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The current COVID-19 pandemics is having a major impact on our global health and economies. There is widespread recognition that ecosystem disruption, including land-use change and illegal wildlife trade, is linked to the increasing emergence of zoonotic diseases. Here, we emphasize that protected areas play a fundamental role in buffering against novel disease outbreaks by maintaining ecosystem integrity. However, protected areas worldwide are facing increasing human pressures, which are being amplified by the unfolding COVID-19 crisis. Increased resources are thus urgently needed to mainstream a One Health approach to protected area management, focusing specifically on i) monitoring illegal wildlife trade, ii) biodiversity trends and iii) surveillance of zoonotic pathogens. Improving integration of public health into global biodiversity conservation policies should be a top priority to reduce the risk of future pandemics.

**Protected areas mitigate zoonotic disease spillover risks**

In the midst of the current pandemic caused by the emergence of the SARS-CoV-2 virus causing COVID-19, it is more evident than ever that emerging infectious diseases are a major threat for our global health and political stability. Ecosystem disruption and subsequent biodiversity loss are related to the emergence of infectious zoonoses worldwide [1]. Land conversion has been linked to changing host population densities and increased pathogen diversification, driving disease spillover in modified landscapes [2,3]. Land-use changes are also associated to the creation of road networks, further enhancing hunting pressure on wildlife populations [4]. A series of emerging infectious diseases, for example, SARS, Ebola and MERS, have been linked to wildlife use, trade and consumption [5]. Wildlife trade in Chinese wet markets has also been implicated as an important factor in the COVID-19 emergence [6].

Land-use changes and wildlife consumption and trade are two important threats impacting the global protected area network [7]. Hunting-induced defaunation has been shown to impact 20% of tropical forest protected areas [8]. Recent research has shown that numerous protected areas are facing intense human pressures [1,9,10], resulting in increased downgrading, downsizing and degazettement events [11]. However, large, well-funded and well-managed PAs are effective in preserving ecosystem health [12–14]. There is increasing recognition that PAs may buffer against the emergence of novel infectious diseases by avoiding drastic changes in host/reservoir abundance and distribution, and reducing contact rates between humans, livestock and wildlife [15–18]. The current COVID-19 pandemics further emphasizes the fact that PAs are at the forefront of preventing future disease outbreaks by maintaining ecosystem integrity [19]. Overall, these successive disease outbreaks have highlighted the importance of a collaborative, multi-sectoral, and transdisciplinary One Health approach with the goal of achieving optimal health outcomes that recognize the inter-connections between people, animals, and the environment [20]. Given ongoing discussions on the elaboration of a post-2020 Global Biodiversity Framework, the time is ripe for showcasing the
essential role of PAs in maintaining biodiversity and promoting global human health.

A line of defence against illegal wildlife trade
There is well-established evidence that PAs are a major source of illegal wildlife trade [7,21]. With wild vertebrates being reservoirs of a large repertoire of zoonotic pathogens, wildlife trade enhances several pathways of zoonotic pathogen spillover [5*]. Hence, in response to COVID-19, there have been several calls to ban all wildlife trade and shut local wet markets [27]. Many of these large-scale blanket bans do have unintended consequences for PAs, as they can undermine safe, legal and sustainable wildlife trade for communities living in and around PAs for whom wildlife constitutes a safety net [21,22*,23,24]. In the absence of strong law enforcement, wildlife trade bans can also drive wildlife trade to move underground [25]. Where bans remove legal supply options (e.g. captive breeding), they can accelerate illegal trade, increasing prices on black markets and driving over-exploitation of wild species [26]. In fact, there are emerging reports that the loss of conservation revenue caused by COVID-19 and the reduced capacity for patrolling and law enforcement has resulted in increased levels of illegal poaching in many PAs worldwide [23,27*,28]. PA managers are one of the first lines of defence against both emerging zoonoses and illegal wildlife trade. Therefore, they can play a critical role in better characterizing wildlife trade pathways, assessing conflicts emerging from wildlife bans, and promoting larger on-the-ground discussions on the complex web of inter-relations between wildlife trade, conservation, and global disease risk [22*,29]. We believe that the COVID-19 pandemics offers an interesting opportunity to reify the role of PAs in reducing the risk of further zoonoses and supporting human health.

