Asymmetric Eigenvector Mapping Applications to Account for Temporal Variability in Fishery Resources and Recruitment Deviations

Presented to:
Gulf of Mexico Fisheries Management Council's Science and Statistical Committee(s)

Presented by:
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University of South Florida, College of Marine Science

Thursday, March 9, 2023

Scope and Objectives

- Investigate temporal variability in stocks' recruitment deviations in the Gulf of Mexico large marine ecosystem
- Explicitly account for temporal autocorrelation
- Relate recruitment variability to ecological considerations
  - Focus on *Sargassum* macroalgae as habitat
  - Focus on Ecosystem Status Report (ESR) indicators for the region
- Describe and interpret the ecosystem trajectory for the Gulf's complex adaptive fishery ecosystem (Gulf CAFE)
- Discuss potential impacts to decision making/assessment

Redundancy Analysis (RDA)

Mechanics of RDA

RESPONSE INDICATORS

Y

Living Marine Resource Structure and Function

Things we care about

Mechanics of RDA

PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

Hypothesized to affect things we care about

RESPONSE INDICATORS

Y

Living Marine Resource Structure and Function

Things we care about

Mechanics of RDA

PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

Effect ?

ONE WAY

RESPONSE INDICATORS

Y

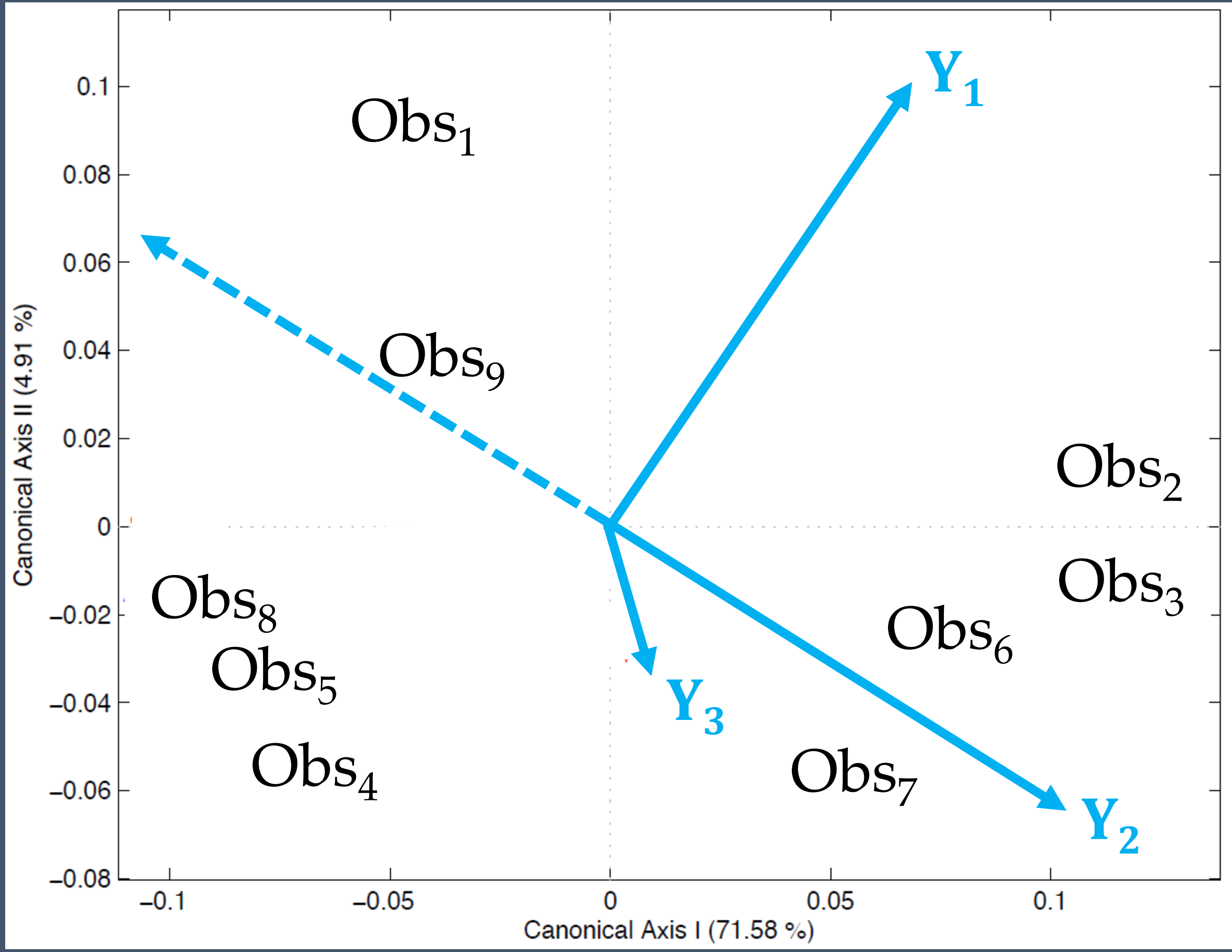
Living Marine Resource Structure and Function

Hypothesized to affect things we care about

Things we care about

What is Redundancy Analysis (RDA)?

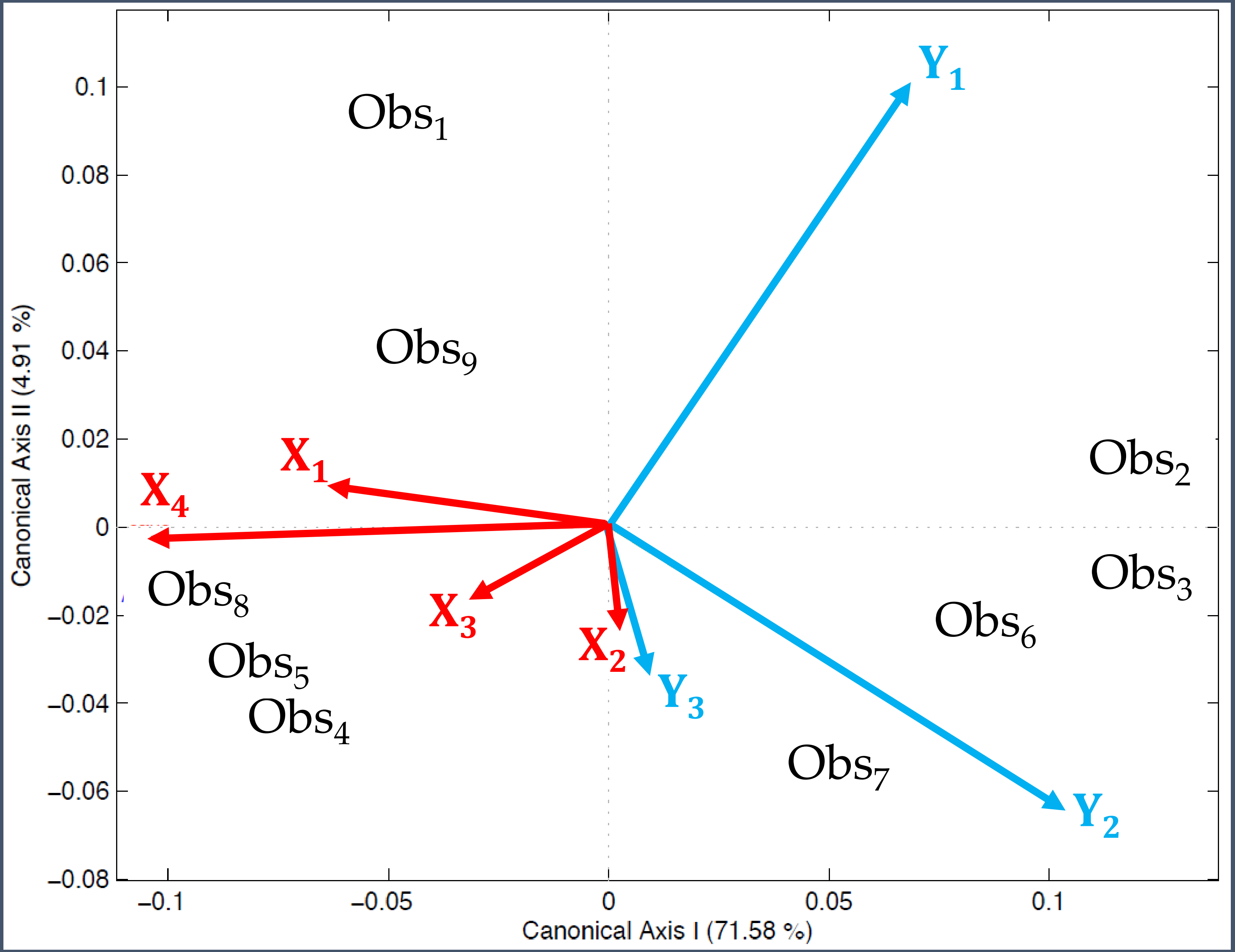
- A form of constrained Principal Components Analysis (PCA)



PCA

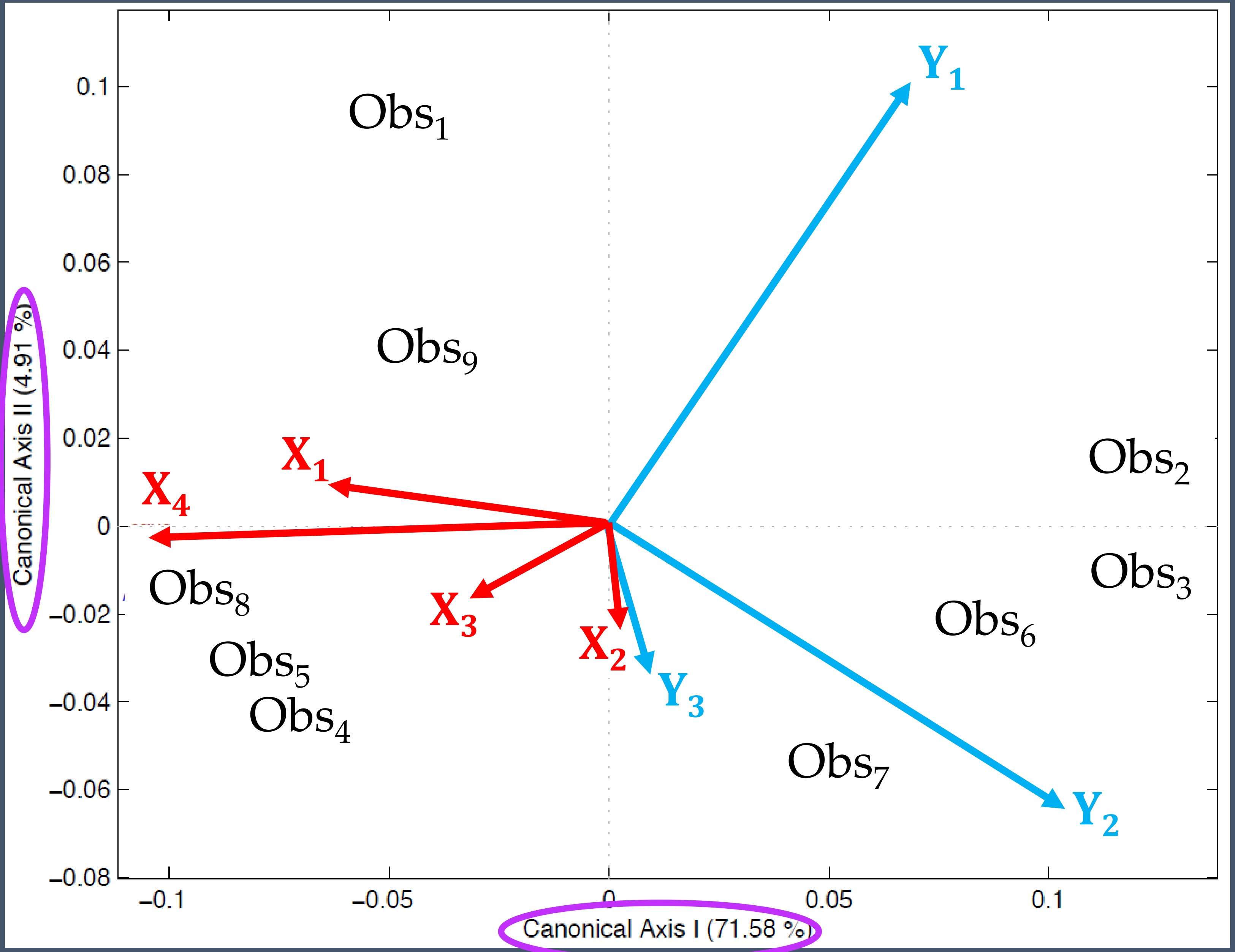
- Axes are orthogonal
- Axes are linear combinations of **Y**

RDA Distance TriPlot



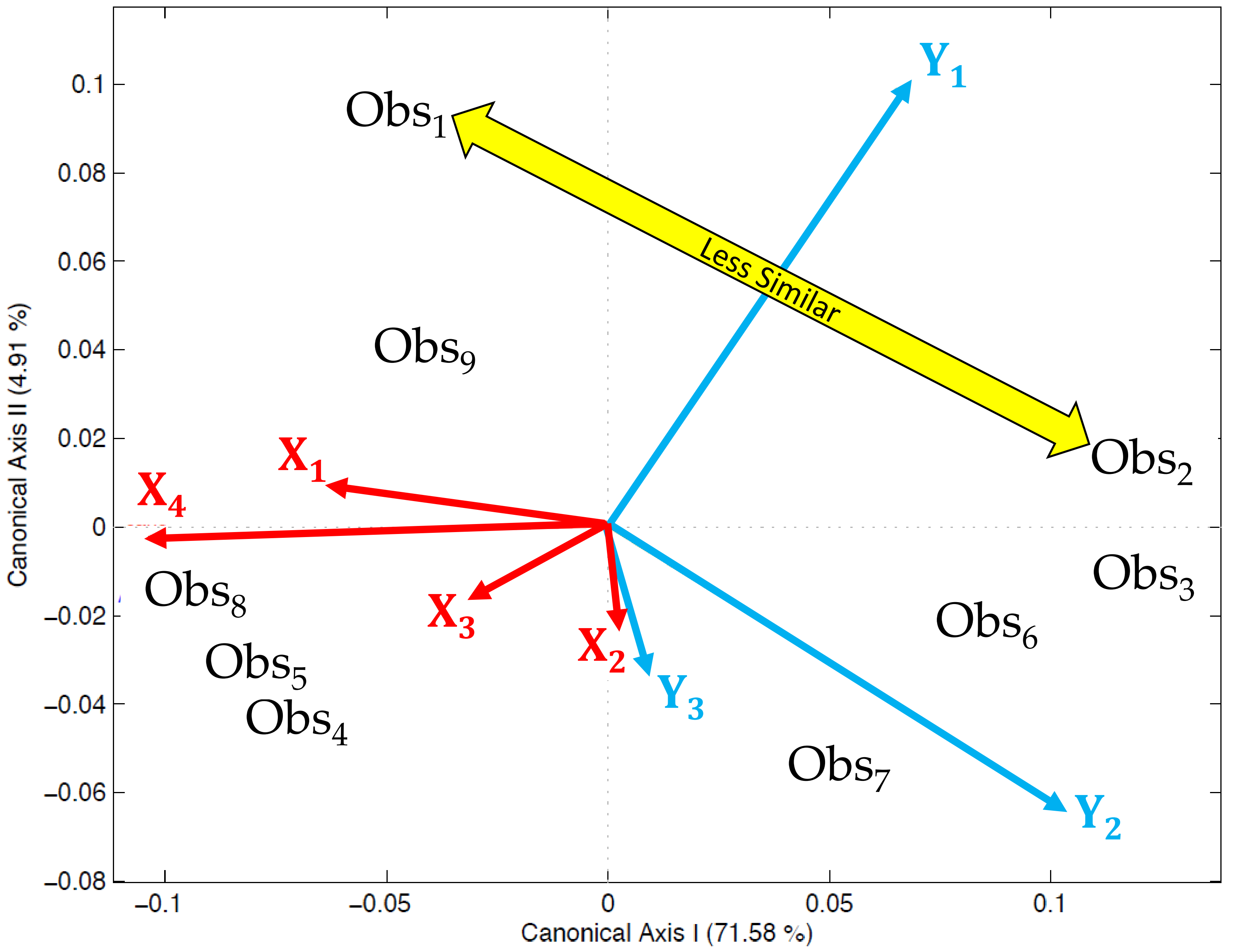
- Summarize multivariate relationships between **Y** & **X**

RDA Distance TriPlot



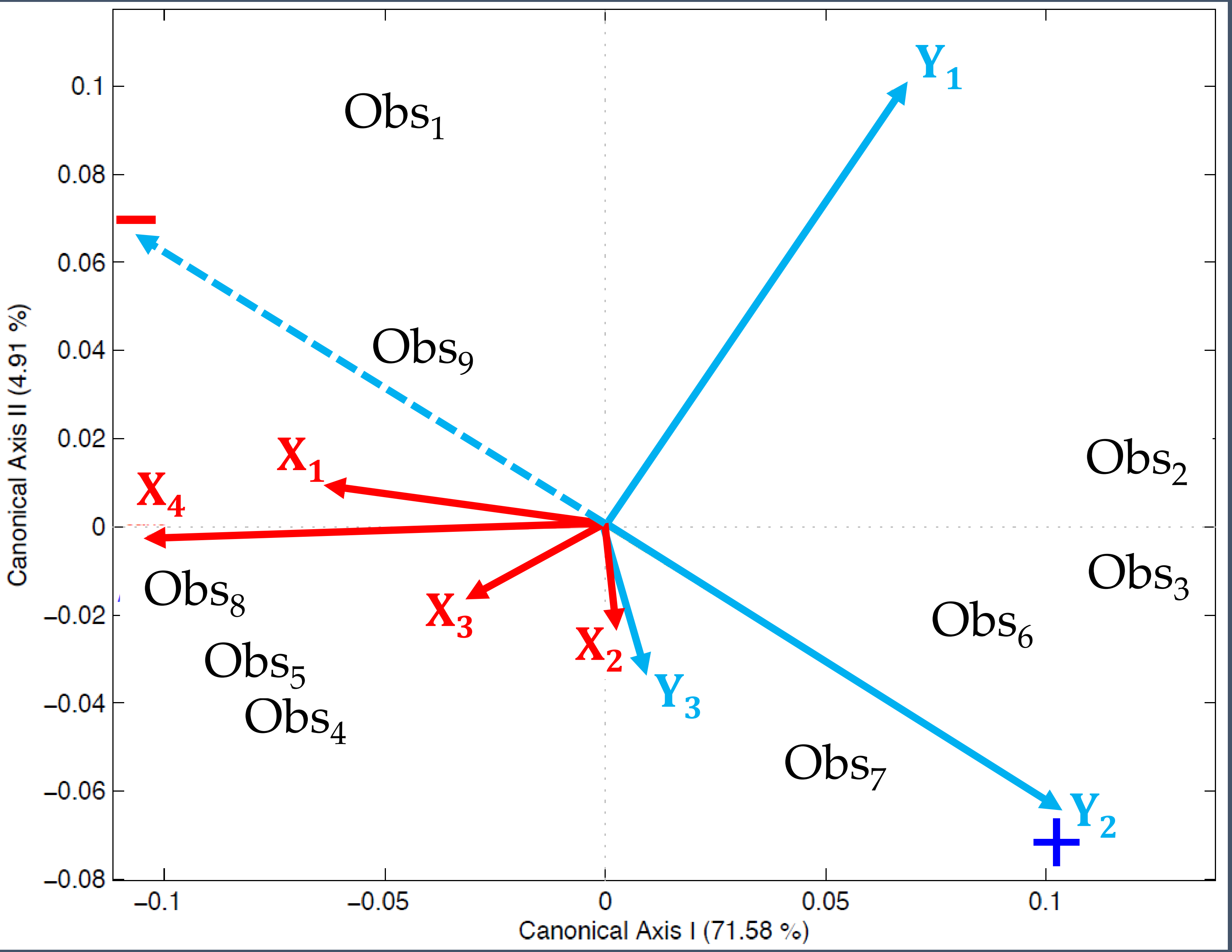
- Summarize multivariate relationships between **Y** & **X**
- Canonical axes sorted according to increasing percent variability explained

RDA Distance TriPlot



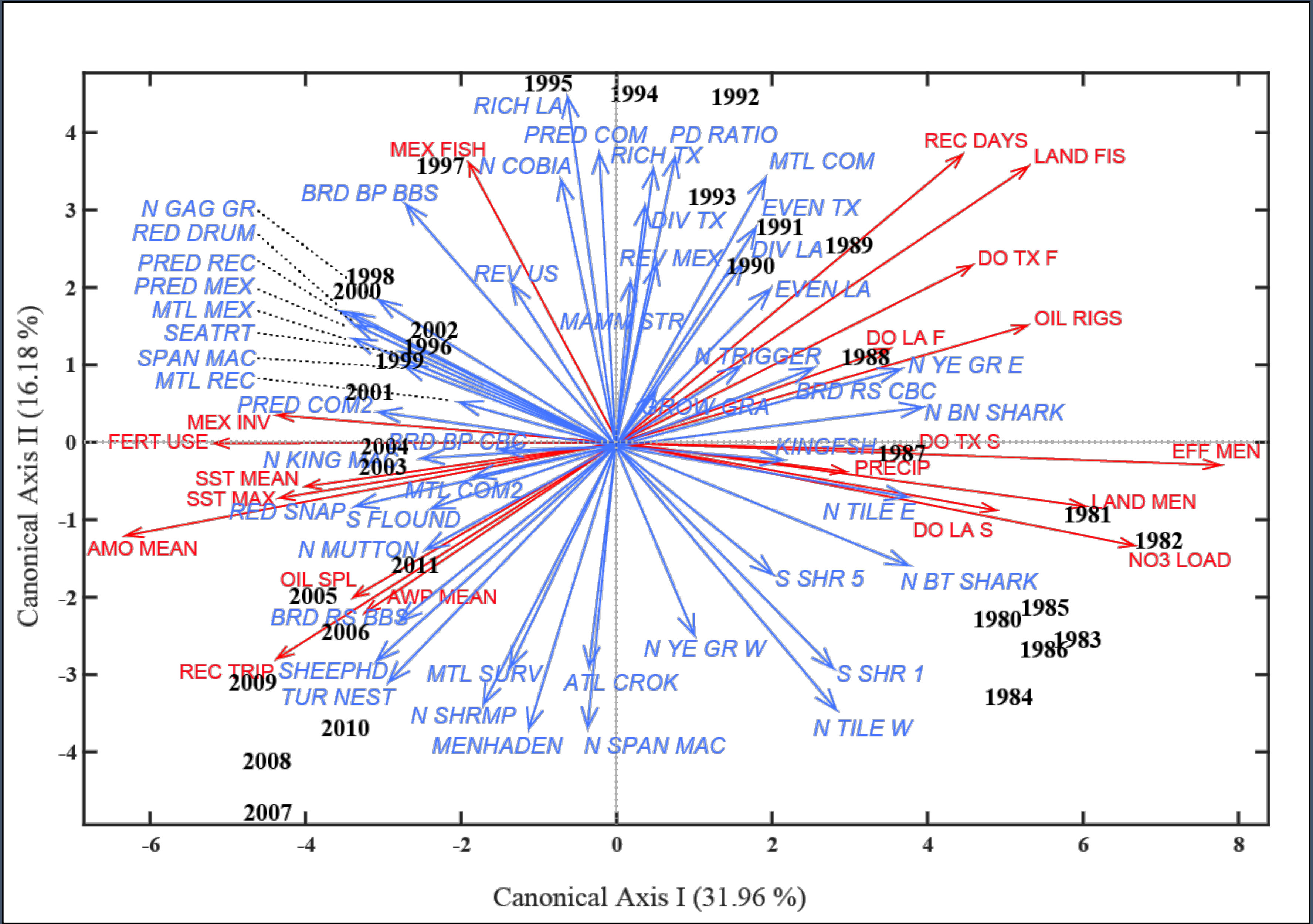
- Summarize multivariate relationships between **Y** & **X**
- Canonical axes sorted according to increasing percent variability explained
- Cartesian distances among objects is proportional to the underlying resemblance

RDA Distance TriPlot



- Summarize multivariate relationships between **Y** & **X**
- Canonical axes sorted according to increasing percent variability explained
- Cartesian distances among objects is proportional to the underlying resemblance
- Vector Heading: Direction indicator gradient increases

EL-MIST for the Gulf CAFE



F = 3.780
R^2 = 0.991
R^2_{adj} = 0.729
p-value = 0.003

Asymmetric Eigenvector Mapping (AEM)

Mechanics of RDA

PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

Effect ?

RESPONSE INDICATORS

Y

Living Marine Resource Structure and Function

Hypothesized to affect things we care about

Things we care about

Mechanics of RDA

PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

TIME

RESPONSE INDICATORS

Y

Living Marine Resource Structure and Function

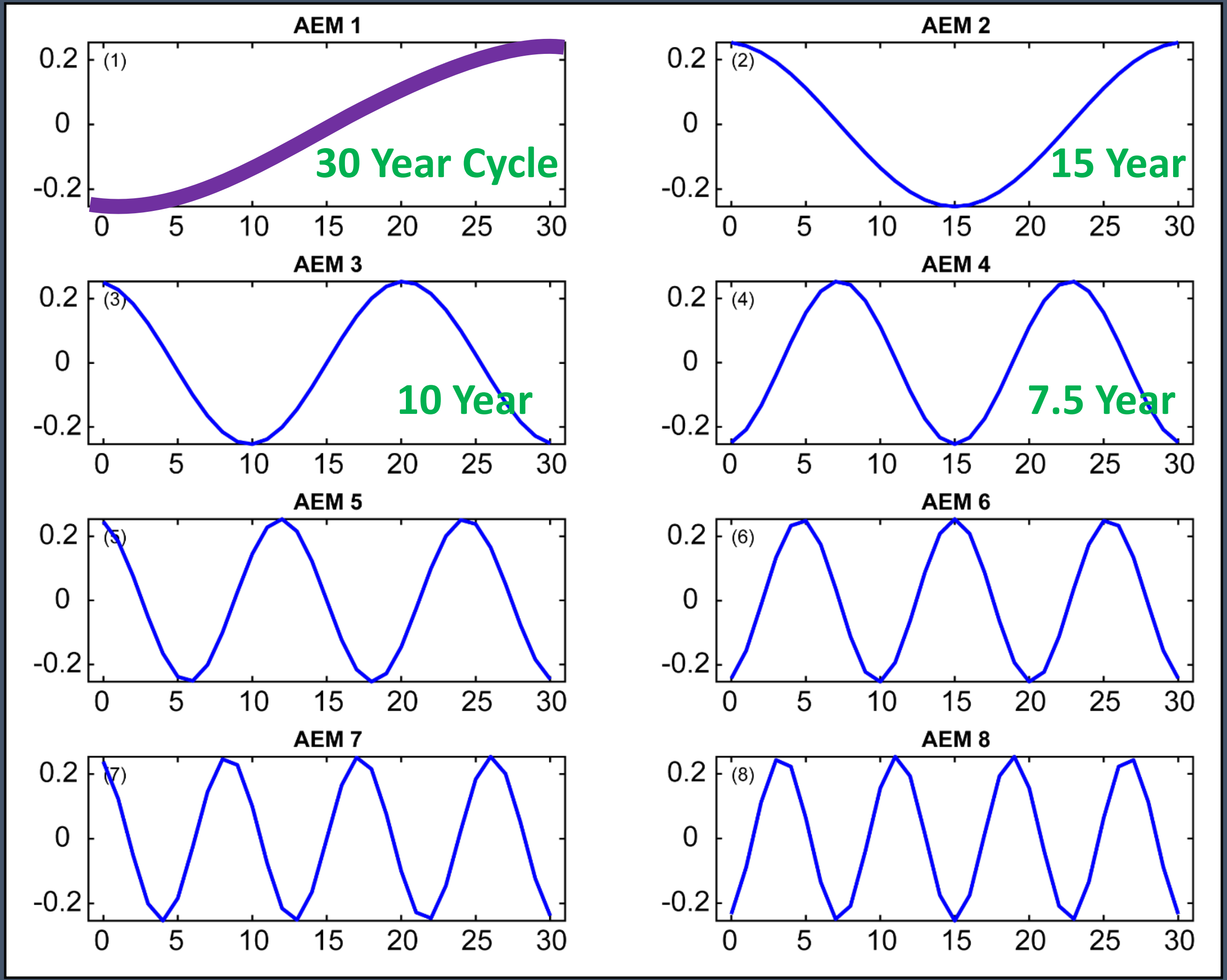
Hypothesized to affect things we care about

Things we care about

Modeling Time with AEMs

TEMPORAL INDICATORS

AEMs



Temporal structure in sampling universe

AEM$^+$ Optimal Model Selection

RESPONSE INDICATORS

Y

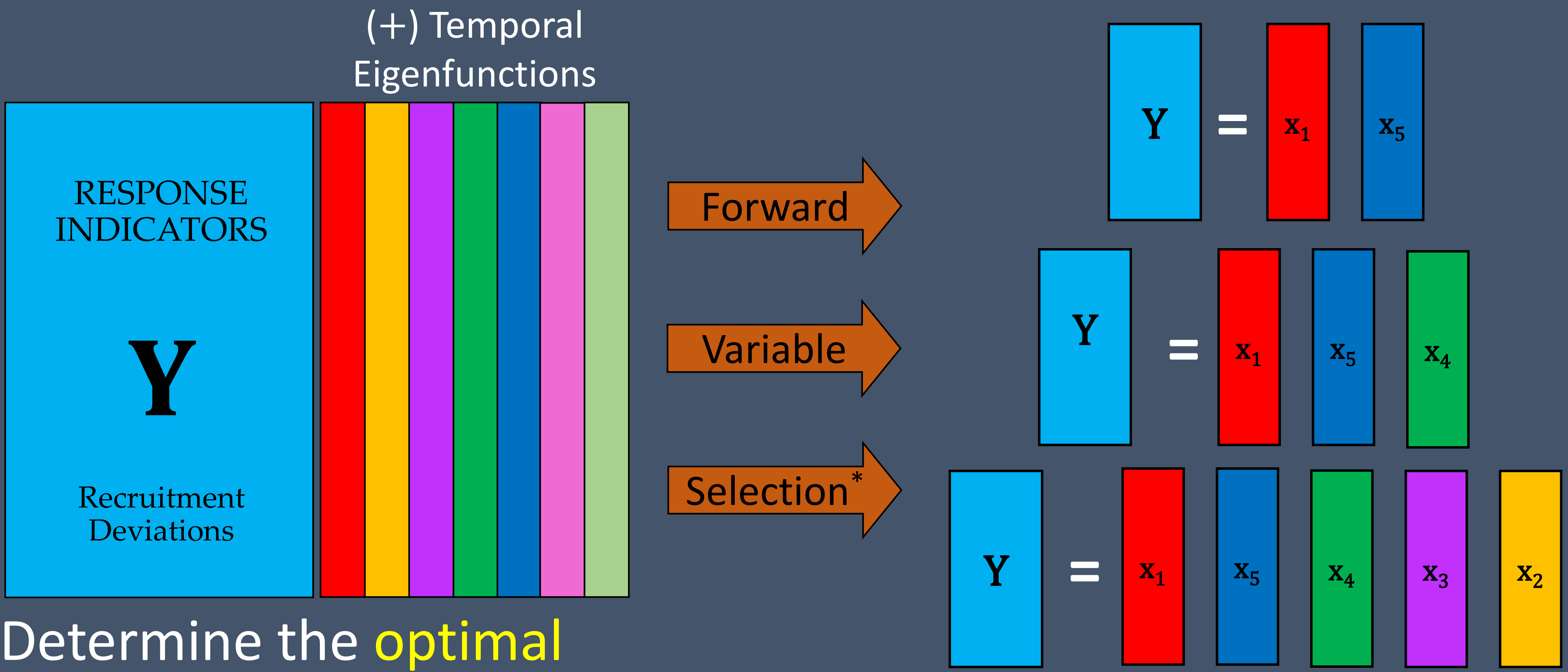
Recruitment Deviations

TEMPORAL INDICATORS

AEMs

Determine the optimal AEM$^+$ model for deviations

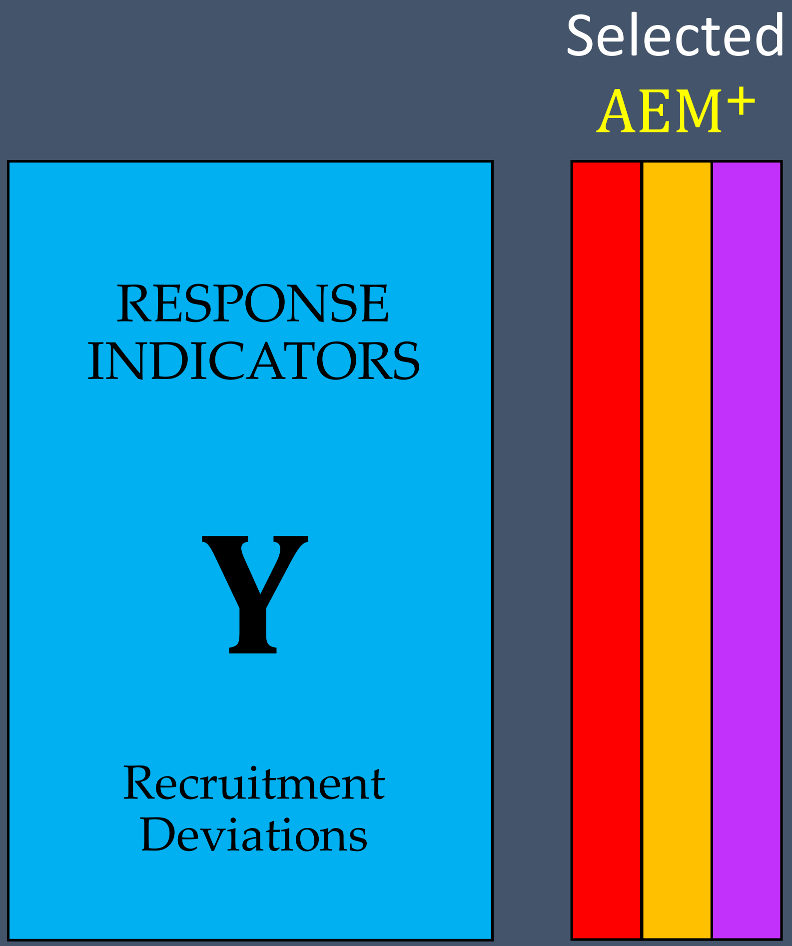
AEM+ Optimal Model Selection



Determine the optimal AEM+ model for deviations

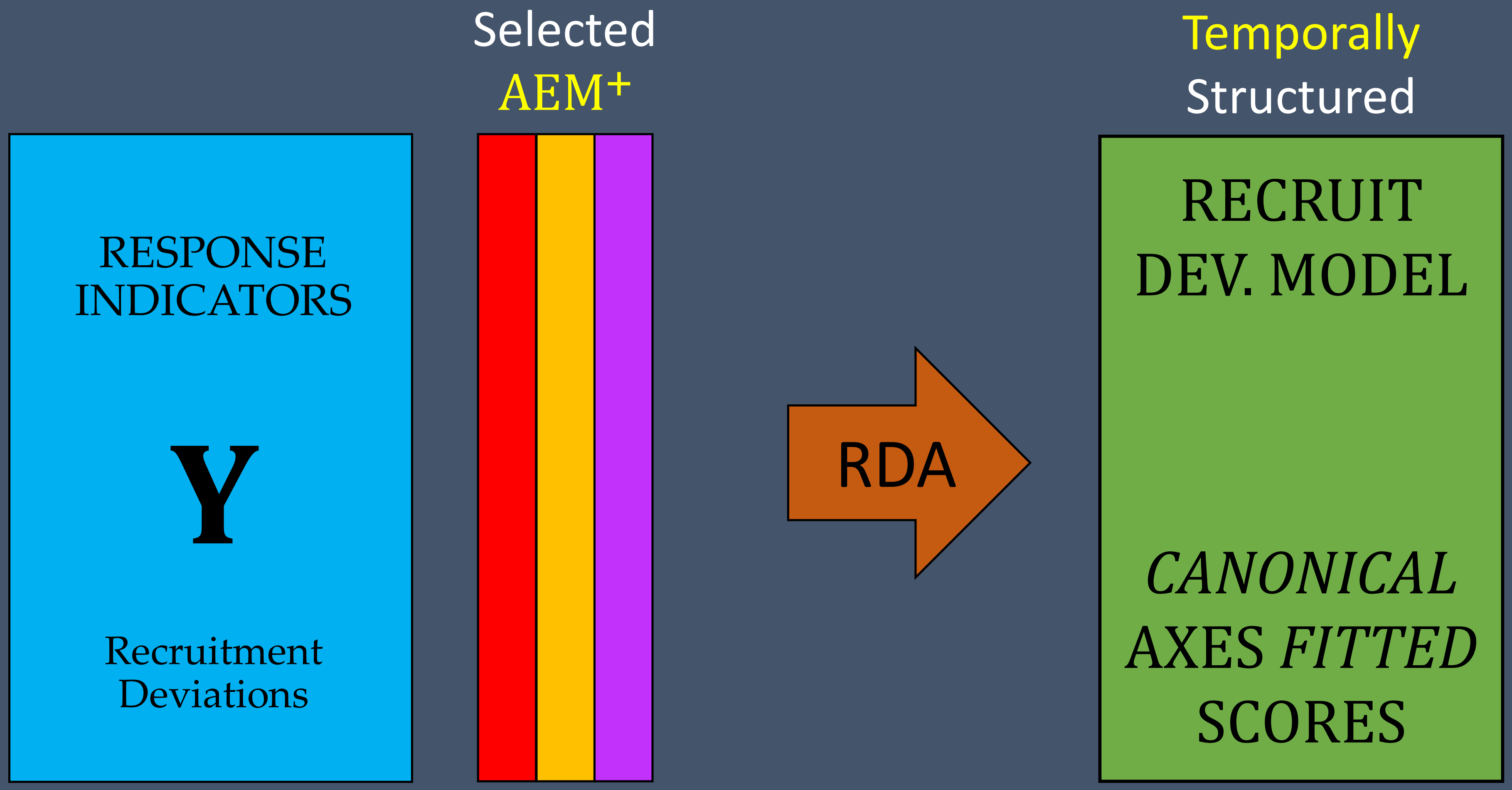
*Using the method of Blanchet, Legendre, and Borcard (2008)

