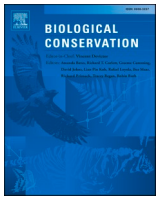
Biological Conservation 260 (2021) 109204

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon



Policy analysis

The conservation and ecological impacts of the COVID-19 pandemic

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ARTICLE INFO

Keywords:
COVID

1. Introduction

The outbreak of the COVID-19 pandemic at the start of 2020 led to dramatic reduction and alteration of human activity. People were confined to their homes, and international travel essentially ceased. National parks and other protected areas either closed or limited visitation, though some parks, particularly in urban areas, showed dramatically increased use. Universities and schools closed or shifted to online teaching, and field work was suspended or disrupted. Businesses closed and economic activity was reduced or changed in substantial ways.

All of these societal shifts have implications for the conservation of biological diversity, and the functioning of ecological communities. At the start of the pandemic lockdown in March and April of 2020, we, along with our colleagues, wrote a series of papers describing how the pandemic might affect conservation in the broadest sense, including education, research, ecotourism, citizen science programs, and wildlife protection (Corlett et al., 2020; Bates et al., 2020; Rutz et al., 2020). We pointed out that even though the pandemic is tragedy of enormous significance, it is also an opportunity to study the relationship between humans and the environment. What happens when tourism to natural areas rapidly declines? What happens when management actions are abruptly suspended? What happens when people's options for recreation are limited to exploring their local communities? How does wildlife respond to reduction of traffic, both on land and in the water, and associated noise? These types of questions both describe the effects of the pandemic, and illuminate the wider impacts we have on biodiversity through management and consumption of natural resources. It is also important to understand how the disruption of university courses, research activities, and employment will impact on research programs and the careers of students and recent graduates, as well as how public opinion and policy towards wildlife will change as a result of the pandemic.

To accomplish this goal, in the middle of 2020, we invited researchers from around the world to contribute articles to a Special Issue of *Biological Conservation* focusing on the conservation impacts of the pandemic lockdown. We wanted to encourage researchers to take an early look at the conservation impacts, with a goal towards describing new methods that could potentially be applied more generally. We recognize that many of the papers presented here are still preliminary and somewhat limited in scope and design, but we felt that it was important to take advantage of this unprecedented opportunity and give researchers a chance to publish early results. This compilation of studies from around the world allows a first look at the variability and scope of wildlife and conservation programs responses that will help formulate better informed hypotheses and improve subsequent research designs.

For all of the papers submitted to this Special Issue, we required the authors to provide a valid control for comparison. In many cases the control would be a natural system that had been monitored for one or more years prior to the pandemic. In the best case, a system would have been monitored for several years prior to the pandemic, during the pandemic, and then again after the pandemic lockdown had been eased. Alternatively, a system could be examined during the pandemic and then followed as it returned to normal after the lockdown.

While we had this requirement for controls, we also recognized that the pandemic is an unplanned experiment that happened suddenly and without warning. Therefore, some of the papers in this Special Issue have smaller sample sizes and less formal designs than we expect from articles submitted in normal times. For the sake of presenting the best available research on this topic as quickly as possible, we were willing to

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https://doi.org/10.1016/j.biocon.2021.109204
Received 26 May 2021; Accepted 28 May 2021
Available online 1 June 2021

accept articles with these limitations but required that authors interpret their results in the context of these limitations.

This Special Issue contains over 30 articles, making this probably the largest Special Issue ever published by *Biological Conservation*. It is striking how many countries and continents are presented in these articles, and the range of topics covered. We have also gathered together additional examples and anecdotes from around the world to create a broad synthesis of the ecological and conservation impacts of the pandemic (Bates et al., 2021).

Our hope is that conservation biologists reading these articles will see opportunities for using these same approaches in their own research and managers will consider possibilities for adjusting their management plans.

2. Changes in visitation and protected areas

Given that the COVID-19 pandemic heavily impacted people's ability and willingness to travel, it is no surprise that several articles in this issue focus on the effects of changes in ecotourism during the pandemic. A study by China et al. (2021) surveyed coral reefs in the Gulf of Aqaba in Israel, and found that the species richness of fish was greater during the lockdown, with tourism suspended, than after the lockdown, when tourism resumed. Similarly, Soto et al. (2021) monitored 29 beaches in Latin America during and after the lockdown. They discovered that in the absence of people, the beach vegetation began to recover, and local animals such as ghost crabs increased in abundance. There was also notably less litter and noise. Quesada-Rodríguez et al. (2021) studied a different aspect of the beach system: the nesting of leatherback sea turtles (*Dermochelys coriacea*) in Pacuare Reserve, Costa Rica. Despite the lack of income from tourists and educational programs, with the absence of humans and increased staff patrolling, the overall percentage of nesting turtles was higher than normal and hatching success of the eggs was at an appropriate level. These studies both demonstrate the influential role tourism has on ecosystems, and show that recovery is possible even for heavily impacted beach and ocean ecosystems.

