When are models good enough? Assumptions and uncertainty in forecasts of ecosystem state and service supply

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Ecosystem models & decision making

“There is a catastrophic misunderstanding about the capability of scientists to provide advice about large-scale dynamics.”
- Carl Walters (2005)

Time to model all life on Earth

Purves et al. 2013, Nature
The problem with uncertainty

• Models use assumptions to reduce scope, creating implicit uncertainties
• If assumptions are implicit, uncertainties are hidden
• It's complicated, and not sexy
• Overconfidence in model results
How implicit assumptions compromise the utility of ecosystem models for decision making

*Gregr & Chan (in prep)*

- Extracted EBM-related literature (1990-2012) (n=560)
- Selected the most popular based on citation rate (n=60)
- Reviewed stated policy relevance, treatment of uncertainty, and design assumptions
Popular papers treat uncertainties and assumptions poorly

- Over half largely ignored uncertainty
- Model design assumptions were mostly implicit
- < 10% described a relevant mgmt application
Implications

Not addressing assumptions & uncertainties:

• Compromises uptake of results
• Can lead to misunderstandings & bad decisions
• Cripples the building of coupled-models

• Good work on uncertainty being done, but papers are not being read
  Fawcett and Higginson 2012 (PNAS)
Clarity is (part of) the solution

To improve understanding:
• A clear research question, objectives
• Describe uncertainties
• Articulate design decisions (Extents, resolution, process, data)

• Is the pursuit of understanding sufficient?
Spiral of complexity

- Adding information to a model assumed to improve accuracy and precision
  - New, improved data
  - Improved resolution
  - New, improved processes

- Costly
- Can lead to unresponsive, overly complex models
- Unclear decision relevance

- No clear end point ...
Sufficiency

A model is sufficient when additional information will not change the decision (Phillips 1984)

• Requires decision context
  (Alternatives, objectives, risk tolerance)

• Contextual sufficiency:
  All model assumptions credible

• Technical sufficiency:
  Predicted difference between alternatives within risk tolerance
Case study

- Sea otter trophic cascade
- Conflict between otters & fisheries
- Management problem:

*How to manage a listed species that consumes valuable fisheries resources?*
Decision context

Alternatives:
- Otters at K
- No otters

Better data:
Urchin life history from
- Literature
- Targeted study

Higher trophic resolution:
- Functional groups
- Individual species

Otter Management

Otter abundance

Invert abundance

Kelp abundance

Ecosystem structure

Resource distribution

Habitat Suitability

Community distribution

Governance

Otters attract tourists

Tourism

Commercial fishing

Economic benefit

Community health

Well-being

Subsistence

Productivity

Resilience
Model response to more information

- Better Data
- Higher trophic resolution
- Reference

![Graph showing living biomass with system states and model response to more information](image)
Evaluating sufficiency

• Technical uncertainty can be quantified
  – Value of Information approach

• Contextual uncertainty reflects belief
  – Fundamental assumptions explicit
  – Consensus based
  – Bayesian Belief Network
  – Weight of Evidence

• Sufficiency needs to combine contextual and technical certainty
Conclusions

• Need to be better at articulating model assumptions & uncertainties

• Ecosystem models can be assessed for sufficiency in specific decision contexts

• PICES Open Science Meeting Workshop (April 2014): Bridging the divide between models and decision-making: The role of uncertainty in the uptake of forecasts by decision makers

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