NWACS-FULL Overview

Andre Buchheister

SEDAR 102

ASMFC Atlantic Menhaden and Ecological Reference Points Review Workshop

August 12-15, 2025

Charleston, SC

NWACS Full – Background

- Model history
  - Builds upon previous EMAX modeling study in the region (Link 2006, 2008)
  - Paper & technical report published in 2017 by Buchheister et al. (data: 1982-2013)
  - Data for ERP spp. updated (1982-2017) for last assessment (SEDAR 2020)
- Main goal
  - Explore broader impacts of menhaden fishing on the ecosystem (e.g., other fishes, birds, marine mammals)

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 9:457–478, 2017
Published with license by the American Fisheries Society
ISSN: 1942-5120 online
DOI: https://doi.org/10.1080/19425120.2017.1360420

ARTICLE

Evaluating Ecosystem-Based Reference Points for Atlantic Menhaden

Andre Buchheister*
Department of Fisheries Biology, Humboldt State University, 1 Harpst Street, Arcata, California 95521, USA

Thomas J. Miller and Edward D. Houde
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Post Office Box 38, Solomons, Maryland 20688, USA

TECHNICAL DOCUMENTATION OF THE NORTHWEST ATLANTIC CONTINENTAL SHELF (NWACS) ECOSYSTEM MODEL

Andre Buchheister[1],
Thomas J. Miller,
Edward D. Houde,
David A. Loewensteiner[2]

Chesapeake Biological Laboratory
University of Maryland Center for Environmental Science
P.O. Box 38,
Solomons, MD 20688
USA

April 1, 2017

SEDAR 69

Ecological Reference Points Stock Assessment Report

Atlantic Menhaden

January 2020

SEDAR
4055 Faber Place Drive, Suite 201 North Charleston, SC 29405

Main changes from 2020 ERP Assessment

1. **Data updated to 2023.** Biomass, catch, fishing mortality, and fishing effort time series updated using recent stock assessment and fishery dependent and independent survey data
2. **Diet composition matrix updated.** Used a more synthetic analytical approach with updated data
3. **Multistanza groups for key ERP trophic groups updated.** Now matching the NWACS-MICE model
4. **Two changes to groups**: Osprey were added as a group & bluefin tuna used as the representative species for the large pelagic highly migratory species (HMS) group
5. **Additional time series or key parameters developed for several trophic groups:** anchovies, five zooplankton groups, osprey, baleen whales, odontocetes, and HMS
6. **Primary production forcing function** was developed and evaluated.

NWACS Full – Spatial Domain

- Continental shelf from NC to Nova Scotia, Canada
- Primary Data Locations
  - Mid-Atlantic Bight, Southern New England, Georges Bank, and Gulf of Maine subregions
  - Estuaries, including Chesapeake Bay, Delaware Bay, Pamlico Sound, and Long Island Sound
- Total area 441,000 km^2
  - increased from 246,662 km^2 to match MICE model & facilitate future development of spatial model

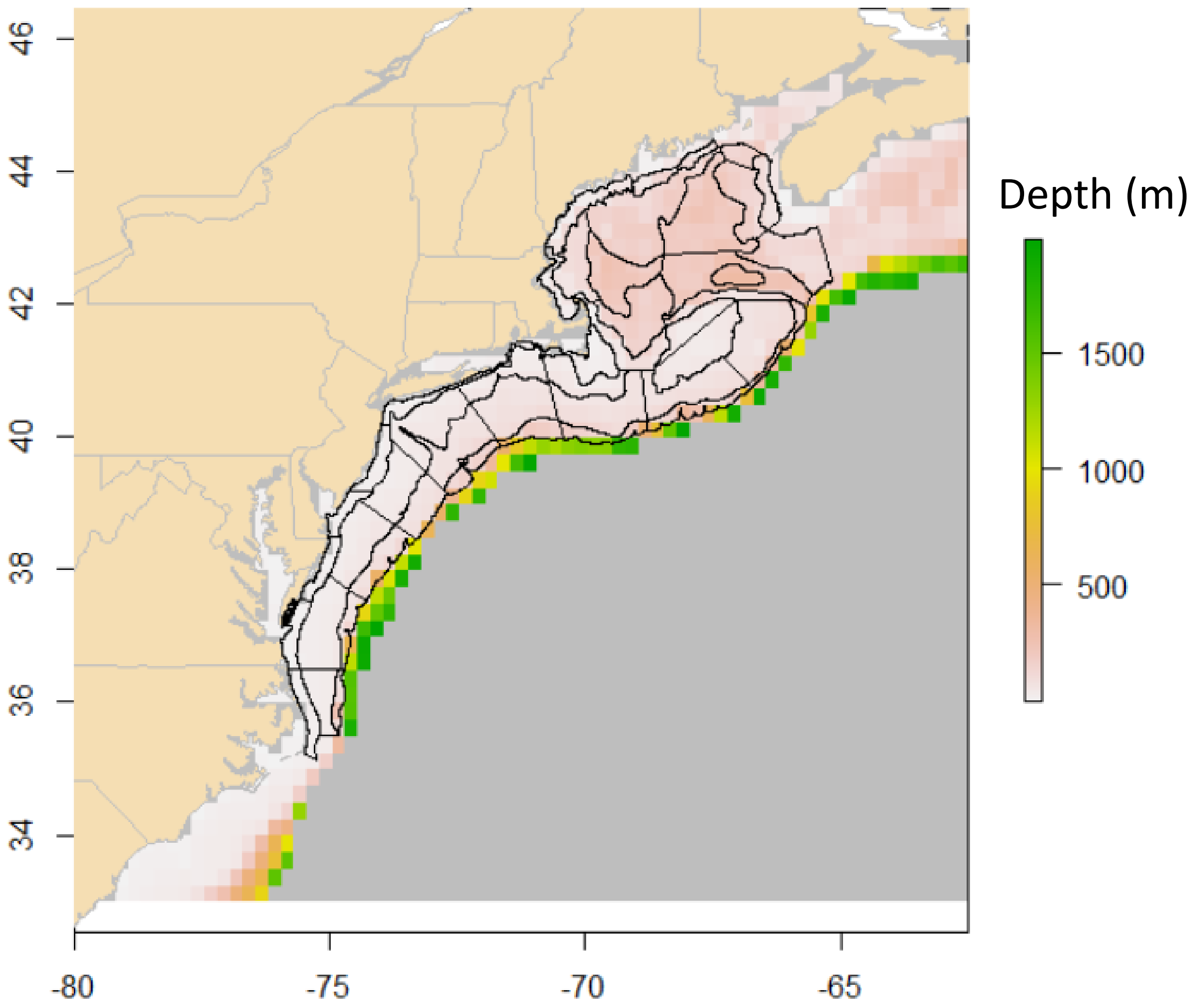


Figure 46. Spatial extent of the Northwest Atlantic Continental Shelf (NWACS) Full Ecosystem model (colored raster), extending from just south of North Carolina, USA to Nova Scotia, Canada. Black lines represent the survey strata for the NEFSC bottom trawl fisheries survey and the general spatial extent of the previous NWACS-FULL ecosystem. Color scale represents depth in meters.

NWACS Full - Trophic Structure

- 59 groups total
    - 2 PP, detritus, bacteria
    - 5 zooplankton
    - 7 Benthic invertebrates
    - 9 forage fish (menhaden & herring with 2 age stanzas)
    - 15 other fish (6 with age structure)
    - 9 apex predators
- Emphasis on menhaden, their predators, and alternative prey
- Some similarities with EMAX models (Link 2006, 2008)
- 8 fishing fleets – defined based on landings by gear from NOAA Fisheries