Monitoring biodiversity on the frontlines of pandemic risk
High-risk areas for the mitigation and surveillance of novel disease emergence can be identified depending on levels of habitat fragmentation and human encroachment into natural habitats [30]. In addition, competent reservoir species are more likely to be generalist species that have adapted to human-dominated landscapes [31,32]. Therefore, shifts in mammalian community composition could be an early warning system indicating decline in threatened wildlife populations, ongoing homogenization at the community level, and ultimately poor PA effectiveness, and high risk of infectious disease emergence. Integrating remote sensing and emerging technologies like iDNA (invertebrate-derived DNA) into PA monitoring schemes is a promising approach to monitor habitat degradation, vertebrate populations, and specific or novel pathogens [33–36]. Increased conservation resources are thus needed to mainstream this One Health approach to wildlife monitoring across networks of PAs [37]. This will allow identifying PAs and surrounding buffer areas needing urgent attention and funding to restore ecological integrity and decrease risk for infectious disease emergence. We argue that a ‘disease risk mitigation’ dimension would complement new protected area targets post-2020 based on ecological outcomes [38] and would improve integration of human health into global biodiversity conservation policies.

Concluding remarks
The current COVID-19 pandemics poses an exceptional opportunity to raise awareness not only of the complex inter-connections between the health of people, wildlife, and our shared environment [5*], but also of the important role that a well-managed, sustainable and effective PA network plays in preventing the spillover of diseases from wildlife to people [39**]. Rampant levels of deforestation, increasing levels of illegal wildlife trade and encroachment in natural areas, threaten the ecology integrity of many PAs and should be therefore understood as a ticking time bomb for further zoonotic disease spillover [40–42]. With a rapidly accelerating human footprint [1], the role that PAs have historically played in regulating zoonotic disease dynamics cannot be considered as unlimited anymore [39**]. As such, there is a greater need than ever to adopt a One Health approach in PA management, targeting areas with a high-risk of emergence of zoonotic diseases for integrated conservation planning and management, and implementing monitoring systems for early detection of emerging infectious disease events and illegal wildlife trade. More broadly, we argue that effective and equitably managed networks of PAs can and should be part of the response to reduce the risk of future zoonotic pandemics.

Conflict of interest statement
Nothing declared.

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References and recommended reading
Papers of particular interest, published within the period of review, have been highlighted as:

* of special interest
** of outstanding interest

1. Jones KR, Venter O, Fuller RA, Allan JR, Maxwell SL, Negret PJ, Watson JEM: One-third of global protected land is under intense human pressure. Science 2018, 360:786-791.
2. Faust CL, Mccallum H, Bloomfield LSP, Gottdenker NL, Gillespie TR, Torrey CJ, Dobson AP, Plowright RK: Pathogen spillover during land conversion. Ecol Lett 2018, 21:471-483
   This study developed a multi-host model for pathogen transmission between species inhabiting intact and converted habitat, providing insights into the mechanisms driving disease emergence and spillover linked to land-use changes.
3. Zohdy S, Schwartz TS, Oaks JR: The coevolution effect as a driver of spillover. Trends Parasitol 2019, 35:399-408.
4. Benítez-López A, Alkemade R, Schipper AM, Ingram DJ, Verweij PA, Eikelboom JA, Hijbeergs MAJ: The impact of hunting on tropical mammal and bird populations. Science 2017, 356:180-183.

5. United Nations Environment Programme and International Livestock Research Institute (Eds): Preventing the Next Pandemic: Zoonotic Diseases and How to Break the Chain of Transmission, UNEP 2009.

This report provides a comprehensive synthesis of our knowledge about the root causes of the emergence of the novel coronavirus and other zoonotic diseases. It also offers a set of policy recommendations to prevent future disease outbreaks by strengthening the links between environmental and human health.

6. Andersen KG, Rambaut A, Lipkin WI, Holmes EC, Garry RF: The proximal origin of SARS-CoV-2. Nat Med 2020, 26:450-452.

7. Schulze K, Knights K, Coad L, Geldmann J, Leverington F, Essom A, Marr M, Bühler SHM, Hockings M, Burgess ND: An assessment of threats to terrestrial protected areas. Conserv Lett 2018, 11:e12435.

