CREATURES

RADICAL ECOLOGICAL CONVERSION AFTER LAUDATO SI'

Discovering the intrinsic Value of all Creatures, Human & Non-human

Nature's Bounty: Why We Need All Other Species on Earth

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What is the intrinsic value of all creatures on earth – what scientists call biodiversity: bacteria, fungi, sponges, insects, flowering plants, and so on? This is the fundamental question of this conference. Most speakers will approach this issue from a religious and ethical perspective. As a scientist and a naturalist, I will (i) present my views on the value of creatures from an ecological perspective, (ii) make a connection to ethics, and (iii) provide support for Pope Francis' call for an 'ecological conversion' to protect our world. In other words, today I want to tell you why we need all other creatures on earth.

I. THE ECOLOGICAL VALUE OF CREATURES

How many creatures?

If we had to make the catalog of creatures on Earth, ninety nine percent of the pages would be blank. To date, scientists have described over 1.2 million species of multicellular organisms. We know the birds pretty well. We also know well the mammals, fish, corals, and flowering plants, even though every year we add a total of 6000 new species to our catalog. But scientists estimate that the total number of higher-level species is probably around 9 million[1]. This does not include single-cell organisms such as Bacteria and Archaea. These could add up a trillion species to the census.[2] If our knowledge of the identity of our fellow earth inhabitants is so scarce, what do we know about what they do?

[1] Mora et al. (2011) How Many Species Are There on Earth and in the Ocean? *PLoS Biol* 9(8): e1001127

[2] Locey, KJ & Lennon, JT (2016) Scaling laws predict global microbial diversity. *PNAS* 113(21): 5970-5

The role of creatures

Today we are discussing the *intrinsic* value of creatures. But there is another way to look at the value of creatures, through their ecological role. If *value* is our assessment of how important creatures are to us, *role* is their ecological function – what they do – regardless of our perception of it. We will see that their role can be extremely valuable to us as well. Value is the domain of philosophy; role is the domain of natural history and ecological science.

How can we know the species' roles in the natural world, if we have described only a minute fraction of the species on our planet? The truth is that we know almost nothing. Most of our deep knowledge comes from a small number of species, mostly charismatic creatures such as wolves and whales, but thanks to advances in molecular biology, also from the smallest creatures such as bacteria. What have we learned from these few species, and how can we generalize about the role of creatures?

Invisible microbes

Let's start with bacteria so small that we did not discover their existence until 1988.[3] *Prochlorococcus* is the scientific name of a bacterium only a millionth of a millimeter in size. It is so small that it took microscopes powerful enough to be invented to be able to see it. Yet it is one of the most abundant creatures on the planet, with 20,000 of them living in a single drop of seawater.[4] *Prochlorococcus* makes a living by using sunlight in the shallow ocean to transform molecules in seawater into energy, and releasing oxygen in the process. It is a process similar to what plants do on land: photosynthesis – they synthesize sugars using sunlight as their energy source, with oxygen as a by-product. Yet terrestrial plants, our forests and grasslands, produce less than half of the oxygen we breath. More than half of it comes from the ocean, from seaweed on our shores, microscopic plants in the open ocean, and microbes. That is, a little bacterium that we did not know only thirty years ago and other marine creatures unknown to most humans give us every other breath. The role of *Prochlorococcus* has a clear value to us, but without having to *exploit* it. We took its role for granted, because it came at no cost to us; but because of our overexploitation of the natural world and global pollution, we may be putting that essential function at risk.

If we lost *Prochlorococcus* and all other creatures that give us oxygen for free, could we replace their role? The replacement value is a common way for economists to determine the value of things. How much would it cost to produce all the oxygen in the atmosphere? Based on current costs, and assuming we had the industrial capacity, the price tag would be US$200,000 trillion[5]. That's about 1600 times the 2017 global GDP.

The little *Prochlorococcus* should make us humble, not only because of its extraordinary role, but also because our advanced technology cannot replace what a bacterium invisible to our naked eye does. What do other invisible creatures do that we take for granted?

