



Recent trends in phytoplankton populations in Lake Kinneret: Alternate stable states hypothesis

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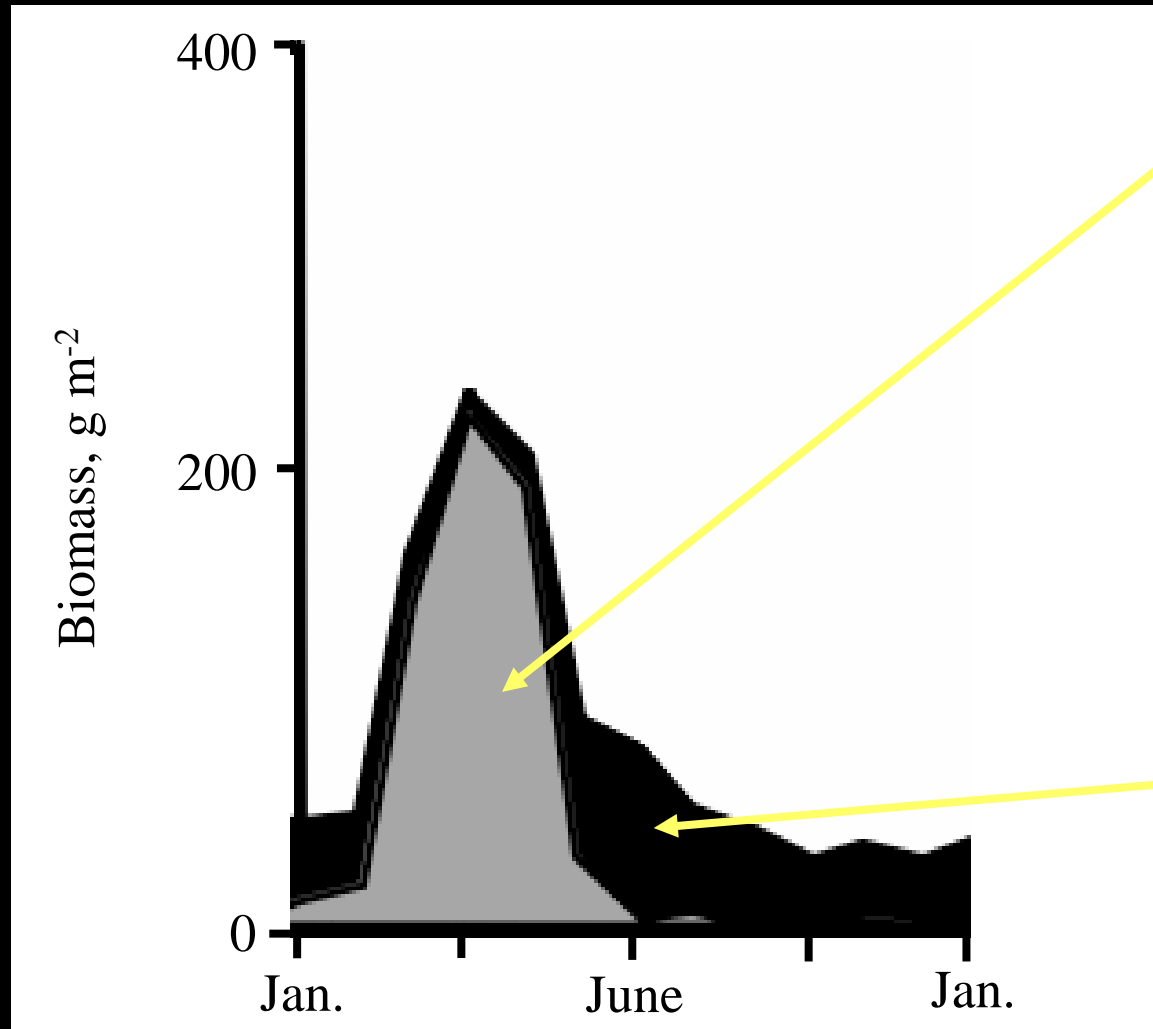
Photo: Matthew Hipsey, May 2005

Lake Kinneret phytoplankton

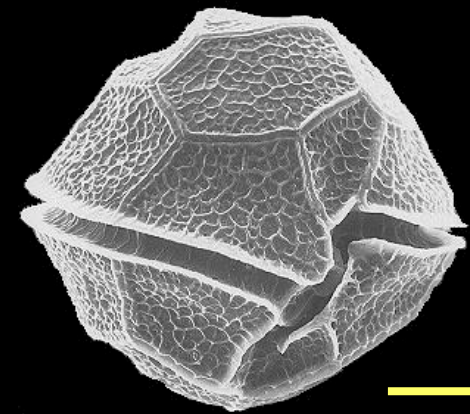
“One of the best-known and best-attested examples of year-to-year similarity in the abundance, distribution and composition of the phytoplankton.”

CS Reynolds, 2002

Representative *P. gatunense* Bloom Typical of L Kinneret till ~ 1994



Peridinium gatunense



5 μm

Other Phytoplankton

Deviations from the stable pattern since ~1994

- No-bloom years
- Invading species
- Cyanobacteria more prominent
- Different summer assemblage

(Zohary 2004 FWB)

