



## What Should We Try to Do in an Age of Extinction?

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Because its loss is irreversible, and since we depend on it completely for every aspect of our lives, the extinction of biodiversity is actually the most important problem that we face today – but few realize that fact, much less take action adequate to prevent it. In our Academy, we held a study week on this subject in spring 2017, the results of which will be published as a book in 2019 by Cambridge University Press. Here I have used the results presented there, and by Raven (2019), largely without specific attribution.

The evolutionary line to which we belong, the hominids, diverged from the African apes about 6-8 million years ago, with our species, *Homo sapiens*, first appearing in the fossil record about 300,000 years ago, in Africa. Concerning our appearance on Earth, *Genesis 2: 15* reads “The Lord God then took the man and settled him in the garden of Eden, to cultivate and care for it”. In fact, we had relatively little impact on the planet and its ecosystems until we began to cultivate plants and domesticate animals as sources of food about 11,000 years ago – barely a blink of an eye in the 4.54-billion-year history of the Earth. When crops were first domesticated, our total human population is estimated to have amounted to about one million people, spread out over all of the habitable continents, with only about 100,000 people, a number that could be accommodated in a single large sports stadium, living in Europe.

Where have we come during the 400 human generations that have succeeded one another since that time? By 1562, when the lovely building in which we are meeting was completed as a summer home for Pope Pius IV, the global population had grown to about 500 million people, equivalent to the present population of Europe. In 1936, when Pope Pius XI revived our Academy and dedicated this building to the use of our Academy, there were 2.5 billion of us! Subsequently, our numbers have now climbed to more than 7.6 billion, growing by about 200,000 per day, and projected to reach 9.9 billion by mid-century, 30 years from now.

In terms of our hopes for future stability it is particularly important to remember that the 1 billion people currently living in Sub-Saharan Africa are projected to grow to approximately 2.2 billion people within the next 30 years and perhaps 4.4 billion by the end of the century. Given the fact that 24 of the world's poorest countries in the world are located in Africa, and that many of them, with increasing poverty, are starting to fall into what Mathis Wackernagel has begun to term an “environmental poverty trap”, a situation in which these countries have nothing left to export to earn money, the future certainly looks bleak for the continent. This is particularly true in view of the growing selfishness and nationalism that are all too evident among the world's rich countries today: can we count on them to intervene massively to help alleviate the problems of Africa?

Today, human beings completely dominate the earth and are destroying its prospects for sustainability through a combination of the impact of our sheer numbers and our activities magnified by the runaway consumption of perhaps the top ten percent of the world's people. The total mass of human bodies and that of our domestic mammals, cattle, sheep, pigs, currently amounts to *twenty times* the mass of all other mammals on earth. Our domestic fowl weigh more collectively than all other birds on earth. About 800 million of us are hungry, even on the edge of starvation, with about a third of the human population lacking at least one essential nutrient. At the same time, eight people currently possess as much wealth as do the poorest 3.6 billion people on earth. Apparently they are unfamiliar with the words of Matthew 25:40, “And the King shall answer and say unto them, Verily I say unto you, Inasmuch as ye have done *it* unto one of the least of these my brethren, ye have done *it* unto me”.

In such a connection, I am also reminded of the words of US Secretary of State Adlai Stevenson, who said in 1965, “We travel together, passengers on a little spaceship, dependent upon its vulnerable reserves of air and soil, all committed for our safety to its security and peace; preserved from annihilation only by the care, the work, and I will say, the love we give our fragile craft. We cannot maintain it half fortunate, half miserable, half confident, half despairing, half slave to the ancient enemies of man, half free in a liberation of resources undreamed of until this day. No craft, no crew can travel safely with such vast contradictions. On the resolution depends the safety of us all”.

We are currently consuming an estimated 175% of the world's capacity for sustainable productivity ([www.footprintnetwork.org](http://www.footprintnetwork.org)), a proportion that has more than doubled, from 70%, over the past 50 years. In the grip of this clearly unsustainable situation, we exhausted the earth's total sustainable productivity on "Earth Overshoot Day", August 1, 2018, and for the past 3.5 months have been drawing down our planet's ultimate capacity to support us and other living beings. Much of this is related to our dependence on fossil fuels, which we clearly must rein in soon or face disaster for us all. Within the overall pattern of consumption, most industrialized nations consume much more than their "share" of the world's productivity, making it extraordinarily difficult for the poorer countries to catch up.

