

The second warning to humanity—Why ethology matters?

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Abstract

In 2017, more than 15,000 scientists signed a second warning to humanity to halt human-made destruction of our planet. The authors of that study encouraged further contributions highlighting specific subjects. With this perspectives article, we follow their call and explore why and how behavioural studies can matter for a better stewardship of the planet. The second warning article suggested 13 effective steps humanity needs to take to transition to a sustainable life. Here, we first provide some examples of how concepts and tools of behavioural biology can aid understanding and solving real-world conservation problems relating to some of the effective sustainability steps suggested by Ripple et al., (Bioscience, 67, 2017, 1026). Then, we outline how ethological research can contribute to sustainability beyond its contributions to conserving species. Finally, we turn to the second warning and the behaviour of scientists themselves. Science has provided unequivocal evidence that we are destroying the very basis of the existence of millions of species including ourselves. To convince humanity about the urgent necessity to halt and change our behaviour, science organizations, funding bodies and scientists themselves need to become role models for sustainability.

KEYWORDS

animal behaviour, biodiversity, climate change, conservation, role model, second warning

1 | INTRODUCTION

More than 15,000 scientists co-signed the “World Scientists’ Warning to Humanity: A Second Notice” by Ripple and colleagues (2017). This “second warning to humanity” renewed a 25-year-old manifesto of concerned scientists to cut back environmental destruction because we are on a heavy collision course with our planet. Human overpopulation and overexploitation of natural resources are fuelling climate change, have led to dramatic deterioration and destruction of habitats, and a massive decline in biodiversity. The recently published biodiversity assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Díaz et al., 2019) fully confirms this and carries to the general public what some biologists have argued for long (see e.g.,

Rockström et al., 2009): the accelerating human-induced decline in biodiversity is one of, if not the most pressing problem of humankind. IPBES Chair Sir Robert Watson stated “Our destruction of biodiversity and ecosystem services has reached levels that threaten our well-being at least as much as human-induced climate change. The loss of species, ecosystems and genetic diversity is already a global and generational threat to human well-being.” (<https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/>). Indeed, climate change and biodiversity loss are intertwined and must be looked at together. Many ethologists are aware of this and have co-signed the “World Scientists’ Warning to Humanity: A Second Notice” (Ripple et al., 2017). Most of us became behavioural researchers because we enjoy nature, marvel at its diversity and exceptionality, and want to learn about and understand

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the behaviour of animals in their natural (and not so natural) environments. For this reason, ethologists should be among those particularly concerned about nature's decline and especially motivated contribute to changing this. More importantly, as we will argue, ethology harbours ample potential to aid understanding of, and sometimes finding solutions to, real-world conservation problems (e.g., Greggor et al., 2016). Caro and Sherman (2011) have stated that global change is threatening our field of research as such. Hence, "it is in the self interest of all behavioural ecologists to get more involved in preserving their study organisms and habitats" (Caro & Sherman, 2011). In the sense of understanding animal behaviour and using this knowledge to inform species conservation, ethology might be more important today than it has ever been in its history.

Human-induced global change threatens survival and reproduction of animals often by affecting and interfering with behaviour. Migratory animals, for example, rely on a whole chain of suitable habitats, resources and conditions that are adequately aligned in space and time to continue to thrive (e.g., Vickery et al., 2014). Migrants are thus particularly vulnerable if small but critical fractions of their annual habitats get destroyed, if resources become limited on critical stop-over sites (e.g., Mizrahi & Peters, 2009), or because climate change may result in phenological mismatches between consumers and food resources (e.g., Both et al., 2009; Visser & Gienapp, 2019). Endocrine disrupting chemicals are not only detrimental to human and animal health, but also change sex ratios, affect fitness-relevant behaviours, such as female mating preferences, and the fecundity of animals (Diamanti-Kandarakis et al., 2009; Gore, Holley, & Crews, 2018; Saaristo et al., 2018). Human-generated noise interferes with mating behaviour of birds and frogs, increases predation risk and disrupts communication and orientation of whales and dolphins (see summaries in Brumm, 2013). Light pollution interferes with orientation and migration of birds, bats, sea turtles and insects (Witherington, 1997). These are just a few examples from ethological research demonstrating how global change is threatening the well-being, performance and reproduction of animals, and that ethology has a role to play in recognizing, understanding and sometimes ameliorating or solving human-generated problems.

