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Moving from Eco-Forecasts to Eco-Projections

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Abstract: Ecological models can provide estimates of future conditions that are useful for decision-making, including long-term planning and resource prioritization. However, these models often rely on assumptions about ecological relationships and trajectories, forcings (e.g., biophysical conditions), and management approaches that may not be explicitly considered. To make assumptions more transparent, disciplines such as economics, demographics, climatology, and national intelligence make a fairly clear and consistent distinction between "forecasts" and "projections". Forecasts are typically more near-term and rely on extending existing relationships and trends to estimate the most likely future conditions; whereas projections evaluate conditions under multiple scenarios that are based on an array of assumptions, often going further out in time. Consistently referring to ecological models of future conditions as either "eco-forecasts" or "eco-projections" could help make modelling assumptions more transparent and thus more effectively focus their application across landscapes and through time. To the extent that ecological modelling is used to support management, policy, and programmatic decisions, practitioners can ask the following. If the modelling is an eco-forecast, is it worth considering different initial conditions, trajectories, or forcings based on alternative scenarios? If the modelling is an eco-projection, are the underlying assumptions and future scenarios explicit, and are decisions properly tempered with respect to those modelling specifications? We demonstrate these concepts and methods for conducting eco-projections through examples from invasion biology and climate adaptation.

Keywords: *ecological forecasts; ecological projections; natural resource management; scenario planning; simulation modelling*

1 INTRODUCTION

Ecological models can provide useful estimates of future ecological conditions, even when accompanied by caveats regarding assumptions and parameter uncertainty. It is important to distinguish among aspects of model uncertainty and the uncertainty of system drivers, especially those further out in the future, to ensure suitable model applications and interpretation. "Forecast" and "projection" are shorthand terms that are useful for making this distinction.

"Eco-forecasting" has become a buzzword in ecology. Although it is perhaps more recognizable to the general public than its cousin "eco-projections", we argue that eco-projections is oftentimes a more accurate term and more appropriate approach. The distinction between eco-forecasts and eco-projections is the focus of this paper, which advocates for more careful and consistent use of these terms, not simply for linguistic accuracy, but also for transparency about sources of uncertainty, the inclusion of subjective assumptions in ecological modelling, and enhanced decision support by considering opportunities to build on eco-forecasts by considering eco-projections.

2 COMBINING TOOLS FOR ECO-PROJECTIONS

Clark et al. (2001) identified ecological forecasting as an "emerging imperative". Since then, papers that refer to ecological prediction, forecasts, and projections have grown steadily (Luo et al. 2011). Despite efforts from the ecological community to distinguish among these terms (Dietze 2017, Luo et al. 2011), there is continued use of the term "ecological forecasting" (or "eco-forecasting" for short) without a clear rationale or distinction from eco-projections. At the same time, eco-projections are often based on different future scenarios, but the process of developing or selecting those scenarios is not always structured or transparent, potentially limiting the relevance of the subsequent modelling work to would-be information users.

Predictions such as these can benefit from multidisciplinary efforts that join human understanding of context with advanced algorithmic capacity (Jasny and Stone 2017). Together with ecological modelling, scenario planning and horizon scanning offer the opportunity to implement such a combined approach and achieve credible and salient eco-projections.

Scenario planning is often defined based on its distinction from forecast-based approaches (Mahmoud et al. 2009, National Park Service 2013, Peterson et al. 2003). A forecast-based approach to planning typically uses a model to calculate probabilities of future events, based on existing data and trends, to build an estimate of a single future. In contrast, scenario planning develops a set of divergent, plausible, relevant, and challenging storylines of future conditions based on uncertainties that are impactful for a focal issue (National Park Service 2013). Scenarios are used to inform strategy by flexing participant thinking about potential future opportunities and threats, and to evaluate how those might influence one's ability to achieve short- and long-term goals (Searce and Fulton 2004). Similarly, horizon scanning is a systematic examination of potential threats and opportunities within a given context; which, in concept, provides a means of informing decisions with robust evidence about the range of possible, plausible future scenarios that might occur (Roy et al. 2015, Sutherland and Woodroof 2009).

Consistent with these definitions, scenarios and models are sometimes placed on opposite ends of a spectrum of methods (Bennett et al. 2003). However, these approaches are not antithetical. Indeed, we and others have recognized the need to combine model uncertainty with that arising from multiple plausible futures (Maier et al. 2016), and even articulated an analytical framework for combining scenario-based and modelling approaches (Miller and Morisette 2014). Applications and refinements of this combined approach are emerging that illustrate its value for natural resource management.