8. Benítez-López A, Santini L, Schipper AM, Busana M, Huijbregts MAJ: Intact but empty forests? Patterns of hunting-induced mammal defaunation in the tropics. PLoS Biol 2019, 17:e3000247.

9. Coad L, Watson J, Geldmann J, Burgess ND, Leverington F, Hockings M, Knights K, Di Marco M: Widespread shortfalls in protected area resourceing significantly undermine efforts to conserve biodiversity. Front Ecol Environ 2019, 17:259-264.

10. Geldmann J, Manica A, Burgess ND, Coad L, Balmford A: A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures. Proc Natl Acad Sci U S A 2019, 116:23209-23215.

11. Golden Kroner RE, Qin S, Cook CN, Krithivasan R, Pack SM, Bonilla OD, Cort-Kphansa KA, Coutinho B, Feng M, Martínez García M et al.: The uncertain future of protected lands and waters. Science 2019, 364:881-886.

12. Nolte C, Agrawal A, Silvius KM, Soares-Filho BS: Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon. Proc Natl Acad Sci U S A 2013, 110:4956-4961.

13. Gray C, Hill S, Newbold T, Hudson LN, Börger L, Contu S, Hoskins AJ, Ferrier S, Purvis A, Scharlemann JPW: Local biodiversity is higher inside than outside terrestrial protected areas worldwide. Nat Commun 2016, 7:12306.

14. Barnes M, Craigie I, Harrison L, Geldmann J, Leverington F, Essom A, Marr M, Bühler SHM, Hockings M, Burgess ND: An assessment of threats to terrestrial protected areas. Conserv Lett 2018, 11:e12435.

15. Golden Kroner RE, Qin S, Cook CN, Krithivasan R, Pack SM, Bonilla OD, Cort-Kphansa KA, Coutinho B, Feng M, Martínez García M et al.: The uncertain future of protected lands and waters. Science 2019, 364:881-886.

16. Kilpatrick AM, Salkeld DJ, Titcomb G, Hahn MB: The one health concept: 10 years old and a long road ahead. Front Vet Sci 2018, 5:14.

17. Terraube J, Fernández-Llamazares A, Cabeza M: The role of protected areas in supporting human health: a call to broaden monitoring tool. Curr Opin Environ Sustain 2017, 28:50-58.

18. Terraube J: Can protected areas mitigate Lyme disease risk in Fennoscandia? EcoHealth 2019, 16:184-190.

19. Dobson AP, Pimm SL, Hannah L, Kaufman L, Ahumada JA, Ando AW, Bernstein A, Busch J, Daszak P, Engelmann J et al.: Ecology and economics for pandemic prevention. Science 2020, 369:379-381.

20. Destoumsieux-Garzen D, Mavingui P, Boetsch G, Boissier J, Darriet F, Duboz P, Fritsch C, Giraudoux P, Le Roux F, Morand S et al.: The one health concept: 10 years old and a long road ahead. Front Vet Sci 2018, 5:14.

21. Strong M, Silva JA: Impacts of hunting prohibitions on multidimensional well-being. Biol Conserv 2020, 243:108451.

22. Vandebroek I, Pieroni A, Steeff JR, Hanazaki N, Ladio A, Nóbrega Alves RR, Picking D, Delgoda R, Maroyi A, van Andel T et al.: Reshaping the future of ethnobiology research after the COVID-19 pandemic. Nat Plants 2020, 6:723-730.

This viewpoint highlights the important role of ethnobiology in a post-COVID-19 world in order to ensure the adoption of a new conception of human health interconnected with the sustainability of the biosphere.

23. Hockings M, Dudley N, Elliott W, Napolitano Ferreira M, MacKinnon K, Pasha M, Phillips A, Stolton S, Woodley S et al.: COVID-19 and protected and conserved areas. Parks 2020, 26:7-24.

24. Roe D, Dickman A, Kock R, Milner-Gulland EJ, Rihoy E, Sas-Roifies M: Beyond banning wildlife trade: COVID-19, conservation and development. World Dev 2020, 136:105121.

25. Conrad K: Trade bans: a perfect storm for poaching? Trop Conserv Sci 2012, 5:245-254.

26. Rivalan P, Delmas V, Angulo E, Bull LS, Hall RJ, Courchamp F, Rossam AM, Leader-Williams N: Can bans stimulate wildlife trade? Nature 2007, 447:529-530.