AEM$^+$ Constrained Analysis



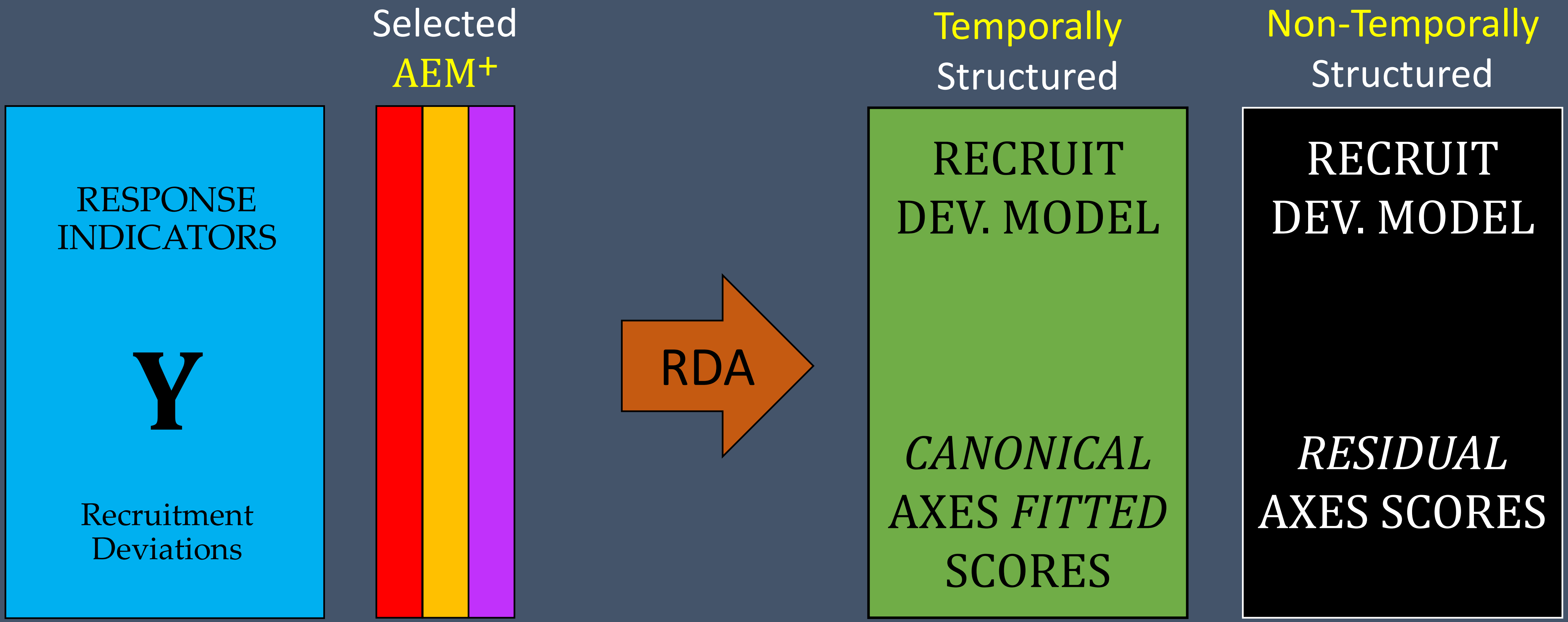
Create the final temporal model for devs. using selected AEM$^+$

AEM$^+$ Constrained Analysis



Create the final temporal model for devs. using selected AEM$^+$

AEM$^+$ Constrained Analysis



Create the final temporal model for devs. using selected AEM$^+$

AEM Constrained Analysis #2 (continued…)

Rec. Dev. MODEL

Fitted Axes

Temporally Structured Biological Response

Temporally Structured Ecological Forcing Models (*Temporal Autocorrelation*)

PREDICTOR MODELS

X

Climate, Habitat, Sargassum, Ecological

Stepwise Variable Selection with Akaike's Information Criterion (AIC)

$$AIC = n * \log_e\left(\frac{SS_{residuals}}{n}\right) + 2K$$

Rec. Dev. MODEL

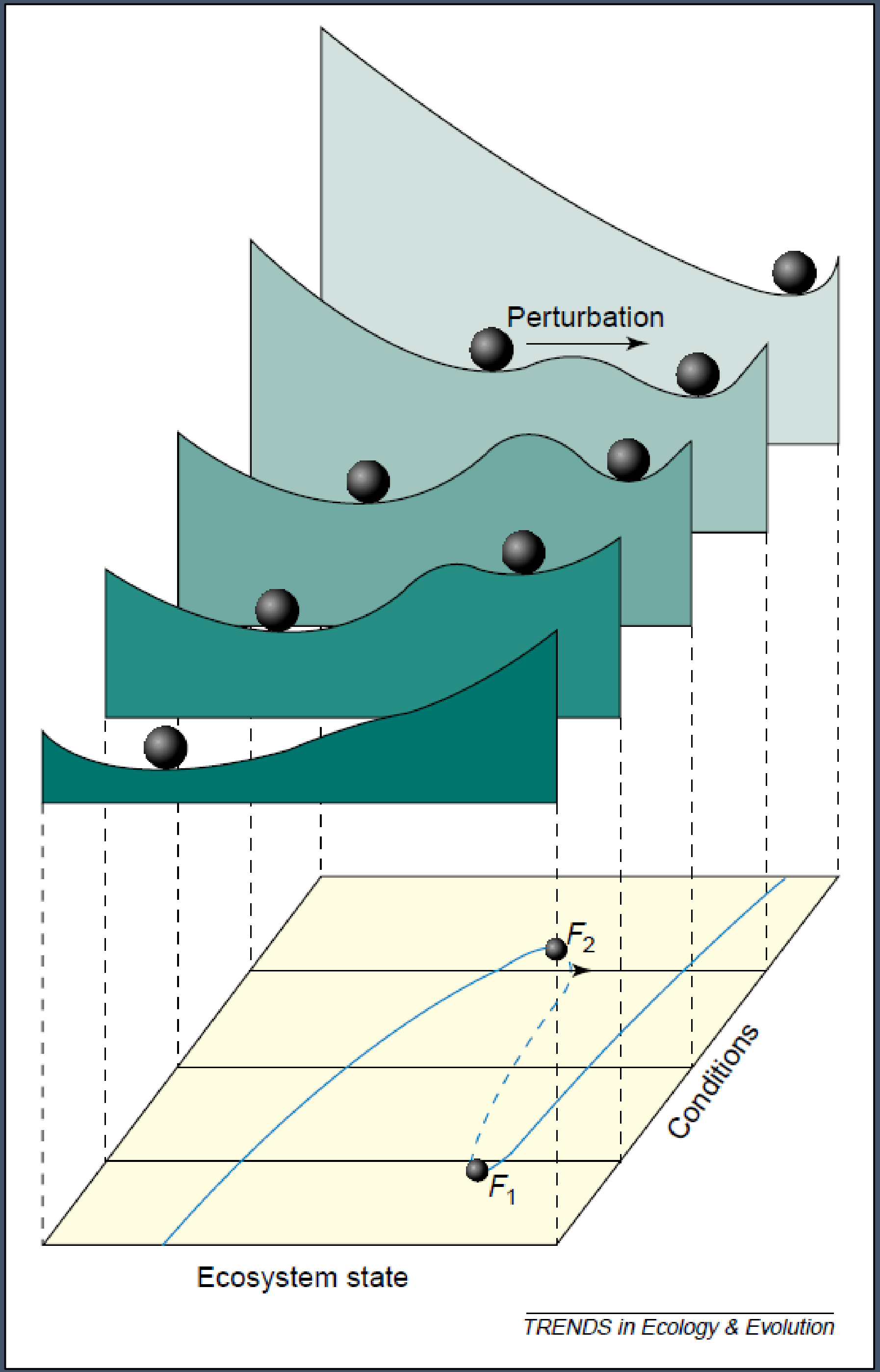
Residual Axes

Non-Temporally Structured Biological Response

Non-Temporally Structured Ecological Forcing Models

Ecosystem Trajectories

Ball and Cup Analogy



- Green surface = System conditions
- Ball = System response
- Location on surface = System state

648 Review TRENDS in Ecology and Evolution Vol.18 No.12 December 2003

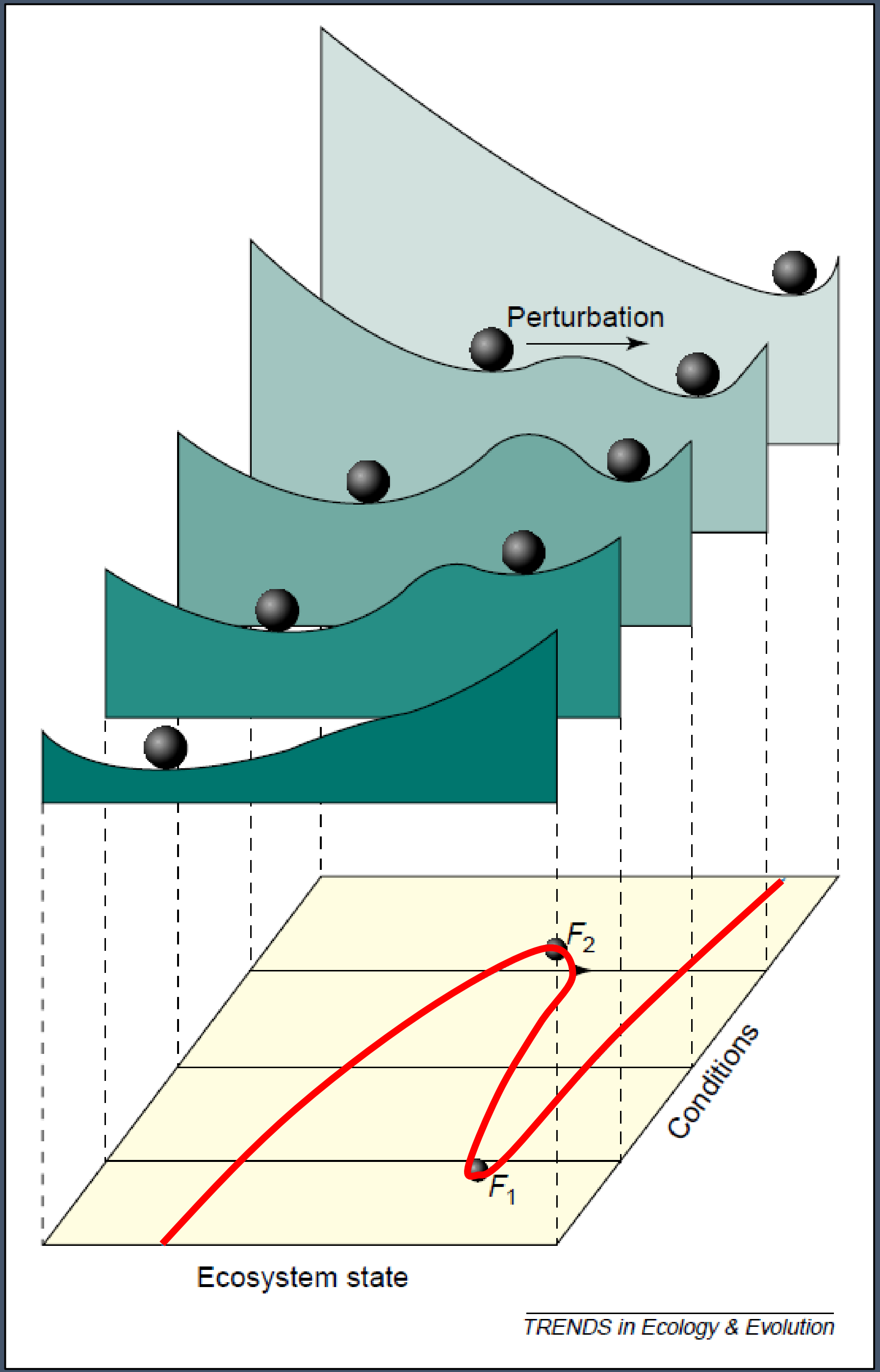
ELSEVIER

Catastrophic regime shifts in ecosystems: linking theory to observation

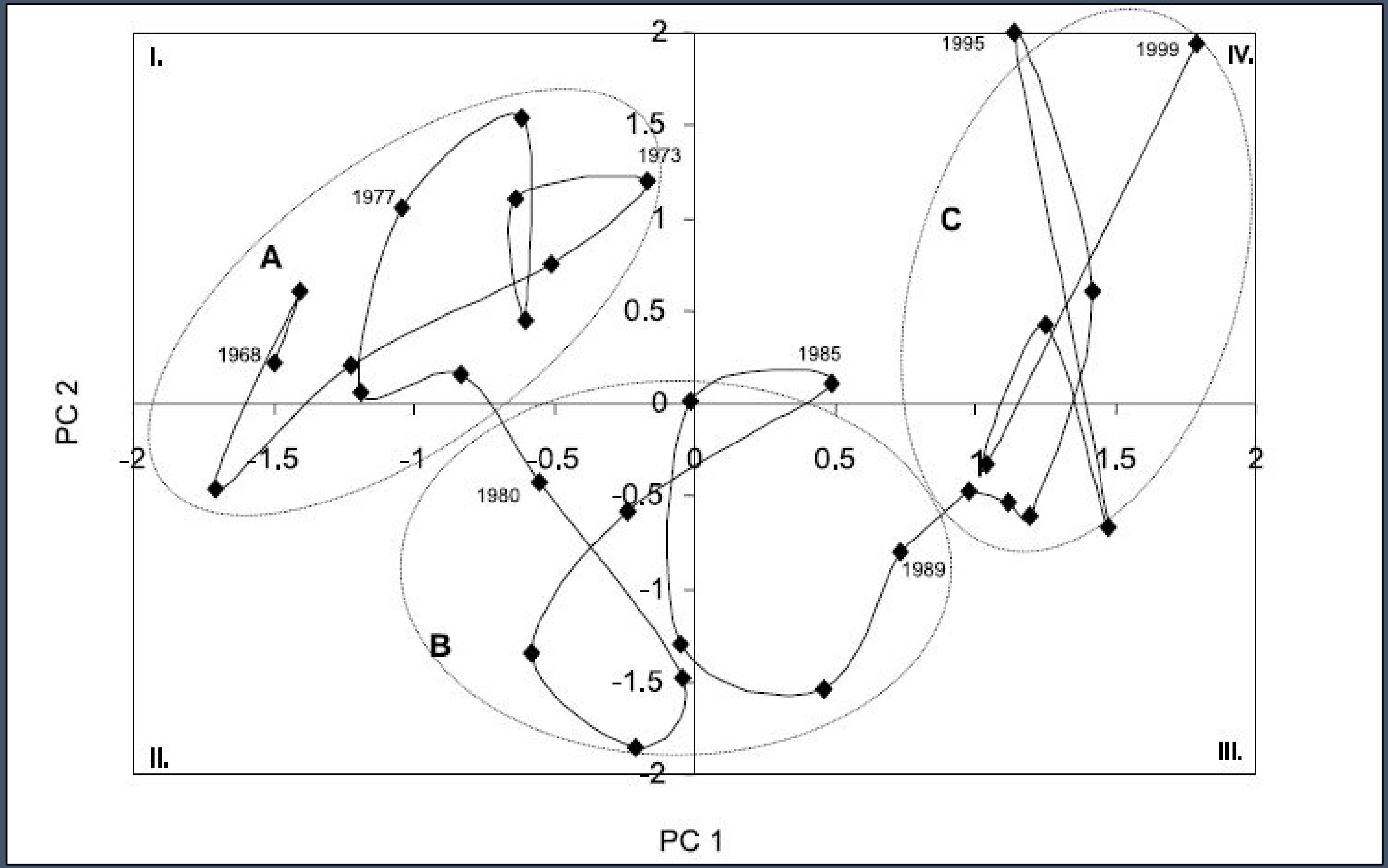
Marten Scheffer[1] and Stephen R. Carpenter[2]

[1]Department of Aquatic Ecology and Water Quality Management, Wageningen University, PO Box 8080, 6700 DD Wageningen, The Netherlands

[2]Center for Limnology, University of Wisconsin, 680 North Park Street, Madison, WI 53706, USA



Ecosystem Trajectories



Marine ecosystem assessment in a fisheries management context

Jason S. Link, Jon K.T. Brodziak, Steve F. Edwards, William J. Overholtz, David Mountain, Jack W. Jossi, Tim D. Smith, and Michael J. Fogarty

Linking the ball-and-cup analogy and ordination trajectories to describe ecosystem stability, resistance, and resilience

KARL A. LAMOTHE,[1,2,†] KEITH M. SOMERS,[1] AND DONALD A. JACKSON[1]

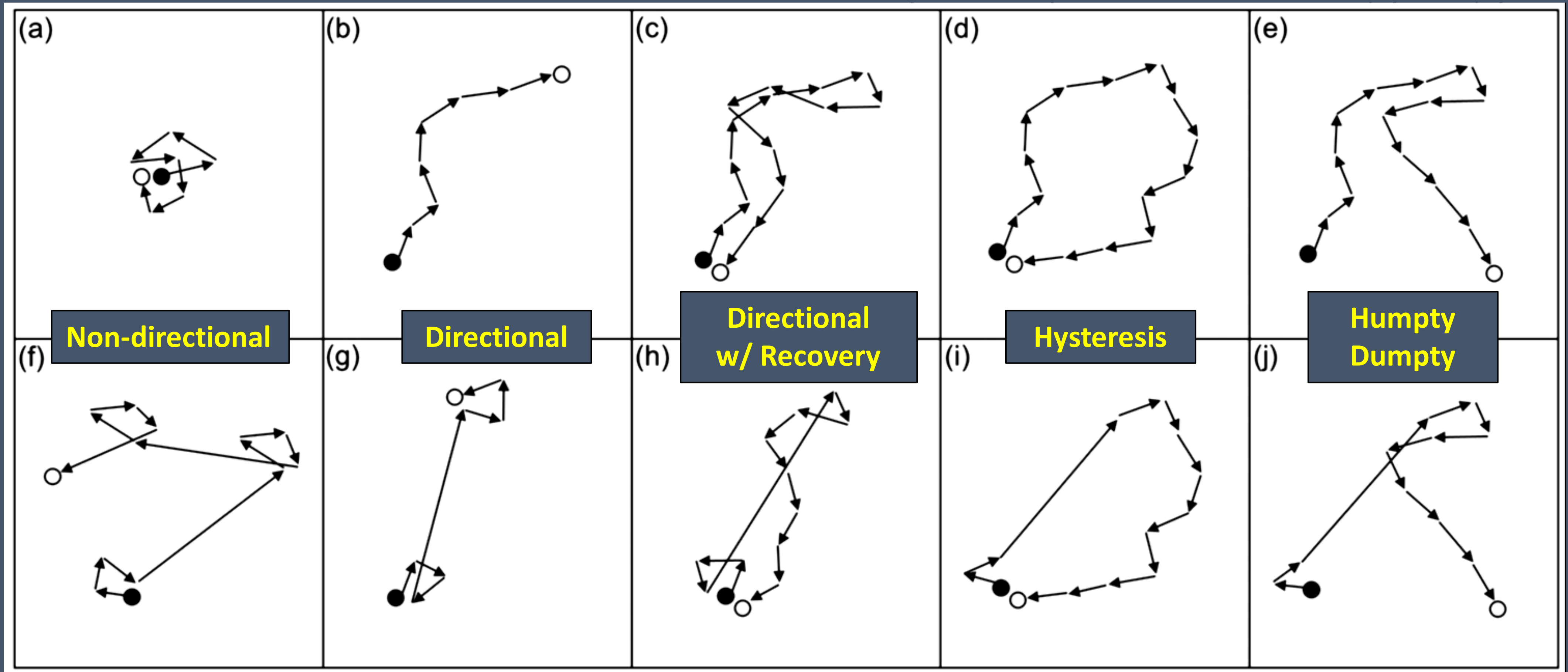
[1]Department of Ecology and Evolutionary Biology, University of Toronto, 25 Willcocks Street, Toronto, Ontario M5S 3B2 Canada

Citation: Lamothe, K. A., K. M. Somers, and D. A. Jackson. 2019. Linking the ball-and-cup analogy and ordination trajectories to describe ecosystem stability, resistance, and resilience. Ecosphere 10(3):e02629. 10.1002/ecs2.2629

