Incorporating nonhuman knowledge into the philosophy of science

Brian Czech

Abstract If the philosophy of science embraces the construction of knowledge to improve the human condition, then it should also embrace the prevention of the demolition of knowledge that supports the human condition. Nonhuman species are endowed with knowledge, albeit with varying levels of cognition. Nonhuman knowledge grows freely, with no political agenda and no methodological bias. Much nonhuman knowledge is unavailable to humans but is used in unwitting support of the human condition by producing human goods and services. Some nonhuman knowledge may be used directly to expand the human knowledge base. The ratio of human knowledge to nonhuman knowledge influences the sum of knowledge and the human condition. There is evidence that the ratio of human economy to total knowledge is too high and that the nonhuman component of total knowledge is deficient. The philosophy of science, led by the wildlife profession, should be expanded to incorporate nonhuman knowledge. Eventually, scientists of all disciplines should unite against the threats to total knowledge and the human condition posed by the erosion of nonhuman knowledge.

Key words animal knowledge, cognition, economic growth, epistemology, human knowledge, moral philosophy, ontology, philosophy of science, technological imperative

Philosophy of science is important to wildlife conservation because it affects the practice and products of scientists of all disciplines, many of which may impact biodiversity. Unfortunately, philosophy is becoming increasingly abstruse, esoteric, and marginal to the applied sciences. Understanding formal philosophical argument requires familiarity with specialized jargon, concepts, and history. Philosophy journals are laden with perpetually finer details, and major breakthroughs in philosophy are no longer expected, even among its practitioners (Horgan 1996). One of the twentieth century's most famous philosophers suggested that non-indoctrinated, amateur philosophers offered the greatest hope for progressing beyond the status quo of formal philosophy (Feyerabend 1978). Accordingly, perhaps a unique offering to the philosophy of science is availed by a wildlife conservation perspective. Prior to considering this possibility, however, a brief survey of the terrain encompassed by the philosophy of science is required.

Throughout the twentieth century, the sciences were subjected to 3 prominent philosophical positions: realism, idealism, and empiricism. Perhaps the most influential realist was Sir Karl Popper (1902–1994). For realists, the goal of science is to construct knowledge of reality (Sismondo 1996). Viewing the universe as an infinity of real phenomena, scientists strive to supplant the unknown with the known. Their efforts may never achieve fruition, however, because in a universe where infinite phenomena transpire, finite knowledge corresponds with infinite ignorance (Popper 1965). Nevertheless, a larger body of knowledge obtained through the testing of falsifiable hypotheses grants us the ability to improve the human condition, i.e., health, happiness, and sustainability.

Author's address: 5101 S. 11th Street, Arlington, VA, 22204, USA; e-mail: brianczech@juno.com.

An alternative philosophy of science is associated with Kuhn (1922–1996), who thought that knowledge was perceived from "paradigms" that were reconstructed only during scientific revolutions and not during "normal science" (Kuhn 1996:10). Kuhn (1996:76) noted that, "Philosophers of science have repeatedly demonstrated that more than one theoretical construction can always be placed upon a given collection of data." Kuhn (1996: 121) also claimed, "…with a change of paradigm, the scientist afterward works in a different world." Because of statements like this, Kuhn has been an unwitting champion of idealist philosophies, which question the independent existence of reality (Hoyningen-Huene 1989). In contrast to Kuhn, George Berkeley (1685–1753) and Georg Wilhelm Friedrich Hegel (1770–1831) were classical idealists, arguing explicitly that all reality was the creation of mind. However, their brands of idealism arose at a time when faith in God was a more prominent feature of society and science; it was God's mind that produced reality (Borgmann 1995). Today, idealists tend to posit the human mind as the creator of reality. Modern forms of idealism are frequently called "constructivism." Because of its disregard for the existence of reality independent of mind, constructivism is sometimes seen as harboring dangerous implications for ecosystem health and for the human condition in general (Shepard 1995). On the other hand, constructivist philosophy can be used judiciously to probe the motives of policy makers and governments (Schneider and Ingram 1997).

Philosophers and scientists, then, are positioned along a spectrum from those who believe in a reality independent of human thought (i.e., realists) to those who do not (i.e., idealists or constructivists). Along the way, one encounters "deflationary realism" (Sismondo 1996: 79), "constructive realism" (Sismondo 1996: 105), and "constrained constructivism" (Hayles 1995: 53)—i.e., decreasing ratios of realism:idealism. Each of these is a theory of ontology, the branch of philosophy dealing with the nature of being.

