Gulf of Mexico Fishery Management Council

SSC Meeting

Southeast Fisheries Science Center

RESTORE SCIENCE PROGRAM

UNIVERSITY of FLORIDA

INTEGRATED ECOSYSTEM ASSESSMENT

UNIVERSITY OF MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

CIMAS

Part I
Ecosystem Modeling the US Gulf of Mexico

Skyler R. Sagarese, Holden E. Harris, Igal Berenshtein, Matthew V. Lauretta, Amy Schueller, David D. Chagaris

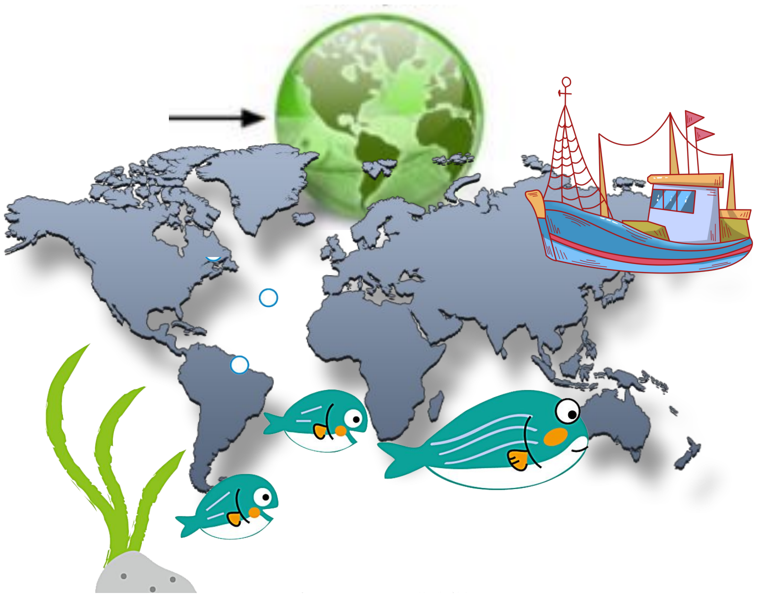
U.S. Gulf of Mexico Ecosystem Model // Presentation Overview

Part I - USGWEM Ecopath and Ecosim

- Diet and food web (Sagarese et al. 2016)
- Fitting to time series (NOAA technical memorandum)
- Gulf menhaden Ecological Reference Points (Berenshtein et al. 2023)

Part II - USGWEM Ecospace (*in dev.*)

- Data synthesis (GitHub: SEFSC/IEA/GWEM/DataSynth)
- Validation and calibration
- Next steps



Part I

- Need for ecosystem modeling
- Brief history of ecosystem modeling in the Gulf of Mexico (GOM)
- U.S. Gulfwide Ecopath Model
- U.S. Gulfwide Ecopath with Ecosim Model development via Restore Science Act Funding
- Developing Ecological Reference Points for Gulf menhaden
- Ecospace and future applications

Some of the many features of the Gulf of Mexico.

Image: http://ecosystems.noaa.gov/WhereIsEBMBeingUsed/GulfofMexico.aspx

Modeling challenges in the Gulf of Mexico

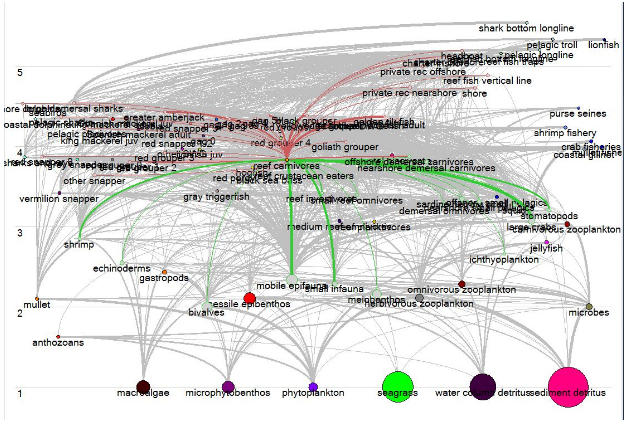
- Diversity
  - > 1,100 fishes
  - > 3,500 invertebrates
  - > 30 marine mammals
    - www.fishbase.org
    - www.sealifebase.org
  - Fisheries

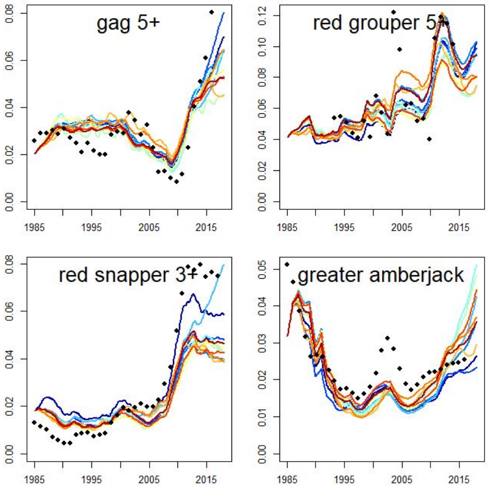
Image: https://flowergarden.noaa.gov/

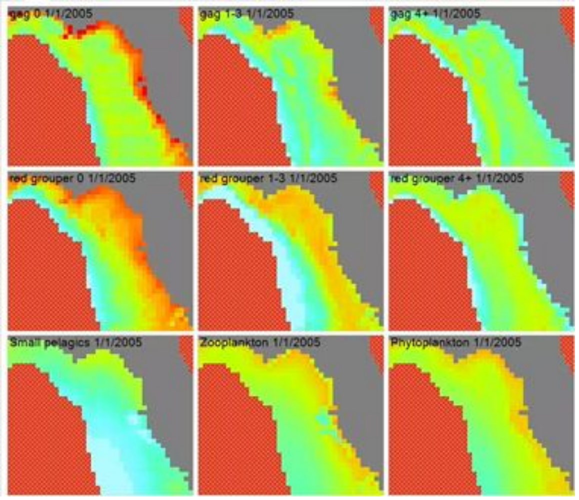
- Lack of detailed food habits data (Simons et al 2013)
  - Sampling difficulties (e.g., reef species)
  - Predator-prey dynamics (e.g., grouper predators)
  - Large bias in available data from Eastern GOM (FWRI database)

Software // Ecopath with Ecosim and Ecospace

www.ecopath.org







Ecopath

- Static snapshot of the ecosystem
- Input: biomass, mortality, consumption, diet, and fishery removals
- Requires mass balance
- Starting point for dynamic simulations

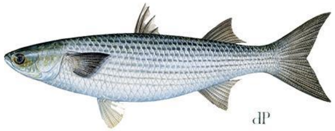
Ecosim

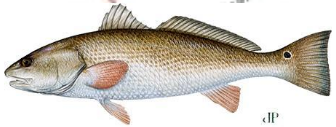
- Time dynamic simulations
- Environmental forcing
- Parameter estimation & time series calibration
- Future projection scenarios
- Policy analysis and tradeoffs

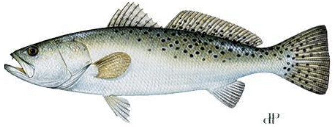
Ecospace

- Spatially explicit simulations
- Input: dispersal rates, habitat maps, habitat preferences, fishing areas, MPAs, port locations
- Spatial-temporal drivers
- Red tide mortality

Coastal GOM // Walters et al. (2008)

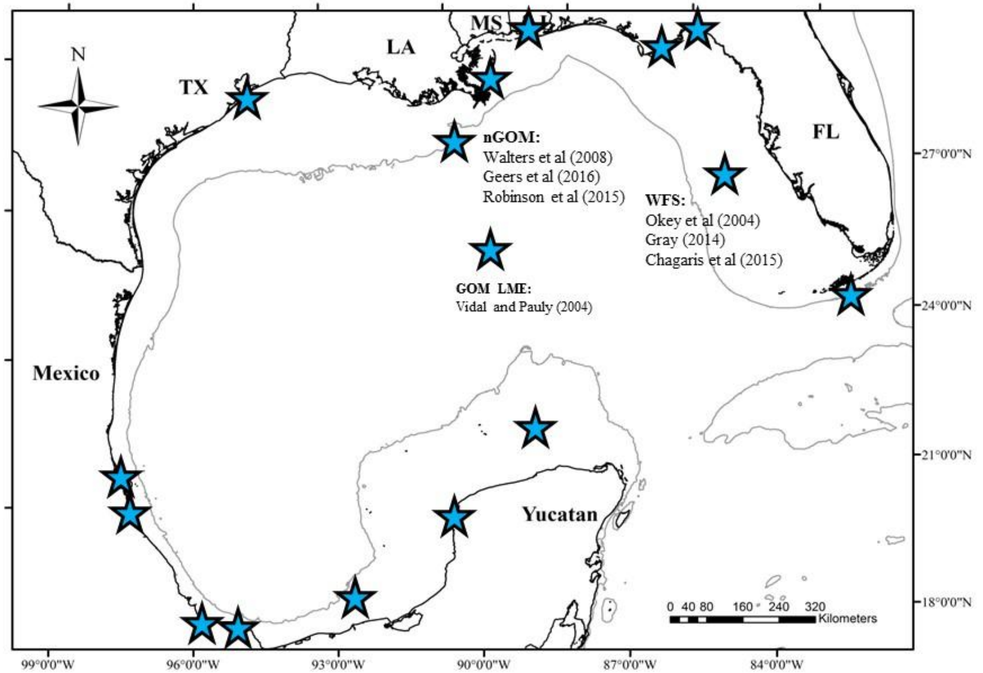




BULLETIN OF MARINE SCIENCE, 83(1): 251–271, 2008

AN ECOSIM MODEL FOR EXPLORING GULF OF MEXICO ECOSYSTEM MANAGEMENT OPTIONS: IMPLICATIONS OF INCLUDING MULTISTANZA LIFE-HISTORY MODELS FOR POLICY PREDICTIONS

Carl Walters, Steven J. D. Martell,
Villy Christensen, and Behzad Mahmoudi



- Focused on shrimp bycatch, red tide
- Functional groups tied closely to Florida
  - Multi-stanzas to represent different life stages
- Demonstrative exercise of the capabilities of EwE, fit to time series
- Geers et al. (2016) modified model to focus on Gulf menhaden

Images: http://myfwc.com/research/saltwater/fish/; http://www.gsmfc.org/profiles/Gulf_menhaden/Gulf%20Menhaden.php

Utility of Ecosystem Models

- Both the Walters et al. (2008) and Geers et al. (2016) models considered as potential tools for informing damages to the Gulf of Mexico ecosystem following the Deep-water Horizon Oil spill, but…

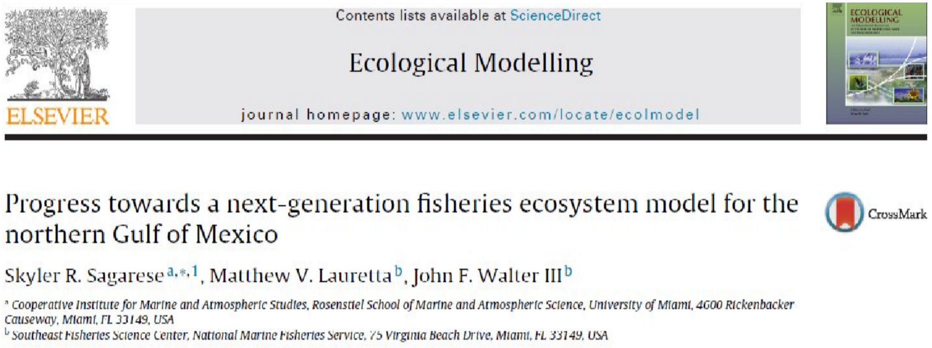
Images: https://en.wikipedia.org/wiki/Deepwater_Horizon

Concerns raised over:

- Diet matrix defining species interactions
  - Previously based heavily on expert opinion
  - Limited information on pelagic food-web and higher trophic level interactions
- Lack of fishery discards

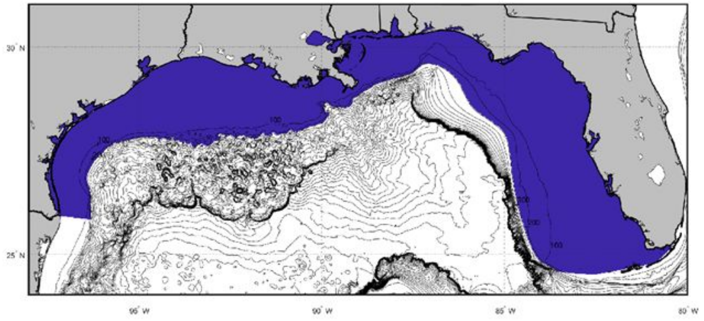
The Gulf-wide Ecosystem Model // Ecopath

- Builds upon previous models and attempted to alleviate concerns
  - Focus on federally and internationally managed species on spatial scale matching management
  - Include a statistically-derived, more comprehensive definitions of species interactions
  - Model bycatch removals from the menhaden reduction fishery and large-scale fisheries


ELSEVIER
Contents lists available at ScienceDirect
Ecological Modelling
journal homepage: www.elsevier.com/locate/ecolmodel

Progress towards a next-generation fisheries ecosystem model for the northern Gulf of Mexico

Skyler R. Sagarese[a,*,1], Matthew V. Lauretta[b], John F. Walter III[b]
[a] Cooperative Institute for Marine and Atmospheric Studies, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
[b] Southeast Fisheries Science Center, National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, FL 33149, USA

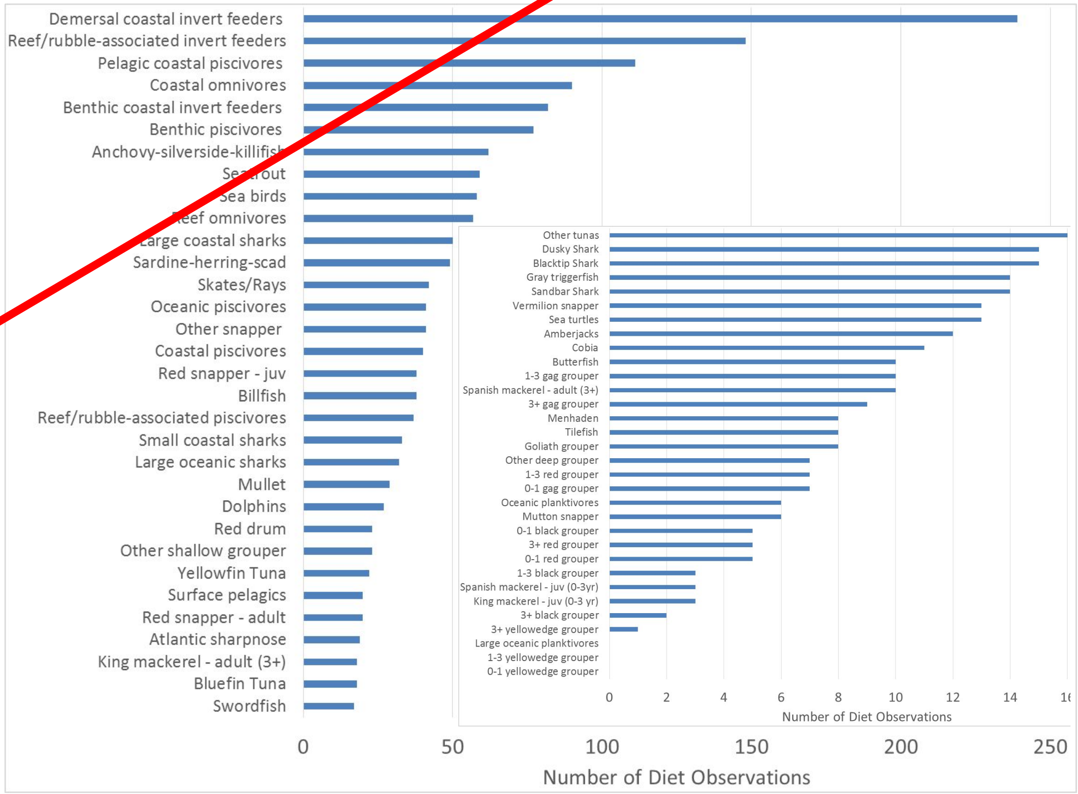


GWEM Ecopath // Literature Review // Diet Matrix

DATA

- **Sources**:
  - GOMEXSI (http://gomexsi.tamucc.edu/)
  - Journal articles
  - Technical documents
  - Theses
- **Diet composition** (%W, %V):
  - %FO only: converted into relative weight composition (Stobberup et al. 2009)
- 1 observation = 1 diet study*
  - *regions or length-classes separated out

- Compiled over 1,906 diet observations



Diet Matrix // Meta Analysis

* = limited sample size

DATA

- **Sources**:
  - GOMEXSI (http://gomexsi.tamucc.edu/)
  - Journal articles
  - Technical documents
  - Theses
- **Diet composition** (%W, %V):
  - %FO only: converted into relative weight composition (Stobberup et al. 2009)
- 1 observation = 1 diet study*
  - *regions or length-classes separated out

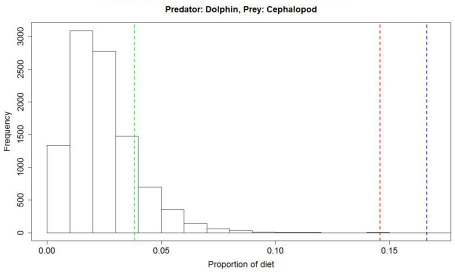
PROCESSING

- **Subsample**:
  - Randomly select 10 observations
  - Average diet proportions
    - weighted by area of study, method reported (i.e., %W vs %FO), and sample size
  - Re-normalize proportions
- **Bootstrap**:
  - 10,000 samples with replacement

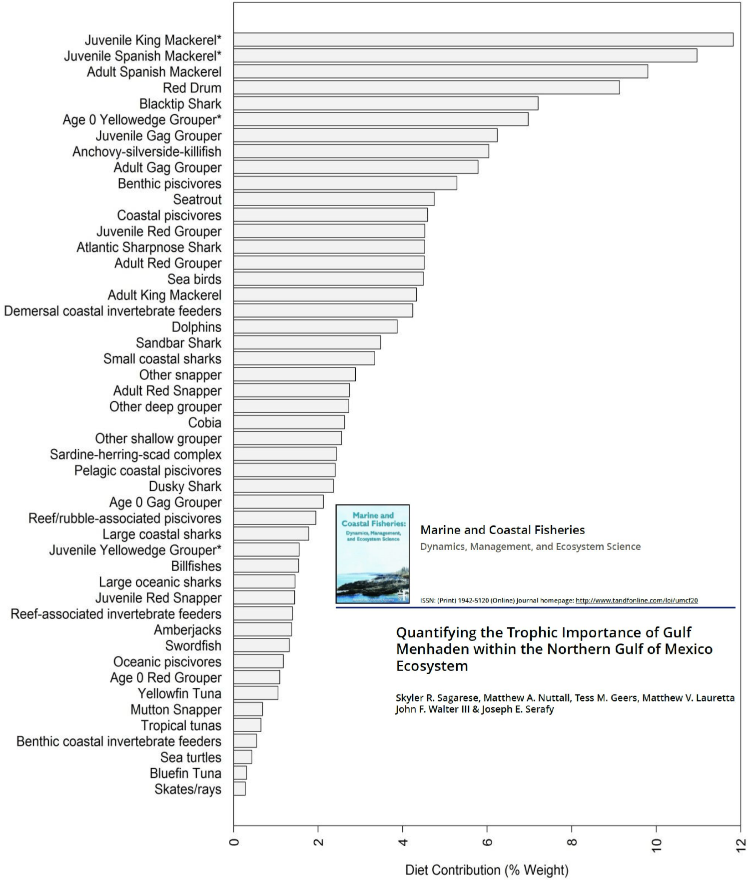
FITTING

- **Dirichlet distribution**
  - Fit to bootstrapped data in R
  - Obtain MLE estimates for each prey group

EXAMPLE

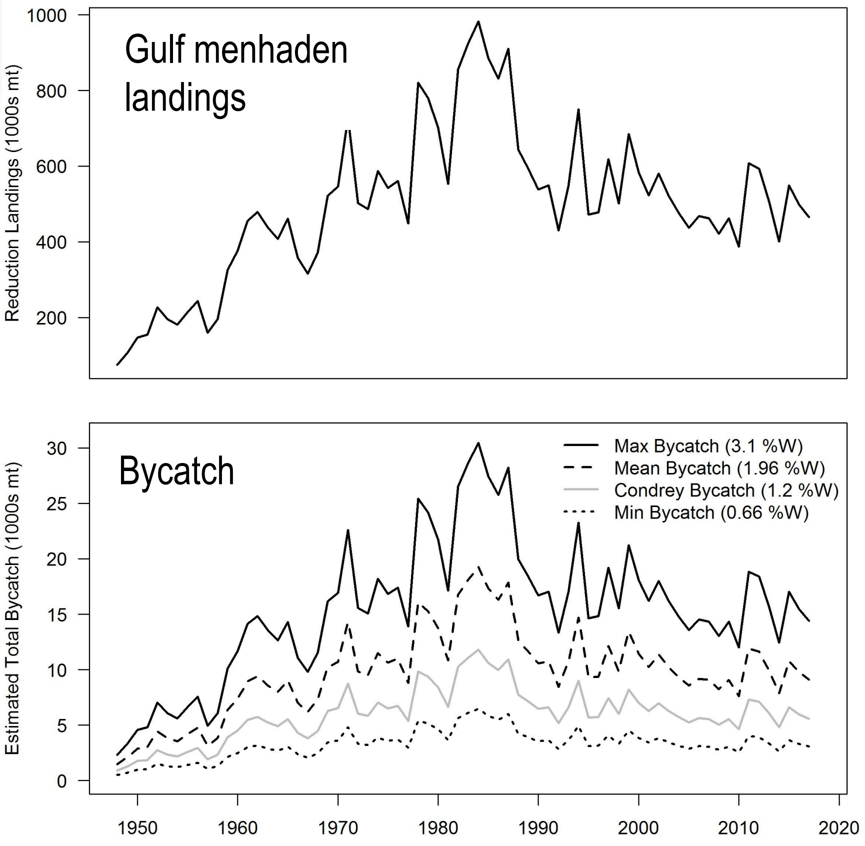


Approach described in depth in Ainsworth et al (2010)



Bycatch // Menhaden purse seine

- Species composition and proportion of retained bycatch for the menhaden purse seine fishery were used to infer bycatch
    - Guillory and Hutton (1982)
    - de Silva and Condrey (1997)
    - de Silva et al. (2001)
- Dead discards (i.e., retained landings) were allocated based on percent by weight in the bycatch (2.35%, Guillory and Hutton 1982)

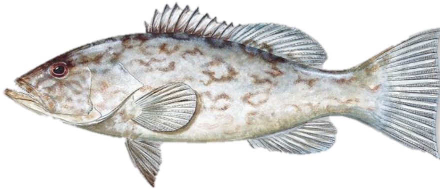


Additional details provided in SEDAR49-DW-04
https://sedarweb.org/documents/sedar-49-dw-04-review-of-bycatch-in-the-gulf-menhaden-fishery-with-implications-for-the-stock-assessment-of-red-drum/

Ecosystem Modeling for GoM Fisheries Management

- Funded by NOAA RESTORE FF0-2017, decision-support tool priority (PI: Chagaris)

- Goal: Integrate information on ecosystem stressors and predator-prey interactions into the assessment and management of fisheries in the Gulf of Mexico



