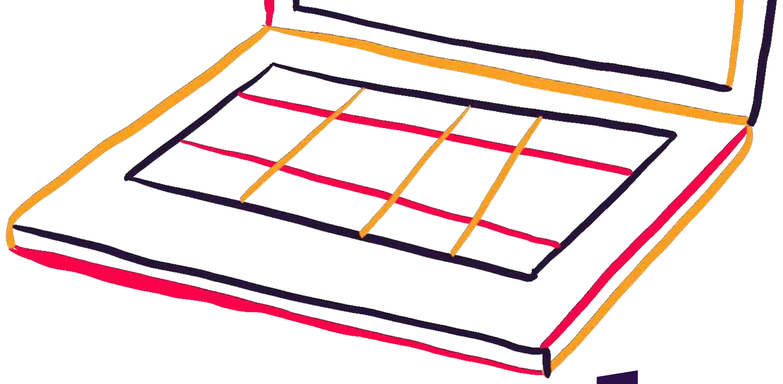

Tech and the Living World

ReThink

How can technology contribute to the understanding, monitoring and preservation of our biodiversity?

Capgemini | aws

Editorial

Why rethinking the importance we place on biodiversity is essential

Even though biodiversity seems to be currently on everyone's lips, there is a significant and disturbing gap between the practical attention we pay to the biodiversity agenda and the more high-profile climate crisis agenda. These are the dual existential challenges facing the world.

In repeating the biodiversity term over and over, we may have reached a form of semantic saturation, where we have lost the sense of what it really means. Biodiversity embeds the entire living world. It's a notion fundamental in all its diversity and potential, the cornerstone of our existence - paradoxically endangered by our own act.

This paper aims to provide a fresh view on the state of this living world, and how we should rethink our place and role in the global ecosystem. If we are to make progress in achieving sustainability, we at Capgemini strongly believe in the value of collaboration - not only to expand our vision and concepts of the challenges facing us, but also in the design and implementation of relevant solutions that embrace the social, environmental, and economic stakes.

That's why we've developed this paper, together with our partner AWS, with additional valuable contributions from key academics, and other businesses, all with the aim of exploring how technology can help protect, maintain, and restore biodiversity.

This first paper – Tech and the Living World - looks at the importance of societal paradigm shifts, as well as specific actions that we can take. So, I invite you to take a deep dive into this first edition of *ReThink*, a series of whitepapers that we hope will make you think again about how to ensure a sustainable future.

Cyril Garcia
Capgemini Group Head of Sustainability Services and Corporate Sustainability, and CEO of Capgemini Invent

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Biodiversity: the woods that can’t be seen for the trees

Complex, and with multiple challenges and stakeholders, biodiversity is too often neglected, or even forgotten entirely. Yet the preservation of the living is a major concern. It is, in fact, the other great challenge for humanity - along with global warming. Indeed, the collapse of biodiversity is a threat to our own human survival and leads us to question the place of humankind in the global ecosystem.

A world with no biodiversity? Without the valuable diversity that characterizes our living world – all the plants, animal and fungus species – our very existence is under threat. In effect, humanity is but an integral part of this rich and complex, but also extremely fragile, ecosystem that is life on Earth.

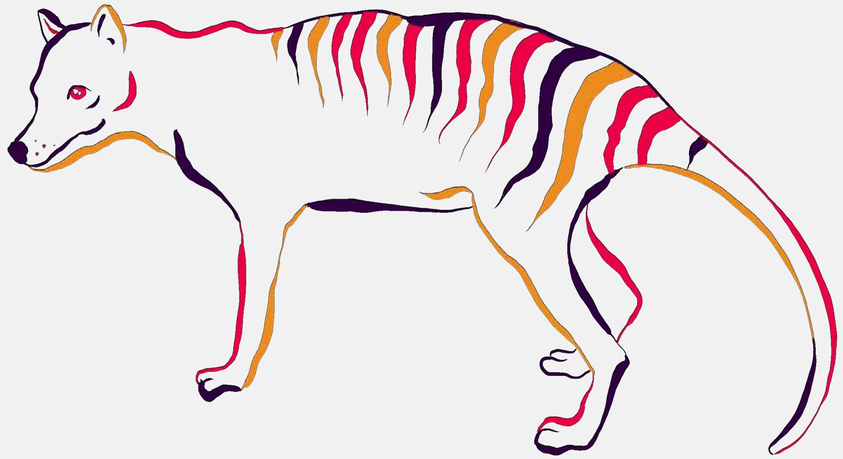
Yet, we are systematically destroying the richness of our biodiversity by destroying habitats, overexploiting, continuing to aggravate climate change, polluting and introducing invasive species. Putting the preservation of biodiversity back on the same level as the fight against global warming is urgent and an absolute necessity.

Climate change has become a source of anxiety, to the point where the term "eco-anxiety" has made its way into dictionaries. An additional concern relies on another, and no less dangerous, threat: the collapse of biodiversity.

The Tasmanian tiger, the Saudi gazelle, the Japanese sea lion … the list of extinct species is already too long. But a million more species could in turn become extinct over the next decades, according to the experts from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Collapse

According to the WWF 2022 Living Planet Report, published on 13th October 2022, wildlife populations declined by 69% on average between 1970 and 2018. *"The health of ecosystems, on which we and all other species depend, is deteriorating more rapidly than ever. We are eroding the very foundations of our economies, livelihoods, food security, health, and quality of life worldwide"*, warns Sir Robert Watson, IPBES Chair [1].



In truth, we could not survive without all that nature provides. *"We reap a multitude of benefits from nature, and from ecosystems, which are vital to our survival"*, explains Tatiana Giraud, a research director at the French National Center for Scientific Research (CNRS) at Paris-Saclay University (Laboratoire Écologie, Systématique et Évolution).

"These benefits, or "ecosystem services", *include flow control (of water, CO_2, etc.) via the oceans, wetlands and forests, pollination carried out by a multitude of insects, without which half our crops would not be able to grow, the manufacture of drugs - the majority of which are directly or indirectly derived from natural substances - as well as the reservoir of natural and genetic resources."*
And the biologist warns: *"These services are free for now, as long as biodiversity allows it. But economically, every year, they exceed the yearly global GDP."*

Ranking in vain

As mentioned above, monitoring, preserving, and restoring this precious biodiversity is one of the two major challenges for humanity, along with the fight against global warming, which in turn is also responsible for the destruction of natural habitats, as well as their fauna and flora.

"Climate change, the spread of invasive species, or the overexploitation of resources are closely linked and act synergistically."

"It would be a vain attempt to rank the causes of damage to our biodiversity," Tatiana Giraud adds. "*Climate change, the spread of invasive species, or the overexploitation of resources are closely linked and act synergistically."*

Unfortunately, the prevalence of climate danger and its extreme manifestations have pushed the threats to biodiversity to the background. Philippe Grandcolas, a research director at CNRS and director of the Institut Systématique, Évolution, Biodiversité (Isyeb), deplores this: *"Biodiversity is invisible. Between a heatwave, a storm, or a flood, and the steady and*

inevitable decline of pollinating insects, there is a difference in intensity that misleads observers" [2] (read also page 13).

Resilience?

In order to get biodiversity out of this blind spot, the IPBES and the Intergovernmental Panel on Climate Change (IPCC) jointly published a report in June 2021, to explore the complex and multiple interconnections between these two existential threats.

"Climate change is, in fact, just one of the symptoms of a much more global systemic crisis. If we miss the point, we run the risk of missing the solution", warns Vincent Bretagnolle, a research director at CNRS.

However, it is not too late to reverse the trend. Biodiversity is actually highly resilient. According to Hélène Soublete, director of the French Foundation for Biodiversity Research (FRB), *"there are scientific controversies relating to the extent of this erosion. Life adapts. Ecosystems affected by human activity change their state and strike a new balance: some species disappear, but others can develop. When a forest is cleared to make way for fields or pastures, the ecosystem loses diversity, it becomes simpler, but all life does not disappear. In plain language, we are not wiping out biodiversity"* [3]. As an example, wild foxes, bison, and horses have returned to the forests around Chernobyl following the nuclear disaster.

