Apr 6th, 9:45 AM - 10:00 AM

Simulating eutrophication effects in Puget Sound using qualitative network models

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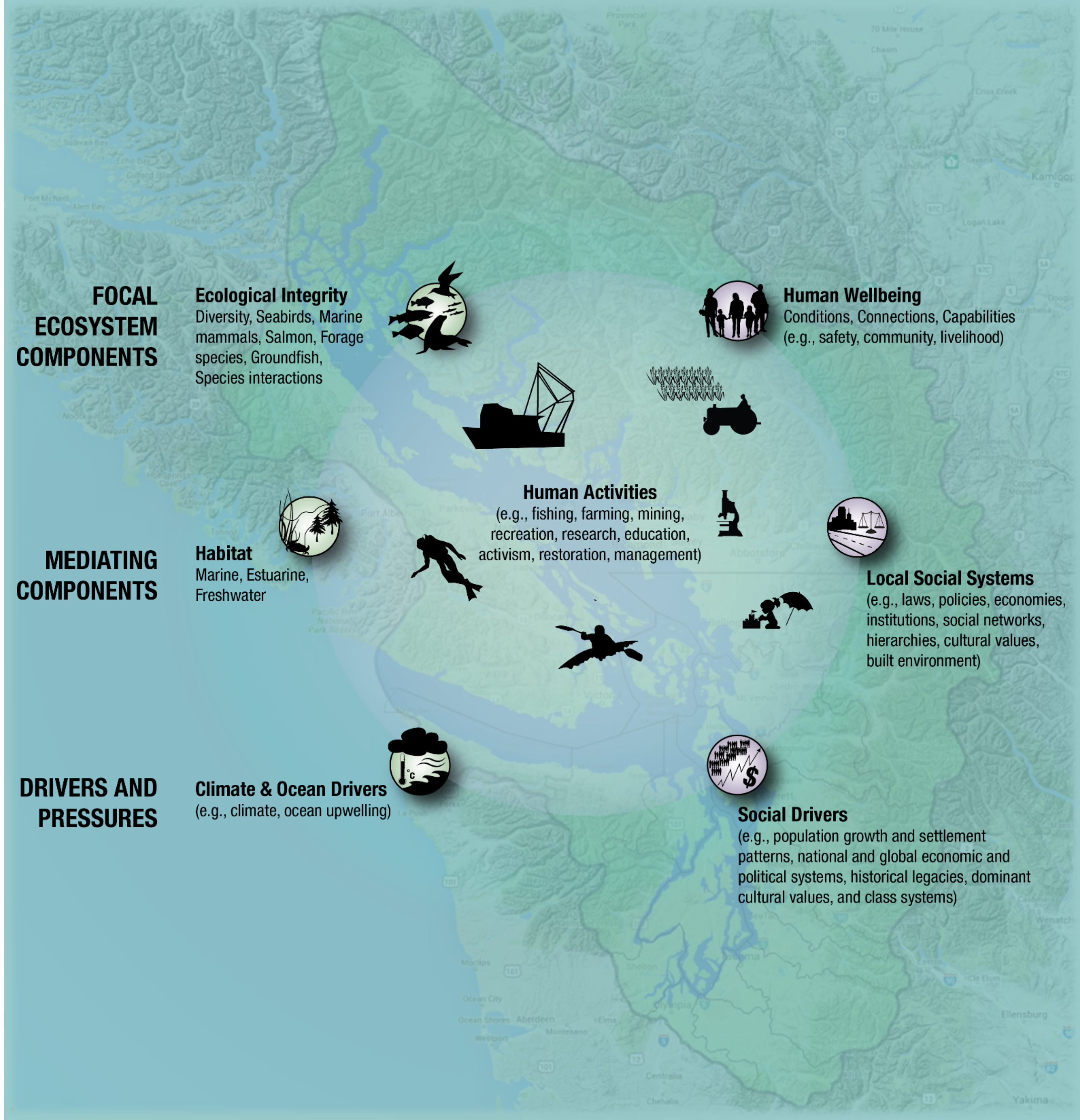
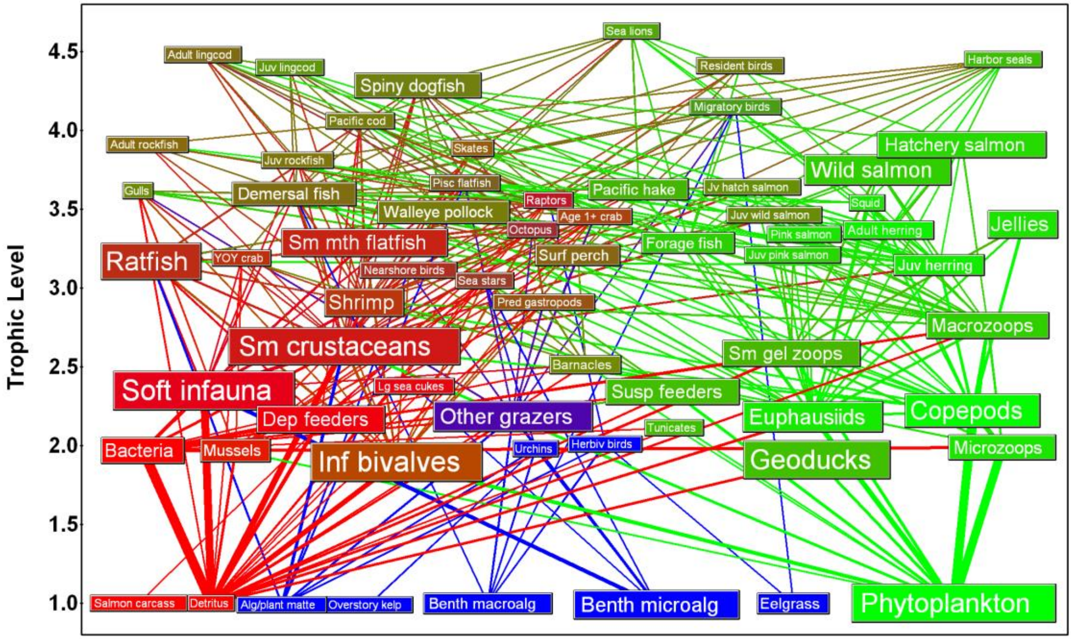
The Salish Sea is a social-ecological system