But how can ethology as a field contribute to nature and species conservation? And what else can we learn from behavioural studies to reduce the human impact on our planet? With this article, we follow a call of William Ripple and colleagues to write discipline-specific follow-up articles to the original scientists' warning paper (Ripple et al., 2017). In their original contribution that has been co-signed by so many scientists Ripple et al. have emphasized 13 key steps humanity needs to take to transition to sustainability, namely "(a) prioritizing the enactment of connected well-funded and well-managed reserves for a significant proportion of the world's terrestrial, marine, freshwater and aerial habitats; (b) maintaining nature's ecosystem services by halting the conversion of forests, grasslands and other native habitats; (c) restoring native plant communities at large scales, particularly forest landscapes; (d) rewilding regions with native species, especially apex predators, to restore ecological processes and dynamics; (e) developing and adopting adequate policy instruments to remedy defaunation, the poaching crisis, and the exploitation and trade of threatened species; (f) reducing food waste through education and better infrastructure; (g) promoting dietary shifts towards mostly plant-based foods; (h) further reducing fertility rates by ensuring that women and men have access to education and voluntary family-planning services, especially where such resources are still lacking; (i) increasing outdoor nature education for children, as well as the overall engagement of society in the appreciation of nature; (j) divesting of monetary investments and purchases to encourage positive environmental change; (k) devising and promoting new green technologies and massively adopting renewable energy sources while phasing out subsidies to energy production through fossil fuels; (l) revising our economy to reduce wealth inequality and ensure that prices, taxation and incentive systems take into account the real costs which consumption patterns impose on our environment; and (m) estimating a scientifically defensible, sustainable human population size for the long term while rallying nations and leaders to support that vital goal" (Ripple et al., 2017). In our view, ethology can contribute to a substantial portion of these key steps (see Figure 1) and we will explain why and how below. We first argue why ethology is relevant for species conservation (section 2) and

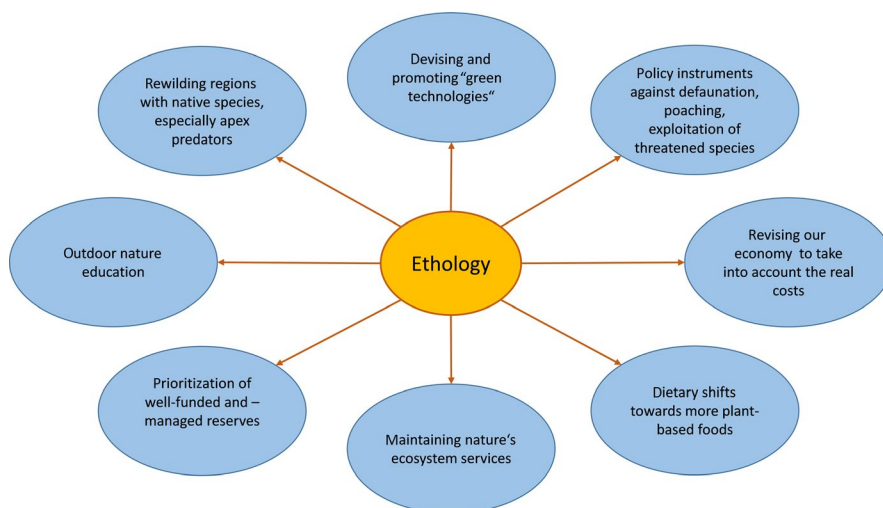


FIGURE 1 . Eight of the 13 key steps to sustainability identified by Ripple et al. (2017) to which ethology can contribute

then emphasize potential impacts of ethology beyond conservation (section 3). Finally, we turn to the behaviour of scientists themselves: ethology is the science of studying behaviour; but ethologists and—in fact all scientists—should reflect their own behaviour and ask how we as scientists need to change if we want to convince people that our current way of living is not sustainable (section 4).

