The Northeast Regional Habitat Assessment:

A collaborative, multi-disciplinary project to develop decision support products for marine fish habitat management

Michelle Bachman, New England Fishery Management Council, Inshore Team Co-Lead (mbachman@nefmc.org)
Jessica Coakley, Mid-Atlantic Fishery Management Council, Coordinator, Inshore Team Co-Lead (jcoakley@mafmc.org)
Chris Haak, Monmouth University/NOAA Northeast Fisheries Science Center, Research Scientist (chaak@monmouth.edu)
Tori Kentner, Mid-Atlantic Fishery Management Council, Spatial Ecologist (tkentner@mafmc.org)
Laurel Smith, NOAA Northeast Fisheries Science Center, Offshore Team Lead (laurel.smith@noaa.gov)

MAFMC Scientific and Statistical Committee
September 13, 2022

NRHA Goal: To describe and characterize estuarine, coastal, and offshore fish habitat distribution, abundance, and quality in the Northeast.

Four actions were identified as necessary to meet this goal:

1) Inshore fish habitat assessment
   a) Fish distribution and abundance
   b) Habitat distribution, status, and trends
2) Habitat vulnerability including response to changes in climate,
3) Spatial descriptions of species habitat use in the offshore area, and,
4) Habitat data visualization and decision support tools.

Geographic Scope: Northeast U.S.

South to North

North Carolina/South Carolina boundary to the western end of the Scotian Shelf and includes the Mid-Atlantic Bight, Southern New England, Georges Bank, and the Gulf of Maine.

Inshore to Offshore

Mean high water including estuaries to the shelf-slope break

Focus Species (65+, important to managers)

- **Mid-Atlantic Council:** Atlantic and chub mackerel, butterfish, longfin and shortfin squid, surfclam, ocean quahog, summer flounder, scup, black sea bass, bluefish, golden and blueline tilefish, spiny dogfish
- **New England Council:** Cod, cusk, haddock, pollock, Acadian redfish, plaice, halibut, winter flounder, witch flounder, yellowtail flounder, wolffish, windowpane, ocean pout, offshore, red, and white hake, monkfish, Atlantic herring, salmon, skates (seven species), red crab, sea scallop
- **Additional Atlantic States Marine Fisheries Commission (ASMFC):** Eel, lobster, croaker, menhaden, striped bass, Atlantic sturgeon, black drum, cobia, horseshoe crab, Jonah crab, northern shrimp, red drum, shad and river herring, Spanish mackerel, spot, spotted seatrout, tautog, weakfish, coastal sharks
- **Highly migratory with Habitat Areas of Particular Concern (HAPC) designations:** Sandbar shark, dusky shark

Assessment Products at a Glance

Data inventory

- Catch data from state and federal fisheries-independent surveys; including comparison table
- Environmental datasets (used as model covariates)
- One page metadata document for each survey or data set

Habitat use

- Species profiles: Summarize life history and habitat use for each focus species
- Stage-based, single species and joint species distribution models (SDMs)
- Inshore Habitat Report

Climate vulnerability - Species-Habitat Crosswalk

- Species-habitat matrix and climate vulnerability narratives

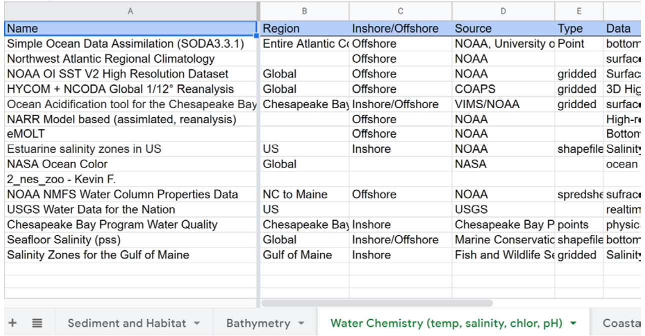
Habitat data visualization and decision support tools

- NRHA Data Explorer: R-Shiny application used to show trends in species distribution and abundance at state and regional scales, and to share other products and documentation
- Working with partners at Mid-Atlantic Ocean Data Portal, Northeast Ocean Data Portal, and possibly NOAA DisMAP to share selected products

Scientific publications/reports

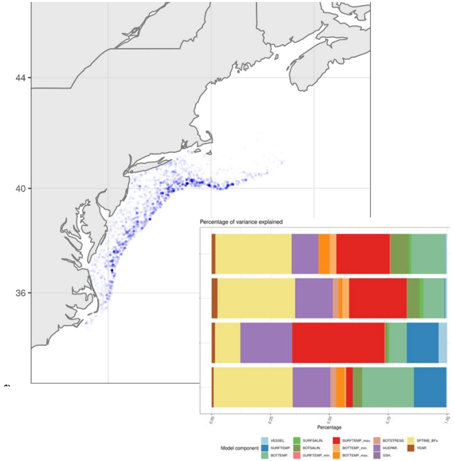
- Community-level Basis Function Modeling methods paper and R package; others in development

Data inventory

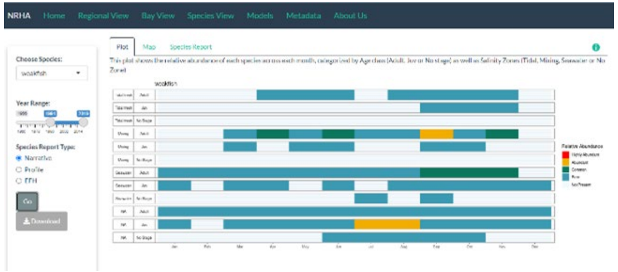


Name	Region	Inshore/Offshore	Source	Type	Data
Simple Ocean Data Assimilation (SODA3.3.1)	Entire Atlantic Cc	Offshore	NOAA, University o	Point	bottom
Northwest Atlantic Regional Climatology		Offshore	NOAA		surface
NOAA OI SST V2 High Resolution Dataset	Global	Offshore	NOAA	gridded	Surfac
HYCOM + NCODA Global 1/12° Reanalysis	Global	Offshore	COAPS	gridded	3D Hig
Ocean Acidification tool for the Chesapeake Bay	Chesapeake Bay	Inshore/Offshore	VIMS/NOAA	gridded	surface
NARR Model based (assimilated, reanalysis)		Offshore	NOAA		High-re
eMOLT		Offshore	NOAA		Bottom
Estuarine salinity zones in US	US	Inshore	NOAA	shapefile	Salinity
NASA Ocean Color	Global		NASA		ocean
2_nes_zoo - Kevin F.					
NOAA NMFS Water Column Properties Data	NC to Maine	Offshore	NOAA	spredshe	surface
USGS Water Data for the Nation	US		USGS		realtim
Chesapeake Bay Program Water Quality	Chesapeake Bay	Inshore	Chesapeake Bay P	points	physic
Seafloor Salinity (pss)	Global	Inshore/Offshore	Marine Conservatic	shapefile	bottom
Salinity Zones for the Gulf of Maine	Gulf of Maine	Inshore	Fish and Wildlife Se	gridded	Salinity

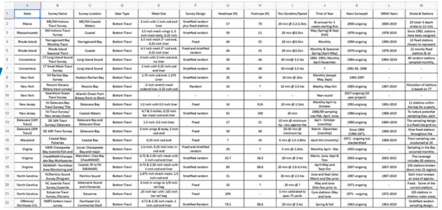
Model-based Approaches



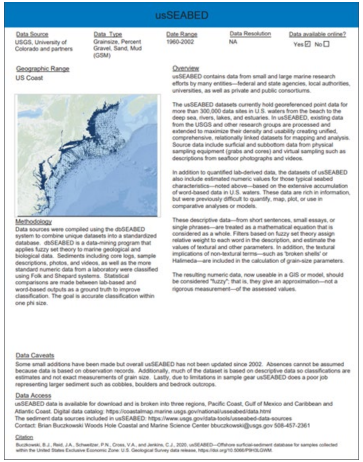
Inshore Fish Data



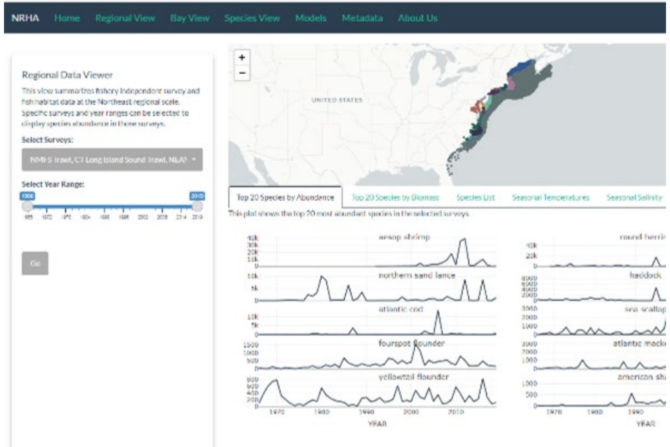
Trawl Survey Comparison



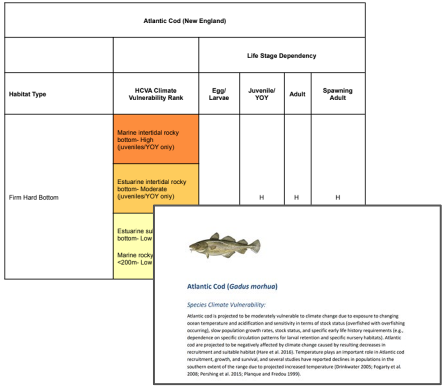
Metadata (1-pagers)



Data Explorer



NRHA/CVA/HCVA Crosswalk

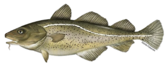


Lots of Reports…

Climate Vulnerability Assessment Crosswalk

- Synthesis of information from NOAA's FSCVA, HCVA, ACFHP species-habitat matrix, and EFH designations
- Matrix that indicates species' dependency on (or association with) habitat types, by life stage
- Narratives that describe species and habitat climate vulnerabilities and habitat dependencies, in text and tables
- Will highlight critical/most concerning intersections of species and habitat climate vulnerability
- Products shared via NRHA Data Explorer

Atlantic Cod (New England)					
		Life Stage Dependency			
Habitat Type	HCVA Climate Vulnerability Rank	Egg/ Larvae	Juvenile/ YOY	Adult	Spawning Adult
Firm Hard Bottom	Marine intertidal rocky bottom- High (juveniles/YOY only) Estuarine intertidal rocky bottom- Moderate (juveniles/YOY only) Estuarine subtidal rocky bottom- Low Marine rocky bottom <200m- Low		H	H	H



Atlantic Cod (*Gadus morhua*)

Species Climate Vulnerability:

Atlantic cod is projected to be moderately vulnerable to climate change due to exposure to changing ocean temperature and acidification and sensitivity in terms of stock status (overfished with overfishing occurring), slow population growth rates, stock status, and specific early life history requirements (e.g., dependence on specific circulation patterns for larval retention and specific nursery habitats). Atlantic cod are projected to be negatively affected by climate change caused by resulting decreases in recruitment and suitable habitat (Hare et al. 2016). Temperature plays an important role in Atlantic cod recruitment, growth, and survival, and several studies have reported declines in populations in the southern extent of the range due to projected increased temperature (Drinkwater 2005; Fogarty et al. 2008; Pershing et al. 2015; Planque and Fredou 1999).

