

Are We Losing the Science of Taxonomy?

LISA W. DREW

As need grows, numbers and training are failing to keep up.

To find a reason that the world needs both more taxonomists and better training for them, mammalogist Michael Mares, director of the Sam Noble Oklahoma Museum of Natural History, has only to open a drawer. An authority on the mammals of Argentina, Mares can find specimens relevant to his work in collections all over the world. But more often than not, the labels are incorrect. During one recent visit to a museum that Mares will not name—“but it’s one everyone on this planet has heard of,” he says—he found that every one of roughly 50 specimens, representing seven species and three genera, was mislabeled. And they were all mammals, arguably the easiest life forms to identify.

For Mares and a growing chorus of other experts, mislabeled specimens are a symptom of a much larger problem, one that starts with field research, far beyond museum walls. The issue, they say, is that even though our rapidly changing world makes the identification of species increasingly important for biodiversity science—and increasingly relevant to the very future of humankind—the field of taxonomy is underfunded and underappreciated.

In the field, it may seem to be only common sense that botanists better trained in plant identification will

be more accurate than those with less training, but it has apparently not been clear just how much this matters. So a group of researchers led by botanist Antje Ahrends of the Royal Botanic Garden Edinburgh, in the United Kingdom, recently looked over records of tropical tree research in Tanzania from 1980 to 2007. Their study, published January 2011 in *Biological Conservation*, concluded that the better-trained scientists found more species, including more species of conservation concern. The new analysis of the research “suggests that it may be necessary to account for recorder training when comparing diversity across sites.”

Concern over the status of taxonomy is not new. It has cropped up regularly over the past few decades in both peer-reviewed and popular publications. The field’s shortage of resources and experts even has a name: the *taxonomic impediment*, which the international Convention on Biological Diversity has worked to address since 1998 through its Global Taxonomy Initiative. Still, the problem persists, and two factors give it a fresh, race-against-time urgency: the pace of climate change and the ongoing human alteration of natural resources that include everything from aquifers to forests to global

nitrogen cycling. “Just as the need to catalog, study, manage, and protect species in their environments has never been greater, the pipeline of adequately trained professionals is trickling dry,” concluded a team of Botanical Capacity Assessment Project researchers, led by Marshall Sundberg of Emporia State University. One of the key problems with the training, they note, is the shrinking number of university courses that emphasize plant identification.

Experts diverge on the numbers

Hard numbers that quantify the shortage are difficult to come by. “Everyone in our community already knows we need more people in the trenches doing this work,” says Patrick



This tiny Australian Passiflora kuranda, only two centimeters in diameter, was described in 2009 by Krosnick. Photograph: Tony Rodd.

Herendeen, a senior botanist at Chicago Botanic Garden and program director, American Society of Plant Taxonomists. “There’s a tremendous amount of biodiversity out there that we have yet to discover and document and describe and publish as new taxa, and overall, we seem to be training fewer new taxonomists, fewer people are coming into the field, [and] more people are retiring, and so that’s pretty disturbing in terms of numbers of people available in [the] future with the expertise to do this work.”

Still, by some measures, more taxonomists may be at work today rather than fewer. The number of herbaria in the world, for example, is at an all time high, at 3400, according to Susanne Renner of Ludwig Maximilians University, in Munich, who is executive vice president of the Society of Systematic Biologists. This means, she concludes, that “there are now more curators than there ever were before.” Although taxonomy may be dying out at universities, she maintains, it is thriving in collections, particularly in Latin America, Asia, and Africa, where collection building is accelerating. That can also mean that the need for taxonomists is increasing.

The numbers of new species being discovered may also reflect an increase



Colostethus kaiei is a new species in the poison dart frog family discovered in 2004 at Kaieteur National Park, Guyana, South America. Males can be as large as 18.9 millimeters, females up to 19.8 millimeters. This is only the second species of *Colostethus* known to provide maternal care for tadpoles. Photograph: Godfrey R. Bourne.

in the numbers of taxonomists. “There is an apparent contradiction in the claim that taxonomy is in crisis and the fact that the annual rate of species description is more than twice that of the historical average,” notes Quentin Wheeler, founding director of the International Institute for Species Exploration at Arizona State University. But there are explanations, he also points out. The definition of *taxonomy* is something of a moving target, often meaning far more than the description and naming of species and often applied to the research of systematists and phylogenists who may be working with molecular and database analyses. “Those who have an interest in describing species cannot find jobs that allow them to do so full time, nor can they secure grant funding for purely taxonomic work,” notes Wheeler. Also, he adds, “For the mega-diverse fauna and flora, the only governor on rate of discovery is the number of taxonomists working.”

