CHIP CLARK/THE SMITHSONIAN

Losing life's variety

2010 is the deadline set for reversing declines in biodiversity, but little has been accomplished

By Susan Milius

No silly hats or shouted countdowns. But entomologist Scott Miller is hosting a small event to mark the beginning of 2010, which the United Nations has declared the International Year of Biodiversity. Miller's occasion is low-key, on a weekday, before noon even, and there's no bubbly in sight. But there are other reasons for not quite calling this a celebration.

This is a poignant year for anyone who cares about the rich diversity of life on planet Earth. 2010 was supposed to be a milestone. The 193 nations participating in a treaty called the Convention on Biological Diversity had agreed to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth."

Fat chance. The official document assessing the 2010 global outlook for biodiversity won't be released until May, but conservationists and trend watchers predict at best a few bright points among worsening losses. Even a preview statement from the treaty secretariat says that, as of late January, "all the indications are that the 2010 target has not been met."

Policy has achieved little for biodiversity, but scientists have fared better in coming to understand just what biodiversity means for the fundamental workings of an ecosystem. From grasslands to oceans, ecologists are finding

Sky-blue hairstreaks display the subtle diversity within one butterfly species.

that greater diversity tends to boost an ecosystem's productivity and reinforce its stability.

Biologists around the world are thus bootstrapping themselves out of despair and seizing the occasion to explain biodiversity and why it matters.

Earth's vast diversity

Miller's mini–New Year's event may be low on champagne, but it's a world-class demonstration of what biodiversity is. He's using insects to convey the variety of life by giving a little tour of his workplace, which happens to be the Smithsonian National Museum of Natural History in Washington, D.C. As the Smithsonian's deputy under secretary for science, he has a lab that looks out on part of the research collection of insect specimens — there are 35 million of them.

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>
> JEAN-CHRISTOPHE VÍE

Leading the way through the public exhibit halls toward the stored collections, Miller strides past dramatic fossil displays: half-billion-year-old remains of weird, spiky creatures from Canada's Burgess Shale, an Irish elk with antlers that loom like roof-mounted satellite dishes and other vanished marvels.

Though things have been disappearing for a long time, humanity has revved up extinction rates in the past few centuries to as much as a thousand times the rates during much of Earth's history, according to the 2005 Millennium Ecosystem Assessment. That status report, the work of some 1,360 scientists, names habitat change, climate change, introduction of invasive species, overexploitation and pollution as the big causes of this anthropogenic extinction. And the report calls for urgent action.

Not far from the elk, Miller opens an inconspicuous security door into the museum's private world. The "nation's attic" has wide, well-lit corridors, and when Miller reaches the giant room storing much of the pinned insect collection, he pauses to let the sight sink in.

It's not attic-y at all, but has the super-clean, bright feel of movie sets for secret, high-tech installations. Ranks of some 1,800 cabinets, almost ceiling-high, near-white and identical, march into the distance.

Miller starts with a few shallow wooden drawers topped with glass. The collection's 135,000 drawers hold specimens from just about every kind of place an insect has ever been: tiny leaf miners that excavate within a single mangrove leaf and harvester ants that scurry over desert sands, for example.

All these insect habitats — the whole range of ecosystems on the planet — rank as a form of biodiversity, Miller says. He lifts trays holding insects grown from larvae picked out of fruits in Papua New Guinea. The assembled rows appear to contain duplicates of a tiny brown-winged thingy, but his trained eye recognizes dozens of species.

Another tray holds dozens of postage-stamp–sized brown moths pinned in evenly spaced rows. The moths also look the same at first glance, and Miller says this drawer holds nothing but a single species of spruce budworm, an infamous pest of eastern forests in North America. Staring closely, though, reveals shades of brown, from mahogany and chocolate to almost beige. And the wings are mottled with yet tinier variations on the theme.

These individual differences count as biodiversity too. Differences at the ecosystem, species and genetic levels all matter, Miller says.