Gag Grouper
Mycteroperca microlepis

Gulf Menhaden
Brevoortia patronus

RESTORE SCIENCE PROGRAM

NATURE COAST BIOLOGICAL STATION | UF IFAS UNIVERSITY of FLORIDA

NOAA Southeast Fisheries Science Center
NATIONAL MARINE FISHERIES SERVICE

GEORGE MASON UNIVERSITY | ENVIRONMENTAL SCIENCE AND POLICY

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

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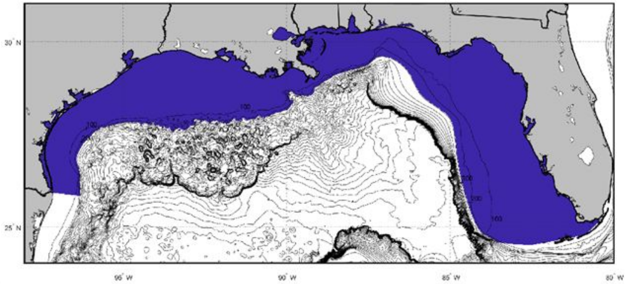
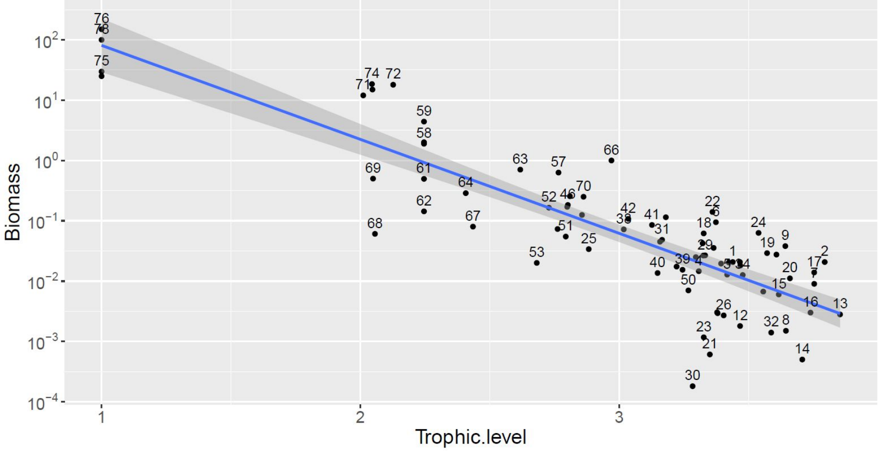
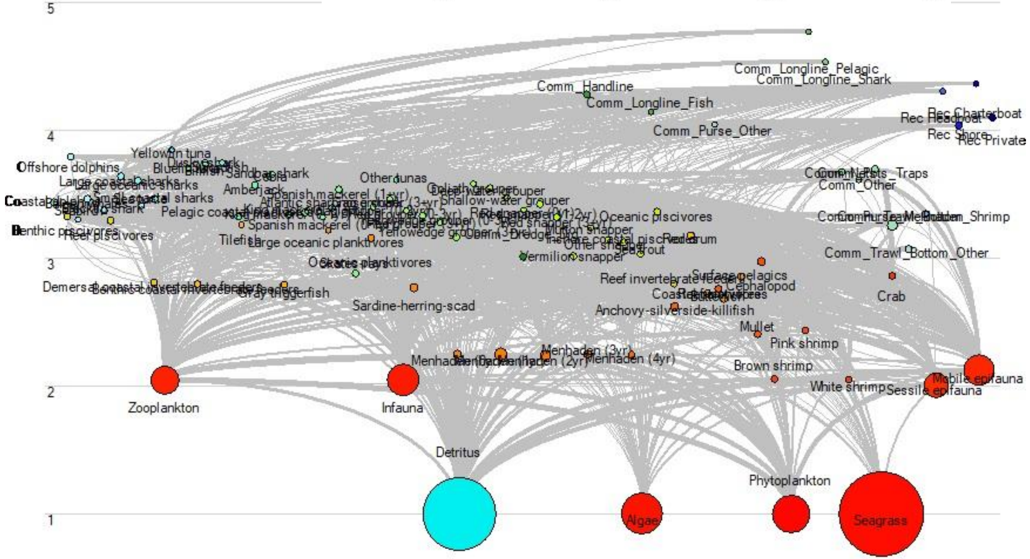
U.S. Gulf-wide Ecosystem Model // Ecopath

- Ecopath snapshot year: 1980
- Added additional age structure following scoping workshop
- 78 functional groups
- 12 commercial fleets and 4 recreational fleets
- Pre-Bal diagnostics (Link 2010)
- Best practices (Heymans et al., 2016)

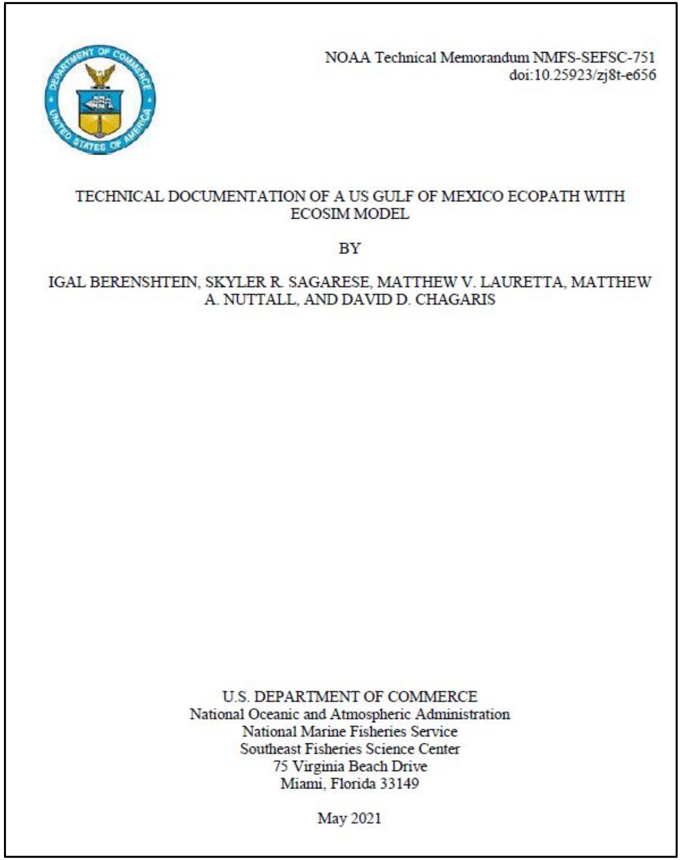






U.S. Gulf-wide Ecosystem Model // Ecosim

- Ecosim: 1980-2016
  - 160 input time series: biomass (B), catch (C), fishing mortality (F), fishing effort (E)
  - Data sources: SEDAR, SEAMAP, ICCAT, NOAA landings
  - Nutrient forcing: total Mississippi-Atchafalaya River Basin Loads
  - Fishing forcing: effort and mortality
  - Manual and automated calibration



NOAA Technical Memorandum NMFS-SEFSC-751
doi:10.25923/zj8t-e656

TECHNICAL DOCUMENTATION OF A US GULF OF MEXICO ECOPATH WITH ECOSIM MODEL

BY

IGAL BERENSHTEIN, SKYLER R. SAGARESE, MATTHEW V. LAURETTA, MATTHEW A. NUTTALL, AND DAVID D. CHAGARIS

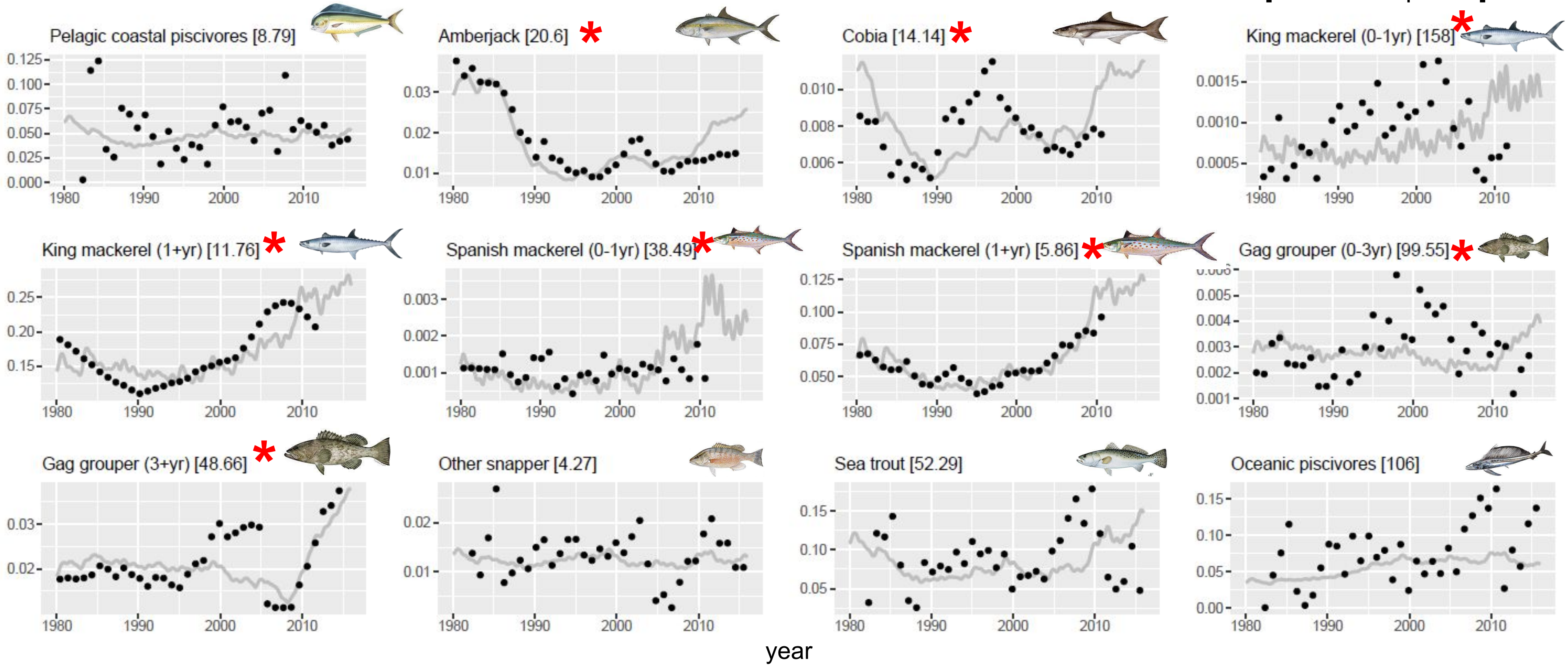
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, Florida 33149

May 2021

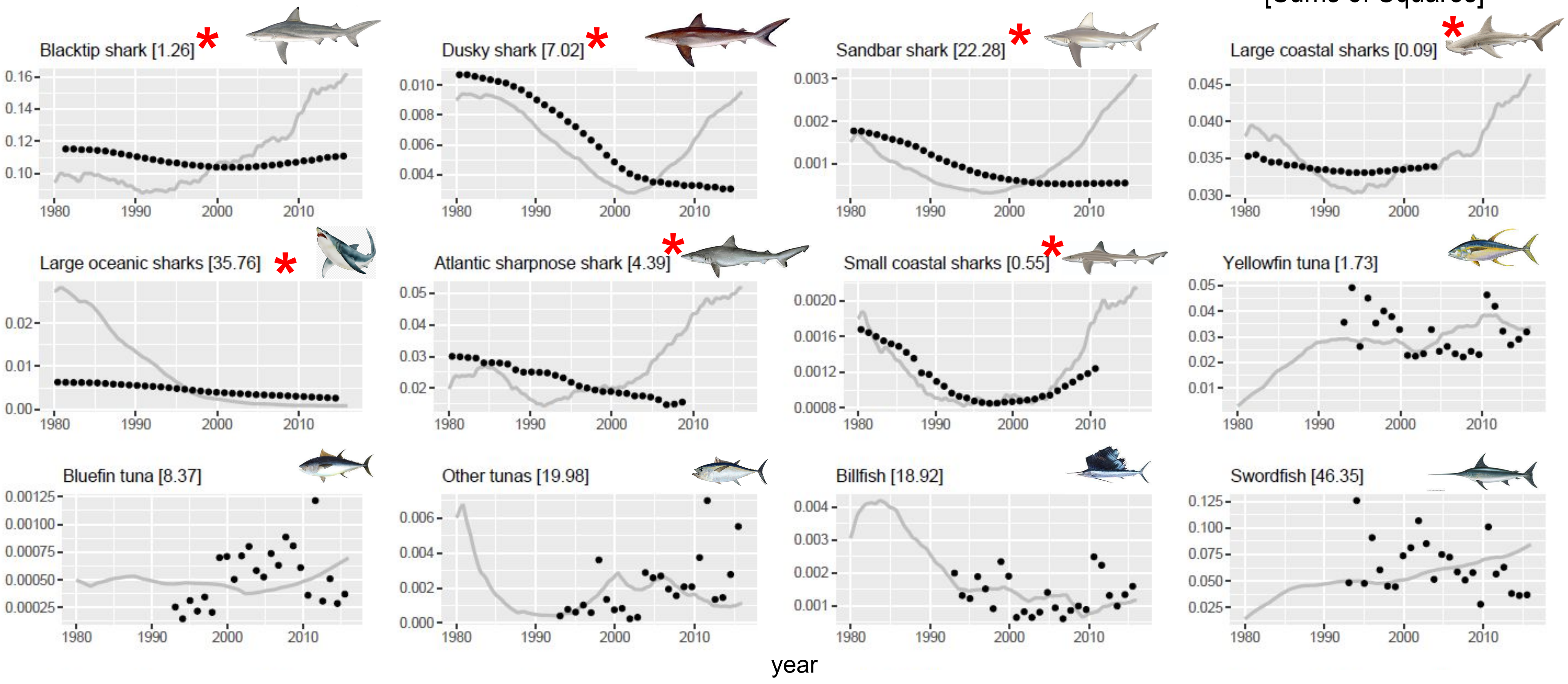
USGWEM // Ecosim // Biomass time series fits

- **Observed data**
  - ***Assessment output**
- – Ecosim prediction

[Sums of Squares]

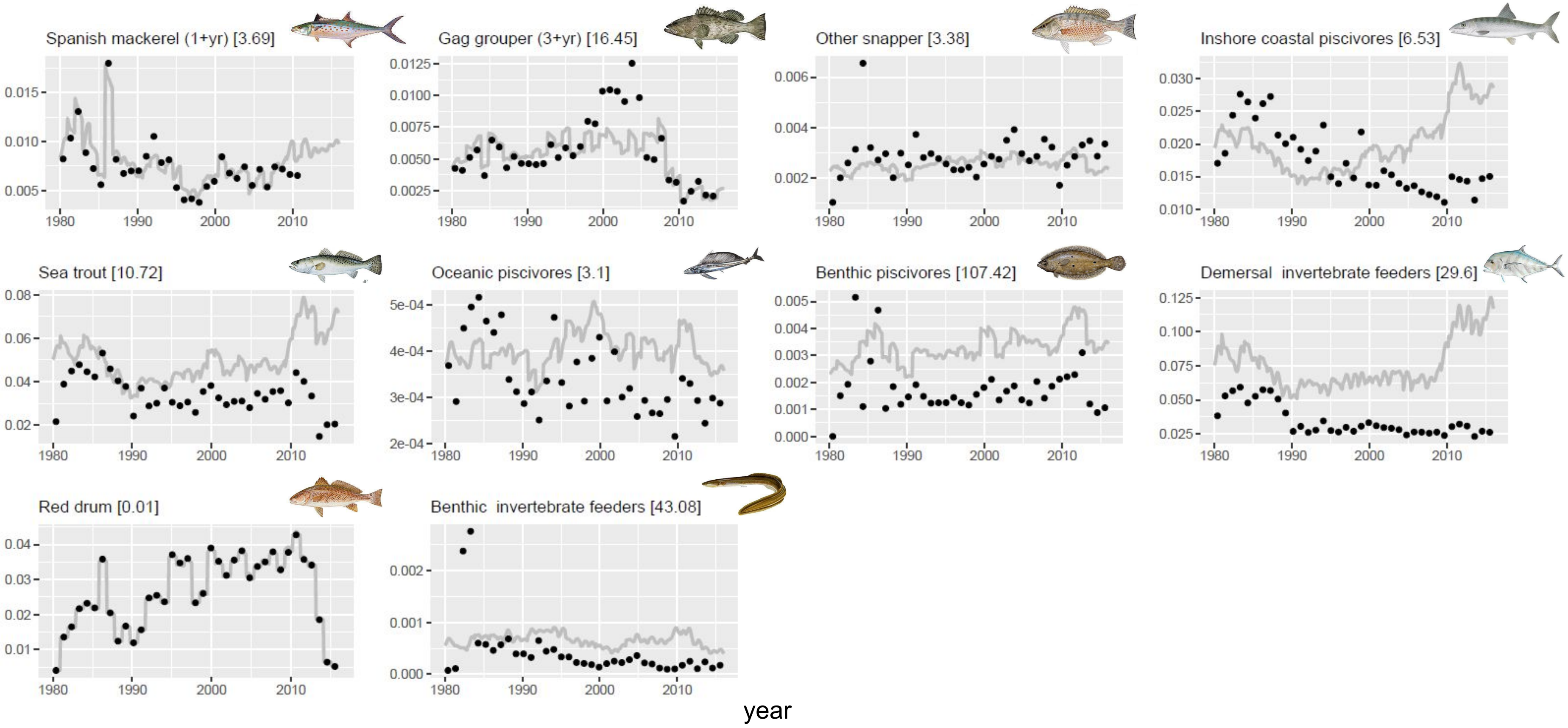


USGWEM // Ecosim // Biomass time series fits



USGWEM // Ecosim // Catch time series fits

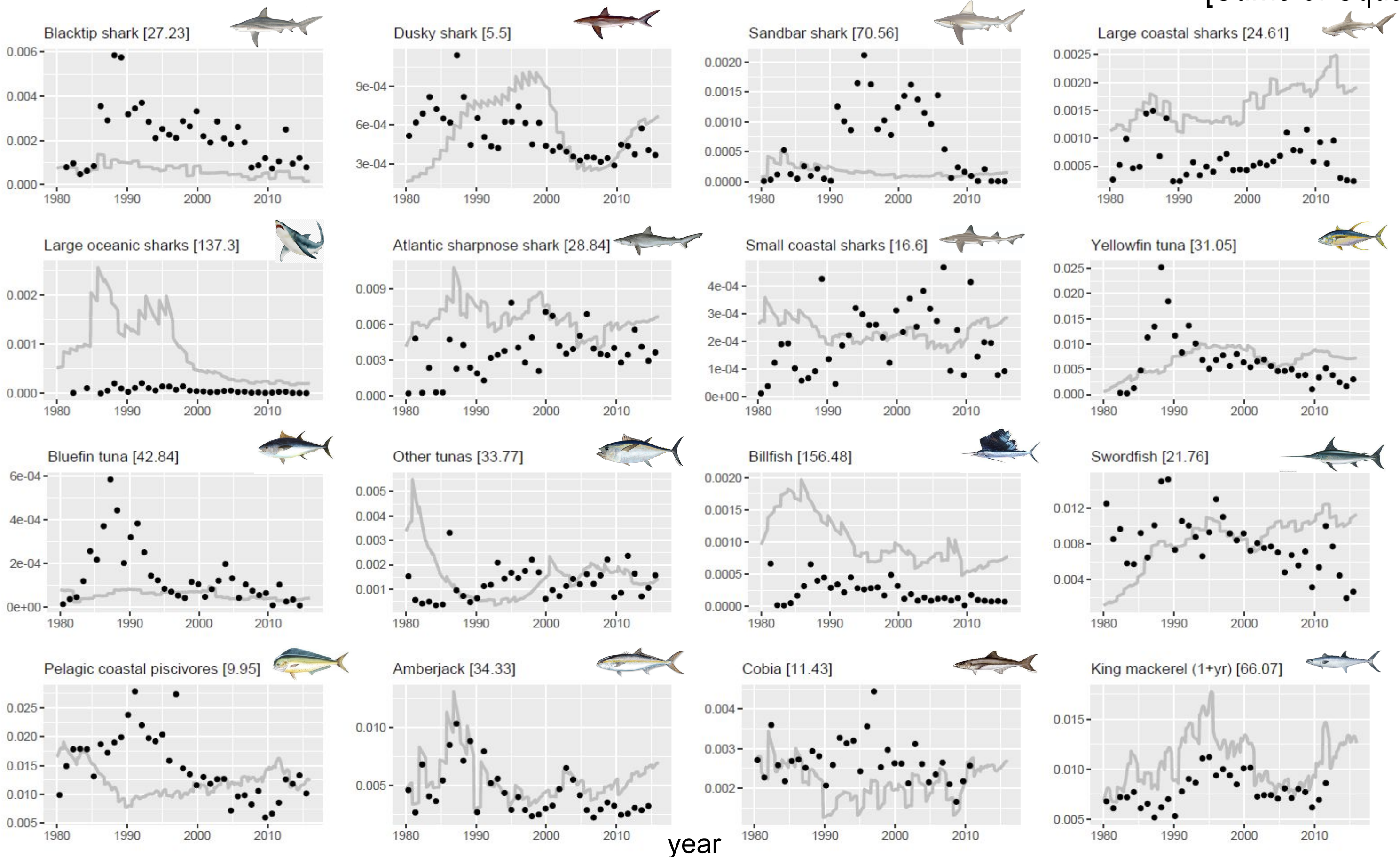
- **Observed data**
– Ecosim prediction
[Sums of Squares]



USGWEM // Ecosim // Catch time series fits

- **Observed data**
- Ecosim prediction

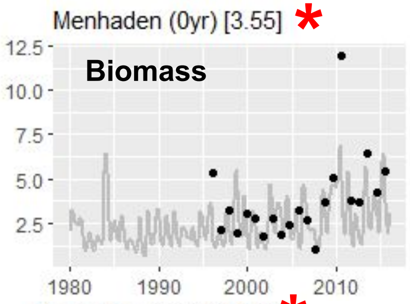
[Sums of Squares]

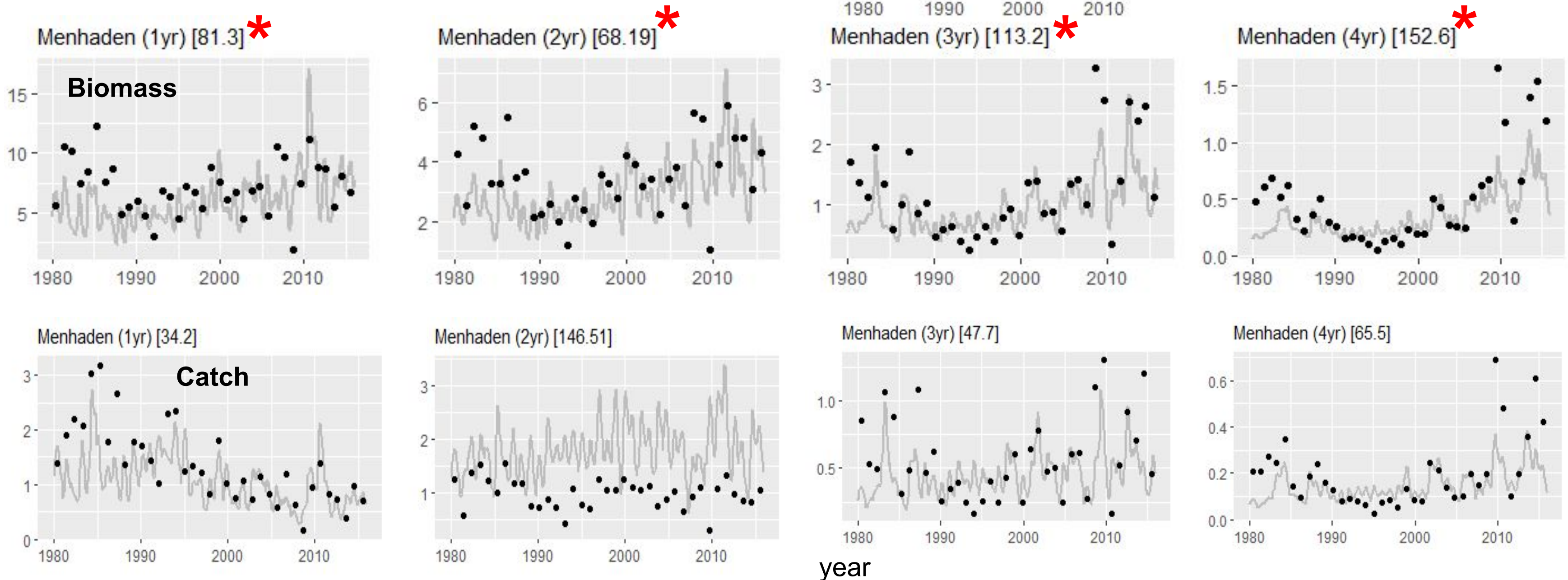


Biomass time series fits // Gulf menhaden

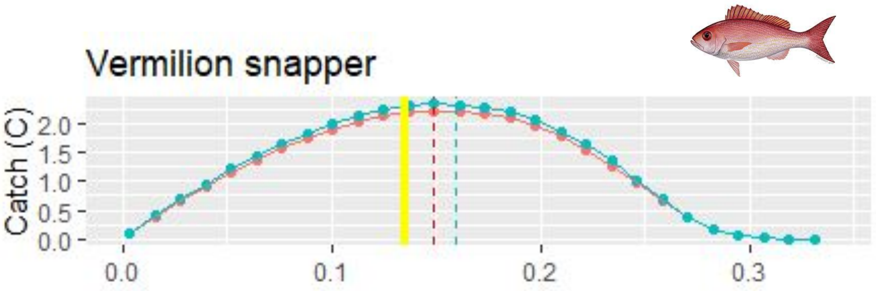
- Oscillatory behavior largely driven by Mississippi River outflow

