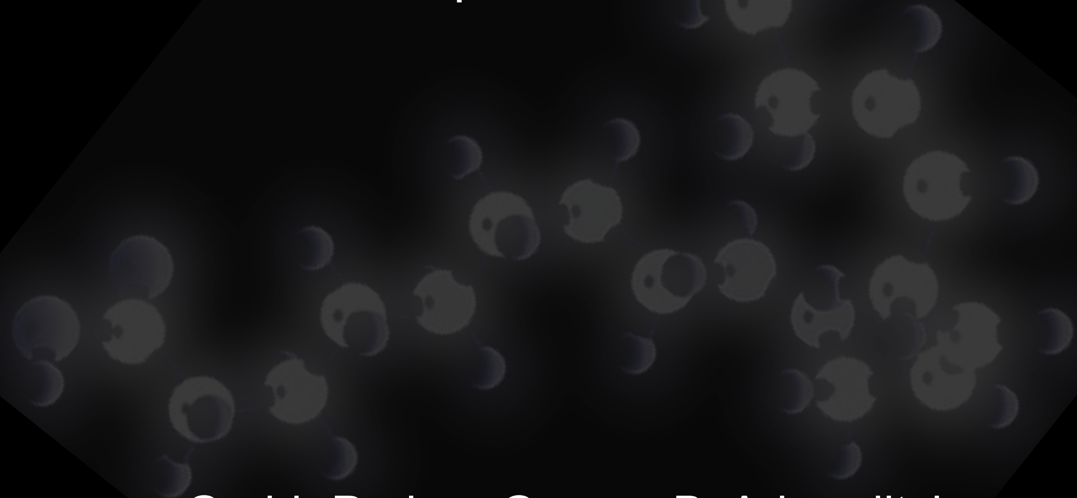
modelling the role of

Essential Fatty Acids

in aquatic food webs



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AGENDA:

Introduction
Objectives
Methods
Results
Conclusions
Future

Introduction

- Fatty Acids, *what are they?*

  - *Among the most important molecules transferred across the plant-animal interface in aquatic food webs*

  - *Particular classes of FA, such as the ω-3 highly unsaturated fatty acids (HUFA), are important somatic growth limiting compounds for herbivorous zooplankton*

  - *Critical for the growth, disease resistance and general well being of juvenile fish*

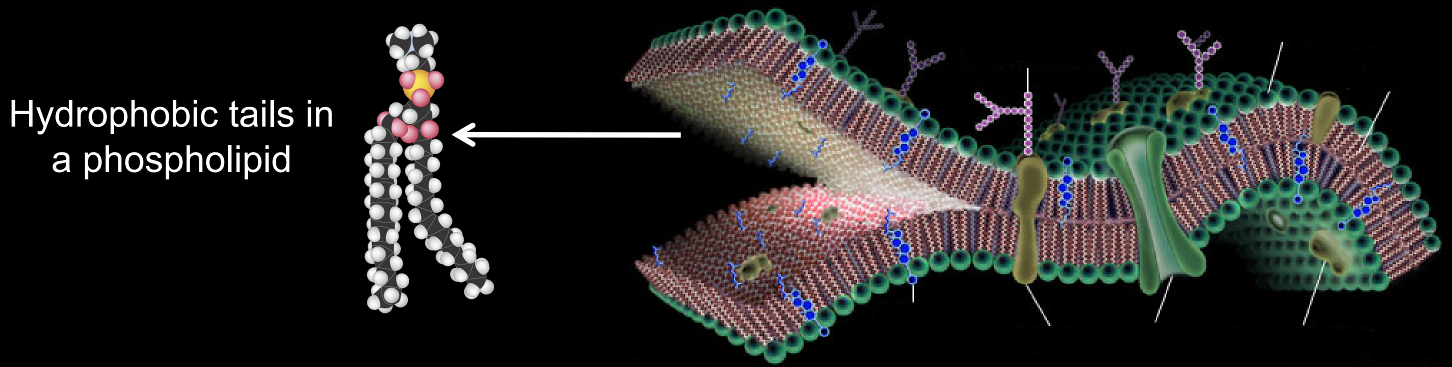
  - *Knowledge of how nutritionally important FA are conveyed through food webs has important implications for policy makers (fisheries) and scientific community (nutritionists, health-scientists, physical scientists)*

Introduction*continued*

- Essential fatty acids Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) are produced almost exclusively in aquatic primary producers

- Control parameters:
  - Inflammation, pain, immunity, vascular permeability, blood pressure, blood clotting and reproductive processes (animals)

  - Cell membrane fluidity (plants)



Introduction*continued*

Interest in scientific community?