Any attempt to assess the numbers of taxonomists is further complicated by an uneven distribution of taxonomic expertise and effort. “The biodiversity to be discovered is in the tropics, but most of the standing expertise is in North America and Europe,” says botanist Herendeen.

“If we’re really worried about documenting and understanding diversity, we need to have more people trained in these various countries where a lot of this biodiversity is endemic. Then the other point is that there’s a lot of cryptic diversity in microorganisms, and there we’re just scratching the surface in terms of what we know and the numbers of people who are able to address bacteria and other kinds of microbes.”

Making the case

Some outreach efforts are aimed at the general public. Entomologists at the US Geological Survey (USGS) boil down the importance of accurately identifying the nation’s 4000 species of bees and their habitats to four words: “Bees are not optional.” The USGS

notes the pollinators’ decline and their annual \$15 billion value to US agriculture alone. Similarly, “botany is not optional” is one of the headings in the full report of the Botanical Capacity Assessment Project—which fills 93 pages with the status of US plants and the vital importance of botany for food, fiber, fuel, medicine, ecosystem services, and more.

The urgency behind such efforts comes in part from the need to understand our biodiversity before it disappears or is altered. So much is unknown about life on Earth that scientists can only begin to estimate what remains to be discovered. “There’s a clear need for training people who are doing taxonomic and systematic research, and I would especially emphasize that in the descriptive aspects of biology—in describing new species and classifying organisms,” says botanist and herbarium curator Alan Prather of Michigan State University. “And we need positions for these people to work in. We’re a long way from having completed Linnaeus’s work of describing all the species on the planet. We have made a lot of progress in the 150-plus years since Linnaeus, but we have a long, long way to go, basically in all groups.”



Varroa mites are a serious threat to honey bee colonies. This species, *Varroa destructor*, is shown on a honeybee host. It was described as a new species by D. L. Anderson and J. W. H. Trueman in 2000. Photograph: Eric Erbe, colored by Christopher Pooley; US Department of Agriculture, Agricultural Research Service, Electron Microscopy Unit.

Even as taxonomy struggles for recognition and funding, many biologists say that we are still in the Age of Discovery—or in a new one. In 2008, the most recent year for which complete data are available, researchers newly described and named 18,225 living species, according to the 2010 State of Observed Species report produced by the University of Arizona. That brought the world total of known species to 1,922,710. Scientists can only guess at how many remain to be found. In August, in a study published in *PLoS Biology*, researchers estimated that there were 8.7 million eukaryotic species—with 86 percent of them awaiting description. Meanwhile, some habitats and ecosystems are such unknown biological frontiers—think deep-sea hydrothermal vents—that every time researchers so much as sample them, they find new species. The decade-long Census of Marine Life, which ended in 2010, estimates that the ocean holds more than one million marine species, excluding microbes. Yet it also concluded in a final report, “After all its work, the Census still could not reliably estimate the total number of species, the kinds of life, known and unknown, in the ocean. The Census found living creatures everywhere it looked, even where heat would melt lead, seawater froze to ice, and light and oxygen were lacking.”

Still, the discovery of new life on Earth does not seem to capture much of the public imagination. Life on



Researchers with the US Geological Survey discovered this Pearl River map turtle, *Graptemys pearlensis*, in 2010. Photograph: Cris Hagen, University of Georgia, Savannah River Ecology Laboratory.

another planet would be another story. “If they find life in space, they’re going to be very excited, and they’re going to ask what are the species, where did they come from, how do they vary, one from the other,” says Mares. “Well, we don’t know those answers for life on Earth...What are the species on Earth?... And how do they vary?... How are species distributed in geographical and geological space? We can’t answer [any of] that.”

