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Review

A 2021 Horizon Scan of Emerging Global Biological Conservation Issues

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We present the results from our 12th annual horizon scan of issues likely to impact biological conservation in the future. From a list of 97 topics, our global panel of 25 scientists and practitioners identified the top 15 issues that we believe society may urgently need to address. These issues are either novel in the biological conservation sector or represent a substantial positive or negative step-change in impact at global or regional level. Six issues, such as coral reef deoxygenation and changes in polar coastal productivity, affect marine or coastal ecosystems and seven relate to human and ecosystem-level responses to climate change. Identification of potential forthcoming issues for biological conservation may enable increased preparedness by researchers, practitioners, and decision-makers.

Highlights

Our 12th annual horizon scan identified 15 emerging issues of concern for global biodiversity conservation.

A panel of 25 scientists and practitioners submitted a total of 97 topics that were ranked using a Delphi-style technique according to novelty and likelihood of impact on biodiversity conservation.

The top 38 issues were discussed at an online meeting held in September 2020 during which issues were ranked according to the same criteria.

Six of the 15 issues primarily affect marine or coastal ecosystems and seven are related to human and ecosystem-level responses to anthropogenic climate change.

Other emerging issues include complete coverage of Indian states for sustainable farming and the potential for use of self-healing building materials.

Horizon Scanning for Conservation

Horizon scanning is one of many forms of foresight research. It is the process of searching for and describing the early warning signs of phenomena that, if realised, may warrant changes to policies and strategies in the medium to long term. The method's chief applications are standardised identification of novel and emerging hazards and opportunities and monitoring of persistent trends that may be manifesting in new ways [1].

This 12th annual horizon scan aims to identify issues that are either novel or represent novelty via a positive or negative step-change in impact on nature and could significantly affect global conservation of biological diversity during the next decade. The attention of regional or global decision-makers and society at large is necessary to maximise the potential opportunities and minimise the potential risks associated with these issues. Recent global assessments of biological diversity and climate change indicate negative trends and a rapidly narrowing window for action to reverse these trends. For example, the Convention on Biological Diversity (CBD) recently announced that none of the 20 Aichi Targets set in 2010 have been fully reached, whereas only six have been partially achieved (https://www.cbd.int/gbo5). The CBD is now defining the next iteration of global goals, which will be released in mid-2021 and will frame the actions of national governments and other social actors for decades to come. We believe that identification of novel or emerging issues for global biological conservation should inform policy making in the context of the Post-2020 Global Biodiversity Framework and encourage research, discussion, and allocation of funds for continued tracking, in addition to informing management and policy change.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus that causes coronavirus disease 2019 (COVID-19) and the ensuing global pandemic, is a strong reminder of the need

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to be prepared to respond to both strengthening trends and emerging issues. Although the risks of pandemics are well known and therefore do not fulfil the novelty criterion for horizon scanning, societies largely dismissed the identified risks and associated needs for public health, surveillance, and societal and security capacities [2] and ultimately failed to prepare an adequate response. The ongoing and future changes driven by the COVID-19 pandemic are likely to have profound consequences for nature. The exact repercussions of these changes for the environment are difficult or impossible to ascertain, but they are the subject of intense societal discussion and debate.

It may seem surprising that our final list for 2021 does not include issues directly related to COVID-19, such as loss of ecotourism, rapid change or dismantling of environmental regulations, changing resource consumption patterns, impacts of plastics associated with personal protective equipment, or reductions in air pollution and carbon emissions. However, society is already acting on or debating how best to deal with these issues. The responses to the COVID-19 pandemic show how quickly new situations may dominate global circumstances. National and local lockdowns have led to swift transitions in the use of green space, political positioning, data collection, risk perceptions, and individual behaviours. Within a few weeks, for example, the pandemic triggered major and possibly long-term shifts in travel, recreational and work patterns, field research, international relationships, and compliance with environmental standards. Illicit activities in protected areas increased [3] as measures taken to contain COVID-19 affected the livelihoods of local people and environmental programmes, including monitoring of the illegal wildlife trade, gathering of security intelligence, and security investigations. These are likely to have long-term impacts on environmental governance. However, given the effects of the COVID-19 pandemic on every sector of society, it is unclear whether environmental deregulation will become widespread and affect conservation policy and practice globally.