Inuits and Americans: Rethinking the role of omega-3 fatty acids in clinical practice (2003)

Conference on lipids in immune function (2003)

Dietary fat in prevention of prostate cancer (2007)

Effects
aggreg

Efficacy

Environ
develop

Fatty ac
product

Genetic
fatty ac

Hyperte

Nonhuman primate model of inherited retinal degeneration (2002)

Omega-3 fatty acids & tumor membrane structure / function (2002)

Omega-3 fatty acids effect on wound healing (2004)

Omega-3 fatty acids in bipolar disorder prophylaxis (2002)

Omega-3 fatty acids in normal visual development (2002)

Omega-3 fatty acids in the treatment of depression (2002)

Postpartum depression: omega-3 FA vs placebo (2002)

Types and amount of dietary fat and colon

eye and brain development in the human? (1990)

Biological effects of omega-3 fatty acids in diabetes mellitus (1991)

Biological mechanisms and cardiovascular effects of omega-3 fatty acids (1988)

Cardiovascular disease and long chain omega-3 fatty acids (2003)

Cholesterol in foods rich in omega-3 fatty acids (1986)

Clinical nutrition: 4. Omega-3 fatty acids in cardiovascular care (2002)

Clinical trial evidence for the cardioprotective effects of omega-3 fatty acids (2001)

Combined effects of aerobic exercise and

Dietary omega-3 fatty acids prevent carbohydrate-induced hypertriglyceridemia (1984)

Do omega-3 fatty acids ease the way to silent cell death? (2003)

Docasahexanoic acid and omega-3 fatty acids in depression (2000)

Effect of dietary omega-3 fatty acids on retinal function of very low birth weight neonates (1990)

Effect of omega-3 fatty acids in the

management of fibromyalgia syndrome (2000)

Effect on serum lipid levels of omega-3 fatty acids of ingesting fish oil concentrate (1979)

Effects of dietary fish oil and omega-3 fatty acids on platelets and blood vessels (1988)

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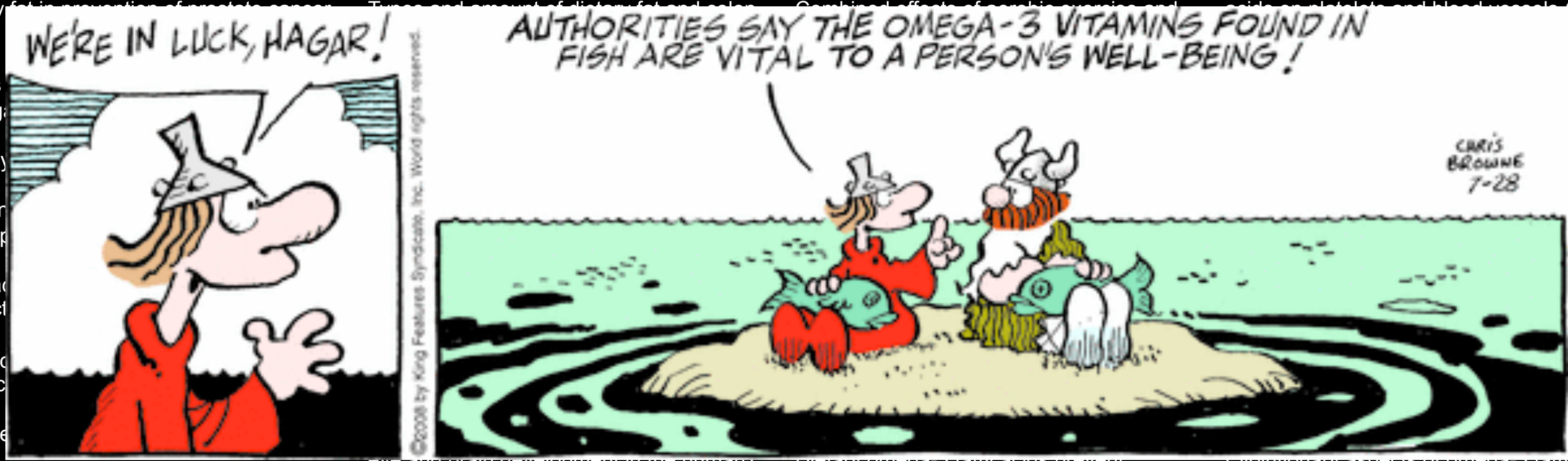
Evolutionary aspects of omega-3 fatty acids in the food supply (1999)

Fish and long chain omega-3 fatty acids could be lifesavers for diabetic women (2003)

Fish consumption, fish oil, omega-3 fatty acids and cardiovascular disease (2003)

Health effects of omega-3 fatty acids (1986)

Immunonutrition: the role of omega-3 fatty acids (1998)



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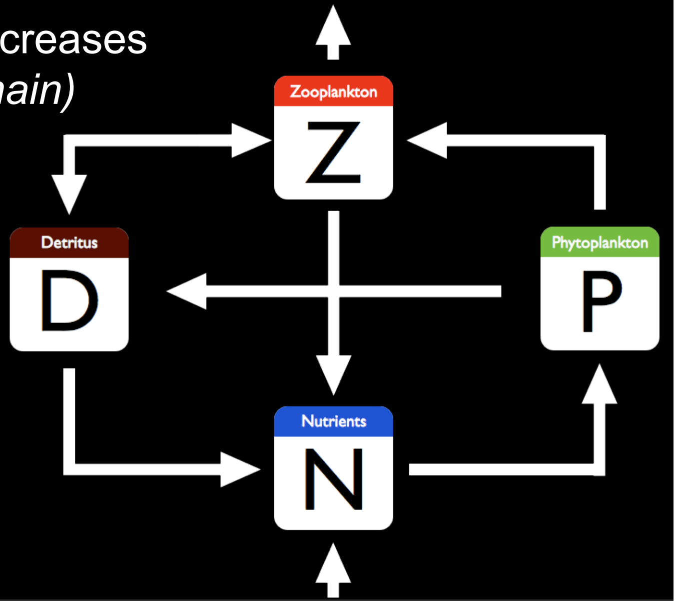
Objectives

