If one wants to delve into the ancestry of natural-history museums, *Cabinets of Curiosities* (Thames & Hudson, 2002) is the most gloriously illustrated work on the subject. *Amazing Rare Things: The Art of Natural History in the Age of Discovery* (Yale, 2007) is a fine anthology of drawings and engravings. And if you are prepared to splurge, *Albertus Seba's Cabinet of Natural Curiosities* (Taschen, 2001) is a jumbo, slipcased volume that includes hundreds of color illustrations from the early years of natural history.

Several books published in recent years that are more scholarly — not for the kids, but not over the heads of the average nonscientist — focus on the history of natural history: *Stuffed Animals and Pickled Heads: The Culture and Evolution of Natural History Museums* (Oxford, 2001) is the most engaging comprehensive history that I have read. More-focused studies include *A History of Paleontology Illustration* (Indiana, 2008), and *Victorians and the Prehistoric: Tracks to a Lost World* (Yale, 2004), and *The Legacy of the Mastodon: The Golden Age of Fossils in America* (Yale, 2008), which chronicles the wild-west era of paleontology in the 19th century, when the great museums were building their collections. *Nature's Museums: Victorian Science and the Architecture of Display* (Princeton Architectural, 2005) makes the case for the ideological significance of museums and the importance of preserving them for cultural reasons as much as for their scientific value.

Fortey asserts — rightly, I think — that the older, interdisciplinary, vocational culture of natural history can no longer comfortably exist in the context of the modern museum. Such work is now wholly professionalized and dependent on advanced, specialized education, expensive technology, and access to the latest research. It depends on the same kind of management strategies and values that are transforming our universities along similar lines. And the experience can be quite alienating. One can only gape at the astounding power of technology. There is not much room left for the museum visitor who is as fascinated by a timeworn marble staircase as by the cast skull of a *T. rex* in a Lucite box.

One goes to a natural-history museum not just to contemplate the minutiae of comparative anatomy — or to watch scientists demonstrate the insidious might of their corporate sponsors — but also to meditate, like Holden Caulfield, on the meaning of time, death, change, and the succession of generations.

Dead Reckoning: Calculating the Costs of an Ongoing Mass Extinction[1]

Scott LaFee

San Diego Union Tribune

On 2 March 2009, an asteroid discovered just three days earlier narrowly missed the Earth. Dubbed 2009 DD45, it passed within 47,000 miles of the planet — a distance only slightly more than twice the altitude of a geostationary communications satellite. The moon is five times farther away.

It was a relatively small asteroid: 100–130 ft in diameter, roughly the size of the comet or asteroid that flattened Russia's Tunguska River region in 1908. If 2009 DD45 had actually collided with Earth, it would not have ended life as we know it. We're doing that ourselves.

Over the past 500 million years, the Earth has endured five mass-extinction events, periods when 50 to more than 90% of all known species perished. The last event — the Cretaceous-Tertiary event 65 million years ago, which spelled the end of the dinosaurs — was likely instigated by the impact of an asteroid far larger than 2009 DD45, but other phenomena have been cited as possible causes of mass-extinction events, including massive volcanism and extreme climate change. Now, most scientists agree, we're in the midst of a sixth mass extinction, this one human-induced. What remains to be seen is just how bad it will be.

"Extinction is a difficult phenomenon to measure because we are still counting and describing the number of living species on Earth," said Mark Wilson, a professor of geology at the College of Wooster in Ohio. "We may be losing tens of thousands of species every year which we haven't even met yet." However, the sense among researchers is that the current mass extinction, known as the Holocene Event, will be very bad indeed. In the past, the Earth invariably rebounded, different but alive, eventually refilling with new and more diverse creatures and plants. Life moved on.

Odds are, humans will, too. At this point, scientists tend to think humanity will persist in some form or fashion. As a species, we are remarkably adaptable and resourceful.

The planet, not so much. Phenomena like global climate change and habitat destruction, both powerfully propelled by modern human activities, have fundamentally changed the rules. A University of Leeds study says current emission trends may raise global temperatures by the end of the century to levels not seen in

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Credits for photographs (left to right, top to bottom): Gary Nafis, Jeff Lemm, Gerald Kuchling, Michael A. Powell, Kenneth L. Krysko, IUCN, Adam Crane, John Binns, Olivier Born, Philipp Maitz, Hans-Jürgen Bräuer, and Wikipedia.

