A Qualitative Assessment of the Relative Effects of Bycatch Reduction, Fisheries and Hypoxia on Coastal Nekton Communities in the Gulf of Mexico

Donald M. Baltz[1], Hiram W. Li[2, 3], Philippe A. Rossignol[3], Edward J. Chesney[4], Theodore S. Switzer[4]

[1]Department of Oceanography and Coastal Sciences, [2]Oregon Cooperative Fish and Wildlife Research Unit, [3]Department of Fisheries and Wildlife, and [4]Louisiana Universities Marine Consortium

Objectives

- Examine other influences on nekton in Louisiana coastal waters that might resemble the effects of hypoxia
- Assess the effects of shrimp-trawl fishing on shrimp and fish populations
- Briefly compare some aspects of our qualitative and quantitative analyses

Using qualitative mathematical models:

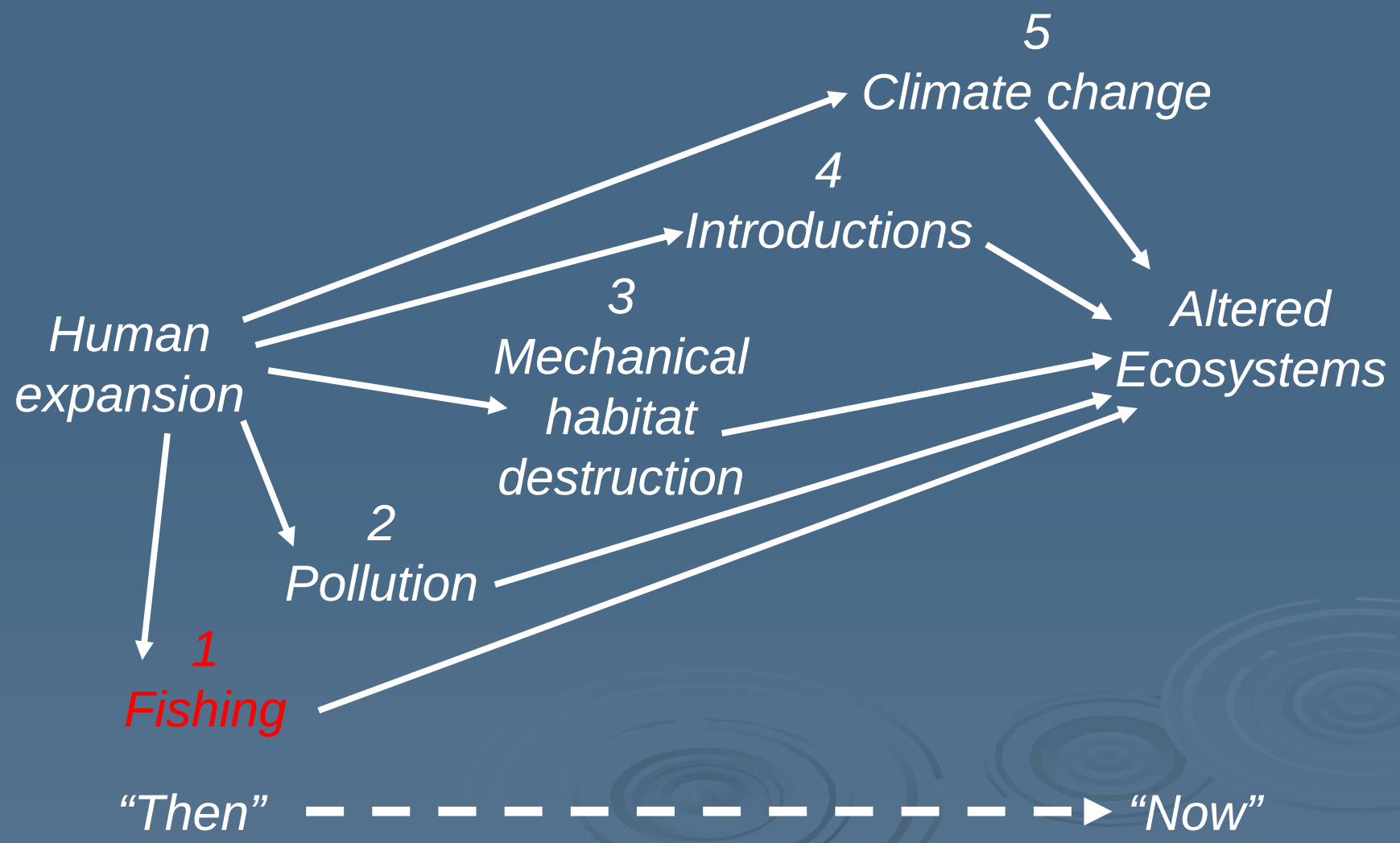
- Generally known as Loop Models
- We can model important fishery species and environmental variables meaningfully
  - to explore and predict how specific environmental perturbations will influence populations in coastal systems
- We can examine the expected and unintended consequences of alternative resource management strategies
- Hopefully, we can identify critical data needs and generate testable hypotheses for complex communities