• Test the effects of fatty acid content on system stability via bifurcation analysis, paying special attention to the producer-consumer interface

• System defined as four compartment NPZD model
  - Nutrient flux from hypolimnion
  - Multiple phytoplankton parameterizations
  - Inclusion of Detritus incorporates bacterial loop and increases realism vs. Lotka-Volterra models *(food web vs. food chain)*
    - Zooplankton has multiple food sources



Objectives *continued*

- Zero dimensional approach; dynamics observed to be internally driven

- No data set, theoretical study; qualitative outputs

- Surrogate term: Food Quality
  - General term encompassing food ingestibility, digestibility, highly unsaturated fatty acid content

Food Quality of seston to zooplankton; notice limitation term.

$$FQ = \left(FQ_1^{\,2}\sqrt{PHYT} + FQ_2^{\,2}\sqrt{DET_C}\right) ZOOP_{C/PLIM}$$

Quality of food sources

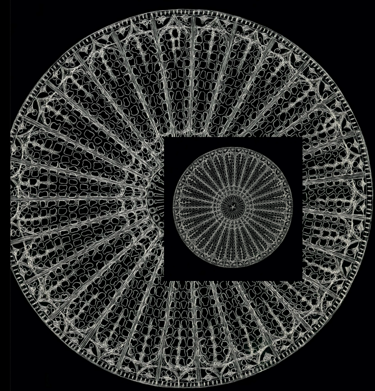
Quantity of food sources

Biochemical food quality, not to be confused with nutrient content

Objectives*continued*

Zooplankton phosphorus limitation.

$$ZOOP_{C/PLIM} = \begin{cases} 1 & \text{if} \quad Graz_{C/P} \leq C:P_Z \\ \dfrac{C:P_Z}{Graz_{C/P}} & \text{if} \quad Graz_{C/P} > C:P_Z \end{cases}$$



