

PERSPECTIVE

Lessons for conservation from the mistakes of the COVID-19 pandemic: The promise and peril of big data and new communication modalities

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Email: jessiegolding@arizona.edu**Abstract**

New datasets and information infrastructure are revolutionizing how societies respond to environmental crises, while creating novel challenges. Conservation biology can learn from other fields that have confronted crises while navigating changes in the scientific process. The COVID-19 pandemic offers one such opportunity. We identify lessons from the use of big data and the sharing of preliminary scientific information in an increasingly “networked” communication system during the pandemic. Although big data were central to early pandemic responses, acquisition and sharing of big data alone were insufficient to produce knowledge for effective crisis response. Some shortcomings could be addressed by validating and automating processing of big data. Preliminary scientific information was widely available and shared through a broad communication infrastructure during the pandemic, contributing to widespread misinformation. Diverse actions connecting information producers and consumers could help mitigate misinformation risk. By examining pandemic lessons, conservation biologists may be better equipped to handle conservation crises.

KEYWORDS

big data, conservation, COVID-19, networked model of science communication

1 | INTRODUCTION

Although society is facing unprecedented conservation challenges, rapid, large-scale responses are possible through innovations linking information and action. There are new data to define environmental problems and new communications tools to share results and motivate action. For example, low-cost,

crowd-sourced air quality monitors have expanded citizens' ability to make real-time decisions about pollution and health (Morawska et al., 2018). In another case, a smart energy grid averted an electric grid collapse by prompting the Governor of California to text citizens to “conserve energy...to protect public health and safety” (Toohey & Petri, 2022). New data sources and modes of communication expand the suite of crisis responses, while creating new ways for them to go awry.

Jessie Golding and Helen Chmura contributed equally to this study.

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Achieving conservation biology's core goal, to produce science that informs real-time conservation solutions, depends on translating environmental data into action. This is often systematized in "adaptive management," which is envisioned as a cyclic process of monitoring, data communication, actions or policy, and system response within responsible agencies. While this cycle remains critical, the current pace of environmental change demands more rapidly implemented, larger-scale solutions that draw upon new actors, data, and communication tools.

Since 2020, the COVID-19 pandemic ("the pandemic") has demanded that public health agencies respond to an unfolding crisis. We argue that the pandemic represents an invaluable case study to examine how innovation in data collection and information exchange across multiple phases of a crisis can facilitate or impede desired outcomes. The pandemic may appear different from conservation crises, however we see important similarities. First, the pandemic and pandemic policies have altered citizens' daily lives, particularly early-on. Conservation crises and policy interventions can also fundamentally alter individual lives and societal practices, making the stakes of policy responses high and effective communication about them critical. Second, early pandemic decision-making occurred in a landscape of constantly changing data availability and public sentiment about desired outcomes. What "best available" science looks like, public conversation about that science sounds like, and policy measures are considered shifted multiple times. Ongoing decision-making despite shifting scientific understanding and public sentiment is common to many conservation challenges. Finally, while the pandemic unfolded rapidly, which differs from slower-moving climate or biodiversity crises, other crises like oil spills must be confronted on similar timescales. We argue that pace and scale of the pandemic magnified patterns common to crises, making them easier to observe.

As of 2023, when this was written, the pandemic is ongoing and has resulted in many societal lessons. Our intent is to highlight two pandemic challenges that inform how adaptive management might function in future conservation crises. The first challenge is the expanded and evolving reliance on big data during the pandemic. The second is the changing structure of scientific communication, which was highlighted during the pandemic by the extensive communication of preliminary scientific findings on new media platforms. In this perspective, we consider how the use of big data and new communication methods during the early pandemic led to failures in the pandemic response and use this to suggest steps conservation biologists can take to increase success when responding to novel challenges. We argue

that using big data and communicating data broadly are not in and of themselves solutions: effective solutions arise in *how* data are used and communicated.