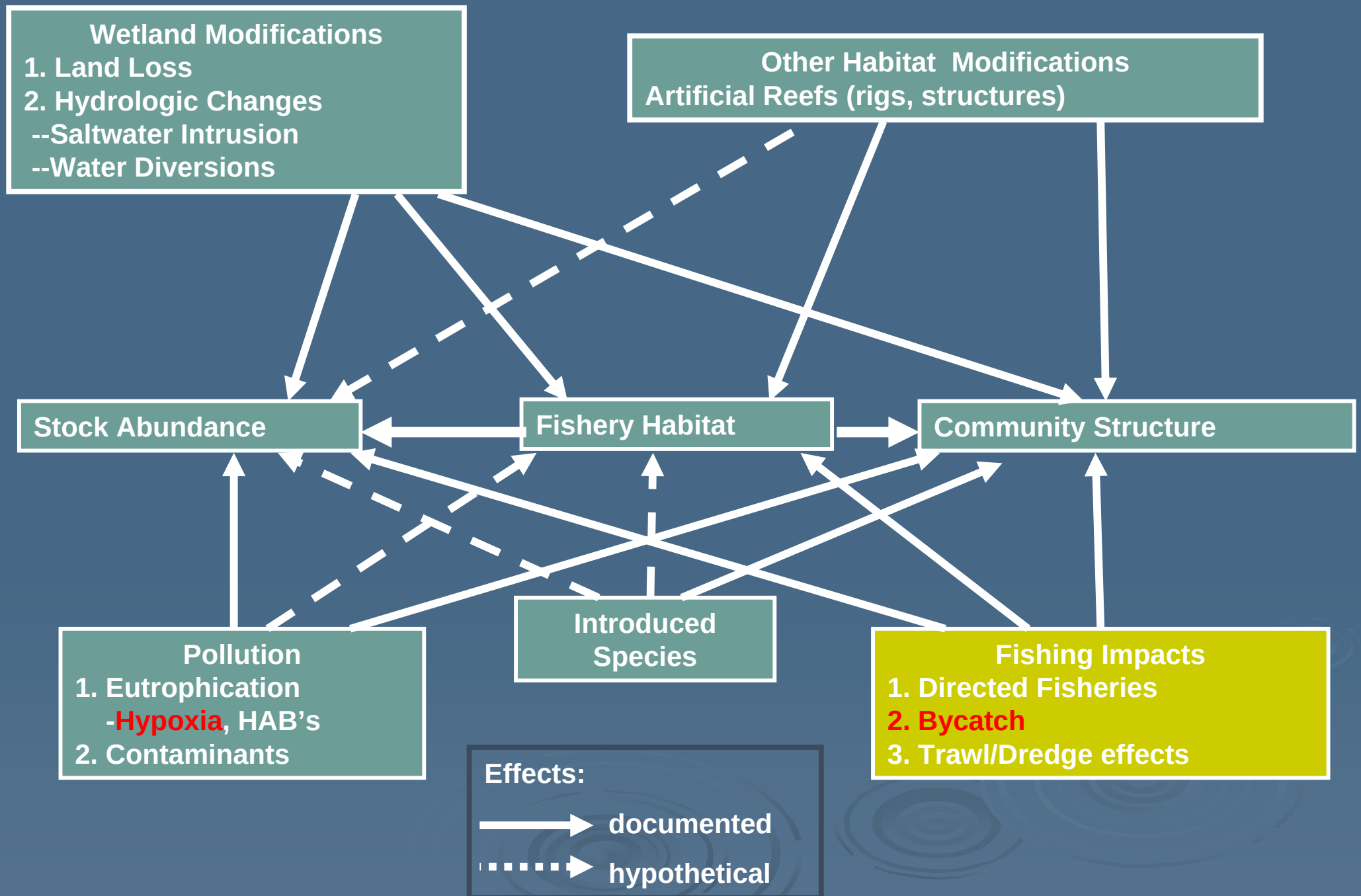
Louisiana Coastal Stresses: Habitat changes and alterations

- Leveeing of Mississippi and Atchafalaya rivers for flood control and navigation
- Canal dredging and spoil bank deposition for navigation
- Oil and gas exploration and production
- Water diversions
- Fishing activities
- Point- and non-point source pollution
- Eustatic sea-level rise
- Subsidence
- Introduction of non-indigenous species
- A lot of things are happening simultaneously, requiring caution in identifying causes and effects

Historical Sequence of Human Disturbance of Coastal Ecosystems

(after Jackson et al. 2001)




Wetland Modifications
1. Land Loss
2. Hydrologic Changes
--Saltwater Intrusion
--Water Diversions
Other Habitat Modifications
Artificial Reefs (rigs, structures)
Stock Abundance
Fishery Habitat
Community Structure
Pollution
1. Eutrophication
-Hypoxia, HAB's
2. Contaminants
Introduced Species
Fishing Impacts
1. Directed Fisheries
2. Bycatch
3. Trawl/Dredge effects
Effects:
documented
hypothetical

Effects of Fishing Model

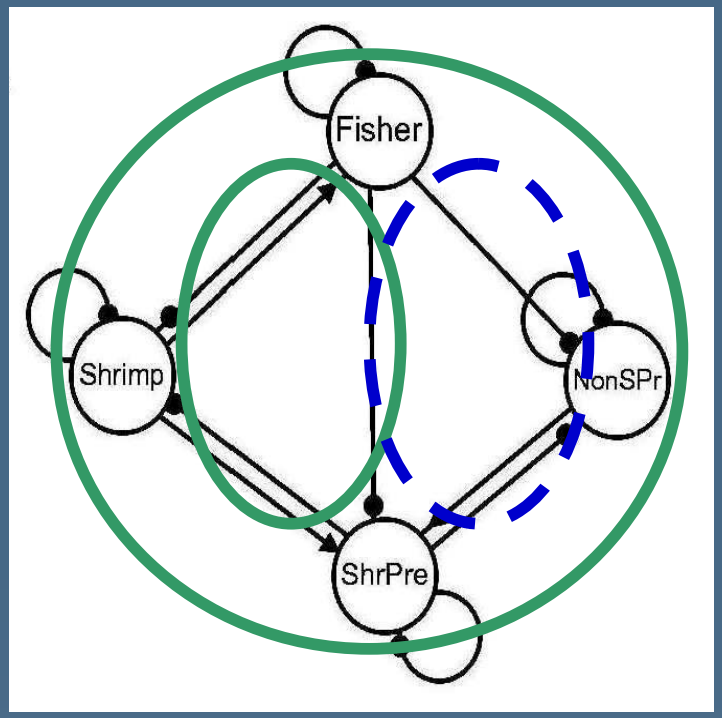
Most fishing gears catch non-target species and/or sizes that are not marketed, these individuals are ‘bycatch’.

Other individuals are not ‘caught’ *per se* but also suffer the ‘effects of fishing’, often injury leading to mortality.

Commercial fisherman separating shrimp from bycatch (NOAA Photo Library)

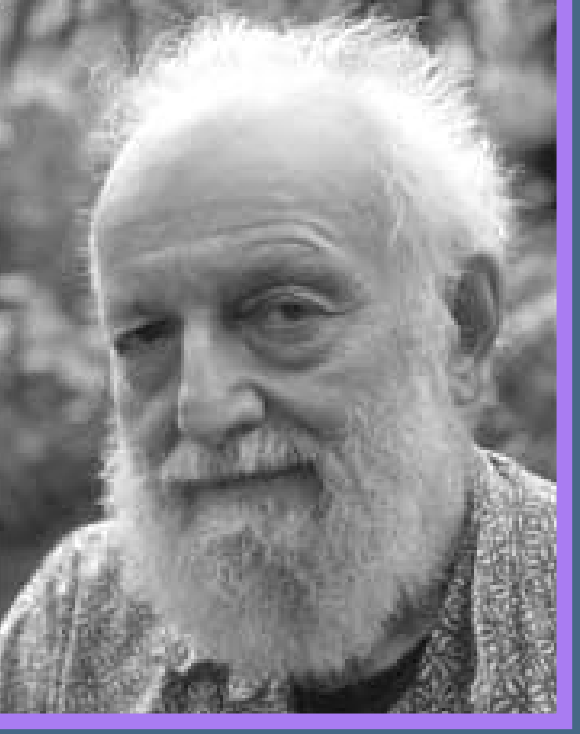
for 2002 the bycatch-to-landings ratio for commercial shrimping in the nGOM was 4.56:1

