Dynamic figures should be a central feature of scientific articles

The pace of human-induced change on Earth is without historical precedent, yet the contents of a typical journal article in ecology have remained static (Ceballos *et al.* 2015). An article published today will likely be limited to fixed text, tables, and figures – a format similar to that employed in the Rhind Papyrus approximately 3700 years ago (Figure 1; Peet 1923). This stasis is worrisome, because effective scientific communication is imperative for conservation and static visualizations are less effective at conveying technical information (Tremayne and Dunwoody 2001). Meanwhile, august media such as the *New York Times* have been using animation and interactive figures to communicate the news for years. Scientific articles should also rely on dynamic figures (defined as representations of data or model predictions employing animation or permitting user-driven changes in what is displayed) for the reasons we outline below.

Dynamic figures can allow readers to display predictions from models to suit their interests. This can especially benefit policy makers, conservation organizations, and natural resource managers. Dynamic figures can deliver the features of decision-support tools to a broader audience without additional costs (Bagstad *et al.* 2013). In journal articles, static figures that display model predictions are typically conditioned on a single set of ecological conditions that may be unrepresentative or ill-matched to reader interests. For example, wildlife researchers using regression models often plot how a single factor affects a predicted outcome, while keeping all other variables fixed at their respective mean values (Guthery and Bingham 2007). However, mean values may not suit the interests of many managers and researchers. Readers should have the option of displaying model predictions with variables fixed at their preferred values instead. Although we emphasize linear regression here for the sake of simplicity, it is possible to generate dynamic figures based on any model that generates quantitative and other curvilinear predictions.

Dynamic figures can promote scientific progress by improving transparency. Open data are increasingly required upon publication across the sciences, and tying open data to easily accessible visualizations might ensure that those data receive more attention (Miguel *et al.* 2014). Graphing data can reveal issues not apparent from summary statistics, which can be the same for very different datasets because of differences in how data are distributed (Fulton *et al.* 2008). Dynamic figures would allow authors to display model fit, show whether model assumptions are reasonable, and highlight influential data points. Finally, readers could "subset" data to identify sources of variation and locate data gaps. We provide an example of a sub-settable dataset made using Tableau Public (https://public.tableau.com/s), illustrating variation in the relationship between mammalian body size and life span (Jones *et al.* 2009; http://tabsoft.co/2vjCsxm). The relationship for all available data is displayed initially, but readers are free to explore the data.

Two things became apparent when developing this example: there were a variety of freely available tools, and we had to make many more judgments than we do when producing standard static figures for publication. In addition to Tableau Public, Vidi (www.dataviz.org), Silk (www.silk.co), and the Shiny application for R are freely available and can be used to generate dynamic figures. There are several innovative features offered by publishers that can incorporate dynamic figures, such as supplementary data files, graphical abstracts, and PDF files (Barnes *et al.* 2013). However, there are a wide variety of dynamic figures being used in media, and at present there is no single standard for authors to learn if they wish to produce dynamic figures, slowing their adoption among scientists. Likewise, authors may be concerned that journals will not feature their dynamic figures prominently or in a way that seamlessly integrates them with the primary text.

Given many options for incorporating dynamic figures into scientific articles, we think journals should develop production standards to encourage participation. Dynamic figures can increase the visibility of articles and promote sharing on social media platforms, thereby increasing citation rates – a boon to journals and researchers alike (Peoples *et al.* 2016). Competition among publishers to develop the most engaging house styles would promote rapid improvement in the quality of dynamic figures while assisting researchers. Finally, publishers are in the best position to ensure that dynamic figures are seamlessly embedded in web pages and PDF versions of articles. This can help to guarantee that readers see data presented simply and as the authors intended first, while making it easy for readers to engage deeply with the data and the models that underpin articles.