Biodiversity loss in figures

Sources: IPBES, WWF

68% decline of the average population size of wild vertebrates between 1970 and 2016

25% of vertebrates, invertebrates, and plants studied precisely are in danger of extinction

70% more invasive species have been spotted since 1970 in the 21 countries that have studied the subject closely

Biodiversity loss in figures

Sources: IPBES, WWF

75% of terrestrial environments and 40% of marine environments are severely altered by human activity

85% at least of wetlands known in 1700 had disappeared by 1980

33% of food fish species were overfished in 2015

Biologist Tatiana Giraud is less optimistic: *“Extinction rates are growing exponentially, and we cannot protect just the species we deem to be useful. Which species will be useful tomorrow for creating new drugs, or for developing new food resources? We don’t know. We know even less about which other species will be necessary for the survival of the previous ones… What we do know, however, using soil cultivation as an example, is that the greater the biodiversity, the greater the increase in productivity.”*

Revolution

In this fight for the preservation of biodiversity, an unprecedented track is being mapped out little by little: the recognition of nature’s building blocks, and even of nature itself, as legal persons.

The concept of the rights of nature takes inspiration from the world views of indigenous populations, according to which humankind is an integral part of nature, on the same level as plants and animals. The adoption of such a legal evolution of the rights of nature could bring down the western anthropocentric vision of nature that, from the Old Testament to Descartes and the Lumières, has structured our thinking. In short, it would be a true Copernican revolution.

“We must stop believing that we are not dependent on nature and that we will always be able to recreate or replace what we have made disappear. Admittedly, awareness on

the topic is growing in an increasing portion of the population, but the resistance of lobbies is still powerful", remarks Tatiana Giraud.

In France, according to article 515-14 of the Civil Code, *"animals are living beings gifted with sentience"*. But the text adds, *"subject to the laws that protect them, animals are subject to the regime of goods"*. Yet material goods have no rights.

"Our environmental law is structurally incapable of recognizing the interdependence of natural entities and the complex mechanisms that govern biodiversity", observes Marine Calmet, a lawyer by training, jurist and president of the organization Wild Legal, a school and incubator for the rights of nature.

Breakthroughs

However, a first breakthrough was made on 28th February 2007 with the adoption, by the Parliament of the Balearic Islands - an autonomous community of Spain - of the first law in the world to grant personhood to all great apes.

Since then, several natural resources have been given protective legal status, such as the Mutehekau Shipu (or Magpie River) in East Quebec, the Whanganui River, the third-longest river in New Zealand, and the sacred Ganges and Yamuna rivers in India. On the island of Corsica, the Tavignano river has had its own "Declaration of rights" since 29 July 2021, which grants it its own legal personhood. This is a major leap forward for biodiversity, as this coastal river is home to several rare species, such as spiranthes aestivalis or summer ladies' tresses (a wet meadow orchid), the Hermann's tortoise, and the horseshoe bat.

But the most advanced project in Europe is the Mar Menor, a saltwater lagoon near Murcia, on the south-east coast of Spain,

"Our environmental law is incapable of recognizing the complex mechanisms that govern biodiversity."

to which the Spanish Parliament granted legal personhood status in September 2022. *“This first step is important because it shows that granting legal personhood to an ecosystem in Europe is possible”*, applauds Maria Teresa Vicente Giménez, a professor of Law at the University of Murcia and prominent figure of the citizen movement at the origin of what has turned out to be an event [(4)].

“Legal personhood of living beings is no longer an issue in many states. Around twenty of them now recognize the rights of nature on a national or local scale. It is no longer a theory but a true practice”, notes Marine Calmet. Her association Wild Legal, often in cooperation with the Rivières Sauvage (Wild Rivers) network, is supporting several pilot sites, experimenting with the transposition of the rights of nature laws into territorial planning documents, such as local town planning. This is the case, for example, of French rivers Chéran in Savoy, Nant Bénin in Upper Savoy, Taravo on Corsica, and the Garonne.

“Man gave names to all the animals, long time ago”, Bob Dylan reminded us over forty years ago[(5)]. And what if we also gave them the right to live, for their good, as well as our own? What if we expanded this vision to all living creatures?

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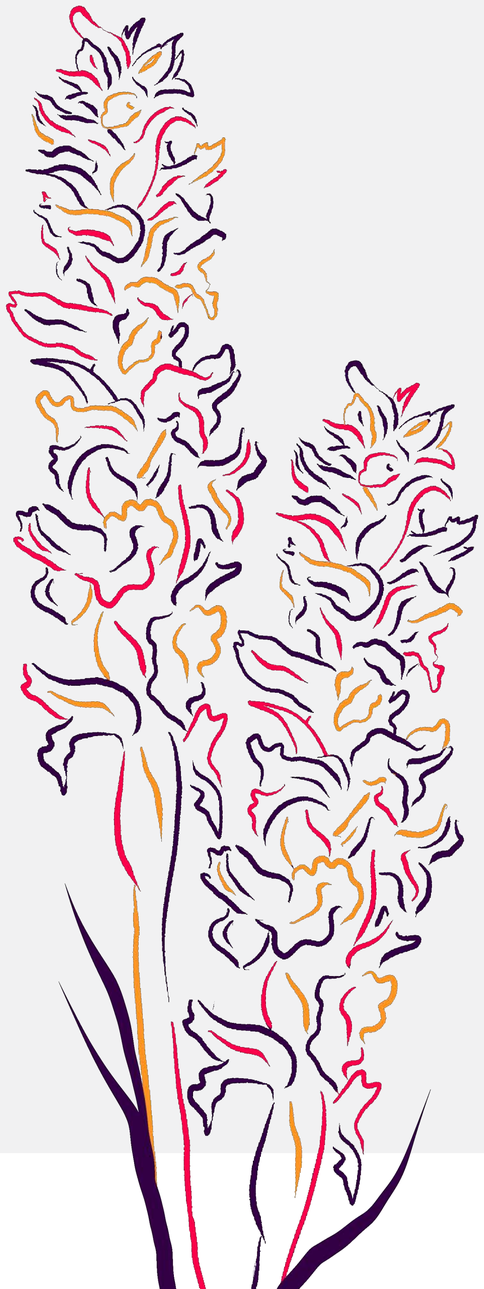
1. unep.org/news-and-stories/press-release/natures-dangerous-decline-unprecedented-species-extinction-rates

2. radiofrance.fr/franceinter/podcasts/camille-passe-au-vert/camille-passe-au-vert-du-lundi-19-septembre-2022-7972666

3. reporterre.net/Tout-comprendre-a-l-effondrement-de-la-biodiversite

4. lemonde.fr/idees/article/2022/10/21/maria-teresa-vincente-gimenez-la-loi-sur-la-mar-menor-montre-qu-accorder-une-personnalite-juridique-a-un-ecosysteme-en-europe-est-possible_6146748_3232.html

5.“Man gave names to all the animals, long time ago”, Slow train coming, Columbia Records, 1979



“Global biodiversity governance needs to move forward”

Philippe Grandcolas
Research Director at CNRS

According to Philippe Grandcolas, research director at CNRS, management and governance tools already exist, but the stakeholders, starting with countries, must develop their investment.

What major threats are a burden on biodiversity today?

Philippe Grandcolas In 2019, IPBES ranked these into five main causes : changes in land use (deforestation, wetland drainage, loss of mangroves, etc.), harvesting natural resources (overfishing, illegal wildlife trade, etc.), pollution (pesticides, toxic substances such as endocrine disruptors or plastic, the total mass of which is greater today than that of all animal species), climate change (more frequent disruptions and variations such as wildfires, floods, heatwaves, ocean acidification, etc.), and finally the transportation of species that can lead to an invasive phenomena and disrupt biodiversity locally. These causes are all as serious as each other and their effects concern the entire planet.

Would a global biodiversity governance be a better solution to combat these threats?

PG In theory, this global governance has already been set up. The 1992 Earth Summit in Rio de Janeiro established the Convention on Biological Diversity, which was ratified by 200 countries. COP 10 in Nagoya set criteria for improving the situation concerning biodiversity. Unfortunately, these criteria have not been met, and the latest COP on biodiversity[1] doesn't seem to be mobilizing international political leaders. Global biodiversity governance has a basis, but it needs to move forward. This is in the interest of all countries, in both the North and the South.

Some people are calling for steering biodiversity. What is your point of view?

PG There are already national competencies in this subject, in many countries, such as the French Office for Biodiversity. But the true question is to ask what actions are being carried out effectively? Take the case of the extension of protected areas, for example; are the protection measures in the field effective?