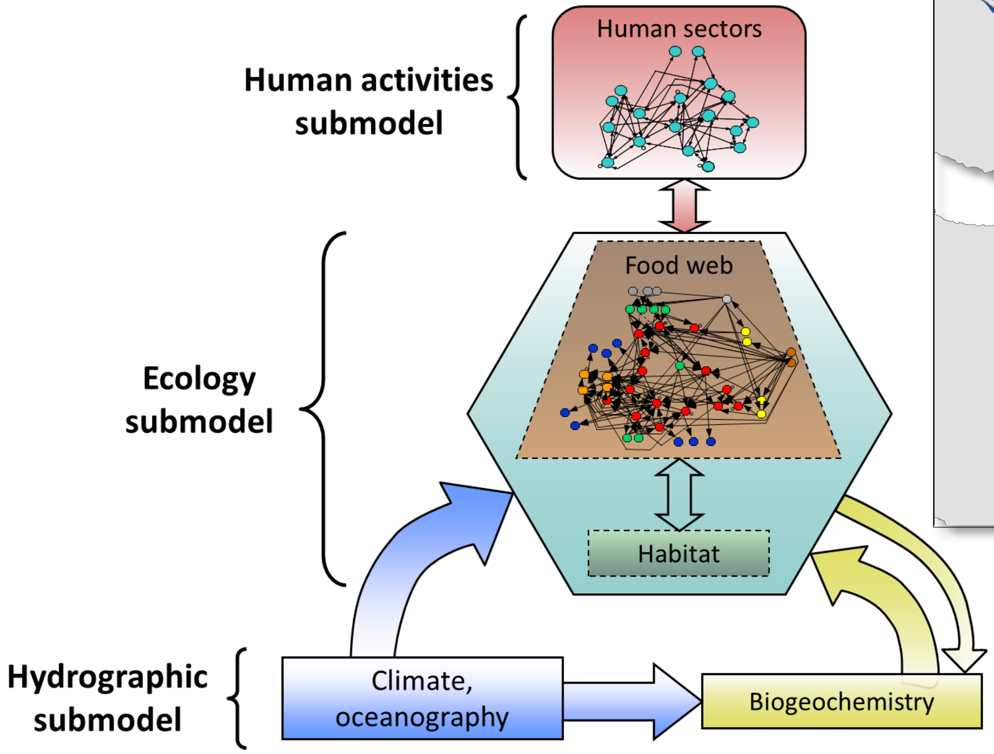
- A complex, interconnected system of natural and social components
- We understand some of these connections far better than others
- Because we don't understand all connections, outcomes of large changes (climate, food web, management) are often hard to predict

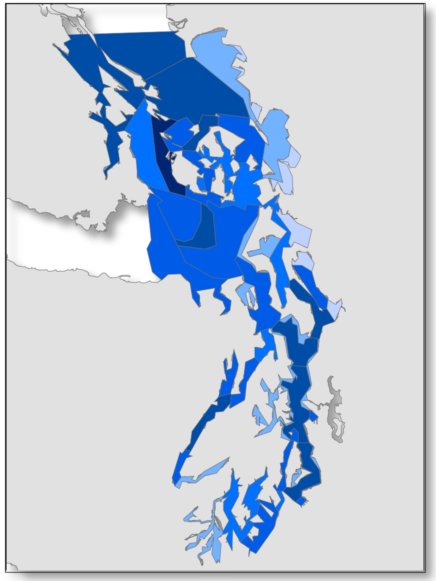


Adapted from Levin et al. 2016
Graphics by Su Kim (NOAA NWFSC)

Ecosystem models can help address this uncertainty…







Ecopath with Ecosim—Harvey et al., 2012 a,b; Busch et al. 2013; Ferriss et al. 2016

Atlantis—Kaplan (NWFSC), Morzaria-Luna and Girardin (LLTK), Fulton (CSIRO) et al., in prep

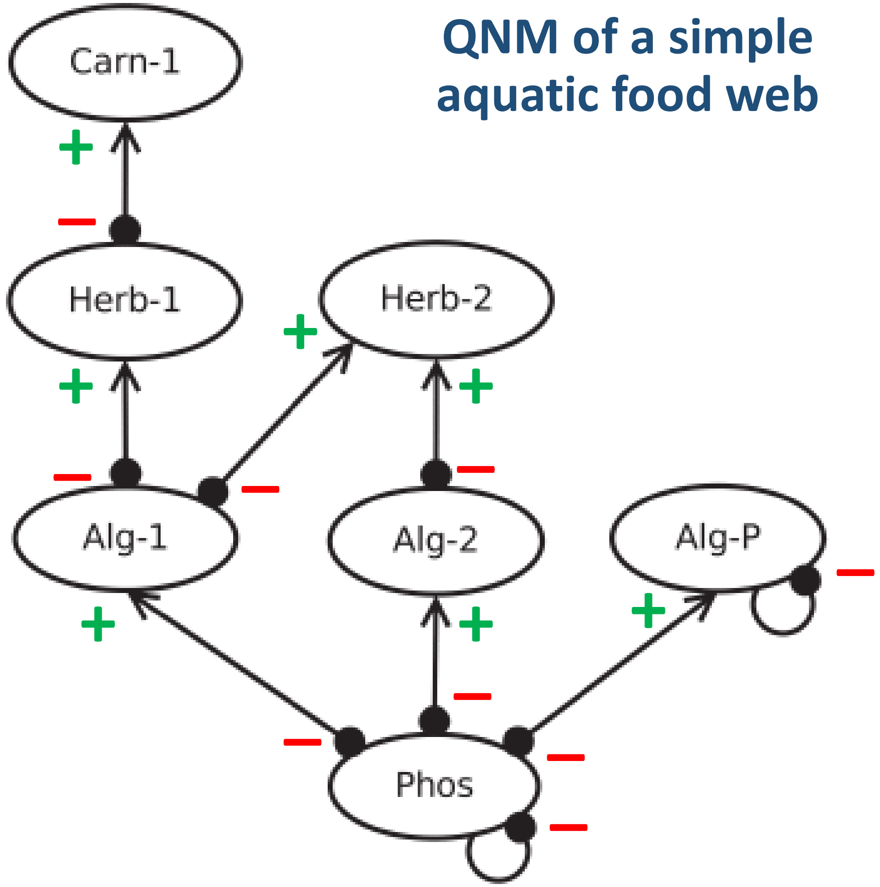
…but, these models are data-hungry; how do we handle all of the data-poor interactions?

