# The role of nutrients in Puget Sound food webs: Insights from empirical and modeling studies

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**NOAA Fisheries**

Do nutrients affect marine survival of Pacific salmon?

- 40-year declines of Pacific salmon
- Testing “bottom-up” hypotheses explaining declines
- Reconstructing long-term patterns of primary production in Puget Sound from growth in geoducks

# Objectives of the Salish Sea Marine Survival Project

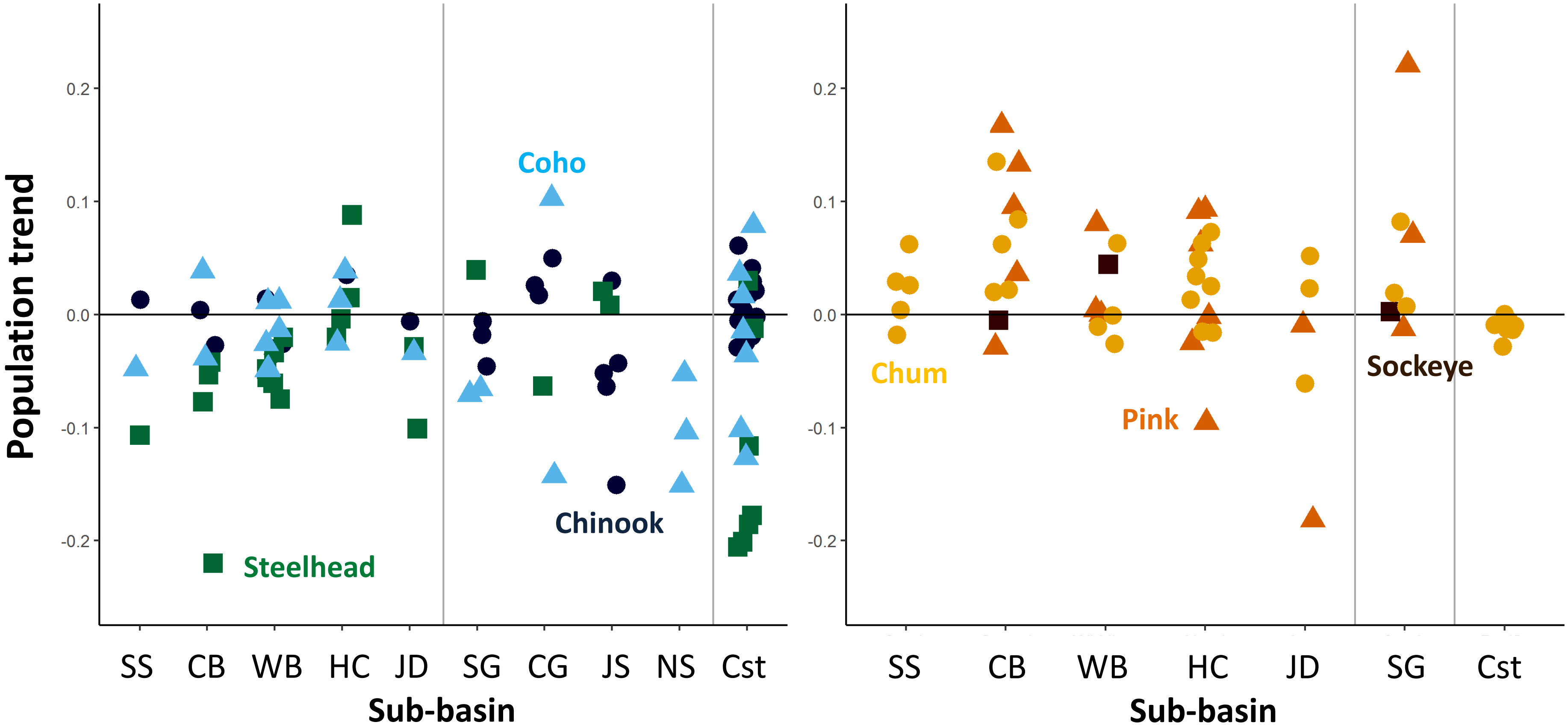
Advance wild salmon recovery and sustainable fisheries

- What happened since the 1980’s and can we improve the situation for juvenile Chinook, coho and steelhead?