In terms of agricultural production – a major topic for steering biodiversity – today, France covers only 60% of its food needs. A large amount of production is destined for export and animal feed, the environmental footprint of which is disastrous.

A profound change of our agricultural system, based particularly on limiting inputs, would not only make it possible to improve profitability, while only marginally affecting production levels, but would also offer co-benefits, such as the restoring of landscape diversity and better climate regulation, for example, via the reimplantation of hedges and other natural environments neighboring cultivation areas.

But is steering the living world not part of the anthropocentric approach that is one of the causes of our problems?

PG The anthropocentric approach is firstly that of mechanized industrial production, which goes ahead at the expense of natural resources and biodiversity. Unlike this concept, taking small steps, with the aim of benefiting from natural balances or acting only when there is an imbalance, seems not only virtuous but also more efficient in the end. Steering implies the consideration of all externalities, including the negative ones that are not carried over to the balance sheet of production systems.

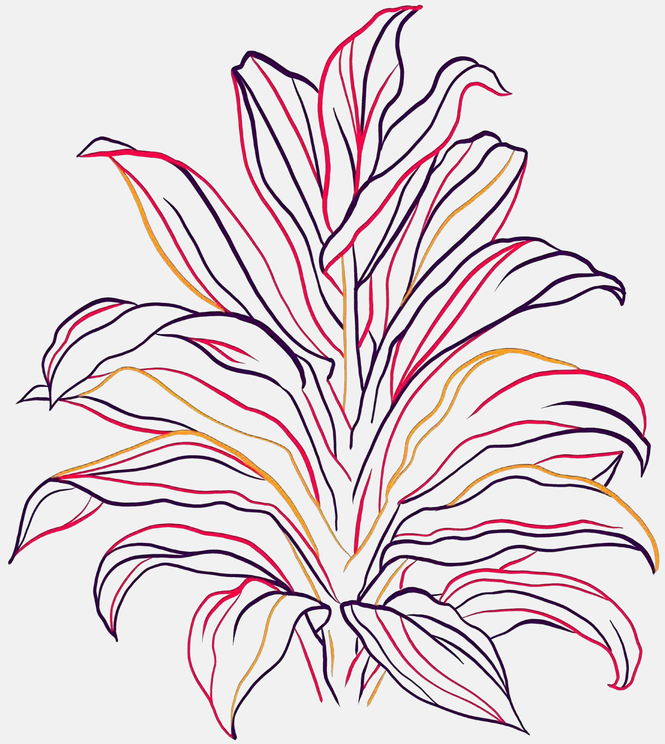
Can technology be this steering instrument?

PG In this area, as in many others, the use of technology is worthy of consideration. One must always consider the negative externalities that could ensue. Bt maize (GMO) or neonicotinoid-coated seeds[(2)] have much greater adverse effects than the benefits they are supposed to provide. By contrast, mathematical and meteorological models, forecasting crop infestations, combined with one-time treatments are not only more economical but also less harmful.

In general, nature-based solutions – more economical, more sustainable, and more powerful – are to be preferred. Opting for a stabilized dune ridge, rather than an artificial breakwater for protecting a stretch of coast, or creating wetlands and bogs rather than retention basins, for regulating a local water regime next to climate-appropriate crops, may be simple solutions, yet their proliferation is turning out to be more efficient and sustainable.

Granting the living world with legal personhood, this idea is still under debate. What do you think?

PG The law is an important form of regulation, which must be used. However, one must be careful of not 'seeing the woods for the trees'. Granting legal personhood to a river does not mean protecting it in isolation from its environment, its ecosystem, the water table, vegetation, and the neighboring crops, which must be considered as a whole.



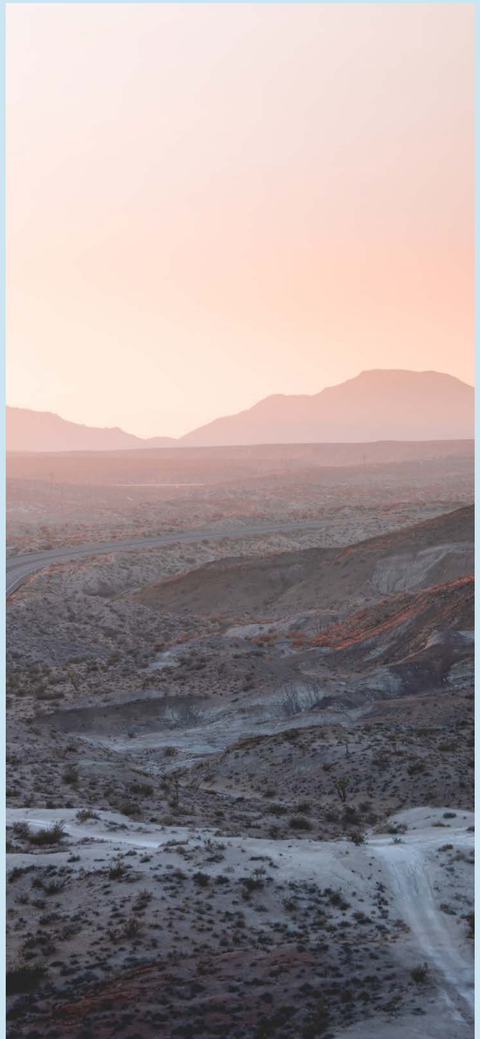
1. United Nations Biodiversity Conference (COP 15), from 7th to 19th December 2022 in Montreal

2. Insecticides whose mode of action affects the central nervous system of insects

Mojave Desert protected from off-road dirt biking by AI

The Mojave Desert in California (US) is a vast 40,000 square kilometers expanse of mountains, dried lake beds, forests, and wildflower fields. It harbors several protected species, such as the golden eagle, desert tortoises, and Joshua trees, some of which are over 900 years old! It's a unique ecosystem which today is under threat from… human recreational activities, including off-road dirt biking. Capgemini's Millennial Garage is a collaborative working space where young professionals gain experience in innovative technologies. Capgemini challenged participants to use this knowledge, including AI, to protect this natural wonder.

A team developed a solution, based on AI and machine learning, to study satellite imagery and identify trails left by bikes. This information was then paired with existing datasets, for example nesting sites of at-risk species, to produce maps aimed at guiding official interventions and protecting the desert and its ecosystem.

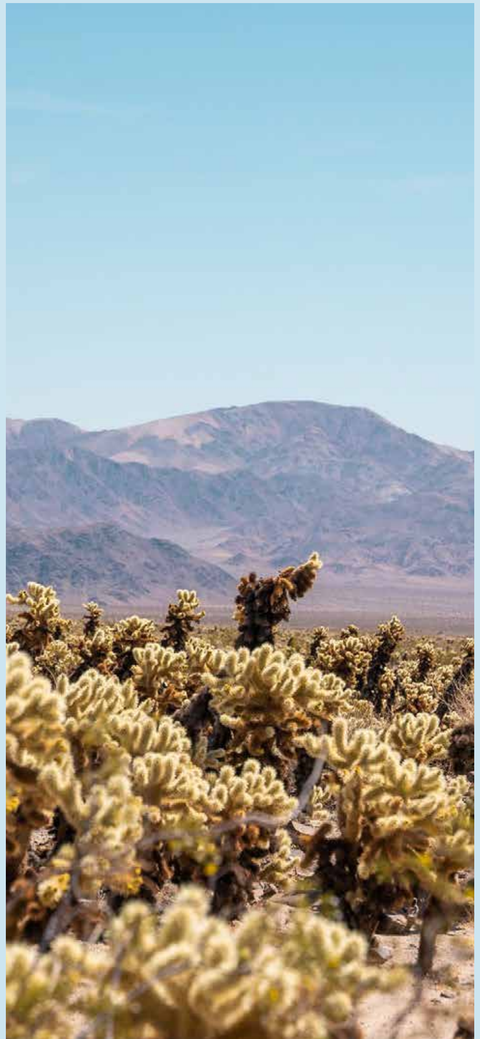


Educating the algorithm

This solution was not always easy to set up, stresses Lukas Agnew, a Capgemini consultant: *"For instance, we had a tough time designing the algorithm to deal with mountains, because, on a satellite image, ridge patterns can resemble trails."* Another challenge was to make the data readable and usable by The Nature Conservancy, an NGO that strives to protect the Mojave Desert.