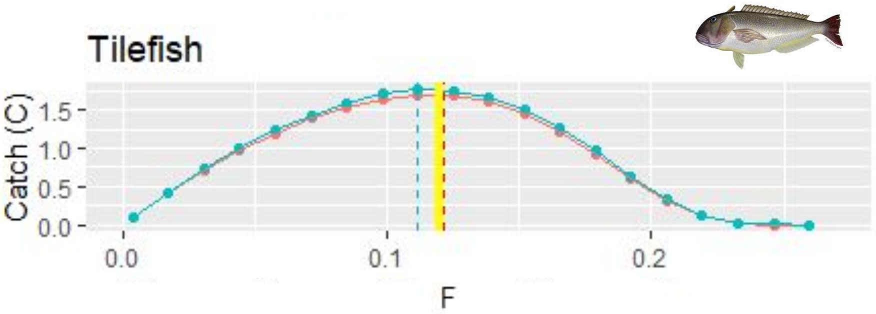
- **Observed data**
  - ***Assessment output**
- – Ecosim prediction
- [Sums of Squares]

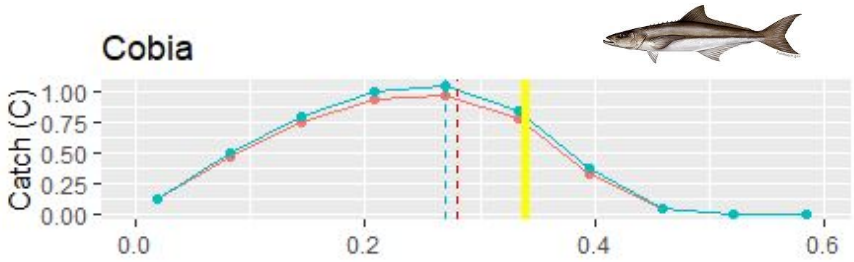


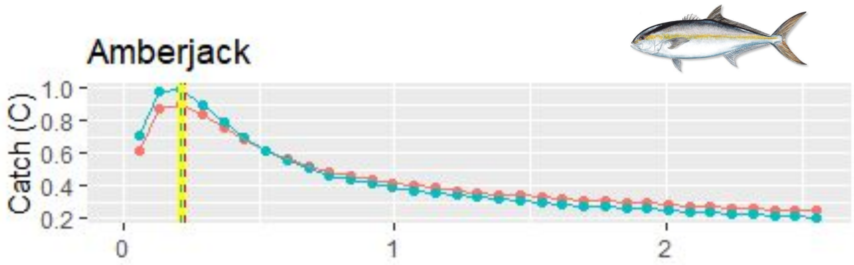


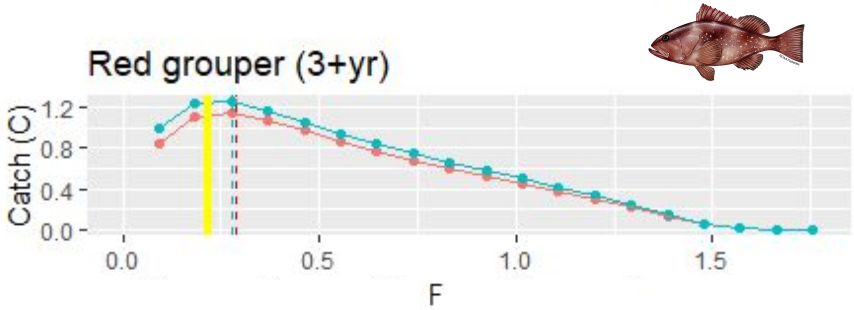
Ecosim // F_{MSY} analysis











<u>FMSY Estimate</u>

- Full compensatory (groups' biomasses change in response to the change in the target group)
- Stationary (other groups biomass fixed)
- Assessment

Ecosim // F_{MSY} analysis

F_{MSY} estimated from the Gulfwide EwE model compared to single-species stock assessment estimates or proxies for key Gulf menhaden predators

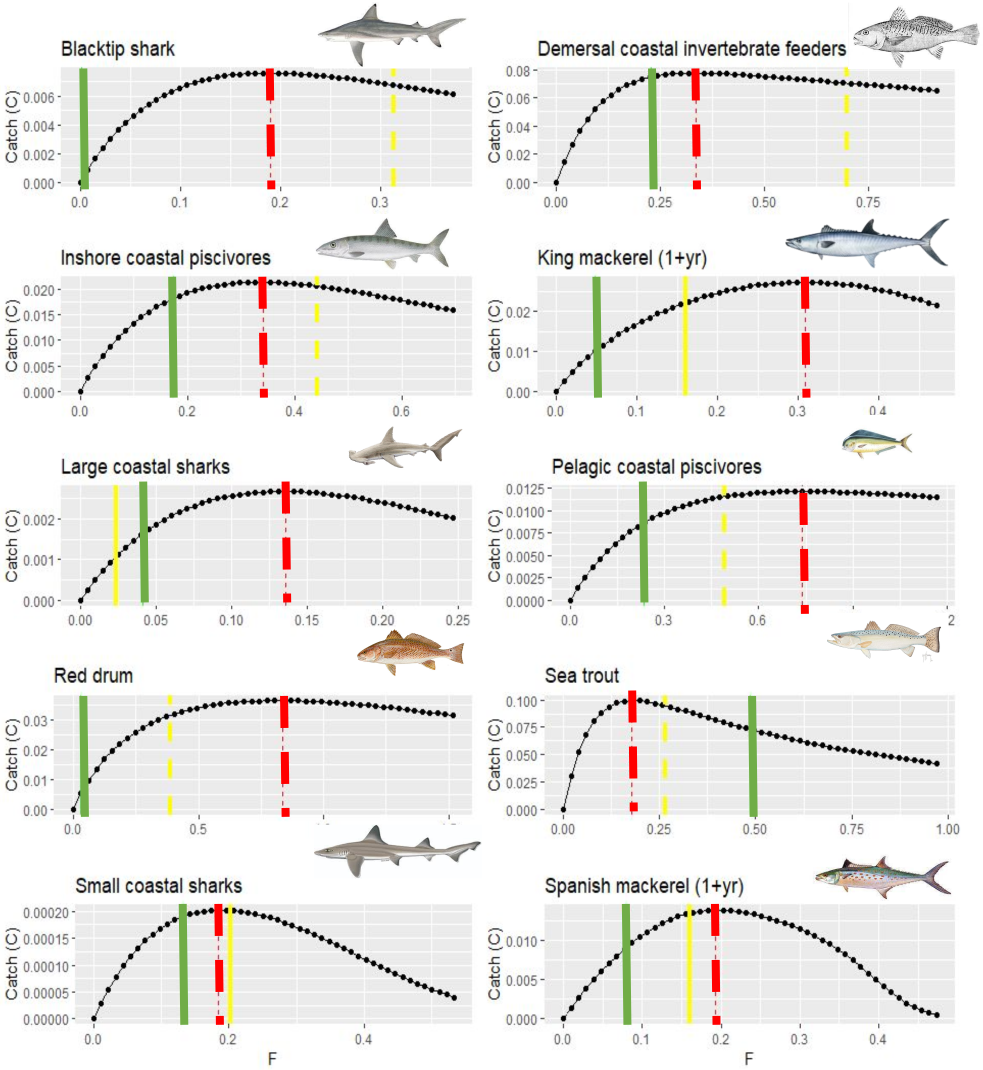
- Compensatory equilibrium analysis

- - EwE F_{MSY} estimates

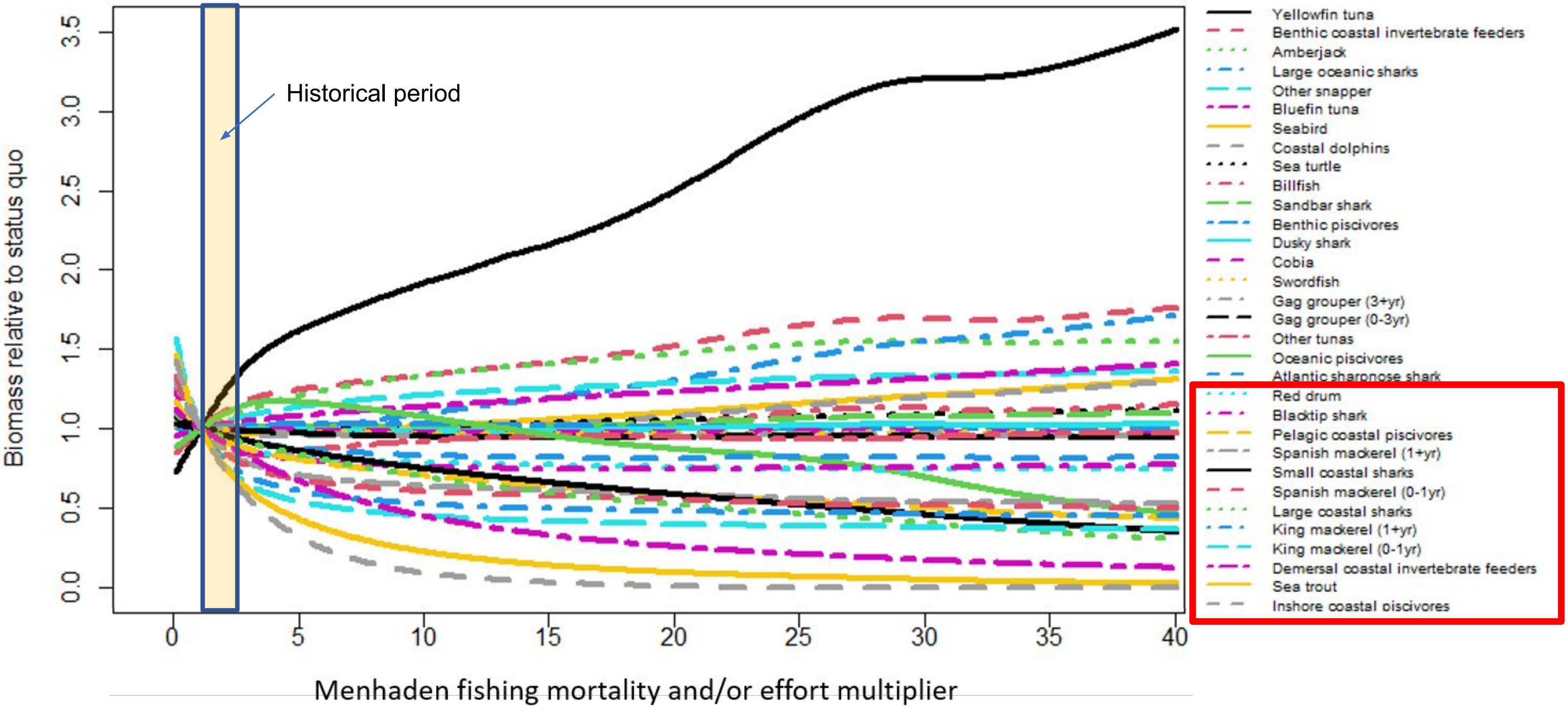
— $F_{current}$ (2016)

— Assessment F_{MSY}

- - Proxy (F_{MSY} = M)



Gulf menhaden // Effect of F & E on predators

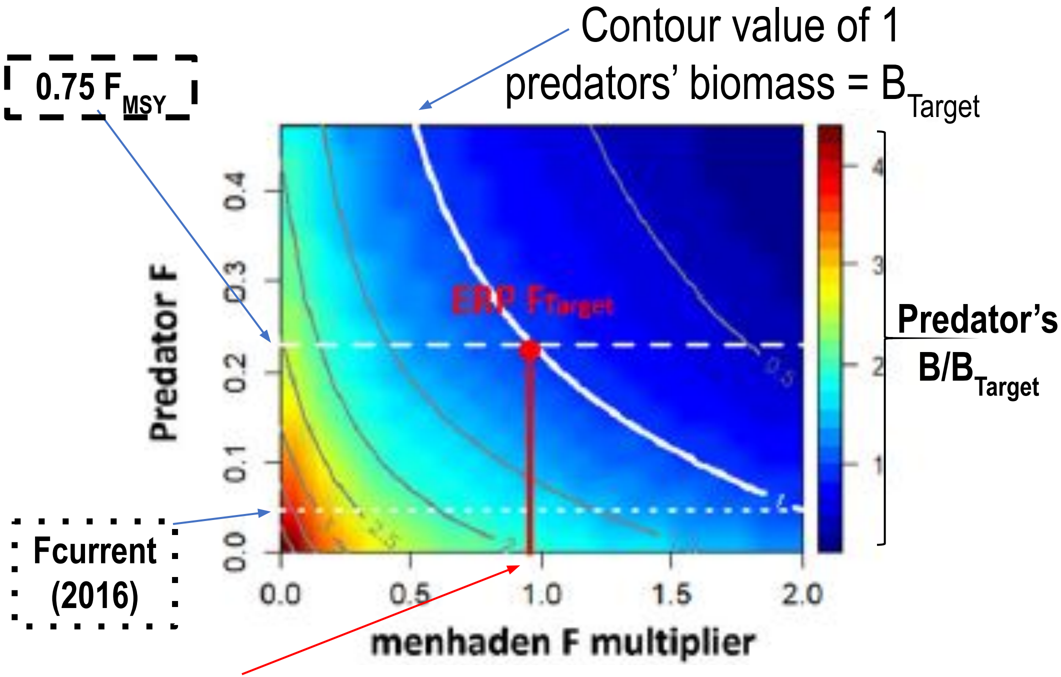


Ecological Reference Points

Berenshtein I, Sagarese SR, Lauretta MV, Schueller AM and Chagaris DD (2023) Identifying tradeoffs and reference points in support of ecosystem approaches to managing Gulf of Mexico menhaden. Front. Mar. Sci. 9:935324. doi: 10.3389/fmars.2022.935324

- Indicator approach adapted from ERPs for Atlantic menhaden (SEDAR 69)

- **Trade-off plot (color map)**
  - Ratios of scenario's biomass relative to the target biomass (B_{Target}) for menhaden predators as a function of variation in fishing mortalities for Gulf menhaden and their predators

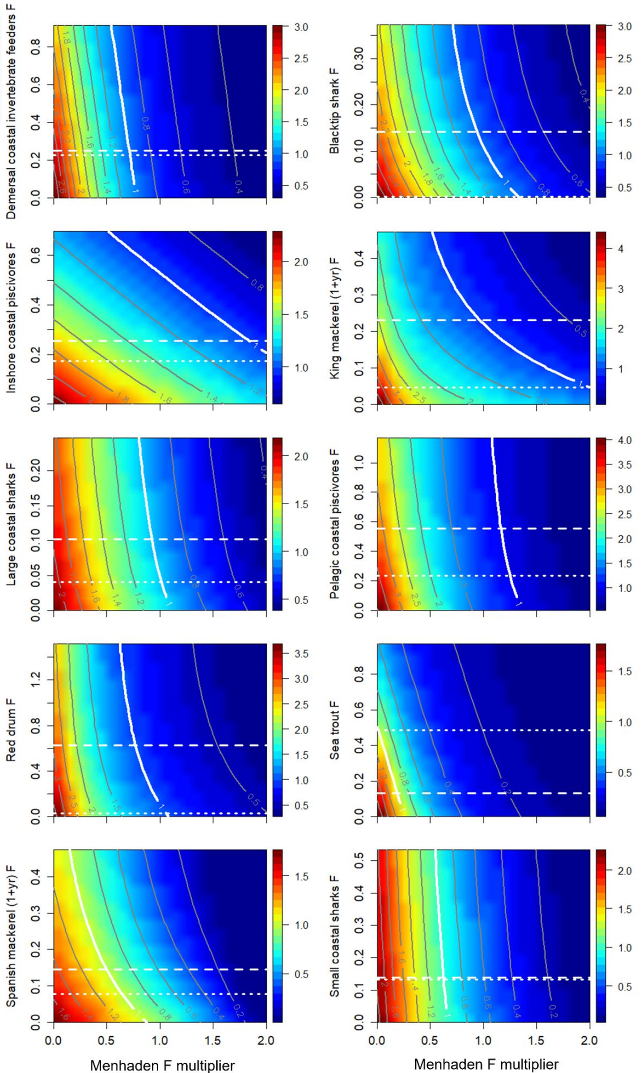


ERP F_{Target} = the multiplier of menhaden F that results in the B_{Target} of a given menhaden predator

- x-value of the intersect between the "1" contour and the horizontal dashed line (predator F_{target})

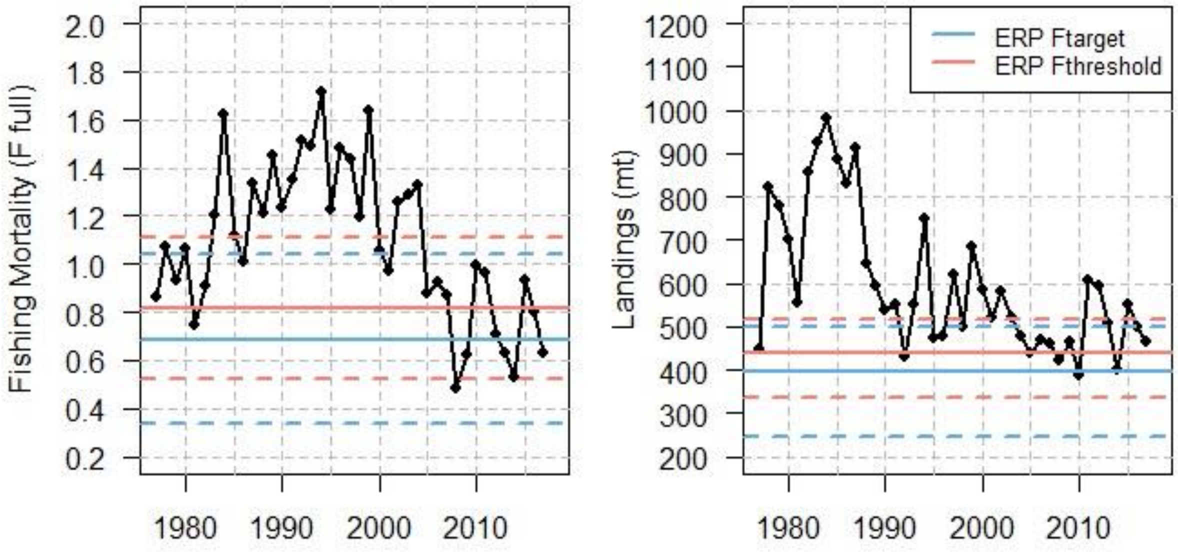
Ecological Reference Points

Group name	F_{MSY}	B_{MSY}	F_{target}	B_{target}	ERP F_{target}	ERP $F_{threshold}$
Blacktip shark	0.19	0.04	0.143	0.051	0.939	**1.232**
Demersal coastal invertebrate feeders	0.336	0.231	0.252	0.292	0.712	0.918
Inshore coastal piscivores	0.341	0.063	0.256	0.081	**1.837**	**>2.0**
King mackerel (1+yr)	0.308	0.089	0.231	0.113	0.964	**1.286**
Large coastal sharks	0.136	0.02	0.102	0.026	0.924	**1.252**
Pelagic coastal piscivores	0.739	0.016	0.554	0.022	**1.164**	**1.559**
Red drum	0.836	0.044	0.627	0.058	0.770	**1.048**
Sea trout	0.178	0.557	0.134	0.699	0.189	0.299
Small coastal sharks	0.185	0.001	0.139	0.001	0.624	0.870
Spanish mackerel (1+yr)	0.193	0.072	0.145	0.09	0.500	0.738
Mean across all 10 groups					**0.86**	**1.02**



ERPs // Gulf menhaden projections

- Gulf menhaden projections were run in Monte Carlo bootstrap mode using the 2019 Beaufort Assessment Model and the above-defined ERP target and threshold

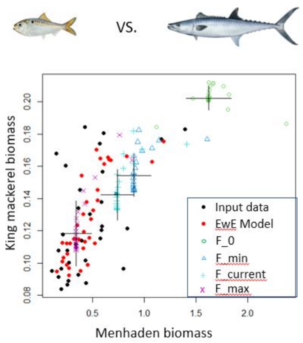


Observed landings since 2003 generally within the range of the projected equilibrium

- Horizontal solid lines = mean ERP **Ftarget** and **Fthreshold** averaged over all 10 predator species
- Horizontal dashed lines = ± 1 standard deviations

Additional Analyses

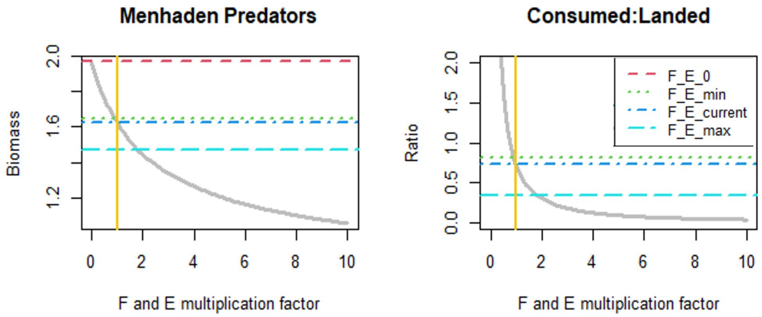
- Ecological sensitivity scenarios



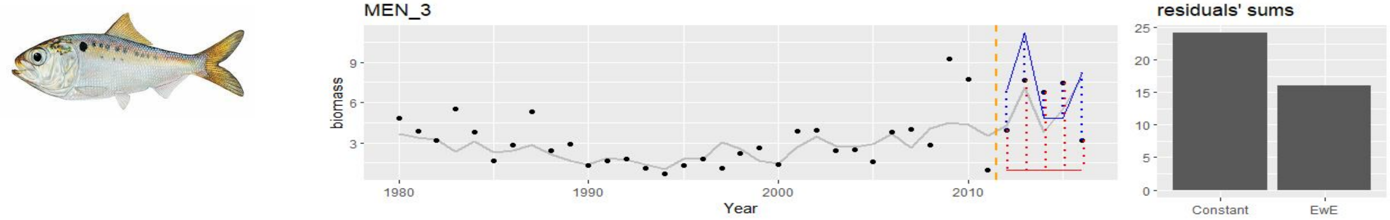
Diagnostics

- Input data – realistic relationship
- Model recreates observed pattern
- Menhaden F Scenarios:
  - F_0 (zero)
  - F_min (historical minimum)
  - F_current (2016)
  - F_max (historical maximum)

- Ecological indicators



- Forecasting ability of the Ecosim model



- Provided a time series of M that was incorporated into a sensitivity run during the 2021 GDAR 03 Gulf Menhaden Stock Assessment Update

USGWEM EwE // Key Takeaways

- The US Gulf-wide EwE model serves as a tool that could be used to address a number of ecological questions
- Gulf menhaden analysis demonstrated how B_{Target} could be achieved for a given predatory group, by modifying menhaden and/or the group's fishing pressure, and based on this relationship, ERPs were established
  - https://igalberenshtein.shinyapps.io/r_shiny_app_menhadenf_4_pub/
- Data and modeling limitations discussed in tech memo & Berenshtein et al. (2023)

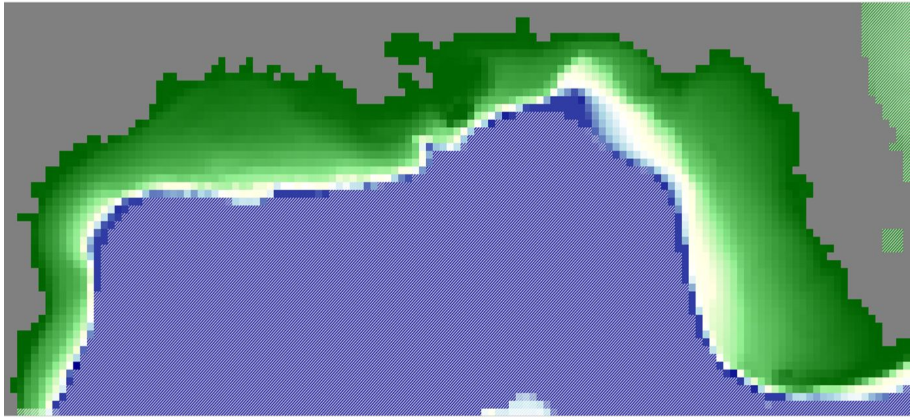
Table 26. Summary of data needs and considerations for applying the U.S. Gulf-wide Ecopath with Ecosim model for each functional group. Usability score (Score) includes: (1) model could be readily modified within a typical model development-review cycle; (2) model needs additional data and a typical model development-review cycle; (3) extensive data needed (e.g., long-time series) or the model is not feasible. Number of diet observations (i.e., studies, see Figure S1.1 for details) and number of stomachs feeding into the diet matrix are shown, as well as time series currently included in the model.

