Chapter 5
Introduction to Biodiversity

Kelly Swing

Abstract Biodiversity has finally entered conversations among scientists and the populace at large as a common topic. With news about high rates of species loss and increased extinction rates, getting an idea of the wealth of species on our planet takes on an air of urgency and significance. In about 250 years of applying scientific names, we have managed to work through only a fraction of what is believed to be out there. Part of human nature involves collecting and categorizing the things around us. Our priority and primordial purpose for keeping collections and catalogs can vary from simple curiosity to economic interests. Only recently has biodiversity, in and of itself, come to be regarded as a valuable resource. Undoubtedly, every species plays a role in nature and as such, has potential to provide humankind rewards at some level.

Keywords Biodiversity • Extinction rates • Significance • Species catalog • Priority • Collections

5.1 Introduction

Biodiversity, a term shortened from biological or biotic diversity in recent decades, is typically seen rather as a bare bones concept—as simply the number of species that inhabit any given area. Within this concept, scientists seek to catalog absolutely all life forms, extant and extinct. The addition of thousands of species per year certainly bolsters our overall knowledge of life, but according to our best estimates of a planetary total, species lists remain surprisingly incomplete. Our understanding of phylogenetic relationships and geographic distribution has grown exponentially in the last century, but we are still relegated to extrapolate from a relatively limited fraction of existing biota.

Conversations about biodiversity commonly begin with purely biological perspectives but quickly stray to include conservation issues as well as philosophical,

K. Swing (✉)
College of Biological and Environmental Sciences, Tiputini Biodiversity Station, University of San Francisco de Quito, Quito, Ecuador
e-mail: kswing@usfq.edu.ec

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utilitarian, and economic considerations. Treatments of how individual species come into being occupy thousands of pages of published literature, presenting nearly endless explanations ranging from diversity-begets-diversity arguments to allopatric speciation and punctuated equilibrium among dozens of theories. Since the eighteenth century when Linnaeus initiated the formal process of documenting all the "divine creations" and subsequently, in the nineteenth century when Lamarck, Darwin, Wallace, and Haeckel attempted to elucidate how species come into being without the need for divine intervention (Milner 2009), multitudes of scenarios have been proffered (Dunn 2010) to explain that "mystery of mysteries" (Darwin 1859). Science has sought equally to explain how multiple species subsequently fit together in ecosystems and ultimately to comprehend their disappearance. The abundant scientific and philosophical theories put forward succeed, to varying degrees, in explaining these processes at different levels for different individuals and cultures, but considering the state of knowledge in other fields, we are just beginning the work of putting together an inventory of life on Earth. It is highly plausible that we already know far more about the processes involved than we ever will about their multitudinous results.

5.2 Perspectives/Perceptions

> Biodiversity is, in essence, the full array of life on Earth. . . . biodiversity is more than just the number and diversity of species . . . The concept of biodiversity includes both the variety of things and the variability within and among them. Biodiversity also encompasses the processes—both ecological and evolutionary—that allow life on Earth to continue adapting and evolving. (Stein et al. 2000)

Recently, as an opening exercise for a conservation-oriented meeting in Quito, Ecuador, all 20 participants, from very different backgrounds, were given 1 min to write on a piece of paper what they as individuals considered biodiversity to be. Upon revealing their notes, everyone was given a brief opportunity to expound upon any underlying meaning related to what they had jotted down. Responses varied from concise to complex, from surprisingly simple to possibly profound. "Biodiversity is beauty." From the perspective of any nature lover, esthetic value may be of central importance, with each kind of organism being an entity which provokes both wonderment and admiration. "Biodiversity is life" sounded rather basic at first, superficially referring to each and every living being, but with further explanation, suggesting that life begets life, that all life is interconnected, as in the Gaia concept, and that in the swirling mass of protoplasm on the planet, an interdependence is both evident and necessary for success, survival, and continuance. "Biodiversity is a legacy that was handed down to us under the condition that we would pass it along intact to future generations." That thought focuses on a sense of responsibility while ignoring any need for a source or justification of said responsibility. At the end, there was a perspective that perhaps implied a value judgment. "Biodiversity is the expressed compilation of millions of years of answers to all the challenges ever presented; it is the tangible product of all biotic trial and error." This last statement hints that every species is an accumulation of information about survival across the millennia. It also implies that, at any given point in the history of Earth, we are merely observing the current winners in an ongoing process that is always sorting out successful forms and strategies from those that are less successful.

