

## LETTER TO THE EDITOR

**Bat conservation and zoonotic disease risk: a research agenda to prevent misguided persecution in the aftermath of COVID-19**

R. Rocha<sup>1,2</sup>, S. A. Aziz<sup>3</sup>, C. E. Brook<sup>4</sup>, W. D. Carvalho<sup>5</sup>, R. Cooper-Bohannon<sup>6,7</sup>, W. F. Frick<sup>8,9</sup>, J. C.-C. Huang<sup>10</sup>, T. Kingston<sup>11</sup>, A. López-Baucells<sup>12</sup>, B. Maas<sup>13,14</sup>, F. Mathews<sup>15</sup>, R. A. Medellin<sup>16</sup>, K. J. Olival<sup>17</sup>, A. J. Peel<sup>18</sup>, R. K. Plowright<sup>19</sup>, O. Razgour<sup>20</sup>, H. Rebelo<sup>1,2</sup>, L. Rodrigues<sup>21</sup>, S. J. Rossiter<sup>22</sup>, D. Russo<sup>23</sup>, T. M. Straka<sup>24</sup>, E. C. Teeling<sup>25</sup>, T. Treuer<sup>26</sup>, C. C. Voigt<sup>27</sup> & P. W. Webala<sup>28</sup>

1 CIBIO/InBIO-UP, Research Centre in Biodiversity and Genetic Resources, University of Porto, Vairão, Portugal

2 CEABN-InBIO, Centre for Applied Ecology "Prof. Baeta Neves", Institute of Agronomy, University of Lisbon, Tapada da Ajuda, Lisbon, Portugal

3 Project Pteropus, Rimba, Kuala Lumpur, Malaysia

4 Department of Integrative Biology, University of California, Berkeley, Berkeley, CA, USA

5 Programa de Pós-Graduação em Biodiversidade Tropical, Universidade Federal do Amapá, Macapá-AP, Brazil

6 School of Biological and Environmental Sciences, University of Stirling, Stirling, UK

7 Bats without Borders, Blantyre, Malawi

8 Bat Conservation International, Austin, Texas, USA

9 Ecology and Evolutionary Biology, University of California, Santa Cruz, Santa Cruz, California, USA

10 Formosan Golden Bat's Home, Shuilin Township, Yunlin County, Taiwan

11 Department of Biological Sciences, Texas Tech University, Lubbock, Texas, USA

12 Natural Sciences Museum of Granollers, Granollers, Catalonia, Spain

13 Department of Botany and Biodiversity Research, University of Vienna, Vienna, Austria

14 Institute of Zoology, University of Natural Resources and Life Sciences, Vienna, Austria

15 University of Sussex, Brighton, UK

16 Instituto de Ecología, Universidad Nacional Autónoma de México, México City, México

17 EcoHealth Alliance, New York, NY, USA

18 Environmental Futures Research Institute, Griffith University, Nathan, Queensland, Australia

19 Department of Microbiology and Immunology, Montana State University, Bozeman, MT, USA

20 Biosciences, University of Exeter, Hatherly Laboratories, Exeter, UK

21 Instituto da Conservação da Natureza e das Florestas, Lisboa, Portugal

22 School of Biological and Chemical Sciences, Queen Mary, University of London, London, UK

23 Dipartimento di Agraria, Università degli Studi di Napoli Federico II, via Università 100, Portici (Napoli), Italy

24 Institute of Ecology, Technische Universität Berlin, Berlin, Germany

25 School of Biology and Environmental Science, University College Dublin, Dublin, Ireland

26 College of Engineering and Mathematical Sciences, University of Vermont, Burlington, Vermont, USA

27 Leibniz Institute for Zoo and Wildlife Research, Berlin, Germany

28 Department of Forestry and Wildlife Management, Maasai Mara University, Narok, Kenya

**Correspondence**

Ricardo Rocha, CIBIO-InBIO, Research Centre in Biodiversity and Genetic Resources, University of Porto, Rua Padre Armando Quintas, 4485-661 Vairão, Portugal. Tel: +351 252 660 400

