A horizon scan of emerging global biological conservation issues for 2020

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Abstract

In this horizon scan we highlight 15 emerging issues of potential relevance to global conservation in 2020. Seven relate to potentially extensive changes in vegetation or ecological systems. These changes are either relatively new, for example conversion of kelp forests to simpler macroalgal systems, or may occur in the future, for example as a result of the derivation of nanocelluose from wood or the rapid expansion of small hydropower schemes. Other topics highlight potential changes in national legislation that may have global effect on international agreements. Our panel of 23 scientists and practitioners selected these using a modified version of the Delphi technique from a long-list of 89 potential topics.

Introduction

This eleventh annual horizon scan identified novel issues that may have substantive positive or negative effects on global biological conservation. We do not aim to predict outcomes but to highlight issues to which societies may wish or need to respond in the future on the basis of improved knowledge. Here we present the 15 topics identified by our panel, which comprised 23 scientists, conservation practitioners, and experts in foresight research and horizon scanning. These topics, about which we believe relatively little is known amongst those working in conservation, are diverse. They include effects on wildlife of a range-expanding, invasive tick species; implications of new legislation to promote sourcing of energy from wood; and the application of a genetically modified fungus to kill malaria-carrying mosquitoes. Many of the issues we identified in previous scans have been realized or become much better understood ([1]).

Identification of Issues

Our annual horizon scanning methods have been consistent (Figure 1). We apply a modified version of the Delphi technique, which facilitates a process that is repeatable, inclusive and transparent ([2], [3]). This year's 23 core participants had diverse subject-matter expertise, including but not limited to agriculture and land use, microbiology, conservation practice and technology, sustainability, environmental management, policy, economics, research programming, science communication and professional horizon scanning.

[FIGURE 1 HERE]

Figure 1: Our process for identifying and evaluating issues during the 2020 scan.

Members of our team used different methods to identify and select issues, including but not limited to consulting with colleagues in person or by email, soliciting issues via Twitter and other forms of social media or through established networks, and tracking via curation tools such as pearltrees (www.pearltrees.com). We engaged approximately 830 people. If face-to-face meetings were held, then we counted all participants. If messages were sent by email or social media, we counted only those who responded. In addition, we noted issues that we encountered throughout the year in the popular and social media, scientific journals, seminars and other professional presentations, and even casual conversations in which we engaged or that we overheard.

We assessed each issue's suitability for inclusion on the basis of criteria established during the first horizon scan ([4]): issues must be novel or represent novelty through a step-change in impact, have potentially substantive positive or negative impacts on conservation of biological diversity at a global or regional level, and seem likely to have greater impact in the future.

For this scan we compiled a long-list of 89 issues and grouped them on the basis of theme. Where two closely related issues were submitted by different participants, we combined the issues and assessed them as one. Participants independently and confidentially scored each issue from 0 – 1000 (low – high) on the basis of its potential effects on biological conservation, and noted if they previously were aware of the issue. Participants often added notes or queries to their scoresheet, e.g., suggesting issues that could be combined or topics that were well-known. These notes and queries informed discussion at the expert meeting (see below). Fatigue can result in attention waning throughout a process of scoring issues (e.g. [5]). To counter this potential bias, the long-list was ordered in three different ways, and participants randomly assigned to each list. Each participant's scores were converted to ranks (1 – 89). The most highly ranked 38 issues (due to a four-way tie for 35th place) were retained for further discussion and a second round of assessment (described below).

Two weeks before the expert meeting, each topic was assigned to two participants for further investigation to ensure detailed preparation. The person who submitted a given topic was not assigned that topic. Therefore, investigators were unlikely to be experts on the topic, but could collate relevant information to allow assessment of its potential impacts. Investigators focused on the issues' novelty, likelihood of occurrence, magnitudes of impact and relevance to biological conservation.