As is the case in other sciences, some areas of taxonomy can seem almost absurdly irrelevant—until they are not. The nation’s natural history collections, with their jars and drawers of specimens, are full of such examples. “We’re always stunned by the unintended uses of such collections,” says Prather. “When you’re making collections and paying people to work on those collections, you don’t always know the outcomes.” During the Southwest’s hantavirus outbreak in 1993, researchers were able to use the drawers of preserved rodents in the University of New Mexico’s Museum of Southwestern Biology to determine that the virus was not new and was hosted in deer mice. In another case, when bee colonies collapsed nationwide in 2006, there was no field guide to identify the nation’s bee species. So researchers used the drawers of bee specimens at the Smithsonian Institution, among other resources, to create online identification guides for the bees of North America.

Perhaps the most unusual example took place in 2007, when FBI agents asked entomologists at the University of California, Davis, Bohart Museum to consult their seven-million-specimen collection to help solve a murder case. The scientists studied the insect carnage on a radiator and air filter from a rental car and determined that the carcasses were from California. But the insects’ deaths, of course, were not the crime. They helped prove that defendant Vincent Brothers had in fact driven from Ohio to California to kill five family members, although he had said that the car had not left Ohio.

Correct species identification of museum collections is also critical for studying the effects of climate change. Collections in North America yield a useful history of the continent’s plants, animals, and fungi over the past 200 years. Prather points to the example of the records of blooming dates for flowering plants at Harvard’s Arnold Arboretum. “They didn’t intend that to be a record of climate change,” he says, “but what they actually found when people went back and studied these collections was that plants are blooming earlier—not every year, but in a trend as the climate has warmed in New England. That’s an example of unintended consequences, and it ended up having tremendous scientific impact.”

Still, even though the value of collections cannot always be known in advance, the rapid pace of climate change may dictate priorities, points out Richard Lane, director of science at London’s Natural History Museum and author of a 2007 report on the status and future of taxonomy in Europe. “We need to worry more and more about shallow seas and alpine flora and fauna, because these are changing fast,” says Lane, “and to measure how fast they’re changing, we’re going to need to know what organisms live there, how many different kinds there are, how we can identify them. This is a good example of where taxonomists need to apply their efforts to fast-changing habitats. They need to do that now—because if we just have long debates, those habitats will have gone.”

That kind of prioritizing also points to the other main reason for the urgency behind the call for more taxonomic expertise: It is vital to many of society’s most pressing needs. “So we’re having that difficult discussion about which groups of organisms we should describe first,” Lane says. With limited resources, he explains, he would choose research on a white fly that is affecting crops over research on an obscure bark beetle that is not causing any known problems. “It’s about trying to make sure that the



A fruit body, part of the sexual phase of the life cycle, of the stinkhorn fungus *Phallus calongei*, described as a new species from Pakistan in 2009. Photograph: Gabriel Moreno.

work we do has broader relevance,” he says.

Examples of such relevance abound. The organization BioNET—a “global network for taxonomy”—lists on its Web site case studies of taxonomists coming to the rescue. In just one example, a species of spider mite that has been increasingly infesting tomato crops in southern Africa over the past couple of decades was misidentified in the 1990s as a longtime problem species. A costly pest management plan was put together using natural

local controls, but before it was implemented, taxonomists recognized that the pest was a newcomer from South America, and biologists developed a new strategy for using an imported predator mite. Taxonomic expertise is needed for invasive species identification of all kinds, from choosing appropriate species for habitat restoration to identifying living vectors of disease, to selecting new sources of biofuel.

Taxonomists not valued in academia

None of that work, however, can take place if we do not have taxonomists to do it, and some worry that taxonomists themselves are “on the verge of extinction,” as ecologist Simon Leather of the Imperial College in London has put it. Author of several pieces about the decline of taxonomy, he has also called it “the bogeyman of science, perceived by many scientists as a second-class or amateur discipline.” The experience of applying for funding for taxonomic initiatives, he says, can be “like banging my head against a brick wall.” He is particularly concerned that young biologists are not learning taxonomy until they specialize, that the few who

do choose taxonomy develop only a very narrow focus, and that generalists or group experts are aging out of the field.