Ecosystem Trajectories

Gradual

Rapid



Data Sources

&

Model Parameterizations

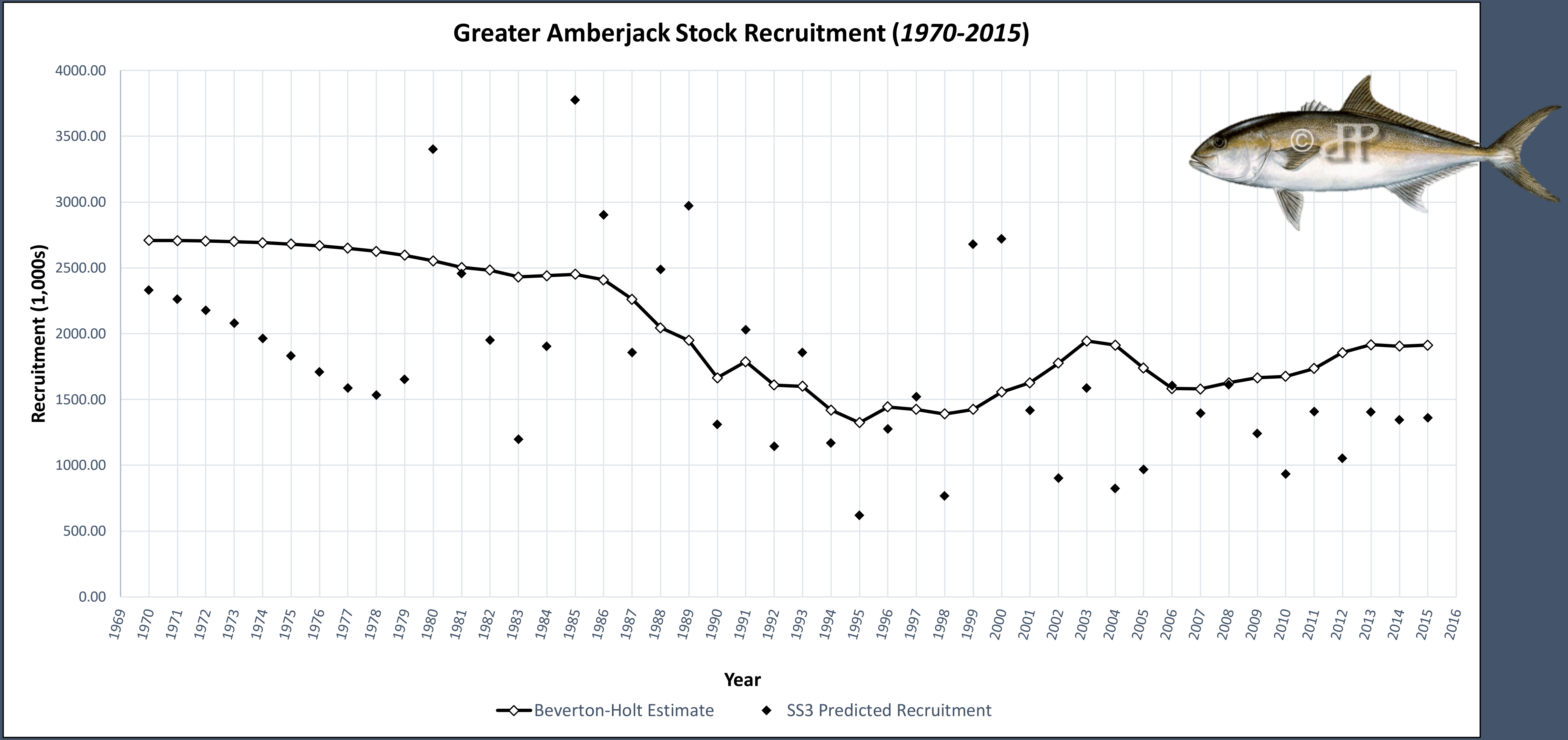
RESPONSE INDICATORS

Y

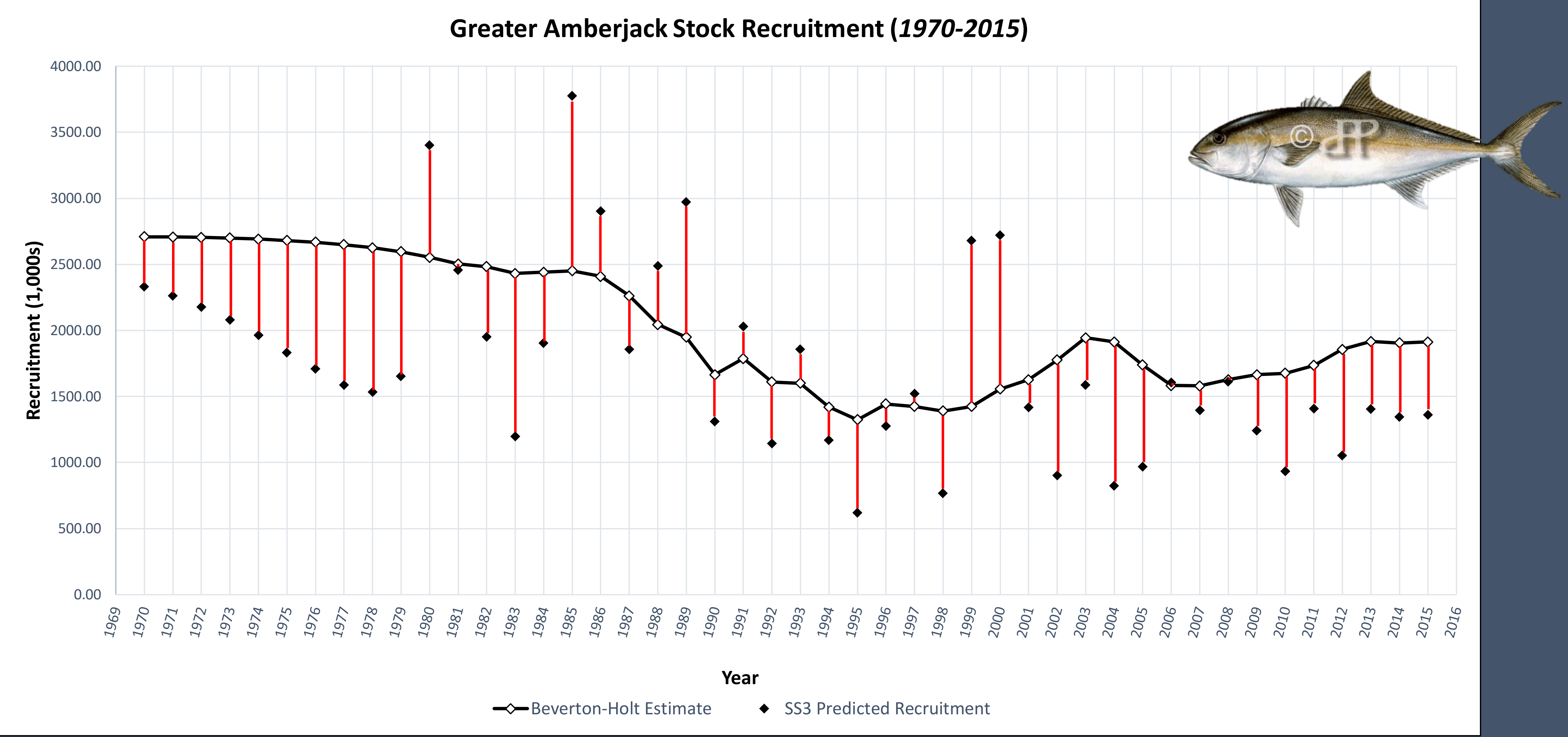
Living Marine
Resource Descriptors

Things we care about

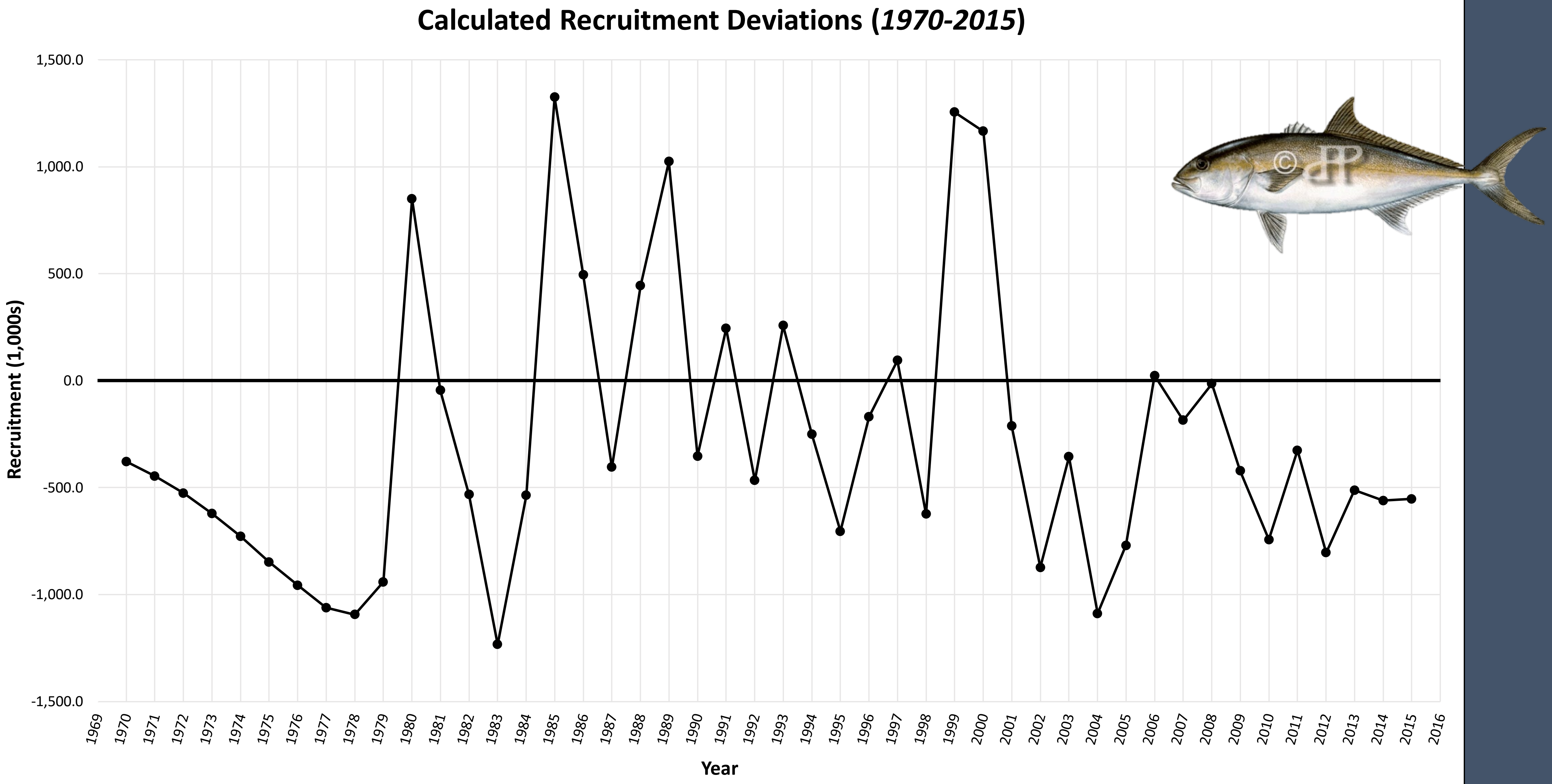
Greater Amberjack Stock Recruitment



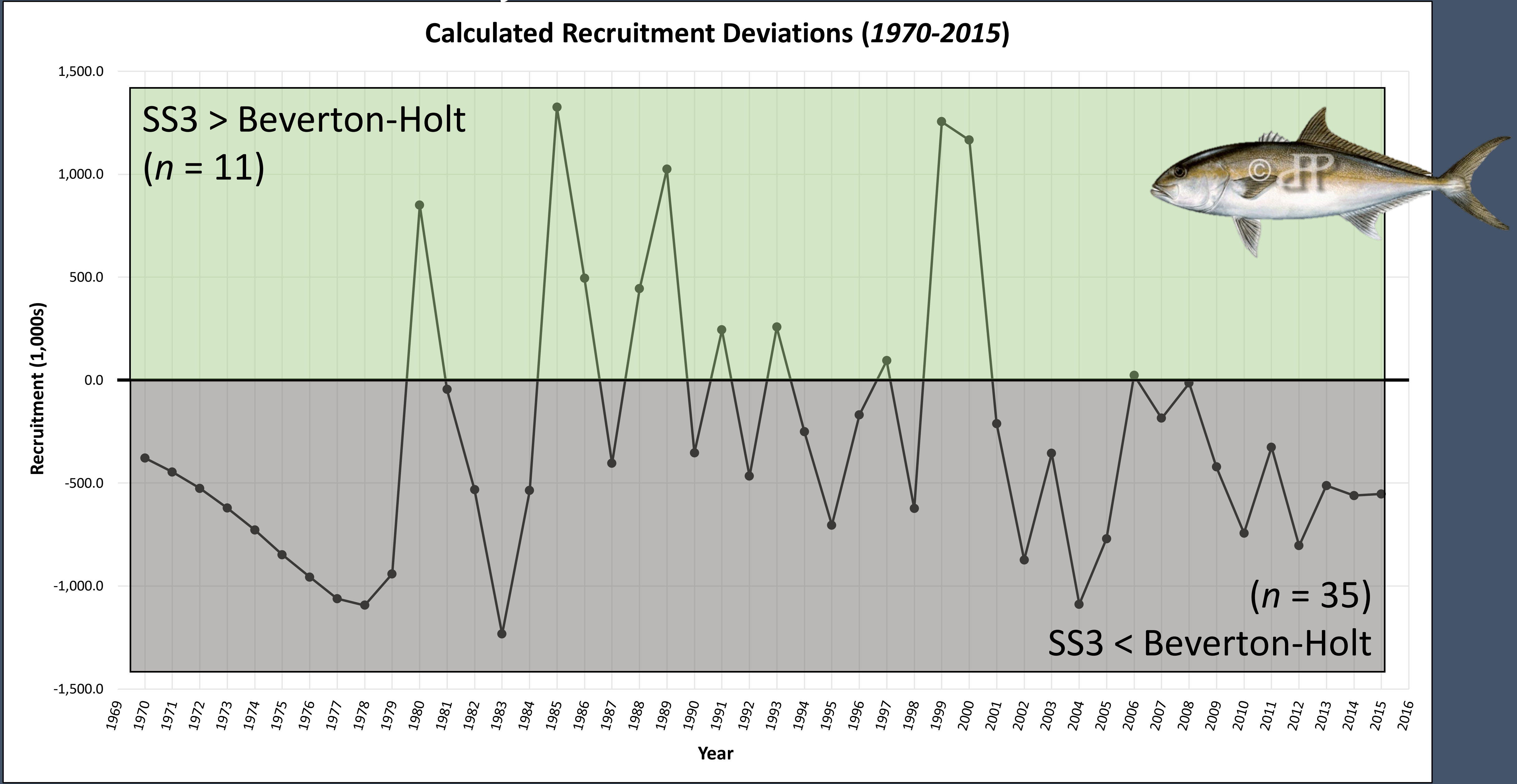
Greater Amberjack Stock Recruitment

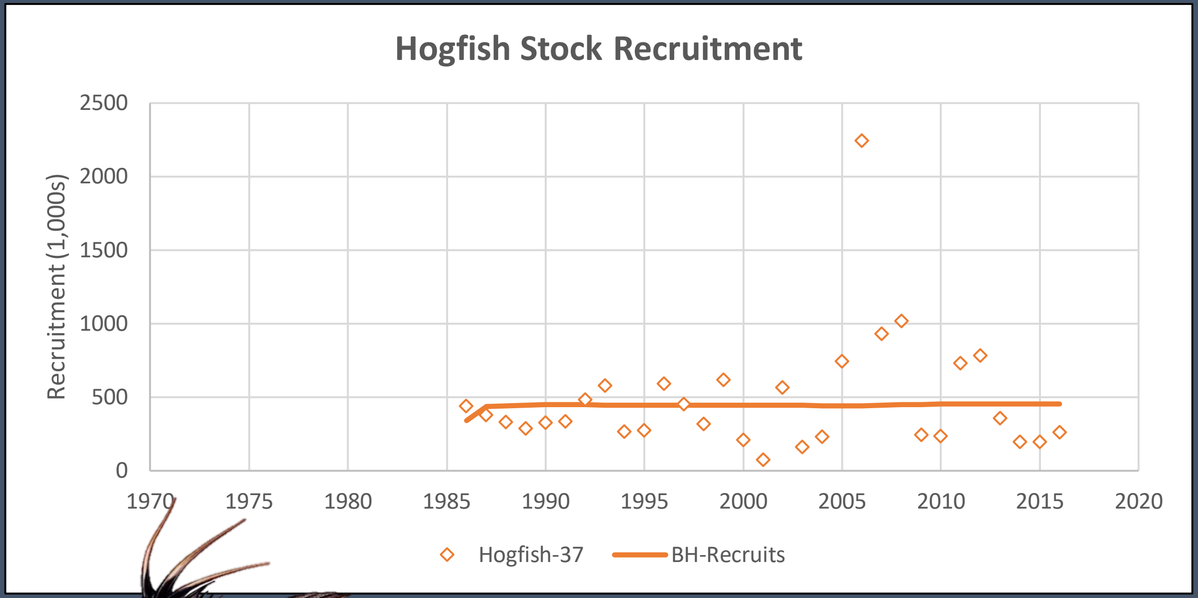


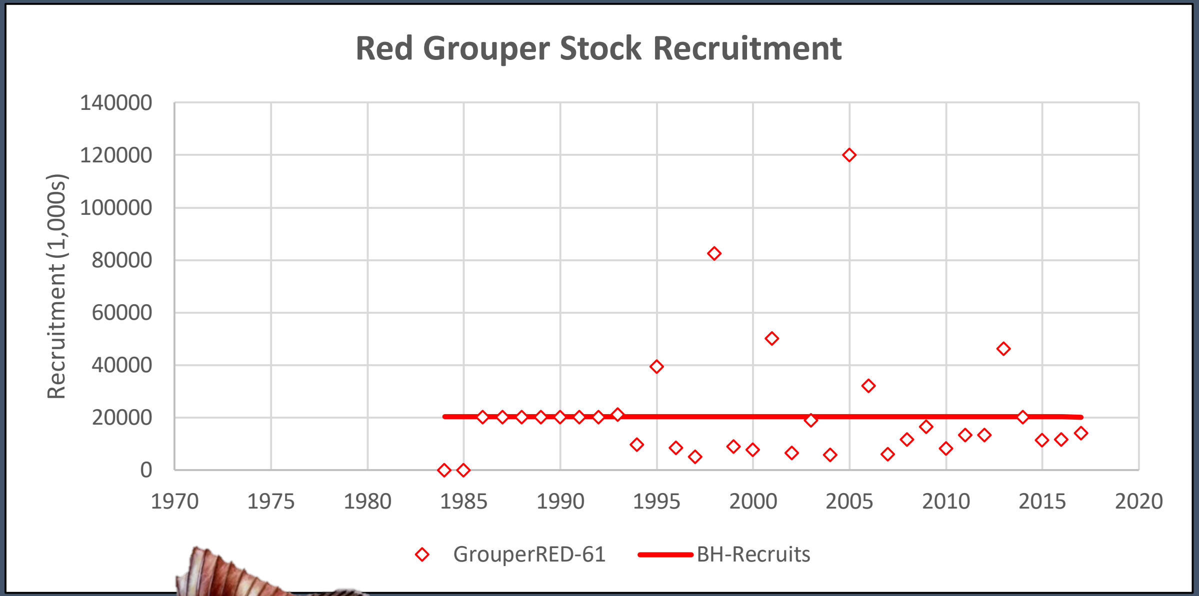
Greater Amberjack Recruitment Deviations

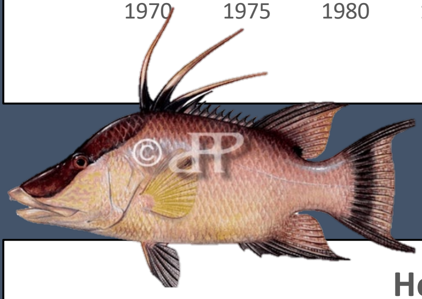


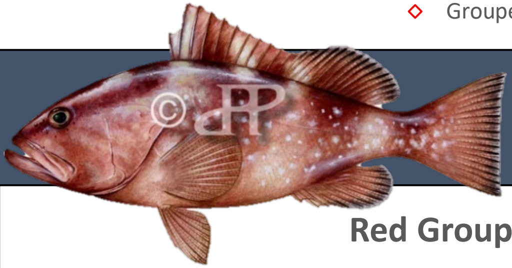
Greater Amberjack Recruitment Deviations

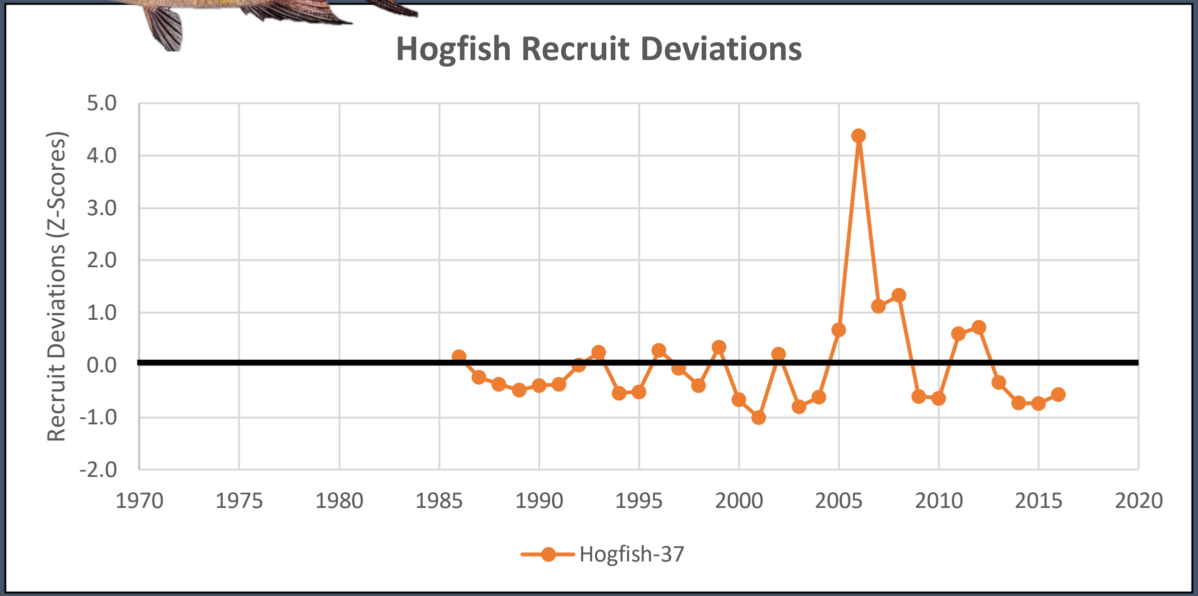


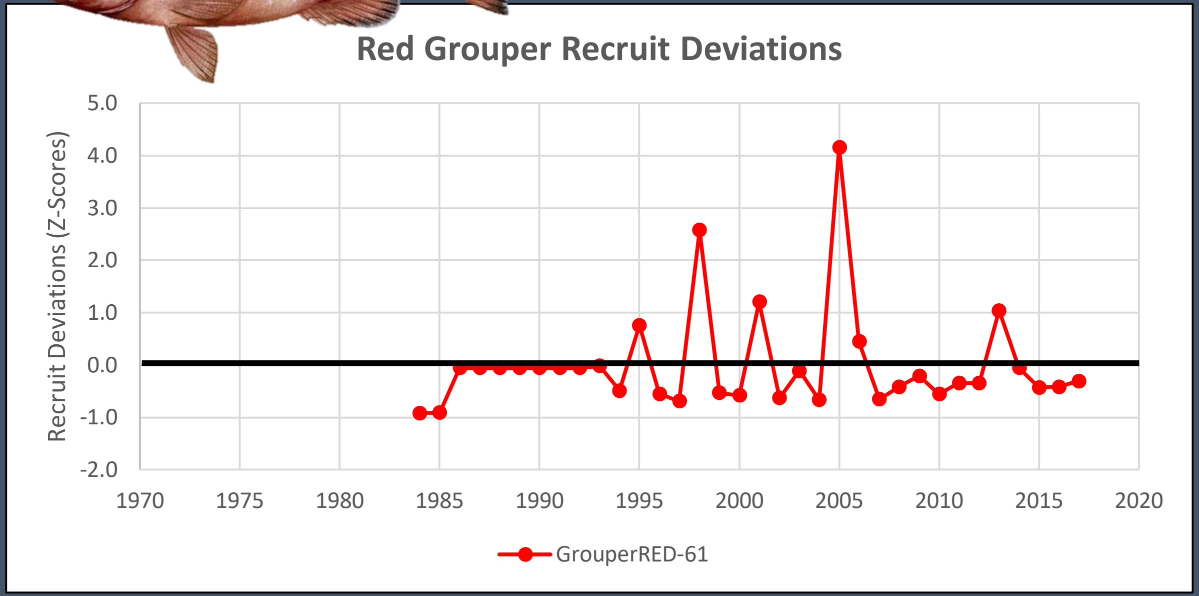

Hogfish Stock Recruitment
Recruitment (1,000s)
2500
2000
1500
1000
500
0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Hogfish-37
BH-Recruits

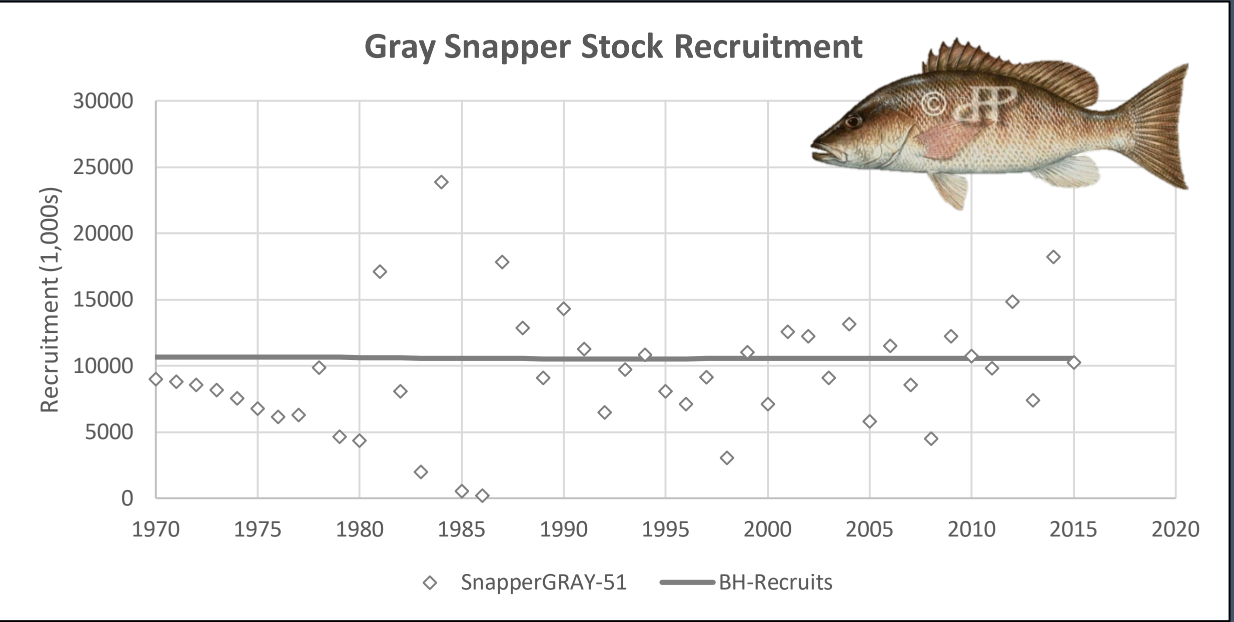

Red Grouper Stock Recruitment
Recruitment (1,000s)
140000
120000
100000
80000
60000
40000
20000
0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
GrouperRED-61
BH-Recruits

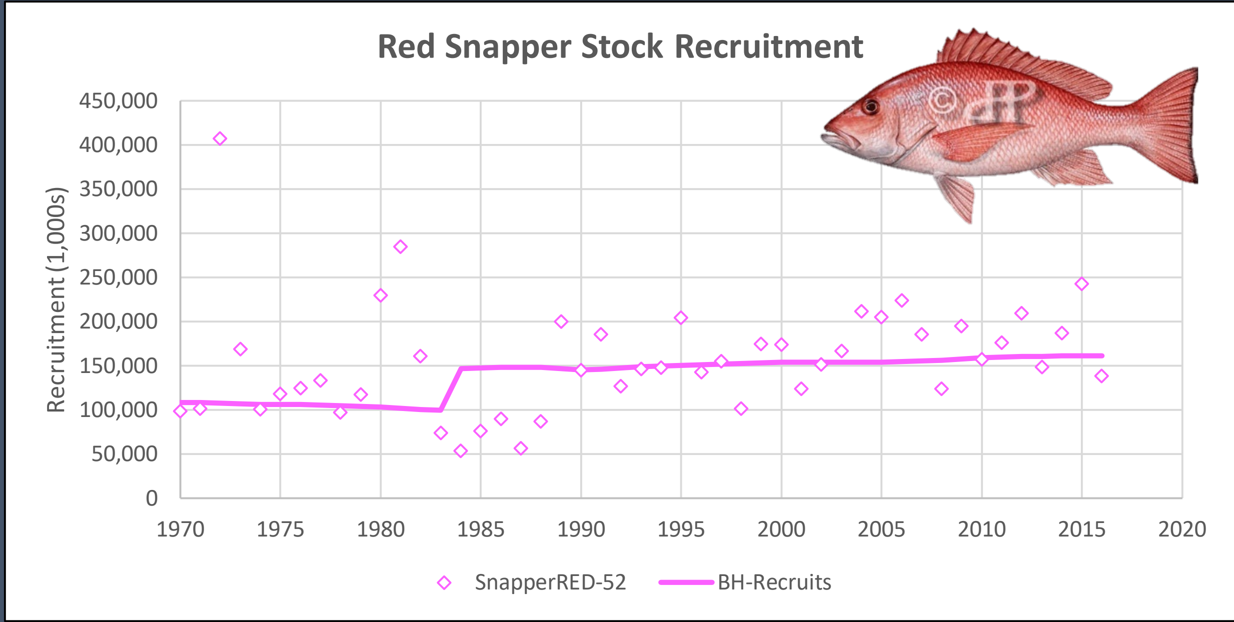


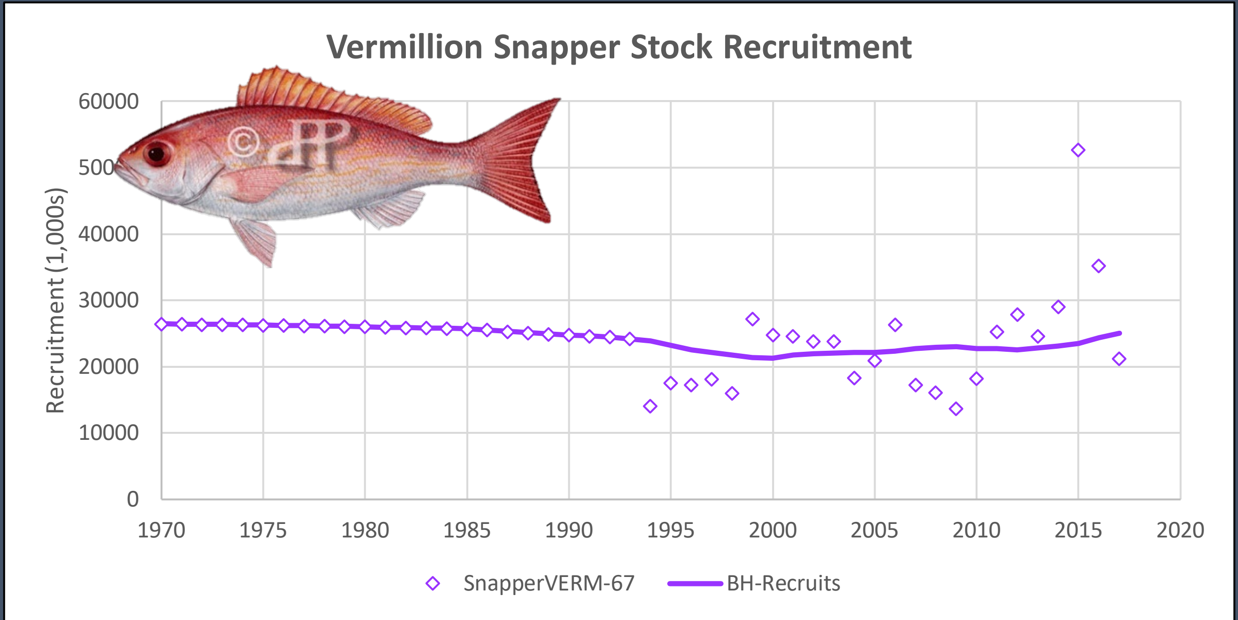


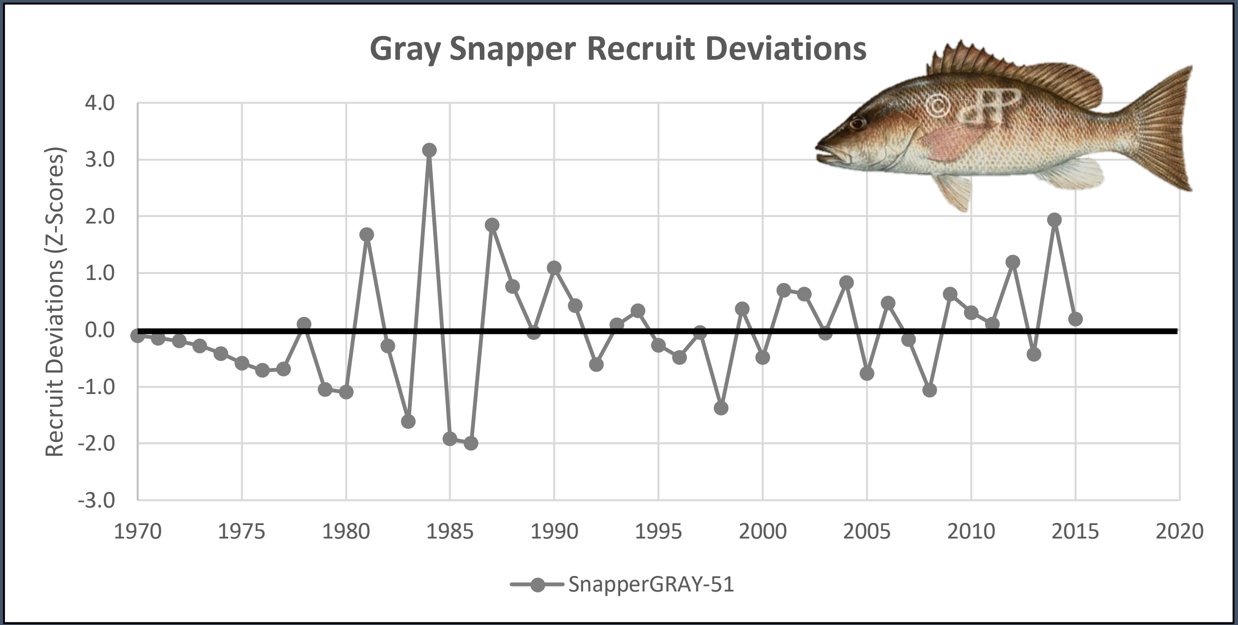

Hogfish Recruit Deviations
Recruit Deviations (Z-Scores)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Hogfish-37

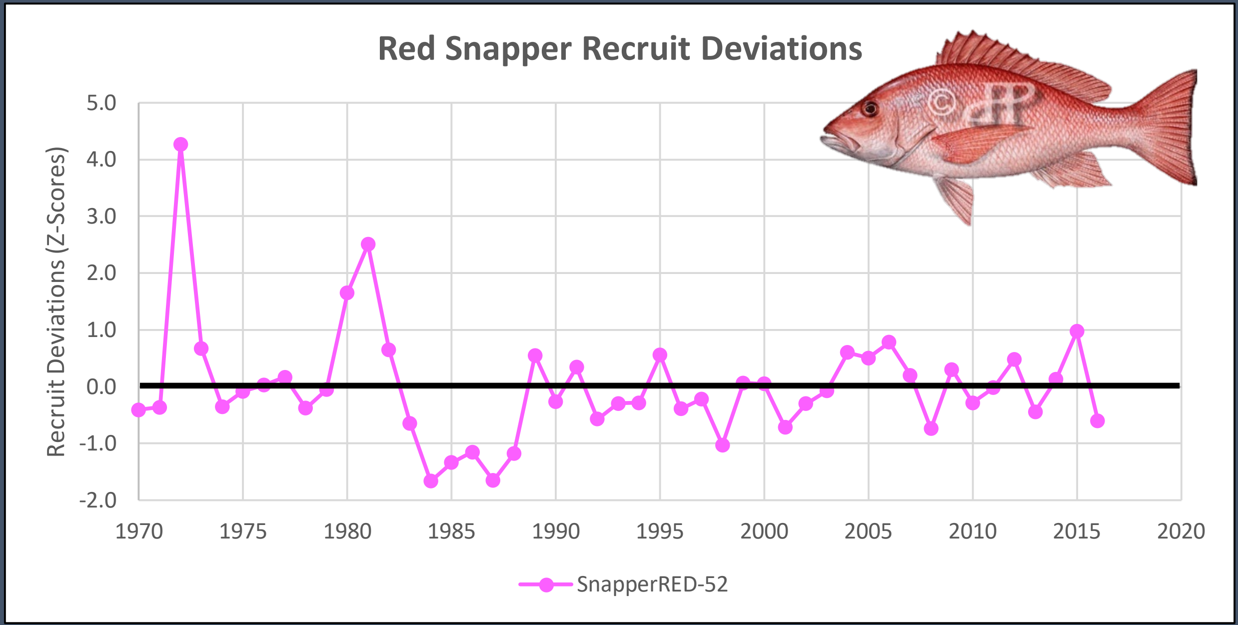

Red Grouper Recruit Deviations
Recruit Deviations (Z-Scores)
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
GrouperRED-61

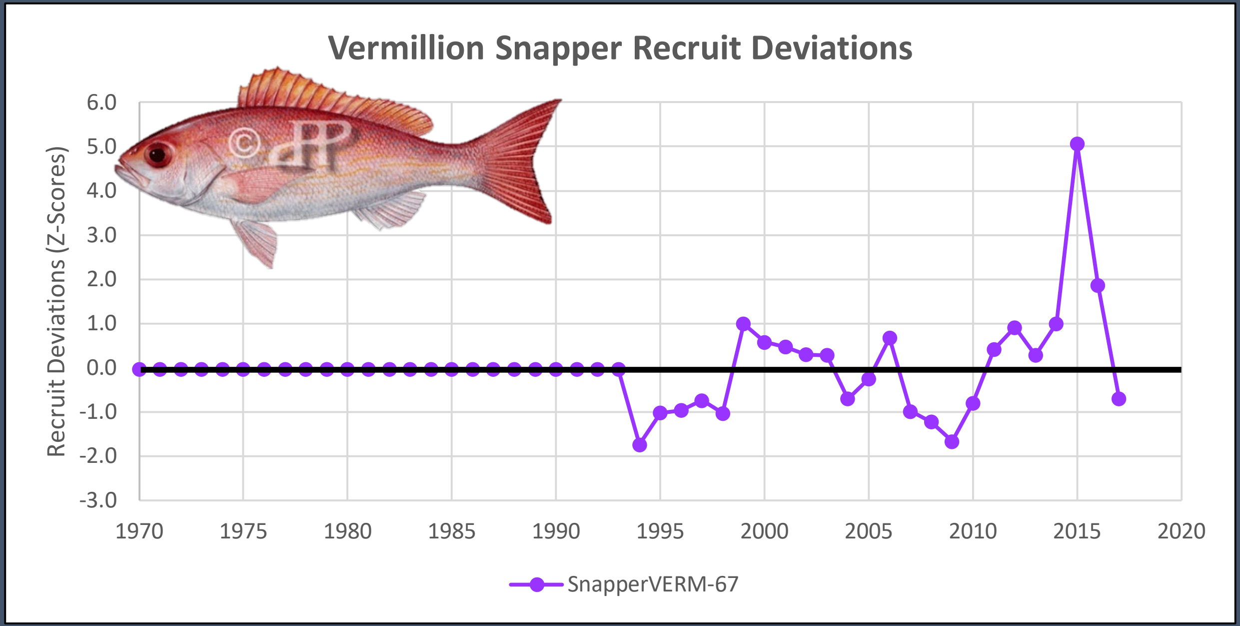

Gray Snapper Stock Recruitment
Recruitment (1,000s)
30000
25000
20000
15000
10000
5000
0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperGRAY-51
BH-Recruits


Red Snapper Stock Recruitment
Recruitment (1,000s)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperRED-52
BH-Recruits

