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Biodiversity: extinction or collapse?


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Summary

■ *Many scientific studies highlight considerable and very rapid loss of biodiversity. The question of a sixth extinction of species has now been raised.*

■ *However, despite the increasing volume and reliability of scientific data, public opinion remains sceptical.*

■ *Scientific research must be encouraged in order to raise awareness of the human origin of biodiversity loss and its consequences for humanity.*

Mr Jérôme Bignon, Senator

■ The notion of extinction

The expression "massive extinction" first appeared in 1796 and has been attributed to French naturalist Georges Cuvier. More recently, several scientists have spoken of a "sixth extinction crisis": Paul and Anne Ehrlich in a work entitled *Extinction* in 1981 and Paul S. Martin in his publications on "the overkill hypothesis" in 1984, but also Robert Barbault who wrote in 2006, "the horizon is dark, and a sixth extinction crisis a certainty". In 2015, the expression saw journalist Elisabeth Kolbert win the Pulitzer prize for her work *The sixth extinction: an unnatural history.*(1)

The notion of **mass extinction** refers to an "extinction of a significant proportion of the world's biota in a geologically insignificant period", according to Anthony Hallam and Paul Wignall.(2) These crises, which usually take place over hundreds of thousands or even millions of years, are **events which generate loss of biodiversity.**

The biodiversity formed by the variety of all living organisms is evaluated on five levels – ecosystems, species, populations, individuals and genes. This is a vast mass(3) which includes living organisms and the relationships they establish between each other and with the environment. Each extinction crisis has resulted in the disappearance of numerous species, followed, several millions of years later, by the appearance of an even greater number of new species, illustrating the **resilience of biodiversity**.(4)

The five major extinction crises

The Earth has suffered sixty extinction crises, five of which are considered massive. These are only the crises which occurred in the past 600 million years, as traces of crises beyond that time are difficult to detect. The oldest, during the Ordovician-Silurian period, occurred around 445 million years ago, leading to the extinction of 86% of the existing species following a cooling global climate which brought the Earth into an ice age. The second extinction crisis, the Devonian, which happened 380 to 360 million years ago, was generated by oceanic anoxia, or a lack of dioxygen. The third and most severe crisis, the Permian-Triassic, took place around 250 million years ago, eradicating 96% of species after a series of volcanic eruptions which released carbon dioxide into the atmosphere, causing the climate to warm and increasing the acidity of the oceans. The fourth extinction crisis, the Triassic-Jurassic event, occurred around 200 million years ago, wiping out three quarters of living species, both marine and terrestrial. The regeneration in biodiversity which followed the fourth crisis led to the appearance of dinosaurs, which then disappeared in the fifth and last extinction crisis, the Cretaceous-Paleogene event. This happened 66 million years ago and is thought to have been caused by an asteroid hitting the Yucatan peninsula in the Gulf of Mexico. These five massive extinctions occurred over a fairly long period, but one which is insignificant in terms of geological time.

Collapse of biodiversity and temporality

All species are destined for extinction, but the speed of the current erosion of biodiversity is alarming as it is ten to one hundred times faster than that noted in previous geological times.[5]

This **rapid change is disproportionate to the natural speed of extinction, and is worrying due to the imbalance** it causes in terrestrial and marine ecosystems in the Anthropocene.

The notion of the **Anthropocene** was introduced in 2002 by Paul Crutzen, Dutch meteorologist and chemist and winner of the 1995 Nobel Prize in Chemistry. It designates a **new geological time, one dominated by humans, their domestic animals and their cultivated plants**.[6] In contrast to the previous geological times where changes were brought on by natural disasters or events, humans are at the centre of the Anthropocene, and are the main drivers of the current change.

It is important to understand the composition of biodiversity as precisely as possible in order to appreciate the scale of the crisis. Each year, **16,000 to 18,000 new species** are discovered, but at the same time **species are disappearing even before having been discovered and therefore described, named, referenced and classified.**[7]

Oceanographers and marine specialists confirm a sharp and worrying decline in the numbers of organisms exploited in the oceans (fish, crustaceans, molluscs), although they are not yet extinct. This understanding gap is due to the currently poor knowledge of marine stocks. By contrast, terrestrial biodiversity had been the subject of many studies and more is known about it.

> There are currently over 2 million identified species. Scientists estimate the number of living species to be between 10 and 20 million.

