



FOUR COMMENTARIES ON THE POPE'S MESSAGE ON  
CLIMATE CHANGE AND INCOME INEQUALITY

IV. POPE FRANCIS' ENCYCLICAL LETTER *LAUDATO SI'*, GLOBAL  
ENVIRONMENTAL RISKS, AND THE FUTURE OF HUMANITY

GERARDO CEBALLOS

*Instituto de Ecología, Universidad Nacional Autónoma de México  
Ciudad de México, México*

E-MAIL: GCEBALLO@ECOLOGIA.UNAM.MX

We live "in a world of wounds" (Leopold 1993:165).

INTRODUCTION

**E**ARTH has the most precious treasure of the endless, cold, and infinite universe: LIFE! Millions of species of animals, plants, and microorganisms share with us this unique planet; a planet with a specific combination of gases that make life possible. But life is at risk. We live in the midst of an environmental crisis of possible catastrophic consequences for biodiversity and mankind (Dirzo and Raven 2003; Ceballos et al. 2015a,b). Global environmental problems, such as habitat destruction and fragmentation, biodiversity loss by population and species extinctions, trade of endangered species, invasive species, toxification and pollution, emerging and reemerging diseases, and more recently climate disruption, were practically unknown or little recognized in the 1950s, but now are the cause of grave concern. The magnitude of the challenge and the relatively little progress that we have made to curb such negative impacts of our development are overwhelming. We need hope. And that is what Pope

Francis gave us when he published his most inspiring and unexpected Encyclical Letter *Laudato Si'*—*On Care for Our Common Home* ("Be Praised" in medieval Latin). *Laudato Si'* is a call for all humans to take action to stop and revert the damage that we have done to "Mother Earth": "It is my hope that this Encyclical Letter . . . can help us to acknowledge the appeal, immensity and urgency of the challenge we face" (sec. 15).

Pope Francis chose his ecclesiastic name from his admiration of St. Francis of Assisi—"the patron saint of all who study and work in the area of ecology" (sec. 10), and the Encyclical's title is a reminder of Assisi's *Canticle of the Sun*, a song where he praised animals as brothers and sisters of mankind, which was written more than 800 years ago. In his Encyclical, Pope Francis offers a rare glimpse of clarity from a major world leader addressing some of the most pressing global environmental issues affecting Mother Nature—our common home, and the titanic efforts that will be required to solve them.

*The Quarterly Review of Biology*, September 2016, Vol. 91, No. 3

Copyright © 2016 by The University of Chicago Press. All rights reserved.

0033-5770/2016/9103-0004\$15.00

Pope Francis (Jorge Mario Bergoglio), an Argentinian priest, was elected the 266th pope of the Roman Catholic Church in March 2013, becoming the first Latin American pope. When I read *Laudato Si'* I was impressed by the fact that the spiritual leader of more than 1.2 billion people from around the world would address critical environmental and social (e.g., poverty and inequality) issues in such a compelling way. And that is good news. As the devastating environmental impacts of human activities increase, derived from the unchecked human population growth, social inequities, and irresponsible consumption, many of us, as Peter Raven has eloquently described in his essay in this special section of the *QRB*, believe that avoiding a collapse of nature and human civilization requires, more than ever, a spiritual approach. And that is what *Laudato Si'* is about: hope that we will find a way to care for our common home, avoiding a possible collapse of civilization.

More than 50 years ago, when the world was at the brink of a nuclear war, Pope John XXIII wrote an Encyclical to warn about the terrible outcomes of war and offered hope and solutions. So, Pope Francis offers hope and solutions in his Encyclical to solve environmental problems, too. Four decades later, with 3 billion more people on Earth, Pope Francis wrote, "Now, faced as we are with global environmental deterioration, I wish to address every person living on this planet" (sec. 3).

The Encyclical covers an extremely broad range of environmental problems, such as global warming, loss of biodiversity, hazardous chemicals and waste, marine pollution, destruction of forests, monoculture plantations, lack of clean drinking water, and social problems such as inequity, greed, and poverty (Bodansky 2015). It had an immediate impact on the media. It was covered in numerous printed and electronic outlets, and became a major contribution to the growing literature on the global environmental crisis. It was received mostly with relief and hope. The Encyclical has been amply discussed in the scientific and humanities technical literature, as well as in

the popular press. It has been praised, but some scientists correctly indicated that although hopeful, it missed the central point of the current environmental crisis, the growth of human population (e.g., Ehrlich and Harte 2015). The Encyclical has had a major impact, especially the discussion of poverty and social inequities in relation to the devastation of nature, and the need to shift to a sustainable economy (e.g., Bodansky 2015; Brito 2015; Ehrlich and Ehrlich 2016).

