Conservation Biology

CONTRIBUTED PAPER

The relative importance of COVID-19 pandemic impacts on biodiversity conservation globally

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Abstract

The COVID-19 pandemic has had an enormous impact on almost all aspects of human society and endeavor; the natural world and its conservation have not been spared. Through a process of expert consultation, we identified and categorized, into 19 themes and 70 subthemes, the ways in which biodiversity and its conservation have been or could be affected by the pandemic globally. Nearly 60% of the effects have been broadly negative. Subsequently, we created a compendium of all themes and subthemes, each with explanatory text, and in August 2020 a diverse group of experienced conservationists with expertise from across sectors and geographies assessed each subtheme for its likely impact on biodiversity conservation globally. The 9 subthemes ranked highest all have a negative impact. These were, in rank order, governments sidelining the environment during their economic recovery, reduced wildlife-based tourism income, increased habitat destruction, reduced government funding, increased plastic and other solid waste pollution, weakening of nature-friendly regulations and their enforcement, increased illegal harvest of wild animals, reduced philanthropy, and threats to survival of conservation organizations. In combination, these impacts present a worrying future of increased threats to biodiversity conservation but reduced capacity to counter them. The highest ranking positive impact, at 10, was the beneficial impact of wildlife-trade restrictions. More optimistically, among impacts ranked 11-20, 6 were positive and 4 were negative. We hope our assessment will draw attention to the impacts of the pandemic and, thus, improve the conservation community's ability to respond to such threats in the future.

KEYWORDS

ambiente, compendio, coronavirus, evaluación, fauna, naturaleza, assessment, compendium, coronavirus, environment, nature, wildlife

Resumen

La pandemia de COVID-19 ha tenido un impacto enorme sobre casi todos los aspectos de la sociedad humana y sus proyectos; el mundo natural y su conservación no han sido la excepción. Por medio de un proceso de consultas a expertos, identificamos y categorizamos en 19 temas y 70 subtemas las maneras en las que la biodiversidad y su conservación han sido o podrían ser afectadas mundialmente por la pandemia. Casi el 60% de los efectos han sido claramente negativos. Posteriormente, creamos un compendio de todos los temas y subtemas, cada uno con textos explicativos, para que en agosto de 2020 un grupo diverso de conservacionistas experimentados con conocimiento de todos los sectores y geografías evaluara cada subtema de acuerdo con su probabilidad de impactar sobre la conservación de la biodiversidad en todo el mundo. Los nueve subtemas con la clasificación más alta tienen un impacto negativo. Estos temas son, en orden de clasificación: los gobiernos dejando de lado al ambiente durante su recuperación económica, reducción de los ingresos basados en el turismo de fauna, incremento en la destrucción de hábitat, financiamiento reducido del gobierno, aumento de la contaminación por plásticos y otros desechos sólidos, debilitamiento de las regulaciones en pro de la naturaleza y su aplicación, incremento en la captura ilegal de animales, disminución de la filantropía y amenazas para la supervivencia de las organizaciones de conservación. La combinación de estos impactos representa un futuro preocupante lleno de amenazas para la conservación de la biodiversidad y una capacidad reducida para contrarrestarlas. El impacto positivo con la clasificación más alta, el 10, fue el impacto benéfico de las restricciones en el mercado de fauna. De manera más optimista, entre los impactos clasificados de los lugares del 11 al 20, seis fueron positivos y cuatro fueron negativos. Esperamos que nuestra evaluación enfoque la atención hacia los impactos de la pandemia y así mejore la habilidad de la comunidad conservacionista para responder a tales amenazas en el futuro.
Importancia Relativa de los Impactos de la Pandemia de COVID-19 sobre la Conservación Mundial de la Biodiversidad

INTRODUCTION

An outbreak of pneumonia emerged in December 2019 in Wuhan City, China. The causative agent was a coronavirus, SARS-CoV-2 (Zhou et al., 2020), and the disease it caused was named COVID-19 by the World Health Organization (WHO). Although the origins of the virus are unproven, there are strong indications of a wild animal source linked to wildlife trade in China (Borzée et al., 2020). The WHO declared COVID-19 a global pandemic in mid-March 2020, and within 12 months 120 million cases and 2.65 million deaths had been reported globally (WHO, 2021).

To slow the pandemic's spread, governments worldwide implemented policies to reduce virus transmission including quarantining citizens, introducing social-distancing measures, confining citizens through lockdowns, closing borders, and restricting travel (Bates et al., 2020; Lecocq et al., 2020). By July 2020, half the world's population had been under some form of sheltering order (Diffenbaugh et al., 2020).

The impact of these measures has been substantial on human society. The pandemic is forecast to cause the deepest global recession in eight decades (World Bank Group, 2021), and the first increase in global poverty for two decades (Lakner et al., 2021). Most sectors of the economy have been affected adversely; hospitality, tourism, and aviation were severely hit (Nicola et al., 2020).

The impacts of COVID-19 on aspects of biodiversity, its conservation, and the environment have been widely reported (e.g., Bates et al., 2020; Bennett et al., 2020; Corlett et al., 2020; Diffenbaugh et al., 2020; Evans et al., 2020; Hockings et al., 2020; Kavousi et al., 2020; Lecocq et al., 2020; Le Quéré et al., 2020; Lindsey et al., 2020; McNeely, 2021; Waithaka et al., 2021). However, a comprehensive review of impacts is missing. Consequently, we created a compendium of the observed and potential impacts of COVID-19 on biodiversity and its conservation globally and assessed the relative importance of each. We aimed to make the compendium and assessment as comprehensive and robust as possible by engaging a diverse group of experts from across the conservation sector.

