A BAYESIAN DECISION NETWORK MODEL FOR ECOSYSTEM-BASED MANAGEMENT OF THE GEORGES BANK SOCIAL-ECOLOGICAL SYSTEM

ROBERT WILDERMUTH, GAVIN FAY, SARAH GAICHAS, AND GERET DEPIPER

OCTOBER 24, 2019

PICES ANNUAL MEETING, SESSION 8

VICTORIA, BC, CANADA

Robert.Wildermuth@umassd.edu
@RPWildermuth
ACKNOWLEDGEMENTS

- Collaborators:
  - Gavin Fay
  - NMFS mentor: Sarah Gaichas
  - WGNARS co-chair: Geret DePiper
- ICES Working Group on the Northwest Atlantic Regional Sea (WGNARS)
- Northeast Fisheries Science Center
- NOAA Integrated Ecosystem Assessment Program

- Funding: NMFS/Sea Grant Population & Ecosystem Dynamics Fellowship

rwildermuth@umassd.edu
@RPWildermuth
Social-ecological models

- Assess multiple management objectives
- Account for multiple interactions and components
- Integrate various sources of knowledge and information
Social-ecological models

- Assess multiple management objectives
- Account for multiple interactions and components
- Integrate various sources of knowledge and information
- Rely on:
  - Data availability
  - Understanding of relationships

Collie et al. 2016 Fish Fish
Caveats

- No statistics
- No dynamics
- Limited evaluation of uncertainty in interactions & structure

CONCEPTUAL MODELS PROVIDE A FRAMEWORK
Bayesian networks provide:

- A systems approach
- Measures of statistical error around variables of importance to management
- Cross-disciplinary inclusion of
  - Expert knowledge
  - Monitoring data
- Visualization of influences
Bayesian networks reflect uncertainty in interaction strengths and functional form.

Data

Structure

Influence Diagram

- Seafloor
- Fishery
- Shellfish
- Primary Production
- Benthos

Low: 13  High: 6

Data Structure

Bayesian networks reflect uncertainty in interaction strengths and functional form.
Bayesian networks reflect **uncertainty in interaction strengths and functional form**

### Structure

- **Seafloor**
- **Fishery**
- **Shellfish**
- **Primary Production**
- **Benthos**

### Data

**Conditional Probability Table (CPT)**

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1/13</td>
<td>3/6</td>
</tr>
<tr>
<td>High</td>
<td>11/13</td>
<td>3/6</td>
</tr>
</tbody>
</table>

**Benthos**

- Low: $\frac{2}{13} = 0.15$
- High: $\frac{3}{6} = 0.5$

- Low: $\frac{11}{13} = 0.85$
- High: $\frac{3}{6} = 0.5$
Bayesian networks reflect uncertainty in structure
Dynamic Bayesian networks allow prediction of effects of management actions

Structures

Decision

Time

Primary Production

Benthos

Shellfish

Primary Production

Benthos

Seafloor

Fishery

Seafloor

Fishery

Seafloor

Fishery

Seafloor

Fishery

Seafloor

Fishery
Georges Bank case study
Georges Bank case study – 58 yrs

Northeast Fisheries Science Center & State of Ecosystem report

Published literature & State mapping products

NOAA modeled products

NMFS Social Science Branch

Survey of social science experts

→ 1,745 parameters
→ 1,206 data points
WELLAMO RESULTS
Wellamo dynamics and model fit
Wellamo dynamics and model fit

Proportional Error Rate at t=2

- Management Indicator
- Other Component

Shellfish
Above $\frac{3}{2}B_{MSY}$
Below $\frac{3}{2}B_{MSY}$

Seafloor & Demersal Habitat
High
Low

Recreational Fishery
High
Low

Seafood
High
Low

Predictions using previous observed state had lower error than Wellamo.
Variance reduction indicates **potential leading indicators** and **indirect correlations**

### Findings Node Queried Node | VR | VR %
--- | --- | ---
$\text{Benthos}_{t=1}$ | $\text{Shellfish}_{t=3}$ | $0.00073$ | $2.2\%$
$\text{PP}_{t=1}$ | $\text{Shellfish}_{t=3}$ | $0.00049$ | $1.5\%$
$\text{GFFishery}_{t=1}$ | $\text{Seafood}_{t=2}$ | $0.11$ | $3.7\%$
$\text{Wind}_{t=1}$ | $\text{Seafood}_{t=2}$ | $0.032$ | $1.1\%$
$\text{MidAtlGF}_{t=2}$ | $\text{Profits}_{t=3}$ | $0.048$ | $1.7\%$
$\text{RecFish}_{t=3}$ | $\text{Profits}_{t=3}$ | $0.57$ | $19.9\%$
$\text{Profits}_{t=3}$ | $\text{RecFish}_{t=3}$ | $0.22$ | $20.2\%$
Influence analysis can reveal *unexpected outcomes*

- 12 “What-if scenarios”
- Dot indicates posterior predicted probability of favored state
- Demersal Habitat reduced in Best Case scenario
TAKE-HOME MESSAGES

- Additional correlation between Recreational Fishing and Profits
- Overall, ~70% of observed data predicted accurately
- These may be driven by autocorrelation in the time series
- Unexpected outcomes for Seafloor & Demersal Habitat in tested scenarios
Hierarchical evaluation:

- State threshold choices (subset of nodes)
- Dynamic feedback structure
- Addition of trophic interactions
- Aggregation of Fishery component(s)
THANK YOU!

I welcome comments and questions

rwildermuth@umassd.edu

@RPWildermuth