Better ignorant than misled: Including uncertainty in forecasts supporting management and policy

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Uncertainty Analysis: A Critical Step in Ecological Synthesis
Annual Meeting of the Ecological Society of America, 8/5/2013
Honest synthesis

Management and Policy

- Published research
- Process studies
- Experiments
- Physical laws
- Theory
- Monitoring
The problem of management:

What actions will allow us to meet goals for the future?
Synthesis with deterministic models
Orrin H. Pilkey and Linda Pilkey-Jarvis 2007

useless arithmetic
Why Environmental Scientists Can't Predict the Future

Orrin H. Pilkey & Linda Pilkey-Jarvis
A broadly applicable approach to ecological modeling in support of management

\[
[E, \theta_{process}, \theta_{data} | \text{data}] \propto \\
[\text{data} | \theta_{data}, E_t] [E_t | \theta_{process}, E_{t-1}] [\theta_{process}, \theta_{data}, E_0]
\]
Posterior predictive distributions

\[
[E'|\text{data}] = 
\int_\theta \int_E [E'|E, \theta_{\text{data}}, \theta_{\text{process}}] [E, \theta_{\text{data}}, \theta_{\text{process}}|\text{data}] \, dE \, d\theta_{\text{data}} \, \theta_{\text{process}}
\]
Posterior predictive distribution of future states, $E'$
How to evaluate actions?

Objective: reduce state below a target

Future state of system, $E'$
Objective: maintain state within acceptable range

Future state of system, $E'$
Objective: increase state above a target

Future state of system, E'
Action: do nothing

Future state of system, $E'$

Probability density

Objective
**Action: implement management**

**Objective**

**Future state of system, $E'$**
Net effect of management

Future state of system, $E'$

Objectives

Probability density
Net effect of management

Future state of system, E'

Probability density

Objective

Motivation
Bayes
Evaluating actions
Example
Conclusions
Example: Managing brucellosis in Yellowstone Bison
Goal: Reduce probability of infection by half in five years.

Action: Annually vaccinate 200 sero-positive females.
Bayesian matrix model with multiple sources of data
Effect of vaccination: Treat 200 sero-positive / year
Effect of vaccination

![Graph showing the effect of vaccination on the probability of transmission over years into the future. The graph compares different vaccination strategies, indicating how they affect the probability of transmission over time.]
Effect of vaccination

Objective: reduce transmission probability by half

Five years in the future

Density

Probablity of transmission

Do nothing

Vaccinate
## Comparison of alternatives

<table>
<thead>
<tr>
<th>Management action</th>
<th>Probability of meeting goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do nothing</td>
<td>.05</td>
</tr>
<tr>
<td>Vaccinate 200 sero-positives</td>
<td>.33</td>
</tr>
<tr>
<td>Cull 200 sero-positives</td>
<td>.29</td>
</tr>
<tr>
<td>Cull 200 females</td>
<td>.15</td>
</tr>
<tr>
<td>Boundary hunting</td>
<td>.03</td>
</tr>
</tbody>
</table>
Multiple objectives, multiple actions

Objectives

- Reduce $P(\text{infection})$ by half
- Sero prevalence $< 40\%$
- Population size between 3000 - 3500
- Appropriate demographic composition

Actions

- Vaccination
- Remove sero-positives
- Remove sero-negatives
- Boundary hunting (or removal)
Closing

▶ Value
  ▶ Provides honest forecasts relevant to actions and goals.
  ▶ Informs the conversation

▶ Limitations
  ▶ Demonic intrusions aren’t included.
  ▶ Forecasting horizons are short.

Develop Bayesian model(s) of system

Forecast system behavior under different policy options

Update model(s)

Observe system behavior

Implement policy (or better, policies)
May 21-30, 2013 Google “NREL Bayes”

Building capacity in Bayesian modeling for practicing ecologists

A workshop for faculty and agency researchers. $1000 stipend. See www.nrel.colostate.edu/projects/bayesworkshop/

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