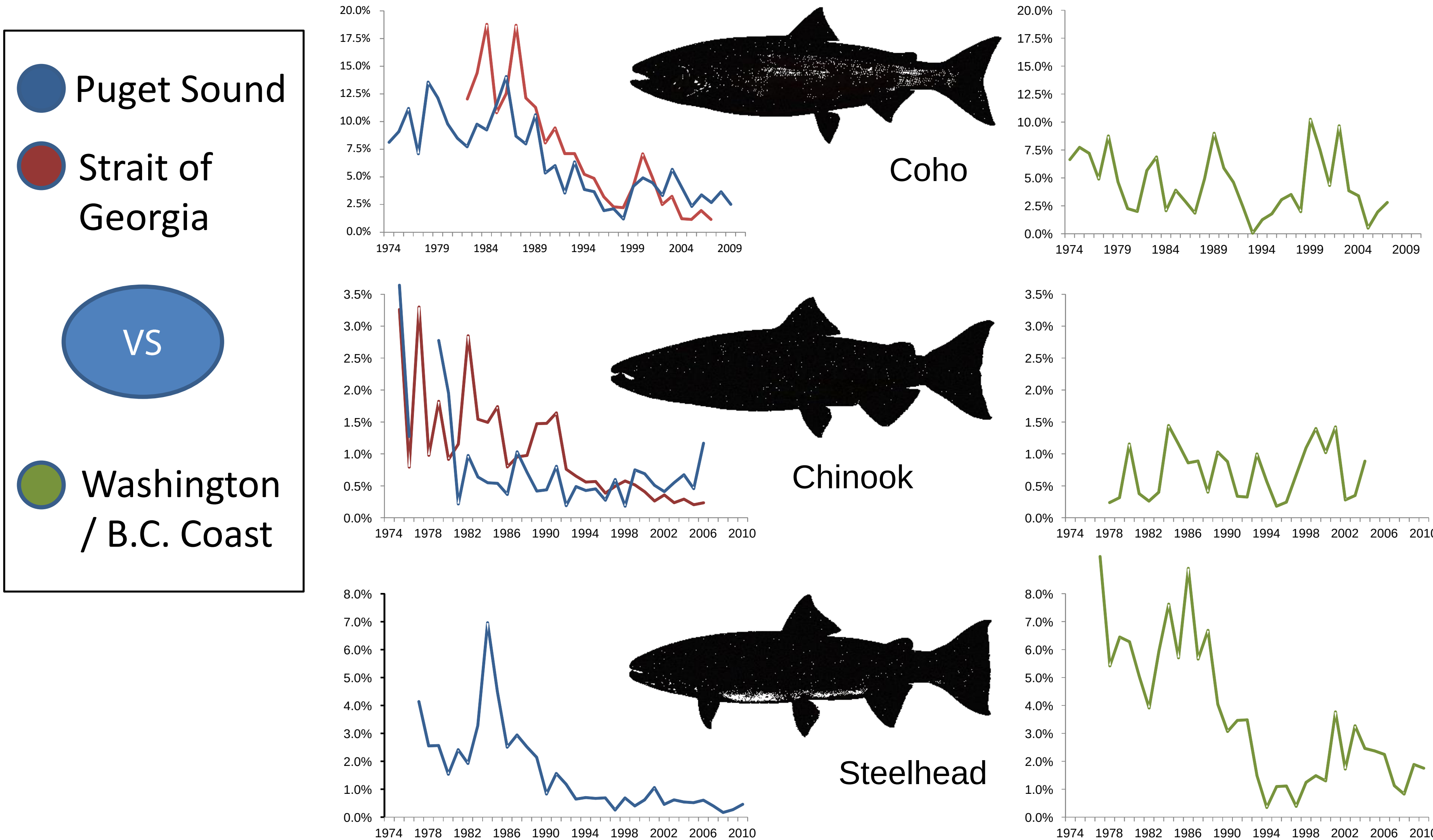
- How do we improve the accuracy of adult return forecasting with early marine survival data: to better manage harvest, hatcheries and natural spawning?

- What actions can we take to improve marine survival?