Giant Garter Snake
(*Thamnophis gigas*)

Mountain Yellow-legged Frog
(*Rana muscosa*)

Yangtze River Softshell Turtle
(*Rafetus swinhoei*)

Hawaiian Goose
(*Branta sandvicensis*)

Mushroomtongue Salamander
(*Bolitoglossa diaphora*)

Purple Marsh Crab
(*Afrithelphusa monodosa*)

Hellbender
(*Cryptobranchus alleganiensis*)

Grand Cayman Blue Iguana
(*Cyclura lewisi*)

Gharial
(*Gavialis gangeticus*)

Squaretail Coral Grouper
(*Plectropomus areolatus*)

Living Rock Cactus
(*Ariocarpus bravoanus*)

Iberian Lynx
(*Lynx pardinus*)

The rare and endangered species shown here are among those at risk in the current human-induced mass extinction.

ROBERT POWELL

Although not as dramatic as the impact that marked the Cretaceous-Tertiary boundary 65 million years ago, being eaten by humans or their domestic companions can be just as lethal. The Navassa Island Iguana (*Cyclura onchiopsis*) presumably was driven to extinction through overexploitation by miners extracting mineralized guano during the late 19th Century. Only a few museum specimens remain.

30 million years. Humans already use about half of all available land on Earth.

"There's this idea of resilience," said Rebecca Lewison, an assistant professor of biology at San Diego State University. "How far can ecosystems be pushed before they permanently collapse? How much ecological havoc can we effect before there can be no rebound? We don't really know what the boundaries are."

Going Rate

Extinction is a part of life, with new species inevitably replacing those less able to adapt or compete. Evolution means that more than 90% of all species that have ever lived on Earth are now extinct — but how long should a species persist? Based on the fossil record, the average lifetime of an invertebrate species, from origination to extinction, is estimated at 5–10 million years. Mammalian species come and go much more quickly, usually within 1–2 million years.

Scientists say that the "normal background extinction rate" is one species per million per year, with maybe 10 to 25 species disappearing in a year. The current extinction rate is projected at 100–1,000 times higher than the normal background rate.

"It's unprecedented," said Lewison. The United Nations Convention on Biological Diversity estimates three species become extinct each hour. That's 72 every day; 26,280 each year. Exact numbers are debatable, but the point is not: Much of the planet's biota is imperiled. The International Union for the Conservation of Nature, which maintains a highly regarded "Red List" of endangered and threatened species, estimates that more than 16,300 species of animals and plants are on the verge of extinction; more than 41,000 are threatened.

The group says one-eighth of all birds, one-third of all amphibians, and half of the world's turtles are in jeopardy. Seventy percent of the world's plants are considered at risk.

Blame people, says conservation biologist Michael Soule, who asserts that modern extinctions are almost entirely the result of human activity — everything from habitat destruction and the introduction of non-native species to pollution, overexploitation, and disease.

For example, the United Nations estimates 32 million acres of forest are lost annually, almost half of that total consisting of forest previously undisturbed by man. Ocean acidity is rising, the result of seawater absorbing more atmospheric carbon dioxide emitted by industry and automobiles. Increased ocean acidity blocks the ability of corals and hard-shelled marine creatures to form, and hinders the growth and reproduction rates of plankton and fish. In central Africa, the gorilla population has declined 60% in the last quarter-century due to local wars, the bush-meat trade, and the Ebola virus.

Remnants and Recovery

The ramifications of lost biodiversity are almost impossible to overstate. Recent studies have shown that grassland ecosystems with

Mass Extinctions of the Past

Cretaceous-Tertiary, 65 million years ago: Most likely caused or aggravated by a miles-wide asteroid striking what is now the Gulf of Mexico. Climate change and massive volcanic eruptions also are blamed. Sixteen percent of marine families and 18% of land vertebrate families died out, including dinosaurs.

Triassic-Jurassic, 205 million years ago: Probably due to massive lava floods in the central Atlantic region, an event that triggered the opening of the Atlantic Ocean. Volcanism could have led to catastrophic global warming. The death toll included 22% of marine families; land vertebrate losses are unclear, but included most non-dinosaurian archosaurs and large amphibians.

