Assessing the effects of freshwater inflows and other key drivers on the population dynamics of blue crab and white shrimp using a multivariate time-series modeling framework

Dr. Edward J. Buskey

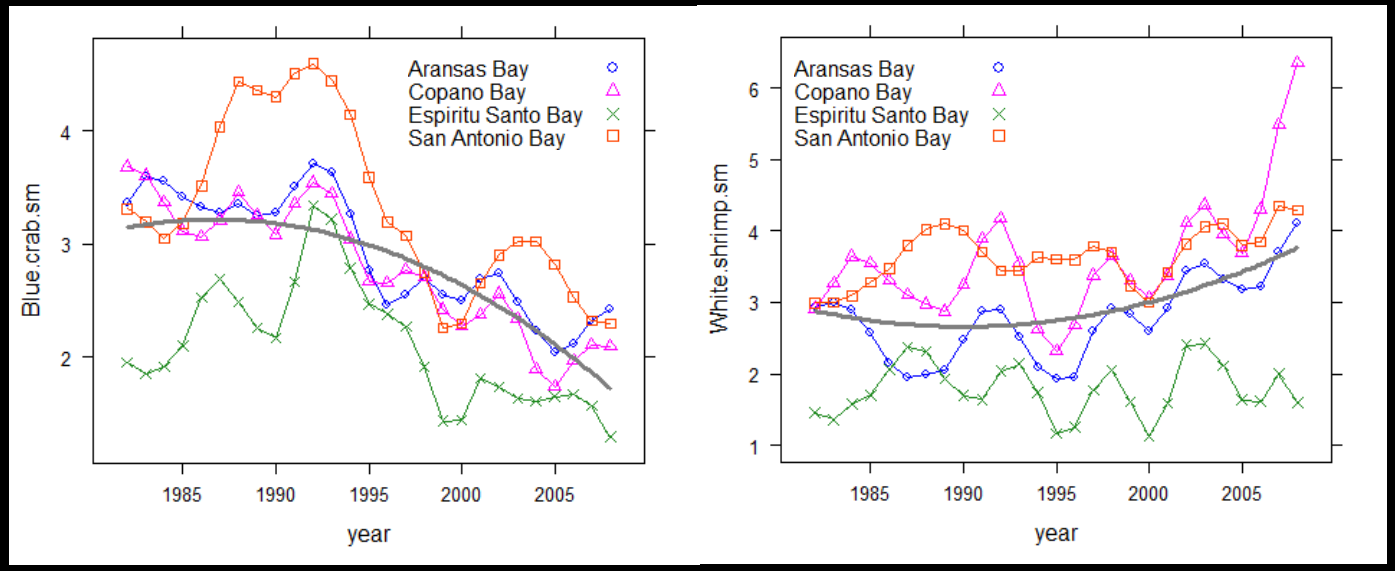
Dr. Lindsay P. Scheef

Dr. Jianhong Xue

Sara Smith

Project Goals

- Compose a review of literature examining blue crab and white shrimp populations
- Assess the drivers of blue crab and white shrimp population dynamics using multivariate autoregressive (MAR) models
  - Texas Parks and Wildlife Department Coastal Fisheries monitoring data



Project Timeline

Literature review

Tentative timeline	Accomplishments
2014 Apr-Jul	✓ Compose annotated bibliography ✓ Outline structure for review
2014 Aug-Dec	✓ Complete annotated bibliography ✓ Begin literature review report
2015 Jan-Mar	• Continue composition of literature review report
2015 Apr-Aug	• Complete final literature review • Present results at final workshop • Submit final report • Submit manuscript for publication

Project Timeline

Data analysis

Tentative timeline	Accomplishments
2014 Apr-Jul	✓ Acquire and prepare datasets for model application
2014 Aug-Dec	✓ Meet with data managers and analysts ✓ Continue to prepare datasets for model application • Construct and assess preliminary models
2015 Jan-Mar	• Select and apply final models to data • Compose data analysis report
2015 Apr-Aug	• Prepare final report • Present results at final workshop • Submit final report • Submit data and annotated R code

Methods

Literature review

Sara

MAR-1 Model

$$\underbrace{X_{t+1}}_{\text{Next abundance value}} = \underbrace{A}_{\text{Constant}} + \underbrace{BX_t}_{\text{Influence of each species}} + \underbrace{CU_t}_{\text{Influence of other factors}} + \underbrace{E_t}_{\text{Error}}$$

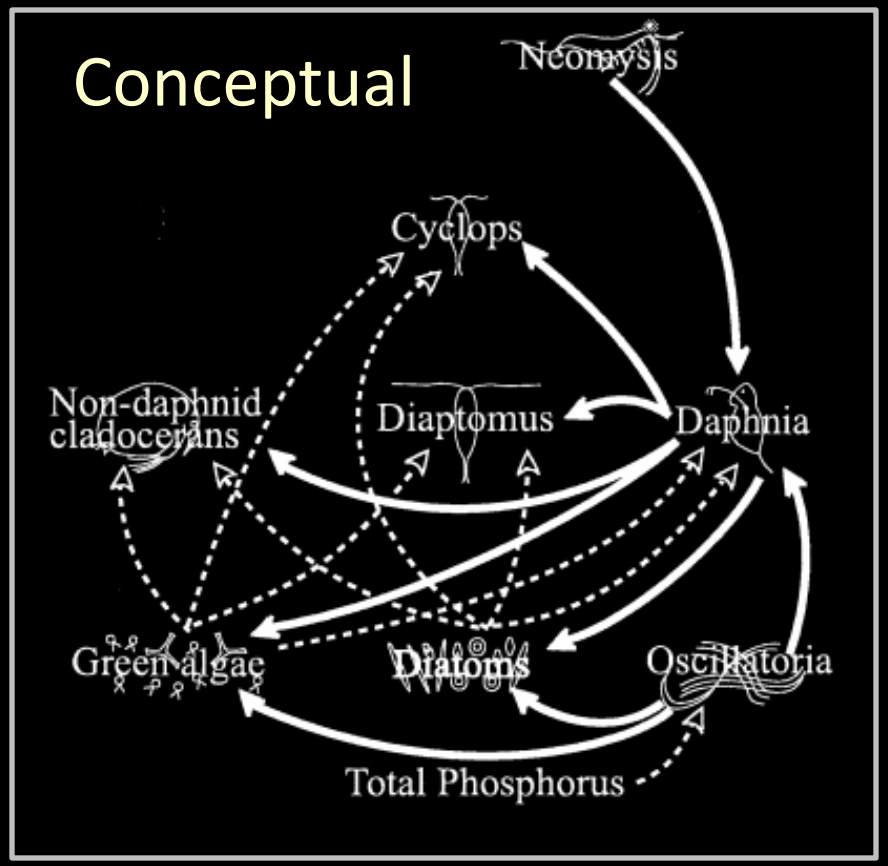
Next abundance value = Constant + **Influence of each species** + **Influence of other factors** + Error

MAR-1 Model

$$\boldsymbol{X}_{t+1} = \boldsymbol{A} + \boldsymbol{B}\boldsymbol{X}_t + \boldsymbol{C}\boldsymbol{U}_t + \boldsymbol{E}_t$$

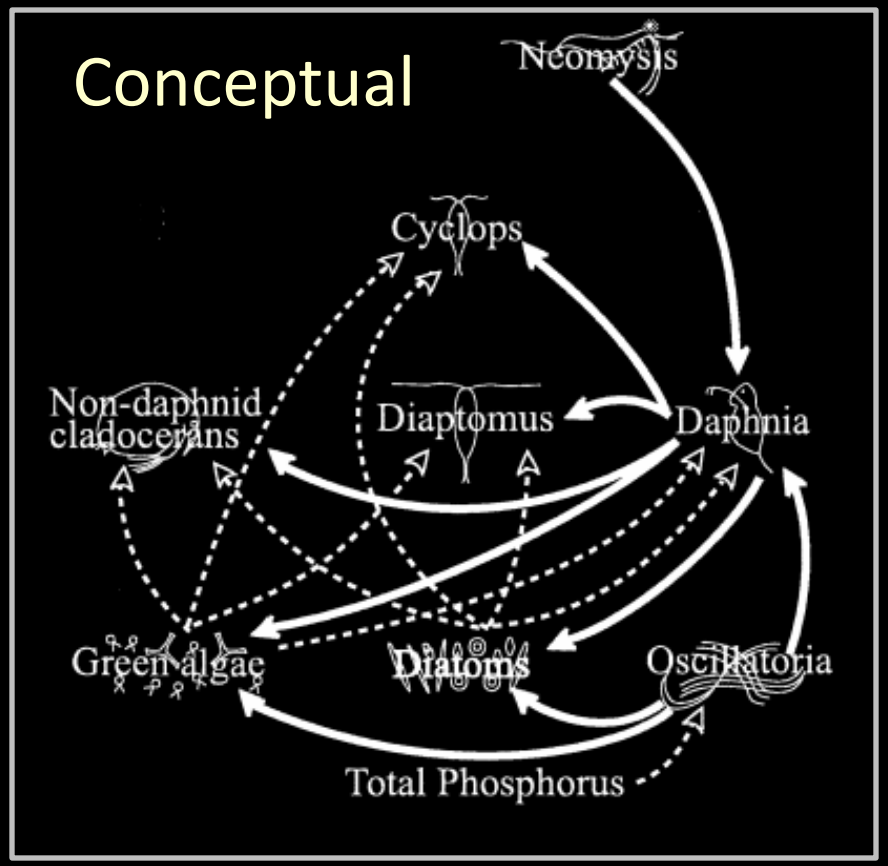
	Species					Environmental		
Species	1	2	3	…	p	1	…	q
1	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
2	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
3	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