All that information about life, the product of infinite experimentation, is stored in a marvelous chemical warehouse known as the genetic code. Although the last half century has yielded astounding documentation of this biochemical system, we have little understanding of just how a series of repetitive units in DNA and RNA chains makes everything work at the cellular, organismal, or behavioral levels. Although we can identify sections called genes and even transfer pieces that we see as advantageous into other species for our own benefit, no one could, from scratch, put together and install even a few letters of the A-C-G-T alphabet and know precisely what the outcome would be. Of course, we talk about applied gene therapy along with genetic engineering and splicing, but we mostly mean extracting functioning combinations and inserting them into other cells or individuals with the hopes that they might work the same way in their new nuclear or cellular surroundings. Sometimes there are great successes, but the challenges are enormous and failures are frequent.

In recent decades, we have mapped the genome of a selection of organisms and that great achievement invites us to work toward deciphering the connections between molecular composition and coded meanings. We have, however, not yet discovered a Rosetta stone that would allow us to interpret directly individual "words" or "phrases" from this language or to convert them into functioning systems or beings. Our inability to read this language does not in any way diminish the value of the information contained there. However, not recognizing the potential value of that information, and complacently allowing it to disappear through extinction, represents an unthinkable tragedy.

If we try to communicate with a person who only speaks a language we do not know, we can generally bumble around until a basic message gets through, but the limitations are staggering and the process is both tedious and frustrating. In the end, depending upon our motivation and resourcefulness, we can seek out ways to share our thoughts, but we tend not to bother unless our curiosity is driven by the promise of some substantial reward. We have a few alternatives but we tend to simply step away. In such a situation, we hope that we are not missing anything particularly important, but we cannot know. What if, however, we truly want to know what is in the mind of that person? What if we somehow had a chance to interact with an historic figure who we profoundly admire but we speak different languages? What if a shaman, who is the sole repository for handed-down information related to a cure for any of the maladies that humans suffer on a regular basis, only speaks an obscure indigenous language and belongs to an uncontacted culture that has no writing? We have no access to his knowledge base and that information is guaranteed to be lost (Plotkin 1988). Our not knowing undoubtedly represents a loss to many and maybe all of humanity. The same is true for all the untapped genetic information accumulated in millions of species over millions of years. We cannot possibly know its value until we have interpreted it, but it would be utterly foolish to discount its potential (Ehrlich 1988).

5.3 Significance

The overall meaning of biodiversity hints at another level of understanding and has undoubtedly occupied some human minds for as long as we have been conscious of our surroundings. Some, possibly from a basal spiritual perspective, tend to interpret mere existence as an indication of inherent significance. The scientific community tends to believe that every species, no matter its size, has some functional value for the ecosystem it inhabits as well as some potential economic value. On the other hand, numerous nonscientists have a way of summarily dismissing a massive portion of species, the majority actually, by simply discounting the unknown, the abstract to them. If one thinks about this situation a bit, we must recognize that everyone has no choice but to do the same at some level. No one can "know" all those millions of species. Even the greatest taxonomists, depending upon their areas of expertise, commonly know somewhere between hundreds and tens of thousands of species by their scientific names, but the ones who are naturalists at heart are familiar with many more and can broadly categorize just about anything upon first sight. This capacity gives them an incalculable edge; they manage to acquire that most difficult of all qualities in this realm, perspective. In contrast, the lack of perspective in everyone else turns out to be a threat to all the unknown. If one categorizes each species as "worthwhile" or not, including only those with some rather obvious "significance" in a practical or economic sense, an underlying interpretation is that many other living "things" are of little to no consequence or concern because of their small size or lack of proven value (Ehrenfeld 1988; Kareiva et al. 2011) or inherent interest. Hence, the frequently asked question in relation to species-specific conservation efforts—"What good is it?" (Thiele 2011) This attitude is probably at the root of why we have not made any effort at national or planetary levels to complete the catalog. As long as potential value is not converted into known, confirmed hard cash value, it remains abstract and is therefore not considered real or worth exploring. As they say, "the bottom line is the bottom line." The argument feeds upon itself. As long as we do not know enough, we cannot say anything about specific value and as long as we know nothing of value, we do not routinely justify making efforts to learn more. Thereby, as our behavior has confirmed repeatedly, biodiversity that matters to humans at large is the only biodiversity that matters. Smith (2015) points out that we should protect the environment so as to keep our options open into the future. The human race has also demonstrated on many occasions that having economic value does not guarantee sustainable management or even survival of some species.