Part of the bogeyman problem lies in how universities evaluate scientists, as was pointed out by Lucinda A. McCade of the Academy of Natural Sciences and colleagues, who found a “remarkable mismatch between professional productivity in systematics—both traditionally and in the twenty-first century—and the prevailing academic assessment system.” Such productivity, especially for systematists, can include specimen collecting; curation; digital objects such as data, video, and images; software applications; and other work that does not fit into the traditional peer-reviewed-publication formula.

Mares has long observed the same problem. “Your rank in a university is based on publishing in journals that have a high citation index,” he points out. Taxonomy is often published in monographs, but monographs are not counted as citations. “So taxonomists are going to have low citations indices,” he says. “And their grants are small. If you had a million-dollar grant for every taxonomist, they’d start moving like big shots on campuses. For better or for worse, for some administrators, that’s their main metric, especially in times of straitened finances.”

Leather sees a vicious cycle at work, in which the academics who sit on Britain’s Research Council funding panels have vested interests in other areas of biology, so they tend not to fund taxonomy, and taxonomists do not make it onto the funding panels because they do not get grants. “And so people like us are then perceived by the universities as not earning money, so they don’t recruit people like us, and so there’s no training,” he says. “I can get very depressed thinking about this.”

At the same time, many recent and new large-scale research efforts are underway that depend on taxonomists. Many take advantage of new methods of DNA analysis, including



As it was described in 2008 in the *Proceedings of the National Academy of Sciences*, *Furcifer labordi* is the shortest-lived four-legged vertebrate, with a four- to five-month lifespan. It is one of 150 new species discovered on Madagascar by Christopher J. Raxworthy. Photograph: Christopher J. Raxworthy.

Box 1. A sampling of taxonomy initiatives.

Taxonomists often collaborate, managing and sharing data in innovative ways. Here is a partial list of large-scale projects.

The Census of Marine Life ended its 10-year effort in 2010. Among the many accomplishments of its 2700 scientists from 80 nations was the collection of an estimated 6200 new species, of which taxonomists have confirmed that 1200 are new. The scientific literature to date has formally described 250,000 marine species (www.coml.org).

The World Register of Marine Species, which describes itself as being controlled by taxonomic experts, not database managers, aims “to provide an authoritative and comprehensive list of names of marine organisms” (www.marinespecies.org).

The National Ecological Observatory Network, a planned, federally sponsored database on the impacts of climate change, land-use change, and invasive species on natural resources and biodiversity, is scheduled to fully launch in 2016 (www.neoninc.org).

BioNet, an arm of the Global Taxonomy Initiative, is in turn a program of the Convention on Biodiversity. BioNet, which has members from more than 100 countries, was formed “to promote the taxonomy needed for decisionmaking, sustainable development, and conservation, particularly in the less-developed countries” (www.bionet-intl.org).

The Integrated Taxonomic Information System is “a partnership of federal agencies formed to satisfy their mutual needs for scientifically credible taxonomic information” (www.itis.gov).

The Encyclopedia of Life is an international effort to compile all information about life on Earth, with the goal of creating a Web page for every species (www.eol.org).

Scratchpads is a social-networking application for facilitating collaboration among different laboratories, managing and sharing taxonomic information, and publishing it online. It is hosted by the Natural History Museum in London (<http://scratchpads.eu>).

metagenomics, and inventive ways to manage and share data using cyber-technology (see box 1).

Meanwhile, Mares is determined to correct the mislabeled Argentine specimens in at least some of the world’s natural science collections. Many of the museums are lending him their specimens, and Mares is building a database of the correct identifications. Eventually, he will send the specimens back to their homes, labeled accurately. “No one who knew what they were looking at ever looked

at these animals, and there were no specialists there to look at them,” he says.

One of his other projects, as a curator, is to deal with riffle beetle collections from all over the world that had been sent for identification to University of Oklahoma zoologist Harley Brown, who died in 2008. Mares would like to send the collections back to their museums. “But a lot of times the people who sent them for identification are dead also,” says Mares. “And that shows the rarity of

a specialist on a complex group. You can have a beetle specialist that’s not going to know one riffle beetle from another, because it’s a different kind of beetle from their specialty. This is a really tough business—and there aren’t enough specialists out there.”

After researching this article, longtime science writer Lisa W. Drew (lisadrew@nasw.org) realizes that she could probably discover new species outside her back door in upstate New York—if only she had the training.