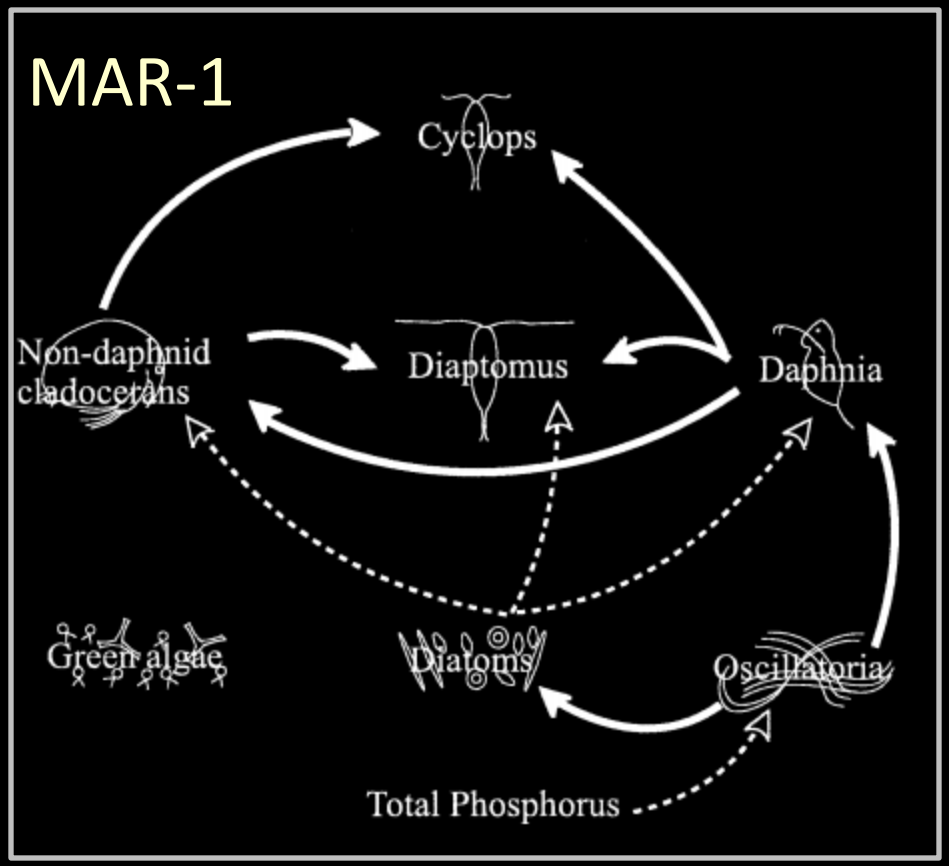
Interaction webs from MAR-1 analysis



Hampton et al. 2006

Interaction webs from MAR-1 analysis





Hampton et al. 2006

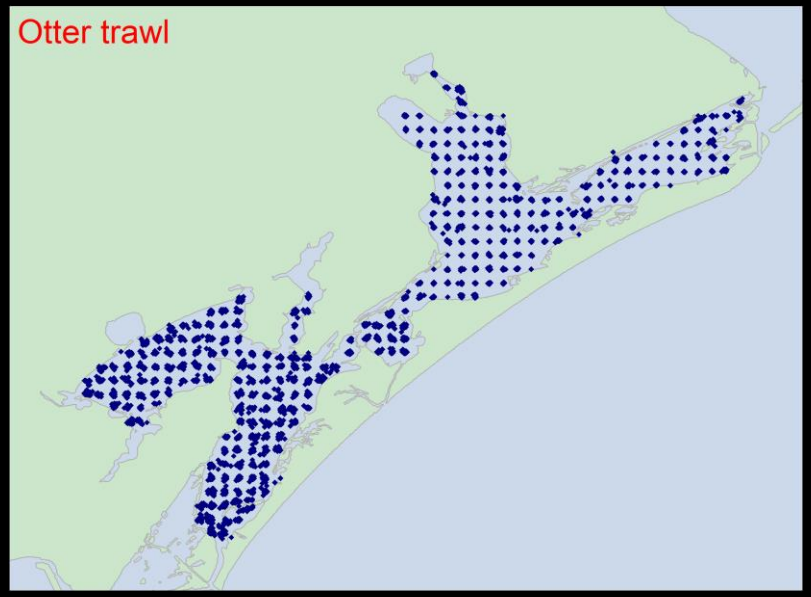
Data

Data type	Source
Species abundance time-series	TPWD Coastal Fisheries monitoring program
Water quality parameters	TPWD Coastal Fisheries monitoring program Mission-Aransas NERR System-Wide Monitoring Program Texas Coastal Ocean Observation Network
Meteorological data	Mission-Aransas NERR System-Wide Monitoring Program Texas Coastal Ocean Observation Network NOAA National Climatic Data Center
Rain gauge data	U.S. Geological Survey
River flow gauge data	U.S. Geological Survey
Climate oscillation indices	NOAA Climate Prediction Center
Along-shore current patterns	Texas Automated Buoy System
Commercial landing data	Marine Aquatic Products Reports (TPWD)

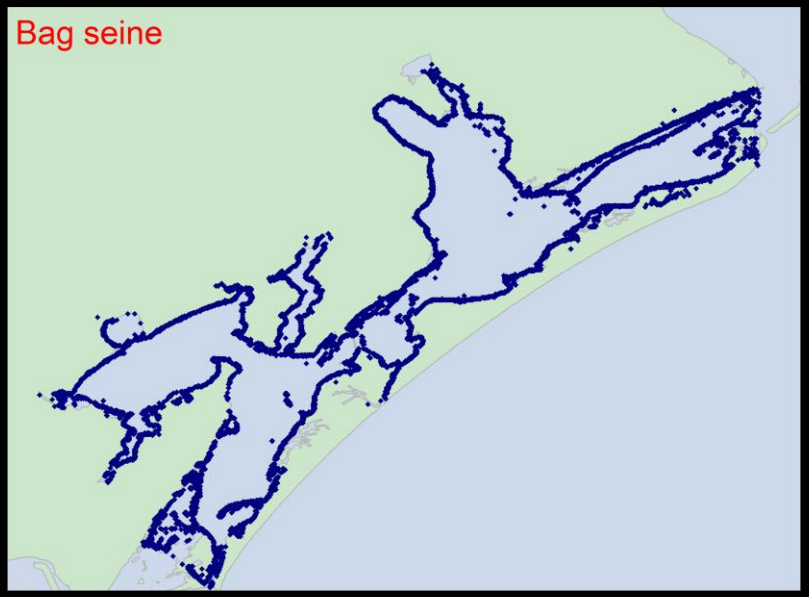
TPWD Survey Data

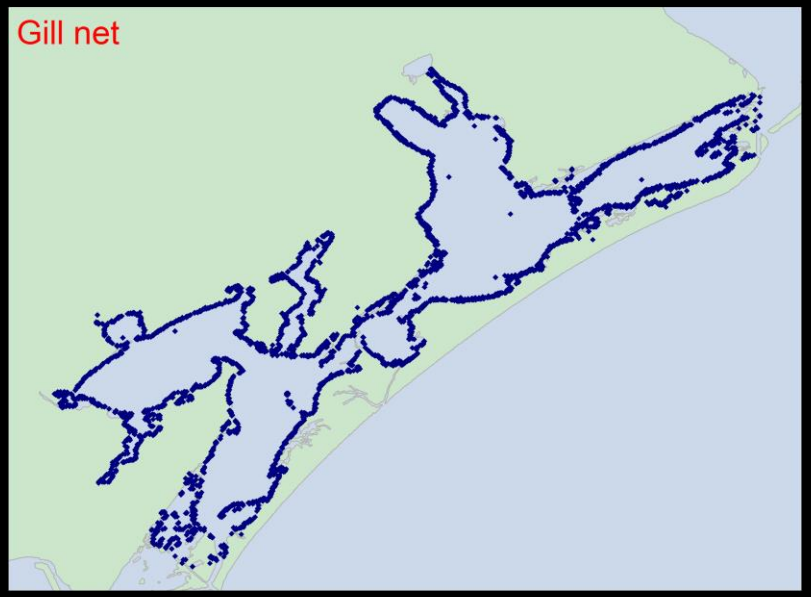
Otter trawl Data

(1982 – 2013)



Bag seine Data (1976 – 2013)



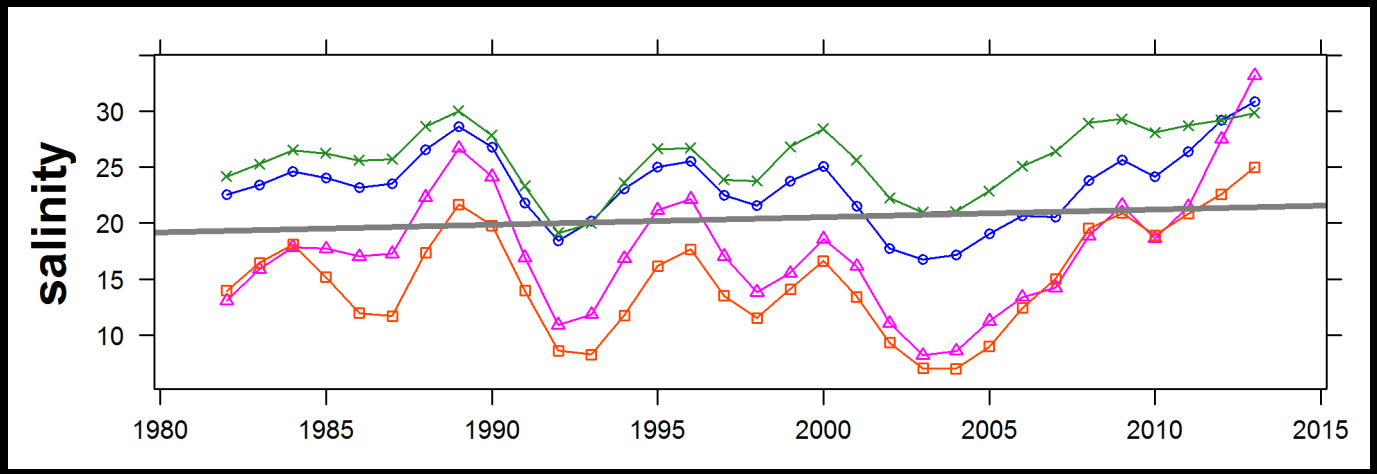


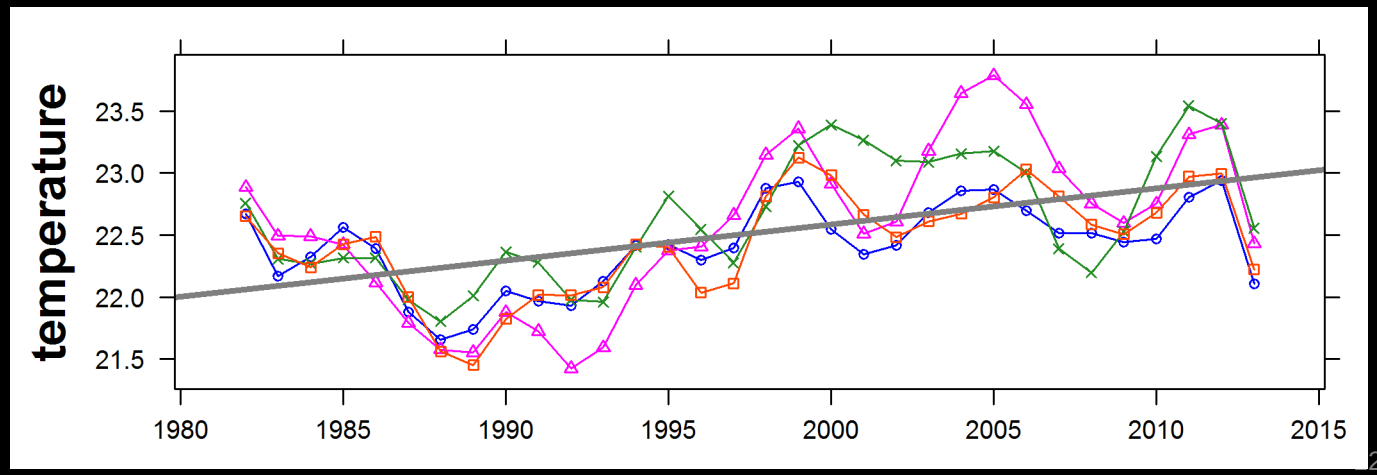
Gill net Data

(1975 – 2013)

Trawl Data
Yearly Means

Aransas Bay
Copano Bay
Espiritu Santo Bay
San Antonio Bay





Trawl Data
Yearly Means

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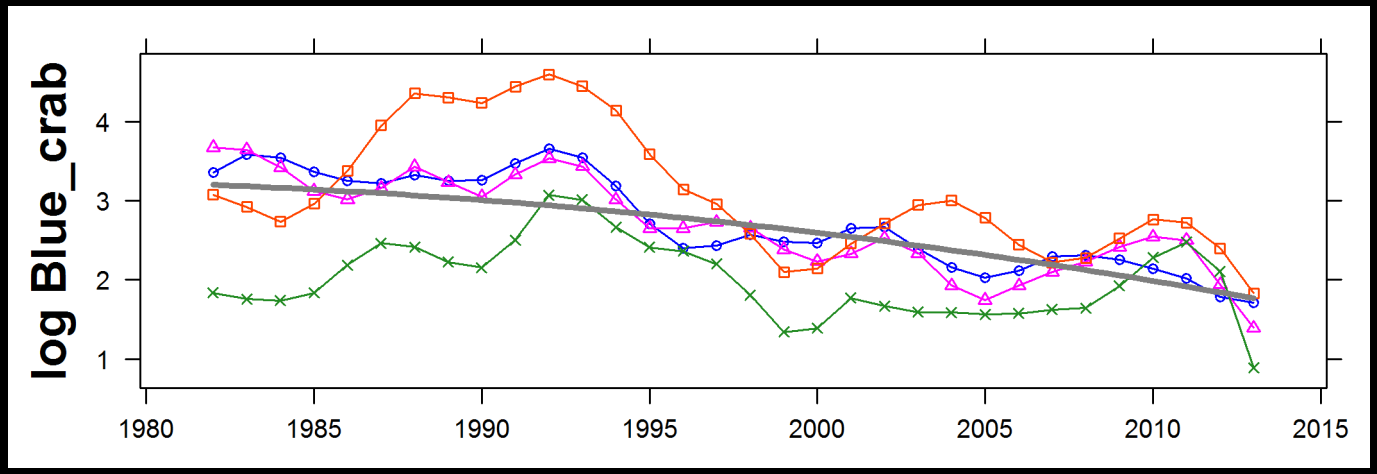