However, not all of the effects from decreased tourism have been positive. In an innovative study, Souza et al. (2021) investigated changes in searches of information about national parks using Google Search. They found that during the pandemic lockdown, there were large declines in searches for information about national parks, especially international parks that depend on foreign travel. This slump in online interest was reflected in real life consequences for many parks. Smith et al. (2021) outline how revenue from international ecotourism in South Africa declined by 90% during the pandemic lockdown as international travelers were unable and unwilling to visit South Africa's parks. Likewise, Miller-Rushing et al. (2021) provide an extensive survey of USA parks, including many iconic parks such as Yellowstone and Great Smokies, and describe the extent of changes and severe reductions in visitation, management, research, staffing and education. Most educational and visitor programs moved online, and much of the research and management activities of the parks were simply cancelled.

Some wildlife populations have been negatively affected as well. In their article, Hentati-Sundberg et al. (2021) describe the effects on the common murre (*Uria aalge*) population of a coastal Swedish island. The absence of tourists to the island during the pandemic in 2020 led to increased visitation to the island of white tailed eagles (*Haliaeetus albicilla*), which normally avoid people. The eagles caused substantial disturbance to common murre colonies and a lower breeding success due to egg predation by gulls and crows during disturbance episodes.

The inability to travel has also affected urban ecosystems. Because traveling to distant locations and using indoor exercise facilities was not possible during the pandemic, many urban dwellers instead crowded into nearby parks to relax and exercise. In a study of a park in the Boston suburbs, Primack and Terry (2021) found that in the first two months of the pandemic, new social trails increased the network of trails by 36%, approximately the same length of new trails that had been created in the previous 48 years.

The COVID-19 pandemic has served to further illuminate the complex relationship between conservation and ecotourism. These studies demonstrate how tourism can both contribute to or impede the restoration of ecosystems, depending on the situation. New approaches need to be developed which allow tourism to have positive impacts on nature, at the same time as flagging those activities with harmful impacts.

3. Urban impacts

At the start of the pandemic, there were many anecdotal reports of wildlife entering cities and becoming more active. However, it was always uncertain if wildlife patterns really changing or if people were just outside more and making more wildlife observations. This topic was examined by Vardi et al. (2021) using an analysis of iNaturalist observations. They found that reports of large mammals venturing into cities during the pandemic appear to be exaggerated. The one exception is mountain lions (*Puma concolor*) which appear to have become more common in cities during the pandemic.

While the influx of wildlife to cities may have been exaggerated in some cases, there have been several instances of wildlife leaving cities. Gilby et al. (2021) examined the regional impact of the pandemic lockdown on coastal and urban ecosystems in Eastern Australia. The most notable change was Torresian crows (*Corvus orru*) departing from urban areas due to lack of food and foraging on nearby beaches, where they had surprisingly large ecological impacts due to outcompeting native scavengers, feeding on insects and invertebrates, and predating on the eggs of native birds. Soh et al. (2021) also examined the effects of the pandemic on bird communities, in this case in Singapore. They found that pigeons and other bird species shifted their foraging areas quite substantially after the pandemic lockdown was implemented as the birds could no longer readily find food discarded by people. Pigeons also spent more time foraging and less time resting due to the presumed difficulty of finding food.

In addition to the animal populations, the environmental characteristics of cities have been impacted. At a site in Colombia, Ulloa et al. (2021) measured noise levels during and after the pandemic lockdown. They found that noise levels were lower during the pandemic due to less human activity, and people noticed the sounds of wildlife more when there was less noise pollution.