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 (QNMs) 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*

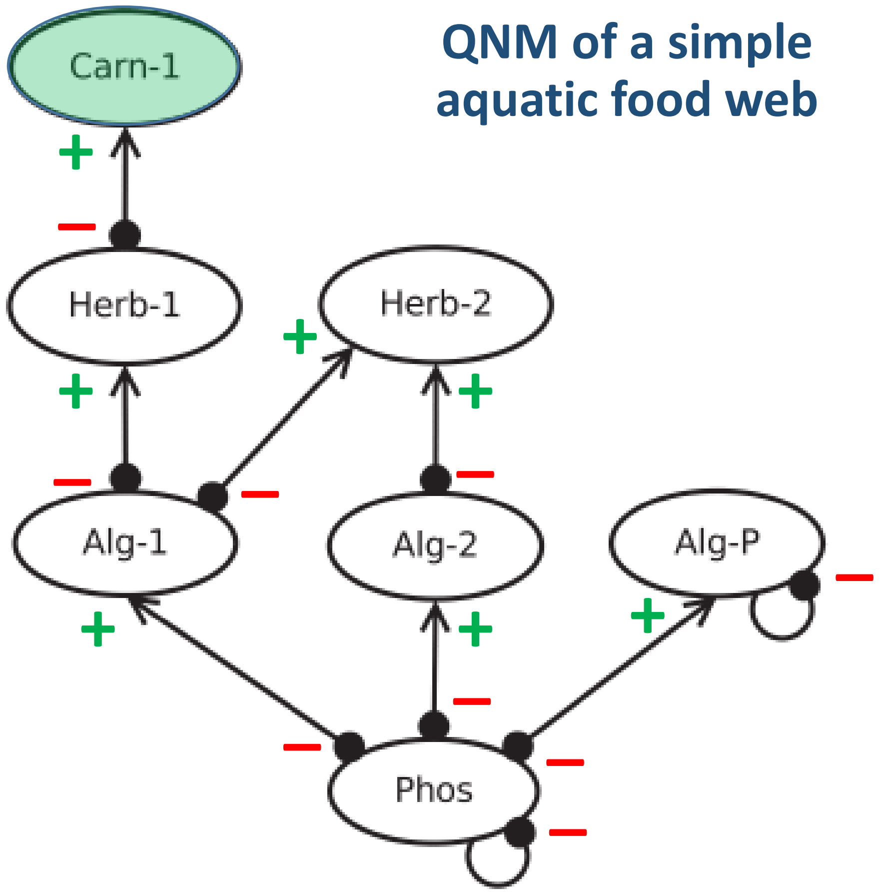
Qualitative ecosystem models

- **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

