

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, Post-Doc (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)

Mid-Atlantic Fishery Management Council (Riverhead, NY)

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Assessment overview

Goals and scope

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.

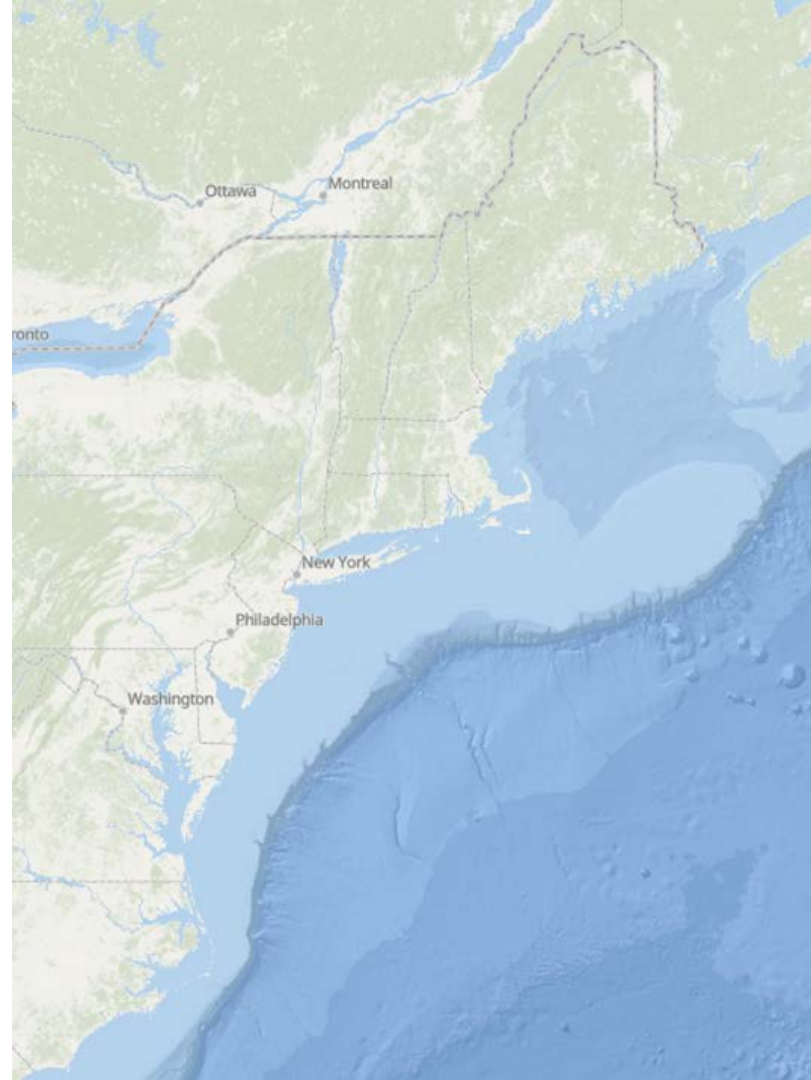
Geographic Scope: Northeast U.S.

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

Summary of products

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 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

A	B	C	D	E	
Name	Region	Inshore/Offshore	Source	Type	Data
Simple Ocean Data Assimilation (SODA3.1.3)	Entire Atlantic Cr	Offshore	NOAA, University of Point		bottom
Northwest Atlantic Regional Climatology		Offshore	NOAA		surface
NOAA OI SST V2 High Resolution Dataset	Global	Offshore	NOAA	gridded	3D Surf
HYCOM + NCOA Data 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-r
eMOLT		Offshore	NOAA		Bottom
Estuarine salinity zones in US	US	Inshore	NOAA		shapfile
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		realtime
Chesapeake Bay Program Water Quality	Chesapeake Bay	Inshore	Chesapeake Bay P	points	physic
Seafoor Salinity (psa)	Global	Inshore/Offshore	Marine Conservativ	shapfile	bottom
Salinity Zones for the Gulf of Maine	Gulf of Maine	Inshore	Fish and Wildlife St	gridded	Salinit

Metadata (1-pagers)

WATERBASE

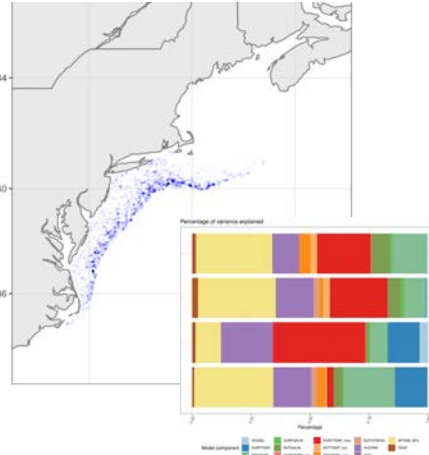
Waterbase provides metadata for the water quality data collected by the Chesapeake Bay Program. The metadata includes information about the data source, collection method, and geographic location.

The WATERBASE metadata currently lists groundwater point data for the Chesapeake Bay region. The metadata includes information about the data source, collection method, and geographic location. The metadata also includes information about the data source, collection method, and geographic location.

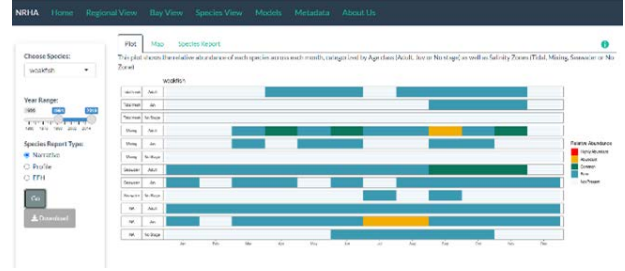
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Model-based Approaches



Inshore Fish Data



Data Explorer

NRHA Home Regional View Bay View Species View Models Metadata About Us

Regional Data Viewer

This view summarizes fishery independent survey and fish catch data for the Northeast regional scale. Specific surveys and year ranges can be selected to display species abundance in these surveys.

Select surveys: NMB's Trawl, CI Long Island Sound Trawl, NLY

Select Year Range: 2009 - 2019

Top 20 Species by Abundance

Top 20 Species by biomass

Species List

Seasonal Temperature

Seasonal Salinity

This plot shows the top 20 most abundant species in the selected surveys.

NRHA/CVA/HCVA Crosswalk

Atlantic Cod

Species Climate Vulnerability: Atlantic cod (*Gadus morhua*) 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, specific early life history requirements (e.g., dependence on specific circulation patterns for larval retention and specific nursery habitats). Atlantic stock status remained stable through the climate change scenario but the resulting low recruitment is projected to reduce the stock to below sustainable levels.