4. Wildlife and technology

The pandemic highlighted the importance of using technology to continue monitoring wildlife and ecosystems even when people could not be in the field. Huveneers et al. (2021) describes the role played by an extensive acoustic monitoring system in the waters off Australia's coast. This system allows researchers to monitor changes in behavior and range of marine species, especially sharks and other fish species, during the pandemic when shark tourism was halted. It was found that species differed in their responses when they were no longer being fed at the site. Camera traps are another technology that will likely be a large part of future wildlife research. Blount et al. (2021) describe the increasing importance of camera traps in monitoring wildlife at night and documenting illegal activities, even before the pandemic. Traps took on greater importance during COVID-19 when in-person wildlife monitoring had to be suspended.

As people are spending more time outside, citizen science networks such as iNaturalist, eBird, and the National Phenology Network have also played a large role during the pandemic; however, increases in reported observations have not been uniform. Crimmins et al. (2021) reports that major citizen science platforms in the USA mostly experienced increases in observations during the pandemic, but most of the growth was in the eastern USA and more in urban areas. This geographic shift in reporting needs to be considered in any analysis investigating changes in species ranges and phenology. The findings by Crimmins

et al. (2021) are confirmed by a more detailed analysis of eBird data in the USA by Hochachka et al. (2021). They show that observers generally shifted towards more urban habitat and away from rare wetland habitat. Also, changes varied considerably among regions, suggesting that generalizations of shifting bias are difficult to make.

Analyses of citizen science networks have been conducted for other countries as well. Sánchez-Clavijo et al. (2021) found that observations of birds in Colombia using eBird and iNaturalist were high during the lockdown but were more concentrated in urban areas. There were also fewer total bird species reported and fewer observations of rare birds in more natural areas. Basile et al. (2021) found similar results in Italy, Spain, and the U.K.; they report an increase in citizen scientist activity in urban areas and a decrease in non-urban areas. These studies suggest that people are making more observations near their urban homes due to the lockdown.

5. Impacts of roads

One of the most serious threats to wildlife in general, and rare and endangered species in particular, is the growing network of roads. For many wildlife species, collisions with vehicles represent the greatest threat to their populations. To reduce this threat, measures have been implemented such as posting signs warning motorists about wildlife crossing, constructing under- and over-passes, and erecting fencing along roads. Wildlife biologists have also been monitoring highways to document the number, location, and species of animals killed by collisions. These baseline studies have allowed wildlife biologists to examine how the pandemic lockdown affected the pattern of wildlife being killed along highways.

Shilling et al. (2021) reports on an extensive study of wildlife mortality along roads in various USA states. This study found that with reduced traffic on highways during the pandemic lockdown, the mortality declined by 34% overall. There was a 58% decline in mortality during the pandemic for the mountain lion (*Puma concolor*), an apex predator of special conservation interest. In a comparable study from the Australian island of Tasmania, Driessen (2021) reports that roadkills decreased by 46% during the time of the pandemic. Bíl et al. (2021) also studied wildlife mortality along roads in 11 European countries. In four countries, Spain, Israel, Estonia, and Czechia, a reduction of road traffic during the pandemic resulted in a 40% decline in wildlife mortality. This situation contrasted with Sweden where there was no major lockdown and correspondingly no reduction in wildlife mortality.

Another major impact from roads is noise pollution. In a study of noise pollution in Boston protected areas, Terry et al. (2021) found that as traffic volumes and other human activities declined with the start of the pandemic, sound levels at two parks decreased as expected. However, at a third park, sound levels actually increased; even though there was less traffic, the vehicles were going much faster and making more noise.

These studies demonstrate that when there is rigorous, quantitative protocol for monitoring the environment near roads, the effects of the pandemic can be clearly demonstrated. The key question is whether the insights gained by this research can lead to changes in management of protected areas, such as the reducing the number of vehicles or speed limits, to reduce the chance of wildlife-vehicle collisions and the level of noise pollution.

6. Wildlife management

The pandemic has caused changes in many management and harvesting practices, with direct impacts on wildlife populations. LeTourneux et al. (2021) describe how reduced hunting activity during the pandemic allowed snow geese (*Anser caerulescens*), an over-abundant species, to feed more effectively on their spring migration grounds. As a consequence, the geese were in better body condition than previous years, leading to higher breeding success. This article emphasizes the importance of hunting for species management. Human impacts on animal populations are also shown by Coll et al. (2021) reporting on a rebound in shrimp populations during the lockdown, due to a decrease in harvesting by the Spanish fishing fleet. However, this effect was short lived once fishing resumed, suggesting that a sustained reduction in fishing is needed for marine ecosystems to recover.