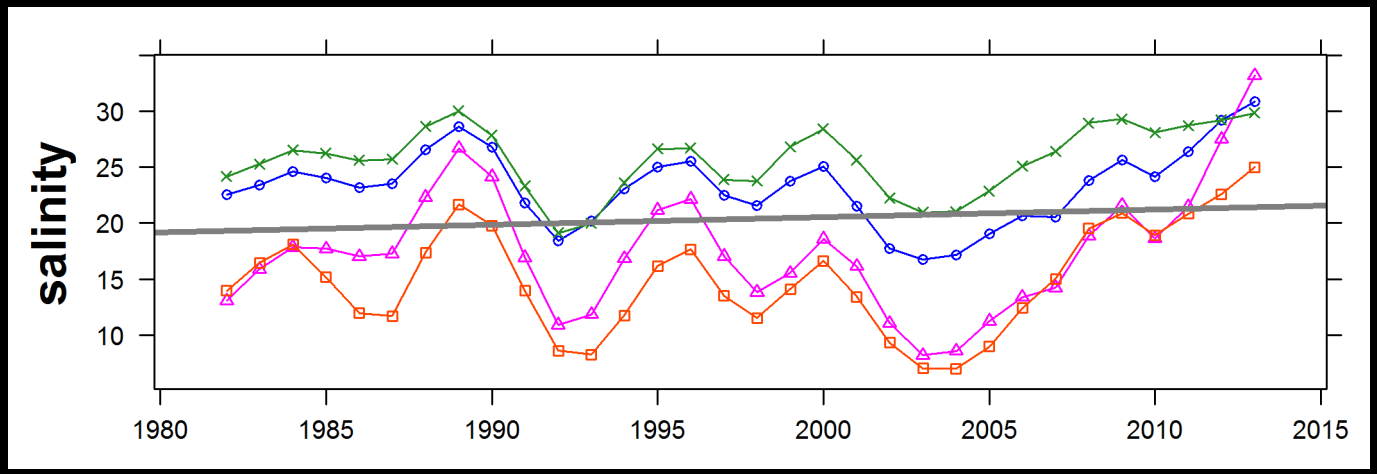

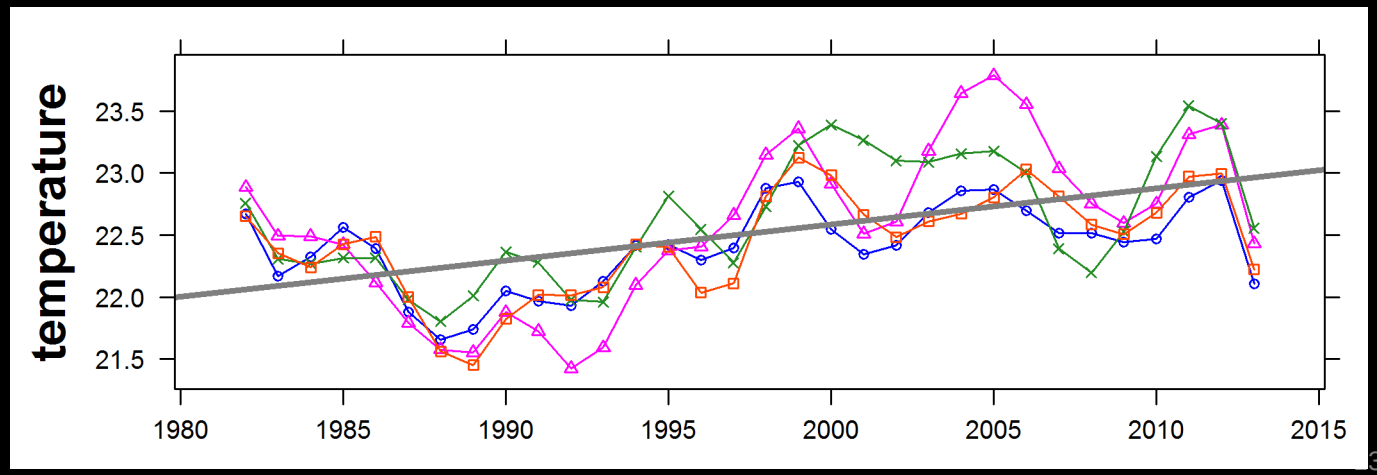

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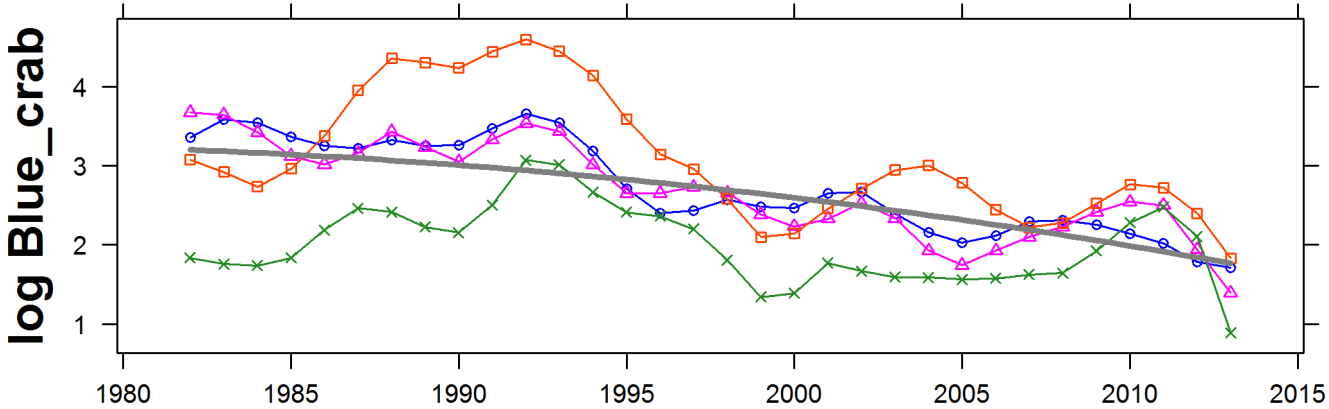