Health Type	HCVA Climate Vulnerability Rank	Egg/Larvae	Juvenile YOY	Adult	Spawning Adult
High End Bottom	Marine intertidal rocky bottom (intermediate) VCI	II	II	II	II
Low End Bottom	Marine rocky bottom (VCI) Low	II	II	II	II

these include intertidal and ending to the 200 m.

Lots of Reports...

Species Profile: Rock Sucker (*Ammocetes*, *Uroloph*)

Species range and distribution

Rock Sucker has been reported from New York and the Bay of Fundy since 1880 and was first described in 1890 and was first described in 1890 and was first described in 1890.

Egg and larvae: Egg and larvae are pelagic, and are most abundant in late April of 1880 and were reported in 1880 and were reported in 1880 and were reported in 1880.

Young of the Year: Young of the Year are found in the continental shelf from within 10 m of the bottom between 100 m and 100 m depth and were reported in 1880 and were reported in 1880.

Adult: Adult Rock Sucker are found in the continental shelf from within 10 m of the bottom between 100 m and 100 m depth and were reported in 1880 and were reported in 1880.

Spawning: Spawning occurs in the continental shelf from within 10 m of the bottom between 100 m and 100 m depth and were reported in 1880 and were reported in 1880.

Modeling Framework

Characterizing Habitat Use

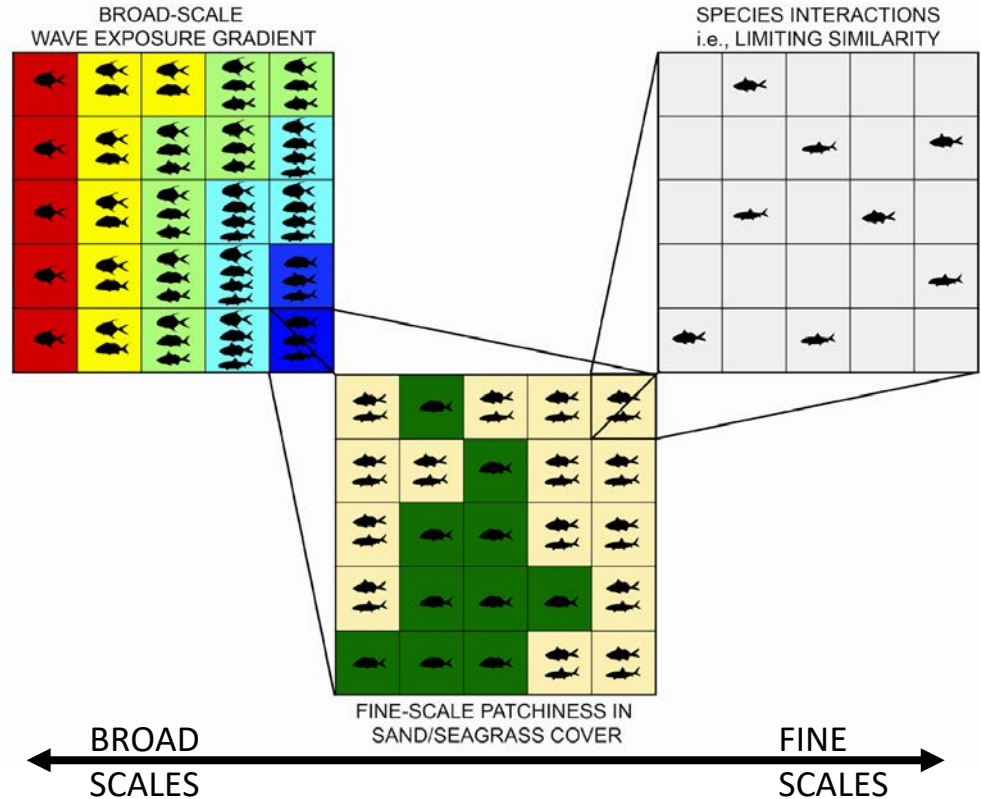
What is Fish Habitat?

- **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
 - Multiple **life stages** (often with differing requirements)
 - ***Dynamic*** factors that fluctuate over time

We generally infer habitat suitability based on species distributions; (i.e., if fish are there, they like something about that place)

Habitat Use & Community Ecology

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



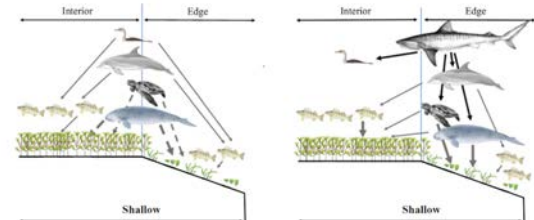
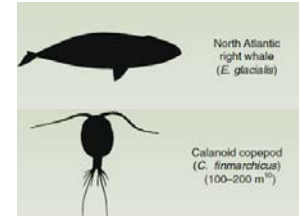
How Can Biotic Interactions Affect Habitat Use?

- **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”!



Connell 1961 – Competition

Furey et al. 2018 –
Migratory coupling



Wirsing et al. 2020 – NCEs



times
turns



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**

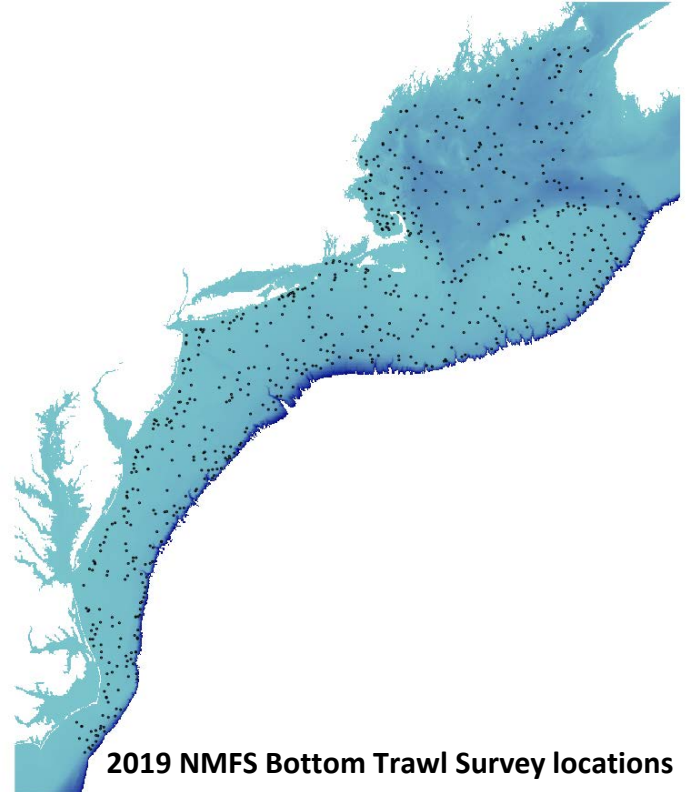
- Using a novel spatiotemporal approach (CBFM) w/ comparison to GAMs
- Improved predictions & possible ecological insights?

