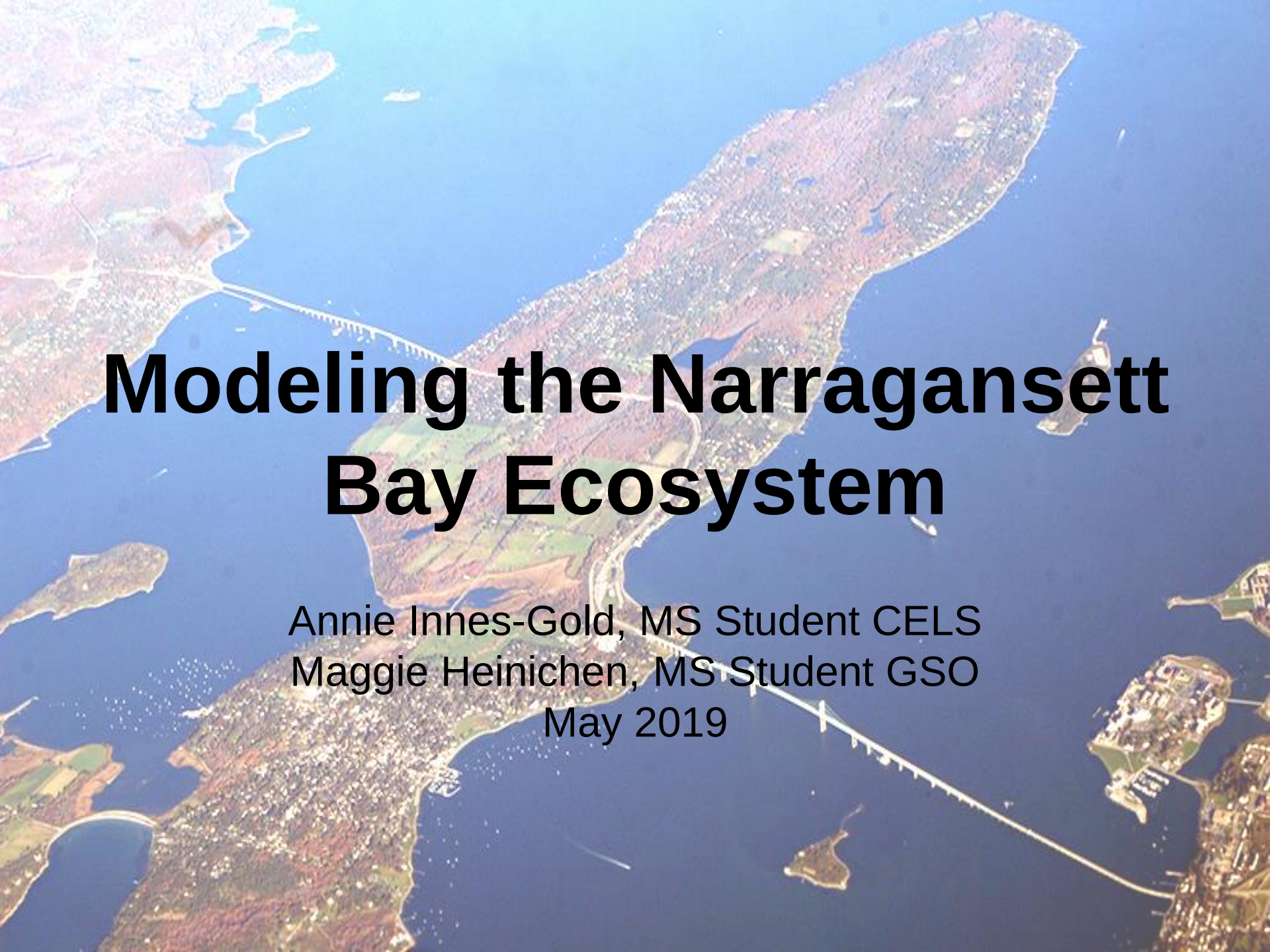

Modeling the Narragansett Bay Ecosystem

Annie Innes-Gold, MS Student CELS
Maggie Heinichen, MS Student GSO
May 2019

Outline

C-AIM Goals

Methods - Ecopath with Ecosim

Data Collection - Diet

Data Collection - Other Biological

Data Collection - External Drivers & Human Dimensions

Next Steps Towards an Ecosystem Model

C-AIM

- This work is supported by the EPSCoR grant through the Rhode Island Consortium for Coastal Ecology Assessment and Innovation Modelling (RI C-AIM)
- Goal 2.3: Develop higher trophic level models for aquaculture and fisheries species of interest and integrate these with the biogeochemical/ecological/circulation models of NB
  - Objective 2.3.1: Build Integrated Ecosystem Models
  - Objective 2.4.3: Identify Social-Environmental Feedbacks and Develop Adaptive Strategies for Communities to Cope, Manage, and Adjust to Change

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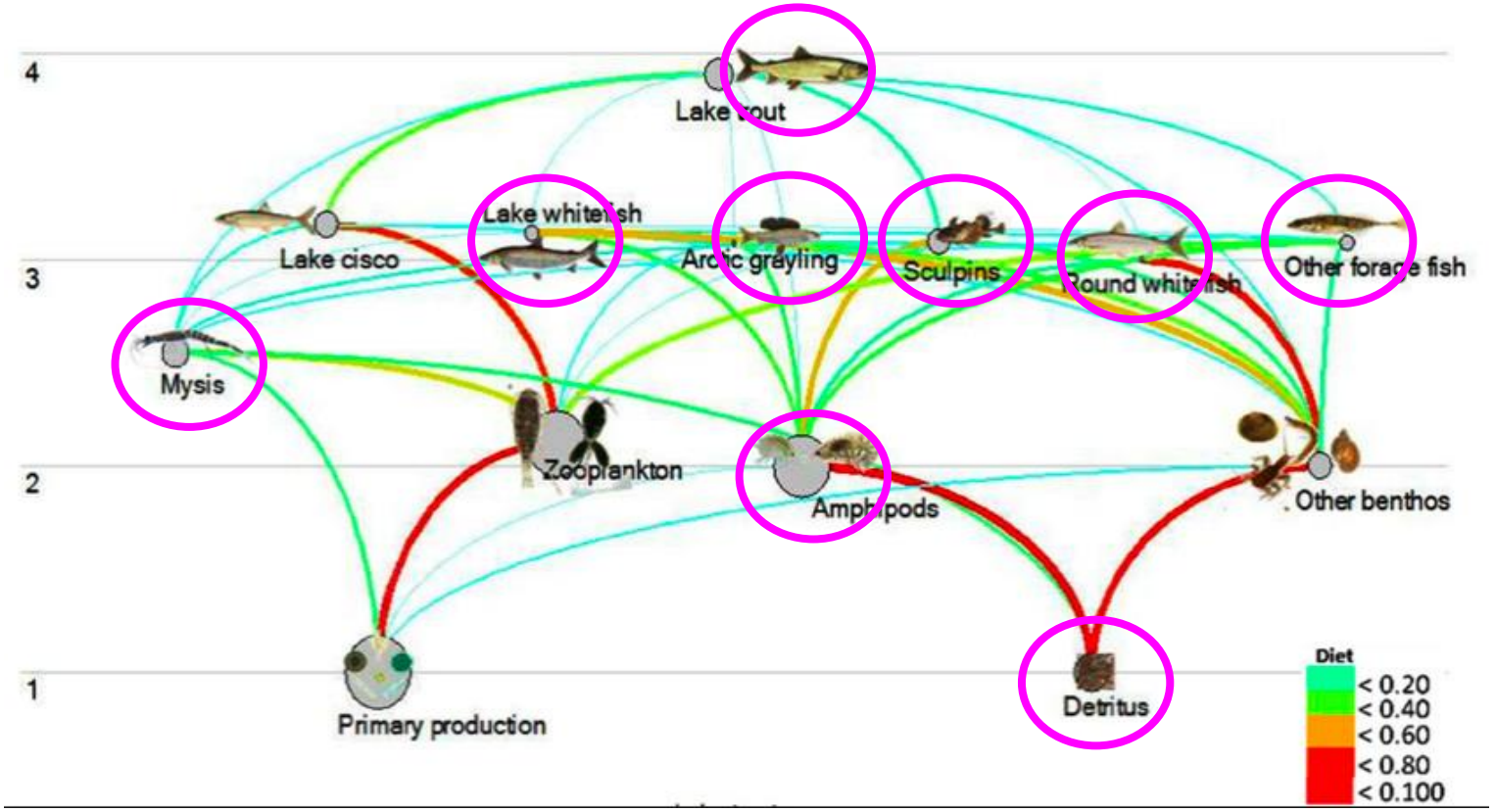
Coastal Ecology
Assessment
Innovation &
Modeling

