



Modeling History, Objectives, and Predator/Prey Selection

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SEDAR 102

August 12-15, 2025

- Use of Single-Species Statistical Catch-at-Age Model (BAM)
 - Since 2004, Atlantic menhaden stock assessments have been based on a single-species statistical catch-at-age model known as the Beaufort Assessment Model (BAM).
 - BAM estimates population size-at-age, recruitment, spawning stock biomass (SSB), egg production, and fishing mortality (F), using a coastwide fleets-as-areas framework.
- Because managers and stakeholders were interested in the ecological effects of menhaden removal, there was a move to estimate M via other approaches

- MSVPA-X (Expanded Multispecies Virtual Population Analysis)
 - The MSVPA-X model, developed in 2001 and peer-reviewed in 2006, extended the original ICES MSVPA to estimate predation mortality (M2) on menhaden by linking single-species VPAs through a feeding model.
 - Included key predators such as striped bass, bluefish, and weakfish, along with an "other prey" pool.
 - Used to estimate M-at-age for input into single-species assessments in 2004 and 2010, but by 2015, concerns over mismatches with predator biomass trajectories and high sensitivity to prey-preference assumptions limited its utility.
 - In 2015, MSVPA-X results were excluded from the base BAM run but used in sensitivity analyses and to inform uncertainty envelopes in bootstrap runs.

- Ecosystem Reference Points (ERP) in 2020
 - 2020 benchmark ERP assessment examined a suite of models:
 - A time-varying surplus production model with intrinsic growth rate (r)
 - A Steele-Henderson production model
 - VADER: a multispecies statistical catch-at-age model
 - Two Ecopath with Ecosim (EwE) models:
 - NWACS-MICE (intermediate complexity)
 - NWACS-FULL (full ecosystem)

- Ecosystem Reference Points (ERP) in 2020
 - Only the EwE models could simulate bottom-up impacts of menhaden harvest on predator populations, a key ecosystem-based management objective.
 - NWACS-MICE (Northwest Atlantic Coastal Shelf – Model of Intermediate Complexity for Ecosystem assessment) was ultimately selected for ERP development due to:
 - Realistic trophic representation, intermediate complexity allowing practical application in a management context, and ability to estimate trade-offs in predator biomass under various menhaden harvest strategies

- As such, a Hybrid Modeling approach was adopted
 - NWACS-MICE is used to generate ecosystem-based reference points (ERP F_{TARGET} and $F_{\text{THRESHOLD}}$).
 - BAM continues to provide tactical, short-term management advice by estimating menhaden fishing mortality and fecundity and evaluating the risk of exceeding ERP targets under alternative harvest levels.
 - Enabled managers to consider both the ecosystem implications of menhaden harvest and the short-term performance of the fishery in a structured, quantitative way.

- Note

- All models assume unit stocks for both predator and prey species, meaning that the ERP framework is designed to inform stock-wide management rather than regional-scale harvest strategies.
- While spatial differences exist in predator-prey dynamics, current data limitations preclude the use of regional modeling approaches.
- A more spatially explicit approach may be explored in the next Benchmark



- Structured Objective Development through the EMO Workgroup
 - In 2015, the Ecosystem Management Objectives (EMO) Workgroup was convened by ASMFC to identify ecosystem-based management objectives.
 - This multidisciplinary group included representatives from the Atlantic Menhaden Management Board, stakeholder Advisory Panel, and Technical Committee.
 - The group used a structured decision-making framework to identify two tiers of objectives:
 - Fundamental objectives: core, value-driven goals to be achieved.
 - Means objectives: operational steps necessary to support those fundamental goals.

- The EMO Workgroup distilled a broad set of priorities into several Fundamental Objectives:
 - Sustain Atlantic menhaden to support commercial and recreational fisheries
 - Sustain menhaden to support predator species
 - Avoid unintended economic consequences of management
 - Support cultural and historical fisheries.
 - Provide ecosystem services and maintain ecosystem stability, ensuring that food web dynamics remain resilient under fishing pressure.
 - Minimize ecological risk from environmental change
 - Achieve broad public support, reflected through Board consensus, positive stakeholder feedback, and legal or compliance stability.