- **Dynamic & ecologically relevant covariates**

- Temporally varying predictors that reflect dynamic nature of the system
- Predictors with direct consequences for ecological function of animals

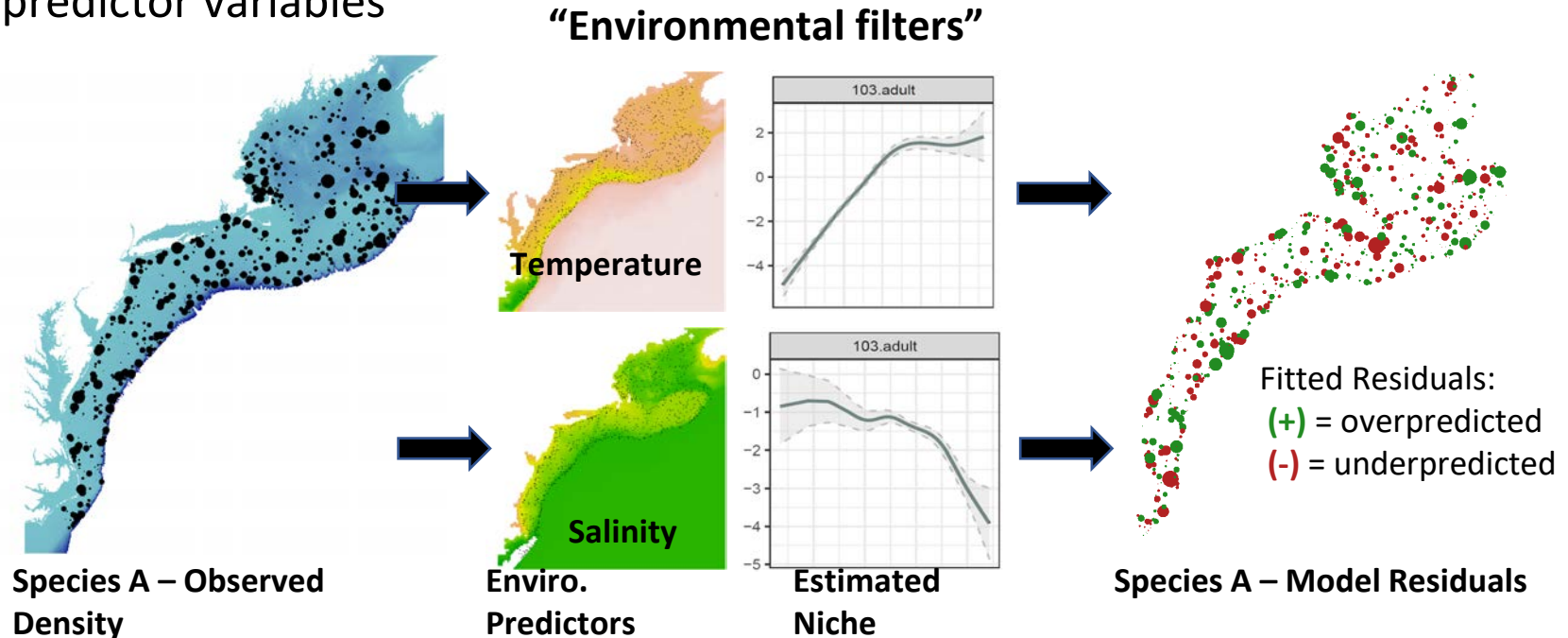
How Do We Assess Habitat Use?