Epistemology, on the other hand, is the branch of philosophy dealing with the origin and nature of knowledge. A prominent epistemological theory is empiricism, the theory that all knowledge originates in experience. However, the experience may be mental or physical; thus, one can speak of an idealist empiricism or an empirical realism. The former would be associated with Kuhn, the latter with Popper. From the wildlife ecology literature, one readily surmises that wildlife ecologists tend to occupy this latter camp with Popper, although they are conscious of constructivism and its conservation implications (Soulé and Lease 1995).

Karl Popper, 1902–1994, realist and critical rationalist.

As realism is juxtaposed to idealism, rationalism is to empiricism. Rationalism is a theory that reason is in itself a source of knowledge superior to and independent of sensory perceptions. However, rationalism is a relatively ambiguous concept and is not as exclusive of empiricism as realism is of idealism. Thus Popper described his own epistemological philosophy as "critical rationalism"—i.e., his rationale produced knowledge, but only to the extent that it withstood his empirical critique (Ho and Lund 1994:1).

As this overview illustrates, the philosophy of science has been most concerned with ontology and epistemology. However, a holistic philosophy of science also must address the other basic philosophical subjects, including logic, aesthetics, and morals. Furthermore, it must recognize a complete set of the sources and possessors of knowledge. This article is a proposal to incorporate a heretofore neglected source of knowledge (i.e., nonhuman knowledge) into a relatively holistic philosophy of science, and will serve to demonstrate how wildlife conservation would incidentally benefit from such a philosophy of science.

Elements of a holistic philosophy of science

The relevance of ontology and epistemology to any philosophy of science is well-established. My purpose in this section is to briefly explore the relevance of logic, aesthetics, and morals to the philosophy of science using examples that would tend to originate from the wildlife profession.

For most of the sciences, logic *per se* is perhaps the least germane philosophical issue. Advances in modern logic are the domain of mathematicians and linguists. Fundamental principles of logic are sufficient to defend positions in most other disciplines (Fogelin and Sinnott-Armstrong 1991).

Aesthetics deals with the nature of beauty, art, and taste and with the creation and appreciation of these qualities. The prioritization of aesthetics above the production of knowledge is not unprecedented in the philosophy of science (Feyerabend 1978), yet it is appropriate for philosophies of science to focus on issues of knowledge more than on aesthetics, provided that the moral foundations are solid (Toulmin 1975). One simple observation should not be overlooked, however: humans have a great deal of appreciation for the aesthetic qualities of nonhuman species (Kellert 1996). Based on a purely aesthetic criterion, then, science should serve to perpetuate and propagate nonhuman species.

As for morals, the philosophy of science has long been faced with a dilemma. Horgan (1996: 3) defined "pure science" as "the search for knowledge for its own sake," unbiased by social agendas. But "moral" science is supposed to be accountable to the society that hosts it (Proctor 1991). As Toulmin (1975: 135) observed, "It is an unsound fancy to expect that man should serve the cause of science rather than science the cause of man." While philosophers of epistemology have long proclaimed that the construction of knowledge should proceed without methodological coercion or bias via the scientific method (Wolf 1925), the moral philosophy that they should do so with an *a priori* goal of improving the human condition has been overlooked.

Let us assume that, at least for those who believe in reality and in the human capacity to know reality, scientists indeed have a moral obligation to society. Toulmin (1975: 123) called it the "Baconian morality," because Sir Francis Bacon (1561–1626), herald and statesman of the scientific age, considered science a meritorious pursuit only within the context of social service. The relevance of Bacon's moral philosophy to wildlife conservation was revealed by Brown (1990: 170), who warned, "There is a particularly ignorant campaign being waged in some Green and feminist circles against Francis Bacon, the father of Western science. By selective quotation he is supposed to have begun a tradition of imposing man's (and not woman's) will upon nature. A more careful examination of what he wrote would show that his whole philosophical criticism of Aristotle [384-322 BC] was based upon the need to start from experience and to work with the grain of nature."

When developing a moral element of a holistic philosophy of science, one must consider the relationship of science to technology. Technology is simplistically considered to be the application of science, therefore scientists can disclaim the relevance of morality to research by drawing a line between science and technology. Drawing a clear line is difficult, however, because the distinction between science and technology has deteriorated throughout modernity, especially since the advent of electrical technology (Keller 1981). As Keller (1981: 414) noted, "Some argue science and technology have now become almost identical. Fundamental research depends on technological apparatus, technology rapidly applies the discoveries of science, and indeed now feeds on its own science… so the same developments—nuclear power, antibiotics, space exploration—can now be regarded as scientific or technological, according to the point of view."