We hope that by identifying these impacts and highlighting those we believe have had, or will have, the greatest impact that attention can be focused on these issues during the current and future pandemics.

METHODS

We used a three-step process of expert consultation and assessment (e.g., Sutherland, 2006) to identify and categorize the impacts the pandemic has had or could have on biodiversity and its conservation worldwide; create a compendium describing those impacts; and assess their relative importance.

Identifying and categorizing impacts (step 1)

Observed and potential impacts were identified by a group of experts, selected for their global experience, and subsequently peer challenged. The process was designed to produce a reasonably comprehensive list of impacts in a short period and in the absence of a substantial peer-reviewed literature on a rapidly evolving topic. To do this, D.W.G. compiled an annotated list of actual and potential impacts in late April 2020. This was derived from personal experience, knowledge gained through networks, and the emerging literature and reporting of the subject. The list was categorized into overarching themes. Similar impacts (subthemes) were grouped in the themes. This list was further developed at two meetings (May and June 2020) of the governing Council of the Cambridge Conservation Initiative, a collaboration of 10 organizations (https://www.cambridgeconservation.org/) working in nature conservation, attended by the chief executive officers or other senior staff from each organization. During these meetings, the list of subthemes and their categorization into themes was challenged; themes and subthemes were added, removed, split, or merged and consensus on a set of 18 themes containing 65 subthemes was arrived at. To capture a more diverse range of views, we asked alumni of the University of Cambridge's Masters' in Conservation Leadership, a network of midcareer conservationists from 75 countries, to suggest additional impacts and modifications to the categorization. Ten alumni provided input, and by mid-June 2020 a list of 19 themes and 66 subthemes had been agreed on.

Creating a compendium of impacts (step 2)

We created a compendium of impacts from this list of themes and subthemes by asking members of Cambridge Conservation Initiative Council (or a nominee) and the 10 alumni to draft explanatory text for one or more subthemes. Twelve members of council, three nominees, and all 10 alumni drafted texts; all are authors of this article. Each person was instructed to ensure that subtheme texts were as independent from one another as possible. To provide clarity and aid subsequent scoring (see step 3), subthemes were written so that the impact had a single directionality, that is, a broadly positive or broadly negative impact on the conservation of biodiversity globally. Themes with both significant positive and negative aspects were separated into paired subthemes. Authors provided evidence for subtheme texts from published references or other sources. The draft subtheme texts were collated into a single document—a compendium—which was edited by D.W.G. in June 2020, returned to authors for modifications, and re-edited in July 2020. At each editing stage, D.W.G. provided additional evidence for subtheme texts by seeking recently published or overlooked peer-reviewed information in Google Scholar. The terms "_COVID-19_" (or "_coronavirus_") and "_biodiversity_" (or "_conservation_," "_nature_," "_wildlife_," or "_environment_") were search terms and "anytime since 2020" selected as the time frame. Where these terms proved too general, search terms relevant to specific subthemes were also used (e.g., "_COVID-19_ (or "_coronavirus_") and _economy_" for economic impacts). Where few sources were available in the peer-reviewed literature, searches were undertaken in Google based on the same search terms and examination of the first approximately

TABLE 1 Measures used to assess the impact of each subtheme in a compendium of impacts of the COVID-19 pandemic on global biodiversity conservation

Measure and category of impact	Description*
Magnitude	
scored from 0–100	combination of geographic scale and the size of impact where it occurs; score of 100, very large and global effect; score of 1, very small, local impact effect
Probability of occurrence	
low	impact unlikely or very unlikely to occur
medium	probability the impact does or does not occur roughly similar
high	impact likely or highly likely to occur or has occurred
Duration from date of survey	
short	impact continues for <1 year
medium	impact continues for 1-5 years
long	impact continues for >5 years

*Some non-COVID-19 examples were provided to help select appropriate magnitude scores and categories for probability and duration; these are shown in Appendix S1.

50 search returns for each subtheme and selection of relevant returns for further investigation.

The categorization of themes and subthemes changed during this step based on author suggestions and new information revealed during searches. The compendium was finalized in early August 2020 and contained 19 themes and 70 subthemes.

The compendium captured information from 139 peer-reviewed papers, 21 reports from governmental or intergovernmental institutions, 38 other reports, 22 articles in scientific or conservation magazines, 40 articles from news outlets, 6 books or chapters, 6 open letters, and 25 internet sources. Subthemes were based on a mean of 5.6 (range 1-17) sources, with the exception of one which was unsourced. No quality filters were used to check the accuracy of information beyond the professional judgment of the authors and the compendium editor. Conditional language was used where appropriate to indicate uncertainty in possible impacts.