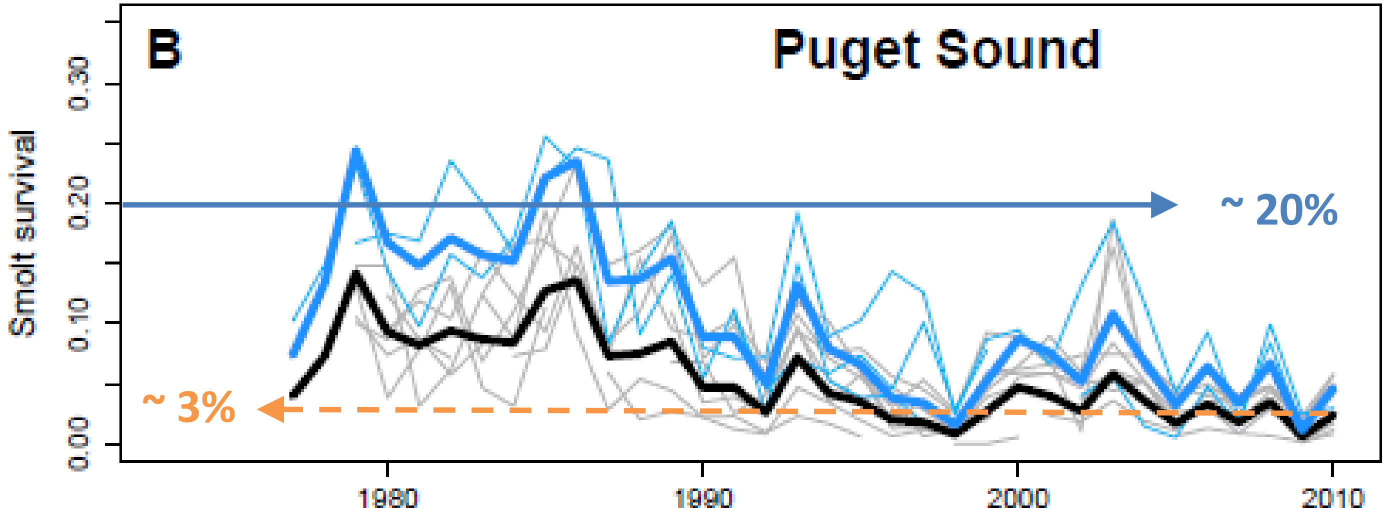
# Declines of salmon in the Salish Sea

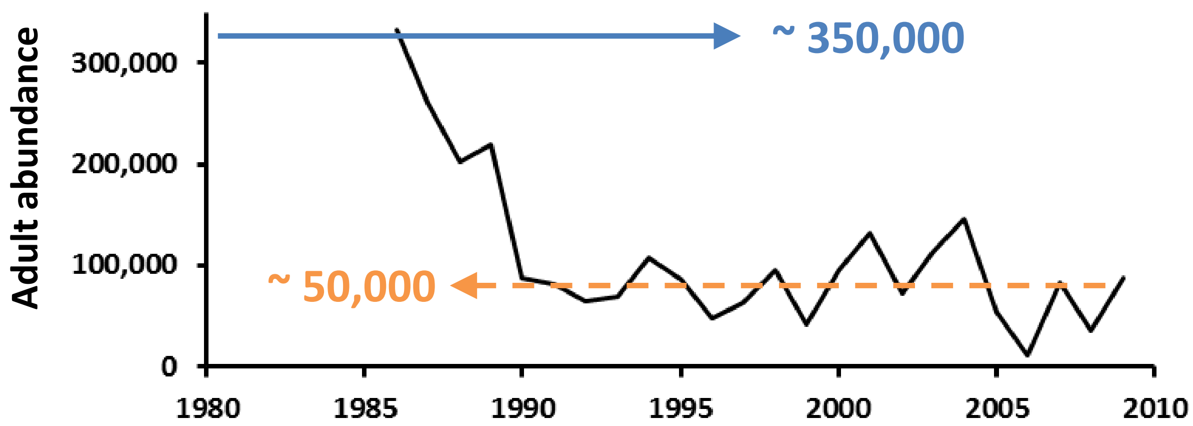


# Declines in Salish Sea Marine Survival



# Marine survival vs abundance trends




Skagit River coho

**Current = 10-12% of historical!**

# Hypotheses

A. **Bottom-up processes** that drive Chinook, coho and forage fish prey availability have changed, and salmon aren't able to compensate.

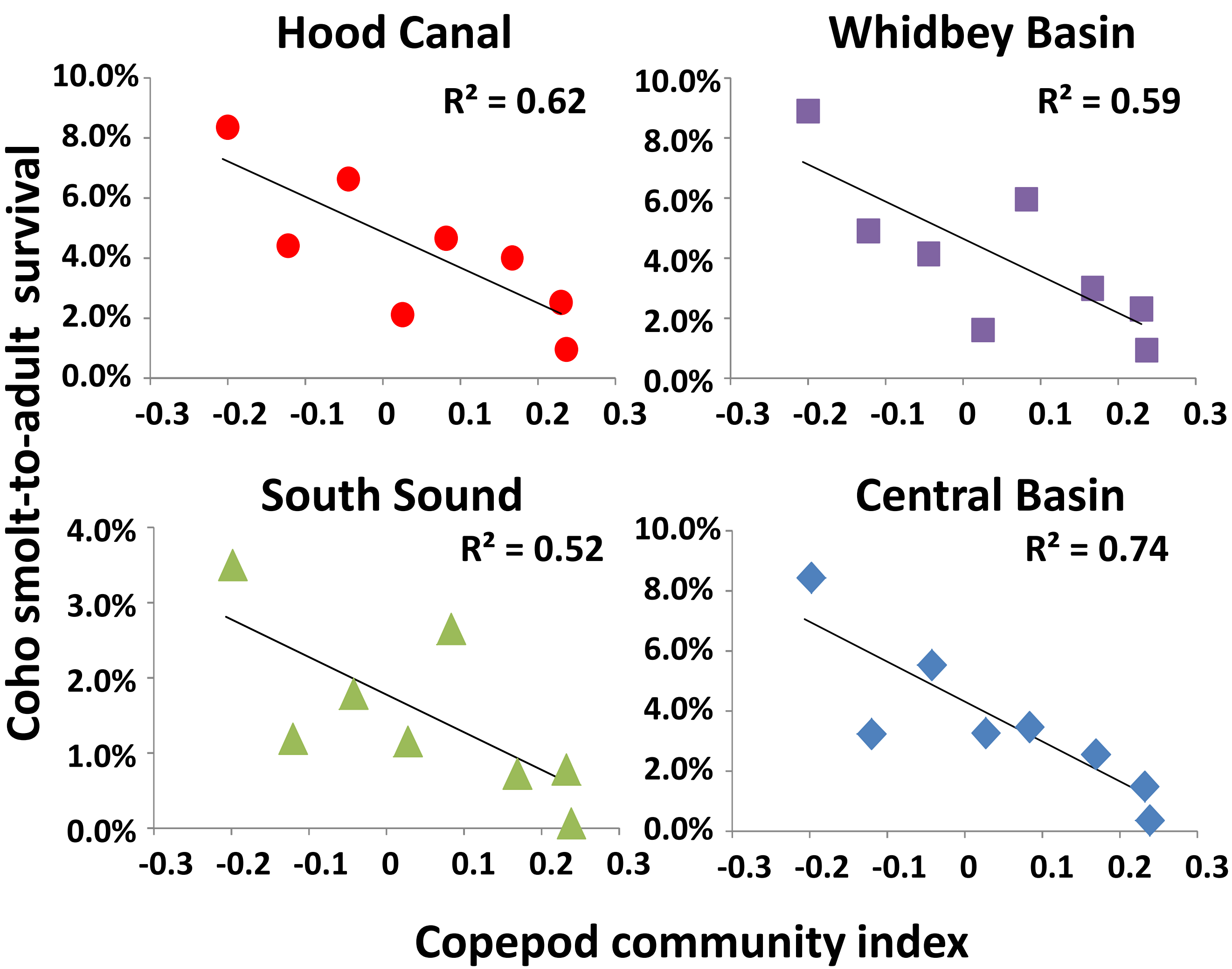
B. **Top-down processes contributing** – More predators making situation worse. Eating larger juvenile steelhead, resident salmon and forage fish.