Ecosystem Modeling using Ecopath

Ecopath with Ecosim

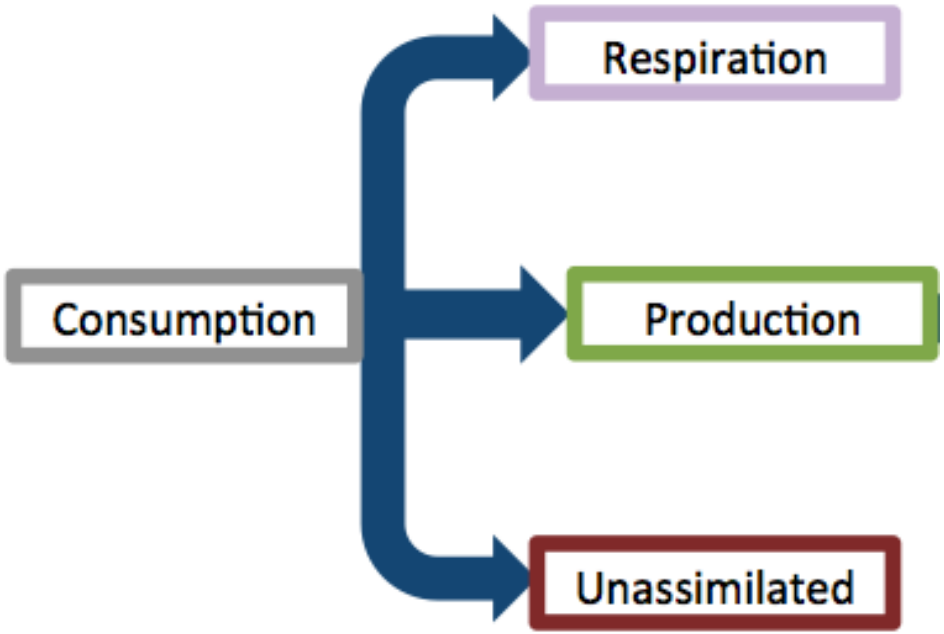
- **Ecopath**: a mass-balanced energetics-based snapshot of an ecosystem



Ecopath with Ecosim

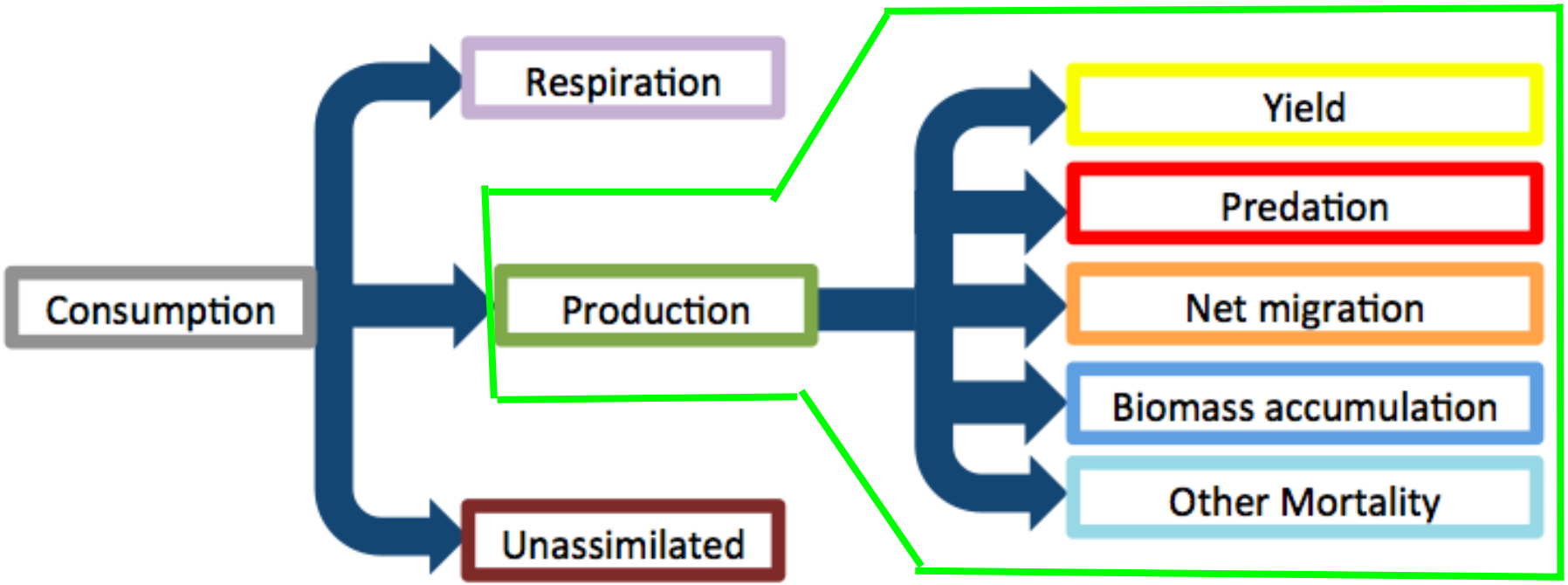
No fish is an island

Janjua et al., 2015



Consumption = Production + Respiration + Unassimilated food

$$\left(\frac{Q}{B}\right)_i \bullet B_i = \left(\frac{P}{B}\right)_i \bullet B_i + R_i + UN_i$$



Production = Predation + Net migration + Yield + Biomass accumulation + Other mortality

$$\left(\frac{P}{B}\right)_i \bullet B_i = \sum_{Predj=1}^{n} \left(\frac{Q}{B}\right)_j \bullet B_j \bullet DC_{ij} + E_i + Y_i + BA_i + \left(\frac{P}{B}\right)_i \bullet B_i \bullet \left(1 - EE_i\right)$$