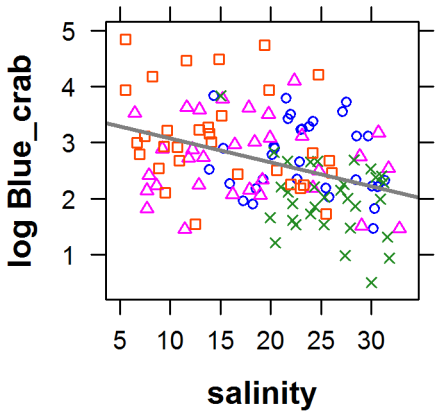

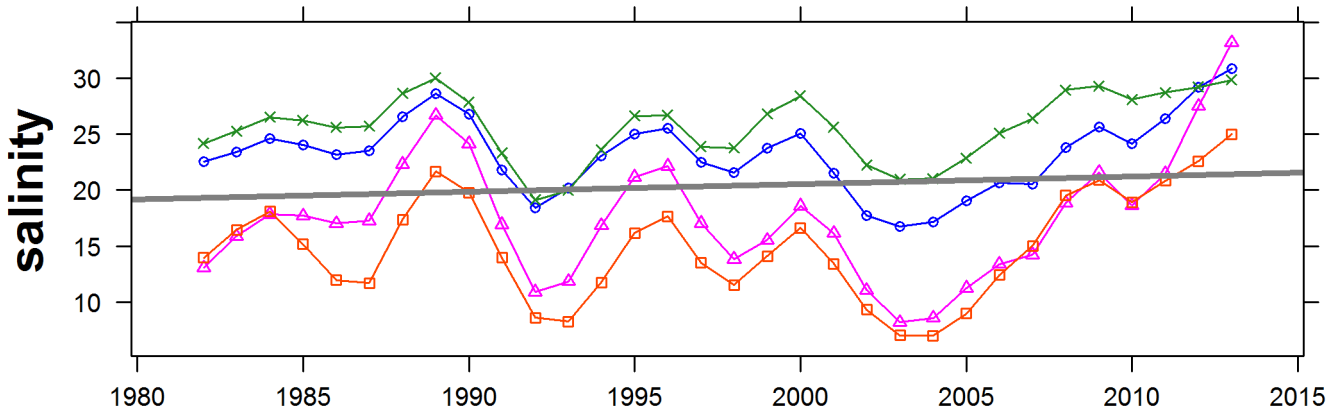

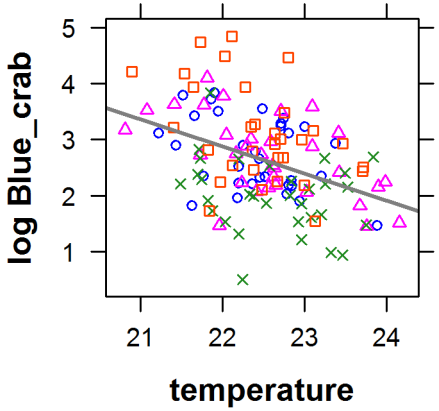

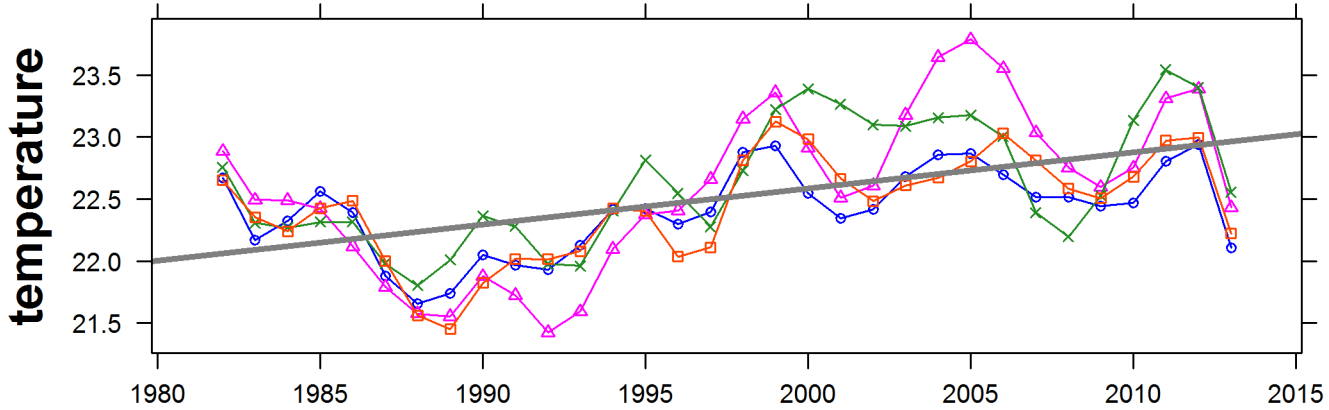

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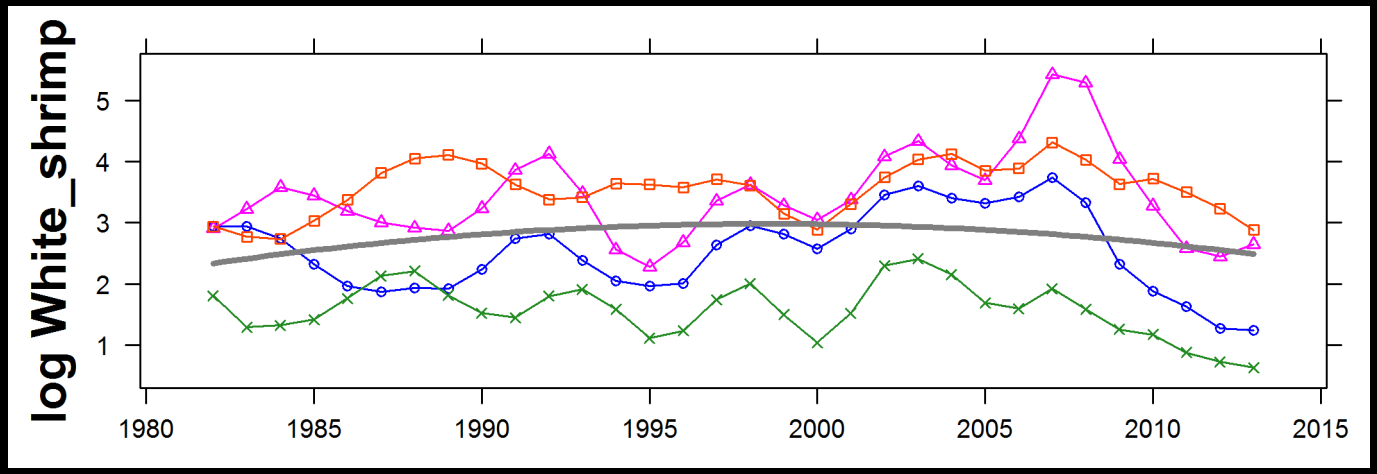
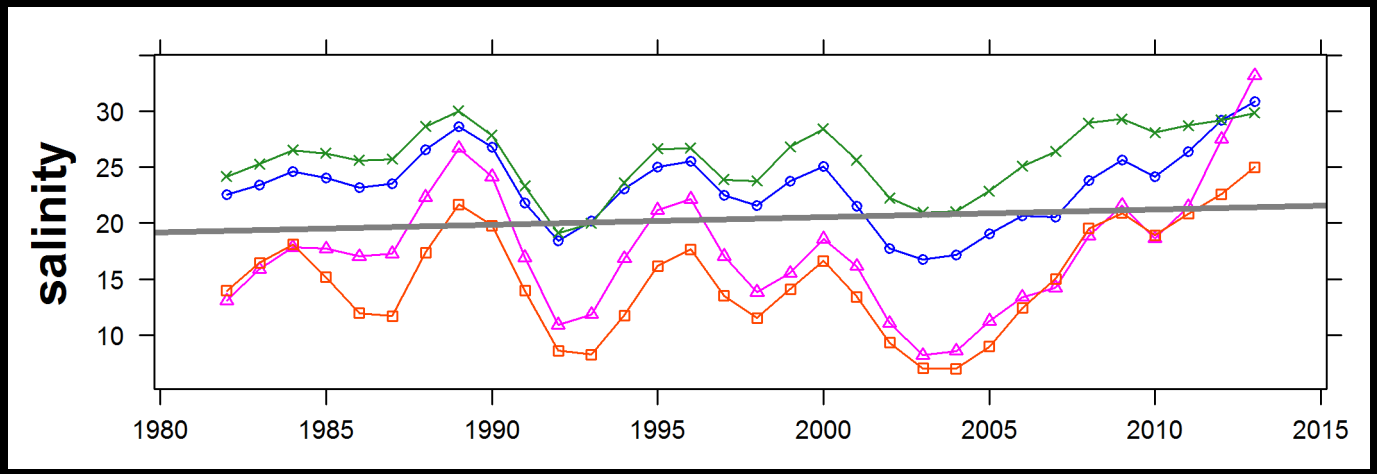
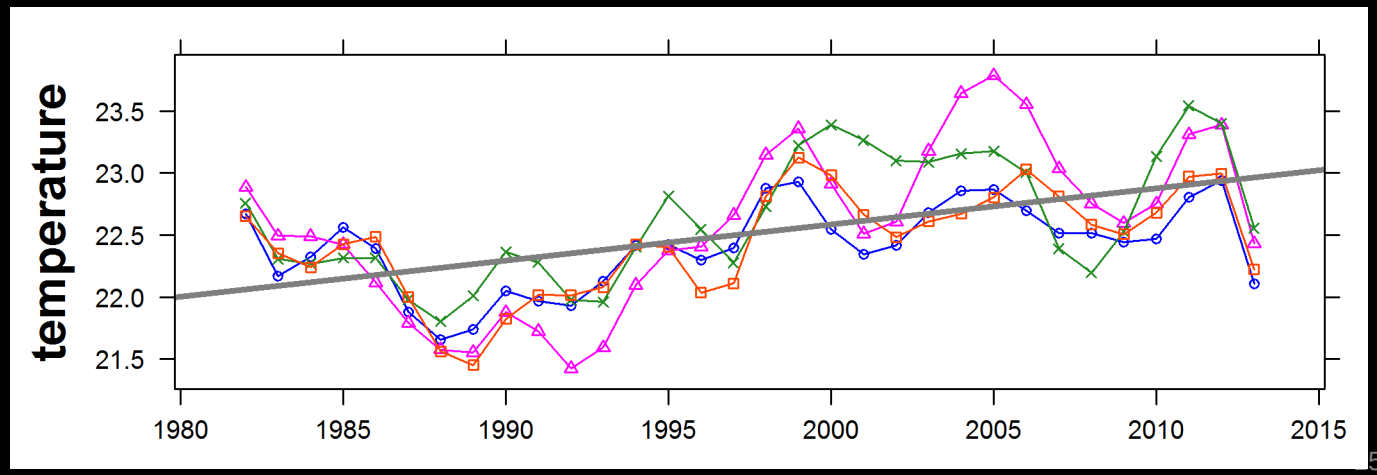
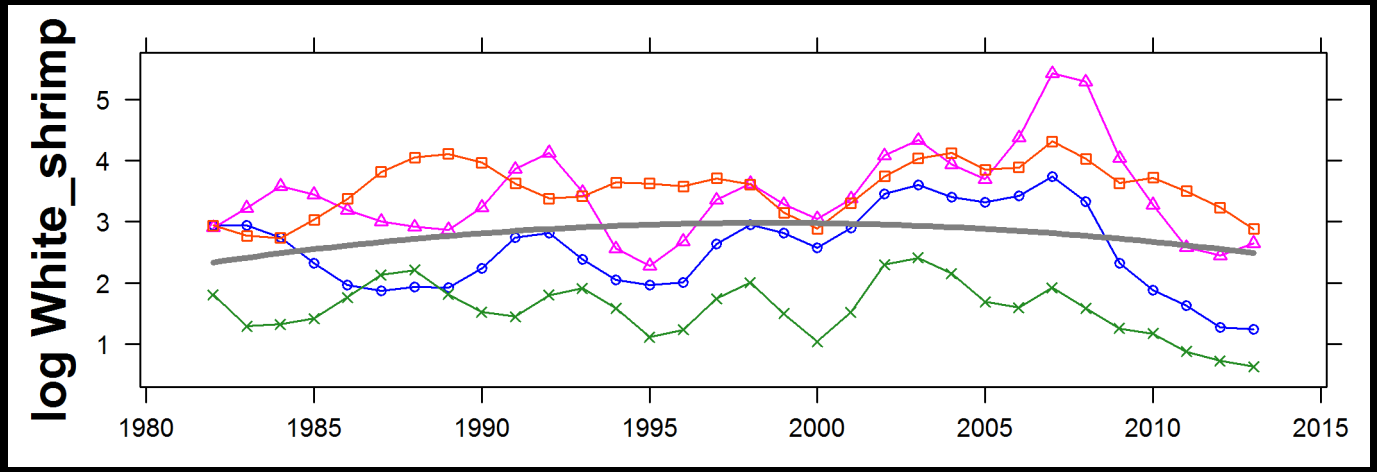
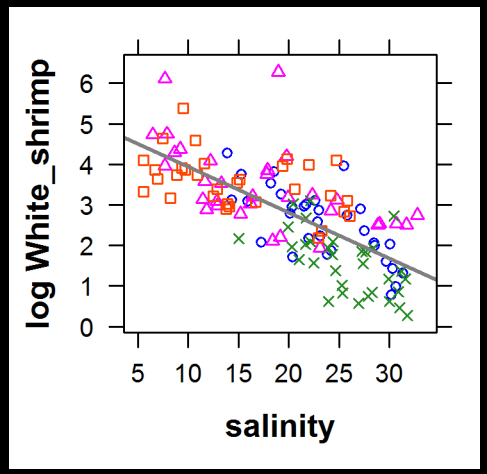