At an expert meeting in Cambridge (UK) in September 2019, we discussed each issue in relation to the above criteria. During discussions, we clarified technical details and levels of awareness, and presented further sources of evidence. After the discussion of each issue, all participants re-scored that issue as in the first round. These scores again were converted to ranks, from which we calculated a median rank. We present the 15 issues with highest median ranks below. The issues are in thematic rather than rank order.

The 2020 Issues

Land-use change in response to derivation of nanocelluose from wood

Innovations in materials science, particularly in nanocomposites, are beginning to create novel opportunities for manufacturing that may increase demand for wood. Cellulose is a strong, stiff polymer produced by plants (particularly trees), animals and bacteria. When cut into nanocellulose, its key properties change ([6]), making it suitable as a feedstock for industrial processes. Nanocellulose is used to produce a wide range of products including construction materials, packaging for clothing, and consumer products such as transparent wood-based packaging. The global nanocellulose market is growing by 18% per annum and is estimated to reach US$660 million by 2023 ([7]), thus increasing demand for wood. In response, tree planting may increase, temporarily boosting carbon stocks and reducing reliance on fossil fuels. Nanocellulose products could replace plastics, so the volume of plastic waste also may decrease. However, unregulated demand for wood for the nanocellulose market could accelerate global forest loss. Biological diversity also will be lost if monoculture tree plantations replace natural ecosystems, or if stands of mature trees are clear harvested.

Policy incentives for derivation of energy from wood

Demand for wood may increase substantially in response to the combination of the European Union (EU) Renewable Energy Directive of 2018, which treats wood, even from biologically diverse forests, as a renewable energy source, and the EU pledge to double Europe's 2015 renewable energy levels by 2030 to meet commitments in the 2015 Paris Agreement. As a result, EU demand may no longer be satisfied by current practices of deriving wood from forests in the United States and Canada and promoting the intensification of European forestry ([8]). Such commercialisation of forest biomass may accelerate the loss of primary forest and exacerbate climate change. The latter changes could be amplified if similar policies are adopted by other countries following the lead of the EU. A lawsuit is now challenging the EU's inclusion of forest biomass as a source of renewable energy.

Manipulating floral species composition to improve bee health

Variation in the nutritional content of nectar and pollen among plant species influences how bee species forage, but little is known about differences in nutritional requirements among species or populations of bees. Land uses that reduce the species richness and abundance of flowering plants are likely to interact with other factors, such as pathogens, to drive bee declines. Two recent studies conducted in the United States suggested that pollen from sunflowers *Helianthus* spp. and closely related Asteraceae species reduces the prevalence of parasite infection in bees. Laboratory studies indicated a reduction in the load of the gut parasite *Crithidia bombi* in bumblebees *Bombus pensylvanicus*, and a field survey indicated lower levels of infection in areas with high cover of planted sunflowers, even though sunflower pollen has relatively low nutritional value compared to other pollens ([9], [10]). *C. bombi* also reduces reproductive success in colonies of the European bumblebee *Bombus terrestris* ([11]). This new knowledge could be used to alter crop choices or planting regimes for bees before impacts on wild bee populations are fully understood. The latter actions may disrupt host-parasite dynamics in wild bees ([12]), and could also potentially reduce nutritional availability relative to native wildflowers.

Asian long-horned tick reaches the Americas

The non-native Asian long-horned tick *Haemaphysalis longicornis* is well established in Australia and New Zealand, where it is associated with economically important cattle pathogens, including *Theileria orientalis*. First detected in the United States in 2017, the tick has spread to nine states. Coincident infection of three unrelated cattle herds in Virginia, USA by the virulent, pathogenic Ikeda genotype of *T. orientalis* led to seven cattle deaths ([13]). The tick has a wide climatic tolerance, with potential to colonise the eastern and western seaboards of the United States and Canada south into Central America ([14]) and to extend across South America. Invasion by both a novel tick and associated pathogens would represent a major emerging disease for the Americas. If the potential effects on animal health and livestock farming are of sufficient magnitude to affect regional and national economies by reducing milk or meat production, land use may change across extensive areas ([13]). *H. longicornis* also has been associated with mortality of cattle in New Zealand and is carried by diverse host mammals and birds ([15]). Its introduction to the Americas with at least one associated pathogen therefore also may have population-level effects on native wildlife.