Sumasgutner et al. (2021) propose establishing a Global Anthropause Raptor Research Network to target how this group of iconic, keystone species responds to changing levels of human disturbance and activity. This project has the potential to provide considerable insight as many raptor species avoid human presence, and so may change their distribution and behavior during the COVID-19 pandemic. This project may also engage the public in conservation, as hawks, eagles, and other raptors hold special interest for many people.

A review by Cooke et al. (2021) also investigates aquatic ecosystems, considering the positive and negative impacts that the pandemic could have on freshwater fish populations. This overview includes demand for food, monitoring, research, compliance, and management interventions. The authors argue that the pandemic provides insights into how this resource could be better managed. Hopefully, fish biologists throughout the world will heed this call to action, and search for the data needed to provide greater insight.

The lack of wildlife management and protection during the time of the pandemic also occurred at a time when rural people were often out of work. Aditya et al. (2021) provides an example of how illegally harvesting of pangolins in India increased during the time of the pandemic, as indicated by wildlife seizures by government officials.

The likelihood that the COVID-19 virus originally spread from wildlife to people has sparked recommendations for management practices aimed at preventing future pandemics. Dobson et al. (2020) suggest that a reduction in the wildlife trade and the handling and eating of wildlife by people is an effective strategy for preventing another pandemic. However, while the most likely source of COVID-19 is mammals, there is also a need to address the problems associated with other groups of animals. Borzée et al. (2021) argue that concerns about the spread of disease in East Asian countries should also extend to amphibians, with increased regulation of amphibian farming and the amphibian pet trade to reduce the chance of disease spread.

The pandemic is also affecting the careers of young conservation biologists who are learning the skills needed to manage protected areas and preserve biodiversity. A survey by Ramvilas et al. (2021) of Indian early-career conservation researchers found that their fieldwork, travel, and funding was highly disrupted by the pandemic. They hope that stakeholders will have a greater role in conservation priorities in the post-pandemic world.

7. Policy and attitudes

Several countries have used the pandemic to enact changes in their conservation policy. A paper by Huang et al. (2021) describes revisions to the Wildlife Protection Law in China which are intended to restrict the use of wild animals for food and traditional medicine. Combined with improved management of protected areas, these changes may provide benefits for wildlife populations and reduce the spread of diseases between humans and wild animals. However, while China and other Asian countries are moving towards increased protection of national parks, endangered species, and wildlife, many countries do not share these priorities. As described by Vale et al. (2021), the Brazilian government is taking advantage of the pandemic to weaken environmental legislation and enforcement in a misguided attempt to stimulate economic activity. As a result, the ability of the Amazon rain forest to protect biodiversity and sequester carbon is being reduced.

Public engagement has also suffered somewhat during the pandemic, although there are strong initiatives at work to get people involved in protecting wildlife and reducing the spread of disease. Special biodiversity events such as City Nature Challenges or Biodiversity Days help

increase interest in community-engaged science, though these types of events have faced difficulties during the pandemic. Kishimoto and Kobori (2021) report that volunteer participation in the Tokyo City Nature Challenge declined by around 60% during the pandemic, though the number of species observed was about the same. The spatial pattern of observations also changed from clustered to scattered. Lack of interest is also sometimes accompanied by negative attitudes towards wildlife. Using a survey, Lu et al. (2021) found that a large proportion of people in China have misconceptions of the role of bats in spreading disease to humans. Such misconceptions can lead to destruction of bats and their habitats, and a loss of the ecosystem services that they provide. After people watched a bat conservation lecture their attitudes towards and knowledge about bats improved. These findings indicates that improved public education about conservation and nature could go far to bolster public engagement and promote positve sentiments towards wildlife.

8. Conclusion

The purpose of this special issue has been to present an early group of studies that have measured the conservation and ecological impacts of the pandemic and associated lockdown. These studies primarily compare systems before and during the pandemic, and as such represent valuable initial studies of natural systems. Many of these systems will continue to be monitored as the pandemic ends, and follow-up studies will document recovery back to pre-pandemic conditions. It is also true that some systems will take years to return to normal, and some systems will not ever return to their pre-pandemic state. Prominent conservation biologist Lovejoy (2021) expresses a nuanced perspective and cautious optimism as he points out the connections between the COVID-19 pandemic, climate change, and the protection of biodiversity. He reminds us that nature is resilient and can recover if we give it a chance.