Assessing the relative importance of impacts (step 3)

In August 2020, all authors and a further 31 members of the alumni network were asked to read the compendium and assess the importance of each of the subtheme impacts by questionnaire survey. The additional alumni increased the number of participants and were chosen to ensure wider geographical representation. Five members were chosen from each occupied continent and two with expertise in polar regions. There were at least two men and two women from each region where possible. Participants read the subtheme texts and scored each for the magnitude of its impact on biodiversity conservation globally, probability of occurrence, and duration. Because in the compendium sources are listed alongside each subtheme text, participants were able to account for the quality of information when scoring. Probability and duration were scored on a three-level ordinal scale of low, medium, or high and short, medium,

or long, respectively (details in Table 1). Magnitude was scored on a numerical scale of 0-100. Pilot testing of the survey by five participants suggested they were able to score magnitude on a finer scale than probability or duration, allowing greater discrimination between subthemes. We used these scores to produce an overall impact score (and from that an overall rank) for each subtheme, calculated as the product of the means (across all participants) of magnitude, probability (scores of 1, 2, and 3 allocated to subthemes scored as low, medium, and high, respectively), and duration (1, 2, and 3 allocated to short, medium, and long). Each measure had equal weight. Finally, for completeness, we calculated a net impact score for each theme by summing the overall impact scores for all subthemes within it; negative impacts were treated as negative values. Participants also provided their gender, nationality, countries worked in, and information about their conservation experience.

Ethical approval for the questionnaire was given by the University of Cambridge's Department of Geography Ethics Review Group (number 1743). The instructions supplied to participants and the questions asked of them are provided in Appendix S1.

Characteristics of questionnaire participants

All 25 authors plus 31 additional members of the alumni network were invited to complete the questionnaire. Twenty-four authors and 22 additional alumni did so (response rate 82%). Forty-three percent of participants were female and 57% male. They were nationals of 27 countries (single participants from Bangladesh, Belize, Bhutan, Bolivia, China, Colombia, Costa Rica, Ecuador, Fiji, Hungary, Israel, Liberia, Mozambique, Namibia, Netherlands, New Zealand, Papua New Guinea, Philippines, Sri Lanka, Sudan, Switzerland, United States, and Zambia; two from Australia and Peru; five from Canada; and 16 from United Kingdom; two had dual nationality) with experience in conservation work spanning 49 countries (Appendix S2). There were at least four participants from each continent

(excluding Antarctica). Seventy-six percent had worked in nonprofit or nongovernmental organizations, 32% in governmental organizations, 26% each in academic, other educational and international organizations, and 15% in the private sector. More worked mostly or exclusively in conservation practice (54%) than in conservation research (13%), and 33% worked in both. Many more worked in fairly or very senior positions (74%) than in fairly or very junior positions (2%), and about 24% worked in neither a senior nor a junior position.

RESULTS

The categorization of impacts (Table 2) and compendium created from it (Appendix S3) contained 19 themes split into 70 subthemes, of which 41 (59%) were broadly negative for biodiversity conservation globally and 28 (40%) were broadly positive. One (1%) subtheme was unclassifiable. Only one potential impact was caused directly by the virus: the infection of wildlife by SARS-CoV-2. All others were a consequence of human responses to the pandemic.

The nine subthemes that were ranked highest in terms of their relative impacts were all negative. These were governments sidelining the environment during economic recovery; weakening of nature-friendly regulations and their enforcement; reduced funding for conservation from governments, philanthropists, and wildlife-based tourism and the consequent existential threat to conservation organizations; and increased habitat destruction, illegal harvest of animals, and plastic and other solid waste pollution. The highest ranking positive impact was the beneficial impact of wildlife-trade restrictions, ranked tenth. More optimistically, within those ranked 11-20, six were positive in their impact, among which were green economic stimulus packages, increased international cooperation, and access to online conservation education.

The themes of funding for conservation, habitat destruction and harvesting of wildlife, conservation projects, and legislation and regulation had the highest negative net impact scores; impact of reduced human mobility on wildlife was the most positive. All these themes scored >500, negative or positive (Appendix S4).

Explanatory texts are presented below in order of overall impact rank for the 10 subthemes assessed as likely to have the greatest impact on biodiversity conservation globally. The texts are abridged and updated (see Materials & Methods) from those used for scoring in August 2020, which are in the compendium (Appendix S3). Table 3 is an annotated list of the 20 highest ranked subthemes.

Environment sidelined in economic recovery (subtheme 10.3)

Economic recovery will be a priority for all nations following the pandemic. However, economic challenges may lead some to reduce efforts to solve the climate and biodiversity crises (López-Feldman et al., 2020; Sandbrook et al., 2020),

for example, by supporting resource-extractive and greenhouse-gas-emissions-intensive industries while reducing support for environmental protection (Kroner et al., 2021). By July 2020, US$11 trillion of economic stimulus had been allocated to pandemic recovery by governments globally; the conservation sector was largely excluded (McCleery et al., 2020). The United States scaled back automobile emissions' targets (Tollefson, 2020), which, combined with low oil prices, may create a rebound in transport-related pollution (Helm, 2020; Le Quéré et al., 2020). In China, massive investments in high carbon infrastructure continue following a loosening of restrictions on construction of coal-fired power stations (Gosens & Jotzo, 2020). Fiscal stimuli will increase demand for energy, transport, timber, and agricultural products and, thus, for natural resources (Helm, 2020). Financial stimuli favoring resource-extractive and high-greenhouse-gas-emissions industries will be a blow to nature conservation because both intensify biodiversity loss (Díaz et al., 2019).