2 | WHAT CAN STUDIES ON ANIMAL BEHAVIOUR CONTRIBUTE TO CONSERVATION?

Behaviour is the most immediate and crucial level at which an individual animal interacts with its environment. Hence, behaviour should evolve to maximize fitness (Krebs & Davies, 1997). Moreover, the environment of an individual is largely determined by its behaviour, for example as a result of dispersal, migration and habitat selection (Wolf & Weissing, 2012). Thus, behaviour is a central mediator of individual fitness, which ultimately affects population dynamics. The behavioural basis of population growth is not only important to understand population and community dynamics, but also to predict changes in face of environmental change (Sutherland, 1996). Curio (1996) was among the first to argue that behavioural studies should play a more prominent role in conservation planning and sparked a discussion among scientists as to what the role of behavioural studies could be (e.g., Clemmons & Buchholz, 1997; Buchholz, 2007; Caro, 2007; Berger-Tal et al., 2015; Caro, 2016; Greggor et al., 2016; Berger-Tal & Saltz, 2017; see also a recent theme issue edited by Bro-Jørgensen, Franks Daniel, & Meise, 2019).

From there, the emerging field of conservation behaviour has developed further. Behavioural studies aiming at conservation problems assess anthropogenic impacts on behaviour and biodiversity, inform and support the management of endangered (or invasive) species, and use behaviour for monitoring and as an indicator of conservation threats (for a conceptual framework see Berger-Tal et al., 2011). As behavioural ecologists, we think that a detailed understanding of animal behaviour and its consequences on the population level can contribute to conservation and to improving our planet's condition. At the same time, conservation problems can inspire and motivate, and sometimes even give additional meaning to research in animal behaviour.

Behavioural studies can assist landscape-level actions for the protection or recovery of suitable habitats. A more detailed understanding of a species' behaviour and ecology may be necessary to promote survival, reproduction and recovery of populations. Concepts and tools from animal behaviour research can contribute to a better understanding of demography, predict population responses to anthropogenic change and exploitation and help to find solutions to specific conservation problems. Tim Caro and Paul Sherman provide 18 excellent reasons why behavioural biologists should not hesitate and instead get involved in conservation studies (Caro & Sherman, 2013) and the Animal Behavior Society (ABS) published guidelines regarding what behavioural biologists can do

to promote conservation (see <https://www.animalbehaviorsociety.org/web-final-download/Committees/ABSConservation/thirteen.html/>). It would be idle to repeat the messages of these publications: just go ahead and read these important contributions! To stimulate further thought, we here provide some examples relating behavioural studies to Ripple et al.'s (2017) thirteen steps to sustainability.

How can ethology contribute to “the enactment of connected and well-funded and well-managed reserves” (Ripple et al., 2017; Figure 1)? Habitat loss, deterioration and fragmentation are primary threats to global biodiversity. To understand and mitigate their complex effects, behavioural research can be crucial. Functional landscape connectivity relies on animal movement behaviour, and the effects of habitat change (such as fragmentation or pollution) or human disturbance on wildlife can be estimated through behavioural responses (Greggor et al., 2016). Naturally, animal movement data are essential for managers to protect the appropriate habitats and corridors at the right time, and recent advances in tracking technology may also help to find novel solutions to human–wildlife conflicts: Real-time tracking of African elephants in Kenya, for example, triggers an alarm when the animals approach a highway, allowing managers to react immediately (Wall et al., 2014). Moreover, animal movement data can aid to discover unexpected or hidden ecological traps. A recent example comes from grizzly bears in Banff National Park, which are frequently killed when trying to cross or moving along railroad tracks. By monitoring individual movement, Murray et al. (2017) identified hotspots and potential causes of increased railroad use by bears. Interestingly, the suggested solution also had much more to do with animal behaviour than with the construction of fences: the installation of warning devices (just like those for humans) signalling approaching trains, might effectively increase perception and relevant learning, and consequently behavioural adaptation of the animals (Backs, Nychka, & Clair, 2017). Similarly, ultrasound could be used to warn bats when they approach wind parks (Nicholls & Racey, 2009).

