On the Termination of Species

Ecologists' warnings of an ongoing mass extinction are being challenged by skeptics and largely ignored by politicians. In part that is because it is surprisingly hard to know the dimensions of the die-off, why it matters and how it can best be stopped

By W. Wayt Gibbs

CHERYL D. KNOTT

END OF AN ORANGUTAN fixes our attention and seems to confirm our worst fears about the decline of biodiversity. But does our focus on charismatic animals blur a view of the big picture? The ape in this photograph died of natural causes. And a much greater part of the earth's evolutionary heritage rises from the banks and sits in the water than lies on the log.

HILO, HAWAII—Among the scientists gathered here in August at the annual meeting of the Society for Conservation Biology, the despair was almost palpable. "I'm just glad I'm retiring soon and won't be around to see everything disappear," said P. Dee Boersma, former president of the society, during the opening night's dinner. Other veteran field biologists around the table murmured in sullen agreement.

At the next morning's keynote address, Robert M. May, a University of Oxford zoologist who presides over the Royal Society and until last year served as chief scientific adviser to the British government, did his best to disabuse any remaining optimists of their rosy outlook. According to his latest rough estimate, the extinction rate—the pace at which species vanish—accelerated during the past 100 years to roughly 1,000 times what it was before humans showed up. Various lines of argument, he explained, "suggest a speeding up by a further factor of 10 over the next century or so.... And that puts us squarely on the breaking edge of the sixth great wave of extinction in the history of life on Earth."

From there, May's lecture grew more depressing. Biologists and conservationists alike, he complained, are afflicted with a "total vertebrate chauvinism." Their bias toward mammals, birds and fish—when most of the diversity of life lies elsewhere—undermines scientists' ability to predict reliably the scope and consequences of biodiversity loss. It also raises troubling questions about the high-priority "hotspots" that environmental groups are scrambling to identify and preserve.

"Ultimately we have to ask ourselves why we care" about the planet's portfolio of species and its diminishment, May said. "This central question is a political and social question of values, one in which the voice of conservation scientists has no particular standing." Unfortunately, he concluded, of "the three kinds of argument we use to try to persuade politicians that all this is important . . . none is totally compelling."

Although May paints a truly dreadful picture, his is a common view for a field in which best-sellers carry titles such as *Requiem for Nature*. But is despair justified? *The Skeptical Environmentalist,* the new English translation of a recent book by Danish statistician Bjørn Lomborg, charges that reports of the death of biodiversity have been greatly exaggerated. In the face of such external skepticism, internal uncertainty and public apathy, some scientists are questioning the conservation movement's overriding emphasis on preserving rare species and the threatened hotspots in which they are concentrated. Perhaps, they suggest, we should focus instead on saving something equally at risk but even more valuable: evolution itself.

Overview/*Extinction Rates*

- Eminent ecologists warn that humans are causing a mass extinction event of a severity not seen since the age of dinosaurs came to an end 65 million years ago. But paleontologists and statisticians have called such comparisons into doubt.
- It is hard to know how fast species are disappearing. Models based on the speed of tropical deforestation or on the growth of endangered species lists predict rising extinction rates. But biologists' bias toward plants and vertebrates, which represent a minority of life, undermine these predictions. Because 90 percent of species do not yet have names, let alone censuses, they are impossible to verify.
- In the face of uncertainty about the decline of biodiversity and its economic value, scientists are debating whether rare species should be the focus of conservation. Perhaps, some suggest, we should first try to save relatively pristine—and inexpensive—land where evolution can progress unaffected by human activity.

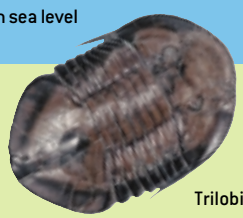
Doom ...

MAY'S CLAIM that humans appear to be causing a cataclysm of extinctions more severe than any since the one that erased the dinosaurs 65 million years ago may shock those who haven't followed the biodiversity issue. But it prompted no gasps from the conservation biologists. They have heard variations of this dire forecast since at least 1979, when Norman Myers guessed in *The Sinking Ark* that 40,000 species lose their last member each year and that one million would be extinct by 2000. In the 1980s Thomas Lovejoy similarly predicted that 15 to 20 percent would die off by 2000; Paul Ehrlich figured

Mass Extinctions Past—and Present?

TIMELINE OF EXTINCTION marks the five most widespread die-offs in the fossil history of life on Earth.