Reduced wildlife-based tourism income (subtheme 11.3)

Wildlife tourism is worth US$350 billion to the global economy annually, employing over 20 million people (WTTC, 2019) and helping governments justify protecting wildlife habitat (Lindsey et al., 2020). Following travel restrictions, international tourism declined 97% in April 2020 year on year, with likely declines of over 70% during 2020 (UNWTO, 2020). This has had a dramatic impact on the operation of protected areas that rely heavily on tourism for funding (Hockings et al., 2020; Lindsey et al., 2020). In South Africa's national parks, which are about 85% funded by tourism-related spending (Lindsey et al., 2020), tourism revenue dropped by 90% between April and June 2020 (Smith et al., 2021). In the Galapagos, at least half the expected 2020 tourism revenue is predicted to be lost (Diaz-Sanchez & Obaco, 2020). Wildlife tourism employees and communities will suffer financial hardship and may lose their livelihoods or be lost from the conservation sector. Recovery of wildlife-based tourism is likely to be slow because the pandemic will likely affect willingness and ability to travel (Spenceley et al., 2021).

Increased habitat destruction (subtheme 7.1)

Limitations on the enforcement of protected areas and their closure to tourists during lockdown may allow increased rates of habitat destruction and resource extraction in marine and terrestrial habitats (Hockings et al., 2020; Lindsey et al., 2020; McNeely, 2021), causing long-term damage to biodiversity. These pressures may be exacerbated by increased poverty (Lakner et al., 2021) and the collapse of alternative, more sustainable livelihoods in surrounding areas. The pandemic is likely to have had negative effects on forest cover (López-Feldman et al., 2020). During the first month following introduction of lockdown measures by individual governments in 2020, tropical deforestation increased by 63, 136, and 63% in the

TABLE 2 Themes and subthemes describing the observed and potential impacts of the COVID-19 pandemic on global biodiversity conservation, their direction of impact, and relative importance assessed via a combination of magnitude, probability, and duration

	Theme Subtheme[a]	Direction[b]	Mean magnitude[c]	Mean probability[d]	Mean duration[e]	Overall score[f]	Overall rank[g]	
1	Infection by SARS-CoV-2							
1.1	direct infection of wildlife by SARS-CoV-2	negative	41.9	1.8	2.2	167.8	51	
2	Impacts of reduced human mobility on nature							
2.1	reduced human disturbance	positive	51.2	2.6	1.4	186.0	47	
2.2	increased human disturbance near residential areas	negative	30.7	2.1	1.3	87.2	67	
2.3	reduced injury and mortality from transport	positive	41.8	2.5	1.3	137.4	61	
2.4	reduced global fishing activity	positive	47.2	2.3	1.3	143.9	59	
2.5	shorter food supply chains	positive	43.1	2.2	1.7	157.2	58	
3	Pollution							
3.1	reduced atmospheric pollution	positive	57.7	2.7	1.5	230.1	29	
3.2	reduced noise pollution	positive	50.3	2.7	1.2	162.3	56	
3.3	reduced light pollution	positive	32.9	2.0	1.1	70.8	68	
3.4	increased plastic and other solid waste pollution	negative	66.4	2.8	2.6	485.2	5	**
3.5	reduced cigarette waste and pollution	positive	24.8	1.8	1.5	67.7	69	
4	Trade in wild animals and plants							
4.1	positive effects of wildlife-trade restrictions	positive	59.7	2.4	2.4	337.3	10	**
4.2	negative effects of wildlife-trade restrictions	negative	49.7	2.1	2.4	249.5	24	
4.3	beneficial wildlife-trade demand trends	positive	52.7	2.3	2.0	249.8	23	
4.4	damaging wildlife-trade demand trends	negative	41.5	2.1	2.0	177.4	48	
4.5	disruption of wildlife-trade management measures	negative	44.6	2.4	1.6	167.3	52	
4.6	problems with disposal of animals in trade	negative	24.2	1.8	1.4	58.5	70	
5	Zoonotic diseases, land use, and biodiversity							
5.1	reducing land-use change to minimize emergence of zoonotic disease	positive	60.5	1.4	2.6	218.2	35	
5.2	potential role of ecological diversity in reducing disease transmission	positive	40.8	1.3	2.4	130.9	63	
6	Nature and human health and well-being							
6.1	nature's well-being benefits increasingly appreciated	positive	52.3	2.3	2.2	259.8	20	*
6.2	reduced opportunities to develop a connection to nature	negative	42.4	2.0	1.9	160.3	57	
6.3	mental health impacts on those involved in conservation	negative	42.4	2.1	1.9	175.1	49	
7	Habitat destruction and harvesting of wildlife							
7.1	increased habitat destruction	negative	75.2	2.8	2.6	548.0	3	**
7.2	increased illegal harvest of wild animals	negative	69.2	2.7	2.2	412.7	7	**
7.3	increased persecution of species involved in human-wildlife conflict	negative	45.0	2.3	1.9	196.1	43	
7.4	increased persecution of disease vectors	negative	45.5	2.3	2.0	212.8	39	

TABLE 2 (Continued)