Email: ricardo.nature@gmail.com

doi: 10.1111/acv.12636

COVID-19 has spread around the globe, with massive impacts on global human health, national economies and conservation activities. In the timely editorial about conservation in the maelstrom of COVID-19, Evans *et al.* (2020) urged the conservation community to collaborate with other relevant sectors of society in the search for solutions to the challenges posed by the current pandemic, as well as future zoonotic outbreaks. Considering the association of COVID-

19 with bats (Zhou *et al.*, 2020), bat conservationists will undoubtedly be key actors in this dialogue, and thus an action plan on how best to adjust bat conservation to this new reality, alongside a transdisciplinary research agenda, are clear priorities.

In spite of widespread recognition that bat-associated zoonotic spill-over events are largely rooted in human activities (Brierley *et al.*, 2016), bats are often presented as the

culprits of viral spill-over, with real-world repercussions for conservation efforts (López-Baucells, Rocha & Fernández-Llamazares, 2018). With around one-third of the world's >1400 bat species classified as threatened or data deficient by the IUCN Red List (Frick, Kingston & Flanders, 2019), even a few misguided actions can have long-lasting impacts on the viability of fragile bat populations. As such, avoiding public vendetta due to unwarranted negative associations between bats and zoonoses has become a pressing need since the emergence of COVID-19 (MacFarlane & Rocha, 2020).

Bats play critical roles in natural and human-modified ecosystems, providing numerous services that contribute to human well-being, such as suppression of agricultural pests, consumption of pathogen-carrying arthropods, and pollination and seed dispersal of ecologically-, culturally- and economically important plants (Kunz *et al.*, 2011; Russo, Bosso & Ancillotto, 2018). Yet, although evidence of important bat-mediated services continues to accumulate, so too does research highlighting links between bats and virulent pathogens (Schneeberger & Voigt, 2016). The recently established phylogenetic link between SARS-CoV-2, the causal agent of COVID-19, and its most similar known coronavirus relatives (Bat CoV RaTG13 and RmYN02), found in wild horseshoe bats *Rhinolophus* spp. (Zhou *et al.*, 2020), has further reinforced the association between bats and zoonotic disease risk. Worryingly, reports of COVID-related backlash against bats are emerging from around the world, including testimonies of actual or intended bat killings in Peru, India, Australia and Indonesia (see Durán, 2020; Goyal, 2020; Lentini *et al.*, 2020; Tsang, 2020), and accounts of Rwandan authorities blasting a colony of straw-coloured fruit bats *Eidolon helvum* (classified as Near Threatened by the IUCN Red List) with water from a high-pressure fire hose (P.W. Webala, pers. comm.). Even stakeholders who stand to gain from bat conservation have concerns resulting from often misleading media statements and assumptions linking all bats to SARS-CoV-2 or transmission of COVID-19. In Malaysia, for example, some sellers of durian, a culturally and economically important fruit crop throughout Southeast Asia that is largely pollinated by fruit bats (Aziz *et al.*, 2017), have declined to associate their businesses with bat-related outreach, fearing that an anti-bat public backlash might affect them (S.A. Aziz, pers. comm.). Increasing awareness about the zoonotic risks associated with the consumption of wildlife might curtail legal and illegal trade of wild animals (Evans *et al.*, 2020), thereby potentially reducing hunting pressure on some bat species. Yet, while communicating the real health risks associated with hunting, trading and eating bats might be needed to change risky human behaviours, negative and fear-inducing messages linking wild bats to zoonoses might further induce animosity towards the group, thereby compromising their conservation (MacFarlane & Rocha, 2020).