Many scientists now work for corporations, government agencies, and other institutions that have clearly identified goals that indicate what the likely applications of their research will be. Most of the technological progress accounting for increasing economic productivity, for example, results from corporate research and development (Rostow and Kennedy 1990). Botkin (2001: 95) noted, "A strong case can be made that the motivation for much significant fundamental science comes from attempts to solve practical problems." There are few scientists today, even those most removed from institutions of direct application, who do not have some

Salmonid knowledge has long resulted in the transfer of resources from the open seas to humans.

understanding of the potential uses of their research results. In fact, few are more privy to the potential uses than those who conduct the research.

The question of what is moral is itself a philosophical topic, but there are situations that leave little to doubt. For example, if a scientist was asked by a dictator intent on genocide to conduct research specifically designed to enhance the killing capacity of a chemical weapon, who would not argue that the scientist has a moral obligation to decline? Although the morality of a decision is rarely so inarguable, few realists would deny that science has a moral obligation to serve the human condition, or at least to avoid degrading the human condition.

To the moral realist, the American people have a social contract with the polity to be governed consistent with the principles of democracy (Lineberry 1980). Furthermore, just as some political scientists (e.g., Schneider and Ingram 1997) view serving democracy as an omnibus role for public policy, some philosophers of science (e.g., Feyerabend 1978, Popper 1992) view serving democracy as an omnibus role for science. One of the bedrock principles of democracy is majority rule (Lineberry 1980). The opinion of the majority is one method with which to gauge the ability of scientific endeavors to serve the human condition.

The application of moral philosophy to science via the democratic principle of majority rule can be ascertained by considering public opinion, including public opinion on species conservation. For example, an overwhelming majority (84%) of Americans want the Endangered Species Act to be retained as written or strengthened to protect more species (Czech and Krausman 1999). Americans value the conservation of nonhuman species just as highly as economic growth or property rights (Czech and Krausman 1999). On moral grounds, then, scientists have an obligation to society to conduct research that would protect nonhuman species from endangerment, or at least to refrain from conducting research that would clearly have the effect of endangering nonhuman species.

Of course, the morality of a research program with the potential to endanger a nonhuman species can be difficult to ascertain relative to the aforementioned case of chemical weapon production. Americans are democratic but not biocentric (Kellert 1996, Czech et al. 1998), so the species to be endangered has to be considered in its societal context. For example, if a geological research facility were constructed on a restive volcano near a heavily populated area, endangering an endemic species of fly in the process, neither the American public nor the typical scientist would view the research program as immoral. If it were a research facility designed to produce a better-selling hamburger and its construction entailed the destruction of the last whooping crane (*Grus americana*) nest, presumably the opposite judgment would prevail.

One thing that distinguishes virtually all philosophies of science from philosophies at large is that one cannot prove one's ontological belief. Therefore, even for extreme constructivists with no belief in reality independent of mind, there are moral grounds for proceeding as if reality exists independently. Whether the practitioner perceives morality as idealistic or realistic is a matter of ontological philosophy; what constitutes moral practice in either case is a matter of moral philosophy. The position adopted hereon is that morality is independent of ontology, that serving the human condition (whether that condition be independently real or mentally constructed) is moral, and that decisions about the morality of a scientific endeavor may be informed via democratic principles.

In summary, 1) certain aesthetic concerns may be incorporated readily into the philosophy of science, 2) scientists along the entire ontological spectrum have moral grounds for striving to improve the human condition, 3) producing knowledge in the service of interests that harm the human condition is immoral, 4) producing knowledge for its own sake is amoral at best, and, 5) producing knowledge for its own sake may be immoral when the resources invested in producing such knowledge may instead be used to produce knowledge for the sake of improving the human condition.

Categories of human knowledge

Popper was perhaps more open-minded than most scientists when he stated, "I regard scientific knowledge as the best and most important kind of knowledge we have—though I am far from regarding it as the only one" (1992: 3). Other forms of human knowledge generally recognized by philosophers include mathematical proof, memorized experience, common sense, and intuition (Schlick 1974, Gallagher 1982, Popper 1992). There also are metaphysical claims to knowledge (Medawar 1984, Oelschlaeger 1994). Even art has been classified as a "mode of knowing" (Bruner 1979:59). There are no clear guidelines to prioritize or legitimize any of these potential ways of knowing, nor is knowledge equivalent to wisdom, which connotes the use of knowledge for the betterment of the human condition. As a method to acquire knowledge, however, science does have one clear advantage: it is the systematic use of rational self-criticism (Popper 1992).

The various forms of knowledge tend to predominate in proportions characteristic of cultures and historical settings (Hargrove 1984, McCarthy 1996). For example, metaphysical knowledge tends to predominate in pre-industrial, tribal societies, while scientific knowledge is most prominent in Western industrialized cultures (Zerner 2000). The development of culture and the acquisition of knowledge are interdependent and mutually deterministic processes and economic forces appear to be foremost in shaping cultures and knowledge sets (Cameron 1989, Kingdon 1993).