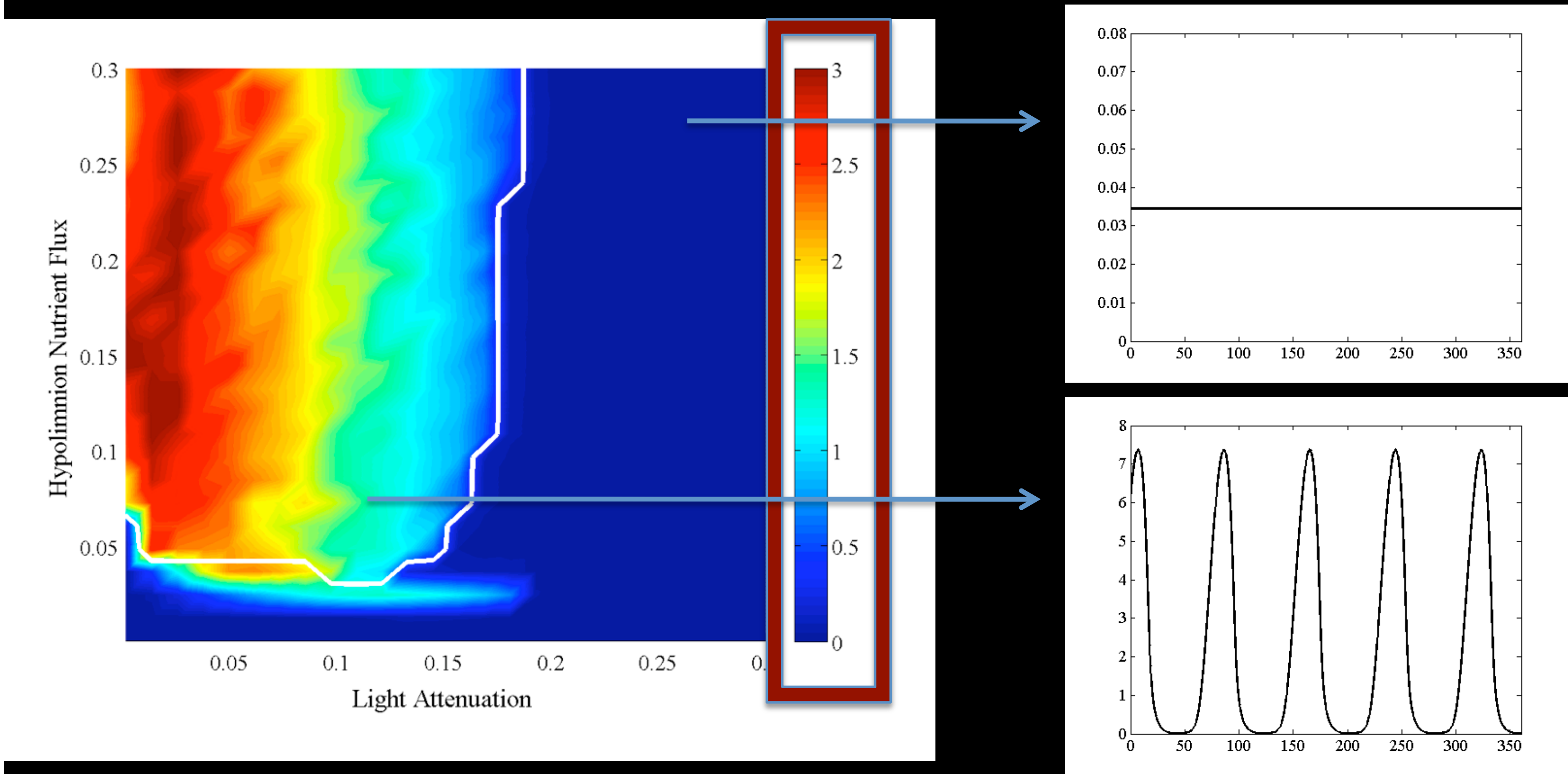
Methods

Numerical Experiments.

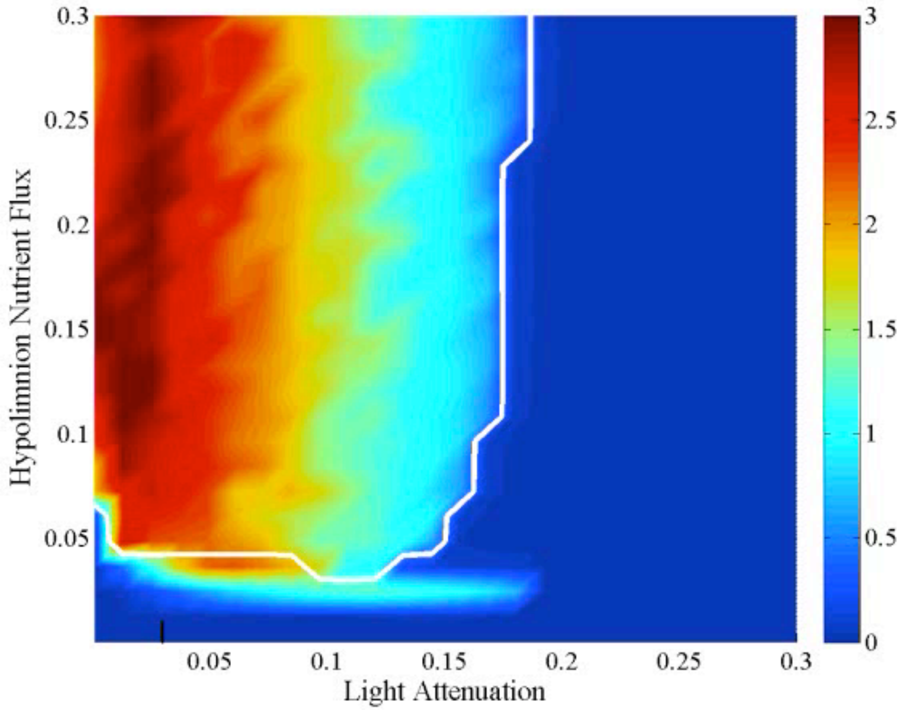
- Four key parameters form foundation for experiments
  - Light attenuation, a surrogate of depth; factor in bottom-up control
  - Hypolimnetic nutrient flux, a representation of nutrient concentration; also a factor in bottom-up control
  - Zooplankton mortality; factor in top-down control
  - Detritus food quality; fluctuations in alternative food source quality may relieve pressure on zooplankton feeding patterns