Miraculous whales

Luke 5:1-11 tells the miracle of the fish, when Jesus asked the fishermen at the depleted Lake of Gennesaret to drop their nets. To the fishermen's surprise, the nets came up so full of fish

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[3] Chisholm, P et al. (1988) A novel free-living prochlorophyte abundant in the oceanic euphotic zone. *Nature*: **334**, 340–343

[4] Pennisi, E (2017) "Meet the obscure microbe that influences climate, ocean ecosystems and perhaps even evolution. http://www.sciencemag.org/news/2017/03/meet-obscure-microbe-influences-climate-ocean-ecosystems-and-perhaps-even-evolution

[5] US$155 is the cost of extracting 1 tonne of pure oxygen from air; and there are 1.2 10^{15} tonnes of oxygen in the atmosphere.

that they broke. But the multiplication of the fish may not be restricted to Jesus. Whales, the largest animals that ever lived, also produce similar feats in the ocean.

Baleen whales – like fin whales and blue whales – eat small creatures such as krill and small fish, which live in the ocean shallows. Toothed whales – like the sperm whales of Moby Dick fame – eat giant squid in the ocean depths. Fishermen, and some scientists funded by the fishing industry, have argued that whales eat too much krill and fish, and that we need to kill them, so there is more fish for us.[6] This is especially blatant in the Southern Ocean, where Japanese vessels continue to slaughter whales.[7] But as the whales were decimated, so was the krill. Why?

Whales are mammals, like us, and they have to breath at the surface. After eating massive amounts of krill and small fish, whales absorb part of the iron contained in the tissues of their prey, but they release much of the iron in their feces near the surface. Iron is an element that is key for photosynthesis in the shallow ocean. By concentrating it in their feces, whales fertilize the shallow waters, thus helping to produce more krill and fish.[8]

And there is more. Whales often eat at depth, with sperm whales hunting squid more than a kilometer deep. Their up-and-down movements mix surface and deeper waters, helping to bring more nutrients from the deep. In fact, a study estimated that marine animals cause as much ocean mixing as wind and tides together.[9] Without the mixing and the consumption by whales, most of the small creatures that live in seawater – the plankton – would sink after death, making their nutrients unavailable for shallow waters, hence impoverishing them.

Therefore, whales help create more krill and more fish. In the absence of whales, the shallow ocean waters could become a desert. In contrast, a third of the fisheries of the word have already collapsed, and studies suggest that, if we continue mismanaging the way we fish, most fisheries will have collapsed by 2050.[10] How many more fish would there be if we hadn't killed so many whales? They definitely manage their fishing much better than we do.

The return of the wolves

Some will argue that it is OK to preserve creatures in far away places, but that we do not really want to have wild nature too close to us. In Europe and North America, wolves are the epitome of this wild nature. The primal, human-manufactured fear makes the wolf *the* beast to exterminate. Wolves were – and are still seen by many – as enemies, which kill livestock, game species like deer, and even people. Government policies made that clear, and wolves were systematically exterminated from many countries, with the expectation of eliminating competition for game, and reducing the risk to human life. Ironically, wolves do not kill people, but dogs kill 25,000 people globally every year – because of rabies.[11] Yet nobody calls for culling of dogs. It seems as though we are happy with the domesticated version of the wolf, which we manipulated genetically over millennia, but do not dare to look into the eyes of the wild wolf and try to understand who they are and what they do. But scientists have looked, and discovered something extraordinary about their role and their value.

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[6] "Whales Eat Fish." (2002) Australian Antarctic Magazine: Issue 4, Spring 2002. Available at: http://www.antarctica.gov.au/magazine/2001-2005/issue-4-spring-2002/feature2/whales-eat-fish!

[7] Hodgson-Johnston, I (2017). Murky waters: why is Japan still whaling in the Southern Ocean? The Conversation. Available at: http://theconversation.com/murky-waters-why-is-japan-still-whaling-in-the-southern-ocean-71402

[8] Nicol, S et al (2010) Southern Ocean iron fertilization by baleen whales and Antarctic krill. *Fish and Fisheries*: 11:2, 203-209.