Functional Group	Notable species and importance	Diet observations (Stomachs)	Time series	Score	Data Needs and Considerations
Coastal dolphins	All protected under Marine Mammal Protection Act (MMPA)	27 (739)	-	3	Need species-specific biomass, incidental bycatch in fisheries, diet composition, and time series

USGWEM // Next steps and Future Applications

Modeling needs:

- Build in spatial component to better capture spatial dynamics, such as species overlap and bycatch
- Incorporate the effect of additional environmental drivers (e.g., temperature and hypoxia)
- Follow approach used for Atlantic Menhaden (SEDAR 69)
    - Develop alternative model configurations or models
        - MICE model focused on key predator groups
    - Technical review akin to a stock assessment review



Ecospace

- Spatially explicit simulations
- Input: dispersal rates, habitat maps, habitat preferences, fishing areas, MPAs, port locations
- Spatial-temporal drivers

Gulf of Mexico Fishery Management Council

SSC Meeting

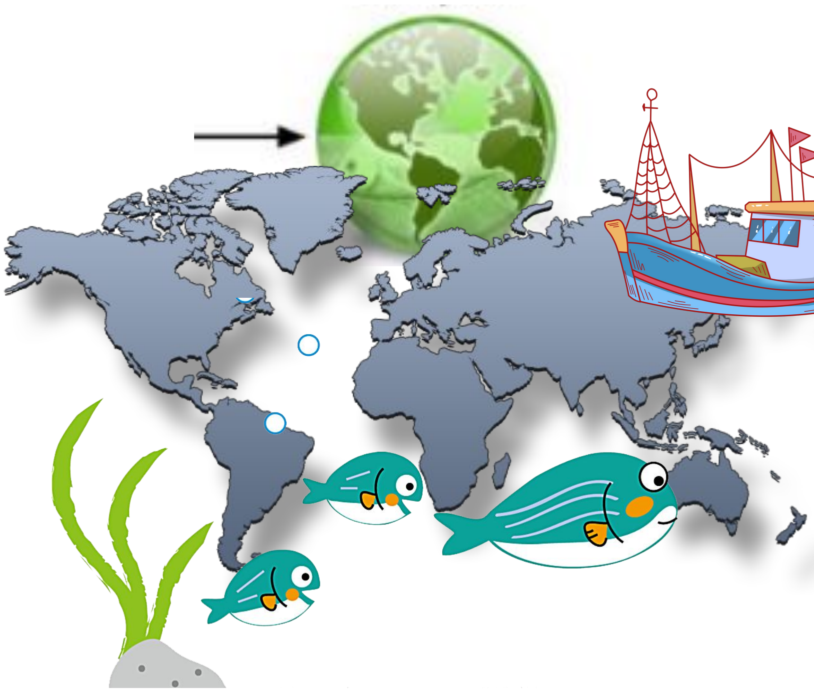
Southeast Fisheries Science Center

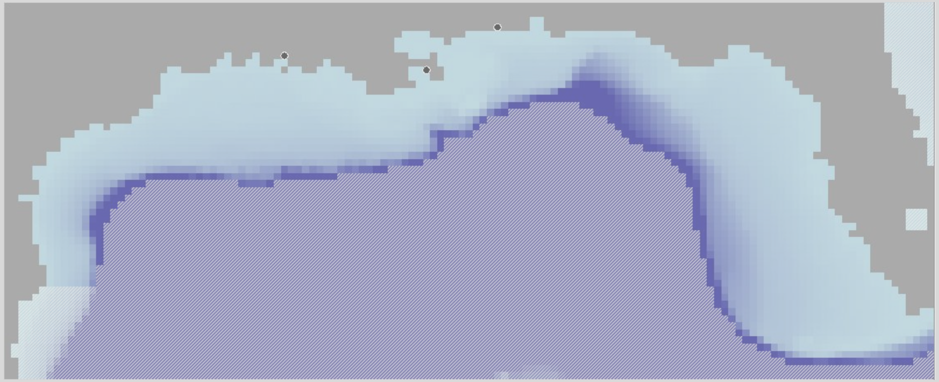
Part II
Ecosystem modeling the US Gulf of Mexico: Ecospace

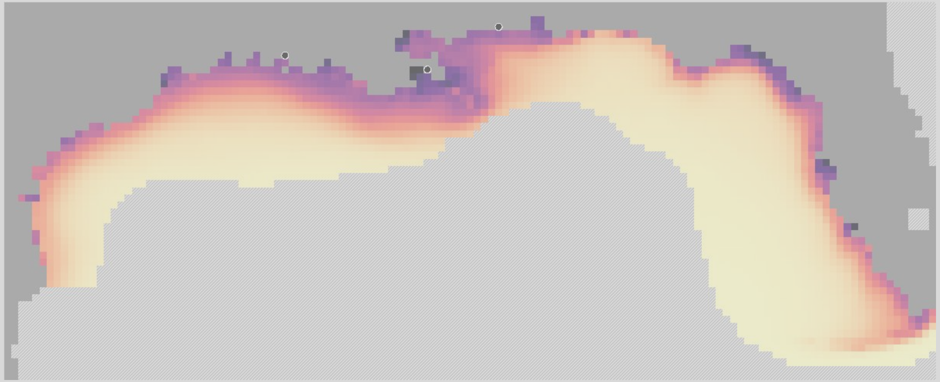
Holden E. Harris, Skyler R. Sagarese, David D. Chagaris

USGWEM // Part II // Outline

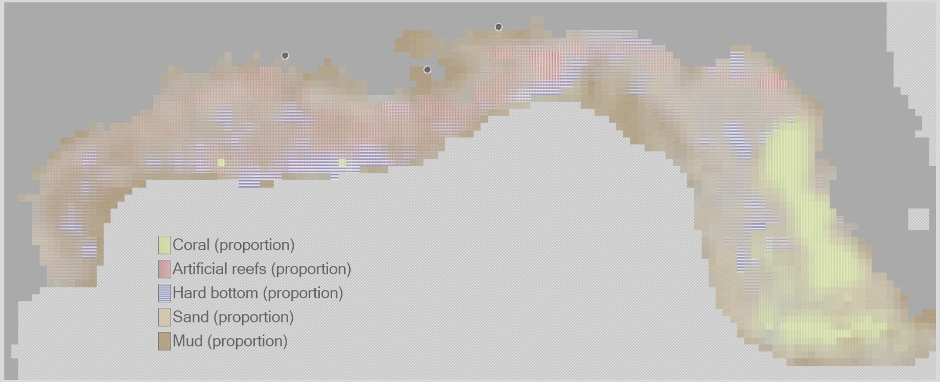
1. Context
   a. Ecospace
   b. and its GoM applications
2. Data inputs
   a. Habitat
   b. Environmental drivers
   c. Preference functions
   d. Dispersal rates
3. Next steps
   a. Fitting & calibration
   b. Qualitative & fisher input
4. Potential research directions
   a. Operationalization into Fisheries Ecosys. Plans
   b. Spatial-temporal closures & bycatch reduction
   c. Climate change
   d. Structured habitat (O&G & wind)

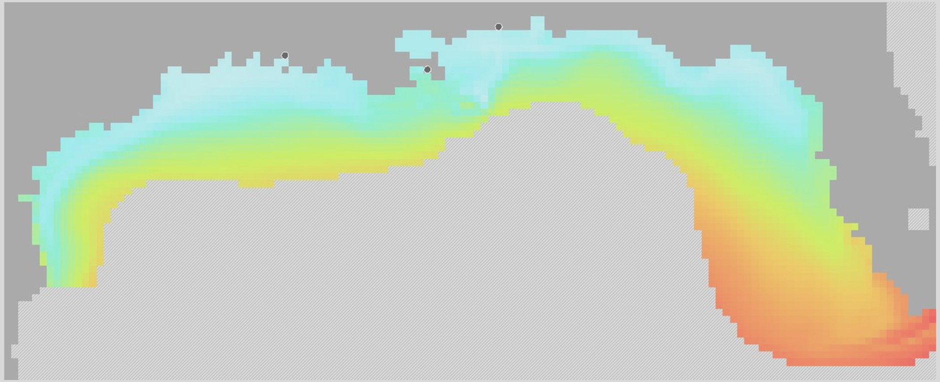






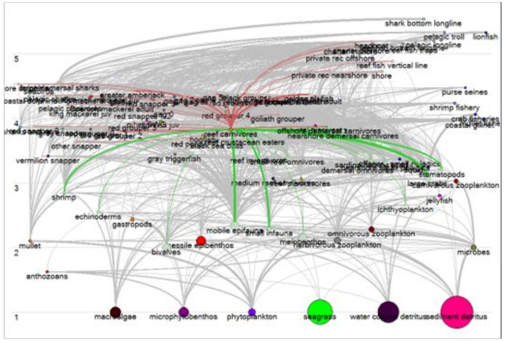
Introduction // Ecospace



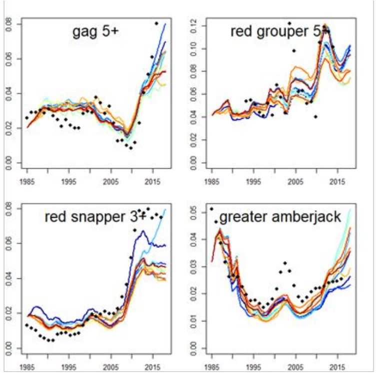


Contact: holden.harris@noaa.gov | GitHub: SEFSC/IEA/GWEM/DataSynth

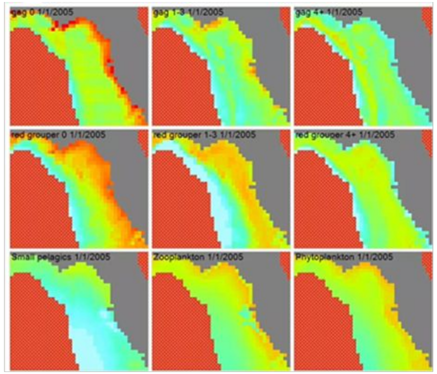
Context // Ecospace



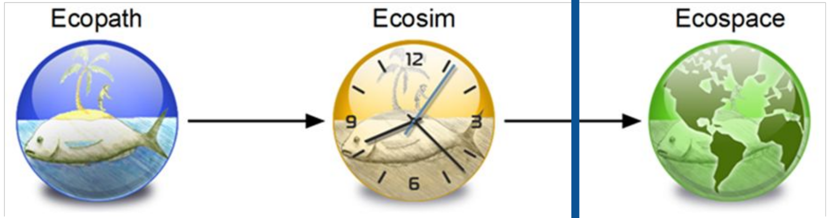
Step 1 - Ecopath
Static mass-balanced model



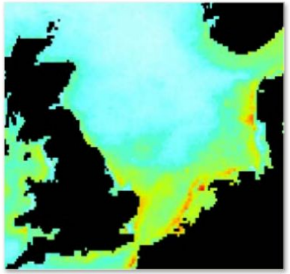
Step 2 - Ecosim
Time dynamic simulations

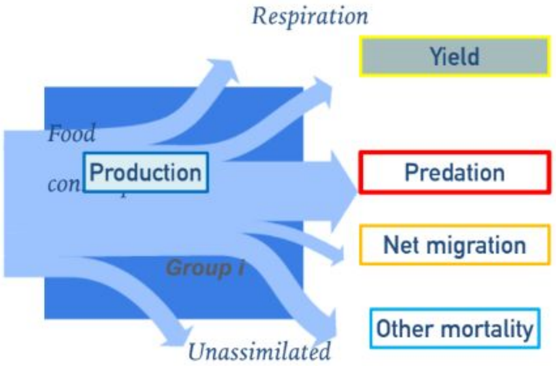


Step 3 - Ecospace
Spatial-temporal dynamics

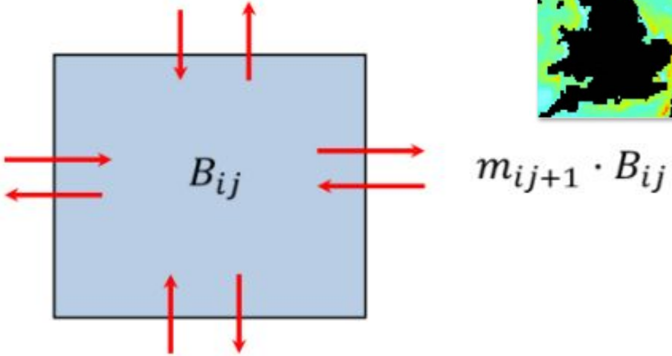


Context // Ecospace





$$\frac{dB_i}{dt} = g_i \cdot \sum_{\text{Pred}\_j=1}^{n} c_{ji}(B_i, B_j) - \sum_{\text{Pred}\_j=1}^{n} c_{ij}(B_i, B_j) + I_i - (M0_i + F_i + e_i) \cdot B_i$$

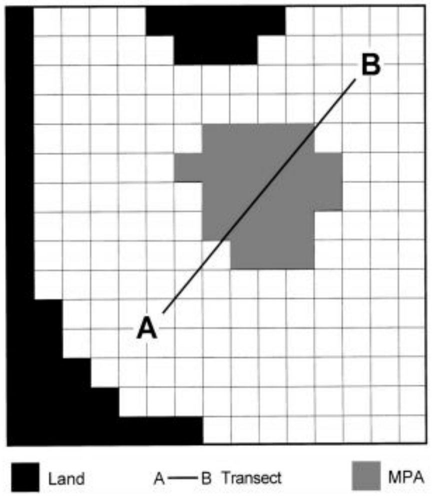


- For each cell, the immigration rate $\boldsymbol{m_i}$ is the sum of emigration flows from the four surrounding cells.
- Immigration / emigration rates based on
  - Abiotic factors: **habitat** & **environmental drivers** (e.g., temp. & salinity)
  - And biotic factors: to **feed** & avoid **predators**
- Fishing effort uses Ecopath base or predicts fleet dynamics with a gravity model

Walters et al. 1999; Christensen & Walaters 2004

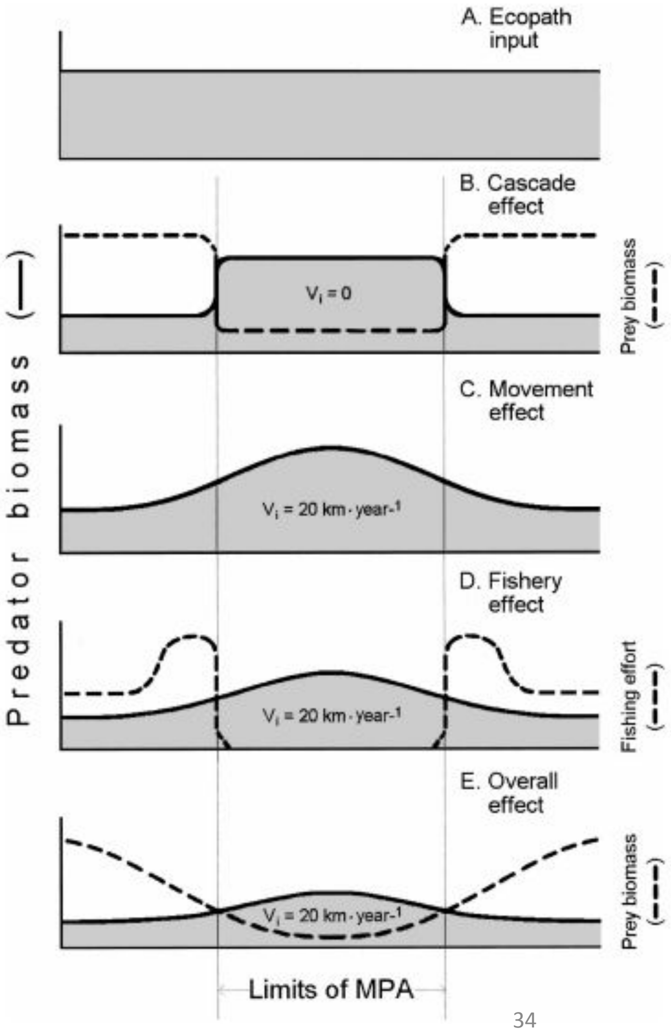
Context // Ecospace // MPAs

Illustrative (and first) Ecospace example:
Walters et al. 1999 examining MPAs



Panels:

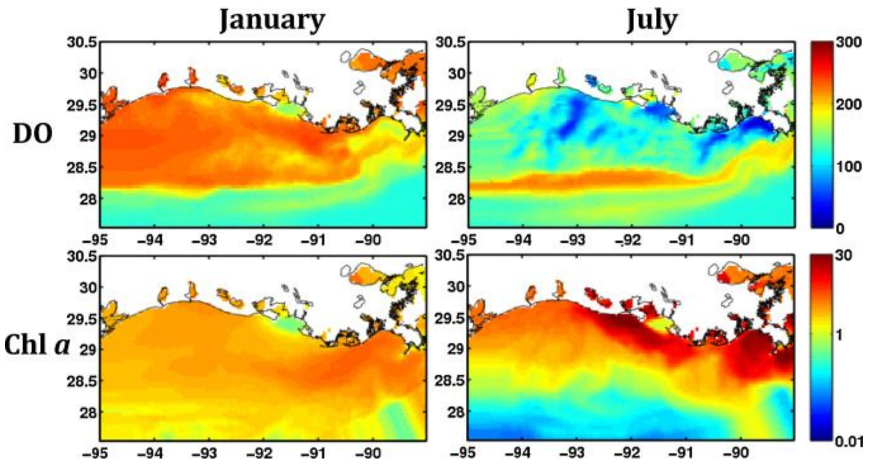
A. Uniform EwE model
B. No spatial mixing
C. Mixing with higher biomass in MPA
D. Aggregated fishing along MPA edges
E. Overall effect

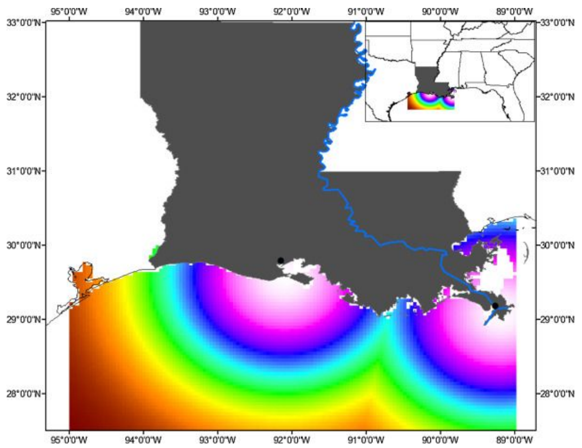


Ecospace // GoM Applications // Hypoxia

de Mutsert et al., 2016: Effects of **hypoxia** on LA fisheries

- Nekton able to move out of poor habitat conditions
- Primary production gains largely counteracted deleterious effects of hypoxia

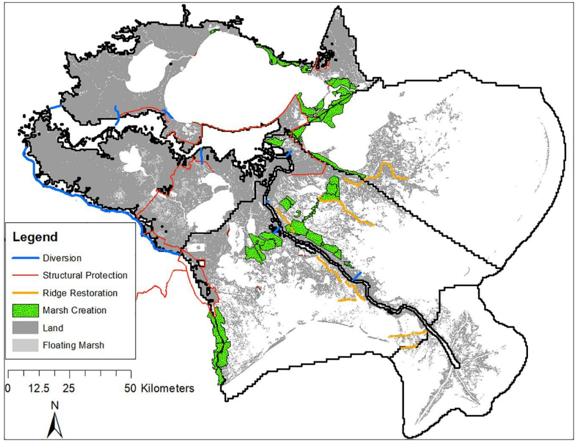


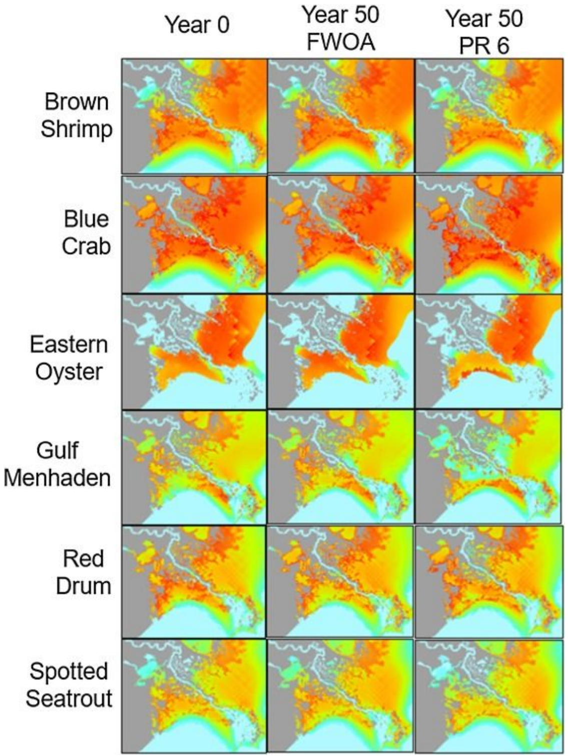


Ecospace // GoM Applications // Habitat Restoration

de Mutsert et al., 2017: Effects of Miss. Rvr. **freshwater diversions** on LA fisheries

- ID'd winners & losers from restoration efforts
- Results used by restoration authority to prioritize diversion projects





Ecospace // GoM Applications // HAB

Vilas et al. 2023: Effects of **red tide** on WFS gag grouper and fisheries

- Incorporated lethal and sublethal effects
- Produced time-series of episodic mortality that can inform stock assessment

Ecosystem Modeling of Red Tide Impacts on West Florida Shelf Fisheries

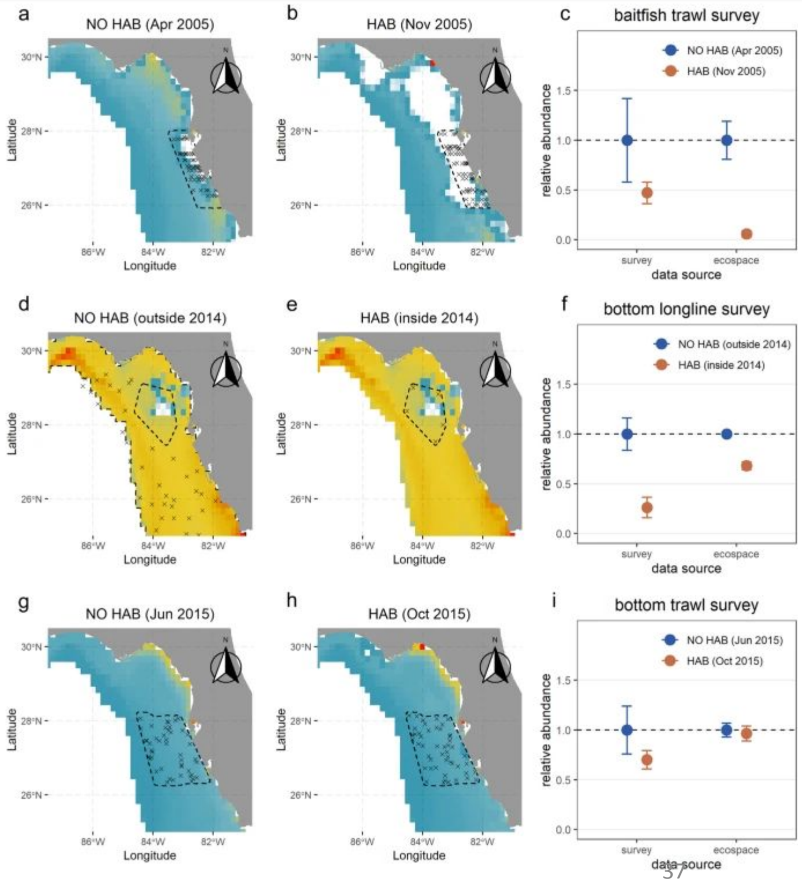
David Chagaris, Daniel Vilas, Joe Buszowski, and Zach Siders

In Collaboration with:

Jeroen Steenbeek, Lisa Ailloud, Skyler Sagarese, Ted Switzer, Dylan Sinnickson, Kim de Mutsert, Matthew Lauretta, Carl Walters, Rob Ahrens

Gulf SSC Meeting, September 28, 2021

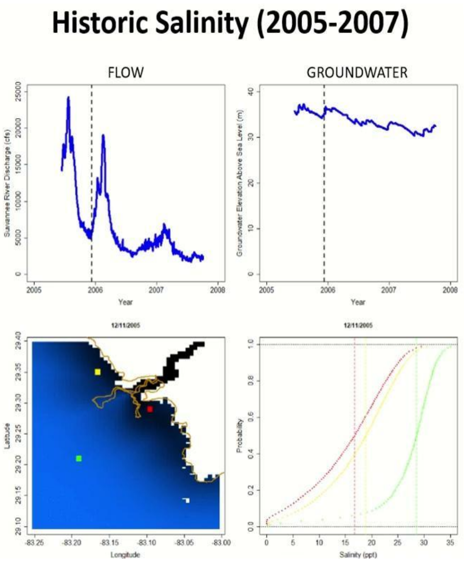
UF UNIVERSITY of FLORIDA · NATURE COAST BIOLOGICAL STATION · Ecopath International Initiative · NOAA · RESTORE SCIENCE PROGRAM