N₂ fixing cyanobacteria invaded L Kinneret

Aphanizomenon ovalisporum, 1994



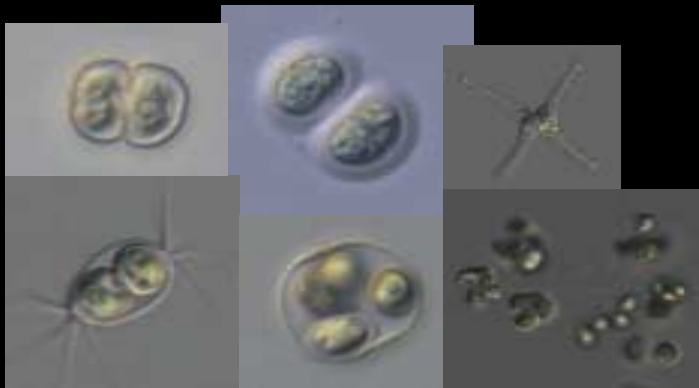
Cylindrospermopsis cuspis, 2000



The summer assemblage

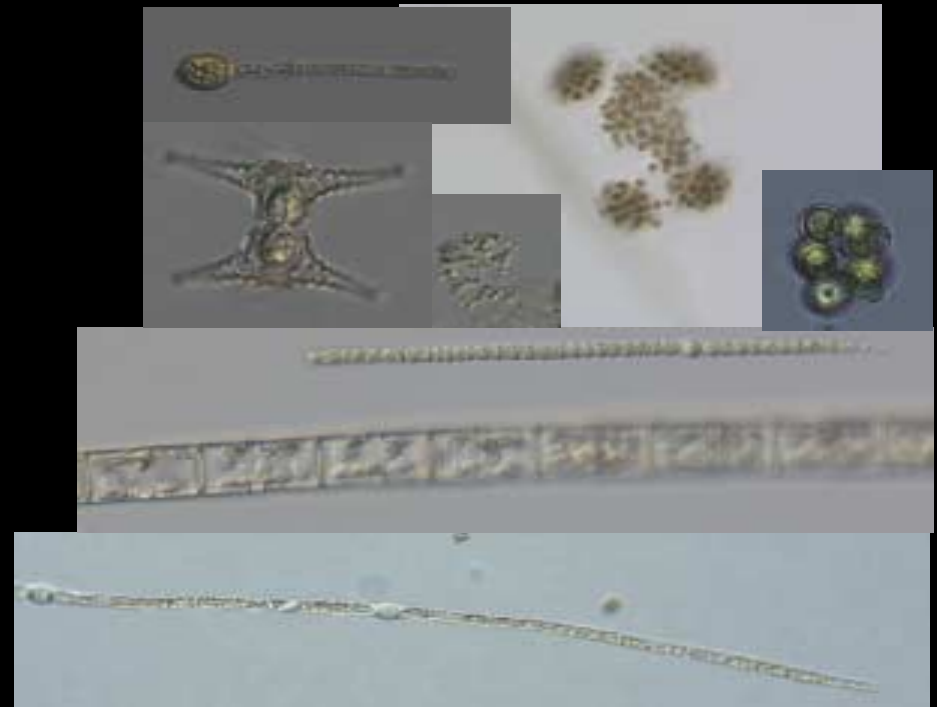
1969 - 1993

Small, round-shaped
Solitary & coenobia

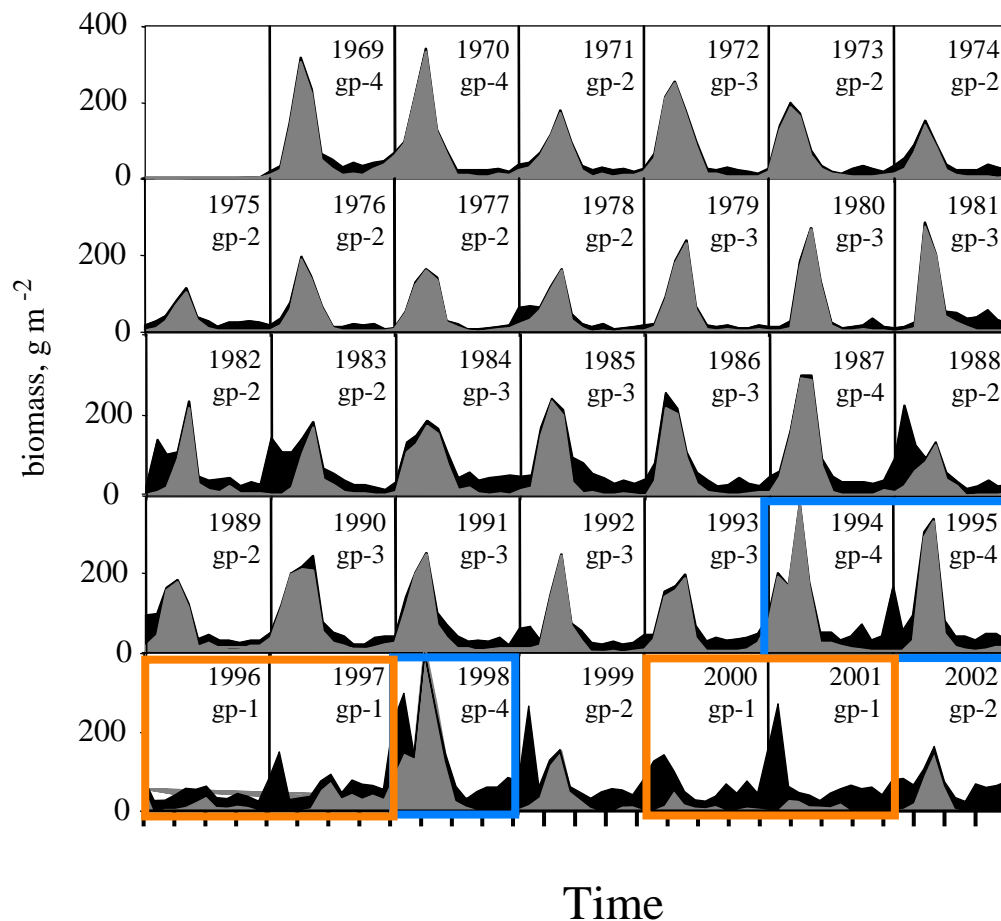


Recent years

Filamentous, spiny,
elongated or colonial



Recurring *P. gatunense* blooms



“Big-Bloom” Years:
1994-95, 1998
2003, 2004

“No-Bloom” Years:
1996-97, 2000-01
2005

Bloom vs. no-bloom years since 1994

What could cause the lack of blooms on some years ?

Lake Kinneret Data Set, 34-Years (1,057)

Weekly and bi-weekly sampling (integrated over mixed layer)

Phytoplankton (128)

Enumeration at genus- and species-level

Zooplankton (35)

Enumeration at genus- and species-level, and life stages

Physicochemical (22)

1. Nutrients (NH_4 ; NO_3 ; NO_2 ; DON; TDP; TP; SiO_3 ; and SO_4)

2. Hydrological (inflow; flushing; loading of NH_4 , NO_3 , DON, TDP, TP, and SO_4)

3. Physical (lake level; thermocline depth; Secchi depth; light penetration to mixing depth ratio; temperature; and conductivity)

Simple Model Explanations

Compare early-season *P. gatunense* with:

1. Early-season physicochemical parameters
2. Early-season zooplankton parameters

Multivariate

Principal Component Analysis

(trends <20% of variability, contradictory trends on pcs)

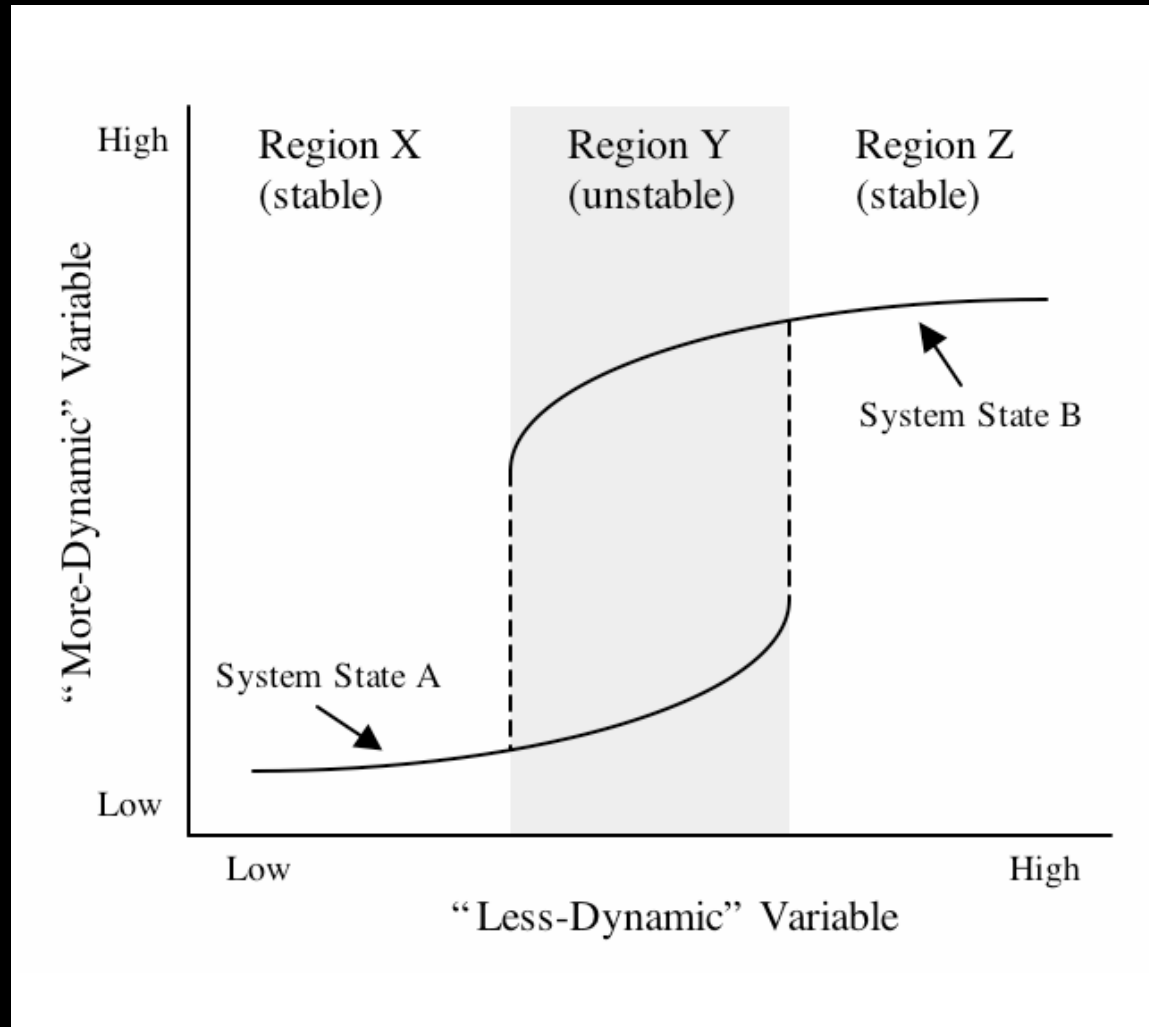
Univariate

Linear and Curvilinear Regression

(poor R^2 values, typically >0.10)