Modeling Framework

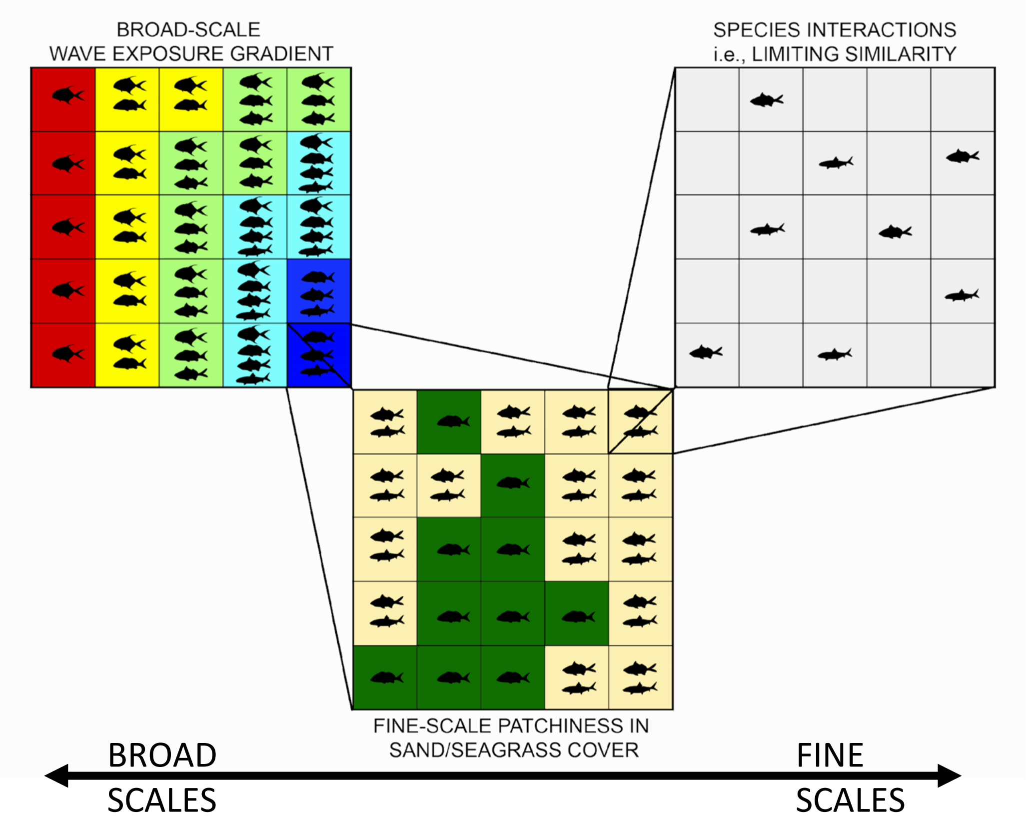
Characterizing Habitat Use

What is Fish Habitat?

- **Necessary for growth, survival & reproduction of a species**
- A function of:
  - Innate **physiological tolerances** of the organism:
    - Temperature, salinity, flow regime
  - Basic **ecological requirements**:
    - Refuge from predators, food availability
  - **Life history stage** (often differing requirements)
  - ***Dynamic*** factors that fluctuate over time

Habitat Use & Community Ecology

- Habitat use patterns are shaped by multiple processes:
  1. **"Environmental filtering" -** Are abiotic conditions compatible with the limitations of the animal?
  2. **Biotic interactions –** Animals act on one another, influencing use of space
  3. **Dispersal limitations**
  - **Induce (+) or (-) correlations in spp pres/abs or abundance**

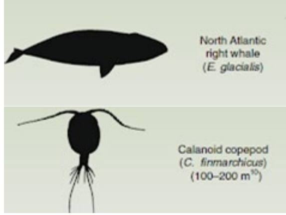


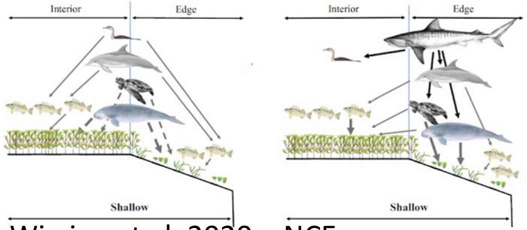
How Can Biotic Interactions Affect Habitat Use?

- **Competition: (-)** Species with similar niches may exclude each other
- **Migratory coupling: (+)** Movement of a consumer is driven by that of its prey
- **Non-consumptive effects: (-)** “Fear” of predators alters use of space by prey
- **Social interactions: (+)** Information exchange b/w species that share common predators or prey
- **Can “scale-up”!**

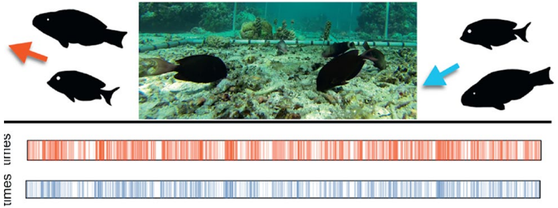
Connel 1961 – Competition

Furey et al. 2018 – Migratory coupling





Wirsing et al. 2020 – NCEs



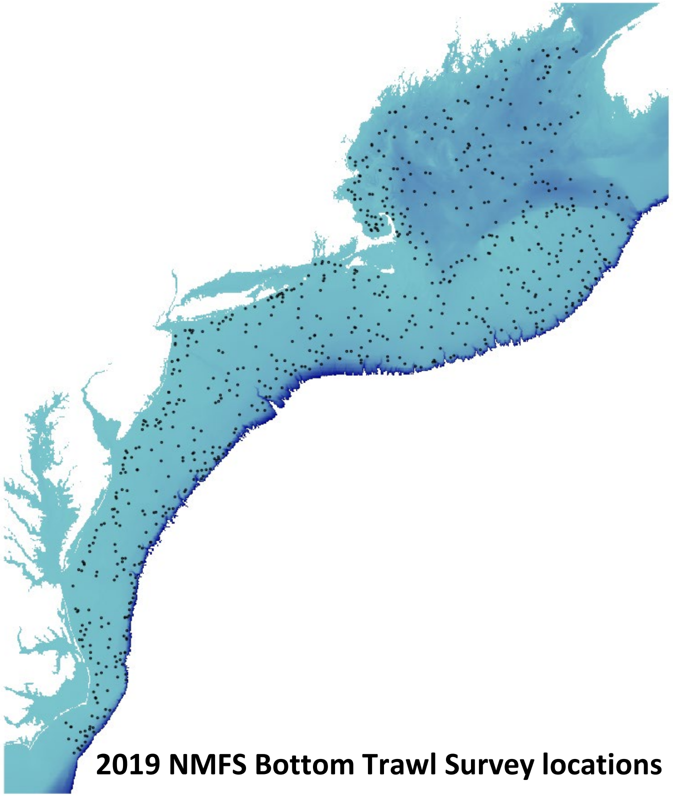
Gil & Hein 2017 – Social Interactions

Characterizing Habitat: A comprehensive strategy

- **Stage-based approach**
  - Partitioning spp. into distinct classes based on ontogeny (i.e., juveniles & adults)
  - Better resolution of stage-specific requirements or habitat shifts?
- **Joint-species distribution model**
  - Using a novel spatiotemporal approach (CBFM) w/ comparison to GAMs
  - Improved predictions & possible ecological insights?
- **Dynamic & ecologically relevant covariates**
  - Temporally varying predictors that reflect dynamic nature of the system
  - Predictors with direct consequences for ecological function of animals

How Do We Assess Habitat Use?

- **Based on observed densities, measured by surveys**
- Sampling is ***very sparse*** in space and time (e.g., NMFS Bottom Trawl)
  - NE Shelf ≈ 260,000 km^2 area
  - ≈700 tows/year (spring & fall)
  - < 0.1 km^2 surveyed by a tow
  - < 0.1% of seabed annually
- **How do we make use of sparse data?**

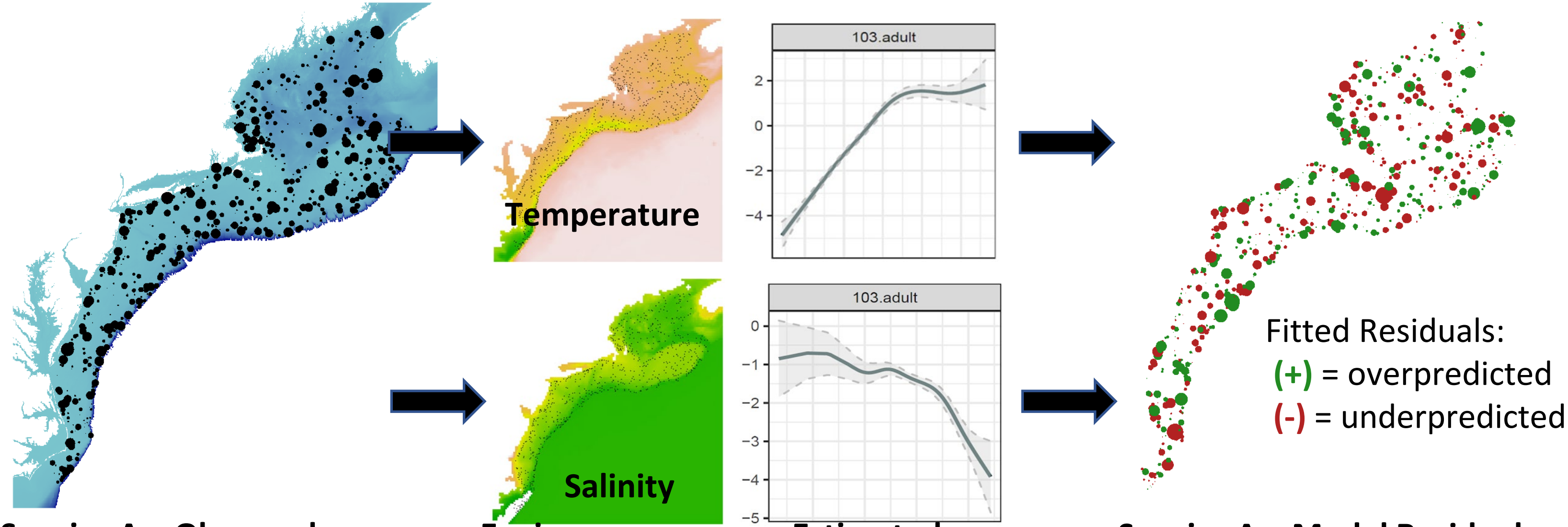


2019 NMFS Bottom Trawl Survey locations

SDMs: A Mechanistic View of Habitat

- **Species Distribution Models** (SDMs) estimate the habitat "niche" of organisms by relating observed densities to measured **environmental** predictor variables