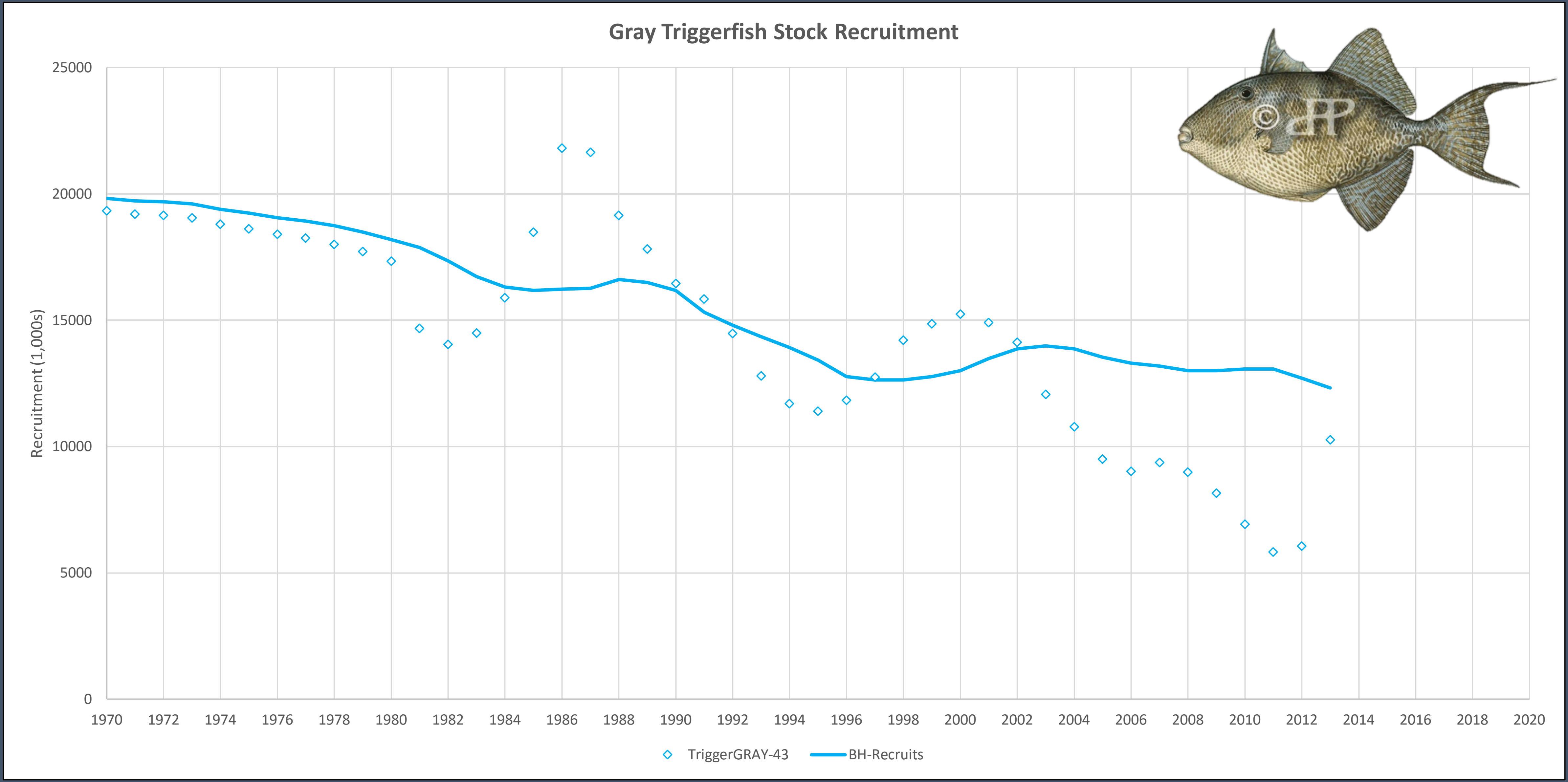

Vermillion Snapper Stock Recruitment
Recruitment (1,000s)
60000
40000
30000
20000
10000
0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperVERM-67
BH-Recruits


Gray Snapper Recruit Deviations
Recruit Deviations (Z-Scores)
4.0 3.0 2.0 1.0 0.0 -1.0 -2.0 -3.0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperGRAY-51

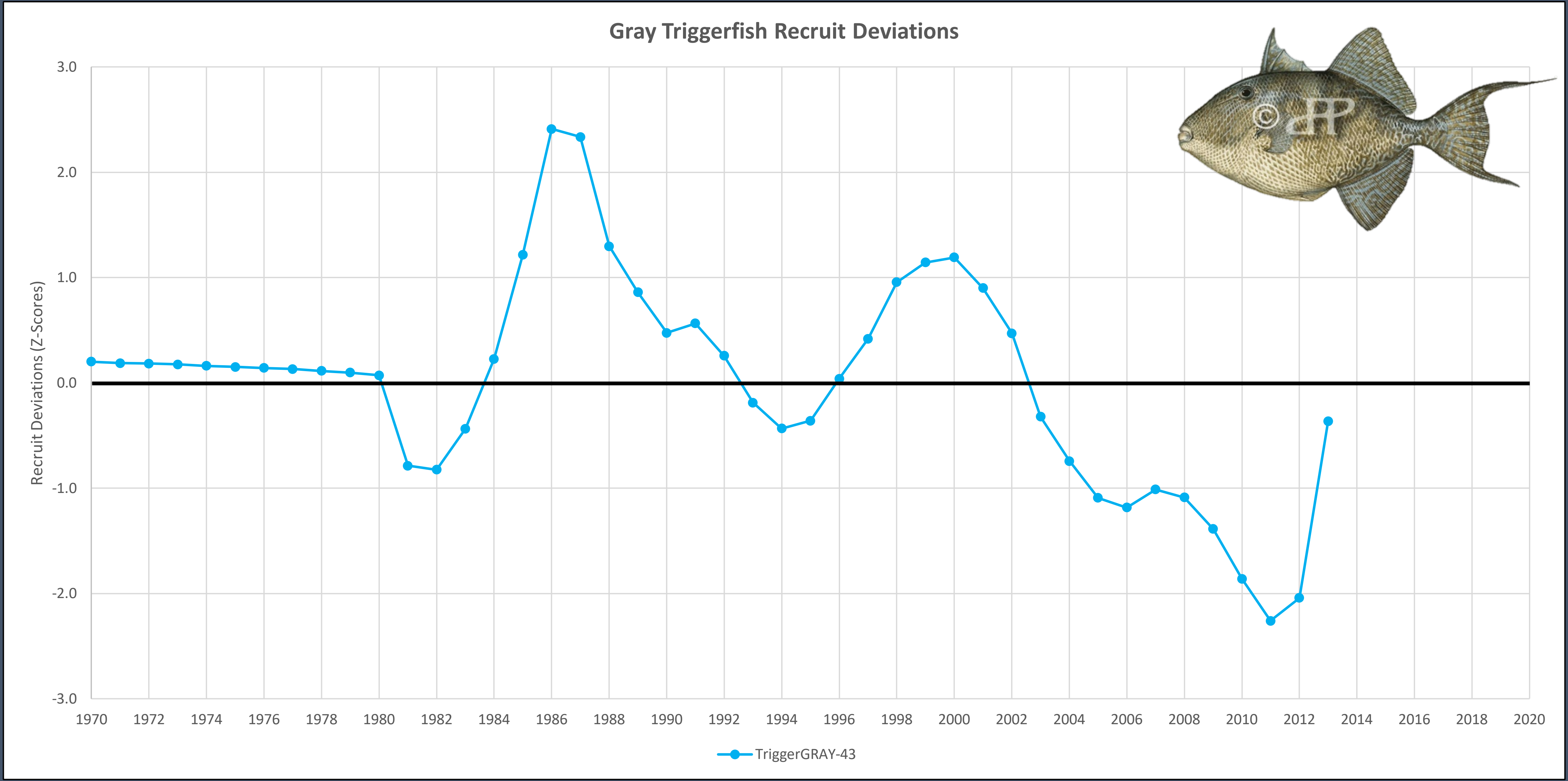

Red Snapper Recruit Deviations
Recruit Deviations (Z-Scores)
5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperRED-52


Vermillion Snapper Recruit Deviations
Recruit Deviations (Z-Scores)
6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0 -3.0
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
SnapperVERM-67

Gray Triggerfish Stock Recruitment



Gray Triggerfish Recruit Deviations



TIME

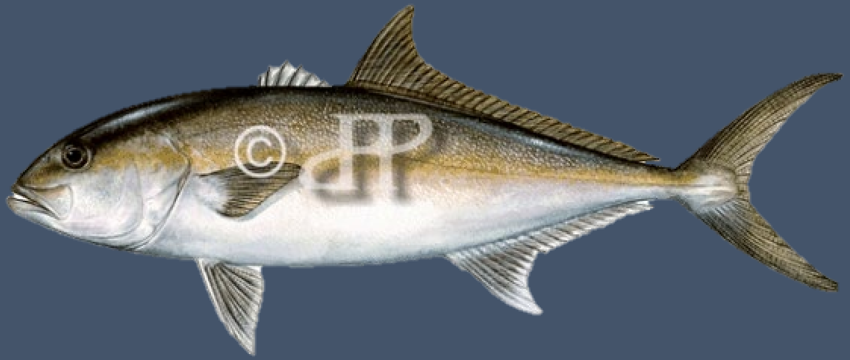
Temporal Scales for Greater Amberjack Models

Sargassum (2000-2015) **16 YRS.**

Eutrophication (1987-2014) **28 YRS.**

Ecological (1982-2010) **29 YRS.**

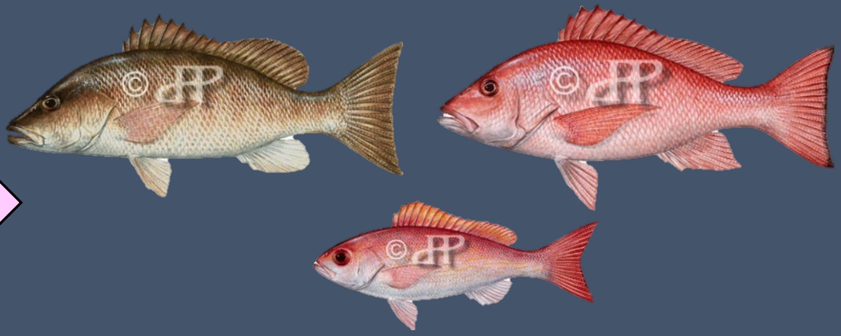
Habitat (1970-2015) **46 YRS.**



Temporal Scales for Reef Fish Models

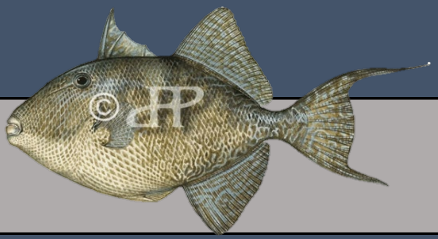
ALL SPECIES (1993-2012) **20 YRS.**

ALL SNAPPERS (GSnap + RSnap + VSnap) (1993-2012) **20 YRS.**



Hogfish + Red Grouper (1992-2012) **21 YRS.**

Gray Triggerfish (1987-2012) **26 YRS.**



PREDICTOR
INDICATORS

X

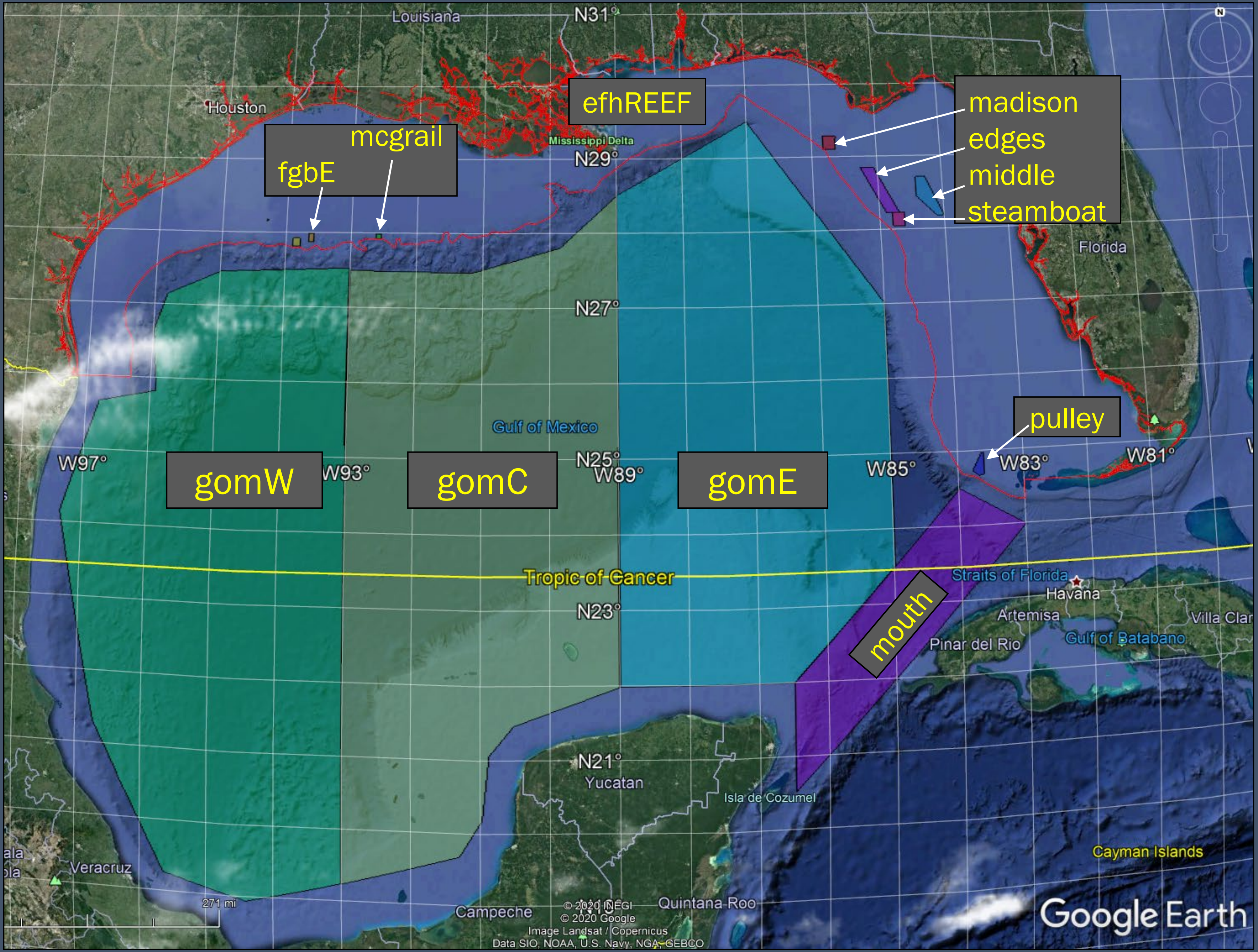
Anthropogenic,
Climate, and
Environmental

Hypothesized to affect things we care about

Greater Amberjack Early Life History Model

	SOUTHBOUND					NORTHBOUND						S
			Spawn/Dispersal			Pelagic/Recruit						
Greater Amberjack Ontogenetic Stage	**Jan.**	**Feb.**	***Mar.***	***Apr.***	***May***	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Spawning			X	X	X	X						
Eggs			X	X	X	X						
Yolk-sack larvae				X	X	X	X					
Larvae (start feeding)				X	X	X	X					
Pelagic Juveniles (feeding pelagic)					X	X	X	X	X	X	X	X
Recruited stage (YOY > 150 days)								X	X	X	X	X
Peak-spawning-period spawned class												
Commercial Fishing Closed												
Recreational Fishing Closed												

- Spawning/Larval Dispersal period model: March → May
- Pelagic Juvenile/Recruitment period model: June → August

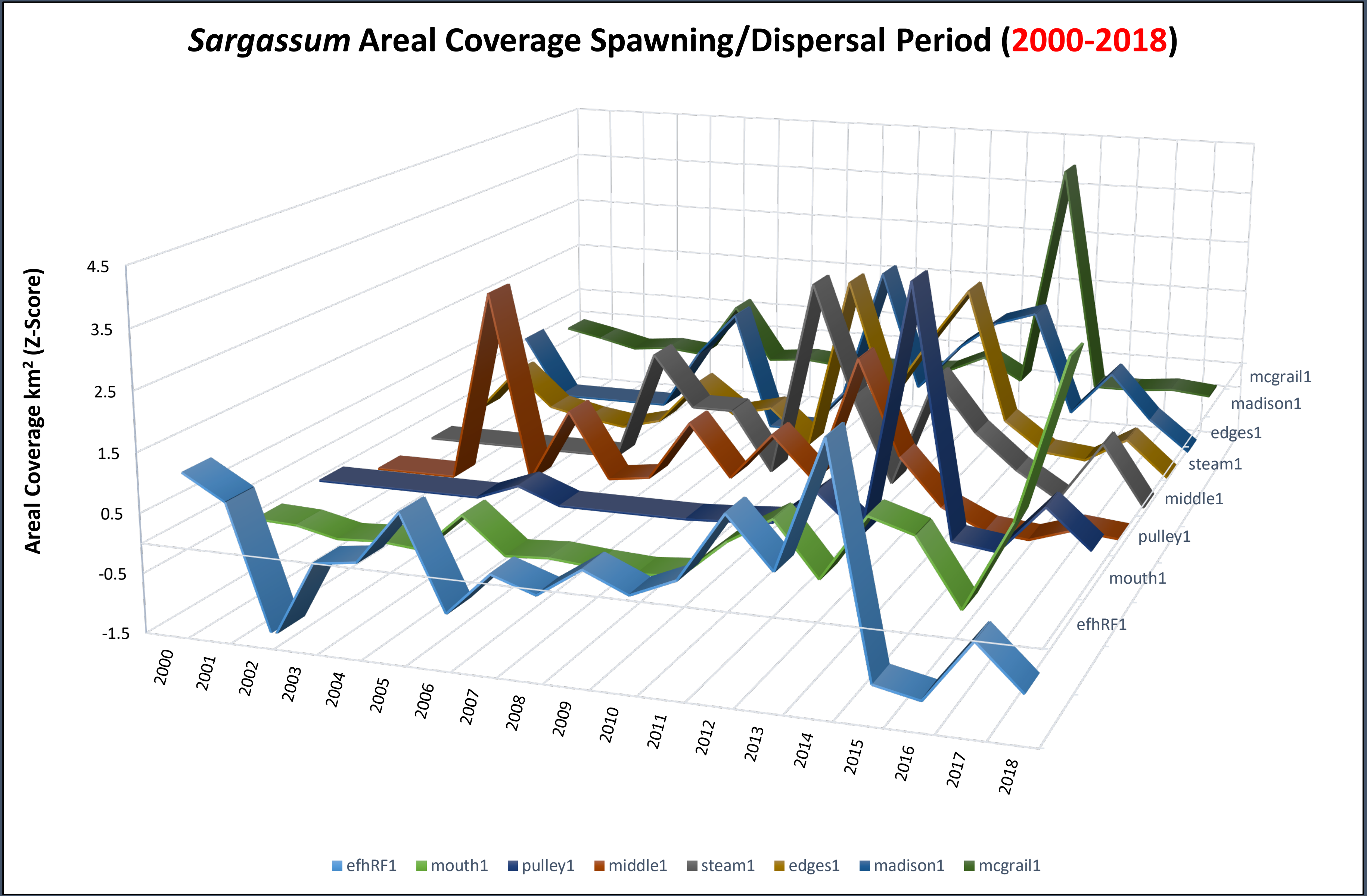


Sargassum Areal Coverage

Sampling the Gulf LME

- Seven Restricted Mgmt. Areas
- Reef-fish EFH
- Five Experimental Basin-scale Areas

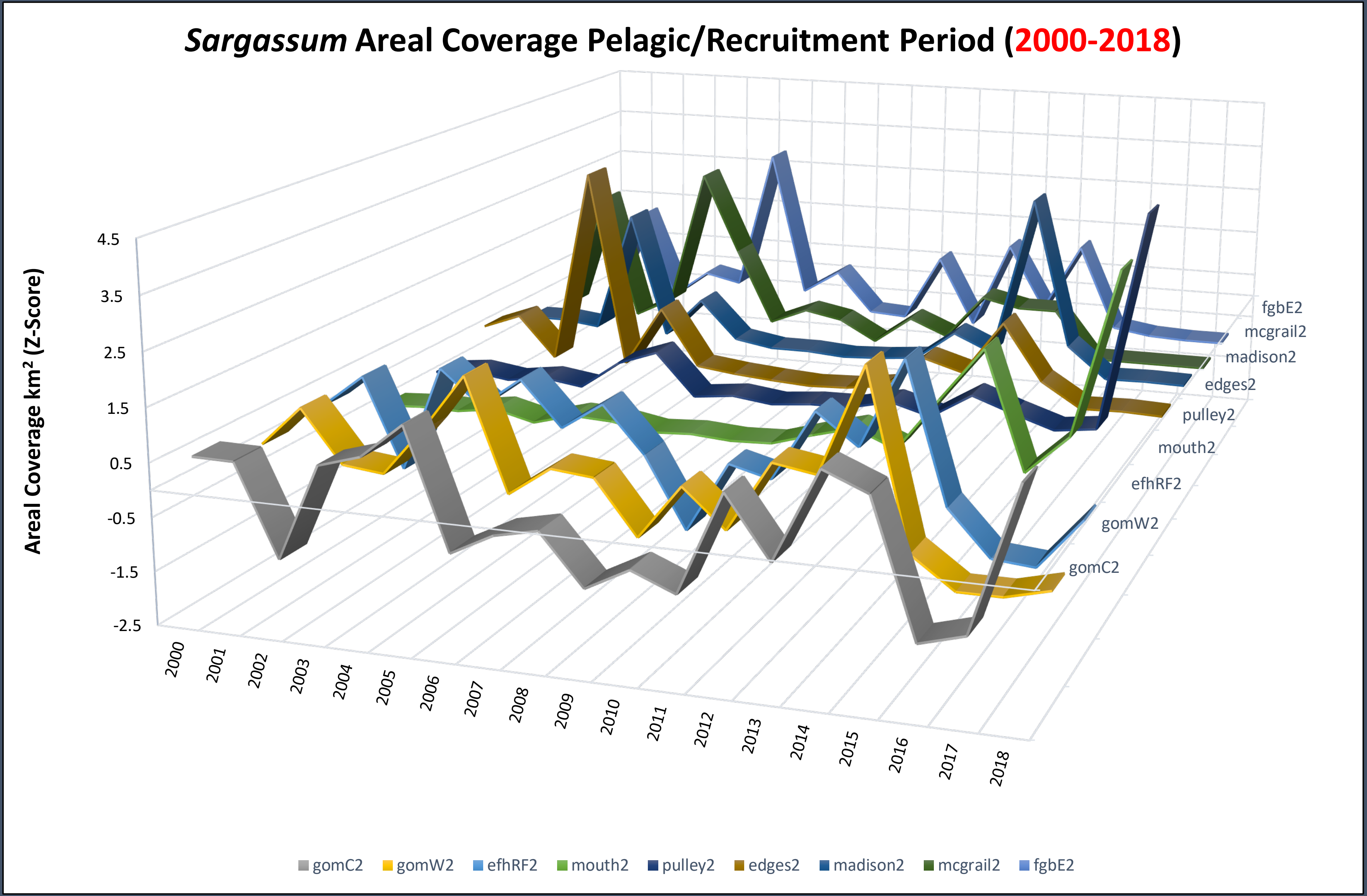
Ecological Models – *Sargassum* Time Series



Spawning/Dispersal Period Model

- Six Restricted Mgmt. Areas
- Reef-fish EFH
- One Experimental Basin-scale Areas

Ecological Models – *Sargassum* Time Series



Pelagic/Recruitment Period Model

- Five Restricted Mgmt. Areas
- Reef-fish EFH
- Two Experimental Basin-scale Areas

Gulf LME Ecosystem Status Reports

NOAA Technical Memorandum NMFS-SEFSC-653

ECOSYSTEM STATUS REPORT FOR THE GULF OF MEXICO

Mandy Karnauskas, Michael J. Schirripa, Christopher R. Kelble, Geoffrey S. Cook and J. Kevin Craig

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

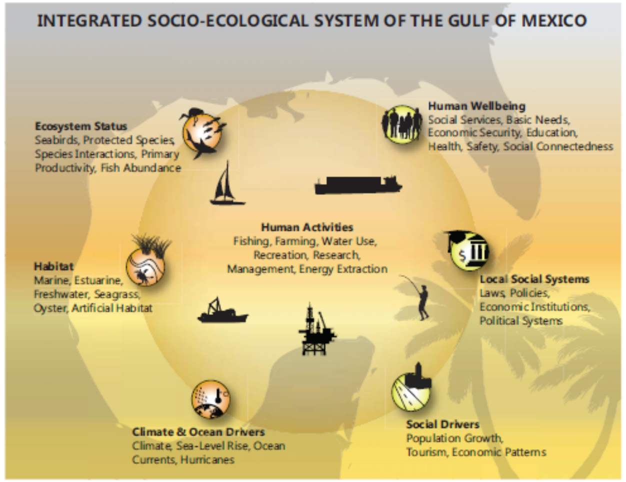
December 2013

(2013)

NOAA Technical Memorandum NMFS-SEFSC-706

2017 ECOSYSTEM STATUS REPORT UPDATE FOR THE GULF OF MEXICO

Mandy Karnauskas, Christopher R. Kelble, Seann Regan, Charline Quenée, Rebecca Allee, Michael Jepson, Amy Freitag, J. Kevin Craig, Cristina Carollo, Leticia Barbero, Neda Trifonova, David Hanisko, and Glenn Zapfe



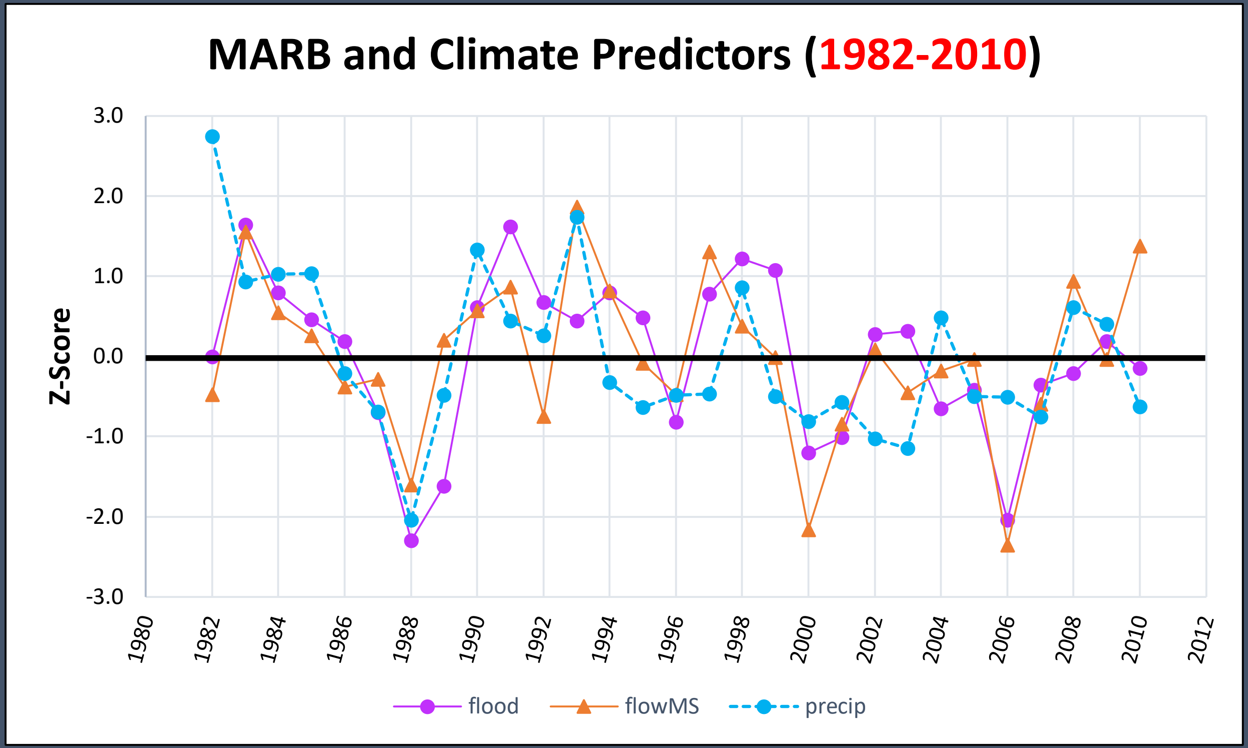
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

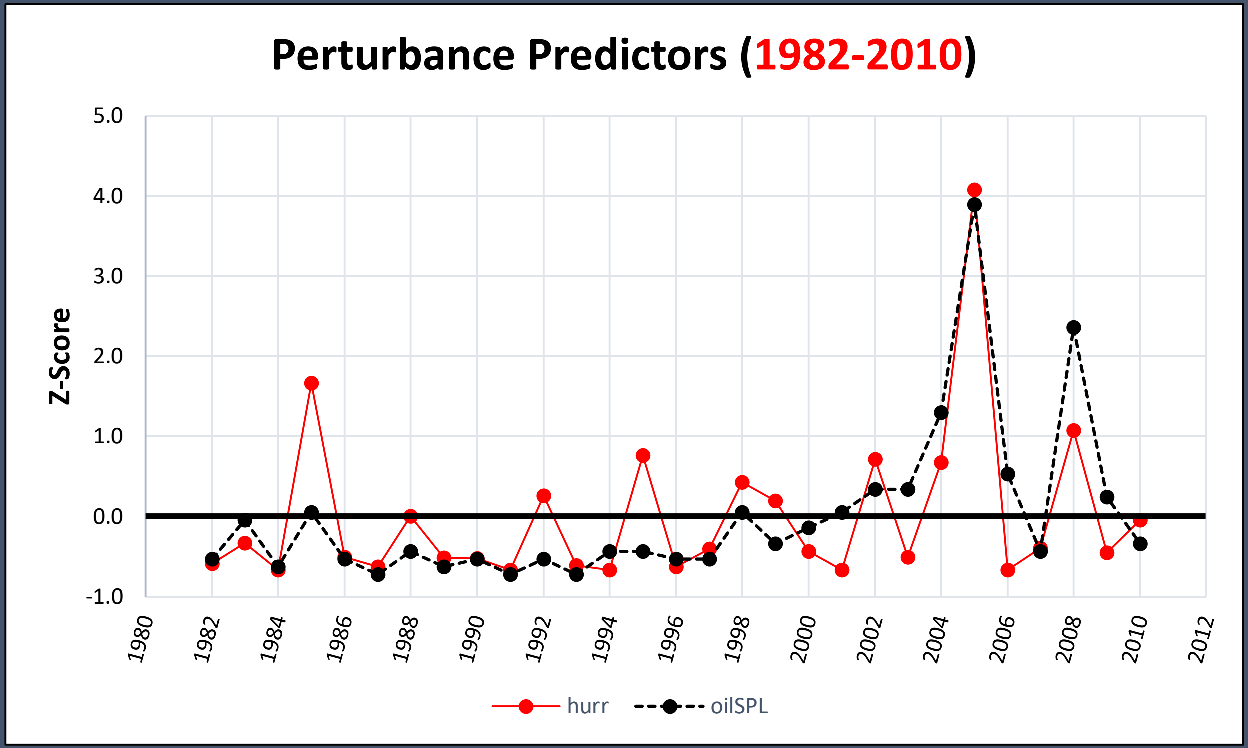
March 2017

(2017)

Predictor Models for Greater Amberjack Deviations

General Ecological Model Indicators





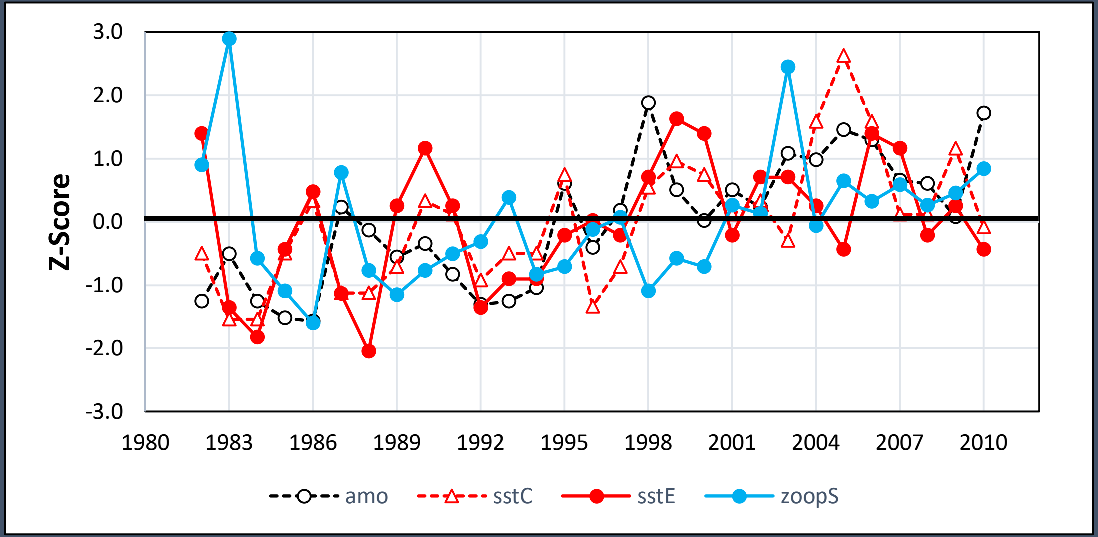
Predictor Models for Greater Amberjack Deviations

Additional Model Indicators

GENERAL ECOLOGICAL MODEL

1982-2010

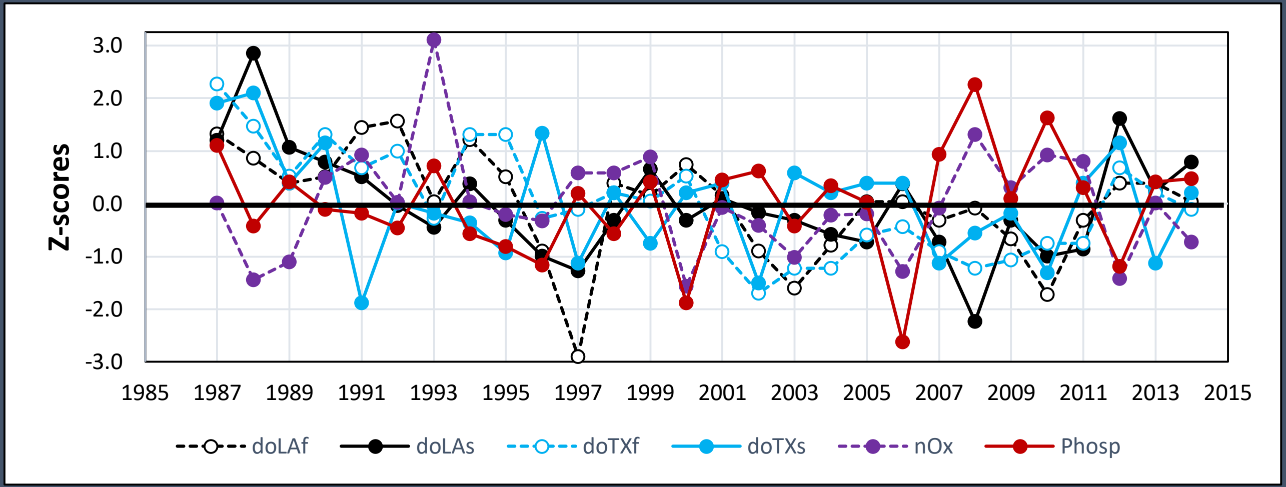
- Climate & Temperature
- Lower Trophic Level Status