Evidence shows that culling and disturbance of bat colonies, have been unsuccessful in eliminating the risk of zoonotic spill-over and even increased the proportion of infected animals in other bat-virus systems (e.g. Streicker *et al.*, 2012; Amman *et al.*, 2014). Added to that, conservationists

have repeatedly emphasized the need for a balanced discourse when communicating zoonotic risks related to bats (López-Baucells *et al.*, 2018). Yet, even well-framed messages risk reinforcing negative associations between bats and infectious diseases, risking unintended consequences (MacFarlane & Rocha, 2020). Conservationists and health officials are, therefore, confronted with the challenge of informing the public about the potential health risks associated with bats, without eroding already limited support for their conservation. This complex problem requires an integrated, transdisciplinary research agenda to support the design of evidence-based guidance and action plans on how to minimize zoonotic health risks while supporting bats and their associated ecosystem services. Although the key priority areas to resolve and some of the intricacies associated with bat conservation and zoonotic disease risk are context-specific, we consider that there is a clear need to prioritise and invest resources into holistic, in-depth applied research, as well as multidisciplinary communication and collaboration, on the following:

- 1 characterization of bat-pathogen ecology and evolution (Hayman *et al.*, 2013; Brook *et al.*, 2020), including further work on host population distribution and pathogen transmission dynamics, pathogenesis and immunology of bat infections, and pathogen and host community interactions;
- 2 identification of potential drivers of bat-associated zoonotic spill-over events, including risk assessments and mitigation strategies related to the effects of:
  - i human encroachment into wildlife habitats and associated habitat loss and deterioration (White & Razgour, in press),
  - ii bat harvesting (Mildenstein, Tanshi & Racey, 2016) and guano extraction,
  - iii cohabitation/coexistence between synanthropic bats and humans (Russo & Ancillotto, 2015; López-Baucells, *et al.*, 2017),
  - iv interactions between bats and other species that may act as intermediate hosts, including domestic (e.g. Pulliam *et al.*, 2012; Khayat *et al.*, 2020) and wild animals (Menachery *et al.*, 2015) that are brought into close proximity with bats by humans, for example, in agricultural settings, animal farming or live-animal markets,
  - v risk of pathogen transmission to bats from humans or other species (Olival *et al.*, in press);
- 3 investigation of the human dimensions of bat conservation (Kingston, 2016). Conservation psychology will play a key role in changing behaviours associated with spill-over risks and in building support for bat conservation following COVID-19 (MacFarlane & Rocha, 2020). Priorities for promoting behaviour change include:
  - i assessment of drivers of human behaviours towards bats (e.g. attitudes, emotions, values) with a focus on conservation and strategies to reduce zoonotic spill-over risk (Shapiro *et al.*, 2020),

- ii identification of human-bat conflicts (e.g. fruit crop raiding, urban roosting) and assessment of evidence-based and ethically acceptable interventions to reduce such conflicts (e.g. Tollington *et al.*, 2019),
  - iii quantification of known and potential ecosystem services provided by bats, including those linked to human health and well-being (e.g. consumption of disease-carrying mosquitoes and suppression of agricultural pests; Williams-Guillén *et al.*, 2016; Kemp *et al.*, 2019),
  - iv development of context-specific guidelines for communicating about bat-borne zoonoses and conservation that deliver accurate information and practical recommendations, caution against persecution of bats and promote public health (MacFarlane & Rocha, 2020);
- 4 investment and increased interaction between bat conservation networks (e.g. <https://gbatnet.blogspot.com/>) and One Health initiatives (e.g. <https://batonehealth.org/> and <https://www.bohrn.net/>) to advance conservation efforts through holistic and ethical research (Costello *et al.*, 2016; Kingston *et al.*, 2016; Phelps *et al.*, 2019).

This list is not exhaustive, but in our view, it represents high-priority collaborative research areas that warrant further development if we are to better articulate how bat conservation is part of global conservation solutions and valued by an increasingly risk-averse society.

The COVID-19 pandemic has reinforced the already pressing need for closer collaboration between bat and human health researchers, conservation practitioners, public health and environmental authorities and, importantly, public communicators and social media ‘influencers’. Bat-associated human health risks are largely driven by habitat degradation, and ecological solutions offer an opportunity for win-win outcomes for both bats and people (Phelps *et al.*, 2019; Sokolow *et al.*, 2019). The pandemic will undoubtedly impact conservation at large (Evans *et al.*, 2020), but its effects on bat conservation, driven by negative perceptions, are likely to be particularly acute. In a world where bats and humans are increasingly connected, all stakeholders must work together to better understand and frame bat-related health risks. Only by doing so will we be able to provide society with a comprehensive and unbiased understanding of our coexistence with bats, thus safeguarding the long-term persistence of this diverse group and the many life-enhancing services it provides.