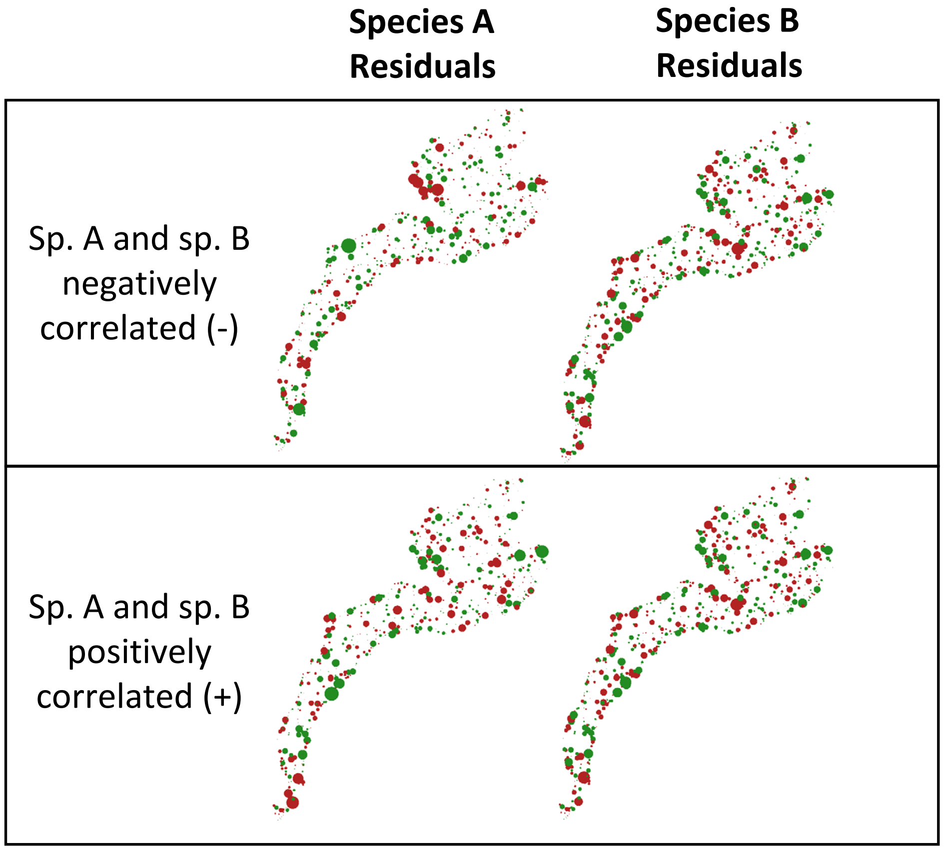
"Environmental filters"



Species A – Observed Density | **Enviro. Predictors** | **Estimated Niche** | **Species A – Model Residuals**

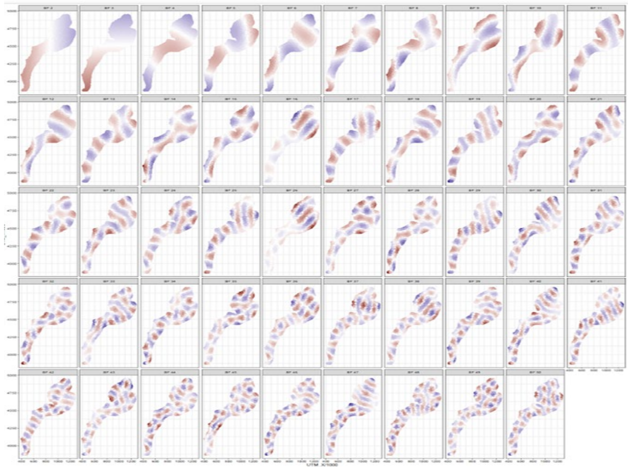
Joint SDMS: Making More of Model Residuals

- In single-species SDMs, **residuals = “error”**
- In a multi-species context, **residual patterns across species may contain information** about underlying processes (i.e., missing predictors, dispersal, interactions)
- Joint SDMs model residual covariance & exploit it to produce **more realistic estimates of species assemblages**



CBFM: Community-level Basis Function model

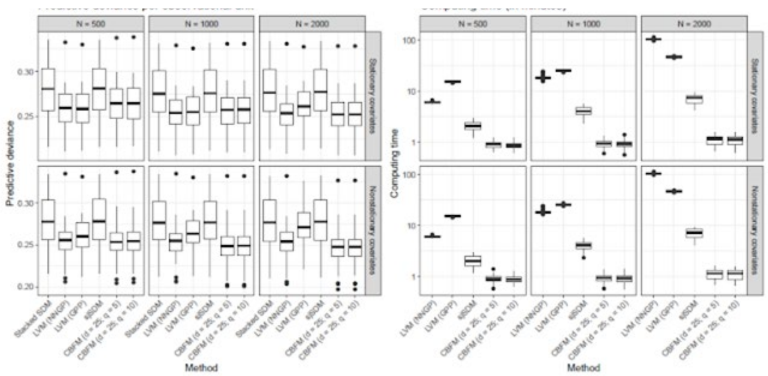
- **Related to GAMS**
  - Basis functions (BF) model covariance in space & time



Spatio-Temporal Joint Species Distribution Modeling:
A Community-Level Basis Function Approach

Francis K.C. Hui*[1], David I. Warton[2], Scott D. Foster[3], Nicole A. Hill[4], and Christopher R. Haak[5]

[1]Research School of Finance, Actuarial Studies and Statistics, The Australian National University, Canberra, Australia
[2]School of Mathematics and Statistics, The University of New South Wales, Sydney, Australia
[3]Data61, Commonwealth Scientific and Industrial Research Organization, Hobart, Australia
[4]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia
[5]Northeast Fisheries Science Centre, National Oceanic and Atmospheric Administration, Highlands NJ, USA



- **Methods Manuscript** w/ Simulation Studies
- **R package** (Github repository, June public release)

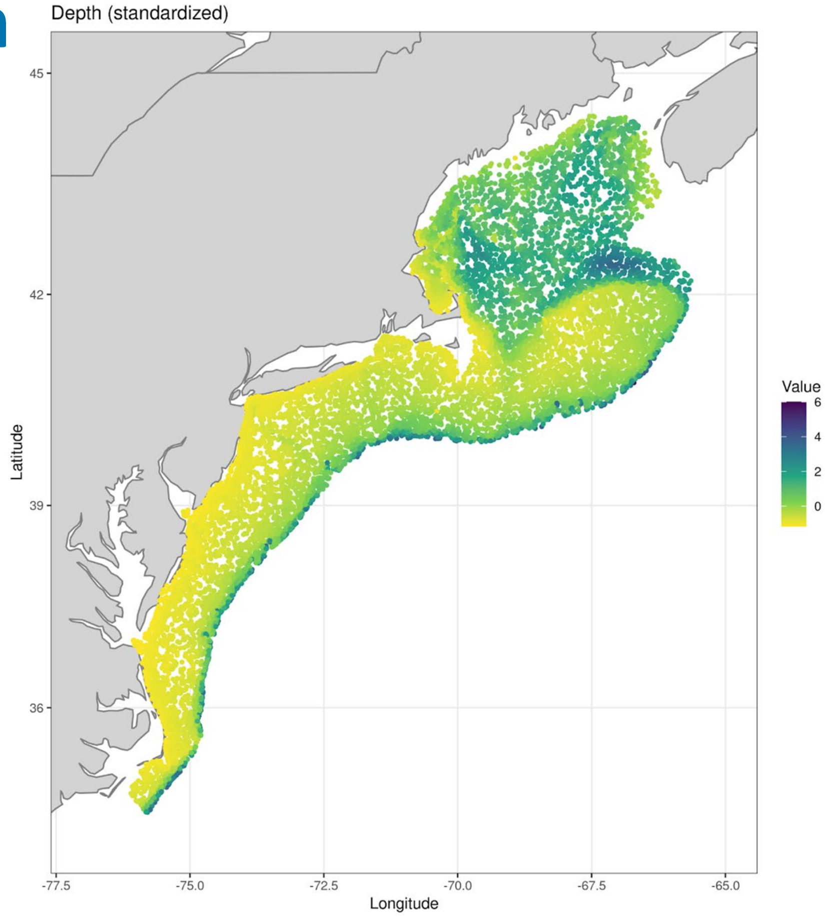
GitHub

CBFM: NRHA Application

- **97 spp-stages** from NMFS bottom-trawl surveys
  - Demersal, pelagic, benthic spp. (managed, common & prey)
  - Training 2000-2015 (n > 10000 obs), testing 2016-2019 (n > 2700 obs)
- Combined **Spring & Fall** surveys
- Predictors:
  - Surface & bottom **temperature** (monthly & annual min/max), **salinity** (surface & bottom), **sea surface height**, depth (or correlates of depth including **optical environment & hydrodynamic stress**), benthic habitat characteristics (topographic position, complexity & sediment type)
- **Hurdle & ZINB models** (presence/absence & count conditional on presence, or covariate-dependent zero inflation)
- Spatiotemporal Basis Functions (intra-year) & GP smooth on year