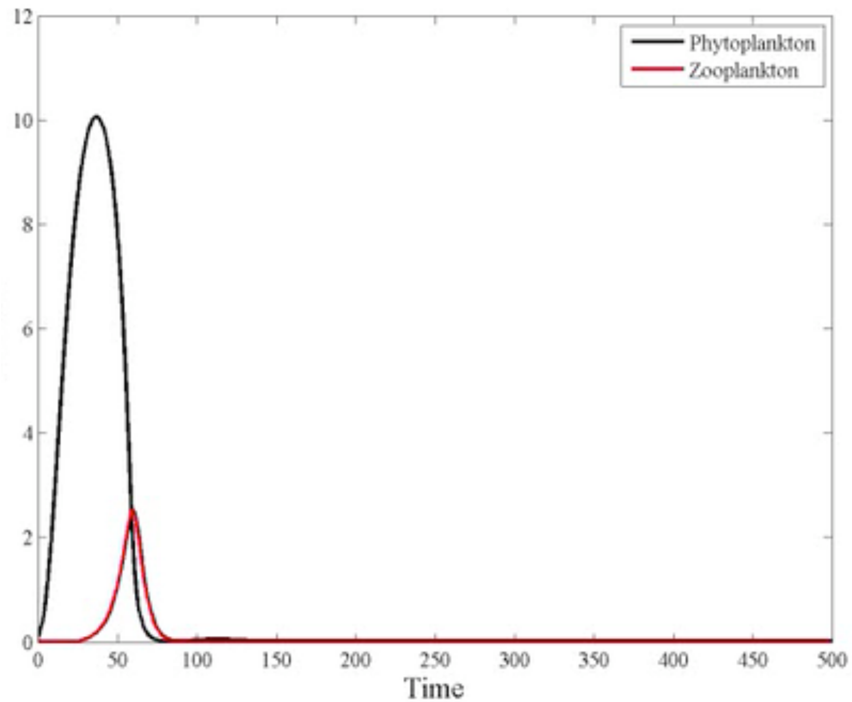
Results

- Typical output from a bivariate scan
  - Parameter ranges taken from literature
  - Color map is representative of average phytoplankton biomass
  - Contour separates steady state equilibrium from oscillating regions



Results *continued*



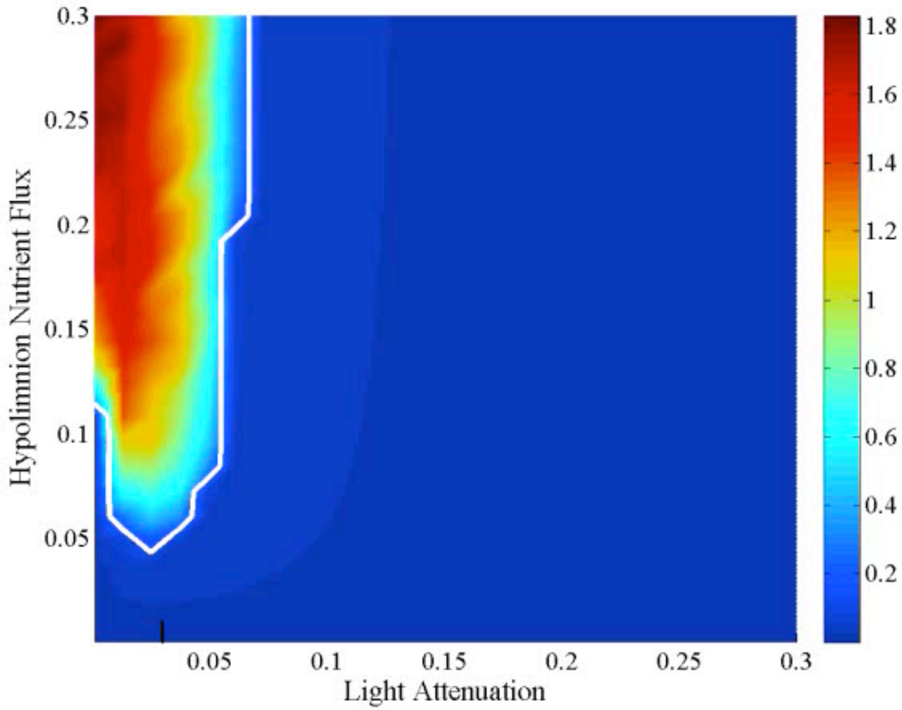


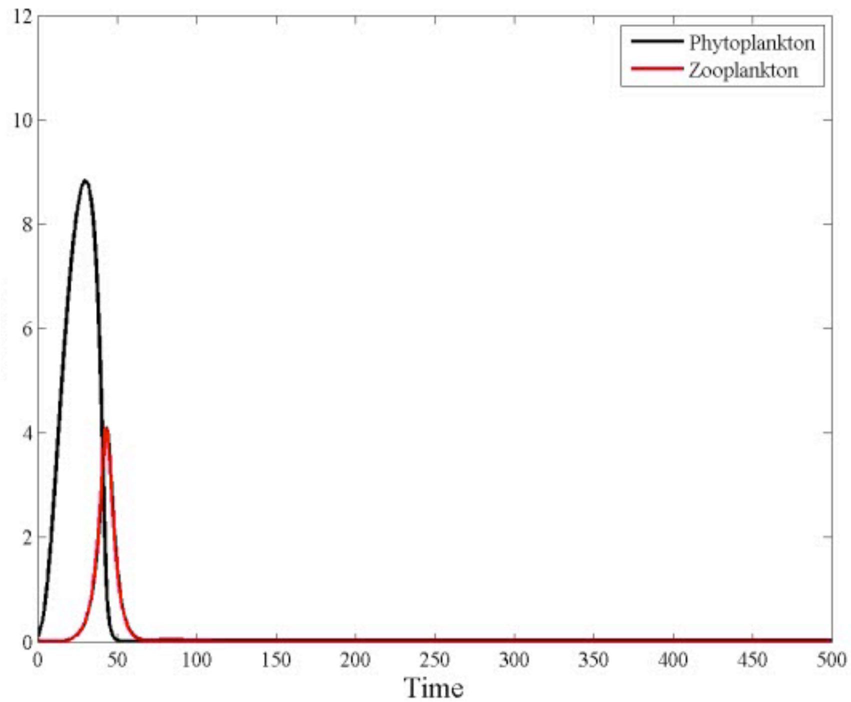
Scenario: Bottom-up control.