We only know what we see;
we only love what we know;
we only take care of what we love.

This Native North American proverb is applicable at just about every possible level, whether in reference to a piece of furniture, a national symbol, a family member, or a species on the brink of extinction.

Another facet of the biodiversity conundrum is the fact that human brains are not especially good at dealing with truly large numbers. Once we get past a few thousand, our grasp becomes ever more tenuous, our perception becomes ever more vague. Our ability to comprehend huge numbers—millions, billions, trillions—in an absolute way is probably simply beyond most of us. This is true whether we are considering the classic grains of sand on a beach or the stars in the heavens. Relative dimensions are easier to absorb so we try to gain a foothold by making comparative scales in our minds. Knowing that there are thousands of times more beetle species than birds does not help a great deal because most people are not familiar with more than a few dozen kinds of birds. Whenever I ask college biology classes how many species of birds exist, the guesses range wildly from hundreds to a few thousand, but the estimates are commonly far fewer than the 10,000 or so that have been documented scientifically. The knowledge gap gets much worse if we move into the realm of invertebrates. Let's think about mollusks, for example. If we ask about this group of relatively familiar organisms, most students will start their calculations by considering how many kinds they have seen personally (including garden slugs and seashells), adding the kinds they have eaten (clams, mussels, oysters, scallops, calamari, octopus, escargot perhaps), plus the ones they remember from interesting nature documentaries (cuttlefish, giant squid, giant clams, nautilus) and eventually arrive at a sum of dozens and then, by extrapolating for the world at large and various unknown factors, toss out numbers between hundreds and thousands. Of course, the real number is closer to 100,000 but because we have such limited experience and such a weak knowledge base in general, our capacity to approach such a number without knowing it by rote memory is almost nil. Being able to make a list helps immensely, but simply hearing big numbers does not do the trick for most of us. Stacking abstractness on top of abstractness does not resolve the problem at all.

Being told that there are nearly 30,000 kinds of fishes in the world does not automatically give each of them any real status. Only when we are able to apply names and images to them does the picture start to become clear. With these vertebrates, we can go through the same process my students used for mollusks, but most people cannot get past the few kinds they personally have consumed (tuna, trout, salmon, flounder, mahi-mahi, sole, cod, red mullet, bass, catfish) or seen in the local pet shop (goldfish, tetras, plecos, angelfish) plus those depicted in exciting documentaries on shark attacks. Dozens versus tens of thousands represents a knowledge gap that may be insurmountable at the level of the masses. This, in turn, probably means that the average person may well not care whatsoever that there could be millions of species of beetles (Farrell 1998) in the world's rainforests or that 80 % of them still have not been cataloged. If we know nothing of them, the majority remain rather abstract and completely unappreciated (Ehrenfeld 1988).

> This must be the wood where things have no names.—Lewis Carroll, *Alice's Adventures in Wonderland*, 1865

5.4 Challenges to Documentation

Understanding the diversity of life on Earth remains a tremendous challenge due primarily to the immensity of the task of recognizing precisely how many kinds of beings exist. Superficially, cataloging the species that share the planet with us sounds like it should be a relatively simple and straightforward chore. After all, how hard could it be to go out into nature, make the necessary observations, collect some images or specimens of all we encounter and put the results in a museum, an encyclopedia or on a website (WWF 2014; EOL website 2008)?

5.4.1 Mentality and Motivation in Relation to Cost Versus Benefit

All indications are that, on the whole, we basically do not care about finding out what's out there. A gargantuan, jaw-stretching yawn would be the most predictable public response to the mention of a world taxonomy campaign. If we suggest that taxpayers should cover the cost of applying scientific names to everything, the response would probably be resoundingly negative and might even provoke protests. The absolute number of species in existence is about as relevant to the common man as the number of bolts in the Eiffel Tower is to a typical holiday traveler in Bangkok. Such a detail might be interesting to a select group of civil or structural engineers, but the average person who has saved up for a visit to this destination would not pay much for this disjunct tidbit of information associated with a monument in Paris, no matter how famous. Neither does an average citizen see any rationale that could justify putting large sums of money into making such a list.