We are currently witnessing the “**rapid decrease in numbers of individuals within some of the remaining populations**”.[8] This phenomenon should be dissociated from the concept of “massive extinction”,[9] but it is a preliminary step. Humans can nonetheless take action to counter this collapse and thus prevent mass extinction. **The rapid decrease in numbers can be curbed**, whereas extinction, once it has happened, cannot be reversed.

Loss of biodiversity must not be reduced to a decline in the diversity of species: it also affects the way communities of species adapt to the most varied of environments.[10] And yet, such rapid change has two consequences: ecosystems are confronted with **homogenisation** (the loss of many specialist species, replaced by a few generalist species which are the same everywhere), a phenomenon which then leads to **a sharp decline in their powers of resilience**. When an ecosystem becomes weakened, it loses complexity, abundance and diversity. And the strength of an ecosystem lies in its composition: the cohabitation of a large number of complementary individuals and species **which do not provide the same ecological services.** This simplification of ecosystems can be seen in a decrease in the number of specialised species, whose adaptation and survival skills are subject to very strict conditions.[11] The phenomenon of **coral bleaching** is a good illustration of this.[12]

Scientific indicators and tools

The scientific world strives both to establish robustly the reality of these observations and the reliability of the research, and to share it with as many people as possible.

Scientists, especially biologists and oceanographers, use many and varied tools to observe the collapse in numbers of individuals in populations.

The main action of the International Union for Conservation of Nature (IUCN), an organisation composed of governments and civil society organisations, **is to compile red lists of endangered species**[13] by identifying the species concerned and making recommendations by category[14] within the list. For France, in order to collect reliable data, the French committee of the IUCN and the French Natural History Museum (MNHN) use a table which can theoretically be applied to all species, with objective criteria including the biological factors associated with extinction risks, the population size of the species, its rate of decline, the surface area of its geographic distribution or its degree of fragmentation.[15] In fact, for the majority of species (especially invertebrates, which make up more than 95% of animal species), the quality of data available on demographics, population dynamics or geographic distribution is insufficient to apply the criteria. The list is not made by a single person as the assessment is conducted by a group of specialists in collaboration with experts and associations. The decision to classify an individual or a species in a particular category is made on a collective, unanimous basis. Declaring a species extinct comes with serious consequences, as it *ipso facto* prevents any conservation actions from being implemented.

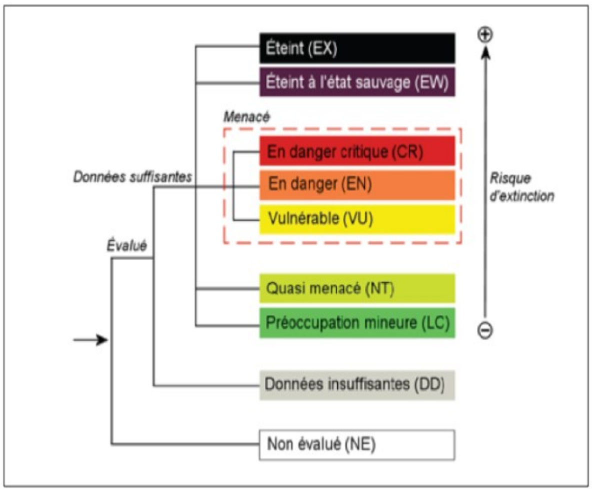
The French Committee of the IUCN and the MNHN have compiled lists for France of mammals, birds, reptiles and amphibians, freshwater crustaceans, as well as dragonflies and butterflies.[16] To date, **the French Committee of the IUCN has only assessed 5% of the species in France, or 93,500 species in Metropolitan France and overseas territories. It is looking to extend the scope of its action to invertebrates, which have long fallen by the wayside**.[17]

The IUCN’s Red List is a reliable tool for finding out the conservation status of the best-known species, but is highly inadequate for the largest portion of biodiversity: insects, molluscs, fungi, etc., which make up the vast majority of living species.

For this reason, researchers have developed a range of other techniques for assessing biodiversity. The **species-area relationship**,[18] following a probability method, **counts species losses based**

on the principle that the larger a territory is, the more species it will contain.

Using a mathematic ratio, it is possible to calculate the number of species brought to extinction when a



given surface area of an ecosystem is lost, especially in the event of deforestation. But this tool is only relevant on territories with significant geographical coherence.[19]

Another method, also probabilistic, is used to build a **mathematical model of the likelihood of extinction based on species collection and observation dates**[20] using three parameters: a *date of change in overall speed of extinction rate* after which extinctions become possible and, for each geographical area, an *extinction probability per year* and a *collection probability for the species during fieldwork*. The results obtained are compared with information provided by experts consulted beforehand, who have local knowledge of regional fauna or worldwide knowledge of the particular groups of species. The results of these two approaches, tested on a random sample of 200 species of terrestrial molluscs around the world, are remarkably congruent.