2.1 Invasive Species Examples

There is a growing interest within the Invasive species science, policy, and management communities to conduct horizon scanning (Matthews et al. 2017, Ricciardi et al. 2017). In the context of alien invasive species, eco-projections, more so than eco-forecast, can be thought of as a quantitative modeling contribution to the larger horizon scanning approach.

There are examples were current eco-forecasts could be built upon to create eco-projections. In 2016, the U.S. Fish and Wildlife Service (FWS) determined that salamanders that can carry the fungus *Batrachochytrium salamandrivorans* (Bsal) are injurious to wildlife and wildlife resources of the United States (DOI, 2016). Bsal has caused major die-offs of salamanders in Europe and poses an imminent threat to U.S. native salamander populations. The fungus is not yet known to be found in the United States, and to help ensure it remains absent, FWS published the interim rule that took effect on January 28, 2016. The determination was based on a wide array of scientific information; including modelling by Richgels et al. (2016). That modelling could arguably be framed as an eco-forecast which used the best available information on 1) importation of salamanders, 2) outlets within the pet trade industry, and 3) past climate data. This work is an example of eco-forecasting that provided critical information for the Service's decision making process. By considering plausible but divergent trajectories for any or all of the three input factors, the modelling could also be used as the basis for eco-projections that enable risk management decision making through time. For example, it would be useful to consider pathogen introductions via disease spread through nature corridors if Bsal is introduced into Mexico or Canada, or situations in which the release of previously captive amphibians (and any associated pathogens) is high (e.g., bait use, disposal of research animals, release of unwanted pets), as well as multiple future climate scenarios that could impact salamander and/or pathogen population dynamics. These analyses would enable a more robust horizon scan of Bsal risk to native salamanders.

In other cases, eco-projections need to be interpreted in light of the underlying scenarios. Sala et al. (2000) explored the impact of invasive species, land use, climate (and other drivers) to model biodiversity projections for the year 2100). The authors clearly articulated the consequences of the assumptions and parameterization used (Sala et al. 2000, table 2) and that different parameterization and assumptions could lead to different results. Indeed, the paper does not use the term *forecast* but rather *projections* of future biodiversity change. While Sala et al (2000) find that changes to land use were the top threat to biodiversity globally, the finding was directly linked to their scenarios. Subsequent work -- built on different scenarios -- found greater threats from climate change (Thomas et al. 2014). Furthermore, Sala et al. (2000) found that their results differed by biome, leading others to produce more regional and taxa-specific analysis to highlight the threat from invasive species (e.g., Beaumont et al. 2009). Clearly any application of the model results to decision making would need to consider both the uncertainty of the modelling and the sensitivity to the underlying scenarios across space and through time.

2.2 Climate Adaptation Examples

Two recent efforts focused on National Park Service (NPS) units employed an eco-projection approach of combining scenario planning and simulation modelling to evaluate climate impacts and potential management responses. In Wind Cave National Park, a qualitative scenario planning exercise revealed incomplete understanding of how key ecosystem dynamics would respond to climate change and interact with management interventions. This awareness led to team members to quantitatively validate the qualitative scenarios and test management options under various climate futures using a simulation model (Symstad et al. 2017). A subsequent effort for Badlands National Park built on this experience by integrating qualitative scenario planning and simulation modelling from the outset (Miller et al. 2017). The team found important differences between qualitative expert-/manager-elicited ideas of how resources would respond to changes in climate and simulation-based projections of resource responses. The Badlands project also revealed that a scenario-based approach to model development and application effectively bracketed the uncertainty associated with climate change and ensured that management concerns were addressed in the simulation. Together, these two efforts suggest that characterizations of resource responses to climate change developed through scenario planning are more plausible -- a key criterion for scenarios (NPS 2013) -- with the inclusion of quantitative eco-projections, and scenario planning can ensure that eco-projections are management-relevant and capture the range of uncertainty in external forcings and management responses.

3 CONCLUSIONS

Understanding estimates of future conditions requires a degree of interpretation by the user. Through careful use of the terms eco-forecasts and eco-projections, the modelling approach and, thus, the appropriate interpretations and applications of model results can be made explicit and transparent. As such, the ecological modelling community would be well-served to follow the example of other disciplines (e.g., demography, economics, national intelligence) to consistently use this terminology in a way that fully acknowledges the uncertainty captured by each approach. The examples considered here demonstrate the utility of combining quantitative ecological modelling with scenario planning or horizon scanning to enhance the relevance of eco-projections and to adequately capture future uncertainty. These examples also illustrate the importance of proper interpretation and tempering of results from eco-projections. We conclude that is worthwhile for the ecological modelling community, and the policy and planning constituents using those models, to recognize the difference between eco-forecasts and eco-projections and consider the benefits of shifting emphasis from eco-forecasts to eco-projections.

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