Global declines of kelp forest

Kelps are an order of brown algae (Laminariales) with high primary productivity that occur on around 25% of the world's coastlines and function as complex habitats for many other species. Declines in kelp abundance have been reported widely, albeit with substantial regional variability ([16]). Kelps long have been considered resilient to environmental stress. However, this resilience may be waning in response to diversification of potential drivers of decline, which include increases in sea temperatures caused by anthropogenic climate change, non-native invasive species, eutrophication, and harvesting ([17]; [18], [16]). The declines may result in fundamental shifts from complex kelp forests to simpler macroalgal turf systems ([18]). Future kelp forest declines in response to accelerating climate change would have significant consequences for biological diversity and ecosystem processes ([17]). The ecological benefits to humans that are supported by kelp forests, including commercial fisheries and shoreline protection, are valued at billions of dollars annually ([17]).

Atmospheric circulation and the shrinking Antarctic ozone hole may affect extent of polar ice

Rising sea levels, in large part caused by melting of the polar ice caps and thermal expansion of water, affect human societies, land uses, and coastal ecosystems worldwide. Understanding of how the extent of Antarctic coastal and sea ice responds to interactions with stratospheric ozone, atmospheric circulation, and storms and waves is evolving rapidly (e.g., [19]). Reduced chlorofluorocarbon emissions since the Montreal Protocol of 1987 have led to less ozone depletion during polar winters and, as a result, a reduction in the size of the ozone holes. However, in the Antarctic, the shrinking of the ozone hole may weaken the north–

south movement of the westerly wind belt that circles the continent ([20]), the Southern Annular Mode (SAM), counteracting the general strengthening of the SAM as concentrations of greenhouse gases increase. Variation in the movement of the (SAM) alters Antarctic temperature and storm patterns ([21]). For example, when the SAM is at its southernmost position, westerly winds strengthen over Antarctica and sea-surface and air temperatures decrease. Decreases in the size of the ozone hole are among the factors implicated in changes in wind and other weather patterns that likely will contribute to decreases in the extent of Antarctic ice and increases in global sea levels.

Effects of small hydropower systems on riverine ecosystems

The cumulative environmental effects of more than 80,000 small hydropower dams built on small upland streams have received much less attention than those of large dams. There are now over 11 small dams for every large dam ([22]), and efforts are underway in the Himalayas, other mountain ranges in Asia, and the Andes ([23]) to increase their use to empower local communities. Such small run-of-river schemes are associated with a much smaller footprint of land-cover conversion than large storage schemes. However, guidance to decrease negative impacts on biological diversity often is not provided. Moreover, impact assessments rarely are required for small individual dams, although they could be associated with considerable cumulative impacts on particular watersheds and species. For example, although few studies of their local and downstream ecological effects have been conducted, small dams can be associated with altered hydrological and sediment flow regimes. These alterations may cause sediment scarcity downstream, limit the dispersal of organisms and serve as barriers to migratory fishes, and reduce oxygen concentrations and increase water temperatures, decreasing habitat quality for some endemic fish species ([24]).

Large Recirculating Aquaculture Systems

Intensive aquaculture is associated with high levels of water use, local environmental pollution ([25]) and loss of coastal ecosystems. Recirculating aquaculture systems (RAS) circulate water around tanks that hold cultured species, treat the water to maintain high quality, and reduce water flow through the system. Such enclosed systems usually have fewer direct environmental effects than traditional aquaculture. Small RAS have been successful, notably in freshwater ecosystems ([26]), but there is a growing trend in the development of large saltwater systems (e.g., for salmon production) capable of producing tens of thousands of tonnes of fish annually (e.g. [27]). Intensive RAS have 1-3% of the water demand of throughflow aquaculture ([26]). Recent technological advances linked RAS to aquaponics systems that utilise the high-nutrient effluents. However, implementation of RAS is constrained by the need for high capital investment, with payback periods of around 8 years or more. Establishment of extensive RAS could increase the sustainability of food production from aquaculture and may reduce the risks from pollution and parasite release often associated with throughflow aquaculture. Other challenges, such as impacts from the sources of aquaculture feed, and energy requirements have not yet been addressed.

