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

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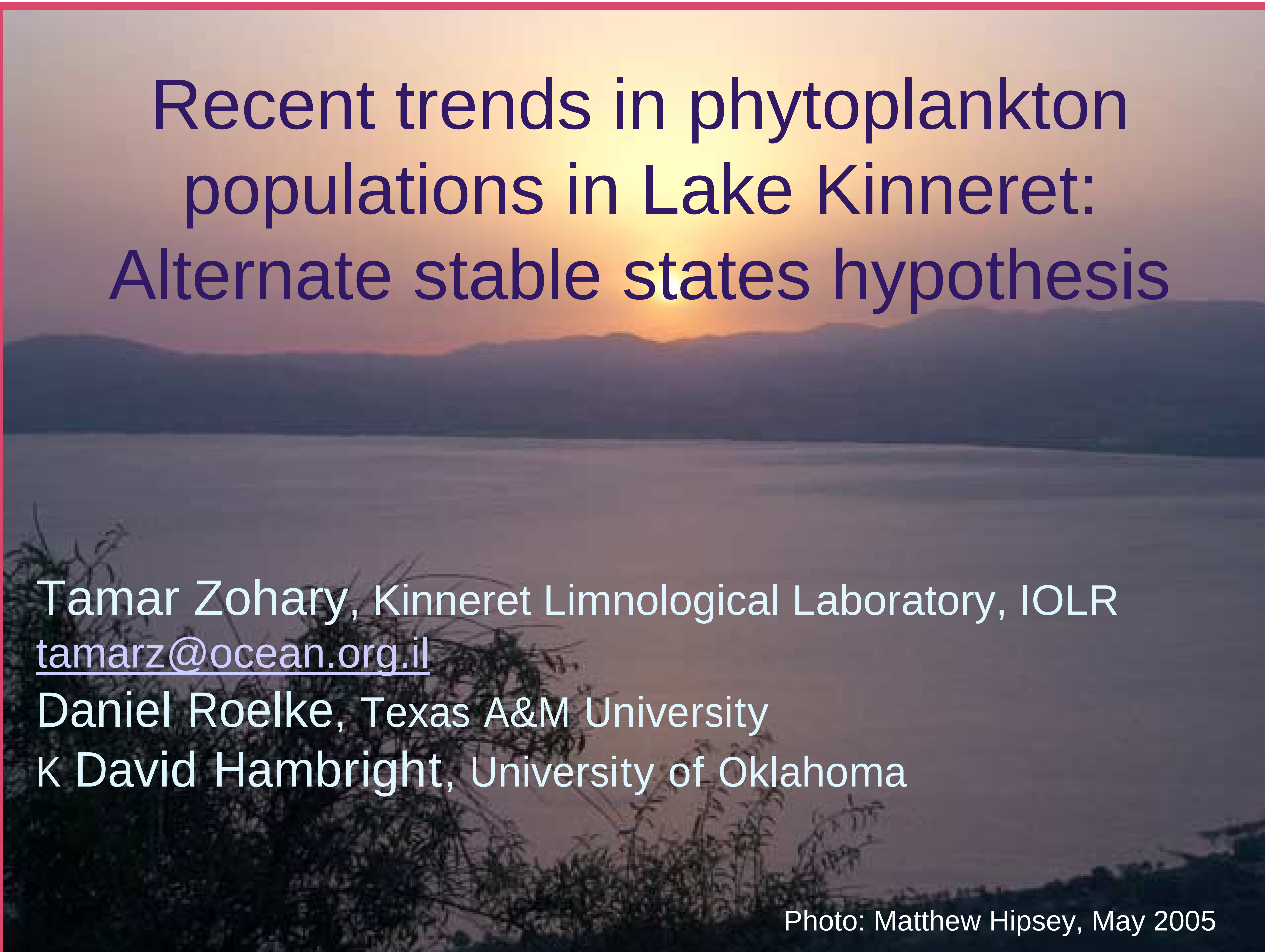