The publication and outreach of *Laudato Si'* played a role in many important global discussions, and very likely had some influence on the outcome of the historic Paris Climate agreement of December 2015 (COP21). Although the Encyclical has a very solid scientific base, its major impact is because of the moral stature of Pope Francis, rather than its scientific novelty: its impact is more because of the author than because of the content (Bodansky 2015). *Laudato Si'* helped to call attention to diverse environmental problems at the time of its publication. One of my papers on the sixth mass extinction was published a day after the Encyclical (Ceballos et al. 2015a). Because of the timing, this paper became viral, reaching millions of people in few days. In many of the radio, television, and news interviews that my colleagues and I gave, we were asked about our perception of the value of the Pope's Encyclical. I responded that by addressing the major environmental problems in general, and the loss of biodiversity in particular, Pope Francis had helped to convey an important message on the need to act. I also indicated that it was rather fortunate that my paper had been published a day after the Encyclical; and that it was likely one of the key factors in generating so much interest on the sixth mass extinction.

I discuss here some of what I perceive are the positive implications of *Laudato Si'* for conservation of biodiversity, ecosystem services, and human well-being. I use the *Laudato Si'* framework to discuss important environmental issues, particularly global climate and biodiversity loss. My own interest is as an ecologist and conservationist.

So, my comments will expand and discuss some of the topics and ideas expressed by Pope Francis in *Laudato Si'*.

#### UNITED BY THE SAME CONCERNS

Humanity faces an increasing global environmental degradation that threatens its long-term stability. Pope Francis wrote, "The urgent challenge to protect our common home includes a concern to bring the whole human family together to seek a sustainable and integral development, for we know that things can change" (sec. 13). He continues, "I urgently appeal, then, for a new dialogue about how we are shaping the future of our planet" (sec. 14). A new dialogue is indeed required. And although solving environmental degradation is an extremely complex issue, its impact (I) can be centered on the relationship of human population (P), affluence (i.e., consumption; A), and technological efficiency (T) in the following equation:  $I = PAT$  (Ehrlich and Holdren 1971); more humans, more consumption, and less technological efficiency results in a more severe environmental degradation, which exacerbates poverty and social inequities (e.g., Dasgupta 2001; Brown et al. 2014). The negative environmental impacts have soared as the human population continues to grow unchecked from less than 1 billion people at the beginning of the 19th century to the present 7.4 billion, with a projected 9.8 billion by 2050 (Ehrlich 1968; Cohen 1995; Population Reference Bureau 2015). The human population adds roughly 250,000 people per day, 1 million every four days, and around 90 million every year (Population Reference Bureau 2015). We are reaching the limits to maintain such an ever-growing human population. *Laudato Si'* clearly indicates the need for a paradigm shift to a more sustainable and integrated development. James H. Brown and collaborators (2014) have eloquently demonstrated that the current economic paradigm based in population, consumption, and economic development "is no longer compatible with the biophysical limits of the finite Earth" (Brown et al. 2014:24). Among the factors

affected by human population are food production, the environment, economics, resources, governance, institutions, and collapse (Ehrlich and Ehrlich 2016). The unchecked human population growth has many repercussions, and is especially acute with the poor.

Pope Francis emphasized, "Following a period of irrational confidence in progress and human abilities, some sectors of society are now adopting a more critical approach" (sec. 19). Indeed, a series of seminal books in the 1960s and 1970s such as Rachel Carson's *Silent Spring* (1962), Paul Ehrlich's *The Population Bomb* (1968), and Jean Dorst's *Before Nature Dies* (1971), among others, have already warned of the dangers of the increasing devastation of nature and shared the same concerns about the future of civilization. I found it very inspiring that some of those books, aside from discussing a plethora of reasons to protect nature, also mentioned love as fundamental to protecting nature, such as St. Francis of Assisi did centuries ago. Particularly interesting is the final paragraph of Dorst's book, where he wrote, "Man has enough objective reasons to safeguard nature. But in the last analysis it will only be saved by our hearts. It will only be saved if man loves it, simply because it is beautiful. . . . For that, too, is an integral part of the human soul" (Dorst 1971: 329).