	Theme	Subtheme[a]	Direction[b]	Mean magnitude[c]	Mean probability[d]	Mean duration[e]	Overall score[f]	Overall rank[g]	
8	Habitat and species management								
	8.1	reduction in habitat and species management	negative	60.2	2.7	1.9	304.5	14	*
	8.2	landscapes rewilding	?	32.8	1.7	1.8	100.9	66	
9	Conservation projects								
	9.1	conservation projects delayed	negative	60.3	2.9	1.8	315.9	12	*
	9.2	conservation staff redeployed	negative	48.1	2.6	1.5	189.4	46	
	9.3	increased costs of conservation projects	negative	46.5	2.4	1.9	215.1	36	
	9.4	long-term monitoring interrupted	negative	47.5	2.8	1.8	234.0	27	
	9.5	successfully adapting to lockdown digitally and remotely	positive	46.3	2.6	2.2	255.5	21	
10	Economic impacts								
	10.1	conservation benefits from reduced economic activity	positive	55.1	2.0	1.7	191.0	45	
	10.2	private sector disengages from conservation	negative	53.2	2.1	2.2	236.2	25	
	10.3	environment sidelined in economic recovery	negative	77.1	2.7	2.7	569.1	1	**
	10.4	green economic stimulus packages	positive	58.5	2.1	2.6	322.0	11	*
	10.5	natural climate solutions included in green economic stimuli	positive	55.4	2.0	2.6	285.3	16	*
11	Funding for conservation								
	11.1	reduced philanthropy	negative	64.6	2.5	2.2	364.4	8	**
	11.2	reduced replace with government funding	negative	73.3	2.8	2.5	510.1	4	**
	11.3	reduced wildlife-based tourism income	negative	76.3	3.0	2.4	552.4	2	**
	11.4	reduced income due to supply chain problems	negative	47.1	2.4	1.9	219.7	34	
	11.5	reduced carbon finance	negative	45.1	2.2	2.2	213.5	37	
	11.6	new funding opportunities	positive	40.3	1.9	2.1	162.7	55	
12	Organizational viability								
	12.1	conservation organizations' survival threatened	negative	58.0	2.6	2.3	339.8	9	**
13	Criminality and corruption								
	13.1	increased criminality and corruption	negative	47.5	2.3	2.1	226.3	32	
14	Legislation and regulation								
	14.1	new legislation and regulation delayed or rushed	negative	52.8	2.7	2.2	306.2	13	*
	14.2	existing nature-friendly regulations and their enforcement weakened	negative	67.5	2.7	2.5	447.4	6	**
	14.3	new nature-friendly legislation and regulation	positive	48.9	1.8	2.6	226.3	31	
15	International cooperation								
	15.1	reduced international cooperation	negative	50.4	1.9	2.3	213.1	38	
	15.2	increased international cooperation	positive	57.3	1.9	2.5	267.7	18	*
	15.3	reduced international support for conservation	negative	52.7	2.1	2.1	234.4	26	
	15.4	enhanced local conservation	positive	47.0	2.1	2.3	221.4	33	

(Continues)

TABLE 2 (Continued)

	Theme Subtheme[a]	Direction[b]	Mean magnitude[c]	Mean probability[d]	Mean duration[e]	Overall score[f]	Overall rank[g]	
16	Multilateral environmental agreements and international conferences							
16.1	postponement of conventions and conferences	negative	52.7	2.7	1.6	233.4	28	
16.2	potential benefits of delay to conventions	positive	49.9	2.1	2.2	226.3	30	
17	Cultural values and religious beliefs							
17.1	motivation from art	positive	28.3	1.9	1.9	104.8	65	
17.2	loss of indigenous knowledge	negative	44.0	1.9	2.6	212.7	40	
17.3	increased respect for nonhuman nature in some belief systems	positive	31.5	1.7	2.2	117.8	64	
17.4	increased adoption of plant-based diets	positive	46.5	1.7	2.4	193.5	44	
18	Education and training							
18.1	practical field education missed or limited	negative	44.7	2.8	1.6	202.9	41	
18.2	increased access to online education	positive	45.6	2.6	2.5	292.3	15	*
18.3	problems posed by a switch to online teaching	negative	42.9	2.5	1.8	196.6	42	
18.4	lost field seasons	negative	38.5	2.7	1.6	165.8	54	
18.5	loss of field education facilities	negative	32.0	2.2	1.9	135.6	62	
19	Employment in conservation							
19.1	protected-area rangers negatively affected	negative	51.3	2.6	1.9	250.1	22	
19.2	recruitment into conservation curtailed	negative	50.4	2.5	2.1	264.8	19	*
19.3	people leaving conservation	negative	40.8	2.0	2.0	170.5	50	
19.4	new jobs created in conservation	positive	39.6	1.6	2.2	141.2	60	
19.5	benefits of remote working	positive	46.5	2.6	2.4	284.8	17	*
19.6	problems with remote working	negative	34.3	2.7	1.8	166.0	53	

[a]Explanatory texts for each subtheme are in Appendix S3.
[b]Positive, broadly positive for biodiversity conservation globally; negative, broadly negative; ?, unclassifiable.
[c]Mean, across all 46 participants, of magnitude of impact scored on a numerical scale from 1 to 100 (details in Table 1).
[d]Mean, across all 46 participants, of probability of impact scored on a 3-level ordinal scale. Scores of 1, 2, and 3 allocated to subthemes scored as low, medium, and high probability, respectively (details in Table 1).
[e]Mean, across all 46 participants, of duration of impact scored on a 3-level ordinal scale. Scores of 1, 2, and 3 allocated to subthemes scored as short, medium, and long duration, respectively (details in Table 1).
[f]Product of means of magnitude, probability, and duration.
[g]Rank of product of means (1, highest; 70, lowest; **, rank 1-10; *, rank 11-20).