QNM of a simple aquatic food web



Melbourne-Thomas et al. 2012,
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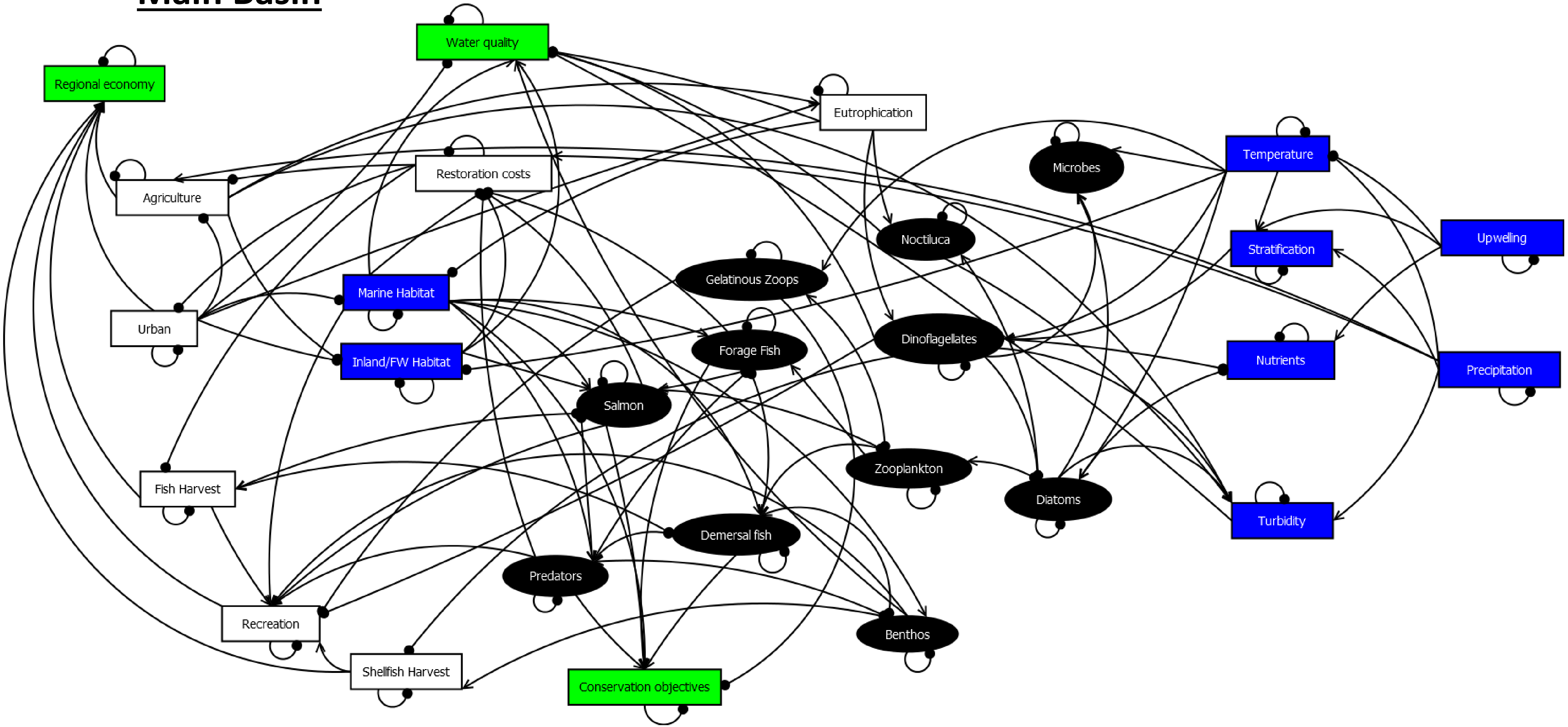
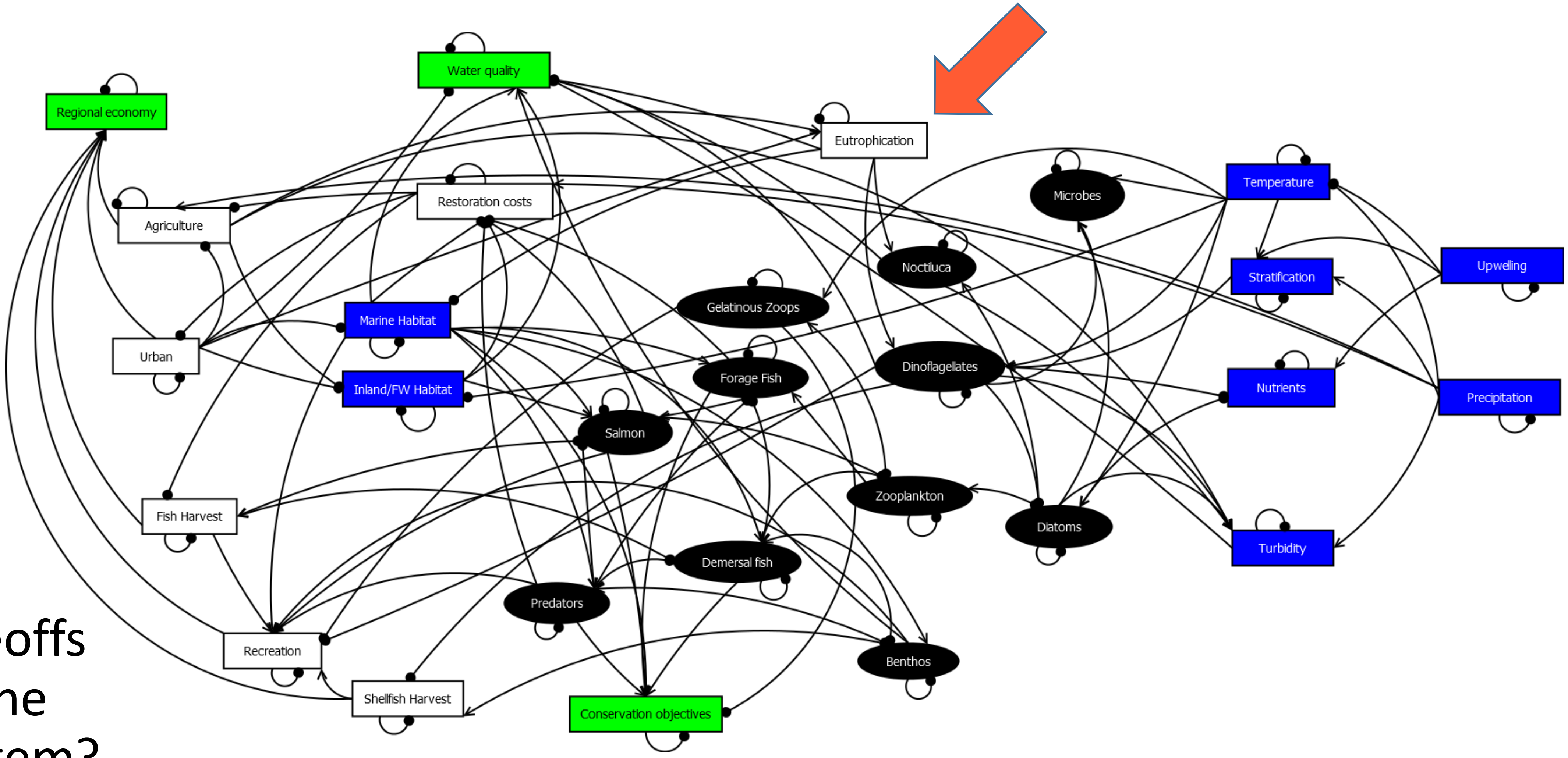
QNMs for eutrophication in Puget Sound