- Means Objectives focused on operational aspects of science, communication, and modeling:
 - Improve the scientific knowledge base and ensure it captures both natural variability and uncertainty.
 - Improve communication of ecological science.
 - Define clear and transparent management objectives.
 - Provide timely and interpretable advice to management bodies.
 - Ensure menhaden availability to individual predators and food web.
 - Account for spatial and temporal variation in predator-prey interactions and ecosystem trade-offs.
 - Minimize the probability of collapse for:
 - Menhaden (via thresholds in biomass or fecundity)
 - The fishery (via economic viability)
 - The ecosystem (via irreversible food web change)

	FUNDAMENTAL OBJECTIVES												
	Sustain menhaden to provide for fisheries				Sustain menhaden to provide for predators				Provide stability for all types of fisheries			Minimize risk to sustainability due to changing environment	
	PERFORMANCE MEASURES				PERFORMANCE MEASURES				PERFORMANCE MEASURES			PERFORMANCE MEASURES	
	Abundance/ biomass of menhaden	Menhaden yield objectives	Age Composition	Historical distribution (Age comp as proxy)	Abundance/ biomass of predators	Predator yield objectives	Predator nutrition	Prey availability relative to predator distribution	Stability in yield for directed menhaden fisheries	Stability in yield for non-menhaden fisheries	Evaluate trade-offs between menhaden harvest and predator abundance	Model explicitly considers uncertainty about future environment for menhaden	Model explicitly considers uncertainty about future environment for predators
Single-Species Models													
BAM Statistical Catch-at-Age Model	•	•	•	•					•			‡	
Multi-Species Statistical Catch-at-Age (MSSCAA)													
VADER	•	•	•	•	○	○	○ (proxy)	○	•	○		‡	‡
Ecopath with Ecosim (EwE)													
NWACS-MICE	•	•	•	•	○	○	○ (proxy)	○	•	○	○	‡	‡
NWACS-FULL	•	•	•	•	•	•	• (proxy)	•	•	•	•	‡	‡

○ For menhaden or key finfish predators
 • For wide range of predator and prey species, including birds and mammals
 ‡: Model could be developed further to meet that performance objective, but would require extensive additional work

- Models used to generate ERPs needed to be aligned with the fundamental and means objectives.
- Specifically, the chosen model had to:
 - Explicitly simulate trade-offs between menhaden harvest and predator population outcomes.
 - Provide quantitative and understandable advice for setting harvest levels under varying predator biomass or fishing mortality regimes.
 - Be capable of evaluating consequences to predators in terms of growth, condition, or mortality rates.
 - Be updateable within management-relevant timeframes (e.g., for setting TACs).

- Because only the NWACS-MICE allowed for the bottom-up process to affect the predator population, the Hybrid approach was adopted.
 - NWACS-MICE is used to generate ecosystem-based reference points
 - BAM continues to provide tactical, short-term management advice, including fishing mortality and fecundity relative to ERP targets.
- The NWACS-FULL model was not used: but still useful
 - Complicated
 - Data Hungry
 - Couldn't be updated regularly as needed for Management Advice
 - Did confirm findings in the MICE model.



- Sources for Diet Data

- The ERP Workgroup (ERP WG) used multiple long-term fish diet datasets to inform predator-prey interactions:
 - NEFSC Food Web Dynamics Program: systematic sampling since 1973
 - NEAMAP and ChesMMAP: regionally focused surveys with consistent protocols, supplementing NEFSC data and extending coverage inshore.
- To fill gaps, incorporated smaller-scale literature studies, especially for predator species with limited representation in long-term programs.
- Additional state-conducted diet surveys in Maine, Rhode Island, and New Jersey for seasonal and length-specific prey information for key predators.

