




Letter to the Editor

# Pandemics and the Need for Automated Systems for Biodiversity Monitoring

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The primary data underlying worldwide conservation efforts come from observational field studies (Butchart et al. 2010, Geijzendorffer et al. 2016, Proença et al. 2017). Large-scale networks for biodiversity monitoring, especially based on citizen science, have been important sources of standardized time-series datasets that feed biodiversity indicators (Bunce et al. 2008, Proença et al. 2017, Guralnick et al. 2018). Human observers are usually the core of a biological record and our inability to foresee the consequences for biodiversity conservation in the midst of pandemics (e.g., 2019 novel coronavirus [COVID-19]) is opening a gap in primary data underlying long-term biodiversity monitoring programs worldwide. Considering the high stakes of disrupting time-series data collections and monitoring programs (Wintle et al. 2010) and the urge to prepare for economic and social effects (Corlett et al. 2020), biodiversity monitoring programs should consider broadening the use of automated methods of *in situ* data collection.

Following advices from the World Health Organization for social distancing, many countries and provinces adopted sanctions and mandatory lockdown. Because ecological fieldwork is seldom considered an essential service, many researchers were prevented from carrying out field collection. Even where lockdown has not been decreed, setting up logistics for a field season may be challenging amidst an ongoing pandemic. For instance, a number of protected areas worldwide have been temporarily closed to safeguard the staff and deter overcrowding (Parks Canada 2020, Repanshek 2020). For the first time in almost 5 decades, the North American Breeding Bird Survey suspended volunteer surveys and field work for the 2020 breeding season (Paul 2020). Other field studies underlying the census of bird populations have also been affected (Renault 2020) and this situation is also being experienced by other researchers around the world (Kimbrough 2020). Although some activities are resuming in countries employing proper population testing and assisted by a good healthcare system, the uncertainties arising from an underestimated spread of COVID-19 elsewhere in the world hinder estimating when normality will resume. Further, ecologists are far from understanding whether COVID-19 can be transmitted to wildlife and generate severe outcomes

on wild populations (e.g., great apes; Gillespie and Leendertz 2020). With the recommendation of suspending and reducing fieldwork during the COVID-19 outbreak, ecologists could more widely adopt the use of regular and remote observational systems as standard practice to avoid data gaps.

With the emergence of new technologies for data collection, there was a broad uptake of sensor technologies into ecology and conservation research (Pimm et al. 2015). Sensors installed in satellites and aircrafts have expanded our capabilities to collect high-resolution environmental data over large spatial extents and in the long term (Turner 2014) and they have become key to tracking environmental changes and ecosystem functioning (Pettorelli et al. 2014, 2016). Nevertheless, many biological indicators require data on the occurrence and abundance of organisms and obtaining standardized baselines for biodiversity monitoring is fundamental for conservation (Beaudrot et al. 2016, Jetz et al. 2019). To improve the capacities of direct observations in fieldwork, automated methods using image, video, and sound sampling emerged as complementary tools for biodiversity monitoring (Hamel et al. 2013, Dell et al. 2014, Weinstein 2018, Sugai et al. 2020). These *in situ* remote sensing methods provide standardized techniques for wildlife research, enabling the monitoring of animal behavior and population dynamics for a variety taxa and ecosystems (Linke et al. 2018, Gibb et al. 2019). For instance, digital cameras can be employed to monitor plant phenology through the time-series analysis of red, green, and blue channels of digital images (Alberton et al. 2017). Motion-sensitive camera techniques enable estimating the composition and abundance of animal communities, especially for medium and large-sized terrestrial vertebrates (Tobler et al. 2008, Burton et al. 2015, Steenweg et al. 2017). Automated acoustic recorders are employed in passive acoustic monitoring of birds, anurans, invertebrates, mammals (terrestrial and aquatic), and freshwater fauna (André et al. 2011, Sugai et al. 2019, Desjonquères et al. 2020).

A network for standardized biodiversity data acquisition is required to track global changes in biodiversity (Steenweg et al. 2017). Large-scale biodiversity monitoring programs can take advantage of standardized spatial designs and include networks of *in situ* sensors (Muelbert et al. 2019). Examples include the standardized motion-sensitive camera arrays across continental tropical forests of Africa, Asia, and

Received: 24 July 2020; Accepted: 29 July 2020

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Latin America provided by the Tropical Ecology Assessment and Monitoring Network (Ahumada et al. 2011) and Wildlife Insights (<https://www.wildlifeinsights.org>, accessed 21 May 2020); the continental-scale network of acoustic sensors of the Australian Acoustic Observatory (<https://acousticobservatory.org/>, accessed 21 May 2020); the Long Term Ecological Research (LTER) Grid Pilot Study using acoustic sensors (Butler et al. 2007); and the multi-sensor network from the Okinawa Environmental Observation Network (Ross et al. 2018).

The implementation and maintenance of a network of sensors in biodiversity monitoring programs can provide better cost-benefit ratios compared to traditional field observation (Marvin et al. 2016, Sugai et al. 2020). The gap between state-of-the-art sensors and budget alternatives has been narrowed with the launch of affordable sensors, reduced size, and optimized microprocessors (Whytock and Christie 2017, Hill et al. 2018, Glover-Kapfer et al. 2019). A remaining challenge is the reduction of manual efforts to maintain such passive biodiversity monitoring systems. Specifically, most motion-sensitive cameras and automated acoustic devices require periodic maintenance for retrieving memory units (Harris et al. 2010, Browning et al. 2017). Thereby, wireless data transfer is becoming a pressing demand by the research community employing passive monitoring systems (Collins et al. 2006, Meek and Pittet 2012) and would likely have broad application with the release of fit-for-purpose and user-friendly solutions. Custom devices that allow researchers to add wireless network units already exist for audio and image trapping (Nazir et al. 2017, Hill et al. 2018) and data transfer can be provided with satellite internet service and radio ethernet (Porter et al. 2005, Aide et al. 2013, Saito et al. 2015). Creative possibilities of data transfer can also be achieved through mobile data networks (Sethi et al. 2018), including smart recycling of cell phones (e.g., Rainforest connection, <https://rfcx.org/>, accessed 21 May 2020), or standard telephony platforms (Garrido Sanchis et al. 2020). Additionally, real-time monitoring could be achieved by merging network sensors with edge computing to enable *in situ* analysis and less bandwidth than raw data for data transfer (Sheng et al. 2019, Sturley and Matalonga 2020).

Long-term and large-scale biodiversity monitoring programs should consider including automated passive monitoring systems to guarantee the continuity of data collection, especially under unusual situations (e.g., COVID-19). In addition to guaranteeing an ecological register for a specific goal, image and sound recordings can also be analyzed in the future (in parallel to satellite-image archives) and provide new opportunities for ecological research (Sugai and Llusia 2019, Jarić et al. 2020).

## ACKNOWLEDGMENTS

I am grateful for comments provided by R. Costa-Pereira, an anonymous reviewer, and the handling editor P. R. Krausman, and for grant PEJ2018-004603-A from the Spanish Ministerio de Economía, Industria Competitividad.

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