EUTROPHICATION MODEL

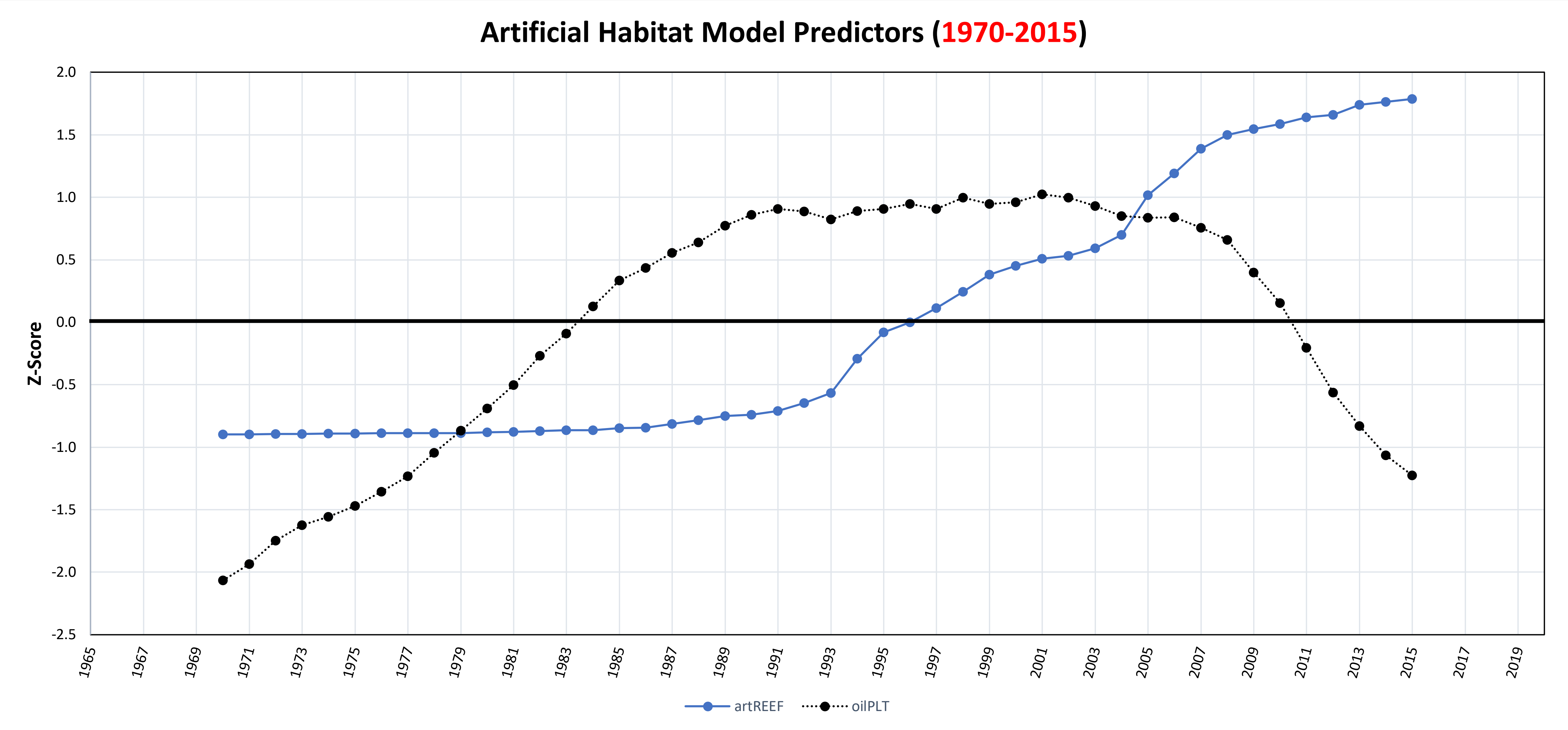
1987-2015

- Dissolved Oxygen
- Nitrogen Oxides
- Total Phosphate



Predictor Models for Greater Amberjack Deviations

Artificial Habitat Indicators



PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

Hypothesized to affect things we care about

Gulf LME Ecosystem Status Reports

NOAA Technical Memorandum NMFS-SEFSC-653

ECOSYSTEM STATUS REPORT FOR THE GULF OF MEXICO

Mandy Karnauskas, Michael J. Schirripa, Christopher R. Kelble, Geoffrey S. Cook and J. Kevin Craig

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

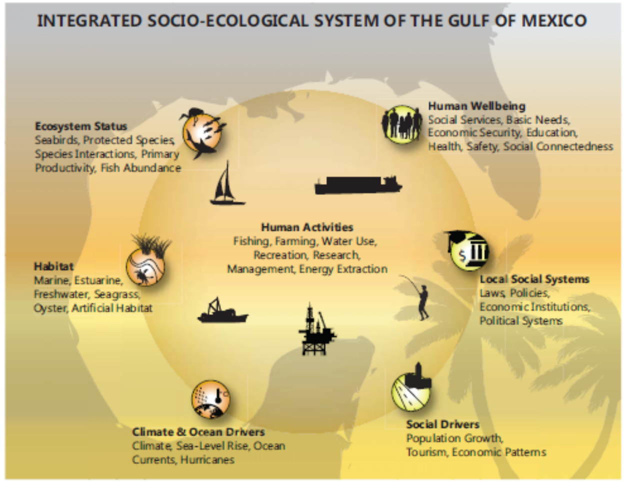
December 2013

(2013)

NOAA Technical Memorandum NMFS-SEFSC-706

2017 ECOSYSTEM STATUS REPORT UPDATE FOR THE GULF OF MEXICO

Mandy Karnauskas, Christopher R. Kelble, Seann Regan, Charline Quenée, Rebecca Allee, Michael Jepson, Amy Freitag, J. Kevin Craig, Cristina Carollo, Leticia Barbero, Neda Trifonova, David Hanisko, and Glenn Zapfe



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
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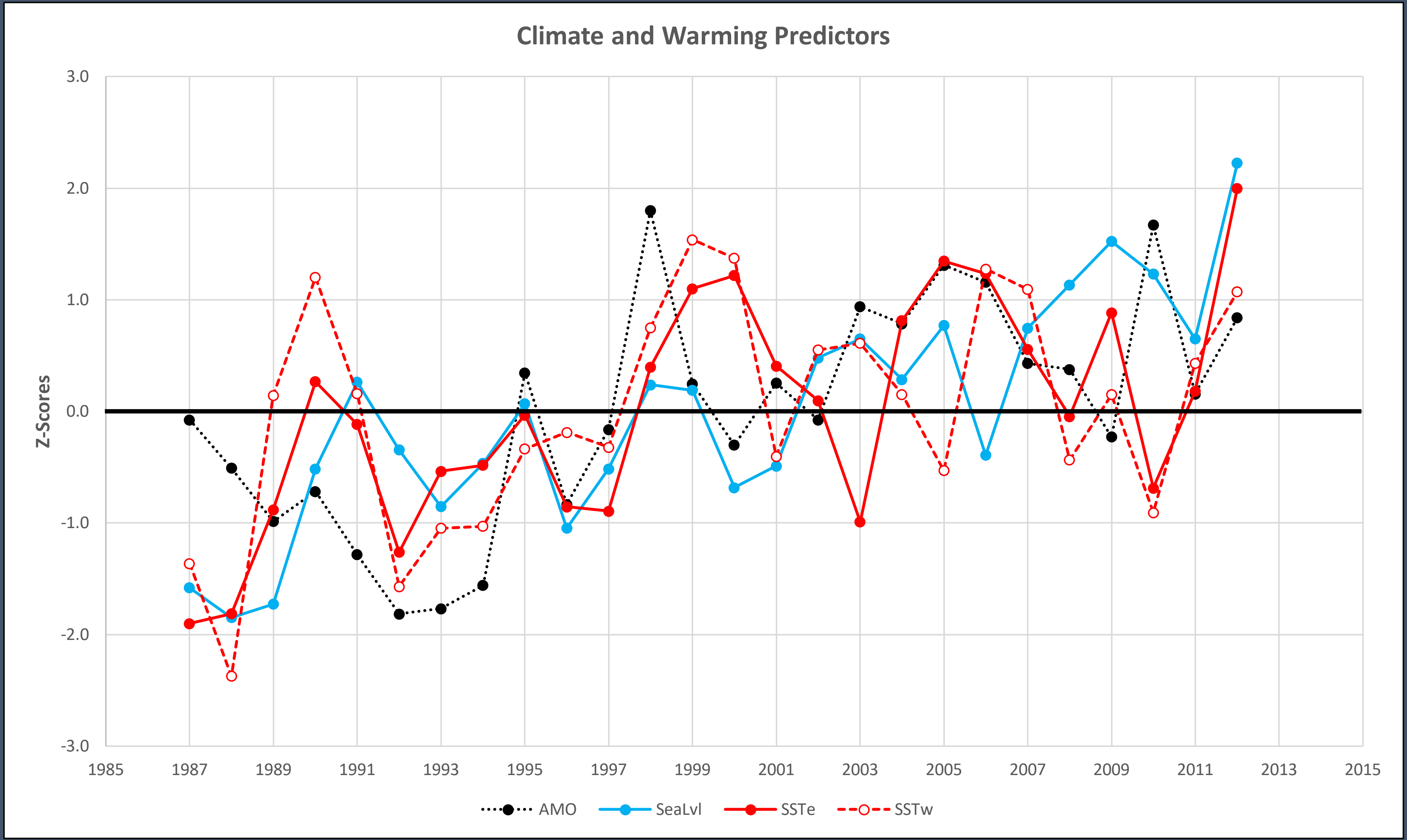
75 Virginia Beach Drive
Miami, Florida 33149

March 2017

(2017)

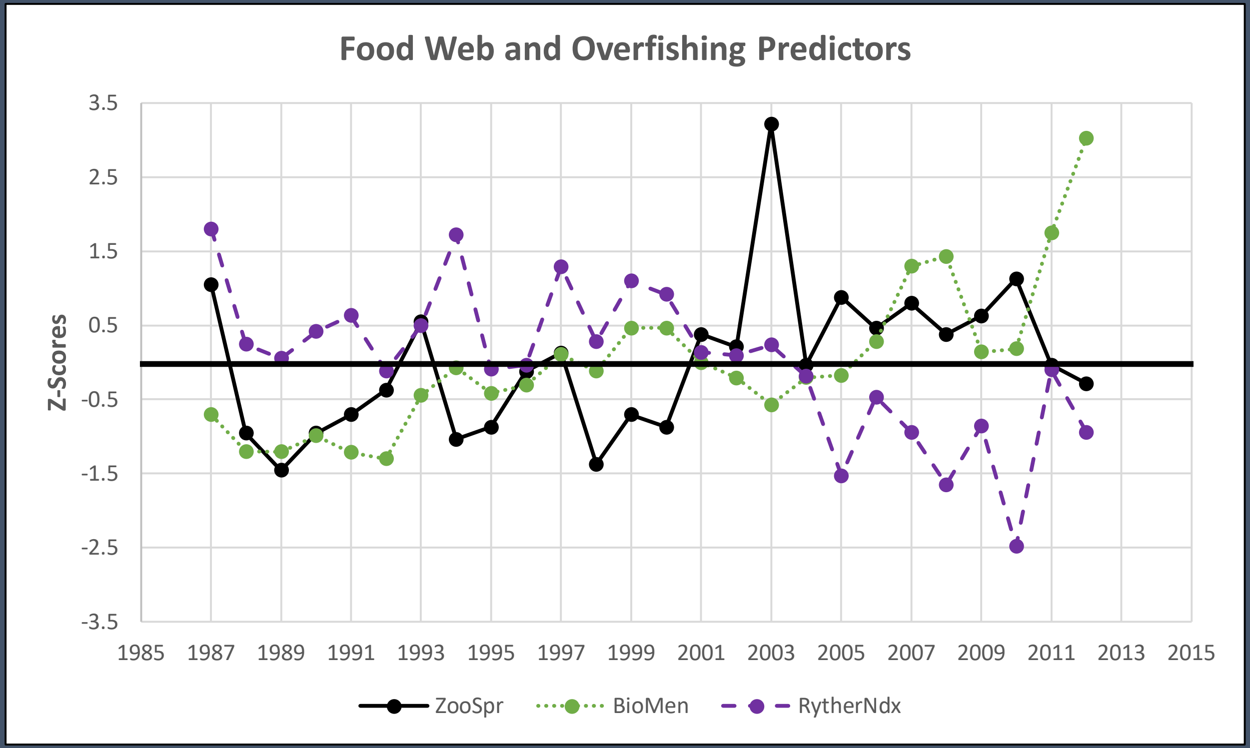
Predictor Models for Reef Fish Deviations

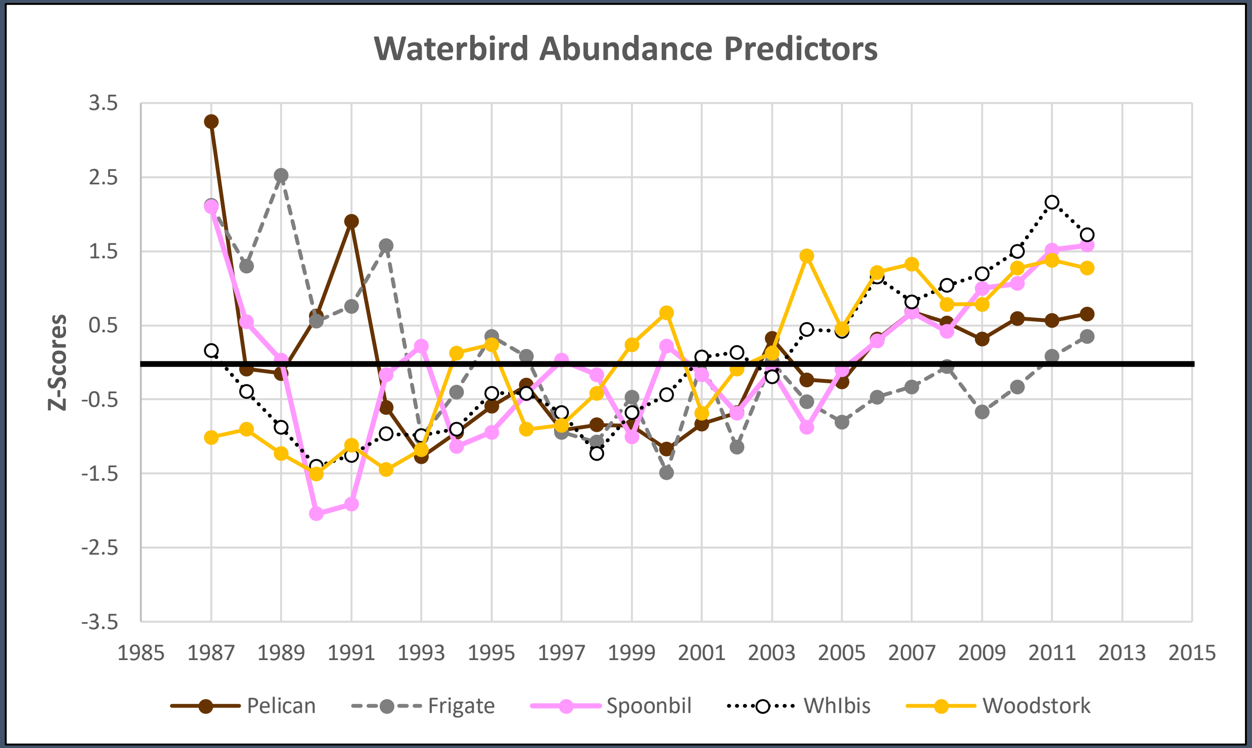
Climate and Sea Surface Temperature Indicators



Predictor Models for Reef Fish Deviations

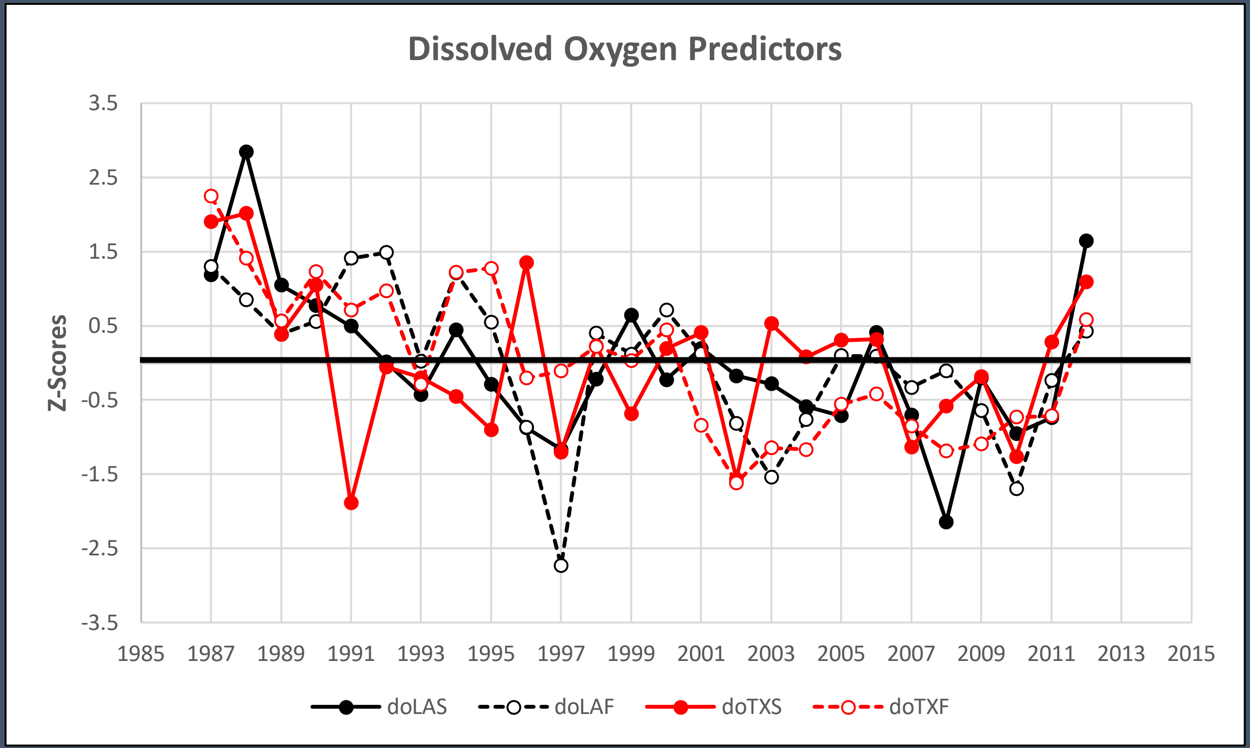
Food Web, Overfishing, and Waterbird Indicators

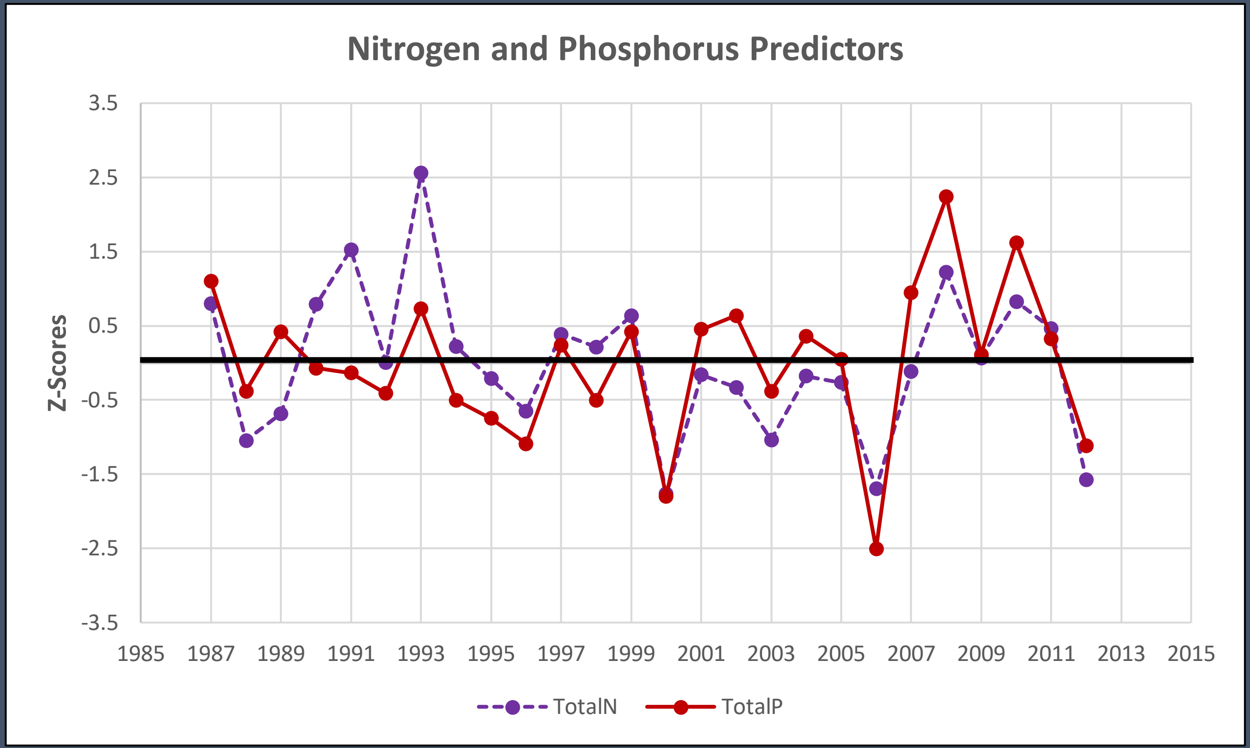




Predictor Models for Reef Fish Deviations

Eutrophication Indicators



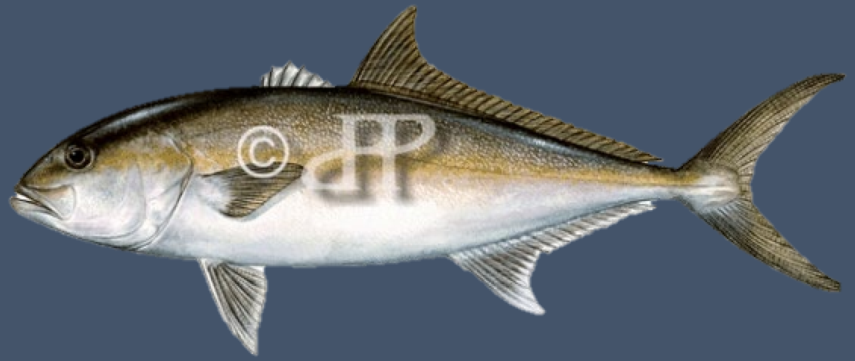


Results

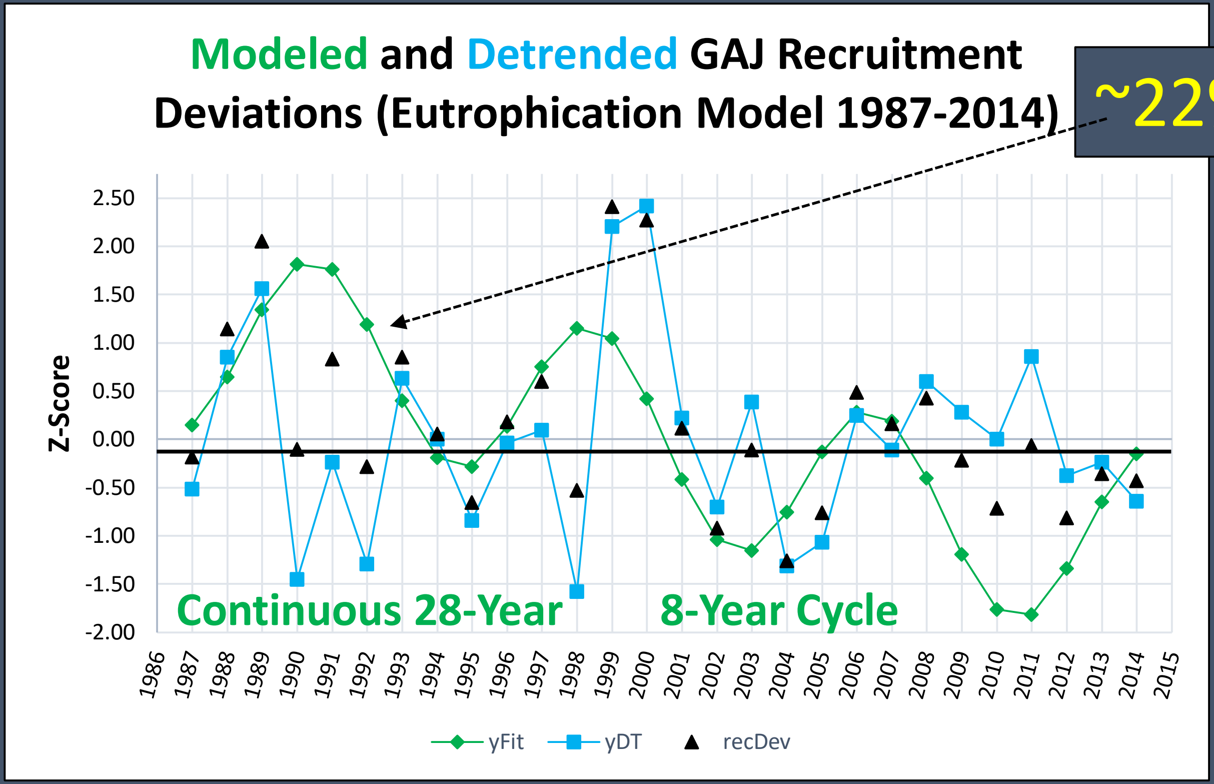
Greater Amberjack
Recruit Deviations
AEM Results

Temporal Detrending Results

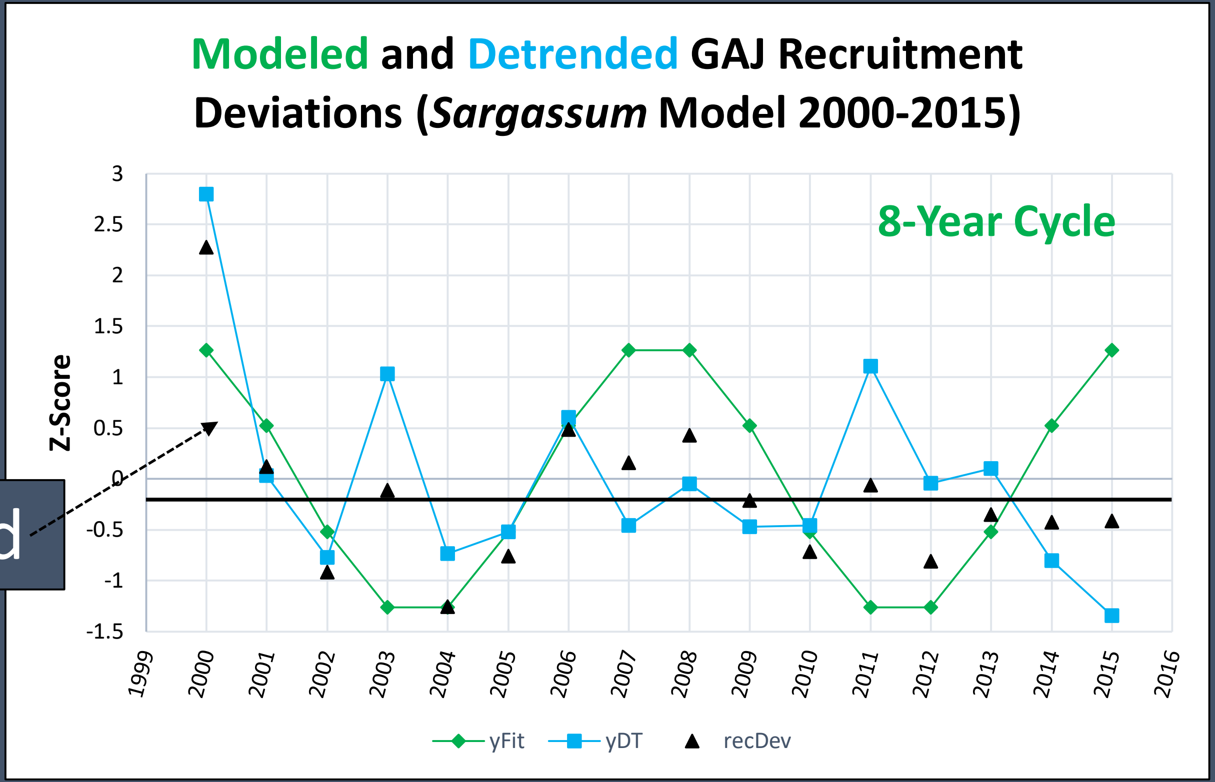
Model	Period	N	Λ_i (Period 1)	Λ_i (Period 2)	F	R^2	R^2_{adj}	p-value
Habitat	1970-2015	46	Λ_2 (23 years)	-	10.5	0.1922	0.1738	**0.003**
Ecological	1982-2010	29	Λ_5 (11 years)	-	7.0	0.2067	0.1773	**0.014**
Eutrophication	1987-2014	28	Λ_1 (28 years)	Λ_7 (8 years)	4.9	0.2794	0.2218	**0.017**
Sargassum	2000-2015	16	Λ_4 (8 years)	-	7.9	0.3621	0.3165	**0.007**



