

**LAMARCK REDUX:
TEMPORAL SCALE AS THE KEY TO THE BOUNDARY
BETWEEN THE HUMAN AND NATURAL WORLDS**
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The Spatial Bias of the Boundary Idea in Western Thought

Arguably the most ancient concern in Western philosophy is boundaries and the lack thereof. Inferring from his answer, Thales—according to Aristotle, the first person to concern himself with questions about nature instead of the gods—posed the first (implicit) question of Western philosophy: Of what is the world composed? His successor, Anaximander, rejected Thales's answer, Water, in favor of what he called the **apeiron**. This word is formed from **peras**, meaning *end, limit, or boundary*, in combination with the alpha privative (**a-**) meaning *-less, un- or non-*. That out of which everything else is composed, the stuff of the world, the cosmic **arch**, is, according to Anaximander at the dawn of Western philosophy, the **apeiron**, the endless, the unlimited, the unbounded. This word, pregnant with so much significance, is often anachronistically mistranslated as the “infinite.” The idea of a spatially infinite substance could only arise a century later in dialectical response to conundrums proffered by Parmenides and Zeno. Though we can never know for sure, Anaximander probably meant to suggest that unlike a common substance—such as water, which is wet, or air, which is dry—the **arch** can have no definite qualities and that it was homogeneous. The **arch** must be **apeiron**, that is, an indefinite stuff without internal boundaries.

Being alive and divine, Anaximander's **apeiron** began to move itself in a swirl, or vortex motion, and thereafter more definite stuff—the hot, the cold, the wet, and the dry—“separated out” of it. These more definite substances—later concretized by Empedocles as fire, earth, water, and air, respectively—were gathered, like to like, into regions. Earth collected in the center of the swirl, surrounded by a hydrosphere, an atmosphere, and a pyrosphere. Naively experiencing our world, unprejudiced by postcopernican astronomy and geography, we do indeed observe the primary substances of the world to be internally bounded, albeit porously and imperfectly, in just such a way. Thus, at the inception of systematic Western thought about nature, it seems that what was believed to be essential to the formation of a **kosmos**—a beautiful world order—is the establishment of **perata**, boundaries. Indeed, the good left hand column of the Pythagorean Table of Opposites begins with **peras** opposed, in the bad right hand column, by **apeiron**. The Limit and the Unlimited, the Boundaried and the Unboundaried are, for the most ancient of Western philosophers, the first, the most primitive of cosmic principles.¹

Thus in Western philosophical thought, as in contemporary political thought, the concept of a boundary is primarily spatial, even more particularly geographical. In the latter, the political context, when we hear “boundary” we are liable first to think spatially of frontiers, borders—often defined geographically by rivers, mountain ranges, sea coasts—that separate nation-states from one another. Crossing or penetrating boundaries strongly suggests, though it certainly does not actually entail, locomotion—that is, motion from one spatial/geographical location to another. But then we extend the originally spatial idea of boundary metaphorically. By means of a delicate nonverbal social dance casual friends establish boundaries between themselves. More intimate friends may actually negotiate the boundaries of their relationship; for example, love making may be across the border. A primary objective of the ideology of identity is to define the boundary of the group—American Indian, African American, Hispanic, Latino/a, Chicano/a, Gay, Lesbian—who is in and who is out. Such are political boundaries of another kind, internal to nation-states. Sometimes hardening the

boundaries of identity politics threatens to fragment nation-states into quasi- or fully independent territories, even new states. The Basque independence movement in Spain and the Kurdish independence movement in Turkey and Iraq are examples; and today we hear much about the possibility of a new Palestinian state. In such cases the metaphorical boundaries of identity are translated into paradigmatic spatial/geographical boundaries.

Thus there remains, at least as I register it, a spatial/geographical residue, in all such metaphorical extensions of the boundary idea. The boundaries of identity politics *in extremis* become lines drawn on a map and fences and check-points and border crossings on the ground. But even when political identity does not run to such extremes, metaphorical boundaries are translated into paradigmatic spatial boundaries. In Beirut a "green line" separates Muslim from Christian quarters of the city. In every metropolis in the United States there is the ghetto, the barrio, the hood, the gay district. The boundaries achieved by casual friends may be defined in part spatially—meeting, for example, only in public spaces, such as cafes and restaurants, rather than in the privacy of their homes. More intimate friends may agree not to transgress sexual boundaries, which are more or less coincident with the erogenous zones and can be anatomically mapped. The spatial boundaries between states may shift with the meandering river separating them or with the *de facto* loco-movement of peoples from one territory of a state to that of another, as Albanians eventually displaced Serbs in Kosovo and Mexicans are displacing Anglos on the US side of the Rio Grande in Texas. So may those separating identity groups, as gays and lesbians, for example, unite with one another and with bi- and trans-sexuals. And so may those between friends as their relationship evolves or changes.

Here I depart from the deeply ingrained spatiality of the boundary idea in Western thought—with all its permutations and metaphorical extensions—and explore ways in which temporal scale creates boundaries that we may not be prepared to recognize as such (precisely because of the deep spatial bias in our boundary thinking). Sometimes, indeed, temporal scale creates spatial boundaries, but often it creates boundaries of a very different kind. My ultimate goal is to resolve a contemporary conundrum of environmental philosophy. Are we human beings set apart from nature by some kind of boundary? Or are all such putative boundaries between people and nature but obsolete theological and philosophical fictions? I argue that *Homo sapiens* is a natural species, but also that, while *Homo sapiens* and human culture evolved in a Darwinian manner, the emergence of culture as a biological adaptation has caused human evolution to take a quantum leap, to use an overworked metaphor, into a novel Lamarckian evolutionary orbit. And I argue that the temporal scale of the Lamarckian evolutionary ambit in which *Homo sapiens* now adapts to and transforms the natural environment creates a boundary between our species and all the others—that is, a boundary between us human beings and the rest of nature. I start with a contemporary classic discussion in ecology of how spatial boundaries emerge at the interface of temporal scales.

How Spatial Boundaries Emerge at the Interface of Temporal Scales

In a deservedly famous paper, "Cross-scale Morphology, Geometry, and Dynamics of Ecosystems," C. S. Holling sets out to explain a curious phenomenon of nature. The body masses of terrestrial birds and mammals, irrespective of cardinal guild (that is, whether the animals are herbivores, omnivores, or carnivores), are "clumped." In other words, there are gaps in the distribution of their sizes. Or, put the other way around, their body masses cluster around certain values. In the plainest of terms, the sizes of birds and mammals are not distributed evenly from small to large; rather, they come in

eight basic sizes—from very small (hummingbirds and chickadees) to small (wrens and sparrows) to several classes of medium (robins, bluejays, crows) to large (hawks and owls) to very large (egrets, herons, cranes, flamingoes). Thus we may say that there are boundaries between the sizes of birds and mammals. Holling argues that these boundaries exist because animals are adapted to discontinuous small, medium, and large home-range ecosystems that are hierarchically ordered—that is, the small-scale ecosystems are nested into the medium and the medium into the large-scale. Animals adapted to the inner, small-scale ecosystems in the hierarchy cluster around the small-size values; those adapted to the mid-size ecosystems, which comprise a number of smaller ecosystems, cluster around the mid-size values and those adapted to the large-size ecosystems that comprise a number of mid-size ecosystems cluster around the large-size values.