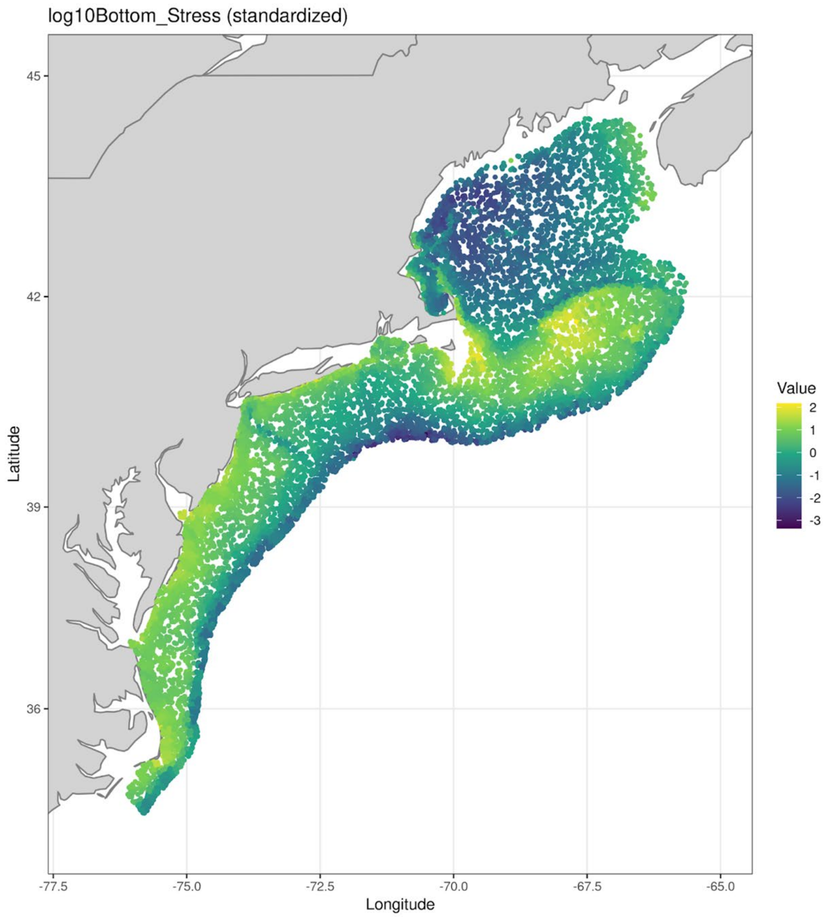
Predictors: Correlates of Depth

- Depth is an informative predictor, but may be a proxy for other, more proximal factors
  - Spp may alter use of depth as they track causal factors (e.g., temperature)
- Correlates of depth with more direct ecological relevance:
  - **Temperature** (physiology)
  - **Visual environment** (navigation, predator-prey interactions)
  - **Hydrodynamic environment** (locomotion, energetic costs)



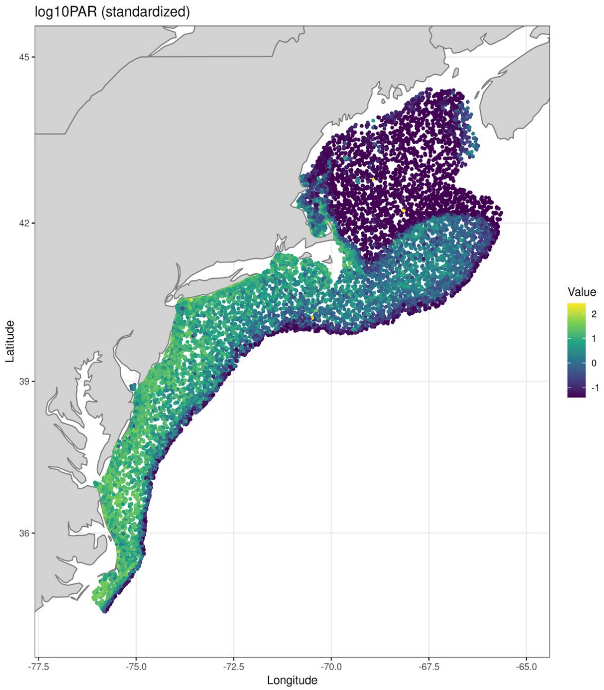
Predictors: Bottom Stress

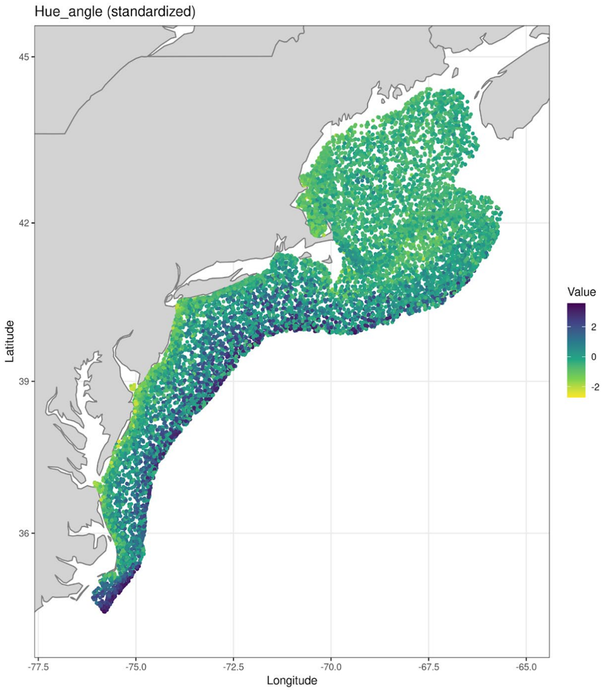
- **Intensity of water movement at the seabed due to waves & currents**
- Inversely related to depth
- 95th quantile (extreme events) - static
- USGS Seabed Stress & Sediment Mobility Database



Predictors: Optical Parameters

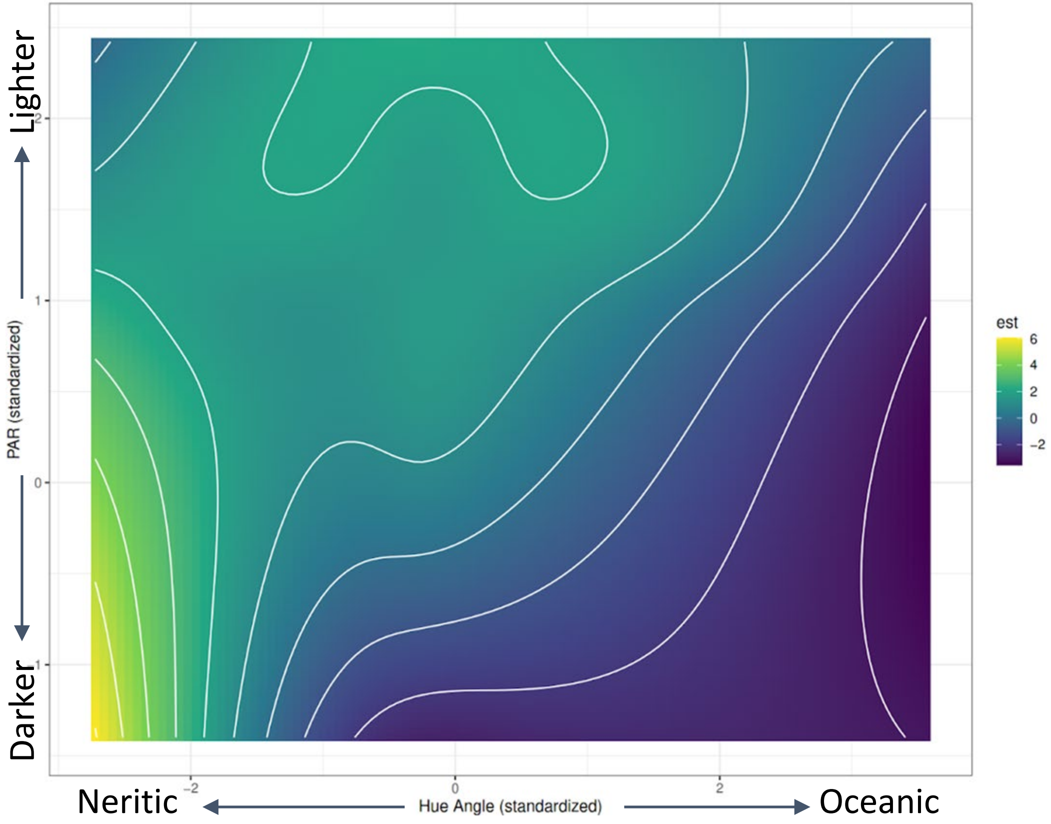
- **PAR = Intensity** of downwelling light
  - Light → Dark
  - (Shallow → Deep)
- **Hue Angle = Spectral distribution** (color) of downwelling light
  - Red → Blue
  - (Coastal → Oceanic)
- @ 0.5 * depth





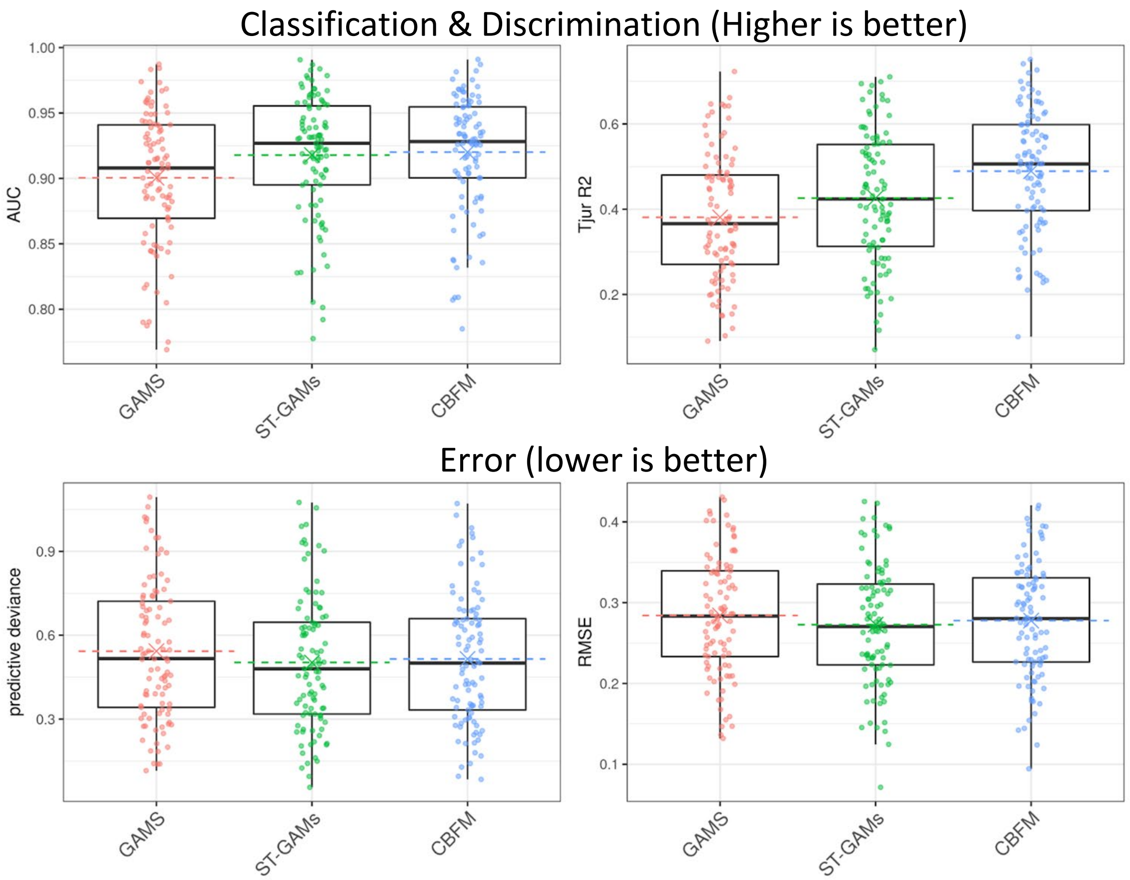
Predictors: Optical Parameters

- Interaction of **PAR** and **Hue Angle** (tensor product)
- Basic quality of underwater optical environment
  - Neritic-oceanic gradients
  - Depth gradients
  - Productivity gradients (Chl)
- Dynamic
  - Season, terrestrial inputs, circulation patterns (e.g., gulfstream position)