## Acknowledgements

RR was supported by a ARDITI – Madeira’s Regional Agency for the Development of Research, Technology and Innovation Fellowship (M1420-09-5369-FSE-000002), CEB by a Miller Postdoctoral Fellowship and NIH Grant # R01-AI129822-01, AJP by an ARC DECRA Fellowship (DE190100710), KJO by a US Defense Threat Reduction Agency Award (HDTRA11710064), RKP by NSF (DEB-1716698 and DARPA D18AC00031) and ECT by an Irish Research Council Laureate Award.

## References

- Amman, B.R., Nyakarahuka, L., McElroy, A.K., Dodd, K.A., Sealy, T.K., Schuh, A.J., Shoemaker, T.R., Balinandi, S., Atimmedi, P., Kaboyo, W. & Nichol, S.T. (2014). Marburgvirus resurgence in Kitaka Mine bat population after extermination attempts. *Uganda. Emerg. Infect. Dis.* **20**, 1761–1764.
- Aziz, S.A., Clements, G.R., McConkey, K.R., Sritongchuy, T., Pathil, S., Abu Yazid, M.N.H., Campos-Arceiz, A., Forget, P.M. & Bumrungsri, S. (2017). Pollination by the locally endangered island flying fox (*Pteropus hypomelanus*) enhances fruit production of the economically important durian (*Durio zibethinus*). *Ecol. Evol.* **7**, 8670–8684.
- Brierley, L., Vonhof, M.J., Olival, K.J., Daszak, P. & Jones, K.E. (2016). Quantifying global drivers of zoonotic bat viruses: a process-based perspective. *The American Naturalist* **187**, 53–64. <https://doi.org/10.1086/684391>
- Brook, C.E., Boots, M., Chandran, K., Dobson, A.P., Drosten, C., Graham, A.L., Grenfell, B.T., Müller, M.A., Ng, M., Wang, L.F. & Van Leeuwen, A. (2020). Accelerated viral dynamics in bat cell lines, with implications for zoonotic emergence. *Elife* **9**, e48401.
- Costello, M.J., Beard, K.H., Corlett, R.T., Cumming, G.S., Devictor, V., Loyola, R., Maas, B., Miller-Rushing, A.J., Pakeman, R. & Primack, R.B. (2016). Field work ethics in biological research. *Biol. Conserv.* **203**, 268–271.
- Durán, T.G. (2020). En defensa de los murciélagos: resistentes a los virus, pero no a los humanos. Retrieved from <https://es.mongabay.com/2020/03/coronavirus-murcielagos-humanos-virus-covid-19/>.
- Evans, K.L., Ewen, J.G., Guillera-Aroita, G., Johnson, J.A., Penteriani, V., Ryan, S.J., Sollmann, R. & Gordon, I.J. (2020). Conservation in the maelstrom of Covid-19—a call to action to solve the challenges, exploit opportunities and prepare for the next pandemic. *Anim. Conserv.* **23**, 235–238.
- Frick, W.F., Kingston, T. & Flanders, J. (2019). A review of the major threats and challenges to global bat conservation. *Ann. N. Y. Acad. Sci.* **1469**(1), 5–25. <https://doi.org/10.1111/nyas.14045>.
- Goyal, Y. (2020) More than 150 bats killed in Rajasthan owing to fear of COVID-19 spread. Retrieved from [https://www.tribuneindia.com/news/nation/more-than-150-bats-killed-in-rajasthan-owing-to-fear-of-covid-19-spread-81668?fbclid=IwAR0WcG8b\\_EIRVDOJCYTi\\_jmVNiFrCduH\\_JRzNVUu\\_2\\_EBmL151LTJxQ9IbY](https://www.tribuneindia.com/news/nation/more-than-150-bats-killed-in-rajasthan-owing-to-fear-of-covid-19-spread-81668?fbclid=IwAR0WcG8b_EIRVDOJCYTi_jmVNiFrCduH_JRzNVUu_2_EBmL151LTJxQ9IbY).
- Hayman, D.T.S., Bowen, R.A., Cryan, P.M., McCracken, G.F., Oshea, T.J., Peel, A.J., Gilbert, A., Webb, C.T. & Wood, J.L.N. (2013). Ecology of zoonotic infectious diseases in bats: current knowledge and future directions. *Zoonoses Public Health* **60**, 2.
- Kemp, J., López-Baucells, A., Rocha, R., Wangenstein, O.S., Andriatafika, Z., Nair, A. & Cabeza, M. (2019). Bats as potential suppressors of multiple agricultural pests: a case