Ecosystems, however, are not constituted by an interacting suite of organisms, but by a linked suite of processes. Organisms, rather, carry out some ecosystem processes, such as photosynthesis and nutrient cycling. Because they are composed of processes, not organisms, the boundaries of ecosystems are determined by the frequency or temporal scale of the processes that compose them. As Holling puts it, “The landscape is hierarchically structured by a small number of structuring processes into a number of nested levels, each of which has its own physical textures and temporal frequencies. That is, the processes that generate discontinuous time dynamics also generate discontinuous physical structure.”² Thus, the temporal scale of ecological processes determines the spatial scale of habitats and the boundaries between them, which in turn determines the boundaries between the body sizes of birds and mammals.

According to Holling, the way animals perceive their environments plays a critical role in the evolutionary selection of their size category: “A hierarchical organization in a landscape generates abrupt shifts in the kind, distances, and size of objects when the grain of measurement reaches a value that aggregates objects into a new set of objects in a new hierarchical level. Since the size of an animal defines the grain of its measurement, then a body-mass gap exists at those sizes and sampling grains where there is an abrupt transition in the attributes of objects (their size and inter-object distance) between two hierarchical levels”³ By way of illustration—mine, not Holling’s—a mouse may be able to see individual trees, but not a patch of woods; whereas a squirrel can see not only individual trees, but patches of woods, and determine whether the distances between woody patches is close enough to attempt safely to run between them. A coyote can not only see but mentally map a congeries of landscapes, each of which is composed of multiple patches. The discontinuity between the sizes of “objects” at these several hierarchical levels—trees at one level, woody, grassy, and shrubby patches at the next level up, and the landscape composed of many patches of different kinds at the next level up from that—is mirrored by the discontinuity of the sizes of animals.

Identifying Temporal Scales of Interest to Ecological Philosophy

We live in a world riddled with processes going on at various temporal scales some of which structure our lives in important ways and some of which do not. The diurnal cycle—the alteration of night and day—structures almost everyone’s life in extremely important ways. The four-year cycle of the Olympic games structures the lives of Olympic athletes and trainers, and the planners, vendors, and so on who are professionally involved with the Games, while, for the rest of us, that cycle is of little structural importance for our lives and of only passing interest. Some of the important ways that processes going on at various temporal scales structure our lives are interesting for some purposes, but not for others. The roughly ten-year business cycle of

the US national economy—growth, punctuated by stagnation and recession—more or less structures the economic lives of every American and is thus of interest to contemporary American environmental philosophers, not, however, qua environmental philosopher, but qua consumer and future retiree. Finally, some processes going on at various temporal scales may not structure anyone's life in any appreciable way, but may be of interest nevertheless. The period of the orbit of Mars in relation to the orbit of the Earth may not structure anyone's life, but for centuries it has been of intense interest to astronomers.

Of interest to ecological philosophy, "At least six hierarchical levels can be identified, each of which is dominated by one category of structuring processes," according to Holling. Curiously, however, Holling goes on to identify only three: "The smaller and faster scales are dominated by vegetative processes, the intermediate by disturbance and environmental processes, and the largest and slowest by geomorphological and evolutionary processes."⁴ I will try to elaborate and refine Holling's insight.

The vegetative (organismic) temporal scale What are vegetative processes and what sort of temporal scales do they define? Obviously, first, there is photosynthesis, which occurs in the daylight hours and ceases at night. Also in temperate latitudes photosynthesis is seasonally pulsed. Thus there are growing seasons of varying length, followed by correlative dormant periods, on an annual cycle. Dead leaves and other detritus fall to the ground and are there decomposed by fungi, worms, and bacteria—also roughly on an annual cycle in temperate latitudes. If the patch is a woods, another important process is crown formation, which, depending on species and other factors may occur in one decade or several. This process scales up from annual vegetative processes by an order of magnitude. At the next order of magnitude, over about a century, depending on species, trees reach their maximum height, and may live for several more centuries.⁵

So the scale range of vegetative processes runs from the day long to the season long to the year long to the decade long to the century long up to and rarely exceeding the millennium long. Holling calls this temporal scale "vegetative," I surmise, because plants dominate the landscape and, as autotrophs, provide the basis of almost all Earth's trophic pyramids. More generally, we might call this the "organic" temporal scale and recognize our own lifetimes—now often lasting eight or nine decades—as spanning a significant portion of it.

The ecological temporal scale The next temporal scale range that Holling identifies he leaves un-named, but I suggest we call it the ecological temporal scale. One fundamental ecological process is succession. Suppose a forest patch is clearcut and left to recover on its own. The first to colonize the cleared ground would be sun-loving herbaceous annuals, followed by weedy perennials. After a decade or so these would be overtopped and replaced by short-lived brush, shrubs, and scrubby trees. After several decades the brush, shrubs, and scrubs would be replaced by longer-lived, taller trees. And over a period of centuries the forest would gradually change in composition as shade-tolerant tree species replaced species whose seeds cannot germinate under closed canopies. So, all told, the temporal scale of ecological succession runs from decades to several millennia.

Disturbance regimes also constitute an important set of ecological processes. In some ecosystems fires occur periodically: every decade or so, at the greatest frequency; every 20-50 years; every 200 years; it varies. Most riparian ecosystems are subject to flooding, often annually, but in some riparian ecosystems there are floods of greater magnitude that occur less frequently: once every fifty years, on average; once every hundred. Coastal plains are periodically disturbed by hurricanes, which come ashore

several times a year to the Atlantic and Gulf coasts of North America, but to the same swath only every hundred years or so, which is often enough to affect the composition of coastal biotic communities and the structure of coastal ecosystems. The North American plains are also subject to violent disturbance by wind. Tornadoes “fire up” (in the parlance of TV meteorologists) seasonally, beginning in late spring in the southern plains and migrating north through the summer months. Tornadoes may fire up and touch down on average several times a week through the season, but with surgical locality. To calculate the frequency with which a given ecosystem is ravaged by a tornado would and if it were frequent enough for tornadoes to be “incorporated” disturbances in plains ecosystems be interesting, just as some forested ecosystems have incorporated disturbance by fire and some riparian ecosystems have incorporated disturbance by flood. That is, do tornadoes—like periodic fires, floods, and hurricanes—constitute a disturbance *regime* on the North American plains?

Another periodic ecological process is population cycles in animals, which usually occur in periods not less than a decade nor more than several decades in length.