Identification of Issues

While our methods for this year's horizon scan were revised slightly due to travel restrictions intended to limit the spread of COVID-19, they were consistent with those for our previous 11 annual horizon scans (e.g., [4,5]) (see Figure 1). By applying a modified version of the Delphi technique, we ensured that the selection process remained repeatable, transparent, and inclusive [5,6].

In March 2020, we asked each panel member to submit two to five issues. This year, we primarily relied on online rather than face-to-face communication with networks and colleagues to facilitate the identification of issues. Additionally, as in previous years, we communicated via email and a range of social media platforms. With these methods, we canvassed approximately 650 people. We counted all contributors to in-person (usually online) discussions, but if messages were sent to networks via email or social media, we counted only those who responded.

Where two or more issues were similar, we pooled them for the next stage. Participants independently and confidentially scored each of the resulting 97 issues from 1–1000 (low–high) according to two main criteria: its potential to impact biological conservation, (whether positively or negatively) and the novelty of the issue. Participants could include notes or queries for discussion should the issue be retained for further consideration. To mitigate the potential for voter fatigue to influence scoring (see [6]), participants randomly were assigned one of three issue lists, each in a different order. Participants' scores were converted to ranks (1–97) and issues with median ranks 1–37 were retained for the second round of assessment. At this point, participants were offered an opportunity to retain an issue that was not among the top 37. This year, one issue was retained, thereby yielding 38 issues for discussion.

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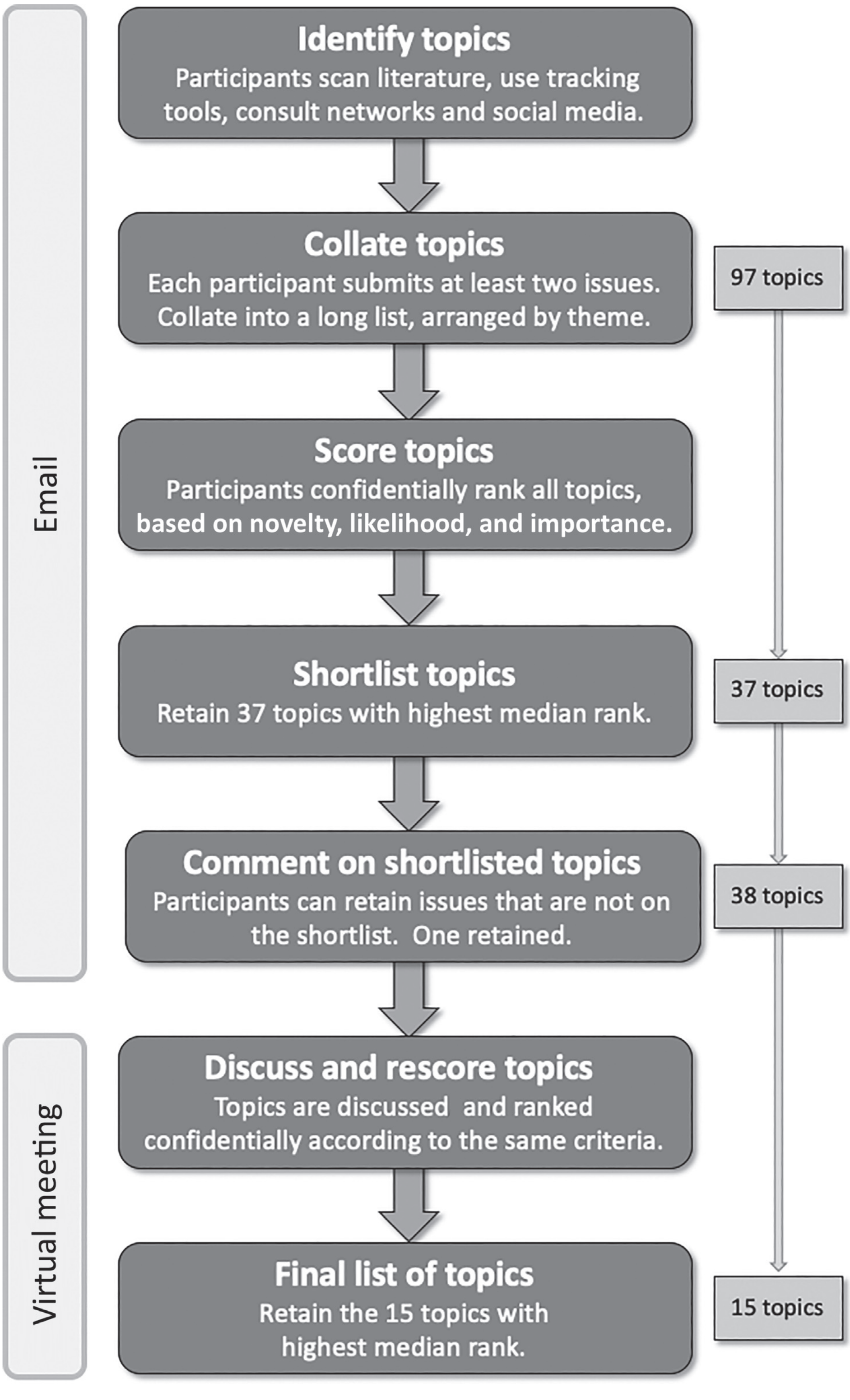