Proposed Complex Model Explanation

Distinct community structure can occur in the same environment

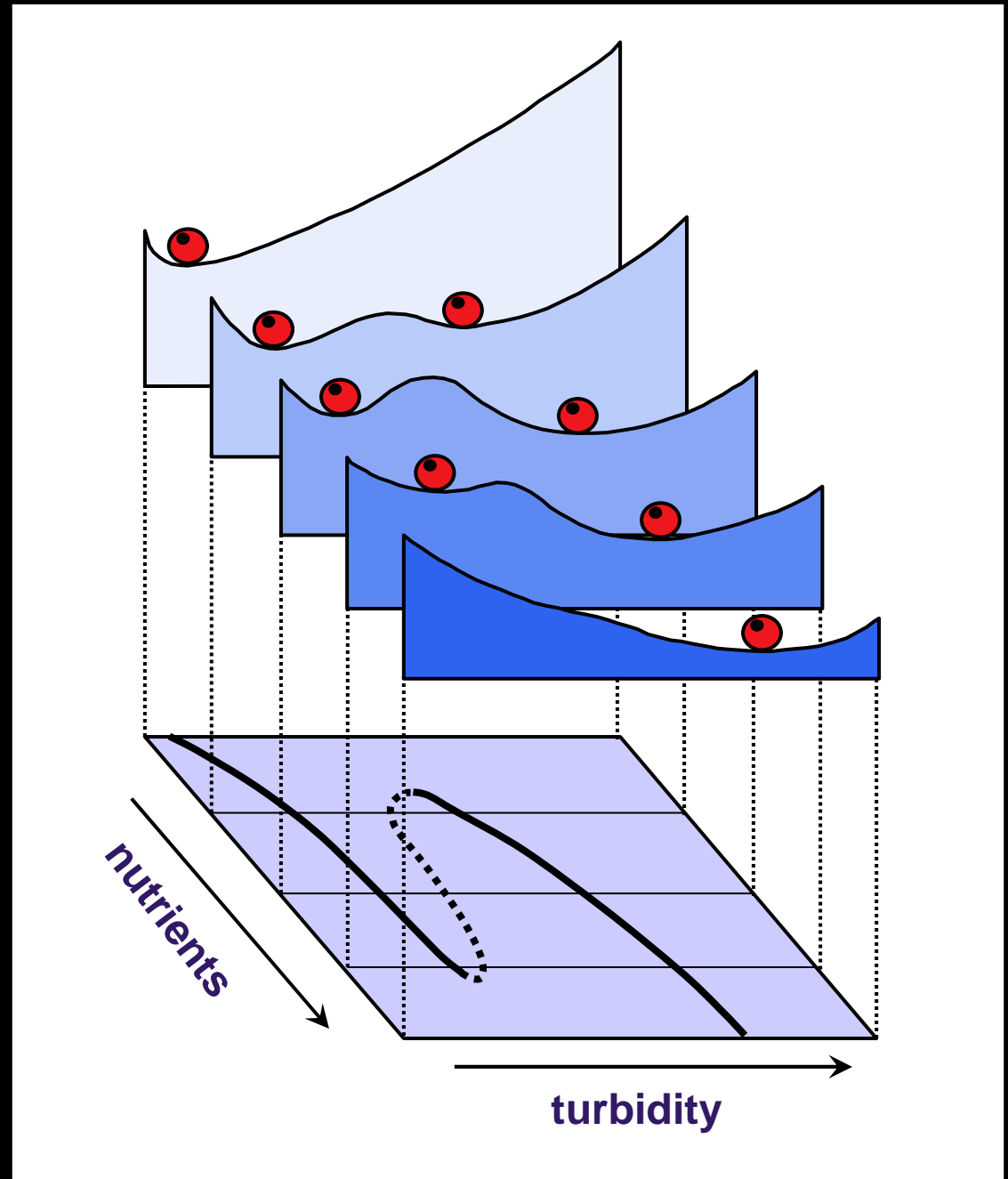


Alternate Stable-States Model

*Figure modified from
Scheffer, 1998;
Carpenter, et al., 2001*

Alternative Equilibria in Shallow Lakes

*M. Sheffer, et al. 1993.
TREE 8: 275–279*



Objectives and Approach

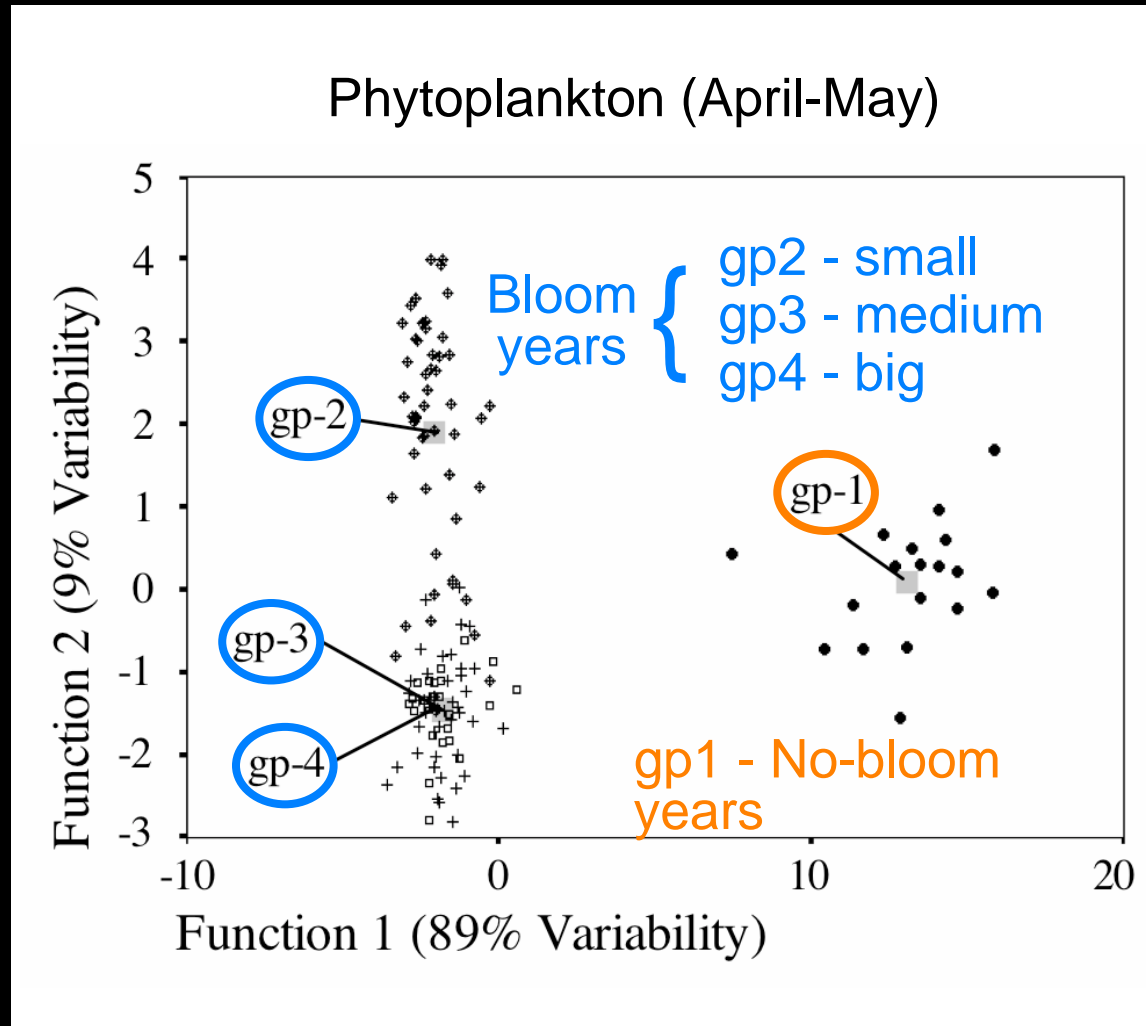
Explore whether distinct phytoplankton community states exist in Lake Kinneret

1. Discriminant Analyses
2. Principal Component Analysis
use two-month "Running-window"

Determine whether the occurrence of these states "fit" into an alternate states model

1. "More-Dynamic" Variable?
2. "Less-Dynamic" Variable?

Representative Discriminant Analysis (Regions X and Y)