Category	Node	GroupName	ParentCode	Code	Age (yr)	Length (cm)	Biomass time-series	Catch time-series
Primary producers	1	Phytoplankton	PHYT	PHYT.1	--	--		
Primary producers	2	Other primary producers	OPP	OPP.1	--	--		
Bacteria	3	Bacteria	BACT	BACT.1	--	--		
Zooplankton	4	Microzooplankton	MICZOO	MICZOO.1	--	--	INDEX	
Zooplankton	5	Small copepods	COPS	COPS.1	--	--	INDEX	
Zooplankton	6	Large copepods	COPL	COPL.1	--	--	INDEX	
Zooplankton	7	Gelatinous zooplankton	GELZOO	GELZOO.1	--	--	INDEX	
Zooplankton	8	Micronekton	MINEK	MINEK.1	--	--	INDEX	
Benthic Inverts	9	Macrobenthos - polychaetes	MACPOLY	MACPOLY.1	--	--		
Benthic Inverts	10	Macrobenthos - crustaceans	MACCRUS	MACCRUS.1	--	--		NOAA
Benthic Inverts	11	Macrobenthos - molluscs	MACMOLL	MACMOLL.1	--	--		NOAA
Benthic Inverts	12	Macrobenthos - other	MACOTH	MACOTH.1	--	--		
Benthic Inverts	13	Megabenthos - filterers	MEGFILT	MEGFILT.1	--	--		NOAA
Benthic Inverts	14	Megabenthos - other	MEGOTH	MEGOTH.1	--	--		NOAA
Benthic Inverts	15	Shrimp and Similar Species	SHRIMP	SHRIMP.1	--	--		NOAA
Forage fishes	16	Mesopelagics	MESOPEL	MESOPEL.1	--	--		
Forage fishes	17	Atlantic herring (S)	AHERR	AHERR.1	0-1	<=13.5	SAR	SAR
Forage fishes	18	Atlantic herring (L)	AHERR	AHERR.2	2+	>13.5	SAR	SAR
Forage fishes	19	Alosines	ALOS	ALOS.1	--	--	NEFSC	NOAA
Forage fishes	20	Atlantic menhaden (S)	MENH	MENH.1	0	<1.52	SAR	SAR
Forage fishes	21	Atlantic menhaden (L)	MENH	MENH.2	1+	>=1.52	SAR	SAR
Forage fishes	22	Anchovies	ANCH	ANCH.1	--	--	INDEX	
Forage fishes	23	Atlantic mackerel	AMACK	AMACK.1	--	--	SAR	SAR
Forage fishes	24	Squid	SQUID	SQUID.1	--	--	NEFSC	NOAA
Forage fishes	25	Butterfish	BTRF	BTRF.1	--	--	SAR	SAR
Forage fishes	26	Small pelagic - other	SMPEL	SMPEL.1	--	--	NEAMAP	NOAA
Fishes	27	Bluefish (S)	BLUE	BLUE.1	0	<=32.3	SAR	SAR
Fishes	28	Bluefish (L)	BLUE	BLUE.2	1+	> 32.3	SAR	SAR
Fishes	29	Striped bass (S)	STBASS	STBASS.1	0-1	<=37.3	SAR	SAR
Fishes	30	Striped bass (M)	STBASS	STBASS.2	2-4	37.4-70.8	SAR	SAR
Fishes	31	Striped bass (L)	STBASS	STBASS.3	5+	>70.8	SAR	SAR
Fishes	32	Weakfish (S)	WEAK	WEAK.1	0	<=26.2	SAR	SAR
Fishes	33	Weakfish (L)	WEAK	WEAK.2	1+	>26.2	SAR	SAR
Fishes	34	Spiny dogfish	SPDOG	SPDOG.1	--	--	SAR	SAR
Fishes	35	Atlantic cod (S)	COD	COD.1	0-1	<=20	SAR	SAR
Fishes	36	Atlantic cod (M)	COD	COD.2	2-3	20.1-50	SAR	SAR
Fishes	37	Atlantic cod (L)	COD	COD.3	4+	>50	SAR	SAR
Fishes	38	Haddock	HAD	HAD.1	--	--	SAR	SAR
Fishes	39	Hakes	HAKE	HAKE.1	--	--	SAR	NOAA
Fishes	40	Atlantic croaker	CROAK	CROAK.1	--	--	NEAMAP	NOAA
Fishes	41	Yellowtail flounder (S)	YTF	YTF.1	0	<=20	SAR	SAR
Fishes	42	Yellowtail flounder (L)	YTF	YTF.2	1+	>20	SAR	SAR
Fishes	43	Summer flounder (S)	SUMFL	SUMFL.1	0	<=25	SAR	SAR
Fishes	44	Summer flounder (L)	SUMFL	SUMFL.2	1+	>25	SAR	SAR
Fishes	45	Skates	SKATE	SKATE.1	--	--	NEFSC	NOAA
Fishes	46	Demersal benthivores - other	DBOTH	DBOTH.1	--	--	NEFSC	NOAA
Fishes	47	Demersal piscivores - other	DPOTH	DPOTH.1	--	--	NEFSC	NOAA
Fishes	48	Demersal omnivores - other	DOOTH	DOOTH.1	--	--	NEFSC	NOAA
Fishes	49	Medium pelagic - other	MEDPEL	MEDPEL.1	--	--		NOAA
Apex predators	50	Sharks - coastal	SHARKC	SHARKC.1	--	--		NOAA
Apex predators	51	Sharks - pelagic	SHARKP	SHARKP.1	--	--		NOAA
Apex predators	52	Large pelagics (HMS)	HMS	HMS.1	--	--	SAR	SAR
Apex predators	53	Pinnipeds	PINN	PINN.1	--	--		
Apex predators	54	Baleen whales	WHALEB	WHALEB.1	--	--		
Apex predators	55	Odontocetes	WHALET	WHALET.1	--	--		
Apex predators	56	Seabirds	SBIRD	SBIRD.1	--	--		
Apex predators	57	Nearshore birds - piscivorous	NSBIRD	NSBIRD.1	--	--		
Apex predators	58	Osprey	OSPREY	OSPREY.1	--	--	INDEX	
Detritus	59	Detritus	DETRITUS	DETRITUS.1	--	--		

NWACS Full – General Inputs

Parameter	Sources
Biomass (B)	stock assess., MARMAP, EMAX, NEFSC, Ecopath models
Consumption rate (Q/B)	EMAX, literature, Ecopath models
Production (P/B) or Total Mortality (Z)	Stock assess., EMAX
Biomass accumulation (BA/B)	Stock assess., NEFSC
Diet	NEFSC, NEAMAP, ChesMMAP, MSVPA, EMAX, literature
Landings	Stock assess., NOAA, MRIP
Fishing Effort	NOAA, MRIP

- Main sources:
  - Stock assessments
  - Fisheries independent surveys (NEFSC, NEAMAP)
  - EMAX & other Ecopath models
  - Literature & Reports
  - Available databases (e.g., NOAA landings, MRIP)

NWACS Full – General Inputs

- Stock assessments
  - Biomass summed across stocks & species as needed
  - Biomass-weighted averages for Z
  - R-scripts written for each species to read report file and extract data

Group	Species Name	Stock	Assess. Year	Term. Year	Model Platform
ERP	Atlantic Herring	UNIT	2024	2023	ASAP
	Atlantic Menhaden	UNIT	2024	2023	BAM*
	Bluefish	UNIT	2023	2022	WHAM
	Spiny Dogfish	UNIT	2023	2022	SS3
	Striped Bass	UNIT	2024	2023	SCA
	Weakfish	UNIT	2024	2023	ASAP
Non-ERP	Atlantic Cod	Western GOM	2024	2023	WHAM
		Eastern GOM	2024	2023	WHAM
		GB	2024	2023	WHAM
		SNE	2024	2023	WHAM
	Atlantic mackerel	UNIT	2023	2022	ASAP
	Bluefin Tuna (HMS)	Western Atlantic	2021	2020	SS3
	Butterfish	UNIT	2024	2023	WHAM
	Haddock	GB	2022	2023	WHAM
		GOM	2022	2023	ASAP
	Longfin (Loligo) squid	UNIT	2023	2022	EMP
	Hake, White	UNIT	2022	2021	ASAP
	Hake, Red	Northern GB / GOM	2023	2022	EMP
		Southern GB / MAB	2023	2022	EMP
	Summer flounder	UNIT	2023	2022	ASAP
	Yellowtail Flounder	CC / GOM	2022	2021	VPA
		SNE / MAB	2022	2021	ASAP

NWACS Full – General Inputs

- Diets
  - Used same methods described for MICE model (Masi et al. 2014)
  - Dataset represents >500k individual stomachs
  - Literature & other models used for most non-fish groups
  - Variability in data availability

Predators	ChesMMAP	MSVPA	NEAMAP	NEFSC	NJOT	RI	Total
alosines	18		6593	5844			12455
anchovies				15			15
atlantic cod 0-1			11	924			935
atlantic cod 2-3			8	8249			8257
atlantic cod 4			14	10537			10551
atlantic croaker	4844		3429	1708	93		10074
atlantic herring 0-1	2		158				160
atlantic herring 2	16		352	23491			23859
atlantic mackerel				9821			9821
atlantic menhaden 0			2	21			23
atlantic menhaden 1	3		8	184			195
bluefish 0	560	5661	3457	2859	117	22	12676
bluefish 1	29	1283	380	2633	64	211	4600
butterfish				10892			10892
demersal benthivore	97		24082		149	612	24940
demersal omnivore	41		4237		490	1125	5893
demersal piscivore	57		210				267
haddock				14854			14854
hakes				119144			119144
medium pelagics	27		1				28
skates	273		18438	75586			94297
small pelagics	76		81				157
spiny dogfish	145		2758	71431	381	15	74730
striped bass 0	2805	2460	57	14	4	12	5352
striped bass 2-5	1449	7166	169	970	47	236	10037
striped bass 6	91	2578	161	614	12	53	3509
summer flounder 0	1492		1094	1695	95	1	4377
summer flounder 1	2364		3922	20577	350	240	27453
weakfish 0	6087	535	7009	1613	291	35	15570
weakfish 1	1185	1459	1275	3864	93	161	8037
yellowtail flounder 0			2	706			708
yellowtail flounder 1			87	9816			9903
Total	21661	21142	77995	398062	2186	2723	**523769**

NWACS Full - Balancing

- Ecopath parameters were adjusted to ensure mass balance with ecotrophic efficiencies (EE) < 1
  - 19 of 59 groups were out of balance initially (EE>1)
- General comments:
  - Any data-processing errors (e.g., coding issues) were investigated and corrected.
  - EEs tended to be high for many of the youngest stanzas of the multistanza groups (a common issue). Typically solved by increasing the BA rate which increased the biomass for the younger stanza.
  - Changes to B or Z for any assessed species (especially the ERP spp.) were typically avoided, but changing B or Z of non-assessed groups would be considered.
  - BA rates and diets would be preferentially adjusted to bring groups into balance.