Figure 1. Process for Identifying and Evaluating Issues for the 2021 Horizon Scan.

Each participant was assigned up to five of the 38 issues to research in depth ahead of the panel meeting. To increase the number of well-informed people contributing to the discussion, individuals were assigned topics that they did not submit and that were outside their core area of expertise. We convened online in September 2020. Despite differences in time zones and the fragility of some internet connections, the discussion was rich and detailed. Accompanying the verbal discussion was an active information exchange (e.g., providing links to articles) via a chat function, which increased efficiency. After each issue was discussed, participants rescored the topic (1–1000, low–high) according to the same criteria. At the end of the meeting, the scores were converted to ranks and collated. The top 15 issues were identified based on median ranks. As part of further research during the writing and editing process, the co-authors identified one issue with potential impacts that were less than originally thought. Therefore, after a vote, the group decided to replace this issue with the issue ranked 16. Our top 15 issues are presented below in thematic groups rather than rank order.

The 2021 Issues

Underestimated Effects of Deoxygenation on Coral Reef Health and Survival

Hypoxia-associated coral mortality has been recorded in the Pacific, Indian, and Atlantic Oceans. Most cases have been in enclosed bays or lagoons, where deoxygenation was driven by nutrient enrichment from aquaculture or terrestrial runoff. Other cases have been linked to still waters that prevented oxygen circulation in lagoons [7]. As water temperature increases, dissolved oxygen concentration decreases. Climate change therefore may further reduce dissolved oxygen availability. Furthermore, warmer water will increase the metabolic demands of most species, leading to more-rapid oxygen depletion. Temperature-induced coral bleaching may be exacerbated in low-oxygen conditions, and ocean acidification may increase the severity of anoxia [7]. Deoxygenation was among the issues we identified in our first horizon scan [5]. Although so far deoxygenation largely has been linked to localised coastal hypoxia, ocean deoxygenation may become widespread [8]. Increasing ocean stratification, the division of the water column into layers with different densities by differences in temperature, salinity, or both could increase the incidence of hypoxia-associated mortality, even in oceanic reefs [9]. Dissolved oxygen rarely is measured in coral reef monitoring programs. It is unclear whether coral reefs are particularly sensitive to hypoxia or whether tropical coastal areas are particularly likely to become hypoxic as climate continues to change. The value of coral reefs to humans, their high species richness, and their well-known vulnerability to increases in ocean temperatures and acidification suggest that any further deoxygenation could reduce reef survival substantially.

Increases in Dissolved Iron Availability and Polar Coastal Productivity

Our earlier horizon scans identified the potential effects of increased high-latitude marine productivity in response to ice retreat in offshore areas and ice-shelf loss [10,11]. Polar coastal zones are among the world's most productive marine ecosystems and account for over 29% of the world's continental shelves [12]. Their peak phytoplankton blooms often are around an order of magnitude greater than those in offshore waters [13]. Recent scientific advances indicate that the high productivity is related to the availability of dissolved iron [14]. In coastal areas, glacial ice-melt runoff and floating ice-melt are the primary sources of iron, supporting intense blooms and enabling large benthic communities to sequester considerable amounts of carbon and other nutrients [15]. Polar coastal regions, especially fjords, are species rich and highly productive. For example, over 17 000 species inhabit the Antarctic continental shelf and biomass is high compared with other marine ecosystems [16]. As sea and coastal ice retreat with climate change, ice flows and iron concentrations will increase [17]. Increased polar coastal productivity and its ultimate incorporation into benthos are already among the major global carbon sequestration processes [18]. During the coming decades, phytoplankton productivity and biomass growth will increase in large polar coastal regions, affecting nutrient fertilisation, changing the structure and complexity of coastal pelagic and benthic communities, and increasing drawdown and sequestration of carbon [19].