Predator & Prey Choices

- Criteria for Selecting Key Predators: NWACS-MICE
 - Degree of Atlantic menhaden consumption
 - Availability and quality of life history data.
 - Management relevance to the ASMFC or partner agencies.
 - Either a major consumer or affected by menhaden availability.
- Striped bass, bluefish, spiny dogfish, and weakfish were used as Main Predators
 - Consumed the largest quantities of Atlantic menhaden.
 - All had reliable biomass and fishing mortality estimates.
 - All were actively managed by ASMFC or relevant partners.
 - Weakfish was retained despite lower consumption rates, to explore if competition from striped bass may have contributed to weakfish declines

	Annual population-level consumption				Ranked levels of consumption			
	1 year	5 year	10 year	All years '81+	1 year	5 year	10 year	All years
Spiny dogfish	142,944,946	96,031,910	85,632,752	80,475,599	1	1	1	1
Striped bass	4,052,220	30,601,675	17,793,908	7,816,855	2	2	2	2
Bluefish	1,465,923	2,049,989	2,196,640	2,608,901	3	3	3	3
Weakfish	463,150	376,622	1,007,166	787,034	4	5	4	4
Smooth dogfish	446,791	588,205	900,819	757,217	5	4	5	5
Atlantic angel shark	345,432	180,740	139,435	141,519	6	7	7	6
Clearence skate	34,830	31,340	18,387	9,554	8	8	8	10
Dusky shark	-	-	3,483	100,672	-	-	10	8
Goosefish	258,958	211,633	145,905	124,572	7	6	6	7
Sandbar shark	-	7,199	5,530	15,533	-	9	9	9
Spiny butterfly ray	4,245,350	4,639,049	6,437,951	4,737,723	2*	3*	3*	3*

*: Spiny butterfly ray consumption estimates were not included in the ranking because of the extremely small sample size of stomachs available for the analysis.

- Evaluation of Additional Predator Candidates
 - Bluefin tuna: Replaced the generic HMS group in Full model due to new diet data and spatial use patterns.
 - Blue catfish: Abundant in Chesapeake Bay and opportunistic feeders, only minor, seasonal consumption of menhaden. Not included due to limited relevance and low spatial overlap.
 - Osprey: Separated from the “nearshore piscivorous bird” group using new abundance and biomass time series from BBS and PIF databases in Full model.
 - Marine mammals: Three broad functional groups were evaluated (Mysticetes, Odontocetes, Pinnipeds), the lack of diet resolution and weak evidence for menhaden consumption led to exclusion. Only bottlenose dolphins had specific diet data showing $\leq 4\%$ menhaden composition
 - **All of these were excluded from the MICE model**

Predator & Prey Choices

- Selection of Additional Prey Species for NWACS-MICE
- Atlantic herring was selected as an additional key prey species
 - It frequently appears as an alternate prey in predator diets.
 - It is well-assessed with an age-structured model, providing biomass, catch, and F estimates.
 - Its inclusion allows the model to represent prey substitution dynamics and evaluate menhaden's unique importance relative to other forage species.
- Other prey and ecosystem species were included: Anchovies, Benthic Invertebrates, Zooplankton, and Phytoplankton
- These and more were included in the NWACS-FULL Model





Review & Synthesis of Results

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Ecosystem Model Development and Integration

- The ERP WG advanced ecosystem modeling by updating NWACS-MICE (preferred), NWACS-FULL, and VADER from the 2020 benchmark.
- A major change was the revised M in the BAM single-species model, integrated across all ERP models.
- This propagation of M improved alignment and ecological coherence in predator-prey modeling.
- VADER's attempted bottom-up feedback did not work out, but validated the value of recruitment-forcing approaches.
- This suite of models supports ERP development and ecosystem-based management across multiple predator-prey linkages.

Biomass and Exploitation Trends

- EwE models tracked biomass of menhaden and striped bass similarly to SS, but with less year-to-year variability due to differing recruitment dynamics.
- NWACS-FULL better matched SS for striped bass ages 2–5; NWACS-MICE better tracked age 6+.
- Differences reflected Ecopath assumptions about biomass accumulation and initial balancing.
- Exploitation rates (F) were consistent across EwE models, as BAM-derived F was used as direct input.