END ORDOVICIAN
DURATION: **10 million years (my)**
MARINE GENERA OBSERVED EXTINGUISHED: **60%**
CALCULATED MARINE SPECIES EXTINCT: **85%**
SUSPECTED CAUSE: Dramatic fluctuations in sea level

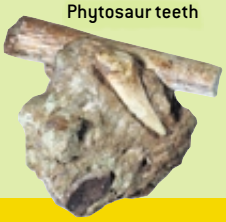

Trilobite


Placoderm

LATE DEVONIAN
DURATION: **<3 my**
MARINE GENERA OBSERVED EXTINGUISHED: **57%**
CALCULATED MARINE SPECIES EXTINCT: **83%**
SUSPECTED CAUSES: Impact; global cooling; loss of oxygen in oceans

END PERMIAN
DURATION: **Unknown**
MARINE GENERA OBSERVED EXTINGUISHED: **82%**
CALCULATED MARINE SPECIES EXTINCT: **95%**
SUSPECTED CAUSES: Dramatic fluctuations in climate or sea level; asteroid or comet impacts; severe volcanic activity


Rugose coral


Phytosaur teeth

END TRIASSIC
DURATION: **3 to 4 my**
MARINE GENERA OBSERVED EXTINGUISHED: **53%**
CALCULATED MARINE SPECIES EXTINCT: **80%**
SUSPECTED CAUSES: Severe volcanism; global warming

END CRETACEOUS
DURATION: **<1 my**
MARINE GENERA OBSERVED EXTINGUISHED: **47%**
CALCULATED MARINE SPECIES EXTINCT: **76%**
SUSPECTED CAUSES: Impact; severe volcanism


Mosasaur

Millions of years ago

570 | 510 | 439 | 409 | 363 | 290 | 248 | 210 | 146 | 65 | 1.64

Cambrian | Ordovician | Silurian | Devonian | Carboniferous | Permian | Triassic | Jurassic | Cretaceous | Tertiary | Quaternary

With more than 1,100 species (*eight at right*) suspected to have disappeared in the past 500 years, ecologists fear a sixth mass extinction event is imminent. The die-offs so far, however, would probably not signal anything unusual to future paleontologists looking back at our time.

SPECIES *(Scientific name)*	LAST SEEN, LOCATION	EXTINCTION CAUSES
Deepwater ciscoe (*Coregonus johannae*)	1952, Lakes Huron and Michigan	Overfishing, hybridization
Pupfish *(Cyprinodon ceciliae)*	1988, Ojo de Agua La Presa, Mexico	Loss of food supply
Dobson's fruit bat *(Dobsonia chapmani)*	1970s, Cebu Islands, Philippines	Forest destruction, overhunting
Caribbean monk seal *(Monachus tropicalis)*	1950s, Caribbean Sea	Overhunting, harassment
Guam flycatcher *(Myiagra freycineti)*	1983, Guam	Predation by introduced brown tree snakes
Kaua'i 'O'o *(Moho braccatus)*	1987, Island of Kaua'i, Hawaii	Disease, rat predation
Xerces Blue Butterfly *(Glaucopsyche xerces)*	1941, San Francisco Peninsula	Land conversion
Tobias' Caddis Fly *(Hydropsyche tobiasi)*	1950s, Rhine River, Germany	Industrial and urban pollution

SOURCES: Committee on Recently Extinct Organisms; BirdLife International; Xerces Society; World Wildlife Fund

LESTER V. BERGMAN *Corbis (trilobite)*; JAMES L. AMOS *Corbis (Placoderm)*; RICHARD PASELK *Humboldt State University/Natural History Museum (Rugose coral* and *Phytosaur teeth)*; MIKE EVERHART *Oceans of Kansas Paleontology (Mosasaur)*

half would be gone by now. "I'm reasonably certain that [the elimination of one fifth of species] didn't happen," says Kirk O. Winemiller, a fish biologist at Texas A&M University who just finished a review of the scientific literature on extinction rates.

More recent projections factor in a slightly slower demise because some doomed species have hung on longer than anticipated. Indeed, a few have even returned from the grave. "It was discovered only this summer that the Bavarian vole, continental Eurasia's one and only presumed extinct mammal [since 1500], is in fact still with us," says Ross D. E. MacPhee, curator of mammalogy at the American Museum of Natural History (AMNH) in New York City.

Still, in the 1999 edition of his often-quoted book *The Diversity of Life,* Harvard University biologist E. O. Wilson cites current estimates that between 1 and 10 percent of species are extinguished every decade, at least 27,000 a year. Michael J. Novacek, AMNH's provost of science, wrote in a review article this spring that "figures approaching 30 percent extermination of all species by the mid-21st century are not unrealistic." And in a 1998 survey of biologists, 70 percent said they believed that a mass extinction is in progress; a third of them expected to lose 20 to 50 percent of the world's species within 30 years.