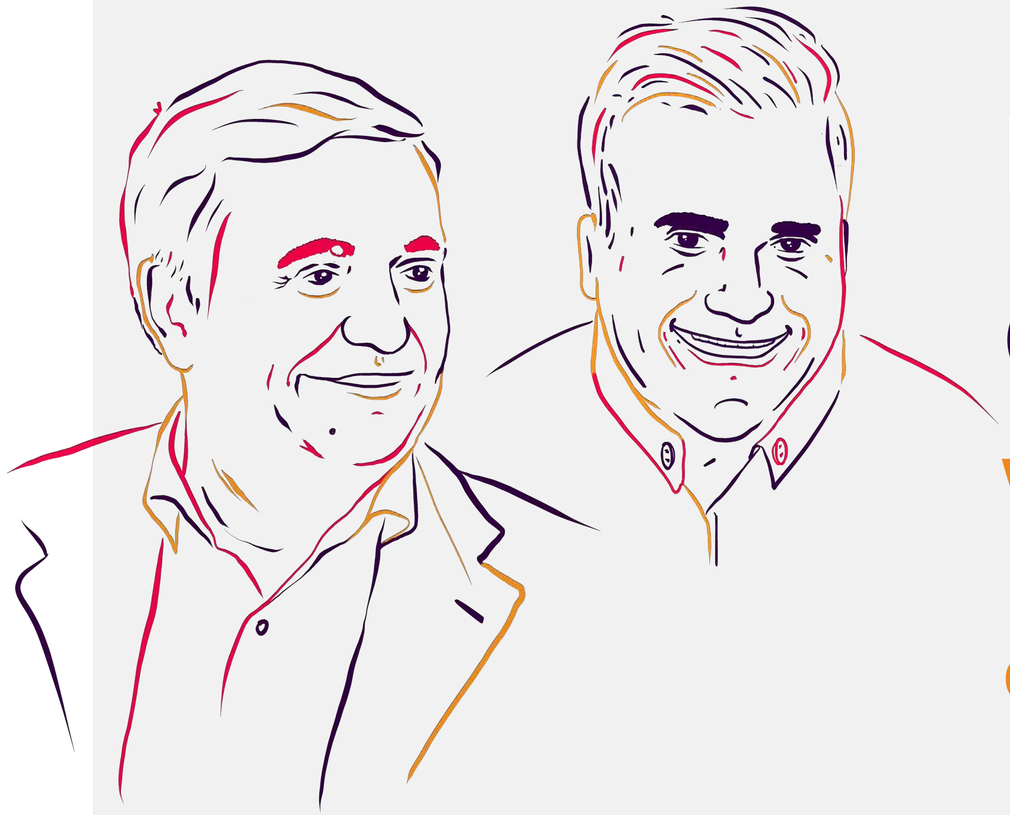
“À la carte” technology

AI, combined with satellite imagery, has a very varied application potential.
The Capgemini Millennial Garage team hopes to be able to extend its work into other areas that are known for their loss of natural habitat. This is the case of the largest primary forest in the world, covering 5.5 million square kilometers and spanning nine countries: the Amazon rainforest.



The richness of its biodiversity and indigenous populations is now under increasing threat from the human activities that are taking place in the forest. From illegal gold mining using mercury that spills into the tributaries of the Amazon, to the slash-and-burn techniques used by large agricultural landowners, the forest is undergoing a potential mass extinction of 10% of the world’s known species.

AI and machine learning have the power to systematize and thus speed up the analysis of datasets so that action can be taken more quickly in a threatened area. This is another initiative that also requires the upstream involvement of key civil, scientific and political stakeholders, to foster a stronger local impact.



Rising to the challenge of biodiversity with technology and collaboration

We asked Cyril Garcia, Capgemini Group Head of Sustainability Services and Corporate Sustainability, and CEO of Capgemini Invent, and Marko Cemovic, AWS Principal of the Global Impact Computing, to sit down and discuss the importance of technology in helping to achieve greater sustainability and protect biodiversity.

Why have Capgemini and AWS placed sustainability at the top of their priorities, including biodiversity?

Cyril Garcia Approaching planetary boundaries leaves us with no other choice than changing our way of working and our relationship with the planet. Biodiversity constitutes one of those planetary boundaries we cannot overshoot, due to its complex, central and interrelated role in helping mitigate climate change and maintaining resilient ecosystems.

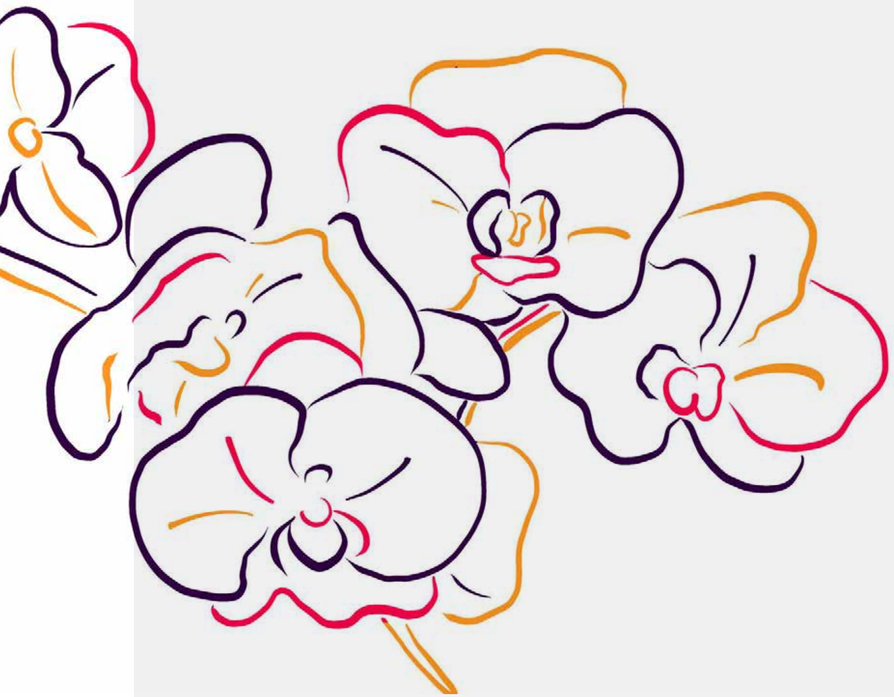
Marko Cemovic Indeed, we must build a sustainable business for our customers and for the world we all share. And as Cyril explained, we talk here about the need to address this issue holistically, covering both climate and biodiversity agendas. That's why we're designing data centers that provide the efficient, resilient service our customers expect, while minimizing our environmental footprint (and theirs) from water to energy consumption.

CG Exactly, and when we see that between 1970 and 2018, on average 69% of wild animals have become extinct, one clear element is that we need to act now. Especially in specific geographies, notably South America which is the most affected area with a loss of 94% of its wild species.

MC And actions can take multiple shapes, such as the LEAF Coalition we are part of; a new public-private global initiative to raise at least $1 billion to protect the world's tropical rainforests.

CG From our net zero commitment to more specific initiatives, there is a wide array of actions that can be explored. At Capgemini, we have for instance incorporated into our net zero journey the commitment to plant 20 million trees as part of the World Economic Forum global initiative, the Trillion Trees Movement.

> "Addressing this issue holistically, covering both climate and biodiversity agendas."



How can Capgemini and AWS, as businesses, act in favor of biodiversity?

CG At a first glance, biodiversity might not be seen as directly business-related. However, the World Economic Forum estimates that nearly half of the world's DP is moderately or highly dependent on nature and its services . Fortunately, we can act to avert the cost of biodiversity loss the World Bank estimated up to 2.7 trillion US$ each year by 2030. We can act at two levels; first by mitigating our negative impact over biodiversity, and then by supporting biodiversity restoration. Both levels require us to reconsider our way of building solutions, from commitments to solid actions, and finally to the monitoring and reporting of such actions.

MC I agree. At AWS, we're working directly with organizations and partners who are tackling large problems in the space of biodiversity and biosecurity. We are able to leverage our scale, technology and infrastructure to deliver on our commitment to leave things better than we found them. This originates from AWS's Global Impact Computing team, which was founded as part of our Worldwide Specialists Organization's commitment to help organizations tackle some of the most pressing global environmental and social challenges.