Substantial Increase in Decommissioning of Offshore Energy Platforms

The projected decommissioning of around 3000 offshore oil and gas platforms and the growth of offshore wind farms will continue over the coming decades. At the same time, by 2040 the estimated global capacity of offshore wind farms will increase by ten or more times the current installed capacity, and extraction of natural gas also is projected to increase (https://www.iea.org/reports/offshore-energy-outlook-2018). Decommissioning strategies could have major negative or positive effects on marine systems. Full removal of decommissioned offshore structures has been standard practice in the North Sea, although regulations on decommissioned offshore infrastructure differ among countries and other entities. By contrast, in Mexico decommissioned platforms have been converted to artificial reefs. Major gaps in knowledge of the impacts of decommissioning and subsequent mode of removal have been highlighted in areas such as Australian coasts [20]. Immediate and long-term environmental trade-offs among full removal, partial removal, conversion, and abandonment are unclear and vary by location and ecosystem [21]. Over time, many structures have come to support high local species richness that is linked to the colonisation of those physical structures and to their conferral of relative protection from fishing and disturbance of surrounding sediments by bottom trawling [22]. Some of the effects of removals may, in the longer term, be counteracted by offshore renewable energy installations, which are likely to be constructed over large areas in coastal seas. The number of these trade-offs and the magnitude of their effects are projected to increase as the number and size of renewable-energy installations rise. Moreover, the locations of these impacts may change with the growth of new markets in areas with relatively little environmental oversight.

Use of Seabirds to Locate Fishing Vessels Remotely

Seabird researchers are exploring the use of tagged birds to locate fishing vessels with the aim of improving global surveillance of illegal, unreported, and unregulated fishing activities, which affect marine ecosystems through bycatch and unsustainable harvest of fish stocks [23]. Transmitters attached to albatrosses and other seabirds can detect, record, and, in near-real time, send the location of radar signals emitted by fishing vessels. Seabirds could follow ships or boats that are fishing, allowing the discovery of vessels that otherwise would not be detected [e.g., those that have deactivated their Global Positioning System (GPS) or are fishing by day so cannot be detected remotely at night by their lights], even in remote areas beyond national jurisdiction. Initial experiments conducted in the Indian Ocean [24] validated this approach. If adopted, it will be important to evaluate whether tagged seabirds are targeted deliberately by vessels that are acting illegally.

Proliferation of False Information Reported by Global Navigation Satellite and Automatic Identification Systems

Nearly all ocean-going ships use Global Navigation Satellite Systems (GNSSs) for navigation and Automatic Identification Systems (AISs) to broadcast identity, position, course, and speed. These systems enhance navigational safety and facilitate remote tracking of vessel movements. In recent years, GNSS spoofing attacks (the broadcasting of false signals to confuse receivers, which can occur for durations of minutes to years) and AIS cloning (transmitting false identities) have proliferated (https://www.c4reports.org/aboveusonlystars) [25]. Manufacturers are integrating new measures into GPS hardware to withstand spoofing attacks, but these enhancements may not be available for a decade. Turning off AIS transponders alerts regulators to possible illicit activity. Therefore, it is conceivable that some actors may spoof GNSS and then covertly fish, dredge sand, or extract other resources from areas in which they are not licenced to operate (https://www.c4reports.org/aboveusonlystars). Spoofing and AIS cloning also allow ships carrying illegally trafficked goods to return to port clandestinely. More-extensive GNSS spoofing may divert vessels into closed areas or dangerous waters or decrease the reliability of GNSS information for enforcement of regulations of activities such as illegal fishing [26]. By compromising the technology needed to police the marine environment, it may be possible to exploit protected marine areas, rare species, and commercial stocks at unsustainable levels [27].

Multigenerational Effects of Low Levels of Exposure to Endocrine Disruptors

It is well established that some compounds used widely as human pharmaceuticals and in domestic, garden, and farm products disrupt endocrine systems in aquatic organisms. Most regulatory approval processes do yet not account for many of these effects. Exposure to individual compounds can alter sex ratios, lower fertility, and cause deformities in fishes [28]. Evidence of multigenerational effects is emerging, suggesting that the effects of exposure to low levels of common endocrine disruptors can be transmitted to future generations that were not directly exposed [29,30]. Elevated temperatures may strengthen multigenerational effects [31]. Although laboratory studies have confirmed multigenerational effects in only a few species of fish, the consequences may be enduring and applicable to a wide range of species. Compounds known to have multigenerational effects include bifenthrin (a pyrethroid insecticide) and synthetic progestin, oestrogen, and androgens, which are used in many products and enter waterways via sewage systems [30]. Although banned in the EU, bifenthrin continues to be permitted and used in other parts of the world.