Americas, Africa, and Asia-Pacific, respectively, relative to the same period in 2019 (Brancalion et al., 2020). In Colombia, forest fires increased during lockdown relative to the number of fires expected in the absence of lockdown (Amador-Jiménez et al., 2020).

Reduced government funding (subtheme 11.2)

Governments have been responsible for unprecedented public spending during the pandemic, and global government debt is expected to rise from 83% of gross domestic product (GDP) in 2019 to 99% in 2020 (World Bank, 2021). Governments will be expected to service these debts and may reprioritize public spending, for example, toward healthcare (López-Feldman et al., 2020), which could potentially crowd out funding for nature conservation for years. With GDP shrinking globally (OECD, 2021), those countries whose overseas development assistance spending is linked to GDP may see aid budgets, and hence development-related conservation work, fall, or be redirected toward healthcare (Brown, 2021). Government funding for conservation dependent on financial markets may also decline, for example, for the Madagascar Biodiversity Fund (Vyawahare, 2020).

TABLE 3 Summary of the 20 subthemes describing the observed and potential impacts of the COVID-19 pandemic on global biodiversity conservation with the highest overall impact ranks, in rank order

Rank	Subtheme	
1	10.3	Environment sidelined in economic recovery
		Huge amounts of money will be invested in the economic recovery following the pandemic, but much is likely to be directed toward resource-extractive and greenhouse-gas emission-intensive industries, intensifying biodiversity and climate crises.
2	11.3	Reduced wildlife-based tourism income
		Restrictions during the pandemic have led to huge declines in international travel and thus significant reductions in wildlife-based tourism income for conservation, notably in protected areas.
3	7.1	Increased habitat destruction
		Difficulties enforcing protected areas during lockdown, exacerbated by increased poverty and the collapse of sustainable livelihoods, have led to increased rates of habitat destruction and resource extraction in both marine and terrestrial habitats.
4	11.2	Reduced government funding
		In the wake of the pandemic, governments globally may prioritize servicing national debt and spending on areas, such as health care, potentially crowding out public funding for nature conservation.
5	3.4	Increased plastic and other solid waste pollution
		The pandemic has led to a substantial increase in plastic pollution with associated negative impacts on biodiversity, with weakened restrictions on single-use plastics and reduced recycling provision.
6	14.2	Existing nature friendly regulations and their enforcement weakened
		A range of nature friendly regulations have been weakened by governments in response to the pandemic in order to support infrastructure development, agribusiness, and the extractive and oil and gas industries.
7	7.2	Increased illegal harvest of wild animals
		The pandemic led to reduced capacity to patrol and enforce protected areas and fewer visitors to witness illegal activities which, combined with loss of livelihoods and increased poverty, resulted in a reported increase in illegal hunting and fishing, threatening some species.
8	11.1	Reduced philanthropy
		The pandemic induced declines and volatility in global stock markets and may have reduced philanthropic funding, which, combined with a potential shift toward supporting humanitarian causes, could have significant consequences for the nonprofit conservation sector.
9	12.1	Conservation organizations' survival threatened
		Many conservation organizations have seen dramatic reductions in income due to the pandemic, particularly those funded by visitor attractions and wildlife tourism; some may not survive.
10	4.1	Positive effects of wildlife-trade restrictions
		The likely zoonotic origin of the virus that causes COVID-19 has led to new restrictions on the import, sale, and consumption of wild animals, which could reduce exploitation of some species, improving their conservation status.
11	10.4	Green economic stimulus packages
		There have been widespread calls for green stimulus packages to aid economic recovery from the pandemic which, if implemented, could mitigate climate-change impacts and, thus, benefit nature conservation.
12	9.1	Conservation projects delayed
		Numerous conservation projects, notably those involving fieldwork, travel, or face-to-face interactions, were postponed or abandoned during the pandemic, which had direct detrimental effects on wildlife.
13	14.1	New legislation and regulation delayed or rushed
		In 2020, the pandemic dominated political and government agendas, leaving little time for environmental legislation and regulations. Some permissive new regulations may have been adopted with less scrutiny than usual.
14	8.1	Reduction in habitat and species management
		Conservation of species and habitats was severely affected by restrictions, with reported disruptions to actions ranging from species reintroductions to invasive species control.
15	18.2	Increased access to online education
		The switch to online teaching by universities and others during lockdowns may accelerate a long-term trend toward virtual teaching which, if made freely available, could improve opportunities for a wider global conservation community.
16	10.5	Natural climate solutions included in green economic stimuli
		Green economic stimuli, which include solutions where natural ecosystems are managed to reduce greenhouse gas emissions and increase carbon sequestration, would benefit biodiversity directly, through protection, restoration, and creation of ecosystems and indirectly by slowing climate change.

TABLE 3 (Continued)

Rank	Subtheme	
17	19.5	Benefits of remote working
		During lockdowns many conservationists continued their desk-based work from home. The pandemic may catalyze a longer-term shift to home working and online meetings, reducing costs, and greenhouse gas emissions associated with travel.
18	15.2	Increased international cooperation
		The pandemic increased recognition that international cooperation between those working in human, animal, and ecosystem health is vital to control emerging zoonotic diseases, which may stimulate growth in multilateralism including in tackling the climate and biodiversity crises.
19	19.2	Recruitment into conservation curtailed
		Employment and recruitment rates were significantly affected by the pandemic, including within the conservation sector, with potentially damaging impacts on conservationists' career development.
20	6.1	Nature's well-being benefits increasingly appreciated
		There were many reports of the benefits of time spent in nature during lockdown, and this increased awareness of the links between nature and physical and mental health could have longer-term benefits for nature conservation; people may be more willing to act to protect biodiversity.