Scientific knowledge in Western society is the form of human knowledge associated with the most powerful technologies. Scientific knowledge tends to increase material production via the "technological imperative," which "implies that the invention of a new technique demands its adoption and development, and although there are countless examples of 'useless' inventions that no one wants and which are not developed but fade away, the general tendency has been to pursue possible developments for their own sake" (Shallis 1984: 64). As Pacey (1983: 79) noted, the technological imperative results in "the greatest feat of technical performance or complexity which is currently available."

The concept of the technological imperative may be extended beyond reason. For example, there would be scant rationale for positing that the most complex mousetrap possible will become the predominant mousetrap. To the extent that a technological imperative exists, it is continually subject to economic forces. The classical philosophers of political economy, including Adam Smith, Thomas Malthus, and Karl Marx, pointed out that new technology will be used continually for the sake of economic growth in Western societies and that economic pressures will drive science incessantly toward the development of technologies that are capable of greater productive efficiency (Rostow and Kennedy 1990). Presumably the same economic pressures result in an increase of the proportion of scientific to other forms of knowledge because of the greater propensity of scientific knowledge to produce the most powerful technologies. Whether science fulfills a technological imperative in fatalistic fashion or contributes to economic growth via carefully selected technologies, it has dramatic effects on nonhuman knowledge in the process. Following the next section, these effects will be considered further along with the implications for a holistic philosophy of science.

Pertinence and properties of nonhuman knowledge

Assuming that the goal of science is to construct knowledge for the purpose of improving the human condition and not for the sake of knowledge itself, then logically it is likewise to prevent the diminution of knowledge that supports that condition. However, humans do not have a monopoly on knowledge, cognition, or intelligence (Allen 1997). The chimpanzee (*Pan troglodytes*) selecting its diet, the black bear (*Ursus americanus*) seeking a cave in which to hibernate, and the arctic tern (*Sterna paradisaea*) navigating from pole to pole—all have the knowledge required to complete their tasks successfully. Natural selection has apparently endowed all animals with knowledge, albeit with varying levels of awareness and intelligence (Pearce 1997).

Nonhumans do not have human reasoning power. Even if they did, they might interpret things differently. Hayles (1995: 50) rationalized that, "… a frog gifted with Newton's reasoning power but with a consciousness constituted through a frog's sensory equipment would have drawn very different conclusions than Newton did from being hit on the head with an apple." Empirical realists would probably argue that Newton's law of gravity has endured a great deal of falsification efforts. It is clear, however, that nonhumans possess cognitive powers unavailable to humans. Were a human mind suddenly equipped with a salmon's body and submerged in the Bering Sea, it might never find the correct spawning stream at the correct time. A human mind equipped with a bee's body would be dumbfounded by the vast array of floral morphologies to land on and extract nectar from. A human mind equipped with a mountain lion's (*Puma concolor*) body would not know how to effectively stalk and prey upon a deer. It could probably acquire this knowledge through learning, perhaps quickly, but these mind–body combinations are surreal. Nonhumans have knowledge that humans will never acquire.

Nonhuman knowledge has some unique properties, from a human perspective. Like human knowledge (with the apparent exception of mathematics), nonhuman knowledge cannot be proven. Unlike human knowledge, however, nonhuman knowledge cannot be falsified, because no hypotheses are communicated and thereby made available for testing. For example, when a gray whale (*Eschrichtius robustus*) is beached, a human cannot assume that the whale's knowledge of tidal phenomena was disproved, because the human cannot know what the whale's intent was. Exceptions may occur as humans learn to communicate with nonhumans.

Non-falsifiability renders the hypothetico-deductive scientific method inapplicable to nonhuman knowledge. That does not make nonhuman knowledge worthless to science; even leading physicists have knowledge that is untestable. For example, developers of superstring theory have been unable to communicate their knowledge in ways that allow hypothesis testing (Horgan 1996). This problem can be blamed on a lack of communication skills or on a lack of intelligence among other scientists. The same problems exist in the communication of knowledge between humans and nonhumans. However, while the supposed knowledge of superstrings amounts to a rationalistic faith, the fact that animals have empirical knowledge is unquestionable (Pearce 1997).