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



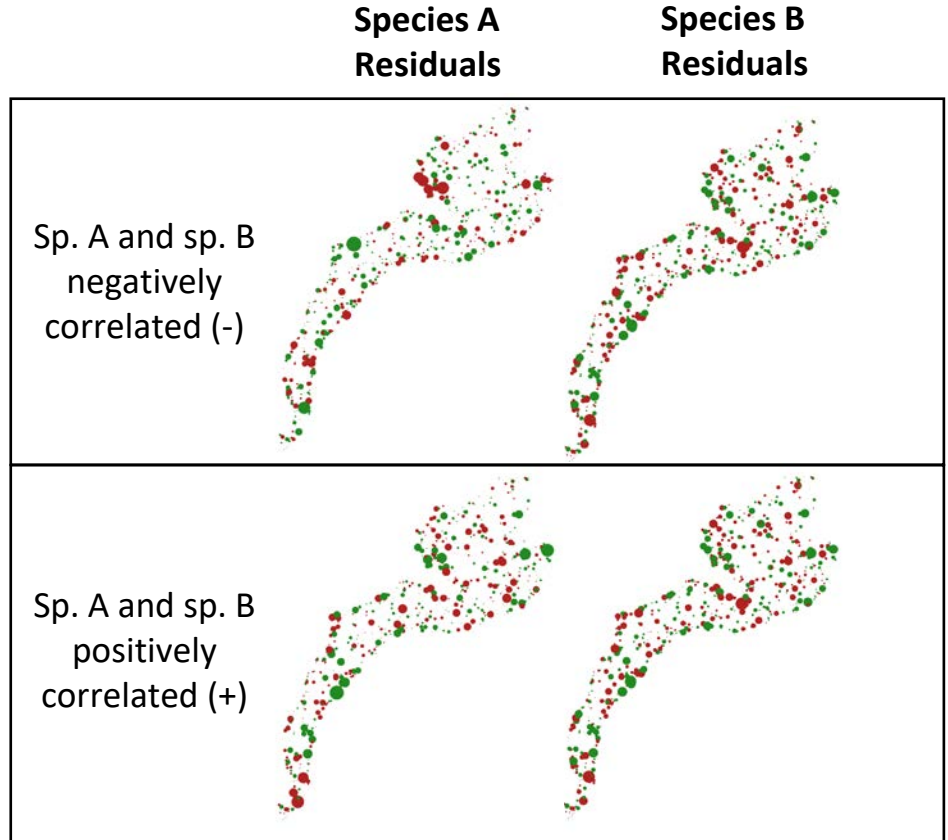
SDMs: A Mechanistic View of Habitat

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



Joint SDMS: Making More of Model Residuals

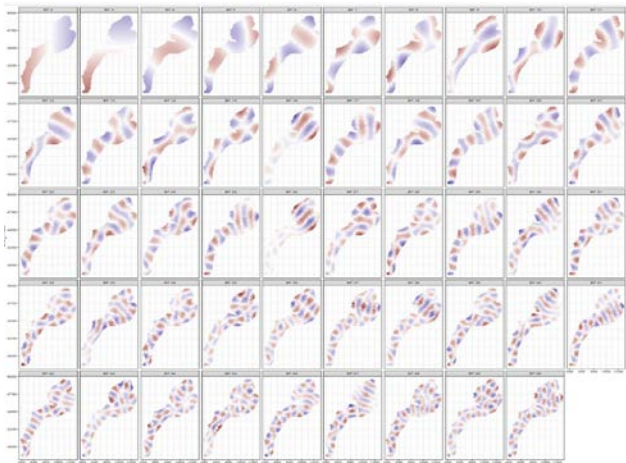
- In single-species SDMs, **residuals = “error”**
- In a multi-species context, **residual patterns across species may contain information** about underlying processes (i.e., missing predictors, dispersal, interactions)
- Joint SDMs model residual covariance & exploit it to produce **more realistic estimates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



CBFM: Community-level Basis Function model

- **Related to GAMS**

- Basis functions (BF) model covariance in space & time



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

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

Francis K.C. Hui^{*1}, David I. Warton², Scott D. Foster³, Nicole A. Hill⁴, and Christopher R. Haak⁵

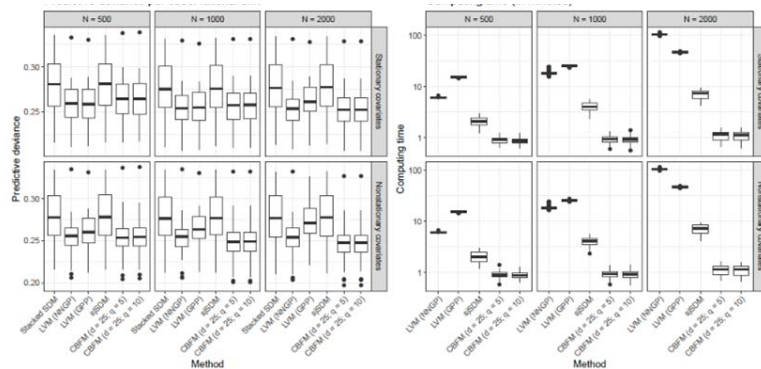
¹Research School of Finance, Actuarial Studies and Statistics, The Australian National University, Canberra, Australia

²School of Mathematics and Statistics, The University of New South Wales, Sydney, Australia

³Data61, Commonwealth Scientific and Industrial Research Organization, Hobart, Australia

⁴Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Australia

⁵Northeast Fisheries Science Centre, National Oceanic and Atmospheric Administration, Highlands NJ, USA

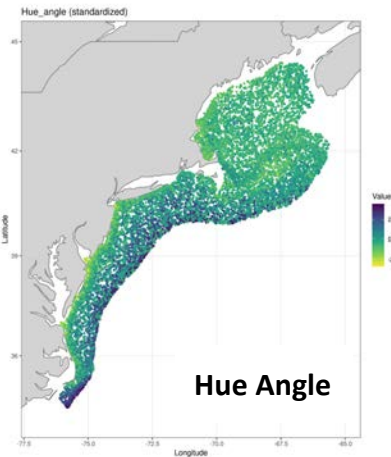
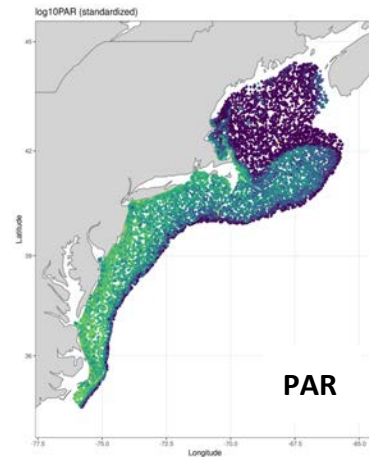
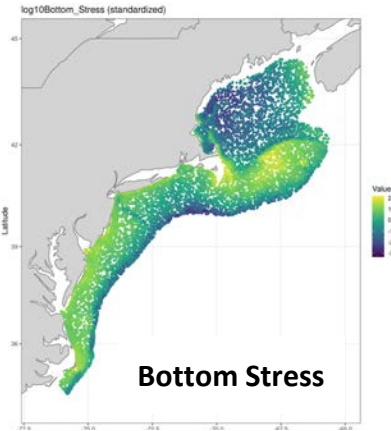
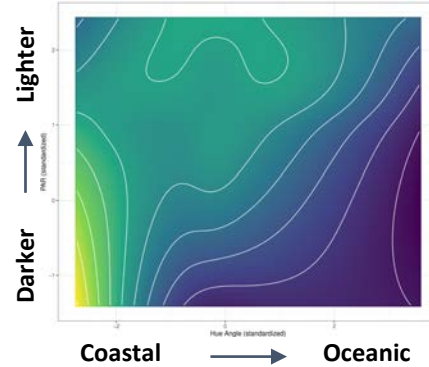


CBFM: NRHA Application

- **97 spp-stages** from NMFS bottom-trawl surveys
 - Demersal & pelagic spp., managed, common, & prey
 - Training 2000-2014 (n > 9000 obs)
 - Testing 2015-2019 (n > 3000 obs)
- Combined **Spring & Fall** surveys
- 13 Predictor variables
 - Surface & bottom **temperature** (monthly & annual min/max), **salinity** (surface & bottom), **sea surface height**, correlates of depth (**optical environment, hydrodynamic stress**)
- Spatiotemporal Basis Functions (intra-year) & random effect of year