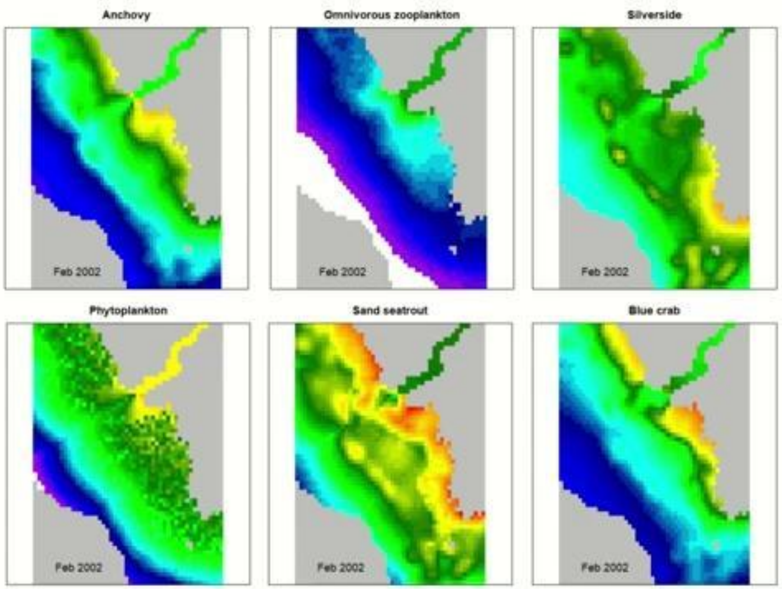


Ecospace // GoM Applications // Climate Change

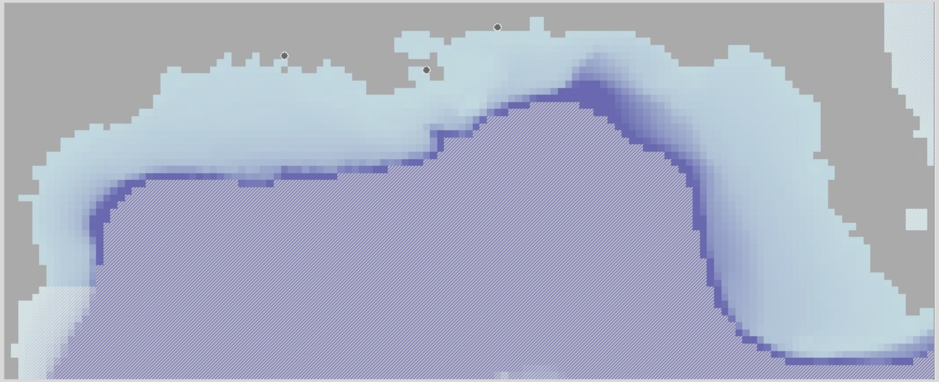
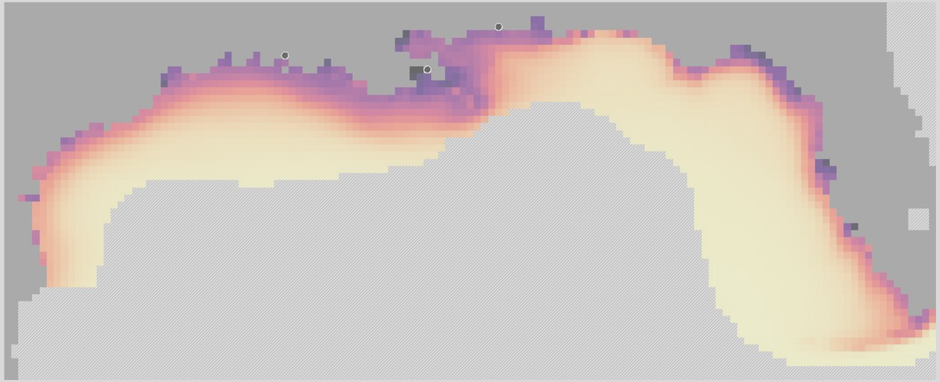
Effects of **freshwater provisioning** on estuary ecosystems & fisheries

- Spatial-temporal changes in salinity, temperature, and nutrients
- Concurrent bottom-up & top-down drivers

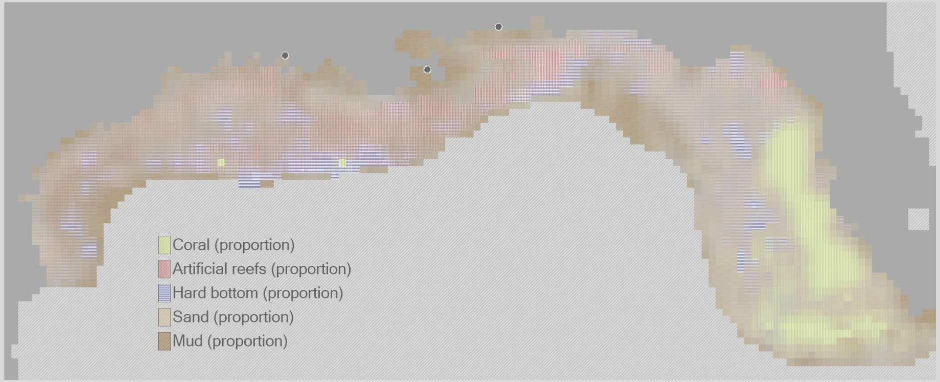


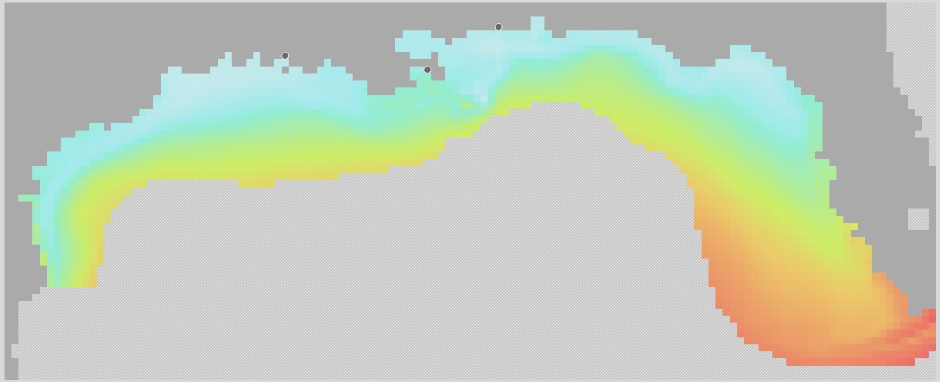


Harris, Chagaris, Reaver, Allen and others; unpublished

USGWEM Ecospace // Data Inputs



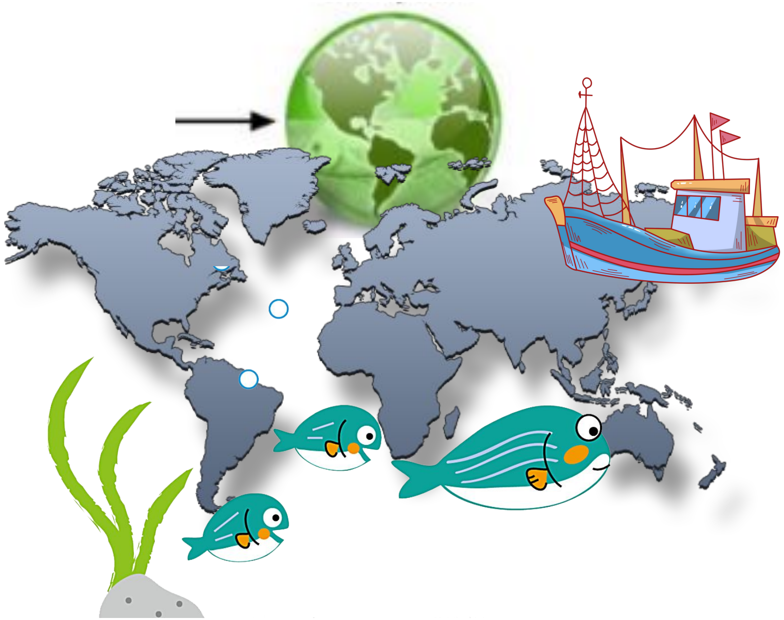


Contact: holden.harris@noaa.gov | GitHub: SEFSC/IEA/GWEM/DataSynth

USGWEM Ecospace // Data inputs // Overview

Maps

- Habitat maps (static)
  - Depth / basemap
  - Habitats
    - Hardbottom
    - Coral
    - Artificial reefs
    - Sand
    - Mud
- Environmental drivers (Spatial-temporal; ST)
  - Primary production
  - Salinity
  - Temperature (bottom, surface, avg.)

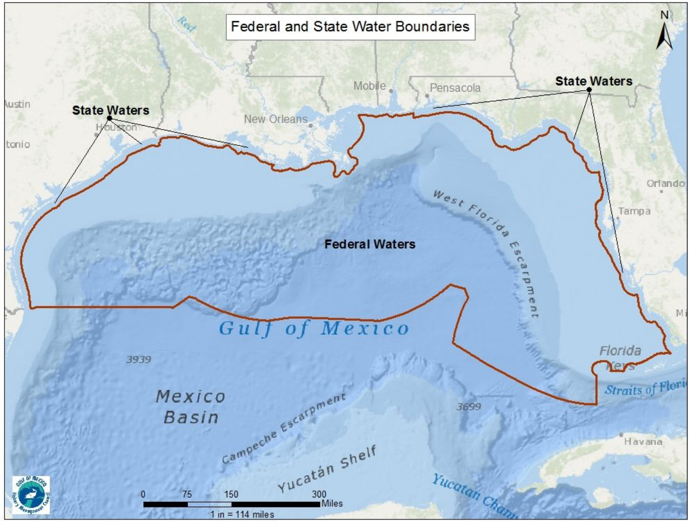


Responses

- Dispersal rates
- Preference functions

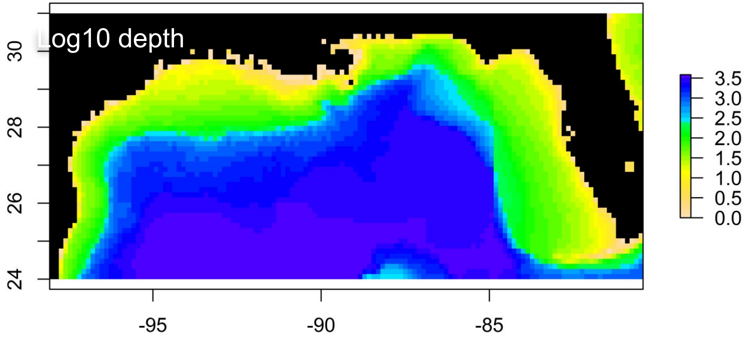
USGWEM // Spatial extent and base map

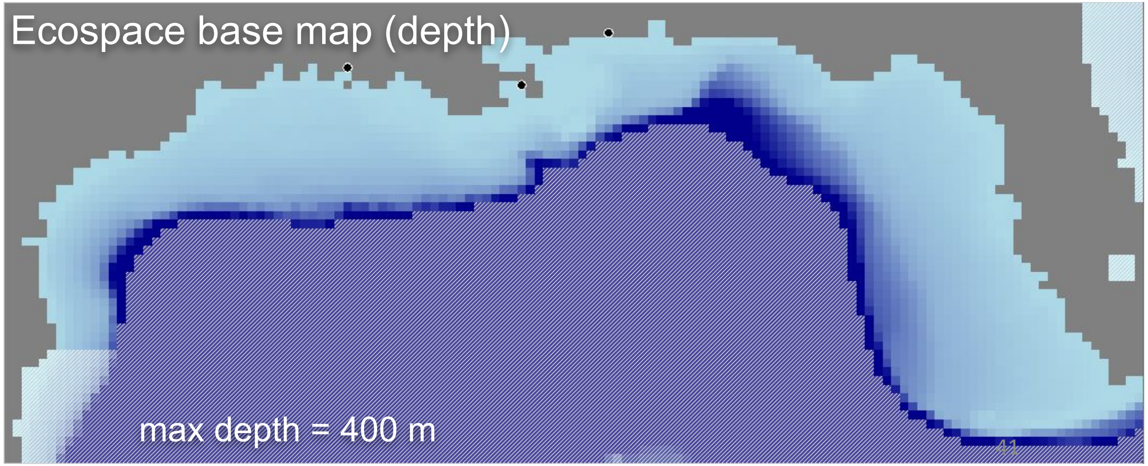
GOM Managed LME



[GitHub repository for making basemap]()

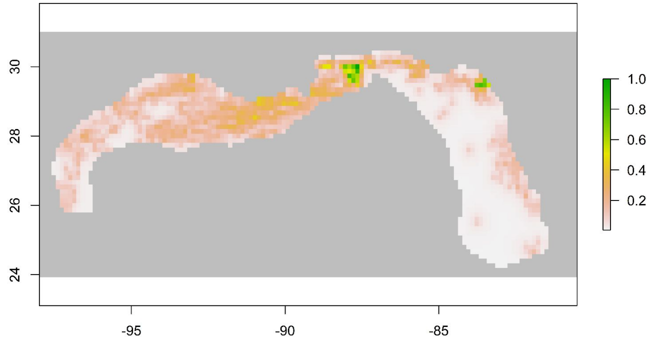
Spans >3 orders of magnitudes



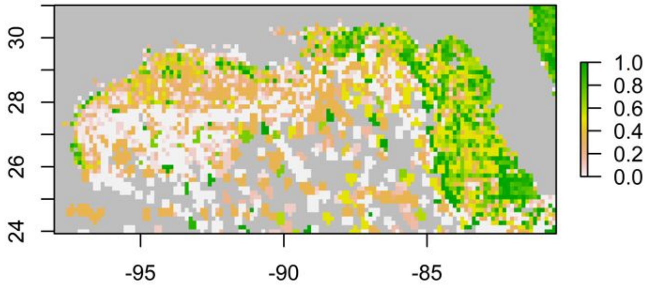


Data Inputs // Habitat Maps

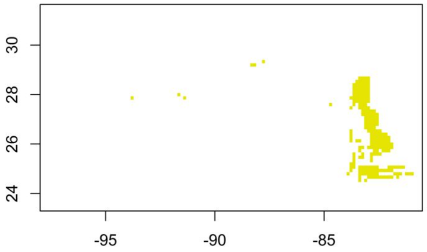
Artificial reefs (scaled inverse distance)



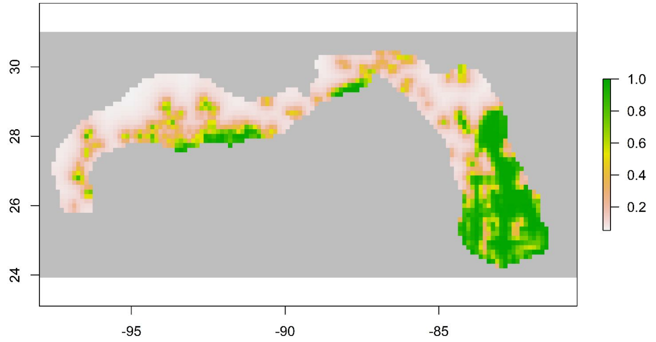
Sand



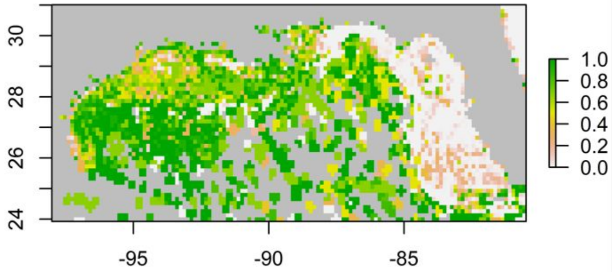
Coral habitat



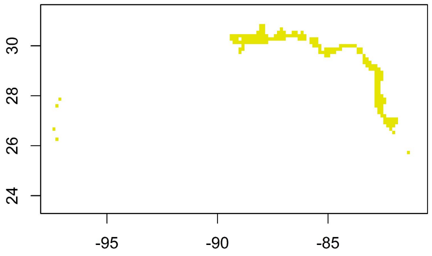
Hard bottom (scaled inverse distance squared)



Mud

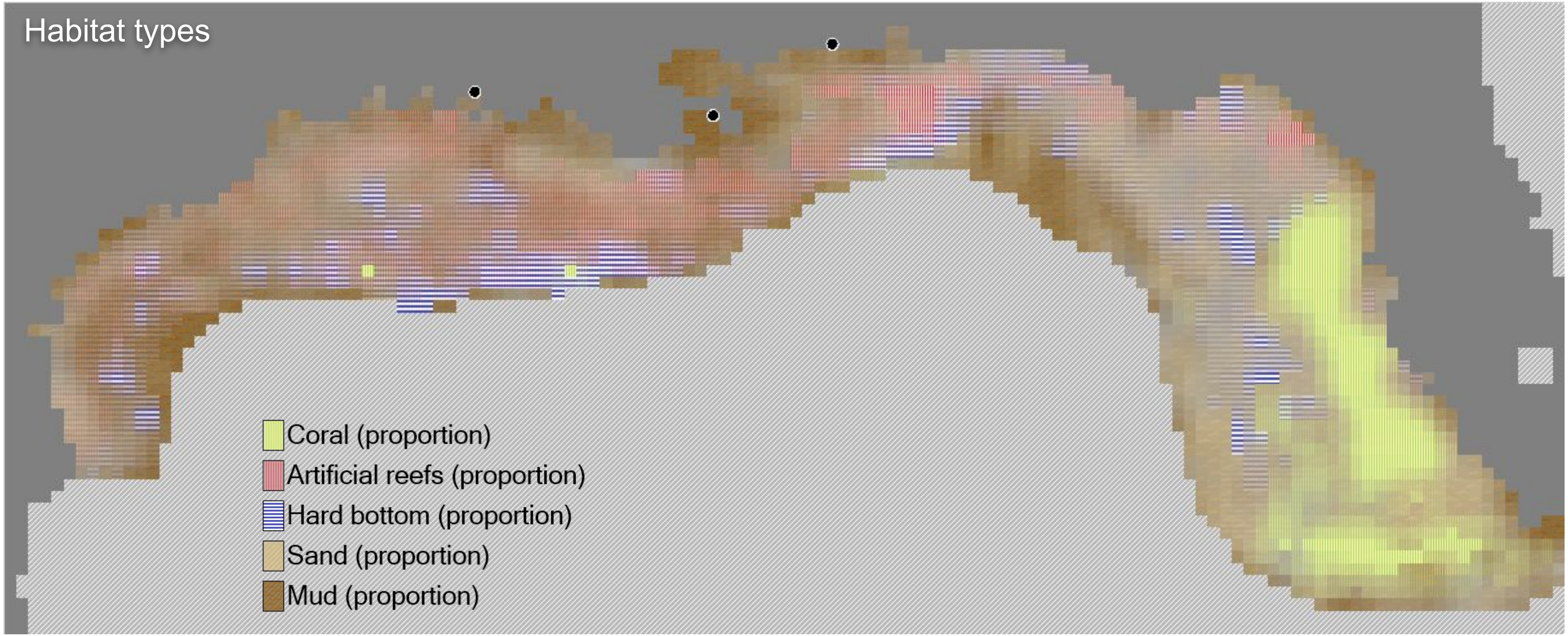


Seagrass habitat

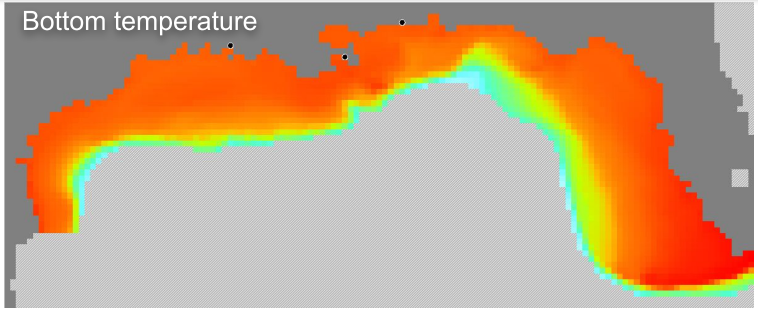


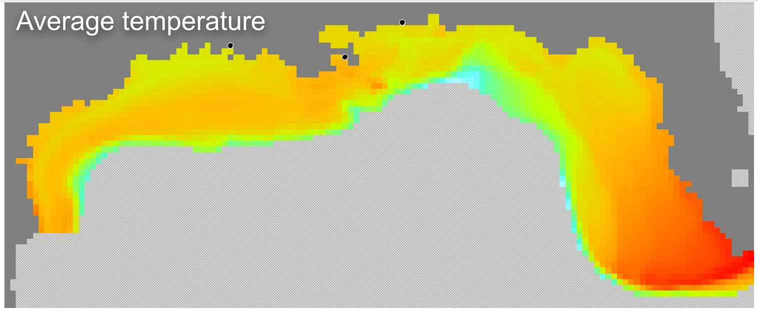
Data collated by NOAA [NCEI GoM Data Atlas] // [GitHub repository for making Ecospace maps]