Summary of model fits

Models fit in 3 phases:

A. Initial fitting
  - PP forcing or not?
  - Two different starting kij values

B. Vulnerability adjustments
  - Manual tuning based on evaluations of Fmsy and stock-recruit curves (vadj)
  - Vulnerability minima (vmin)
  - Vulnerability caps (vcap)

C. Additional adjustments
  - 2 minor adjustments to improve menh dynamics

Model selection

- Best model of each phase advanced (bold)
  - Based on fits (SS), diagnostics, no. parameters on bounds, & behavior
- *Sim 2.9 selected as base run*

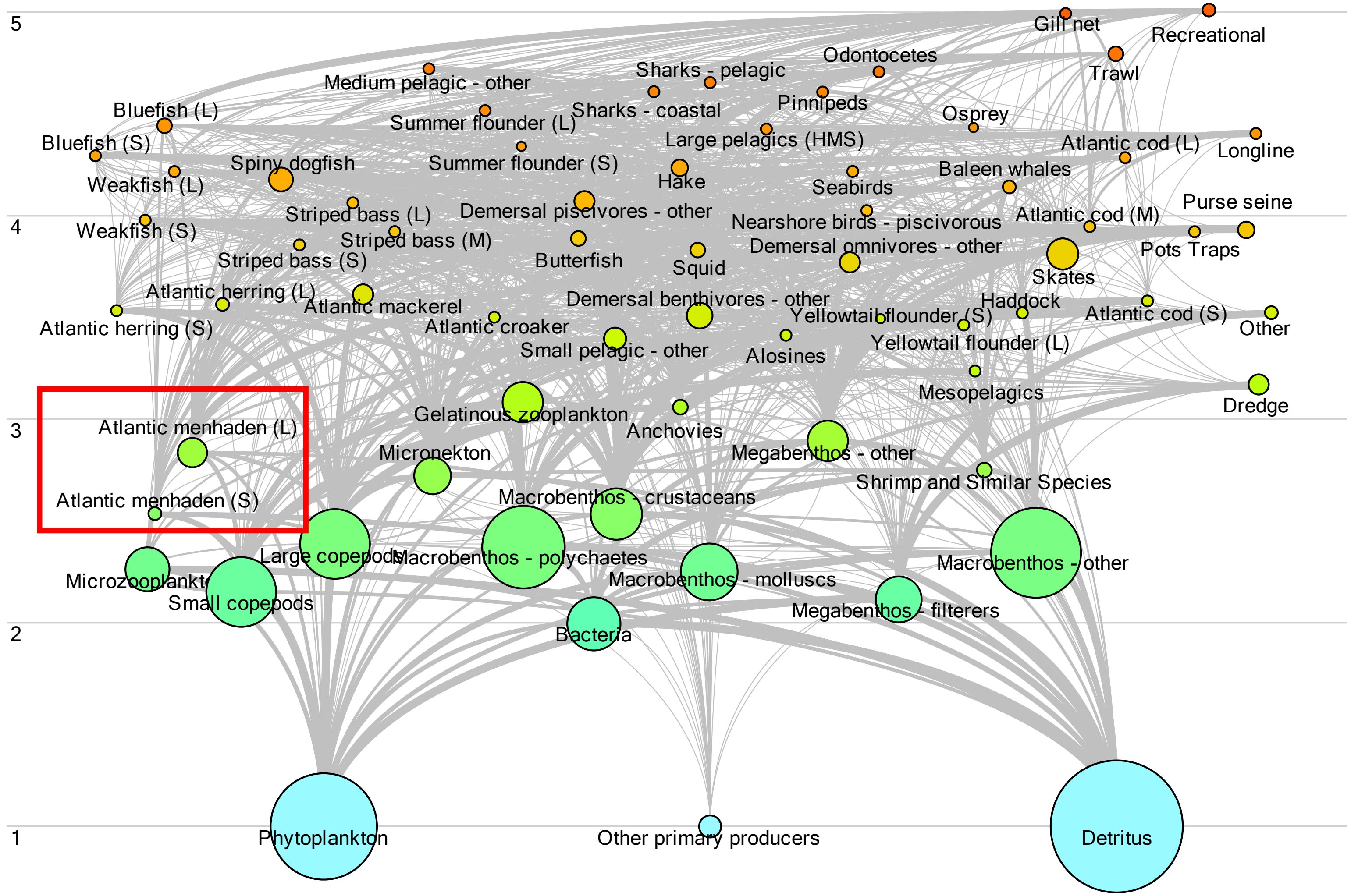
Phase	Sim	Forcing	v_{adj}	v_{min}	v_{cap}	k_{ij} start	Iter	SS	Num k_{ij} est	Est. k_{ij} / data pts	Est. k_{ij} / total k_{ij}	Num k_{ij} <1.01	Num k_{ij} >=1e9
A	1.1	none				k_{ij} =2	11	4708	239	0.08	0.22	85	32
	2.1	**none**				**B_{unf}/B_0**	**06**	**4552**	**230**	**0.08**	**0.21**	**70**	**57**
	3.1	PP				k_{ij} =2	13	4755	281	0.09	0.26	96	48
	4.1	PP				B_{unf}/B_0	15	4647	293	0.10	0.27	88	55
B	2.2	none		X		B_{unf}/B_0	--	6067	230	0.08	0.21	0	57
	2.3	none			X	B_{unf}/B_0	--	8535	229	0.07	0.21	71	0
	2.4	none		X	X	B_{unf}/B_0	--	7431	229	0.07	0.21	0	0
	2.5	**none**	**X**			**B_{unf}/B_0**	**--**	**4767**	**230**	**0.08**	**0.21**	**49**	**57**
	2.6	none	X	X		B_{unf}/B_0	--	6086	230	0.08	0.21	0	57
	2.7	none	X		X	B_{unf}/B_0	--	8819	229	0.07	0.21	50	0
	2.8	none	X	X	X	B_{unf}/B_0	--	7493	229	0.07	0.21	0	0
C	**2.9**	**none**	**X**			**B_{unf}/B_0**	**--**	**4769**	**230**	**0.08**	**0.21**	**49**	**57**

- Forcing function: PP = Primary production forcing.
- vadj = Manual adjustments made to vulnerabilities for ERP spp based on MSY curves.
- vmin = minimum kij vulnerability set to 1.01
- vcap = Vulnerability capped, assuming max M2 by a pred is 75% of M_{1985}