[9] Dewer, WK et al. (2006) Does the marine biosphere mix the ocean? *Journal of Marine Research*: 64: 541-561.

[10] Worm, B et al. (2006) Impacts of biodiversity loss on ocean ecosystem services. *Science* 314(5800):787–790

[11] Gates, B (2014) The Deadliest Animal in the World. *Gates Notes*. https://www.gatesnotes.com/Health/Most-Lethal-Animal-Mosquito-Week?WT.mc_id=MosquitoWeek2014_SharkWeek_tw&WT.tsrc=Twitter

Created in 1872 by the United States government, Yellowstone was the first official National Park in the world. It was protected because of its natural beauty and outstanding ecological value. Yet wolves there were killed until the last was seen in the 1920s. In 1994, Yellowstone was a beautiful world of geysers and winter snowy landscapes, with abundant deer (called 'elk' in North America). But the riversides were devoid of vegetation; riverine forests were all but gone – because there were too many elk, which overgrazed the vegetation. Park managers tried to 'manage' the elk population and culled them, but they did not succeed in reducing their impacts.

In 1995, 31 wolves were reintroduced in Yellowstone.[12] These wolves and their descendants acted like landscape engineers that transformed the entire park. First, the wolves reduced – and regulated – the number of elk, but they also changed their behavior. By their presence alone, the wolves created a landscape of fear whereby deer would spend less time in the open, to avoid being killed. Because of that, within a few years the trees on the riverbanks were coming back, in turn providing more habitats for songbirds, whose populations increased. The returning trees became forests of cottonwood, aspen and willow, now shading and cooling the adjacent streams, reducing stream bank erosion, and providing cover for fish and other aquatic life.

The new riverside forests also fed and help grow the beaver population by 12 times in only 13 years, with the resulting increase in beaver dams and the creation of new habitats, which in turn resulted in an increase of opportunities – and abundance – of otters, frogs and reptiles. In addition, the wolves hunted coyotes, which caused an increase of the coyote's prey: rabbits, mice, and other small mammals. That led to more prey for eagles, foxes, and other small predators.[13]

Before the reintroduction of the wolf, the winter mortality of elk was greater during severe winters and at the end of moderate winters. The winter mortality is caused by decreased access to food resources buried in deep snow. In the absence of wolves, scavengers such as ravens, eagles, bears and coyotes relied heavily on weather-related deer mortality. However, since 1948 winters are getting shorter because of global warming. Early snow thaw reduces late-winter deer mortality and, hence, carrion, harming the scavengers that depend on carrion, such as eagles and foxes. Once wolves were reintroduced, they became the primary source of elk mortality throughout the year, making carrion available throughout winter. The increase in carrion resulted in an increase in the number of scavengers, including bears.[14]

Therefore, the return of the wolves caused the return of all creatures, from small to large, and is also helping to buffer the impacts of global warming. The wolves' role in the terrestrial ecosystem is one of landscape engineer and provider of life for all types of creatures, in contrast to the demonizing image with which humans tend to portray them.

The human ecosystem

For a final example of the important role of creatures, let's look inside of us. Our bodies have about 30 trillion cells. [15] That is more cells than stars in our galaxy. I found it hard to comprehend. What's more shocking is that for everyone one of our cells, our bodies carry a

[12] Smith, D et al. (2003) Yellowstone after Wolves. *Bioscience*: 53(4): 330-340
[13] Ripple, WJ & Beschta, RL (2011) Trophic cascades in Yellowstone: The first 15 years after wolf reintroduction. *Biological Conservation*: 145:1, 205-213.
[14] Wilmer, CC & Getz, WM (2005) Gray wolves as climate change buffers in Yellowstone. *PLoS Biol* 3: e92
[15] Locey, KJ & Lennon, JT (2016) Scaling laws predict global microbial diversity. *PNAS* 113(21): 5970-5

similar number of microbes.[16] That's 38 trillion microbes, living mostly in our gut, and covering our skin. What do all these creatures do?