Logically, the game changer would be to show people at large that such expenditures should be viewed as investments. It is indeed a lottery but there can be real rewards. Unfortunately, few individuals have heard much about the limited number of true success stories. Science gets little publicity outside the realm of medicinal applications, so getting the message out continues to present an important hurdle. Here, scientists can only point a finger at themselves for not making more efforts to share the results of our research in an accessible form.

Pharmaceuticals represent one realm of possibilities that could change public opinion. Every estimate available suggests that well over half of all clinically available drugs are derived, directly or indirectly, from wild plants (Farnsworth

1988). Some of the related information came to us through our grandparents and some has come through indigenous shamans (Plotkin 1988) and the rest has come through direct investigation or pure dumb luck. In any case, less than 5 % of the world's flora has been scientifically screened for biochemical activity or potential medical applications. Chemical defense compounds, which seem to work in countless ways, evolved over millions of years within the tissues of many organisms, help them combat all sorts of challenges. Based on observations of what is referred to as "self-medication" in nonhuman primates, it can be inferred that certain terrestrial plants have been used "intentionally" since before humans existed. Many marine invertebrates and algae are particularly promising sources as well (Graneli and Pavia 2006). Considering that innumerable molecular innovations in nature have served their producers well for millennia, it is only reasonable that some portion could also be put to good use in the human organism. Instead of having to work from zero to develop molecules that can treat or cure specific ailments and diseases, it would be, in all probability, more efficacious for laboratory technicians to take hints from naturally occurring substances that have already been evaluated in nature over huge expanses of time (Plotkin 1988).

5.4.2 Dimension/Scale

When humans go out into nature anywhere, we readily notice certain species and tend to ignore others altogether (Balmer 2013). This is mostly a matter of scale, based primarily on the fact that we are ourselves rather large as compared to most life forms. Right around the globe, we have done a reasonable job documenting the existence of organisms that exceed 10 cm or 10 g. Anything less than that has proven to be a much greater challenge (Vaijalainen et al. 2012). Through technological advances, mostly related to improved imaging and genetic/molecular techniques, science has managed to overcome this perspective bias to some extent, but the fact that the majority of organisms fall into this minute size category continues to present a massive stumbling block. Being small certainly pushes many organisms into the state of being "out of sight, out of mind" for lay people and keeps taxa mostly made up of diminutive forms (Lucky et al. 2002) from ever being noticed by a new generation of potential systematists or conservationists. Ecotourists and even young biologists typically focus their search on the large species associated with any particular ecosystem and quickly become bored when they are unsuccessful at observing animals like jaguars or tapirs in the Neotropical rainforest, all the while entirely overlooking the unending parade of varied arthropods that appear on nearly every leaf. We basically could not care less about small organisms and ignore the fact that this is precisely where the real diversity of the planet lies. Two hundred years ago, Lamarck astutely pointed out that "we should chiefly devote our attention to the invertebrate animals, because of their enormous multiplicity in nature" (Milner 2009). Nonetheless, fervently searching the deep blue sea in order to apply names to dozens of species of tiny crustaceans or the jungles of darkest Peru to catalog even thousands of beetle species 2–3 mm in length does not sound exciting to the masses so funding will continue to be limiting. In contrast, one might expect that the addition of vertebrates (Aldred 2013; Butler 2013) to the list would attract the world's attention for a moment, but the recent discovery of several new species of giant fish (Stewart 2013a; Stewart 2013b), a frog in New York City (Feinberg et al. 2014), more than a dozen birds (Hance 2013), a tapir (Cozzuol et al. 2013), a bat (Dias et al. 2013), a shrew-opossum (Ojala-Barbour et al. 2013), a raccoon, the "olinguito" (Helgen et al. 2013), an ocelot (Trigo et al. 2013), a porcupine (Mendes Pontes et al. 2013), even dolphins (Morell 2014; WDC 2014) previously unknown barely made headlines beyond a few specialized blog sites.