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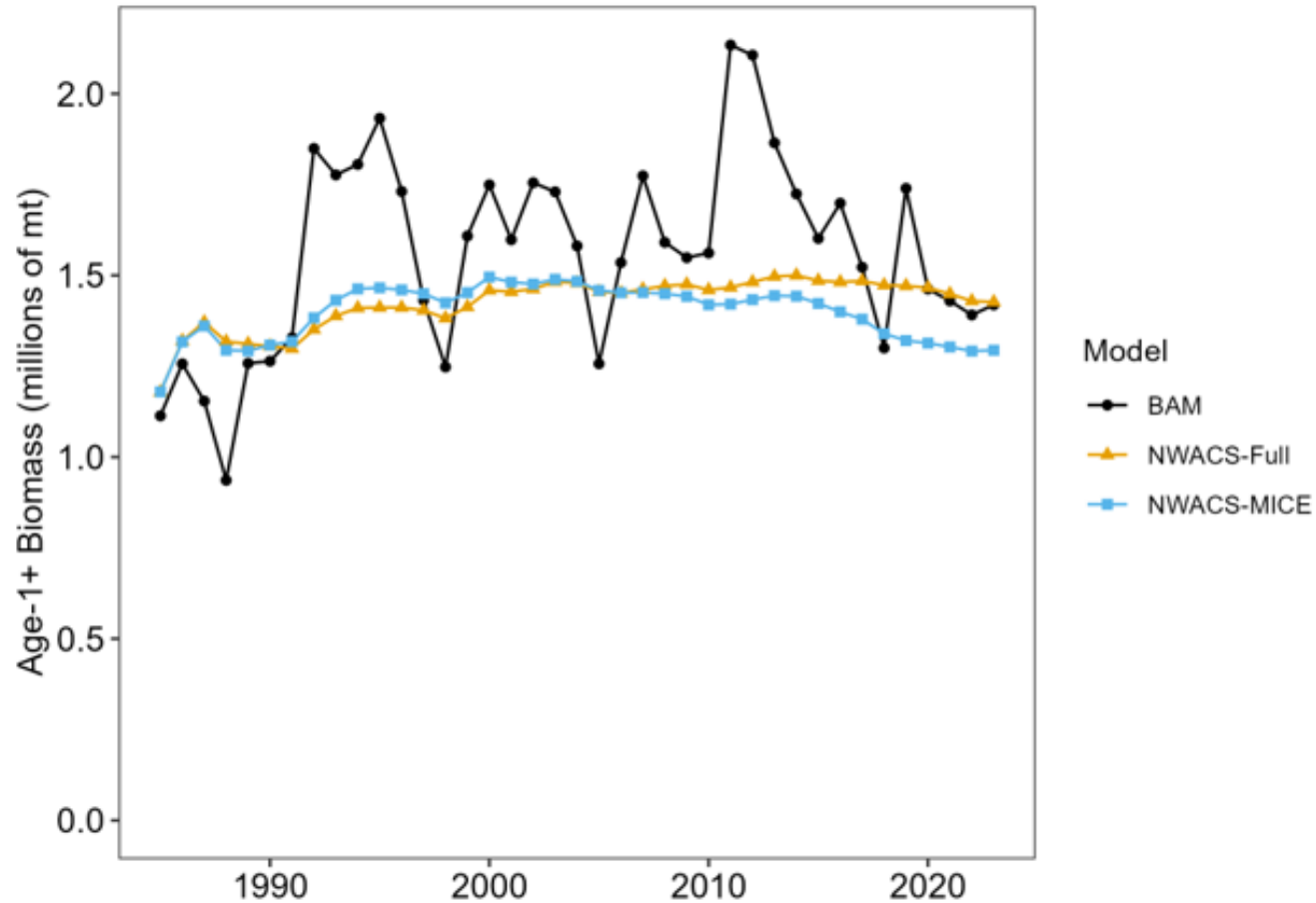


Figure 70. Age-1+ biomass of Atlantic menhaden from the single-species assessment (BAM) and the NWACS ecosystem models, 1985-2023.