"Although these assertions of massive extinctions of species have been repeated everywhere you look, they do not equate with the available evidence," Lomborg argues in *The Skeptical Environmentalist*. A professor of statistics and political science at the University of Århus, he alleges that environmentalists have ignored recent evidence that tropical deforestation is not taking the toll that was feared. "No well-investigated group of animals shows a pattern of loss that is consistent with greatly heightened extinction rates," MacPhee concurs. The best models, Lomborg suggests, project an extinction rate of 0.15 percent of species per decade, "not a catastrophe but a problem—one of many that mankind still needs to solve."

... or Gloom?

"IT'S A TOUGH question to put numbers on," Wilson allows. May agrees but says "that isn't an argument for not asking the question" of whether a mass extinction event is upon us.

To answer that question, we need to know three things: the

The Portfolio of Life

How severe is the extinction crisis? That depends in large part on how many species there are altogether. The greater the number, the more species will die out every year from natural causes and the more new ones will naturally appear. But although the general outlines of the tree of life are clear, scientists are unsure how many twigs lie at the end of each branch. When it comes to bacteria, viruses, protists and archaea (a whole kingdom of single-celled life-forms discovered just a few decades ago), microbiologists have only vague notions of how many branches there are.

Birds, fish, mammals and plants are the exceptions. Sizing up the global workforce of about 5,000 professional taxonomists, zoologist Robert M. May of the University of Oxford noted that about equal numbers study vertebrates, plants and invertebrates. "You may wish to think this record reflects some judicious appreciation of what's important," he says. "My view of that is: absolute garbage. Whether you are interested in how ecosystems evolved, their current functioning or how they are likely to respond to climate change, you're going to learn a lot more by looking at soil microorganisms than at charismatic vertebrates."

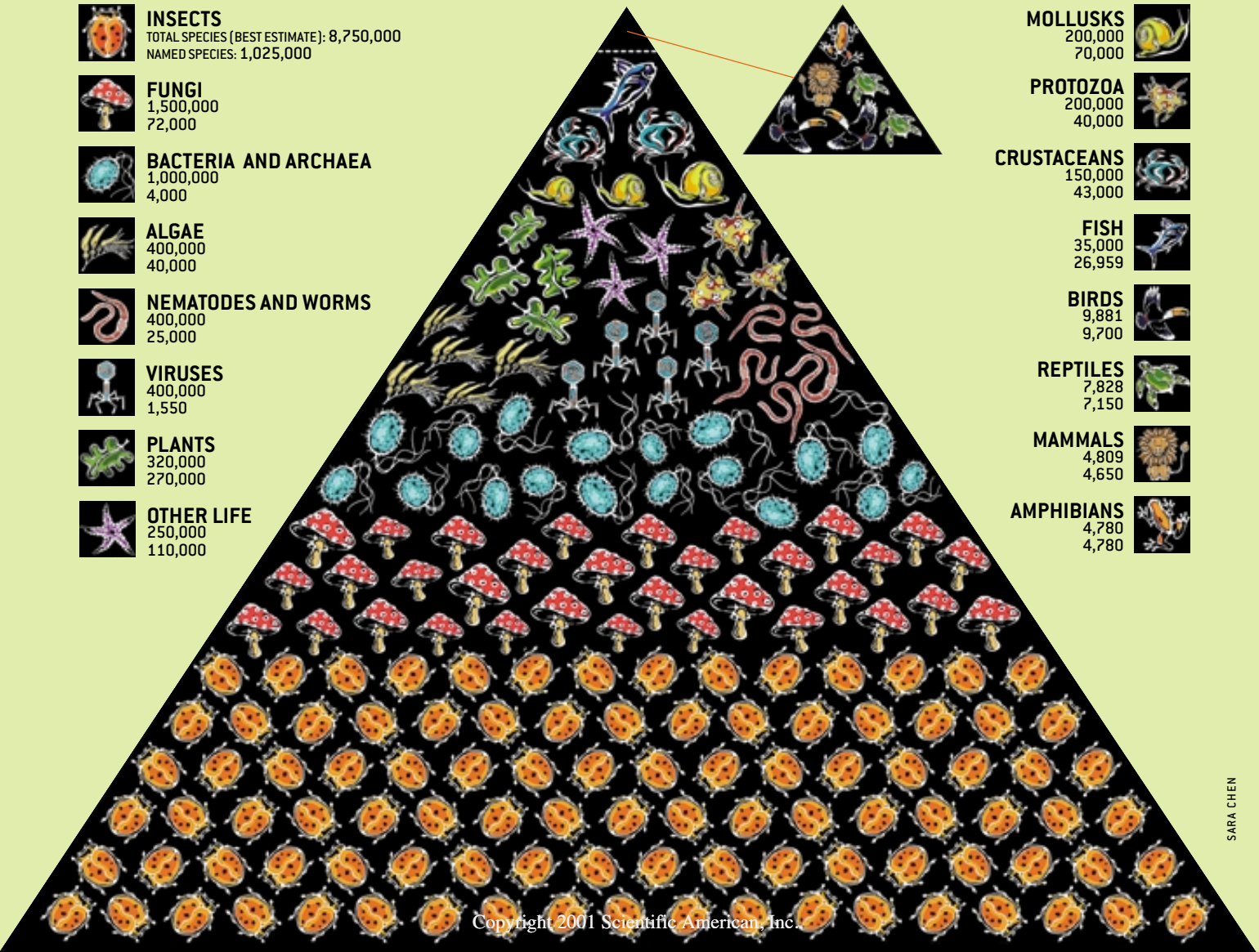
For every group except birds, says Peter Hammond of the National History Museum in London, new species are now being discovered faster than ever before, thanks to several new international projects. An All Taxa Biodiversity Inventory under way in Great Smoky Mountains National Park in North Carolina and Tennessee has discovered 115 species—80 percent of them insects or arachnids—in its first 18 months of work. Last year 40 scientists formed the All Species Project, a society devoted to the (probably quixotic) goal of cataloguing every living species, microbes included, within 25 years.