Let's start with breast milk. It contains complex sugar molecules – oligosaccharides – that infants cannot digest because they lack the necessary enzymes. That puzzled nutritionists for years, but advances in medical technologies have shown that these complex sugars are not destined for the baby, but for a bacterium in the baby's gut, called *Bifidobacterium infantis*. When this bacterium is well fed, it proliferates and preempts the gut space, preventing the establishment of 'bad' microbes. In addition, by digesting these complex sugars, *Bifidobacterium* releases fatty acids that feed the baby's gut cells. Finally, *Bifidobacterium* helps maintain the integrity of the lining of the baby's intestines, which is crucial to protect it from infection and inflammation. [17]

Most of our gut bacteria are acquired during birth. But we acquire other bacteria from dust or our pets. A study showed that children with a family dog or who spend more time playing outside have lower rates of asthma or lung allergies.[18] The exchange of bacteria also happen between people, as we are continuously sending them through the air through our moving and breathing – at the rate of 37 million per hour.[19] Exposure to 'good' bacteria helps our immune system and overall health. Once inside our bodies, bacterial genes can 'jump' into our own DNA through a process called 'lateral gene transfer'. As a matter of fact, at least 145 bacterial genes made it into human DNA over the course of our evolution.[20] Needless to say, people who are more exposed to antibiotics reduce the diversity and abundance of their 'natural' microbes. That brings negative consequences that include higher rates of obesity and Type 2 diabetes.[21]

Our gut bacteria help keep us healthy, from body to mind. They play an important role in the synthesis of hormones, enzymes, vitamins, and molecules that influence the immune system. Some of these molecules may help regulate stress and even our temperament.

The role of microbes in our body carries evident value from a selfish, utilitarian perspective. Would that then equal their important role with an intrinsic value? Do microbes have a right to exist *if* we know what they do for us? If creatures that we do not know are essential to our very survival *within* us, how many other creatures are essential to our survival *outside* of us? We know a few, but do we have the luxury – or the right – of triage? Ecosystems – from our human body to the entire biosphere – are complex systems with millions of connections between species. Which ones can we live without? Which species' removal will cause the ecosystem to collapse? Is it an unknown fungus, or the mighty blue whale? The precautionary principle calls for maintaining all creatures. But there is more to it than just utility and playing it safe. There is a fundamental ethical issue at play, one that requires that humans understand our place in the world, and our *role* in the world – as we seek to understand the role of other creatures.

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[16] Sender, R et al. (2016) Revised estimates for the number of human and bacteria cells in the body. *PLoS Biol*:14(8)
[17] Garrido, D et al. (2013) Consumption of human milk glycoconjugates by infant-associated bididobacteria: mechanisms and implications. *Microbiology*: 159(Pt 4): 649-664.
[18] Huang, YJ and Boushey, HJ (2014) The microbiome and asthma. *Annals of the American Thoracic Society*: 11(Suppl 1): S48-S51.
[19] Qian, J et al. (2012) Size-resolved emission rates of airborne bacteria and fungi in an occupied classroom. *Indoor Air*: 22:4: 339-351.
[20] Crisp, A et al. (2015) Expression of multiple horizontally acquired genes is a hallmark of both vertebrate and invertebrate genomes. *Genome Biology*. 16: 50.
[21] Mikkelsen, KH et al. (2015) Use of Antibiotics and Risk of Type 2 Diabetes: A Population-Based Case-Control Study. *The Journal of Clinical Endocrinology & Metabolism*: 100:10.

II. A PLANETARY ETHIC

An ethic is a limitation on individual action for the benefit of the community. Science has clearly shown that humans are part of a larger ecological community of interdependent parts. Therefore, our ethic should extend to the entire ecological community, and not just to our immediate social network.

In 1949, Aldo Leopold wrote that a "land ethic enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land." [22] Now we know that that community encompasses the entire biosphere: land, seas, and even the atmosphere – where bacteria live on clouds and may help produce rain. Therefore we should act on the basis of a *planetary ethic*.

The planetary ethic moves humans away from a self-proclaimed center of the world to a humble and respectful membership of the greater biosphere. It moves us from *over* to *within* the natural world. Humility must be an integral part of this ethic, because we have seen that it is impossible for humans to recreate all other creatures and their roles in the world. It is out of our reach to reproduce the works of even the tiniest microbe.