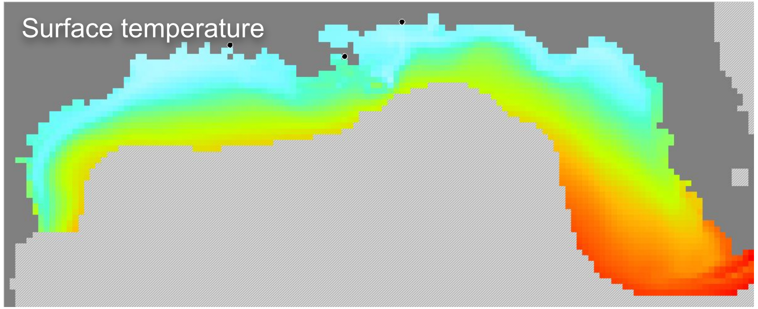
Data Inputs // Habitat Maps

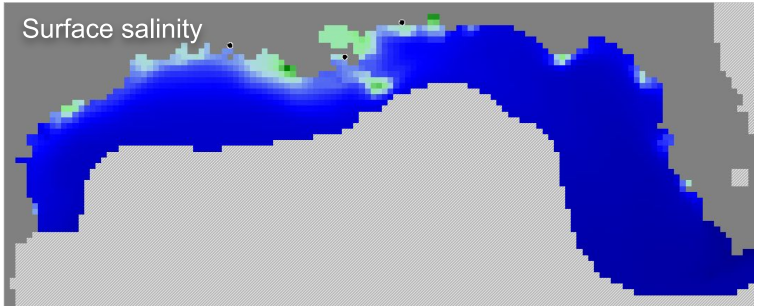


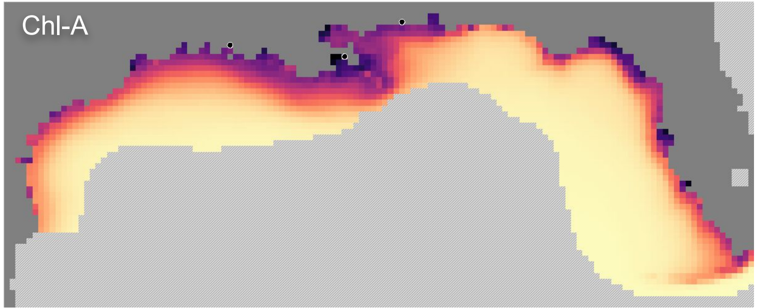
Data Inputs // Environmental Drivers





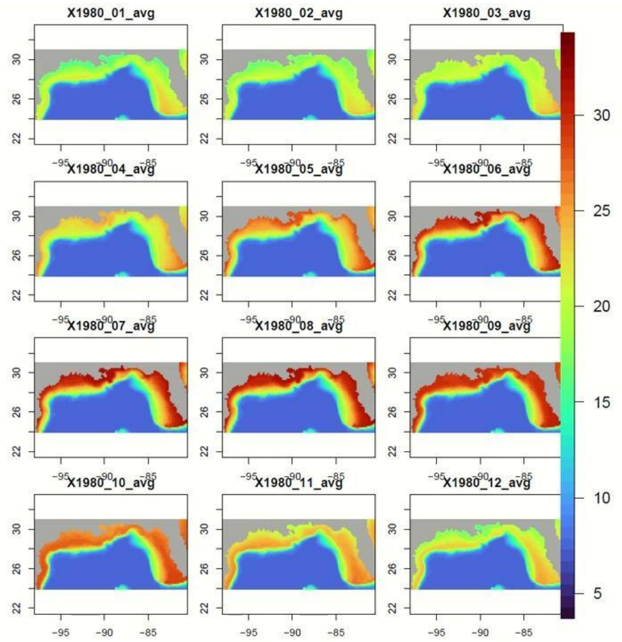




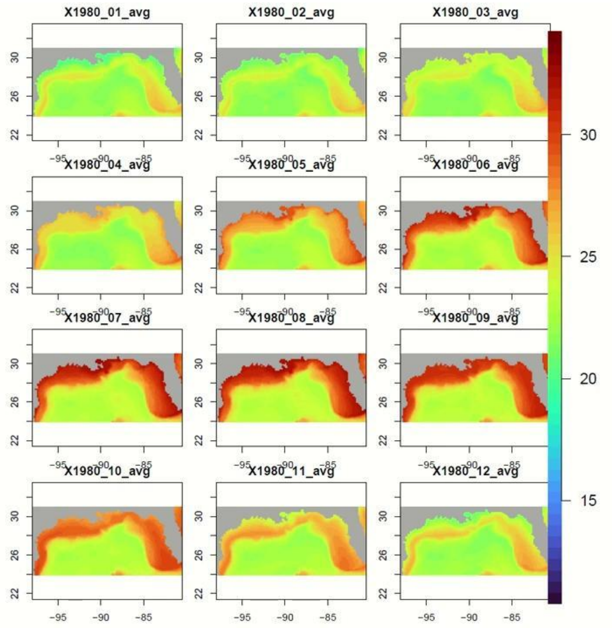


Data Inputs // ST Env. Drivers // Temperature

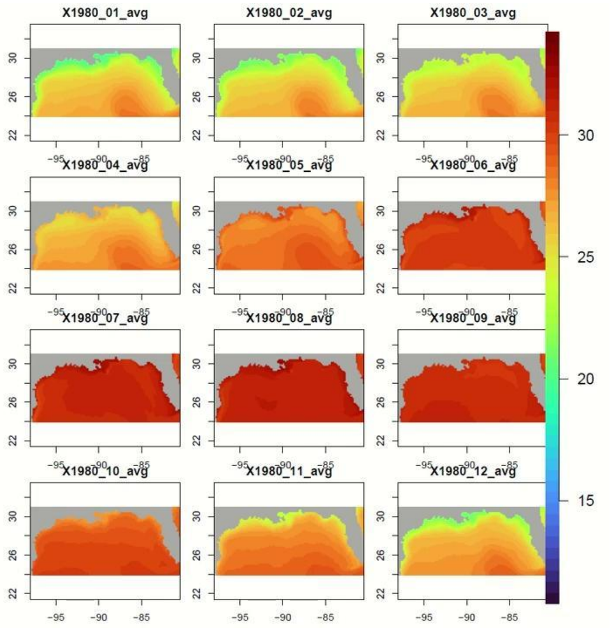
Bottom



Average



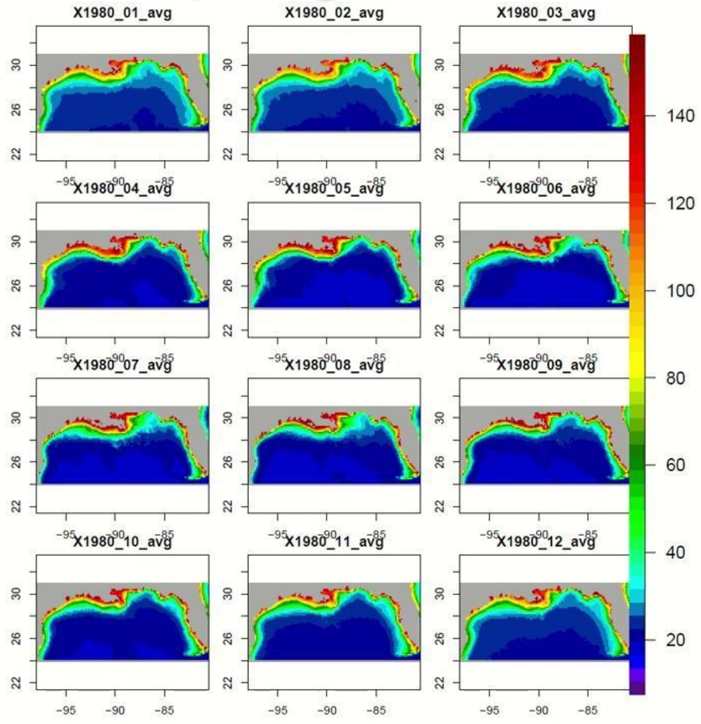
Surface



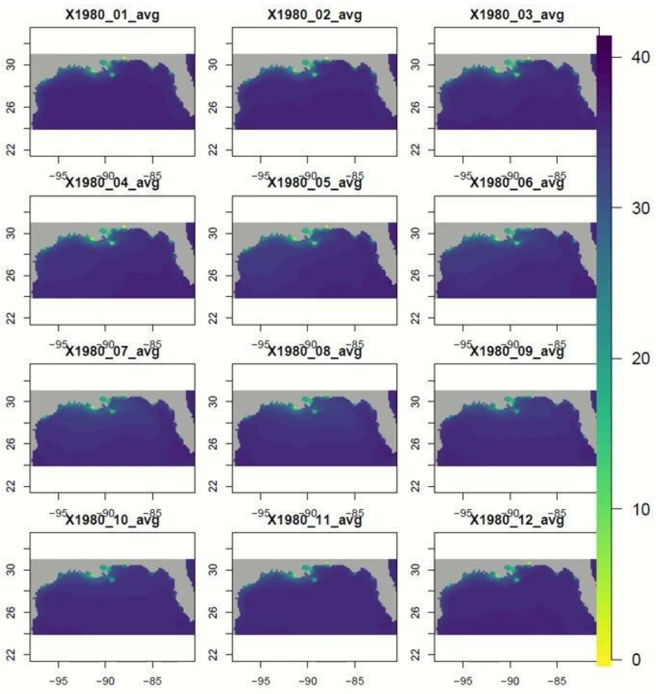
Monthly averages: 1980-1993 | Years of data available: 1993-2022
Data source: HYCOM | Files and PDF maps

Data Inputs // ST Env. Drivers // Prim. Prod. & Salinity

Depth Integrated Chl-A



Surface salinity



PP monthly averages: 1980-2003 | Years of data available: 2003-2020
Data source: MODIS | [Files and PDF maps]

Data inputs // Dispersal rates

Step 1: Query characteristics from FishBase R
Step 2: Estimate a relative swim speed (Simbilay 1990),

$$\log\_10(S) = -0.828 + 0.61961 \log\_10(L) + 0.3478 \log\_10(A) + 0.7621 (M)$$

where *L* represents a species' common length in mm, *A* is the aspect ratio of its caudal fin, and *M* is a binary swimming mode

Step 3: Scale to experimentally determined dispersal rates.

$m_{red\ drum}$ = 60.75 km y^{-1} and
$m_{spotted\ seatrout}$ = 28.26 km y^{-1} (Nelson et al., 2021)

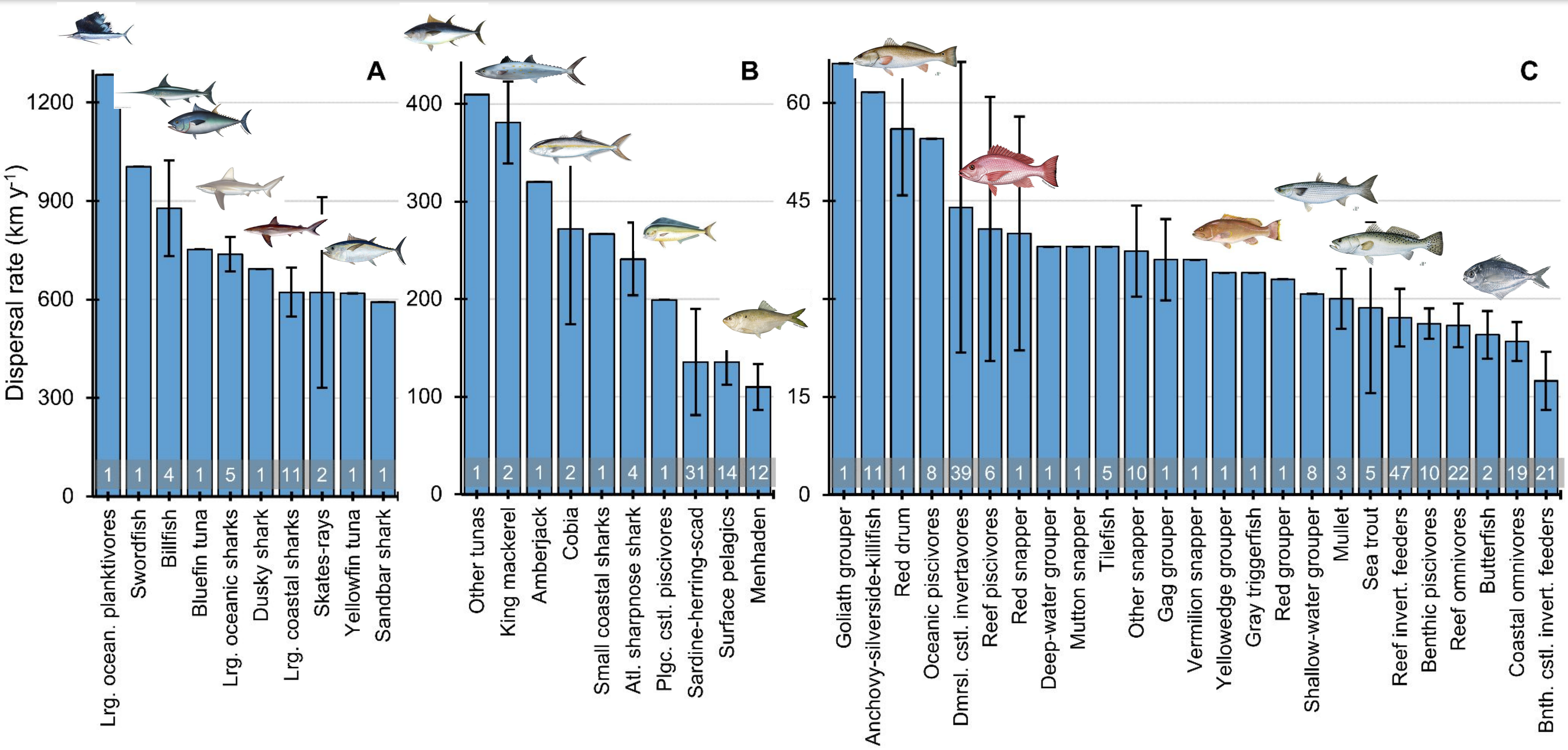
Step 4: Average and aggregate by functional group

Table 1 – Relative swim speed and scaled dispersal rates per species based on common length, tail aspect ratio, and swim mode.

Scientific name	Common name	EwE FG	FG num	Aspect ratio	Common length (cm)	Swim mode	Rel. swim speed km h^{-1}	Scaled dispersal rate km y^{-1}
Cetorhinus maximus	Basking shark	Lrg. oceanic planktivores	55	3.162	700	1	68.4	1285
Makaira nigricans	Blue marlin	Billfish	16	7.829	290	1	54.3	1020
Xiphias gladius	Swordfish	Swordfish	17	7.052	300	1	53.5	1005
Istiophorus albicans	Atlantic sailfish	Billfish	16	8.502	240	1	49.7	934
Istiophorus platypterus	Indo-pacific sailfish	Billfish	16	5.921	270	1	47.1	886
Carcharhinus brevipinna	Spinner shark	Large cstl. sharks	09	5.879	250	1	44.8	842
Alopias vulpinus	Common thresher shark	Large oceanic sharks	10	1.815	450	1	42.9	806
Galeocerdo cuvier	Tiger shark	Large cstl. sharks	09	1.386	500	1	41.7	783
Pristis pectinata	Smalltooth sawfish	Skates-rays	25	1.116	550	1	41.0	770
Alopias superciliosus	Bigeye thresher	Large oceanic sharks	10	2.486	350	1	40.9	769
Isurus oxyrinchus	Shortfin mako shark	Large oceanic sharks	10	3.761	270	1	40.2	756
Thunnus thynnus	Bluefin tuna	Bluefin tuna	14	6.342	200	1	40.1	753
Sphyrna mokarran	Great hammerhead	Large cstl. sharks	09	1.854	370	1	38.2	719
Prionace glauca	Blue shark	Large oceanic sharks	10	2.084	335	1	37.5	704
Sphyrna lewini	Scalloped hammerhead	Large cstl. sharks	09	1.808	360	1	37.3	701
Carcharhinus obscurus	Dusky shark	Dusky shark	07	3.360	250	1	36.9	693
Tetrapturus pfluegeri	Longbill spearfish	Billfish	16	6.420	165	1	35.7	671
Carcharhinus longimanus	Oceanic whitetip shark	Large oceanic sharks	10	2.470	270	1	34.8	654
Acanthocybium solandri	Wahoo	Pelagic cstl. piscivores	18	5.619	170	1	34.7	653
Carcharhinus altimus	Bignose shark	Large cstl. sharks	09	2.520	250	1	33.4	627
Thunnus albacares	Yellowfin tuna	Yellowfin tuna	13	6.014	150	1	32.9	619
Hexanchus griseus	Sixgill shark	Large cstl. sharks	09	1.570	300	1	31.7	596
Carcharhinus plumbeus	Sandbar shark	Sandbar shark	08	3.178	200	1	31.5	592
Carcharhinus falciformis	Silky shark	Large cstl. sharks	09	2.026	250	1	30.9	582
Carcharias taurus	Sand tiger	Large cstl. sharks	09	1.614	250	1	28.6	537
Carcharhinus leucas	Bull shark	Large cstl. sharks	09	1.444	260	1	28.2	530
Pristis pristis	Largetooth sawfish	Skates-rays	25	1.116	250	1	25.1	473
Carcharhinus signatus	Night shark	Large cstl. sharks	09	1.638	200	1	25.0	470
Negaprion brevirostris	Lemon shark	Large cstl. sharks	09	1.073	240	1	24.2	455
Katsuwonus pelamis	Skipjack tuna	Other tunas	15	6.498	80	1	22.9	431
Carcharhinus limbatus	Blacktip shark	Blacktip shark	06	2.000	150	1	22.4	422
Caranx lugubris	Black jack	Pelagic cstl. piscivores	18	6.261	70	1	20.8	391
Thunnus atlanticus	Blackfin tuna	Other tunas	15	5.808	72	1	20.6	388
Seriola rivoliana	Almaco jack	Pelagic cstl. piscivores	18	3.744	90	1	20.3	382
Scomberomorus cavalla	King mackerel	King mackerel	21,22	5.815	70	1	20.3	381
Seriola dumerili	Amberjack, greater	Amberjack	19	2.832	100	1	19.7	370
Euthynnus alletteratus	Little tunny	Pelagic cstl. piscivores	18	4.184	80	1	19.7	369
Trachinotus falcatus	Permit	Dmrsl. cstl. invert. fdrs.	47	2.870	94	1	19.0	358
Auxis thazard	Frigate mackerel	Pelagic cstl. piscivores	18	5.799	60	1	18.4	346
Coryphaena hippurus	Common dolphinfish	Pelagic cstl. piscivores	18	2.235	100	1	18.1	341
Caranx hippos	Crevalle jack	Pelagic cstl. piscivores	18	3.413	75	1	17.6	331
Sarda sarda	Atlantic bonito	Pelagic cstl. piscivores	18	5.758	50	1	16.4	309
Carcharhinus porosus	Smalltail shark	Small cstl. sharks	12	2.014	90	1	16.4	308
Caranx latus	Hose-eye jack	Pelagic cstl. piscivores	18	3.534	60	1	15.5	291
Caranx ruber	Bar jack	Pelagic cstl. piscivores	18	4.228	50	1	14.7	277
Sphyrna tiburo	Shark, bonnethead	Small cstl. sharks	12	1.774	80	1	14.6	274
Rachycentron canadum	Cobia	Cobia	20	0.987	110	1	14.5	272

GitHub: SEFSC/IEA-GWEM-DataSynth/Ecospace-dispersal-rates

Data inputs // Dispersal rates

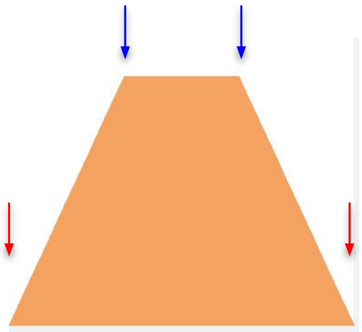


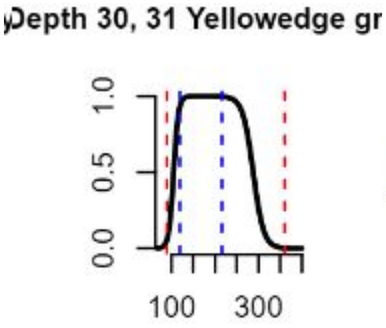
Results consistent with "300-30-3 rule" for assigning dispersal rates to relatively fast-moving, slow-moving, and sedentary species, respectively (e.g., Zeller and Reinert, 2004, Chen et al., 2009, Piroddi et al., 2011, Fouzai et al., 2012)

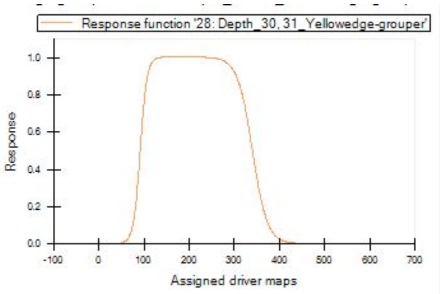
Data Inputs // Preference Functions

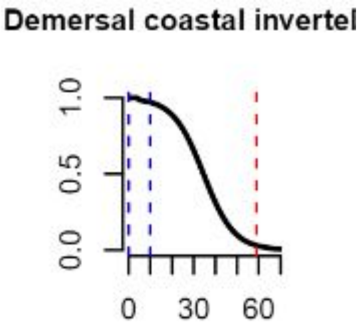
Step 1: Query environmental preferences from FishBase R (code here)
Step 2: Aggregate by species and functional group (table)
Step 3: Review and adjust based on expert opinion (table)
Step 4: Make double logistic function (code)

Four Parameters: minimum, preferred minimum (10th %ile), preferred maximum (90th %ile), maximum
Three environmental drivers: depth (static), temperature (monthly), salinity (monthly)



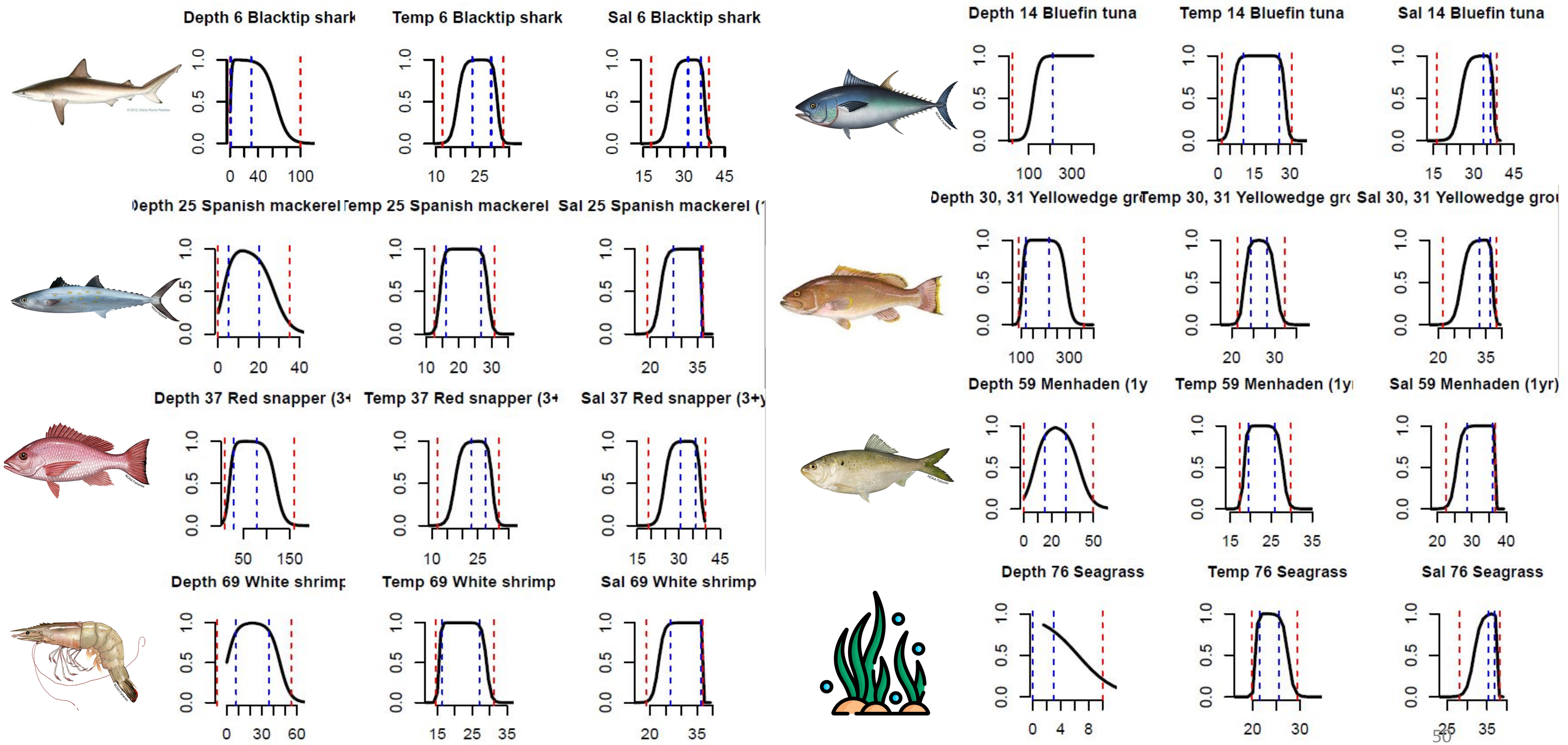




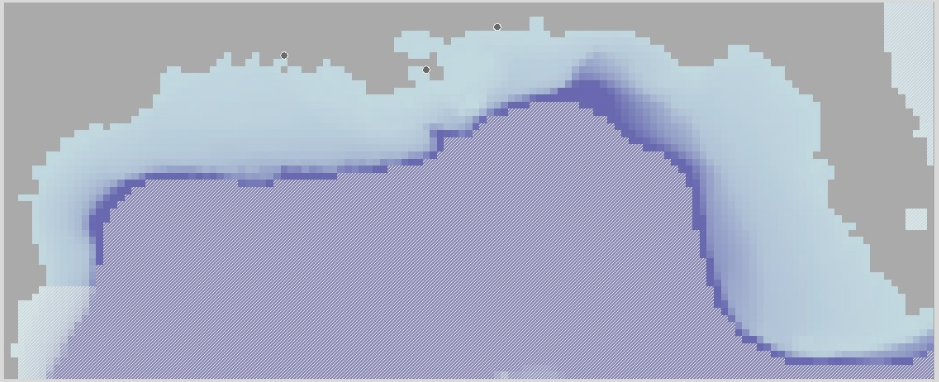


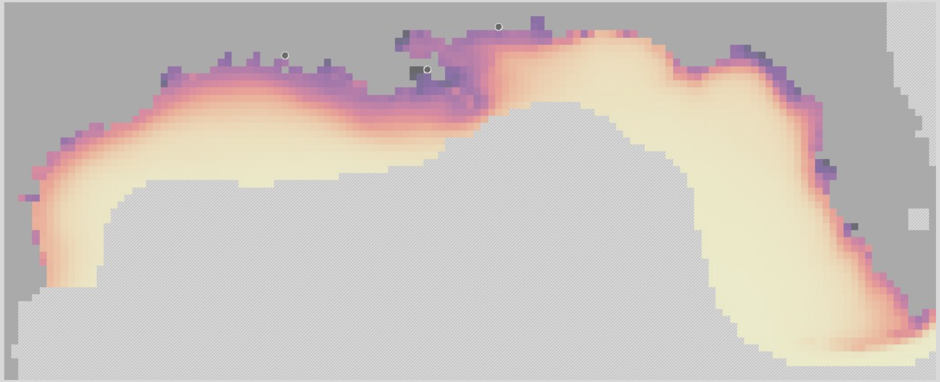
GitHub: SEFSC/IEA-GWEM-DataSynth/Ecospace-preference-functions