CG Yes, and as mentioned by Marko, to provide a complete solution to such cross sectorial challenges, we need to build strong networks, based on a multiplicity of partners across geographies, such as AWS. It is key to combine efforts and foster innovation to better address biodiversity loss, notably on data processing.

MC Exactly, this is one area where AWS and partners like Capgemini are well positioned to help 'accelerate time to insights', better enable the sectors' ability to respond and develop capacity that is commensurate with the scale of the problem.

To what extent can technologies be part of the new solutions supporting biodiversity?

MC The experts in their respective fields are demonstrating that technologies are proving to be critical elements in the advancing of biodiversity efforts. Today, conservationists, researchers and scientists are applying and adapting AWS technologies to develop new solutions to meet their unique needs.

There's a wide variety of use cases; from applying computer vision to analyze still images from field cameras to detect invasive species on remote islands, to using machine learning to rapidly analyze satellite imagery of oceans to assess the health of kelp forests in the Pacific.

CG Indeed, we also have a common use project, leveraging AI and machine learning, to track the state of whales and how they are impacted by global warming, showing how precise the tasks can be when leveraging technologies.

> "Tech and data constitute **key levers** to act for biodiversity."

And I would add that technologies and data are crucial to understanding the complexity of the living and they constitute key levers to act for biodiversity. Data and the modelization of ecosystems for instance help us learn about the functioning of an endangered ecosystem and where to act. While, as part of the living ourselves, we have this great ability to build technologies, working with and inspired by nature; an interconnection reiterating the need to protect biodiversity.

This is with such a combination of technologies with data that we can scale up solutions, fast. It enables us to process high quantities of data, that answer to specific challenges and help make informed decisions.

MC Absolutely. Much of the work around biodiversity relies on gathering data and gaining insights into what is happening, at scale and at speed. Gaining a timely understanding from data that exists, or that is being collected, is a foundational challenge that researchers and conservationists are grappling with every day.

Also, developing new technology solutions takes time and is rarely a core competency within the biodiversity community. Accelerating and supporting these technology innovation efforts with expertise and human capital is an important way in which AWS and partners like Capgemini can engage together to advance the great work underway.

Do you think new collaborative business models will emerge to support solutions in favor of biodiversity?

MC Collaboration has been foundational to support new solutions for biodiversity and the broader conservation and sustainability space. And as I mentioned before, AWS Global Impact Computing was founded for this very purpose.

CG It is for us the same approach; collaboration has always been at the core of our overall sustainability activities and practices. That's why we have incorporated within our Road to Net Zero initiative a collaborative global framework as a key pillar. We strongly believe in rising to sustainability challenges with core technology partners such as AWS.

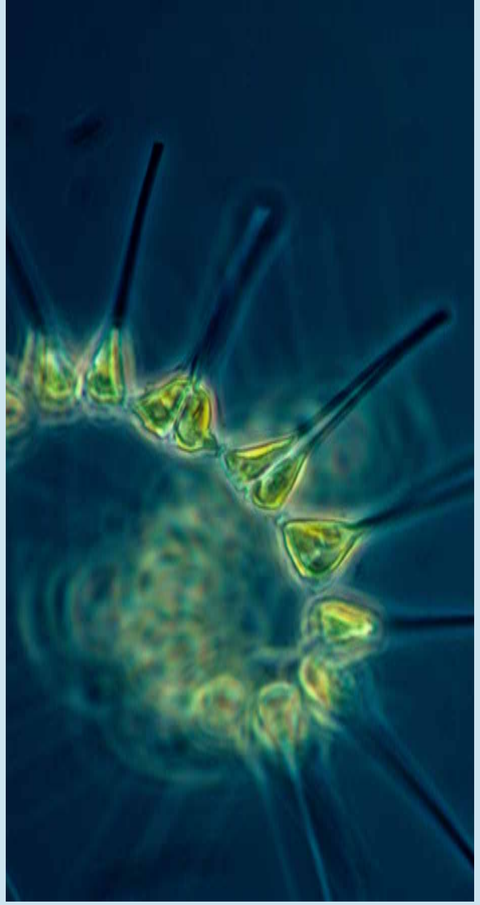
MC Delivering mission-specific capabilities in this sector through collaboration with partners like Capgemini, who have both an organizational mandate and the technical expertise to invest, is a scalable mechanism that we can apply today. But, in doing so, we must also consider how to make these capabilities more accessible and repeatable for the broader sector. This can be accomplished through thoughtful coordination amongst partners, conservationists, academia, researchers and the start-up community.

CG Absolutely. Opening our collaboration to the broader ecosystem of academics and startups is key to creating more synergies between research, innovative ideas and applied solutions.

Use Case: Climate change

Tracking sperm whales, thanks to AI

Sperm whales were famously the inspiration behind the epic novel “Moby Dick” by Herman Melville, published in 1851. The book was a global success, but not for the whales because alas, since this date, their population has dropped dramatically by 67%. These marine mammals have been considered vulnerable since 2008 as they are at danger from entanglement in fishing nets, collisions with ships, ingestion of marine debris, as well as ocean chemical and noise pollution. A significant series of threats - on top of which now comes climate change and its consequences on the oceans. Paradoxically, sperm whales constitute by themselves carbon sinks and climate change mitigators, by providing nutrients to phytoplankton. To help protect sperm whales around the world, a team from Capgemini Norway developed an intelligent data



solution based on artificial intelligence (AI) and machine learning. The solution uses the computing power of AWS to identify sperm whales thanks to image processing, and to help scientists track migration routes, look at the social structure of the sperm whale groups, and protect the whales’ natural habitats. This mechanism is fueled by the many photos taken over the past 35 years by Azores-based marine biologist Lisa Steiner.

“We’ve been able to identify individual whales thanks to images of their tail fins, which show unique markings and structure, the equivalent of human fingerprints”, according to Pedram Sherafat, from the Norwegian team.

In effect, the Capgemini solution makes it possible to spot these tail fins, within a multitude of images, within 97.5% accuracy.
In fact, this helped the team win Capgemini's 2020 Global Data Science Challenge, an annual internal competition during which employees use AI to address real world challenges.

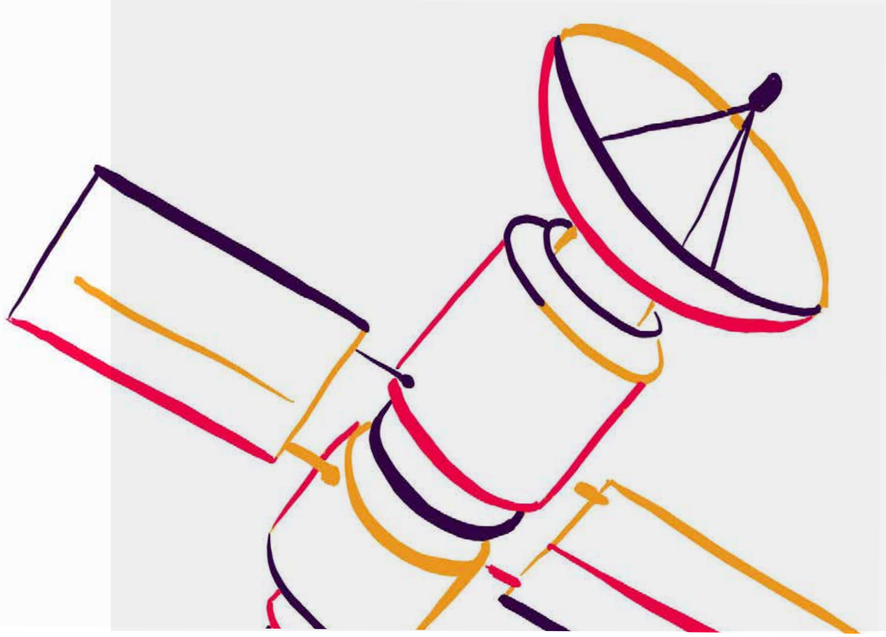
Beneath the data, whale song

In 2021, the Capgemini teams partnered with The LoVe Ocean Observatory, a Norwegian research center that records data on the ocean's biological and chemical environment in real time. Buried deep beneath the

Lofoten archipelago, a network of sensors continuously records the sounds of the ocean and produces a series of readings. Hidden within these recordings are the haunting songs of humpback whales and the vibrations of shoals of herrings - precious clues about climate change.