Other projects, such as the Global Biodiversity Information Facility and Species2000, are building Internet databases that will codify species records that are now scattered among the world's museums and universities. If biodiversity is defined in strictly pragmatic terms as the variety of life-forms we know about, it is growing prodigiously.

PYRAMID OF DIVERSITY

TO A FIRST APPROXIMATION, all multicellular species are insects. Biologists know the least about the true diversity and ecological importance of the very groups that are most common.

SOURCES: Encyclopedia of Biodiversity, *edited by S. A. Levin; "Biodiversity Hotspots for Conservation Priorities," by N. Myers et al. in* Nature, *Vol. 403, pages 853–858, February 24, 2000; William Eschemeyer (fish species); Marc Van Regenmortel (virus species); IUCN Red List 2000*



SARA CHEN

natural (or "background") extinction rate, the current rate and whether the pace of extinction is steady or changing. The first step, Wilson explains, is to work out the mean life span of a species from the fossil record. "The background extinction rate is then the inverse of that. If species are born at random and all live exactly one million years—and it varies, but it's on that order—then that means one species in a million naturally goes extinct each year," he says.

In a 1995 article that is still cited in almost every scientific paper on this subject (even in Lomborg's book), May used a similar method to compute the background rate. He relied on estimates that put the mean species life span at five million to 10 million years, however; he thus came up with a rate that is five to 10 times lower than Wilson's. But according to paleontologist David M. Raup (then at the University of Chicago), who published some of the figures May and Wilson relied on, their calculations are seriously flawed by three false assumptions.

One is that species of plants, mammals, insects, marine invertebrates and other groups all exist for about the same time. In fact, the typical survival time appears to vary among groups by a factor of 10 or more, with mammal species among the least durable. Second, they assume that all organisms have an equal chance of making it into the fossil record. But paleontologists estimate that fewer than 4 percent of all species that ever lived are preserved as fossils. "And the species we do see are the widespread, very successful ones," Raup says. "The weak species confined to some hilltop or island all went extinct before they could be fossilized," adds John Alroy of the University of California at Santa Barbara.

The third problem is that May and Wilson use an average life span when they should use a median. Because "the vast majority of species are short-lived," Raup says, "the average is distorted by the very few that have very long life spans." All three oversimplifications underestimate the background rate—and make the current picture scarier in comparison.

Earlier this year U.C.S.B. biomathematician Helen M. Regan and several of her colleagues published the first attempt ever to correct for the strong biases and uncertainties in the data. They looked exclusively at mammals, the best-studied group. They estimated how many of the mammals now living, and how many of those recently extinguished, would show up as fossils. They also factored in the uncertainty for each number rather than relying on best guesses. In the end they concluded that "the current rate of mammalian extinction lies between 17 and 377 times the background extinction rate." The best estimate, they wrote, is a 36- to 78-fold increase.

Regan's method is still imperfect. Comparing the past 400 years with the previous 65 million unavoidably assumes, she says, "that the current extinction rate will be sustained over millions of years." Alroy recently came up with a way to measure the speed of extinctions that doesn't suffer from such assumptions. Over the past 200 years, he figures, the rate of loss among mammal species has been some 120 times higher than natural.