Increased plastic and other solid waste pollution (subtheme 3.4)

From discarded personal protective equipment and other hospital waste to disposable take-out utensils and delivery packaging, the fight against the pandemic has led to a substantial increase in plastic pollution (Vanapalli et al., 2021). An estimated 129 billion face masks and 65 billion gloves were used globally each month during the pandemic (Prata et al., 2020), creating a potential new source of microplastic pollution (Ardusso et al., 2021). Furthermore, citing health and safety, many jurisdictions rolled back restrictions on single-use plastics (Prata et al., 2020; Vanapalli et al., 2021). Compounding the problem, many recycling providers ceased to function during the pandemic, all contributing to an uptick in environmental pollution and associated negative impacts on biodiversity.

Existing nature-friendly regulations and their enforcement weakened (subtheme 14.2)

There have been many reports of nature-friendly regulations being weakened by governments during the pandemic (Kavousi et al., 2020) to support infrastructure development, agribusiness, and extractive industries including in protected areas (Kroner et al., 2021). The government of the United States froze enforcement of environmental regulations, notably monitoring of toxic emissions (Persico & Johnson, 2021), and opened an important marine protected area to fishing (Holden, 2020a). Both the United States (Holden, 2020b) and Australia (Cox, 2020) weakened environmental reviews of big infrastructure projects. The Canadian province of Alberta dismantled barriers to oil-sands development (Alexander & Stanley, 2020); the Brazilian government intensified its pattern of weakening environmental protection (Vale et al., 2021); and the Indonesian government abandoned its system for checking the legality of timber to boost exports (Jong, 2020). Many of these regulatory changes might otherwise have been resisted but were pushed through during the crisis (Schwartz et al., 2020).

Increased illegal harvest of wild animals (subtheme 7.2)

The pandemic led to reduced capacity to patrol and enforce protected areas and fewer visitors to witness illegal activities. This, combined with a loss of rural livelihoods and increased poverty, fueled by movements of workers from urban to rural areas (McNamara et al., 2020), may have increased hunting, much of it illegal, and thus, threatened some species (Hockings et al., 2020; Lindsey et al., 2020; McNeely, 2021; Usui et al., 2021). Reduced human presence may have contributed to an increase in black rhinoceros (*Diceros bicornis*) deaths (Maron, 2020). In the Comoro Islands, 28 endangered green sea turtles (*Chelonia mydas*) were killed (Marshall, 2020), and in India illegal wildlife hunting more than doubled during lockdown (Badola, 2020). Although some species may have been hunted less because of travel restrictions or supply-chain disruption, collapse of food supply chains, by contrast, may have contributed to increased wildlife harvesting (Bates et al., 2020; McNamara et al., 2020). A reduction in patrols and removal of observers from ships led to fears of an increase in illegal fishing incentivized by economic downturns; increased illegal fishing was reported in Argentina and Indonesia (Bennett et al., 2020).

Reduced philanthropy (subtheme 11.1)

Pandemic-induced declines and volatility in global stock markets (Nicola et al., 2020) may decrease wealth overall, at least temporarily, and thus, reduce capacity to give (Kavousi et al., 2020). A total of 93% of not-for-profit organizations surveyed worldwide in December 2020 reported being negatively affected by the pandemic; reduced income was among their greatest

concerns for 2021 (CAF America, 2021). In the United Kingdom, a 24% reduction in income during the financial year from 2020 to 2021 is forecast (Institute of Fundraising, 2020). Environmental organizations in the United Kingdom estimated they would each lose, on average, US$5 million from March 2020 to March 2021 (Wildlife & Countryside Link, 2020), and 38% of member organizations in one global conservation partnership forecast serious income reductions in 2020. This was compounded by a reluctance among environmental fundraisers to ask donors for support during a humanitarian crisis (NPC, 2020). Declines in philanthropic funding could have a dramatic impact on the nonprofit conservation sector.

Organizational survival threatened (subtheme 12.1)

One quarter of nonprofit organizations surveyed worldwide in August 2020 expected to close within a year if the impacts of the pandemic remained unchanged (CAF America, 2020). In late March 2020, 27% of environmental organizations in the United Kingdom reported they were either at high risk of becoming financially unviable in the coming months or had <4 months financial reserves remaining (Wildlife & Countryside Link, 2020). Similarly, a survey in April-June 2020 revealed that 16% of member organizations in one global conservation partnership expected to fail to meet their short-term cash-flow requirements during 2020 and risked closure. Conservation organizations funded from visitor attractions, including zoos and botanic gardens (Marshall, 2020), and from wildlife tourism (Waithaka et al., 2021), have been particularly affected. Some conservation organizations may not survive the pandemic, and the financial resilience of those that do will have been reduced.