Data Inputs // Preference Functions // A few examples

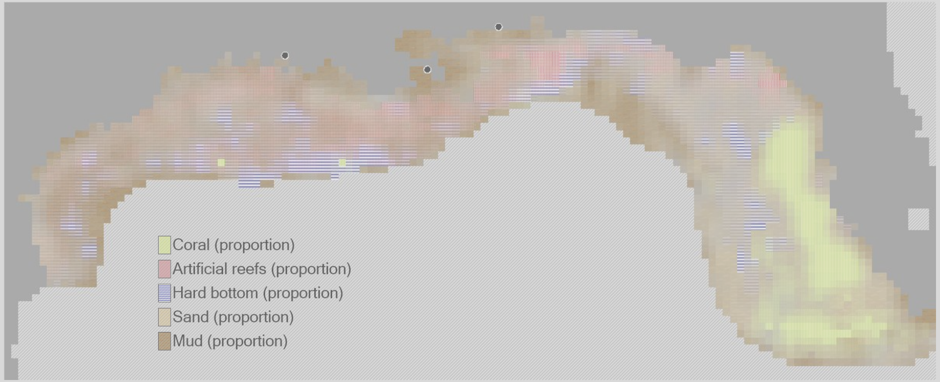


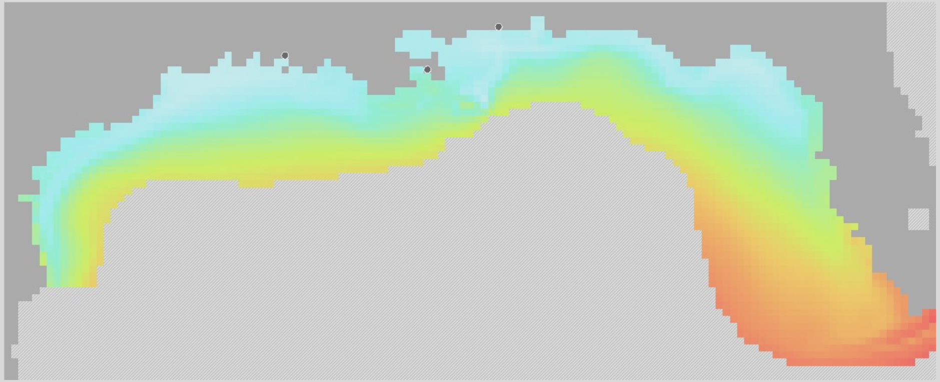
[PDF with all preference functions](#) | GitHub: [SEFSC/IEA-GWEM-DataSynth/Ecospace-preference-functions](#)





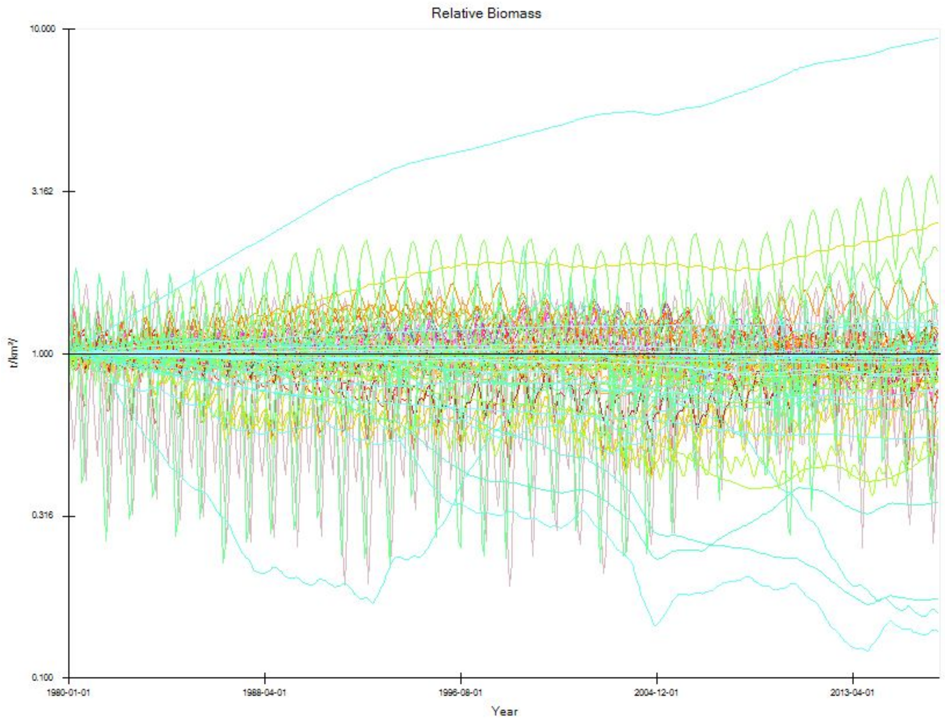
USGWEM Ecospace // Next Steps

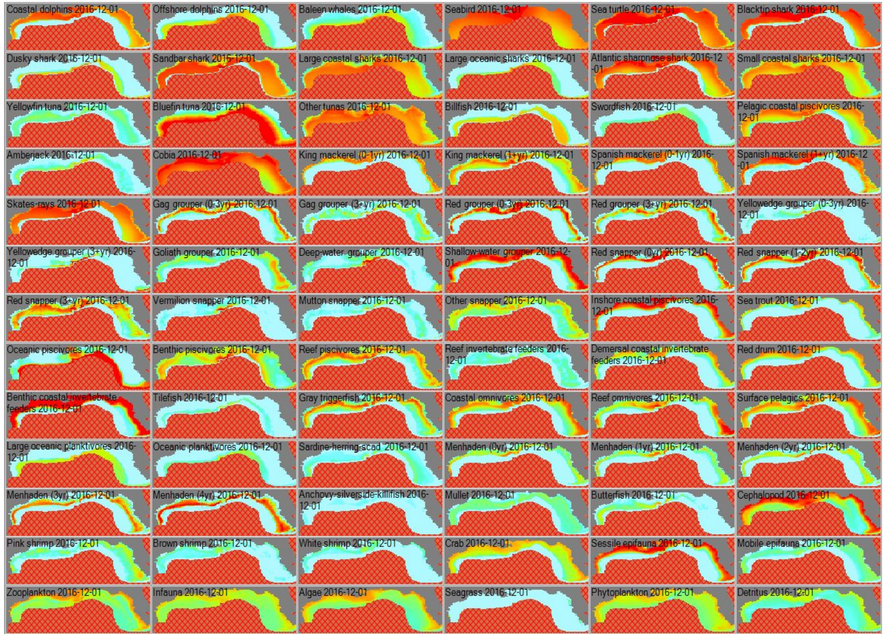




Contact: holden.harris@noaa.gov | GitHub: SEFSC/IEA/GWEM/DataSynth

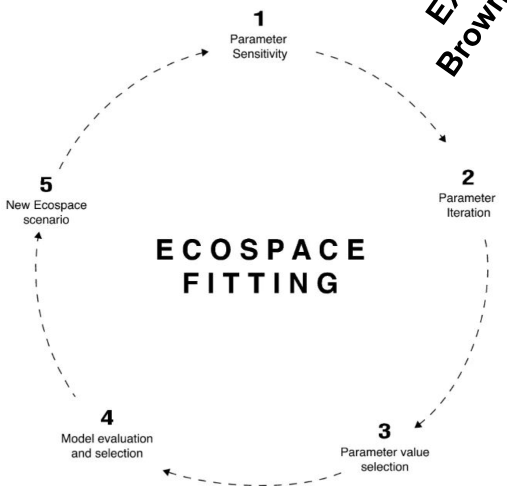
USGWEM Ecospace // 10,000 foot view



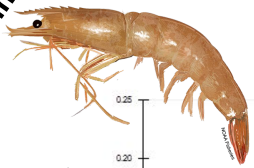


Next steps // Calibration and fitting

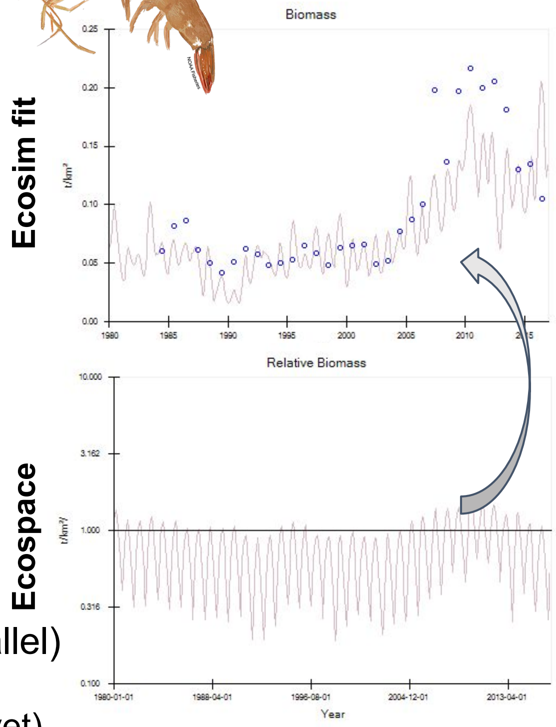
Schematic: [Vilas et al. 2023]



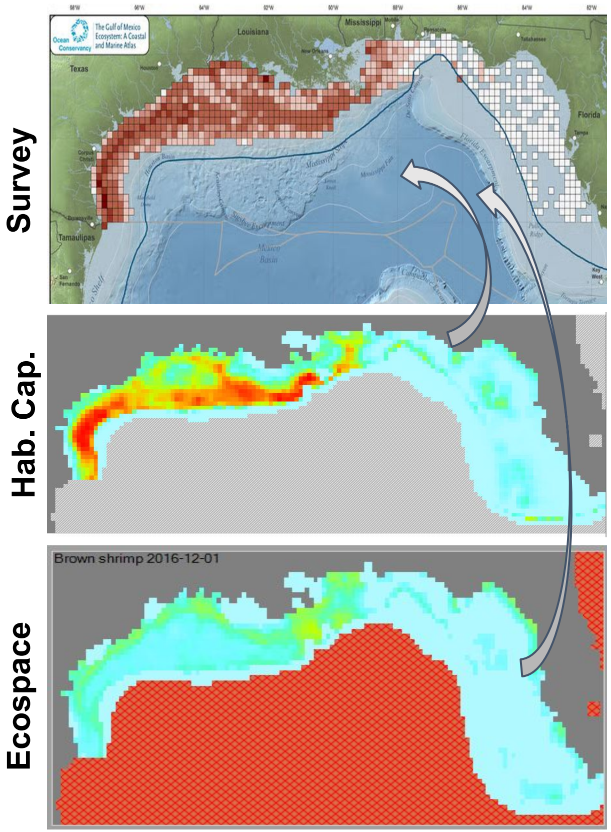
Example: Brown shrimp



Fit to **time…**



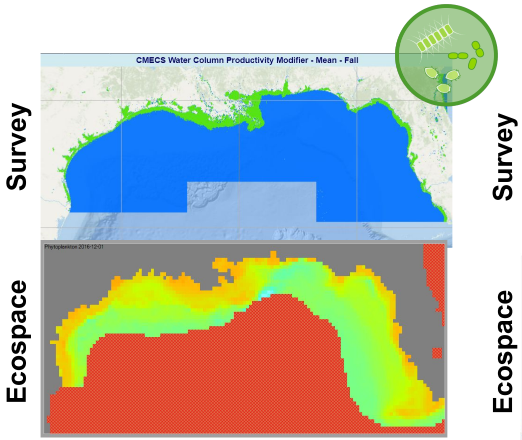
…and **space…?**

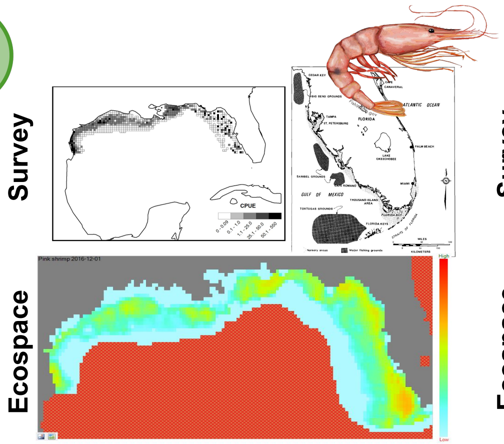


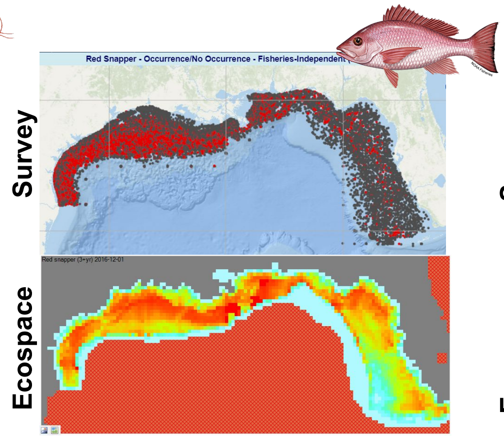
Calibration via iterative parameter adjustments (simulations run in parallel)

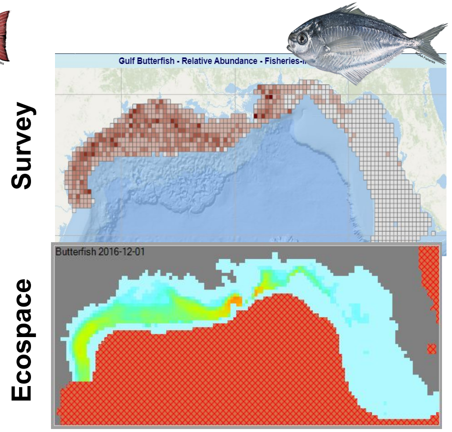
- Ecosim times series (done)
- Empirical time series (not done yet)
- Spatial surveys (not done yet)

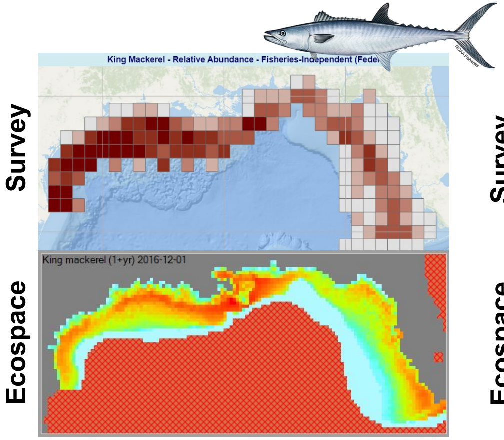
Next steps // Validation, calibration, and fitting

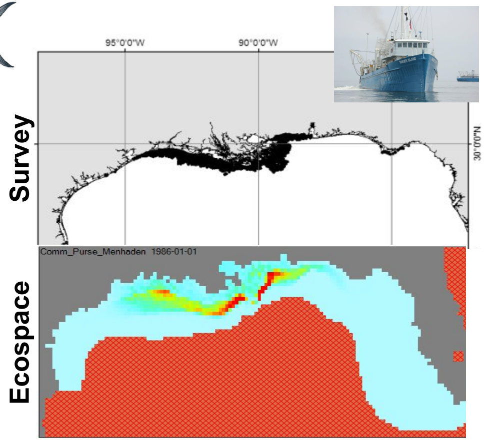








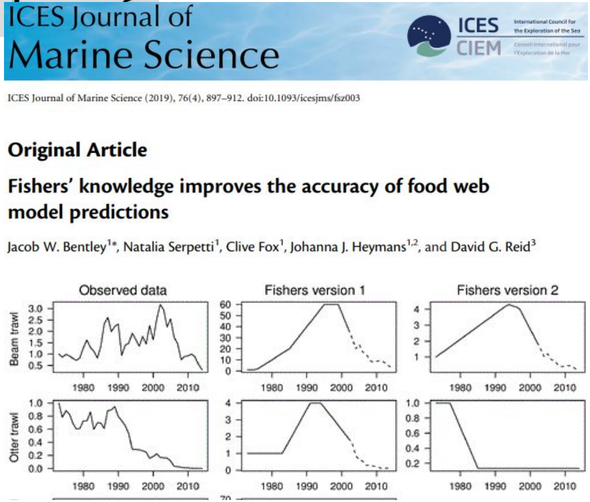




Data sources for validation, calibration, and fitting:

- NOAA NCEI GoM Data Atlas
- MODIS (e.g., CMEC PP)
- SEAMAP surveys (e.g., reef fish, long lines; https://www.gsmfc.org/seamap-gomrs.php)
- Literature (e.g., Pink shrimp Drexler & Ainsworth 2013, Pelagic longline Baum et al. 2003)
- SEDAR (https://sedarweb.org/)

Next steps // Incorporate expert and stakeholder knowledge


ICES Journal of Marine Science

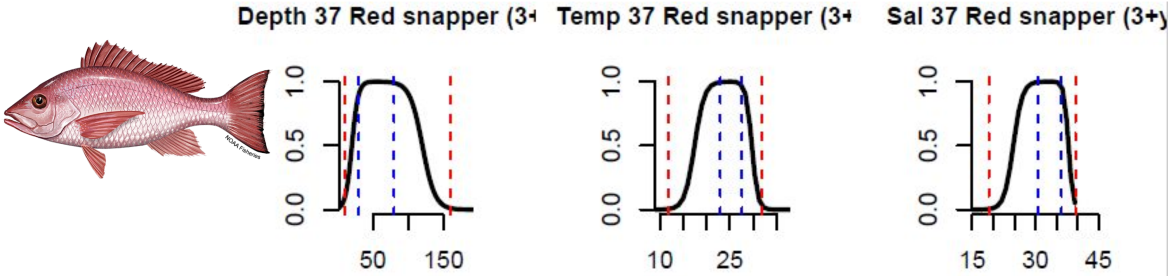
ICES CIEM

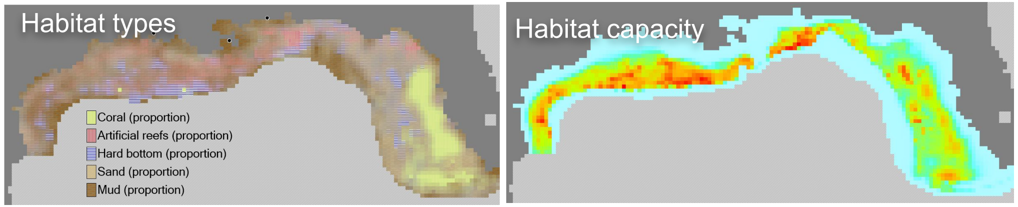
ICES Journal of Marine Science (2019), 76(4), 897–912. doi:10.1093/icesjms/fsz003

Original Article

Fishers' knowledge improves the accuracy of food web model predictions

Jacob W. Bentley[1]*, Natalia Serpetti[1], Clive Fox[1], Johanna J. Heymans[1,2], and David G. Reid[3]

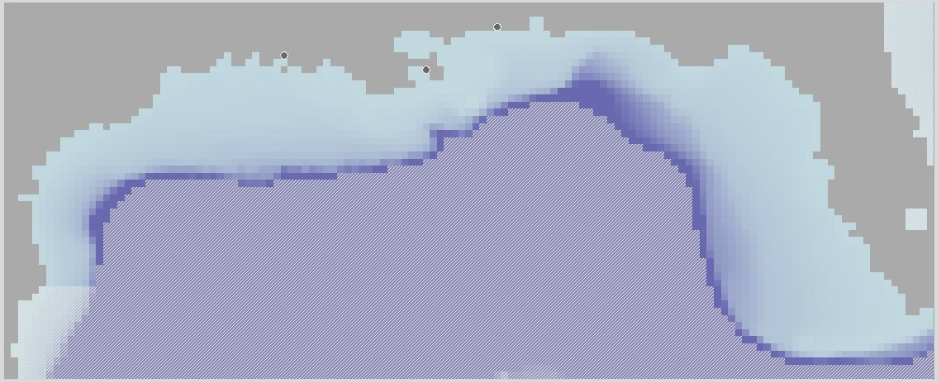


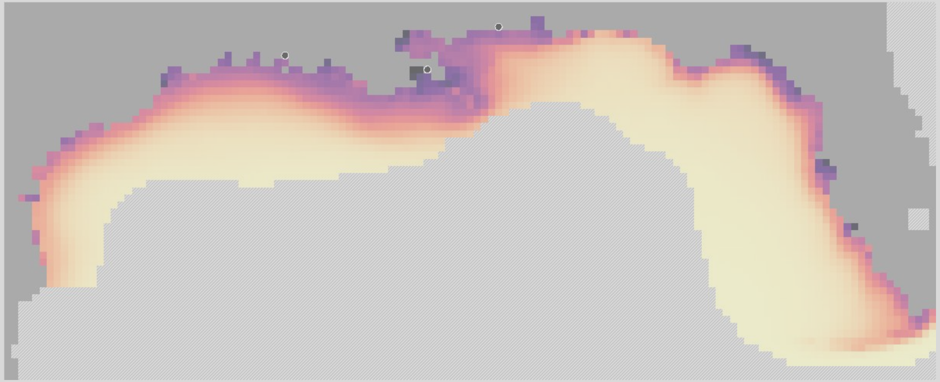


Incorporate scientific and fisher qualitative knowledge to…

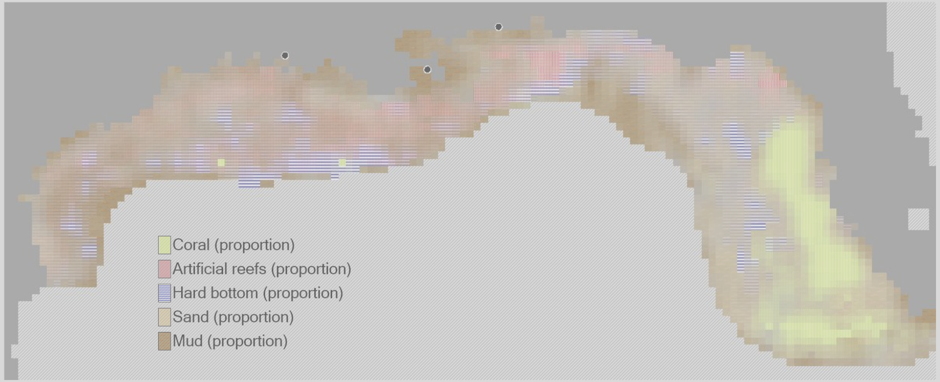
- Review and validate results & trends
- Update parameters for preference functions
  - Depth, temperature, salinity
  - Habitat use, spatial validation

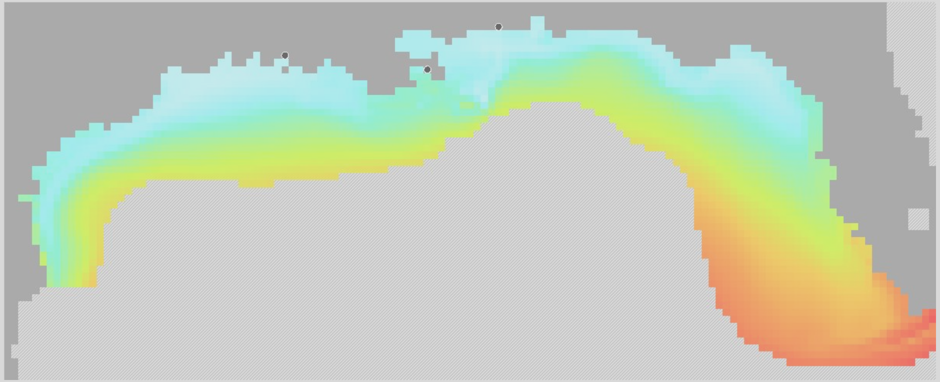
Harris 2022; Bentley et al. 2019a; Bentley et al. 2019b





USGWEM // Direction & Operationalization





Contact: holden.harris@noaa.gov | GitHub: SEFSC/IEA/GWEM/DataSynth

The Way to Operationalization

ORIGINAL ARTICLE | Full Access

It is past time to use ecosystem models tactically to support ecosystem-based fisheries management: Case studies using Ecopath with Ecosim in an operational management context

J. Kevin Craig, Jason S. Link

First published: 27 February 2023 | https://doi.org/10.1111/faf.12733

"The requisite conditions for enhanced operational use of EwE to support and inform resource management decisions exists, and these models can contribute to both strategic and tactical management decisions."