A Grim Guessing Game

ATTEMPTS TO FIGURE out the current extinction rate are fraught with even more uncertainties. The international conservation organization IUCN keeps "Red Lists" of organisms suspected to be extinct in the wild. But MacPhee complains that "the IUCN methodology for recognizing extinction is not sufficiently rigorous to be reliable." He and other extinction experts have formed the Committee on Recently Extinct Organisms, which combed the Red Lists to identify those species that were clearly unique and that had not been found despite a reasonable search. They certified 60 of the 87 mammals listed by IUCN as extinct but claim that only 33 of the 92 freshwater fish presumed extinct by IUCN are definitely gone forever.

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> —KIRK O. WINEMILLER, TEXAS A&M

For every species falsely presumed absent, however, there may be hundreds or thousands that vanish unknown to science. "We are uncertain to a factor of 10 about how many species we share the planet with," May points out. "My guess would be roughly seven million, but credible guesses range from five to 15 million," excluding microorganisms.

Taxonomists have named approximately 1.8 million species, but biologists know almost nothing about most of them, especially the insects, nematodes and crustaceans that dominate the animal kingdom. Some 40 percent of the 400,000 known beetle species have each been recorded at just one location—and with no idea of individual species' range, scientists have no way to confirm its extinction. Even invertebrates known to be extinct often go unrecorded: when the passenger pigeon was eliminated in 1914, it took two species of parasitic lice with it. They still do not appear on IUCN's list.

"It is extremely difficult to observe an extinction; it's like seeing an airplane crash," Wilson says. Not that scientists aren't trying. Articles on the "biotic holocaust," as Myers calls it, usually figure that the vast majority of extinctions have been in the tropical Americas. Freshwater fishes are especially vulnerable, with more than a quarter listed as threatened. "I work in Venezuela, which has substantially more freshwater fishes than all of North America. After 30 years of work, we've done a reasonable job of cataloguing fish diversity there," observes Winemiller of Texas A&M, "yet we can't point to one documented case of extinction."

A similar pattern emerges for other groups of organisms, he

claims. "If you are looking for hard evidence of tens or hundreds or thousands of species disappearing each year, you aren't going to find it. That could be because the database is woefully inadequate," he acknowledges. "But one shouldn't dismiss the possibility that it's not going to be the disaster everyone fears."

The Logic of Loss

THE DISASTER SCENARIOS are based on several independent lines of evidence that seem to point to fast and rising extinction rates. The most widely accepted is the species-area relation. "Generally speaking, as the area of habitat falls, the number of species living in it drops proportionally by the third root to the sixth root," explains Wilson, who first deduced this equation more than 30 years ago. "A middle value is the fourth root, which means that when you eliminate 90 percent of the habitat, the number of species falls by half."

"From that rough first estimate and the rate of the destruction of the tropical forest, which is about 1 percent a year," Wilson continues, "we can predict that about one quarter of 1 percent of species either become extinct immediately or are doomed to much earlier extinction." From a pool of roughly 10 million species, we should thus expect about 25,000 to evaporate annually.

Lomborg challenges that view on three grounds, however. Species-area relations were worked out by comparing the number of species on islands and do not necessarily apply to fragmented habitats on the mainland. "More than half of Costa Rica's native bird species occur in largely deforested countryside habitats, together with similar fractions of mammals and butterflies," Stanford University biologist Gretchen Daily noted recently in *Nature*. Although they may not thrive, a large fraction of forest species may survive on farmland and in woodlots—for how long, no one yet knows.

That would help explain Lomborg's second observation, which is that in both the eastern U.S. and Puerto Rico, clearance of more than 98 percent of the primary forests did not wipe out half of the bird species in them. Four centuries of logging "resulted in the extinction of only one forest bird" out of 200 in the U.S. and seven out of 60 native species in Puerto Rico, he asserts.

Such criticisms misunderstand the species-area theory, according to Stuart L. Pimm of Columbia University. "Habitat destruction acts like a cookie cutter stamping out poorly mixed dough," he wrote last year in *Nature*. "Species found only within the stamped-out area are themselves stamped out. Those found more widely are not."

Of the 200 bird types in the forests of the eastern U.S., Pimm states, all but 28 also lived elsewhere. Moreover, the forest was cleared gradually, and gradually it regrew as farmland was abandoned. So even at the low point, around 1872, woodland covered half the extent of the original forest. The species-area theory predicts that a 50 percent reduction should knock out 16 percent of the endemic species: in this case, four birds. And four species did go extinct. Lomborg discounts one of those four that may have been a subspecies and two others that perhaps succumbed to unrelated insults.