From these examples of important ecological processes—succession, disturbance regimes, population cycles—ecological temporal scales appear to range from periods of a decade to several thousand years.⁶

The evolutionary temporal scale It seems to me that Holling’s crude category of the “geomorphological and evolutionary” temporal scale should be divided in two and reversed in order as we move from consideration of smaller to larger temporal scales. How long does it take for species to evolve by natural selection? What is the natural life span—from origin to extinction—of a naturally selected species? The answer to these questions depends on the species. Some insects can segregate into races and evolve into full species in a few hundred generations in only ten years. A diatom endemic to Yellowstone Lake evolved from its parent (now sister) species over several centuries and has remained stable for 8,000 years. The charismatic megafauna on which so much conservation effort is lavished required hundreds of thousands of years to evolve into what they presently are. We *Homo sapiens* have remained anatomically and physiologically stable for somewhere between 100,000 and 200,000 years. The genus *Homo* has existed for somewhere between 1.5 and 2.5 million years. The 1,100 or so extant species of sharks have existed on average for about 100 million years. The average life span of a vascular plant species or vertebrate animal species is about a million years. So the evolutionary temporal scale (ignoring outliers such as rapidly evolving insects and the incredibly long-lived family of sharks) appears to range from 100,000 to several million years.⁷

The geomorphological temporal scale The temporal scale of geomorphology—the processes shaping the face of the Earth—is much greater still. By far the most potent earth-shaping process is plate tectonics, which is a manifestation of an even more fundamental geomorphological process, the rock cycle. The Earth’s lithosphere is broken into about fifteen plates which float on the denser molten material beneath them and move, relative to one another, in different directions. When these moving plates collide they cause continental plains to rise in elevation and, more extremely, for mountain ranges to thrust up. For example, the eastward moving Nazca plate colliding with the westward moving South American plate created the Andes; and the Himalayas were created by the north-eastward moving Indian-Australian plate colliding with the south-westward moving Eurasian plate. The plates move at rates of between 2 to 15 centimeters per year. At this pace, it takes about 15 million years to build a mountain range, such as the Sierra Nevada. At the boundary between colliding plates, such as the north-westward moving Pacific plate and the south-eastward moving

Eurasian plate, the heavier, lower-elevation rock of the oceanic plate is forced back down into the molten rock below, as the continental plate is lifted up.

Molten igneous rock oozing from ridges in the middle of the Atlantic, the eastern Pacific, the Indian and Southern oceans cooling and solidifying, forces the plates on either side to move in opposite directions. The elevated continental rocks weather—from the action of wind, water, and carbonic acid—creating sediments that gravity slowly carries into the oceans. It takes about 100 million years for a mountain range to erode away. Adding to the weathered sediments are calcium carbonate biosediments produced by shellfish and corals. These sediments accumulate and are compacted by more sediments washing in on top of them, eventually to form limestone and other sedimentary rocks. As the process of deposition continues, pressure and heat transform sedimentary into metamorphic rocks. This closely coupled set of process—spreading, plate movement, subduction, uplift, weathering, and sedimentation—constitutes a cycle in which the Earth's rocky mantle actually turns over completely. But the process is so slow that the Earth, in its 4.5 billion year existence, has only completed one full rock cycle. Thus the geomorphological temporal scale appears to range from hundreds of thousands to millions up to a couple billion years.⁸

The boundary at the interface of the geomorphological temporal scale of plate tectonics and the vegetative (or more generally organismic) temporal scale of human affairs is so profound that one pair of writers make it a joking matter: "The Pacific plate is moving north relative to the North American plate at a rate of approximately 5 cm/year. . . . As a result, Los Angeles, now more than 500 km south of San Francisco is moving slowly toward that city. If this motion continues, in about 10 million years San Francisco will be a suburb of Los Angeles."⁹ Of course in 10 million years, *Homo sapiens* will almost certainly be extinct and all traces of San Francisco and Los Angeles will have weathered away and washed into the eastern Pacific sediment basin. On the other hand, the boundary at the interface of the geomorphological and the organismic temporal scales is by no means impenetrable. For the inching northward of the Eastern Pacific plate against the North American along the San Andreas fault (the spatial boundary between the two) causes numerous earthquakes and occasional volcanic eruptions (such as the recent Mount Saint Helens eruption in Oregon) at frequencies that fall well within the range of the organismic temporal scale.

The climatic temporal scale Although not mentioned by Holling, the temporal scale of climate change should also be of particular interest to ecological philosophy. Especially important to the proliferation of biodiversity, which peaked in the Pleistocene, has been the cycle of glaciation and glacial interstadials during that geologic epoch—because a significant factor in speciation is geographic isolation. The isolation of continents and large islands produced by plate tectonics, for example, allowed very different fauna to evolve in the Americas, Australia, Eurasia and Africa—a case of interpenetration at the boundary of the geomorphological and evolutionary temporal scales. Glaciation driven by climate change has produced similar isolation as single species are driven into small unconnected refugia, by either the advance of glaciers or the associated desiccation of the climate, there to evolve independently into different species. In this instance, we have an interpenetration at the boundary between climatic and evolutionary temporal scales.

The major factor influencing global climate change appears to be changes in Earth's average temperature, which are notoriously unpredictable and may occur rather suddenly. For example, a sudden drop in temperature lasting 300 years—1550-1850 CE—had such an impact on the climate that it is sometimes called the Little Ice Age. It was too brief to have any notable evolutionary significance, but it may have lasted long

enough to have had some ecological significance. If so, in this instance, we have an interpenetration at the boundary between the climatic and ecological temporal scales.

What the Earth's climate was in the distant past is confounded by many uncertainties. It seems that during most of Earth's biography, global temperatures were probably warmer than they are presently. During the last billion years, it appears that glacial pulses began at roughly 925, 800, 680, 450, 330, and 2 million years BP. Of these pulsations, the most severe seems to be the one that began 800 million years ago, during which glaciers may have come within 5 degrees of the equator. The most recent glacial pulsation, the Pleistocene, began 2-3 million years ago and is characterized by four major long periods of glaciation—reaching 40 degrees latitude—punctuated by shorter interstadials. It began to end, if indeed it is ending, 14,000-16,000 years ago.¹⁰

So what are the parameters of the climatic temporal scale? Getting a grip on this temporal scale seems more complicated than getting one on the organismic, ecological, evolutionary, and geomorphological. For the concept of climate includes not only temperature, but rainfall and seasonality.

At its upper end, defined by slower and spatially global climate change—such as glacial advance and retreat—climatic temporal scale is easier to grasp. The Earth as a whole has no seasons and—assuming average constant elevation of land forms at the geomorphological temporal scale—global rainfall appears to be a function of global temperature. For more of the Earth's water is sequestered in glacial ice; less is evaporated from the diminished oceans; and the colder atmosphere holds less moisture. So when it gets cold enough for glaciers to advance, the global climate also gets drier. At the lower end of the climatic temporal scale and at regional spatial scales rainfall and seasonality greatly complicate the picture. The difference in the climate, for example, of Louisiana and West Texas is more a matter of rainfall than temperature. And the difference in the climate of Dallas Texas and Seattle Washington is more a matter of seasonality, for both receive about the same amount of annual rainfall.