27. Evans KL, Ewen JG, Guiller-Alarcoita G et al.: Conservation in the maestrom of Covid-19 – a call to action to solve the challenges, exploit opportunities and prepare for the next pandemic. Anim Conserv 2020, 23:235-238 http://dx.doi.org/10.1111/acc.12601

This Editorial identifies three main conservation challenges and a set of potential opportunities linked to current COVID-19 pandemics.

28. Lindsey P, Allan J, Brethony P, Dickman A, Robson A, Begg C, Bhammar H, Blanken L, Breuer T, Fitzgerald K et al.: Conserving Africa’s wildlife and wildlands through the COVID-19 crisis and beyond. Nat Ecol Evol 2020 http://dx.doi.org/10.1038/s41559-020-1275-6.

29. Volpato G, Fontefrancesco MF, Gruppuso P, Zocchi DM, Pieroni A: Baby pangolins on my plate: possible lessons to learn from the COVID-19 pandemic. J Ethnobiol Ethnomed 2020, 16:19.

30. Wilkinson DA, Marshall JC, French NP, Hayman DTS: Habitat fragmentation, biodiversity loss and the risk of novel infectious disease emergence. J R Soc Interface 2018, 15 20180463.

31. Johnson CK, Hitchens PL, Pandit PS, Rushmore J, Evans TS, Young CCW, Doye MM: Global shifts in mammalian population trends reveal key predictors of virus spillover risk. Proc R Soc B 2020, 287 20192736.

32. Gibb R, Redding DW, Chin KO, Donnelly CA, Blackburn TM, Newbold T, Jones KE: Zoonotic host diversity increases in human-dominated ecosystems. Nature 2020, 584:398-402.

33. Bitme-Essono PY, Ollomo B, Amathia C, Durand P, Mokoudom ND, Yacka-Mouele L, Okouga AP, Boundenga L, Mve-Okoko B, Obame-Nkoghe J et al.: Tracking zoonotic pathogens using blood-sucking flies as ‘flying syringes’. eLife 2017, 6:e22069.

34. Schnell IB, Boheim K, Schultz SE, Richter SR, Murray DC, Sinding MHS, Bass D, Cadle JE, Campbell MJ, Dolch R et al.: Debugging diversity - a pan-continental exploration of the potential of terrestrial blood-feeding leeches as a vertebrate monitoring tool. Mol Ecol Resour 2018, 18:1282-1298.

35. Abrams JF, Hoerig L, Brozovic R, Axtner J, Crampton-Platt A, Niederer A, Komora M, Richard M, Malik B et al.: Trade bans: a perfect storm for poaching? Trop Conserv Sci 2012, 5:245-254.

36. Rivalan P, Delmas V, Angulo E, Bull LS, Hall RJ, Courchamp F, Rossam AM, Leader-Williams N: Can bans stimulate wildlife trade? Nature 2007, 447:529-530.

37. Pringle R: Upgrading protected areas to conserve wild biodiversity. Nature 2017, 546:91-99.
38. Visconti P, Butchart SHM, Brooks TM, Langhammer PF, Marnewick D, V. Vergara S, Yanosky A, Watson JEM: Protected area targets post-2020. Science 2019, 364:239-241.

39. Di Marco M, Baker ML, Daszak P, De Barro P, Eskew EA, Godde CM, Harwood TD, Herrero M et al.: Sustainable development must account for pandemic risk. Proc Natl Acad Sci U S A 2020, 117:3888-3892.

   Key reading on the need for better integration of human health within sustainable development planning.

40. Veldhuis MP, Ritchie ME, Ogutu JO, Morrison TA, Beale CM, Estes AB et al.: Cross-boundary human impacts compromise the Serengeti-Mara ecosystem. Science 2019, 363:1424-1428.

41. Anderson E, Mammides C: The role of protected areas in mitigating human impact in the world’s last wilderness areas. Ambio 2020, 49:434-441.

42. Leberger R, Rosa IMD, Guerra CA et al.: Global patterns of forest loss across IUCN categories of protected areas. Biol Conserv 2020, 241:108299.