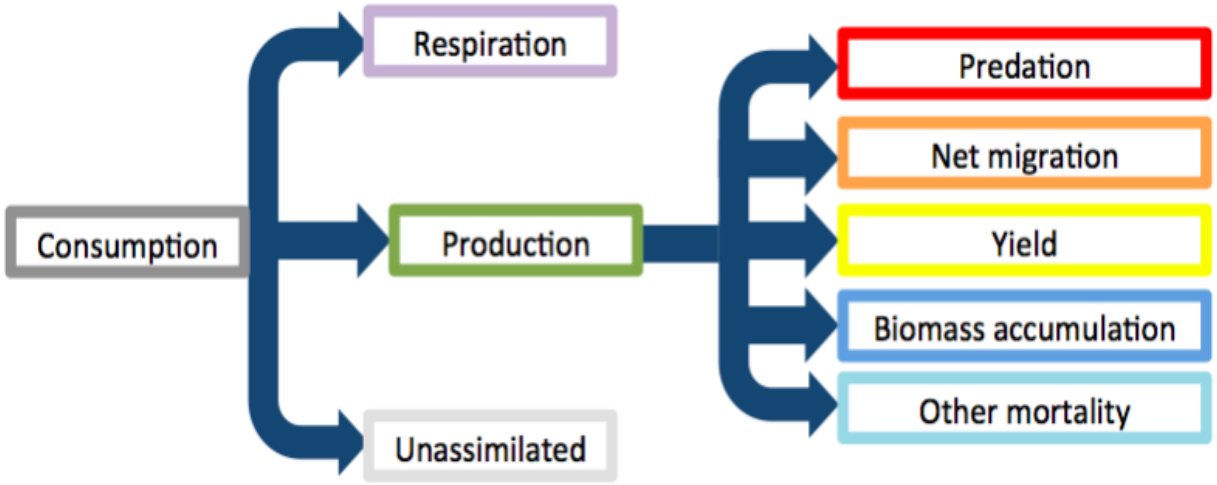
Ecopath Inputs

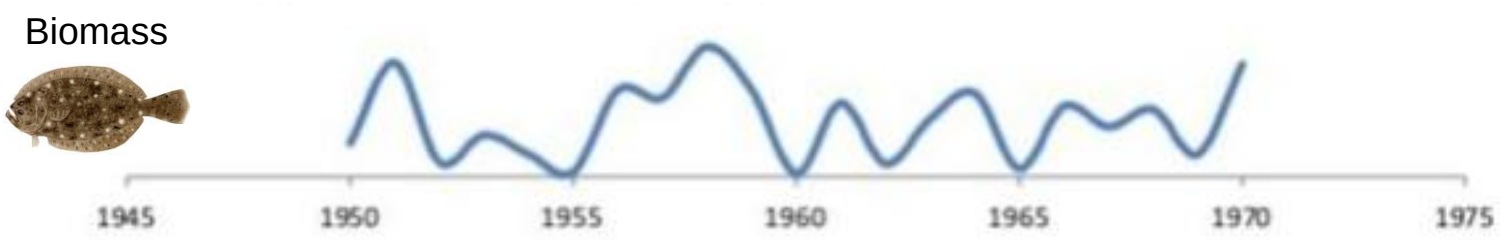
Term	Abbreviation	Definition	Unit
Biomass	B	Mass of an organism	$t.km^2$
Production/Biomass	P/B	Turnover rate	$year^{-1}$
Consumption/Biomass	Q/B	Food consumption rate	$year^{-1}$
Ecotrophic Efficiency	EE	Proportion of production used in system	proportion

- Ecopath requires three of four parameters for the energetics to balance

Ecosim: temporal dynamics

How does the ecosystem balance change over time?



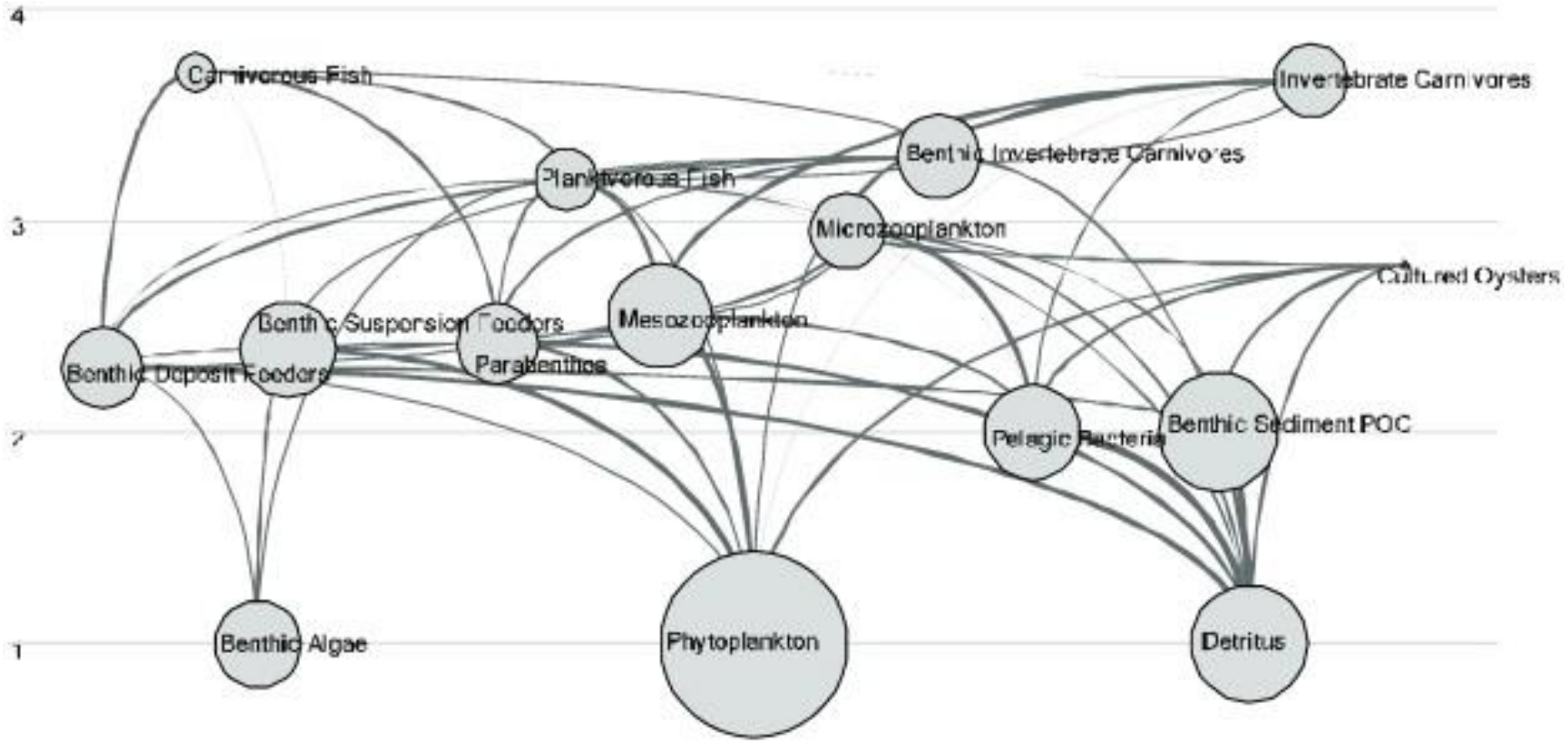


Walters et al. 1997. Rev. Fish Biol. and Fish., 7: 139-172; Christensen and Walters 2004. Ecol. Model., 172(2-4): 109-139

Previous Ecopath Work in Narragansett Bay

Calculating ecological carrying capacity of shellfish aquaculture using mass-balance modeling: Narragansett Bay, Rhode Island

Carrie Byron[a,b,*], Jason Link[c], Barry Costa-Pierce[a,d], David Bengtson[a]



Byron et al., 2015


Narragansett
Bay Data

Creating our Ecopath model

- Identify functional groups and diet matrix to be appropriate for our question

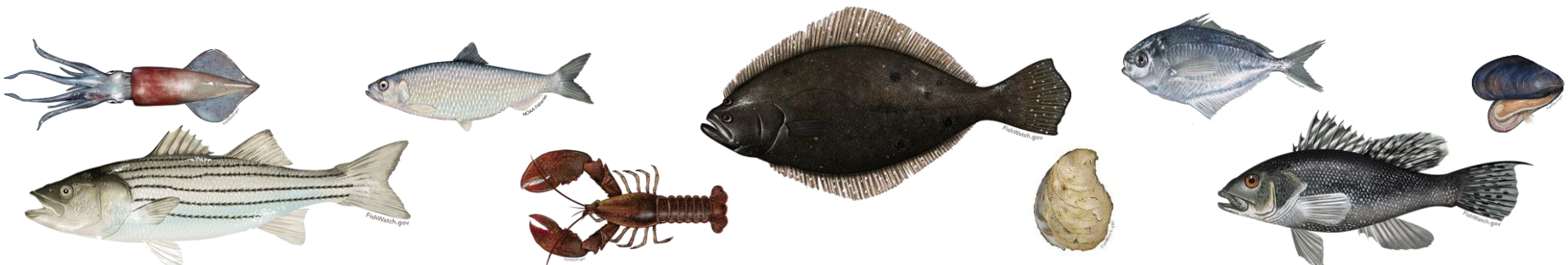
- Determine biomass, production, and consumption parameters that are important to the model

- Make it a dynamic model - Ecosim
  - Integrating time series data on fish/invertebrate abundance to validate model
  - Forcing functions: primary production and fishing pressure

