Simulating eutrophication effects in Puget Sound using qualitative network models

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Simulating eutrophication effects in Puget Sound using qualitative network models

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The Salish Sea is a social-ecological system

- A complex, interconnected system of natural and social components
- We understand some of these connections far better than others
- Because we don’t understand all connections, outcomes of large changes (climate, food web, management) are often hard to predict

Adapted from Levin et al. 2016
Graphics by Su Kim (NOAA NWFSC)
Ecosystem models can help address this uncertainty...

Ecosystem models—Harvey et al., 2012 a,b; Busch et al. 2013; Ferriss et al. 2016

...but, these models are data-hungry; how do we handle all of the data-poor interactions?
Qualitative ecosystem models

• Qualitative models increasingly are being used to simulate dynamics of complex systems that have significant data-poor components
  • Bayesian Belief Networks
  • Mental Modeler
  • Qualitative Network Models

• Qualitative Network Models (QNM) are based on community matrices
  • “Nodes” & “Links” (+, − or 0)
  • Randomly draw weight for each link, |0.01 - 1.0|
  • Construct 1000s of randomly drawn matrices
  • Explore press perturbation scenarios among the stable matrices

QNM of a simple aquatic food web

Melbourne-Thomas et al. 2012, Ecological Monographs 82:505-519
Qualitative ecosystem models

- **Scenario Example: Increase in Carn-1**
  - Randomly draw stable matrices
  - Select $n$ (e.g., 10,000) in which Carn-1 increases
  - What other nodes consistently increase? Decrease?
  - What other nodes are more ambiguous?

- This approach is being used throughout the world, including the Salish Sea (e.g., Reum et al. 2015, Sobocinski et al. 2018)

- QPress package in R available on GitHub

*Melbourne-Thomas et al. 2012, Ecological Monographs 82:505-519*
QNMs for eutrophication in Puget Sound

Main Basin

Water quality

Regional economy

Agriculture

Urban

Inland/Inland Water habitat

Fish harvest

Recreation

Shellfish harvest

Conservation objectives

Eutrophication

Microbes

Nocílucuas

Dinoflagellates

Diatoms

Zooplankton

Forage fish

Gelatinous Zooplankton

Salamon

Demersal fish

Predators

Benthos

Temperature

Stratification

Nutrients

Upwelling

Precipitation

Turbidity
Model simulations

• How does the model system respond to a “press” of eutrophication?

• What tradeoffs appear in the human system?
Results:
Main Basin

(n = 10,000 simulations per scenario)

• Eutrophication has profound effect on summer food web

• Productivity routed into dinoflagellates, Noctiluca

• Some declines in aggregate societal nodes
QNMs for eutrophication in Puget Sound

Hood Canal

Regional economy
Forestry
Septic systems
Fish harvest
Recreation
Shellfish harvest

Water quality
Restoration costs

Eutrophication

Marine habitat
Inland/PW habitat

Temperature
Stratification
Nutrients
Dissolved oxygen
Turbidity
Upwelling
Precipitation

Gelatinous zoops
Forage fish
Dinoflagellates
Zooplankton
Detrims
Benthos

Conservation objectives
Predators
Demersal fish
Salmon
- A summer eutrophication event alone did not cause hypoxia.
- Upwelling-driven hypoxia caused different system responses.
- So, combine them…

Results:

Hood Canal

*(n = 10,000 simulations per scenario)*

- Summer eutrophication, Hood Canal
  - Diatoms
  - Microbes
  - Zooplankton
  - Benthos
  - ForageFish
  - Salmon
  - DemersalFish
  - Predators

- Summer hypoxia event, Hood Canal
  - Diatoms
  - Microbes
  - Zooplankton
  - Benthos
  - ForageFish
  - Salmon
  - DemersalFish
  - Predators

- Dinoflagellates
- Noctiluca
- GelatinousZooplankton

- Forestry
- FishHarvest
- ShellfishHarvest
- Recreation
- SepticSystems
- RestorationCosts

- ConservationObjectives
- RegionalEconomy
- WaterQuality

0% 20% 40% 60% 80% 100%

- Increased
- Decreased
- No change
Results:

Hood Canal

*(n = 10,000 simulations per scenario)*

- Eutrophication + hypoxia is pretty similar to the hypoxia scenario
- Distinct outcome from Main Basin summer eutrophication
- Consider scales of economies in these 2 basins
The not-so-good conclusions

- This is as preliminary as it gets...in fact, this might be whatever comes before “preliminary”. Take this all with a few tablespoons of salt.

- Models like this should be developed in collaboration, across disciplines, which I have not done yet

- Don’t blame my co-author!

- Next step will be to solicit input from experts (scientists, managers, stakeholders) to ensure models are structured reasonably, ESPECIALLY in the economic, social and governance portions of the models
Some more hopeful conclusions

Salmon are a challenge to “manage” in the model; also, some big changes only derive from cumulative pressures…that’s all believable!

These models are easy to tailor to appropriate spatiotemporal scales, which facilitates seasonal or across-basin comparisons.

Data-rich nodes can be “calibrated” using the data & models that we have heard about in this session and the rest of this week.

Then the real value of this approach comes in: simulating the data-poor nodes and linkages and bringing full conceptual models to life.