To this point, a philosophy common to Toulmin (1975), Feyerabend (1978), Proctor (1991), and Popper (1992) has been supported—i.e., that science is subject to a Baconian moral of serving the human condition. However, the properties of nonhuman knowledge are pertinent to amoral philosophies of science, too. If knowledge is to be constructed "for its own sake," perhaps nonhumans are best suited for the project, because neither the development nor the application of nonhuman knowledge is politically motivated. The volume of nonhuman knowledge grows via molecular evolution and experience, with no disembodied storage (e.g., libraries, magnetic tapes, silicon chips), because it escapes expression in human terms. It cannot be distorted by faulty editing or misquoted by unscrupulous authors, as human knowledge can (Toulmin 1975, Feyerabend 1978). In a sense, then, nonhuman knowledge is the purest form of knowledge on earth. The remainder of this article, however, proceeds from a philosophy of science that is noncommittal ontologically and epistemologically but is committed to the construction of knowledge for the sake of improving the human condition. Most importantly, this philosophy recognizes the contribution of nonhuman knowledge to total knowledge. The aesthetics of this philosophy prescribe the protection of nonhuman species, but this aspect shall not be further developed and it must be acknowledged that other sources of aesthetic value exist. The task immediately ahead is to integrate the moral component of this philosophy with the existence of nonhuman knowledge.

Nonhuman knowledge and the human condition

Much nonhuman knowledge is used in unwitting support of the human condition (Mercuro et al. 1994). The bees that fertilize our orchards and the nematodes that aerate our soil have the knowledge, in tandem with the anatomy and physiology, to conduct services vital to human economy. For example, the annual value of pest-control services conducted by nonhuman species has been estimated at $54 billion (Naylor and Ehrlich 1997). The application of human knowledge has transformed many ecosystems, however, into pesticide-maintained monocultures in which the nonhuman knowledge and physical capital comprising the nonhuman pest-control system has been lost. These areas tend to exhibit declining productivity and debilitating processes like soil erosion and flash flooding. Integrated pest management is an attempt to re-employ nonhuman knowledge in combination with human knowledge to produce more effective pest-control systems (Braden 1979).

Other species have knowledge that is transformed directly into human goods. For example, the knowledge possessed by several anadromous salmonids enables them to hatch in mountain streams of the Northwest, fill a foraging niche in the Pacific Ocean, and find their way back to spawn years later. That knowledge has long brought resources of the open sea to native peoples on the mainland in the form of nourishing and palatable salmon flesh (Barker 1993). Vast applications of human engineering and agricultural knowledge, however, have decimated much of the salmonid knowledge and rendered much of the surviving salmonid knowledge inapplicable (Huntington et al. 1996). Now, vast applications of human knowledge are employed in an urgent attempt to restore the production that once flowed freely from nonhuman knowledge (Bugert 1998).

Nonhuman knowledge has another value for humans. Although we do not communicate directly with other species, we can learn from them (Graham 1981). Pre-agricultural humans could follow the bear in spring to learn where tubers and salmon were abundant and in fall to learn the whereabouts of berries and mast. A modern human equipped with radiotelemetry can do the same and more efficiently. Human techniques for learning have changed, as has the bear's knowledge, but the relationship has not. Nonhuman species possess knowledge that helps humans build their own knowledge.

Neither scientists nor philosophers have addressed the balance between human and nonhuman knowledge, but this balance is important to the sum of total knowledge, which is important to all philosophers of science. For example, to maximize the body of nonhuman knowledge, the logical strategy would be humanicide, which would allow nonhuman species to reclaim vast stores of natural capital (e.g., forests, grasslands, rivers) needed to retain knowledge and develop more knowledge via evolution. But that would minimize the body of human knowledge. Human knowledge, on the other hand, could be maximized in the short term via massive liquidation of natural capital. The money derived could be spent on science. But that would deplete the body of nonhuman knowledge upon which the human condition depends. If the depletion proceeded far enough, the economic foundation of human endeavors, science included, would crumble.

If we could quantify knowledge, perhaps formulae could be derived to guide us in balancing human and nonhuman knowledge. For example, human knowledge may constitute a sigmoid function similar to populations of K-selected animal species (Caughley and Sinclair 1994). It would proliferate as humans, in possession of abundant natural capital, expanded exponentially and practiced science proportionately. As they reached carrying capacity (K), however, their efforts would become increasingly focused on nourishment, whereas research and other formal pursuits of knowledge would become a luxury. Thus, human knowledge could conceivably reach a steady, stationary state. Horgan (1996), in fact, reached this conclusion using nondemographic rationale.

If humans behaved demographically as an r-selected species (Caughley and Sinclair 1994), human knowledge could likewise follow suit. As the human population grew at an increasing rate and overdrew natural capital accounts, institutions of knowledge (e.g., libraries and universities) would fall into disrepair. Because natural capital depletion would result in the extinction of many species, however, much nonhuman knowledge would disappear as well. Total knowledge would decline precipitously.