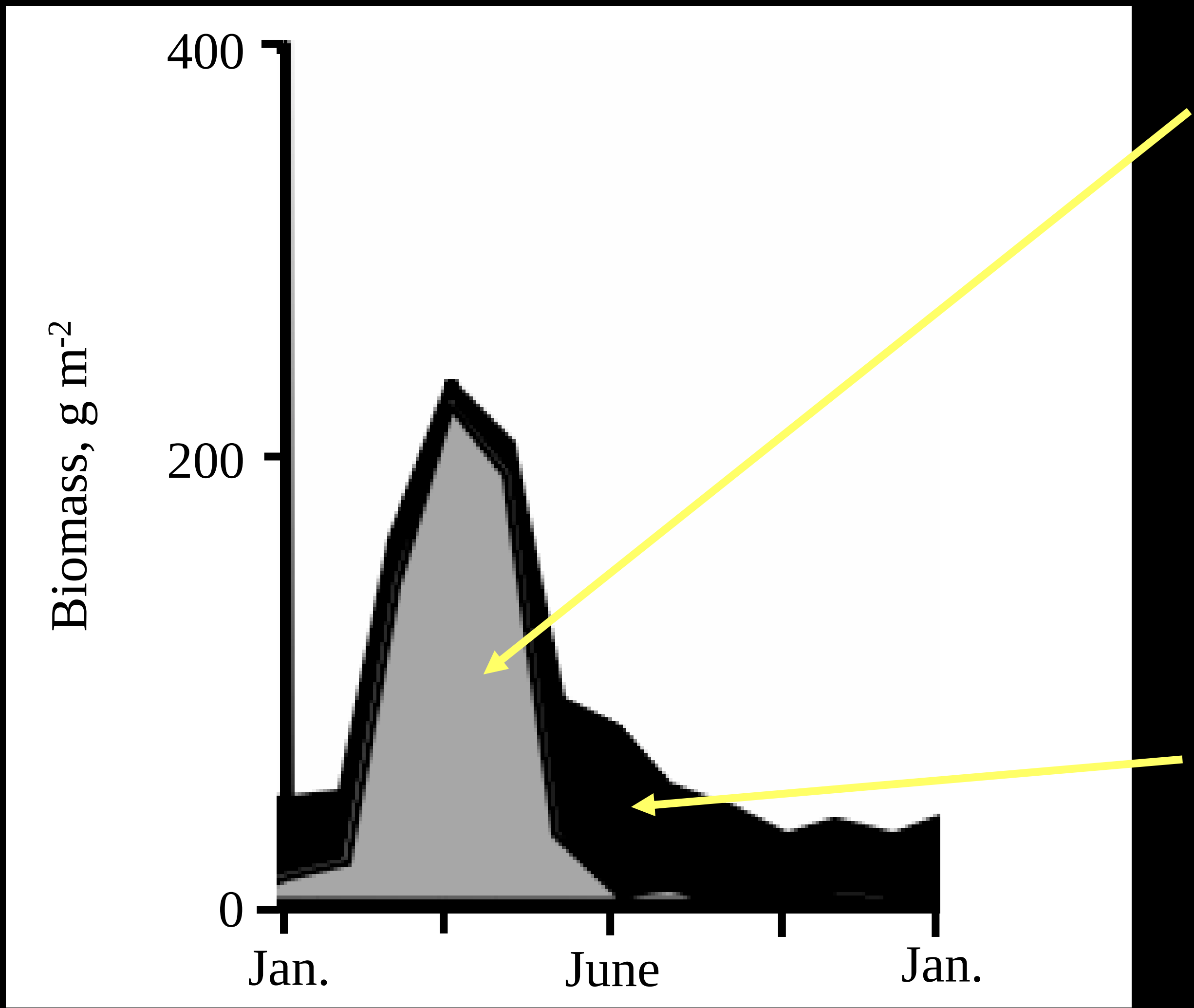
Photo: Matthew Hipsey, May 2005

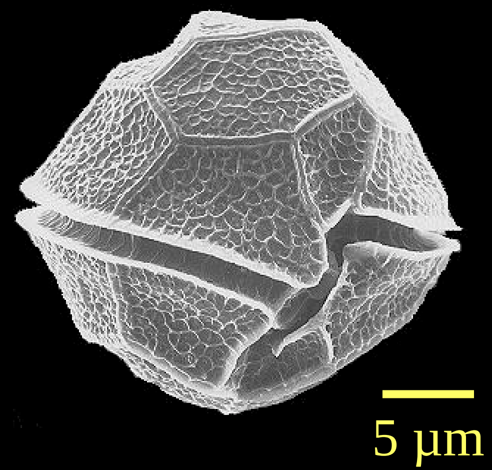
Lake Kinneret phytoplankton

"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





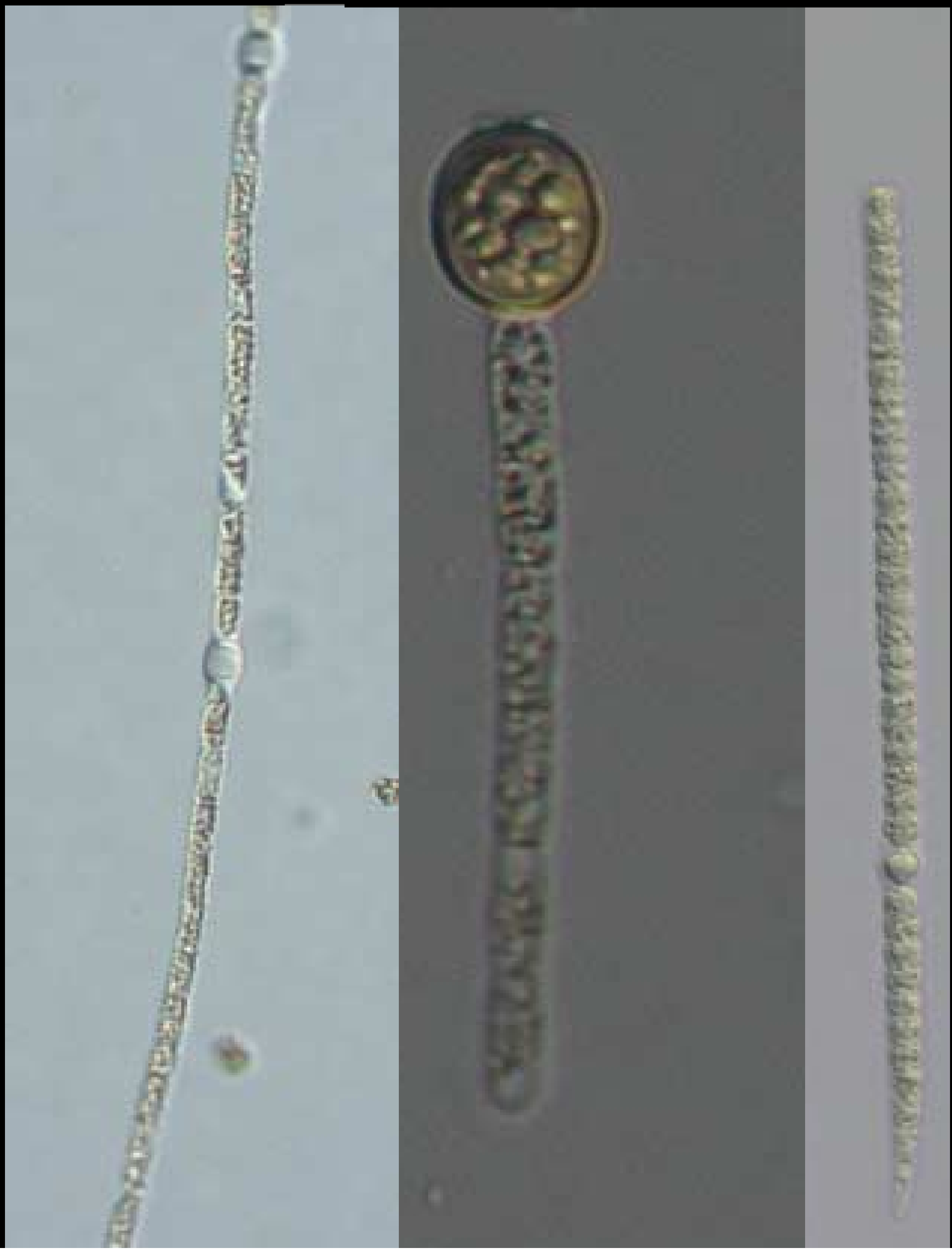
Deviations from the stable pattern since ~1994

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

(Zohary 2004 FWB)

N_2 fixing cyanobacteria invaded L Kinneret

Aphanizomenon ovalisporum, 1994



Cylindrospermopsis cuspis, 2000

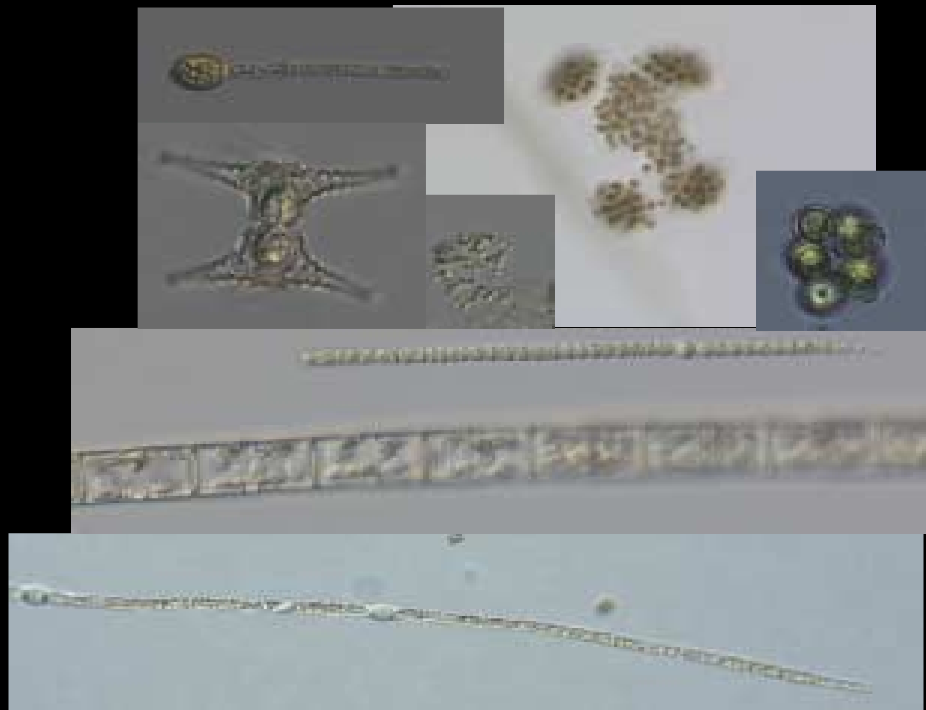
The summer assemblage

1969 - 1993

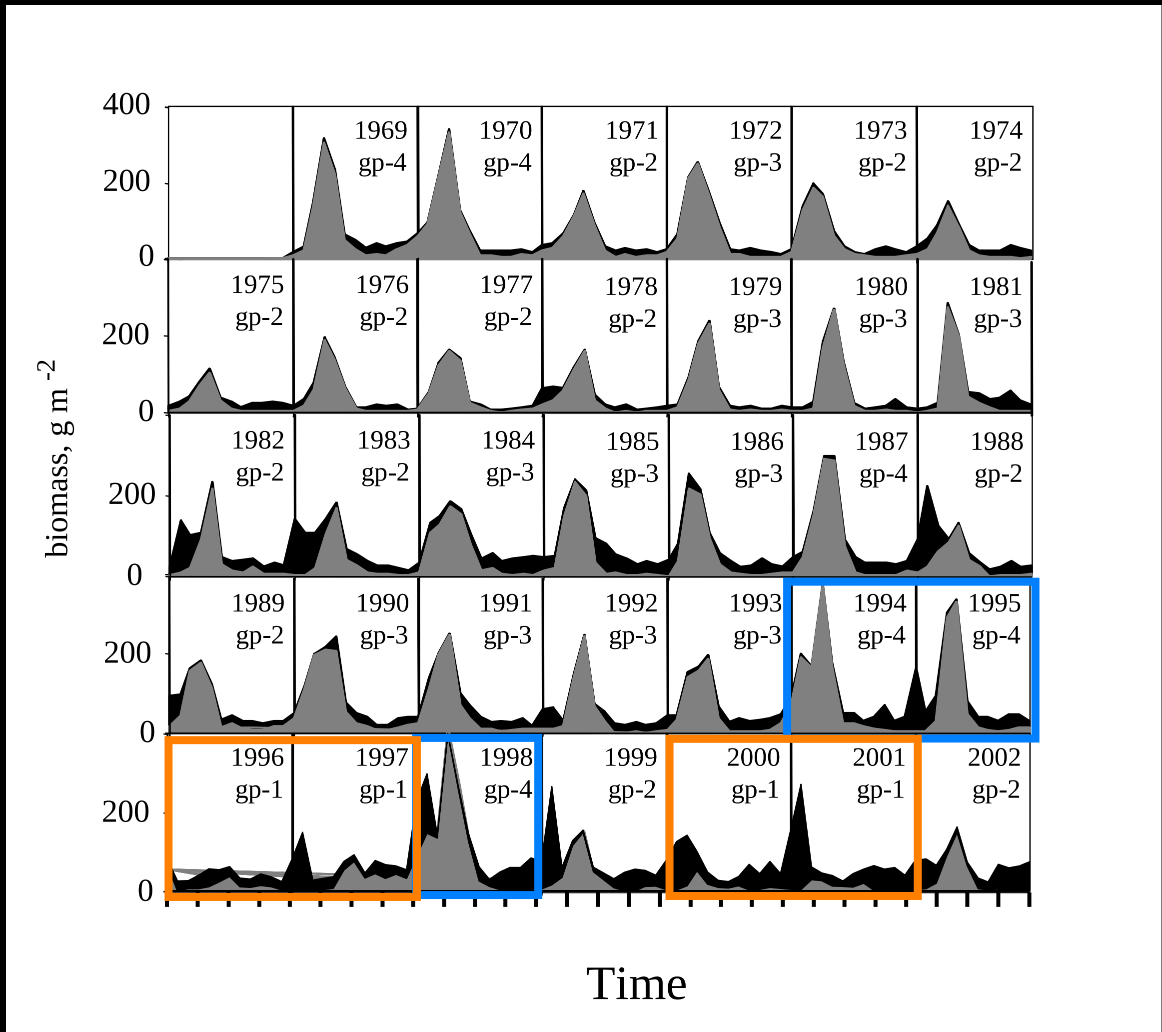
Small, round-shaped
Solitary & coenobia

Recent years

Filamentous, spiny,
elongated or colonieal



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)