5.4.2.1 Accessibility

Precisely where biota is distributed is also part of the challenge (ter Steege et al. 2013). Generally speaking, the first few hundred thousand or so species to be described were those easiest to find and recognize as being distinct. A half century ago, in North America we still celebrated the discovery of a new species because we considered these special events that only resulted from intense, pain-staking searches that deserved recognition. Now, we know that undescribed species abound in specific ecosystems among certain taxa and understand that we best move ahead with the task at hand and need not be distracted by celebrating each one. Nonetheless, in a way that is very parallel to oil or gold extraction, it looks like the phase of easy finds has passed. Those remaining valuable deposits are typically more remote or difficult to access, but that does not stop us from going to the ends of the Earth to get at them. To continue bringing more material into the hands of taxonomists sorting through museum collections, we will need to apply more money and physical effort to explore the places (Natural History Museum website 2012) that 99 % of the human population has no intention of ever visiting simply because it is too difficult (ter Steege et al. 2013). We cannot, however, discount the fact that even some species of vertebrates have been overlooked right under our noses in places like New York City (Feinberg et al. 2014). What does that imply for remote areas? For some context, in eastern Ecuador, in the very recent past, trees over 40 m in height have been described (Pérez et al. 2014; Neill et al. 2003, 2011). How could an organism of such stature have escaped our discerning loupe for so long?

5.4.3 Interest/Incentive

Just as we keep pushing to find more oil and gold, the same should be true of the species of our planet, but the incentives are admittedly quite different. As each discovery inevitably grows in difficulty, the costs of collecting specimens from remote sites will become increasingly prohibitive due to political, geographical or logistical challenges, safety and security risks, the need for specialized equipment and methods, etc. In turn, our willingness to invest public funding in finding them will undoubtedly wane, as a result of diminishing returns. And on top of that, the more we know about the biota around us, the more we will be documenting species in decline, and the more we would be obligated by laws to manage and defend them, implying greater and greater expenditures over time. Ignorance is indeed bliss.

No one becomes famous for finding a new species of fruit fly and most discoveries will never produce money for those who managed to apply genus and species names to them. Now and again, however, something almost magical happens to change the scenario altogether; another kind of impetus enters the story. The 1993 Hollywood blockbuster, *Jurassic Park*, made a huge difference in the level of public interest in dinosaurs and paleontology. As the movie's teenage viewers reached college age, they swelled the rosters for related university courses and then set off energetically down the path of joining research efforts. More hands took to digging for fossils and more minds were put to the task of deciphering their meaning and relationships. The number of discoveries of all kinds of fossils, not just dinosaurs, took a leap forward starting in the mid-1990s. Ultimately, our understanding of the geological past of many taxa was improved astronomically by the input of enthusiasm and excitement into a new generation because of the creative use of computer-generated images in a popular movie. Fantastic beasts were brought to life on the silver screen and in the passions of new recruits to the ranks. Scientists should probably not be expecting such miraculous events to provide the impetus for a wave of science nerds to fill the back halls of museum collections in order to catalog the remaining biodiversity.

Nonetheless, one intended purpose of nature documentaries is expressly to provoke a response parallel to that dinosaur movie. The idea, especially related to conservation is "the more you know, the more you care." Producers always hope their particular film is going to make a difference in the world, by including footage meant to capture the hearts and minds, and wallets, of all its viewers. In turn, those viewers are expected to insist that all their friends see this wonderful exposition of nature at its glorious best. *Animal Planet* and *National Geographic* have their established fan bases just like other outlets and tend to reach the same audience year after year so the likelihood of capturing a new segment of the population is seemingly minimal no matter the quality or rarity of the content. Unfortunately, many people who watch these videos are apparently lulled into the belief that as long as someone can still go out into the wild and bring such images to the television screen, the organisms at the center of the stories must be doing just fine. The moment is ripe for such shows to include some indication of how much time and effort are required to capture the material that inspires awe, so that a typical viewer might appreciate what has been lost already as opposed to celebrating the fact that one of those things can still be found somewhere on the planet even in these modern times.

5.4.4 Level of Expertise and Distribution

Novotny (2009) pointed out that the majority of species live in the tropics, but most biologists do not. Complications abound in getting specimens into the hands of the experts. In many countries, fully formed specialists are truly rare creatures and they are already overwhelmed by a backlog of specimens sitting in jars on museum shelves waiting to be studied and allocated to their corresponding families and genera. No country, university, or institution of any kind has taxonomists on staff who can deal with all the diversity of their region. When an article is published on specimens that have been in collections for half a century, governmental accountants and politicians tend to ask why the scientists have been so inefficient, sitting on this for so long, as opposed to recognizing that more funding and personnel are necessary to make the wheels of the machine turn efficiently.

So far, all we can do is estimate how many species there are, while recognizing that no one knows for sure. While many parks and countries have published lists and field guides to aid in the identification of some groups of large organisms, the invertebrates remain sorely underrepresented.