Main Basin



Model simulations

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

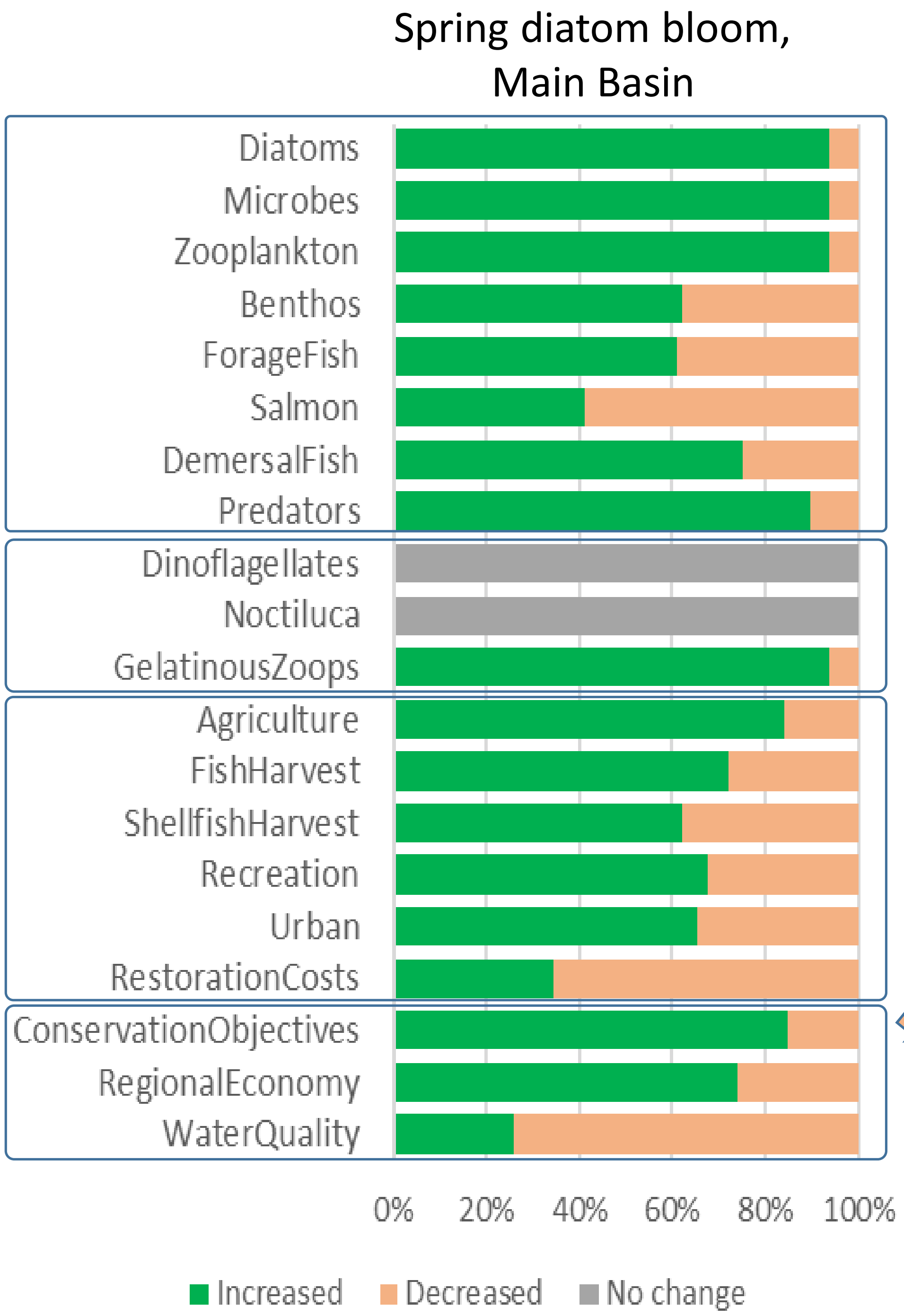


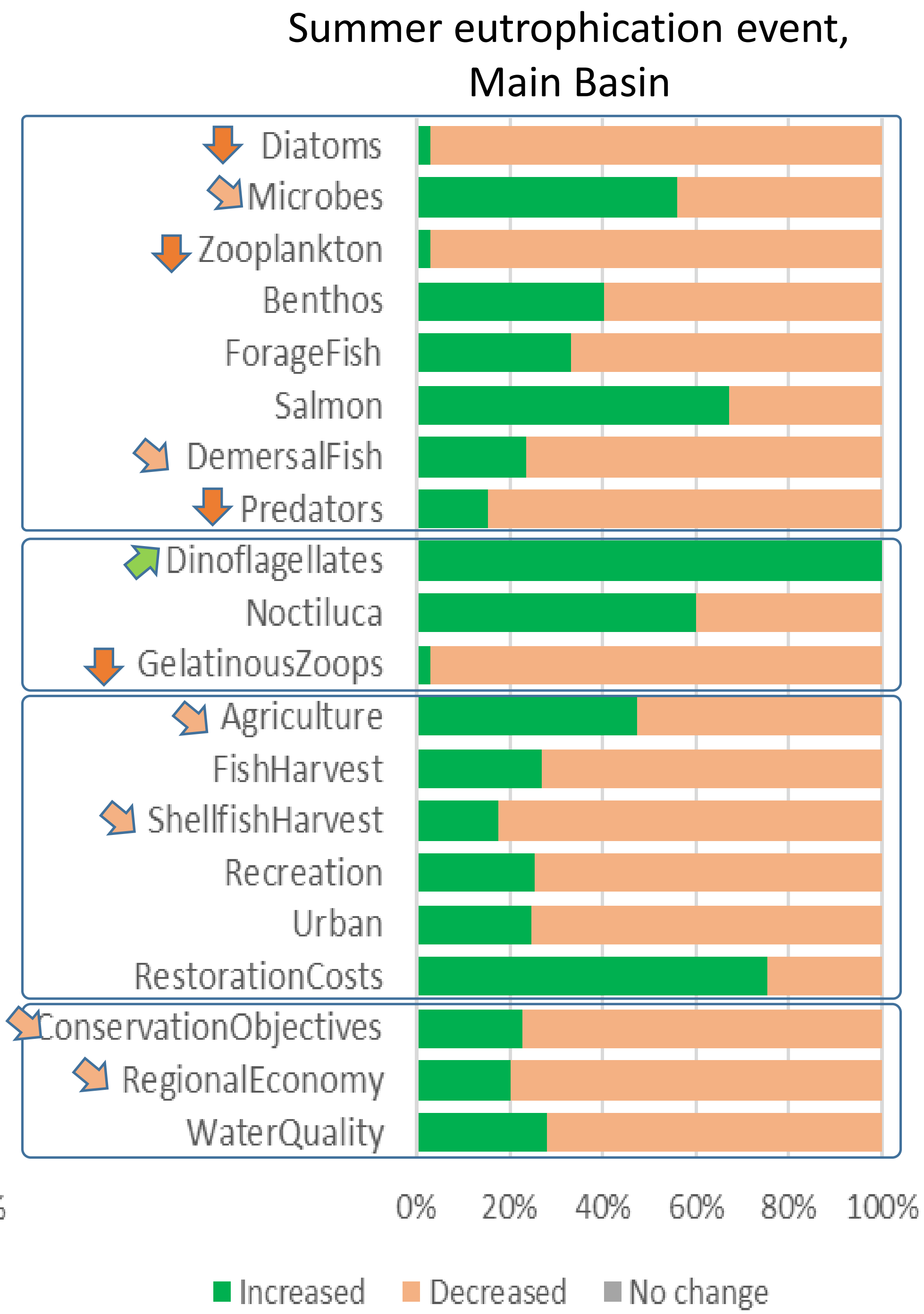
- What tradeoffs appear in the human system?