- study from Madagascar. *Agric. Ecosyst. Environ.* **269**, 88–96.
- Khayat, R.O., Grant, R.A., Ryan, H., Melling, L.M., Dougill, G., Killick, D.R. & Shaw, K.J. (2020). Investigating cat predation as the cause of bat wing tears using forensic DNA analysis. *Ecol. Evolution* **10**(15), 8368–8378. <https://doi.org/10.1002/ece3.6544>.
- Kingston, T. (2016). Cute, creepy, or crispy—how values, attitudes, and norms shape human behaviour toward bats. In *Bats in the anthropocene: Conservation of bats in a changing world*. 571–588. Voigt, C.C. & Kingston, T. (Eds.) Springer.
- Kingston, T., Aguirre, L., Armstrong, K., Mies, R., Racey, P., Rodríguez-Herrera, B. & Waldien, D. 2016. Networking networks for global bat conservation. In *Bats in the anthropocene: Conservation of Bats in a Changing World*. 539–569. Voigt, C.C. & Kingston, T. (Eds.). Springer.
- Kunz, T.H., de Torre, E.B., Bauer, D., Lobo, T. & Fleming, T.H. (2011). Ecosystem services provided by bats. *Ann. N. Y. Acad. Sci.* **12323**, 1–38.
- Lentini, P., Peel, A., Field, H. & Welbergen, J. (2020) No, Aussie bats won't give you COVID-19. We rely on them more than you think. The Conversation <https://theconversation.com/no-aussie-bats-wont-give-you-covid-19-we-rely-on-them-more-than-you-think-137168>.
- López-Baucells, A., Rocha, R., Andriatafika, Z., Tojoso, T., Kemp, J., Forbes, K.M. & Cabeza, M. (2017). Roost selection by synanthropic bats in rural Madagascar: what makes non-traditional structures so tempting? *Hystrix*, **28**, 28–35.
- López-Baucells, A., Rocha, R. & Fernández-Llamazares, Á. (2018). When bats go viral: negative framings in virological research imperil bat conservation. *Mammal Rev.* **48**, 62–66.
- MacFarlane, D. & Rocha, R. (2020). Guidelines for communicating about bats to prevent persecution in the time of COVID-19. *Biol. Conserv.* **248**, 108650.
- Menachery, V.D., Yount, B.L., Debbink, K., Agnihothram, S., Gralinski, L.E., Plante, J.A., Graham, R.L., Scobey, T., Ge, X.Y., Donaldson, E.F. & Randell, S.H. (2015). A SARS-like cluster of circulating bat coronaviruses shows potential for human emergence. *Nat. Med.* **21**, 1508–1513.
- Mildenstein, T., Tanshi, I. & Racey, P.A. (2016). Exploitation of bats for bushmeat and medicine. In *Bats in the anthropocene: Conservation of bats in a changing world*. 325–375. Voigt, C.C. & Kingston, T. (Eds.) Springer.
- Olival, K., Cryan, P., Amman, B., Baric, R., Blehert, D., Brook, C., Calisher, C., Castle, K., Coleman, J., Daszak, P., Epstein, J., Field, H., Frick, W., Gilbert, A., Hayman, D., Ip, H., Karesh, W., Johnson, C., Kading, R., Kingston, T., Lorch, J., Mendenhall, I., Peel, A., Phelps, K., Plowright, R., Reeder, D., Reichard, J., Sleeman, J., Streicker, D., Towner, J. & Wang, L.F. (in press). Possibility for reverse zoonotic transmission of SARS-CoV-2 to free-ranging wildlife: a case study of bats. *PLOS Pathog.* <https://doi.org/10.1371/journal.ppat.1008758>
- Phelps, K.L., Hamel, L., Alhmod, N., Ali, S., Bilgin, R., Sidamonidze, K., Urushadze, L., Karesh, W. & Olival, K.J. (2019). Bat research networks and viral surveillance: Gaps and opportunities in Western Asia. *Viruses* **11**, 240.