Effects of Fishing Model



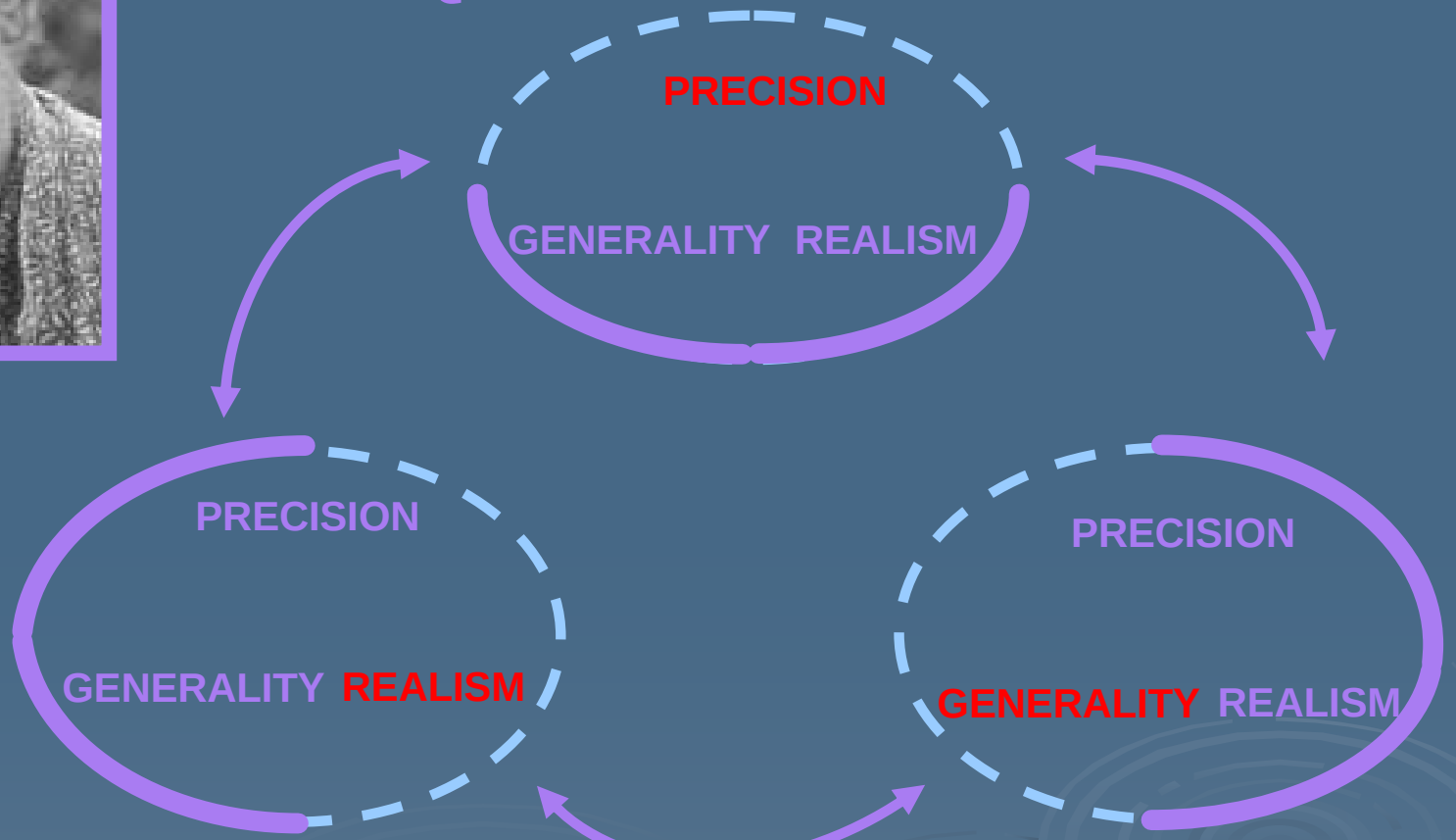
Simple interactions may be positive &/or negative and feedback along paths is positive if it returns the same sign, negative if the sign changes, or non-existent (if path is incomplete, i.e., no return)

Symbolic Relationship	Name	Feedback
	Predator-Prey	Negative
	Interference	Positive
	Mutualism	Positive
	Commensalism	None
	Amensalism	None
	Self-effect	+ or -

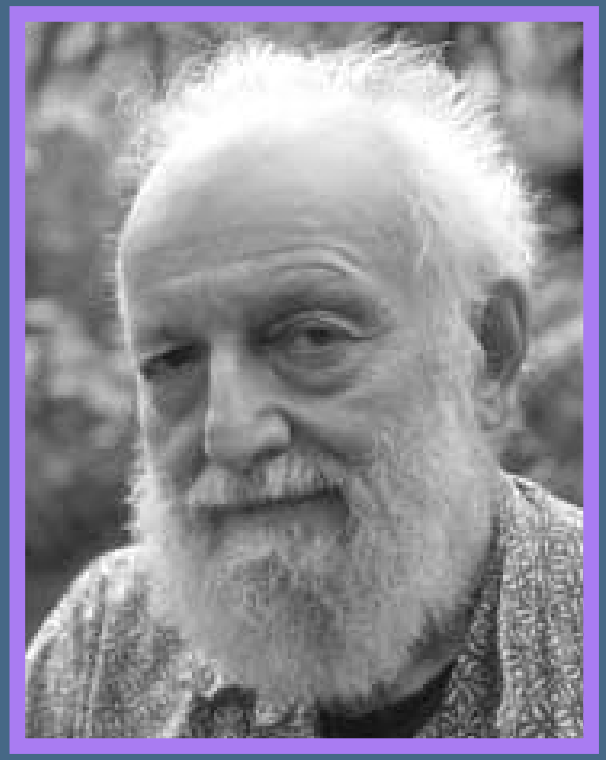


Richard Levins

"...we may want to work with models that maximize generality, reality and precision, but we can only maximize two of three."



