Ecological Forecasting for Meaningful Change

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Climate change and other anthropogenic factors are affecting ecosystems at unprecedented rates. Historical experience in harvesting natural resources and navigating the environment is less reliable as a tool for future decisions. Ecological Forecasting can aid with environmental decision-making by predicting the near or long-term future of ecosystems, exploring different conservation scenarios, and anticipating ecosystem change[2].

The definition of a "useful" forecast for environmental decision-making is under active development. In the landmark paper by Clark et al. (2001), Clark defined a useful forecast as one that is motivated by conservation scenarios and specifies uncertainty. These tenants are widely accepted within the forecasting community, but many published forecasts still lack tangible effect on decision-makers and some even disadvantage end-users[4]. Defining better properties and techniques for impactful ecological forecasts will benefit end-users and the field as a whole. **Here we propose a set of established and developing ideals for each stage of forecasting to consider for every forecasting project.**

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Scoping Phase: define a problem, identify collaborators and funding, and determine goals of end product

Established:

End-User Collaboration

Forecasts should be designed to be decision-relevant. If possible, forecasts should be designed in **active collaboration** with end-users such as stakeholders, decision-makers, and rights-holders to define and understand desired outputs[3,4]. Spatial and temporal scales should be matched to user needs.

Developing:

Indigenous Voices

Collaboration should expand to include local communities and Indigenous knowledge. Local knowledge adds invaluable perspective and increases usability[8]. **Blending Western and Indigenous forecasting** techniques can increase model accuracy and uptake[6].

Case Study

Nyadzi et al. (2022) found that **93%** of local Ghanain farmers preferred forecasts that statistically blended Indigenous and Scientific agricultural predictions over either forecast alone.

Developing:

Funding Equity

Funding sources for impactful forecasts should be **long-term and center local community needs.** Funding sources that require applications should ensure that low-resource communities are not sidelined[7]. Large scale funding programs should value actionable impact over scientific novelty[3].

Development Phase: build models using environmental data to predict ecosystem states

Established:

Clarify Uncertainty

Forecasts must include clear, definite measures of uncertainty. Researchers are obligated to **carefully consider the risk associated with predictions** and ensure that end-users understand how uncertainty affects their decisions[5]. Withholding uncertainty provides false confidence to end-users.

Developing:

Social-Ecological Feedback

Social factors influence ecosystems, and social factors are influenced by forecasts. Social and environmental systems are **interdependent** and should be treated as such[1]. Models should include social-ecological drivers if data is available, or otherwise contextualize forecast results.

Delivery Phase: present forecast to end-users through short or long-term methods

Established:

Multi-format Delivery

Delivery formats should be understandable to the end user and **adjusted to their needs**. When there are multiple end-user groups, multiple delivery options should be provided that are each adjusted to a specific group's needs[4].

Developing:

Ecosystem Health

Natural resource forecasts can eliminate the time/space refuge that prey species require to maintain their population. **Sustainable harvesting** must be ensured, even if it means removing information from model delivery[9].

Developing:

Winner-Loser Dynamics

Forecast delivery must carefully **consider any unintended effects** on end-user dynamics. Private forecasts can give an edge to wealthier industries, and public forecasts can give an "unfair" advantage to less skilled users or dealers[4].

Case Study

A 2016 forecast of early lobster catches in the Gulf of Maine caused dealers to offer **lower prices** to lobstermen than expected, putting harvesters at an unexpected disadvantage (Pershing et al. 2018)

Ecological forecasting is a rapidly expanding field with increasing application as data collection techniques advance, more forecasts and data move to open-source methods, and forecasts improve through iterative design. Forecasts have demonstrated utility in environmental decision-making, but not all forecasts are impactful. Applying the principles above to create useful forecasts will allow for further advances in the field and better-informed decision-making.

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