### **The Role of the Catholic Church**

The Industrial Revolution, which reached full force about two centuries ago, has played a major role in exacerbating human inequality and social injustice and at the same time led directly to widespread environmental destruction. Virtually no uncut forests remained in Europe by 1840: these forests re-grew only when their use as the primary source of fuel was shifted to coal. By 1891, Pope Leo XIII, in his Encyclical *Rerum Novarum*, was calling attention to the growing social problems and proposing ways to rectify them. As our global population swept up from its Napoleonic level of 1 billion people to the current 7.6 à 9.8 billion in just two centuries, more than 200 million people were killed in wars, while social inequality grew rapidly both within and between nations.

Selfishness and nationalism are still the dominant ambitions driving us on, the kind of tribalism so well described in the Bible gaining strength rapidly, with the world completely divided into nations by the early 19th century, each of them striving for more than its neighbors possessed. By the second half of the 20th Century, the signs of environmental deterioration had become evident and were increasingly emphasized by religious and national leaders. The 1971 Stockholm Conference on the environment, when Pope St. Paul VI participated and spoke out strongly on the environmental problems facing humanity, was effectively the first true global conference on the environment, with evidence for global warming just becoming convincing and biological extinction starting to attain major levels. From that point on, the Roman Catholic Church has been deeply and outspokenly concerned with the environment, the Popes often emphasizing its attendant problems, but never more convincingly or thoroughly than Pope Francis, in his Encyclical *Laudato si'* of 2015, promulgated just two and a half years ago.

In that document, Pope Francis not only forcefully emphasized the enormous danger of climate change for humanity but also devoted a significant section of his message to the irreversible problems relating to the accelerating loss of biodiversity. His words brought that second problem into sharper focus than any earlier official Church pronouncement had done, and it is on that complex problem that I shall focus my presentation today.

In chapters 32-41 of *Laudato si'*, the ways in which the earth's resources are also being plundered because of our shortsightedness in economic development are emphasized both in relation to the loss of functionality in both terrestrial and marine ecosystems and also in relation to the attendant loss of species at a rate that has grown to many thousands per year. Pope Francis emphasizes that we have no right to drive those species to extinction, but rather an obligation to try to save them so that they will be able to continue to give glory to God by their existence and at the same time "convey their message to us". As species are lost, ecosystems often malfunction and we attempt to intervene in ways that often make the situation worse. The Pope calls for aggressive action to learn about species and the ways in which they support the functioning of ecosystems, which is certainly insufficiently known at present. As they lose their constituent species, the ecosystems will function increasingly poorly; as we wreck whole ecosystems, they will continue to lose their species rapidly. Thus our greed for short-term gain can only place unfair burdens on the majority of poor who live among us now, and seemingly intractable problems that future generations will need to try to solve with the curtailed resources that we are leaving them (*Laudato si'*, Chapter 34-35).

The Encyclical continues to point out that some countries are trying hard to preserve their biological diversity and relatively intact ecosystems, establishing sanctuaries both on land and in the oceans, and often in areas where species diversity is relatively rich, but that these efforts need to be greatly amplified for our common benefit. It also emphasizes the great importance of the tropics and the rapidity of extinction there as their forests are being cut, largely to benefit wealthy individuals or international corporations. It recommends that each country carry out its responsibility to preserve its environment and natural resources, a subject to which I shall return later in this paper. Equally strong measures are urged to protect the abundant life and ecosystems of the oceans, both because of their role in global ecology and in supplying food to so many of us. They are certainly more fragile than they seem, and ignoring them could easily lead to changes in the whole planet in ways that we understand incompletely (*Laudato si'*, Chapters 38-40). In addition, the Encyclical stresses that

many of the individual species being lost may constitute extremely important resources for the future, not only for food but for medicines and many other purposes that remain unknown to us as they disappear.

In relation to with modern methods of breeding improved crops, domestic animals, and other organisms to serve our needs and regulating environmental problems, it is pointed out that different species contain genes that could become key resources in years ahead. Indeed, the deeper modern molecular probes, the more impressive the differences between entire genetic systems in different organisms become. This relationship constitutes yet another reason for not throwing away the diversity that we have inherited simply because of our short-term greed and the further enrichment of those who are already wealthy.