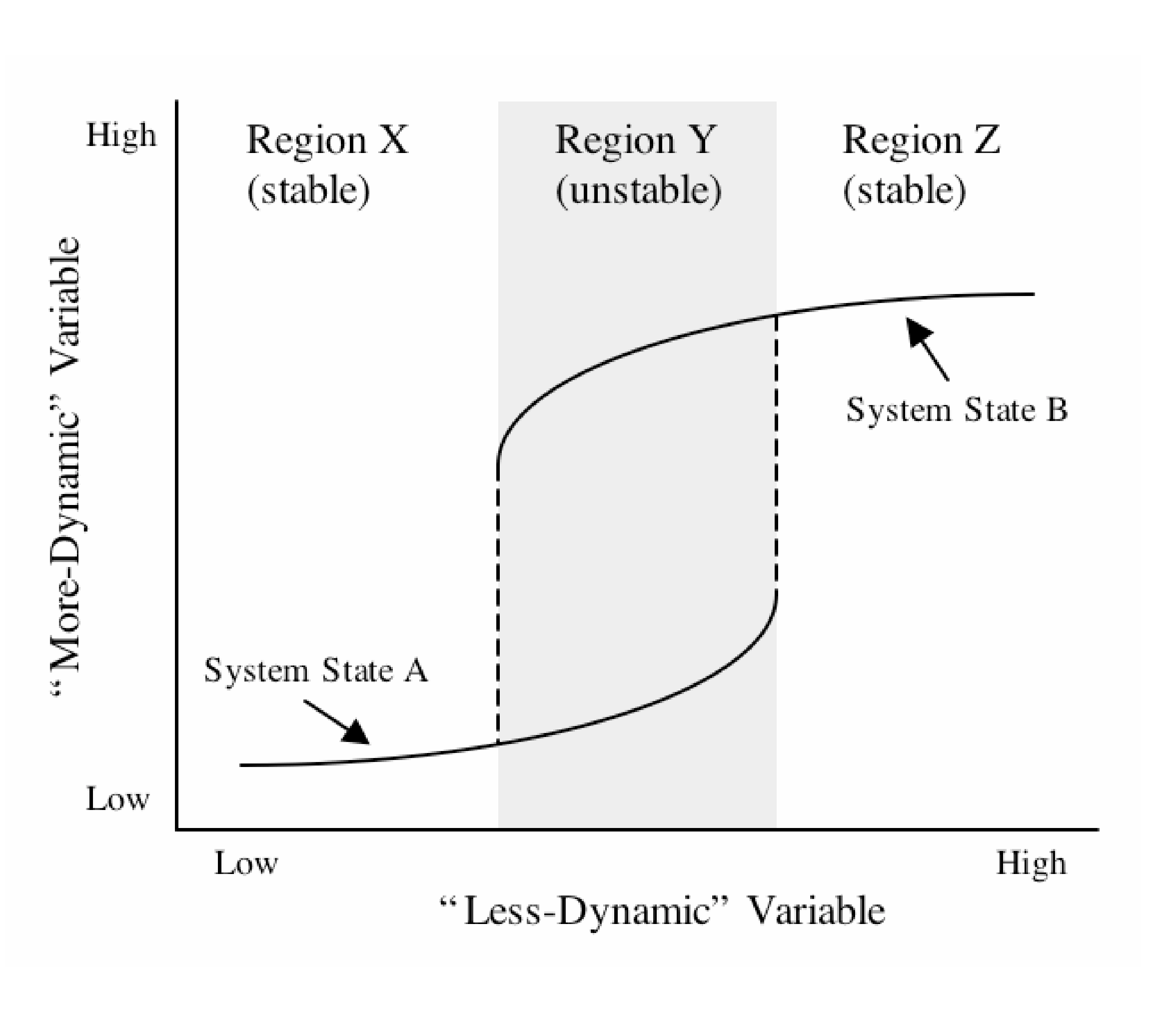
Univariate

Linear and Curvilinear Regression

(poor R^2 values, typically >0.10)