As it turns out, there are far more species than we had thought just a few decades ago (Alonso et al. 2011). We have gone from a situation in which the majority of people believed that most life forms had already been catalogued to one in which no knowledgeable person sincerely believes we will ever complete this task (Raven and Wilson 1992; Wheeler et al. 2012; Costello et al. 2013; Phys.org website 2013). This may sound rather defeatist and daunting, but at the macroscopic level, we are convinced that there are several million species left to discover and describe, maybe five times what we have accomplished so far in two-and-a-half centuries. For microscopic organisms, we are sure that we have only just begun. On the other hand, we are quite convinced that we have already done a reasonable job of classifying the large organisms—or at least the land dwelling things that are larger than several centimeters in size, diurnal or nocturnal. The reliability of our lists tends to be directly related to the size of the organisms. Therefore, we have no choice but to depend on this known portion of the flora and fauna to give us hints about what is left to discover among the more diminutive realms of life. Until we advance at all levels, this strategy seems rational and simply must suffice; although there is some controversy, science has produced evidence that the species diversity of any taxon tends to serve well as an indication that other taxa in the same places are similarly diverse. So by specifically looking at what we know about the big stuff—trees and vertebrates—we can extrapolate to make informed guesses about the other smaller, more hidden species. For these generally well-known groups, relatively reliable information is available from most regions of the world. Indeed, many countries have produced lists and even published illustrated guidebooks to their birds, mammals, reptiles, and amphibians; additions come out in the form of scientific publications and the process can be tracked.

5.4.5 Estimates Down Through History

In the early years, investigations primarily depended upon that which could be seen with the naked eye. Naturalists went out into the landscape and noted the various organisms that could be observed within some practical distance of where they lived and worked. So far, science has been formally working on this project fairly constantly for over 250 years. In the eighteenth century when Swedish biologist Carolus Linnaeus officially started this endeavor of documenting all the biota, he saw his work of applying names to all of life as a religious mission, a mandate originally assigned to Adam (Genesis 2:20) but never fully realized. By recognizing each and every one of the magnificent beings in existence, the idea was to give credit, and thereby praise, to their creator. From the perspective of a scientist who grew up at a high latitude in the temperate zone, the number of organisms to be listed probably seemed challenging but rather manageable. We can imagine that the related work would be expected to represent a gratifying pastime but not something that might occupy the rest of his life. When Linnaeus died in 1778, he and his "apostles" had applied binomials to about 10,000 species. The European scientific community was duly impressed by this tremendous opus and was satisfied that a goodly portion of the project had been completed. They could not have guessed that Linnaeus' life work would not represent even 1 % of the global total. Half a century later, in 1833, Westwood suggested that there could be as many as 600,000 species of insects alone and reported that his botanical colleagues had arrived at an estimated total of between 110,000 and 120,000 species of plants. Westwood also remarked that John Ray had proposed in 1691 that the number of insects could approach 20,000.

Since WWII, our perceptions of the biota have continued to be modified drastically. In the middle of the twentieth century (Sabrosky 1952), with a list of around half a million species, most people believed that the majority of life forms had already been recognized. The rate of discoveries was diminishing because we continued to look in the same places for new species that were as large as vertebrates or vascular plants. But then, in the 1970s and 1980s, science started to look in different regions more carefully using different techniques (Erwin 1982). Upon turning our focus toward the tropics and the previously unexplored parts of the sea, we began to notice that many specimens being brought back from far-flung areas were different and still required recognition. The rate of accumulation lunged ahead with unprecedented fervor. The astounding upward trend in the growth curve led some scientists to project that there might be 30 million, or 50 million, or 100 million species living in our time (Wilson 1988). By the beginning of the new millennium, we were approaching the 1.5 million mark for named species. The rate has continued to race along with an estimated 18,000 additions per year (Wheeler et al. 2012). In an effort to get a handle on a potential total, in light of all this progress, new calculations have been made (Alonso et al. 2011). Of course, our estimations should be based upon the portion of the biota that is best known (Nielson and Mound 2000) so as to give us a reliable answer. We presume to have a reasonable perception of macroscopic organisms but are still flummoxed by the microbial world. Some advances are certainly occurring there, but estimates of bacterial and viral diversity are mostly seen as guesses. For the things visible to the naked eye and just beyond, a total of somewhere between five and nine million seems to be the most widely acceptable estimates available at present (Hilton-Taylor and Stuart 2009; Mora et al. 2011). The best we can do currently is to, by applying species accumulation curves, extrapolate out to the potential number of species and to estimate where we stand along a scale of progression toward our ultimate goal (Stuart et al. 2010).