Change is often challenging. Less than 20 years ago, newspapers began embracing interactive online strategies such as forums and live chats, trying to remain relevant in the digital age. The spirit of experimentation embodied in those efforts was laudable and augured the recent emergence of FiveThirtyEight.com and other dynamic data-centered media. Adopting dynamic figures across the sciences in a similarly enterprising spirit will improve the reader experience and increase the visibility of authors and journals while promoting rigor and transparency in scientific research. We acknowledge that scientific communication does not guarantee action on the conservation challenges we face, but we believe there is a better chance of fostering an informed discussion around ecological findings if we present our research in an accessible

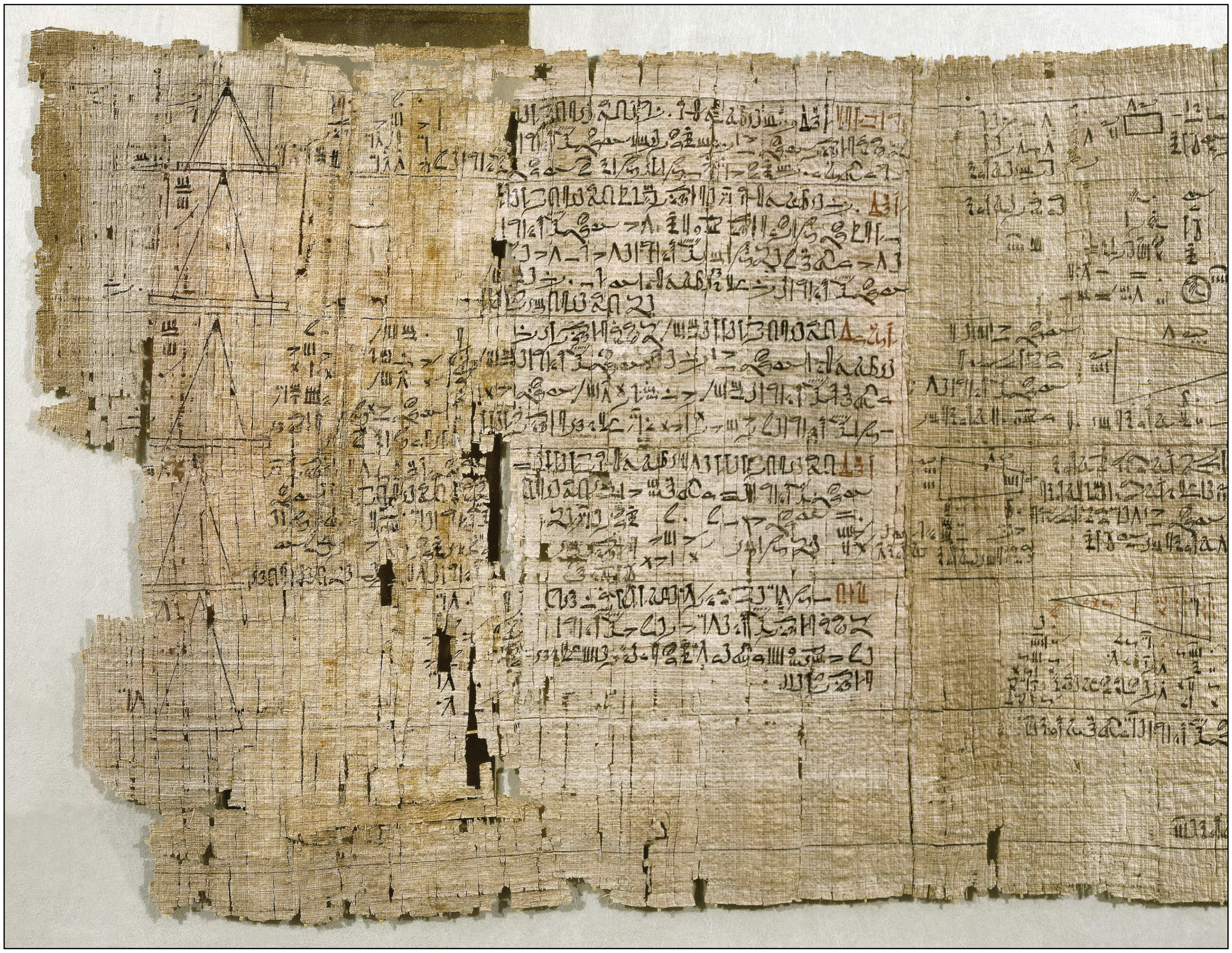

Figure 1. *The Rhind Papyrus (an Egyptian manuscript dating to the 2nd millennium BCE) is among the earliest pieces of technical communication, and its static properties bear a striking resemblance to how we communicate scientific research in journals today.*

manner. We are eager to see wider adoption of dynamic figures driven by authors and publishers alike, and the progress that can be expected as we learn to use them to our greatest advantage.

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