- **Bold = best fit for each of the 3 phases**

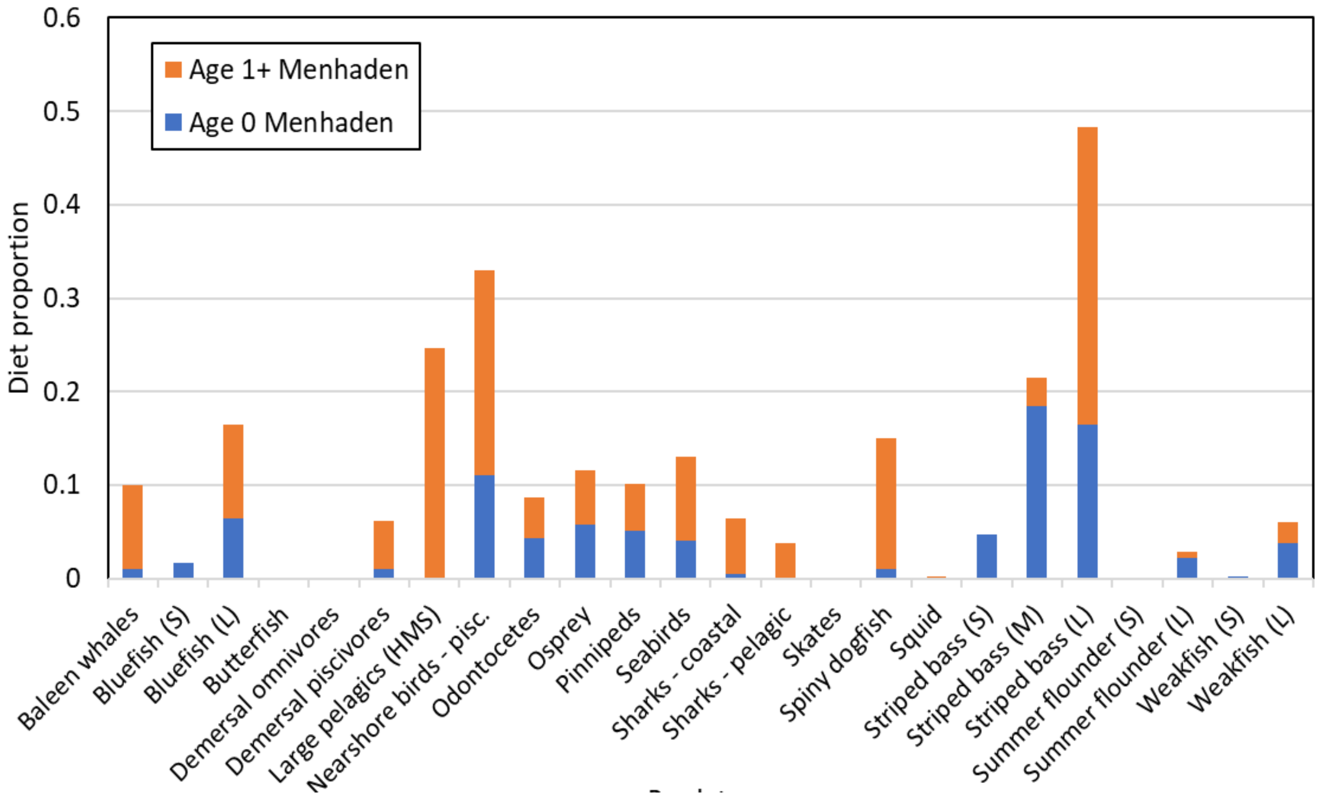
Results – Ecopath

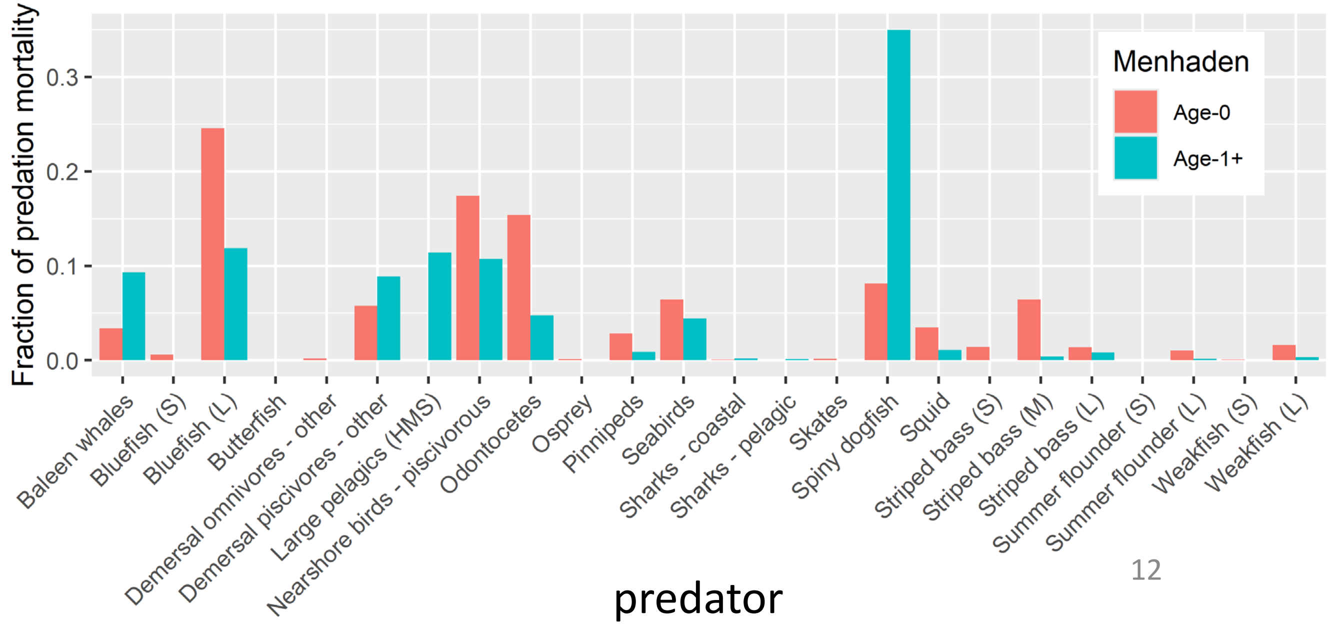
- highly interconnected and complex food web
- 1,083 trophic links
- Menhaden consumed by 24 groups (40.7% of groups)
    - but six were negligible (<0.05% diet)



Results: Menhaden Predators

- Diets
  - Highest:
    - striped bass, NS birds, HMS, Bluefish, Spiny dogfish
- Fraction of menhaden M2 by predator
  - Highest:
    - Age-0: Bluefish, NS Birds, odontocetes, spiny dogfish, striped bass
    - Age-1+: spiny dogfish, Bluefish, HMS, NS Birds



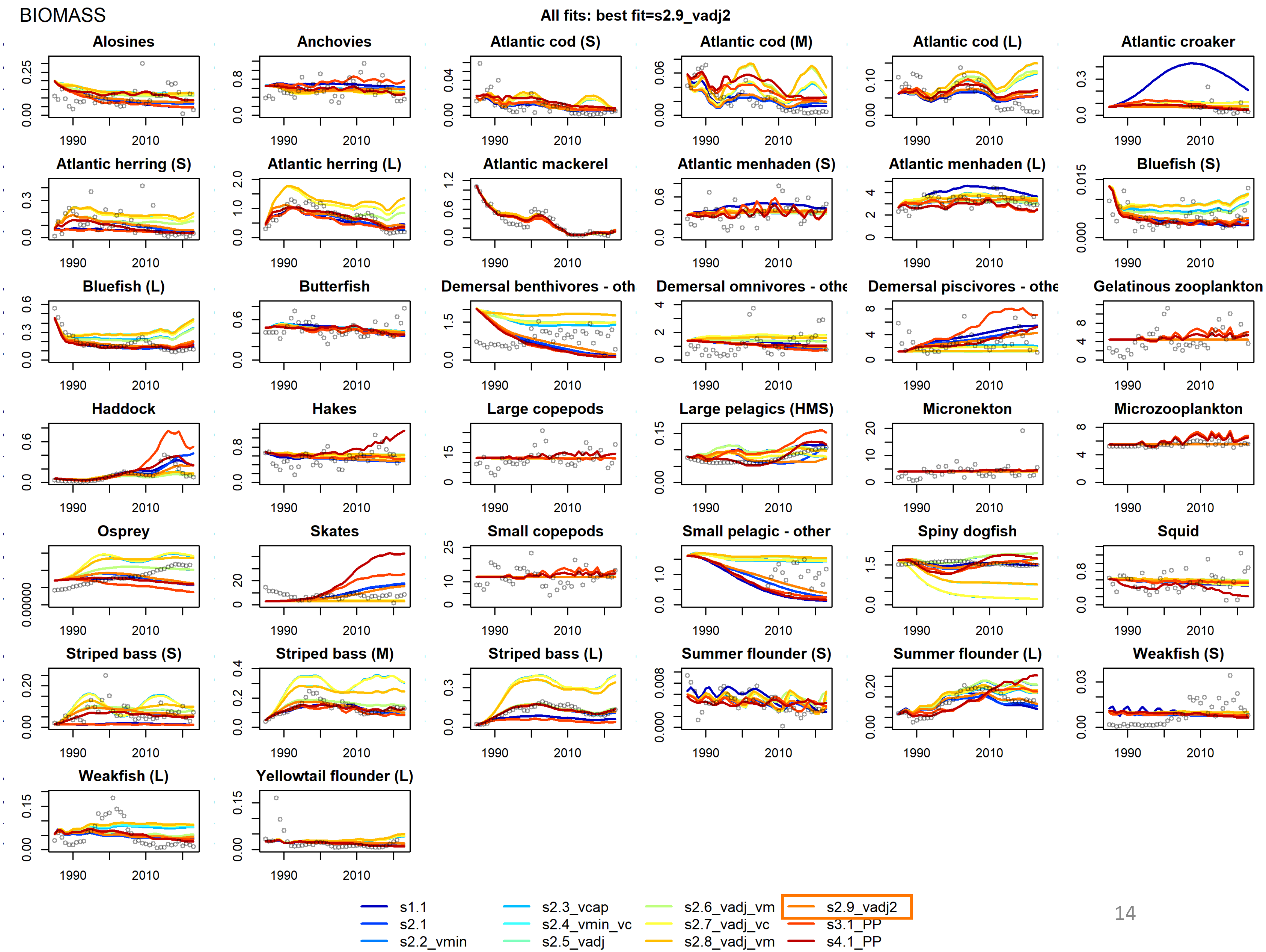


Model Fits

- General observations
  - There are tradeoffs in the fits to so many time series
  - Fits were generally comparable to the 2020 NWACS-FULL model
  - Catch tends to fit better than Biomass (if F time series present)
  - Groups without F tend to be relatively flat
- For ERP spp:
  - Some fits better than others
- Other notes
  - Strong recruitment events not captured well (e.g., Haddock, YTF)