#### CLIMATE CHANGE

There is no doubt that climate disruption with its multiple manifestations, such as changes in temperature and rainfall patterns, melting of the poles, rising sea levels, methane emissions, permafrost melting, sea currents, and impact on plants and animals, among many other factors, is one of the most severe and urgent environmental problems. It is threatening the survival of mankind. So it not surprising that Pope Francis dedicated a great deal of *Laudato Si'* to discussing climate change and its implications. "The climate is a common good, belonging to all and meant for all. At the global level, it is a complex system linked to many of the essential conditions for hu-

man life. A very solid scientific consensus indicates that we are presently witnessing a disturbing warming of the climatic system” (sec. 23).

Climate disruption is caused by climate warming that is the result of an increase in the concentration in the atmosphere of CO<sub>2</sub> from burning fossil fuels (such as oil and carbon) and an increase in the concentration of methane from cattle growth and the loss of the permafrost layer in the Arctic, among other factors. Many scientists have warned of the likely implications of climate disruption for Mother Nature and human civilization. There are literally thousands of papers on the impacts of climate disruption on ecosystems, biodiversity, and humans (see Pachauri et al. 2014; Barnosky and Hadly 2016 for recent reviews). It has been suggested that 2047 will be the year of global climate departure, meaning that from there on, the coldest year on the planet will be hotter than any previous year from 1866 to 2005 (Mora et al. 2013). The “normal” will no longer be normal. On this point, Pope Francis wrote, “Warming has effects on the carbon cycle. It creates a vicious circle which aggravates the situation even more, affecting the availability of essential resources like drinking water, energy and agricultural production in warmer regions, and leading to the extinction of part of the planet’s biodiversity” (sec. 24). The pervasive negative effects of global climate disruption are already being seen in many regions of the world. There are islands that are sinking due to sea-level rise, food production is disrupted by flood and drought, emerging and reemerging diseases are becoming more frequent, and many species are facing extinction.

#### BIODIVERSITY LOSS

Pope Francis is right when he notes the “loss of forests and woodlands entails the loss of species which may constitute extremely important resources in the future, not only for food but also for curing disease and other uses” (sec. 32). Indeed, a critical issue to really appreciate the magnitude of the current extinction crisis is the under-

standing that the knowledge of the diversity of life on Earth is very limited. So, the call from Pope Francis to take care of Mother Earth could not be more opportune. Most of the biological diversity on Earth is unknown. Life originated some 3.7 billion years ago with unicellular species. It is estimated that the current number of living species is the largest in the history of life (e.g., May 1992; Mora et al. 2013). It is likely that the number of eukarotic species probably ranges between 5 and 100 million (Erwin 1982; Ehrlich and Wilson 1991; May 1992; Mora et al. 2013). But only an estimated 2 million have been described, so that most species are unknown to science (Ceballos and Ehrlich 2002; IUCN 2016). Methodological advances in the study of morphology, genetics, and acoustics, to mention a few topics, and availability of accessible technological tools such as camera traps, GPS, satellite information, and so on, has produced a wealth of discoveries of new species in what has been called a “New Age of Discovery” (Donoghue and Alverson 2000; Ceballos and Ehrlich 2002; Ceballos et al. 2010). Species described in the last decade likely exceed 200,000, and range from mammals to microorganisms (Sogin et al. 2006; ISSE 2009). Most of the newly discovered species and the undiscovered biological diversity are found in the tropics and in developing countries. Within the tropics, hotspots of species discoveries are concentrated in the Neotropics (i.e., from central Mexico to South America), Southeast Asia, and Madagascar (e.g., Ceballos et al. 2010).

A few examples will suffice to illustrate the wealth of the new discoveries. The number of amphibians described from 1992 to 2003 accounted for 26% of all known species (roughly 6000 species; Köhler et al. 2005). Hundreds more have been described since then. With my colleague Paul Ehrlich we published a paper a few years ago that showed that 10% of all mammals were described between 1993 and 2006 (Ceballos and Ehrlich 2009). The new species included whales, a 100 kg antelope-like species—the soala (*Pseudoryx nghetinhensis*) from Vietnam, more than 40 species of monkeys, and hundreds of smaller species. The trend