Recent wipeout

Losses at all these levels had roused enough concern by 1992 for an Earth Summit in Brazil to produce the Convention on Biological Diversity treaty. Enough nations had ratified the treaty by 1993 for it to become a binding legal document. By now, all nations have agreed to participate except for Andorra, the Holy See and the United States. Political opposition in 1993 prevented the full U.S. Senate from voting on whether to ratify the treaty, and the issue has lain dormant since.

At a meeting in 2002, the participants adopted the strategic plan that set the date, 2010, for achieving the reduction in losses. Now, like serial New Year's resolvers pledging to lose 10 pounds, signatory nations have to get on the scale.

The treaty secretariat's January preview of the reckoning provided only broad trends with arrows and pie charts to indicate whether various goals had been met. (On a global scale, they had not.)

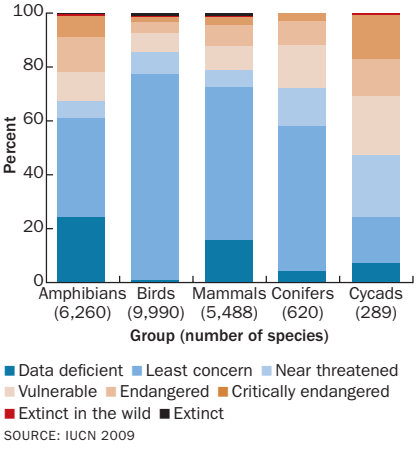
"It's not looking good," says Jean-Christophe Vié, deputy coordinator of the species program at the International Union for Conservation of Nature in Gland, Switzerland. The nonprofit maintains the Red List, a registry that ranks the status of various species, from thriving ("least concern") to extinct.

Though comparing IUCN data over time is difficult because the scope and criteria have changed, the Red List provides a snapshot of where biodiversity is now.

At the end of 2009, an IUCN report found plenty of creatures, mostly animals and plants, still in peril. Of the 44,838 species that the IUCN had evaluated by 2008, 16,928 met at least the criteria for

Categorizing concern The International Union for Conservation of Nature assigns each assessed species a category of concern. Of the groups below, amphibians and cycads have the largest portions of endangered species, thanks in part to habitat destruction and overcollection.

Red List status of species within various groups



SOURCE: IUCN 2009

A. NANDY

"facing a high risk of extinction in the wild." Evaluators said some of them met more dire criteria, facing "very high" or "extremely high" extinction risks. That troubled group included one in eight of the bird species, one in five mammals, one in four corals and one in three amphibians. (Scientists have formally described some 1.7 million species, and estimates of total richness run from 3 million to 10 million.)

Another indicator, the Living Planet Index, averages changes in the sizes of populations of 1,686 vertebrate species. The index, put out by the World Wildlife Fund, the Zoological Society of London and their partners, slid almost 30 percent from 1970 to 2005.

In this deadline year, "biodiversity is still declining — there's no doubt about it," Vié says.

Though species losses are only one measure of diversity, if a species is crashing, so is any genetic variety within it. And taking more and more species from an ecosystem raises concerns that the swamp, woods or pond will lose its distinctive traits, becoming something else, in a form of system-level extinction. So, as crude as they are, tallies of species' statuses let conservationists take the pulse of life on the planet.

The meaning of loss

As for the impact of these declines, Vié says, "I don't think people get it." Too often biodiversity loss has come to mean extinction of some creature a continent away. "It's not because one beetle or one frog is going extinct that we are worried," he says. "It's that the losses are massive."

So just what's going to happen when so much biodiversity disappears has become a pressing question. Plenty of experiments, albeit accidental ones, have already demonstrated that subtracting even one species can change an ecosystem. The Millennium Assessment report lists 21 such "experiments," carried out by fishing fleets, overenthusiastic gardeners or even wildlife managers.

Removing sheep and cattle in an attempt to restore Santa Cruz Island, Calif., for example, let nonnative plants spread over the landscape unchecked. And harvesting of triggerfish in Kenya's reefs allowed sea urchin populations to boom, leading to increased coral erosion.

Ecologists have also started intentional experiments that explore how biodiversity affects the basic workings of an ecosystem, such as how much life it supports or whether it will repair itself after a disaster such as a drought.