Examined Species

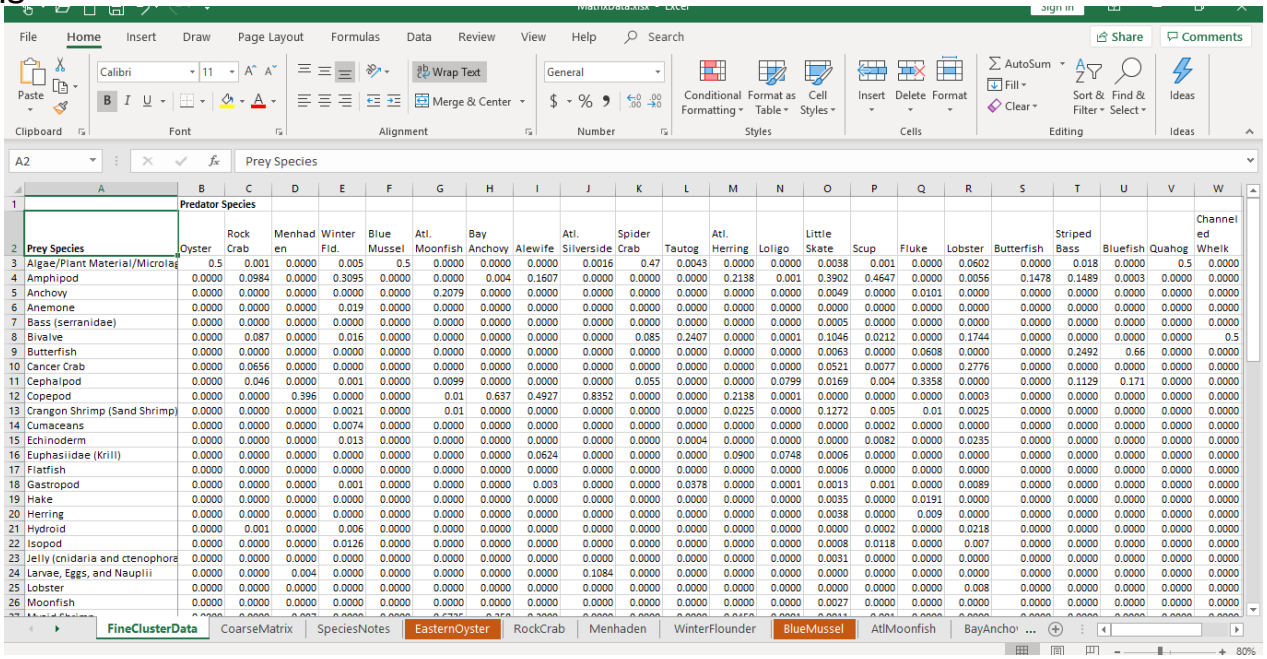
- Ecopath parameters will be found for 28 species thought to be representative of the larger invertebrates and fish in Narragansett Bay.
  - Species are thought to be of ecological, recreational, or commercial importance
  - These species will be used to create the functional groups.

Alewife	American Lobster	Atlantic Herring
Atlantic Menhaden		
Atlantic Moonfish	Atlantic Rock crab	Atlantic Silverside
Atlantic Striped Bass		
Bay Anchovy	Black Sea Bass	Blue Mussel
Blueback Herring		
Bluefish	Butterfish	Channeled Whelk
Eastern Oysters		
Green Crab	Little Skate	Longfin Squid
Quahog		
Scup	Spider Crab	Spiny Dogfish
Striped Sea Robin		
Summer Flounder	Tautog	Weakfish
Winter flounder		



Diet Data

- Started by Corinne Truesdale and Lauren Josephs in 2018
- Literature search or DEM/GSO data used to determine the diets of the 28 species
  - No published diet data found for 4 species
- Ideally want recent data from the Bay or RI waters
  - Best available peer-reviewed data
  - % weight of each prey species in the ‘predator’s diet
  - Standardized into ~50 prey categories in Excel
  - Unknown categories extrapolated if possible.
- Put into matrix for analysis



File Home Insert Draw Page Layout Formulas Data Review View Help Search Share Comments

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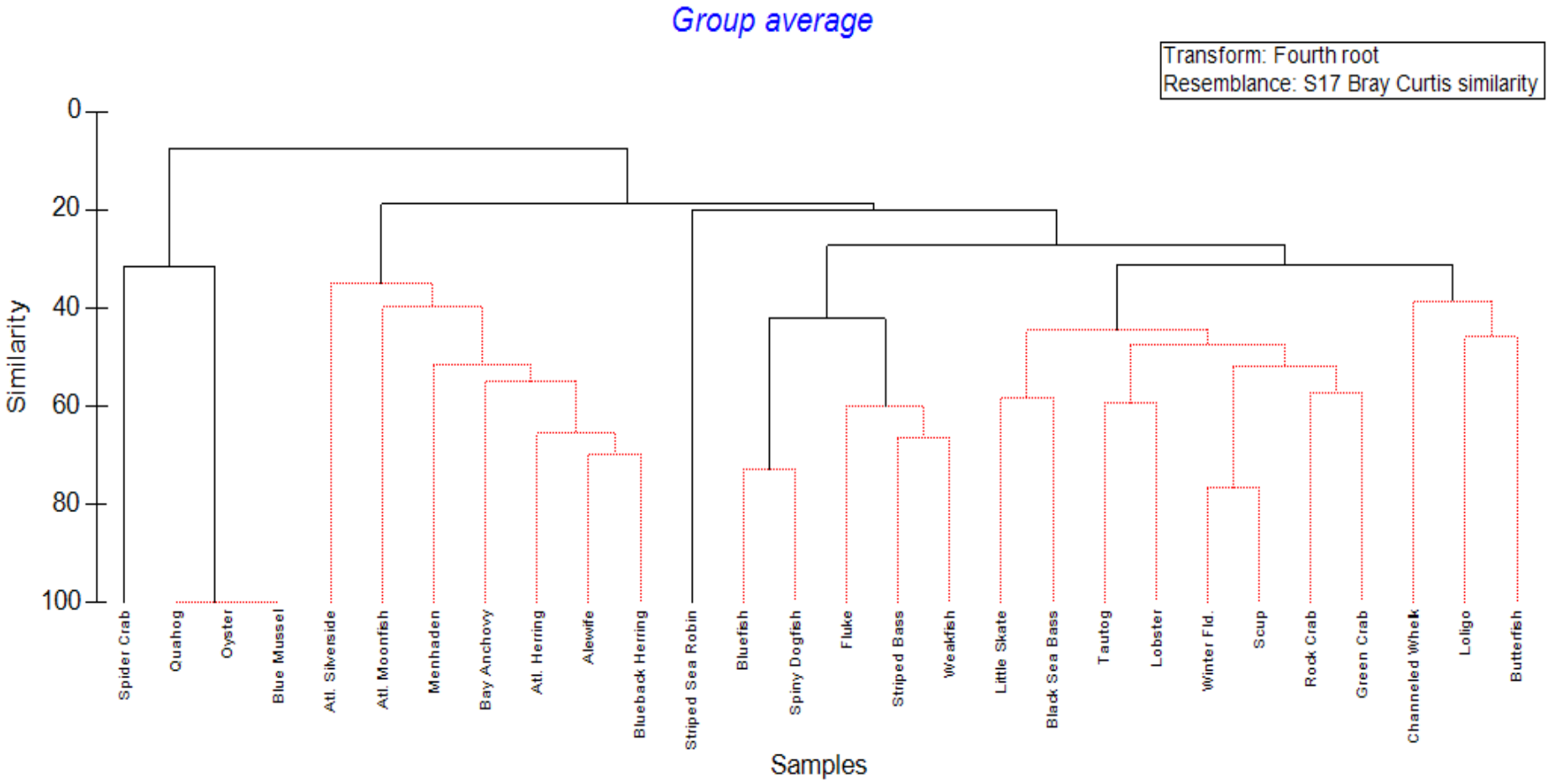
A2 Prey Species