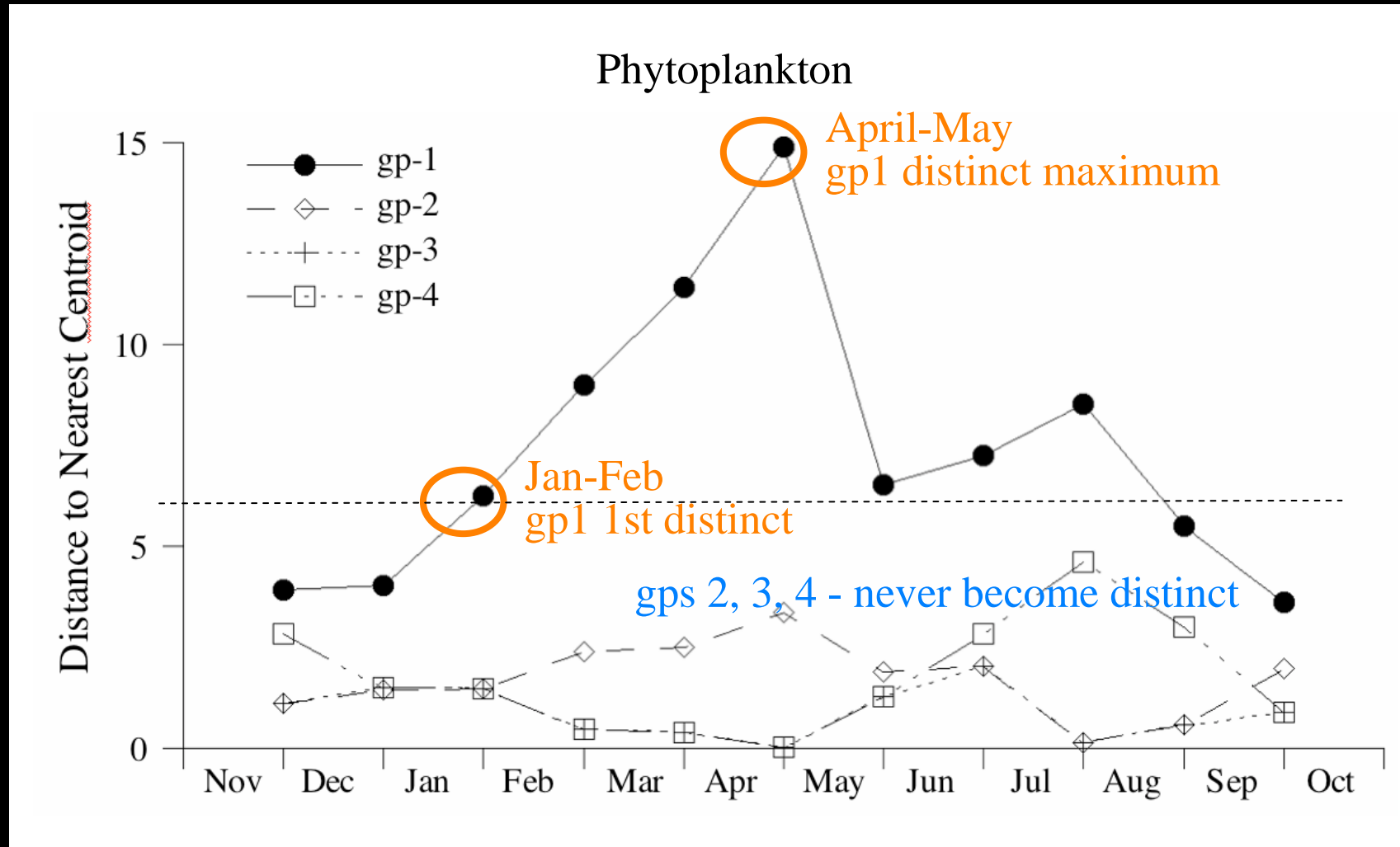
Distinct if:

1. Six unit separation between group centroids
2. No overlap between group members

Group 1 is distinct from groups 2, 3, and 4

Groups 2, 3, and 4 are not distinct from each other

Discriminant Analyses, All Years (Regions X and Y)



Phytoplankton Community Structures (Regions X and Y)

Principle component analysis 

Spring
Phytoplankton

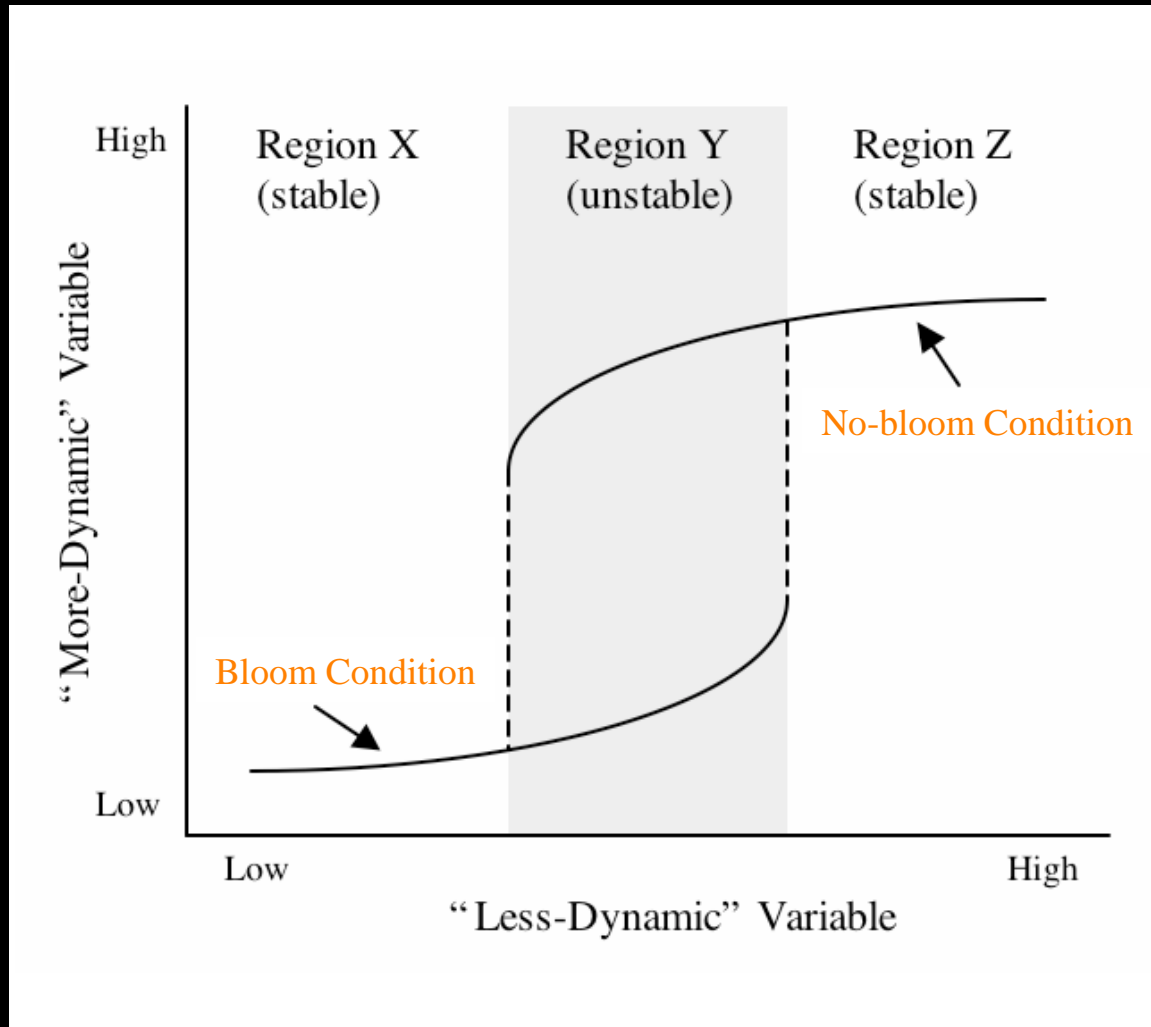
Select for
no-bloom year

Chodatella sp.
Closterium acutum
Oocystis sp.
Cyanodictyon imperfectum
Microcystis aeruginosa
Microcystis wesenbergii
Carteria cordiformis