Drought inspired the longest-running of the post-treaty wave of biodiversity experiments, says David Tilman of the University of Minnesota in St. Paul. For reasons that had little to do with biodiversity, he and his colleagues were monitoring grassland plots at the university's Cedar Creek Ecosystem Science Reserve. Then a drought hit.

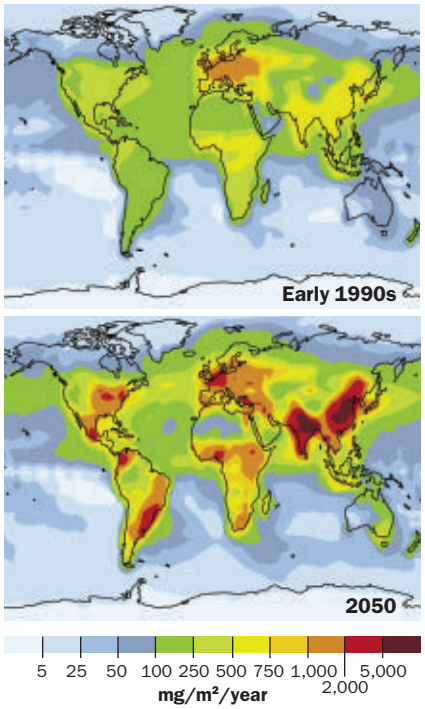
In looking at the pathetic, shriveled plants, Tilman and his team found that plots with 20 or so species had about half the living matter, or biomass, recorded in the same plots in a normal year. But plots with one or two produced only one-tenth of the biomass of a normal year.

"We actually didn't believe the results when we first saw them," Tilman says.

Tweaking the analysis this way and that still produced the same findings. So Tilman set up an experiment as a deliberate test of the effects of species number on biomass. With 168 plots of one to 16 species, the experiment has been running for 16 years. In the early years it led to a paper presenting evidence that yes, under the same conditions, plots with more species of plants eventually tend to yield more biomass than plots with fewer species.

A 2006 paper in *Nature* by Bradley Cardinale of the University of California, Santa Barbara and his colleagues supports these findings. The team concludes that, overall, tests have shown that greater diversity in systems from grassland plants to rock-hugging marine invertebrates increases the basic productivity of an ecosystem.

Trends in reactive nitrogen deposition

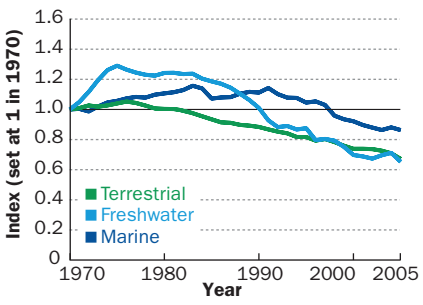


SOURCE: MILLENNIUM ECOSYSTEM ASSESSMENT

Drivers of change The Millennium Ecosystem Assessment lists the deposition of reactive nitrogen, due in part to increased fertilizer use, as an important cause of ecosystem change. Other drivers include habitat fragmentation, overexploitation and climate change.

Monitoring losses The Living Planet Index, actually an average of three indexes, tracks populations of 1,686 species to provide measures of vertebrate status. Tropical species have been hardest hit. Rabb's fringe-limbed treefrog (shown) is categorized by the IUCN as "critically endangered."

Changes in living planet indexes, 1970–2005



SOURCE: WWF, WWW.PANDA.ORG

TREEFROG: BRAD WILSON; LIVING PLANET INDEX CHART: A. NANDY

WHAT TO DO: Count the costs

Nature is underpriced, says economist Partha Dasgupta. No one pays the mountainside for the trees it grows or the sea for the fish it provides.

Figuring out the economic values of nature's services and incorporating them into such indicators may be one way to curb destruction of biodiversity. For without a fair accounting, nature looks like a free lunch, and, Dasgupta says, "If you don't pay for something, you overuse it."

To highlight the economic value of nature on a big scale, Dasgupta, of the University of Cambridge in England, is pushing for a nature-inclusive alternative to the Gross Domestic Product as an economic indicator. The GDP reports the total value of human-made goods and services without deductions to reflect losses of capital, especially natural capital. Gross, as opposed to net, is "the rogue word" in Gross Domestic Product, he says.