In contrast to the rate of 0.04% suggested by the IUCN Red List, this approach shows that, since the early 1980s, nearly 10% of the world's terrestrial fauna has become extinct.

Participatory science is another tool used by the French Bird Protection League (LPO) and the French Natural History Museum to gather data which is then analysed by scientists and compared with data from previous years. Birds in particular are studied in this manner as they are good indicators of biodiversity loss due to their presence in all environments – forests, urban and rural areas – and their position at the top of the food chain.

The **STOC programme (*Suivi Temporel des populations d'Oiseaux Communs*), which monitors populations of common birds**, is supported by local LPOs and a network of naturalists. It was established in 1989 by the Centre for Research on the Biology of Bird Populations of the French Natural History Museum, and estimates the variation in numbers of common nesting birds in the short and long term, as well as establishing more complex indicators to measure the development of ecosystems. These data are collected by volunteer naturalists during listening sessions. The programme has highlighted the severe decline in numbers of common birds in France, especially in agricultural areas, with the loss of a third since 2001.

The most recent project, launched in July 2017, is the **interactive site for naturalists, Faune-France, which has collected 70 million data items in one year**, thanks to a large network of volunteers working with 80,000 subscribers, 20,000 of whom contribute on a regular basis. The Faune-France network includes the STOC data, as well as opportunistic data and research data. The Faune-France site records the bird species, the sighting location and the time. **These data are processed using artificial intelligence, enabling Faune-France to analyse biodiversity loss and behavioural changes, such as the impact of climate change on bird migration**. The indicators make it possible track the advance or delay in migration dates compared to the date considered normal. Their analysis highlights behavioural changes in birds.

Artificial intelligence is also the focus **of work being conducted by the "Tara Expeditions" Foundation,**[21] **both during collection and in the analysis of data.** Using *Tara*, a schooner equipped for carrying cutting-edge scientific materials and teams, 283 different ocean areas have been analysed, along with 600 marine ecosystems, transposing human genomic medical techniques to the ocean to develop "ocean science". A massive, public, free-to-access database has been created. It serves as a reference for all scientists, and in the space of two years has received three million requests. Analysing and modelling these data requires the use of increasingly sophisticated algorithms.

The causes of biodiversity loss

A collapse in the number of individuals is the result of many causes which come together to impact biodiversity. While there is consensus in the scientific world on these factors, not all researchers rank them in the same order. They nonetheless agree that climate change must not overshadow the other causes. These factors are currently being assessed by IPBES.[22]

The main causes are:

- **Destruction** and **artificialisation** of habitats and natural environments;[23]
- All forms of **pollution** (pesticides and rapid decrease in insect numbers; light; agricultural and maritime noise; marine hydrocarbons);
- **Overuse** of **natural resources** and **overfishing**, when the reproduction or renewal threshold is not respected;
- **Dissemination of invasive species, whether voluntary or involuntary**, which is especially significant in maritime and island ecosystems. Because of the absence of their predators and parasites, these species reproduce, upsetting the balance of the ecosystem;[24]

- **Global warming**;[25]
- **Population growth**, which itself is linked to several other factors.[26]

Scientific facts and scepticism

The scientific world is stepping up its efforts to raise awareness among the general public of these massive losses in biodiversity. **The data are increasingly numerous and reliable. Yet there is a gulf, a disconnect between the reliability of these data and the absence of reaction from decision makers and public opinion** in putting a stop to this collapse.

This **scepticism has been the subject of major studies in the United States,** though unfortunately much less so in Europe, based on social psychology, but also by combining sociological and philosophical approaches. These research works are complementary: the former explains the population's current refusal to recognise biodiversity loss, and the latter highlights the lack of coherence in the ecological discourse, which is not sufficiently in touch with the interests of the population.

Environmental generational amnesia,[27] as theorised by Peter Kahn in 2002, establishes that environmental identity is constructed within a reference framework, which for each individual corresponds to a **normal nature**. This frame of reference, built during childhood, means that each generation has different references. It is simply impossible to be aware of something we have not experienced, which means that we protect only what we know: this amnesia is a first cause.