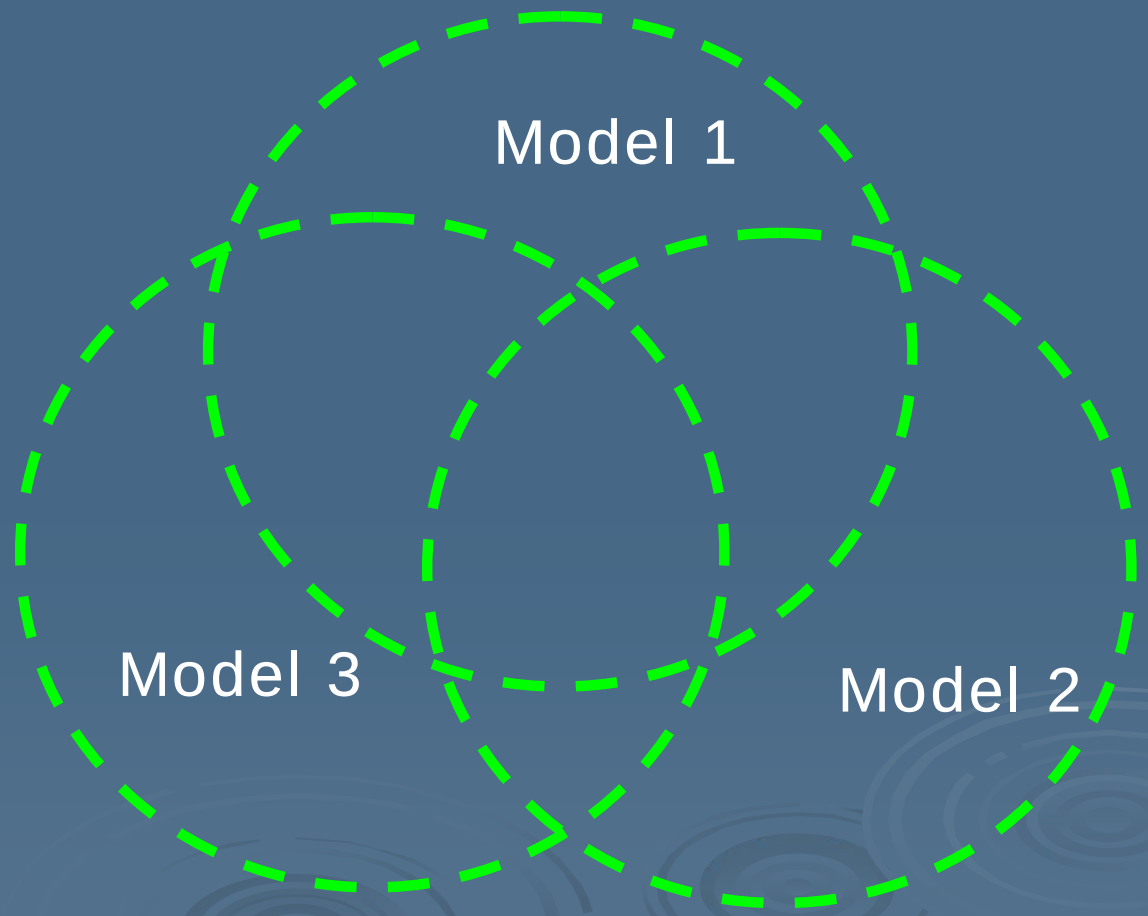
LEVINS 1965



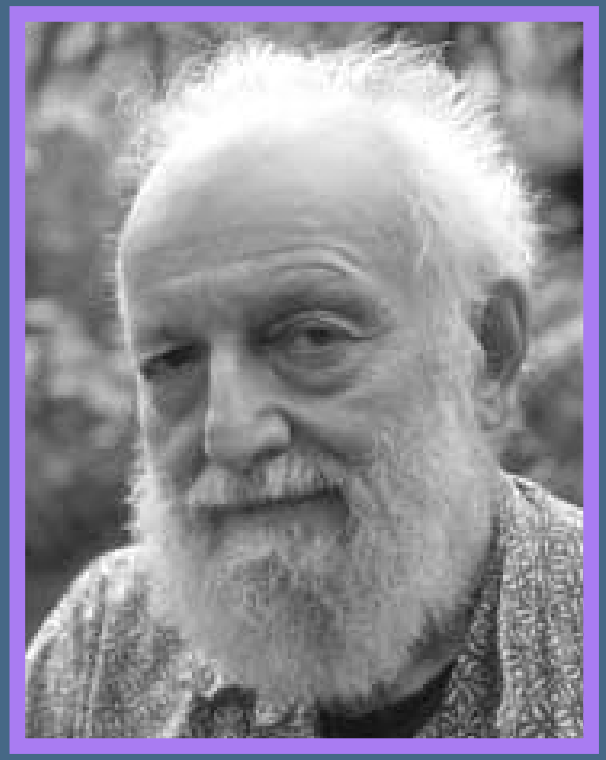
Richard Levins

All models are lies

Qualitative Models



Levins 1965



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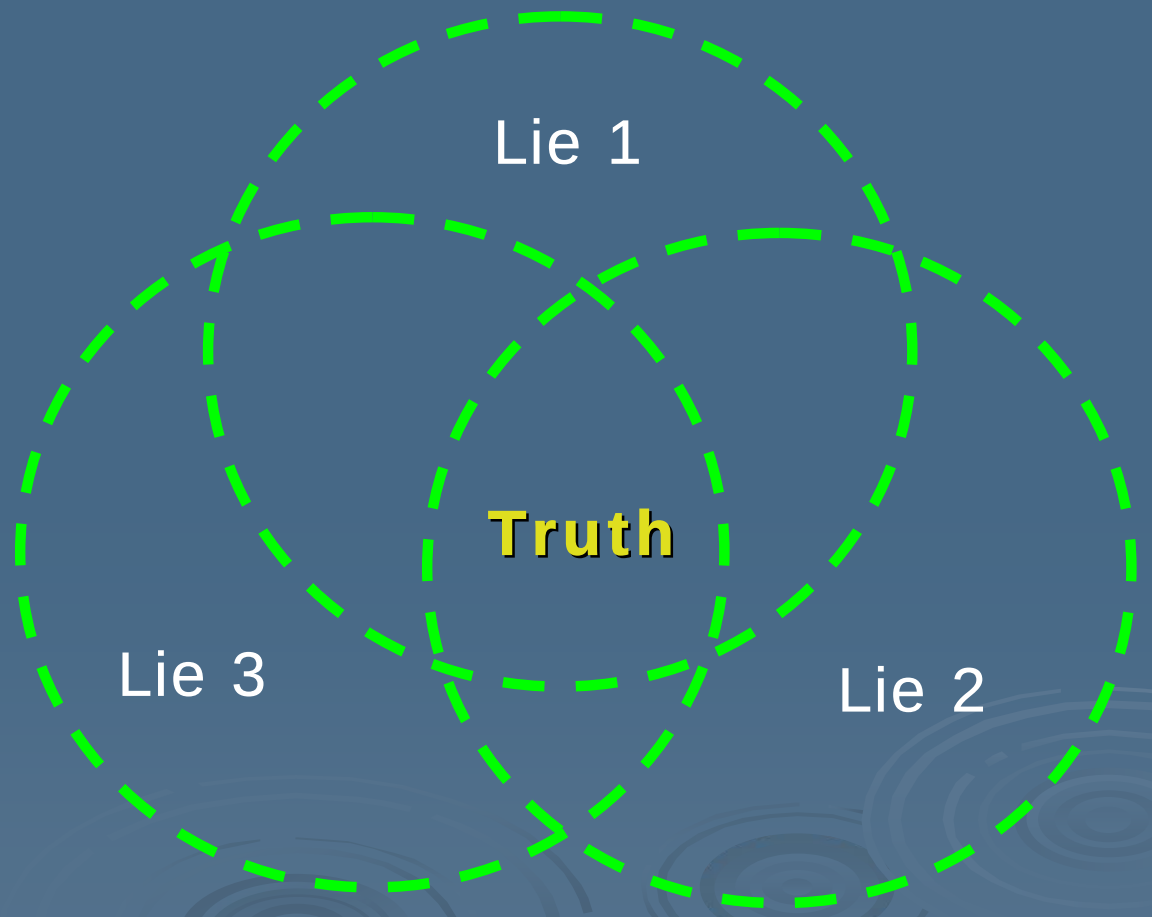
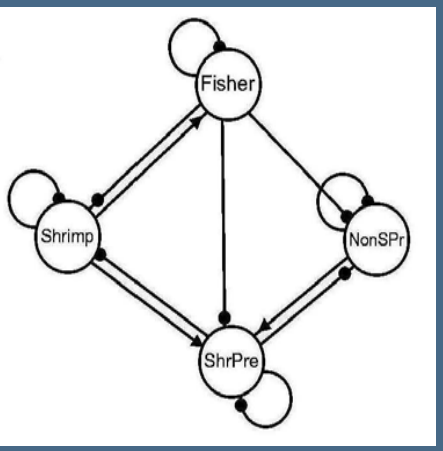
"…our truth is the intersection of independent lies."