Dynamic parameters: Hypolimnetic nutrient flux vs. Light attenuation

Static parameters: Zooplankton mortality (moderate) & Detritus food quality (**low**)

Results*continued*





Scenario: Bottom-up control.

Dynamic parameters: Hypolimnetic nutrient flux vs. Light attenuation

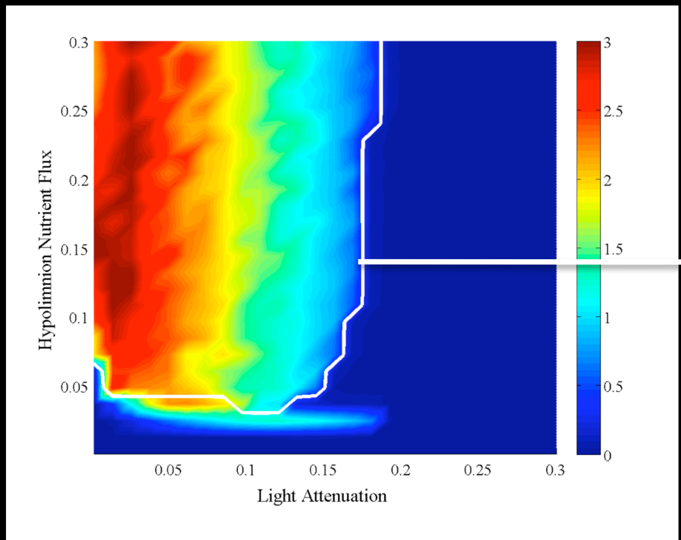
Static parameters: Zooplankton mortality (moderate) & Detritus food quality (**high**)

Results*continued*

• **Bifurcation theory:** the mathematical study of changes in the qualitative structure of a given family of differential equations.

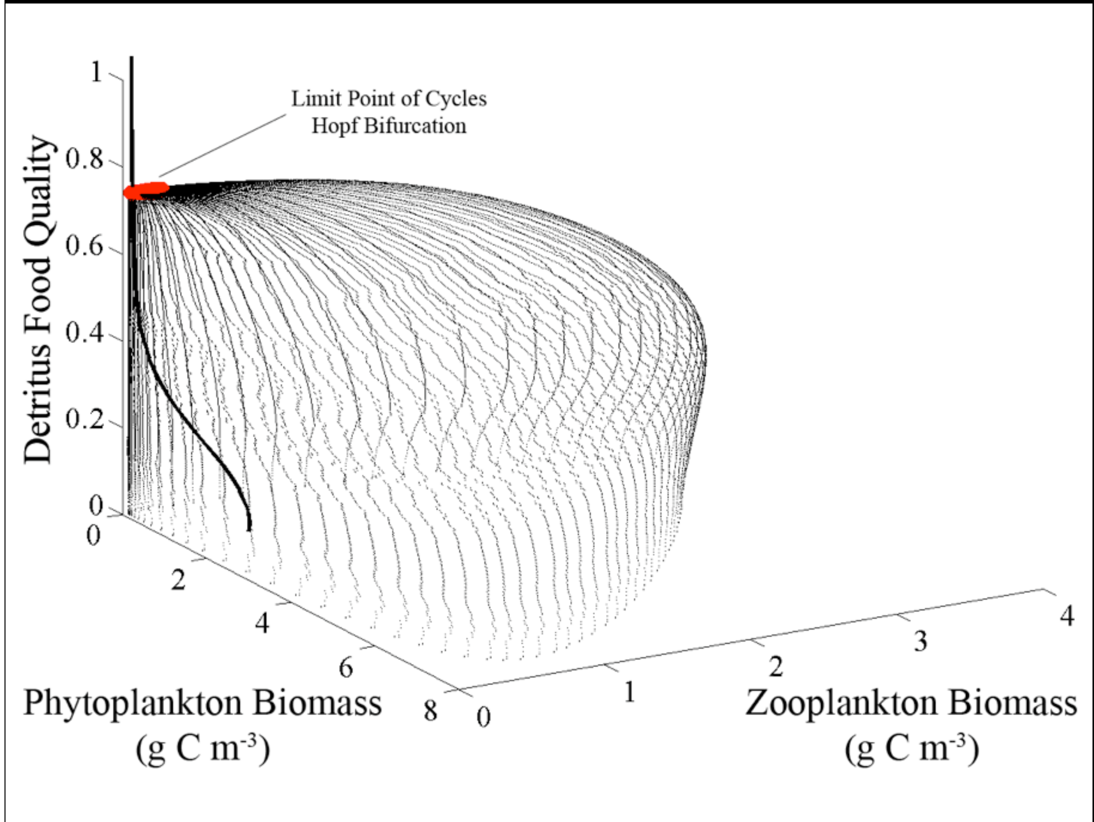
• **Bifurcation point:** point of a dynamical system where stability is lost as a pair of conjugate eigenvalues of the linearization around the fixed point cross the imaginary axis of the complex plane.