But even if the species-area equation holds, Lomborg responds, official statistics suggest that deforestation has been slowing and is now well below 1 percent a year. The U.N. Food and Agriculture Organization recently estimated that from 1990 to 2000 the world's forest cover dropped at an average annual rate of 0.2 percent (11.5 million hectares felled, minus 2.5 million hectares of new growth).

Annual forest loss was around half a percent in most of the tropics, however, and that is where the great majority of rare and threatened species live. So although "forecasters may get these figures wrong now and then, perhaps colored by a desire to sound the alarm, this is just a matter of timescale," replies Carlos A. Peres, a Brazilian ecologist at the University of East Anglia in England.

Extinction *Filters*

SURVIVAL OF THE FITTEST takes on a new meaning when humans develop a region. Among four Mediterranean climate regions, those developed more recently have lost larger fractions of their vascular plant species in modern times. Once the species least compatible with agriculture are filtered out by "artificial selection," extinction rates seem to fall.

REGION (in order of development)	EXTINCT (per 1,000)	THREATENED (percent)
Mediterranean	1.3	14.7
South African Cape	3.0	15.2
California	4.0	10.2
Western Australia	6.6	17.5

SOURCE: "Extinctions in Mediterranean Areas." Werner Greuter in Extinction Rates. *Edited by J. H. Lawton and R. H. May. Oxford University Press, 1995*

An Uncertain Future

ECOLOGISTS HAVE TRIED other means to project future extinction rates. May and his co-workers watched how vertebrate species moved through the threat categories in IUCN's database over a four-year period (two years for plants), projected those very small numbers far into the future and concluded that extinction rates will rise 12- to 55-fold over the next 300 years. Georgina M. Mace, director of science at the Zoological Society of London, came to a similar conclusion by combining models that plot survival odds for a few very well known species. Entomologist Nigel E. Stork of the Natural History Museum in London noted that a British bird is 10 times more likely than a British bug to be endangered. He then extrapolated such ratios to the rest of the world to predict 100,000 to 500,000 insect extinctions by 2300. Lomborg favors this latter model, from which he concludes that "the rate for all animals will remain below 0.208 percent per decade and probably be below 0.7 percent per 50 years."

It takes a heroic act of courage for any scientist to erect such

WEALTH OF RAIN FORESTS, this one in Borneo, is largely unmeasured, both in biological and economic terms.

FRANS LANTING *Minden Pictures*

long and broad projections on such a thin and lopsided base of data. Especially when, according to May, the data on endangered species "may tell us more about the vagaries of sampling efforts, of taxonomists' interests and of data entry than about the real changes in species' status."

Biologists have some good theoretical reasons to fear that even if mass extinction hasn't begun yet, collapse is imminent. At the conference in Hilo, Kevin Higgins of the University of Oregon presented a computer model that tracks artificial organisms in a population, simulating their genetic mutation rates, reproductive behavior and ecological interactions. He found that "in small populations, mutations tend to be mild enough that natural selection doesn't filter them out. That dramatically shortens the time to extinction." So as habitats shrink and populations are wiped out—at a rate of perhaps 16 million a year, Daily has estimated—"this could be a time bomb, an extinction event occurring under the surface," Higgins warns. But proving that that bomb is ticking in the wild will not be easy.

And what will happen to fig trees, the most widespread plant genus in the tropics, if it loses the single parasitic wasp variety that pollinates every one of its 900 species? Or to the 79 percent of canopy-level trees in the Samoan rain forests if hunters kill off the flying foxes on which they depend? Part of the reason so many conservationists are so fearful is that they expect the arches of entire ecosystems to fall once a few "keystone" species are removed.

Others distrust that metaphor. "Several recent studies seem to show that there is some redundancy in ecosystems," says Melodie A. McGeoch of the University of Pretoria in South Africa, although she cautions that what is redundant today may not be redundant tomorrow. "It really doesn't make sense to think the majority of species would go down with marginally higher pressures than if humans weren't on the scene," MacPhee adds. "Evolution should make them resilient."

If natural selection doesn't do so, artificial selection might, according to work by Werner Greuter of the Free University of Berlin, Thomas M. Brooks of Conservation International and others. Greuter compared the rate of recent plant extinctions in four ecologically similar regions and discovered that the longest-settled, most disturbed area—the Mediterranean—had the lowest rate. Plant extinction rates were higher in California and South Africa, and they were highest in Western Australia. The solution to this apparent paradox, they propose, is that species that cannot coexist with human land use tend to die out soon after agriculture begins. Those that are left are better equipped to dodge the darts we throw at them. Human-induced extinctions may thus fall over time.