Temporal Detrending Results

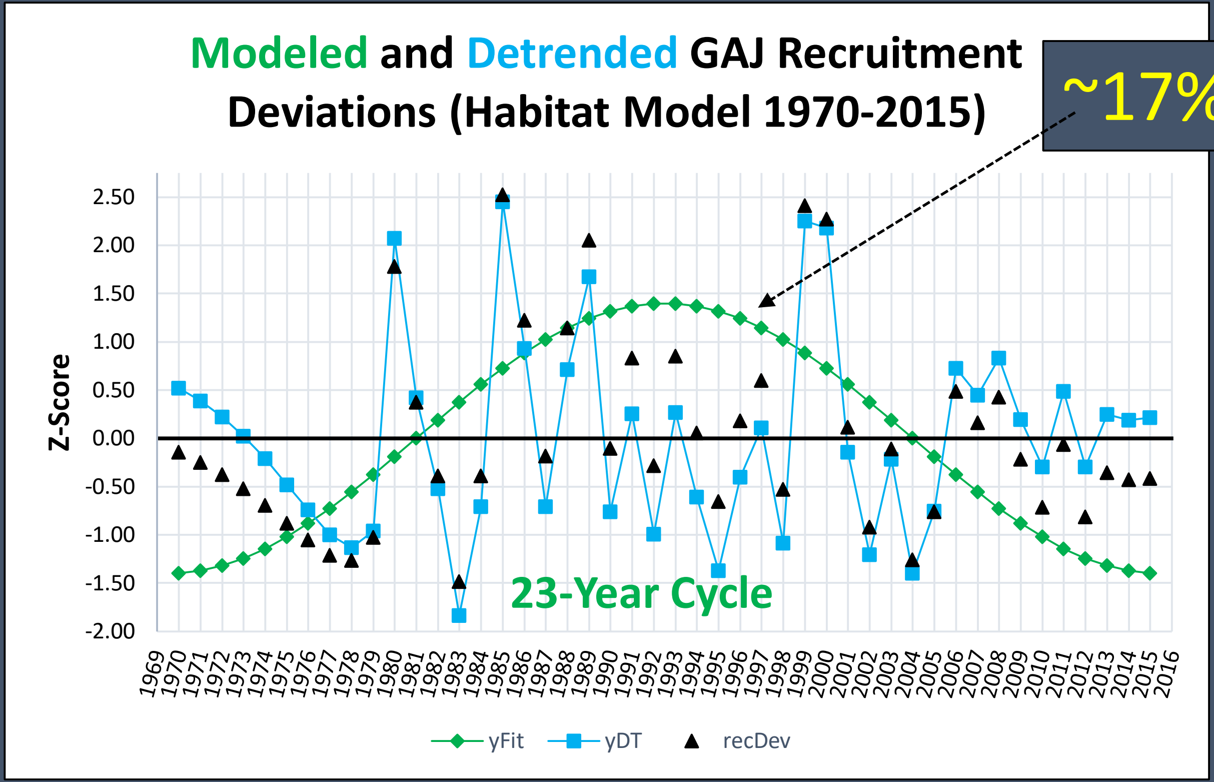


~22% of GAJ recruit deviations expl. by AEMs

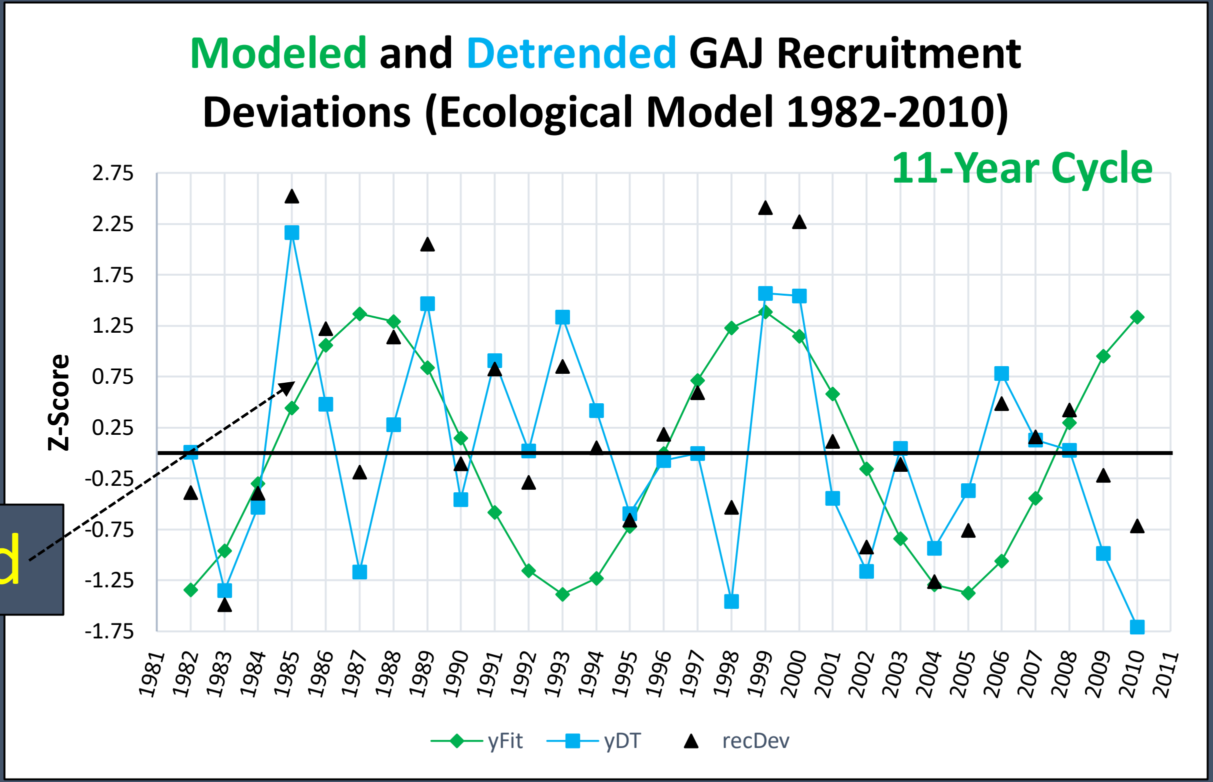


~32% of GAJ rec. dev. explained

Temporal Detrending Results



~17% of GAJ recruit deviations expl. by AEMs



~18% of GAJ rec. dev. explained

Temporal Autocorrelation Considerations

Model	Period	N	Λ_i (Period 1)	Λ_i (Period 2)	F	R^2	R^2_{adj}	p-value
Habitat	1970-2015	46	Λ_2 (23 years)	-	10.5	0.1922	0.1738	0.0029
Ecological	1982-2010	29	Λ_5 (11 years)	-	7.0	0.2067	0.1773	0.0141
Eutrophication	1987-2014	28	Λ_1 (28 years)	Λ_7 (8 years)	4.9	0.2794	0.2218	0.0169
Sargassum	2000-2015	16	Λ_4 (8 years)	-	7.9	0.3621	0.3165	0.0071

- Between 17-32% of all GAJ recruitment deviation explained by synthetic autocorrelation structures (AEMs)
- Between 8 and 11-year “decadal” signal apparent in 60% models
- Approximately 25-year “multi-decadal” signal in 40% of models
    - ➢ *Unaccounted for temporal processes?*
    - ➢ *Mechanistic bias in assessment model?*

Evaluating the Environmental Control Model

GAJ MODEL

Fitted Axes

Temporally Structured
Biological Response

Temporally Structured
Ecological Forcing Models
(*Temporal Autocorrelation*)

PREDICTOR MODELS

X

Climate, Habitat, Sargassum, Ecological

Stepwise Variable Selection with
Akaike's Information Criterion (AIC)

$$AIC = n * \log_e\left(\frac{SS_{residuals}}{n}\right) + 2K$$

GAJ MODEL

Residual Axes

Non-Temporally Structured
Biological Response

Non-Temporally Structured
Ecological Forcing Models

Model Selection Results

Model	Fit R^2_{adj} (Dtrnd.)	Period	Selected Predictors		F		R^2_{adj}		p-Value	
			Fit	*Dtrnd.*	*Fit*	*Dtrnd.*	*Fit*	*Dtrnd.*	*Fit*	*Dtrnd.*
Habitat	0.1738 (0.8262)	1970-2015	**'oilPLT' + 'artReef'**		239.12	-	**0.9137**	-	**0.0001**	-
Ecological	0.1773 (0.8227)	1982-2010	'precip'	**'amo' + 'oilPLT'**	3.94	6.75	0.0949	**0.2910**	0.0586	**0.0050**
Eutrophication	0.2218 (0.7782)	1987-2014	**'doTXf'**		9.69	-	**0.2434**	-	**0.0045**	-
Sargassum #1	0.3165 (0.6835)	2000-2015	**'middle1'**		5.15	-	**0.2167**	-	**0.0378**	-
Sargassum #2	0.3165 (0.6835)	2000-2015	'mouth2'		-	2.57	-	0.0949	-	0.0884

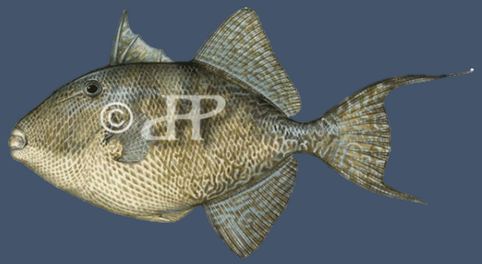
Model	Proportion of Total	Modeled Prop.	Total % Modeled
Habitat	0.1738	0.9137	16%
Ecological*	0.8227	0.291	24%
Eutrophication	0.2218	0.2434	5%
Sargassum #1	0.3165	0.2167	7%

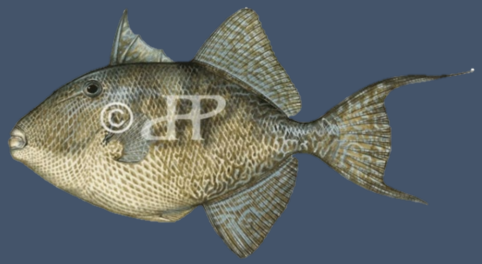
NO AEM CONSTRAINTS

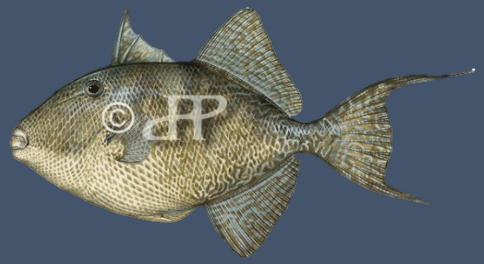
Reef Fish
Recruit Deviations
AEM Results

Temporal Detrending Results

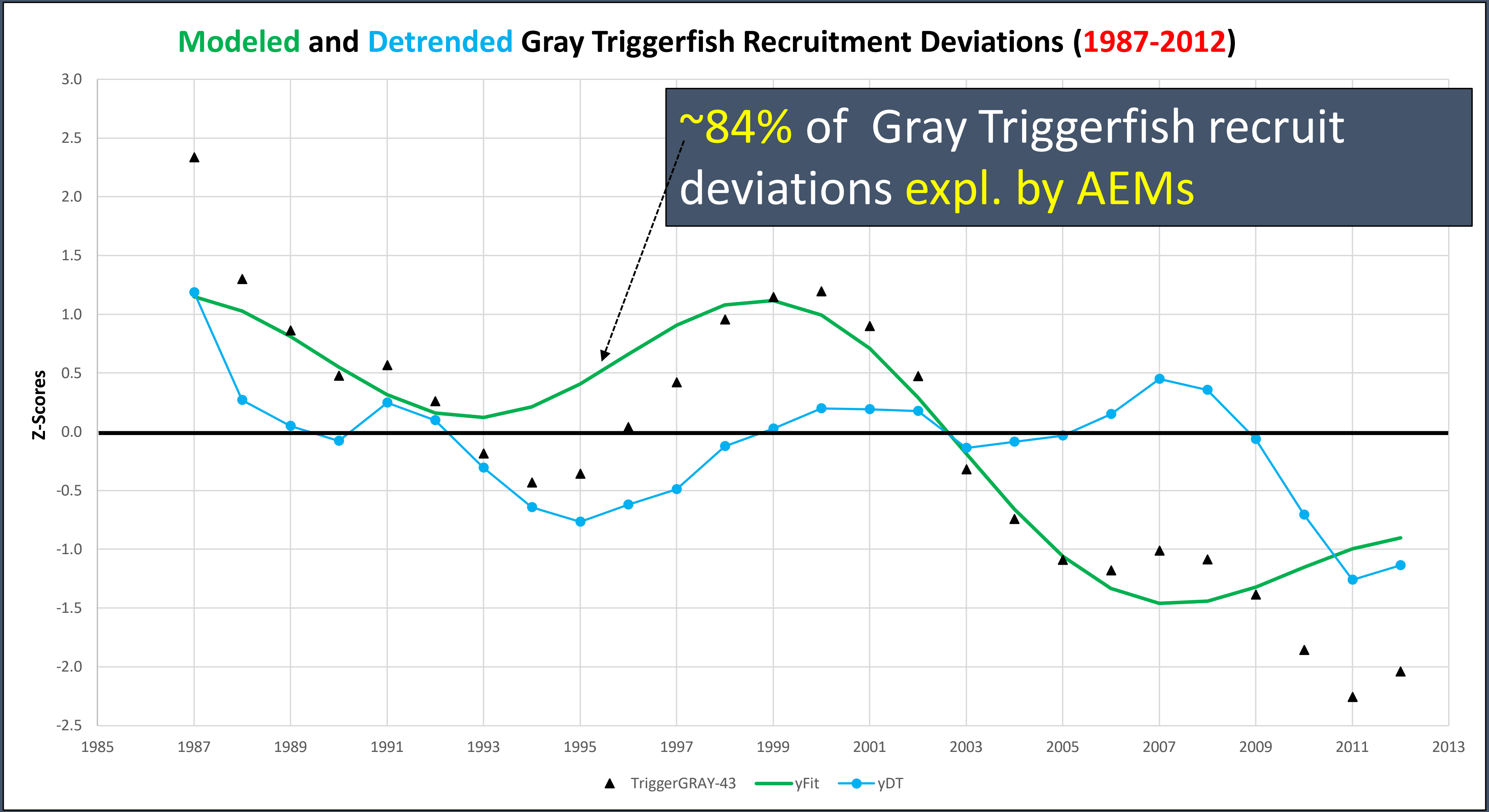
Response Group	Period	N	Λ_i^+ (Period 1)	Λ_i^+ (Period 2)	Λ_i^+ (Period 3)	F	R^2	R^2_{adj}	p-value
All Species	1993-2012	20				1.0	0.5229	-0.0071	0.5164
Hogfish/ Red Grouper	1992-2012	21				0.5	0.3416	-0.3168	0.8419
All Snappers	1993-2012	20				1.3	0.5825	0.1187	0.3701
Gray Triggerfish	1987-2012	26	Λ_1^+ (26 years)	Λ_4^+ (7 years)	Λ_2^+ (13 years)	43.7	0.8564	0.8368	**0.0001**



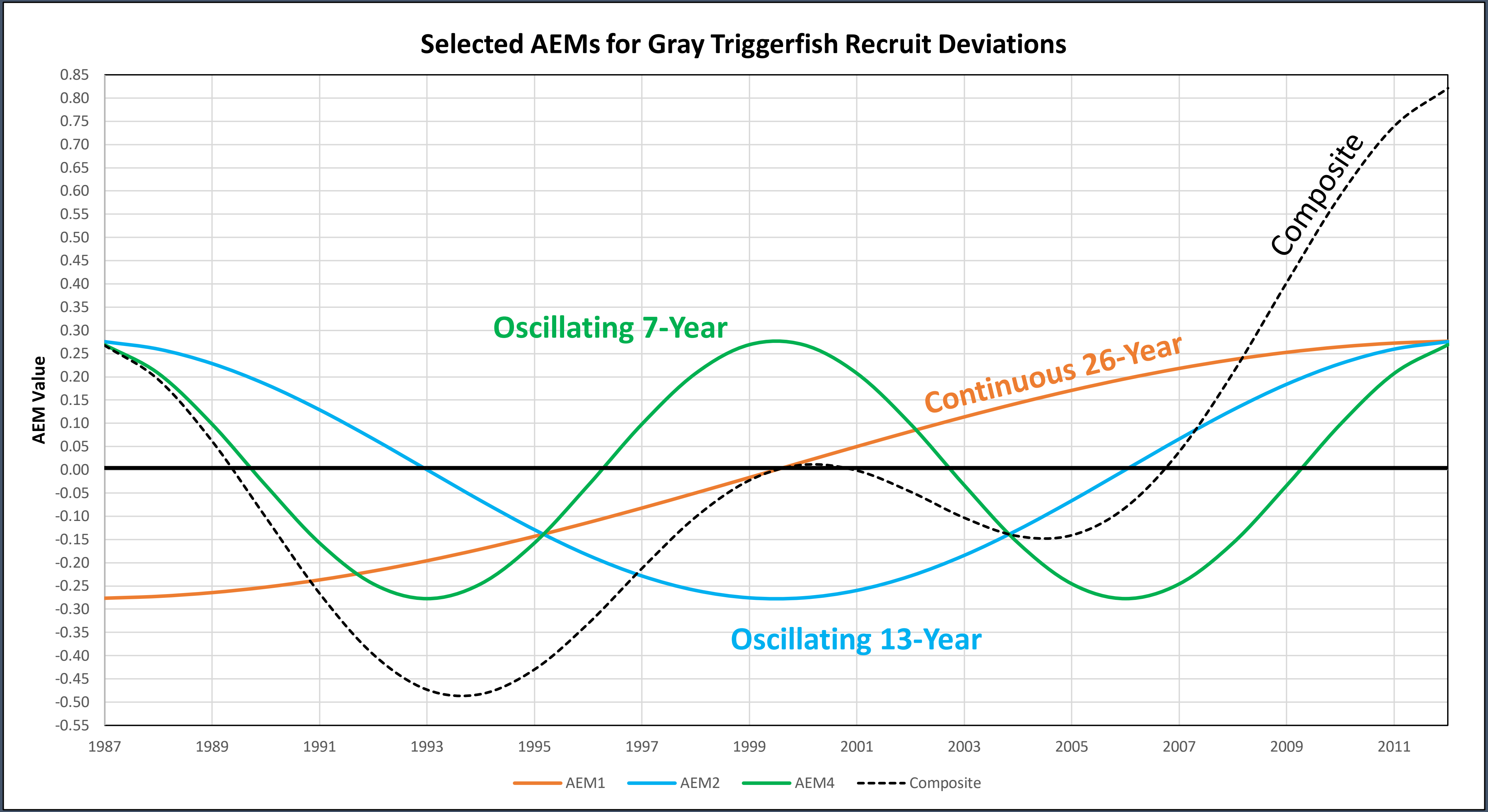




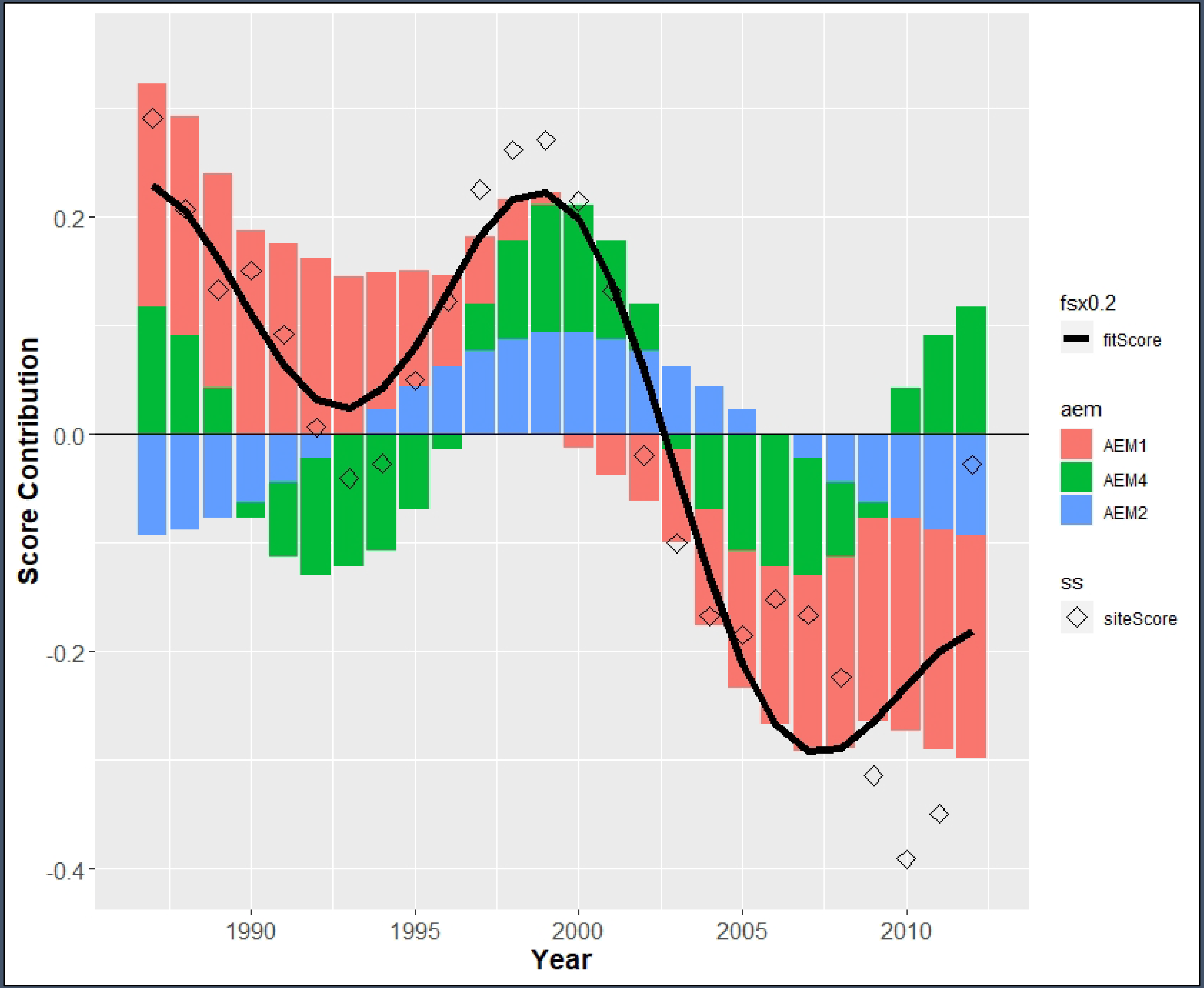
Temporal Detrending Results



Selected AEM Predictors



AEMs' Contributions to Fitted Scores



Temporal Autocorrelation Considerations

Response Group	Period	N	Λ_i^+ (Period)	Λ_i^+ (Period)	Λ_i^+ (Period)	F	R^2	R^2_{adj}	p-value
All Species	1993-2012	20				1.0	0.5229	-0.0071	0.5164
Hogfish/ Red Grouper	1992-2012	21				0.5	0.3416	-0.3168	0.8419
All Snappers	1993-2012	20				1.3	0.5825	0.1187	0.3701
Gray Triggerfish	1987-2012	26	Λ_1^+ (26 years)	Λ_4^+ (7 years)	Λ_2^+ (13 years)	43.7	0.8564	0.8368	**0.0001**

- ~84% of Gray Triggerfish recruitment deviation was explained by three (3) synthetic autocorrelation structures (AEMs)
- Short-term 7 and 13-year "decadal" signals apparent
- Long-term 26-year "multi-decadal" signal dominant
  - *Unaccounted for temporal processes?*
  - *Mechanistic bias in assessment model?*

Evaluating the Environmental Control Model

G-TRIG MODEL

Fitted Axes

Temporally Structured
Biological Response

Temporally Structured
Ecological Forcing Models
(*Temporal Autocorrelation*)

PREDICTOR MODELS

X

Climate, Habitat, Sargassum, Ecological

Stepwise Variable Selection with
Akaike's Information Criterion (AIC)

$$AIC = n * \log_e\left(\frac{SS_{residuals}}{n}\right) + 2K$$

G-TRIG MODEL

Residual Axes

Non-Temporally Structured
Biological Response

Non-Temporally Structured
Ecological Forcing Models

Temporal Autocorrelation Considerations

Gray Triggerfish		Selected Predictors		*F*		R^2_{adj}		*p*-value	
Predictor Model	Fit R^2_{adj}	Fit	Dtrnd	Fit	Dtrnd	Fit	Dtrnd	Fit	Dtrnd
All X	0.8368	*WhIbis+RytherNdx*	*SSTe+doTXf*	32.36	7.03	0.7150	0.3255	**0.0001**	**0.0044**
Food Web	-	*WhIbis+RytherNdx*	-	32.36	1.45	0.7150	0.1278	**0.0001**	0.2553
Water Temp.	-	*SeaLvl*	*SSTe*	25.29	5.21	0.4828	0.1441	**0.0001**	**0.0306**
Eutrophication	-	*doTXf*	-	11.74	0.51	0.3005	-0.1328	**0.0032**	0.7981

Temporal Autocorrelation Considerations

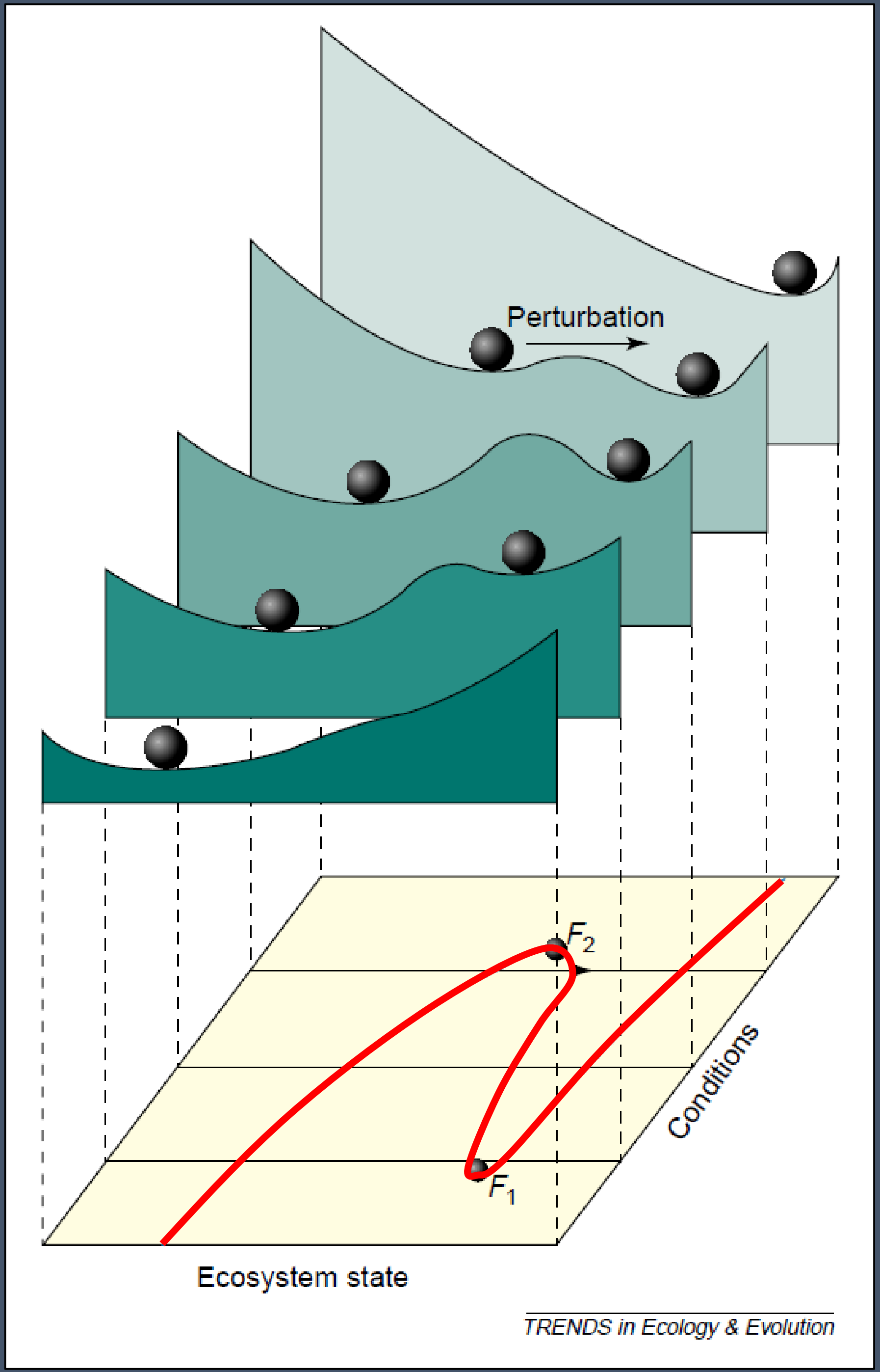
Gray Triggerfish		**Selected Predictors**		***F***		R^2_{adj}		***p*-value**	
Predictor Model	Fit R^2_{adj}	Fit	Dtrnd	Fit	Dtrnd	Fit	Dtrnd	Fit	Dtrnd
All **X**	0.8368	*WhIbis+RytherNdx*	*SSTe+doTXf*	32.36	7.03	0.7150	0.3255	**0.0001**	**0.0044**
Food Web	-	*WhIbis+RytherNdx*	-	32.36	1.45	0.7150	0.1278	**0.0001**	0.2553
Water Temp.	-	*SeaLvl*	*SSTe*	25.29	5.21	0.4828	0.1441	**0.0001**	**0.0306**
Eutrophication	-	*doTXf*	-	11.74	0.51	0.3005	-0.1328	**0.0032**	0.7981

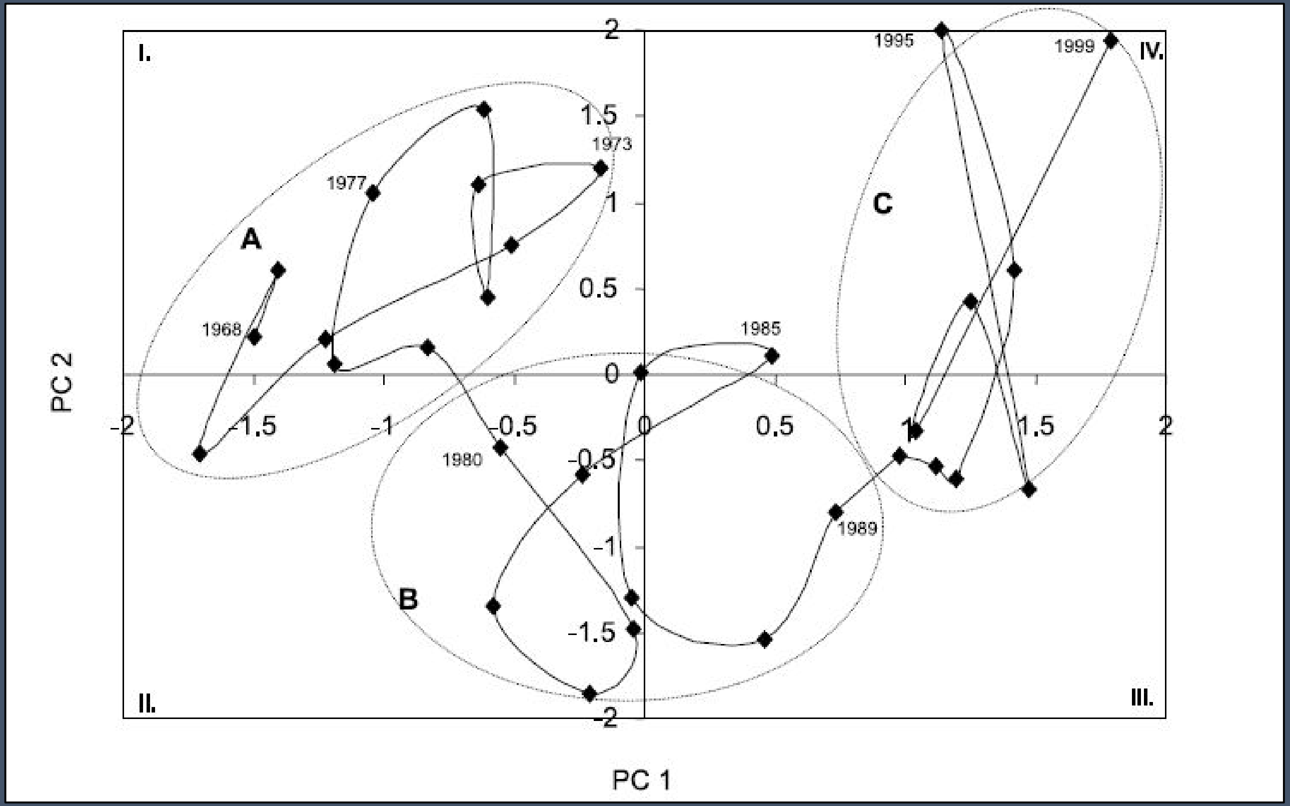
Discussion Points for the SSC

- Why do AEMs "work" at all for SS3 outputs?
  - Is this behavior expected given the way SS3 operates?
  - Can AEMs be used to "tune" the internal recruitment estimates?
  - Can AEMs be used to inform bias-corrections?
- Temporal *observation scale matters*
- AEMs as proxies/substitutes for unknown processes:
  - All models identified new covariates of interest
  - Potential for describing Gulf-wide teleconnections (e.g., AMO)
- Useful for informing simulation studies and management strategy evaluations?

Discussion?

Remember
Ecosystem Trajectories?





Marine ecosystem assessment in a fisheries management context

Jason S. Link, Jon K.T. Brodziak, Steve F. Edwards, William J. Overholtz, David Mountain, Jack W. Jossi, Tim D. Smith, and Michael J. Fogarty

Gulf of Mexico ESR Update (2017)

NOAA-NMFS Ecosystem Status Report Update for the Gulf of Mexico

(2017) Karnauskas, M., C.R. Kelble, S. Regan,C. Quenee, R. Allee, M. Jepson, A. Freitag, J.K. Craig, C. Carollo, L. Barbero, N. Trifonova, D. Hanisko, G. Zapfa. NOAA Tech. Memorandum NMFS-SEFSC-706, 56 p.

Gulf CAFE (1986-2013) Response Indicators - **Y**

23 Responses

- Population status estimates:
  - Upper trophic level spp. (x16)
  - Lower trophic level spp. (x1)
- Multispecies stock structure (x4)
- Fishing revenues (x1)
- Ryther index of large marine ecosystem overfishing (x1)

RESPONSE INDICATORS

Y

Living Marine Resource Structure and Function

Things we care about

Gulf CAFE (1986-2013) Predictor Indicators - X

PREDICTOR INDICATORS

X

Anthropogenic, Climate, and Environmental

Hypothesized to affect things we care about

15 Predictors

- Climatological Indicators:
  - Regional spatial scale (x4)
  - Basin-wide spatial scale (x1)
- Eutrophication estimates (x3)
- Fishery utilization:
  - Commercial extractions (x1)
  - Recreational effort (x2)
- Fishery ecosystem:
  - Basal resource levels (x1)
  - Habitat availability (x2)
- Coastal population change (x1)

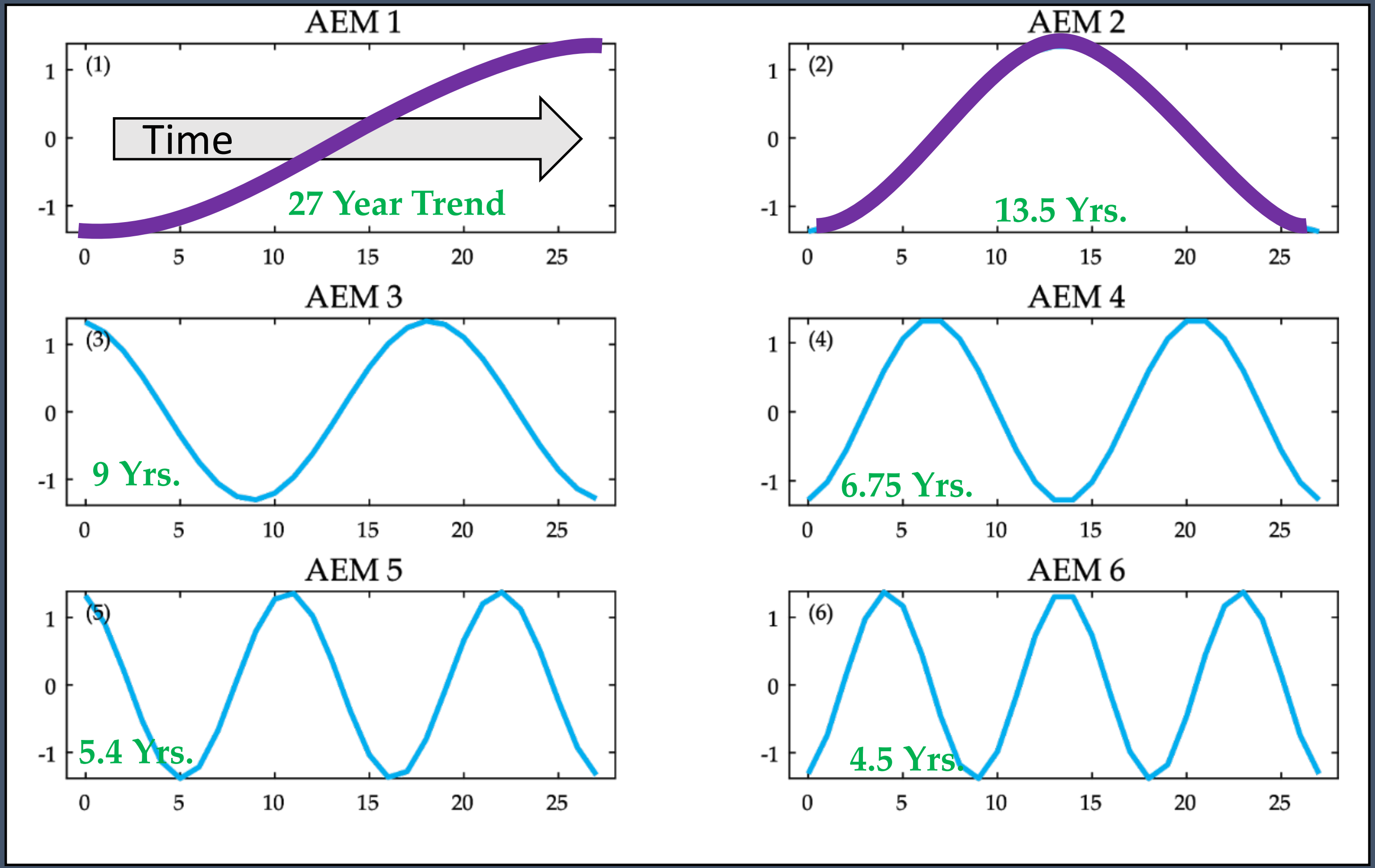
Modeling Time with AEMs

(Asymmetric Eigenvector Mapping)

PREDICTOR INDICATORS

AEM

Positive Temporal Autocorrelation



Selected temporal scales within the sampling universe (i.e., 1986-2013) relevant to fisheries ecosystem response

Constrained Analysis Framework

PREDICTOR INDICATORS

$\mathbf{AEM_{Sel}}$

Positive Temporal Autocorrelation

Effect ?