A further key transition step identified by Ripple et al. (2017), to which animal behaviour research can contribute, is to develop and adopt “adequate policy instruments to remedy defaunation, the poaching crisis and the exploitation and trade of threatened species” (Figure 1). How does animal behaviour research relate to this? For example, different degrees of sexual selection result in different mating systems such as monogamy, polygyny and polyandry which can have a profound impacts on population viability: extreme polyandry or polygyny reduce the effective population size, because only a fraction of the total population contributes to the gene pool. As a consequence genetic variance may decline, drift may become more important, and the risk of extinction may increase (Holman & Kokko, 2013; Parker & Waite, 1997; Saether et al., 2004). Another aspect of sexual selection is fierce competition for mating opportunities. This can result in infanticide, which typically happens when a new male takes over a female group and kills the offspring sired by previous males. Infanticide is common in lions, brown bears and many primates (Hrdy, 1999). Trophy hunting of males in such species can have severe implications for the population development and

needs to be taken into account in conservation practice (Swenson et al., 1997; Whitman et al., 2004). In conclusion, sexual conflict often affects population-level processes and has implications for conservation (Holman & Kokko, 2013; Rankin & Kokko, 2007).

A second example relevant for developing and adopting “adequate policy instruments” (Ripple et al., 2017) is to understand how individuals are connected within social networks and population structures. Animals that live in social groups may need a critical group size to be successful. African wild dogs, for instance, have been hunted and persecuted by humans for centuries and still suffer a strong population decline despite recent efforts to protect the remaining populations. The behaviour of wild dogs has been an important element to understand their ongoing decline: foraging, successful breeding and survival strongly depend on a critical group size, since packs of less than five adults rarely reproduce. Hence, for the persistence of packs and populations, it is important to alleviate the major causes of individual mortality due to persecution and human activities (Courchamp & Macdonald, 2001).

In highly social and hierarchical organized killer whales, social position can limit access to food and affect mortality risk in males (Ellis et al., 2017). In these groups, some matrilineal appear to play a more central role than others, and apparently, network cohesion is largely maintained by female juveniles. Based on social network analysis of a wild population, Williams and Lusseau (2006) simulated removal of different individuals and found that the network was robust to random removal of individuals but highly vulnerable to targeted removal of matrilineal animals. A long-term data set analysed by Busson et al. (2019) confirmed the importance of forming social groups with close relatives in killer whales: a period of enhanced mortality due to interactions with illegal fishing vessels weakened social associations and affected the fitness of and survival of killer whales even for years after the mortality event. Many other social and cooperative species are equally susceptible to group-level processes, and behavioural studies can help to assess population status, identify threats and potential ways of mitigating human impact. However, to really translate research into “adequate policy instruments,” we must make studies visible for and relevant to the public and policymakers, particularly on a local scale.

In many cases, success or failure of conservation programs will critically depend on the acceptance and participation of local stakeholders. Behavioural biologists can contribute by working on local conservation problems, involving and informing the public, and by scientifically accompanying measures to solve human–wildlife conflicts. By doing so, ethologists can also contribute to the key step “increasing outdoor nature education ..., as well as in the overall engagement of society in the appreciation of nature” (Ripple et al., 2017; Figure 1).

“Rewilding regions with native species, especially apex predators” (Ripple et al., 2017) is another key step to sustainability to which behavioural research can contribute (Figure 1). Large apex consumers such as wolves, elephants, sea otters, beavers or wild-beest function as top-down ecosystem engineers. The removal of such apex consumers represents one of the most pervasive influence