Total knowledge, human economy, and Baconian morality

According to neoclassical economic theory, a simple (albeit materialistic) way to gauge the human condition is by the number of people and their per capita consumption. At a given level of population, increases in per capita consumption imply a better human condition (Heilbroner and Thurow 1987). This hypothesis is founded upon the rationale that, at a given level of per capita consumption (assuming that the level sustains people comfortably), increases in population allow the expansion of the total amount of human comfort experienced (Simon 1996). The human condition, then, can be gauged by the scale of human economy—i.e., the product of population size and per capita consumption. But the size of the economy is a function of the human:nonhuman knowledge ratio. There can be no human economy with zero human knowledge, and there can be no human economy with zero nonhuman knowledge. Presumably a ratio of human:nonhuman knowledge exists that optimizes the human condition. The optimal ratio probably changes over time, as a function of technological and biological evolution.

Knowledge defies precise measurement; Popper's (1965) "infinity of ignorance" prevents us from calculating total knowledge at various human:nonhuman ratios. We can, however, identify 2 extremes. The maximization of natural capital stocks and nonhuman knowledge would require a human population of zero. That would set the ratio of human economy to total knowledge equal to zero and is obviously a prospect to avoid from the perspective of the human condition. At the other extreme, maximization of the human:nonhuman knowledge ratio would court r-selective human demography and a breach of carrying capacity.

If it were possible to liquidate all natural capital (including all nonhuman habitats and therefore all other species) to obtain funding for research, the human:nonhuman knowledge ratio would become a non-number as nonhuman knowledge would disappear. This mathematical nullity may imply that comprehensive consumption is impossible, but it does not preclude severe environmental and economic deterioration via extensive application of human knowledge.

Because of the impossibility of measuring knowledge and quantifying the optimum human:nonhuman knowledge ratio, perhaps the best strategy is to avoid the more apparent extremes of the human economy:total knowledge spectrum. In the face of uncertainty, we may continually assess which extreme we are closest to and move away from it. Applying this strategy to the present, we are nowhere near the extreme of zero human economy; human production and consumption is at an all-time high (Heilbroner and Thurow 1987). There are signs that we are near the extreme of unsustainably large human economy, however, including natural capital shortages and health problems associated with pollution (Goodland 1992, Jansson et al. 1994). This indicates that the ratio of human economy to total knowledge is too high.

The increasingly unsustainable ratio of human economy to total knowledge begs a simpler question about the human:nonhuman knowledge ratio than the question of its precise measure: i.e., which component is lacking, human or nonhuman? As with human economy, human knowledge is at an all-time high due to the proliferation of science (Sussman 1975, Horgan 1996). This situation in combination with another sign, unprecedented species endangerment (National Research Council 1995), readily identifies nonhuman knowledge as the lacking component of total knowledge. This interpretation is further supported by the fact that nearly all species endangerment today is a function of human economy (Czech et al. 2000).

Conclusion

To serve the sum of knowledge and the human condition, the goal of science should be expanded from the construction of human knowledge to include preventing the destruction of nonhuman knowledge. Nonhuman knowledge is often used in the unwitting betterment of the human condition, and the benefits to humans often go unnoticed until the knowledge has been destroyed. Nonhuman knowledge may be more important to protect than human knowledge, because most human knowledge may presumably be reproduced by the human mind, whereas nonhuman knowledge cannot.

The construction of human knowledge requires natural capital, which comprises habitat for nonhuman species (Czech 2000). Therefore, in an epistemological application of the ecological principle of competitive exclusion, human knowledge and the application thereof is obtained at the expense of nonhuman knowledge. From the perspective of Baconian morality, a certain amount of trade-off is good. But human knowledge has cost enough natural capital to throw it out of balance with nonhuman knowledge; now both are in danger. Ecological economists are documenting theoretical and empirical evidence in support of this conclusion (Krishnan et al. 1995).

Now is the time for philosophers and scientists from all disciplines to unite and defend the foundation of nonhuman knowledge that supports our house of human knowledge. Such a unified defense will not materialize from perpetual ontological and epistemological colloquy. A holistic philosophy of science that recognizes the contribution of nonhuman knowledge, embraces the moral virtue of advancing the human condition, and protects the aesthetic values of nonhuman species could, on the other hand, constitute the front line.

Acknowledgments. I thank Margo Martinez, Paul R. Krausman, Bill Mannan, and the late Gene Maughan for encouragement and thought-provoking discussion pertaining to the incorporation of nonhuman knowledge into the philosophy of science.

Literature cited

ALLEN, C. 1997. Species of mind: the philosophy and biology of cognitive ethology. Massachusetts Institute of Technology, Cambridge, USA.