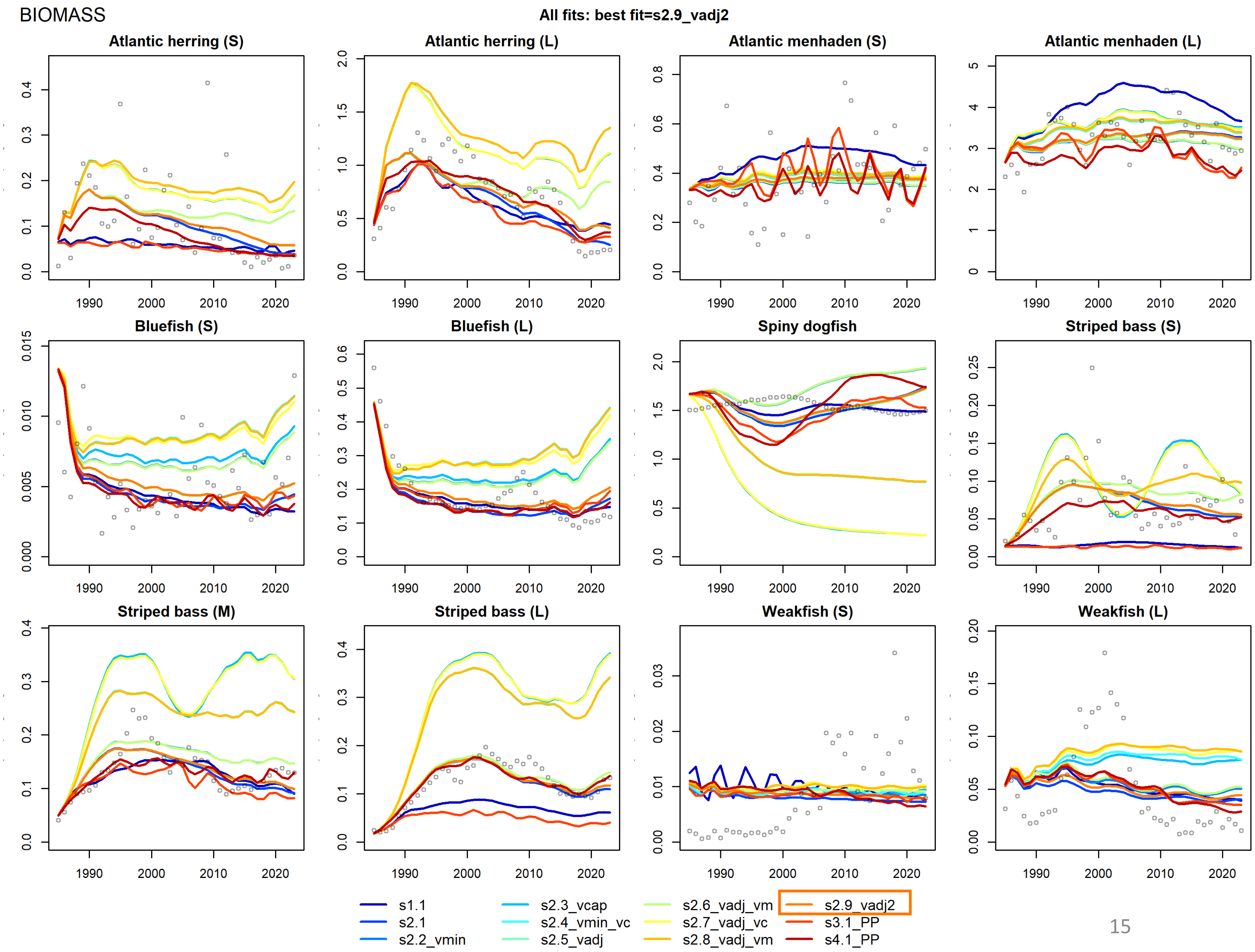
Biomass fits

- There are tradeoffs in the fits across the many time series (ie, some fit better than others)
- Patterns and trends differed across the different simulations, but generic vmins and vcaps led to much poorer fits
- Catch tends to fit better than Biomass (if F time series present). Predicted Catch could better capture interannual changes compared to Biomass because of the interannual changes in F.
- Groups without F as a driver tend to be relatively flat
- Fits to “new” groups (e.g., osprey, anchovies, zooplankton) were variable



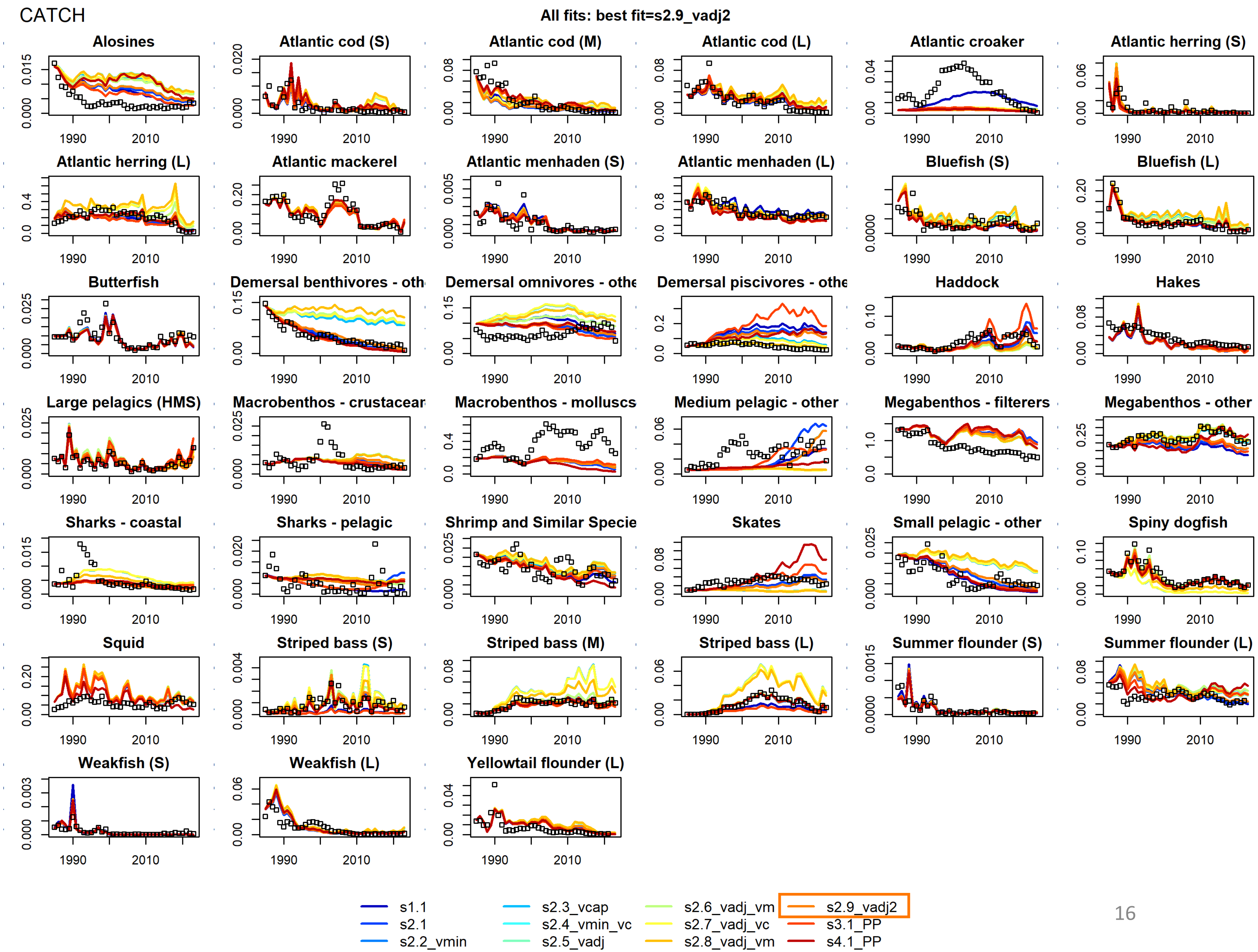
Biomass fits (ERP Spp)