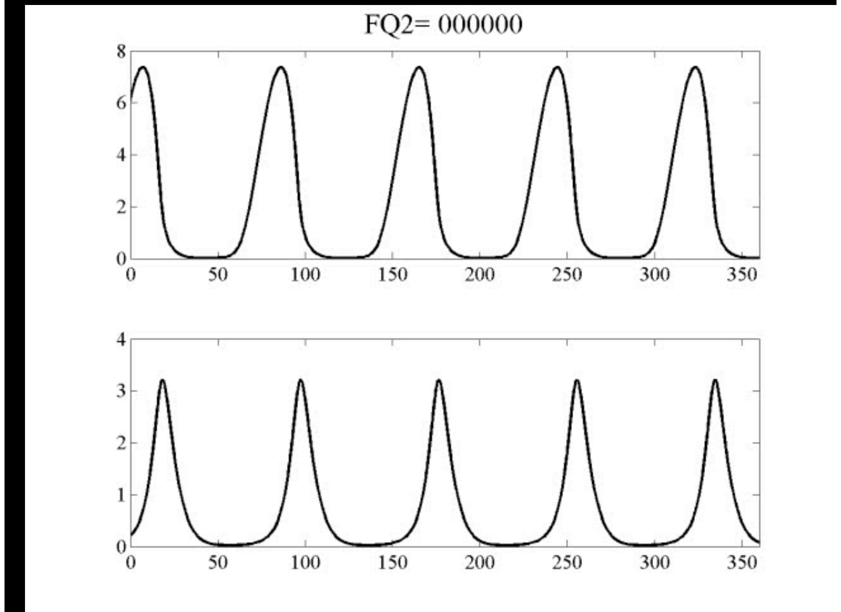
- • Plain English: point at which the system <u>shifts from steady state equilibrium to oscillatory behavior.</u>



Each point along white contour is a bifurcation point

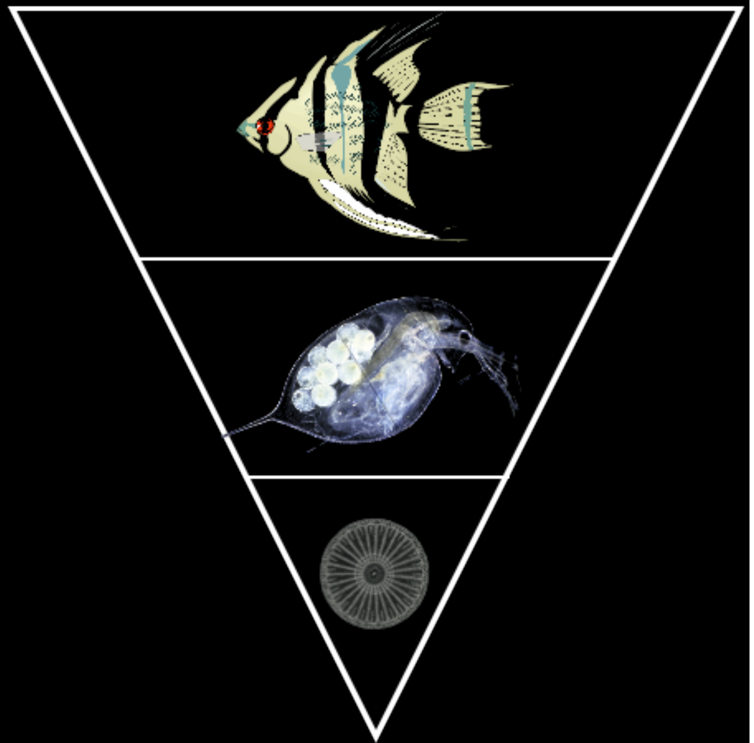
Results *continued*





Conclusions

• System parameterized with primary producer high in essential fatty acids.



• Top down control

• Primary producer limited by grazing stress

• Energy transferred well between trophic levels; system can maintain large fish stocks

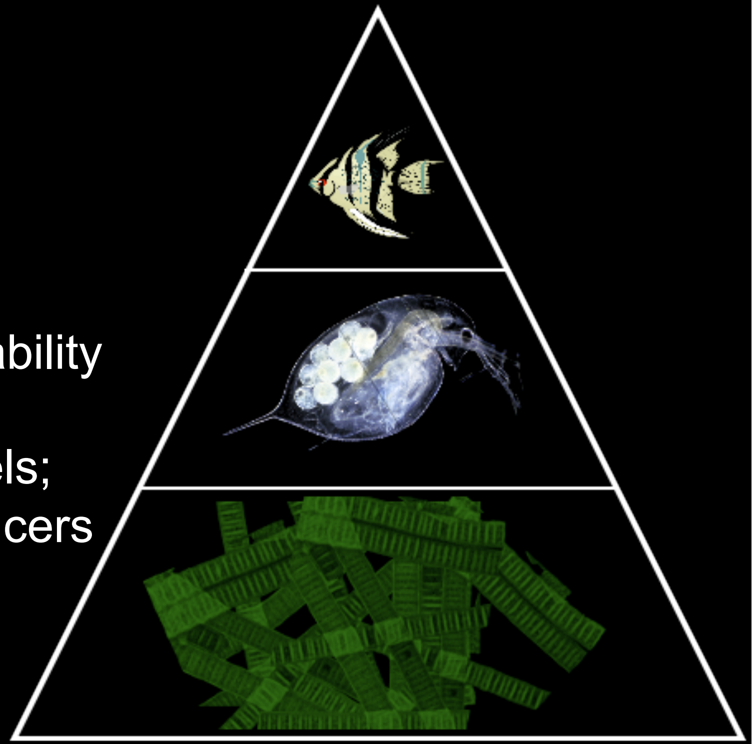
Conclusions*continued*

• System parameterized with primary producer low in essential fatty acids.

