Forecasting a bright future for ecology

The discipline of ecology is changing rapidly, and changing for the better. Ecologists are organizing into networks and interdisciplinary teams to tackle larger questions and more synthetic scientific challenges. New computational methods provide a richer, more detailed understanding of ecological patterns and processes. Technical advances unimaginable to previous generations are increasing the amount of information we have about the natural world at an ever-accelerating pace. Shifts in cultural norms toward open, reproducible science mean data and code are increasingly accessible. Monitoring data are increasingly available close to real-time. However, when it comes to testing predictions, we often rely on a combination of vague predictions (variable *x* will affect outcome *y*), quantitative predictions that are not practical to validate (eg projections to 2100), and in-sample validation. The independent testing of quantitative predictions remains surprisingly rare.

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One important way forward is with an iterative approach, where forecasts (probabilistic, out-of-sample predictions) are continually tested and updated as new information becomes available. Iterative forecasts represent a win–win: they accelerate science and make it more robust, while making ecology more directly relevant to near-term societal needs. All decisions, whether individual or international, are fundamentally about what we think will happen in the future, given what we know now and the alternatives being considered. In other words, they require forecasts. Decision makers crave relevant, quantitative, evidence-based forecasts – even if our current forecasts are imperfect – and yet this information is often unavailable. That said, no forecast is perfect, so it is critical to incorporate key uncertainties and provide probabilistic assessments that clearly articulate (rather than merely minimize) the uncertainties involved. As ecosystems move outside their respective envelopes of historical variability, iterative forecasts will become increasingly important for ecologists who are tasked with rapidly responding to society's needs.

Iterative forecasts are not just practically useful; they also provide a mechanism for learning about ecosystems more quickly. Forecasts require models, and models are ultimately distillations of our hypotheses about how ecosystems work. Indeed, just establishing the capacity to make forecasts can drive both conceptual and quantitative synthesis (eg model development and calibration). Iterative forecasts confront predictions with new data as the data become available, allowing more frequent hypothesis testing and a rapid learning cycle. At the same time, forecasting forces predictions to become specific, quantitative, and a priori; provides natural protection against overfitting (it's a lot harder to fish for "significant" statistics if the validation data haven't been collected yet); and ultimately makes science more robust. Furthermore, refuting a specific, quantitative prediction is more meaningful than falsifying null hypotheses that we often know are trivial before we start. Iterative forecasting also isn't limited to "big data", but is just as valuable for experimental manipulations, field monitoring, and citizen-science efforts. Indeed, "big data" rarely tell the whole story, so that "small data" studies are, and will remain, critical in ecology for diving deeper into understanding processes, discerning between competing hypotheses, and generating new ideas. Overall, the fastest route to improved forecasts is learning by doing, not waiting for forecasts to be "good enough".

While iterative forecasts represent an important opportunity, we acknowledge that there are many important slow processes in ecology, that many trends and thresholds only emerge over time, and that some policy and management questions hinge on long-term change. However, we fear that long-term threats, such as climate change, have shifted the conversation so far into the future that we risk missing important near-term science and management opportunities.

Iterative forecasting also provides a framework for understanding and testing that can be applied across ecology. Indeed, comparing across ecological forecasts allows us to ask higher-level questions about predictability in ecology. What features of ecosystems and forecasts explain which processes are predictable? What new theories are needed to explain predictive uncertainty? Questions like these allow us to transcend subdisciplines and to think about ecology broadly and synthetically. Indeed, they get at the heart of an essential science question in ecology (and arguably the elephant in the room): whether nature is predictable, and even if it is, whether ecology is more than just a collection of case studies.

So, where do we start? Progress is already being made across a range of agencies that support near-term forecasts (eg NOAA, NASA, USGS, NSF, DOE). However, we believe there are numerous opportunities to work and learn together on cross-cutting issues such as technology development, scientific synthesis, education, and decision support. We recently launched the Ecological Forecasting Initiative (EFI; https://ecoforecast.org) to help build a forecasting community of practice. We're predicting a bright future for ecology, and we hope you'll join us.

Both authors are writing on behalf of the Ecological Forecasting Initiative Steering Committee.