If true, that has several implications. Millennia ago our ancestors may have killed off many more species than we care to

Why Biodiversity Doesn't (Yet) Pay

FOZ DO IGUAÇU, BRAZIL—At the International Congress of Entomologists last summer, Ebbe Nielsen, director of the Australian National Insect Collection in Canberra, reflected on the reasons why, despite the 1992 Convention on Biological Diversity signed here in Brazil by 178 countries, so little has happened since to secure the world's threatened species. "You and I can say extinction rates are too high and we have to stop it, but to convince the politicians we have to have convincing reasons," he said. "In developing countries, the economic pressures are so high, people use whatever they can find today to survive until tomorrow. As long as that's the case, there will be no support for biodiversity at all."

Not, that is, unless it can be made more profitable to leave a forest standing or a wetland wet than it is to convert the land to farm, pasture or parking lot. Unfortunately, time has not been kind to the several arguments environmentalists have made to assign economic value to each one of perhaps 10 million species.

A Hedge against Disease and Famine

"Narrowly utilitarian arguments say: The incredible genetic diversity contained in the population and species diversity that we are heirs to is ultimately the raw stuff of tomorrow's biotechnological revolution," observes Robert May of Oxford. "It is the source of new drugs." Or new foods, adds E. O. Wilson of Harvard, should something happen to the 30 crops that supply 90 percent of the calories to the human diet, or to the 14 animal species that make up 90 percent of our livestock.

"Some people who say that may even believe it," May continues. "I don't. Give us 20 or 30 years and we will design new drugs from the molecule up, as we are already beginning to do."

Hopes were raised 10 years ago by reports that Merck had paid $1.14 million to InBio, a Costa Rican conservation group, for novel chemicals extracted from rain-forest species. The contract would return royalties to InBio if any of the leads became drugs. But none have, and Merck terminated the agreement in 1999. Shaman Pharmaceuticals, founded in 1989 to commercialize traditional medicinal plants, got as far as late-stage clinical trials but then went bankrupt. And given, as Wilson himself notes in *The Diversity of Life,* that more than 90 percent of the known varieties of the basic food plants are on deposit in seed banks, national parks are hardly the cheapest form of insurance against crop failures.

Ecosystem Services

"Potentially the strongest argument," May says, "is a broadly utilitarian one: ecological systems deliver services we're only just beginning to think of trying to estimate. We do not understand how much you can simplify these systems and yet still have them function. As Aldo Leopold once said, the first rule of intelligent tinkering is to keep all the pieces."

The trouble with this argument, explains Columbia University economist Geoffrey Heal, is that "it does not make sense to ask about the value of replacing a life-support system." Economics can only assign values to things for which there are markets, he says. If all oil were to vanish, for example, we could switch to alternative fuels that cost $50 a barrel. But that does not determine the price of oil.

And although recent experiments suggest that removing a large fraction of species from a small area lowers its biomass and ability to soak up carbon dioxide, scientists cannot say yet whether the principle applies to whole ecosystems. "It may be that a grievously simplified world—the world of the cult movie *Blade Runner*—can be so run that we can survive in it," May concedes.

A Duty of Stewardship

Because science knows so little of the millions of species out there, let alone what complex roles each one plays in the ecosystems it inhabits, it may never be possible for economics to come to the aid of endangered species. A moral argument may thus be the best last hope—certainly it is appeals to leaders' sense of stewardship that have accomplished the most so far. But is it hazardous for scientists to make it?

They do, of course, in various forms. To Wilson, "a species is a masterpiece of evolution, a million-year-old entity encoded by five billion genetic letters, exquisitely adapted to the niche it inhabits." For that reason, conservation biologist David Ehrenfeld proposed in *The Arrogance of Humanism,* "long-standing existence in Nature is deemed to carry with it the unimpeachable right to continued existence."

Winning public recognition of such a right will take much education and persuasion. According to a poll last year, fewer than one quarter of Americans recognized the term "biological diversity." Three quarters expressed concern about species and habitat loss, but that is down from 87 percent in 1996. And May observes that the concept of biodiversity stewardship "is a developed-world luxury. If we were in abject poverty trying to put food in the mouth of the fifth child, the argument would have less resonance."

But if scientists "proselytize on behalf of biodiversity"—as Wilson, Lovejoy, Ehrlich and many others have done—they should realize that "such work carries perils," advises David Takacs of California State University at Monterey Bay. "Advocacy threatens to undermine the perception of value neutrality and objectivity that leads laypersons to listen to scientists in the first place." And yet if those who know rare species best and love them most cannot speak openly on their behalf, who will?