Capgemini's Global Data Science Challenge in 2021recognized not one but two teams. The first, based in India, was rewarded for its AI solution capable of analyzing these data flows and detecting any potential anomalies. *"We tackled each data source individually, designing a model that would identify the outliers in each set"*, explains Anupam Saga. The second team, in the UK, was singled out for its approach to managing the huge volumes of data: *"We had to normalize the data and pad out the missing areas"* adds David Gilhooley, who is convinced that AI can play a significant role in helping to better understand and combat climate change and global warming.

How tech can come to the rescue of the living world



AI, machine learning, datafication, drones, robots and satellites: many technologies can help to preserve biodiversity. By monitoring, cataloging, and analyzing a range of ecosystems – in the air, in the earth and under the water, these tools contribute towards a better knowledge of endangered species and to their protection.

However, the alliance between biodiversity and technology is currently not self-evident. In effect, although today technological solutions for protecting and restoring biodiversity are emerging, up until now, technological progress has mainly helped destroy part of our fauna and flora. *"The first goal of technology should be to improve human life, but it can paradoxically destroy vital foundations of our life"*, sums up Aurélie Gillon, Sustainability Director at Capgemini Invent.

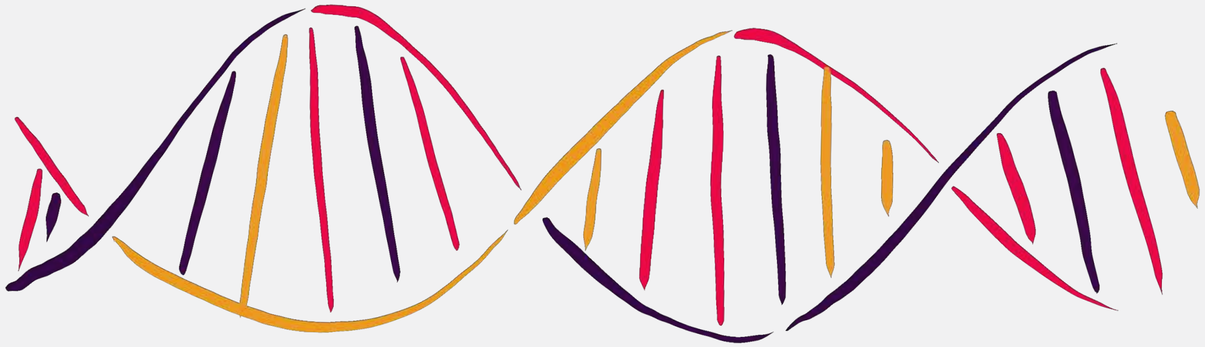
Thus, the loss of habitat and the disruption of natural systems, caused by mining and the extraction of raw materials, as well as by the laying and burying of telecommunication lines, leads to biodiversity loss.
The electromagnetic pollution that disturbs birds, bees and bats; overfishing; the mass slaughter of small mammals and amphibians crossing roads; or the massive use of pesticides that destroys insects and affects the entire food chain; these are also part of these disturbances.

Faced with the breakdown of biodiversity, *"there is a consensus that technology is not a miracle solution. It is however hard to imagine how this problem could be solved without it, when looking at its potential to transform entire systems, including agriculture"*, Aurélie Gillon adds. Furthermore, she states: *"It is up to us to make technology an enabler of paradigm shifts along key value chains. I strongly believe agriculture is at the core of this transformation. Indeed, agritech is an essential solution to restore not only biodiversity but also the synergies with the living world we depend on. It is not too late to reverse the crisis, as biodiversity is highly resilient, and the process of restoration could turn out to be swift."*

Minimal interference

Finding a balance between technology and the living world is therefore at the heart of the challenges for the future of biodiversity and the future habitability of the planet.

But with which guiding principle?
In its ethical manifesto entitled *"The future of life, our values for action"*, published in 2021, the International Union for Conservation of Nature (IUCN) French Committee puts forward the objective of *"minimal interference"*. *"Any action should be designed and conducted in such a way that it interferes in the least possible way with spontaneous biological and ecological processes. (…) In any case, technology must remain a humble servant."*

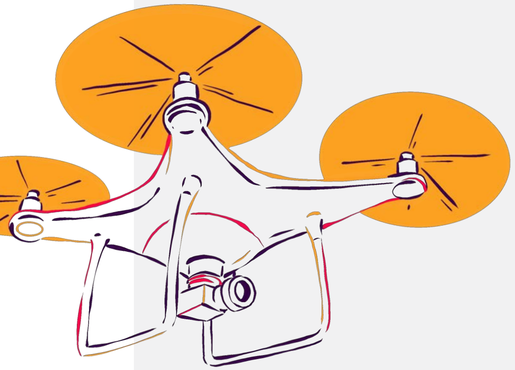


Entomologist Patrick Blandin, professor emeritus of the French Natural History Museum and Honorary President of the IUCN French Committee, also reflects upon *"the ethical dimension of the manipulation of spontaneous processes of nature, in other words the steering of biodiversity. It is necessary to leave behind the anthropocentric approach, by being guided more by respect and the living together of humans and non-humans."*

In addition, Tatiana Giraud, observes that *"mutagenesis techniques [aimed at voluntarily introducing genetic mutations within a living organism] will never be able to innovate as nature does. It is impossible to combine millions of mutations in the laboratory, which have required thousands of years of evolution. And this is without taking into account the adverse consequences of these cultured organisms on biodiversity."*

Ecological engineering

Yet, the biologist admits, *"ecological engineering can be useful"*. It can help to limit and even stop biodiversity loss, by reducing the pressure from the five major factors that affect ecosystems: habitat loss, overexploitation, climate change, pollution, and invasive species (read also the interview with Philippe Grandcolas, research director at the CNRS, page 11).



“We can take advantage of new technologies to reduce the impact of industry on biodiversity.”

“Technology has transformed conservation work,” observes Tom Quigley, Founding Partner of Superorganism, a venture capital fund for biodiversity, *“thanks, among others, to drones, satellite imaging, camera traps, and new gene-sequencing techniques. We can also take advantage of new technologies to reduce the impact of industry on biodiversity.”*

A consensus is taking shape that ecological engineering can provide innovation in three main areas: monitoring that sheds light on actions and decision making; nature-based solutions that use interactions with ecosystems to provide benefits to society; and technological and non-technological developments that help to divert or reduce impacts.

Pests tracked from space

Bark beetles, or Scolytinae, may be very small but they are highly destructive for conifers. The spruce bark beetle is a pest beetle, 2 to 7 millimeters long, that is destroying the white spruce forests of North America and Europe. For example, 3 to 4 million cubic meters were destroyed in this way in 2018, according to the Swedish Forest Agency, leading to the loss of a precious carbon sink and habitats for many species.

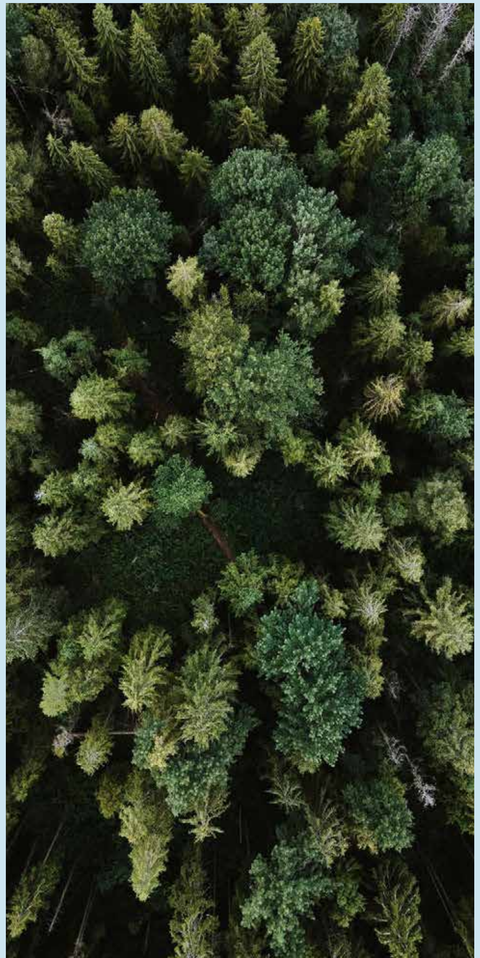
In order to stop this destruction, Sveaskog, the public corporation that manages 14% of Swedish forests, partnered with Sogeti Sweden, which resulted in the Geo Satellite Intelligence solution. This combines satellite images, artificial intelligence (AI), and analysis algorithms to produce detailed maps of the progress of these pest beetles, and trigger a rapid intervention, targeting the infested trees, to prevent these insects from spreading.