5.5 Extinction Rate

Human history is basically a story of one species dominating the planet by using its wit to overcome most of the challenges nature has thrown at it. Our ingenuity has allowed us to occupy almost every niche and habitat (Kolbert 2014) because we, among all species, have uniquely seen opportunity everywhere and uniformly ignored adversity. We are able to make use of an inordinately wide array of resources but tend to be unaware or wasteful of the less than obvious. This incessantly repeated behavior is responsible for our overrunning every part of the globe that we enter.

We never set out to destroy the landscape or its nonhuman occupants, but we do set out to change things for our own benefit, almost always thinking exclusively about short-term payoffs without considering in depth the long-term drawbacks. At the global scale and at the local scale, we start off small and then grow in numbers and force, and geographical distribution. As a consequence, nature cedes at every turn; it is tamed and diminished in every dimension.

"One weedy species has unwittingly achieved the ability to directly affect its own fate and that of most of the other species on this planet." (Wake and Vredenberg 2008)

If we were losing money from our bank accounts as quickly as we're losing species from our forests and oceans, we would certainly take notice and we would undoubtedly do something about it. For most people, if dollars or euros or yen disappear from an account, we immediately look for explanations and remedies. At the same time, we remain completely complacent about the loss of valuable natural patrimony every day, and in most cases, are never even aware that this is happening. Even the lowliest of species must be worth at least a few dollars, but essentially all the large animals, terrestrial and aquatic, have experienced population decreases of 75–90 % (Safina 1997; Myers and Worm 2003; National Geographic 2007; Swing 2013; Ripple et al. 2014; FAO website) just in the last half century, and most humans were never aware of what was going on or just how fast. If one day you wish to see mountain gorillas foraging in the mist, an orangutan brachiating through the forest canopy, or a black rhino ambling on the savannah, you better go now because there is no guarantee whatsoever that any of them will exist until the middle of this century.

We have always needed nature and now, what remains of nature needs us. Basic human behavior has resulted in our nibbling away, like locusts, everything in our surroundings. Once we start down the path of exploitation, a gold-rush mentality takes over and we have never been able to stop. Current extinction rates are estimated at 100–10,000 times background rates measured during intervals between previous extinction peaks; approximately 27,000 species are disappearing annually (Myers 1988; Stevens 1995) and the rate is likely increasing with each passing year (Wheeler et al. 2012; Natural History Museum 2012). Will humankind be able to change? Will we be able to draw a line in the sand (Fowlie 2014) in relation to our exploitation of nature and natural resources? What might drive us to make such a decisive change?

As we have transformed the Earth into our rather exclusive habitat, we have left little of the original version. The result is that we will be relegated to fewer resources in the future. No one seems to have a clear idea of how much the world ecosystem can withstand and we apparently have no intention of using our vision to change our trajectory as long as we are benefited in the immediate sense.

Can we choose what will remain? Shouldn't we be proactive as opposed to accepting by random chance what tatters are left over? Each form of life represents an enormous collection of information about how to survive on this planet. Each undescribed species is a book without a title that has never been opened. With every extinction event, we're discarding a volume that could hold the key to our own survival in the context of climate change.

Most other species on the planet have existed much longer than humans. That means that they have endured events that our own lineage has not. We can infer that, in their genetic makeup, they likely have answers to many of the challenges that lie ahead for our species in relation to current impending global changes. As technology gives us increasing abilities to interpret the molecular/genetic language of form and function, it may become possible to tap into those reference sources at some moment in the future, if, and only if, we have not already naively eliminated the living repositories represented by the diversity of biota.

5.5.1 Role of Scientific Collections

Despite widespread recent perceptions, the collection of research specimens remains vital to the advance of modern science (Phillips 1974; Foster 1982; Herholdt 1990; Remsen 1995; Lundmark 2004; Rocha et al. 2014; Swing et al. 2014). If a shopkeeper does not have an inventory record, it is impossible to manage his merchandize; if we do not know what is living in the world's forests and seas, we cannot even hope to manage the biota for its own well-being or in relation to its potential for our use.