Select against
no-bloom year

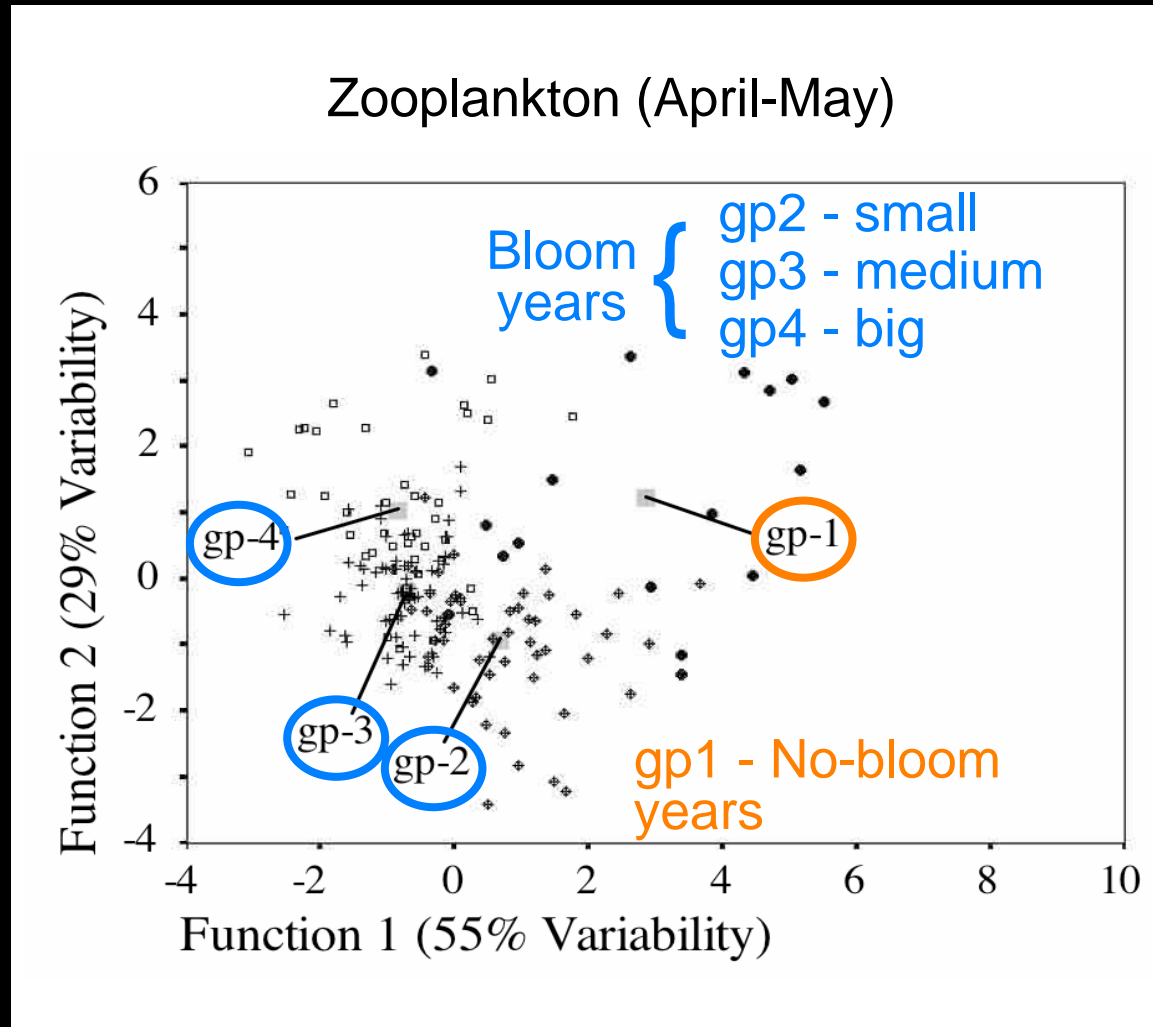
Peridiniopsis elpatiewski

Proposed Complex Model Explanation



**Alternate
Stable-States
Model**

Representative Discriminant Analysis (Regions X and Y)



Distinct if:

1. Six unit separation between group centroids
2. No overlap between group members

Group 1 is not distinct from groups 2, 3, and 4

Groups 2, 3, and 4 are not distinct from each other

Discriminant Analyses, All Years (Regions X and Y)

However ...

Zooplankton

gps 1, 2, 3, and 4 never became distinct

Physicochemical

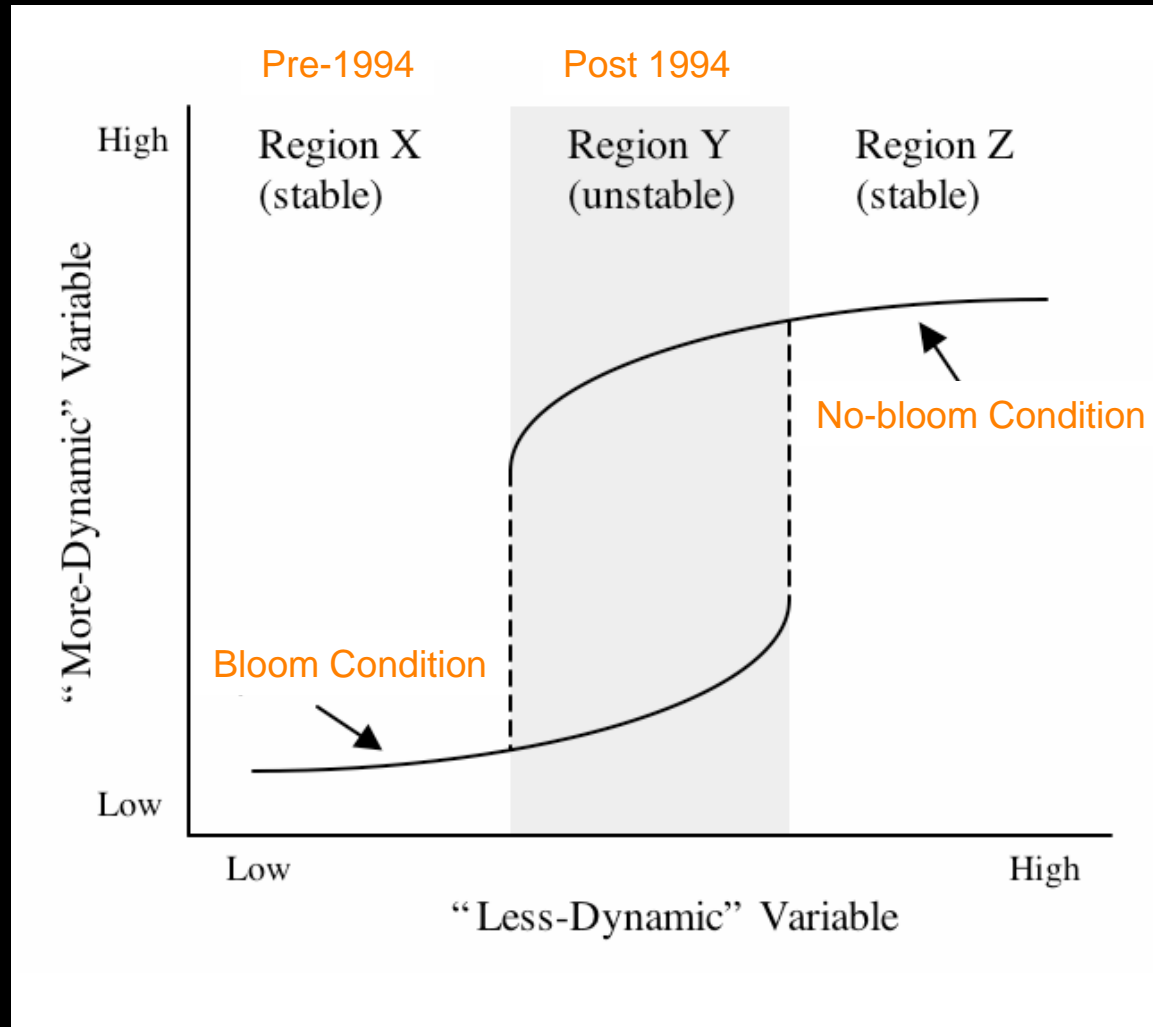
gps 1, 2, 3, and 4 never became distinct

But what if ...