We plan to organize a second Special Issue later in 2021/2020 of papers that take a more thorough and long-term perspective of the conservation impacts of the pandemic lockdown, including impacts on biodiversity itself as well as management, monitoring, education, training, community science networks, and ecotourism.

Declaration of competing interest

There is no conflict of interest regarding this paper.

Acknowledgments

Canada Research Chairs program.

References

Aditya, V., Goswami, R., Mendis, A., Roopa, R., 2021. Scale of the issue: mapping the impact of the COVID-19 lockdown on pangolin trade across India. Biol. Conserv. 257, 109136 https://doi.org/10.1016/j.biocon.2021.109136.

Basile, M., Russo, L.F., Russo, V.G., Senese, A., Bernardo, N., 2021. Birds seen and not seen during the COVID-19 pandemic: the impact of lockdown measures on citizen science bird observations. Biol. Conserv. 256, 109079.

Bates, A.E., Primack, R.B., Moraga, P., Duarte, C.M., 2020. COVID-19 pandemic and associated lockdown as a "global human confinement experiment" to investigate biodiversity conservation. Biol. Conserv. 248, 108665.

Bates, A.E., Primack, R.B., Duarte, C.M., PAN-Environment Working Group, 2021. Global COVID-19 lockdown highlights humans as both threats and custodians of the environment. Biol. Conserv., 109175 https://doi.org/10.1016/j.biocon.2021.109175.

Bíl, M., Andrášik, R., Cícha, V., Arnon, A., Kruuse, M., Langbein, J., Náhlik, A., Niemi, M., Pokorny, B., Colino-Rabanal, J., Rolandsen, C.M., Seiler, A., 2021. COVID-19 related travel restrictions prevented numerous wildlife deaths on roads: a comparative analysis of results from 11 countries. Biol. Conserv. 256, 109076.

Blount, D., Chynoweth, M.W., Green, A.M., Sekercioğlu, Ç.H., 2021. Review: COVID-19 highlights the importance of camera traps for wildlife conservation research and management. Biol. Conserv. 256, 108984 https://doi.org/10.1016/j.biocon.2021.108984.

Borzée, A., Kielgast, J., Wren, S., Angulo, A., Chen, S., Magellan, K., Messenger, K.R., Hansen-Hendrikx, C.M., Baker, A., Santos, M.M.D., Kusrini, M., Jiang, J., Maslova, I. V., Das, I., Park, D., Bickford, D., Murphy, R.W., Che, J., Van Do, T., Nguyen, T.Q., Chuang, M.F., Bishop, P.J., 2021. Using the 2020 global pandemic as a springboard to highlight the need for amphibian conservation in eastern Asia. Biol. Conserv. 255, 108973.

China, V., Zvuloni, A., Roll, U., Belmaker, J., 2021. Reduced human activity in shallow reefs during the COVID-19 pandemic increases fish evenness. Biol. Conserv. 257, 109103 https://doi.org/10.1016/j.biocon.2021.109103.

Coll, M., Ortega-Cerdà, M., Mascarell-Rocher, Y., 2021. Ecological and economic effects of COVID-19 in marine fisheries from the Northwestern Mediterranean Sea. Biol. Conserv. 255, 108997.

Cooke, S.J., Twardek, W.M., Lynch, A.J., Cowx, I.G., Olden, J.D., Funge-Smith, S., Lorenzen, K., Arlinghaus, R., Chen, Y., Weyl, O.L.F., Nyboer, E.A., Pompeu, P.S., Carlson, S.M., Koehn, J.D., Pinder, A.C., Raghavan, R., Phang, S., Koning, A.A., Taylor, W.W., Bartley, D., Britton, J.R., 2021. A global perspective on the influence of the COVID-19 pandemic on freshwater fish biodiversity. Biol. Conserv. 253, 108932.

Corlett, R.A., Primack, R.B., Devictor, V., Maas, B., Goswami, V.R., Bates, A.E., Koh, L.P., Regan, T.J., Loyola, R., Pakeman, R.J., Cumming, G.S., Pidgeon, A., Johns, D., Roth, R., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biol. Conserv. 246, 108571.

Crimmins, T.M., Posthumus, E., Schaffer, S., Prudic, K.L., 2021. COVID-19 impacts on participation in large scale biodiversity-themed community science projects in the United States. Biol. Conserv. 256, 109017.