Changes in Coastal Low Clouds

Low clouds cover some 20% of low-latitude and subtropical coastal oceans, where they cool the planet by shading large proportions of its surface during warm seasons [32]. By 2100, if the atmospheric concentration of carbon dioxide continues to rise at current rates, the instability of these clouds is predicted to increase [33]. Coastal low clouds are highly sensitive to global atmospheric circulation patterns (e.g., Hadley cells), fine-resolution coastal topography, sea surface temperatures, and synoptic weather patterns. Simulating these clouds is difficult in current dynamic climate models. In areas where cover of coastal low clouds decreases substantially, the risks of coastal wildfires are likely to increase via changes in evaporative demand and reductions in fuel moisture [34]. Many intertidal and coastal species have evolved in the presence of low clouds, which insulate them from increases in water and air temperatures. Decreases or increases in the extent of these clouds are likely to affect species distributions and ecosystem function in both marine and nearshore environments. Moreover, in regions where the incidence or extent of coastal low clouds decreases substantially, the health of human populations that are not well acclimatised to higher temperatures may be affected. The latter may result in changes to energy use or settlement patterns, which in turn may affect natural and human communities.

Challenges to Tree Plantations as a Simple Carbon Sequestration Solution

Estimates of the global carbon sequestration potential of tree planting [35] have been accompanied by international, national, and corporate commitments to plant large areas (e.g., Trillion Trees, 1t.org, Billion Tree Tsunami), and further commitments are being made in Nationally Determined Contributions for COP-26. Application of land-use change to mitigate climate change is complex (e.g., [36]), and extensive tree planting, especially afforestation with monocultures of non-native species, is unlikely to be either effective in mitigating climate change or consistent with the conservation of biological diversity [37]. Tree plantations may result in a reduction in net sequestration or an increase in net emissions relative to previous land-cover types, such as grassland or peat, and may divert attention away from efforts to reduce emissions from deforestation and degradation. Furthermore, plantations dominated by single tree species tend to be low in value for native species. Potential negative outcomes for biological diversity include loss of non-forest ecosystems, particularly grasslands and wetlands [38], and increases in local temperature as trees reduce albedo relative to snow cover. Plantation-style tree planting over large areas is likely to become more common. Unless tree planting is planned and implemented across extensive regions on the basis of an understanding of ecological systems and their restoration [39], the plantings could have serious negative consequences for biological diversity. We are aware this has been widely discussed in the scientific and policy communities, and it was put forward as an emerging issue by at least four external consultees. The novelty is that the mechanisms for implementation are being put in place currently and will start to have large-scale impacts over the coming decades. It is clear that there are real risks for certain habitat types, such as grassland and peatland, from being incorrectly classified as degraded forest in need of restoration.

Increased Logging in Response to Fire Risk

As the frequency, size, and intensity of forest wildfires increase globally, emerging policies reflect the suggestion that tree removal may reduce the magnitude of these fires and therefore decrease human mortality and economic losses. The effectiveness of logging or thinning trees is uncertain. For example, logging or thinning exacerbates fire risk [40] and has limited potential to reduce fire severity in the western USA [41]. Moreover, any short-term reduction of the risk of fire from tree removal often is offset by the expansion of non-native, invasive grasses and herbaceous flowering plants (e.g., [42]), which themselves may be highly flammable. Media coverage may strongly affect public perceptions of the effectiveness of tree removal despite the limited scientific evidence. In the USA and Australia, for example, media coverage of fuels management policies emphasised the potential that such policies not only could reduce the risk of extreme wildfires but could justify increases in logging [40,43]. Given the recent increase in extreme fires worldwide, including in central Africa, South America, southern Australia, Russia, the USA, and Canada, and the evidence that such fires will increase in extent, frequency, and severity because of anthropogenic climate change, extensive tree removal in the name of protection from fire may become increasingly likely.