“We’ve developed a deep learning algorithm to define the patterns of damage caused by these insects, thanks to the satellites, which obtain images of the territories using the entire light spectrum, from ultraviolet to infrared. By comparing these images at different dates, we can identify the areas where attacks are taking place”, explains Marcus Norrgren, Sogeti Sweden.

A solution that is efficient in 80% of cases.
“Instead of using planes or drones, or simply roaming through the forests trying to spot diseased trees, you can now rely on satellites that can cover millions of hectares”, he adds.

The key role of images

Forest management companies, both public and private, can thus quickly figure out whether forests are under threat from bark beetles and where. Then they can act accordingly by eliminating the insects locally or, if the problem is more serious, by increasing logging, to harvest the wood before it is too damaged.



“We’ve also developed tools that can be used for similar attacks, like in Canada where there’s a problem of invasive earthworms. All we need are the images”, says Marcus.

“We’ve been able to check, by using drones, that this data was 100% reliable. We can now detect and manage the affected areas and therefore reduce the spread of spruce bark beetles”, adds Fredrik Klang, Forestry Director at Sveaskog.

This is a solution that is going to become even more crucial with increased global warming, which is causing the pest beetles to migrate northwards towards the arctic forests.

Monitoring without damaging

Let's take a prominent example, coral reefs, which are home to 25% of the planet's marine life. WWF estimates that close to 2 million different species live on these reefs and that a quarter of the oceans' fish mature there. Coral reefs are also a natural barrier against violent phenomena such as cyclones, typhoons, and hurricanes. Collectively, these reefs form a fragile ecosystem, whose overall surface has decreased by half since 1950, according to the University of British Columbia.

The question is, how can we observe and monitor them without damaging them even more? To this aim, Professor Erik Engeberg of Florida Atlantic University has designed the JenniFish, a bio-inspired robot. With the appearance of a jellyfish, it drifts along with the currents and can propel itself by ejecting water - just like its living counterpart!
It therefore makes it possible to analyze coral reefs without damaging them.

The question is, how can we observe and monitor reefs without damaging them even more?

Taking inspiration from nature: synthetic biology

The World Biodiversity Summit, held in New York on 21 September 2022, was the chance to showcase various innovations, attesting to the positive contribution of technology in the protection of the living world.

Among these nature-inspired solutions, one of the most fascinating is synthetic biology, which combines biology with engineering principles, to build organisms that achieve complex functions. This technique makes it possible to combat the harmful effects of pollution on living beings. In this area, British

company Cambridge Consultants (part of Capgemini Invent) joined up with Japanese group Hitachi's Central Research Laboratory to develop a synthetic enzyme that eats and digests plastic matter.

Drawing from the living world: the eDNA revolution

Another innovation that is radically transforming our knowledge of biodiversity is environmental DNA (or eDNA), which makes it possible to detect the traces of DNA left by a living being in a water or sediment sample.

"Decisions are being made about nature and biodiversity without a real understanding of the living world's complexity. Now we have a tool for turning nature into data at scale: eDNA. Thanks to the eDNA technologies that we've validated across many ecosystems globally, environmental DNA methods are already generating large scale data that captures the entire chain of living beings from bacteria to vertebrates and more", explains Dr Molly Clavey, Communications Manager at NatureMetrics, a leading provider of nature data in this area.

For Laura Plant, Business Development Director at NatureMetrics, this technique provides new possibilities: *"The fact that*

"Now we have a tool for turning nature into data at scale: eDNA."

there is now data available for precisely analyzing biodiversity enables companies to set environmental objectives that are measurable and avoid greenwashing lawsuits. Thus, they can know accurately the impact of their activity on nature."

"It is probable," she adds, *"that in the future, regulations will impose a more precise measure of the impact of businesses on the environment. All those that already use eDNA are laying the foundations for what will, in time, become the norm"*, with nations already benefiting from the environmental DNA revolution. For them it is also *"the chance to better evaluate their nature protection and conservation policies"*, Laura Plant concludes.

Among the many projects NatureMetrics is working on, one of the most emblematic is its partnership with NGO Fauna & Flora International, a nature conservation specialist. A project in Liberia set up to identify, localize and better protect pygmy hippopotamuses has been a success, and also resulted in data collected on 165 other vertebrate species [(1)], including a critically endangered fish that can now be better managed in the remote region of a West African country.

Preventing biodiversity loss: a concern for us all

Technologies to help preserve biodiversity certainly exist, but they need to be known about and used as widely as possible. And this is where civil society organizations and individuals have a role to play.

"These organizations have developed on-the-ground expertise and environmental protection know-how," observes Jérôme Duberry, a teacher-researcher at the University of Geneva Global Studies Institute and associate researcher at the Geneva Graduate Institute (IHEID). And *"The services provided by this group of bodies are numerous, ranging from*

Huge financial needs

To preserve biodiversity and in particular to support technological innovation, financing needs are very high. A report published in 2020 by The Nature Conservancy, titled *"Closing the Nature Funding Gap"*[2], estimates that an additional $824 billion per year needs to be invested, in order to protect nature. 70% more invasive species.

the protection of species and threatened ecosystems, to tracking poaching and overfishing offences."

For example, anyone can register on the iNaturalist.org website and download its free application to collect information on flora and fauna. This joint initiative, by the California Academy of Sciences and the National Geographic Society, enables the sharing of this information with the Global Biodiversity Information Facility, an international network of 750,000 scientists, whose mission is to *"provide anyone, anywhere, open access to data about all types of life on Earth."*

Of course, while there are significant highly advanced technologies coming through, AI and the abundance of data are very much part of the essential tools and techniques. AI is on the front line in the fight against climate change and the impacts on biodiversity, Scientists from the Descartes Lab in Santa Fe USA, have designed an AI-based solution that can detect fire outbreaks earlier and prevent them from becoming megafires by alerting firefighters within a few minutes.

In addition to AI, satellites and drones, an everyday device such as the smartphone, which is sophisticated in concept and ordinary in its use, can also help to count, describe, and therefore protect an endangered biodiversity. The fight to defend the living world is a concern for us all.

1. naturemetrics.co.uk/case-study/ffi-detects-pygmy-hippoin-southeast-liberia/

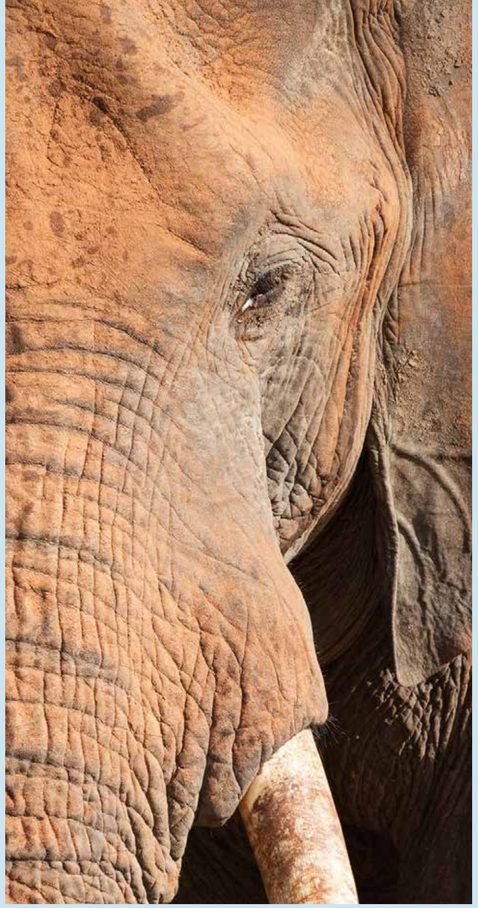
2. nature.org/en-us/what-we-do/our-insights/perspectives/closing-nature-funding-gap-global-biodiversity-finance/

Use Case: Overexploitation

Open data to the rescue of elephants and sharks

African elephant populations are being dramatically reduced because of human activity: deforestation, poaching, mining, and human-elephant conflict. To help protect them, acoustic monitoring is an efficient way of tracking them, by recording and analyzing ambient noise. Open data now makes it possible to support and improve this type of initiative.