2 | THE CHALLENGES AND OPPORTUNITIES OF USING BIG DATA IN A NOVEL CRISIS

The COVID-19 pandemic is the first pandemic in the era of "big data," or data that are numerous, rapidly acquired, and atypical in structure (Khan et al., 2014). Big data have been used with mixed success during the pandemic. Some big data applications that were piloted previously have been scaled and deployed globally. For example, while genetic sequencing of novel pathogens was used during other 21st century pandemics (reviewed in: World Health Organization, 2021) the COVID-19 genome was sequenced within days of the virus's discovery (Zhou et al., 2020). Genome sequencing allowed rapid development of diagnostic tests, which are essential tools for disease monitoring and monitoring to track viral evolution. Monitoring genetic material within wastewater, a technique previously validated for polio eradication (Asghar et al., 2014), has provided more up-to-date prevalence information than case testing (Peccia et al., 2020), paving the way for more efficient public health decisions (although methods can be refined; reviewed in: Zhu et al., 2021). Other big data sources that have been used in COVID-19 monitoring were not effective. Early-on, cell phones provided individual movement data that was used to infer disease transmission rates (Jewell et al., 2021). Unfortunately, the utility of this information was limited by uneven participation across social groups, which was created by discrepancies in technology access, concerns over personal privacy, and other factors (Budd et al., 2020). Also, this technology could only identify transmission events in early phases of the pandemic (first 15 weeks), when COVID-19 arrived in a new location (Kishore et al., 2022). Despite the weaknesses of some big data, the investment in and availability of it has been unprecedented (Budd et al., 2020).

The mixed success of big data thus far in the pandemic is due to several factors including: the challenge of connecting big data to immediate information needs, human factors, and lack of validation. Big data surveillance monitoring, or observational monitoring not guided by hypotheses, was important early in the pandemic to track where cases were. However, its utility has decreased (Ricks et al., 2022). Targeted monitoring data that addressed questions such as effectiveness of social distancing, public closures, and self-imposed or mandated quarantines were needed to inform policy and individual

decision-making. These data were not immediately available. Even though many corporations sought to make commercial data available “for good” to fill information gaps early in the pandemic, the data they provided were complex and unfamiliar, which meant decision-makers found it difficult to interpret and use. Additionally, many early pandemic response efforts lacked the technical capacity to standardize and analyze these datasets because background required for evaluating biases and conducting validations were missing, requiring complex analytical approaches (Buckee et al., 2022). Like other data, big data monitoring is most useful when it is clearly linked to underlying mechanism and there is a clear path from data collection to use and decision-making. Synthesizing data and establishing these connections is not trivial and may occur iteratively over time. When links were tested, many big data sources failed to show a reliable connection to disease dynamics. For example, although individual movement data derived from personal devices was useful for predicting dynamics in early spreading events, that prediction became less informative or wrong as time went on and transmission became more complex (Kishore et al., 2022).

Conservation will face similar challenges with big data. The pandemic demonstrated that in the absence of centralized entities that conduct long-term monitoring, big data becomes a data source of choice in a novel crisis because it appears immediately available. This availability leads people to believe it is also immediately usable to inform real-time decision-making (Buckee et al., 2022). In conservation, despite repeated calls for long-term monitoring connected to specific management decisions (e.g., Nichols & Williams, 2006) or large-scale surveillance monitoring (Wintle et al., 2010), typically monitoring data will not exist prior to a crisis due to chronic underfunding and lack of common monitoring goals. Thus, in a novel conservation crisis, scientists may turn to validated and unvalidated big data for situational awareness and initial attempts to address targeted questions. Already, conservation biologists rely on big data (e.g., remote sensing, citizen science observations) for conservation monitoring and decision-making (Dobson et al., 2020), but these are vulnerable to processing and validation concerns that hampered the ready application of big data early in the pandemic.