Complete Coverage of Indian States with Sustainable Farming

The implementation of diverse forms of the sustainable intensification of agriculture is expanding globally [44]. Uptake is going through a step-change increase, with entire states in India adopting forms of sustainable farming (also known as zero-budget, natural, or community-managed natural farming) as a consequence of policy-based incentives and local innovation. Natural farming promotes the use of non-synthetic inputs, sourced locally, to reduce direct costs while boosting yields and farmer health. The Indian state of Sikkim has adopted organic farming as a state policy [45]. Similarly, the state of Andhra Pradesh has targeted uptake of natural farming by the state's 6 million farmers by 2025. A state-led programme of training, extension, and social capital development has stimulated adoption by 250 000 farmers to date, many of whom transitioned from high-input, post-green revolution methods. Evaluations of this early adoption indicate increases in crop yields, income, diversity, and rotations; improvements in farmer health; and increased organisation of rural women and their access to microfinance [46,47]. As of mid-2020, the states of Gujarat and Himachal Pradesh have announced policy support for exclusive use of natural farming, and four more states (Bihar, Kerala, Maharashtra, and Rajasthan) are working toward similar policies. With such governmental support, adoption and update rates could be as rapid as in Andhra Pradesh and could induce similar agricultural changes in other parts of the world.

Low Earth Orbit Satellites May Mislead Animals Responding to Celestial Cues

More than 2600 active artificial satellites currently orbit Earth. This number is likely to increase over the next decade, in large part due to the planned launch of thousands of low Earth orbit satellites that provide high-speed internet access [48] and Earth imaging services. Although not all of these projects will be realised, Space X's Starlink program already has launched more than 700 satellites and other undisclosed or *ad hoc* programmes are likely to be implemented. Astronomers have expressed concerns about the detrimental effects of tens of thousands of satellites on ground-based observations of the night sky [49]. Environmental impacts also may extend beyond those from launch infrastructure and rocket emissions, exacerbated by the need to use reflective surfaces and solar panels. For example, many organisms, including species of insects, night-migrating birds, and mammals, use celestial objects or rely on light polarisation patterns for local orientation and long-distance migration (e.g., [50]). The extent to which satellites will disrupt these cues is unknown but probably depends on the total number and visibility of satellites.

Emergence of a Global Market for Stranded Energy

Stranded energy refers to energy generation that is no longer economically or logistically viable. For example, methane byproducts that have low economic value are frequently vented or flared from oil wells rather than combusted to produce energy [51]. Excess energy from hydropower, wind turbines, or solar panels also are forms of stranded energy. Innovation to increase use of stranded energy has focused on decentralisation of the grid and alternative means of energy storage. An emerging novel use of stranded energy is Bitcoin mining, the process that secures the Bitcoin network by solving complex algorithms. Bitcoin mining uses 45–60 TWh of electricity per year (https://cbeci.org/) and because it is extremely competitive, relies on cheap energy to remain profitable. On-site Bitcoin mining, which can occur from any location with an internet connection, delivers a highly liquid global market (>$US4 billion daily) for the otherwise stranded energy from renewable and non-renewable sources. On the one hand, currently unprofitable fossil fuel sources could become profitable again. On the other hand, the demand for renewable energy could be increased, and the pace of climate change decreased, by stabilising the grid during periods of peak demand or peak supply and by guaranteeing a minimum selling price at all hours [52].

Open-Source Investigation of Environmental Threats

Recent successes of open-source intelligence and fact checking, such as the Bellingcat investigations of the downing of Malaysia Airlines Flight 17 and the exposure of suspects responsible for the poisoning of Sergei Skripal [53], demonstrate the considerable potential for interventions by civil society groups to address diverse threats beyond the rule of law. Investigators access and collate data through social media mining and other analytical and forensic tools, verify the authenticity of the data, confirm the temporal and spatial dimensions of the incident, and provide actionable evidence for media exposure, political engagement, and potential international legal action [54]. Although the use of open-source methods for environmental protection has been limited to date, their potential was demonstrated via documentation of the effect of locust swarms in East Africa through correlation with online videos posted on social media [55]. Internet connectivity is increasing in countries where official incident response is limited, as is consumer access to smartphones capable of recording, processing, and posting high-quality visual materials, GPS tracks, and audio recordings. The application of high-quality open-source intelligence to investigate environmental threats could become increasingly influential.