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		Predator Species																					
2	Prey Species	Oyster	Rock Crab	Menhaden	Winter Fld.	Blue Mussel	Atl. Moonfish	Bay Anchovy	Alewife	Atl. Silverside	Spider Crab	Tautog	Atl. Herring	Loligo	Little Skate	Scup	Fluke	Lobster	Butterfish	Striped Bass	Bluefish	Quahog	Channeled Whelk
3	Algae/Plant Material/Microlag	0.5	0.001	0.0000	0.005	0.5	0.0000	0.0000	0.0000	0.0016	0.47	0.0043	0.0000	0.0000	0.0038	0.001	0.0000	0.0602	0.0000	0.018	0.0000	0.5	0.0000
4	Amphipod	0.0000	0.0984	0.0000	0.3095	0.0000	0.0000	0.004	0.1607	0.0000	0.0000	0.0000	0.2138	0.001	0.3902	0.4647	0.0000	0.0056	0.1478	0.1489	0.0003	0.0000	0.0000
5	Anchovy	0.0000	0.0000	0.0000	0.0000	0.0000	0.2079	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0049	0.0000	0.0101	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	Anemone	0.0000	0.0000	0.0000	0.019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	Bass (serranidae)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	Bivalve	0.0000	0.087	0.0000	0.016	0.0000	0.0000	0.0000	0.0000	0.0000	0.085	0.2407	0.0000	0.0001	0.1046	0.0212	0.0000	0.1744	0.0000	0.0000	0.0000	0.0000	0.5
9	Butterfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0000	0.0608	0.0000	0.0000	0.2492	0.66	0.0000	0.0000
10	Cancer Crab	0.0000	0.0656	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0521	0.0077	0.0000	0.2776	0.0000	0.0000	0.0000	0.0000	0.0000
11	Cephalpod	0.0000	0.046	0.0000	0.001	0.0000	0.0099	0.0000	0.0000	0.0000	0.055	0.0000	0.0000	0.0799	0.0169	0.004	0.3358	0.0000	0.0000	0.1129	0.171	0.0000	0.0000
12	Copepod	0.0000	0.0000	0.396	0.0000	0.0000	0.01	0.637	0.4927	0.8352	0.0000	0.0000	0.2138	0.0001	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
13	Crangon Shrimp (Sand Shrimp)	0.0000	0.0000	0.0000	0.0021	0.0000	0.01	0.0000	0.0000	0.0000	0.0000	0.0000	0.0225	0.0000	0.1272	0.005	0.01	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000
14	Cumaceans	0.0000	0.0000	0.0000	0.0074	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	Echinoderm	0.0000	0.0000	0.0000	0.013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0082	0.0000	0.0235	0.0000	0.0000	0.0000	0.0000	0.0000
16	Euphasiidae (Krill)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0624	0.0000	0.0000	0.0000	0.0000	0.0900	0.0748	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17	Flatfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	Gastropod	0.0000	0.0000	0.0000	0.001	0.0000	0.0000	0.0000	0.003	0.0000	0.0000	0.0378	0.0000	0.0001	0.0013	0.001	0.0000	0.0089	0.0000	0.0000	0.0000	0.0000	0.0000
19	Hake	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0035	0.0000	0.0191	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20	Herring	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0038	0.0000	0.009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21	Hydroid	0.0000	0.001	0.0000	0.006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0218	0.0000	0.0000	0.0000	0.0000	0.0000
22	Isopod	0.0000	0.0000	0.0000	0.0126	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0118	0.0000	0.007	0.0000	0.0000	0.0000	0.0000	0.0000
23	Jelly (cnidaria and ctenophora	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0031	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	Larvae, Eggs, and Nauplii	0.0000	0.0000	0.004	0.0000	0.0000	0.0000	0.0000	0.0000	0.1084	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
25	Lobster	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.008	0.0000	0.0000	0.0000	0.0000	0.0000
26	Moonfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FineClusterData | CoarseMatrix | SpeciesNotes | EasternOyster | RockCrab | Menhaden | WinterFlounder | BlueMussel | AtlMoonfish | BayAnchov ...