of humans on ecosystems (Estes et al., 2011). Reintroducing apex consumers typically leads to an increase in biodiversity and ecosystem function (Estes et al., 2011; Jones, Lawton, & Shachak, 1994; Ripple & Beschta, 2012; Willby et al., 2018) and thus can have a profound impact on nature and species conservation. Many European countries have shown that coexistence between large apex consumers and humans is possible, but needs to come along with cautious management of social conflict to be successful (Chapron et al., 2014; Chapron & López-Bao, 2016). For example, several studies have shown that non-lethal control of apex predators is more effective in reducing conflict between farmers and wildlife than killing predators (e.g., Bergstrom, 2017; Stone et al., 2017; Treves et al., 2016). Lethal predator control is problematic from an ethical (Vucetich & Nelson 2007) and—when applied to native predators—from a conservation point of view. Removing top predators also often has unintended ecological impacts, such as mesopredator release and herbivore irruption (e.g., Colman, Gordon, Crowther, & Letnic, 2014), and often fails to prevent, shifts or even increases human–wildlife conflicts. In contrast, non-lethal measures, such as guardian animals, fences or night shelters, were more effective and left ecological communities and social structures (e.g., of carnivore groups) intact (reviewed by Treves et al., 2016). Predator control measures need to be rigorously evaluated regarding their effectiveness in preventing further conflicts, their ecological impact, their ethical justifiability and their acceptance in the public and the participation of stakeholders (Treves et al., 2016)—all aspects where conservation meets behavioural research.

Conservation translocations of predators and other animals have been important for conservation management, often with varying success (reviewed by Bell, 2016). Considering behaviour can make the difference for breeding success in captivity (e.g., mate-choice in giant pandas, Martin-Wintle et al., 2015) and for post-release survival and reproduction of translocated individuals. Behavioural training in captivity endows animals with improved antipredator responses (e.g., West et al., 2017), and evaluating their behavioural competence can guide training and selection of animals to be released (Swaigood et al., 2018). Monitoring the movement behaviours of animals in the post-release environment can be used to assess and improve reintroduction success (conceptually described by Berger-Tal & Saltz, 2014 and Bell, 2016, but see also Wittemyer et al., 2019 for integrating landscape, movement ecology and animal behaviour). Several studies have highlighted the particular importance of familiar social structures for translocation success (e.g., Shier, 2006, Clarke, Boulton, & Clarke, 2002), even in highly territorial “solitary” species: after many attempts to translocate endangered Stephen’s kangaroo rats (*Dipodomys stephensi*) to a restored site failed, Shier and Swaisgood (2012) tested whether translocation success could be enhanced by maintaining neighbour relationships at the new site—with overwhelming success: Kangaroo rats that were translocated with their neighbours established territories quicker, spent less time fighting and more time foraging than those translocated without their neighbours. Consequently, survival probability and reproductive success were much higher in the “intact neighbourhood.”

Generally, apex consumers and large animals are in the focus of conservation management, but we know way too little regarding more subtle ecosystem engineers such as earthworms, ants or termites that can have a profound influence on biodiversity and nutrient recycling (Jones et al., 1994). More basic behavioural and ecological research on such animal groups is required to learn how such animals and their engineering activities help to maintain and restore biodiversity (for a recent example see Ashton et al., 2019).

3 | BEYOND CONSERVATION: WHAT ELSE CAN ETHOLOGY CONTRIBUTE FOR SUSTAINABILITY?

Beyond conservation, is there more that curiosity-driven (“blue sky”) behavioural research can contribute to making our lives more sustainable? Ripple et al.’s (2017) suggestions for key transitions include the promotion of “dietary shifts towards mostly plant-based foods” (Figure 1). How does ethology relate to this?