Reflecting on its deep grammar, "climate" is not subject to annual fluctuation. For example, we might well say of the recent New England climate that it is characterized by long, cold winters, but not that it radically changes from winter to summer. Average global and regional temperatures do fluctuate slightly from year to year; and they do so noticeably from decade to decade. So does average regional rainfall. Still, we would not say that the New England climate has changed if several years of severe winters are followed by several years of mild winters or if several wet years are followed by several dry. But during the 300 years of the Little Ice Age, we would say that a change in the New England climate then occurred. So it seems that the bottom range of the climatic temporal scale is measured in centuries. The cycle of the glacial incursion and retreat during the Pleistocene occurred over thousands of years and may still be going on—that is, we may at present be living in an interstadial to be followed in the future by another more prolonged Ice Age. The cycle of Pleistocene-scale glacial pulsations occurred over millions of years. This suggests that the scale of global climate change is very broad and is itself hierarchical. At the base of the hierarchy are changes that register only after a century or more; still more severe fluctuations register after thousands of years; and so on, through several more orders of magnitude.

How Processes at Different Temporal Scales Interact at the Boundary

The world is dynamic at every temporal scale, but the processes occurring at slower temporal scales can be regarded as stable (unchanging) at the boundary or interface with processes occurring at more rapid temporal scales. For example, if an ecologist is studying the interacting population dynamics of snowshoe hare and lynx, both of which cycle, he or she may regard the altitude and latitude of his or her study areas to be

constant. Both are in fact changing. The altitude of Canada, where most lynx and snowshoe hare reside, is rising as the Earth's mantle rebounds from the weight of the glacial ice that burdened northern North America 14,000 years ago. But that climatic-geomorphological process is occurring at such a slow temporal scale that changes in elevation measured at the ecological temporal scale of population dynamics and the organismic temporal scale of the ecologist's research grant will be so slight as to be an insignificant factor for lynx-snowshoe hare population dynamics. Similarly, the North-American plate is moving and so the latitude of Canada is changing, but again, relative to ecological and organismic temporal scales, so slowly as to be of no more significance to ecology than the future proximity of Los Angeles and San Francisco is to the real estate industry.

Processes at slower temporal scales also constrain processes at faster temporal scales. For example, the relatively constant climate of a region constrains processes going on at the ecological scale in that region. In a region with, say, a four-season (spring, summer, fall, winter) temperate climate, the potential species diversity of biotic communities is more limited than in a region with a two season (wet and dry) tropical climate. And, for another example, processes occurring at ecological temporal scales constrain processes occurring at organismic temporal scales. In a locale with, say, a frequent fire regime (which is in turn climatically constrained) trees may be prevented from reaching maturity and reproducing.

Processes occurring at faster temporal scales are damped out before they reach distant boundaries; they do not cross remote borders. For example, the most industrious human effort to locally influence geomorphology—dam building, strip mining, stream straightening—will have no measurable effect on plate tectonics or the rock cycle. Processes occurring at faster temporal scales are sometimes essential to the function and persistence of processes occurring at proximate slower temporal scales. Obviously, for example, plant growth and reproduction, occurring at the organismic scale, are essential to succession and, as fuel, to fire regimes occurring at the proximate ecological temporal scale. But processes occurring at slower temporal scales are normally unresponsive to the *vagaries* of processes occurring at more rapid temporal scales. The often vital functional effects of processes occurring at faster temporal scales on those at proximate slower temporal scales are modulated through averaging as they migrate across the border. For example, the life cycle of individual trees in a temperate forest occurs at the higher end of the organismic temporal scale, and at a relatively small, gap-sized spatial scale of say a maximum radius of 15 meters. The life cycle of individual trees is registered at ecological temporal and relatively large landscape spatial scales as an average: so many dead and down trees, so many new seedlings of some species sprouting under the canopy and of other species in the gaps per hectare per year. In general, at ecological temporal scales, change in the overall composition and structure of the forest is driven in part by processes occurring at organismic scales, but the stochasticity of the events at the organismic temporal scale (more dead and down trees this year, fewer next; more dead and down trees in this hectare, fewer in that) is averaged out at the ecological temporal scale.

Sudden changes in the rate of processes occurring at one scale can storm across the border like an invading army and appreciably alter processes at neighboring scales. Ecologists usually assume that the climate of their study areas is changing so gradually as to be—relative to the ecological temporal scale—as constant or stable as latitude and elevation. Indeed, F. E. Clements, the dean of early 20th-century ecology, assumed that regional climate was unchanging, relative to the ecological temporal scale, and thought that stable regional climate was the sole determinant of the climax community—the putative end-point of ecological succession. (He chose the name

"climax" for this hypothetical point of successional equilibrium precisely to link it with "climate" semantically.) However, if Clements were investigating ecological succession at the beginning of the Little Ice Age, then the sudden cooling might have appreciably altered community composition and succession, for that three hundred year period, especially at the spatial boundaries between biotic communities called ecotones. That is an example of a rate change so sudden at a slower level in the hierarchy of temporal scales that it impinges on processes going at the next faster level. A temporal border is invaded. Conversion of the Amazonian rain forest to brush and pasture on a large spatial scale—an anthropogenic ecological process; succession in reverse, as it were—can affect the otherwise slow-changing regional climate. For much of the atmospheric moisture (and thus rainfall) in the Amazon basin is produced by transpiration. Reduced forest cover—>reduced transpiration—>reduced atmospheric moisture—>reduced rainfall = regional climate change. A little clearing here, a little more there, a little more this year, a little less next year, gets averaged out and damped down when it registers at the temporal scale of regional climate change. Presently, the reverse successional processes occurring at the ecological temporal scale in the Amazon basin has become so accelerated and spatially widespread that they cease to be damped down and averaged out—and thus threaten to initiate a change at the next higher temporal scale, that is, to initiate a change in the regional climate.¹¹

Temporal Boundaries in the Proto-Ecological Philosophy of Aldo Leopold

Aldo Leopold died in 1948, a year before the publication of his chef d'oeuvre, *A Sand County Almanac*. Many of the "facts" and theories which informed Leopold's ecological philosophy and land ethic, after more than half a century of scientific "progress" (for lack of a better word), are now obsolete.

As to facts, Leopold states "falsely" in an essay, "Conservation: In Whole or in Part?," written in 1944 and published for the first time in 1991, that "The pollens embedded in peat bogs show that the native plants comprising the prairie, the hardwood forest, and the coniferous forest are about the same now as they were at the end of the glacial period, 20,000 years ago," in the upper Midwest.¹² Leopold nearly doubles the "actual" interval since the last glacial period—only reflecting the then current opinion, I hasten to add. And palinologists currently believe that the plant communities of the upper Midwest are *not* now the same as they were at the end of the last glacial period.