- Pulliam, J.R., Epstein, J.H., Dushoff, J., Rahman, S.A., Bunning, M., Jamaluddin, A.A., Hyatt, A.D., Field, H.E., Dobson, A.P. & Daszak, P. (2012). Agricultural intensification, priming for persistence and the emergence of Nipah virus: a lethal bat-borne zoonosis. *J. R. Soc. Interface* **9**, 89–101.
- Russo, D. & Ancillotto, L. (2015). Sensitivity of bats to urbanization: a review. *Mamm. Biol.* **80**, 205–212.
- Russo, D., Bosso, L. & Ancillotto, L. (2018). Novel perspectives on bat insectivory highlight the value of this ecosystem service in farmland: research frontiers and management implications. *Agric. Ecosyst. Environ.* **266**, 31–38.
- Schneeberger, K. & Voigt, C.C. (2016). Zoonotic viruses and conservation of bats. In *Bats in the Anthropocene: Conservation of Bats in a Changing World*. 263–292. Voigt, C.C. & Kingston, T. (Eds.). Springer.
- Shapiro, H.G., Willcox, A.S., Tate, M. & Willcox, E.V. (2020). Can farmers and bats co-exist? Farmer attitudes, knowledge, and experiences with bats in Belize. *Hum-Wildl Interact.* **14**, 5–15.
- Sokolow, S., Nova, N., Pepin, K., Peel, A., Pulliam, J., Manlove, K., Cross, P., Becker, D., Plowright, R., McCallum, H. & Leo, G. (2019). Ecological interventions to prevent and manage zoonotic pathogen spillover. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* **374**, 20180342.
- Streicker, D.G., Recuenco, S., Valderrama, W., Gomez Benavides, J., Vargas, I., Pacheco, V., Condori Condori, R.E., Montgomery, J., Rupprecht, C.E., Rohani, P. & Altizer, S. (2012). Ecological and anthropogenic drivers of rabies exposure in vampire bats: implications for transmission and control. *Proc. R. Soc. B* **279**, 3384–3392.
- Tollington, S., Kareemun, Z., Augustin, A., Lallchand, K., Tatayah, V. & Zimmermann, A. (2019). Quantifying the damage caused by fruit bats to backyard lychee trees in Mauritius and evaluating the benefits of protective netting. *PLoS One* **14**, e0220955.
- Tsang, Y. (2020) Hundreds of bats culled in Indonesia to 'prevent spread' of the coronavirus. Retrieved from <https://www.scmp.com/video/asia/3075441/hundreds-bats-culled-indonesia-prevent-spread-coronavirus>.
- White, R.J. & Razgour, O. (2020). Emerging zoonotic diseases originating in mammals: a systematic review of effects of anthropogenic land-use change. *Mammal Rev.* <https://doi.org/10.1111/mam.12201>
- Williams-Guillén, K., Olimpi, E., Maas, B., Taylor, P.J. & Arlettaz, R. (2016). Bats in the anthropogenic matrix: challenges and opportunities for the conservation of Chiroptera and their ecosystem services in agricultural

landscapes. In *Bats in the anthropocene: Conservation of bats in a changing world*. 151–186. Voigt, C.C. & Kingston, T. (Eds.). Springer.  
Zhou, H., Chen, X., Hu, T., Li, J., Song, H., Liu, Y., Wang, P., Liu, D., Yang, J., Holmes, E.C., Hughes, A.C., Bi, Y. &

Shi, W. (2020). A novel bat coronavirus closely related to SARS-CoV-2 contains natural insertions at the S1/S2 cleavage site of the spike protein. *Curr. Biol.* **30**, 2196–2203.