The second is **a cognitive dissonance**[28] **between individual belief and scientific information, which is perceived as too violent.**[29] Individuals, refusing to readjust their cognitive balance, reject the information they are given. Despite improved dissemination of information and many scientific publications, the scale of biodiversity loss requires us to question human behaviour to such a degree that pure and simple ignorance is preferred.

Finally, according to other studies combining philosophy and sociology, scepticism is thought to come down to the difficulty for environmental issues to be dealt with from a political standpoint. For example, **rather than talking about nature and biodiversity, it would be preferable to speak of soil or territory.**[30] This change in vocabulary could foster the emergence of environmental matters as issues of the future which involve citizens directly. The notions of territory and soil facilitate the link between abundance or prosperity targets and environmental preoccupations. This helps the individual to feel directly affected by losses in biodiversity and to agree to get involved in prevention.

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All scientific research now agrees that this extinction crisis is rapidly outstripping previous crises, and that it is of human origin. Biodiversity is collapsing, with consequences on humanity that are difficult to foresee but which will affect services which are essential to our wellbeing and survival (pollination, soil regeneration, water cycle, leisure activities, etc.).

We therefore need to **fully understand the many causes** of the phenomena which lead to biodiversity loss. In order to do so, it is essential to **develop a psychological and sociological approach** to acceptance of these losses by citizens. Finally, we must **continue to encourage scientific research,** including participative science. We should move forward on this threefold basis, with clearly defined concepts: we should not mix things up.

OPECST Office websites:
http://www.assemblee-nationale.fr/commissions/opecst-index.asp
http://www.senat.fr/opecst/

Endnotes

[1] KOLBERT E., *The Sixth Extinction. An Unnatural History*. London: Bloomsbury, 2014, 325 pages.

[2] HALLAM R and WIGNALL R., *Mass extinctions and their Aftermath*, Oxford: Oxford University Press, 1997, 320 pages.

[3] Biodiversity includes (non-exhaustive): fungi, bacteria, vertebrates, invertebrates, as well as humans and protists, living single-cell organisms. For protists, see CARRADEC Q., PELLETIER E., DA SILVA C., ALBERTI A., SEELEUTHNER Y., BLANC-MATHIEU R., LIMA-MENDEZ G., ROCHA F., TIRICHINE L., LABADIE K., KIRILOVSKY A., BERTRAND A., ENGELEN S., MADOUI M.-A., MÉHEUST R., POULAIN J., ROMAC S., RICHTER D.J., YOSHIKAWA G., DIMIER C., KANDELS-LEWIS S., PICHERAL M., SEARSON S., "A global ocean atlas of eukaryotic genes", *Nature communication*, 9 (373), 25 January 2018.

[4] *Environmental vocabulary*, "Resilience", JORF n° 0087, 12 April 2009 page 6438: "ability […] to resist and survive alterations or disturbances affecting its structure functioning, and eventually find a new balance".

[5] DUMAS Ch. « La biodiversité végétale : une richesse à connaître et à protéger » in *La biodiversité*, Lettre de l'Académie des Sciences, n° 31, p. 10.

[6] CAREY J., *Are we in the "Anthropocene", Proceedings of the National Academy of Sciences of the United States of America*, vol. 113, n°15, 12 April 2016, p. 3908–3909.

[7] BŒUF G. (Préface), *#Sobériser. Innover pour un monde durable*, Paris: Presses des Mines, FNEP, 2018, p. 15 to 17.
BŒUF G. et LE BRAS H., « 10 milliards d'humains et alors ? », *Idées Le Monde*, 9 December 2017, p. 2-3.
BŒUF G. (DIR), *L'homme peut-il accepter ses limites ?,* Versailles : éditions Quae, 2017, 198 pages.

[8] CEBALLOS G., EHRLICH P. R. and DIRZO R., "Biological annihilation via the ongoing sixth mass extinction signalled by vertebrate population losses and declines", *Proceedings of the National Academy of Sciences of the United States of America*, vol 114, no. 30, 10 July 2017, p. 6089 to 6096.

[9] SARTORI A. F., FONTAINE B. and OLIVIER G., "Anthropogenic Extinction of Pacific Land Snails: a case study of Rurutu, French Polynesia, with description of eight new species of Endodontids", April 2013.