has continued until today. From 2000 to 2016 roughly 430 new species representing 9% of all known living species have been described throughout the world. More have already been discovered and are in the process of being scientifically described. My research group with colleagues in Peru has discovered approximately 17 species of new mammals in that country. Every year we carry out a scientific exploration to a remote, little-studied region in Peru, while we teach a course on conservation biology. Our most important discoveries have been carried out in the Tabaconas Namballe wildlife sanctuary in the Pacific versant of the Andes near the Ecuador border. In the new species “heaven” we found a new marsupial, a shrew, a night monkey, a porcupine, and several rodents (Figure 1; Andries 2012). In 2009 and 2012 we explored the forests in the vicinity of the Machu Picchu archeological site and found an “extinct” arboreal chinchilla (*Cuscomys oblativa*) that was known from two prehistoric skulls found in a tomb at the beginning of the 20th century (Figure 1). The long-thought extinct species was found alive walking slowly on the ground. It apparently fell from a tree and was caught by a tourist who gave it to a member of my research group. It was a very beautiful and tame animal, similar in size to a large squirrel. It had striking coloration with a light grey body and a conspicuous white band on its head. The long hairy tail had a tuft at the end. This was a rather remarkable finding of an elusive and beautiful species, in a place that has been relatively well explored by biologists and is visited by more than a million tourists every year. This is a clear example of the countless undiscovered species that are threatened by human activities before they can even be scientifically described.

Newly described species have been discovered in the most unusual places such as a 3 km deep gold mine, in the bottom of the ocean at 10 km deep, in the frigid water of Antarctica, and the sand dunes of Namibia (e.g., Ceballos et al. 2010). Some new species are so unique that there is no agreement among specialists where to



FIGURE 1. NEW SPECIES OF ANIMALS DISCOVERED IN THE LAST DECADE

New night monkey (*Aotus* nov sp.) and shrew (*Cryptotis* nov sp.) from the northern Peruvian Andes (photos: Alexander Pari), and “extinct” arboreal chinchilla (*Cuscomys oblativa*) from the Machu Picchu region in Peru (photo: Roberto Quisque).

place them in the systematic classification. That is the case of a mushroom-like species (*Dendrogramma enigmatica*) collected in deep waters off Australia, representing a new family of animals that could be related to jellyfish, coral, and sea anemones (Just et al. 2014). Indeed, there is so much interest in new species that popular science magazines such as *National Geographic* and *Discovery* report every year on the most interesting newly discovered species (Clemens 2015). *Newsweek* recently published what it called The 21 Coolest New Animal Species of 2015 (Main 2015) that included photographs of an incredible variety of species such as the world's smallest snail (*Angustopila dominikae*) found in China; the hog-nosed rat (*Hyorhinomys stuempkei*) found on a mountain in Sulawesi, Indonesia; a toothed frog (*Odontobatrachus arndti*) from Western Africa; an anglerfish (*Lasiognathus regan*) found at depths between 3200 and 4900 feet in the Gulf of Mexico; and the Cerro Fatal giant tortoise (*Chelonoidis donfaustoi*) from the Galapagos Islands, one of the biologically best-studied places on Earth.

The distribution of species on Earth is not homogeneous. There are regions and countries that have more species than others. The top countries are referred to as megadiverse countries (Mittermeier et al. 1999). Brazil, Colombia, Indonesia, Peru, and Mexico are among the top 12 megadiverse countries, which altogether are estimated to contain roughly 60 to 70% of all species. Most biodiversity is found in developing countries, many with rapidly growing human populations, and a large percentage of poor people. For example, Mexico ranks fifth or sixth in the top megadiverse countries. However, its population has increased from around 40 million in 1950 to 120 million today; more than 60 million are considered poor. It is expected that the countries to be the hardest hit first by climate disruption are those developing countries, especially in Africa and Asia. Pope Francis remarked, "Climate change . . . represents one of the principal challenges facing humanity in our day. Its worst impact will probably be felt by developing countries in coming decades. Many of the poor

live in areas particularly affected by phenomena related to warming" (sec. 25).

#### POPULATION AND EXTINCTION LOSSES

One of the main topics of *Laudato Si'* is the disappearance of species. We are in the midst of a massive assault on living things on the planet, causing the loss of millions of populations and thousands of species (e.g., Pimm et al. 2014; Ceballos et al. 2015a,b). The Encyclical devotes many paragraphs to this fundamental issue. Pope Francis said, "Each year sees the disappearance of thousands of plant and animal species which we will never know, which our children will never see, because they have been lost for ever" (sec. 33). Lost forever indeed. William Beebe once wrote, "The beauty and genius of a work of art may be reconceived, though its first material expression be destroyed; a vanished harmony may yet again inspire the composer; but when the last individual of a race of living beings breathes no more, another heaven and another earth must pass before such a one can be again" (Beebe 1906:18).