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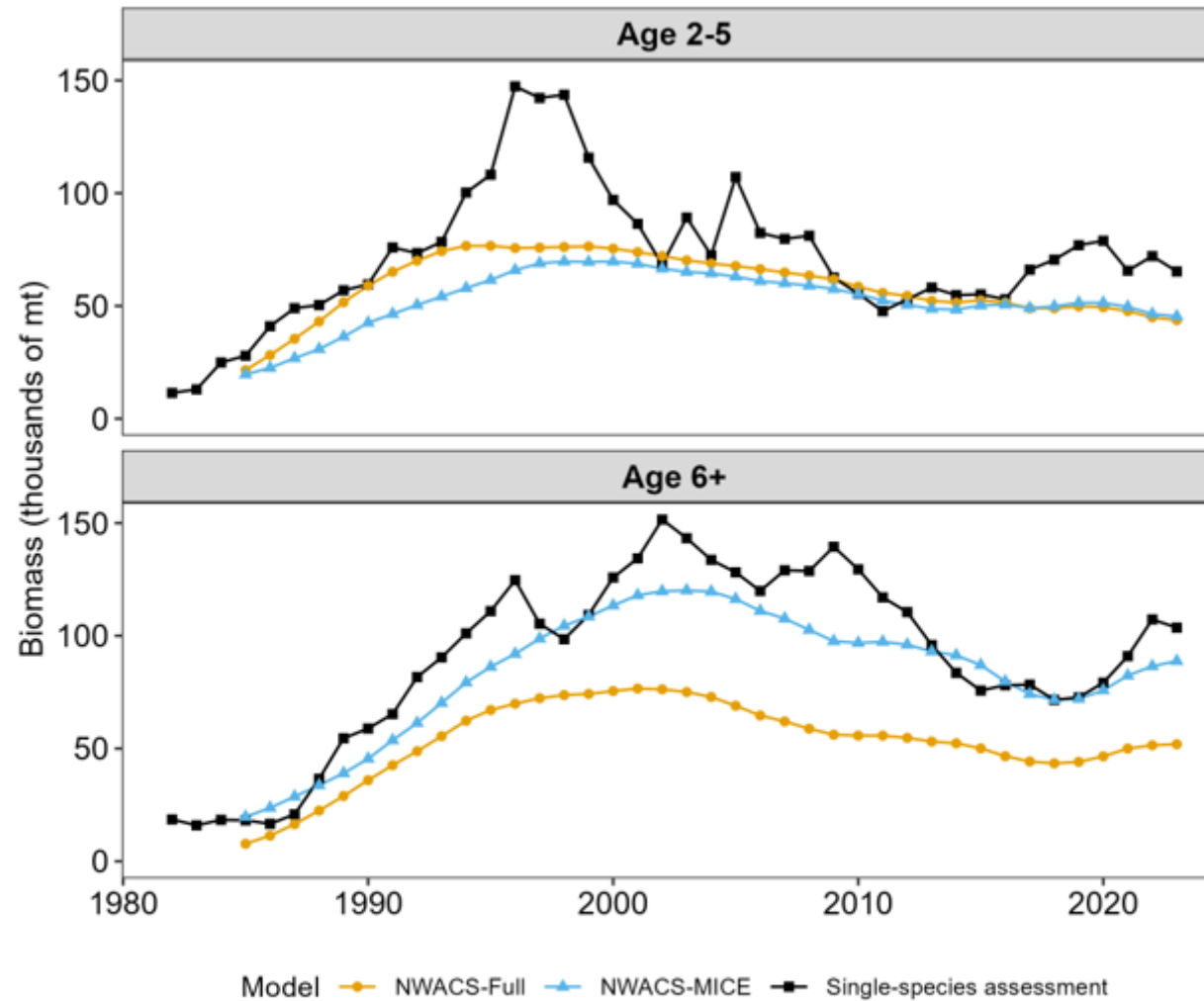


Figure 71. Comparison of striped bass biomass estimates for the non-recruit stanzas for the single-species assessment and the NWACS ecosystem models.