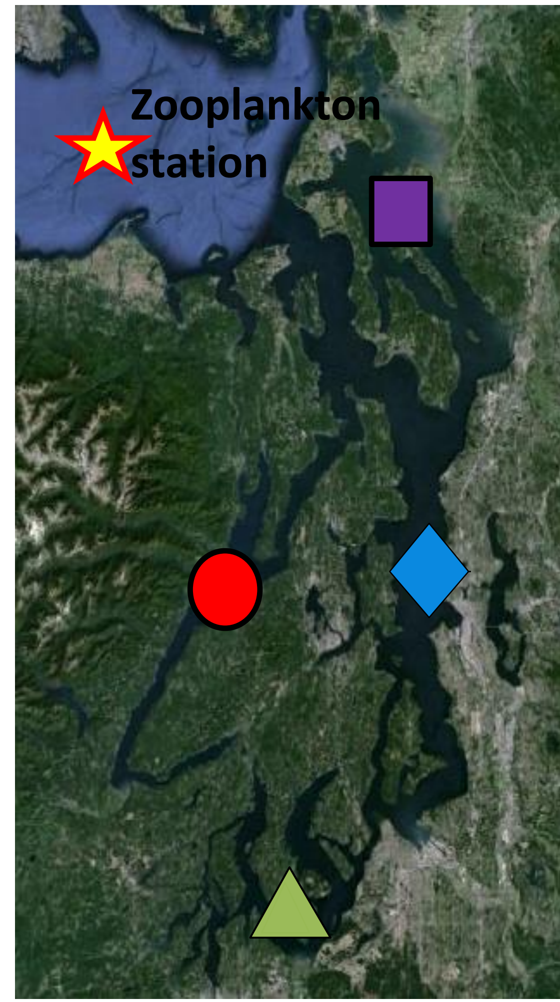
C. **Multiple factors may compound the problem**:
- Microbes & disease
- Contaminants
- Habitat loss
- Cumulative effects


Ultimately, must weigh the contribution of:

- Local, human influence (water quality, predator management, hatchery management)
- Regional or global impacts (climate change, ocean acidification, natural cycles)

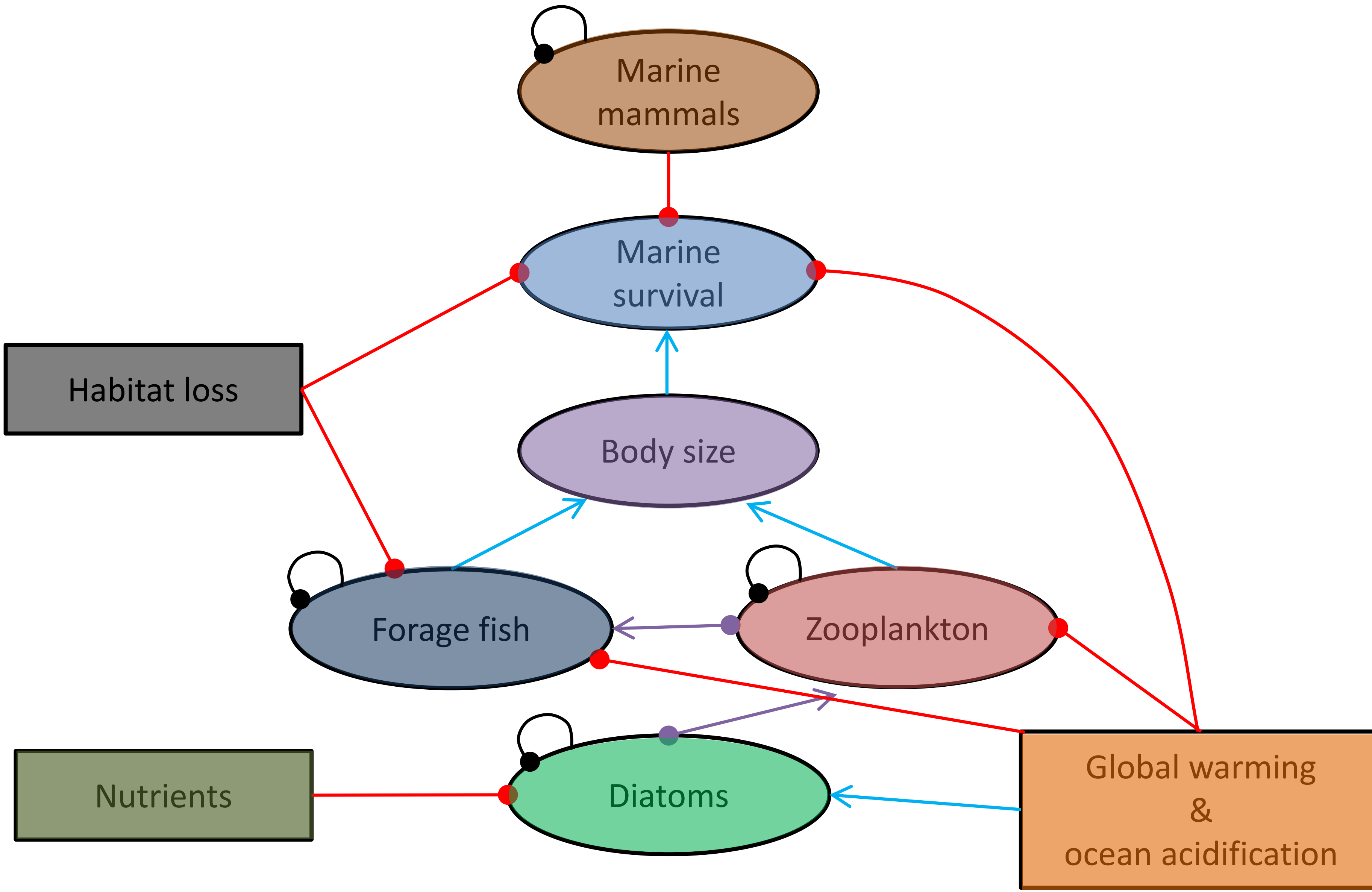
# Evidence for “bottom-up” effects: Zooplankton and coho survival (2003-10)