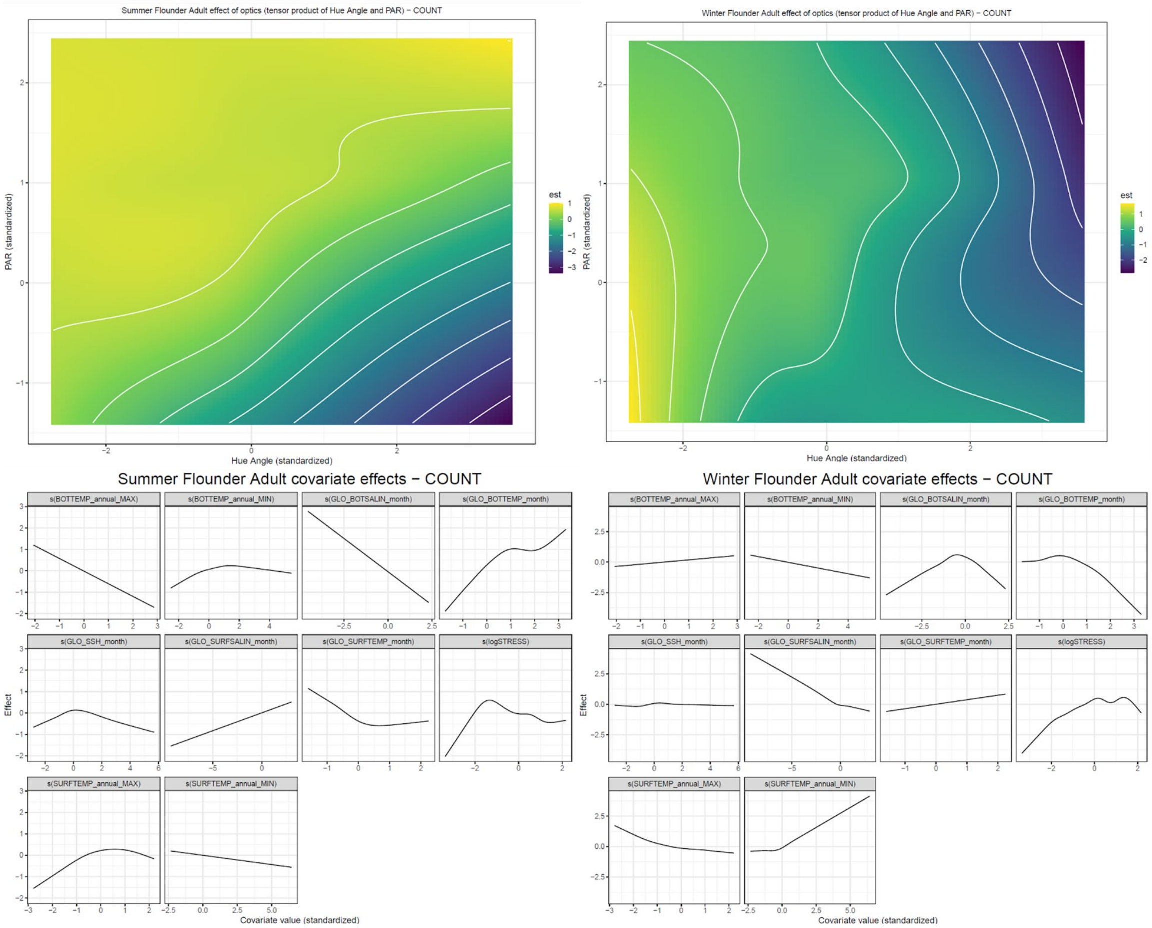
NRHA Application: Predictive Performance

- Out-of-sample prediction: (extrapolated to years 2015 -2019)
  - Median AUC = 0.93 (range from 0.78 - 0.99)
  - Median Tjur R^2 = 0.50 (0.1 - 0.75),
  - Median RMSE = 0.28 (0.09 - 0.42)
- Outperforms stacked (i.e., single-species) spatiotemporal GAMS



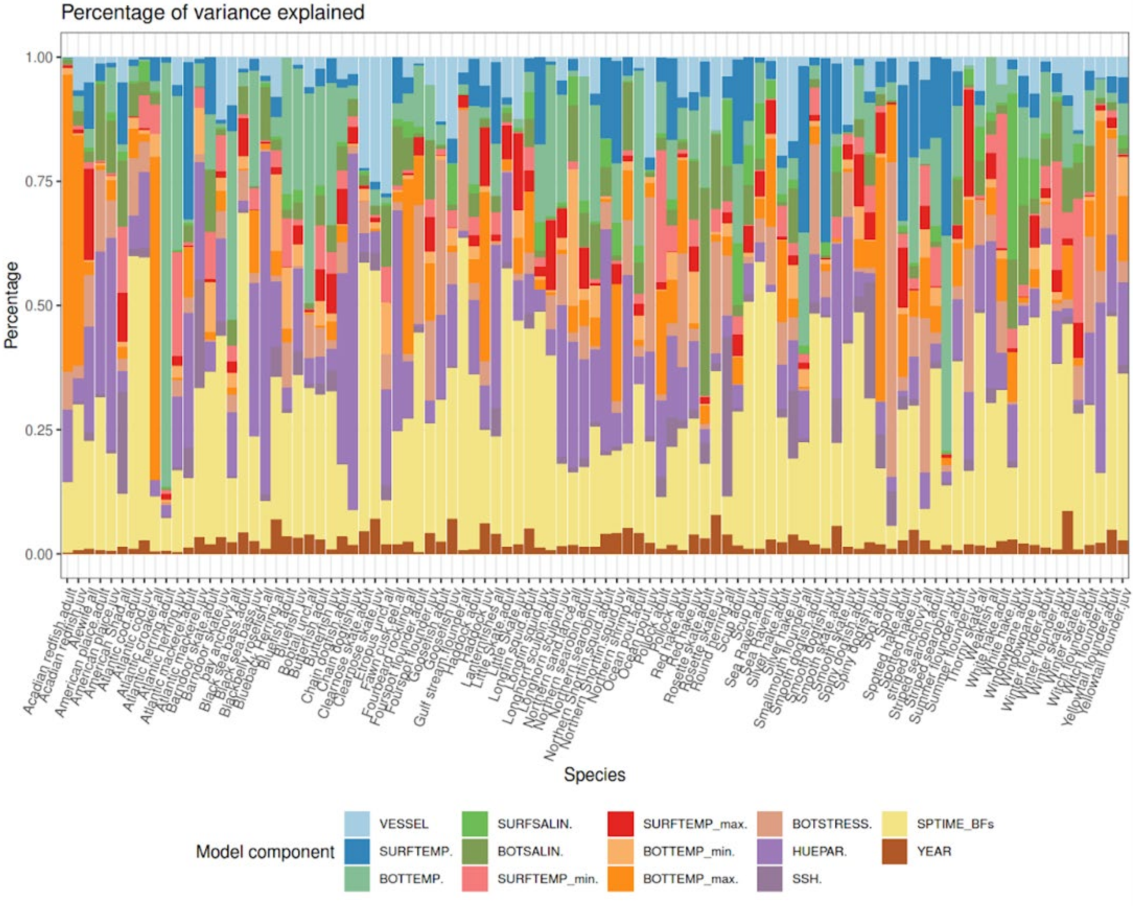
Response to Predictors: Flounders

- Relationship b/w abundance or P/A & environmental predictor variables; “**habitat niche**”
- Summer Flounder (left) vs Winter Flounder (right) “optical niche”
- SF spans both coastal & more oceanic waters, WF confined to more coastal



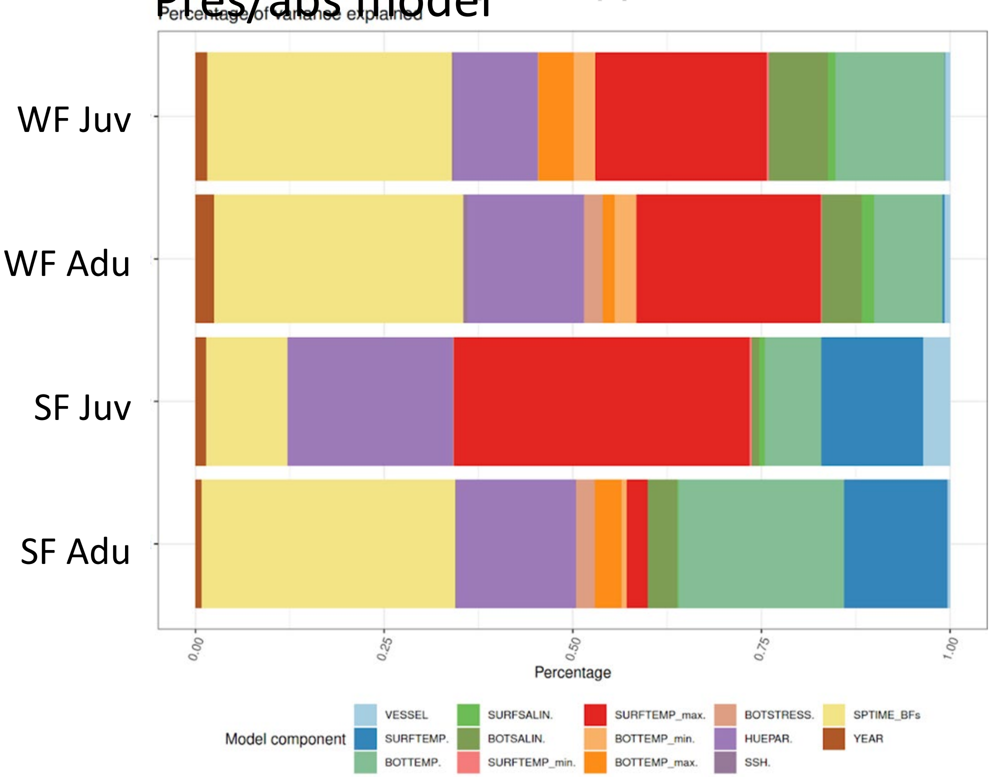
Predictor Importance

- **% variance** explained by each predictor (and spatiotemporal BFs & year effect)
- **What factors are most influential** in driving habitat use of a spp?