State-of-the-art animal behaviour research suggests that vertebrates (and some invertebrates) express affective emotional states (e.g., Panksepp, 2011; Paul, Harding, & Mendl, 2005) and that many animals have sophisticated cognitive skills; some animals even may have a concept of “self” (for a very accessible treatment of emotions and cognition in animals see Safina, 2015). In many countries, these findings have been implemented in legislation on the use of animals in research, resulting in very strict and effective regulations about the proper treatment of animals for research purposes (e.g., ASAB, 2019). But how come that knowing about emotional states and cognitive capacities of animals still does not spark a virulent discussion on the integration of public moral values with objective analyses of animal welfare not only for animals in research, but also for raising, keeping, transporting and slaughtering farm animals? For example, in Germany, each year ca. 3.7 million cows, ca. 59 million pigs and ca. 700 million chickens are slaughtered for food production (<https://www.bmel.de>). Typically, welfare conditions of these farm animals have a much lower standard than those of the 2.8 million animals (mainly mice, rats and zebrafish) used in animal experiments. Scientific knowledge of animal behaviour is essential to define welfare from an animal’s perspective (e.g., Barnard, 2007; Barnard & Hurst, 1996; Ohl & van der Staay, 2012), and we have no doubt that there is large consensus among behavioural biologists that a drastic change and reduction in the “factory farming” of livestock animals is urgently required (Dawkins & Bonnerly, 2008). Ethical guidelines (based on sound animal behaviour research) for proper care of livestock animals can provide scientific evidence for a change in legislation. This will likely lead to a reduction in animal numbers since they need adequate space and the possibility to behave in a species-typical manner. Further, transport of live animals should be minimal or avoided completely, and slaughtering them should be done in a way to minimize stress (e.g., Idel, 2016). As a consequence, “production costs” will increase and animal products such as meat,

eggs and milk will become more expensive. Meat will return to be what it used to be until not so long ago: a Sunday treat instead of a daily meal.

A small-scale dairy farmer recently told us he would be completely happy with mowing all of his grasslands only twice instead of four or five times a year if that would enable him to make a living with just half of the number of dairy cows he currently keeps. This example shows that an adequate price for dairy products and meat would (a) reduce the discharge of nitrogen into the soil because farmers would be enabled to keep only the number of cows that is supported by local resources (i.e., a closed-loop economy). Such a reduction in cattle would further (b) reduce greenhouse gas emissions, (c) help to increase plant and insect biodiversity because artificial fertilizers may no longer be needed and (d) properly managed grasslands may effectively sequester carbon dioxide (e.g., Dass, Houlton, Wang, & Warlind, 2018). Finally (e), extensive grassland use would support meadow-breeding birds such as corn crakes, larks, whinchats or pipits, which could raise their broods without their nests and incubating females being killed by the blade of mowing tractors (e.g., Grüebler et al., 2008). Hence, if we take the results of animal behaviour research on affective emotional states and cognitive capacities of animals serious, then legislation and the way we raise, keep and kill farm animal’s needs to change. As a consequence of these ethical requirements, we would automatically arrive at a more sustainable “use” of farm animals, thus reducing the ecological footprint of animal husbandry, while at the same time improving habitat quality for wild plants and animals and thus contributing to Ripple et al.’s (2017) key step of “maintaining nature’s ecosystem services” (Figure 1).

Ethology can also contribute to the key step of “devising and promoting new green technologies” (Ripple et al., 2017; Figure 1). As behavioural ecologists, we wonder about the unreflecting use of pesticides in current industrial agriculture contributing to defaunation (not only because they affect and kill numerous non-target species): in the face of strong directional selection imposed by pesticides, it is evident that quick development of pesticide resistance is inevitable. Evolutionary knowledge and a background in animal behaviour and ecology can help to reduce or replace chemical pesticides in agriculture in many ways. For example, biological “pest” control uses predators, parasites, pathogens or herbivores to minimize the damage of “pest” species to agriculture (van Lenteren et al., 2018). Also, human and animal disease vectors, such as mosquitos that carry malaria, dengue or zika, can be biologically controlled using an endosymbiotic bacterium (*Wolbachia pipientis*), which manipulates host reproduction and in addition prevents pathogen reproduction within the host (Flores & O’Neill, 2018). Using such endosymbionts may be more effective and has fewer side effects than chemical vector control. However, the *Wolbachia* treatment still has to stand up to long-term examination, because it may generate strong selection pressure on the mosquitos, resulting in an arms race between host and parasite.

The behaviour of animals can also be used as a bioindicator of water and soil quality. For example, *Gammarus pulex* and other

freshwater copepods have been successfully implemented in the monitoring of water and soil quality. When exposed to a mixture of trace metals or organic pesticides, the copepods change their behaviour, which is detected by an automated system to discover and monitor irregularities in the chemical composition of water and soil (e.g., Gerhardt, 1996; Gerhardt et al., 2007; Kunz, Kienle, & Gerhardt, 2010).