As to theory, Leopold goes on to say that "these major plant communities were pushed northward and southward several times by long climatic cycles, but their membership and organization remained intact."¹³ This is a declaration of the now discredited Clementsian community-unit theory, so graphically, but not unfairly caricatured by Arthur Tansley: "all the zoned climaxes which are subjected to . . . decreasing and increasing temperature will, according to Clements's conception, move across the continent 'as if they were strung on a string,' much as the plant communities zoned around a lake will move toward its center as the lake fills up."¹⁴ The community-unit theory has now been abandoned in ecology in favor of the Gleasonian individualistic theory—according to which species are adapted individually to a variety of environmental "gradients," temperature among them, and respond individually at different rates to changes in those gradients. The pollen record appears actually to indicate that as the ice retreated after the last glaciation, the plant species now composing the prairie, the hardwood forests, and the coniferous forests of the upper Midwest, migrated from different Pleistocene refugia in different directions and at different rates to form—for perhaps the last 5,000 years, far too little time for them to be co-evolved—the coincidental ensembles we find today.¹⁵

Despite often being enthralled by some of the ecological myths of his time, Leopold, just as often, prophetically anticipated subsequent developments in ecology. For example, in "A Biotic View of Land," published in 1939, Leopold anticipated the link that Raymond Lindeman would later forge—with the concept of measurable energy flows—between Charles Elton's conceptual constellation of food chains, food webs, and the pyramid of numbers, on the one hand, and Tansley's concept of the ecosystem on the other. An ecosystem "is a fountain of energy flowing through a circuit of soils, plants, and animals. Food chains are the living channels which conduct energy upward; death and decay return it to the soil," as Leopold would put the point that Lindeman more fully and technically elaborated in his revolutionary 1942 paper, "The Trophic-Dynamic Aspect of Ecology."¹⁶

In this instance, Leopold was only a little ahead of the wave. In the same paper he was way ahead of it in challenging the balance-of-nature ecological myth: "To the ecological mind, balance of nature has merits and also defects. Its merits are that it conceives of a collective total, that it imputes some utility to all species, and that it implies oscillations when balance is disturbed. Its defects are that there is only one point at which balance occurs, and that balance is normally static."¹⁷ Here Leopold parts company with Clements who thought that the climax community was the state at which the unique and static balance of nature was achieved in a particular region. Indeed, he anticipates Holling who posits multiple states of ecological attraction between which a region may alternate in response to critical changes.

According to Holling a change can "flip" a region or landscape into another domain of ecological attraction. Perhaps Leopold anticipated this idea because he had thought deeply about one such flip. The Southwest, where he had first been posted in the Forest Service and where he remained for 15 years, had flipped from a mosaic of grassy savannas and forests dominated by juniper, pinion and ponderosa pine to a mosaic in which these forest types remained, but the grassy savannas had been replaced by brush. Accompanying this flip, and perhaps caused by it: streams became flashy and intermittent—they experienced extreme hydrologic oscillation, in other words, between flooding and drying up—instead of flowing steadily as they had done; and soil erosion had greatly accelerated. Leopold surmised that the main cause of these inter-related (and unwelcome) ecological changes in the Southwest was anthropogenic fire suppression and grazing by domestic cattle and sheep. The alternative cause offered by others was climate change. The question was politically charged: if the cause were fire suppression and grazing, severe hydrologic oscillations and soil erosion and the ecological flip from grass to brush could be halted and, perhaps, reversed were these activities to be stopped; but if the cause were climate change, they could be chalked up to an unremediable "act of God." In "Some Fundamentals of Conservation in the Southwest," Leopold set out to argue that climate change could not be the culprit because climate change and ecological change are separated from one another by a temporal boundary. Let us assume that Leopold correctly states the facts; at issue is only the conceptual possibility that climate change was the cause of severe hydrologic oscillations and soil erosion and the ecological flip from grass to brush in the Southwest, all of which happened both suddenly and recently, measured on the ecological temporal scale.

Leopold notes that "In discussing climate changes, a clear differentiation between geological and historical viewpoints is essential. The status of our climate from the geological viewpoint has nothing to do with the question at hand [the cause of severe soil erosion and hydraulic oscillations and the ecological flip from grass to brush]. Any such changes that may be taking place would be too slow to have any bearing on human problems."¹⁸ Here it is not entirely clear to what temporal scales Leopold means

to refer by “geological and historical viewpoints,” but he does clearly indicate that a boundary exists between the two. After cautiously noting that there is some evidence against it, he claims that the preponderance of the evidence indicates that “*Historically speaking . . .* there has been no great increase or decrease in aridity during the last 3,000 years.”¹⁹ If the “historical” temporal scale extends to 3,000 years, by “geological” he must have in mind the next order of magnitude—during which, of course, the global climate would have changed from glacial to interstadial with correlative effects on the regional climate of the Southwest. In any case, he points out that there “appears to be no clear evidence of desiccation during any recent unit of time small enough to be considered from an economic standpoint.”²⁰

Suppose the climate of the Southwest had been stable only over the last 1000 years or even only over the last 500. The associated phenomena of severe soil erosion and hydraulic oscillations and the ecological flip from grass to brush had begun only a human generation ago; and stable soils, steadily flowing streams, and grassy savannas remained in the living memory of old timers. Whatever the vagaries of change at the climatic temporal scale, they are too slow to so penetrate the boundary of the ecological temporal scale as to register at the organismic temporal scale.

There do exist, however, Leopold notes, annual fluctuations of rainfall in the Southwest, which seem to form a 10-14 year cycle—such that several years of “normal” rainfall are punctuated by 1-3 years of drought. This cycle occurs on the ecological scale and should be regarded not as a climatic fluctuation, but as a disturbance regime. And that drought regime—as one might call it—occurring at the ecological temporal scale, represents a constraint for human undertakings at the organismic temporal scale. Leopold puts the point vividly:

The point is that, if every eleven years we may expect a drought, why not manage our ranges accordingly? This means stocking them only to their drought capacity, or arranging to move the stock or feed it when the drought appears. But instead, we stock them to their normal capacity, and, when drought comes, the stock eat up the range, ruin the watershed, ruin the stockman, wreck the banks, get credit from the treasury of the United States, and then die. And the silt of their dying moves on down into our reservoirs to someday dry up the irrigated valleys—the only live thing left.²¹

Marshaled to Leopold’s argument, one finds many of the conceptual features of temporal scales and the interactions at the boundaries between them. The vagaries of annual temperature and rainfall and the roughly decade-long drought disturbance regime at the ecological temporal scale register at the higher, centuries-long climatic scale; indeed they constitute the climate of the Southwest. But, as they cross the border from the ecological to the climatic temporal scale they are averaged out. When thus averaged out and summed up over a century or more one may say that the climate of the Southwest is temperate and arid overall. The temperate and generally arid climate of the Southwest is itself subject to change, but at a temporal scale measured in thousands of years. Because such slow changes are of no significance at the ecological and organismic temporal scales, the climate of the Southwest serves as a constant or context, as well as a constraint, for ecological and organismic processes. In turn, the vagaries of annual temperature and rainfall and the drought disturbance regime at the ecological temporal scale constrain processes going on at the organismic—Leopold calls it the “economic”—temporal scale. Abstractly expressed, Leopold’s point seems then to be twofold: (1) that adverse changes occurring at the ecological and organismic temporal scales cannot be attributed to changes occurring at the climatic temporal scale, simply as a rule of the boundary relationships between these scales; and (2) that failure

to take account of the constraint represented by the drought disturbance regime occurring at the neighboring ecological temporal scale on anthropogenic processes at the organismic temporal scale led to untoward periodic interruptions of those processes and to untoward changes in other processes occurring at the ecological temporal scale.