J. Keister

# A tangled web of possibilities



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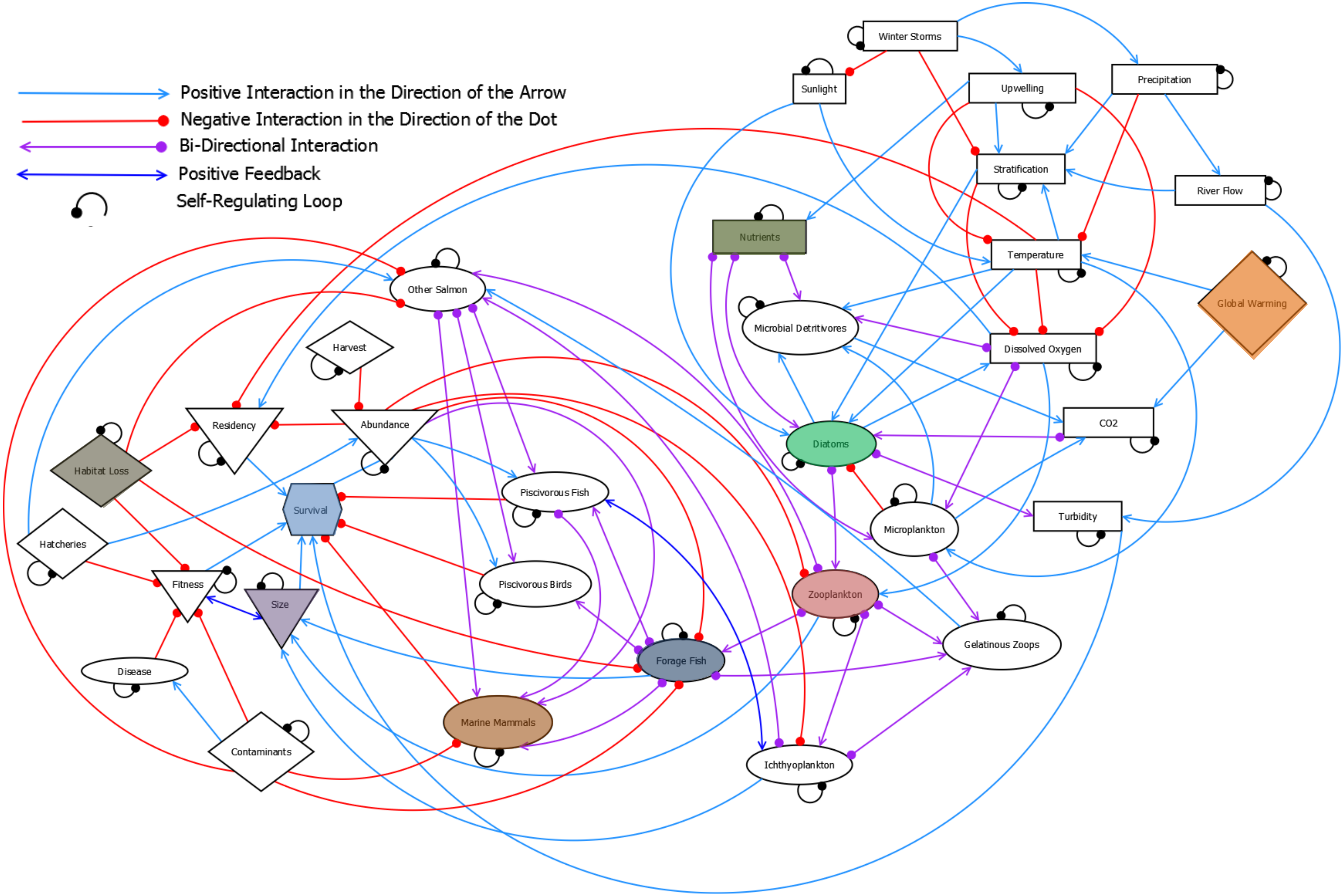
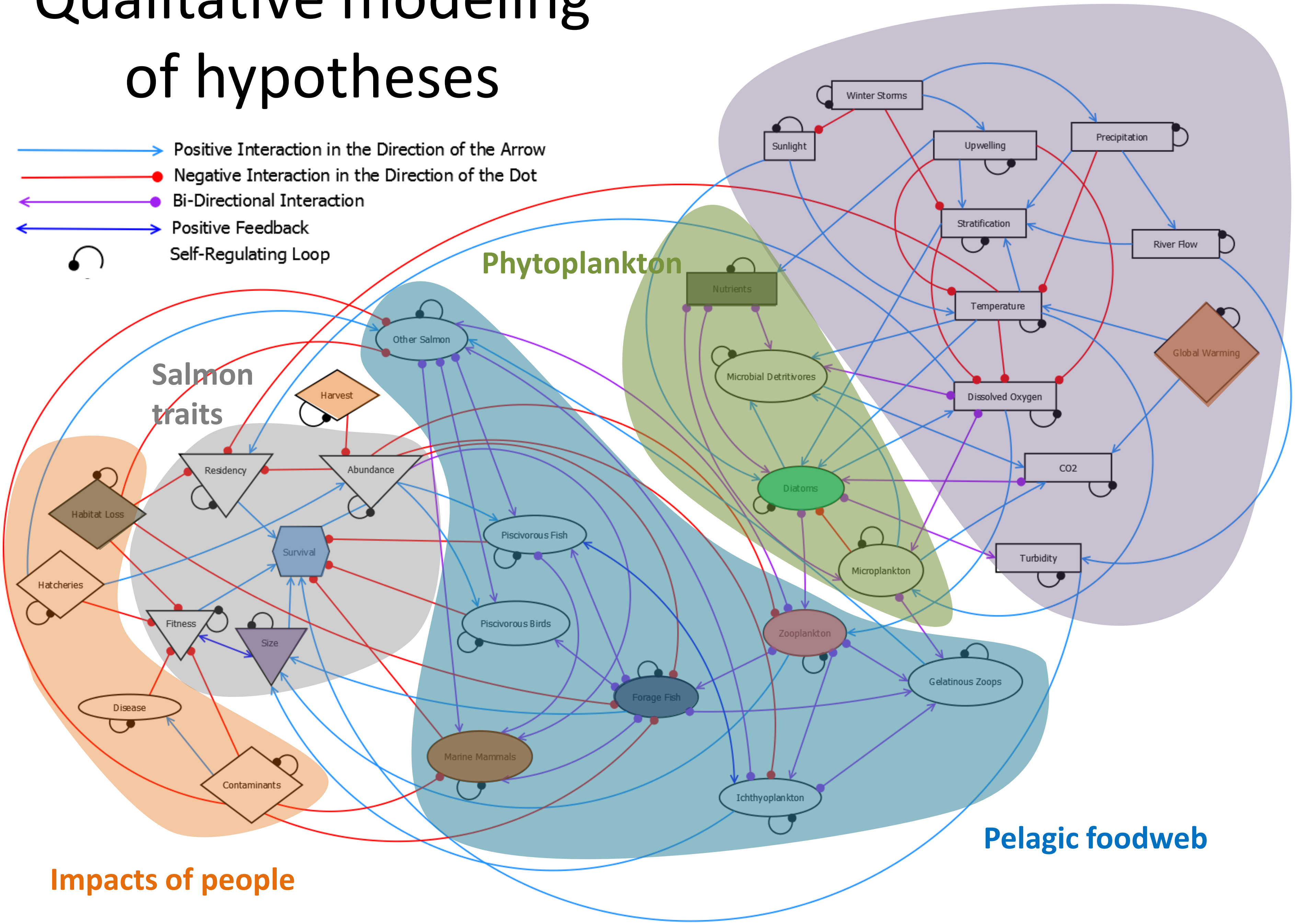


# Qualitative modeling of hypotheses



# Model results

## Environmental drivers

| Variables | Perturbation | Surv | Abund |
|---|---|---|---|
| Sunlight | ↑ | | |
| Winter Storms | ↑ | | |
| Precipitation | ↑ | | |
| Stratification | ↑ | | |
| Temperature | ↑ | | |
| River Flow | ↑ | | |
| Upwelling | ↓ | | |
| Turbidity | ↓ | | |
| Dissolved Oxygen | ↓ | | |

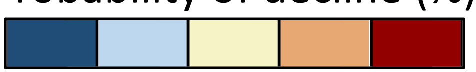
## Pelagic foodweb groups

| Variables | Perturbation | Surv | Abund |
|---|---|---|---|
| Gelatinous Zooplankton | ↑ | | |
| Other Salmon | ↑ | | |
| Marine Mammals | ↑ | | |
| Zooplankton | ↓ | | |
| Forage Fish | ↓ | | |
| Ichthyoplankton | ↓ | | |
| Piscivorous Fish | ↓ | | |
| Piscivorous Birds | ↓ | | |

## Phytoplankton production

| Variables | Perturbation | Surv | Abund |
|---|---|---|---|
| Nutrients | ↑ | | |
| Microplankton | ↑ | | |
| Microbial Detritivores | ↑ | | |
| Diatoms | ↓ | | |