Dobson, A.P., Pimm, S.L., Hannah, L., Kaufman, L., Ahumada, J.A., Ando, A.W., Bernstein, A., Busch, J., Daszak, P., Engelmann, J., Kinnaird, M.F., Li, B.V., Loch-Temzelides, T., Lovejoy, T., Nowak, L., Roehrkranz, P.R., Vale, M.M., 2020. Ecology and economics for pandemic prevention. Science 369, 379–381.

Driessen, M.M., 2021. COVID-19 restrictions provide a brief respite from the wildlife roadkill toll. Biol. Conserv. 256, 109012.

Gilby, B.L., Henderson, C.J., Olds, A.D., Ballantyne, J.A., Bingham, E.L., Elliott, B.B., Jones, T.R., Kimber, O., Mosman, J.D., Schlacher, T.A., 2021. Potentially negative ecological consequences of animal redistribution on beaches during COVID-19 lockdown. Biol. Conserv. 253, 108926.

Hentati-Sundberg, J., Berglund, P.A., Hedjströmb, A., Olsson, O., 2021. COVID-19 lockdown reveals tourists as seabird guardians. Biol. Conserv. 254, e108950.

Hochachka, W.M., Alonso, H., Gutiérrez-Expósito, C., Miller, E., Johnston, A., 2021. Regional variation in the impacts of the COVID-19 pandemic on the quantity and quality of data collected by the project eBird. Biol. Conserv. 254, 108974.

Huang, Q., Wang, F., Yang, H., Valitutto, M., Songer, M., 2021. Will the COVID-19 outbreak be a turning point for China's wildlife protection: new developments and challenges of wildlife conservation in China. Biol. Conserv. 254, 108937.

Huveneers, C., Jaine, F.R.A., Barnett, A., Butcher, P.A., Clarke, T.M., Currey-Randal, L. M., Dwyer, R.G., Ferreira, L.C., Gleiss, A.C., Hoenner, X., Ierodiaconou, D., Lédée, E. J.I., Meekan, M.G., Pederson, H., Rizzari, J.R., van Ruth, P.D., Semmens, J.M., Taylor, M.D., Udyawer, V., Walsh, P., Heupel, M.R., Harcourt, R., 2021. The power of national acoustic tracking networks to assess the impacts of human activity on marine organisms during the COVID-19 pandemic. Biol. Conserv. 256, 108995.

Kishimoto, K., Kobori, H., 2021. COVID-19 pandemic drives changes in participation in citizen science project "city nature challenge" in Tokyo. Biol. Conserv. 255, 109001.

LeTourneux, F., Grandmont, T., Dulude-de Broin, F., Martin, M.C., Lefebvre, J., Kato, A., Bêty, J., Gauthier, G., Legagneux, P., 2021. COVID19-induced reduction in human disturbance enhances fattening of an overabundant goose species. Biol. Conserv. 255, e108968.

Lovejoy, T.E., 2021. Nature, COVID-19, disease prevention, and climate change. Biol. Conserv. (in press).

Lu, M., Wang, X., Ye, H., Wang, H., Qui, S., Zhang, H., Liu, Y., Luo, J., Feng, J., 2021. Does public fear that bats spread COVID-19 jeopardize bat conservation? Biol. Conserv. 254, 108952.

Miller-Rushing, A.J., Athearn, N., Blackford, T., Brigham, C., Cohen, L., Cole-Will, R., Edgar, T., Ellwood, E.R., Fisichelli, N., Pritz, C.F., Gallinat, A.S., Gibson, A., Hubbard, A., McLane, S., Nydick, K., Primack, R.B., Sachs, S., Super, P.E., 2021. COVID-19 pandemic impacts on conservation research, management, and public engagement in US national parks. Biol. Conserv. (in press).

Primack, R.B., Terry, C., 2021. New social trails made during the pandemic increase fragmentation of an urban protected area. Biol. Conserv. 255, 108993.

Quesada-Rodríguez, C., Orientale, C., Diaz-Orozco, J., Sellés-Rios, B., 2021. Impact of 2020 COVID-19 lockdown on environmental education and leatherback sea turtle (Dermochelys coriacea) nesting monitoring in Pacuare Reserve, Costa Rica. Biol. Conserv. 255, 10898.

Ramvilas, G., Dhyani, S., Kumar, B., Sinha, N., Raghavan, R., Selvaraj, G., Dikavar, N., Anoop, V.K., Shalu, K., Sinha, A., Kulkarni, A., Das, S., Molur, S., 2021. Insights on COVID-19 impacts, challenges, and opportunities for India's biodiversity research: from complexity to building adaptations. Biol. Conserv. 255, 109003.