Proposed Complex Model Explanation

Distinct community structure can occur in the same environment

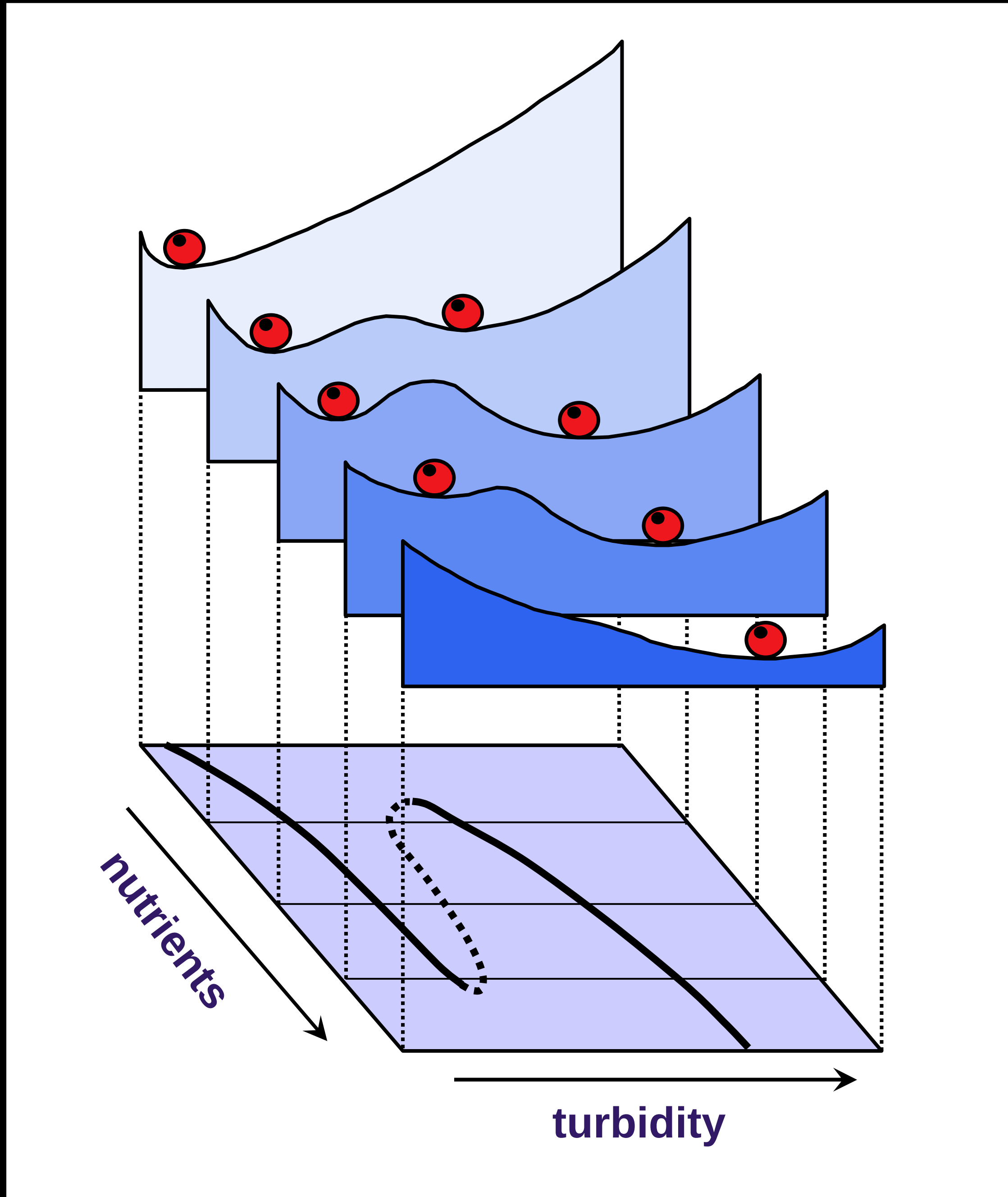


Alternate Stable-States Model

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

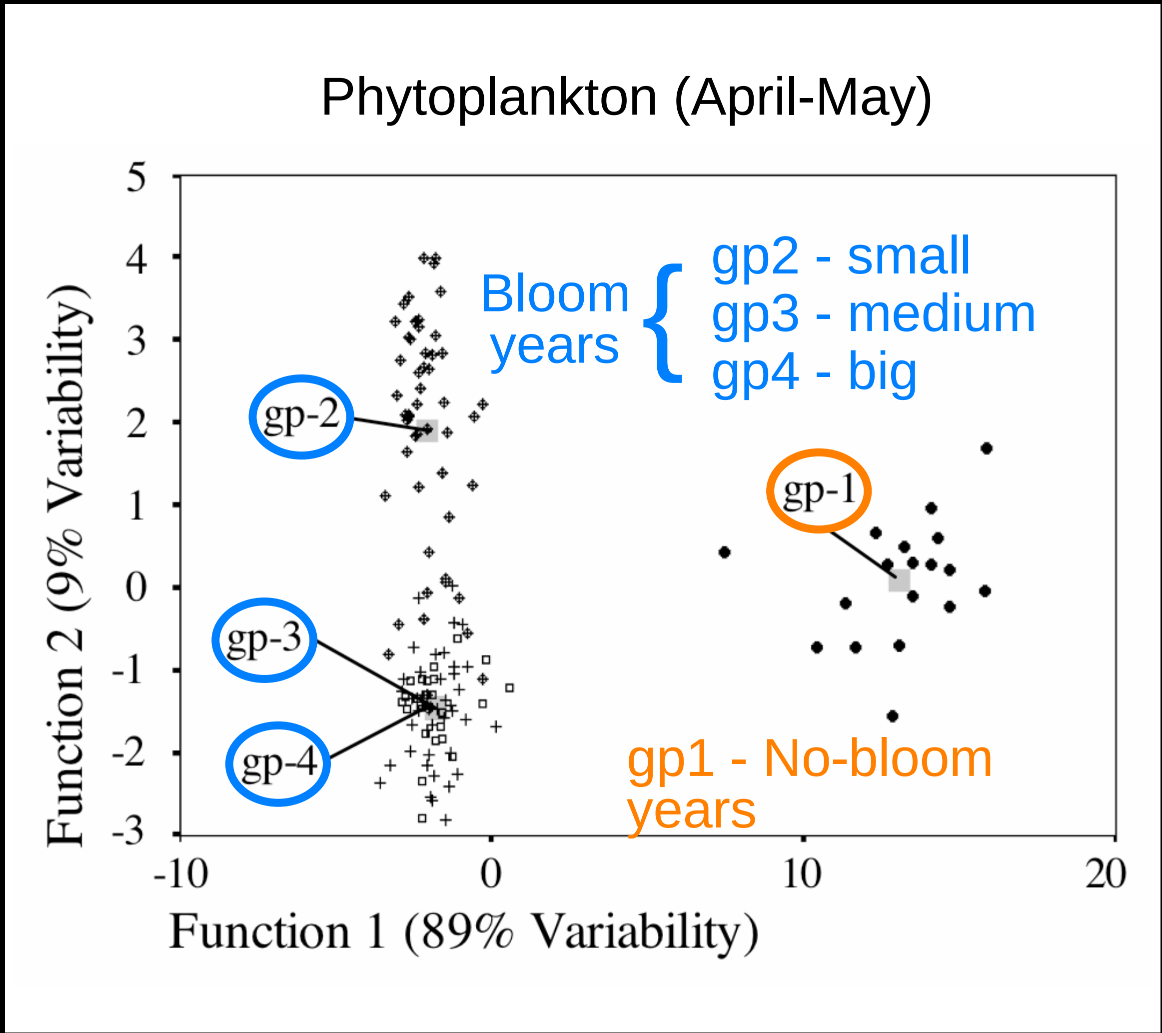
1. Discriminant Analyses
2. Principal Component Analysis

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)



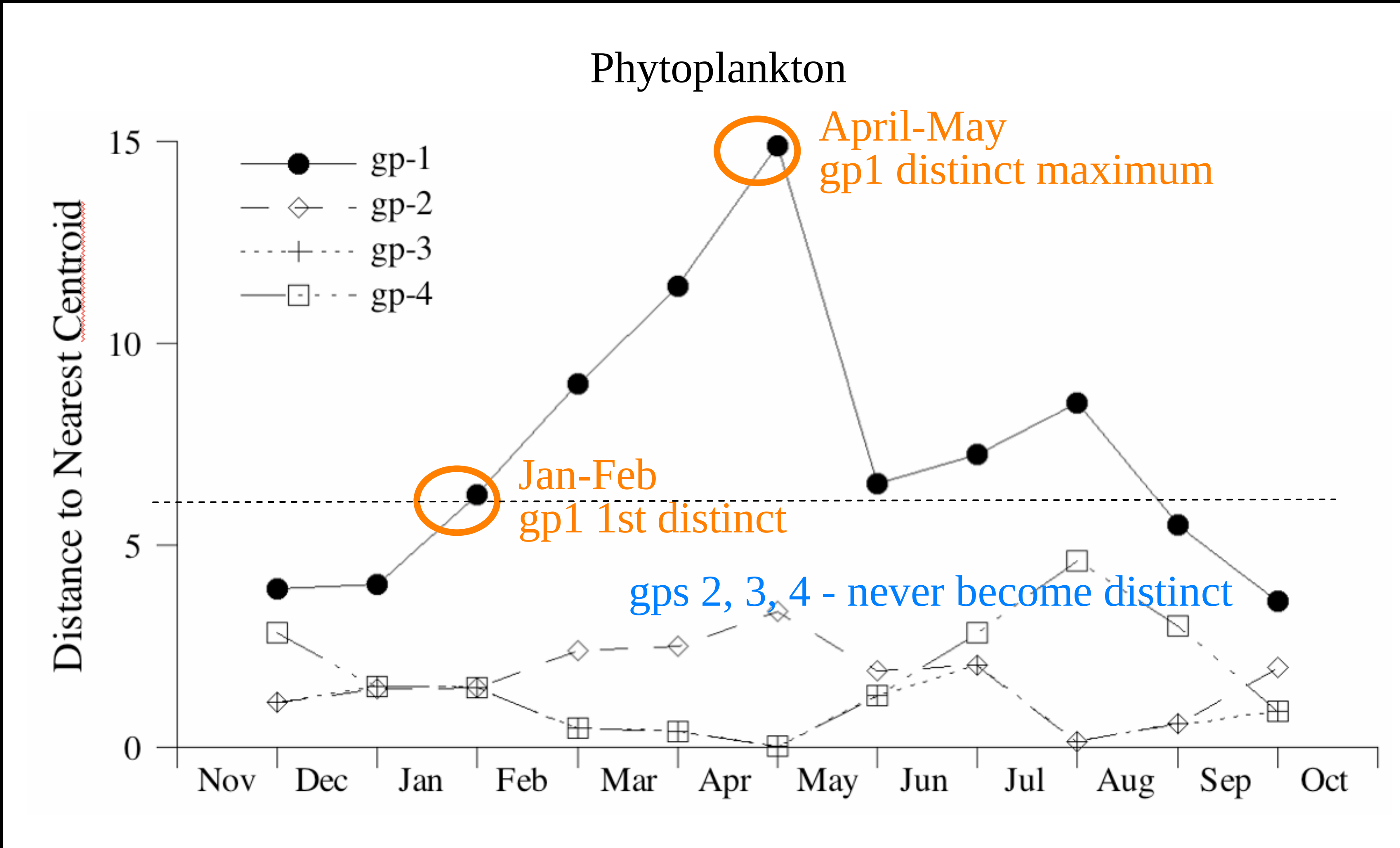
Distinct if:

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)

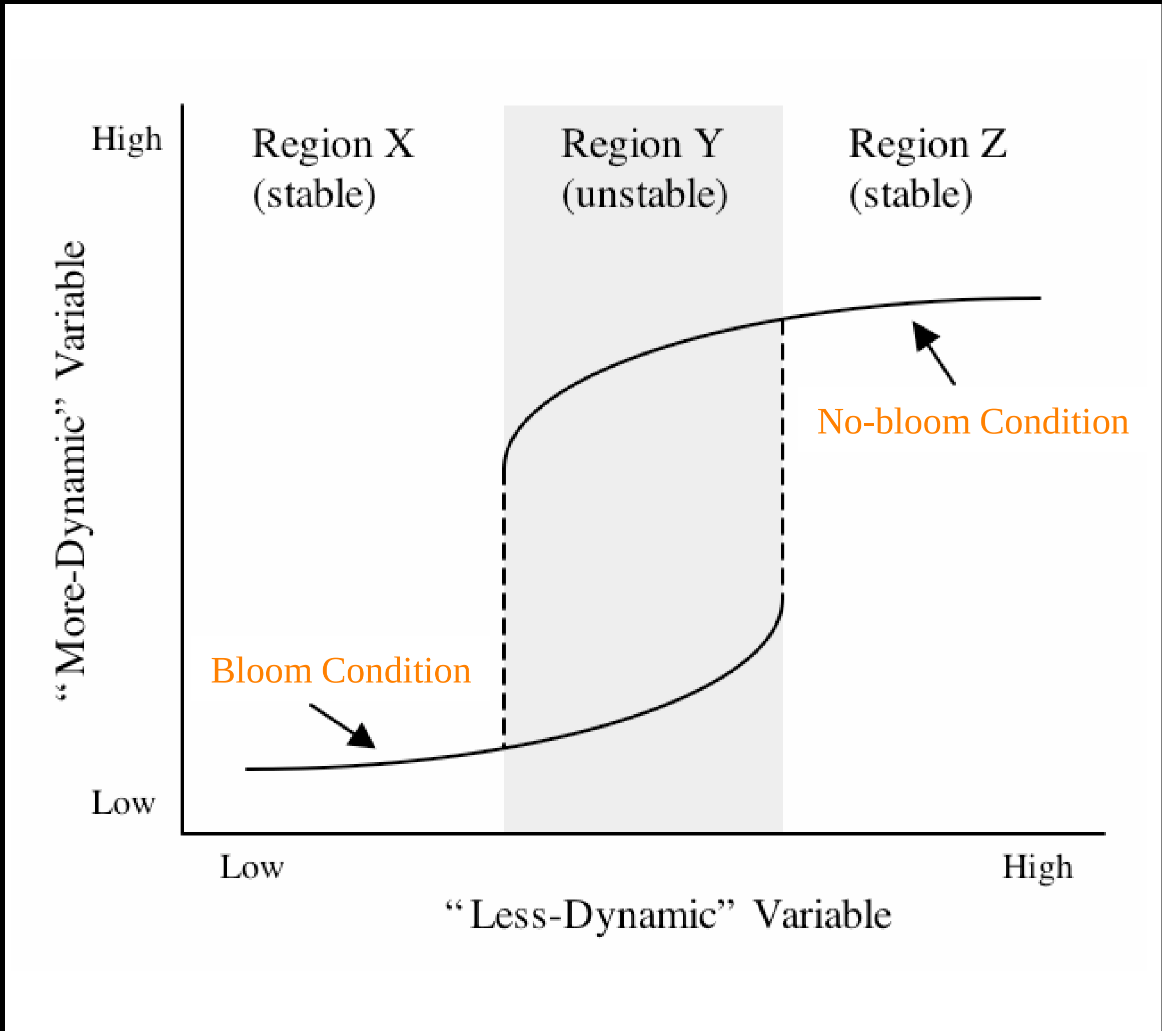


Phytoplankton Community Structures (Regions X and Y)

