

STATE OF THE ART IN VISUALIZING ECOLOGICAL DATA

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INTRODUCTION

The nature of complex ecological problems, new interdisciplinary partnerships to solve them, the emergence of tools for collecting and processing data have introduced challenges and opportunities. Information and scientific visualization plays an important role in research and discovery, potentially revealing patterns and trends in data by compressing information into a more easily interpretable form (Thomas, 2006, Keim et al., 2008; Keim, Qu, & Ma, 2013; Kohlhammer, Keim, Pohl, Santucci, & Andrienko, 2009). Further, emerging technological innovations could give scientists-in-the-know options for creating arguably better visualization (Andrienko, 2010; Keim, 2008). However, creating data visualizations to deal with complex data is not easy (Fox and Hendler, 2011, *Science*) and various barriers and pitfalls prevent scientists from using visualization to full capacity.

Barriers to visualization use include access to tools and methods, cost of learning new approaches and tools (Desnoyers), and the considerable time and effort it can take to produce effective visualizations (ManyEyes, QuestVis; Cushing et al, LTER ASM Workshop 2016; McKane and Halama, Personal communications). Pitfalls (of which scientists are rarely aware) include biases in interpretation, cognitive overload, and the potential disconnect between data (or models) and visual output. Fortunately, current research might help overcome these barriers and institutionalize best practices to avoid pitfalls.

This paper first presents a scheme for categorizing visualization tools, and then categorizes some visualization tools applicable to ecologists and environmental scientists. We also state the kinds of data or problem for which each visualization type might be used and give one or more illustrative visualization example for each type. We then discuss visualization barriers and pitfalls, and propose measures to alleviate these, including specific educational innovations, use of interdisciplinary partnerships, and best practices for visualization publication and presentation.

NB: Changing the Equation on Scientific Data Visualization (Peter Fox, James Hendler, *Science* 11 Feb 2011) covers some of the same ground as we envision for this paper. In a background section, we will articulate the similarities and differences between that article and this one.