• Bottom up control

• Primary producer limited by nutrient/light availability

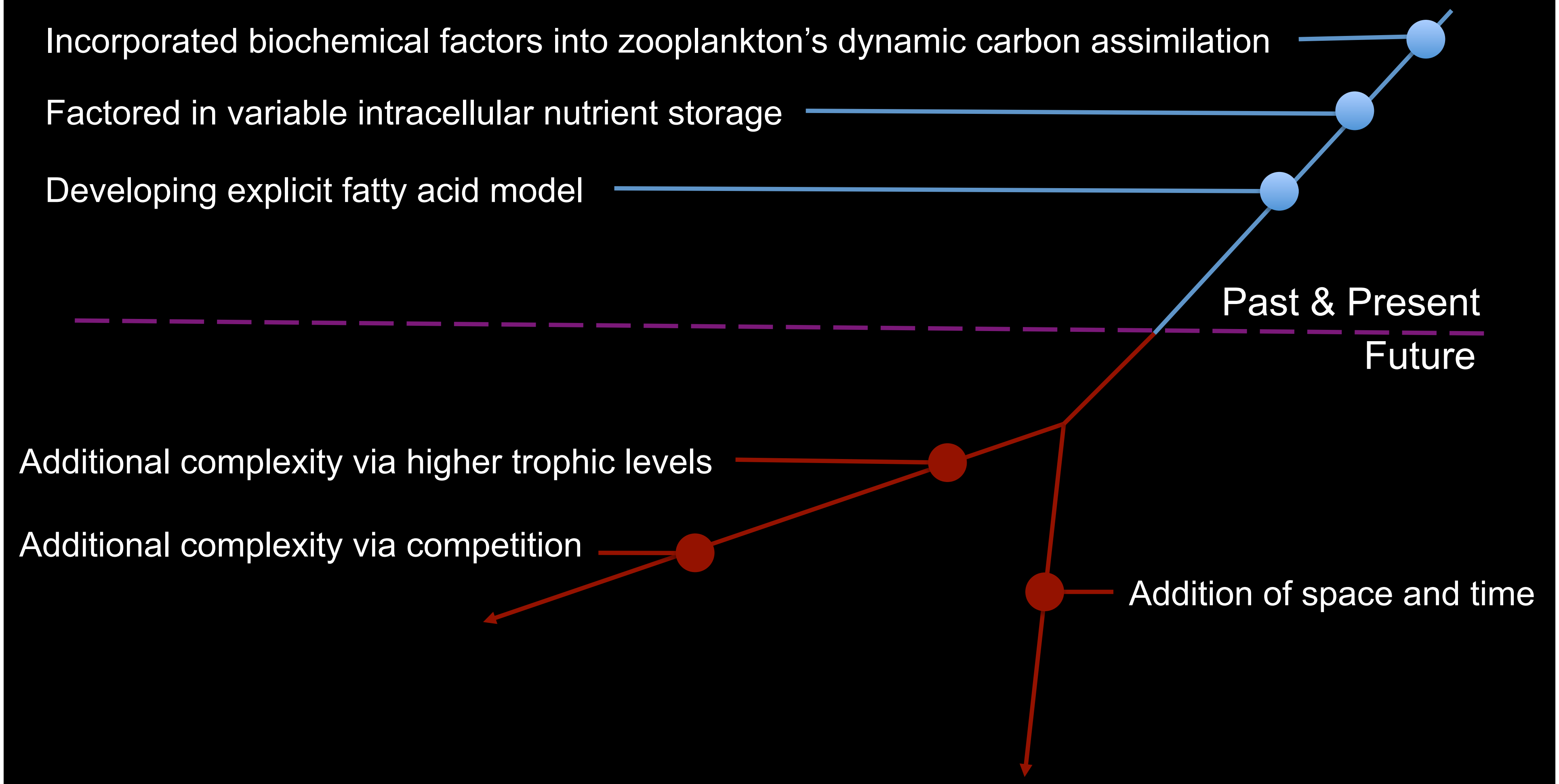
• Energy transferred poorly between trophic levels; low fish biomass, accumulation of primary producers



Conclusions*continued*

- Model complexity
  - Classical prey predator models
    - Formed theoretical ecology
    - Lack realism
    - e.g. inclusion of alternate food can modulate system dynamics
- Zooplankton grazing needs to be reconsidered
  - Factors other than nutrient availability can affect system stability

Roadmap


Incorporated biochemical factors into zooplankton's dynamic carbon assimilation
Factored in variable intracellular nutrient storage
Developing explicit fatty acid model
Past & Present
Future
Additional complexity via higher trophic levels
Additional complexity via competition
Addition of space and time

modelling the role of

Essential Fatty Acids

in aquatic food webs

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