Around the world, increasing popular awareness of extinctions has resulted in policies and regulations that run counter to this necessity. Within the scientific community as well as among the lay citizens of the planet, confusion abounds regarding the causes of impacts on wild populations and the loss of species. In the vast majority of cases throughout human history, rational collection of specimens for scientific study has neither been connected with extirpations nor extinctions. Habitat loss, global climate change, emergent pathogens, environmental pollution, and targeted harvest (hunting and fishing) have provoked much more important impacts and have already transformed entire ecosystems. These are the factors that have led primarily to the sixth mass extinction.

Undoubtedly, informed regulations and oversight are necessary for efficient and functional management. Regulation cannot depend upon heartfelt sentiments or popular opinions; instead, controls must be based on ecological principles and scientific reality. While the sacrifice of individuals of certain species for any reason would be totally unethical and should be punished, the lack of broad collections drastically affects our capacity to catalog the biodiversity of the planet. If we do not know the species in our surroundings, we cannot recognize potential resources among them, and we can certainly not take advantage of all our opportunities in a reasonable way. As in any arena, the lack of information represents a loss of opportunity (Sukhdev 2010). Without a complete list of species and a basic understanding of their roles in nature, it is impossible to comprehend the overall functioning of ecosystems and in the end, effective management of "renewable" resources in light of increasing demands becomes more difficult and less likely every day. Without access to relatively complete collections (accompanied by a plethora of data and meta-data including genetic material), it is impossible to recognize and analyze phylogenetic relationships and to properly position known species into existing classification schemes. In Ecuador, arguably the country with the greatest concentration of species on the globe (Bass et al. 2010), only about 75,000 species of macroscopic organisms have been catalogued (Peter Raven, pers. comm.) This total is estimated to represent less than 10 % of the country's existing biodiversity. In megadiverse countries like Ecuador, this problem is of greater relative importance because the lack of scientific collections and complete biotic inventories imposes serious limits on possibilities for conservation, generation of biological knowledge, and ultimately diminishes potential for development and access to an improved standard of living (Sukhdev 2010).

The proportion of known versus unknown species, according to best estimates, is similar for the entire planet. Worldwide, we have about 1.5 million kinds cataloged and an estimate of nine million or so in total for macroscopic life (Mora et al. 2011). The situation may look far worse in developing tropical countries because the total numbers of species within their borders are so much greater and rates of loss are likely faster due to rapid development in highly biodiverse settings. For politicians and developers, a not-too-obvious corollary of having the greatest concentrations of species per hectare implies the greatest loss of species per impacted area.

We should take a moment to return to the idea of how we apply the terms "known" and "unknown" to various organisms and must admit that using such language leaves a lot to be desired. Just because we have curated a specimen in a museum and have applied a scientific name to it, that does not mean we know anything about it beyond what it looks like. We actually have a very superficial knowledge base for the vast majority of species that are named. The exceptions lie primarily in ourselves, our mono-cultured crops and domesticated animals, but include a few dozen other species that have turned out to be especially apt for laboratory life and prodding.

5.6 Conclusion

> There are more things in Heaven and Earth, Horatio, than are dreamt of in your philosophy.—Shakespeare, *Hamlet*

While good intentions abound, cataloging our fellow inhabitants of Earth has turned out to be exacerbated by a long list of complications. First of all, there are far more kinds than we ever expected. Unfortunately, expertise remains broadly lacking. Because we have only classified a small portion of species so far, our confidence in estimating the possible total is quite weak. Over the years, this has led to the publication of figures ranging from a few million to over one hundred million if we include absolutely every form of life no matter its size. Also, it costs something to find and categorize species so funding is ever a concern. There is always some reticence in moving forward in the face of demands for justification of any endeavor. Out of ignorance, we cannot typically assign any value to organisms before we make the effort to find, dissect, observe, and analyze them. Until we write about them, we cannot share information with other potential collaborators so as to advance our overall knowledge base. Classically, by the way, science has not often been in the business of carrying out financial appraisals. As it turns out, relatively few taxonomists exist and they do not have access to all the species or specimens necessary to complete the catalog—not even close. Discovery is challenging and description is tedious. The rate of additions is inherently slow due to requirements for detailed evaluations in light of already known species. The rate of extirpations and extinctions puts us in a perverse race to label organisms before they disappear altogether.

We must recognize that the diverse biota around us is the product of natural processes across immense expanses of time and that we have many vested interests in its well-being. We still have the opportunity to make decisions that will leave an indelible mark on the planet. In relation to climate and extinctions, we can choose to be remembered as villains or as heroes for all time.

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