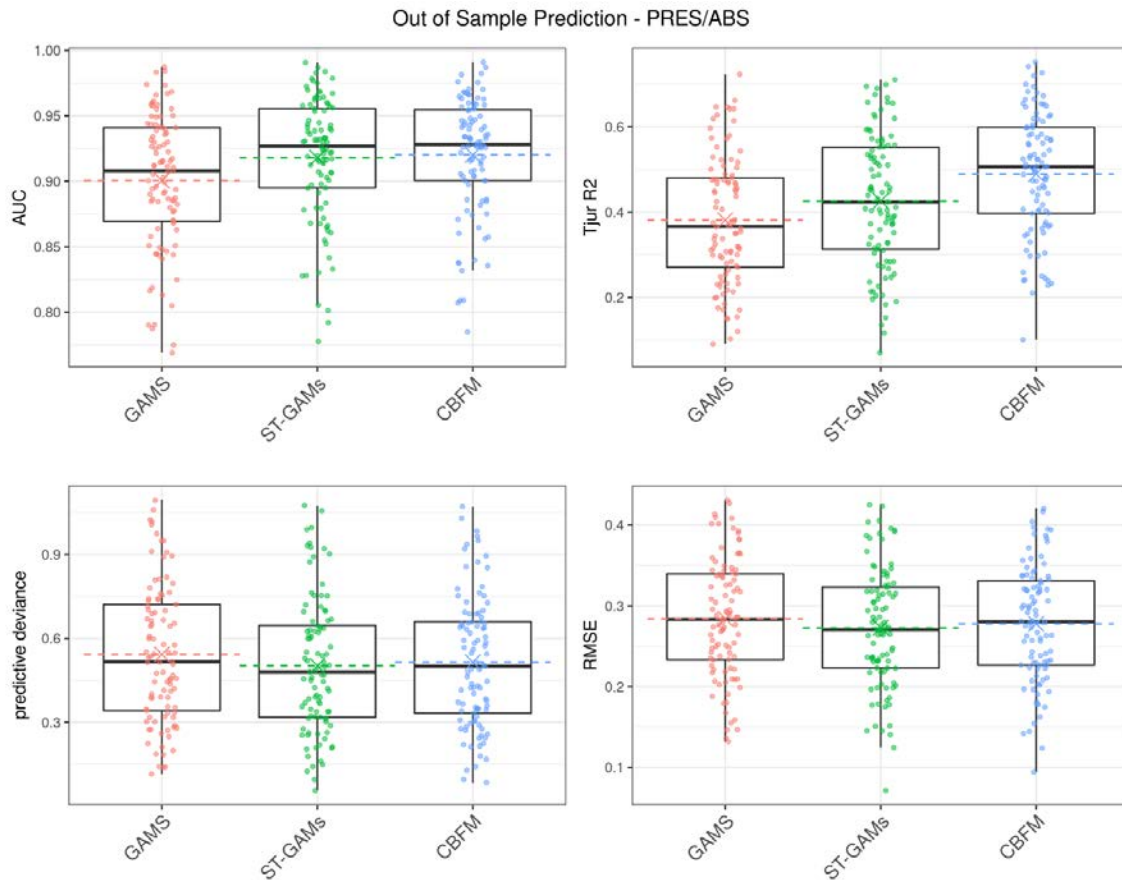
Predictor Variables: Correlates of Depth

- Depth is an informative predictor, but mostly a proxy for other factors
 - Spp may alter use of depth as they track other causal factors (e.g., **temperature**)
- **Bottom Stress**
 - Strength of wave & current-driven water movement at the seabed
- **PAR = Intensity** of underwater light
 - Light → Dark (shallow → deep)
- **Hue Angle = Spectral distribution** (i.e., color) of light
 - Red → Blue (coastal → oceanic)



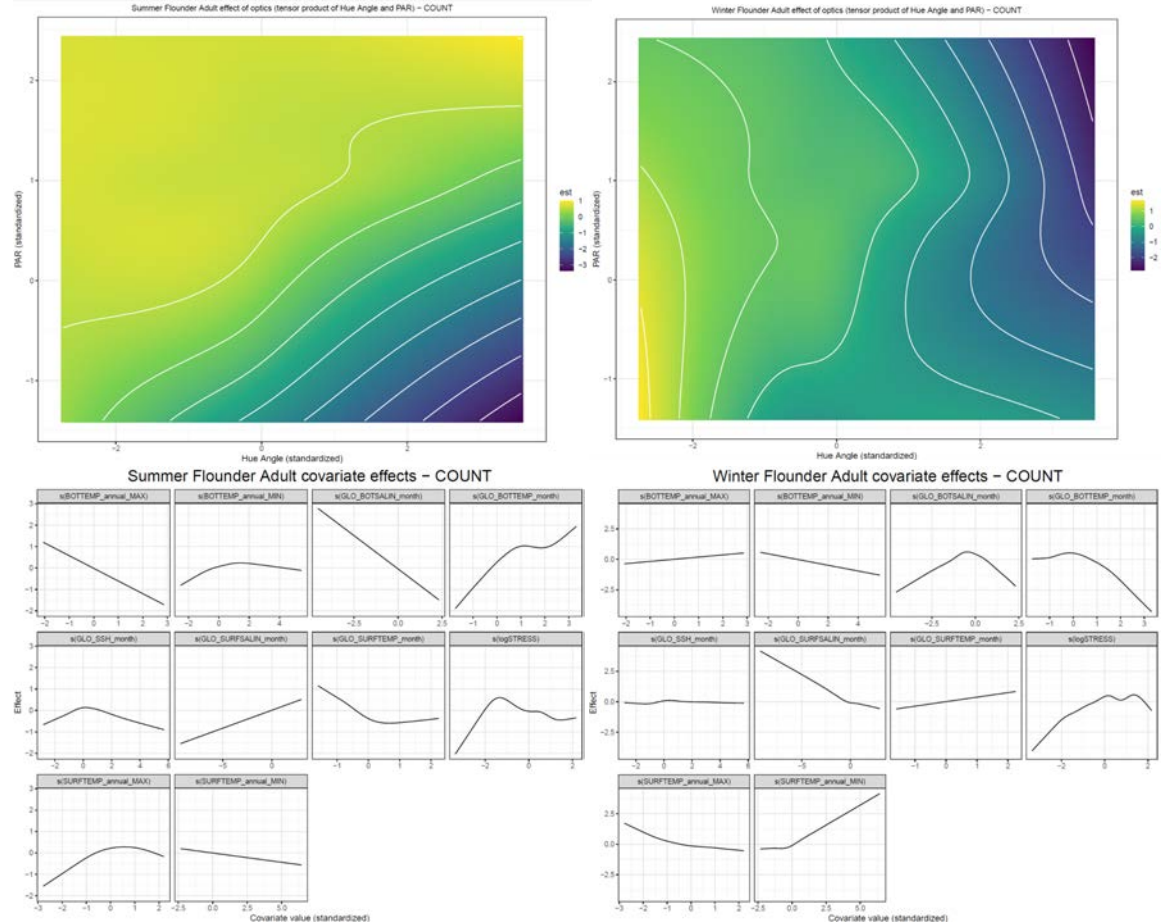
NRHA Application: Performance

- Out-of-sample prediction
 - Median AUC = 0.93 (range from 0.78 - 0.99)
 - Median Tjur R² = 0.50 (0.1 - 0.75),
 - Median RMSE = 0.28 (0.09 - 0.42)
- Outperforms stacked (i.e., single-species) spatiotemporal GAMS



