The Northeast Regional Habitat Assessment:
A collaborative, multi-disciplinary project to develop decision support products for marine fish habitat management

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MAFMC Scientific and Statistical Committee
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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
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
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?
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

Temperature

Salinity

Enviro. Predictors

Estimated Niche

Species A – Model Residuals

Fitted Residuals:
(+)= overpredicted
(-)= underpredicted
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)
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

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

**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, 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

Welcome to the Northeast Regional Habitat Assessment Data Explorer

Survey View
Northeast regional and inshore basin/estuarine 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 and species distributional models that describe species distributions as a function of dynamic environmental factors, species interactions and predicted change in habitat use under various climate scenarios.

Habitat Crosswalk
Habitat species vulnerability matrix and species narratives for 65 managed and forage species in the region.

This application shares 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.

*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 cannot 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
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  
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