Predictor Importance: Summer and Winter Flounders

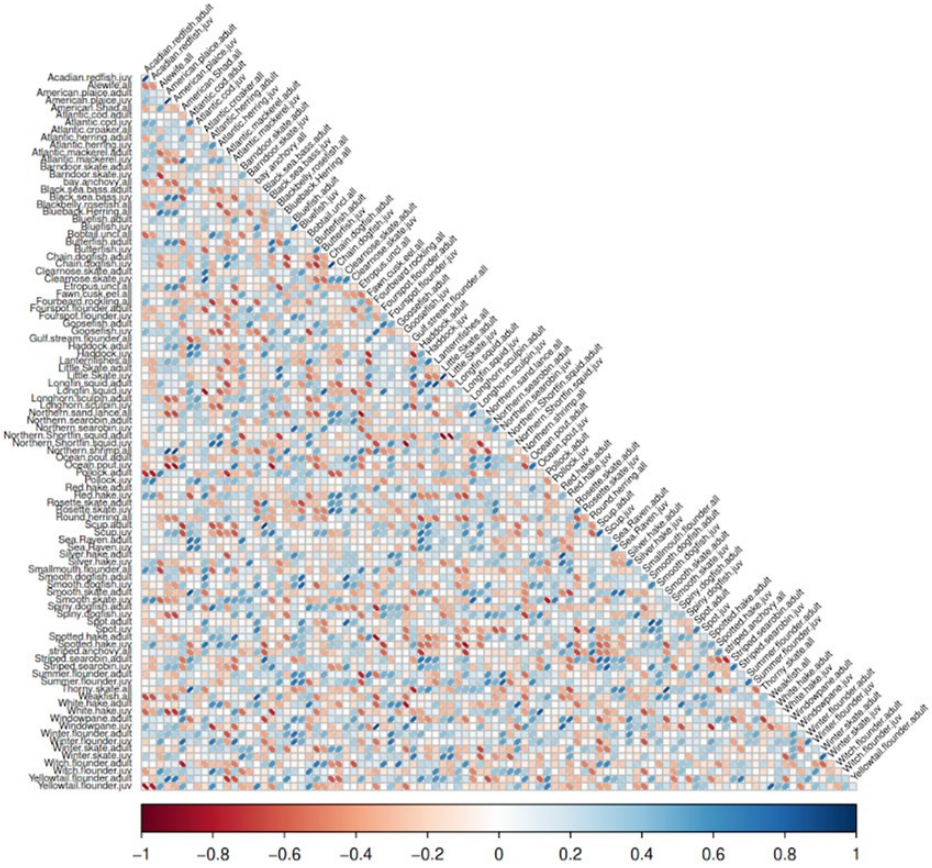
Pres/abs model



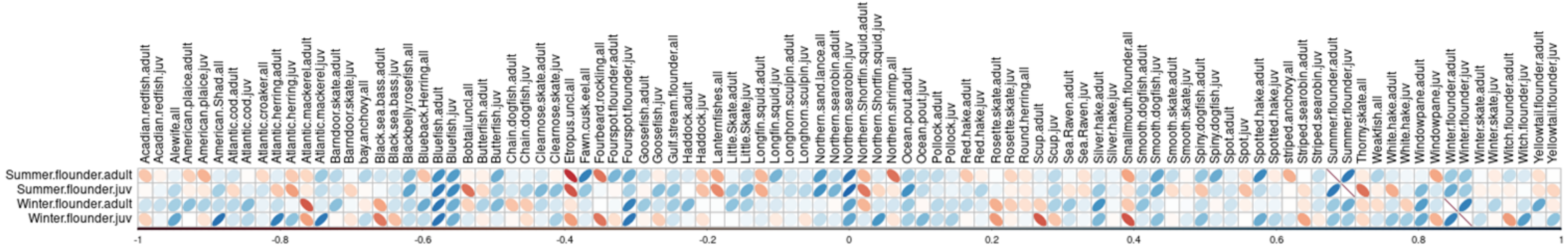
- **Bottom temp, annual max surface temp, & optical parameters** influential
- Surface temp more important for SF, salinity more important for WF
- Similar patterns for juvs and adults

Residual (& Partial) Correlations

- Correlation b/w spp. that is ***not*** explained by measured predictors
- May be evidence of:
  - **Biotic interactions?**
  - Responses to “**missing**” **covariates**?
  - **Dispersal** effects
- Partial correlations control for “indirect” interactions (e.g., shared avoidance of a predator)

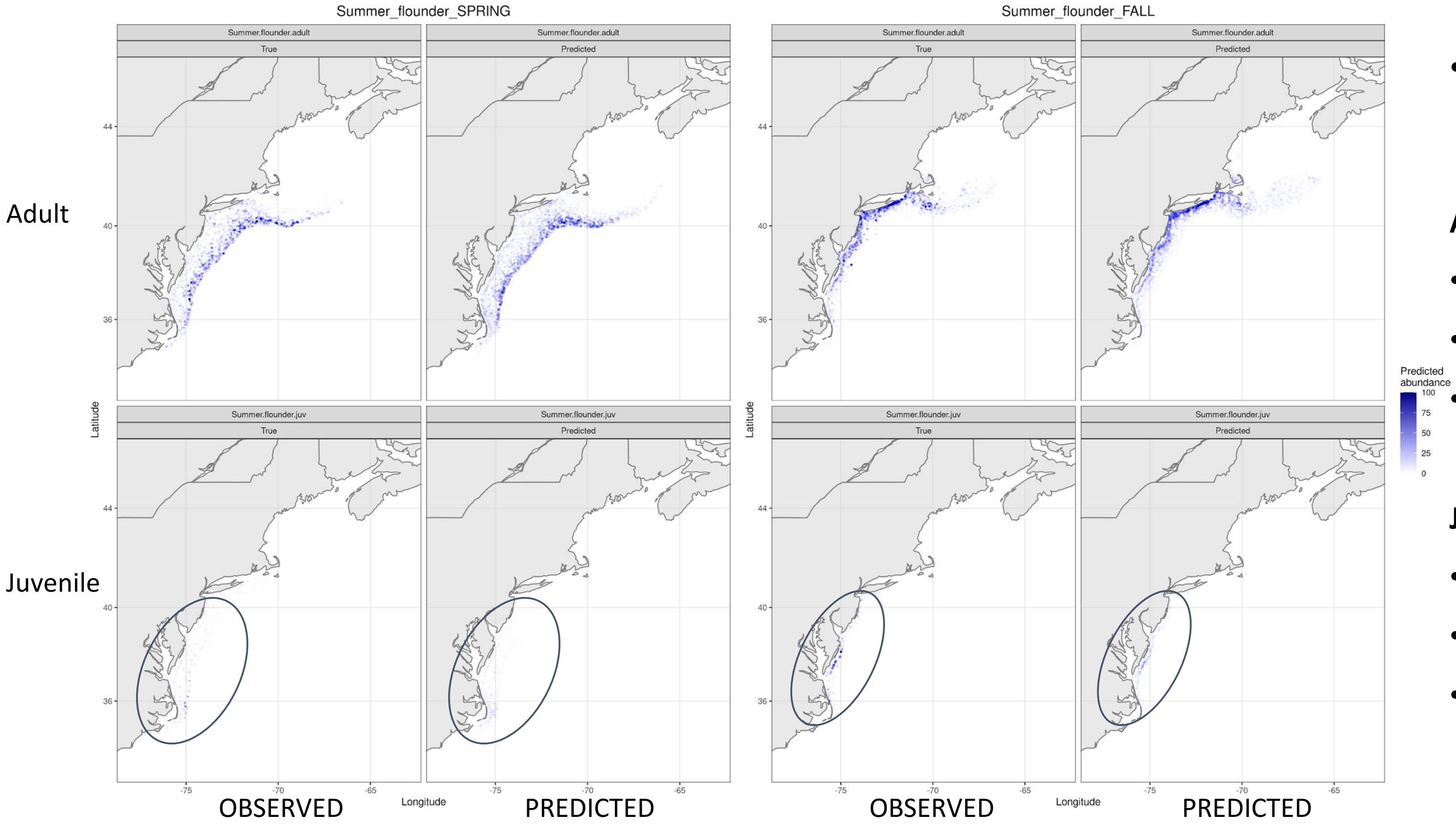


Residual (Partial) Correlations: Flounders



- **Strong +** corrs b/w adults and juveniles within species (dispersal?)
- Weaker + Corrs w/ each other (Summer & Winter)
- + Corrs w/ Bluefish and Northern Searobin?
- - Corrs w/ Etropus & Smallmouth flounders