The Erased Boundary Between the Human and Natural Worlds in Aldo Leopold's Environmental Philosophy

Controversy and confusion about the boundary between the human and natural worlds confounds many domains of ecological philosophy from environmental ethics to conservation theory. Leopold, for example, seems to locate the human in the natural world, that is, to erase what may have seemed to him to be an indefensible boundary between the two drawn in traditional Western religious and philosophical ideology. Taking the anthropological consequences of the theory of evolution seriously, *Homo* is but one extant genus of anthropoid ape among four others—a monkey's uncle (or cousin), so to speak. As Leopold put it, "It is a century now since Darwin gave us the first glimpse of the origin of species. We know now what was unknown to all the preceding caravan of generations: that men are only fellow-voyagers with other creatures in the odyssey of evolution. This new knowledge should have given us, by this time, a sense of kinship with fellow creatures"22

This evolutionary naturalization of the human sphere is a cornerstone of Leopold's land ethic which "changes the role of *Homo sapiens* from conqueror of the land community to plain member and citizen of it."²³ For if *Homo sapiens* were not in fact a plain member and citizen of the biotic community then he would, Leopold seems to have supposed, be under no obligation to evince "respect for . . . fellow-members, and also respect for the community as such." That is because Leopold also borrowed from Darwin the idea that "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts."²⁴ If this is true, then, if one is not a member of a given community (biotic or otherwise), one has no duties to fellow members of that community (*qua* that community) or to that community as such.

Peter Fritzell points out the contradiction in Leopold's argument: "To be a part, yet to be apart; to be a part of the land community, yet to *view* or *see* oneself as a part of that community (and thus to remain apart from it)—that is the dilemma. . . . If man is a plain member and citizen of the land community, one of thousands of accretions to the pyramid of life, then he cannot be a nonmember and conqueror of it; and his actions (like the actions of other organisms) cannot but express . . . his position within the pyramid of life."²⁵ That is, if people are plain members and citizens of their biotic communities, then what people do in and to their biotic communities as such and to their fellow members of those communities is amoral—no different in this regard than the destruction of African forests by elephants or of American forests by gypsy moths. Conversely, if people are not plain members and citizens of proximate biotic communities, then they have no obligations to their non-fellow non-members and to their non-communities as such. So have it either way—*Homo sapiens* either is or is not a part of nature—an environmental ethic of the kind Leopold envisioned is conceptually incoherent.

Fritzell's conception of the boundary between the human and natural worlds, on reflection, seems quaintly classical—harking all the way back to the tree of the knowledge of good and evil in the Bible. Upon eating its fruit Adam and Eve could *view* or *see* themselves and discover that they were naked. This unique human capacity for self-consciousness is the fountainhead, Fritzell seems to suggest, of both disinterested science and compassionate ethics.

Thus, as Fritzell unwittingly reminds us, the boundary between the human and natural worlds was classically drawn by appeal to some *essential* difference. Human

beings are uniquely created in the image of God, or are uniquely self-conscious, or uniquely rational. That tradition has survived into the contemporary debate about the existence and location of that great divide when the putatively unique human capacities for language use and / or tool making are enshrined as boundary markers (or makers).

Also, without a sharp boundary between the human and natural worlds, conservation biology lacks a clear notion of what to conserve. Biological diversity, the most ubiquitously evoked target of conservation efforts, can in principle be enhanced anthropogenically by introducing species to communities with empty niches—which would be anathema to most conservation theorists. And from a postdarwin Leopoldian perspective (the view that *Homo sapiens* is a part of nature) it seems arbitrary actively to conserve “native” species that arrived in a place by some other-than-human means and to eradicate those “exotics” that got there by deliberate or inadvertent human agency. An alternative conception of what to conserve is biological integrity, which is defined in terms of a “natural” biotic community, free of human influence. But again, from the postdarwin perspective, it seems arbitrary to single out human influence as opposed to, say, beaver influence or coyote influence, as an influence which compromises the “naturalness” of an area.²⁶

The Boundary Between the Human and Natural Worlds Drawn by the Temporal Scales of Biological and Cultural Evolution

Paul Angermeier reviews the conservation-biology literature on the confounding and paradoxical boundary between what Fritzell defiantly calls “man” and nature, and points the way out of this postdarwin fly-bottle. At first hearing, Angermeier seems to affirm only a small variation on one of the age-old essentialist themes: “Human activity becomes unnatural when it involves technology.”²⁷ *Homo sapiens* is not the uniquely rational animal; we are, rather, the uniquely technological animal, a variation on the tool-using essence.

But the reason that Angermeier gives for technology being the boundary marker (and maker) separating the human and the natural worlds is the temporal scale of the “*evolution*” of technology. “Human activities that exceed our genetically evolved—as opposed to *culturally evolved*—abilities are unnatural,” he avers.²⁸ At bottom, as Angermeier ultimately recognizes, what draws the boundary between the human and natural worlds is not technology per se, but the disparity between the temporal scale of cultural evolution and genetic evolution. Technology is only one component of culture, but the one Angermeier singles out as boundary-defining because that component of culture has the most impact on nature: “Humans are cultural as well as biological animals. For conservation, the most important outgrowth of culture is technology, with which we transform nature Because technological [and more generally cultural] evolution is much more rapid than genetic evolution, we transform ecosystems faster than other biota can adapt”²⁹

What is cultural *evolution*? Culture appears to “evolve” in the sense that simpler and more rudimentary cultural items are succeeded by more complex and sophisticated cultural items. For example, a sharpened stick used for spearing is succeeded by a stone- or antler-tipped spear, which is succeeded in turn by a simple bow and stone-tipped arrow, which is succeeded by a cross bow and an iron-tipped arrow, which is succeeded by a blunder buss, which is succeeded by a rifle. Or, a birch-bark/hot-stones cooking vessel is succeeded by a clay pot, which is succeeded by an iron kettle, which is succeeded by a Dutch oven, which is succeeded by a gas oven, which is succeeded by a microwave oven. Or, pictographs are succeeded by hieroglyphs, which are succeeded by alphabets; and clay tablets are succeeded by papyrus scrolls, which are succeeded by paper manuscripts, which are succeeded by printed books, which are succeeded by

digital or virtual docs. Or mythopoeia is succeeded by speculative natural philosophy, which is succeeded by modern Newtonian science, which is succeeded by postmodern Einsteinian science. One may be reluctant to call such lines of succession in cultural items "progress," because the abandonment of simpler, more rudimentary cultural items in favor of more complex and sophisticated cultural items may come at a high cost in personal satisfaction and happiness and social stability. But whether progressive or not culture appears to evolve in this way.

Cultural evolution is much faster than genetic evolution because it is Lamarckian, not Darwinian. Lamarck believed that species evolved through the transmission to offspring of characteristics acquired by parents. For example, if a man were a right-handed blacksmith and had acquired an enlarged right arm as a result of repeated hammering with that arm, while the other remained mostly at rest holding the molten iron, then half his children on average would be born with a larger right than left arm. That notion has long been abandoned in biological evolution in favor of Darwin's scenario of chance variation (later become genetic mutation) and natural selection among genotypes. But the inheritance by subsequent generations of novelties acquired by previous generations is indeed the mode of cultural evolution. And Lamarckian evolution is much, much faster than Darwinian evolution.