A so far little considered potential of ethology to contribute to Ripple et al.'s (2017) key steps could lie in "revising our economy to reduce wealth inequality and ensure that prices, taxation and incentive systems take into account the real costs" (Figure 1). Theories of decision-making in economics are remarkably similar to evolutionary theories of adaptation by natural selection. In fact, Darwin's theory of adaptation by natural selection was most likely inspired by Adam Smith's *laissez-faire* economy (about whom he read a lot, see Gould, 1980). Many fields of evolutionary ecology such as optimal foraging, evolutionary game theory or biological markets rely on concepts derived from economic theory (and economists adopted evolutionary game theory to explain human behaviour). By now, evolutionary ecologists and economists are engaged in interdisciplinary research and cross-inspiration (Hammerstein & Hagen, 2005). Studies in animal behaviour can help to inform economic theory of decision-making (Kalenscher & Van Wingerden, 2011), because "a theory that works well across species has a greater likelihood of being valid" (Kagel, Battalio, & Green, 1995, p. 4). For instance, cleaner fish at coral reefs and their customers represent a good example for biological markets and several other concepts from evolutionary ecology that are relevant for economics, such as deception and manipulation, cooperation and punishment (e.g., Bshary & Noë, 2003; Triki et al., 2018). Studies on collective animal behaviour (e.g., Couzin, 2018; Couzin et al., 2011; Rosenthal et al., 2015) reveal principles that are remarkably similar to human behaviour: hence, the same mathematical models that describe collective patterns in animals can be applied for collective behaviour of humans (Sumpter, 2006). In contrast to humans, animal models can be studied with experimental approaches and the results can be used to model, understand and predict the dynamics of human markets, movements and societies. By default, natural selection in the long run only works when taking into account the real costs of natural markets. Hence, insights from evolutionary theory can guide the development of more sustainable human market systems. In this sense, animal behaviour studies can be of very practical value in economy. For example, evolution has shaped biological transport systems for millions of years, and natural selection has solved network optimization problems that are very similar to those faced by modern human networks of transportation and logistics. Hence, transportation logistics can become more efficient using algorithms derived from animal societies with similar problems, such as ants (Cabanes, Wilgenburg, Beekman, & Latty, 2015). This is just an example how curiosity-driven research on animal behaviour can impact our daily life and help to mitigate our impact on our planet, or as Wedell and Hosken (2017) put it: we should make use of the 3 billion years of research and development by evolution!

4 | THE SECOND WARNING, SCIENCE AND THE BEHAVIOUR OF SCIENTISTS THEMSELVES

When the world's scientists warn humanity, they should also critically reflect their own role and behaviour. How convincing can we as scientists be in persuading humanity that "a great change in our stewardship of the Earth and the life on it is required if vast human misery is to be avoided" (Ripple et al., 2017)? It is not sufficient to just utter another warning. To convince humankind, scientists need to become role models in reducing their own "ecological backpack", that is the total quantity of materials moved from nature to create a scientific product or service (Lettenmeier, Rohn, Liedtke, & Schmidt-Bleek, 2009; Schmidt-Bleek, 1993), to demonstrate that we mean what we say on at least two further levels, as scientific institutions and as individual researchers. That is, we need to change our own behaviour. With the "Scientists for Future" movement such a move may slowly gain momentum.