Dasgupta is now urging nations and the World Bank to monitor another measure that he and others have been refining in recent years. "Comprehensive wealth per capita" adds human and natural assets to tallies of capital, and should provide a much-needed way to see whether growth is sustainable, he argues in the January 12 *Philosophical Transactions of the Royal Society B*.

Dasgupta compared GDP to his new measure of wealth per capita for five countries and for sub-Saharan Africa from 1970 to 2000 (see table). All the nations averaged annual increases in GDP, and sub-Saharan Africa was slipping only 0.1 percent a year. But when Dasgupta used his wealth indicator, the figures looked different. He incorporated natural resources and human resources. With this measure, sub-Saharan Africa looked even worse than it had based on GDP, and the nations, except China, slipped from the positive into the negative column.

Average percent growth in two economic indicators, 1970–2000

Country/region	Wealth per capita	GDP per head
Sub-Saharan Africa	-2.8	-0.1
Bangladesh	-0.8	1.9
India	-0.4	3.0
Nepal	-0.4	1.9
Pakistan	-1.4	2.2
China	4.5	7.8

SOURCE: ADAPTED FROM DASGUPTA, 2010

What's still missing from the new indicator, Dasgupta says, is a calculation for the complete range of services that ecosystems perform. Many more ecosystems need assessment before there's enough data to include these factors in a wealth analysis.

Edward Barbier of the University of Wyoming in Laramie, who has studied Thailand's coastal mangroves, is building up some of the information on ecosystem damage and services. Since 1975 an estimated 50 percent or more of the country's mangroves have been destroyed to make way for shrimp farms along the coast. The tsunami that bashed the coast in December 2004 raised interest in one of the mangroves' previously underappreciated services—their ability to soften the wallop of incoming waves.

Barbier factored storm protection into a 2007 economic analysis that speaks to land use and restoration choices. He estimated the net returns for shrimp farms at $1,078 to $1,220 per hectare (in 1996 dollars, based on investing for five years and then abandoning the farm). If farmers were required to restore the farms with their acidified, compacted soil so that the mangrove ecosystem could thrive again, shrimp farming wouldn't be worthwhile. Restoration costs at least $8,812 per hectare, the researchers calculate.

But, Barbier found, a fully functioning mangrove ecosystem would be worth the restoration cost. The value of the mangroves—including the protection they give to larvae in fisheries, products harvested directly from the mangroves and storm protection—added up to at least $10,158 per hectare. —*Susan Milius*

What causes that burst of productivity has led to lively debate. Having more species may increase the chances of getting one super-producing plant that plumps up biomass. That scenario, called a sampling effect, could play out in some systems, but Tilman says he thinks his plots are getting an extra boost from the powers of competition. When species crowd into an area, they compete for resources and become efficient at using them.

Experiments so far suggest that sampling effects explain about one-third of this productivity increase, Cardinale and his team reported in 2007 in *Proceedings of the National Academy of Sciences*. The other portion, the team says, comes from ways that species in a mix complement each other—by promoting growth and through division of labor.

Plants sprout at the foundation of an ecosystem's food web, capturing energy from the sun. Diversity, though, also has an effect on the creatures that eat the plants, says marine ecologist Emmett Duffy of the College of William & Mary's Virginia Institute of Marine Science in Gloucester Point.

Duffy has worked with flowering plants called seagrasses that grow entirely under water. Much of their success depends on the little arthropods called amphipods and isopods that graze on the seagrass blades and remove algal scum that can dim the light. With more species of grazers at work, over time, algae were cleared off more efficiently and grazers increased in number, Duffy says.

Another underwater experiment supports the notion that biodiversity provides stability. A study published in the December 2009 *Ecological Applications*

shows that keeping more fish in the sea may give an ecosystem some protection against unwanted algae.