The Elephant Listening Project, (K. Lisa Yang Center for Conservation Bioacoustics / Cornell University) for example, has over a million hours of recordings of northern Congo elephant populations and provides this information to environmental NGOs in the field. This huge volume of data requires public, accessible cloud hosting. This is provided by AWS as part of its Open Data Sponsorship Program.



In this region of Africa, over 50 acoustic monitoring units have been installed over the last five years, covering an area of 1,250 square kilometers. The wide range of data collected – including poachers' gunshots – are analyzed and processed by algorithms, making it possible to count the elephants precisely. Detailed heatmaps of the distribution of the pachyderms, and the poachers, are then published, increasing the in-depth knowledge available to conservators.

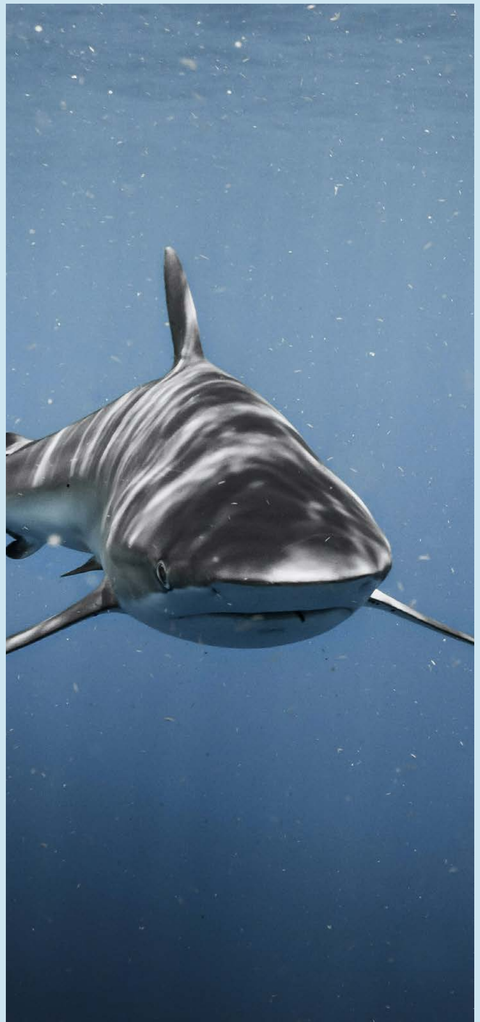
Breaking down silos

Sharks are another endangered species. Since 1970, their population has decreased by 70% due to overfishing and illegal fishing.

Ocearch, a non-governmental organization, whose mission is to help scientists collect previously unattainable data in the ocean on sharks and other large fish, is using AWS to help it study the migratory patterns of sharks.

Working in cooperation with the Amazon Sustainability Data Initiative (ASDI), the data collected by Ocearch is published in real time on their website.

This approach has the double benefit of breaking down silos both between scientists, as well as between science and the general public.



Beyond the “stars”

These initiatives also have the potential to be applied to plants and animals that do not have star status in the media as elephants and edelweiss do, both of which are now protected. Data is key to help us discover new species and protect them. About 8 to 12 million of current species remains to be discovered.

Thus, open data is a tool that could become crucial for surveying and providing alerts on species that are silently disappearing, and on species that have not been discovered yet.

Appendices

Glossary

ABIOTIC FACTORS
"An abiotic factor is a non-living part of an ecosystem that shapes its environment. Abiotic and biotic factors work together to create a unique ecosystem."(1)

BIODIVERSITY
The variability among living organisms, at the genetic, species and ecosystem levels.

BIOLOGICAL RESOURCES
Genetic resources, organisms (or elements thereof), populations, and all other biotic elements of ecosystems that have an actual or potential use or value for humanity.

BIOTIC FACTORS
"A biotic factor is a living organism that shapes its environment."(2)

DIRECT FACTORS
Natural and anthropogenic (originating in human activity) factors that directly affect biodiversity. Direct anthropogenic factors can be conceptualized as all the activities carried out by humans that lead to loss of biodiversity. These include land and sea usage, overexploitation of living resources, the introduction of invasive species, pollution, and climate change.

ECOSYSTEM
A community of living organisms (plants, animals, fungi, and various microorganisms), linked with the non-living components of their environment (energy, air, water, and mineral soil), the whole interacting as a functional unit.

ECOSYSTEM SERVICES
Advantages that we take from nature. The IPCC defines them as "ecological processes or functions, having value to individuals or society".

HABITAT
A place or type of site where an organism or population occurs naturally.

INDIRECT FACTORS
Forces that underlie and shape the extent, severity, and combination of the direct anthropogenic factors at work, in any given place, including institutional and governance structures, and social, economic, and cultural contexts.

NATURE-BASED SOLUTIONS
Actions aimed at protecting, sustainably managing, and restoring natural or modified ecosystems, which tackle social challenges in an adaptive way, while simultaneously providing benefits in terms of human wellbeing and biodiversity.

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1. education.nationalgeographic.org/resource/resource-library-abiotic-factor
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nature.org/en-us/what-we-do/our-insights/perspectives/closing-nature-funding-gap-global-biodiversity-finance/

Dynamique et évolution de la biodiversité et des écosystèmes. (Dynamics and evolution of biodiversity and ecosystems). Against the threats brought about by climate change, Tatiana Giraud, research director at the French National Center for Scientific Research (CNRS) and member of the French Academy of Sciences, explains the most intriguing aspect of biodiversity: its adaptability in changing and even hostile environments.
Éditions Fayard and Collection Collège de France, 2022

De la Protection de la nature au pilotage de la biodiversité. (From Protecting nature to steering biodiversity). Patrick Blandin, Professor Emeritus of the Natural History Museum and Honorary President of the IUCN French Committee, analyzes the evolution of ideas from the start of the twentieth century, when we were concerned with protecting nature, to the present day, when it is a matter of managing biodiversity.
Éditions Quæ, Collection "Sciences en questions", 2009

Mieux connaître la nature pour mieux la préserver. (Get to know nature better so as to preserve it better). In this podcast episode of the National History Museum, Philippe Grandcolas, a research director at the French National Center for Scientific Research (CNRS) and director of the Institut Systématique, Évolution, Biodiversité (Isyeb), explains the importance of better describing and naming the living world's diversity. This is the role of taxonomy, a science that aims to know, name, and classify species, even though our knowledge of the living world is still very fragmented.
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World Biodiversity Summit. The link between biodiversity loss and climate change is growing ever clearer. The World Climate Foundation launched the World Biodiversity Summit in recognition of this inherent interconnectedness. The Summit is the pioneering platform for global public-private partnerships to address the urgent need for biodiversity restoration, through nature-based solutions and nature-positive investments.
www.worldbiodiversitysummit.org/

Acknowledgements

Capgemini and AWS would like to thank the following organizations for their contributions to the articles in this point of view.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
The French National Centre for Scientific Research (CNRS)
Paris-Saclay University (Laboratoire Écologie, Systématique et Évolution)
Institut Systématique, Évolution, Biodiversité (Isyeb),
French Foundation for Biodiversity Research
Wild Legal
International Union for Conservation of Nature (IUCN) French Committee
Superorganism
Florida Atlantic University
NatureMetrics
University of Geneva Global Studies Institute and the Geneva Graduate Institute (IHEID)
The LoVe Ocean Observatory

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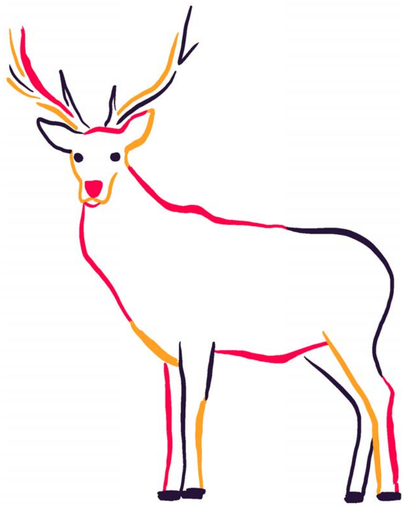

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