To illustrate graphically and mythically the difference in temporal scale between biological and cultural evolution, suppose you are Ursa, the bear deva, and you are seized with a desire to live in the arctic and eat the delicious flesh and luscious fat of seals. To satisfy your desire to be a polar bear, you must increase your body size, modify your digestive tract, change the color of your fur, modify your hibernation cycle, and make a thousand other anatomical, physiological, and behavioral adaptations, each of which must await the chance of a favorable genetic mutation, a process requiring more than a million years to complete. Then these changes must accumulate in the gene pool of a population and become stabilized. If you are a *Homo sapiens* and wish to adapt to life in the arctic and consume its rich protein resources, you may thoughtfully and deliberately modify your existing material and cognitive culture—you may transform a spear into a harpoon, a pole and bark lodge into an igloo; you may learn the difference between the ways of grizzly and polar bears, and the difference between the dispositions of the spirits in the taiga forest and those of the drift ice. If these and a thousand other such cultural adaptations work and you are successful in your arctic enterprise you may pass them on not only to your own offspring, but to the offspring of all the members of your band, a process completed in just a few human generations.

The postdarwin human-natural paradox can now be stated more clearly. The genus *Homo*, from a Darwinian evolutionary point of view, is—with four other genuses: *Pongo*, *Hylobates*, *Gorilla*, and *Pan*—an anthropoid ape. Unlike the other apes, *Homo sapiens* evolved culture, or perhaps better—allowing that other species may have some rudimentary culture—what Charles Lumsden and Ed Wilson call "euculture."³⁰ Lumsden and Wilson argue that, having reached a certain take-off point, human cultural and genetic evolution were linked in a positive feedback loop. Culture became in effect a selective environment in which *Homo* evolved. Culturally adept individuals—those who could learn, use, and store information and communicate it to their offspring and other close kin—reproduced more successfully than those who were less so. The greater an individual's capacity for acquiring cultural skills, the greater their inclusive fitness.

The principle organ of human culture, the brain, evolved rapidly (on the scale of biological evolution), tripling in size over just three million years. The Australopithecine cranial capacity was 400-500 cc, comparable to that of the modern chimpanzee and gorilla; that of *Homo erectus* was about 1000 cc; that of *Homo neanderthalus* about 1500cc; and that of *Homo sapiens* about 2000 cc. In sum: *Homo sapiens* is an

anthropoid ape, evolved, as any other species, by the general neodarwinian process of random genetic mutation and natural selection. Human culture is similarly evolved, but itself became part of the selective environment in which *Homo* evolved. That is, both human beings and human culture are a part of and product of nature. But because the temporal scale of cultural evolution, vis-a-vis biological evolution, is so disparate, euculture has propelled *Homo sapiens* out of nature. The disparity, moreover, between the human and natural worlds is increasing precisely because the rate of cultural evolution is increasing. In other words, cultural evolution occurs at a faster temporal scale than biological evolution; but not only that, while the rate of biological evolution remains constant, the rate of cultural evolution increases dramatically. Perhaps that's one reason why we tend to think that premodern iterations of *Homo sapiens* are closer to nature than the postmodern ones.

Back now to the contradiction Peter Fritzell finds in Leopold's land ethic. Leopold seems to think that not only are we a part of nature, but, for a land ethic to emerge, we must *acknowledge* that we are indeed a part of nature—we must view or see ourselves as a part of nature. And, from the evolutionary point of view assumed here, we are indeed a part of nature. But, as Fritzell points out, to have an evolutionary point of view is—as we may now say—a “meme” an item of culture. And to the extent that we are eucultural animals, we are set apart from nature. Now, with the help of this analysis of the linkage between biological and cultural evolution and the disparity between the temporal scales at which adaptive processes proceed in either scale, that we are both a part of nature and set apart from it ceases to be a contradiction; indeed it ceases to be even paradoxical.

How Drawing the Boundary Between the Human and Natural Worlds in terms of the Temporal Scales of Biological and Cultural Evolution Establishes Defensible Norms for Environmental Ethics

Understanding the boundary between the human and natural worlds to be drawn by the disparity between the temporal scales of cultural and biological evolution is useful not only for purposes of defending conservation biology's classic naturalness norm; it is useful for establishing norms for environmental ethics, as well (now that the penumbra of contradiction and paradox surrounding environmental ethics has been dispelled).

At this late date on the Lamrkian temporal scale of cultural evolution, every cubic centimeter of the biosphere has suffered measurable effects of human culture, but some, obviously, much more than others. Naturalness admits of degrees and conservation biologists can aim to preserve or restore relatively or comparatively natural areas, even though purely natural areas (pristine areas) are nowhere to be found.

One concern of environmental ethics is to suggest and justify principles or precepts to govern the human treatment of nature. As noted, the idea that nature is in a state of static equilibrium has long been abandoned in ecology. Contemporary ecology has shifted from the “balance-of-nature” paradigm to the “flux-of-nature” paradigm. And as here amply summarized, nature constantly changes at multiple temporal scales. So why should some human changes imposed on nature be ethically problematic? If volcanoes blow off mountain tops and raze the forests on the slopes below, fill valleys with debris, and pollute streams, what's wrong with strip mines that have comparable destructive effects? If fires periodically rage through forests, burning them to the ground, what's wrong with clear-cuts that have comparable destructive effects? If hurricanes erode ocean-front sand dunes, what's wrong with beachside cottage developments that have comparable destructive effects? Because *Homo sapiens* is a part of nature, we cannot simply answer, without further consideration, that such effects are anthropogenic, as if they were caused by a species of space alien.

What renders strip mines, clear cuts, and beach developments unnatural is not that they are anthropogenic—for, biologically speaking, *Homo sapiens* is as natural a species as any other—but that they occur at temporal and spatial scales that were unprecedented in nature until nature itself evolved another mode (the Lamarckian mode) of evolution: cultural evolution. Steward Pickett and Richard Ostfeld note that “For all its scientific intrigue and poetic beauty, the flux of nature is a dangerous metaphor. The metaphor and the underlying ecological paradigm may suggest to the thoughtless and greedy that since flux is a fundamental part of the natural world, any human-caused flux is justifiable. Such an inference is wrong because the flux in the natural world has severe limits.”³¹ Pickett and Ostfeld go on to identify the general kinds of radical constraints on natural change (as we may now call it without confusion about whether anthropogenic change is a subset of natural change). And one of these is the incursion of the temporal scale of cultural change on that of biological (or Darwinian) evolutionary change. “In general terms, these limits of natural flux are functional, historical, and evolutionary. . . . Problematic human changes or fluxes are those that are beyond the limits of physiology to tolerate, history to be prepared for, or evolution to react to. Two characteristics of human-induced flux would suggest that it would be excessive: fast rate and large spatial extent.”³²

So, back to our examples of natural versus anthropogenic environmental changes. Catastrophic volcanic eruptions, such as that which literally blew the top off Mount St. Helens in 1980 occur at widely scattered frequencies and localities. However, “mountaintop removal” coal mining in West Virginia occurs at such a huge scale that no figures are available for its spatial extent and temporal frequency—an anthropogenic flux now so intensive that a mountainous region of North America is well on its way to becoming a region of table-top plateaus. Clearcuts could be ethically justified, on the other hand, if their spatial and temporal scales approached those of natural fire regimes or insect-infestation cycles that afflict forests on the ecological temporal scale. Cottage developments on beachfront property could also be justified if they were mindfully fitted, at comparable scales, into a matrix otherwise subject only to natural disturbance regimes.