Results: Main Basin

(n = 10,000 simulations per scenario)

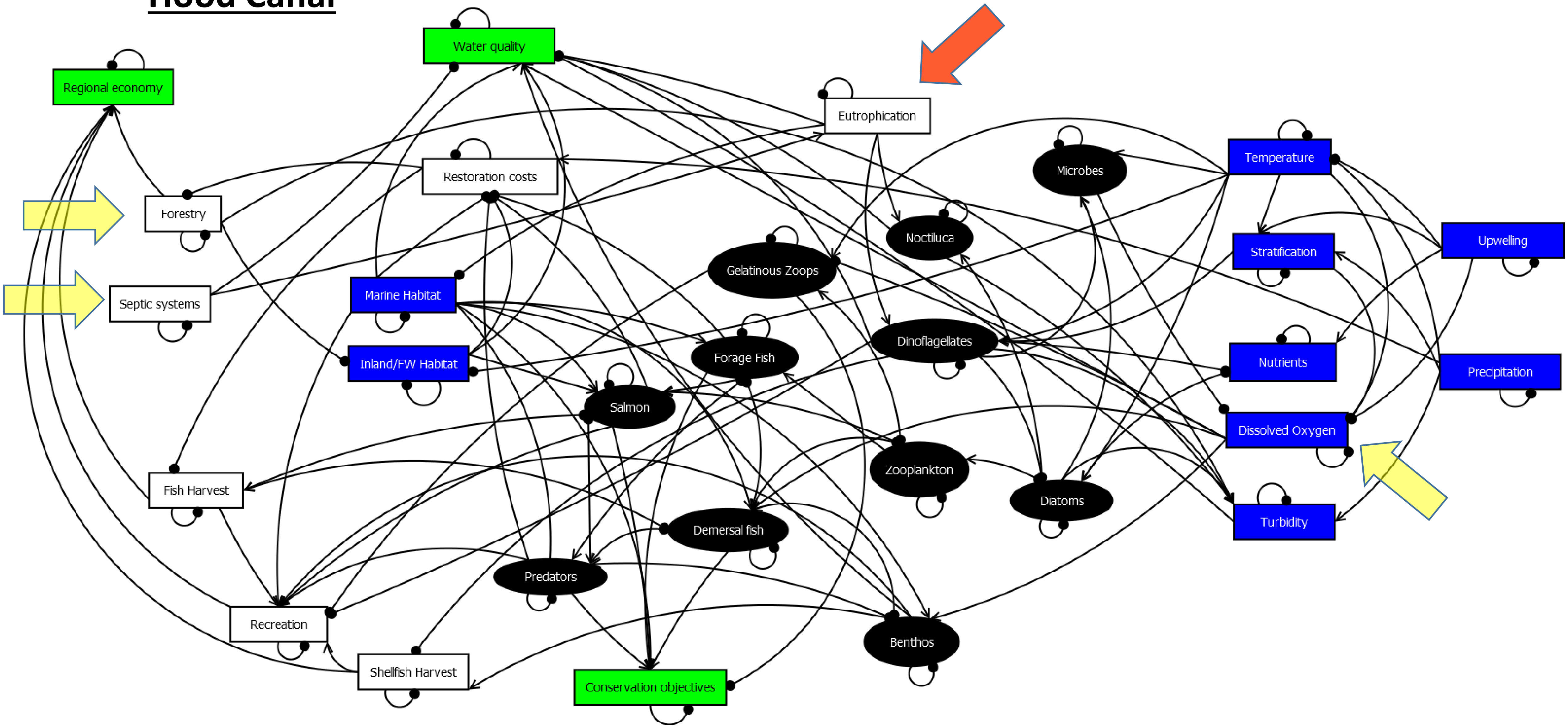
- Eutrophication has profound effect on summer food web
- Productivity routed into dinoflagellates, Noctiluca
- Some declines in aggregate societal nodes