### **Extinction Rates and their Consequences**

First of all, let us consider the extent of biodiversity that exists on earth today. There are two major kinds of living organisms, Eukaryotes, which include animals, plants, fungi, and complex microorganisms, and Prokaryotes, which are the bacteria, and Archaea (the latter might better be viewed as their own distinct branch of life). Eukaryotes, all of which are made up of complex cells like ours, appear in the fossil record about 2 billion years ago, and Prokaryotes, possibly Archaea, about 4 billion years ago, with our planet having originated and started cooling 4.54 billion years ago.

The number of Eukaryotes inhabiting our planet now is estimated by various authorities to amount to some 8-12 million species, and the actual total could be much larger. What is striking is that only between 1.7 and 2 million species have been detected by science and given names, so that the great majority of existing species are unknown – and likely will remain so as they disappear forever. Only birds, mammals, and other terrestrial vertebrates; land plants; and a few other groups of organisms, such as butterflies and mosquitoes, are reasonably well known, but probably still have 10-20% of their species to be discovered. The simple, and at the same time awful, relationship that this reveals can be demonstrated by pointing out that most of the species that are forecast to become extinct during ours and the next two generations will never even have been seen by any scientist – we are literally throwing them away. It as if we not only are burning the Library of Alexandria, but a library in which relatively few of the books have been examined by anyone before they vanish permanently.

For Prokaryotes (bacteria and Archaea), the story is even more difficult to imagine. Only a few thousand species have been given names, and yet estimates of the total number on Earth range all the way up to *one trillion* kinds! We know that individually and in the aggregate they are of fundamental importance for the functioning of ecosystems, of soils, or aquatic systems – of everything living – and yet we are scarcely trying, in relation to the immensity of the problem, to know anything about them, or indeed about Eukaryotes, while they are still supporting our lives and every other living system on our planet.

Given this base, how fast are we losing species? Using the fossil record or well-represented groups, we calculate a rate of extinction for them of about 0.1 species per million per year. Comparing these rates with those observed now for the same groups leads us to the conclusion that they have already increased by about 1,000 times, to about 100 species/million/year. Because of the factors discussed earlier in this paper and below, we have become certain that these numbers are accelerating rapidly (summaries in Dasgupta, Raven, and McIvor, 2019; Raven, 2019).

A second way that we may approach the problem of estimating probable biological extinction in the remainder of this century is as follows. Comparing IUCN Red List rankings (IUCN 2016) with extinction probabilities determined in alternative ways for particular groups, including vertebrates and flowering plants, leads to an estimate that perhaps 20% of species in these groups are in danger of extinction during the next several decades. This, if actually attained, would be a much higher rate than the likely present one we calculated comparing actual extinctions with the fossil record.

If that rate (100 species/million/year) were to remain constant, and assuming that there are about 10 million species of Eukaryotes, about 50,000 of them would be expected to disappear over the next 40 years. If, instead, 20% of all species were to become extinct during this period, 40 times that many species, some 2 million, would have to be lost, that would mean an average rate of extinction of 40 times as high as the one we have calculated. This would amount to losing 50,000 species per year (higher in the future, lower now, of course). Whether our destructive activities will actually drive such a high rate remains to be seen, but we are clearly heading in that direction. By the end of the century then, the actual loss would certainly be cataclysmic. Considering these trends, it seems to many scientists likely that we may already be entering a Sixth Major Extinction event, with a large proportion of all species likely to be lost by the end of this century and in the decades immediately following.

What are the principal factors involved, and how could we slow them down?

The first and most important since the invention of agriculture has clearly been habitat destruction. Crops are currently being grown on about 11% of the Earth's land surface, with grazing, mostly on natural grasslands and therefore largely unsustainable, on another 30% of the land. Current estimates are that we would have to produce 70-100% more food by 2050 to feed the 9.9 billion people projected to be living then adequately, but the actual growth in production amounts to only about half that rate. Estimates of the amount of additional food necessary to feed 9.9 billion (Gustafson *et al.*, in press). At the same time that our numbers are increasing rapidly, people want to consume more and more, and the problem of hunger and starvation remains intractable or continues to grow. The probable effects on biodiversity of the drive to solve those problems will likely be enormous.

In synchrony with the expansion of agriculture, natural habitats everywhere are being destroyed rapidly too. Tropical forests are home to the richest and most poorly known biodiversity anywhere on earth, and their destruction is accelerating. Since the implementation of the highly-regarded Convention on Biological Diversity 25 years ago, a quarter of all tropical forests have been cut, mainly for industrial-scale agriculture. Considering the relationship between species numbers and our knowledge of the plants and animals that inhabit those forests, it is likely that 19 out of 20 of the kinds of Eukaryotes living there and subject to extinction are currently unknown to science, an appalling thought in relation to our future.