Principle component analysis

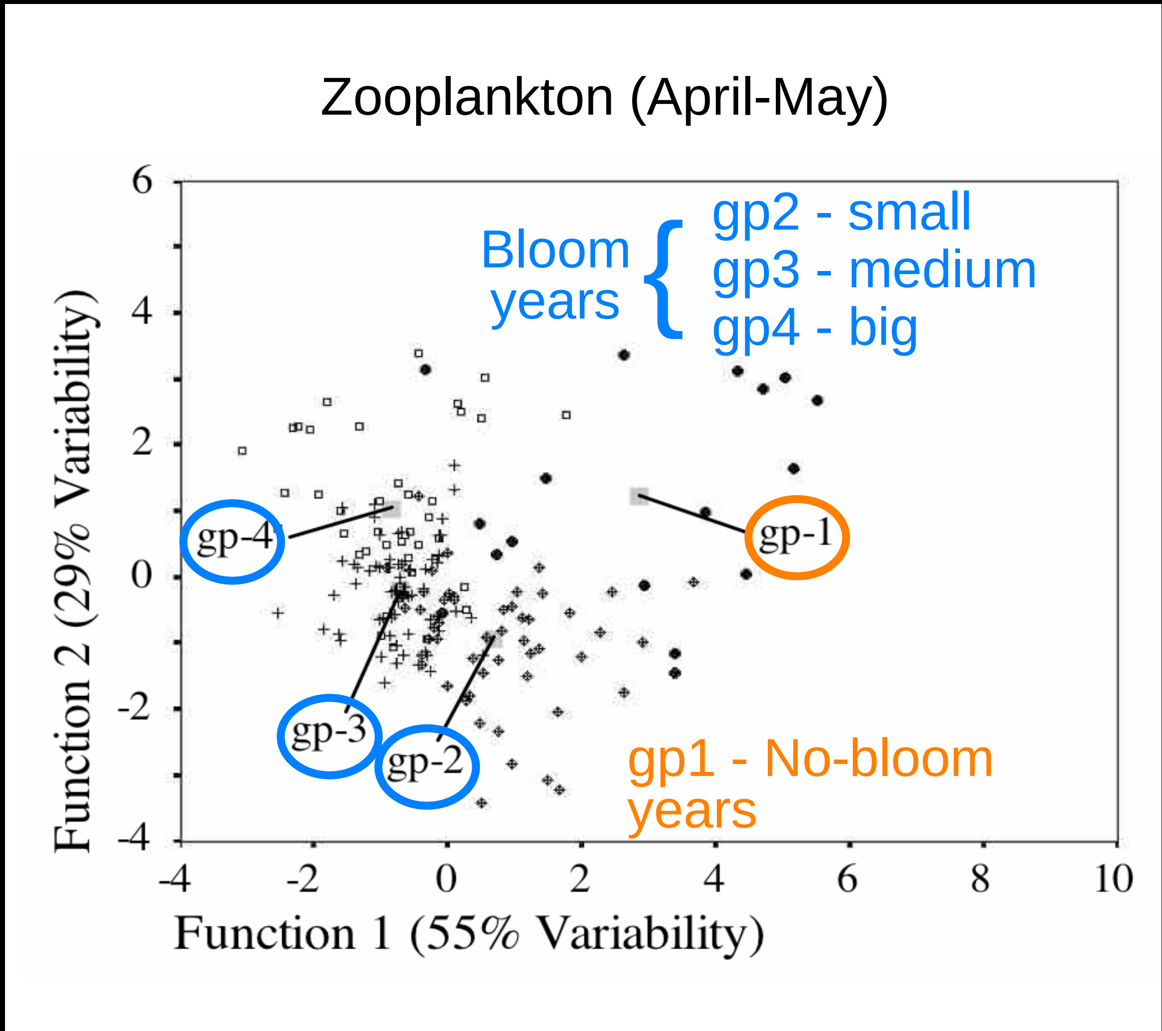
	Spring Phytoplankton
Select for no-bloom year	*Chodatella* sp. *Closterium acutum* *Oocystis* sp. *Cyanodictyon imperfectum* *Microcystis aeruginosa* *Microcystis wesenbergii* *Carteria cordiformis*
Select against no-bloom year	*Peridiniopsis elpatiewski*

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 <u>not</u> distinct from groups 2, 3, and 4

Groups 2, 3, and 4 are <u>not</u> distinct from each other

Discriminant Analyses, All Years (Regions X and Y)

However …

Zooplankton

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

Physicochemical

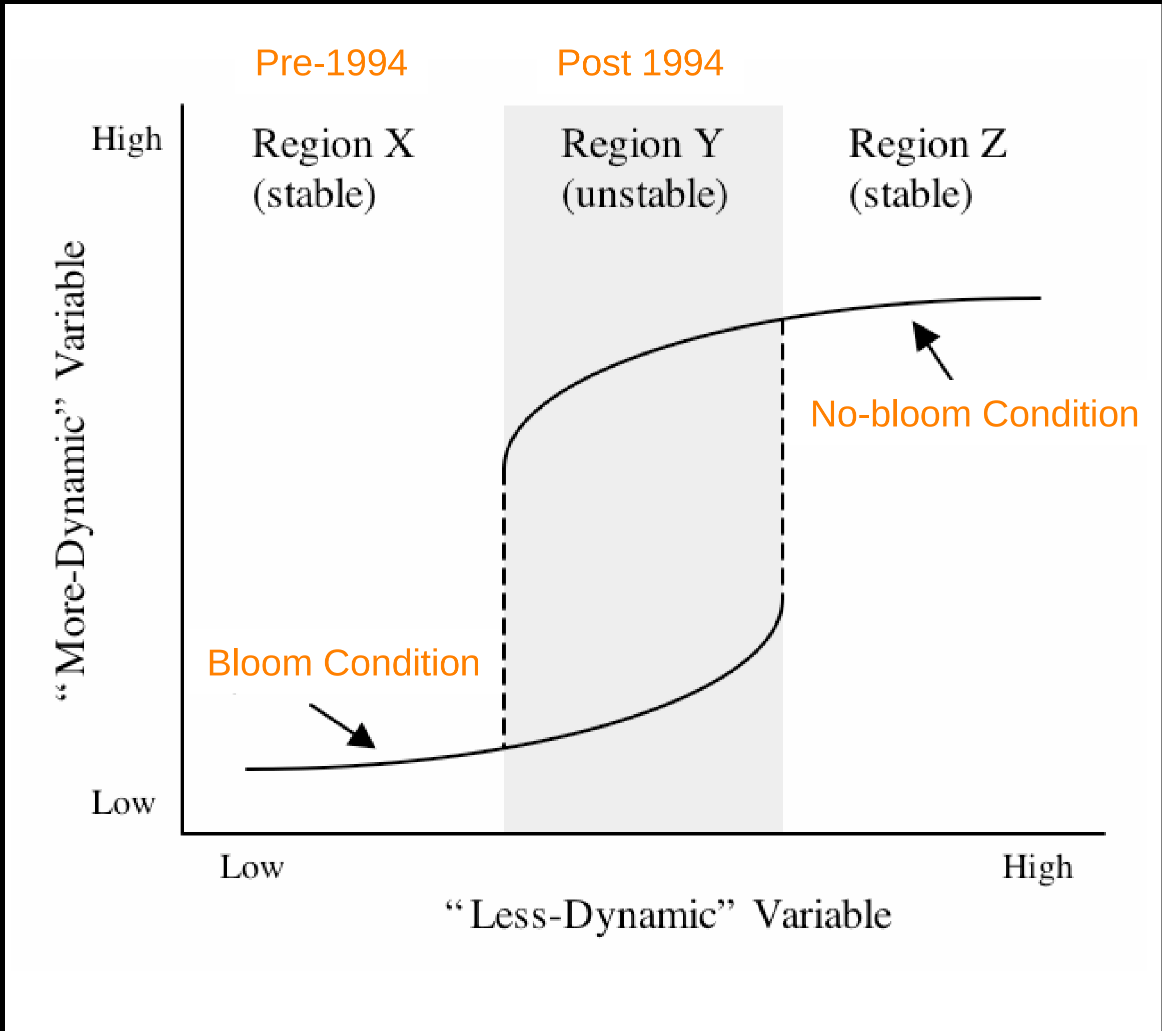
gps 1, 2, 3, and 4 never became distinct