[10] Ecosystems have been evaluated on a regional basis by experts at IPBES. IPBES is an intergovernmental platform on biodiversity and ecosystem services, established in April 2012. It is open to all members of the United Nations, and its main role is to improve the links between knowledge and decision-making, particularly in the development of tools and methods for supporting decisions which take into consideration all scientific knowledge. In doing so, IPBES relies on scientific research, civic society and governments, as well as local autochthonal stakeholders.
A 2014 – 2018 work programme was developed with four objectives: strengthening capacity and knowledge foundations, making regional and global assessments of the Africa, America and the Caribbean, Asia-Pacific and Europe and central Asia areas, developing thematic and methodological assessments, communicating and evaluating activities.

[11] VAN DER PLAS et al., "Biotic homogenization can decrease landscape-scale forest multifunctionality", *Proceedings of the National Academy of Sciences of the United States of America*, 16 March 2016.
BŒUF G., « La biodiversité, marine et continentale », *L'adaptation au changement climatique, une question de société,* Paris: CNRS éditions, 2017, p. 141-148.

[12] Coral is an animal belonging to the same branch as jellyfish and anemones. It lives in symbiosis with single-cell micro-algae known as zooxanthellae. These algae are what give coral its bright colour, and provide 90 to 95% of the energy essential to their survival in the form of slow sugars. In return, the coral provides the micro-algae with nutrients and shelter. When placed under stress, such as a lasting rise in water temperature over 31°, the zooxanthellae are expelled, causing the coral to lose its bright colour. Without these micro-algae, coral can survive two to three weeks, and if the rise in temperature stops, thy suffer only minor mortality. This bleaching does not immediately lead to its death, as regeneration may occur following a period of stress. Nonetheless, these temperature changes greatly modify environmental resilience and balance in coral reefs. See ADJEROUD M., CHANCERELLE Y. and LISON DE LOMA T. « Vulnérabilité et résilience des récifs face aux perturbations » in *Le courrier de la nature*, 2010 vol. 252, p. 20–25.

[13] http://www.iucnredlist.org/ access page for the IUCN Red List.

[14] Under the IUCN Red List system, each species or sub-species is classified into one of the following eleven categories:
• Extinct (EX), Extinct In The Wild (EW) or Regionally Extinct (RE),
• Critically Endangered (CR), Endangered (EN) or Vulnerable (VU): consisting of threatened species,
• Near Threatened (NT): species close to the threshold of threatened species or which could be threatened if specific conservation measures are not taken,

• Least Concern (LC): species for which the risk of extinction is low,
• Data deficient (DD): species for which an assessment has not been possible due to insufficient data,
• Non Applicable (NA): species not subject to assessment as recently introduced (generally after 1500) or present in the region only occasionally or marginally,
• Not Evaluated (NE): species which have not yet been assessed based on IUCN criteria.

[15] IUCN Species Survival Commission, "IUCN Red List Categories and Criteria", Version 3.1, Second edition, 2012, 40 pages.

[16] http://uicn.fr/wp-content/uploads/2018/07/resultats-synthetiques-liste-rouge-france.pdf Summary table of red lists for France, established by the French Committee and the French Natural History Museum.

[17] REGNIER C., ACHAZ G., LAMBERT A., COWIE R. H., BOUCHET P. and FONTAINE B., "Mass extinction in poorly known taxa", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 12, no. 25, 23 June 2015, p. 7761–7766.

[18] COWLISHAW G., "Predicting the Pattern of Decline of African Primate Diversity: an Extinction Debt from Historical Deforestation", *Conservation Biology*, 24 September 2008.

[19] Three criteria must be taken into account: the variation in the slope and starting point of the curve, the variation in the definition and evaluation of deforestation as well as the variation in the evaluation of the number of species on Earth and in tropical forests. Although this instrument is based on a probabilistic method, the extinction rates calculated are always 1,000 to 10,000 times greater than natural extinction rates.

[20] REGNIER C., ACHAZ G., LAMBERT A., COWIE R. H., BOUCHET P. and FONTAINE B., "Mass extinction in poorly known taxa", *Proceedings of the National Academy of Sciences of the United States of America*, vol. 12, no. 25, 23 June 2015, p. 7761–7766.

[21] VILLANI C. *Donner un sens à l'intelligence artificielle : pour une stratégie nationale et européenne,* Parliamentary mission entrusted by French Prime Minister E. Philippe to Mr C. Villani, mathematician and Deputy of Essonne, March 2018, Paris: La Documentation Française, p. 126-127.

[22] Two causes in particular are subject to evaluation by a group of experts from IPBES; the first group is working on guidelines for assessing the degradation and restoration of land, the second is working on the assessment of invasive exotic species. Their conclusions are due in 2019.