Qualitative Models



Levins 1965

Community interaction matrix



$$A := \begin{bmatrix} -1 & 1 & 0 & 0 \\ -1 & -1 & 0 & -1 \\ -1 & 0 & -1 & -1 \\ -1 & 1 & 1 & -1 \end{bmatrix}$$

1: Fishery, 2: Shrimp, 3: Non-Shrimp Preds, 4: Shrimp Preds

Adjoint [-A] or prediction matrix

An interesting observation here is that the shrimp trawl fishery has little (0) effect on shrimp abundance

$$\begin{bmatrix} 3 & 2 & -1 & -1 \\ 0 & 2 & -1 & -1 \\ 0 & -1 & 2 & -1 \\ -3 & -1 & 2 & 2 \end{bmatrix}$$

--this is a point alluded to in the 1930s by Gordon Gunter--bycatch of demersal predators reduces natural mortality on shrimp

Total Mortality =

Fishing M ▲

+ Natural M ▼

1: Fishery, 2: Shrimp, 3: Non-Shrimp Preds, 4: Shrimp Preds

Adjoint [-A]

Positive 'presses' on Non-Shrimp & Shrimp Predators (i.e., Bycatch reduction)

$$\begin{bmatrix} 3 & 2 & -1 & -1 \\ 0 & 2 & -1 & -1 \\ 0 & -1 & 2 & -1 \\ -3 & -1 & 2 & 2 \end{bmatrix} \begin{matrix} =-2 \\ =-2 \\ =+1 \\ =+4 \end{matrix}$$

1: Fishery, 2: Shrimp, 3: Non-Shrimp Preds, 4: Shrimp Preds

Consequences of Bycatch Reduction

Positive presses on Non-Shrimp & Shrimp Predators

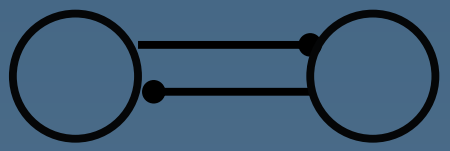
- Fishery -1 -1= -2
- Shrimp -1 -1= -2
- Non-shrimp predators 2 -1= 1
- Shrimp predators 2+2= 4

The Fishery and Shrimp populations suffer

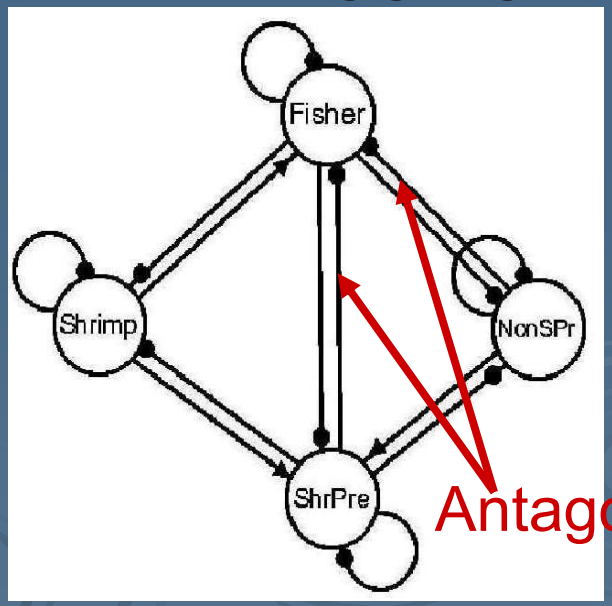
Non-Shrimp & Shrimp predators are enhanced

Second 4-node model includes handling of bycatch

- Placing a direct negative interaction on fishery due to handling of bycatch
- Bycatch is antagonistic to fishery in terms of cost of handling discards, net clogging, etc.



Adding antagonism results in interference between the bycatch and the fishery



Consequences of Bycatch Reduction

With Antagonism added to the 4-node model

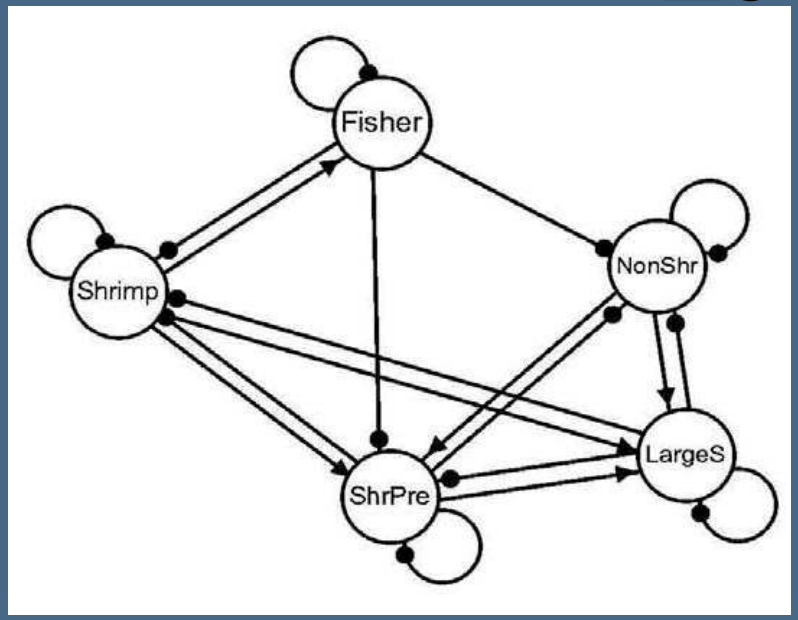
Positive presses on Non-Shrimp & Shrimp Predators