But what if …

Zooplankton and/or Physicochemical

were a "More-Dynamic" Variable

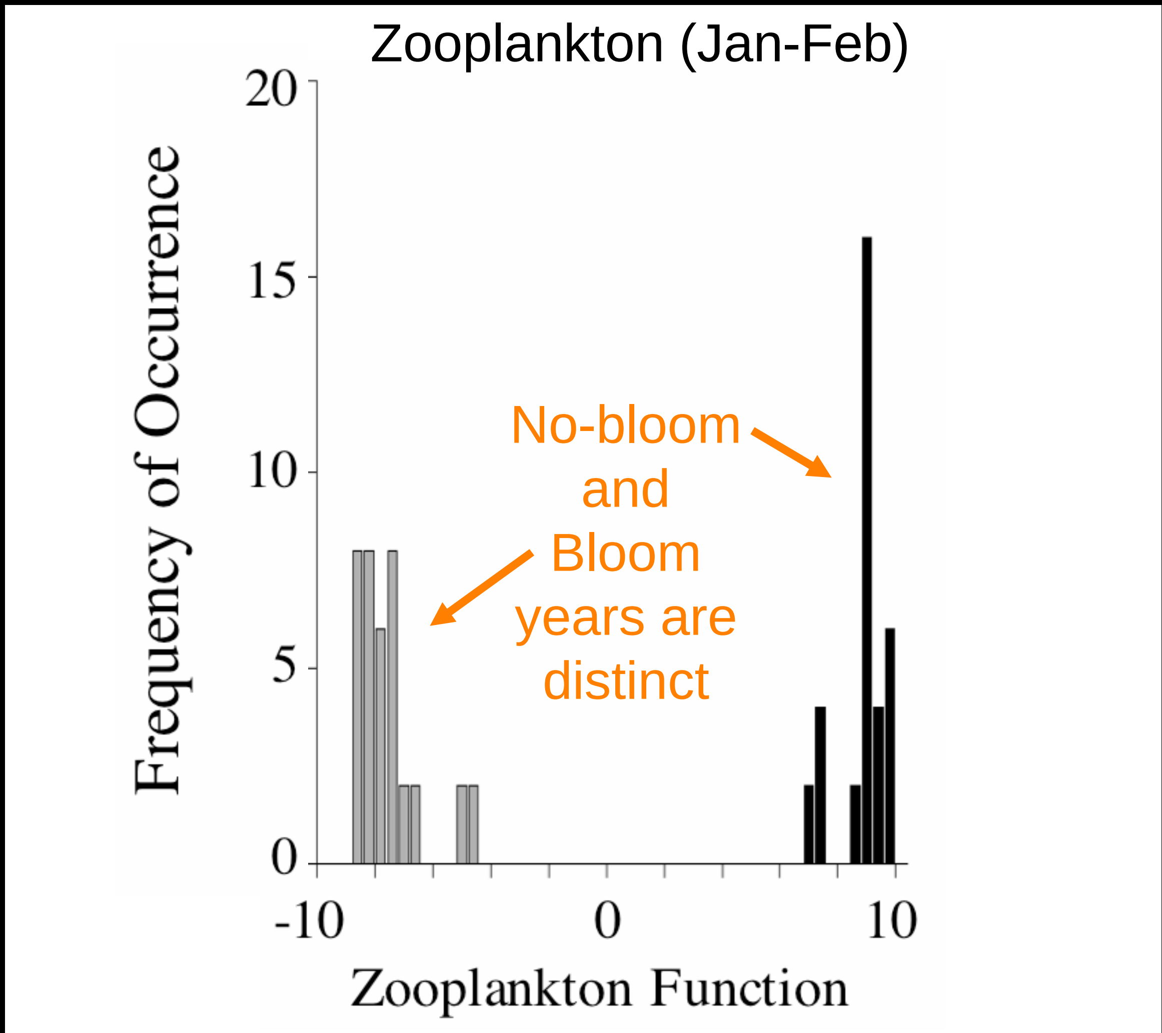
Proposed Complex Model Explanation



Alternate Stable-States Model

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

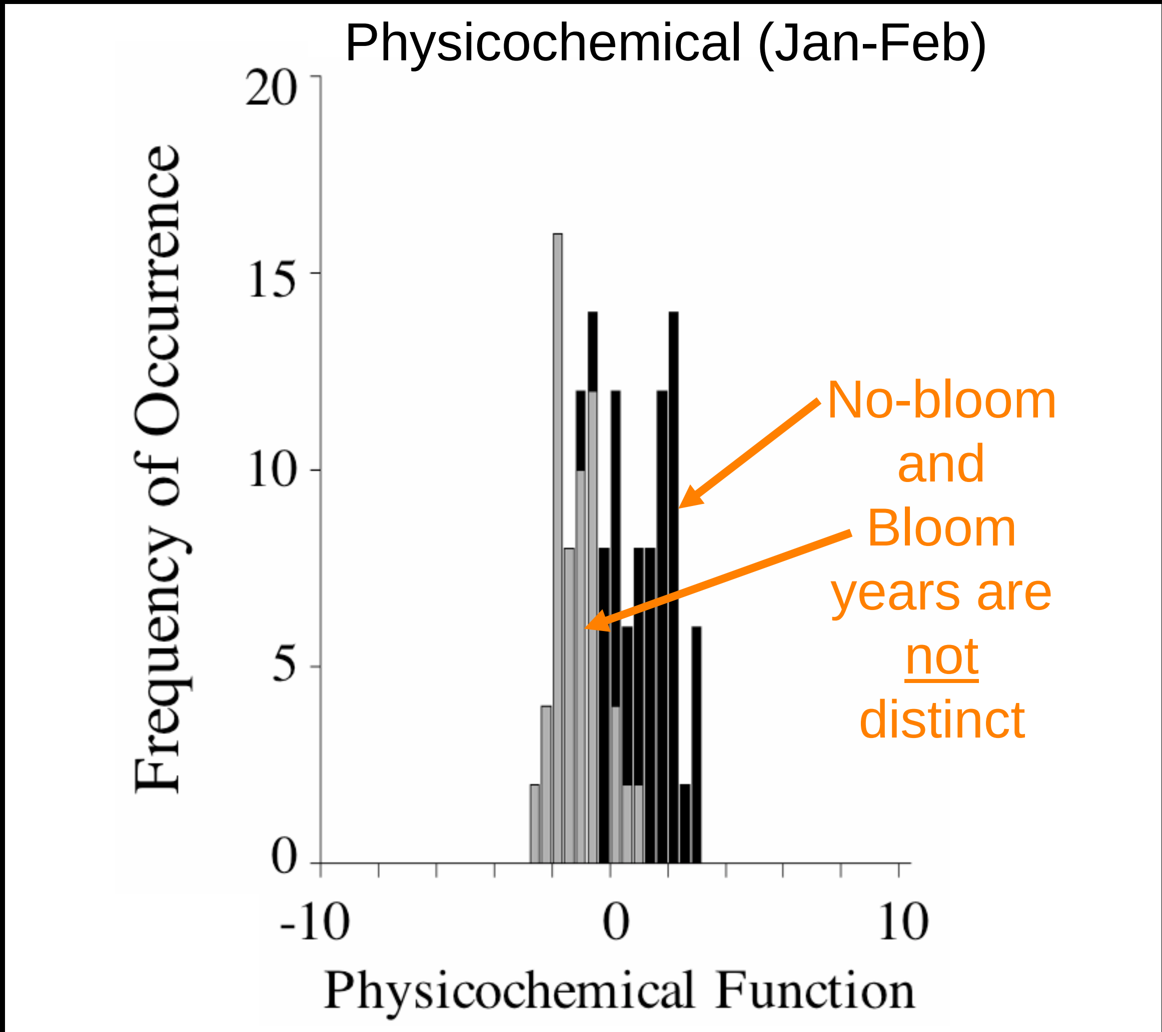
Representative Discriminant Analysis (Region Y)