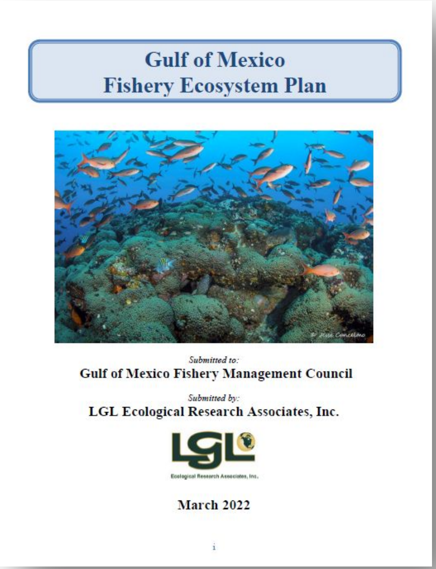
Criteria to operationalize EwE:

1. Well-defined **objective(s)** for managing fisheries ecosystem issues
2. Clear **trade-offs**
3. A **mgmt process** that can respond to these trade-offs
4. Model(s):
   a. That are accessible, well-documented, and follow best practices
   b. Ideally, multiple models to assess structural uncertainties
5. Coproduction:
   a. Early engagement from scientists, stakeholders, and managers (here we are!)
   b. Collaborative, iterative model development
6. A rigorous **review** process

Craig & Link 2023; GoM Fisheries Ecosystem Plan

Operationalization // Fisheries Ecosystem Plans

"FEPs require models of the ecosystem for stakeholders and managers to visualize and make predictions about how fishery ecosystems function . . . Perhaps the most effective use of Mathematical Ecosystem Models is within a hypothesis-testing framework" (pg. 29, GoM Fisheries Ecosystem Plan)



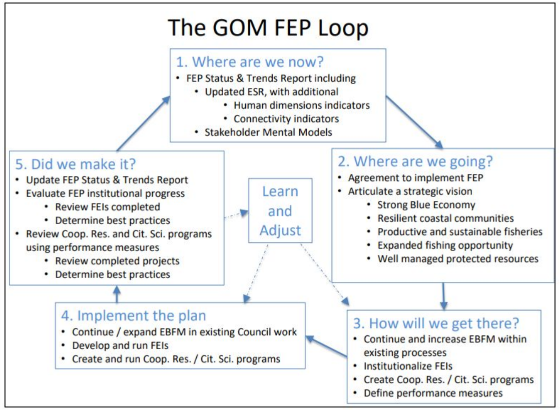
Gulf of Mexico
Fishery Ecosystem Plan

Submitted to:
Gulf of Mexico Fishery Management Council

Submitted by:
LGL Ecological Research Associates, Inc.

March 2022

i



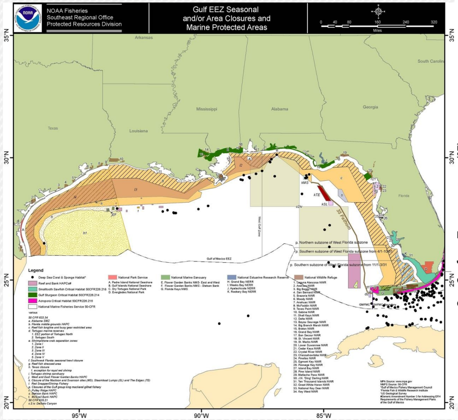
The GOM FEP Loop

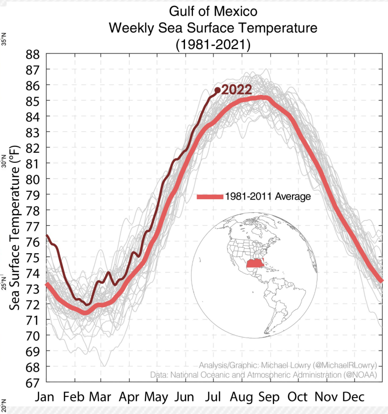
1. Where are we now?
2. Where are we going?
3. How do we get there?
4. Implement the plan
5. Did we make it?
   (Again, where are we now?)
   Learn & adjust

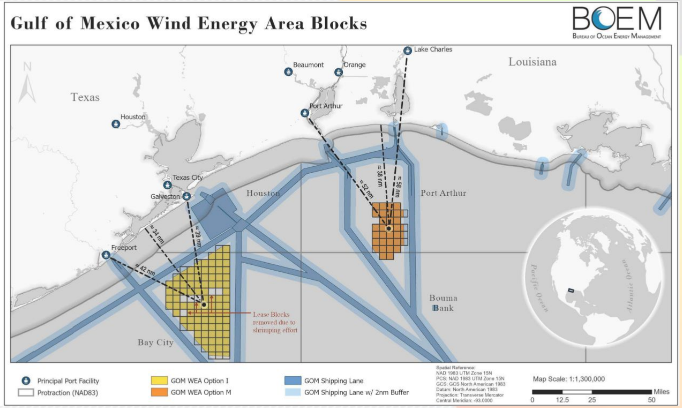
Assess trade-offs
Simulate mgmt actions
Inform MSE

Potential research directions // Fisheries Ecosystem Issues

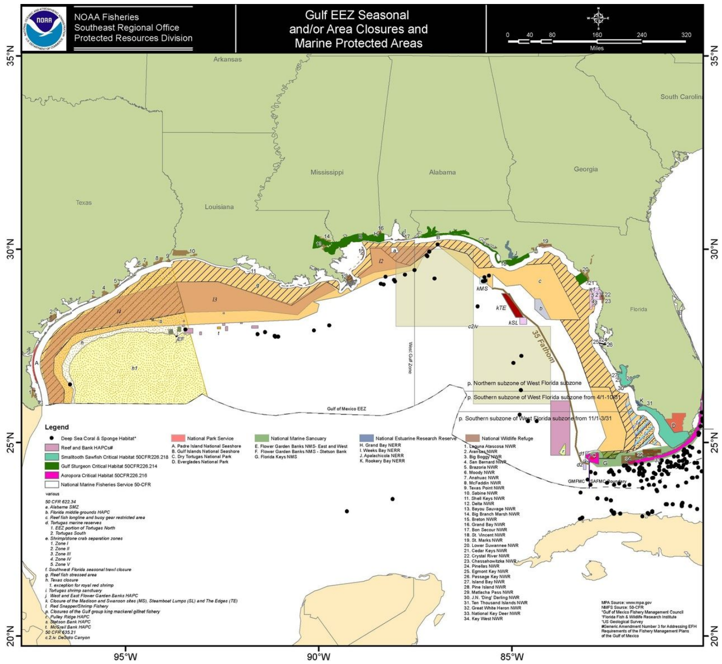
1. Spatial-temporal fishery closures and bycatch reduction
2. Climate change and environmental stressors
3. Changing artificial habitat: oil and gas (O&G) decommissioning & offshore wind farm (OWF) development



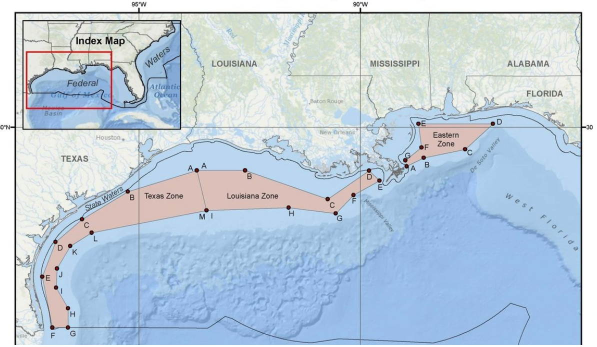




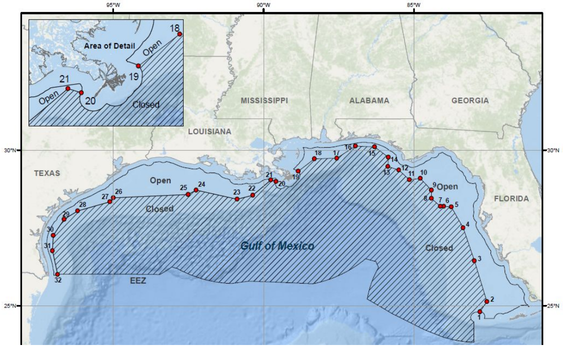
Potential research directions // Spatial-temporal fishery closures & bycatch reduction



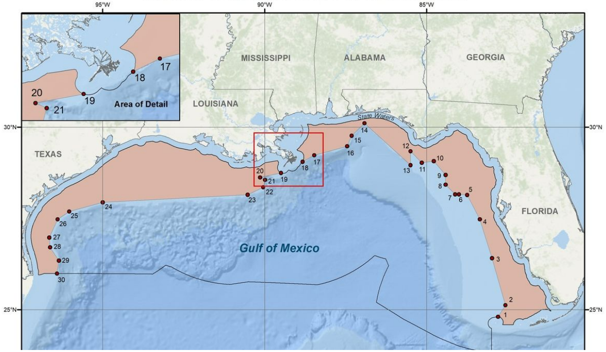
Closures of Gulf Shrimp Fishery to Reduce Bycatch



Seasonal closure (Feb 1 - Mar 31) of the recreational sector for shallow-water grouper (SWG)



Reef Fish Longline and Buoy Gear Restricted Area

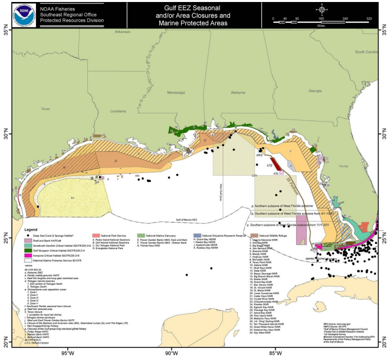


Fisheries ecosystem issue (EAF) Multi-species, overlapping fisheries with bycatch and discard mortality

Map from fisheries.noaa.gov

Strengths

Potential research directions // Spatial-temporal fishery closures & bycatch reduction



Key trade-offs

- ↑Reef fish discard mortality *vs.* recreational fishing effort
- Temporal fishing access *vs.* out-of-season catches and high-grading
- Commercial net fishing (e.g., by Menhaden purse seine and shrimp trawls) *vs.* potential future yield of bycatch of juvenile finfishes

Potential decision support from the USGWEM

- ID times and places where bycatch interactions should be monitored or limited
- Setting opening/closing dates for fisheries
- Optimize time and place for annual spawning season closures

Strengths

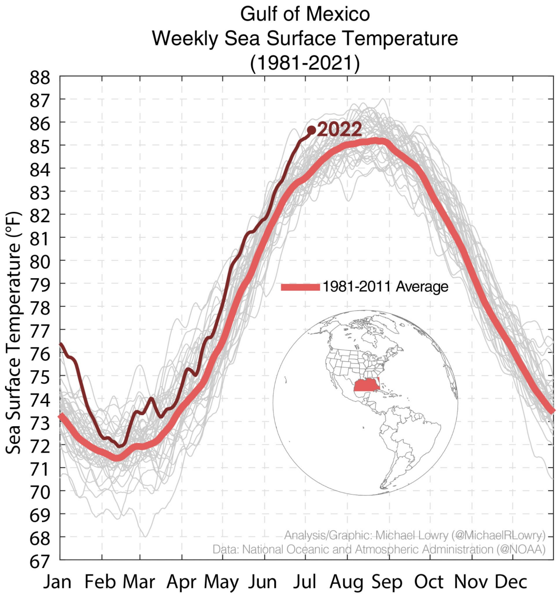
- ST management a traditionally capacity of Ecospace and could inform mgmt decisions

Weaknesses/Caveats

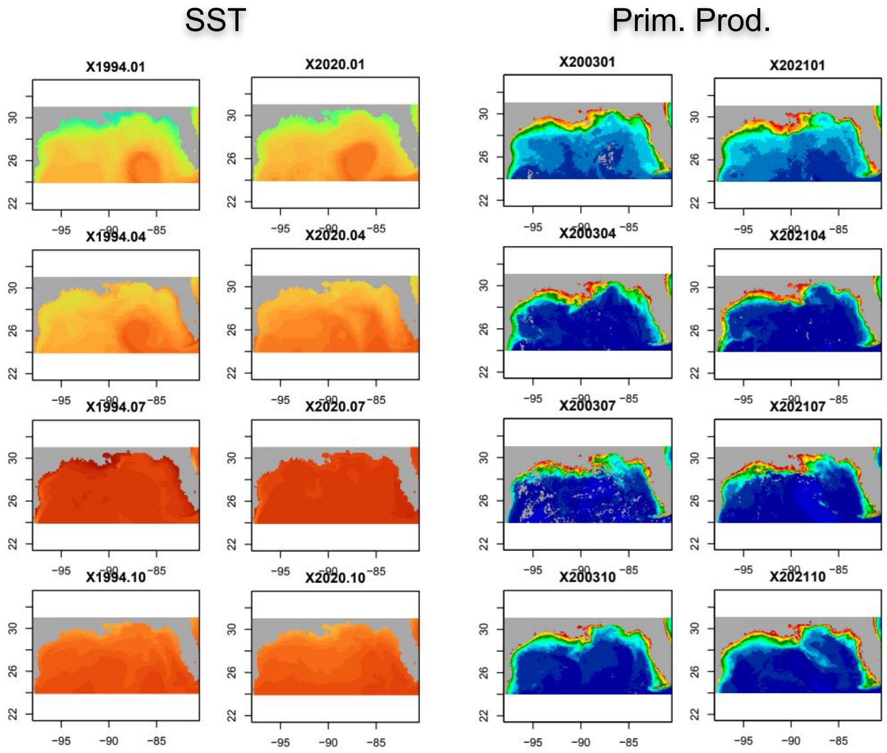
- Gulf-wide scale model may be too large/complex for some applications
- Model of finer scale or lower complexity may be appropriate for specific deliverables, e.g., MICE model for Atlantic Menhaden generated inputs for SEDAR (Chagaris et al. 2020, Drew et al. 2021)

Potential research directions // Climate change & environmental stressors

Fisheries ecosystem issue (EBFM)
Wide-ranging and potentially compounding environmental stressors from climate change



Example USGWEM environmental driver maps:



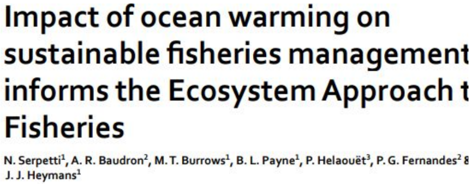
Potential research directions // Climate change & environmental stressors

Key trade-offs

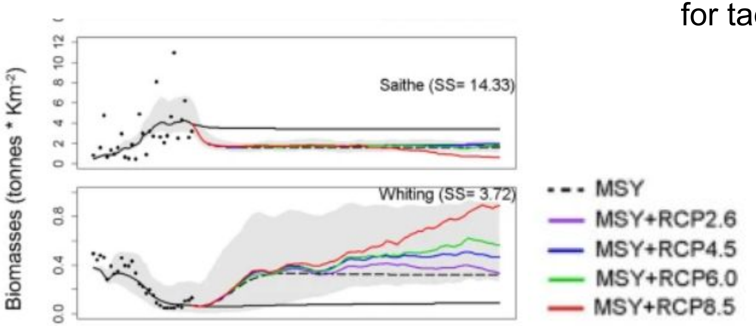
- ↓Current yield *vs.* long-term precautionary management
- US agriculture production *vs.* Miss. Rvr. nutrification
- Winners *vs.* losers from rising temperatures and changing environment

Possible EBFM/EBM decision support from the USGWEM

- Forecast winners & losers, e.g., Serpetti et al. 2017 → support precautionary management of impacted species
- Anticipate long-term responses to changing environment (e.g., warmer waters, changing Miss. Rvr. discharge)
- Model “tropicalization” food-web impacts from poleward range expansions of tropical species (e.g., mangroves, snook)


Impact of ocean warming on sustainable fisheries management informs the Ecosystem Approach t Fisheries

N. Serpetti[1], A. R. Baudron[2], M. T. Burrows[1], B. L. Payne[1], P. Helaouët[3], P. G. Fernandes[2] & J. J. Heymans[1]



Strengths

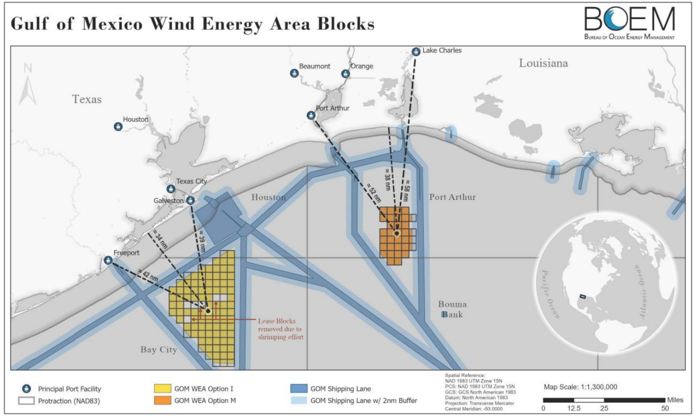
- Gulf-wide spatial scale could consider climate change impacts
- Support for and from NOAA Climate, Ecosystems, and Fisheries Initiative

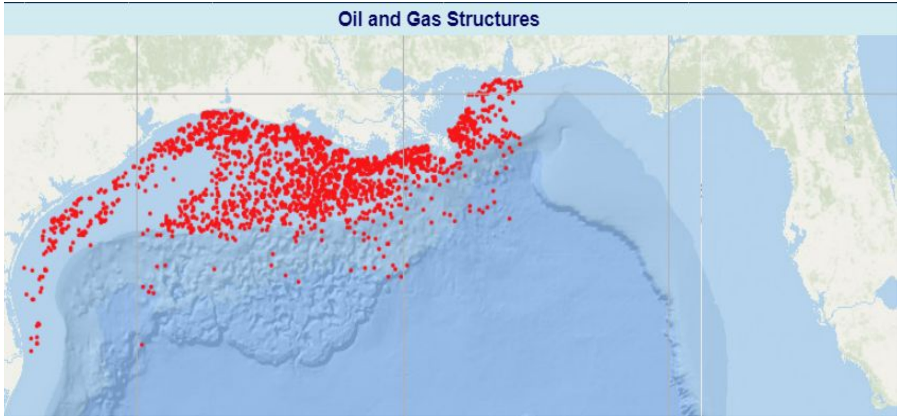
Weaknesses/caveats

- Advice will be long-term and strategic
- Unclear how model results might be used for tactical decision making

Potential research directions // Changing artificial habitat (OWF + O&G)

Fisheries ecosystem issue (EBM)
Cross-sector management of fisheries, protected species, and habitat management facing forthcoming changes in O&G decommissioning and OWF infrastructure development





Literature // Recent EwE applications for OWF development

Contents lists available at ScienceDirect
Marine Policy
journal homepage: www.elsevier.com/locate/marpol

Trade-offs between fisheries, offshore wind farms and marine protected areas in the southern North Sea – Winners, losers and effective spatial management

Miriam Püts[a,*], Alexander Kempf[a], Christian Möllmann[b], Marc Taylor[a]
[a] Thünen Institute of Sea Fisheries, Herwigstraße 31, 27572 Bremerhaven, Germany
[b] Institute of Marine Ecosystems and Fishery Science, Center for Earth System Research and Sustainability (CEN), Große Elbstraße 133, 22767 Hamburg, Germany

Contents lists available at ScienceDirect
Ecological Modelling
journal homepage: www.elsevier.com/locate/ecolmodel

Spatial ecosystem modelling of marine renewable energy installations: Gauging the utility of Ecospace

Karen A. Alexander[a,*], Sophie A. Meyjes[b], Johanna J. Heymans[a]
[a] Scottish Association for Marine Science, Scottish Marine Institute, Oban, Argyll PA37 1QA, United Kingdom
[b] University of St Andrews, North St, St Andrews, Fife KY16 9AJ, United Kingdom

ICES Journal of Marine Science
ICES CIEM

ICES Journal of Marine Science (2020), 77(3), 1238–1246. doi:10.1093/icesjms/fsy125

Contribution to the Themed Section: *'Decommissioned offshore man-made installations'*
Original Article

An ecosystem approach for studying the impact of offshore wind farms: a French case study

Jean-Philippe Pezy[1*], Aurore Raoux[1], and Jean-Claude Dauvin[1]

Estuarine, Coastal and Shelf Science
Volume 237, 31 May 2020, 106690

Isotopic analyses, a good tool to validate models in the context of Marine Renewable Energy development and cumulative impacts

Aurore Raoux[a b], Jean-Philippe Pezy[b], Bruno Ernande[c], Nathalie Niquil[a], Jean-Claude Dauvin[b], Karine Grangeré[a]

JOURNAL ARTICLE

Spatialized ecological network analysis for ecosystem-based management: effects of climate change, marine renewable energy, and fishing on ecosystem functioning in the Bay of Seine FREE

Quentin Nogues, Emma Araignous, Pierre Bourdaud, Ghassen Halouani, Aurore Raoux, Éric Foucher, François Le Loc'h, Frédérique Loew-Turbout, Frida Ben Rais Lasram, Jean-Claude Dauvin, Nathalie Niquil

ICES Journal of Marine Science, Volume 79, Issue 4, May 2022, Pages 1098–1112,
https://doi.org/10.1093/icesjms/fsac026
Published: 24 February 2022 **Article history** ▾

Ocean & Coastal Management
Volume 171, 1 April 2019, Pages 111-118

Effects of established offshore wind farms on energy flow of coastal ecosystems: A case study of the Rudong offshore wind farms in China

Junjie Wang[a b], Xinqing Zou[b c], Wenwen Yu[b c d], Dongju Zhang[b c], Teng Wang[b c]

Ecological Indicators
Volume 114, July 2020, 106302

The environmental impact from an offshore windfarm: Challenge and evaluation methodology based on an ecosystem approach

Jean-Philippe Pezy, Aurore Raoux, Jean-Claude Dauvin

Modeling Small Scale Impacts of Multi-Purpose Platforms: An Ecosystem Approach

Natalia Serpetti[1,2*], Steven Benjamins[1], Stevie Brain[1], Maurizio Collu[3], Bethany J. Harvey[4], Johanna J. Heymans[1,5], Adam D. Hughes[1], Denise Risch[1], Sophia Rosinski[6], James J. Waggitt[7] and Ben Wilson[1]

EwE assessments for OWF:

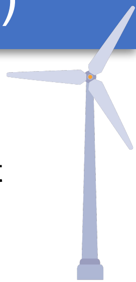
The North Sea
- Puts et al. 2023
- Serpetti et al. 2021
- Alexander et al. 2016

West Coast of France
- Jean-Philippe et al. 2020
- Halouani et al. 2020
- Raoux et al. 2020
- Pezy et al. 2020
- Nogues et al. 2022

China
- Wang et al. 2019

EwE can help assess trade-offs, e.g.,
Positive spillover effects predicted from OWF spatial closures in W. coast of France model (Halouani et al. 2020) but not W. coast of Scotland model (Alexander et al., 2016)

Potential research directions // Changing artificial habitat (OWF + O&G)



Key trade-offs
- Energy sector *vs.* fisheries sector *vs.* impacts to protected species (e.g., birds, mammals, turtles)
- Reef effect: ↑production *vs.* ↑catchability from aggregation; also habitat for invasive lionfish
- Exclusion effect: ↑fisheries spillover *vs.* ↓fishing access
- Hydrologic and primary production: hypoxia *vs.* up/downwelling and mixing (Daewal et al. 2022)

Possible EBM decision support from the USGWEM
- Consider designs of reef structures (e.g., scour aprons as reef structures)
- Inform experimental design and monitoring programs for artificial habitat
- Ultimately, help inform O&G decommissioning plans (e.g., “rigs to reefs”) and spatial management OWF

NCEAS proposal in review: Ecosystem impacts of GoM wind energy development on fish and fisheries (Harris, Sagarese, Chagaris, Klajbor)

Strengths
- Ecosystem modeling can inform management and research design *before* wide-scale OWF construction and O&G decommissioning
- Stakeholder & management interest

Weaknesses/Caveats
- No precedent for EwE in ecosystem impact assessments
- USGWEM spatial scale may be too large to assess artificial habitat in specific areas (e.g., OWF development in W. Gulf)

USGWEM // Ultimate Goals

An **operational model** that supports decision making
- EAF (e.g., spatial-temporal closures)
- EBFM (e.g., climate stressors in fisheries management), or
- EBM (e.g., artificial habitat effects from marine energy infrastructure)

A **co-produced model** that's valuable for management
- Early and iterative direction and input
- Leverage collaboration with stakeholders for validation and guidance

A **robust model** that withstands rigorous review, e.g.,
- ERPs for Atlantic Menhaden (Anstead et al. 2021, Chagaris et al. 2020, Drew et al. 2021)
- NEFSC Groundfish Assessment and Review Meeting
- CIE review for California Current Atlantis model (Kaplan & Marshall, 2016)

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Further info

Sagarese et al. (2016)
NOAA technical memorandum
Berenshtein et al. (2023)
SEFSC/IEA/GWEM/DataSynth

RESTORE SCIENCE PROGRAM

Southeast Fisheries Science Center