Positive effects of wildlife-trade restrictions (subtheme 4.1)

Although the origins of the SARS-CoV-2 virus that causes COVID-19 are unproven, there are strong indications of a wild animal source (Zhang et al., 2020; Zhou et al., 2020) linked to wildlife trade in China (Borzée et al., 2020). Consequently, a spotlight has fallen on zoonotic risks from the wildlife trade, leading to new restrictions on import, sale, and consumption of particular species and products in some countries, most notably China and Vietnam (Borzée et al., 2020; Yang et al., 2020). Such measures may be extended and expanded as part of national strategies to reduce the risk of zoonotic disease. There are calls for adoption of increased international restrictions on wildlife trade for health-protection purposes through extension of the mandate of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or other means, which could amplify this impact (Scanlon, 2020). These restrictions may help reduce overexploitation of some wild species and, thus, improve their conservation status.

DISCUSSION

Our compendium documents the range of impacts that the COVID-19 pandemic has had and potentially will have on biodiversity conservation globally, 60% of which were negative. Which of these will have the greatest overall impact on biodiversity will become apparent only in time. Consequently, to aid the conservation community's response to the current and future pandemics, we sought the views of a diverse group of experienced conservationists on which impacts were likely to be greatest.

The nine subthemes that ranked highest overall (Table 3) were all individually damaging to biodiversity conservation. In combination, they present a worrying future of increased threats to conservation and reduced funding to counter them.

Two actions commonly proposed to protect against future zoonotic outbreaks (Dobson et al., 2020) are restrictions on wildlife trade (ranked highly here) and reducing land-use change, particularly deforestation. Enhanced restrictions on land use change ranked high on both magnitude and duration of impact, but very low on probability, suggesting participants were pessimistic it would be implemented in practice.

Several beneficial impacts were commonly reported in the media early in the pandemic including reduced human disturbance of wildlife, atmospheric pollution, and noise pollution (Bates et al., 2020). However, our scoring suggests that although these had moderately high magnitudes and probabilities of impact, they were of short duration; thus, they were not highly ranked overall.

While there are many ways our themes and subthemes could have been organized, we believe our categorization is pragmatic, although others could be equally valid. We could have merged impacts to make them broader, for example, all economic impacts. Merged impacts may have been scored higher than more narrowly defined impacts, but they may have been harder for participants to score, not least because of differing directions of impact. In addition, different subthemes may require different responses from the conservation community, so keeping them separate may provide clarity and aid responses.

The net impact scores for each theme (Appendix S4) showed some interesting differences from the subtheme analysis, particularly highlighting the mostly negative impacts on conservation projects and the mostly positive impacts of reduced human mobility. In contrast, the pandemic-induced economic impacts on nature appeared less severe at the theme level because harmful effects, such as the environment being sidelined in economic recovery (the most highly ranked subtheme), were somewhat balanced by positive impacts of green economic recovery and reduced economic activity. While these net theme-level findings are interesting, we believe they should be treated with caution. The scores were highly sensitive to the particular categorization of themes and subthemes adopted, and themes with one or few subthemes were likely to score lower than those containing more subthemes. In addition, the net impact scores are based on the assumption that, for example, a theme containing

two subthemes with equal scores, one positive and one negative in impact, is equivalent to a theme containing two subthemes both with zero impact, which seems inappropriate.

While our rankings cannot represent those of the entire conservation community, participants were reasonably balanced in gender, had worked in conservation in 47 countries in all occupied continents and in all sectors, and spanned the continuum from pure researcher to pure practitioner. Although most worked in relatively senior roles, this may have been beneficial because of their broader knowledge and experience.

Many of the impacts we documented have been identified previously (e.g., Bates et al., 2020; Corlett et al., 2020; Evans et al., 2020). However, our approach goes further by using a formal expert assessment approach to collate a comprehensive list of impacts, organizing them into a novel categorization of themes and subthemes and assessing their relative impact on global nature conservation. This approach could be applied to other sectors affected by the pandemic or to other circumstances in which dramatic disruption is occurring or expected.

We hope our compendium and results can inform approaches to prepare for and mitigate impacts of current and future pandemics, especially because these are increasingly likely (e.g., Dobson et al., 2020). For example, our compendium could provide the structure for a playbook on nature conservation responses to a pandemic. Our results suggest priority areas for rapid mobilization of monitoring during future pandemics (e.g., habitat destruction) and highlight the need for conservation organizations to stand up for hard-won environmental commitments when threatened by a crisis.

While the short-term policy implications of our work relate to identifying opportunities for a more sustainable postpandemic recovery and to ensuring that existing critical conservation capacity is not lost, in the longer term our results highlight the importance of creating a more resilient conservation community with diverse sources of funding. This could include, for example, funding from proper valuation of natural capital and ecosystem services and more sustainable management of natural resources (Lindsey et al., 2020).

The pessimism our results reveal toward the narrative of green recovery and build back better suggests that, although some measures have been adopted in some countries (Sandbrook et al., 2020), this approach is unlikely to be implemented more widely. This is borne out by experience to date; many countries have reduced environmental protections to enable rapid economic recovery (e.g., Kroner et al., 2021). Tackling this failure to embrace the opportunity for transformative change provided by the disruption caused by COVID-19 will require highly effective advocacy by conservation organizations and visionary leadership from politicians.

Inevitably, some impacts will change in importance through time, whereas others will have been missed or may emerge. Nevertheless, according to our assessment, the conservation and environmental optimism reported in the media during lockdown was a short-term phenomenon and, in practice, conserving the natural world will become substantially tougher in the coming years.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.