Particularly since the development of international commerce over the past five centuries, the introduction and establishment of weeds, pests, and pathogens has expanded rapidly worldwide and is clearly an important factor accelerating extinction and ecosystem disturbances worldwide.

Humans gathering medicines, wood, and other forest products from natural communities is driving many of them to very low population levels and potentially extinction also. To the extent that these products could be obtained from cultivated crops must be worked out for each of them, and of course would compete with food production, as we are seeing in the case of biofuel production in the US and elsewhere.

Coming strongly into view recently as a cause of species extinction is global climate change, which we are certainly managing inadequately so far. Larger than anticipated changes are perfectly feasible, and it has become almost certain that agriculture will be substantially disturbed or even displaced over the coming several decades. And in the so-called "biological hotspots", areas with large numbers of species found nowhere else that have already been substantially disturbed by human activities (e.g., Madagascar, California, the Mediterranean generally), the risk of large amounts of rapid extinction is extremely high, as would be the case along the southern edges of the world's southern lands, in coastal areas, and on islands generally. Estimates offered to date for the additional extinction due to climate change in this century mainly range from 15 to 40% – and they do not depend on any further habitat loss!

Whether the loss of species is caused by global warming or another factor, there are many possible, poorly-understood global consequences that may ensue. Thus Lenton (2018) inquires to what extent the projected high levels of species loss would compromise the function of ecosystems and the biosphere. Changes at a certain order of magnitude could certainly result in the loss of entire biomes by the tipping of critical balance points. In the seas, acidification resulting from increases in carbon dioxide concentration have already become a major problem. Marine anoxia resulting from the runoff of nitrogen and phosphorus from agricultural systems on land is leading to increased ocean warming and thus further reducing the capacity of the water to absorb oxygen. Changing temperatures for offshore currents could certainly cause massive change both on land and in the seas, certainly with consequences for increasing biological extinction.

## Summary

Following the appearance of *Homo sapiens* about 300,000 years B.P. cultural evolution led eventually to the development of agriculture as the last ice age waned, about 11,000 years B.P. About one million of us existed then, and now there are 7.6 billion growing rapidly, with more than a third of the earth's surface devoted to agriculture. As a result of this and our other activities we are estimated to be driving the species of organisms to extinction at about 1,000 times the historical rate, with about 20% of all species endangered now and many more likely to disappear before the end of the 21st Century. Since the functioning of our planet depends on biodiversity, so do our lives; and, in addition, we obtain virtually everything we use from it, including our food and many of our medicines. We need to feed the 800 million hungry people on earth now, and to take care of the 2.3 billion projected to be added in the next 30 years, and yet to keep our planet functioning. No result of our activities will harm our future prospects more decisively than biological extinction, which is irreversible.

Nothing we are doing to damage the functioning of the living world and the stability of its ecosystems will do more harm than biological extinction. We must find effective ways to address the loss before it is too late (e.g., Tilman *et al.*, 2017; Lovejoy, 2017). While pollution and global warming are obviously directly hurting us badly

today, our ability to recover will depend to a large extent to whether we save the biological units, species, that interact to produce the habitable earth we are damaging so radically at the present time.

As Dasgupta & Ehrlich (2018) have concluded, seeking to limit the proximate causes of extinction will not ultimately prevail unless the basic drivers are addressed – “continued population growth, policies seeking economic growth at any cost, overconsumption by the rich, and racial, gender, political, and economic inequality (including failure to redistribute). Collectively addressing these are possibly the greatest challenges civilization has ever faced”.

Achieving the goals just outlined clearly must be taken as our common responsibility; without doing so we simply haven't got a chance. Learning about how to achieve them and then working to achieve them ultimately will be responsible for our survival, and we must learn, teach, act, and vote in such a way as to advance our common cause, the search for a sustainable world. Doing so will require a degree of humility, compassion, and love that we have yet to exhibit, but which is indicated very clearly in our topical Encyclical *Laudato si'*. We do not seem likely to do so on the basis of facts and logical reasoning alone, and therefore highly praise the leadership of Pope Francis in contemplating the beauty and importance of life as it is and the urgency of working to preserve it for the future. As Pope Francis has stated so clearly in *Laudato si'*, Chapter 43, “Because all creatures are connected, each must be cherished with love and respect, for all of us as living creatures are dependent on one another”.

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