Zooplankton and/or Physicochemical

were a “More-Dynamic” Variable

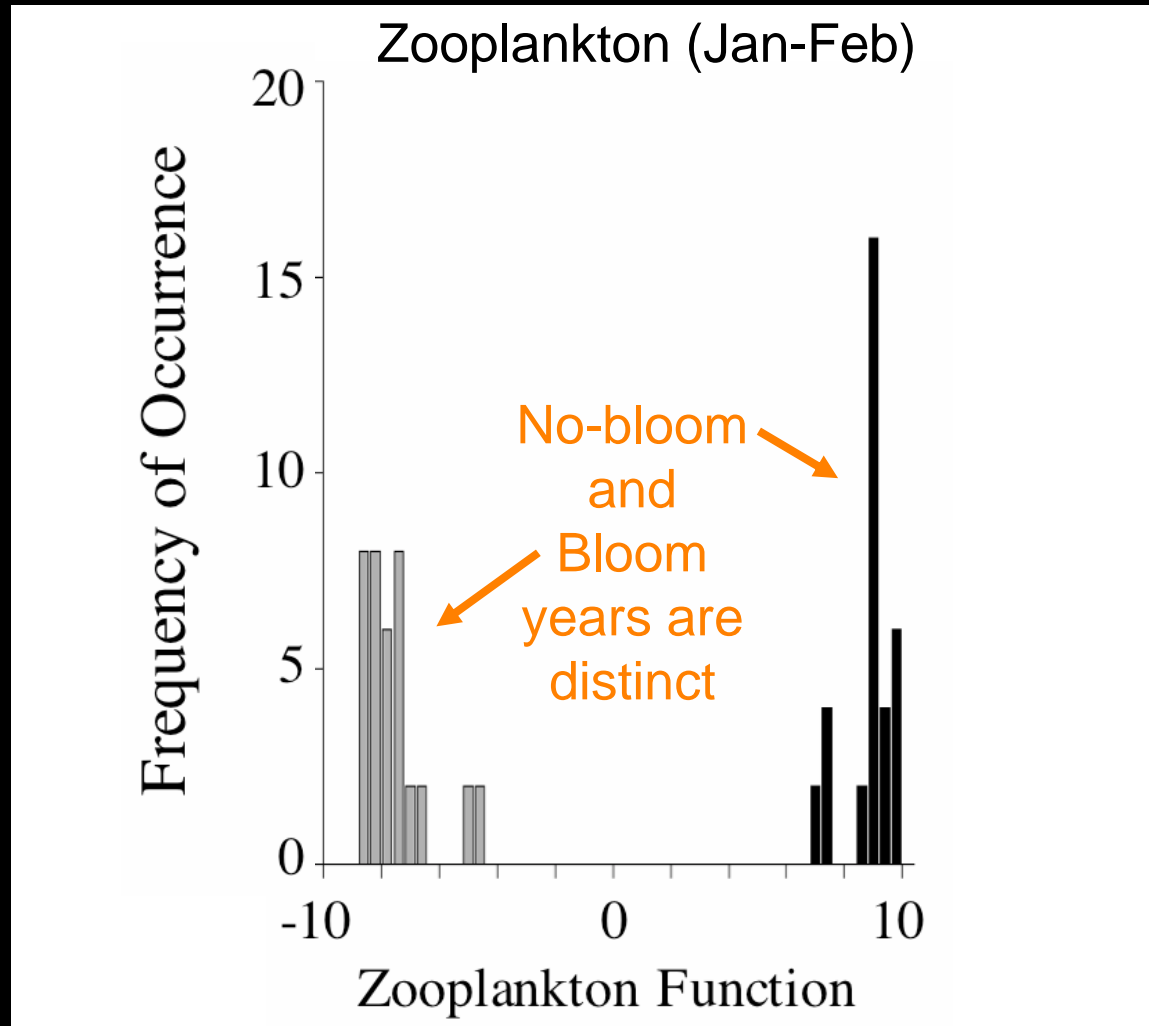
Proposed Complex Model Explanation



Alternate Stable-States Model

“Lumping” data from Regions X and Y would mask correlation between “Condition” and the “More-Dynamic” Variable

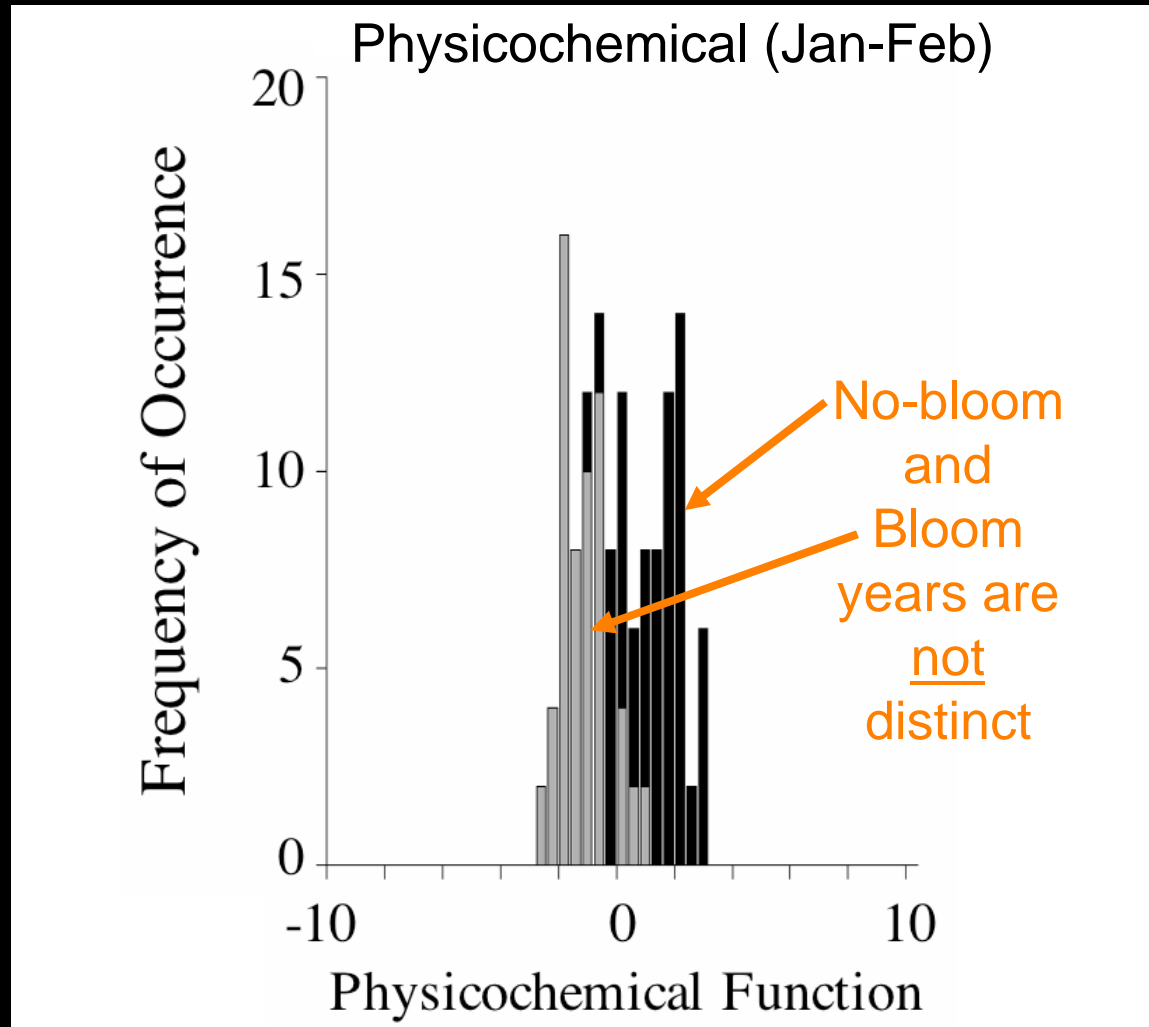
Representative Discriminant Analysis (Region Y)



Distinct if:

1. Six unit separation between group centroids
2. No overlap between group members

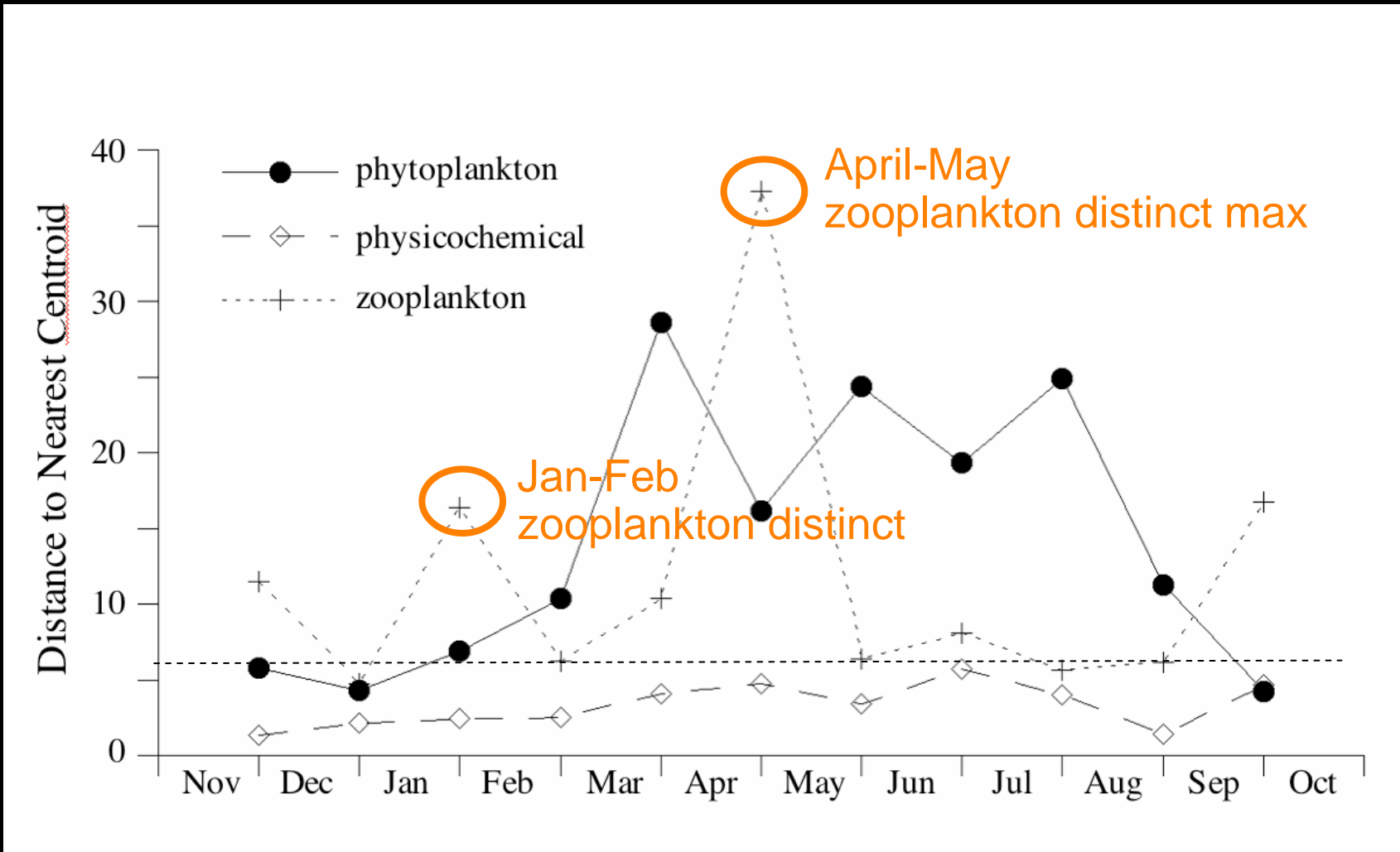
Representative Discriminant Analysis (Region Y)