Predation Mortality and Diet Composition

- NWACS-FULL estimated higher predation mortality (M2) for both age-0 and age-1+ menhaden than MICE.
- Both models showed rising M2 over time, particularly for age-0 menhaden.
- Differences in predator diets were notable: FULL showed a concave diet trend in medium striped bass, while MICE showed a convex one.
- FULL predicted more menhaden in large striped bass, bluefish, and spiny dogfish diets.
- These differences stemmed from model design, vulnerability parameter estimation, and prey switching.

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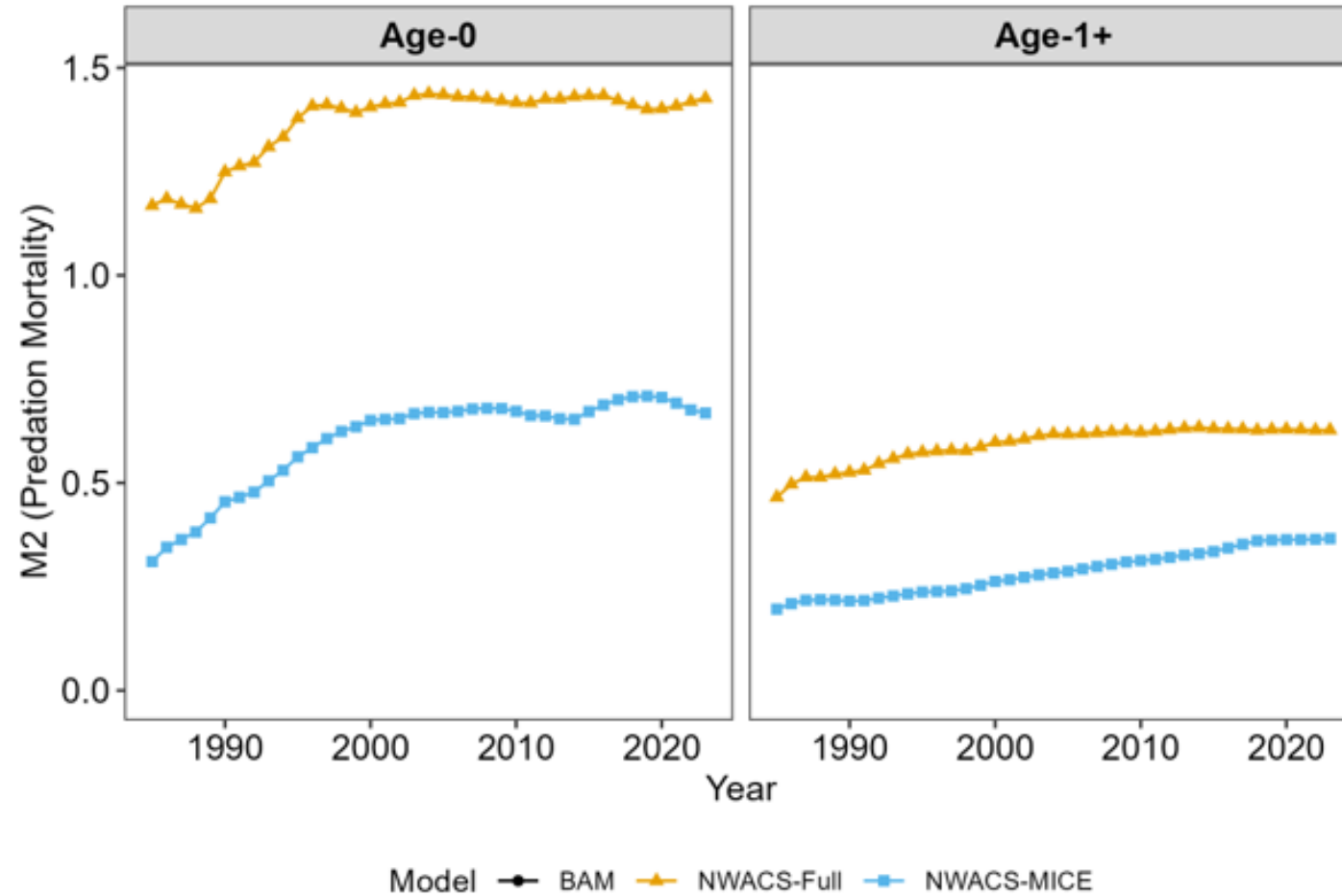
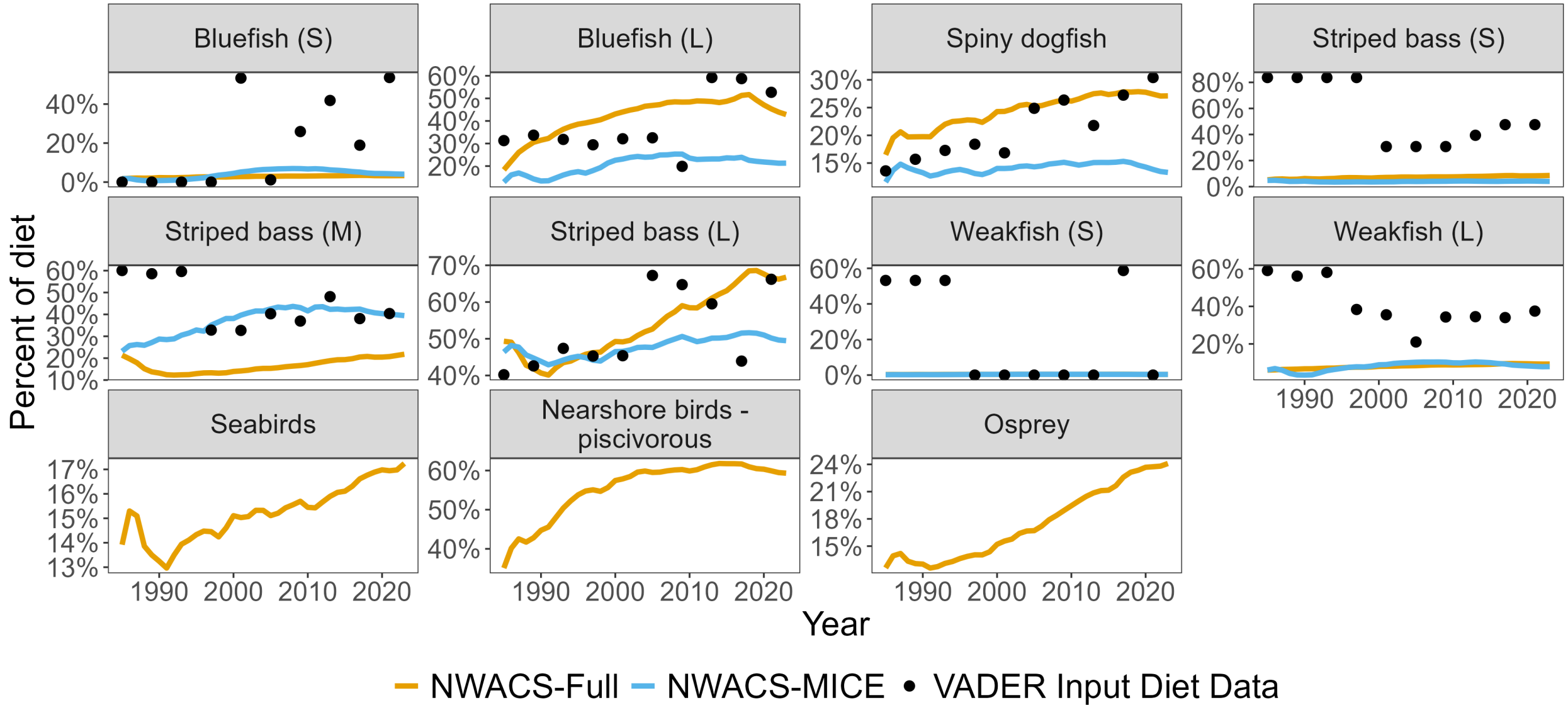


Figure 73. Estimates of M_2 (predation mortality) by stanza for Atlantic menhaden from the NWACS ecosystem models, 1985-2023.