Predictions: Summer flounder



- **Seasonal & stage-specific differences**

Adults

- AUC = 0.94
- TjurR^2 = 0.62
- RMSE = 0.34

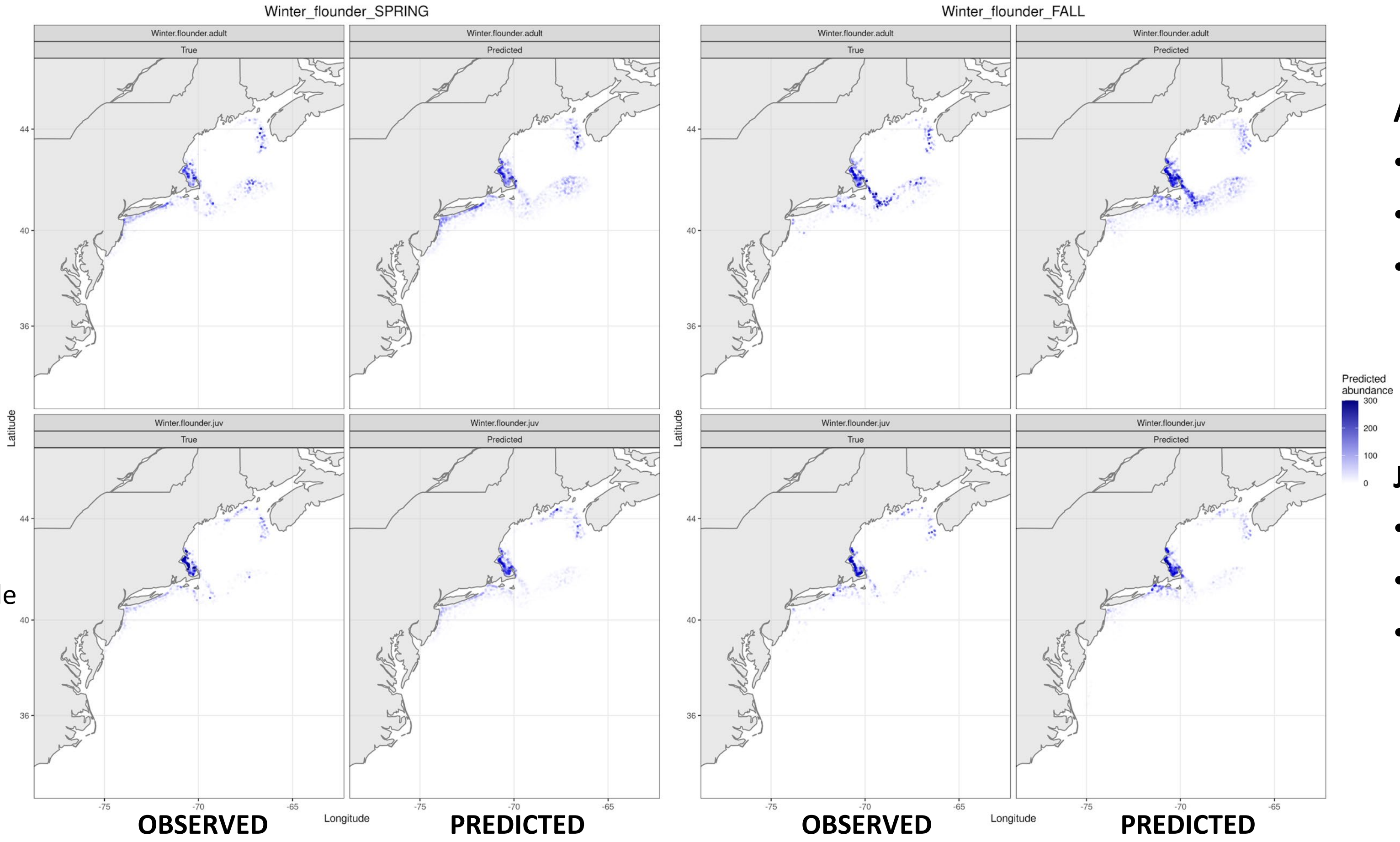
Juveniles

- AUC = 0.93
- TjurR^2 = 0.30
- RMSE = 0.22

Predictions: Winter flounder

Adult

Juvenile



Adults

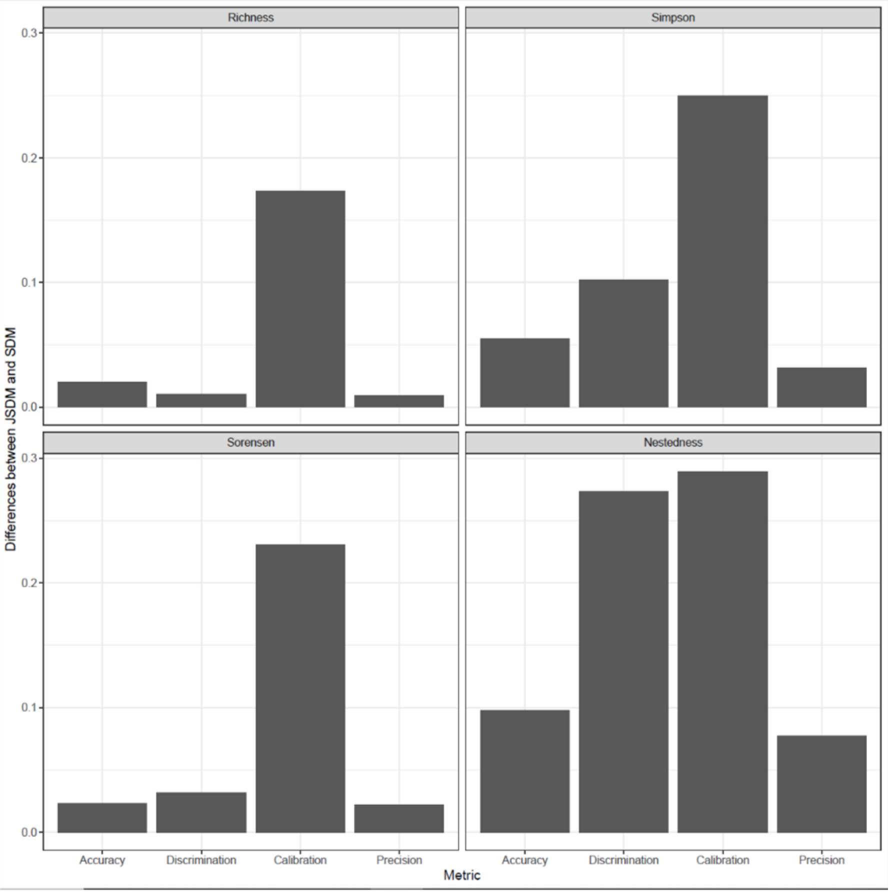
- AUC = 0.95
- TjurR^2 = 0.66
- RMSE = 0.30

Juveniles

- AUC = 0.96
- TjurR^2 = 0.65
- RMSE = 0.26

Predictions: Community-level metrics

- Community-level or "joint" predictions (account for estimated residual covariances)
  - 100 simulations (extrapolation to 4-year test set) estimated by CBFM vs. stacked GAMS
  - Species richness & community composition are more accurately predicted by CBFM



Ongoing work & Recent Improvements

- New fits include response data for benthic invertebrate taxa as well as benthic habitat predictor variables
- Yearly temporal trends are now modeled via a community-level gaussian process smooth with exponential structure (instead of a random int.)
- Covariate-dependent zero inflation has been added as an alternative approach (to the NB hurdle model) for count data ; comparisons are ongoing
- Parallel fits of models that include: (1)Depth vs. (2)Correlates of depth, for comparison

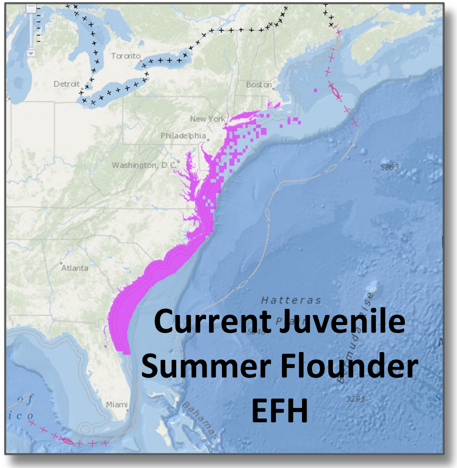
Next Steps

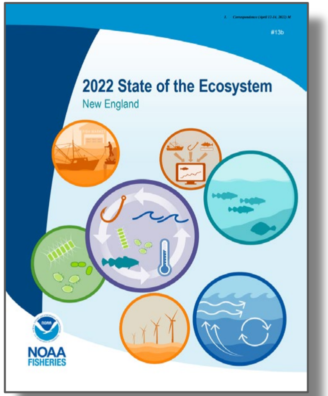
- Explore & visualize final results & make available via NRHA Data Explorer and regional data portals
- Develop long-term projections of changes in distributions/habitat use, driven by climate model outputs
- Also considering:
  - Inclusion of response data for some zooplankton taxa (ECOMON)
  - Integrating response data from additional surveys (e.g., NEAMAP) to improve coverage in the nearshore region

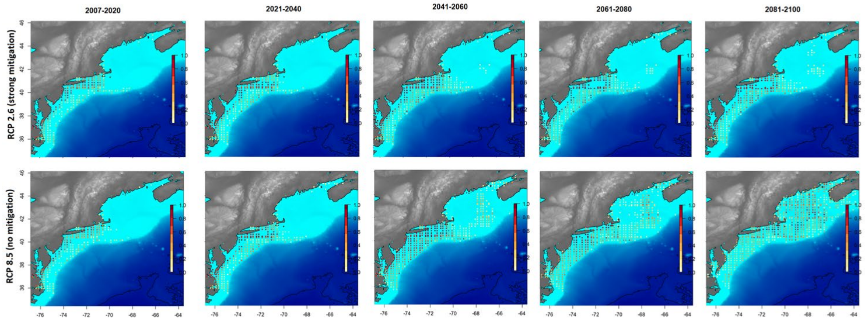
Selected applications for NRHA products

Applications for NRHA Products

- **Essential Fish Habitat:** NRHA provides more specificity on which environmental factors influence species distribution.
    - EFH text descriptions and maps
    - Habitat area of particular concern (HAPC) designations
    - Potential for shifts due to climate change and adaptive approach with automated updates
- **State of the Ecosystem Reports:** NRHA provides habitat and climate change information on managed species
- **Single Species Assessments:** Addresses Ecosystem TORs (e.g. butterfish 2022)
    - NRHA provides historic distributions and projected distributions due to climate change
    - Links between environmental drivers and stock health and recruitment