Self-Healing Building Materials

A wide variety of approaches for the engineering of living, self-healing building materials have been proposed, including the use of chemicals, polymers, and bacteria [56]. Although the practicality of these approaches and their environmental effects remain uncertain, the use of these materials may reduce the need for repair and reduce emissions of carbon dioxide from buildings, bridges, and roads [57]. If successful, the widespread adoption of self-healing building materials would lower demands for cement, reducing both greenhouse gas emissions and disturbance of geological formations, such as karsts, that currently are mined for cement production. With new major infrastructure developments such as China's Belt and Road Initiative, the use of self-healing materials could reduce pressure on local ecosystems that provide building materials while lowering the costs of maintenance in remote areas and carbon dioxide production [58]. The application of such materials also could reduce waste from old buildings and therefore reduce the environmental footprint of building and maintaining infrastructure [59].

2000-km E40 Waterway Linking the Baltic and Black Seas

A large-infrastructure project aims to create a 2000 km navigable waterway between the Baltic and Black Seas. This project would link the Polish port of Gdańsk with the Ukrainian port of Kherson by using the Vistula, Bug, Mukhavets, Pina, Pripyat, and Dnipro rivers to cross Poland, Belarus, and Ukraine. The project involves extensive dredging and construction of new channels, locks, and dams. Its proponents claim a range of environmental, social, and economic benefits, including increased trade and cargo flows throughout the region [60]. However, the proposed route of the waterway passes through Polesia, which is one of the largest (186 000 km^2) intact wilderness areas in Europe, inhabited by major populations of large mammals and a stopover for large populations of migratory birds [e.g., 150 000–200 000 wigeon *Anas penelope* (12–21% of the European population), 200 000–400 000 ruff *Philomachus pugnax* (60–75%), and 20 000–25 000 black-tailed godwit *Limosa limosa* (6–12%)]. The waterway may affect 70 wildlife reserves and numerous international conservation areas recognised by entities including Natura 2000, Ramsar, and the UN Educational, Scientific, and Cultural Organisation. There are concerns that national regulatory measures to protect these ecosystems and parks are inadequate [61]. The E40 has the potential to change regional hydrology and ecology dramatically, to change the carbon balance, to affect protected areas, protected species, and other species, and to introduce non-native invasive species. Ongoing dredging inside the Chernobyl Exclusion Zone may disturb and disperse radioactive sediment [62]. Past floods, however, have resulted in the mobilisation of large volumes of sediment without significant radiological risk to the downstream Kyiv Reservoir [63]. The social, economic, and environmental impacts along the project's 2000-km corridor remain uncertain.

Concluding Remarks

The 15 issues we identified for this 2021 horizon scan span several multidisciplinary themes. Six relate to the functioning and conservation of marine and coastal ecosystems, seven to human and ecosystem-level response to anthropogenic climate change, five to the potential impacts of technological developments, and two to contaminants and their potential effects on biological diversity. In contrast to the two previous horizon scans, none of the issues is related to changes in global policy design or implementation and governance approaches.

The 2021 scan again highlights the potential for major and rapid changes in the functioning of polar ecosystems. The annual scans consistently suggest that changes at the highest latitudes drastically could affect social and economic systems and conservation priorities. Similarly, changes in the carbon cycle continue to feature in our horizon scans. This year, a number of issues underscored risks from developments that could be perceived as positive for conservation, such as tree planting, facilitated access to high-resolution satellite imagery, and the use of tagged seabirds to locate fishing vessels acting illegally.

As in previous years, we have collated a broad range of novel issues with potential effects on conservation of biological diversity. A subset of our group evaluated the success of this process [64] by reviewing the progress of issues identified in our first horizon scan, published 10 years earlier in 2010 [5]. One-third of the 15 topics from that year, including microplastic pollution, have since developed into major issues or caused considerable environmental impacts; three, such as nanosilver in wastewater and high-latitude volcanism, have not emerged, and other issues developed in a more modest manner.

Following that process of review, we reconsidered the issues that we selected for the 2011 scan [10]. One of these, denial of biodiversity loss, began to emerge more clearly in 2019 following the widely reported estimate that 1 million species are at risk of extinction [65]. Potential responses to denial are now a focus of discussion by the conservation sector [66]. Other issues with substantial environmental impacts since 2011 [10] are expansion of lithium mining for rechargeable batteries [67] and hydraulic fracturing. The status of two other issues we identified in 2011 [10], climate governance and protected area failure, have gained public and media interest but not action, funding, or commitments, despite a shift in climate change leadership from the public to the private sector. Both remain risks to global policy to reduce climate change and loss of biological diversity.

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