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
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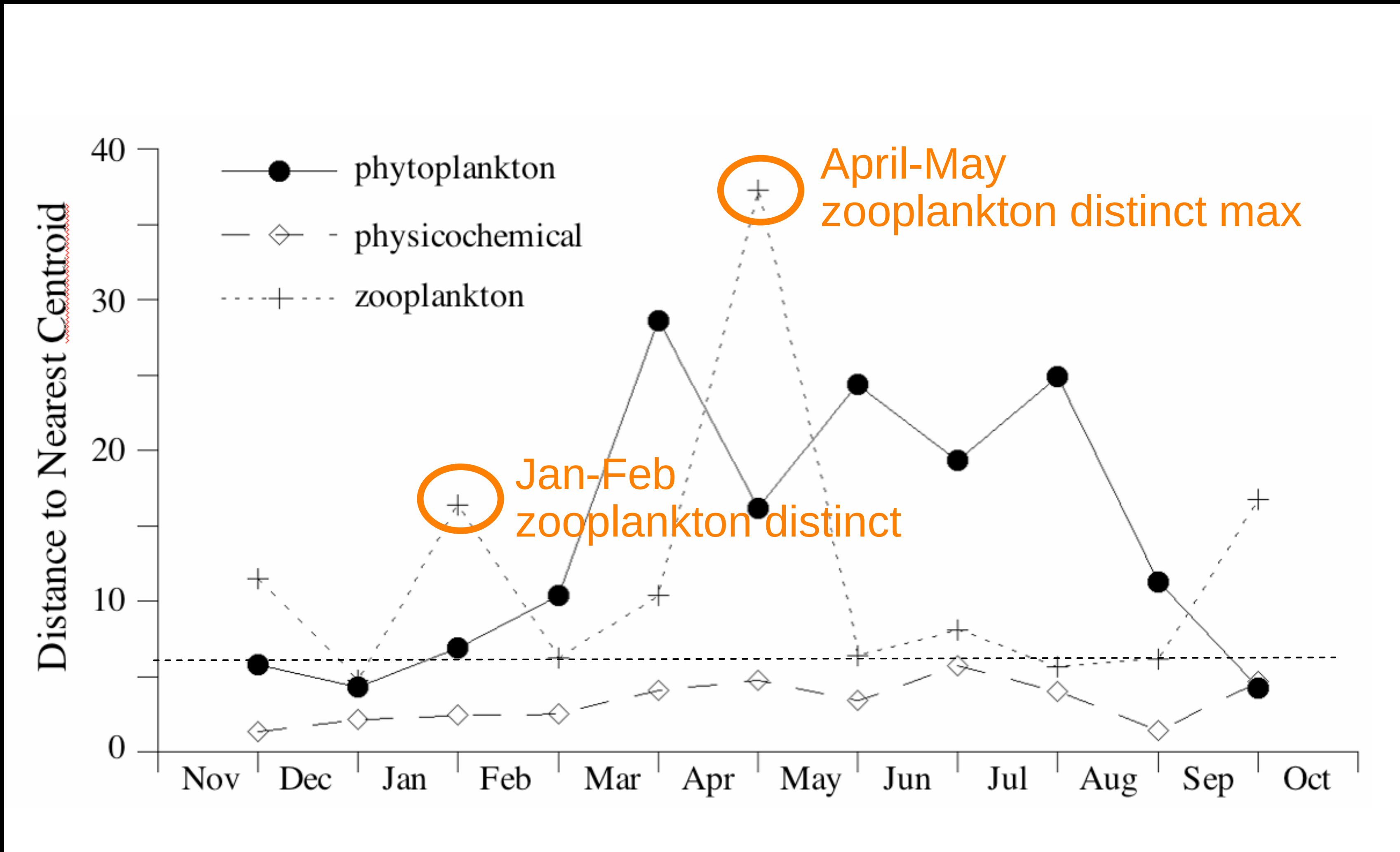
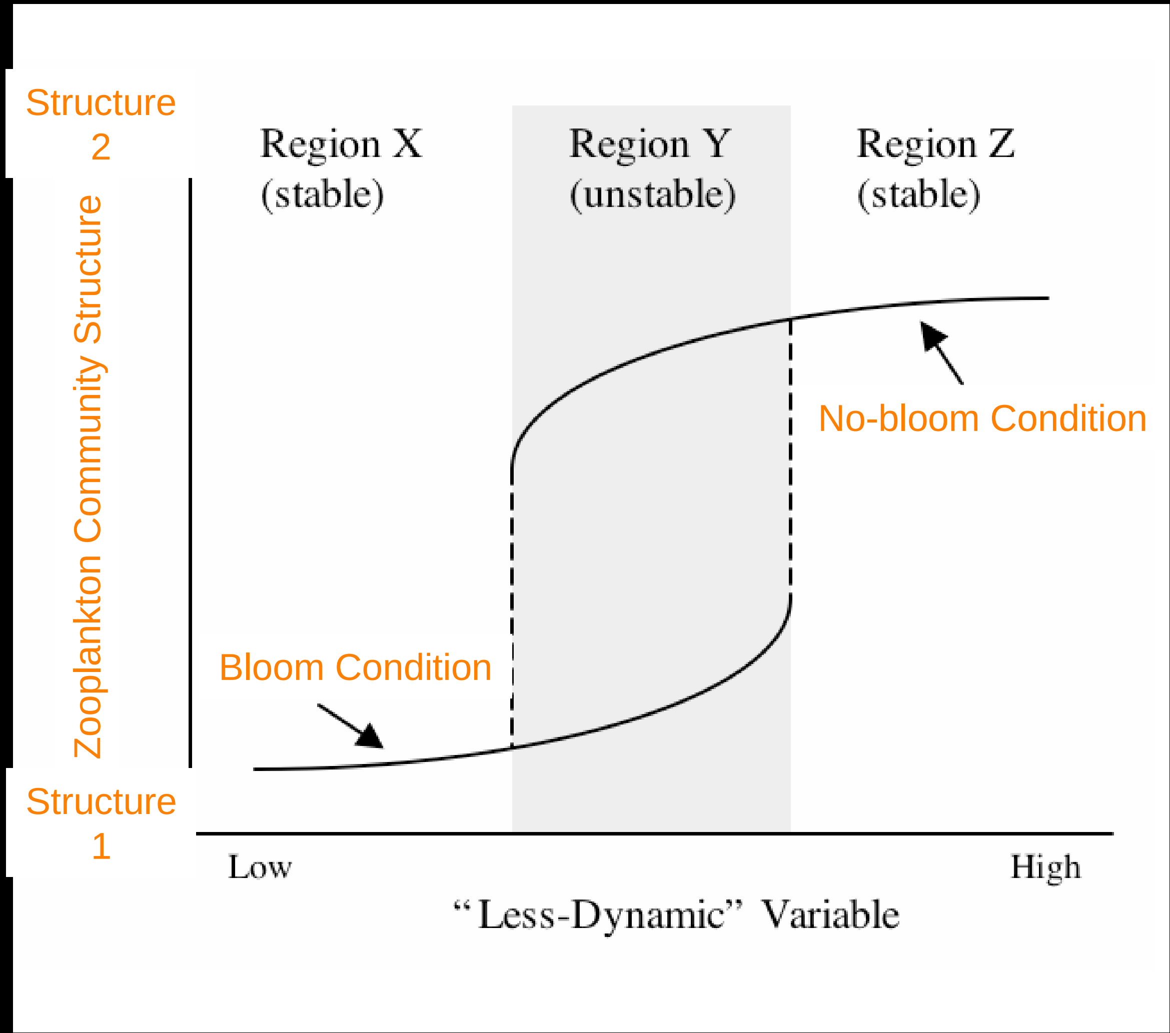
Discriminant Analyses, 1994-2001 (Region Y)