Distinct if:

1. Six unit separation between group centroids
2. No overlap between group members

Discriminant Analyses, 1994-2001 (Region Y)



Assume Causation (Region Y)

Early-Spring Zooplankton

Spring Phytoplankton

Select for
no-bloom year

Ceriodaphnia rigaudi
Eudiaptomus dreischi nauplii
Aneuropsis sp.
Synchaeta pectinata
Hexarthra sp.
cyclopoid copepod nauplii

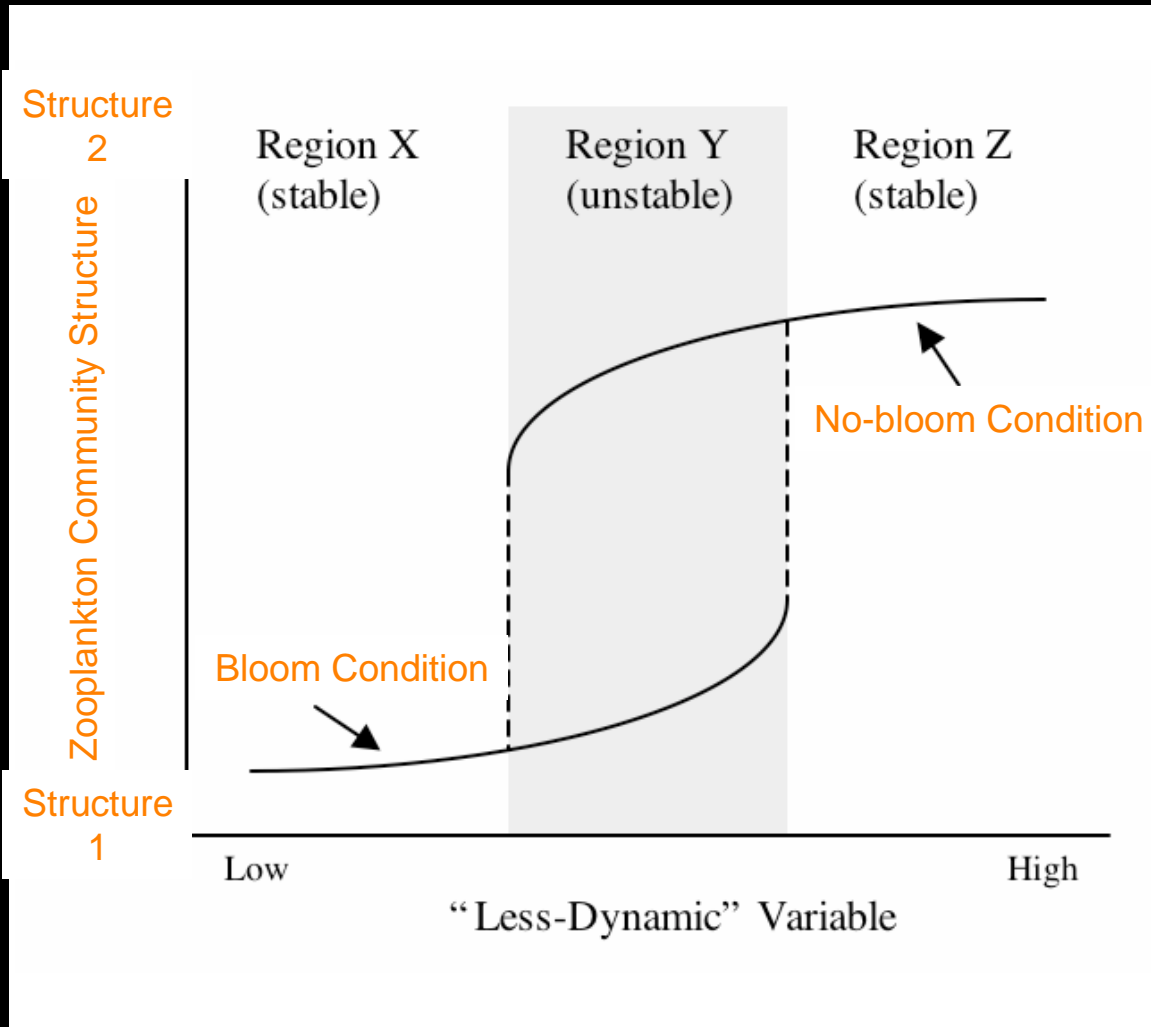
Chodatella sp.
Closterium acutum
Oocystis sp.
Cyanodictyon imperfectum
Microcystis aeruginosa
Microcystis wesenbergii
Carteria cordiformis