QNMs for eutrophication in Puget Sound

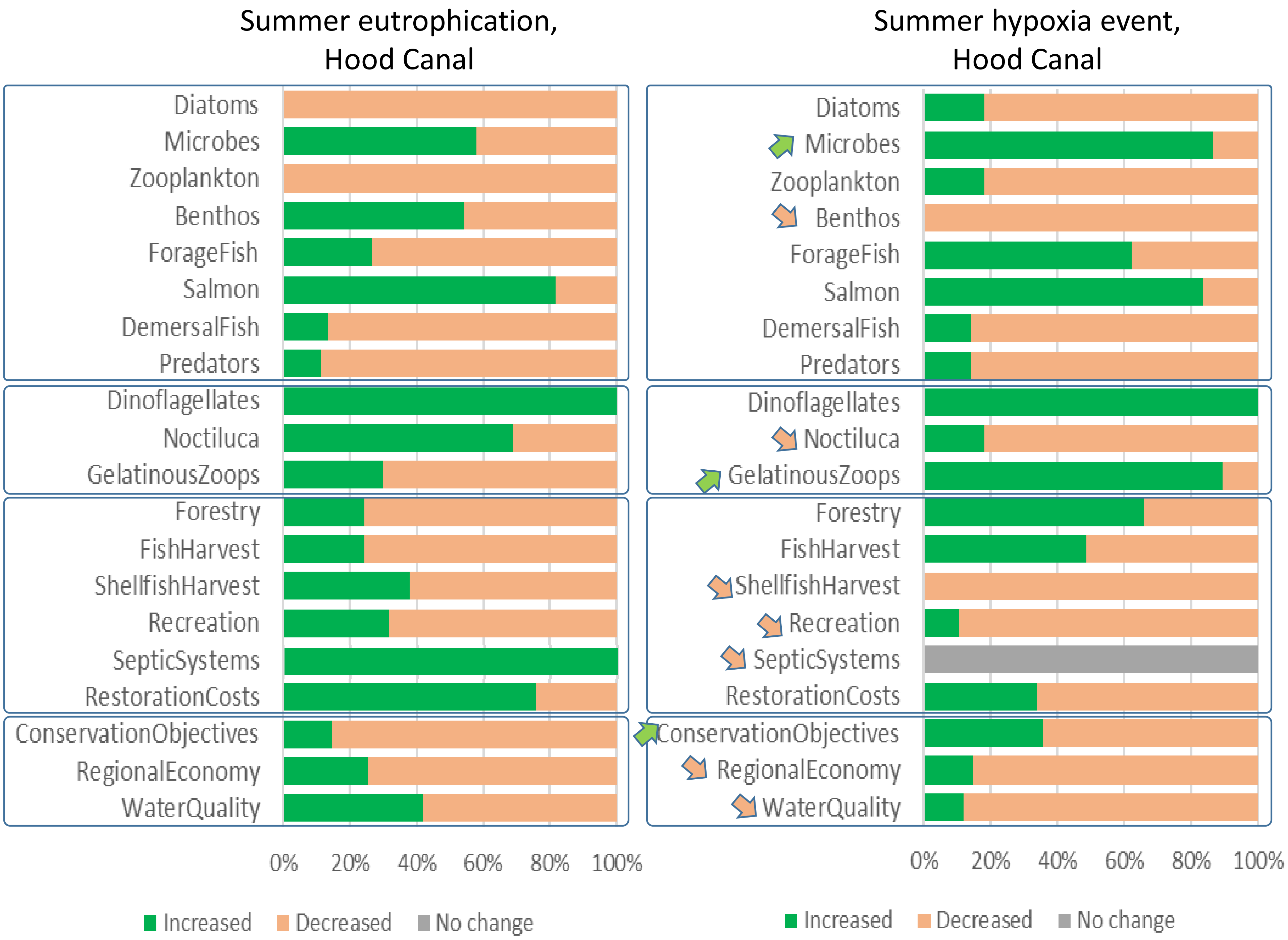
Hood Canal



Results: Hood Canal

(n = 10,000 simulations per scenario)

- A summer eutrophication event alone did not cause hypoxia
- Upwelling-driven hypoxia caused different system responses
- So, combine them…