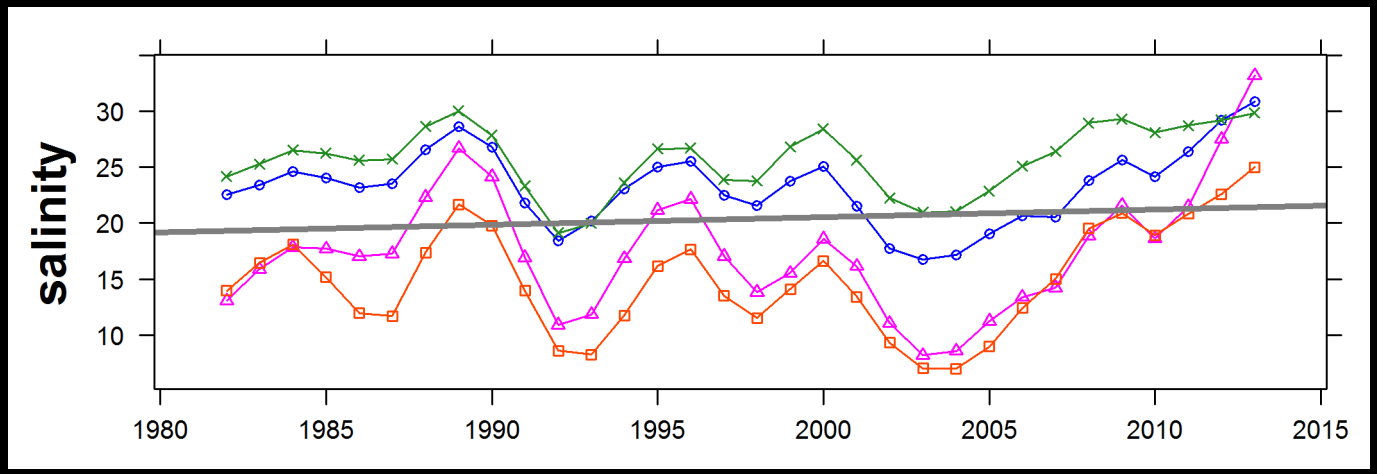


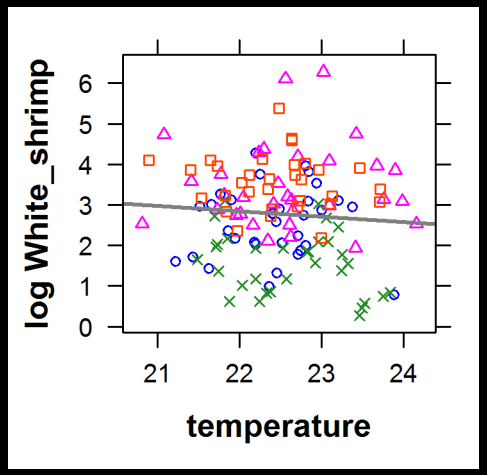


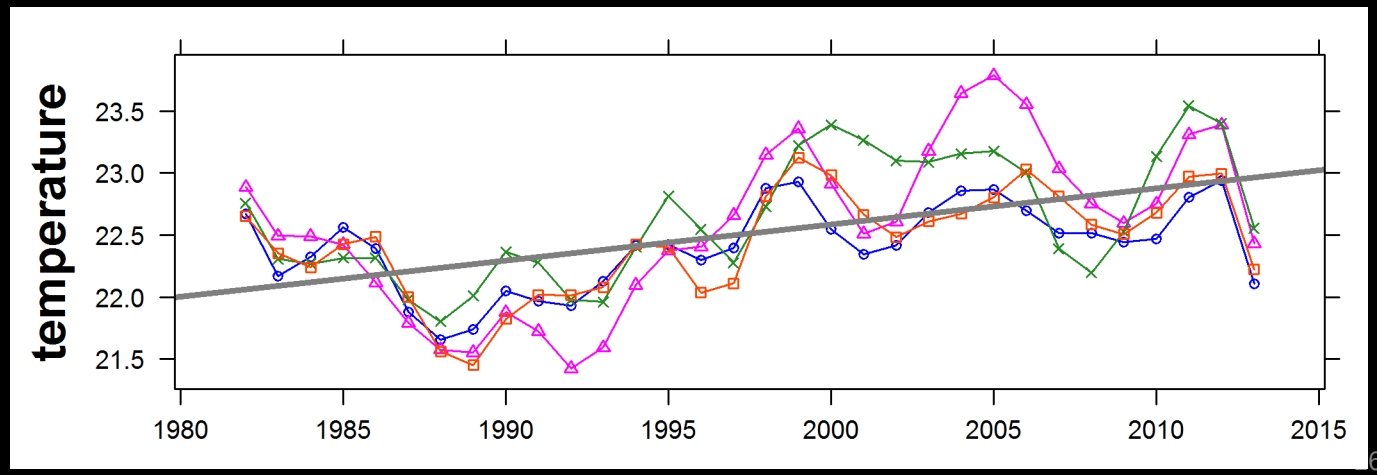
Trawl Data
Yearly Means



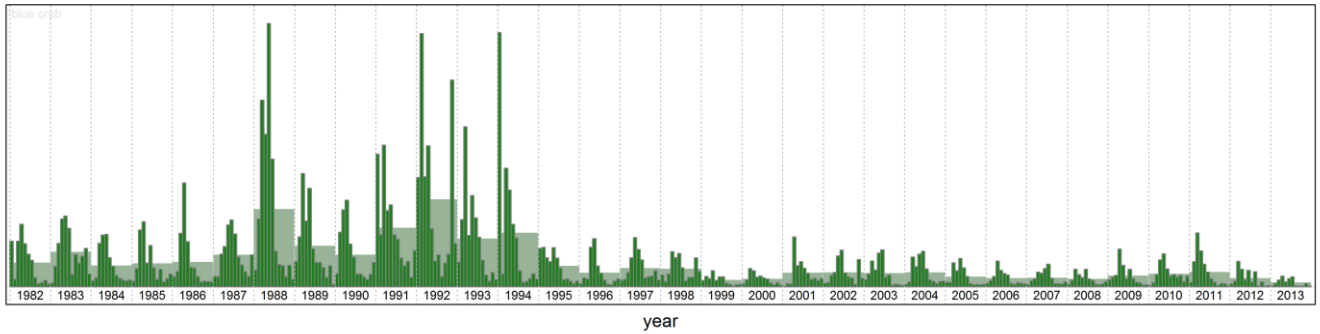




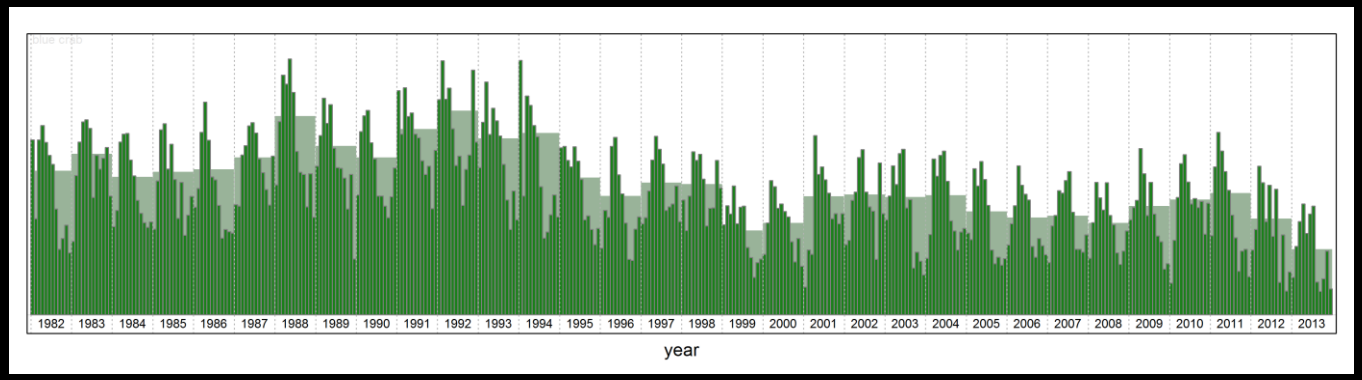




Blue Crab trawl data

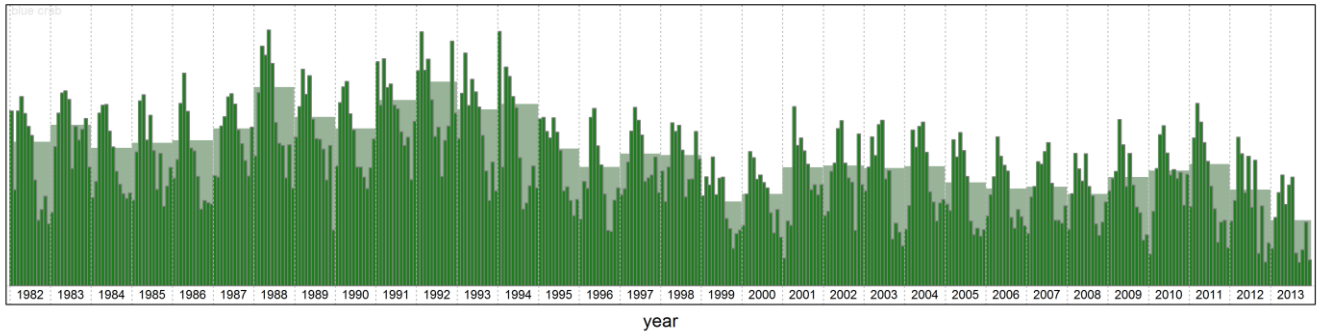


Blue Crab trawl data

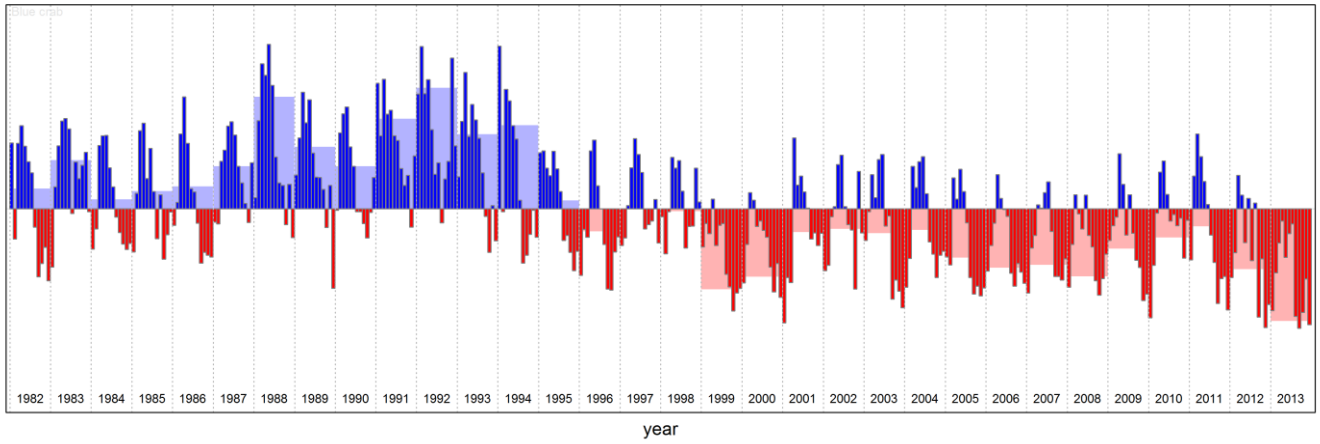


Log-transform

Blue Crab trawl data

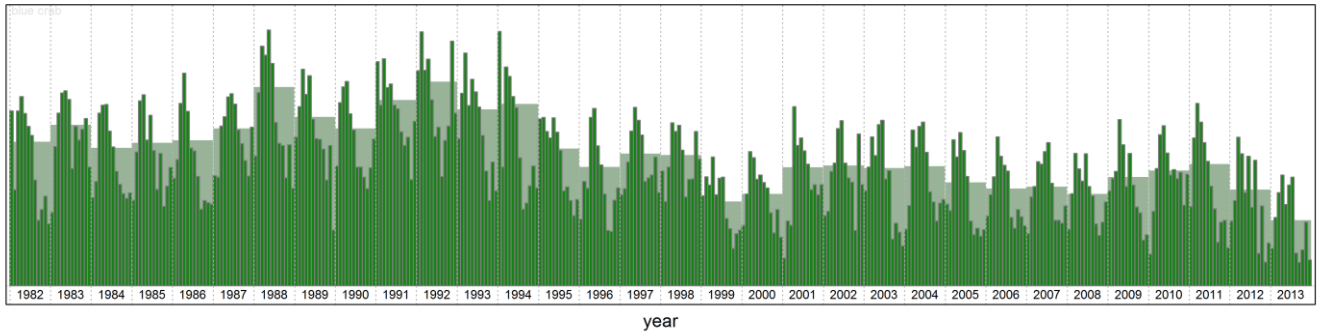


Log-transform

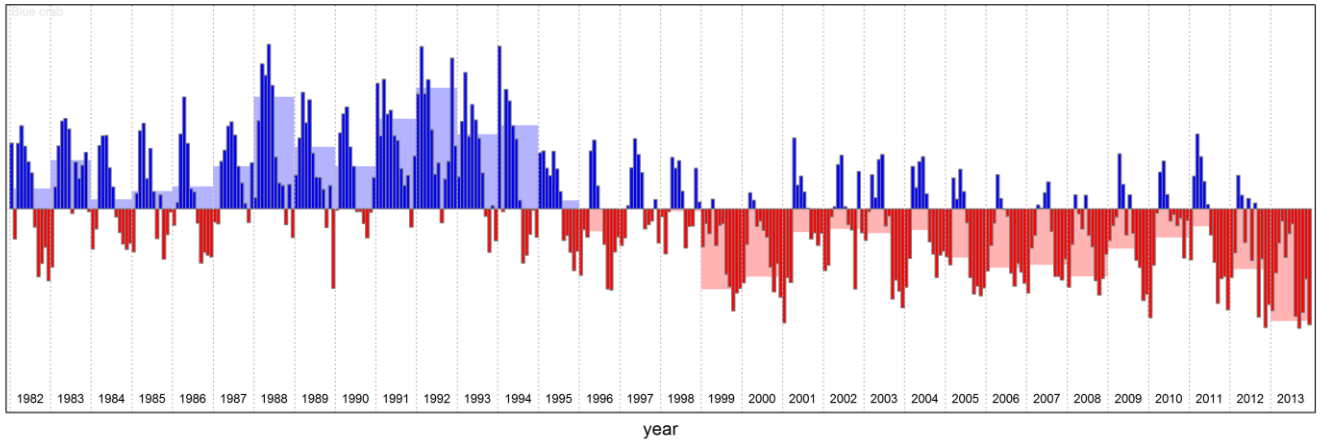


Z-score

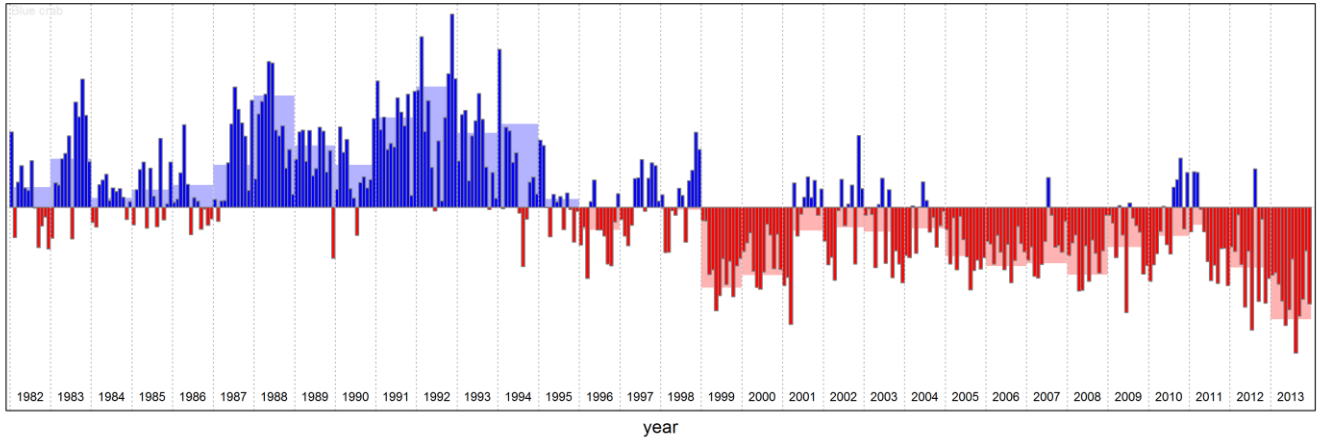
Blue Crab trawl data



Log-transform



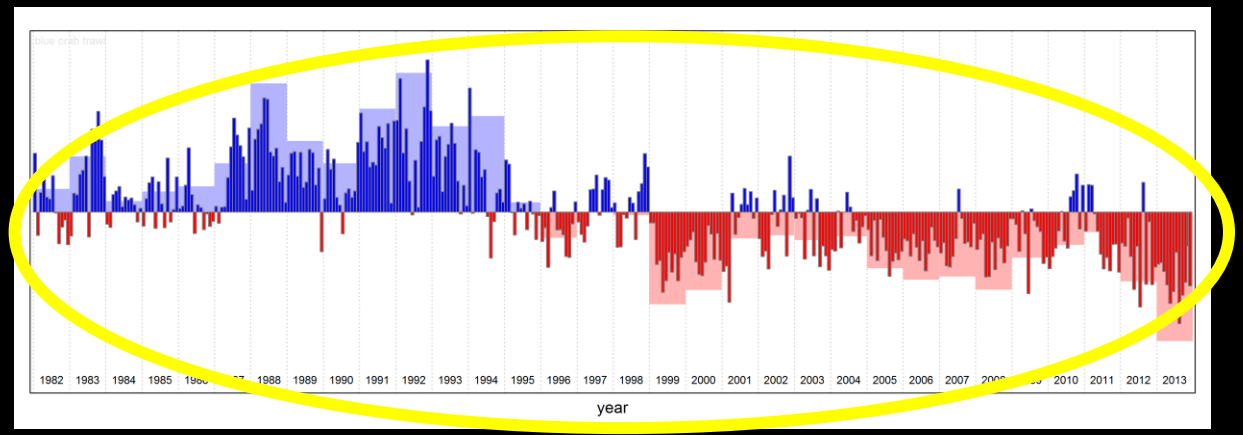
Z-score



Z-score w/ seasonal trend removal

MAR-1 model

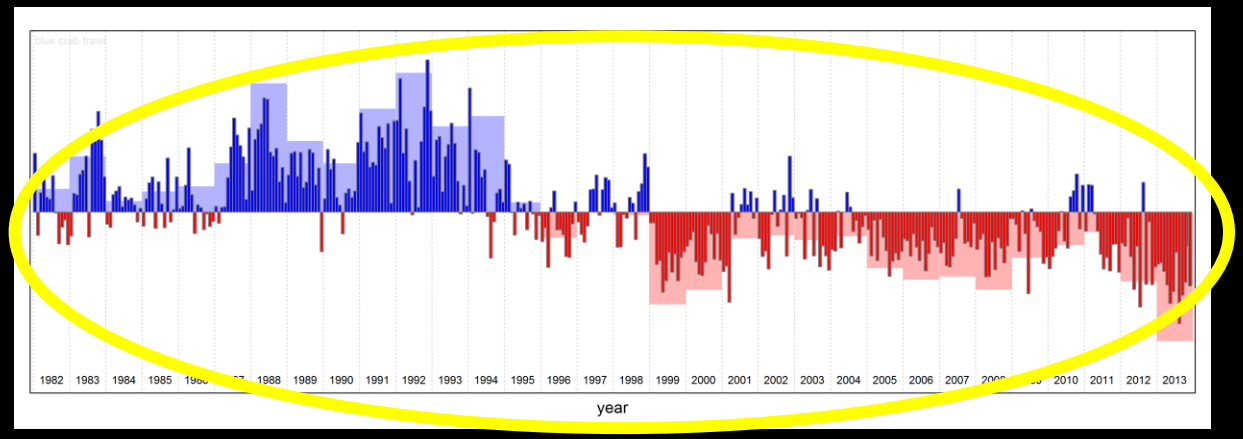
Blue crab



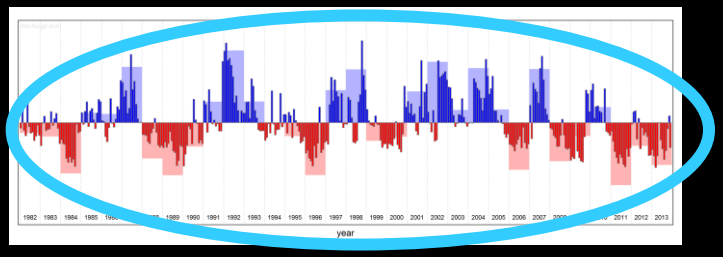
	Species					Environmental		
Species	1	2	3	…	p	1	…	q