Select against
no-bloom year

Chydorus sphaericus
Collotheca sp.
Moina rectirostris

Peridiniopsis elpatiewski

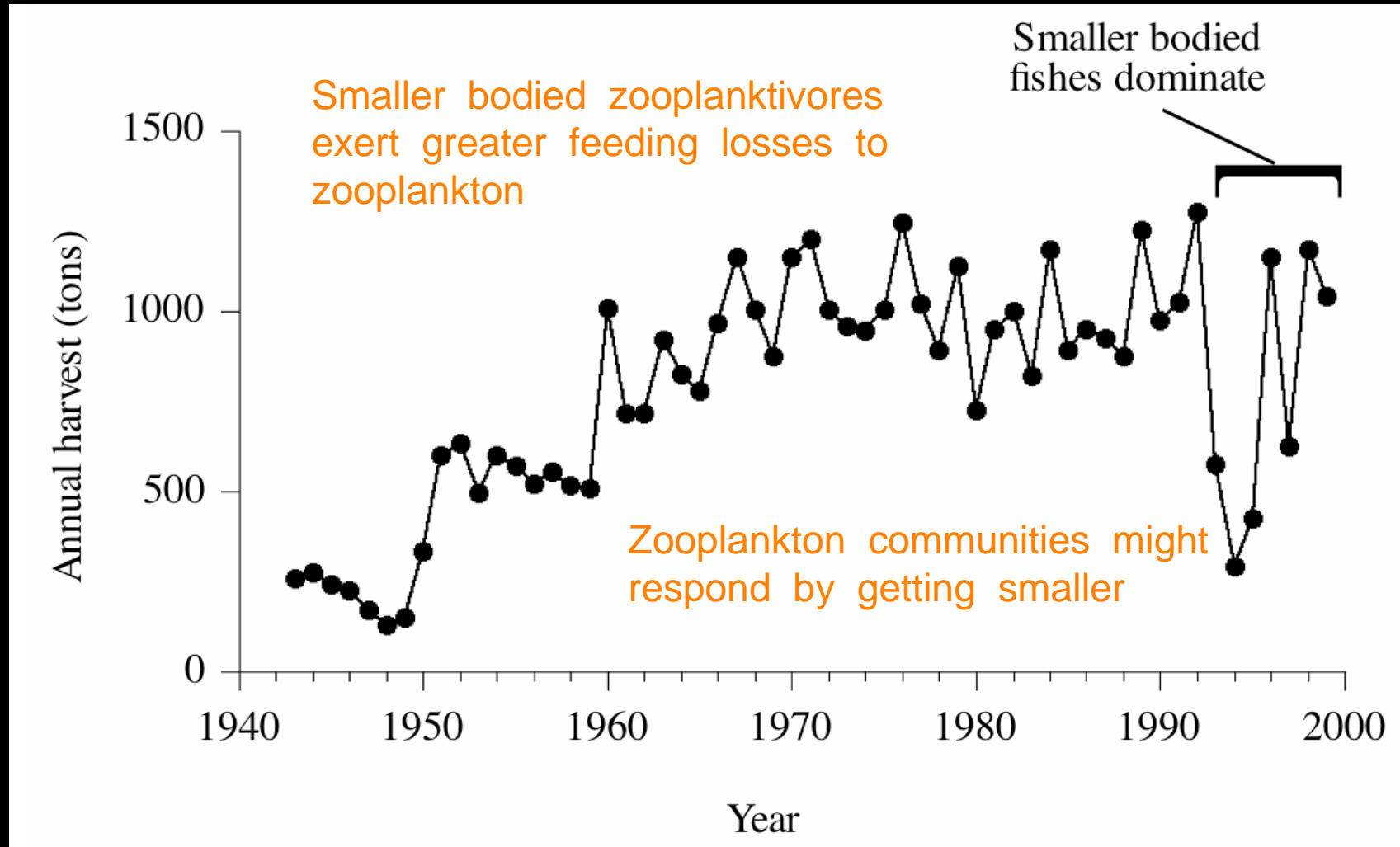
Proposed Complex Model Explanation



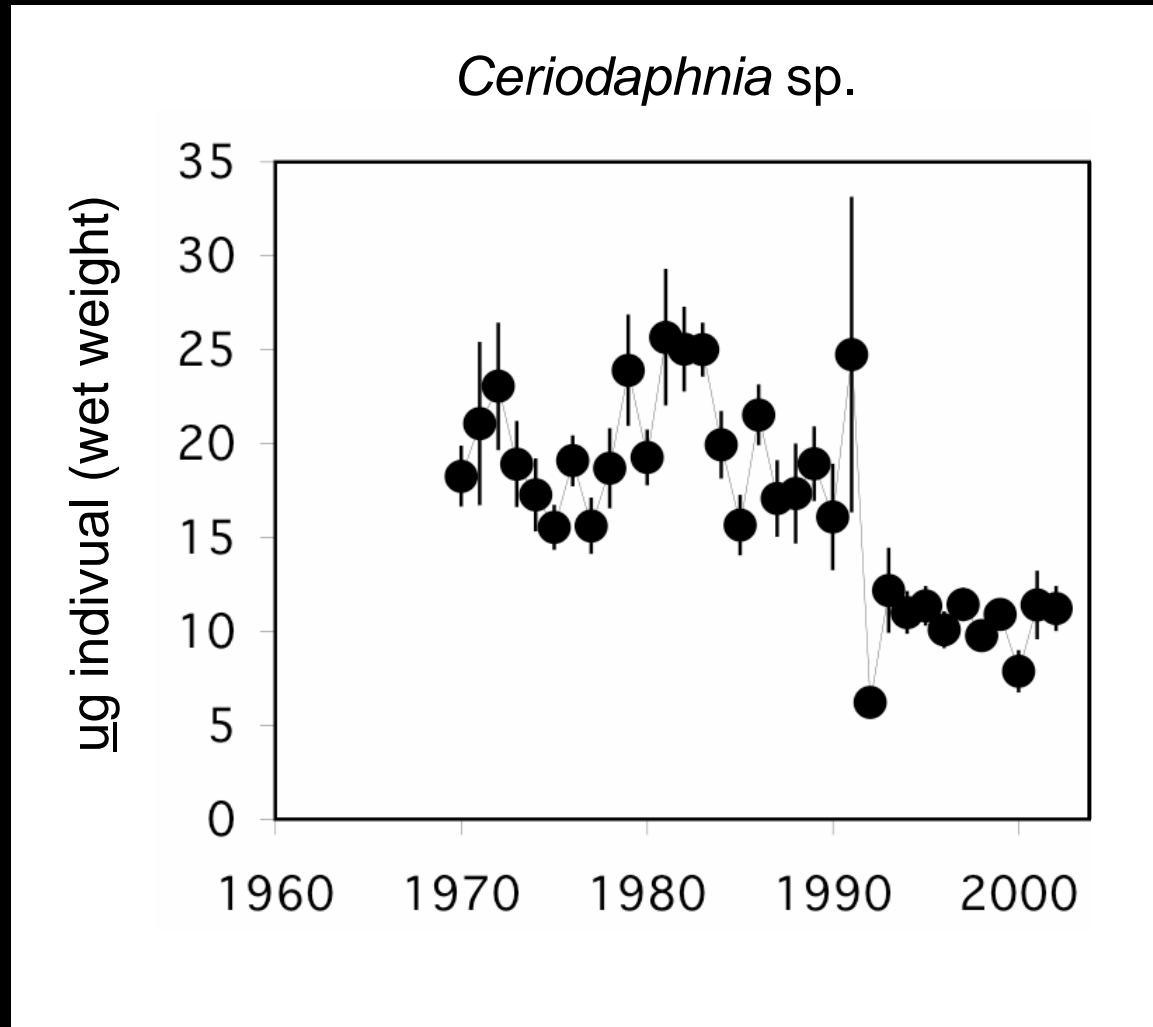
Alternate Stable-States Model

“Hysteresis” would mask correlation between “Condition” and the “Less-Dynamic” Variable

State of the Kinneret Fishery



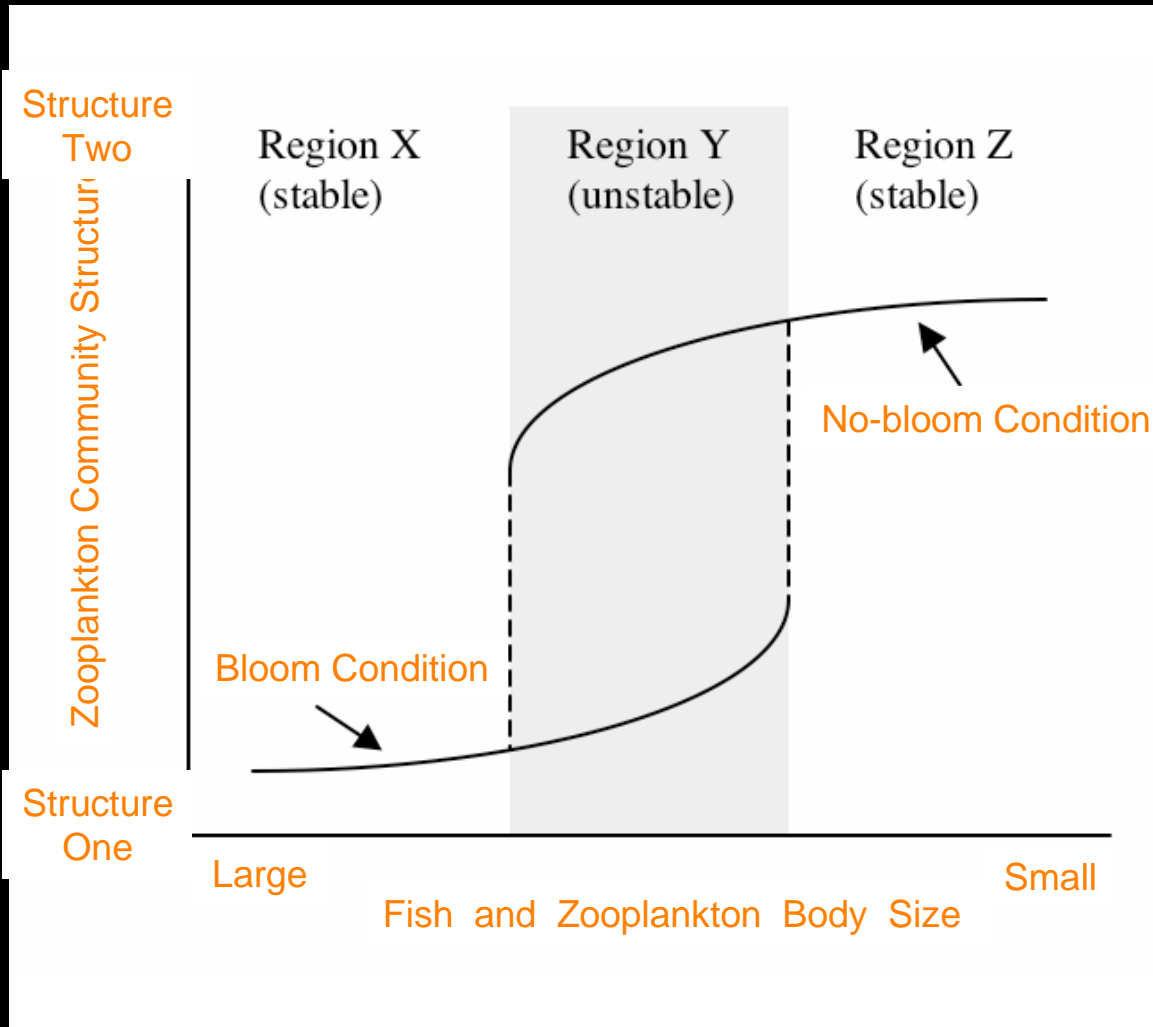
State of the Kinneret Zooplankton



Members of the zooplankton community do get smaller!

Smaller zooplankton likely exert greater grazing losses to phytoplankton, which might select for more quickly growing phytoplankton taxa

Proposed Complex Model Explanation



**Alternate
Stable-States
Model**

Phytoplankton Phase Space - Hypothesis

When fish and zooplankton body size are “large”, only these trajectories are possible

When fish and zooplankton body size are “small”, both trajectory paths are possible -
Zooplankton community structure is the trigger