A fundamental question is whether the rate of modern extinctions caused by human activities is higher than the normal or background extinction rate. This is important because it would let us understand if we are causing a mass extinction. Species extinction is, perhaps, the only truly irreversible environmental problem in the sense that once a species is lost there is no way to recover it. When the dinosaurs were gone, for example, they were gone forever. But it is important to emphasize that life on Earth will likely recover in a few million years after the mass extinction caused by humans. Extinction and speciation are two of the forces driving the evolution of life on Earth. In the past 600 million years, there has been five episodes of mass extinction, which mark the end of geological periods. Those five extinctions are known as the Ordovician-Silurian (450–440 million years ago), the Late Devonian (375–360 mya), the Permian (252 mya), the Triassic-Jurassic (201 mya), and the Cretaceous-Tertiary (66 mya) mass extinctions (see Jablonski

2001; Ceballos et al. 2015b). All of this mass extinction marked the future of life on Earth by causing the extinction of many groups of animals and plants (e.g., Ceballos et al. 2015b). Those mass extinctions share some characteristics; all were caused by natural catastrophes, a large percentage of species became extinct, and they were relatively rapid in geologic times (from thousands to a few million years). In the Cretaceous-Tertiary mass extinction all of the dinosaurs disappeared. It was likely caused by the impact of a huge meteorite, which crashed into Earth at the Yucatán Peninsula traveling at an astounding 40,000 miles (64,000 kilometers) an hour and hitting with an explosive force estimated at 100 trillion tons of TNT. From the impact, the Chicxulub crater on the Yucatán coast of Mexico can be seen from space (Smith 2016). Everything within a 1000 km radius was instantly vaporized. The blast was followed by a huge tsunami that was 400 m high. And then the debris of the impact that had been sent half the distance to the moon came down and ignited endless fires—a real inferno.

The normal or background rate of the species extinction of mammals in the last 2 million years, derived from a thorough analysis of thousands of mammal fossil and subfossil records, was two species for every 10,000 species present, every 100 years (Barnoski et al. 2011). For example, we would expect eight extinctions in a century if we analyzed 40,000 species (i.e., two extinctions per 10,000 species times four). A rate much higher across many different taxa would indicate a mass extinction. In the last 100 years some 477 species of vertebrates became extinct. Under a normal extinction rate, it would be expected to have only nine extinctions in that century. But there were 468 more extinctions than would be expected. Putting it a different way, the species lost in the last 100 years would have become extinct in between 1000 to 10,000 years, depending on the vertebrate group, under a normal extinction rate (Figure 2). We can confidently conclude that modern extinction rates are exceptionally high, that they are increasing, and that a mass extinction is under way—the sixth of its kind in Earth's

4.5 billion years of history (Ceballos et al. 2015a).

The current extinction crisis is more complex than species losses. It involves both species and populations (Ceballos and Ehrlich 2002). Indeed the concept of “defaunation” has been coined to refer to the loss of animal populations (Dirzo et al. 2014). Population extinctions are the prelude of species extinction and a very important, and often neglected, problem. For example, Figure 3 clearly shows that most regions in Africa, Southeast Asia, Australia, and Europe have lost more than 75% of the population of 177 mammal species analyzed (see also Ceballos and Ehrlich 2002).

#### ECOSYSTEM SERVICES

Ecosystem goods and services are the benefits that humans receive from the function of an ecosystem, and include supporting services such as the combination of the gases of the atmosphere, the quality and quantity of freshwater, soil fertility, flood and disease control, pollination and seed dispersal, and spiritual and cultural benefits (Daily 1997). *Laudato Si'* reminds us: “It may well disturb us to learn of the extinction of mammals or birds, since they are more visible. But the good functioning of ecosystems also requires fungi, algae, worms, insects, reptiles and an innumerable variety of microorganisms. Some less numerous species, although generally unseen, nonetheless play a critical role in maintaining the equilibrium of a particular place” (sec. 34).

But losing thousands of species and hundreds of thousands of populations is dramatic and tragic. We are losing species much more rapidly now than in the last two million years. At that pace, we may lose a large proportion of vertebrates, including mammals, birds, reptiles, amphibians, and fishes, in the next two to three decades (see recent reviews in Ceballos et al. 2015a,b; Barnoski and Hadly 2016). Those species are our companions in our travel across the universe. Losing them has many consequences. By losing species, we are eroding the conditions of Earth that are essential to