1	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
2	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
3	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

MAR-1 model

Blue crab



River Discharge

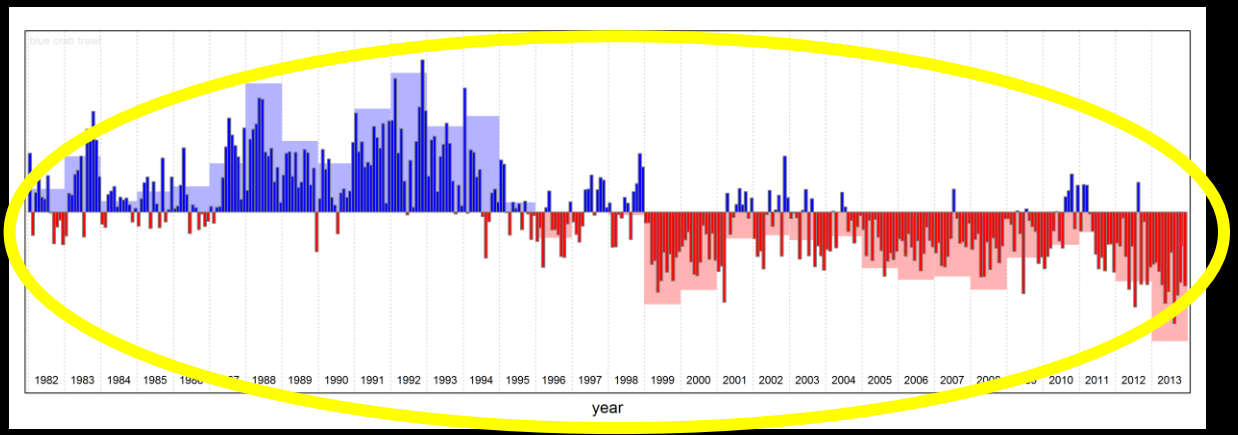


Species **Environmental**

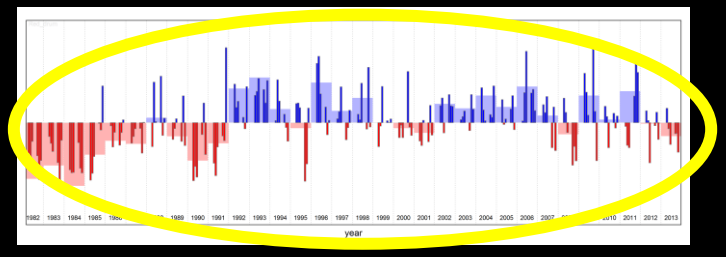
Species	1	2	3	…	p	1	…	q
1	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
2	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
3	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

MAR-1 model

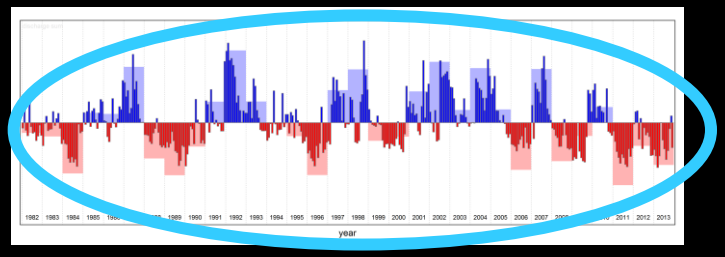
Blue crab



Red drum



River Discharge

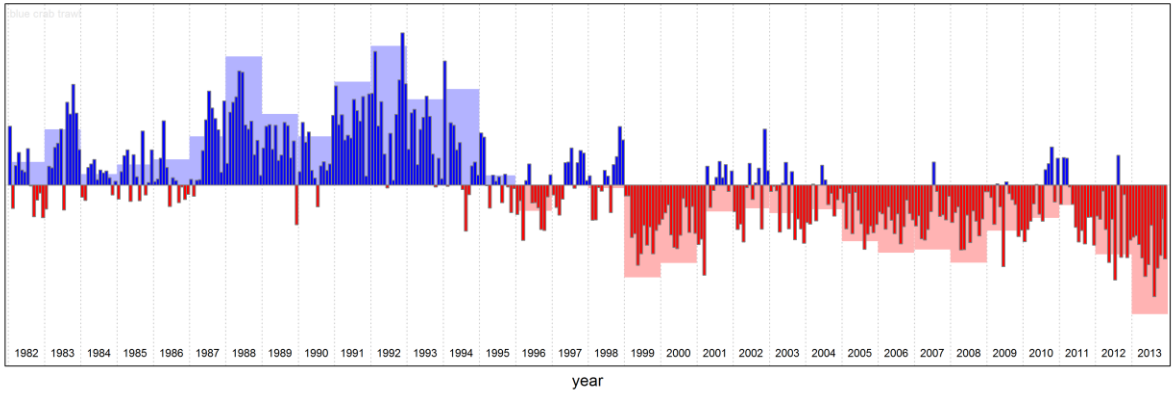


Species **Environmental**

Species	1	2	3	…	p	1	…	q
1	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
2	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
3	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