Genetically modified fungus kills malaria-carrying mosquitoes

The evolution of insecticide resistance by mosquito species that serve as malaria vectors means that development of novel approaches to limit the spread of malaria-carrying mosquitos is becoming necessary to reduce prevalence of the disease

([28]). Entomopathogenic fungi are promising in this regard, but their use is limited by the time lag in host mortality and the high dose required for infection. The fungus *Metarhizium pingshaense,* which naturally infects a mosquito species capable of carrying malaria, recently was genetically modified to produce a toxin derived from spider venom. The modified pathogen killed mosquitoes faster and at lower spore doses than the unmodified fungus. Its mode of action differs from that of pyrethroids, enabling the two control agents to act synergistically ([29]). In a demonstration village that was isolated for bioinsecticide application, the modified fungus led to increased fungal lethality and likelihood of mosquitoes being eliminated locally. Although fungal insecticides are not new ([30]), successful translation to semi-field conditions, with high mortality of the mosquito population, is novel ([28]). Reduced use of insecticides, particularly in wetlands close to urban centres, could have ecological benefits. However, any change in the host range of the modified pathogen could affect non-target organisms.

Use of artificial wombs and ectogenesis in mammalian conservation

Biobags are artificial wombs that allow partial ectogenesis (foetal development outside the mother's body). Lamb foetuses that had partially developed *in utero* were successfully transferred into biobags to continue their gestation to full term *ex utero* ([31]). Biobags contain the foetus, a pumpless oxygenator circuit and a synthetic amniotic fluid, and are designed for human neonatal intensive care. Although human testing is several years off, biobags could be used by parents to overcome troubled pregnancies or to aid premature children ([32]). Artificial wombs also could assist conservation breeding programmes for threatened mammals, particularly if the technology matures to support complete ectogenesis (embryos created with in vitro fertilisation and gestated entirely within an artificial womb), and the rate of production of mammalian offspring increase markedly. Complete ectogenesis will raise numerous practical, ethical and financial challenges ([33]). These challenges include developmental or behavioural problems for embryos not biologically attached to a mother. Additionally, understanding of the role of the placental environment on gene activation in embryos and its effects on immunity in offspring is quite limited.

International growth of traditional Asian medicine

Traditional medicine, largely centred on ancient Asian medicine, has been included for the first time in the International Classification of Disease ([34]), endorsed by the World Health Assembly in May 2019. Inclusion has been viewed as an endorsement of traditional medicine and may accelerate already increasing patterns of its use ([35]). Traditional medicine applies diagnostics and treatments that often have few similarities to western medicine, although efforts to expand the use of randomised controlled trials are increasing ([35]). The government of China is investing in promotion of traditional Asian medicine through methods including health tourism and international market expansion. China has established some 25 traditional Asian medicine institutes in a range of cities, and more will be launched as a major component of Belt and Road Initiative ([35]). Sales of traditional Asian medicine products such as herbal medicines are growing: sales in Belt and Road countries grew by 54% in 2016 and 2017, reaching US$295 million annually ([35]). The growth of traditional Asian medicine will increase demand for ingredients that include some plant and animal species already endangered by harvest for international trade ([36]). Increased connectivity across the Belt and Road route may increase access to formerly inaccessible wildlife populations and increase trafficking of wildlife for use in medicine ([37]).