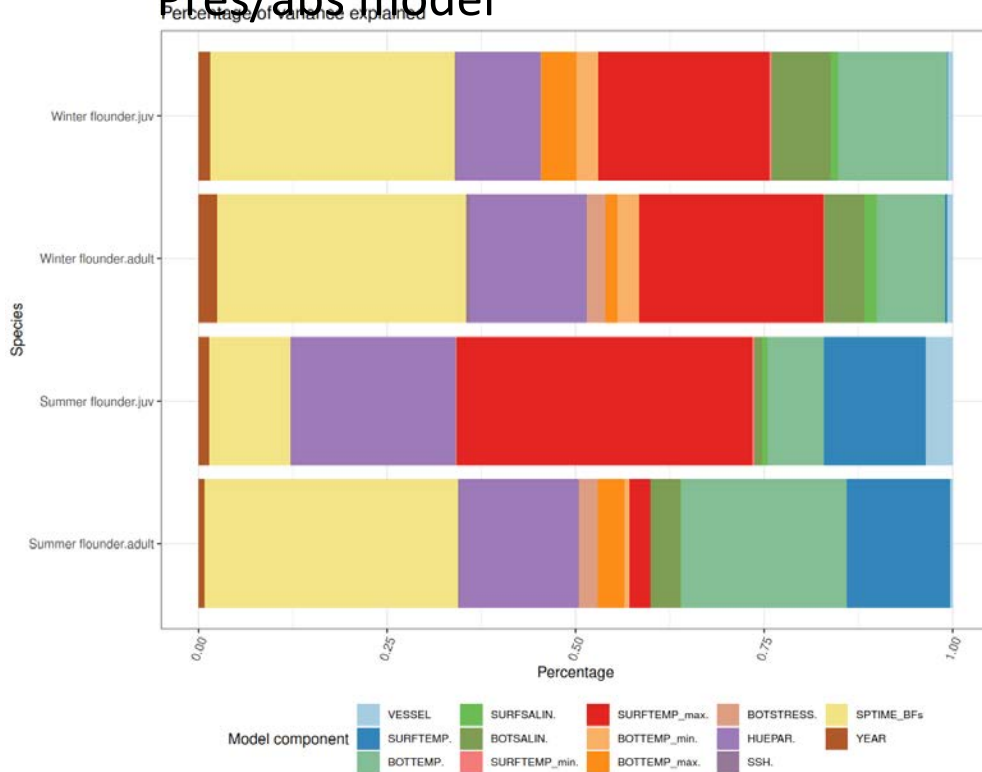
Response to Predictors: Flounders

- 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: Summer and Winter Flounders

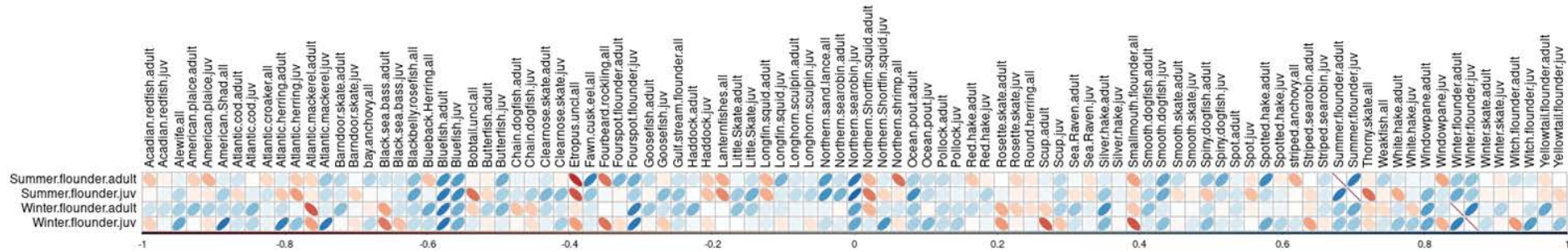
Pres/abs model



- **What factors are most influential** in driving habitat use of a spp?
- Bottom temp, annual max surface temp, and optical parameters universally influential
- Surface temp more important for SF, salinity more important for WF
- Similar patterns for juvs and adults

Residual Correlations: Flounders

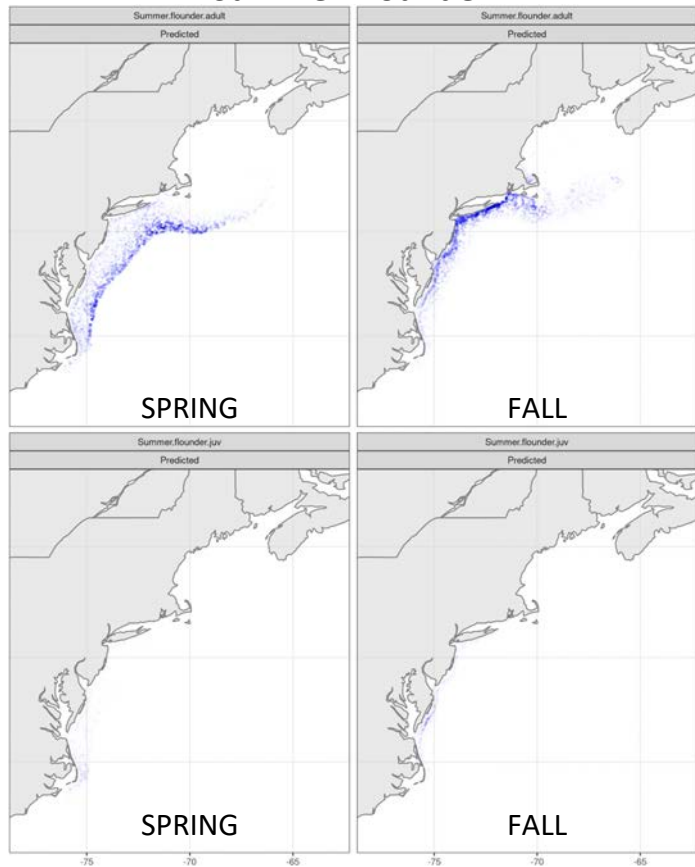
- Spatio-temporal correlations b/w species after accounting for the effects of predictor variables (evidence of **missing predictors** or **biotic interactions**?)