Conservation biologists can learn from the pandemic to improve the utility of big data in crises. Rapid successful uses of big data, such as the sequencing of the COVID-19 genome, occurred because of prior validation. Biologists should continue to proactively test and validate big data sources that show promise and utility; for example natural history collections (Davis et al., 2023) and observations collected through participatory science

programs like eBird (Johnston et al., 2021). Proactive validation includes encouraging corporate partners participating in big data “for good” initiatives to provide the proprietary information necessary to conduct robust validation. Biologists should also explore more automated analyses of validated big data sources to overcome capacity limitations. For example, scientists created a simple app based on Google Earth Engine processed satellite data to give anyone access to automated measurements of land cover change since 2016 in the United States (Evans & Malcom, 2021). Additionally, biologists may consider ways to transition how big data is used as monitoring needs change across a crisis. Although this transition occurred organically during the first 3 years of the pandemic, a plan for how and when to switch between different monitoring modalities may allow more effective direction of resources. For example, monitoring needs changed for western snowy plovers (*Charadrius nivosus nivosus*) from when they were first protected, and population censuses were conducted, to recently, when they were declared a recovered population and goals were re-evaluated to include measures like reproductive success (Marcot et al., 2021).

3 | NOVEL EXPANSION OF COMMUNICATION IN A CRISIS

The novelty and severity of the early pandemic prompted large communication efforts. The substantial communications needs created by the pandemic co-occurred with a rapidly changing media landscape, which has been characterized as shifting from “linear” communication (from experts to citizens via professional journalists) to a “horizontal” structure with exchange between experts and citizens alike, often on social media (Van Dijck & Alinejad, 2020). We argue that the information demands created by the pandemic, interacting with the increasingly networked structure of scientific communication, led to misunderstandings by consumers and erosion of public trust (Balakrishnan et al., 2022; Scannell et al., 2021).

Policy makers and the public were hungry for pandemic solutions and in early phases, only preliminary data were available to provide situational awareness. Thus, preliminary data were widely publicized, including on social media, which became integral to delivering information about the emergency (Wong et al., 2021; Neely et al., 2021). For example, while pre-print servers had been used within the scientific community for years, many publishers made pre-prints mandatory for COVID-19 research. In a networked communications structure, this meant that pre-prints that had not undergone

peer-review were publicized by news media, social media, and even cited in government documents (Fraser et al., 2021). Pandemic data dashboards that were updated in almost real-time were another widely publicized preliminary data source. The first, a student-initiated effort at John's Hopkins University, was created to fill a void in traditional media. It quickly became a fixture in traditional reporting, a perfect example of "horizontal" communication. Other dashboards followed this example and used similar data types (case counts, hospitalizations, deaths) displayed in maps or graphs to tailor pandemic information for different constituencies (Ivanković et al., 2021).

The widespread publicization of preliminary data from pre-print servers and dashboards in the networked media landscape had pros and cons. Although some pre-prints had benefits (e.g., saving lives with dexamethasone), scientifically questionable pre-prints initiated and fueled COVID-19 misinformation (e.g., treatment via ivermectin) long after the pre-print was retracted (Watson, 2022). When pre-prints were discredited, they had "staying" power (even in peer reviewed literature—see Piller, 2021) partly because of the difficulty of retraction in a networked communication structure when information is abundant and shared diffusely by thousands or millions of actors. In networked communication, correction requires approaches (reviewed in: Chen et al., 2023) beyond retraction statements; for example, the independent entity Retraction Watch started tracking retracted COVID-19 publications (<https://retractionwatch.com/retracted-coronavirus-covid-19-papers/>). The proliferation of dashboards sharing preliminary COVID-19 information led to other problems. Dashboards varied in whether data were presented as raw or processed, how data were classified, how regularly they were updated, how methods were documented (Clarkson, 2023), and how actionable the information was (Ivanković et al., 2021). This variation became a source of confusion for consumers, and for some, evidence that dashboards were not reliable (Zhang et al., 2022).

