ecology* 77: 1661–1666.

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