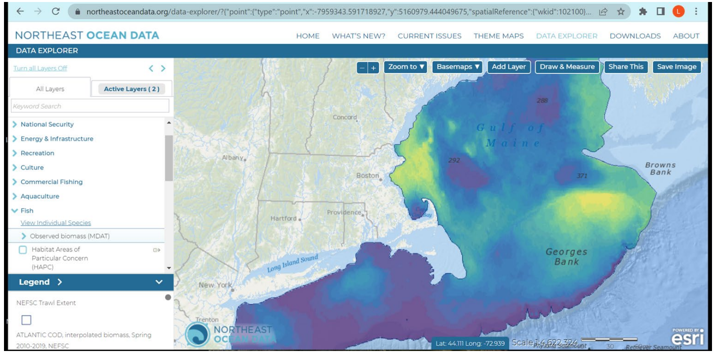


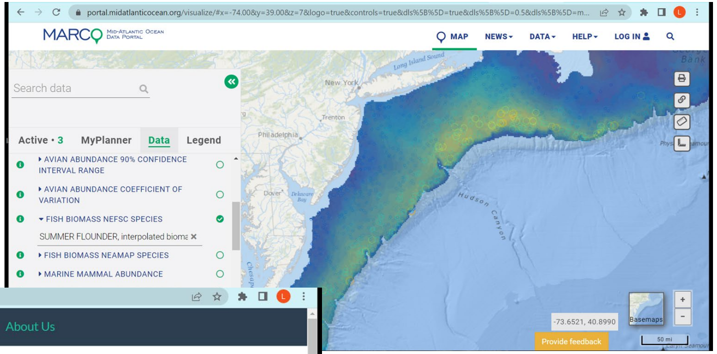


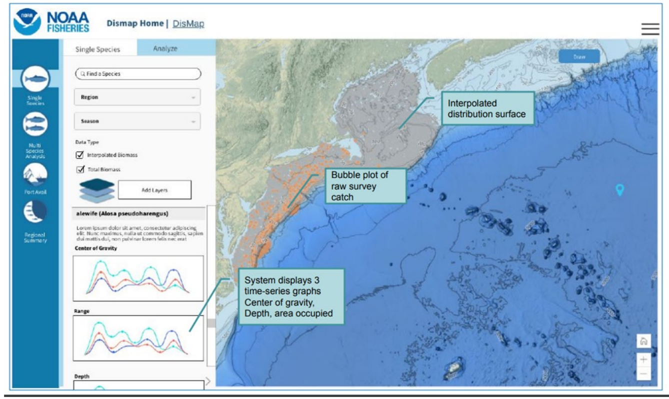


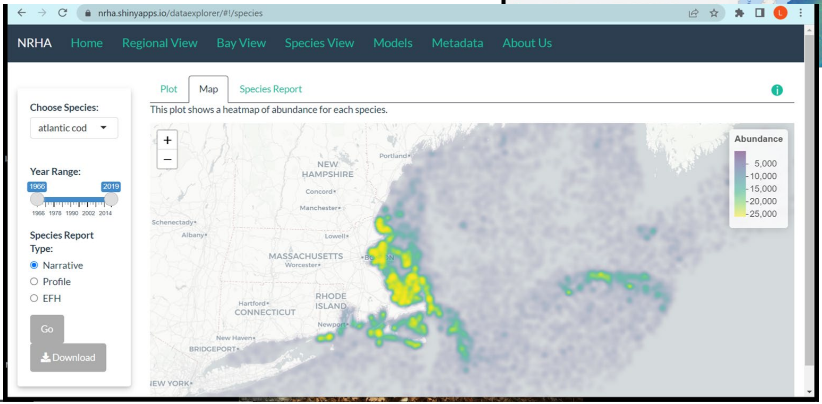
Publicly Available Data Portals

- Intent is to make NRHA products as widely available as possible
- Northeast Ocean Data Portal
- Mid-Atlantic Ocean Data Portal (MARCO)
- NMFS Distribution Mapping and Analysis Portal (DisMAP)
- NRHA Data Explorer (R-Shiny)





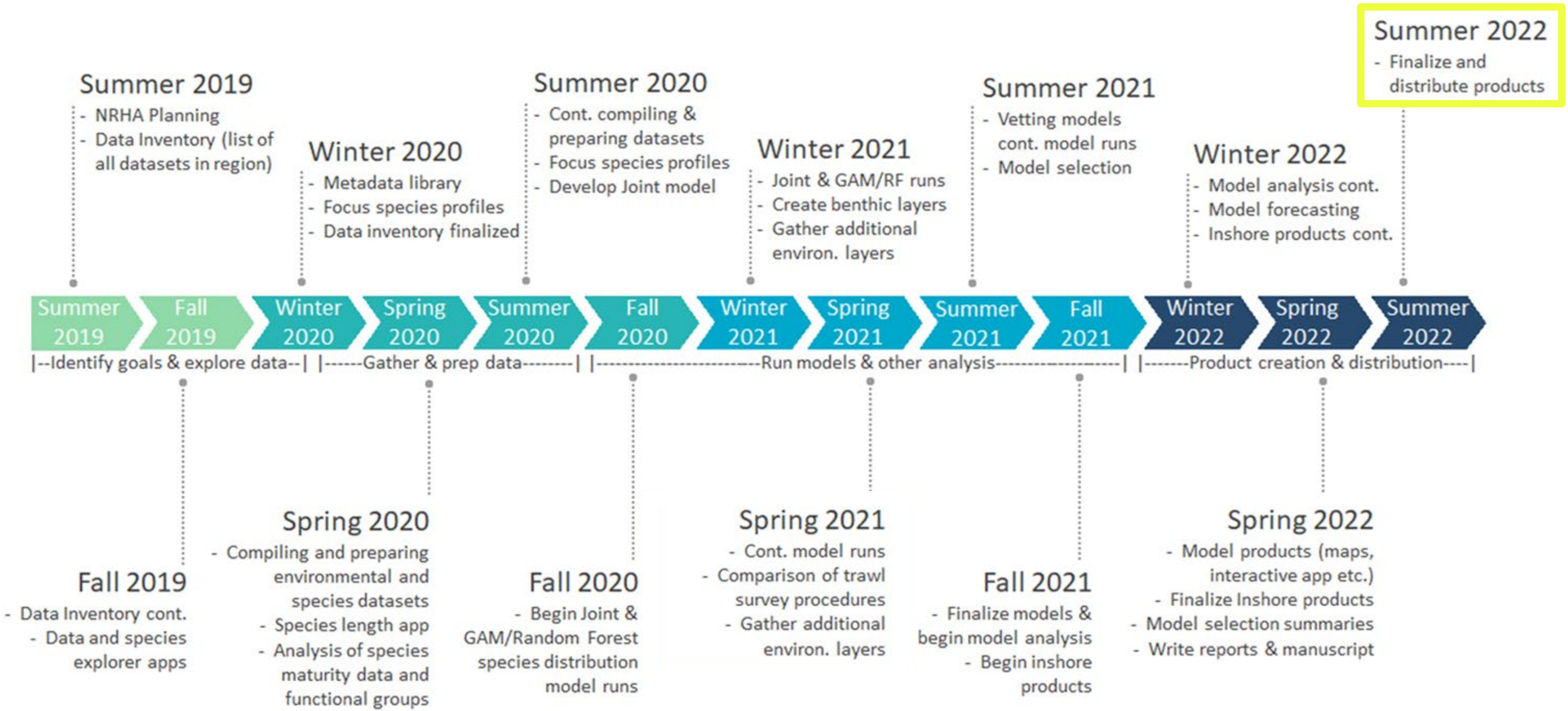




Northeast Regional Habitat Assessment:

Describe and characterize estuarine, coastal, and offshore fish habitat distribution, abundance, and quality in the Northeast

NRHA Timeline



NRHA Data Explorer Demonstration

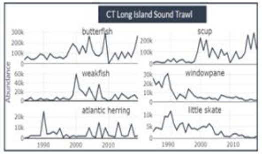
Available here: https://nrha.shinyapps.io/dataexplorer

NRHA Home Survey View Species View Models Habitat Crosswalk Reports About Us

Welcome to the Northeast Regional Habitat Assessment Data Explorer

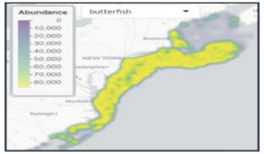
Survey View

Northeast regional and inshore bay/estuary view of fishery independent survey data including top 20 species abundance and biomass, similarity clusters, and survey temperature and salinity data.



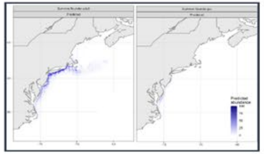
Species View

Species view of fishery independent survey data, including distributions, relative abundance, and reports on habitat use and vulnerability to climate change.



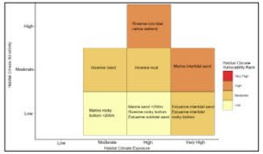
Model View

Outputs from spatiotemporal models that describe species distributions as a function of dynamic environmental factors, species interactions and predicted change in habitat use under various climate scenerios.



Habitat Crosswalk

Habitat species vulnerablity matrix and species narratives for 66 managed and forage species in the region.



This application shares products from the **N**ortheast **R**egional Marine Fish **H**abitat **A**ssessment (NRHA)and provides tools to explore fish habitat data*, with an emphasis on habitat use at different regional scales and by diverse fish and shellfish species in the Northeast. For more info about our history and team see About Us.

*Datasets displayed on this site in summary format have associated caveats related to the collection of these data and their use. Please refer to the Reports page for additional details on each dataset, including contact information to obtain the source data. NRHA did not create the data and cannot guarantee its accuracy, or its suitability for use for other applications. NRHA encourages proper use and attribution of any datasets summarized on this site. Interested parties should directly contact the data providers noted in the metadata inventory for additional details on these data and their proper use.

MAFMC/NEFMC
SSC Sub-Panel
Review of NRHA Products

June 1, 2022

Panel members:

Michael Frisk, John Boreman, Ed Houde, MAFMC SSC

Samuel Truesdell, Jeremy Collie, Adrian Jordaan, NEFMC SSC

Report available here

SSC Input

- NRHA Team greatly appreciated the SSC Sub-Panel Input
- NRHA Team has worked to address many of the SSC recommendations
- Improvements to modeling framework & expansion of response and predictor variables
- Improvements to Data Explorer:
  - Combined regional/bay pages and added direct links to metadata pages
  - Overhaul of species page including improved distribution maps with season, year and **age class filters**, improved relative abundance plots, new abundance and biomass time series graphs, new narratives, profiles and EFH documents
  - Newly added habitat crosswalk page
  - Front end overhaul including streamlined style, more intuitive navigation, improved info buttons and text, and homepage redesign
- Also in process of bringing on communications contractor to help with products/outreach

Acknowledgments

The Steering Committee:
Mid-Atlantic Fishery Management Council - Christopher Moore
New England Fishery Management Council - Thomas Nies
Atlantic Coast Fish Habitat Partnership - Lisa Havel
Atlantic States Marine Fisheries Commission - Bob Beal (designee Patrick Campfield)
Duke University, Marine Spatial Ecology - Patrick Halpin
Monmouth University, Urban Coast Institute - Tony McDonald
National Fish Habitat Partnership, Science and Data Committee - Gary Whelan
NOAA Fisheries Offices of Habitat Conservation - Kara Meckley, Lou Chiarella
NOAA NCCOS Marine Spatial Ecology Division - Mark Monaco
NOAA Fisheries Office of Science and Technology - Peg Brady, Tony Marshak
NOAA Northeast Fisheries Science Center - Thomas Noji (retired), Dan Wieczorak
The Nature Conservancy - Kate Wilke

Action Teams:
Gulf of Maine Research Institute - Kathy Mills
Maryland DNR - Marek Topolski
Massachusetts DMF - Mark Rousseau
NOAA Fisheries GARFO - David Stevenson, Alison Verkade,
NOAA Fisheries NEFSC - Kevin Friedland, Donna Johnson, Ryan Morse, Dave Packer, Vince Saba, Harvey Walsh
NOAA NCCOS - Andrew Leight
The Nature Conservancy - Bryan DeAngelis, Rich Bell, Marta Ribera
The PEW Charitable Trusts - Zack Greenberg
Rhode Island DEM - Eric Schneider
US Fish and Wildlife Service -Julie Devers
US Geologic Service - Stephen Faulkner
Virginia Institute of Marine Sciences - Robert Latour

NRHA/FSCVA/HCVA Crosswalk: UMass/SMAST Gavin Fay and Madeleine Guyant, and Project CoPIs, Mike Johnson, Tauna Rankin, Wendy Morrison (NOAA Fisheries)

Other Collaborators: David (Moe) Nelson (NOAA NOS), Aaron Kornbluth (PEW), Lisa Havel and Pat Campfield (ASMFC/ACFHP), Karl Vilacoba, Emily Shumchenia, and Nick Napoli (MARCO/NROC), Sarah Gaichas and Kim Hyde (NOAA Fisheries NEFSC), and Emily Farr.

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