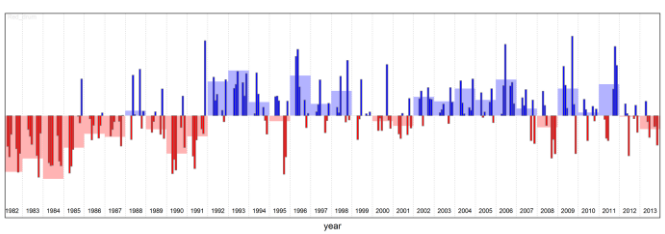
MAR-1 model

Blue crab

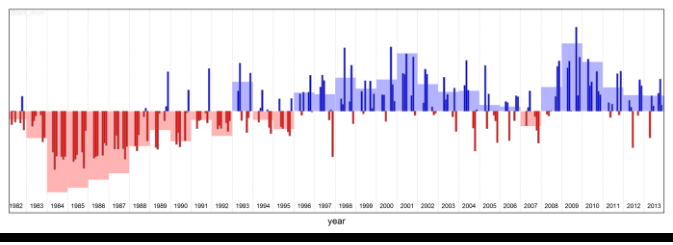


Variates

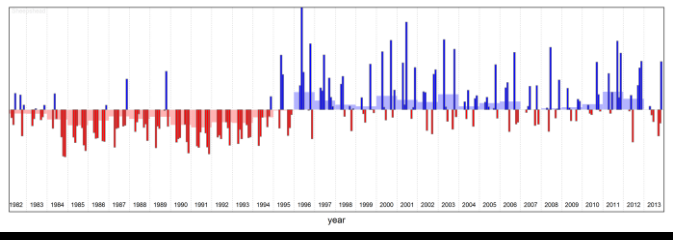
Red drum



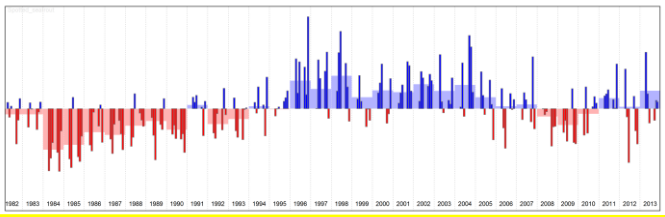
Black drum



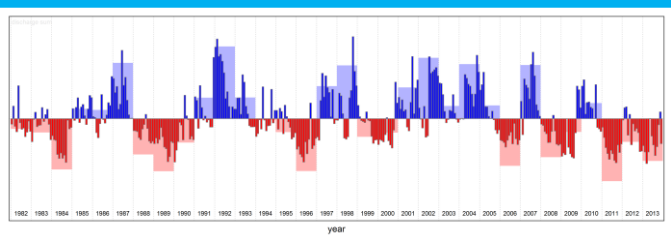
Sheepshead



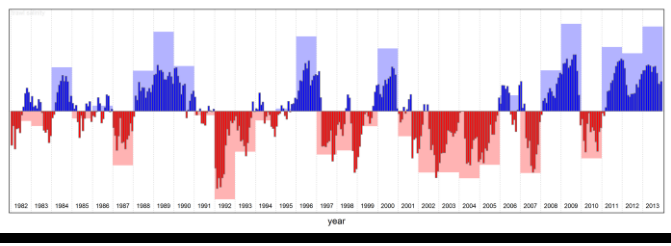
Spotted seatrout



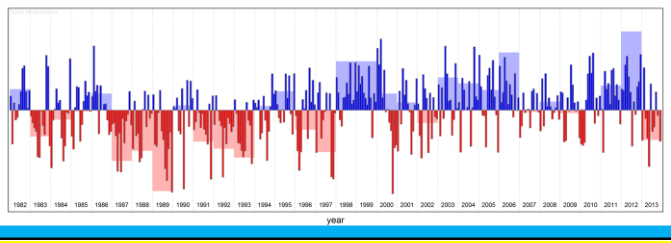
River Discharge



Salinity

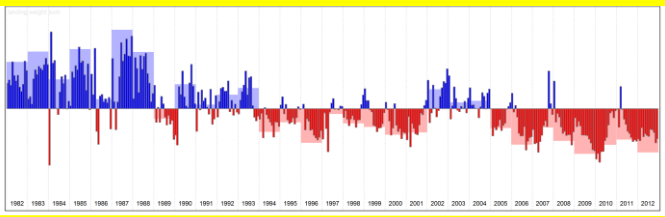


Temperature



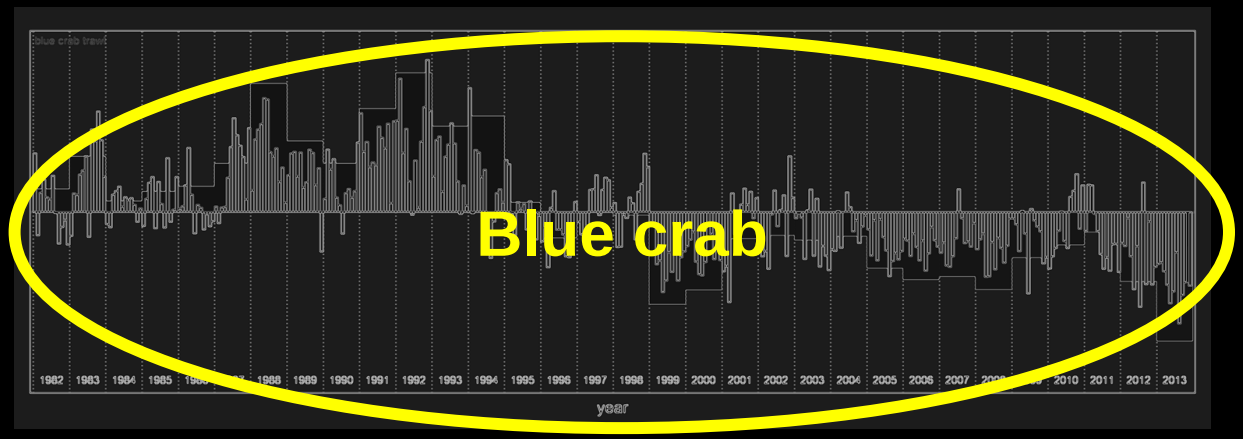
Co-variates

Commercial Landing

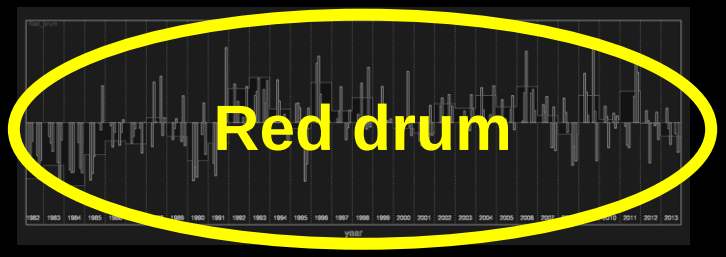


MAR-1 model

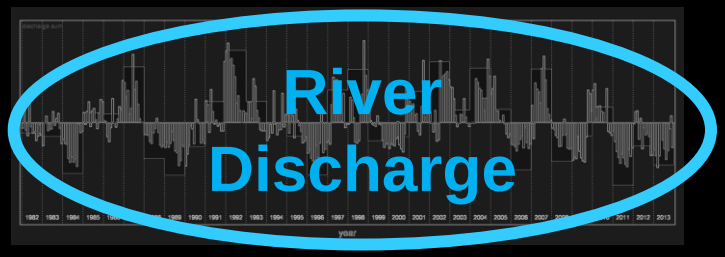
Blue crab



Red drum



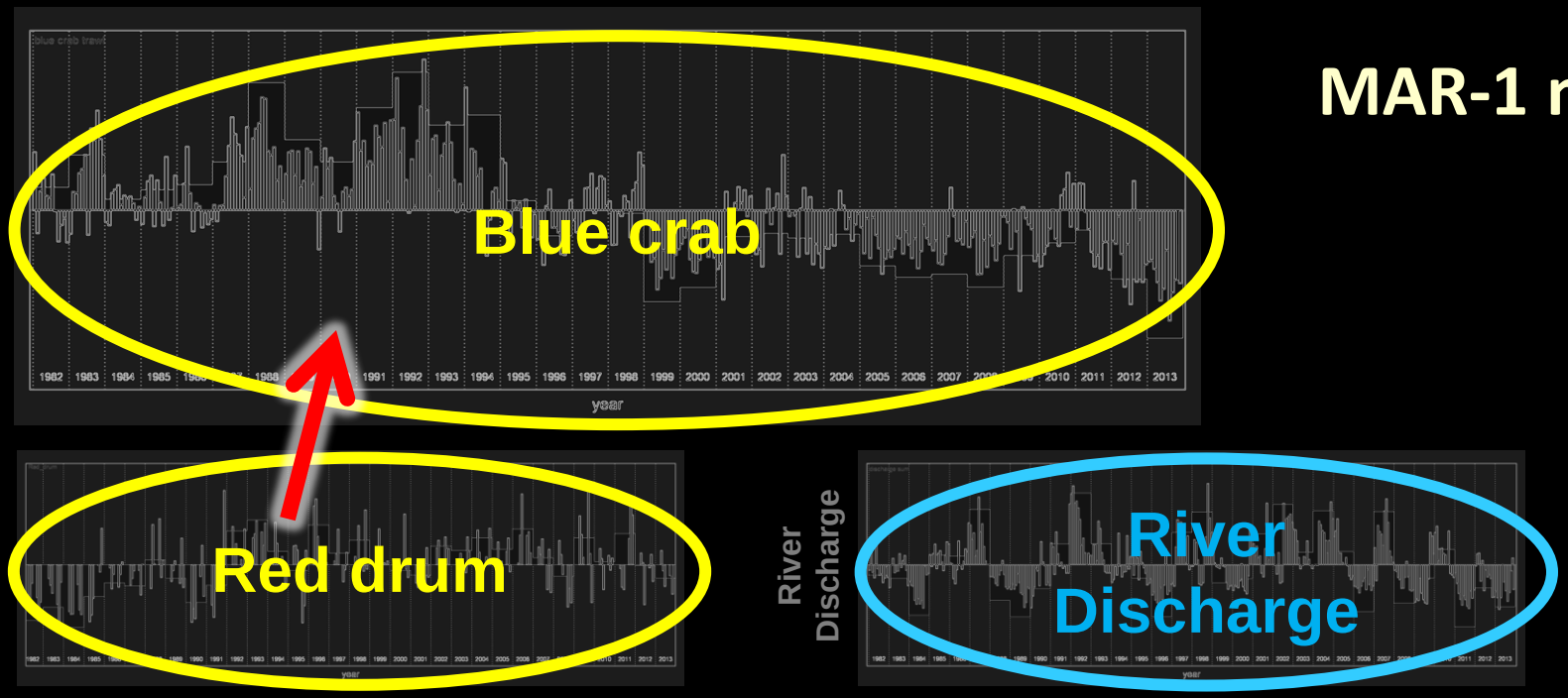
River Discharge



Species **Environmental**

Species	Blue crab	Red drum	Black drum	…	*p*	Discharge	…	*q*
Blue crab	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
Red drum	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

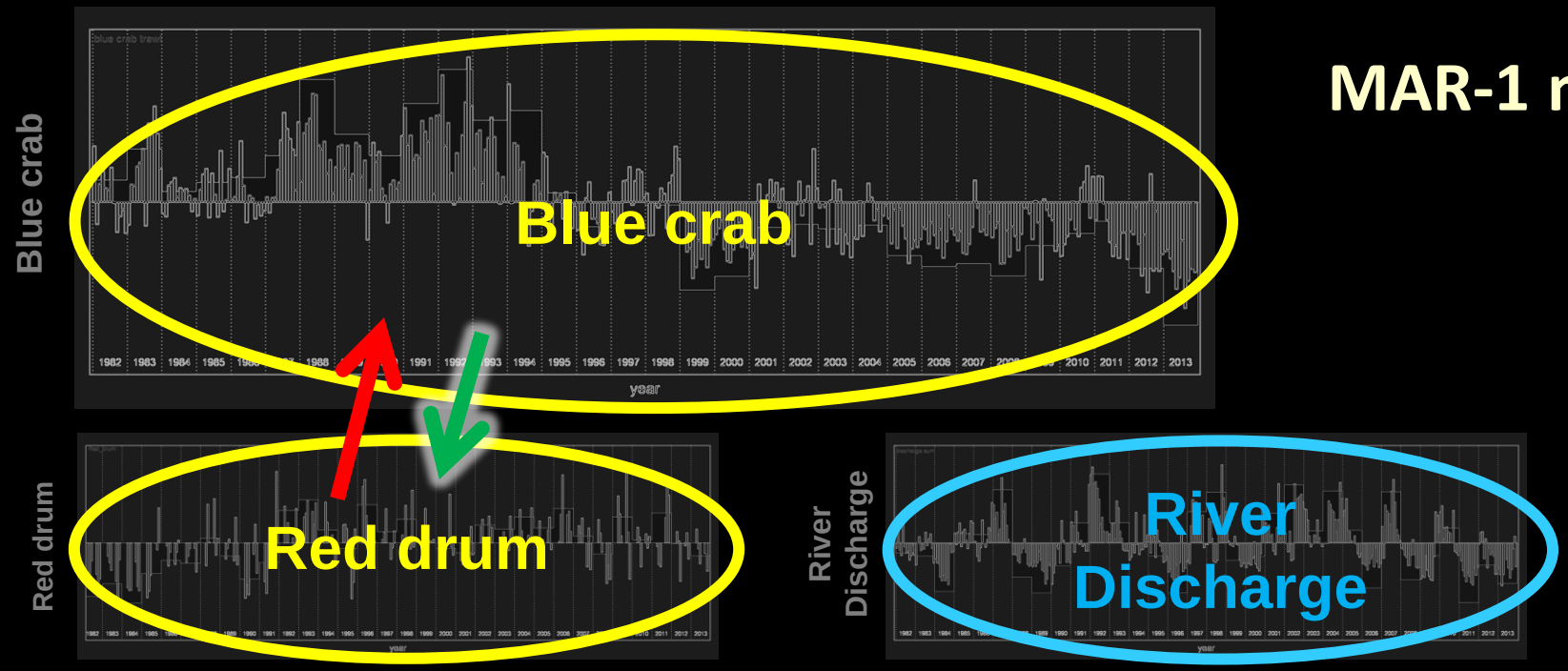
MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$\boxed{-b}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
Red drum	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

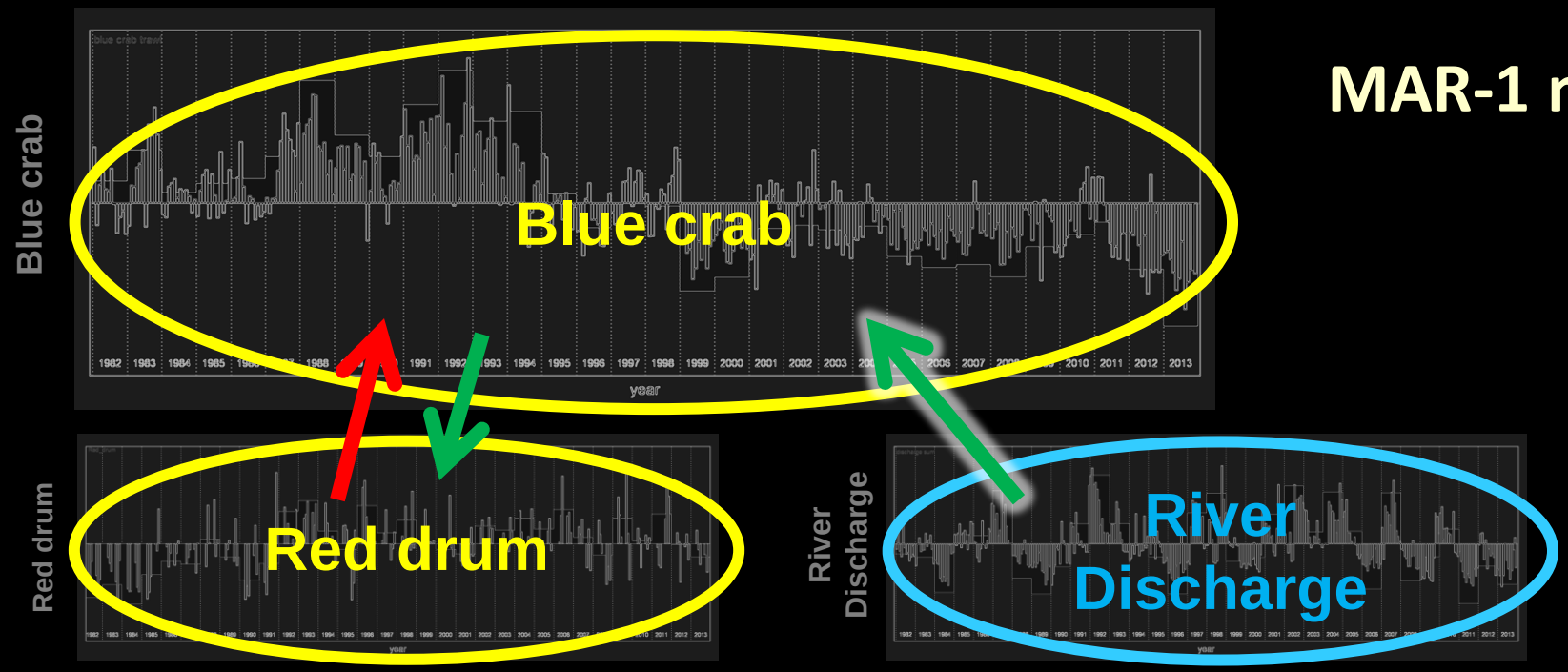
MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
Red drum	$+b$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