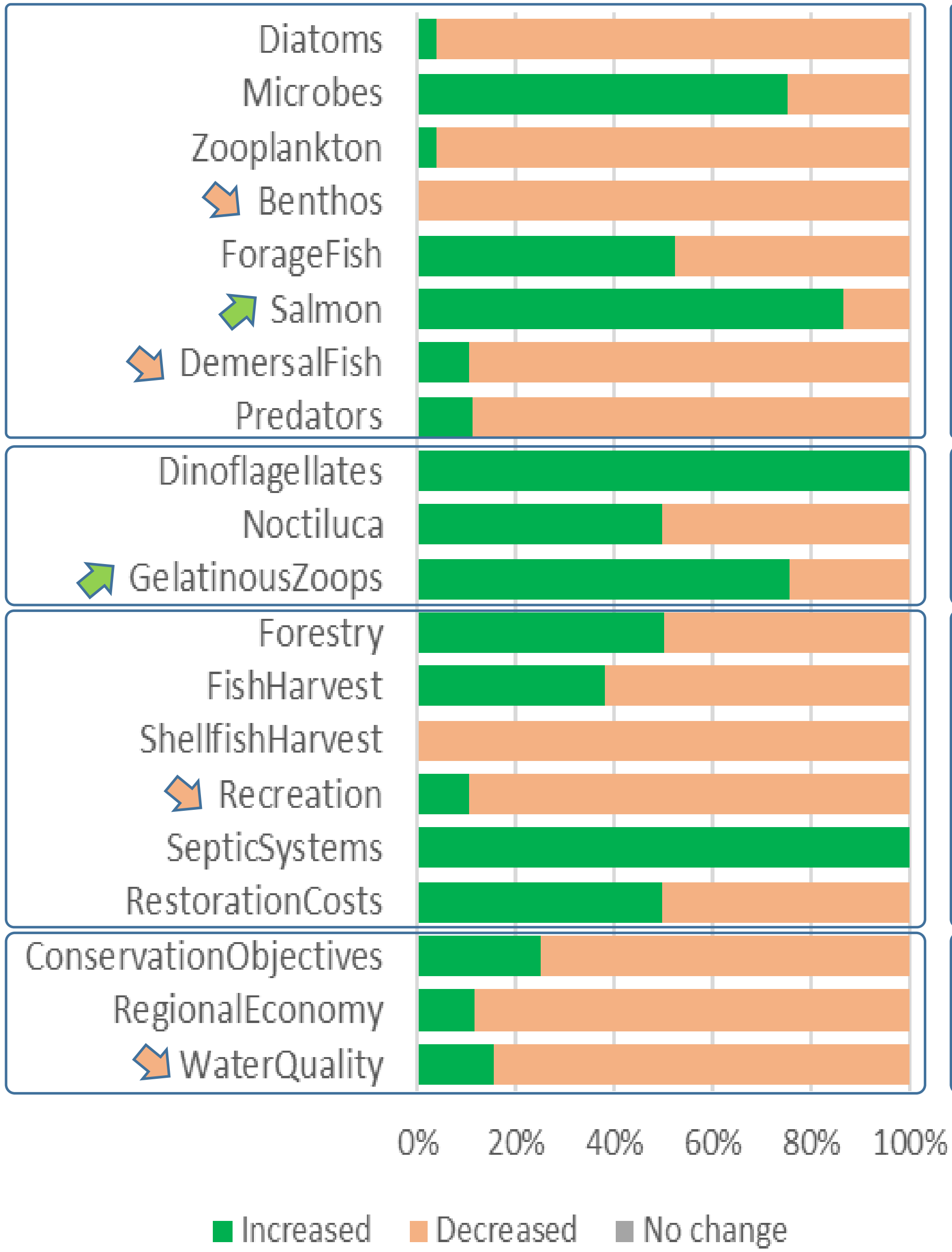


Results: Hood Canal

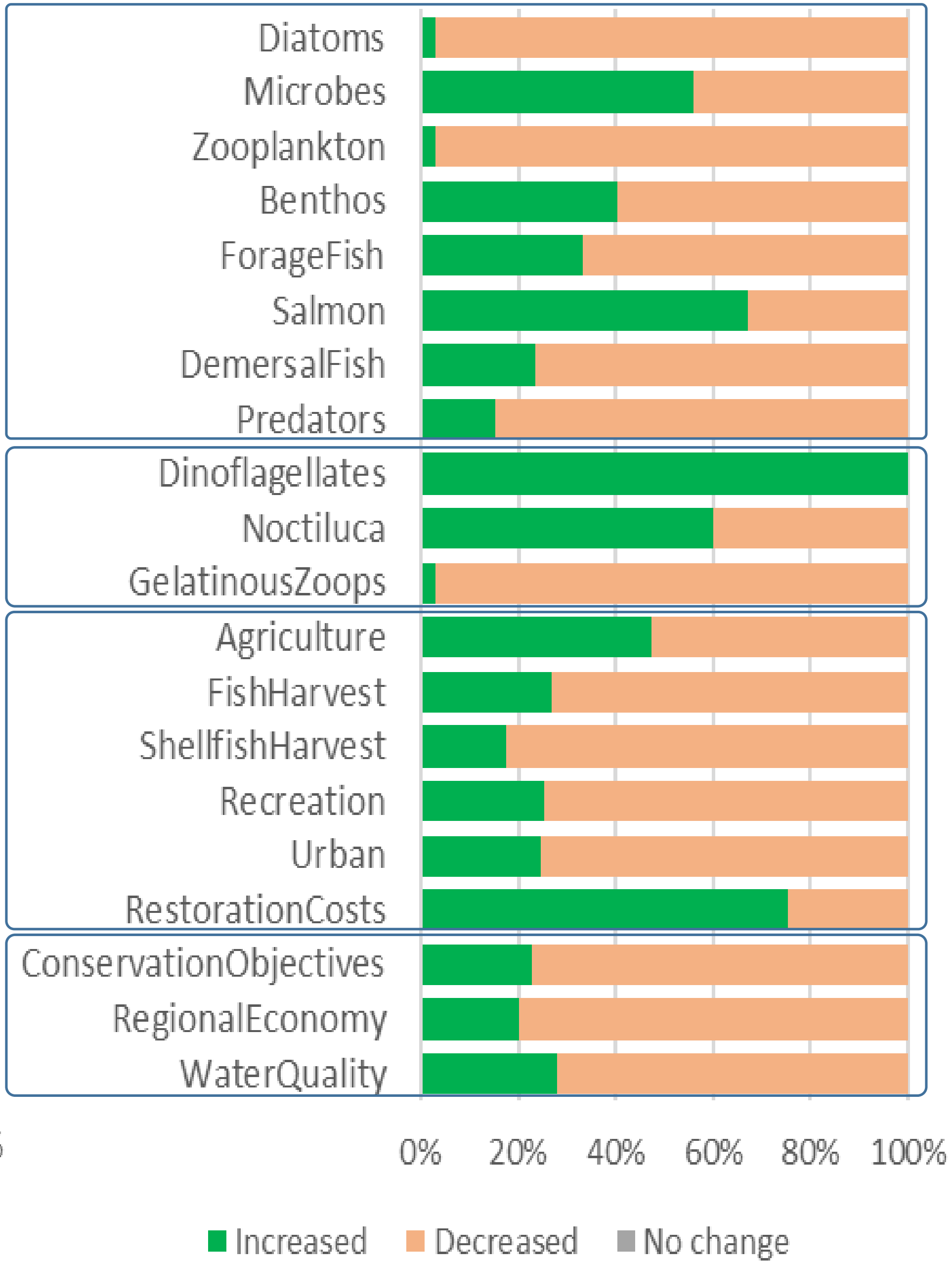
(n = 10,000 simulations per scenario)

- Eutrophication + hypoxia is pretty similar to the hypoxia scenario
- Distinct outcome from Main Basin summer eutrophication
- Consider scales of economies in these 2 basins

Summer eutrophication + hypoxia, Hood Canal



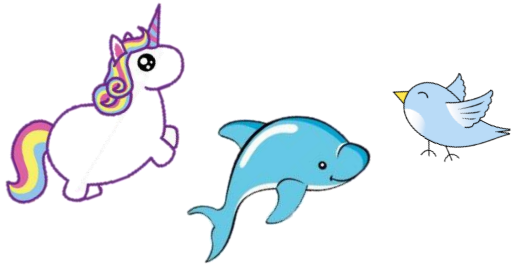
Summer eutrophication event, Main Basin



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