Open data facilitate resilience in science during the COVID-19 pandemic

The ongoing disruption of the COVID-19 pandemic felt by society worldwide provides an opportunity to reflect on how resilient ecologists are in adapting to the "new normal" of our professional lives with the virus. At a recent virtual meeting funded by the MSB–NES (National Science Foundation Macrosystems Biology and National Ecological Observatory Network [NEON]-Enabled Science), participants across career stages discussed impacts of COVID-19 on research and teaching in the US. While there was ample and important conversation about the pandemic's adverse effects on the mental health and work–life balance of researchers, especially scientists who are early in their careers and/or primary caregivers for children (Aubry *et al*. 2021), the discussion also highlighted how the availability of open data coupled with skills in data science helped some participants (including the authors of this letter) to innovate despite the challenges posed by the pandemic. More specifically, scientists working in ecological data science – the nexus of computer science, statistics, and ecology – have been well poised to take advantage of nationally and internationally available data streams, such as those provided by NEON, the Long Term Ecological Research (LTER) Network, and the International LTER Network, to continue to move environmental science forward during the pandemic. Here, we focus on the use of open data from NEON, given that these data were central to the MSB–NES meeting's discussions.

Facing pandemic-related closures of field sites and laboratories, many researchers with ecological data science skills made use of NEON data to perform analyses (both impromptu and planned) and to prepare for future field seasons. Many graduate students also pivoted from dissertation chapters focused on field or lab work to modeling-based topics relying on data already collected by NEON or streamed from NEON sensors. Similarly, summer research programs for undergraduate students switched from field-based experiences focused on the collection of new data to computer-based analyses of existing NEON data. For example, the Harvard Forest Summer Research Program in Ecology ran virtually during summer 2021 with a heavy emphasis on using data from NEON and the Harvard Forest LTER site.

In undergraduate and graduate classrooms throughout the US, instruction largely went from in-person to virtual in March 2020 as students and faculty were encouraged to shelter-in-place (Lashley *et al*. 2020). Generally, the use of open data for data-driven inquiry has been a common theme for "emergency" virtual ecological instruction during the pandemic (Acevedo 2020; Thompson *et al*. 2020), and participants of the MSB–NES meeting indicated that NEON datasets were instrumental in making the change to remote classrooms. For instance, participants at the MSB–NES meeting who teach in higher education used NEON data for quantitative exercises in place of data that students would have otherwise collected in the field during class (eg the Macrosystems Environmental Data-Driven Inquiry and Exploration [EDDIE] modules for modeling ecosystem simulations at NEON sites [Carey *et al*. 2020]). Likewise, the NEON–EREN (Ecological Research as Education Network) collaboration produced flexible learning projects in which ~700 students collected their own local datasets (that is, from campuses, parks, and backyards) to compare with NEON's continental-scale datasets.

In considering the resiliency of ecological science to ongoing and future natural disasters, which are likely to become more frequent with climate change (IPCC 2007), habitat loss (Gibb *et al*. 2020), and species exploitation (Dobson *et al*. 2020), it is important to highlight the lessons learned during this pandemic. Ecological data science has been central to making progress in ecological research and education despite the working conditions imposed by the pandemic.

Moreover, open data have made research logistically possible not only for many scientists during the pandemic but also for those with limited resources. This has been especially true for early career scientists who may not have had adequate time to accrue their own large datasets. However, a lack of data science skills has been a key challenge for researchers and educators wishing to use NEON and other open datasets (Hampton *et al*. 2017; Balch *et al*. 2020). This highlights the importance of ensuring that current and future ecologists have skills in computer science and statistics (Acevedo 2020) that can be readily applied to ecological questions. Looking forward, ecologists should reflect on the critical importance of embracing and investing in open data and data science skills, now more than ever, to help ensure that our science is able to withstand the challenges we face today and may encounter tomorrow.

Data Availability Statement
No data were collected for this study.

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