Because of our higher intelligence, we also carry a great deal of responsibility. In an ironic twist, the fate of all creatures our existence depends on is now in our hands. Now is the time to use our intelligence and compassion to protect the right of all other creatures to exist.

Some groups of species have been around for hundreds of millions of years – much longer than *Homo sapiens*, whose oldest remains are dated at about 315,000 years ago.[23] Some individual creatures, such as deep-sea corals and giant sequoias, can be 4,000 years old – the Methuselahs of the natural world. It is unethical to destroy creatures that precede us. They are our elders, and carry precious genetic information whose destruction would be akin to the burning of the Library of Alexandria.

We would not think of killing the microbes in our guts, because we know our health depends on them. Yet we have no problem deciding the fate of thousands of species every time we eat processed food that uses palm oil, for instance. Those species include endangered orangutans and rhinos, hundreds of species of birds, and thousands of insect species that no human has yet seen. All these creatures are being driven to extinction as tropical forests in Southeast Asia are clear cut and replaced with palm oil plantations – only for the enrichment of a few and the convenience of many. We need resources to survive and prosper, but a planetary ethic affirms the right of creatures to continue to thrive. That is, overexploitation of other creatures becomes anathema, no matter how economic it is. In the same way that we agree that genocide is a crime, *ecocide* (the mass slaughtering of other creatures that are part of our community) is also a crime. Patriarch Bartholomew has been very clear about this: "To commit a crime against the natural world is a sin against ourselves and a sin against God".[24]

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[22] Leopold, A (1949) *A Sand County Almanac: And Sketches Here and There*. Oxford University Press, 240 p.

[23] Hublin, JJ et al. (2017) New fossils from Jebel Irhoud, Morocco and the pan-African origin of Homo sapiens. *Nature* 546(7657): 289-292.

[24] *Address in Santa Barbara, California* (8 November 1997); cf. John Chryssavgis, *On Earth as in Heaven: Ecological Vision and Initiatives of Ecumenical Patriarch Bartholomew*, Bronx, New York, 2012.

III. THE CASE FOR A 'RADICAL ECOLOGICAL CONVERSION'

Why do many people try and act ethically in their human community, and even profess high moral values based on their religious beliefs, yet they act unethically with regards to other creatures? They see man as the master of the earth instead of one more member of the ecological community. This may have been a consequence of ambiguity from religious texts regarding our place in the world, or of utilitarian and self-serving interpretations of those texts. But *Laudato Si'* clearly stated that man is not master but community member. A new planetary ethic shall reflect this renewed understanding of our place in the world. Pope Francis' call for an 'ecological conversion', which requires a personal spiritual conversion as well as a community conversion.[25]

How is this ecological conversion related to environmental conservation projects? The objective is one and the same, however I believe that Pope Francis' ecological conversion goes deeper and farther as it seeks a permanent solution ingrained in spirituality, rather than tactical approaches to specific environmental impacts.

Radical changes in personal and community behavior should slow down the demise of many creatures and the environments they live in, with benefits for human communities – because healthier ecological communities provide more for people. But that may not be sufficient. Humans have failed, over and over, at managing extractive activities sustainably at industrial scales, and the poor have suffered the consequences as much as other creatures. For example, industrial fishing fleets develop access agreements with local governments in exchange for meager fishing fees. This practice, alongside illegal fishing, has resulted in depletion of local resources, and local fishers are outcompeted, driving them to fish ever-declining fish stocks more intensively. Illegal fishing in West Africa, for example, is responsible for a loss of over $2.3 billion a year that could have benefited local economies.[26] Moreover, almost all of the fish caught by foreign fleets is consumed in industrialized countries, thus threatening food security and biodiversity in the developing world. We could enumerate similar examples of deforestation in tropical countries and many other activities and places.

Hence the need for the '*radical* ecological conversion' that Cardinal Turkson called for this morning,[27] which goes beyond incremental gains in environmental conservation, or even worst, simply a slight deceleration of the pace of environmental degradation. Therefore, the ecological conversion and a planetary ethic shall include protected areas where creatures can recover from human impacts and self-organize in complex ecosystems with rich biodiversity. This is akin to provide reparations to communities that have been oppressed.