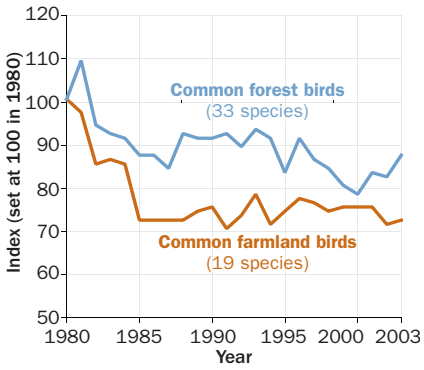
Biologists have warned that burgeoning algae, encouraged by excess nutrients in the water, ranks as one of the most serious threats to the Baltic Sea. To see if the region's declines in perch and other predatory fish also encourage algal outbreaks, Britas Klemens Eriksson of the University of Groningen in Haren, the Netherlands, and his colleagues set up field experiments. Keeping top predators away from study plots began a cascade of changes that eventually led to fewer small creatures grazing on algae.

"Not all species are created exactly equal," says Boris Worm of Dalhousie University in Halifax, Canada. If a top predator disappears, change can shoot through an ecosystem. "It's like hitting a node in a power grid — and the lights go out everywhere," he says.

Worm's own work suggests that fisheries in the more species-rich of the world's marine ecosystems appear less likely to collapse and faster to recover than fisheries in species-poor regions. The analysis, based on more than 50 years of data from the Food and Agriculture Organization of the United Nations, was published in *Science* in 2006.

Even genetic variation within the same species has been shown to affect how well ecosystems pull up their socks and repair themselves. Jay Stachowicz of the University of California, Davis remembers a New Year's Eve call from his then-student Randall Hughes. Brant geese had found Hughes' study plots of eelgrass clones, which she had genetically analyzed with great care. And the geese had eaten just about all of the eelgrass.

Population declines in European birds



SOURCE: CONVENTION ON BIOLOGICAL DIVERSITY

Close-up on birds Scientists have been tracking declines in bird populations around the globe for decades. *Eriocnemis isabellae*, native to Colombia, has recently been labeled critically endangered by the IUCN.

WHAT TO DO: Prioritize wild spaces

Reversing the downward spiral of biodiversity will take more than protecting wild places, but that's where scientists are starting. Declaring protected zones across a range of terrestrial ecosystems is the one area where clear progress toward saving biodiversity has been made, says an upcoming United Nations report. Now researchers are making strategic picks for sheltered zones to fill in the gaps on land and in the sea.

Just documenting diversity doesn't guarantee that a place becomes a park. Selecting good bits requires understanding how critters use space and weighing competing claims for it.

One recent approach looks to double the punch of the case for setting aside land by identifying biodiverse places that also provide documented ecosystem services, says Taylor Ricketts, who heads the World Wildlife Fund's Conservation Science Program, based in Washington, D.C. Though the two don't match tidily, Ricketts has found a few natural sweet spots important for their variety of living things and for such boons as storing abundant carbon or collecting water.

The Natural Capital Project, based at Stanford University, is refining software to allow fine-scale analyses, and Tanzania, the state of Hawaii and others are already using the software.

To pick worthy spots, scientists must also understand how protectees use space, a big puzzle in the seas. Selecting a reef (Papahānaumokuākea marine reserve shown), requires knowledge of where the juvenile fish and corals that populate those waters traveled from.

A modeling technique that includes ocean currents can give a broad picture of dispersing sea creatures, says Eric Treml of the University of Queensland in St. Lucia, Australia. The technique predicts that coral larvae in the Pacific travel some 50 to 150 kilometers before settling in. Of particular interest to conservationists, Treml says, might be reefs that serve as stepping-stones for surfing corals and reef clusters that are especially isolated. — *Susan Milius*

FROM TOP: ALEX CORTES; JAMES WATT

"I tell my students, you've got to make lemonade out of the lemons," Stachowicz says. Hughes kept monitoring the disaster zone. Eelgrass plots with more genetic diversity tended to regrow to their former density faster, she and Stachowicz reported in *Proceedings of the National Academy of Sciences* in 2004.