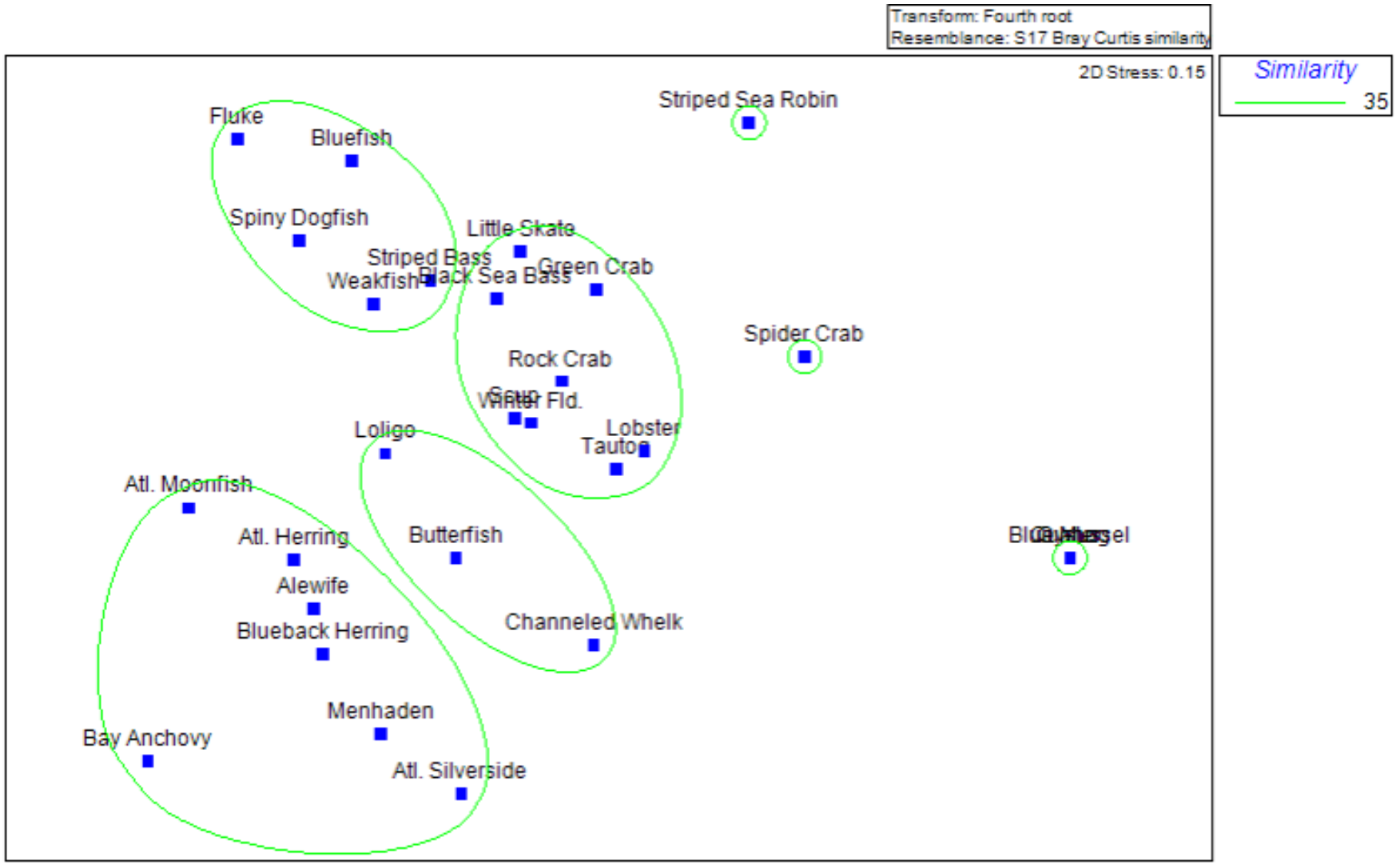
80%

Diet Data

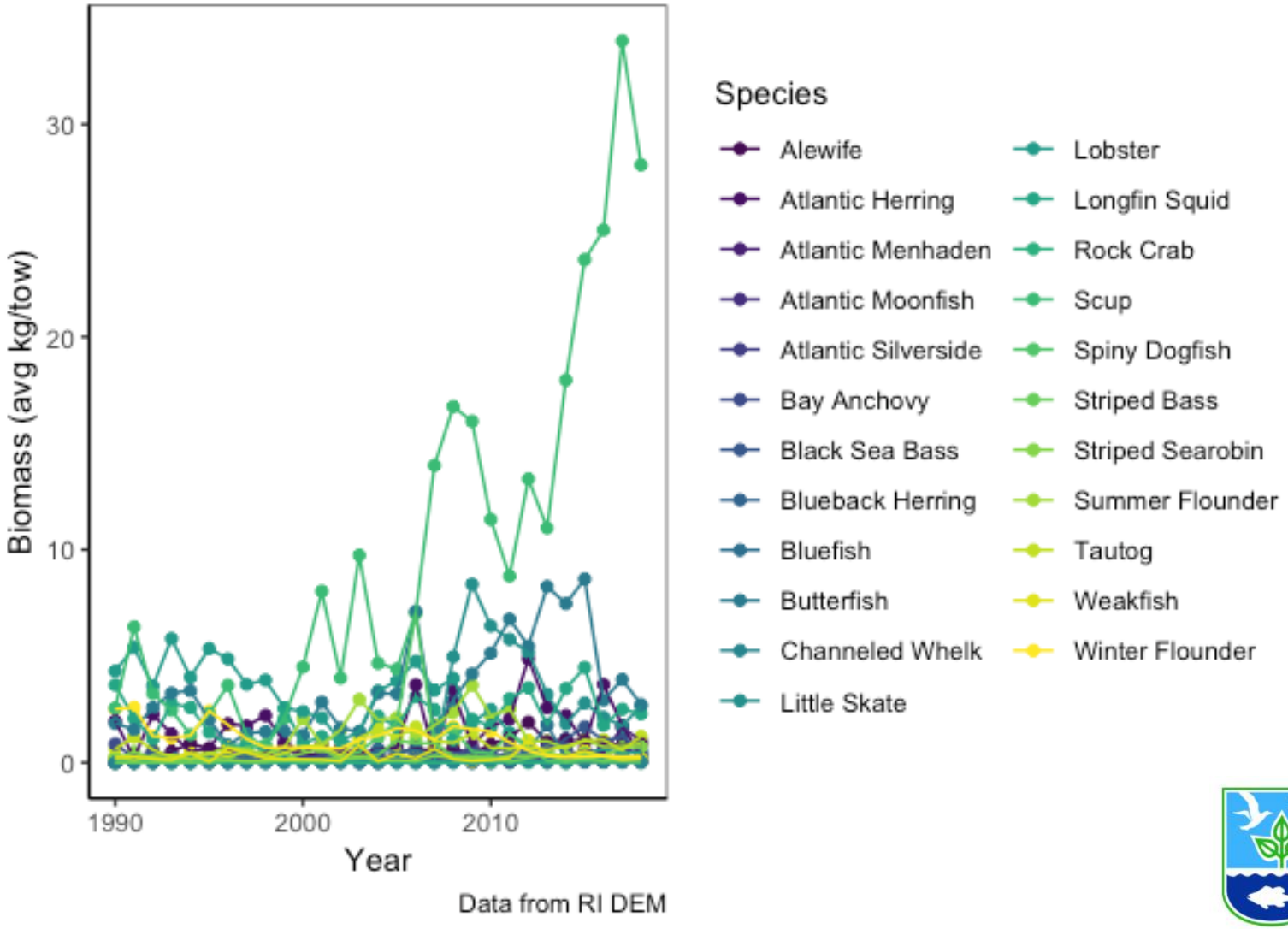


NB ‘Predator’ Species of Interest

Diet Data


Transform: Fourth root
Resemblance: S17 Bray Curtis similarity
2D Stress: 0.15
Similarity
35
Striped Sea Robin
Fluke
Bluefish
Spiny Dogfish
Little Skate
Striped Bass
Green Crab
Weakfish
Black Sea Bass
Spider Crab
Rock Crab
Winter Fld.
Lobster
Loligo
Tautog
Atl. Moonfish
Atl. Herring
Butterfish
Alewife
Channeled Whelk
Blueback Herring
Menhaden
Bay Anchovy
Atl. Silverside

DEM Biomass Data



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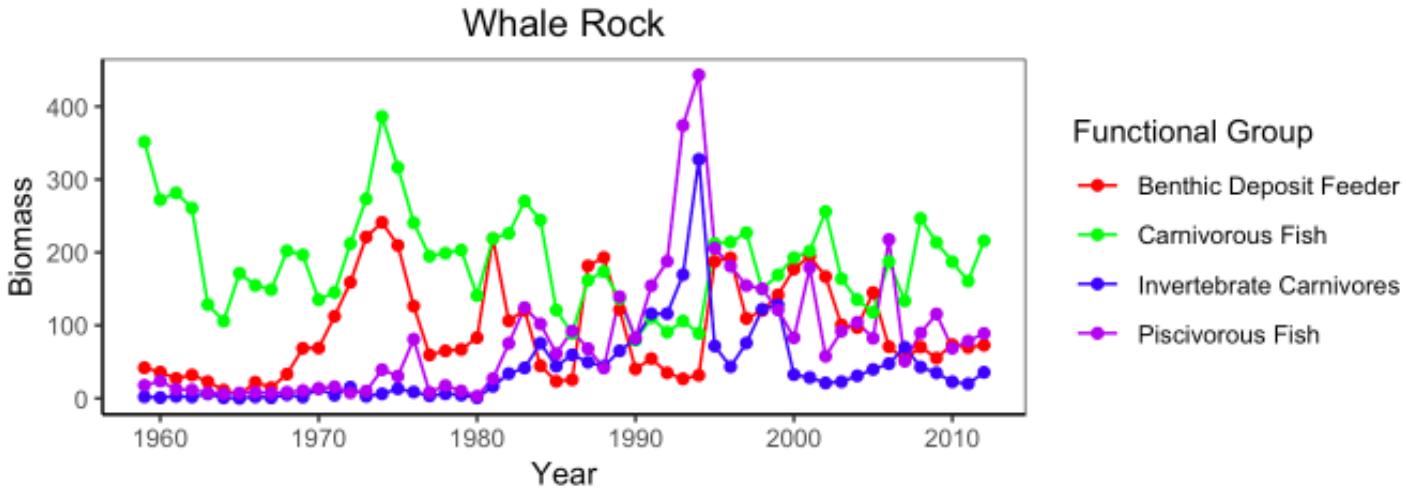
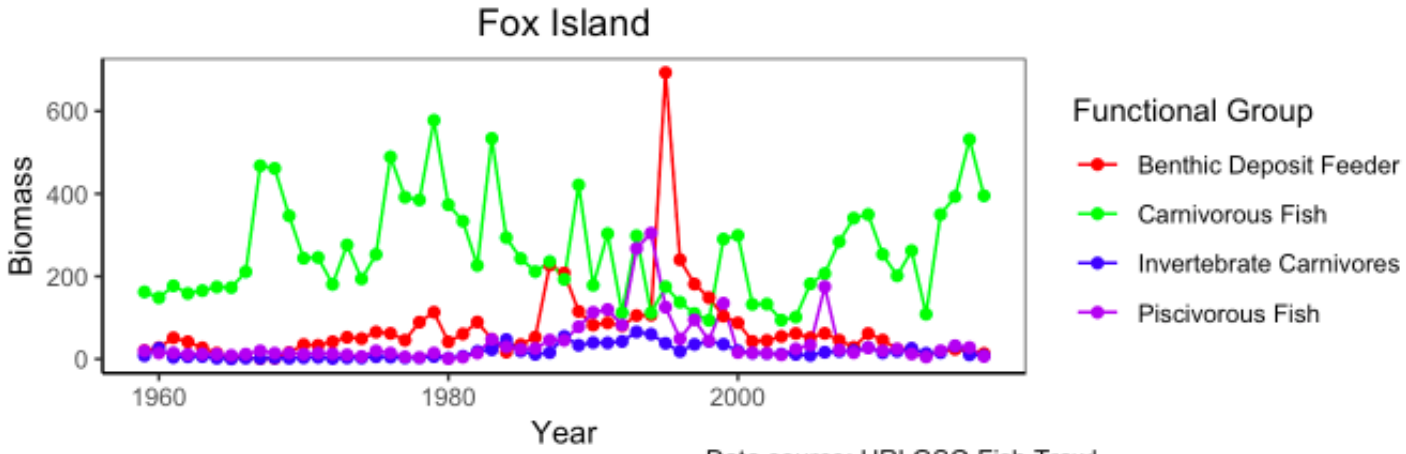
URI GSO Biomass Data





Data source: URI GSO Fish Trawl.

Figures by Kelvin Gorospe.