- Fishery -4 -1= -5 (-2)
- Shrimp 0+0= 0 (-2)
- Non-shrimp predators 0+0= 0 (1)
- Shrimp predators 4+1= 5 (4)

The Fishery suffers more, Shrimp and Non-shrimp predators are neutral

Shrimp predators are enhanced more

New 5- and 7-node models included Large Shrimp Predators, Algae, Benthos, and Zooplankton



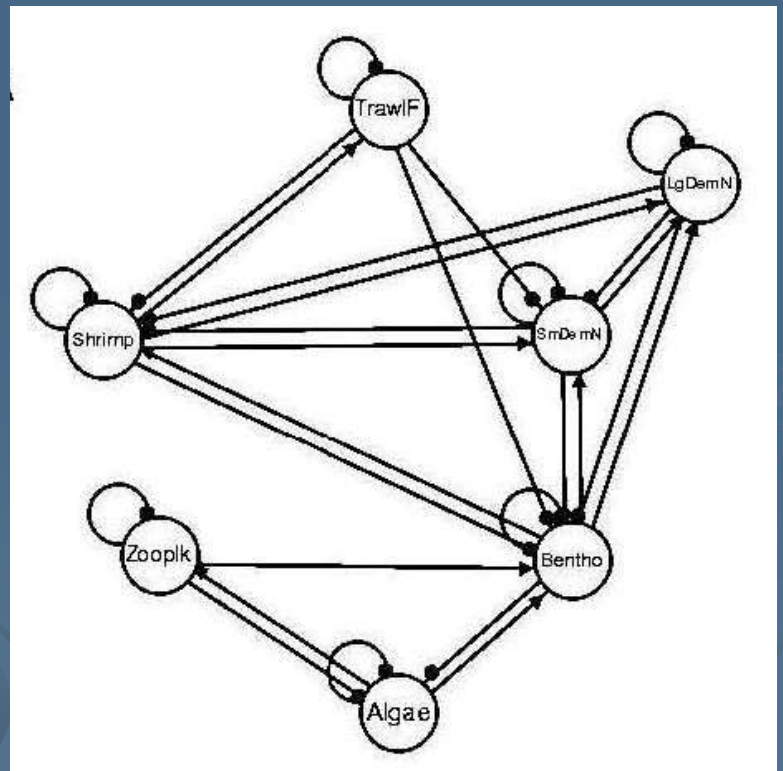
5-node models included Large Shrimp Predators

added as a guild, e.g., spotted seatrout, and 20 other species

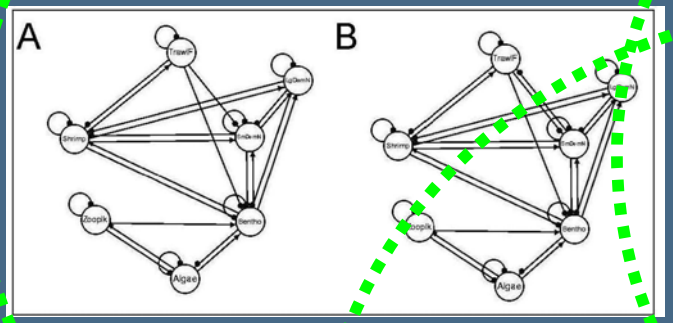
With and without antagonism

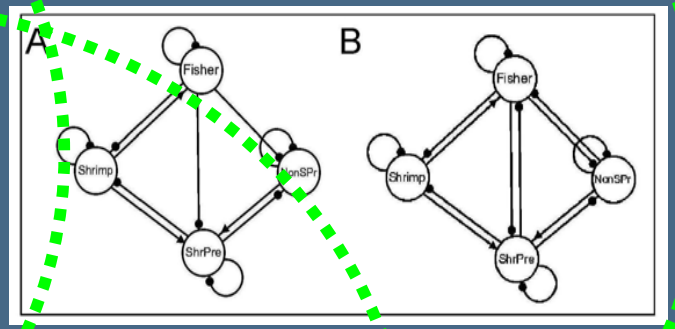
7-node models also included Algae, Benthos, and Zooplankton

With and without antagonism

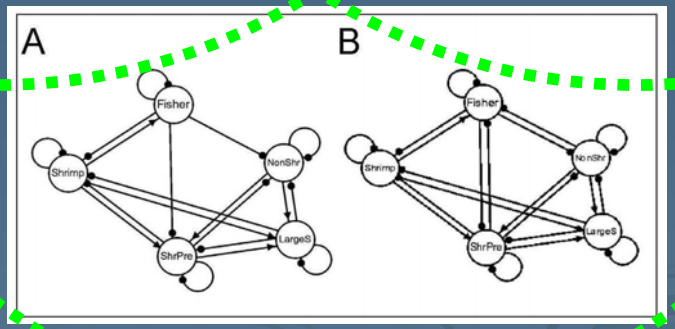


“…our truth is the intersection of independent lies.”