Probability of decline (%)



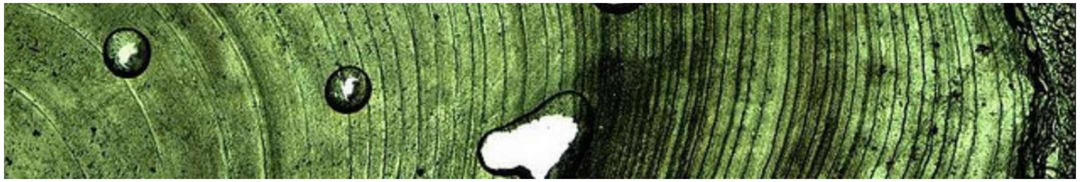
0 20 40 60 80 100

## Impacts of people

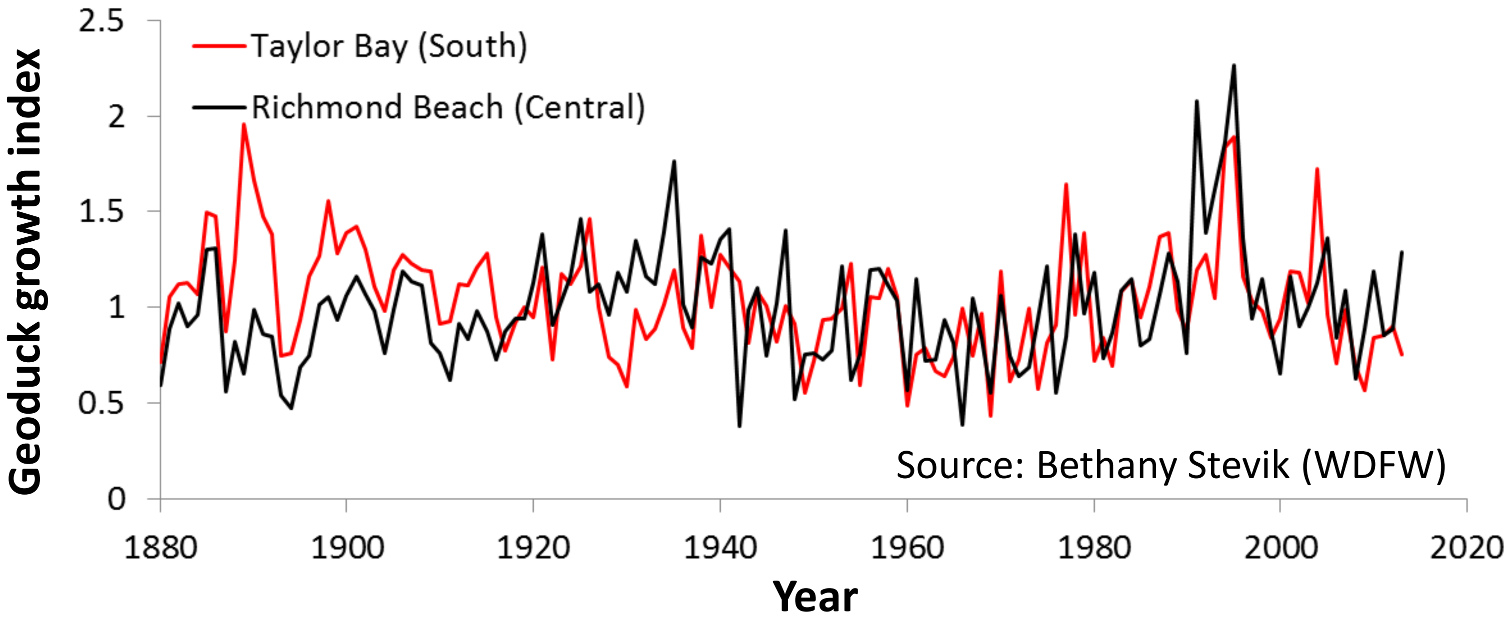
| Variables | Perturbation | Surv | Abund |
|---|---|---|---|
| Hatcheries | ↑ | | |
| Harvest | ↑ | | |
| Habitat Loss | ↑ | | |
| CO2 | ↑ | | |
| Global Warming | ↑ | | |
| Contaminants | ↑ | | |
| Disease | ↑ | | |