FRANS LANTING *Minden Pictures*

think about in Europe, Asia and other long-settled regions. On the other hand, we may have more time than we fear to prevent future catastrophes in areas where humans have been part of the ecosystem for a while—and less time than we hope to avoid them in what little wilderness remains pristine.

"The question is how to deal with uncertainty, because there really is no way to make that uncertainty go away," Winemiller argues. "We think the situation is extremely serious; we just don't think the species extinction issue is the peg the conservation movement should hang its hat on. Otherwise, if it turns out to be wrong, where does that leave us?"

Long-Term Savings

IT COULD LEAVE conservationists with less of a sense of urgency and with a handful of weak political and economic arguments [*see box on opposite page*]. It might also force them to realize that "many of the species in trouble today are in fact already members of the doomed, living dead," as David S. Woodruff wrote in the *Proceedings of the National Academy of Sciences* this past May. "Triage" is a dirty word to many environmentalists. "Unless we say no species loss is acceptable, then we have no line in the sand to defend, and we will be pushed back and back as losses build," Brooks argued at the Hilo meeting. But losses are inevitable, Wilson says, until the human population stops growing.

"I call that the bottleneck," Wilson elaborates, "because we have to pass through that scramble for remaining resources in order to get to an era, perhaps sometime in the 22nd century, of declining population. Our goal is to carry as much of the biodiversity through as possible." Biologists are divided, however, on whether the few charismatic species now recognized as endangered should determine what gets pulled through the bottleneck.

"The argument that when you protect birds and mammals, the other things come with them just doesn't stand up to close examination," May says. A smarter goal is "to try to conserve the greatest amount of evolutionary history." Far more valuable than a panda or rhino, he suggests, are relic life-forms such as the tuatara, a large iguanalike reptile that lives only on islets off the coast of New Zealand. Just two species of tuatara remain from a group that branched off from the main stem of the reptilian evolutionary tree so long ago that this couple make up a genus, an order and almost a subclass all by themselves.

But Woodruff, who is an ecologist at the University of California at San Diego, invokes an even broader principle. "Some of us advocate a shift from saving things, the products of evolution, to saving the underlying process, evolution itself," he writes. "This process will ultimately provide us with the most cost-effective solution to the general problem of conserving nature."

There are still a few large areas where natural selection alone determines which species succeed and which fail. "Why not save functioning ecosystems that haven't been despoiled yet?" Winemiller asks. "Places like the Guyana shield region of South America contain far more species than some of the so-called hotspots." To do so would mean purchasing tracts large enough to accommodate entire ecosystems as they roll north and south in response to the shifting climate. It would also mean prohibiting all human uses of the land. It may not be impossible: utterly undeveloped wilderness is relatively cheap, and the population of potential buyers has recently exploded.

"It turns out to be a lot easier to persuade a corporate CEO or a billionaire of the importance of the issue than it is to convince the American public," Wilson says. "With a Ted Turner or a Gordon Moore or a Craig McCaw involved, you can accomplish almost as much as a government of a developed country would with a fairly generous appropriation."

"Maybe even more," agrees Richard E. Rice, chief economist for Conservation International. With money from Moore, McCaw, Turner and other donors, CI has outcompeted logging companies for forested land in Suriname and Guyana. In Bolivia, Rice reports, "we conserved an area the size of Rhode Island for half the price of a house in my neighborhood," and the Nature Conservancy was able to have a swath of rain forest as big as Yellowstone National Park set aside for a mere $1.5 million. In late July, Peru issued to an environmental group the country's first "conservation concession"—essentially a renewable lease for the right to *not* develop the land—for 130,000 hectares of forest. Peru has now opened some 60 million hectares of its public forests to such concessions, Rice says. And efforts are under way to negotiate similar deals in Guatemala and Cameroon.

"Even without massive support in public opinion or really effective government policy in the U.S., things are turning upward," Wilson says, with a look of cautious optimism on his face. Perhaps it is a bit early to despair after all. SA

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MORE TO EXPLORE

Extinction Rates. Edited by John H. Lawton and Robert M. May. Oxford University Press, 1995.

The Currency and Tempo of Extinction. Helen M. Regan et al. in the *American Naturalist*, Vol. 157, No. 1, pages 1–10; January 2001.

Encyclopedia of Biodiversity. Edited by Simon Asher Levin. Academic Press, 2001.

The Skeptical Environmentalist. Bjørn Lomborg. Cambridge University Press, 2001.