Rise of blockchain companies with hidden owners

Blockchain, the distributed ledger technology, is revolutionising traditional corporate structures. The distributed consensus mechanism fundamental to blockchain technology ensures the network's security, integrity and performance. . Although blockchain technology is secure in principle applications running on top of them, such as self-enforcing contracts, can be subject to coding errors or security vulnerabilities just like any other software and security systems will need to evolve in order to meet the needs of different applications. Companies that use blockchain need not adhere to a conventional management or financial infrastructure. In particular, self-enforcing agreements embedded in computer code may change how energy resources ([38]) and other natural assets are owned and managed. For example, in Berlin, two artists launched terra0, a blockchain experiment in which a forest autonomously sells its trees, harvests timber, and eventually uses the accumulated capital to buy itself and become a self-owned economic unit ([39]). The rapid development in these self-enforcing contracts could enable companies to confirm resource streams and commit to future actions well beyond current political and regulatory timeframes and without the need for any physical or identifiable company. These resource transactions, which are secure, immutable and verifiable, may strengthen environmental governance. They also can be used to reinforce entitlements to long-term resource extraction or even to substantiate indigenous land rights. Additionally, it may be necessary to clarify or amend existing laws, for example, to recognise the use of distributed ledgers as records of ownership ([40]).

Ecocide as an internationally recognised crime

Currently, the International Criminal Court, governed by the Rome Statute, can prosecute individuals and states for ‘widespread, long-term and severe’ environmental destruction ([41]), but only in certain circumstances, such as during conflict or when the destruction has serious humanitarian consequences. However, as currently drafted, the Rome Statute contains no provisions to protect non-human inhabitants of a given territory or indigenous or cultural rights. Nor does the Rome Statute cover environmental loss, damage or destruction during peacetime. Legal scholars (e.g. [42]) argue that this international law must change to allow the crime of ecocide. Ecocide is defined as ‘the extensive damage, destruction or loss of ecosystems of a given territory … to such an extent that peaceful enjoyment by the inhabitants of that territory has been severely diminished’ ([43]). Research to establish forensic standards for admissible evidence of ecocide is advancing ([44]). Efforts to encourage the ICC to recognize ecocide focus on either the inclusion of ecocide under crimes against humanity or the establishment of ecocide as a distinct Crime Against Peace. Such changes to international law would enable individuals, states and perhaps corporations (not possible under the current statute) to be prosecuted for extensive land-cover modification, pollution and even contributing to climate change.

New United Nations legal principles to reduce the environmental impact of armed conflict

In July 2019, the United Nations’ International Law Commission adopted draft principles on the protection of the environment in relation to armed conflicts. Its action represented a major step toward conclusion of a process to review the international law that was passed in 2013 (http://legal.un.org/ilc/sessions/71/). This new international legislation, which would oblige states and other actors to protect the environment during periods of armed conflict, could have substantial effects on species and ecosystems worldwide given the environmental impacts of modern warfare ([45]). The detrimental effects of armed conflicts on species and ecosystems can be direct, through tactical military operations, or indirect, through their effects on institutions, human migration, and economies ([46]). At the same time, degradation of ecosystems could cause armed conflict and human migration, e.g. as demonstrated in the Sahel, where the degradation of wetlands has resulted in conflict over resources ([47]). Given that the most common links between armed conflicts and ecological responses are subsequent changes to institutions, societies, and economies rather than direct impacts of conflict ([46]), the new legislation's set of principles applicable after armed conflict (http://legal.un.org/ilc/sessions/71/) are particularly relevant; draft principle 14 encourages parties to an armed conflict to address environmental restoration during the peace process.