Truth



... the intersection of independent lies

- Fishery does influence small demersal nekton (i. e., bycatch mortality and effects of fishing)
- Fishery does not appear to influence shrimp numbers
- Reducing bycatch has a negative effect on fishery (landings) and maybe on shrimp abundance (unless antagonism is included)
- Reducing bycatch enhances the abundances of small and large shrimp predators and non-shrimp predators

Real Data

- We used real data from the National Marine Fisheries Service and the Louisiana Department of Wildlife and Fisheries to
  - examine relationships between the abundances and landings of shrimp and the abundances of ~ 50 other nekton species

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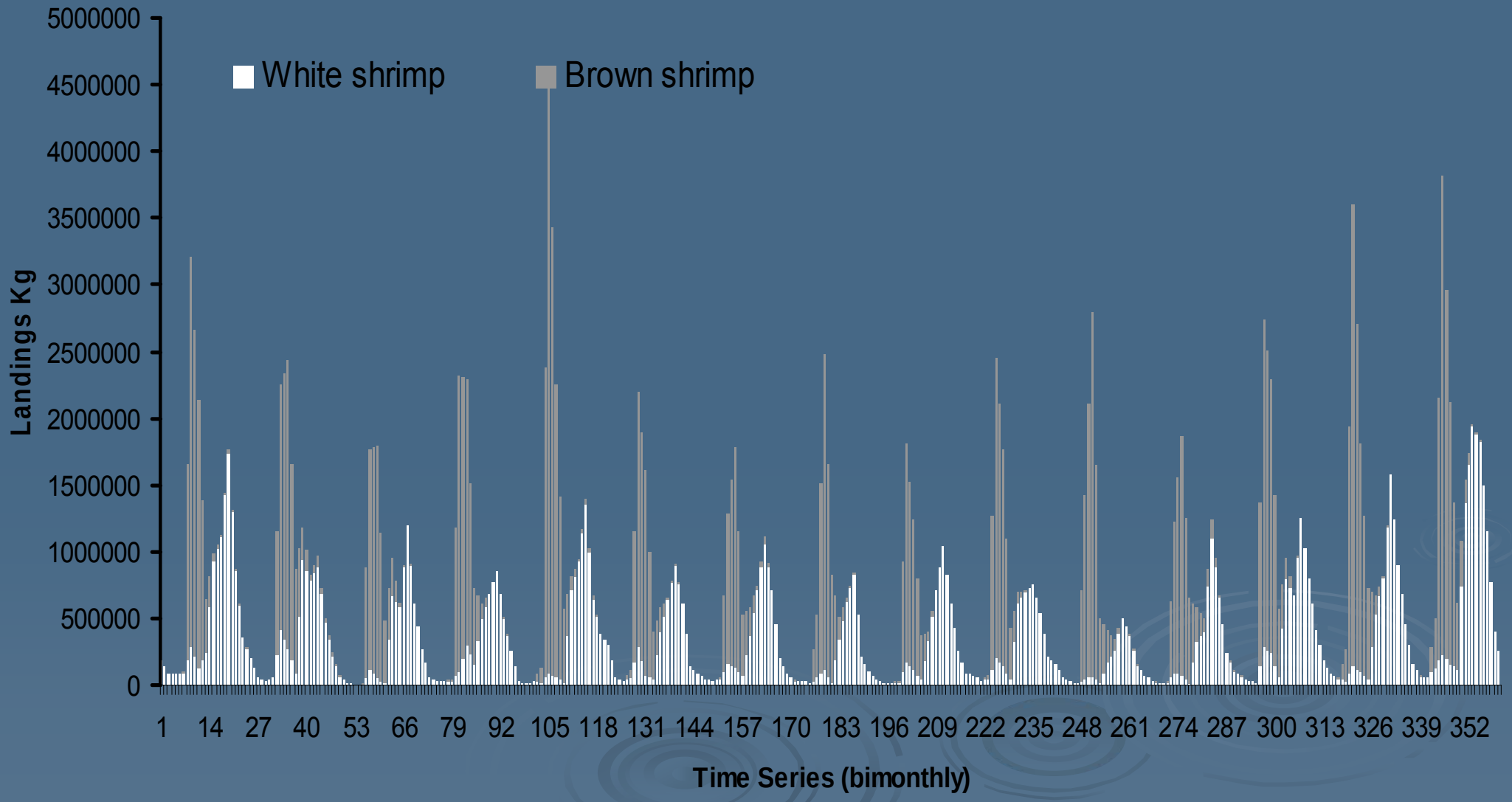
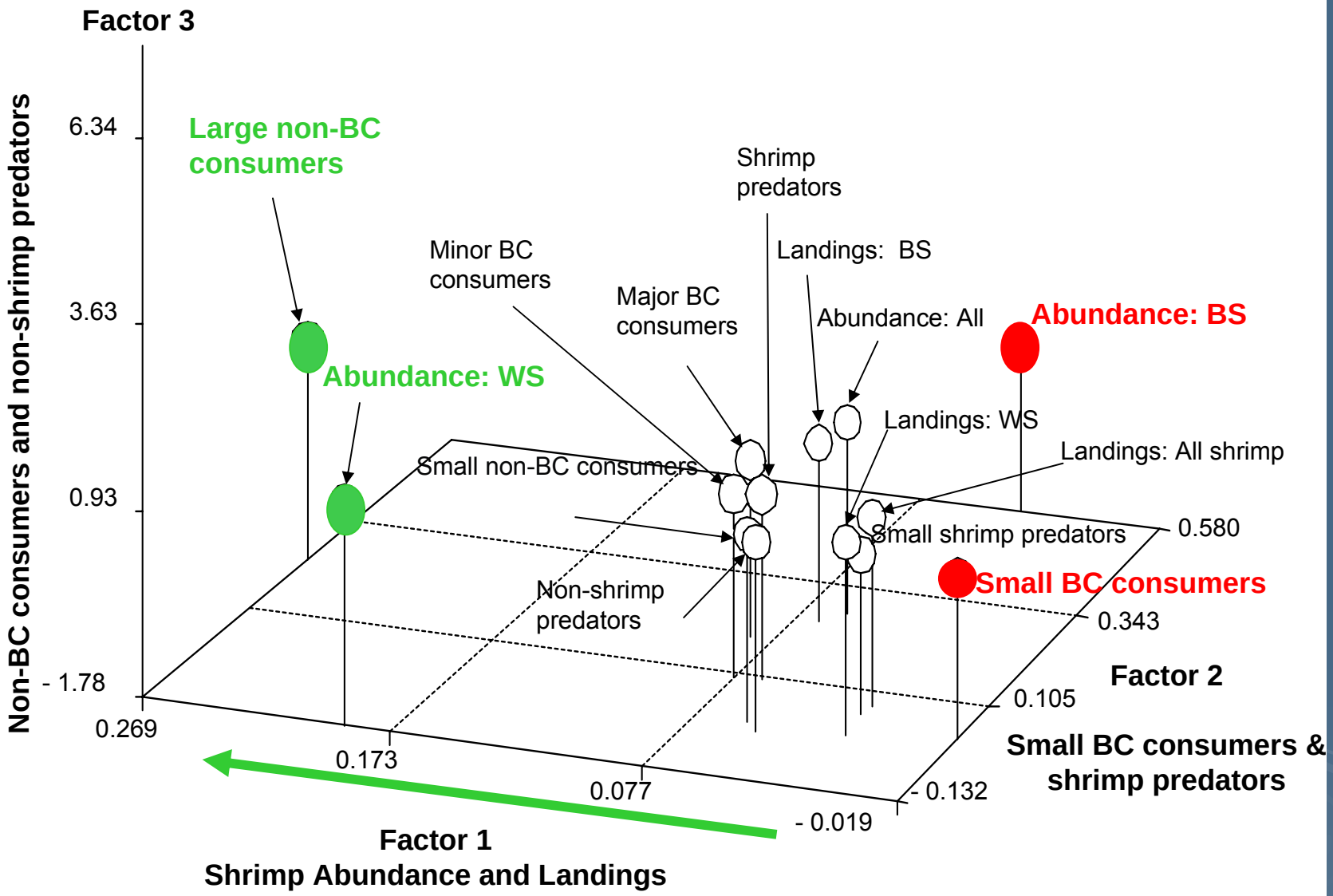
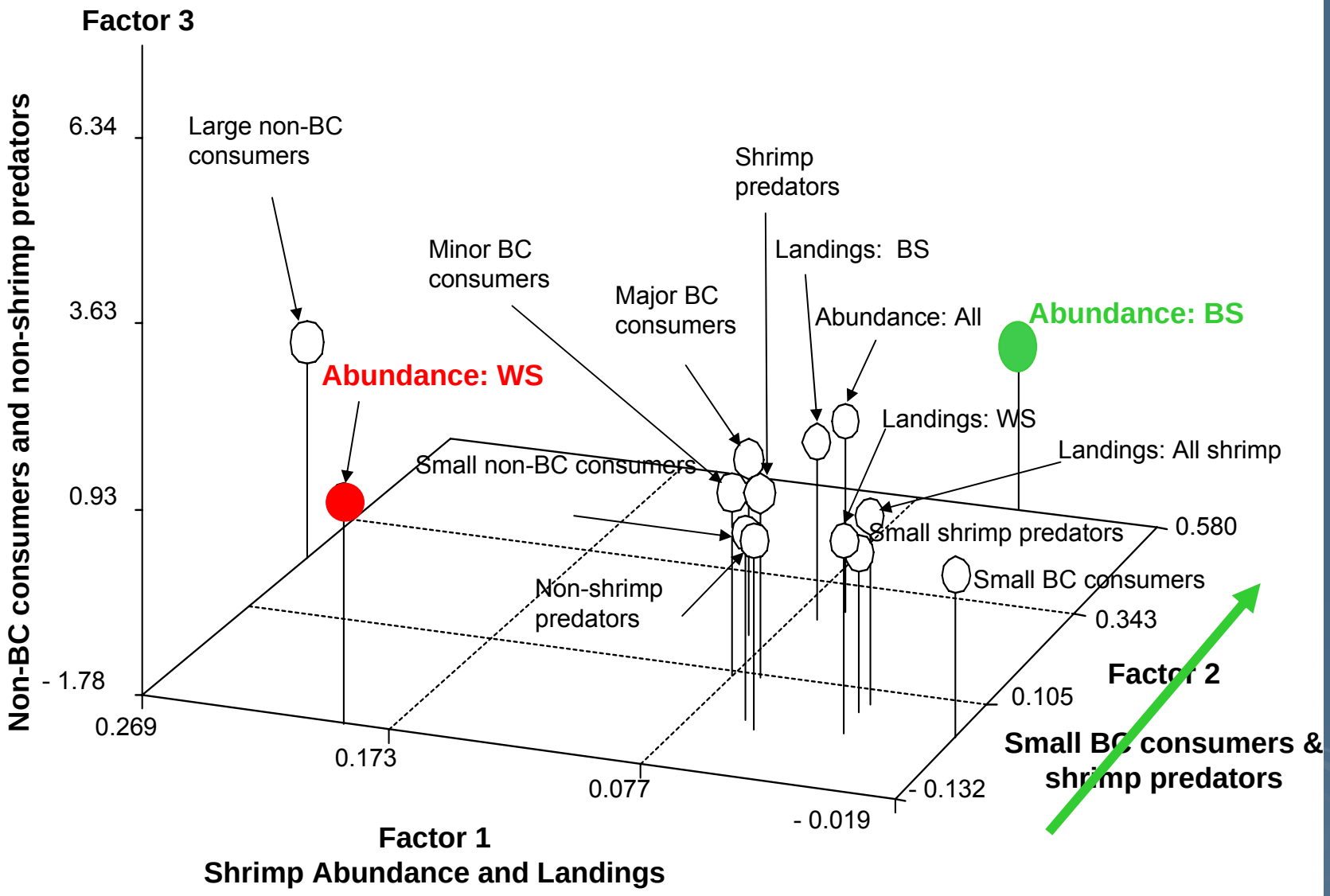
  - examine relationships between the abundances and landings of shrimp and the abundances of ~ 50 other nekton species
  - There are no long-term data sets on bycatch composition, fishery-independent data is proxy
- 15 years of bi-weekly data were analyzed as nekton functional groups in a Factor Analysis