The environmental immorality of the most disturbing of all anthropogenic changes imposed on nature—the sixth great extinction event in the 3.5 billion biography of planet Earth—can only be persuasively articulated as the boundary violation of the evolutionary temporal scale by the cultural. Species extinction is a natural process, but the scale at which it normally occurs—the “background rate” of extinction—is slower than speciation. We can know that *a priori*, for if the rate of extinction were not slower than the rate of speciation, Late Pleistocene biodiversity—to the tune of five to thirty million coexisting species, when human beings inherited the Earth—could not have accumulated. Natural species extinction thus occurs normally on the evolutionary temporal scale. Anthropogenic species extinction now occurs at a boundary-busting rate many orders of magnitude faster. There is nothing environmentally unethical about anthropogenic species extinction *per se*. What is wrong with the current episode of abrupt, mass, anthropogenic species is—and is only—the temporal scale on which it is occurring.

Endnotes

¹ For this historical background I consulted Liddell and Scott's *Greek-English Lexicon*, 7th Edition (Oxford: The Clarendon Press, 1964); G. S. Kirk and J. E. Raven, *The Presocratic Philosophers: A Critical History with a Selection of Texts* (Cambridge: Cambridge University Press, 1962); W. K. C. Guthrie, *A History of Greek Philosophy*, Vol 1: *The Earlier Presocratics and the Pythagoreans* (Cambridge: Cambridge University Press, 1962); and Richard D. McKirhan, Jr., *Philosophy Before Socrates: An Introduction with Texts and Commentary* (Indianapolis: Hackett Publishing Co., 1994).

² C. S. Holling, "Cross-scale Morphology, Geometry, and Dynamics of Ecosystems," *Ecological Monographs* 62 (1992): 447-502, p. 449.

³ *Ibid.*

⁴ *Ibid.*, pp. 449-450.

⁵ For this discussion of vegetative processes I have consulted Michael J. Crawley, ed., *Plant Ecology*, 2nd Edition (Blackwell Science, 1997).

⁶ For this discussion of ecological processes I consulted Crawley, ed., *Plant Ecology*, S. T. A. Pickett and P. S. White, *The Ecology of Natural Disturbance and Patch Dynamics* (San Diego: Academic Press, 1985); and R. Moss, A. Watson, and J. Ollason, *Animal Population Dynamics* (New York : Chapman and Hall, 1982).

⁷ For this discussion of the evolutionary temporal scale, I consulted E. O. Wilson, *The Diversity of Life* (Cambridge: Harvard University/Belknap Press, 1992) and Ralf Hennemann, *Sharks & Rays: Elasmobranch Guide to the World*, (Frankfurt: Unterwasserarchiv, 2001).

⁸ For this discussion of plate tectonics and the rock cycle, I consulted B. C. Birchfield, R. J. Foster, E. A. Keller, W. M. Melhorn, D. G. Brookins, L. W. Mintz, and H. V. Thurman, *Physical Geology: The Structures and Processes of the Earth* (Columbus, Ohio: Charles E. Merrill, 1982) and F. Press and R. Siever, *Understanding Earth* (New York: W. H. Freeman and Co., 1994)

⁹ D. B. Botkin and E. A. Keller, *Environmental Science: Earth as a Living Planet*, 2nd Edition (New York: John Wiley & Sons, 1998), p. 56.

¹⁰ For this discussion of the climatic temporal scale I consulted, W. F. Ruddiman, *Earth's Climate: Past and Future* (New York W. H. Freeman & Co., 2001) and R. G. Barry and R. J. Chorley, *Atmosphere, Weather, and Climate*, 6th Edition (New York: Routledge, 1992).

¹¹ For this discussion of interactions at the boundaries between temporal scales I consulted R. V. O'Neill, D. L. DeAngelis, J. B. Waide, and T. F. H Allen, *A Hierarchical Concept of Ecosystems* (Princeton: Princeton University Press, 1986).

¹² Aldo Leopold, "Conservation: In Whole or in Part?," in S. L. Flader and J. B. Callicott, eds., *The River of the Mother of God and Other Essays by Aldo Leopold* (Madison: University of Wisconsin Press, 1991): 310-319, p. 312.

¹³ *ibid.*

¹⁴ A. G. Tansley, "The Use and Abuse of Vegetational Concepts and Terms," *Ecology* 16 (1935): 284-307, p. 336.

¹⁵ This discussion of current "facts" and theories in community ecology is informed by Crawley, *Plant Ecology*; MacIntosh, *Background of Ecology*; and M. B. Davis, "Climatic Instability, Time Lags, and Community Disequilibrium," in J. Diamond and T. J. Case, eds., *Community Ecology* (New York: Harper and Row, 1984): 269-284.

¹⁶ Aldo Leopold, "A Biotic View of Land," *Journal of Forestry* 37 (1939): 727-730, p. 728; R. L. Lindeman, "The Trophic-Dynamic Aspect of Ecology," *Ecology* 23 (1942): 399-418.

¹⁷ Leopold, "Biotic View," p. 727.

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- ¹⁸ Aldo Leopold, "Some Fundamentals of Conservation in the Southwest," in S. L. Flader and J. B. Callicott, eds., *The River of the Mother of God and Other Essays by Aldo Leopold* (Madison: University of Wisconsin Press, 1991): 82-97, p. 89.
- ¹⁹ *Ibid.*, emphasis added.
- ²⁰ *Ibid.*, p. 90.
- ²¹ *Ibid.*, p. 91.
- ²² Aldo Leopold, *A Sand County Almanac and Sketches Here and There* (New York: Oxford University Press, 1949), p. 109.
- ²³ *Ibid.*, p. 204.
- ²⁴ *Ibid.*, p. 203.
- ²⁵ Peter Fritzell, "The Conflicts of Ecological Conscience," in J. B. Callicott, ed., *Companion to A Sand County Almanac* (Madison: University of Wisconsin Press, 1987): 128-153. p. 142
- ²⁶ This discussion of norms for conservation biology is informed by P. L. Angermeier and J. L. Karr, "Biological Integrity versus Biological Diversity as Policy Directives," *BioScience* 44 (1994): 690-697.
- ²⁷ Paul L. Angermeier, "The Natural Imperative for Biological Conservation," *Conservation Biology* 14 (2000): 373-381, p. 374.
- ²⁸ *Ibid.*
- ²⁹ *Ibid.*, p. 375.
- ³⁰ Charles L. Lumsden and Edward O. Wilson, *Genes, Mind, and Culture: The Coevolutionary Process* (Cambridge: Harvard University Press, 1981).
- ³¹ S. T. A. Pickett and R. S. Ostfeld, "The Shifting Paradigm in Ecology," in R. L. Knight and S. F. Bates, eds., *A New Century for Natural Resources Management* (Washington: Island Press, 1995). p. 273.
- ³² *Ibid.*, p. 274.