When data (reliable or not) is abundant, it becomes challenging and draining for consumers to identify relevant data and decide how to act. The proliferation of COVID-19 misinformation led the World Health Organization to proclaim that public health officials were responding to an "infodemic," or excessive pandemic misinformation, as well as a viral disease (World Health Organization, 2020). This infodemic led to confusion and mistrust across information producers, communicators, and consumers (Fleerackers et al., 2022; Frampton et al., 2021) and contributed to challenges in identifying and implementing pandemic policy solutions (Caceres et al., 2022).

Consumers of conservation-related media must also separate fact from fiction in a landscape of abundant communication. For example, one study that found that less than half of news stories published after a whale shark stranding event contained factually accurate descriptions of whale sharks (Jaafar & Giam, 2012). Producers of conservation data also struggle to communicate effectively to citizens when the narrative about the current situation (and best available data) changes. Another study showed that even after authoritative sources demonstrated that market seafood after the Deepwater Horizon oil spill was safe, "after seeing...images of oil-covered shores and birds day after day...many people had difficulty believing that...seafood testing was reliable" (Lubchenco et al., 2012). While it is tempting to conclude that increasing literacy around data and uncertainty will ameliorate misunderstandings in these situations, we suggest that these are partial solutions. While scientists can and should turn to the literature on communicating scientific uncertainty, (see Retzbach & Maier, 2015; Boan et al., 2018; Van Der Bles et al., 2019; Gustafson & Rice, 2020, for examples), we argue that conservation biology must also grapple with new pathways of data sharing in networked communication, demands for sharing data early and often, and how these pressures interact.

Scientists can increase the likelihood that preliminary data is communicated appropriately in diverse media. For example, immediately after the Deepwater Horizon oil spill, scientists called for a community dialog about when and how to share preliminary findings that balanced the need for rapid communication within the scientific community for research and development, and the hazards of communicating incorrect information to the public before results are substantiated (Lubchenco et al., 2012). The pandemic highlights the need for this conversation to continue. Scientists can also proactively engage with media to shape how science is shared. While there has been a push to advise conservation biologists on how to co-produce science with stakeholders (e.g., Cook et al., 2013; Fisher et al., 2020), these guidelines focus on creating new science collaboratively, not communicating emerging science in a networked communication structure. To address this gap, conservation biologists could co-develop communication guidelines with media personnel to improve reporting of preliminary data. Scientists can aid policy makers by using social science research to link results to decision-making needs (e.g., identifying the state of knowledge, choosing among options, generating choices; Fischhoff & Davis, 2014). This can help policy-makers identify scientifically defensible actions even in situations where the scope of the

crisis is unclear. Scientists can also aid policy-makers by clarifying what data is and is not. Communicators frequently call both scientific findings and scientifically-informed policy “science”, but this is not appropriate. Even the most “science-based” policies reflect choices about social values (e.g., risk tolerance, cost, trade-offs), not just data. While data should be value-neutral, there is the risk of data being disputed and called into question when a policy conflates facts with social values that shape how facts are used in decision-making. Finally, scientists and policymakers can engage with social media companies to understand how information is shared online and what that means for scientific communication. On social media, software developers can add behavioral interventions into platforms (e.g., a prompt to ask a user if they are sure they want to share a post and go from a data consumer to a data communicator), which can reduce the spread and belief of misinformation (Chen et al., 2023; Pennycook et al., 2020). While there is no single solution when science is shared through a diffuse network of actors, efforts to strengthen connection and understanding between actors within the network may improve communication.

4 | CONCLUSIONS

Inspiring scientific successes have come from the exchange of ideas across disciplines. The pandemic offers an unprecedented opportunity to inform conservation biologists about how big data and communication efforts succeed or fail in solving the world's challenges. While themes that we raise such as data integrity, transparency, and communication, have always been with conservation biology, the rise of big data and new communication modalities have changed the way these conversations unfold and amplified the potential for unfortunate missteps. We hope that the conservation community can use the lessons of the pandemic to learn how to efficiently respond to the conservation crises we are facing and have yet to face.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

No new data associated with publication.

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