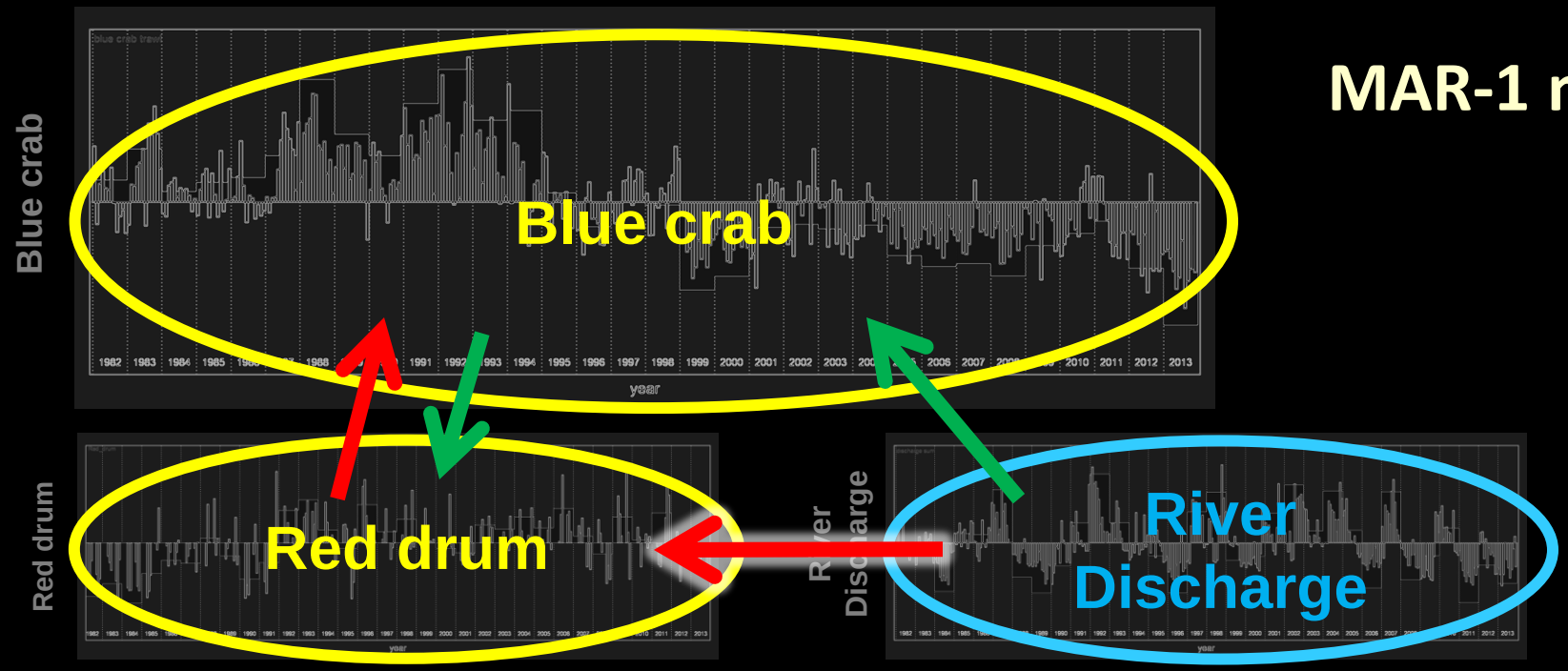
MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	+c	…	$c_{1,q}$
Red drum	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$c_{2,1}$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

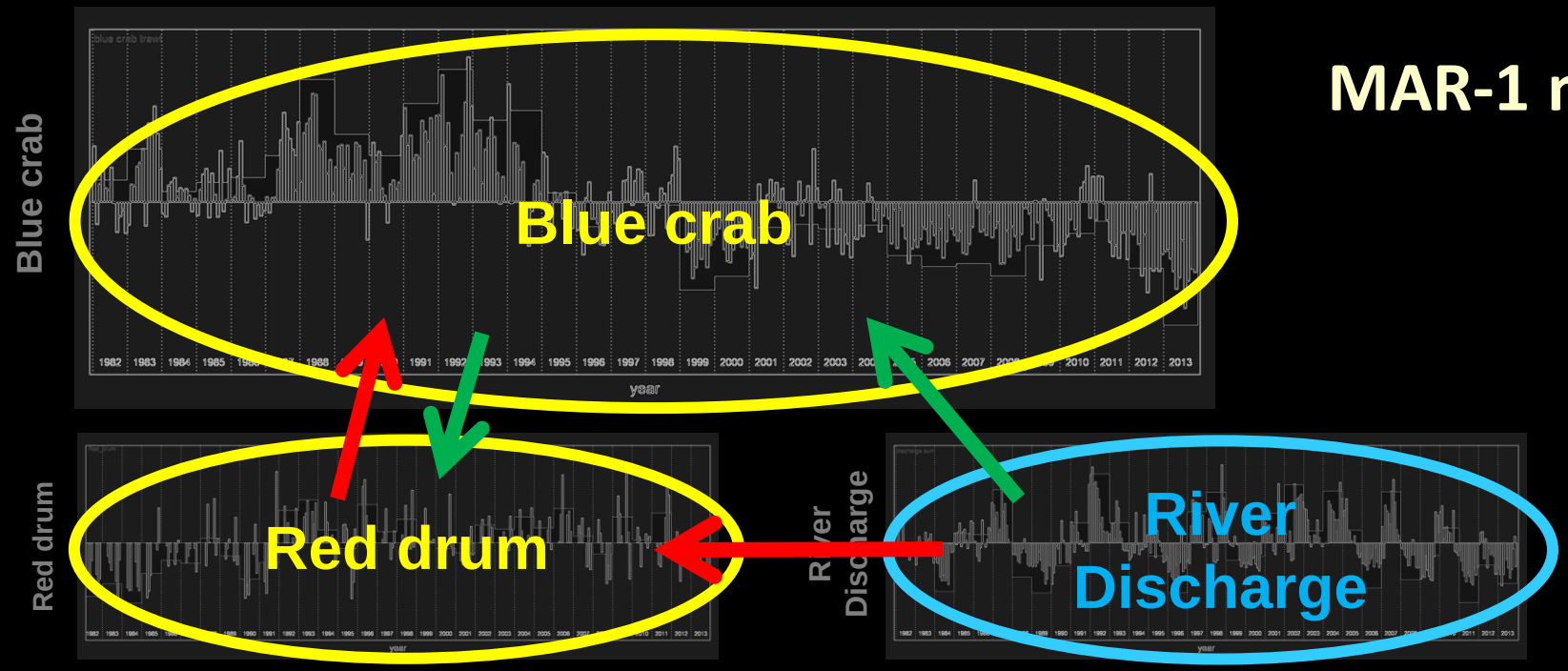
MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$b_{1,2}$	$b_{1,3}$	…	$b_{1,p}$	$c_{1,1}$	…	$c_{1,q}$
Red drum	$b_{2,1}$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	-c	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$-b$	$b_{1,3}$	…	$b_{1,p}$	$+c$	…	$c_{1,q}$
Red drum	$+b$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$-c$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

Model results

- Interactions at different time lags

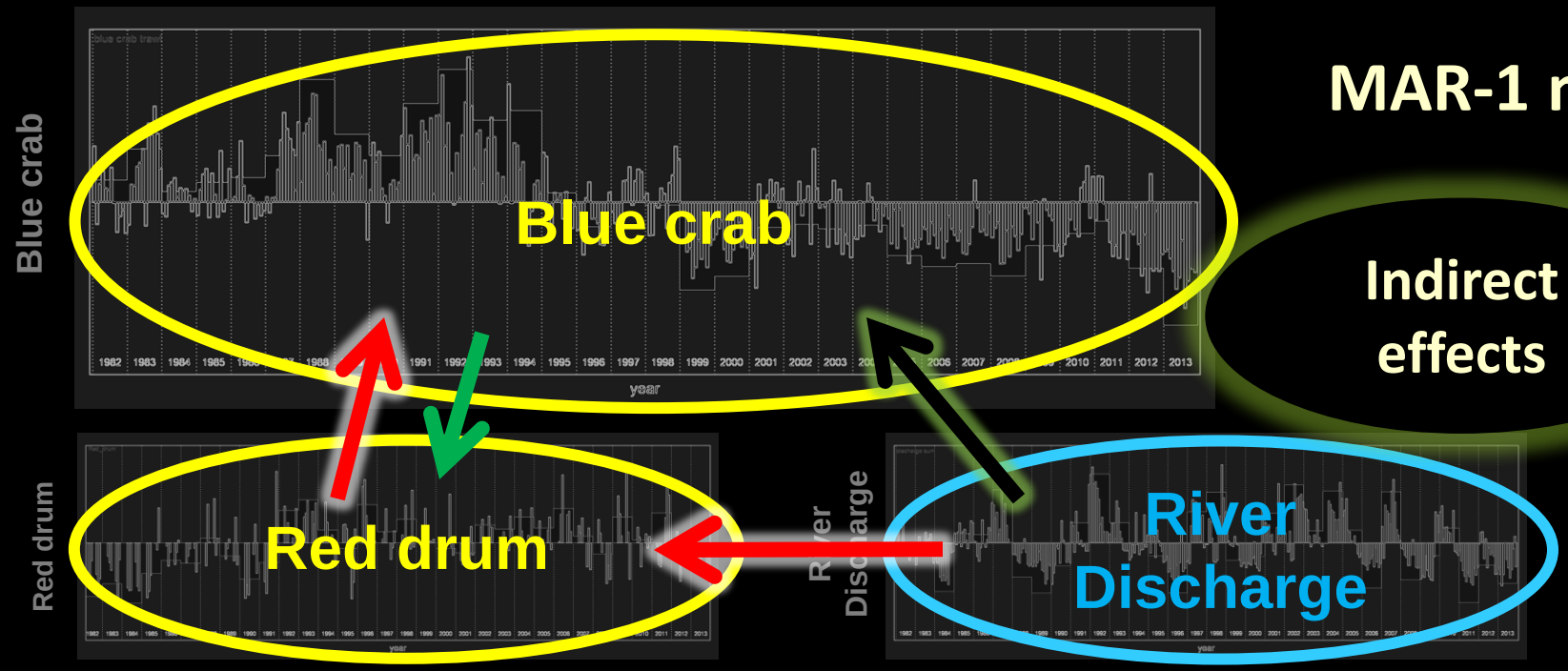
	Species					Environmental		
Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$-b$	$b_{1,3}$	…	$b_{1,p}$	$+c$	…	$c_{1,q}$
Red drum	$+b$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$-c$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

Model results

- Interactions at different time lags
- Indirect effects

	Species					Environmental		
Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$-b$	$b_{1,3}$	…	$b_{1,p}$	$+c$	…	$c_{1,q}$
Red drum	$+b$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$-c$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

MAR-1 model



Species | **Environmental**

Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	**-b**	$b_{1,3}$	…	$b_{1,p}$		…	$c_{1,q}$
Red drum	**+b**	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	**-c**	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$

Model results

- Interactions at different time lags
- Indirect effects
- System stability under different conditions

	Species					Environmental		
Species	Blue crab	Red drum	Black drum	…	p	Discharge	…	q
Blue crab	$b_{1,1}$	$-b$	$b_{1,3}$	…	$b_{1,p}$	$+c$	…	$c_{1,q}$
Red drum	$+b$	$b_{2,2}$	$b_{2,3}$	…	$b_{2,p}$	$-c$	…	$c_{2,q}$
Black drum	$b_{3,1}$	$b_{3,2}$	$b_{3,3}$	…	$b_{3,p}$	$c_{3,1}$	…	$c_{3,q}$
…	…	…	…	…	…	…	…	…
p	$b_{p,1}$	$b_{p,2}$	$b_{p,3}$	…	$b_{p,p}$	$c_{p,1}$	…	$c_{p,q}$