[23] STANTON R. L., MORRISSEY C. A. et CLARK R. G., "Analysis of trends and agricultural drivers of farmland bird declines in North America: A review", *Agriculture, Ecosystems and Environment*, 254 (2018), p. 244 to 254.

[24] Central Administration of French Southern and Antarctic Lands, "The overall strategy of preserving natural heritage in the French Southern and Antarctic lands". In ocean environments, it is usually the most resistant individual of an invasive species which survives the most difficult journeys. In France's Southern and Antarctic territories, invasive species such as cats, rabbits and dandelions increase the erosion of biodiversity and upset the balance in ecosystems.

[25] STEFFEN W., ROCKSTRÖM J., RICHARDSON K., LENTON T. M., FOLKE C., LIVERMAN D., SUMMERHAYES C. P., BARNOSKY A. D., CORNELL S. E., CRUCIFIX M., DONGES J. F., FETZER I., LADE S. J., SCHEFFER M., WINKELMANN M., AND SCHELLNHUBER H. J., "Trajectories of the Earth System in the Anthropocène", *Proceedings of the National Academy of Sciences of the United States of America*, 0027-8424, 1 August 2018.
Oxygen Minimum Zones (OMZs) are characterised by a low level of oxygen and are located in tropical regions, in the East Pacific and the north of the Indian Ocean. In the ocean, oxygen is contained in the coldest waters, not the warmest. Climate change modifies the penetration of oxygen in deep oceanic waters. Penetration is slowed down and the size of the area in which deep waters and surface waters meet is reduced. This leads to impoverishment of intermediary areas as the mixing areas are reduced in size, creating oxygen minimum zones. The warming of surface waters has the immediate consequence of preventing oxygen from reaching the deep waters of the ocean. Also, in the deep water, oxygen consumption by respiration of organisms and decomposition of organic matter is not compensated for by photosynthesis, which adds to the oxygen impoverishment of intermediate and deep waters. Photosynthesis is the ability plants have to consume the carbon dioxide in the air and assimilate the carbon compounds by letting off oxygen. However, photosynthesis requires energy from light, and can only take place in surface waters.

[26] O'NEIL B. C., DALTON M., FUCHS R., JIANG L., PACHAURI S., and ZIGOVA K., "Global demographic trends and future carbon emissions", *Proceedings of the National Academy of Sciences of the United States of America,* Vol 107, no. 41, 12 October 2010, p. 17521–17526.
BŒUF G. et LE BRAS H., « 10 milliards d'humains et alors ? », *Idées Le Monde*, 9 December 2017, p. 2-3.
GUILLOU M. et MATHERON G., *Neuf milliards d'hommes à nourrir. Un défi pour demain*, Paris: François BOURIN, 2011, 420 pages.

[27] KAHN, P.H. 2002. Children's affiliations with nature: structure, development, and the problem of environmental generational amnesia. In P. H. Kahn & S. R. Kellert (Eds.), Children and nature: psychological, sociocultural, and evolutionary investigations, pp. 93–116. MIT Press.

[28] The cognitive dissonance theory proposed by Léon Festinger in 1957 makes it possible to analyse relations between cognitions, “any knowledge, opinion, or belief about the environment, about oneself, or about one's behaviour”. These elements may hold three relations: dissonance, consonance or irrelevance, that is, neutral. The cognitive dissonance theory is based on the fact that each individual is striving for cognitive balance. Thus, for each receipt of a cognition, the individual tries to readjust their cognitive balance to reduce dissonance, most often by post-behavioural change in behaviour.

[29] PRÉVOT A.-C et FLEURY C., *L'exigence de la réconciliation : biodiversité et société*, Paris: Fayard: Muséum National d'Histoire Naturelle, 2012, 471 pages.
PRÉVOT A.-C et FLEURY C., *Le souci de la nature : apprendre, inventer, gouverner*, Paris: CNRS éditions, 2017, 377 pages.

[30] LATOUR B., *Où atterrir ? : Comment s'orienter en politique*, Paris : La Découverte, 2017, 155 pages.

List of scientific experts consulted

Mr Gilles BŒUF, biologist, former President of the French Natural History Museum and President of the Scientific Council of the French Agency for Biodiversity;

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Ms Pascale JOANNOT, oceanographer, head of conservation at the French Natural History Museum;

Mr Bruno LATOUR, philosopher, anthropologist and sociologist, associate emeritus professor at Médialab, Sciences-Po Paris;

Mr Cédric MARTEAU, Director of Environment and Director of the French Southern and Antarctic Lands Nature Reserve;

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