- Several had reasonably good fits, and captured the general patterns (although variability across the different sims), specifically:
  - bluefish, menhaden (L), striped bass
- Atl Herring fit was intermediate
- Some fits were poor, and did not capture the overall trends in the assessment's time series
  - Spiny dogfish
  - weakfish



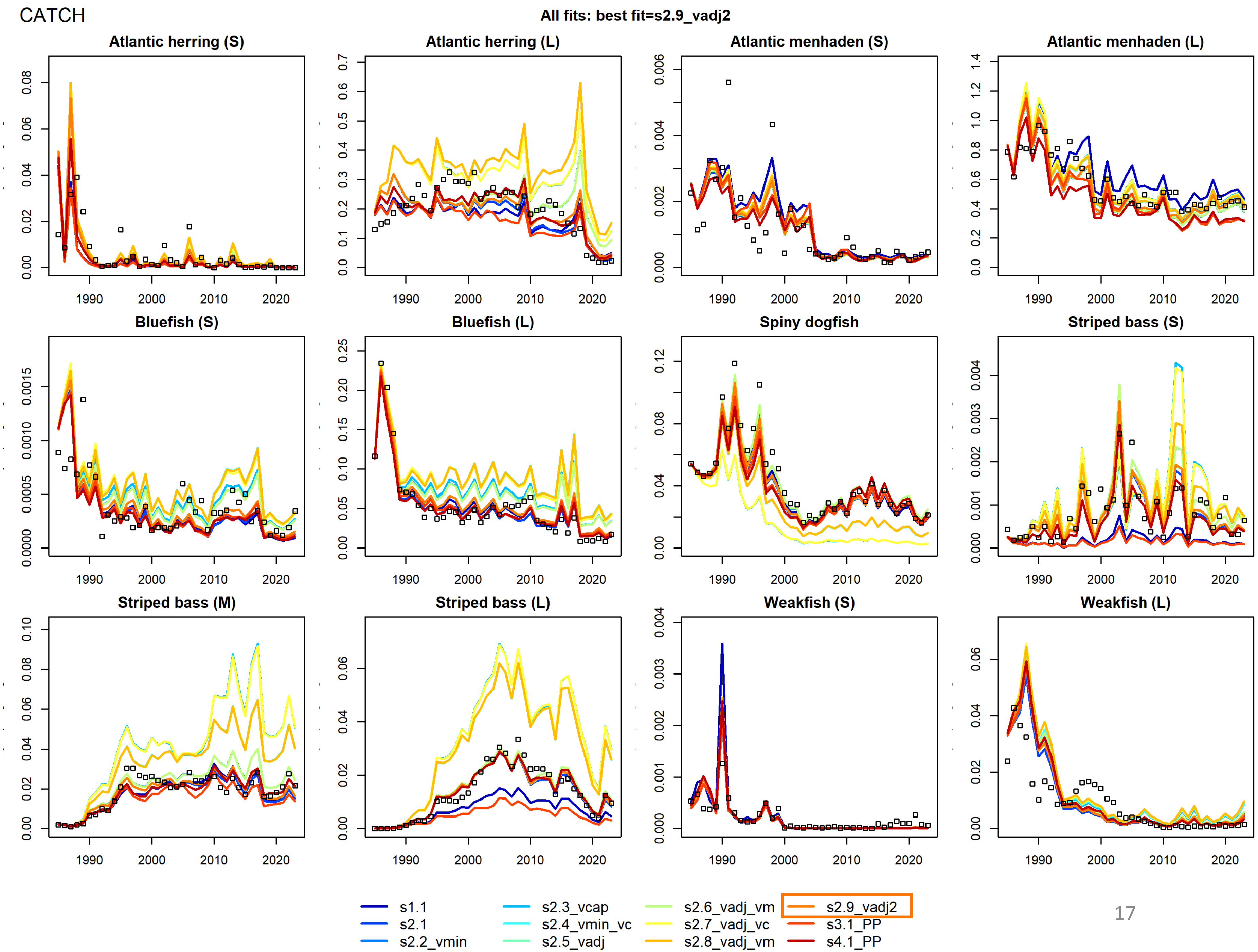
Catch fits

- There are tradeoffs in the fits across the many time series (ie, some fit better than others)
- Patterns and trends differed across the different simulations, but generic vmins and vcaps led to much poorer fits
- Catch tends to fit better than Biomass (if F time series present). Predicted Catch could better capture interannual changes compared to Biomass because of the interannual changes in F.
- Groups without F as a driver tend to be relatively flat



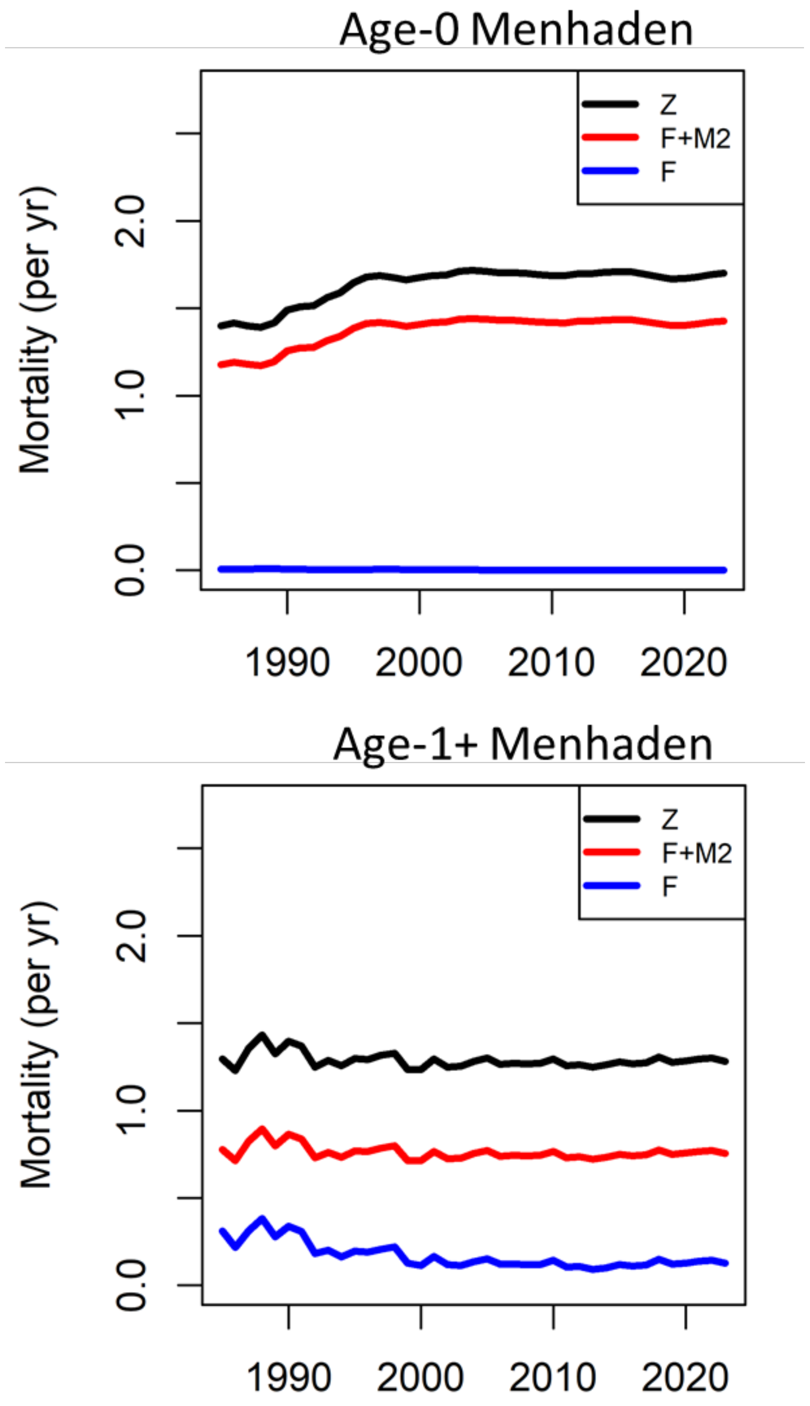
Catch fits (ERP Spp)

- Several had good fits, capturing the general patterns as well as some of the interannual variability (although variability across the different sims), specifically:
  - Atl Herring (S), Bluefish, Menhaden, Spiny dogfish, Striped bass (S, M), Weakfish
- AHERR.2, STBASS.3, and WEAK.2 fits were intermediate, not always capturing the overall trend or the magnitude of change over the time series.