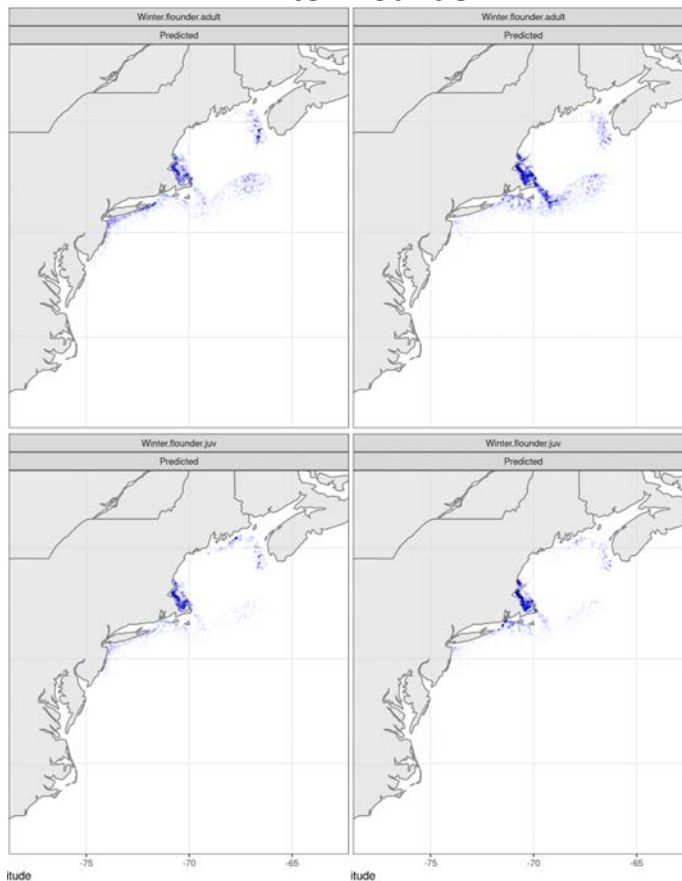
- **Strong +** corrs b/w adults and juveniles within species (dispersal lims?)
- **Weaker +** Corrs w/ each other (Summer & Winter)
- **+** Corrs w/ Bluefish and Northern Searobin?
- **-** Corrs w/ Etropus & Smallmouth flounders

Predictions: Flounders

Summer Flounder



Winter Flounder



Seasonal differences in habitat use (particularly Summer Flou)

Stage-specific differences b/w adults and juveniles

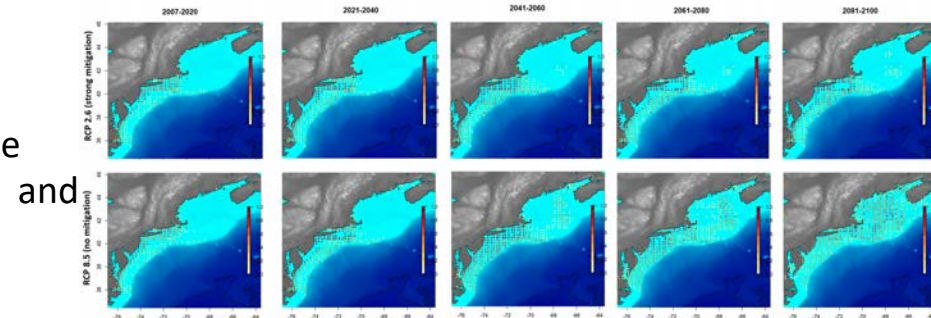
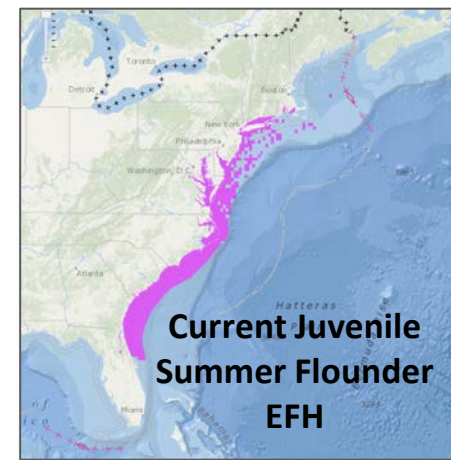
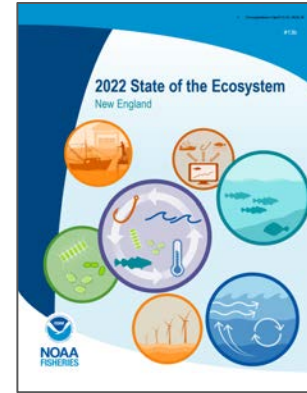
Next Steps

- Expand predictor variables to include benthic habitat characteristics (e.g., BPI, topographic complexity, sediment type)
- Visualize results & make available via NRHA Data Explorer and regional data portals
- Long-term projections of changes in habitat use, driven by climate model outputs?
- Include response data from additional surveys (e.g., NEAMAP) to improve coverage in the nearshore

Selected applications for NRHA products

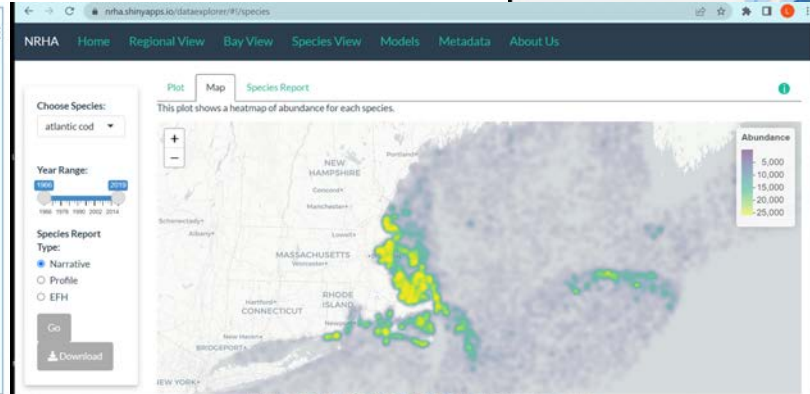
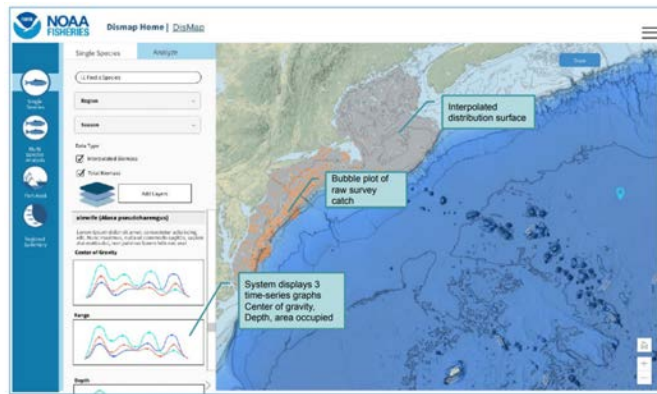
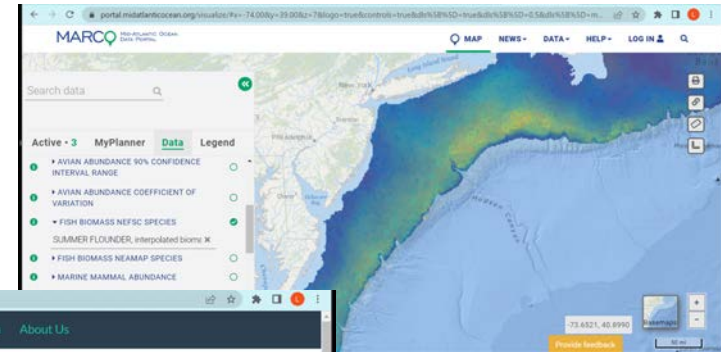
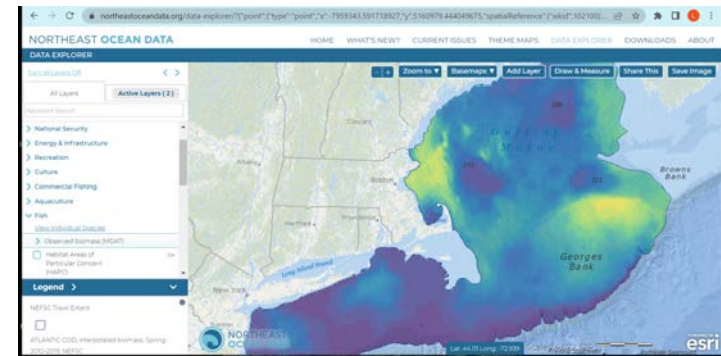
Applications for NRHA Products