Giving creatures more space

Can we bring creatures back? Can we restore what we have lost? For the last 30 years I have been diving and seeing what happens when we stop killing creatures in the ocean. They come back spectacularly, and former underwater deserts become kaleidoscopes of life and color. Within no-take marine reserves – the national parks of the sea – the number of species increases on average 20 percent relative to unprotected areas nearby,[28] and the abundance of

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[25] FRANCIS, Encyclical Letter *Laudato Si'* (2015), 216-219

[26] Doumbouya, A et al. (2017) Assessing the effectiveness of monitoring control and surveillance of illegal fishing: The case of West Africa. *Frontiers in Marine Science* 4 (50)

[27] *Inaugural Lecture, Radical Ecological Conversion After* Laudato Si' *Conference, Rome* (7 March 2018); Cardinal Peter Turkson, *Radical Ecological Conversion.*

[28] Lester, S et al. (2009) Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series* 384: 33-46

fish increases by almost seven times within a decade.[29] Moreover, the increased abundance and reproduction of ocean creatures within these reserves helps to replenish local fishing outside the reserve boundaries, benefitting local fishermen.[30]

Studies suggest that half of the planet should be protected for the preservation of most creatures on earth, and also for us to obtain maximum benefits from the natural world – and that includes the concerns of indigenous peoples. Yet to date only 15 percent of the land is protected, and only 2 percent of the ocean is fully protected from fishing. Those who overexploit other creatures for their economic benefit argue that we cannot protect more, that we need a balance. The situation is indeed unbalanced – but on their side. The powers-at-be based economic growth on the destruction of biodiversity and excessive use of fossil fuels, and we have been told that this growth is a better metric than human development and prosperity. We have been running our planet like a Ponzi scheme. A Ponzi scheme works as long as there are new investors to fool. Once the pyramid becomes too large and we run out of new investors, the whole construct collapses. Ditto for our land and ocean. We're running out of forests to destroy, of fishing grounds to empty. [31] But we do not need to tap the last ones to realize that the growth-based construct is unsustainable. Consumption grows, but our planet and the number of other creatures within do not. Now is the time to repair the damage we have done to our brothers and sisters, and give them more space, so they can heal – and heal us along the way.

Final thoughts

The study of natural history has taught us that other creatures are *necessary* – that is a measure of *usefulness*. Without other creatures, there would be no humans. But other creatures have as much intrinsic value as we do because we are all part of an interconnected web of life, where the lines between 'me' and 'others' are often blurred – as the recent discoveries on our bodily microbes have taught us. That makes the need for humility and acknowledgement of our place and role in the natural world only more evident. If we give our lives intrinsic value – regardless of our own utility – then we shall accept that all other creatures have intrinsic value too. The German bishops therefore rightly concluded that, concerning other creatures, *being* should be prioritized over *being useful*. [32]

Science and spirituality converge here. Personally, it is not the rational understanding of the role of creatures and the dynamics of ecosystems that makes me believe on the value of other creatures. It is mainly the sense of awe and wonder, a spiritual feeling when I am walking on an old growth forest, diving on a pristine coral reef, or simply when in the spring morning I hear the woodpecker that visits the Gingko trees on our street in Washington, D.C. Every time I intuitively feel part of something larger and greater.

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[29] Sala, E & Giakoumi, S (2017) No-take marine reserves are the most effective protected areas in the ocean. *ICES Journal of Marine Science,* doi:10.1093/icesjms/fsx059

[30] Sala, E et al. (2013) A general business model for marine reserves. *PLoS One* 8(4): e58799. doi:10.1371/journal.pone.0058799

[31] Pauly, D (2009) Aquacalypse now – The end of fish. *The New Republic*, September 28, 2009

[32] German Bishops' Conference, *Zukunft der Schöpfung – Zukunft der Menschheit. Einklärung der Deutschen Bischofskonferenz zu Fragen der Umwelt und der Energieversorgung*, (1980), II, 2.