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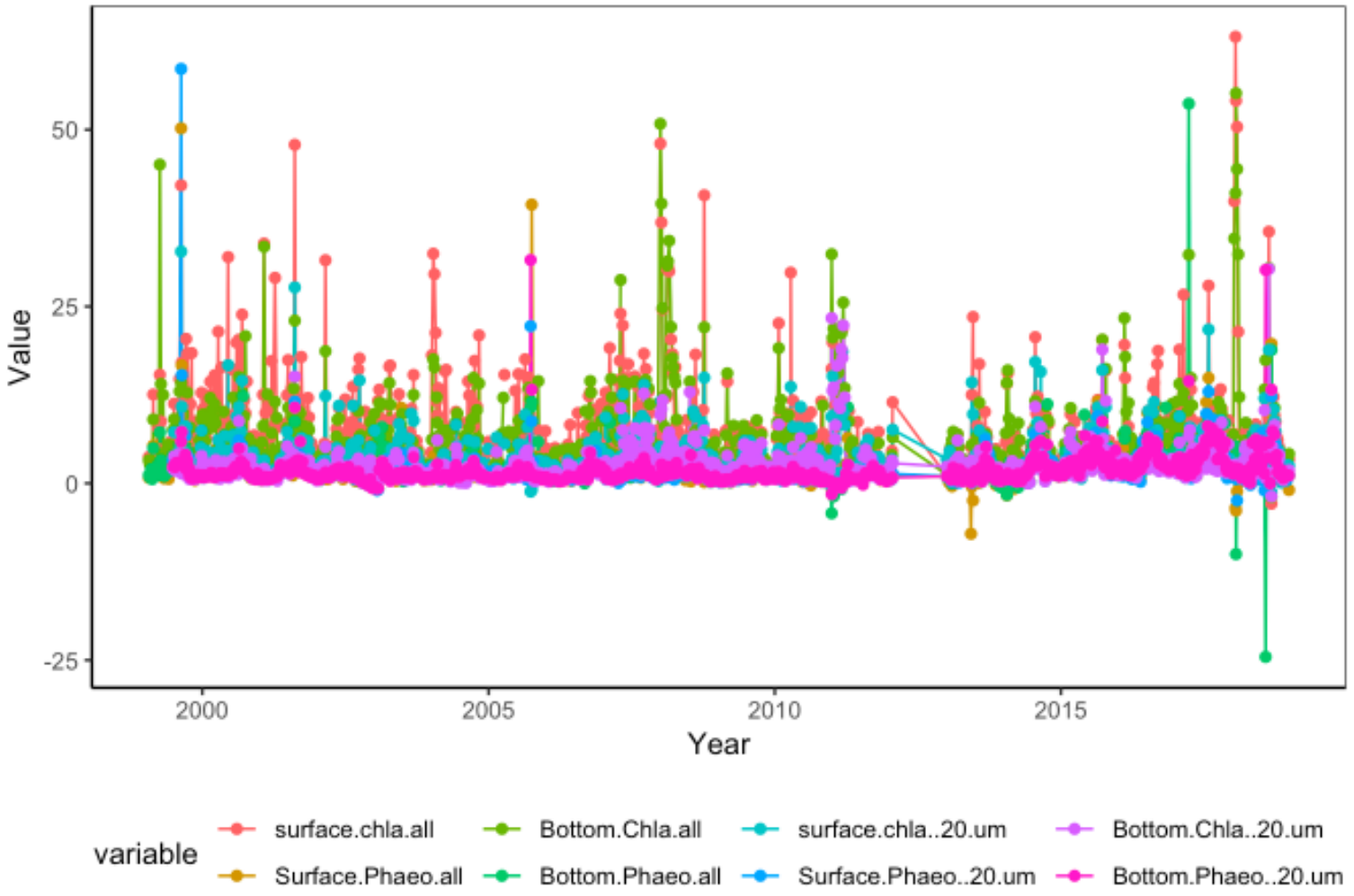
Other Parameters

- Consumption (Q/B)
  - Fish species from fishbase.org, invertebrates calculated from http://www.thomas-brey.de/
- Production (P/B) is equivalent to Z (total mortality)
  - Total Mortality = Natural Mortality + Fishing Mortality
  - Natural mortality from fishbase.org, sealifebase.org, and stock assessments
  - Fishing mortality = Catch / Biomass, will be calculated from fisheries and biomass data

External Drivers: Primary Production



Data from URI. Figure by Kelvin Gorospe.

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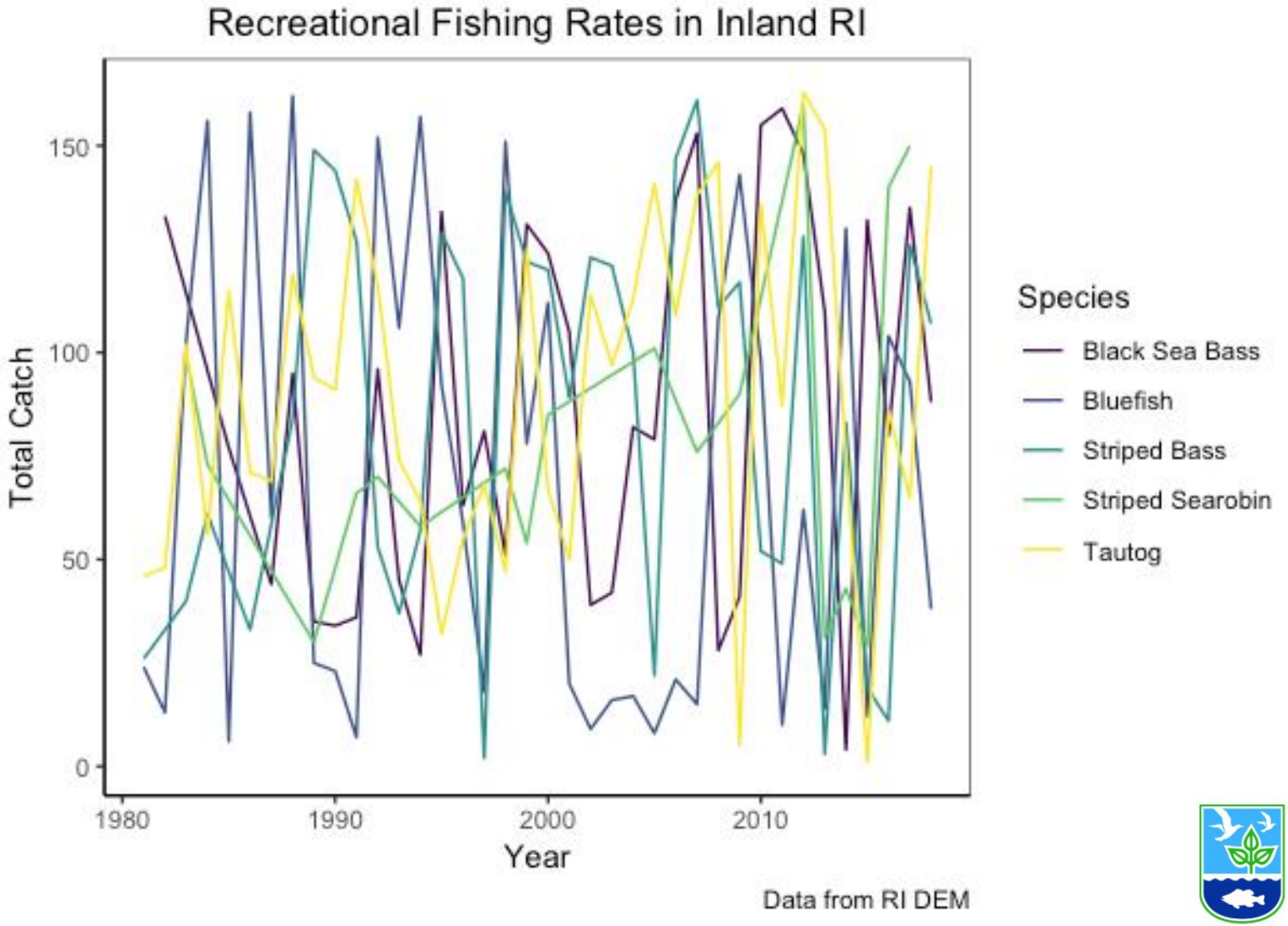
External Drivers: Fisheries Landings