BARKER, R. 1993. Saving all the parts: reconciling economics and the Endangered Species Act. Island, Washington, D.C., USA.

BORGMANN, A. 1995. The nature of reality and the reality of nature. Pages 17–30 *in* M. E. Soulé and G. Lease, editors. Reinventing nature?: responses to postmodern deconstruction. Island, Washington, D.C., USA.

BOTKIN, D. B. 2001. No man's garden: Thoreau and a new vision for civilization and nature. Island, Washington, D.C., USA.

BRADEN, L. 1979. Integrated pest management in the developing world. Annual Review of Entomology 24: 225–254.

BROWN, M. B. 1990. Models in political economy: a guide to the arguments. Second edition. Penguin, London, United Kingdom.

BRUNER, J. S. 1979. On knowing: essays for the left hand. Belknap, Cambridge, Massachusetts, USA.

BUGERT, R. M. 1998. Mechanics of supplementation in the Columbia River. Fisheries 23(1): 11–20.

CAMERON, R. 1989. A concise economic history of the world: from Paleolithic times to the present. Oxford University, Oxford, United Kingdom.

CAUGHLEY, G., AND A. R. E. SINCLAIR. 1994. Wildlife ecology and management. Blackwell Scientific, Boston, Massachusetts, USA.

CZECH, B. 2000. Economic growth as the limiting factor for wildlife conservation. Wildlife Society Bulletin 28: 4–14.

CZECH, B., AND P. R. KRAUSMAN. 1999. Public opinion on endangered species conservation and policy. Society and Natural Resources 12: 469–479.

CZECH, B., P. R. KRAUSMAN, AND R. BORKHATARIA. 1998. Social construction, political power, and the allocation of benefits to endangered species. Conservation Biology 12: 1103–1112.

CZECH, B., P. R. KRAUSMAN, AND P. K. DEVERS. 2000. Economic associations among causes of species endangerment in the United States. Bioscience 50: 593–601.

FEYERABEND, P. 1978. Science in a free society. NLB, London, United Kingdom.

FOGELIN, R. J., AND W. SINNOTT-ARMSTRONG. 1991. Understanding arguments: an introduction to formal logic. Harcourt Brace Jovanovich, San Diego, California, USA.

GALLAGHER, K. T. 1982. The philosophy of knowledge. Fordham University, New York, New York, USA.

GOODLAND, R. 1992. The case that the world has reached limits: more precisely that current throughput growth in the global economy cannot be sustained. Population and Environment 13(3): 167–182.

GRAHAM, L. R. 1981. Between science and values. Columbia University, New York, New York, USA.

HARGROVE, B. 1984. Religion and the sociology of knowledge: modernization and pluralism in Christian thought and structure. E. Mellen, New York, New York, USA.

HAYLES, N. K. 1995. Searching for common ground. Pages 47–63 *in* M. E. Soulé and G. Lease, editors. Reinventing nature?: responses to postmodern deconstruction. Island, Washington, D.C., USA.

HEILBRONER, R. L., AND L. C. THUROW. 1987. Economics explained, second edition. Simon and Schuster, New York, New York, USA.

HO, E. Y. C., AND P. C. LUND. 1994. Sir Karl Raimund Popper: in memorium. Intellectus (Bulletin of Hong Kong Institute of Economic Science) No. 31: 1–3.

HORGAN, J. 1996. The end of science: facing the limits of knowledge in the twilight of the scientific age. Addison-Wesley, Reading, Massachusetts, USA.

HOYNINGEN-HUENE, P. 1989. Idealist elements in Thomas Kuhn's philosophy of science. History of Philosophy Quarterly 6: 393–401.

HUNTINGTON, C., W. NEHLSEN, AND J. BOWERS. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3): 6–14.

JANSSON, A. M., M. HAMMER, C. FOLKE, AND R. COSTANZA, editors. 1994. Investing in natural capital. Island, Washington, D.C., USA.

KELLER, A. G. 1981. Technology. Pages 412–414 *in* W. F. Bynum, E. J. Browne, and R. Porter, editors. Dictionary of the history of science. Princeton University, Princeton, New Jersey, USA.

KELLERT, S. R. 1996. The value of life. Island, Washington, D.C., USA.

KINGDON, J. 1993. Self-made man: human evolution from Eden to extinction? John Wiley and Sons, New York, New York, USA

KRISHNAN, R., J. M. HARRIS, AND N. R. GOODWIN, editors. 1995. A survey of ecological economics. Island, Washington, D.C., USA.

KUHN, T. 1996. The structure of scientific revolutions. Third edition. University of Chicago, Chicago, Illinois, USA.