ONE WAY

RESPONSE INDICATORS

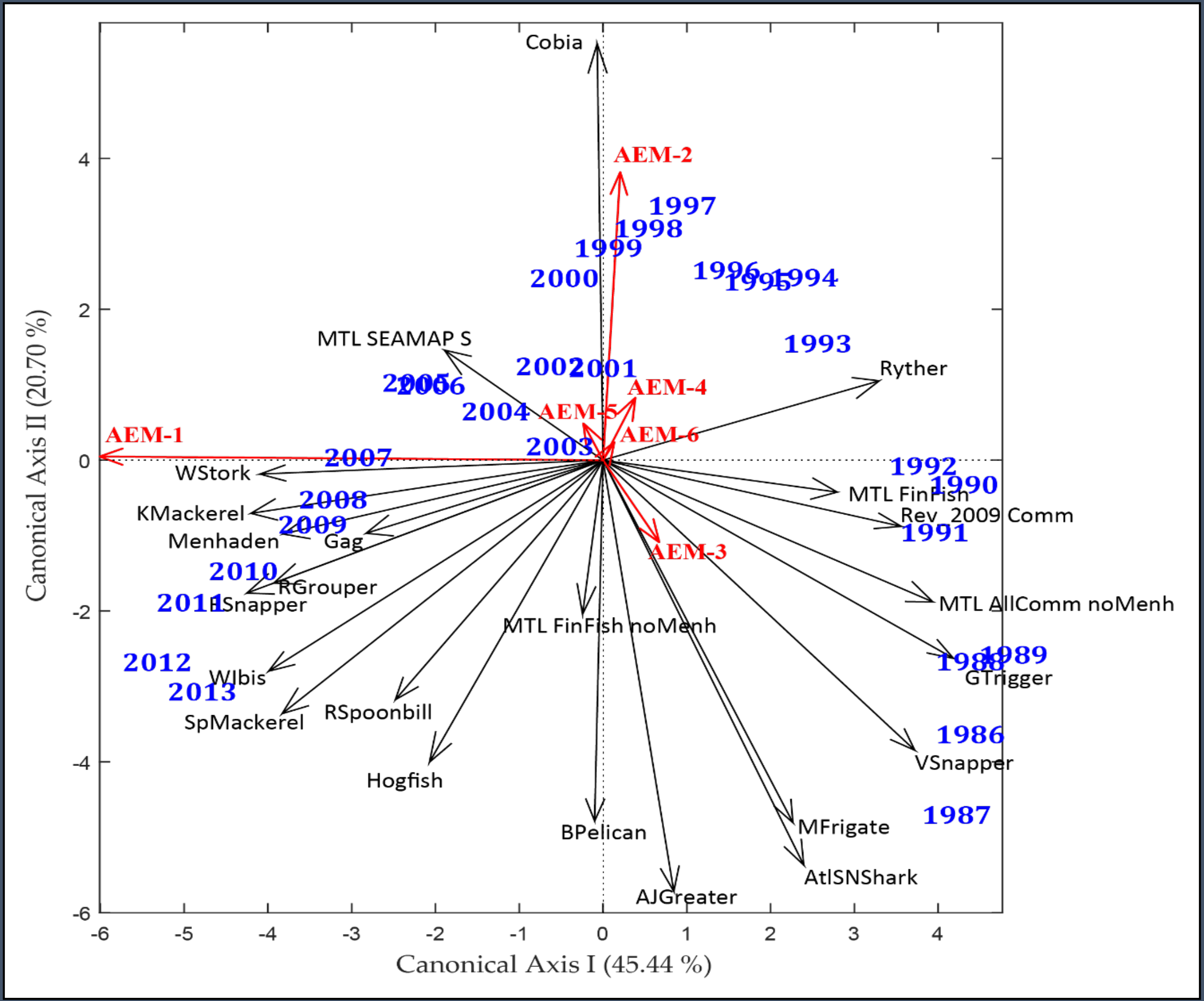
Y

Living Marine Resource Structure and Function

Hypothesized to affect things we care about

Things we care about

Gulf CAFE AEM Model



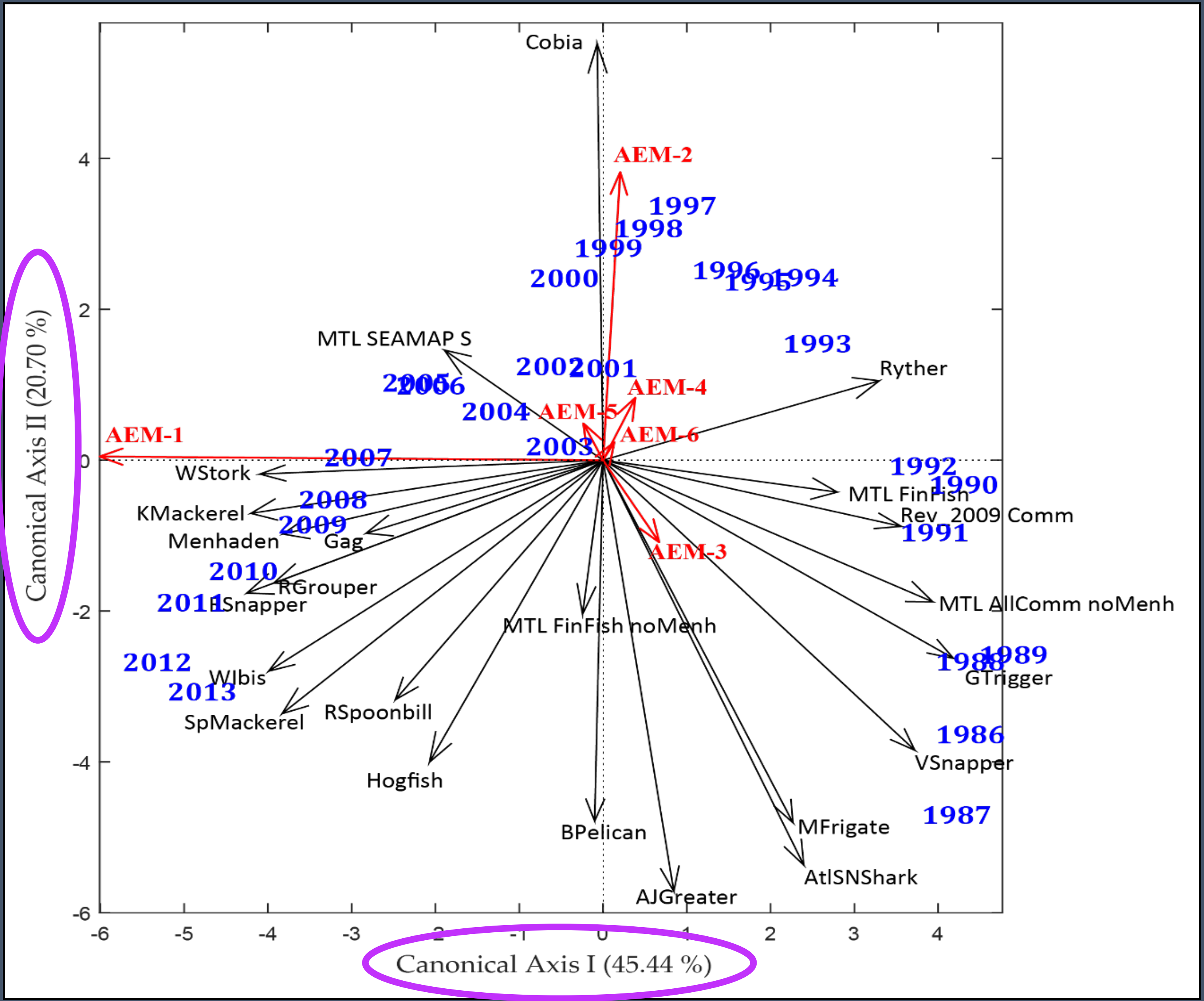
F = 15.31

R^2 = 0.8139

R^2_{adj} = 0.7608

p-value = 0.0001

Gulf CAFE AEM Model



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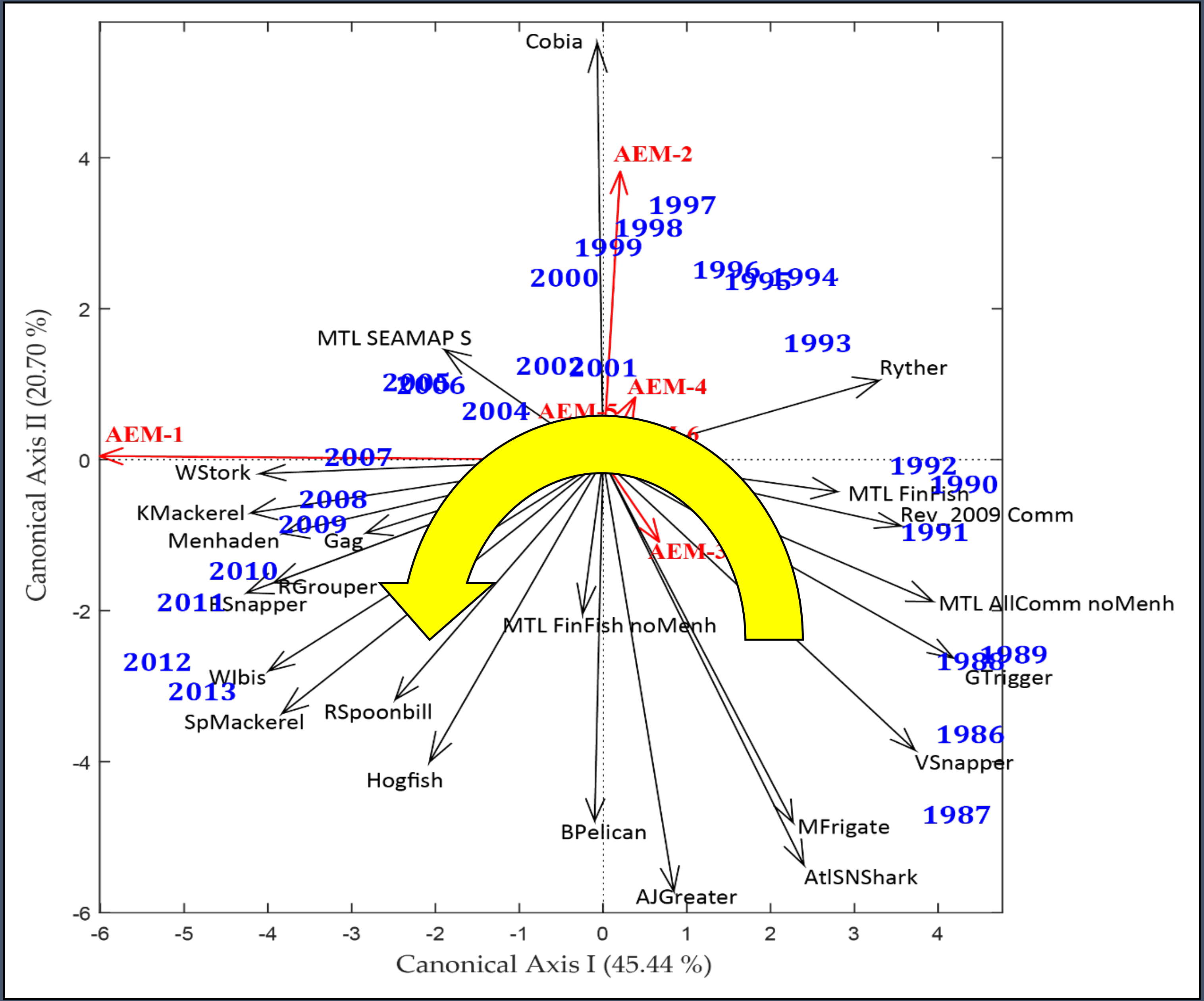
Gulf CAFE AEM Model



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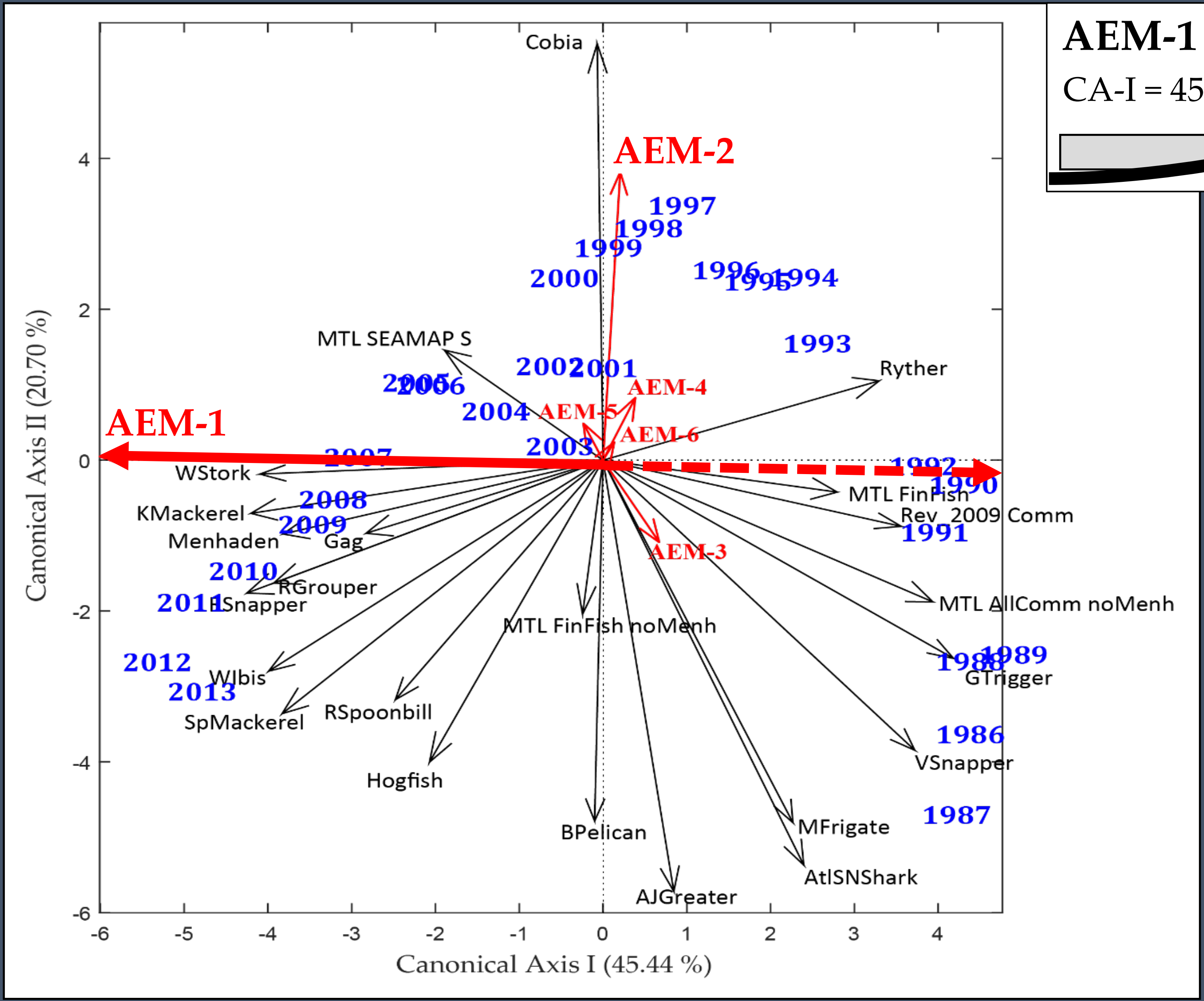
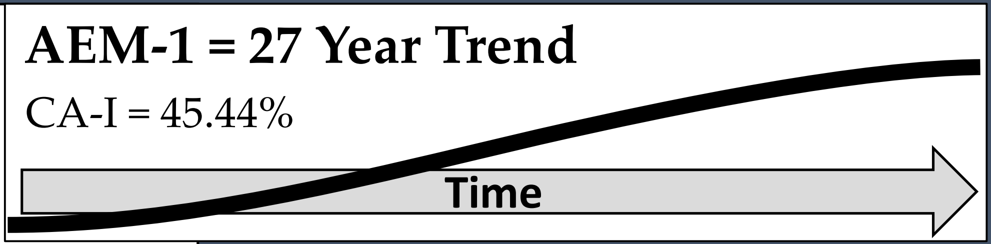
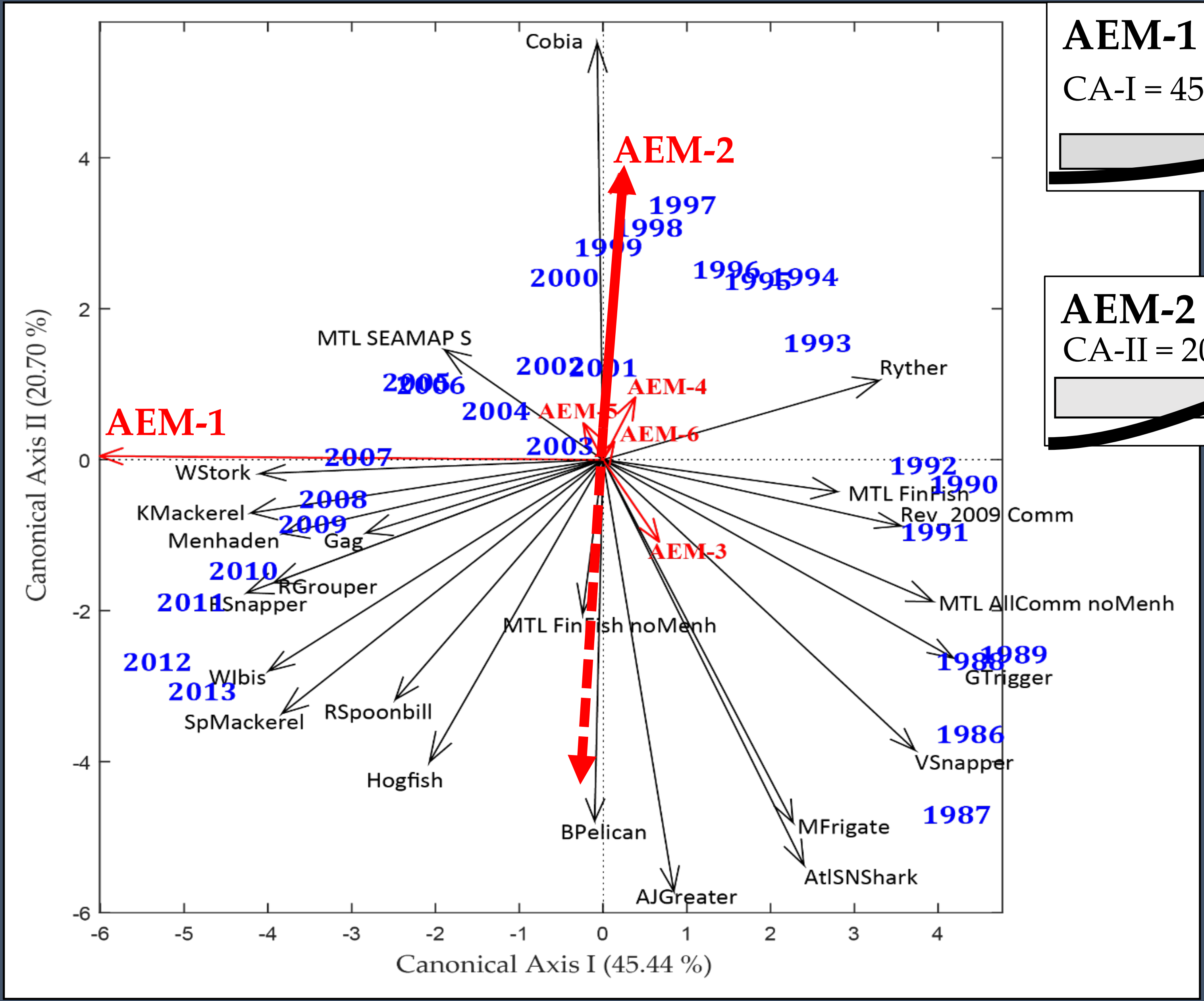
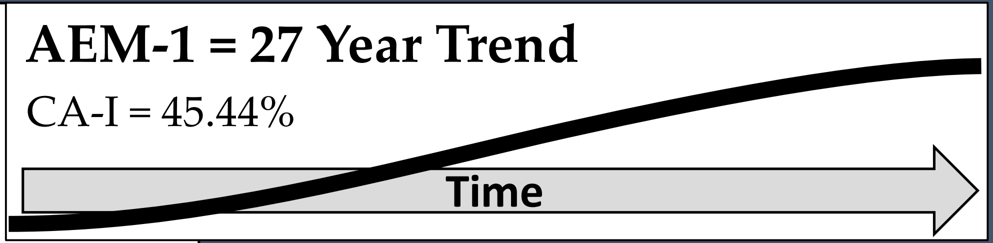
Gulf CAFE AEM Model



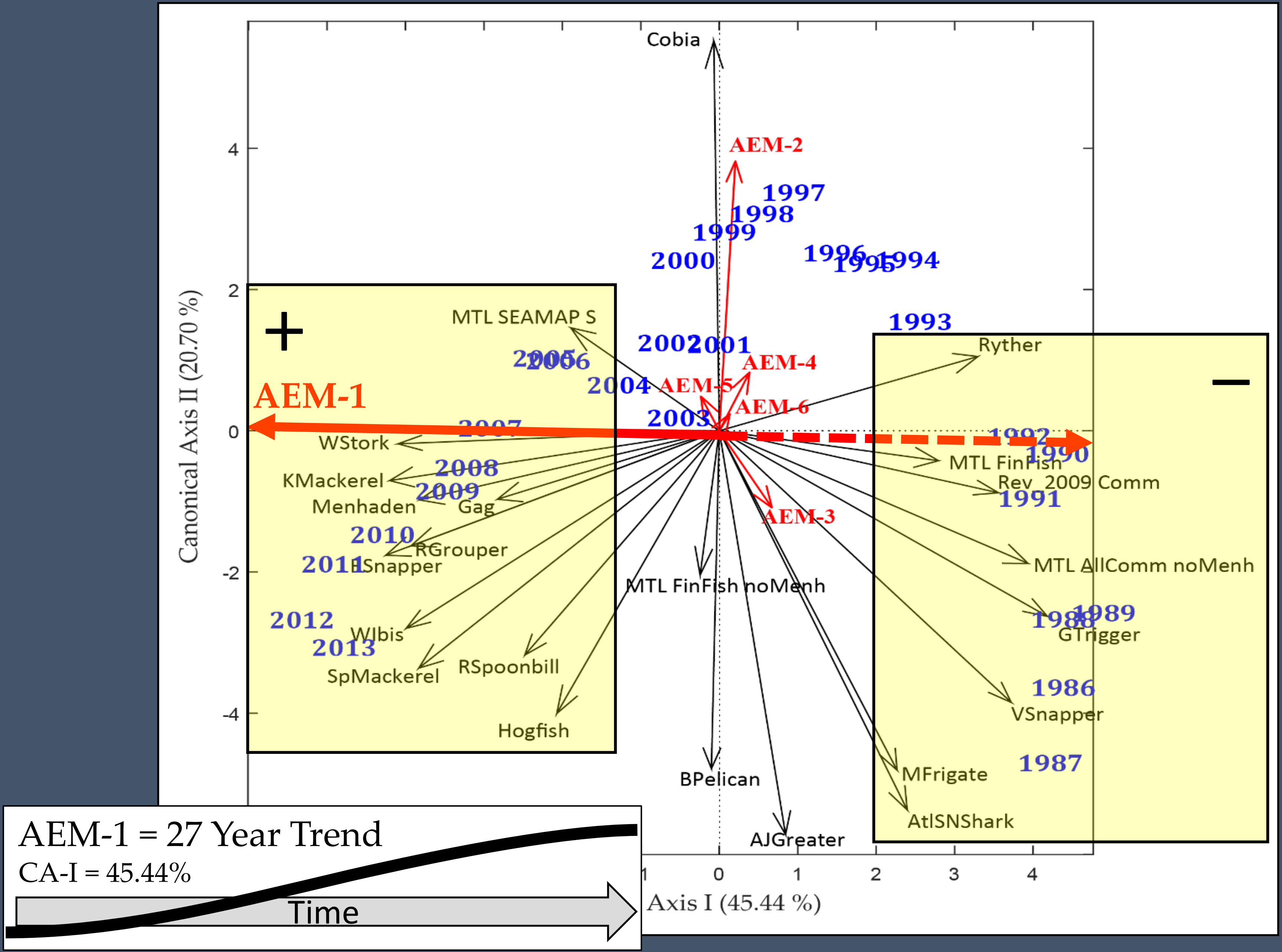


Gulf CAFE AEM Model





Gulf CAFE AEM Model



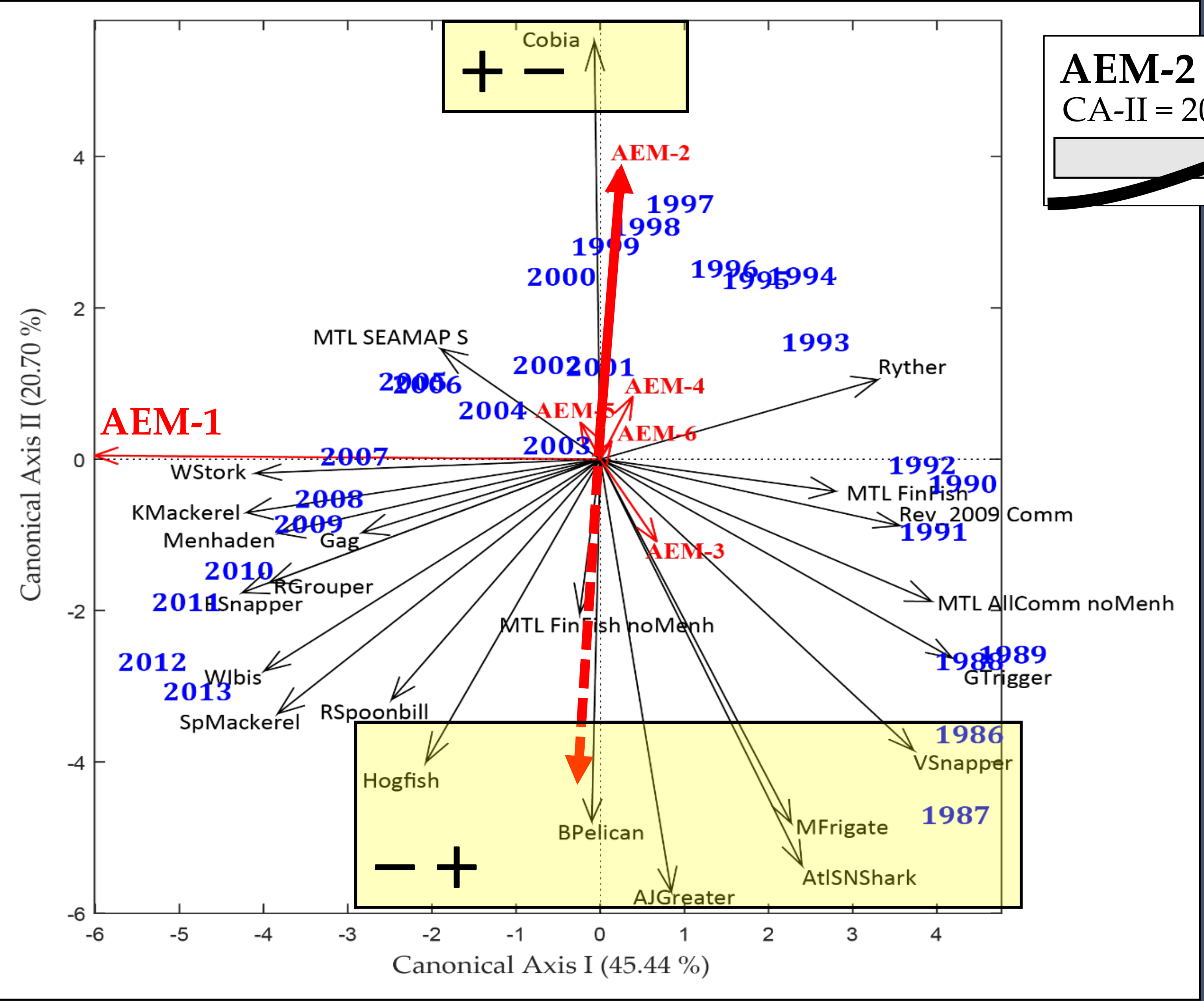
Increase over time

- ↑ Red Snapper
- ↑ King Mackerel
- ↑ Red Grouper
- ↑ Menhaden
- ↑ Wood Stork
- ↑ MTL SEAMAP

Decrease over time

- ↓ Gray Triggerfish
- ↓ MTL Com. Catches
- ↓ Com. Revenues
- ↓ MTL Com. Finfish Catch
- ↓ Ryther Index
- ↓ Vermillion Snapper

Gulf CAFE AEM Model



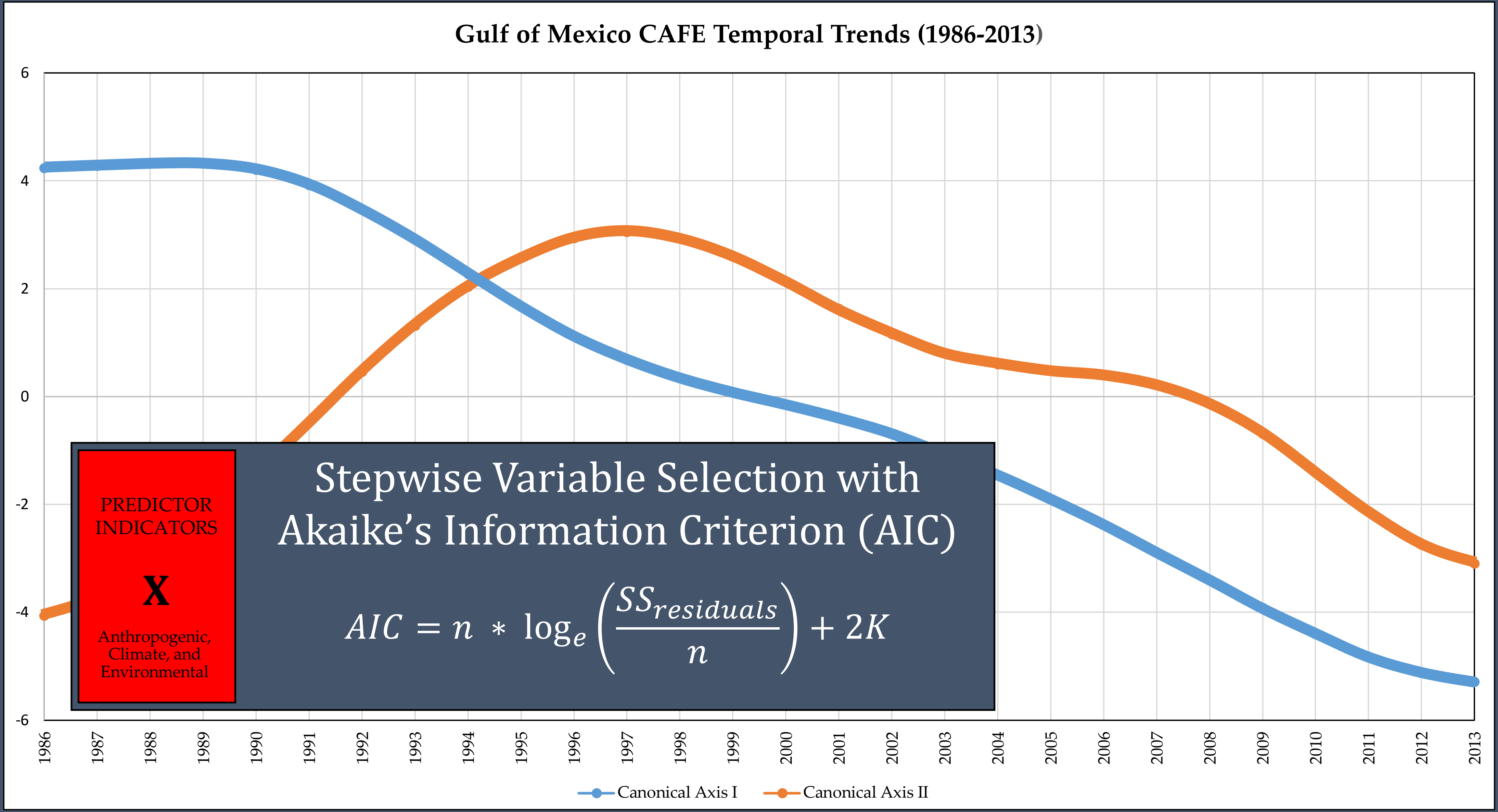
Up-Down over time

↑↓ Cobia

Down-Up over time

↓↑ Greater Amberjack
↓↑ Atl. Sharpnose Shark
↓↑ Mgnfcnt. Frigatebirds
↓↑ Brown Pelicans
↓↑ Hogfish