New regulations jeopardise net neutrality

Conservation relies on the communication of knowledge to, and engagement with, the general public ([48]). Digital tools such as blogging and social media provide authors who have diverse perspectives or agendas ([49]) with unprecedented access to the general public, often with no filter between author and audience. Easy and equal access to all websites and types of data underlies net neutrality, i.e. all internet data are treated equally by internet service providers. Without network neutrality, providers may block or restrict access to pages and content on the basis of their corporate policies or interests, allowing accurate information to be restricted or distorted. Such blocking already affects content in some countries, but network neutrality is now under a general threat: it was repealed in the United States (vote of the Federal Communications Commission, July 2018) ([50]), and other countries could follow suit. Loss of network neutrality could have major effects on conservation and climate regulation if access to accurate or sensitive information is denied or biased, or conversely if guaranteeing such access is prioritised.

Discussion

The pace of data exchange and the volumes of information available continues to accelerate, with the quantity of data available on the internet doubling every two years. The challenges of horizon scanning include not only the process of searching for issues but also understanding whether such information is sufficiently unknown to a given community to warrant inclusion. Some topics we initially considered, such as the effect of nocturnal harvesting of olives on roosting songbirds, subsequently were widely reported by the press, and consequently we considered them too well-known to include in this year's scan. However, this does not mean that the issues are any less relevant to policy-making and conservation.

Last year we identified the importance of national government policy or economic decision making in driving global environmental impacts ([51]), a theme echoed by two of our issues this year, the potential impact of the new European Union policy on the derivation of energy from wood and the repealing of network neutrality in the United States. Another two of our issues this year are based on the potential for decisions by global institutions, such as the International Criminal Court and United Nations, to drive change, whilst a third highlighted the potential impact of decisions by the World Health Assembly. Whether these international instruments determine global environmental trajectories ultimately will depend on the extent to which countries become signatories and then incorporate decisions into national legislation. This challenge was exposed by the high profile public protests over climate change during 2019, which highlighted the failure of national governments to realise their international commitments. With a number of major international meetings focused on the protection, restoration and sustainable use of biological diversity, such as the IUCN World Conservation Congress and the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity, scheduled for 2020, this tension between national decision-making and international commitment is likely to persist. In particular, new conservation agendas, the European green deal, and indicators and targets to 2030 and beyond will focus attention on addressing future threats and opportunities, such as those we seek to identify through horizon scanning.

There is increasing awareness of the role that unconscious bias can play in decision-making ([52]). We recognise that the majority of the people participating in the horizon scan are residents of the United Kingdom, Europe, or the United States, which may create implicit biases in both the scope of the topics considered and the levels of awareness of the issues. We aim to incorporate a wider range of perspectives, particularly from the global south, into future horizon scans. Solicitation of topics could better reflect scientific knowledge and ways of knowing from individuals and societies in regions where biological diversity is frequently stated to be at the greatest level of risk. Nevertheless, we believe that the topics identified this year may affect global conservation, and we hope that this paper will prompt discussion and new research.

Strategic foresight can be defined as “The systematic examination of potential threats, opportunities and likely future developments which are at the margins of current thinking and planning. [The research] may explore novel and unexpected issues, as well as persistent problems or trends. Overall, it is intended to improve the robustness of policies and the evidence base" ([53]). Strategic foresight methods are relevant to experts in any discipline. Horizon scanning is one of many methods used in strategic foresight research, which also includes, but is not limited to, risk prioritisation, trend extrapolation, scenario development, backcasting, and stress-testing ([54]). Although no single method is applicable in all situations, horizon scanning provides the foundations on which all subsequent foresight research is based. The initial stages of horizon scanning are highly inclusive and by definition emphasise novelty, but are not intended to prioritise topics that are well-known or proven. Horizon scanning aims to identify and explore new insights and evidence regardless of whether they are consistent with existing trends and developments ([55]). The focus of horizon scanning is to provide an evidence base of current knowledge that suggests the potential for future change. Horizon scanning can be used to identify, assess and understand gaps in knowledge, identify potential opportunities and risks, and inform research programing and resource allocation. As a tool for decision makers, horizon scanning aims to support strategic activities ([56]). The insights identified through horizon scanning are intended to stimulate multi-party discussion and debate, leading to potentially collaborative solutions to complex issues ([57]).

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