Shrimp landings, central LA, NMFS data, 1986-2000




Factor 3
Non-BC consumers and non-shrimp predators
6.34
3.63
0.93
- 1.78
Large non-BC consumers
Abundance: WS
Minor BC consumers
Major BC consumers
Shrimp predators
Landings: BS
Abundance: All
Abundance: BS
Landings: WS
Landings: All shrimp
Small non-BC consumers
Small shrimp predators
Small BC consumers
Non-shrimp predators
0.580
0.343
0.105
- 0.132
Factor 2
Small BC consumers & shrimp predators
0.269
0.173
0.077
- 0.019
Factor 1
Shrimp Abundance and Landings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Conclusions

- Loop models corroborate previous quantitative analysis of changing community structure due to shrimping (Chesney et al. 2000)
  - ‘Effects of fishing’ may be responsible for some changes attributed to hypoxia
- An unexpected finding: Models support Gunter’s suggestion that reducing bycatch might hurt fishery landings and shrimp populations
  - Reduction in bycatch mortality may mask effects of hypoxia for some species
- Our quantitative (Factor) analysis of coastal Louisiana shrimp landings and nekton abundance data at least partially corroborates the qualitative Loop analyses
  - We see similar shifts in some functional groups
- There are lots of good reasons to reduce bycatch, but we should be aware of the consequences, and we should not leap to conclusions about the causes of changes in coastal ecosystems
  - Nevertheless, ‘the effects of fishing’ are almost always first and foremost in terms of anthropogenic stressors
- Utility of Loop analyses - they can reveal unexpected relationships,
  - but they are also useful in that they rely on natural history information rather than mounds of data (which are often unavailable)

Acknowledgments

- NOAA's Coastal Ocean Program for funding
- NMFS and LDWF for access to real data
- Oregon State University's LOOP Group for developing the freeware