Results: Menhaden mortality

- Explaining more mortality than 2020 model
  - Age-0: EE = 0.84
  - Age-1+: EE = 0.60
  - Previously: EE = 0.15-0.45
    - *Largely driven by changes to SS Menhaden model (lower mortality & B)*
- *F* represents a small proportion of Z;
- M_2 was the bulk of the estimated mortality
- Predator contributions to M_2 relatively consistent (1985 to 2023)
  - Except for initial uptick due to striped bass

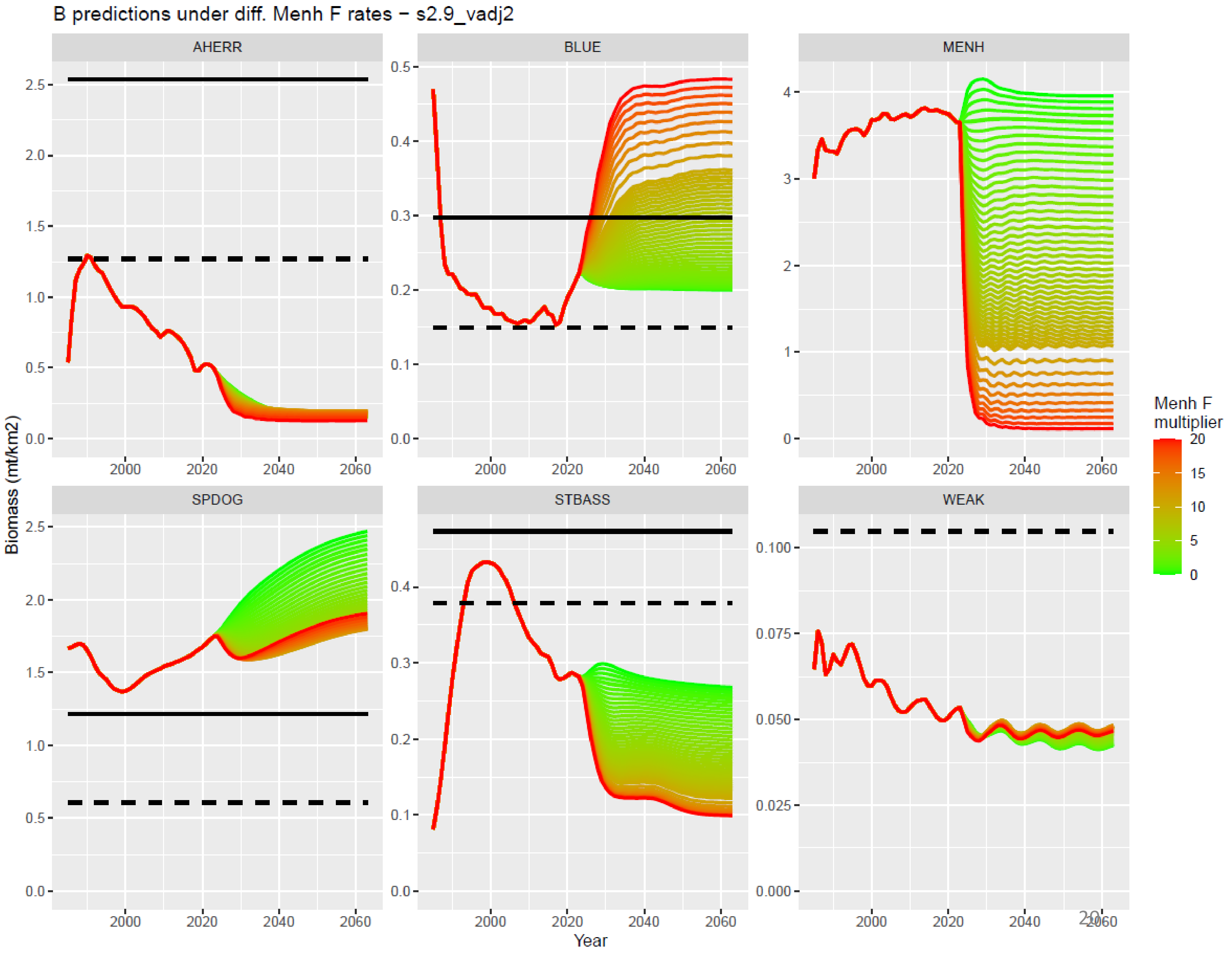


Model Projections (with sim 2.9)

- Conditions
  - 40 years
  - ERP spp. held at their Ftarget
  - non-ERP spp. held at status quo (2023) F
  - All fishing fleet effort held at 2023 levels
- Menhaden F Scenarios
  - *F*-multipliers (ranging from 0 to 20) used to modify F_{2023} for each age stanza (i.e., $F = F_{2023} * F$-multiplier)
  - Key scenarios:
    - $\boldsymbol{F_0}$ = no menhaden fishing
    - $\boldsymbol{F_{SQ}}$ = status quo (2023) menhaden fishing
    - $\boldsymbol{F_{max}}$ = maximum menhaden *F*
- Outputs for each F scenario
  - $\boldsymbol{B_{2063} / B_{SQ}}$ = equilibrium B relative to status quo scenario
  - $\boldsymbol{C_{2063} / C_{max}}$ = equilibrium catches relative to max equil. catch across all F scenarios

Projected B for s2.9_vadj2 (ERP Spp.)

- Most ERP spp not reaching $B_{threshold}$ or B_{target}, regardless of F scenario
- Possibilities:
  - NWACS underestimates recovery
    - E.g., sensitive to trophic parameters (kij, switching)
  - SS models overestimate recovery
    - E.g., Striped bass recovery dependent on recruitment regime in SS model
  - proxies inappropriate



Equilibrium (40yr) Biomass relative to Status Quo

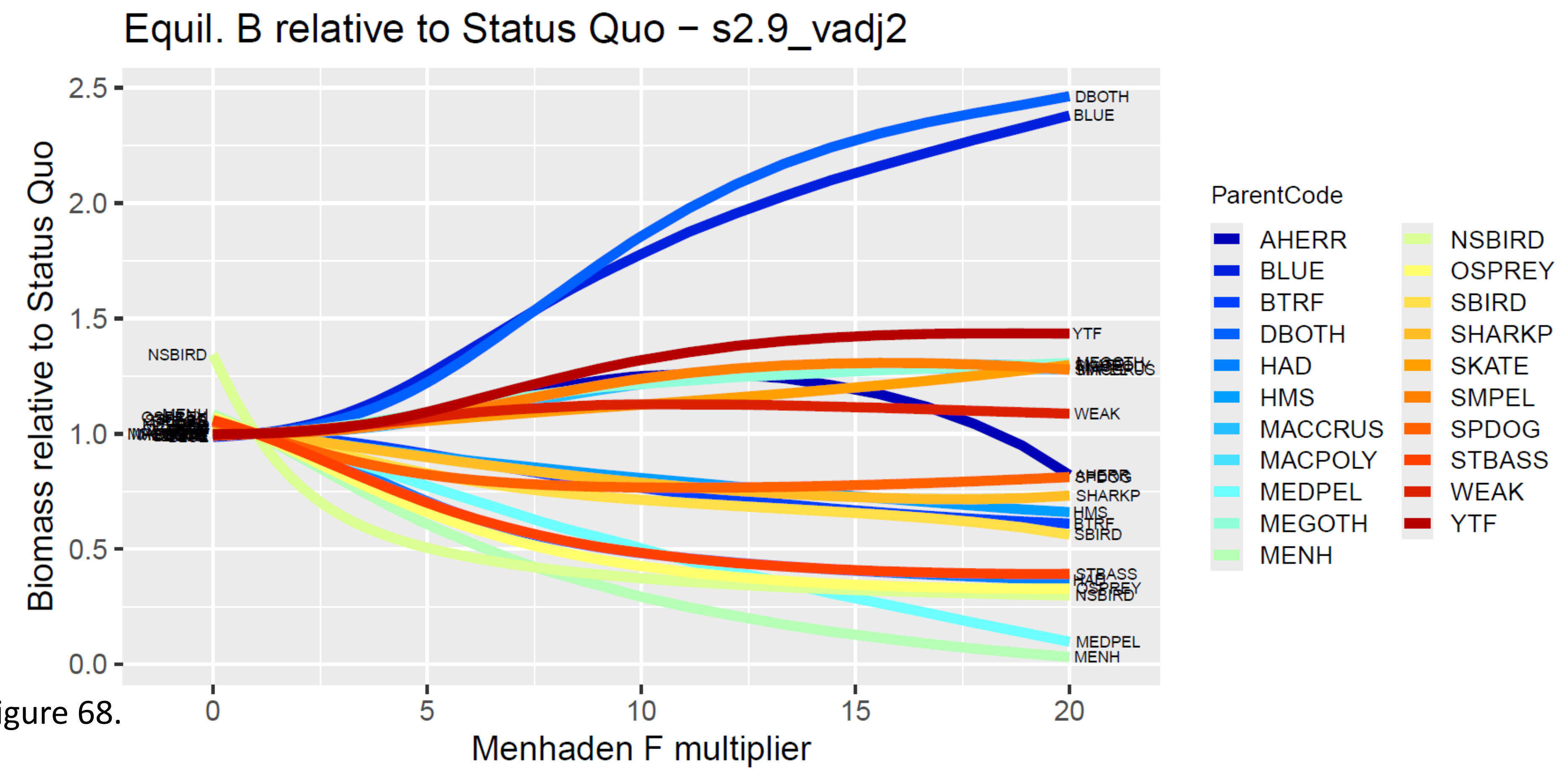


Figure 68.