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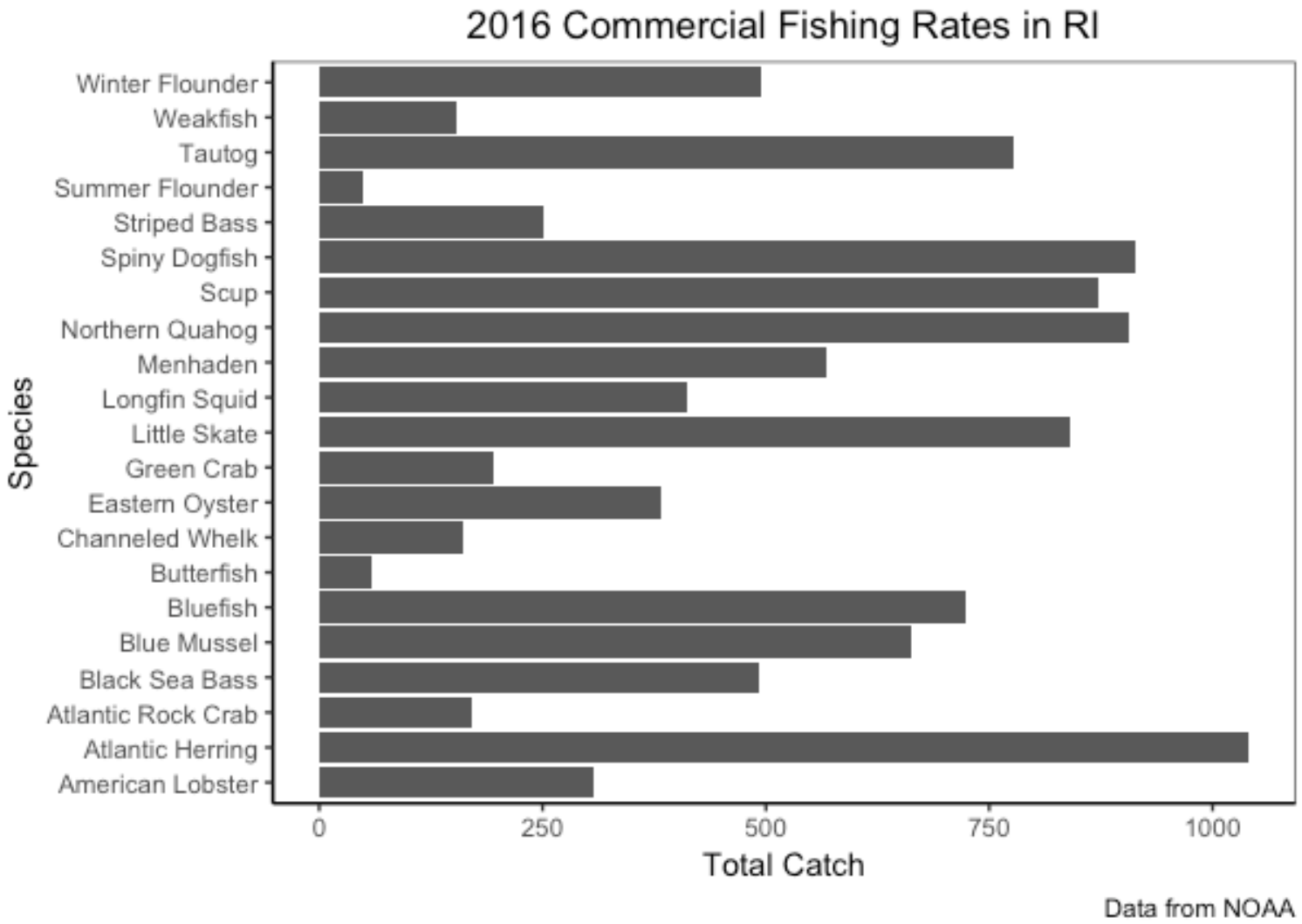
External Drivers: Fisheries Landings



Divide and Conquer!

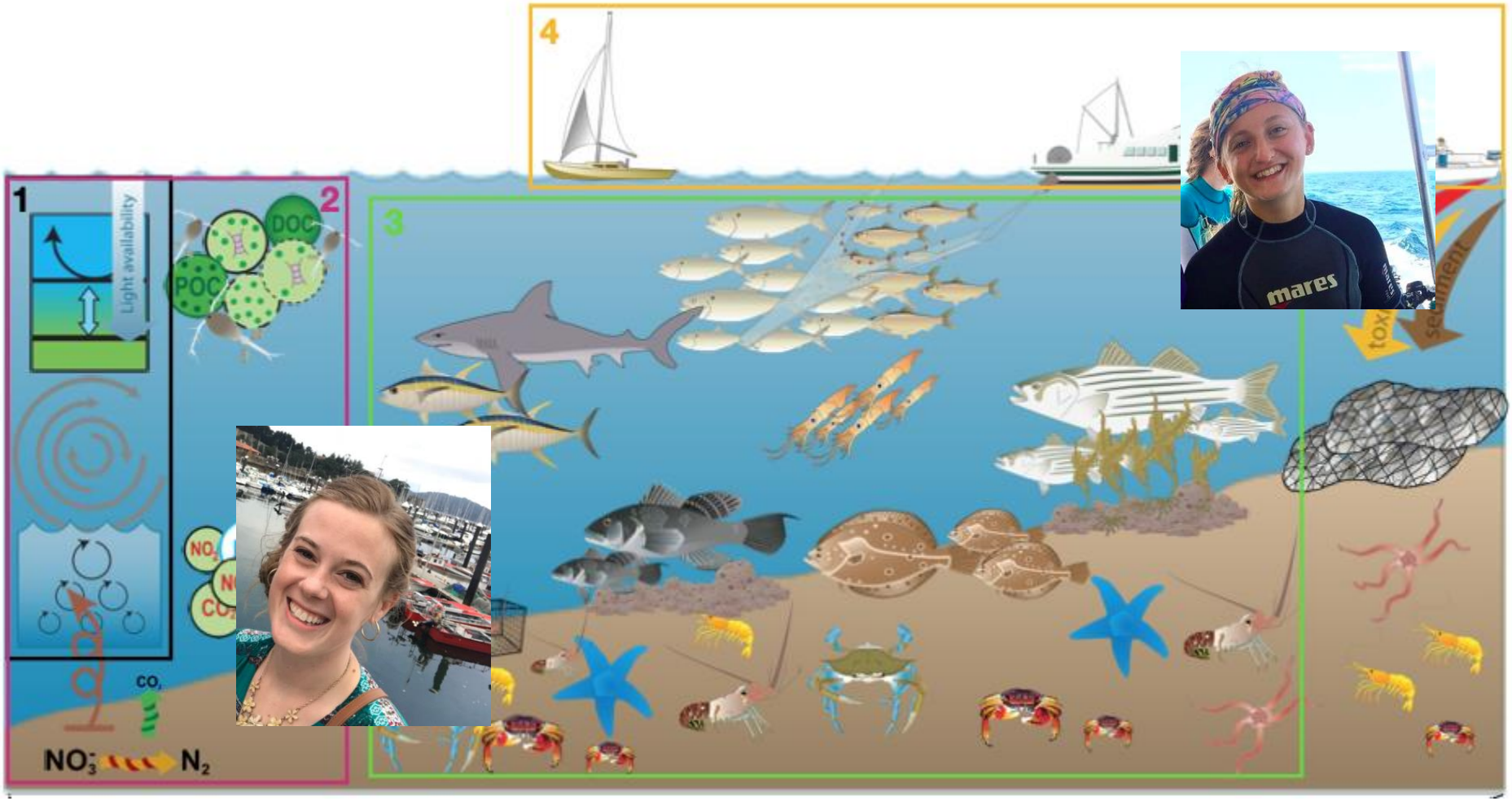


Figure from *Gorospe et al. in review*

Next Steps Toward an Ecosystem Model

Next Steps

- Finalize our qualitative Narragansett Bay social-ecological systems model
- Finish data collection for biological parameters
- Scale by proportion of time spent in Bay by species of interest
- Update striped sea robin diet data
  - Summer SURF undergrad will examine diets of sea robins caught in the GSO and DEM fish trawls
- Aggregate diet data by trophic guilds, weighting species diets by their biomass in the Bay
- Aggregate other biological data by guilds
- Balance model
- Fit model to historical data
- Utilize forcing function capabilities of Ecosim

Acknowledgements

- Austin Humphries
- Jeremy Collie
- Kelvin Gorospe
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  - Conor McManus
  - Jason McNamee
  - Nicole Lengyel
- NOAA
- URI GSO
- RI NSF EPSCoR