Permian-Triassic, 251 million years ago: Multiple causes cited — asteroid impact, volcanism, long-term atmospheric change — but no conclusive evidence for any one of them. This was the worst mass extinction of all, sometimes called "The Great Dying": 90% of marine species, 70% of land species perish.

Late Devonian, 364 million years ago: Actually a series of extinction events; temperatures dropped sharply, but the specific cause is not known. Twenty-two percent of marine families disappeared; little is known about land organisms at the time.

Ordovician-Silurian, 439 million years ago: Attributed to extensive glaciation, falling sea levels, global cooling. The toll included 27% of marine families.

C. HORWITZ

Passenger Pigeons (*Ectopistes migratorius*) were perhaps the most numerous birds on the planet. Over-hunting and the clearing of forests to make way for agriculture doomed the species. The last nesting birds were reported in the Great Lakes region in the 1890s. The last reported individuals in the wild were shot at Babcock, Wisconsin in 1899, and in Pike County, Ohio on 24 March 1900. Some individuals, however, remained in captivity. The last Passenger Pigeon, named Martha, died alone at the Cincinnati Zoo at about 1 pm on 1 September 1914.

fewer plant species generally produce less biomass (living matter) than ecosystems with more species. Less plant biomass means less atmospheric carbon dioxide is absorbed and less oxygen is produced. A global decline in vegetable biomass can change the composition of gasses in the atmosphere. It means fewer plants for herbivores to eat. Entire food chains may be disrupted.

In a recently published paper, Paul Ehrlich, the Bing Professor of population studies at Stanford University, and his wife, Anne, a senior research scientist, noted that, since 1993, an astounding 408 new species — of mammals alone — have been discovered. That might seem like news to celebrate, but Ehrlich, famous for his 1968 book, *The Population Bomb*, suggests that it also reveals how little we know about the planet's biosphere. "Our analysis indicates how much more varied biodiversity is than we thought and how much bigger our conservation problems are if we're going to maintain the life-support services that we need from biodiversity," Ehrlich said. He compares nature's biodiversity to the engineered redundancy in an airplane. The "rivet hypothesis" holds that you can lose some rivets in a plane's wing and it will continue to fly, said Ehrlich. At some point, however, the loss of just one more rivet becomes catastrophic. "Even though you don't know the value of each rivet," said Ehrlich, "you know it's nuttier than hell to keep removing them. There is some redundancy (in nature), but we don't know how much — and facing serious climate disruption, humanity is going to need more redundancy in the little rivets, the species and populations that run the world."

However, nothing will improve as long as human behavior and activity do not, said Barry Goldstein, a biology professor at the University of Puget Sound in Washington. "The current event will last as long as habitat loss and rapid climate change continue to occur at the present rate" — and, if mass extinction goes on long enough (past events have lasted from hundreds of thousands to millions of years), what's left may consist only of "weedy survivors," said Peter Ward, a paleontologist at the University of Washington. These are animals supremely adaptable and opportunistic, such as flies, rats, crows, coyotes, and intestinal parasites.

These "recovery fauna" might be the dominant organisms on Earth for a very long time. In a 2000 paper, UC Berkeley environmental scientist James Kirchner and Duke University paleontologist Ann Weil found that the average amount of time it took for the Earth's biodiversity to regain levels prior to a mass extinction event was 10 million years. The length of time didn't vary whether an extinction event was large or small. That's far beyond any human time scale. Modern humans have only been around for a few hundred thousand years. Ancestral hominids date back only a few million years. A recovery period of 10 million years, said Kirchner at the time of his study, "is well past the expected life span of the human species, or even of the genus *Homo*."

Like all sea turtles, Green Turtles (*Chelonia mydas*) are threatened by predators such as dogs, mongooses, and rats (often introduced by humans), as well as humans themselves. In addition, they are killed in fishing nets and by boat strikes, and their nesting sites are increasingly rendered unusable as a consequence of coastal development.

The Cuban Crocodile (*Crocodylus rhombifer*) has the smallest known natural distribution of any extant crocodilian. In addition to illegal hunting for food and sales of mounted specimens as souvenirs and live juveniles as pets, hybridization with the American Crocodile (*C. acutus*) threatens the genetic purity of the few remaining wild populations.