At F_{max}:

↑ "winners"

ParentCode	B_{2063}/B_{SQ}
DBOTH	2.46
BLUE	**2.38**
YTF	1.43
MEGOTH	1.31
SKATE	1.30
MACPOLY	1.29
MACCRUS	1.28
SMPEL	1.28
SHARKP	0.73
HMS	0.66
BTRF	0.61
SBIRD	0.56
STBASS	**0.39**
HAD	0.36
OSPREY	0.33
NSBIRD	0.30
MEDPEL	0.10
MENH	**0.03**

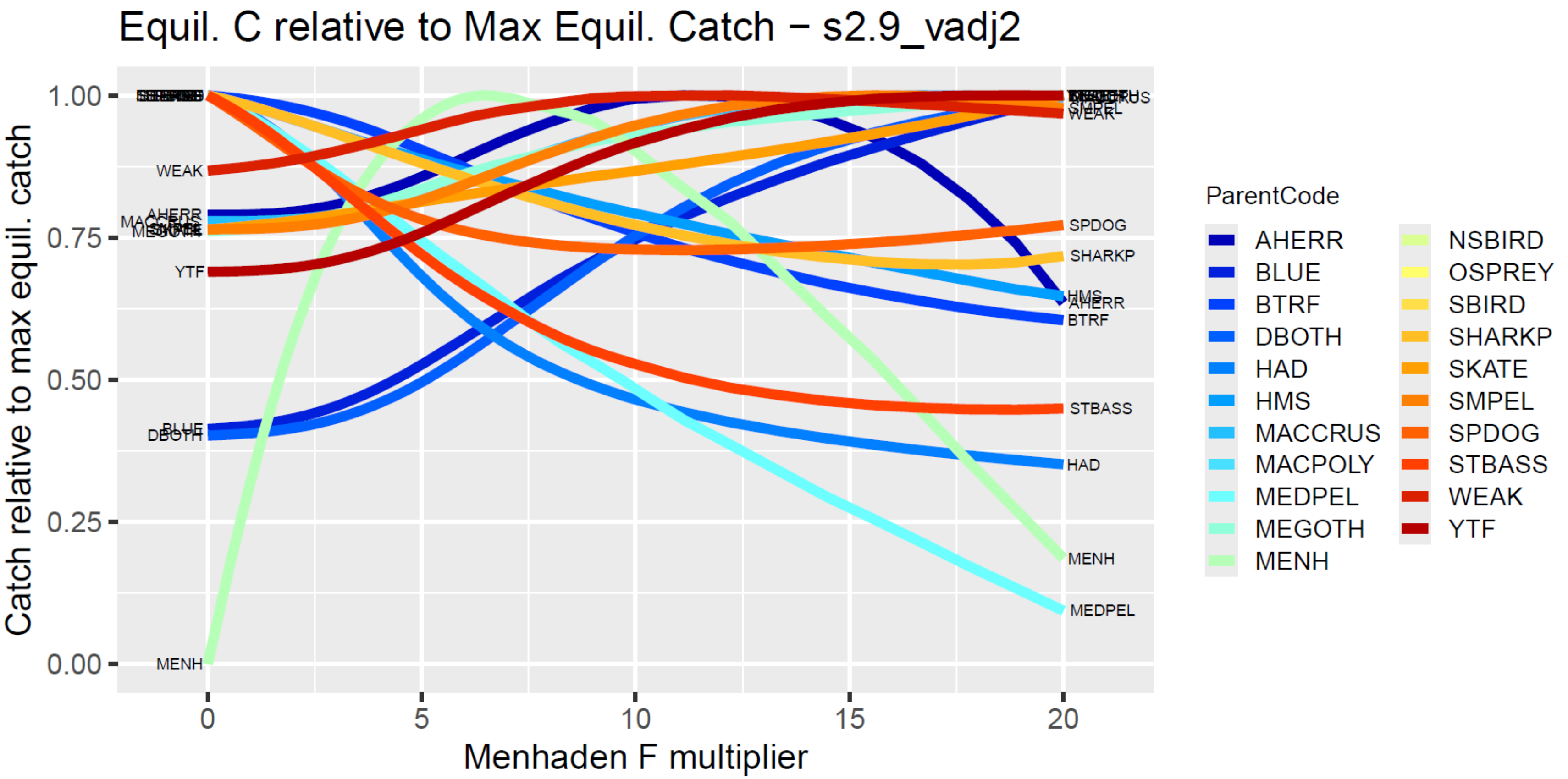
"losers" ↓

- At F_{max}, several groups with B gains (winners) or B loses (losers)
- At F_0, most groups had small change (-1% to +8% for menhaden)
  - Nearshore Pisc. Birds were the exception (+34%)

Equilibrium Catch relative to C_{max}

At F_0:

Parent Code	C_{2063}/C_{max}
AHERR	**0.79**
CROAK	0.79
MACCRUS	0.78
SMPEL	0.76
SKATE	0.76
MEGOTH	0.76
ALOS	0.71
YTF	0.69
BLUE	**0.41**
DBOTH	0.40
MENH	**0.00**



At F_{max}:

Parent Code	C_{2063}/C_{max}
ALOS	0.78
AMACK	0.77
SPDOG	0.77
SHARKP	0.72
COD	0.69
HMS	0.65
AHERR	**0.64**
BTRF	0.60
STBASS	**0.45**
HAD	0.35
MENH	**0.19**
MEDPEL	0.09

- Catch trends related to biomass
  - At F_{max}, groups with lowest C_{2063}/C_{max} were the biomass *losers* at F_{max}
  - At F_0, groups with lowest C_{2063}/C_{max} were the biomass *winners* at F_{max}

Assumptions, Uncertainties, & Challenges

- Simplified representation of ecosystem
  - Not spatially-explicit
  - Only accounts for predation & fishing → missing other abiotic/env drivers (e.g., long-term osprey recovery, haddock recruitment events)
  - *But possible to add these things in the future… as in MICE*
- Tradeoffs in fitting to so many time-series (emphasizing ERP groups)
- Lack of data, time-series, and F drivers for several groups
- Recommend appropriate caution when extrapolating (e.g., F_{max})
- Sensitivity to parameters (esp. vulnerabilities, switching)
  - e.g., bluefish B increase tied to 1 low kij parm with age-1+ menhaden.
- Most ERP species did not recover when they were fished at Ftarget
  - Possibilities: NWACS-FULL underestimates recovery; SS models overestimate recovery; proxies inappropriate
- Assumed spiny dogfish biomass resided in model domain, but this should be revisited in future (e.g., Carlson et al. 2014)

Main Findings – Striped Bass

- Striped bass remain the most negatively sensitive ERP spp. to menhaden fishing
- This result is more robust (despite the model uncertainties highlighted) because:
    1. **Striped bass age stanzas did not have any vulnerability parameters estimated on the lower bound and only one kij parameter on the upper bound** (for a non-menhaden prey group).
    2. **Striped bass historical data was well represented** by NWACS-FULL predictions and those fits were not as sensitive to minor changes in vulnerability parameters (unlike bluefish).
    3. **Menhaden are a substantially more important prey group in the diets** of striped bass compared to other ERP species.
    4. **Striped bass have repeatedly emerged as one of the most sensitive predator groups** through various parameterizations and updates of the NWACS FULL model (2017, 2020, 2025). Responses of other ERP species to menhaden fishing have been more muted or variable
    5. **The NWACS-MICE model also affirms striped bass as a more sensitive predator**, and that simplified model avoids the additional challenges and uncertainties inherent in the NWACS-FULL model stemming from its complexity.
- **"Consequently, the ERP WG recommends the continued focus on striped bass as a sensitive predator that should be used to inform ERP development for menhaden."**

Main Findings

- Other groups were identified as “losers” and “winners” at high menhaden F, but those results less robust
  - Reduced data quality and availability, indirect ecological mechanisms that are harder to predict, and greater sensitivity to model parameterization
- Small changes to menhaden fishing rates away from F_{SQ} are not expected to lead to substantial changes in biomasses for the modeled groups.
  - Nearshore birds was an exception, but data quality was low
- Continued research recommended for many groups that are understudied (including those for which enhanced efforts were made)
  - E.g., birds, marine mammals, large pelagics, demersal piscivores.
- Biomass scaling of some groups (based on single species models) may be inconsistent with rest of system
  - Atlantic herring total B may be low (high EE when balancing)