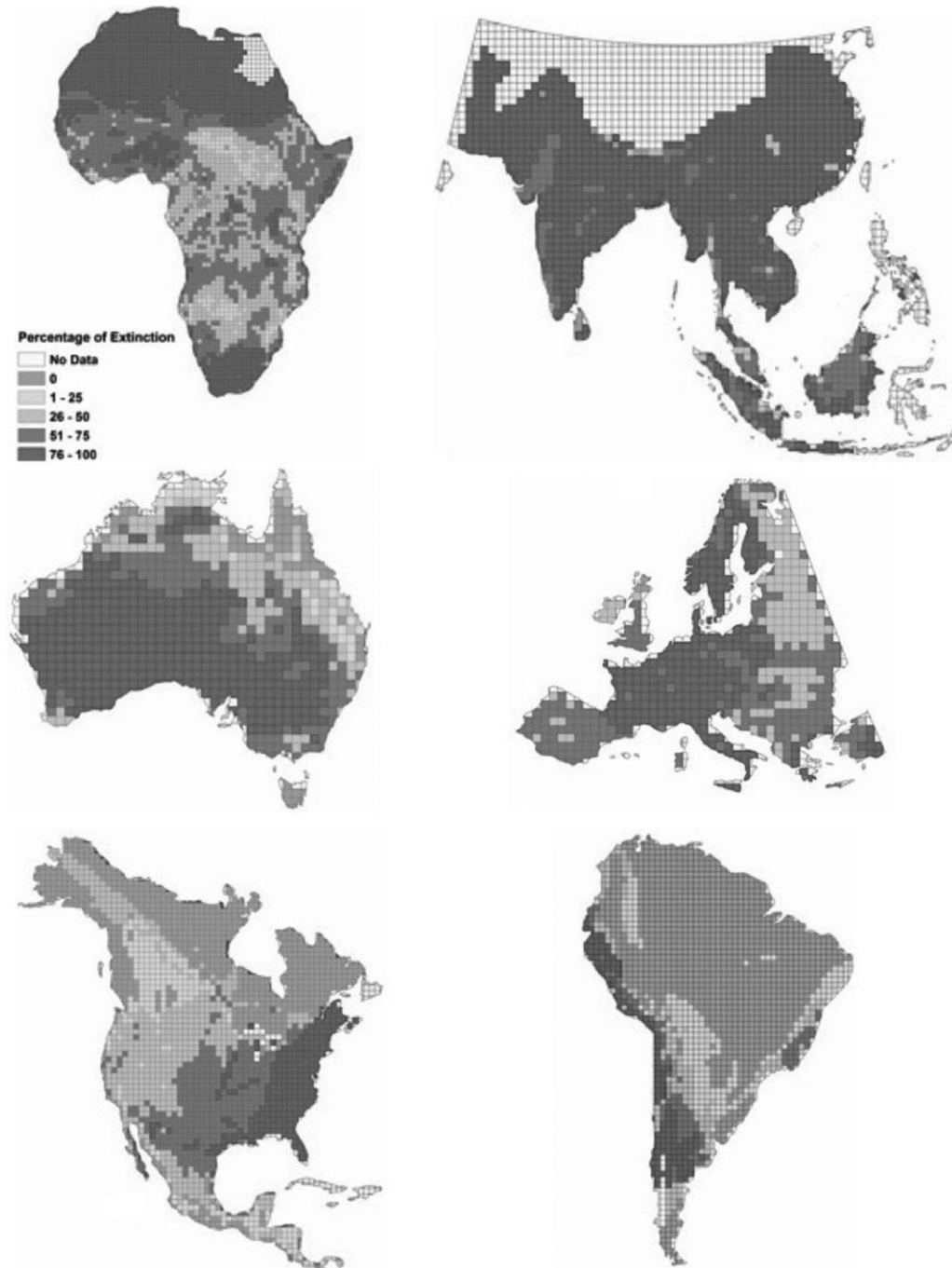


FIGURE 2. POPULATION LOSSES IN 177 SPECIES OF MAMMALS ARE AN INDICATION OF THE SEVERITY OF THE PROBLEM

Large regions on all of the continents have lost more than 50% of the evaluated mammals (data from Ceballos and Ehrlich 2002).



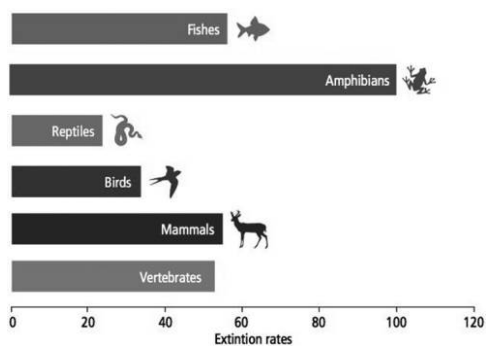


FIGURE 3. MODERN EXTINCTION RATES IN VERTEBRATES

Rapid rates of vertebrate species losses in the last five centuries clearly indicate that we have entered the Sixth Mass Extinction (modified from Ceballos et al. 2015a).

maintain life. We are eroding our human well-being and threatening our existence. In that respect, Pope Francis reminds us of the remarkable comments that Pope Paul VI expressed in 1971, “‘Due to an ill-considered exploitation of nature, humanity runs the risk of destroying it and becoming in turn a victim of this degradation’” (sec. 4). There is still time to avert the most tragic consequences of a sixth mass extinction, because we caused this one. We need to curb human population growth and social inequality, use natural resources more efficiently, and reduce habitat loss, overfishing,

overhunting, and pollution, as well as all of the other factors causing the current high rate of extinction. We are the only species that has the capability to save all endangered animals. Paradoxically, saving them is the only way to save humanity.