Rutz, C., Loretto, M.-C., Bates, A.E., Davidson, S.C., Duarte, C.M., Jetz, W., Johnson, M., Kato, A., Kays, R., Mueller, T., Primack, R.B., Ropert-Coudert, Y., Tucker, M.A., Wikelski, M., Cagnacci, F., 2020. COVID-19 lockdown allows researchers to quantify the effects of human activity on wildlife. Nat. Ecol. Evol. 4, 1156–1159.

Sánchez-Clavijo, L.M., Martínez-Callejas, S.J., Acevedo-Charry, O., Díaz-Pulido, A., Gómez-Valencia, B., Ocampo-Peñuela, N., Ocampo, D., Olaya-Rodríguez, M.H., Rey-Velasco, J.C., Soto-Vargas, C., Ochoa-Quintero, J.M., 2021. Differential reporting of biodiversity in two citizen science platforms during COVID-19 lockdown in Colombia. Biol. Conserv. 256, 109077.

Shilling, F., Nguyen, T., Saleh, M., Khant Kyaw, M., Tapia, K., Trujillo, G., Bejarano, M., Waetjen, D., Peterson, J., Kalisz, G., Sejour, R., Croston, S., Ham, E., 2021. A reprieve from US wildlife mortality on roads during the COVID-19 pandemic. Biol. Conserv. 256, 109013.

Smith, M.K.S., Smit, I.P.J., Swemmer, L.K., Mokhatla, M.M., Freitag, S., Roux, D.J., Dziba, L., 2021. Sustainability of protected areas: vulnerabilities and opportunities

as revealed by COVID-19 in a national park management agency. Biol. Conserv. 255, 108985.
Soh, M.C.K., Pang, R.Y.T., Ng, B.X.K., Lee, B.P.Y.-H., Loo, A.H.B., Er, K.B.H., 2021. Restricted human activities shift the foraging strategies of feral pigeons (*Columba livia*) and three other commensal bird species. Biol. Conserv. 253, 108927.
Soto, E.H., Botero, C.M., Milanés, C.B., Rodríguez-Santiago, A., Palacios-Moreno, M., Díaz-Ferguson, E., Velázquez, Y.R., Abbehusen, A., Guerra-Castro, E., Simoes, N., Muciño-Reyes, M., Souza Filho, J.R., 2021. How does the beach ecosystem change without tourists during COVID-19? Biol. Conserv. 255, 108972.
Souza, C.N., Rodrigues, A.C., Correia, R.A., Normande, I.C., Costa, H.C.M., Guedes-Santos, J., Malhado, A.C.M., Carvalho, A.R., Ladle, R.J., 2021. No visit, no interest: how COVID-19 has affected public interest in world's national parks. Biol. Conserv. 256, 109015.
Sumasgutner, P., Buij, R., McClure, C.J.W., Shaw, P., Dykstra, C.R., Kumar, N., Rutz, C., 2021. Raptor research during the COVID-19 pandemic provides invaluable opportunities for conservation biology. Biol. Conserv. (in press).
Terry, C., Rothendler, M., Zipf, L., Dietze, M.C., Primack, R.B., 2021. Effects of the COVID-19 pandemic on noise pollution in three protected areas in metropolitan Boston (USA). Biol. Conserv. 256, 109039.
Ulloa, J.S., Hernández-Palma, A., Acevedo-Charry, O., Gómez-Valencia, B., Cruz-Rodríguez, C., Herrera-Varón, Y., Roa, M., Rodríguez-Buriticá, S., Ochoa-Quintero, J. M., 2021. Listening to cities during the COVID-19 lockdown: how do human activities and urbanization impact soundscapes in Colombia? Biol. Conserv. 255, 108996.
Vale, M.M., Berenguer, E., Argollo de Menezes, M., Viveiros de Castro, E.B., Pugliese de Sigueira, L., Portela, R.C.Q., 2021. The COVID-19 pademic as an opportunity to weaken environmental protection in Brazil. Biol. Conserv. 255, 108994.
Vardi, R., Berger-Tal, O., Roll, U., 2021. iNaturalist insights illuminate COVID-19 effects on large mammals in urban centers. Biol. Conserv. 254, 108953.