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*

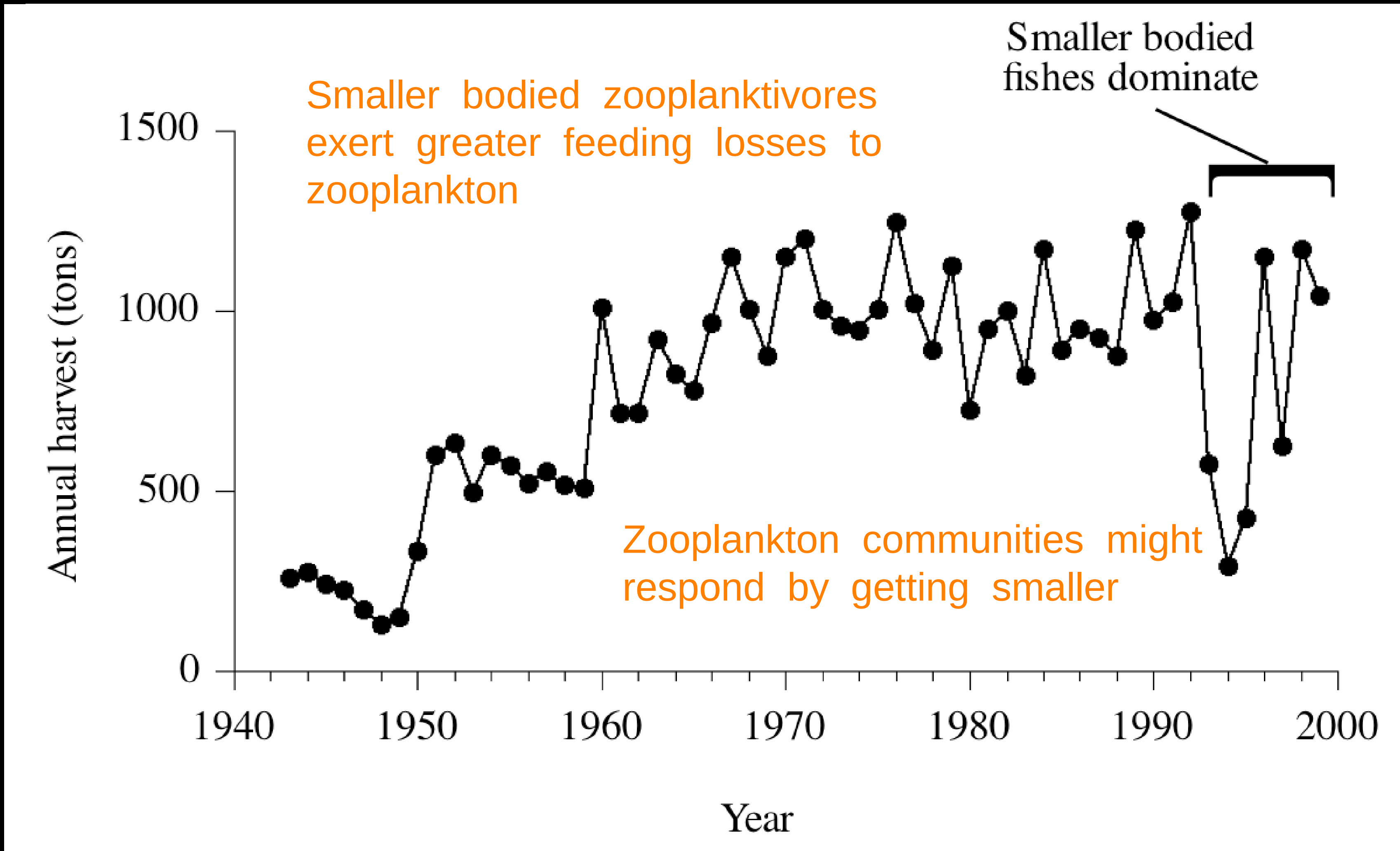
Proposed Complex Model Explanation



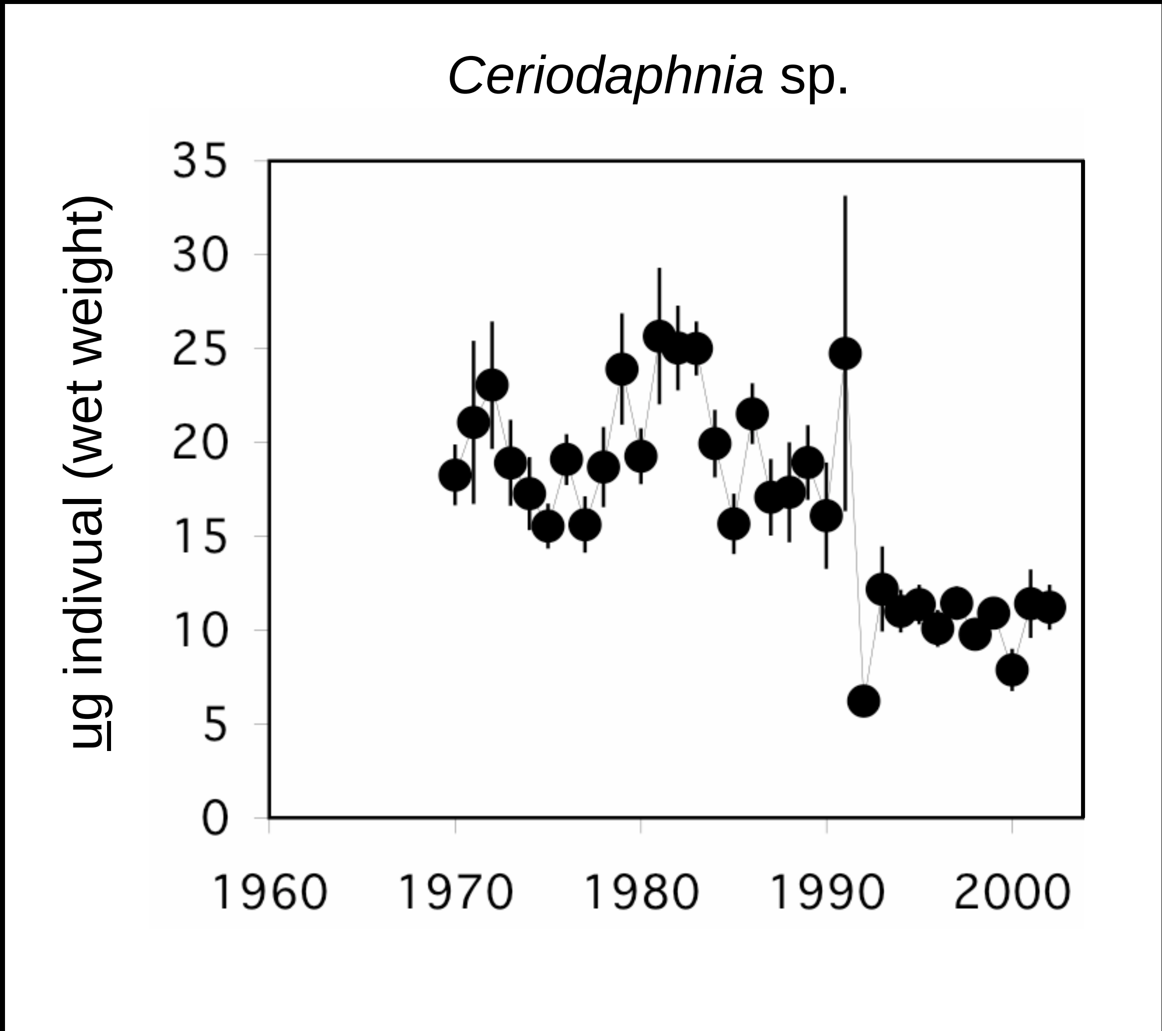
Alternate Stable-States Model

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

State of the Kinneret Fishery



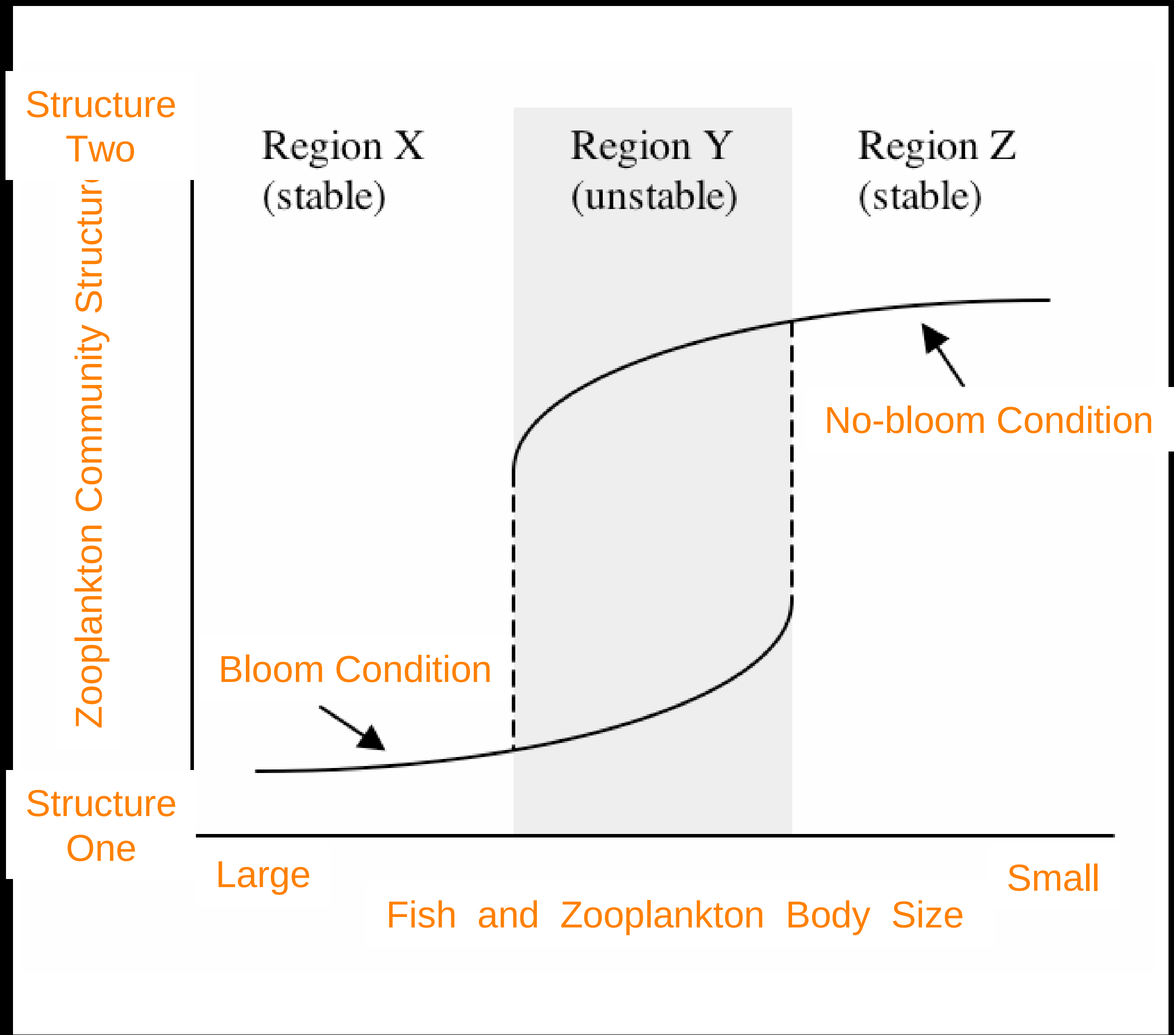
State of the Kinneret Zooplankton



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