#### THE FUTURE OF MANKIND

There is a consensus among scientists and large sectors of society, the private sector, governments, and international institutions such as United Nations that environmental problems, especially climate disruption and biodiversity loss, are threatening the long-term viability of civilization. Pope Francis reminds us, “We all know that it is not possible to sustain the present level of consumption in developed countries and wealthier sectors of society, where the habit of wasting and discarding has reached unprecedented levels” (sec. 27). “We are free to apply our intelligence towards things evolving positively, or towards adding new ills, new causes of suffering and real setbacks. This is what makes for the excitement and drama of human history, in which freedom, growth, salvation and love can blossom, or lead towards decadence and mutual destruction” (sec. 79). What is at stake is the survival of mankind. Our future is in our hands. Pope Francis’ Encyclical is a call to action and breath of fresh air and hope in times of darkness.

#### REFERENCES

- Andries K. 30 September 2012. Pictures: new-species “heaven” discovered in Peru. Washington (DC): National Geographic. <http://news.nationalgeographic.com/news/2012/09/pictures/120927-new-species-peru-monkeys-animals-science/>.
- Barnosky A. D., Hadly E. A. 2016. *Tipping Point for Planet Earth: How Close Are We to the Edge?* New York: Thomas Dunne Books.
- Barnosky A. D., Matzke N., Tomiya S., Wogan G. O. U., Swartz B., Quental T. B., Marshall C., McGuire J. L., Lindsey E. L., Maguire K. C., Mersey B., Ferrer E. A. 2011. Has the Earth’s sixth mass extinction already arrived? *Nature* 471:51–57.
- Beebe W. 1906. *The Bird: Its Form and Function*. New York: Henry Holt and Company.
- Bodansky D. 2015. Should we care what the pope says about climate change? *AJIL Unbound* 109:127–131.
- Brito R. S. 2015. La relación entre la ética ambiental y la carta encíclica Laudato Si’. *Terra Mundus* 2:227.
- Brown J. H., Burger J. R., Burnside W. R., Changa M., Davidson A. D., Fristoe T. S., Hamilton M. J., Hammond S. T., Kodric-Brown A., Mercado-Silva N., Nekola J. C., Okie J. G. 2014. Macroecology meets macroeconomics: resource scarcity and global sustainability. *Ecological Engineering* 65:24–32.
- Carson R. 1962. *Silent Spring*. Boston (Massachusetts): Houghton Mifflin Company.
- Ceballos G., Ehrlich P. R. 2002. Mammal population losses and the extinction crisis. *Science* 296:904–907.

