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

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COVID-19 has spread around the globe with massive impacts to 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 and 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.

Although widespread recognition that bat-associated zoonotic spill over events are largely rooted in human activities (Olival, 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 >1,400 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 misguided public vendetta due to unwarranted negative associations between bats and zoonoses, a clear need prior to the current pandemic, became even more pressing after 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*) 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 anti-bat public backlash might affect them (S.A. Aziz, pers. comm.). On the other hand, 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), thus 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 and thus compromise their conservation (MacFarlane & Rocha, 2020).

Evidence shows that culling attempts, 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), and conservationists have repeatedly emphasized the pressing 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, potentially leading to unintended consequences (MacFarlane & Rocha, 2020). Conservationists and health officials are thus 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 necessitates 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 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 more resources into holistic, in-depth, applied research, 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 assessment and mitigation strategies related to the effects of:

    ○ Human encroachment into wildlife habitats and associated habitat loss and deterioration (White & Razgour, in press),
    ○ Bat harvesting (Mildenstein, Tanshi & Racey*,* 2016) and guano extraction,
    ○ Cohabitation/coexistence between synanthropic bats and humans (Russo & Ancillotto, 2015; López-Baucells, *et al.,* 2017),
    ○ Interactions between bats and other species that may act as intermediate hosts, including domestic (e.g., Pulliam *et al.,* 2012; Khayat *et al.,* in press) and wild animals (Menachery *et al.*, 2015) that are brought into close proximity with bats by humans, in e.g., agricultural settings, animal farming, or live-animal markets,
    ○ 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:

    ○ 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),
    ○ 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),

    - 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-Guillèn *et al*., 2016; Kemp *et al*., 2019),
    - 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).

The list is not exhaustive, but in our view 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, is 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.

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