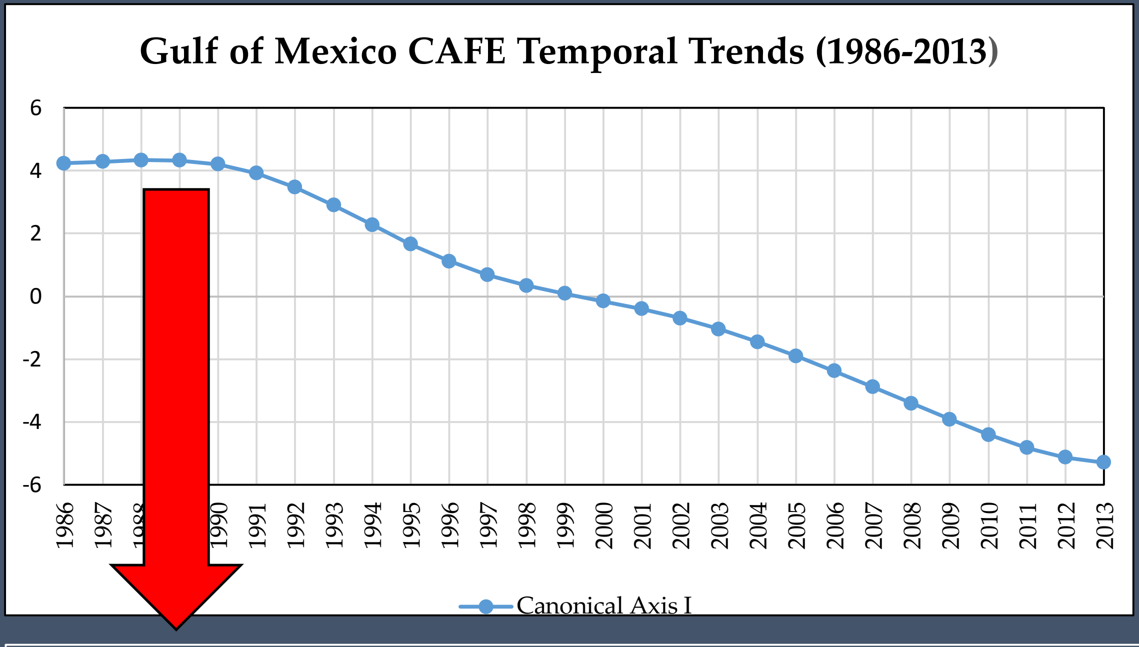
Gulf CAFE Trends & Predictor Influences



Stepwise Variable Selection with Akaike's Information Criterion (AIC)

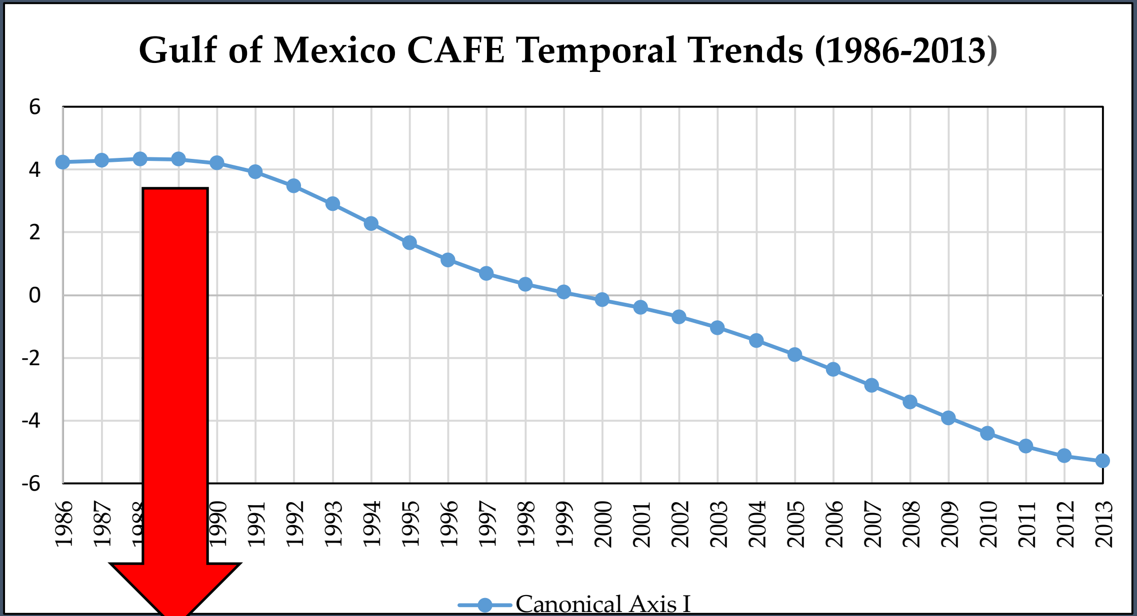
$$AIC = n * \log_e\left(\frac{SS_{residuals}}{n}\right) + 2K$$

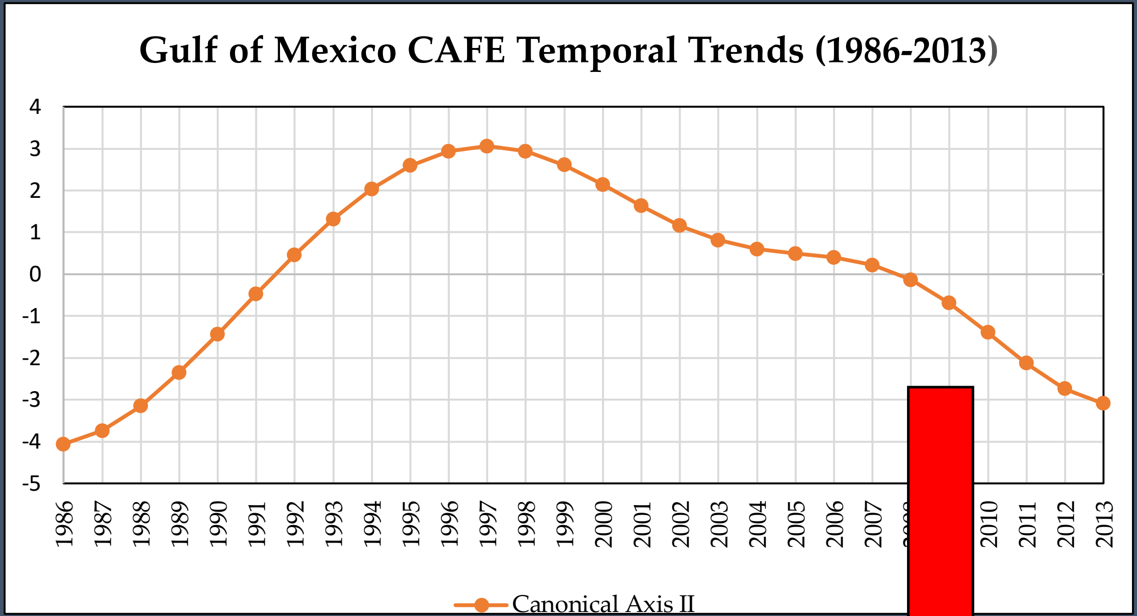
Temporally Structured Predictors



- Net change in number of oil platforms Gulf-wide
- Atlantic Multidecadal Oscillation (AMO)
- Total # of recreational fishing trips taken
- Sea surface temperature (SST) in eastern Gulf

Temporally Structured Predictors





- Net change in number of oil platforms Gulf-wide
- Atlantic Multidecadal Oscillation (AMO)
- Total # of recreational fishing trips taken
- Sea surface temperature (SST) in eastern Gulf

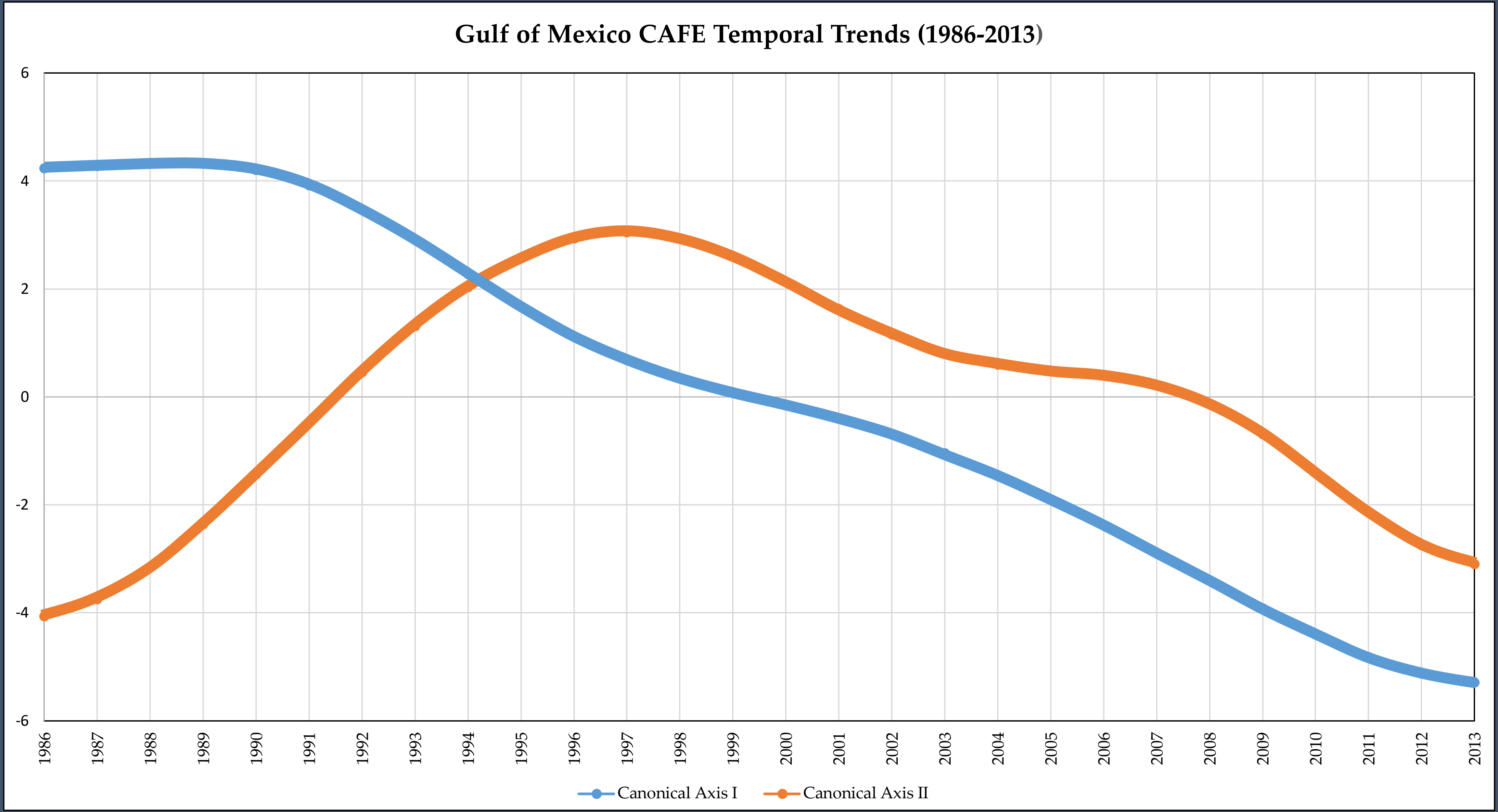
- Net change in # of artificial reefs (excl. oil platforms)

AEM and Variation Partitioning Summary

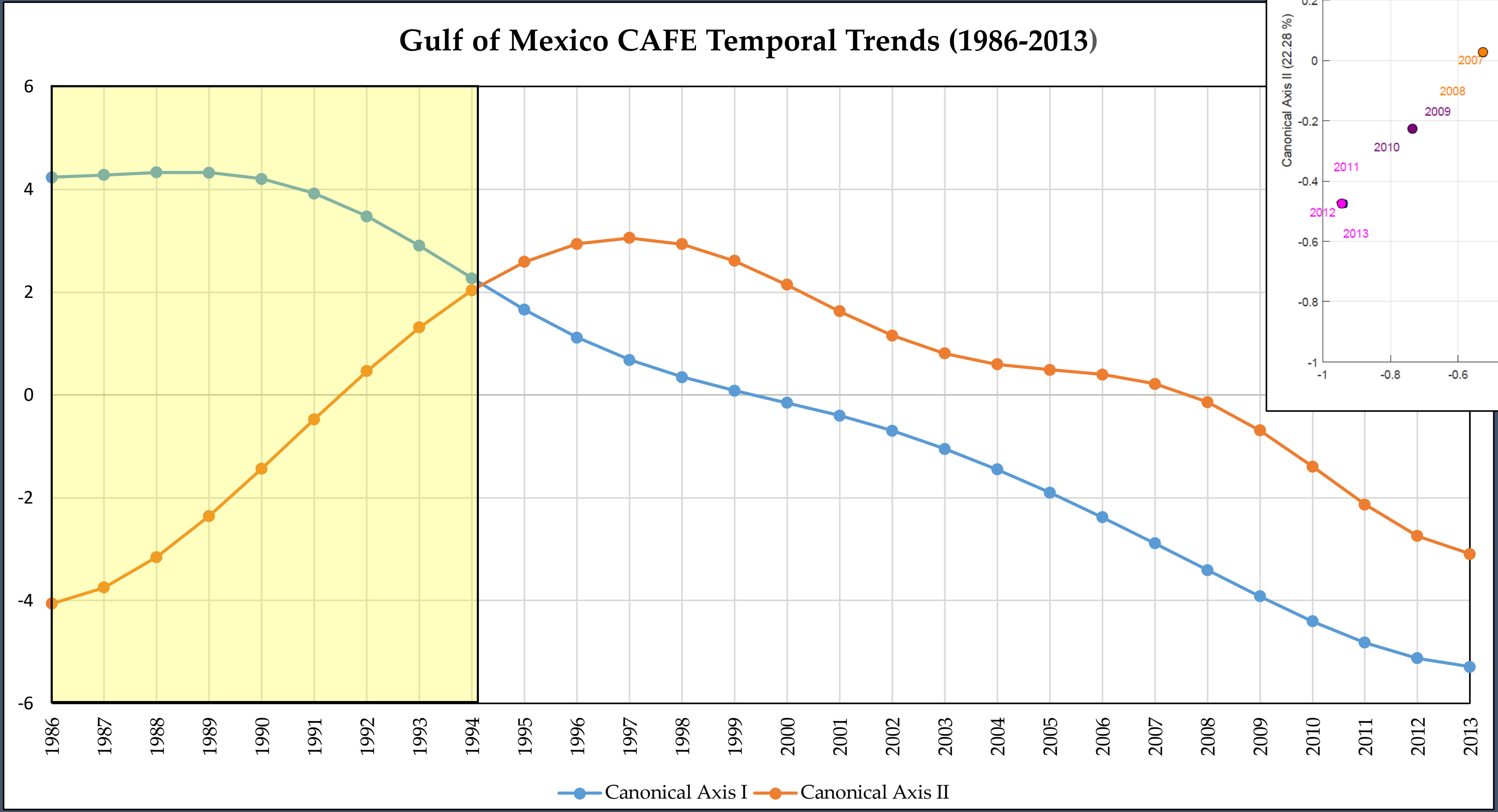
- The Gulf CAFE response followed two major temporal trends
  - 27 years (dominant)
  - 13.5 years (secondary)
- 27 yr. → Discouraging: Commercial indices
  → Encouraging: UT spp. & Structural
- 13.5 yr. → Discouraging: Cobia stock
  → Encouraging: UT spp. & System health

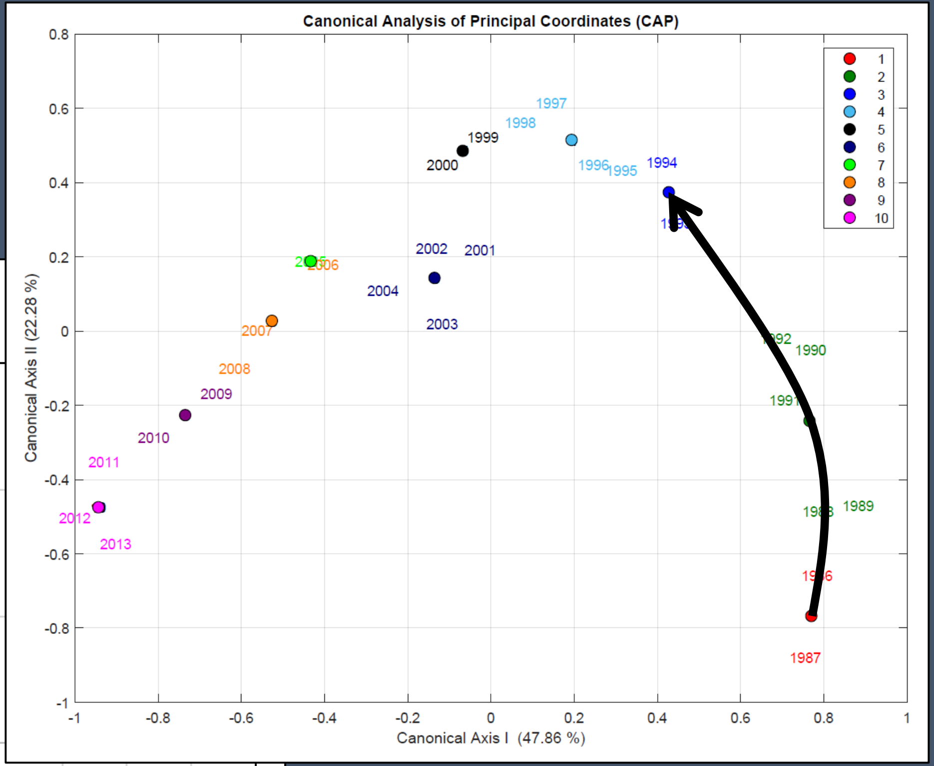
Gulf CAFE
Ecosystem Trajectory
(1986-2013)

Gulf CAFE Response Trends

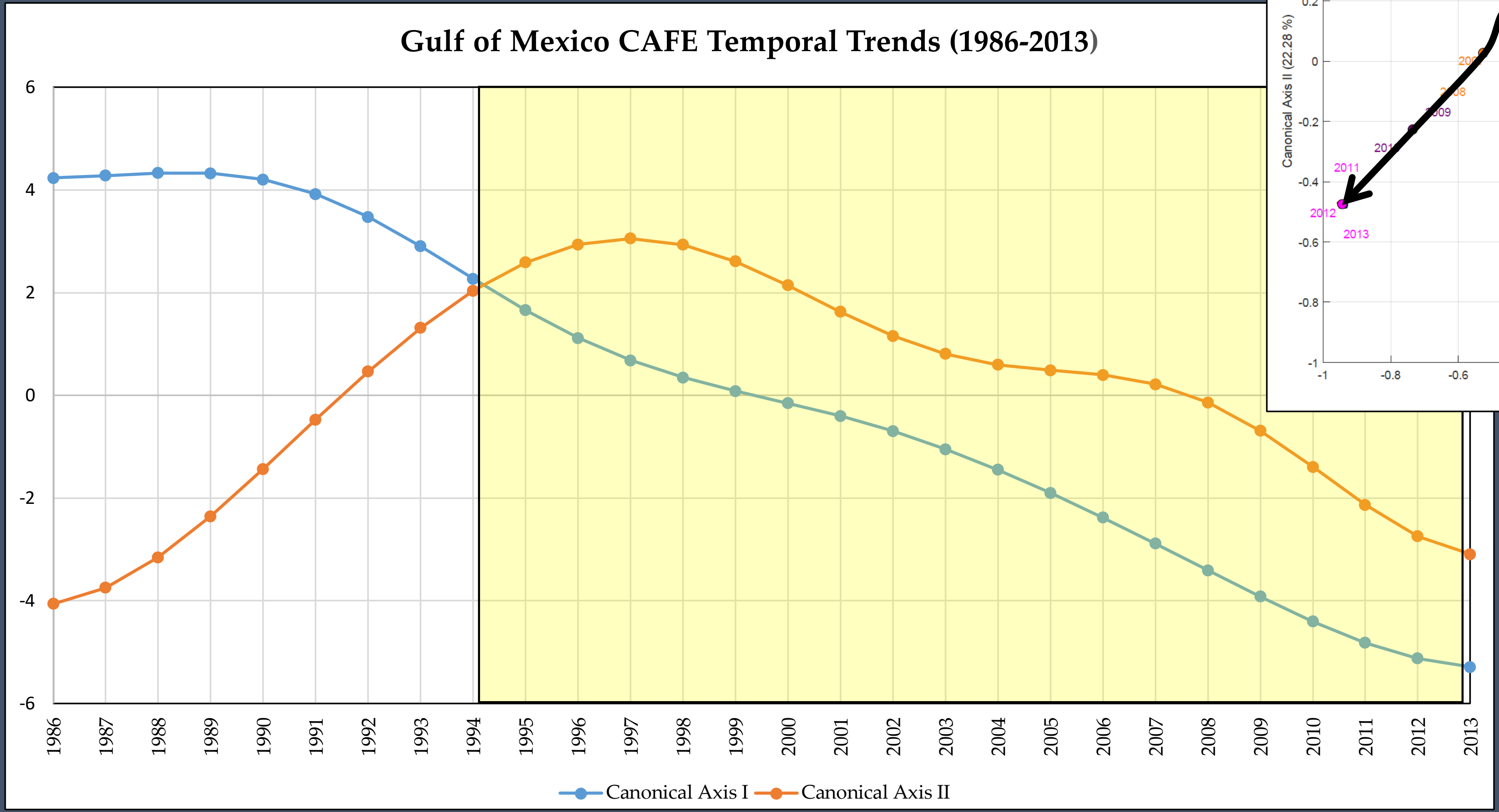


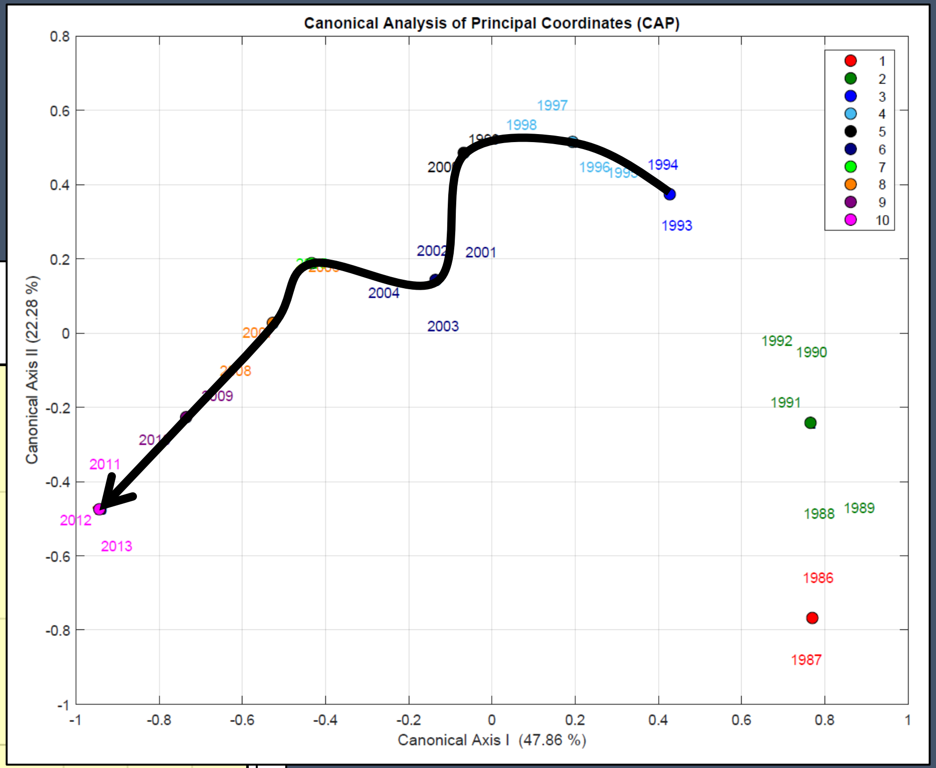
Gulf CAFE Response Trends





Gulf CAFE Response Trends





Linking the ball-and-cup analogy and ordination trajectories to describe ecosystem stability, resistance, and resilience

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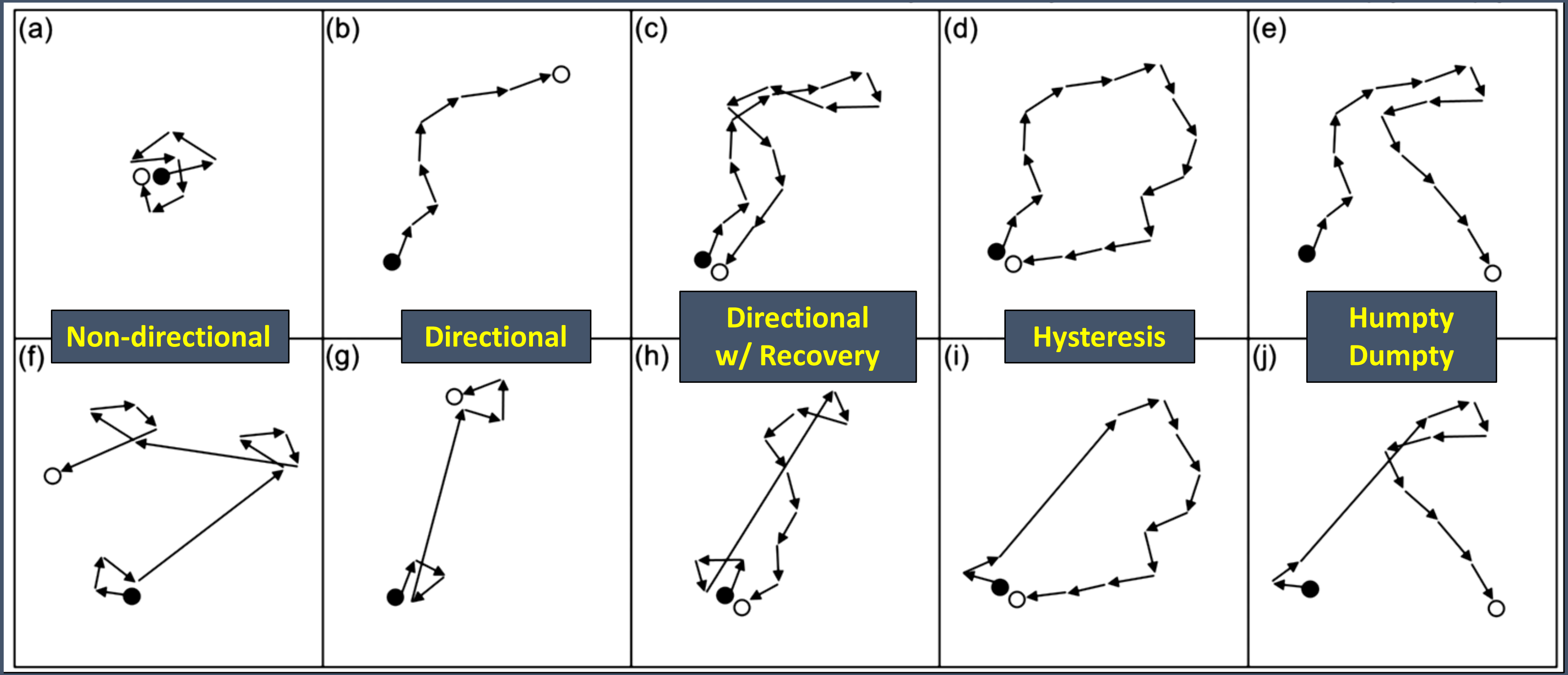
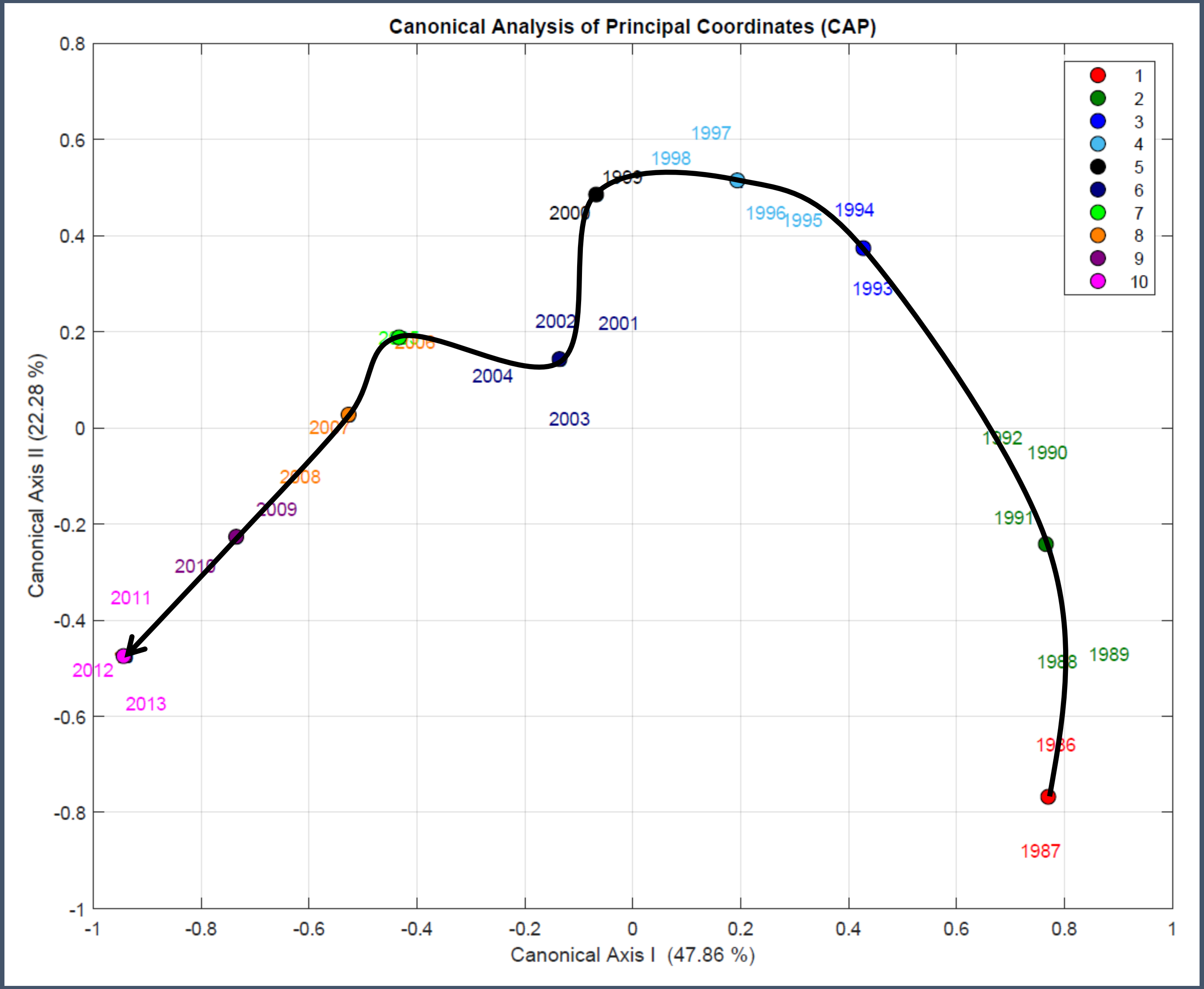
Ecosystem Trajectories

Gradual

Rapid



Gulf of Mexico CAFE Trajectory



- Ecosystem Status Report for Gulf of Mexico (2017)
- Period: 1986-2013
- 23 Response indicators of marine resource structure and function
- Gradual directional change? Humpty dumpty?

Discussion Points for the SSC

- Identify trade-offs?
  - Between response states and long-term CAFE changes
  - Can see the effects of management on the system's LMRs
- Useful for multispecies complex monitoring?
- How to operationalize results for fishery management?
  - Update risk probabilities for management options (implicit)
  - Implementation of covariates in assessment models (explicit)
  - Fishery management plan control rules based on system state placement, and any trade-offs elucidated (explicit)

Discussion?

fin.