# Reconstructing primary production

Evergreen College



Bryan Black

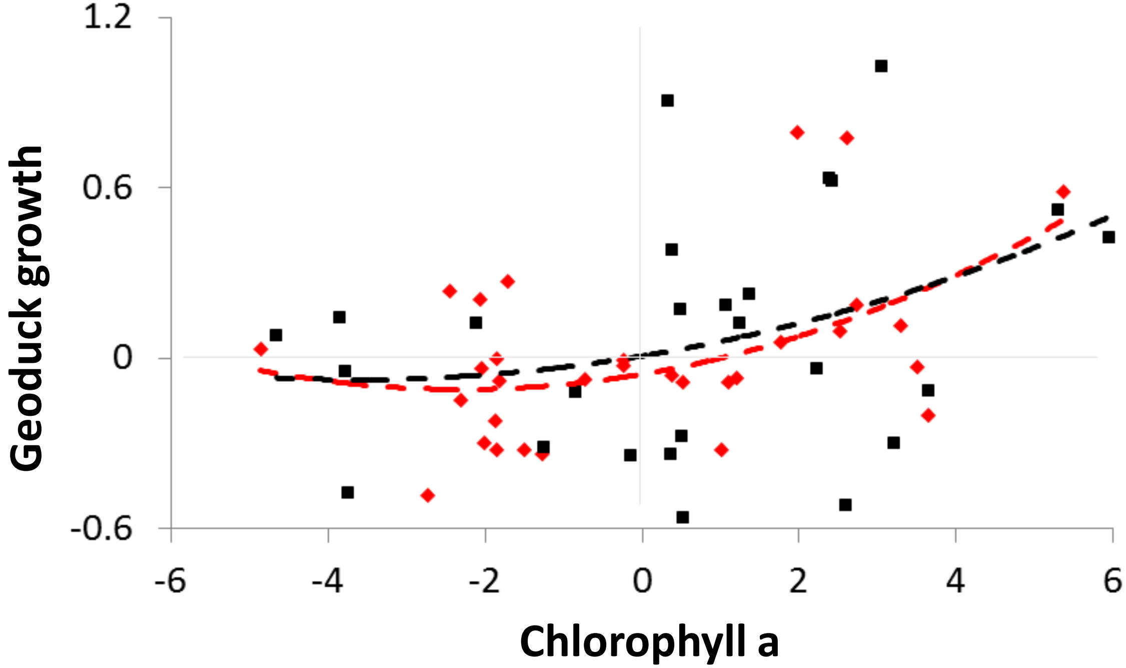



**Uncertainties**

- Geoducks may not eat just phytoplankton
- Geoduck growth may reflect benthic conditions, not water column
- Temperature affects both geoduck growth and primary production

# Reconstructing primary production

- Link growth with temperature and Chlorophyll measurements at DOE water quality monitoring stations
- After accounting for effects of temperature…




- Lots of noise, so other factors appear to affect growth

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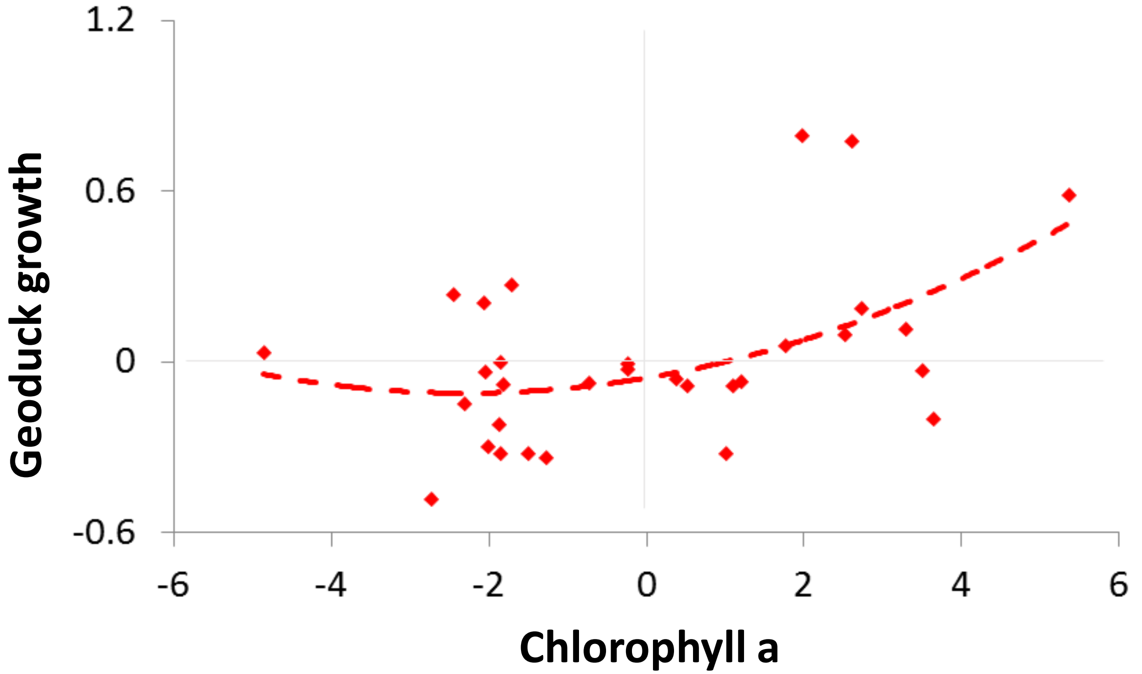


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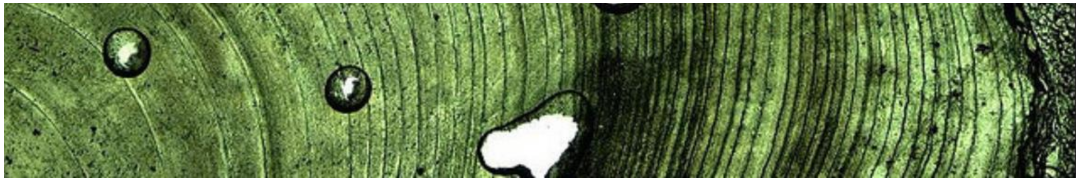
# Reconstructing primary production

## Next steps



- Whidbey Basin geoducks
- Refine models using other water column metrics
- Find appropriate time series to extend analysis backward in time
- Relate primary production to marine survival, in context of other foodweb elements