But biodiversity doesn't always show a short-term effect. For eelgrass growing in the wild, only one of the two characteristics that Hughes and Stachowicz measured, shoot density, correlated with genetic diversity, and only in the winter. That's the time for goose attacks and other miseries, so maybe that's when bounce-back power really matters, Stachowicz and Hughes, now of Florida State University Coastal & Marine Laboratory in St. Teresa, speculated in May 2009 in *Ecology*. Likewise, biodiversity effects showed up in the long run but not the short-term in work on algal-species mixes, Stachowicz and colleagues reported in *Ecology* in 2008.

Regardless of the technical ecology research, Miller says, preserving biodiversity is just common sense. He makes what's been called the "intelligent tinkerer" argument: When fiddling with something complicated and not entirely understood, it's not smart to throw away parts — especially when those systems keep humanity alive on the planet. Miller hands over a printout of a list he's made of some services: clean water, wild fish, pollinators for crops, protection from erosion, clean air.... Pulling pieces out of ecosystems puts these services at risk.

Also, he points out, biodiversity has aesthetic and spiritual values. Stewardship of the natural world stands as an obligation of certain religious traditions. And some deep urge in humankind, what entomologist Edward O. Wilson of Harvard University has called "biophilia," may draw people to other living things.

Back among the insects, Miller pulls out a drawer with row after row of ranks of iridescent blue *Morpho* butterflies to illustrate his point. Most people have at one time or another admired portraits of these beauties, but such images don't do justice even to museum specimens, which shimmer and glow as the angle of view tilts. Next, Miller displays something less familiar: a drawer of adult Heliodinidae moths, which are bigger than rice grains but not by much. Bending close, he points out blazes of russets and rich browns mixed with white on tiny but lovely wings. There's inspiration in known diversity and in the variety that has yet to be admired. And that is indeed something to celebrate. ■

WHAT TO DO: Tend the not-so-wild

Maintaining biodiversity by protecting wild or lightly inhabited land alone would overlook the realities of this crowded century, says Mark Goddard of the University of Leeds in England. Humankind's footprints already cover a lot of space.

In 2008, for the first time, more than half the planet's people lived in cities. So bits of greenery in yards or urban parks need attention, Goddard and his colleagues argue in the February *Trends in Ecology and Evolution*. Surveys show that remnants of nature in built-up environments can boast impressive populations of some species. Bumblebees of several kinds proved more abundant in San Francisco's urban parks than in two parks outside the city. In Britain, the density of one bumblebee species's nests in suburban yards matched the density in hedgerows in the countryside. And the frog *Rana temporaria* declined in the English countryside but thrived in towns. If biodiversity can be promoted in a city's crazy quilt of greenery, the areas could add up, Goddard says.

Conservationists are already experimenting with incentives, pledges and certification programs to coax private landowners to make the most of their yards. In the United Kingdom, the Royal Society for the Protection of Birds has inspired more than 25,000 people to improve their habitats through the Homes for Wildlife plan. And in the United States, the National Wildlife Federation's Certified Wildlife Habitat program has reached more than 100,000 properties. Yards and urban parks do present harsh challenges, such as bird-unfriendly cats. But early research has started sorting out what factors might soften urbanization's impacts.

Even the most artificial of landscapes might be rendered at least a little friendlier to biodiversity, say two forest ecologists at the University of Quebec City in Montreal. Tree plantations, usually created as rows of a single species destined for harvest for timber or pulp, "have a bad reputation," Alain Paquette says. In the February *Frontiers in Ecology and the Environment*, he and Christian Messier argue that plantations need not become biodiversity deserts. Foresters might leave patches of previous stands for animal habitat as the next stand grows, or tighten up soil preparation to reduce erosion. One hefty change would be to trade monocultures for polyculture plantations growing several tree species.

Foresters have resisted the mix, in part because harvesting gets complicated. But Paquette and Messier report that planting fast-growing hybrid poplar as nursemaid species to shelter slower-growing trees shows promising early results. Last year the researchers set out young trees in test plots of up to a dozen species to find out what kinds grow well together. Paquette says he hopes that experiments that have predicted higher biomass in the presence of greater species diversity will apply to practical forestry, too. — *Susan Milius*

Explore more:

- IUCN: www.iucnredlist.org
- Millennium Ecosystem Assessment: www.millenniumassessment.org

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