On an institutional level, we need to ask ourselves what does our university or research institution do to reduce the ecological backpack of research? To sustain life on earth, people of the wealthier countries need to reduce their impact by Factor 10 (Schmidt-Bleek, 1993; Schmidt-Bleek, 2008). Science institutions should be at the forefront of this necessary move and reduce the ecological backpacks of science facility construction, maintenance and running. For example, this may mean using existing rather than building new infrastructure. If new infrastructure is required, it should be built with lasting materials that have a small ecological backpack or a low material input per service (MIPS; Schmidt-Bleek, 1993). This rather technical term basically refers to how much natural resource input (abiotic and biotic resources, including water and energy) is required for any kind of "service" and aids us in giving preference to materials that require fewer resource input, such as wood in comparison with concrete. Science facilities should run on renewable energy sources or even generate energy themselves, and equipment should be bought from companies with a sustainable and resource-efficient production chain (i.e., a cradle-to-cradle approach). Guidelines on how to improve resource productivity can be applied also to scientific services and research projects (Lettenmeier et al., 2009). For example, scientific services and research proposals could be evaluated in a similar manner as animal experiments. Guidelines for animal experimentation focus on the 3 R's, that is, animal experiments should be REPLACED with other methods when possible, the number of animals in experiments should be REDUCED, and animal experiments should be REFINED, so that the potential for animal suffering is minimized. Science organizations and funding bodies could adopt a very similar approach to evaluate the impact of research on our planet: (a) resources with a high material input per scientific service should be REPLACED with resources (including energy) that have a lower material input per service; (b) material input per scientific service should be REDUCED; and (c) research projects should be REFINED to minimize material input per scientific service.

By law, most research institutes and universities have representatives that are responsible for work, health, and bio-safety, radio-safety, data security, etc.; our institute even has a representative for ladder safety! In our view, every research facility should have a working group for resource efficiency, with the aim to increase resource efficiency of each institution by factor 10 until 2025. Very simple examples for reducing the impact of science include the use of recycled paper in offices, lowering the air-flow in laboratories during the night, using electricity from renewable energy sources, using small, light-weight and fuel-efficient institutional vehicles that can easily be repaired and thus used for a long time, or promoting organic and low-meat diets in canteens. Reducing air travel and carbon offsetting of unavoidable air travel should become standard for any scientific institution and grant agencies.

Albeit slowly, initiatives to reduce the footprint of science and education gain momentum. For example, some German University canteens promote regional, vegan and vegetarian food to reduce the consumption of meat. The rectorate of the University of Neuchâtel in Switzerland has decided to make sure each flight pays for carbon offsetting (R. Bshary, pers. comm.), and “Scientists for Future” and sustainability groups are forming at several universities and research institutions across the globe.

We are aware that the ecological backpack of science is minimal compared to, for instance, global industry, transport and agriculture. But scientists warn the rest of the world about our path to destroy earth and our own future. Hence, we should act as societal and political role models and start with science itself. It is quite disturbing that the majority of scientific institutions led by scientists who should be well aware of our ecological impact and climate change—still care little about lowering science's own impact! Even major international research institutions with a focus on the ecology, evolution and behaviour of wild animals or plants rarely do so.

But also as individual researchers, we have to ask ourselves what we can do to reduce the ecological backpack of our science. For example, why do most of us still use airplanes to go to conferences on the same continent, when using a train would take only little more time and would be more efficient (a substantial part of this manuscript was written while riding on a train)? Do we really need to attend an overseas conference every year? How often do we really need a new and fancy laptop computer and the tablet on top of it? The average laptop has an ecological backpack of approximately 440 kg of abiotic resources and an additional 1,000 L of water. We better use it for a long time!

Science is an international and in many respects a resource-intensive endeavour. But this means that we need to be especially sensitive about our own impact as science organizations and scientists and reduce it as much as possible. Only then are we in a good position to convince the rest of humanity about reducing their impact. If we lead the way we are in a much better position to convince politicians, industry, agriculture and the public to do their share. As biologists and ethologists, we should care about nature, and as a consequence, we should act as role models; if it is not us, who else is going to do it? Factor 10 (Schmidt-Bleek, 1993, 2008) does not only apply to politics, industry, agriculture and our private lives. Factor 10 should also guide our efforts to reduce our impact as scientists, and

teachers of the next generation of students (who are now marching on the street for their right to have a future!), and as research institutions and funding organizations. What we want for our children and grandchildren is to go out and to experience nature's beauty and be fascinated by animal behaviour. Still, this variety of the future is possible, but the time to act is now, we will not get another opportunity.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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