LINEBERRY, R. L. 1980. Government in America: people, politics, and policy. Little, Brown, and Company, Boston, Massachusetts, USA.

MCCARTHY, E. D. 1996. Knowledge as culture: the new sociology of knowledge. Routledge, London, United Kingdom.

MEDAWAR, P. 1984. The limits of science. Oxford University, Oxford, United Kingdom.

MERCURO, N., F. A. LÓPEZ, AND K. P. PRESTON. 1994. Ecology, law and economics: the simple analytics of natural resource and environmental economics. University Press of America, Lanham, Maryland, USA.

NAYLOR, R. L., AND P. R. EHRLICH. 1997. Pages 151–174 *in* G. C. Daily, editor. Nature's services: societal dependence on natural ecosystems. Island, Washington, D.C., USA.

NATIONAL RESEARCH COUNCIL. 1995. Science and the Endangered Species Act. National Academy, Washington, D.C., USA.

OELSCHLAEGER, M. 1994. Caring for creation. Yale University, New Haven, Connecticut, USA.

PACEY, A. 1983. The culture of technology. Basil Blackwell, Oxford, United Kingdom.

PEARCE, J. M. 1997. Animal learning and cognition: an introduction. Second edition. Psychology, East Sussex, United Kingdom.

POPPER, K. R. 1965. Conjectures and refutations; the growth of scientific knowledge. Basic, New York, New York, USA.

POPPER, K. R. 1992. In search of a better world: lectures and essays from thirty years. Routledge, New York, New York, USA.

PROCTOR, R. N. 1991. Value-free science?: purity and power in modern knowledge. Harvard University, Cambridge, Massachusetts, USA.

ROSTOW, W. W., AND M. KENNEDY. 1990. Theorists of economic growth from David Hume to the present: with a perspective on the next century. Oxford University, New York, New York, USA.

SCHLICK, M. 1974. General theory of knowledge. Springer-Verlag, New York, New York, USA.

SCHNEIDER, A. L., AND H. INGRAM. 1997. Policy design for democracy. University Press of Kansas, Lawrence, USA.

SHALLIS, M. 1984. The silicon idol: the social implications of the micro revolution. Oxford University, Oxford, U.K.

SHEPARD, P. 1995. Virtually hunting reality in the forests of Simulacra. Pages 17–30 *in* M. E. Soulé and G. Lease, editors. Reinventing nature?: responses to postmodern deconstruction. Island, Washington, D.C., USA.

SIMON, J. L. 1996. The ultimate resource 2. Princeton University, Princeton, New Jersey, USA.

SISMONDO, S. 1996. Science without myth: on constructions, reality, and social knowledge. State University of New York, Albany, New York, USA.

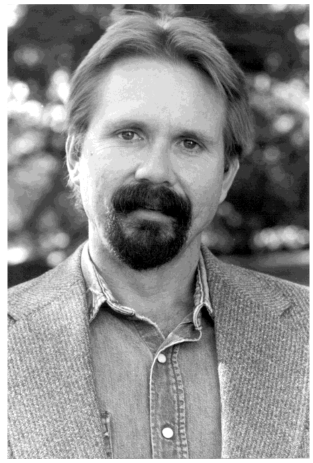
SOULÉ, M. E., AND G. LEASE, editors. 1995. Reinventing nature?: responses to postmodern deconstruction. Island, Washington, D.C., USA.

SUSSMAN, M. B. 1975. The standard of value and role of knowledge in society. Pages 35–44 *in* International Cultural Foundation, editor. The centrality of science and absolute values (Volume 1). International Cultural Foundation, Tarrytown, New York, USA.

Toulmin, S. E. 1975. The twin moralities of science. Pages 111–123 *in* N. H. Steneck, editor. Science and society: past, present, and future. University of Michigan, Ann Arbor, USA.

Wolf, A. 1925. Essentials of scientific method. G. Allen and Unwin, London, United Kingdom.

Zerner, C. 2000. People, plants, and justice: the politics of nature conservation. Columbia University, New York, New York, USA.



Brian Czech is a conservation biologist with the United States Fish and Wildlife Service, National Wildlife Refuge System Headquarters. He is a certified wildlife biologist with 15 years' experience in federal, tribal, and state government. He has a B.S. in wildlife ecology from the University of Wisconsin-Madison, an M.S. in wildlife science from the University of Washington, and a Ph.D. in renewable natural resources from the University of Arizona. He is the author of Shoveling Fuel for a Runaway Train: Errant Economists, Shameful Spenders, and a Plan to Stop Them All and, with Paul R. Krausman, The Endangered Species Act: History, Conservation Biology, and Public Policy.