- **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. butterflyfish 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)



NRHA Data Explorer Demonstration

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

NRHA Home Regional View Bay View Species View Models Metadata About Us

Welcome to the Northeast Regional Habitat Assessment Data Explorer

This application was developed to share products from the Northeast Regional Marine Fish Habitat Assessment (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](#).

Regional View

This view summarizes fishery independent survey and fish habitat data at the Northeast regional scale. Specific surveys and year ranges can be selected to display species abundance in those surveys.

Bay View

This view summarizes fishery independent survey and fish habitat data for inshore waters at a bay/estuary scale. Specific surveys and year ranges can be selected to display species abundance in those surveys.

Species View

This view provides a deeper dive into species-specific fishery independent survey data, as well as detailed reports on habitat use by species and vulnerability of the species and their habitat to climate change.

Model View

This view provides outputs from spatiotemporal models that describe fish species distributions as a function of dynamic environmental factors, as well as species covariances with one another. Some of these outputs are informed by climate models to project how fish habitat use might be altered under different environmental change scenarios.

Metadata

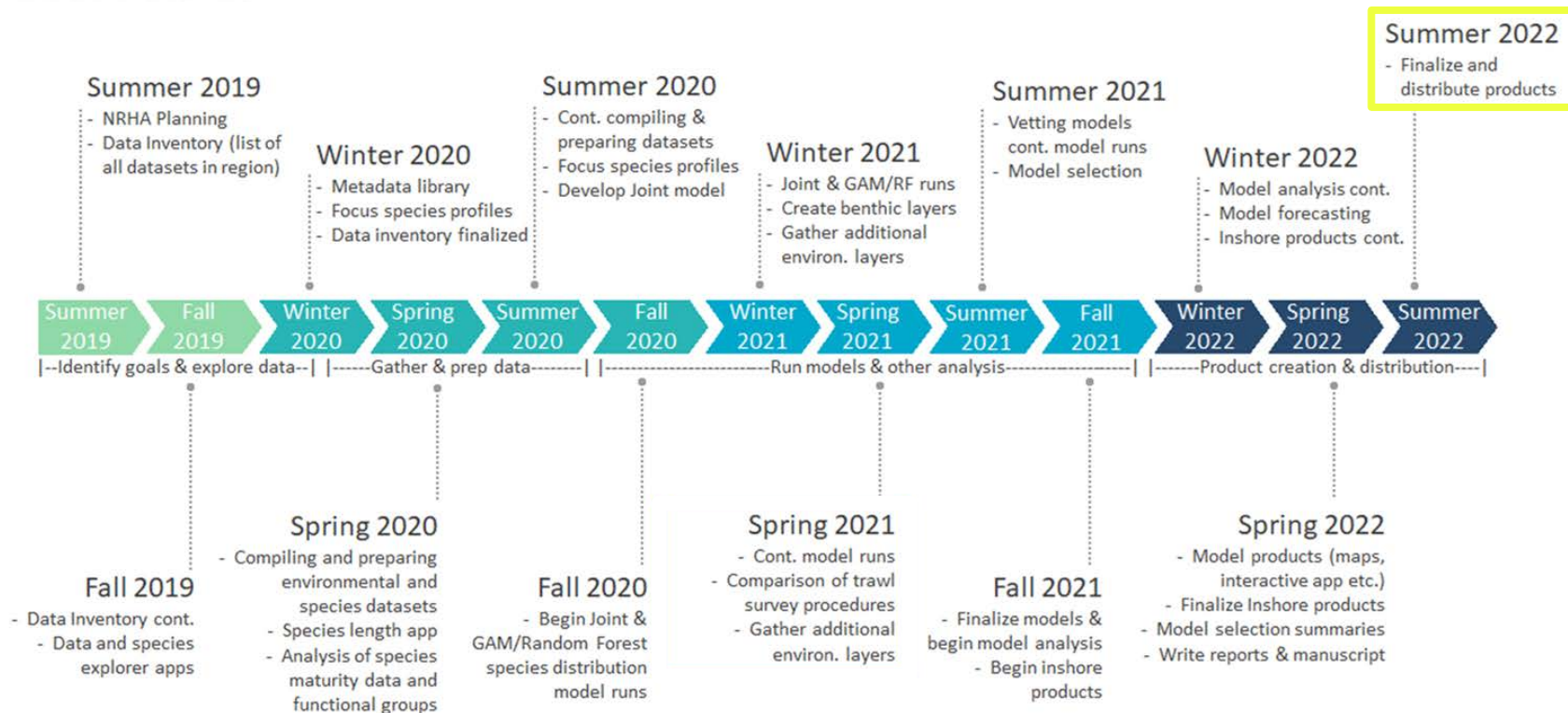
For each of the datasets considered for this habitat assessment, a metadata report was created that provides the data source, an overview of the data product, and information about data access.

*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 metadata inventory tab 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.

Northeast Regional Habitat Assessment:

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

NRHA Timeline



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 Wiczorak
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/SMASST 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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