- Ceballos G., Ehrlich P. R. 2009. Discoveries of new mammal species and their implications for conservation and ecosystem services. *Proceedings of the National Academy of Sciences of the United States of America* 106:3841–3846.
- Ceballos G., García A., Ehrlich P. R. 2010. The sixth extinction crisis: loss of animal populations and species. *Journal of Cosmology* 8:1821–1831.
- Ceballos G., Ehrlich P. R., Barnosky A. D., García A., Pringle R. M., Palmer T. M. 2015a. Accelerated modern human-induced species losses: entering the sixth mass extinction. *Science Advances* 1:e1400253.
- Ceballos G., Ehrlich A. H., Ehrlich P. R. 2015b. *The Annihilation of Nature: Human Extinction of Birds and Mammals*. Baltimore (Maryland): John Hopkins University Press.
- Clemens D. 22 May 2015. Top 10 new species of 2015. New York: Discovery. <http://www.discovery.com/dscovrd/wildlife/top-10-new-species-of-2015/>.
- Cohen J. E. 1995. *How Many People Can the Earth Support?* New York: W. W. Norton and Company.
- Daily G. C. 1997. *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington (DC): Island Press.
- Dasgupta P. 2001. *Human Well-Being and the Natural Environment*. Oxford (United Kingdom): Oxford University Press.
- Dirzo R., Raven P. H. 2003. Global state of biodiversity and loss. *Annual Review of Environment and Resources* 28:137–167.
- Dirzo R., Young H. S., Galletti M., Ceballos G., Isaac N. J. B., Collen B. 2014. Defaunation in the Anthropocene. *Science* 345:401–406.
- Donoghue M. J., Alverson W. S. 2000. A new age of discovery. *Annals of the Missouri Botanical Garden* 87: 110–126.
- Dorst J. 1971. *Before Nature Dies*. Baltimore (Maryland): Penguin Books.
- Ehrlich P. R. 1968. *The Population Bomb*. New York: Bantam Books.
- Ehrlich P. R., Ehrlich A. H. 2016. Population, resources, and the faith-based economy: the situation in 2016. *BioPhysical Economics and Resource Quality* 1:3.
- Ehrlich P. R., Harte J. 2015. Biophysical limits, women's rights and the climate encyclical. *Nature Climate Change* 5:904–905.
- Ehrlich P. R., Holdren J. P. 1971. Impact of population growth: complacency concerning this component of man's predicament is unjustified and counter-productive. *Science* 171:1212–1217.
- Ehrlich P. R., Wilson E. O. 1991. Biodiversity studies: science and policy. *Science* 253:758–762.
- Erwin T. L. 1982. Tropical forests: their richness in Coleoptera and other arthropod species. *Coleopterists Bulletin* 36:74–75.
- ISSE. 2009. *State of Observed Species: A Report Card on Our Knowledge of the Earth's Species*. Tucson (Arizona): International Institute for Species Exploration, Arizona State University.
- IUCN. 2016. *The IUCN Red List of Threatened Species*. Glanz (Switzerland): International Union for Conservation of Nature. <http://www.iucnredlist.org>.
- Jablonski D. 2001. Lessons from the past: evolutionary impacts of mass extinctions. *Proceedings of the National Academy of Sciences of the United States of America* 98:5393–5398.
- Just J., Kristensen R. M., Olesen J. 2014. *Dendrogramma*, new genus, with two new non-bilaterian species from the marine bathyal of southeastern Australia (Animalia, Metazoa *incertae sedis*)—with similarities to some Medusoids from the Precambrian Ediacara. *PLOS ONE* 9:e102976.
- Köhler J., Vieites D. R., Bonett R. M., García F. H., Glaw F., Steinke D., Vences M. 2005. New amphibians and global conservation: a boost in species discoveries in a highly endangered vertebrate group. *BioScience* 55:693–696.
- Leopold A. 1993. *Round River: From the Journals of Aldo Leopold*. Oxford (United Kingdom): Oxford University Press.
- Main D. 30 December 2015. The 21 coolest new animal species of 2015. New York: Newsweek. <http://www.newsweek.com/21-coolest-new-animal-species-2015-410008>.
- May R. M. 1992. How many species inhabit the Earth? *Scientific American* 267:42–48.
- Mittermeier R. A., Myers N., Mittermeier C. G., Robles Gil P. 1999. *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Mexico City (Mexico): CEMEX.
- Mora C., Frazier A. G., Longman R. J., Dacks R. S., Walton M. M., Tong E. J., Sanchez J. J., Kaiser L. R., Stender Y. O., Anderson J. M., Ambrosino C. M., Fernandez-Silva I., Giuseffi L. M., Giambelluca T. W. 2013. The projected timing of climate departure from recent variability. *Nature* 502:183–187.
- Pachauri R. K., Meyer L., Core Writing Team. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva (Switzerland): Intergovernmental Panel on Climate Change.
- Pimm S. L., Jenkins C. N., Abell R., Brooks T. M., Gittleman J. L., Joppa L. N., Raven P. H., Roberts C. M., Sexton J. O. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. *Science* 344:1246752.
- Population Reference Bureau. 2015. World Population Data Sheet with a special focus on women's empowerment. Washington (DC): Population Reference Bureau. <http://www.prb.org/wpds/2015/>.

Smith R. 2016. Here's what happened the day the dinosaurs died. Washington (DC): National Geographic Society. <http://news.nationalgeographic.com/2016/06/what-happened-day-dinosaurs-died-chicxulub-drilling-asteroid-science/>.

Sogin M. L., Morrison H. G., Huber J. A., Welch D. M., Huse S. M., Neal P. R., Arrieta J. M., Herndl G. J.

2006. Microbial diversity in the deep sea and the underexplored "rare biosphere." *Proceedings of the National Academy of Sciences of the United States of America* 103:12115–12120.

Handling Editor: Daniel E. Dykhuizen