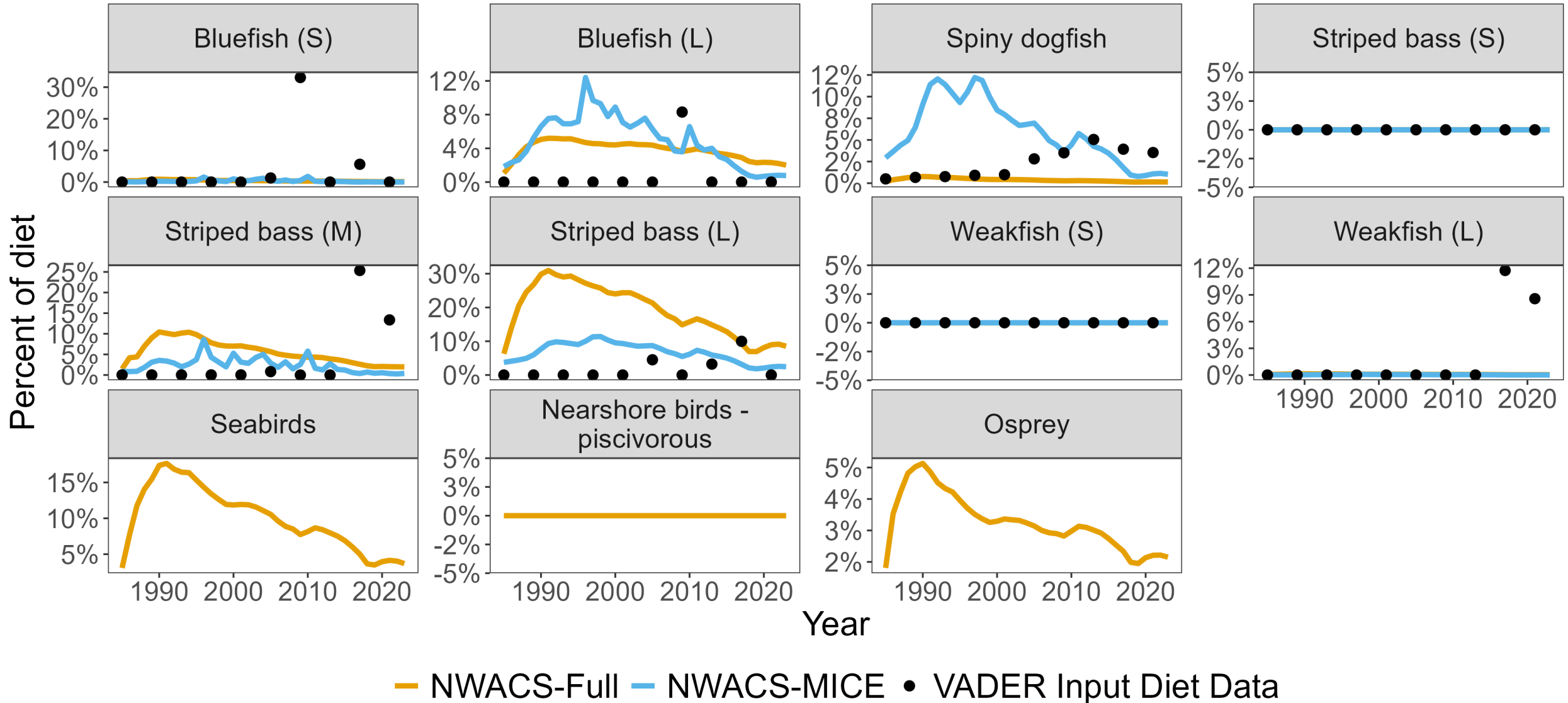
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Atlantic Herring and Diet Dynamics

- Both models projected a declining role of herring in predator diets, with greater variability in NWACS-MICE due to recruitment forcing.
- MICE predicted more herring in dogfish diets; FULL projected more in large striped bass diets.
- The MICE model included a **seasonal vulnerability forcing function**, moderating unrealistic herring consumption by striped bass.
- This function was excluded from FULL, leading to higher apparent herring dependence in striped bass diets.
- Seasonal dynamics and prey field differences significantly influenced diet trends across models.

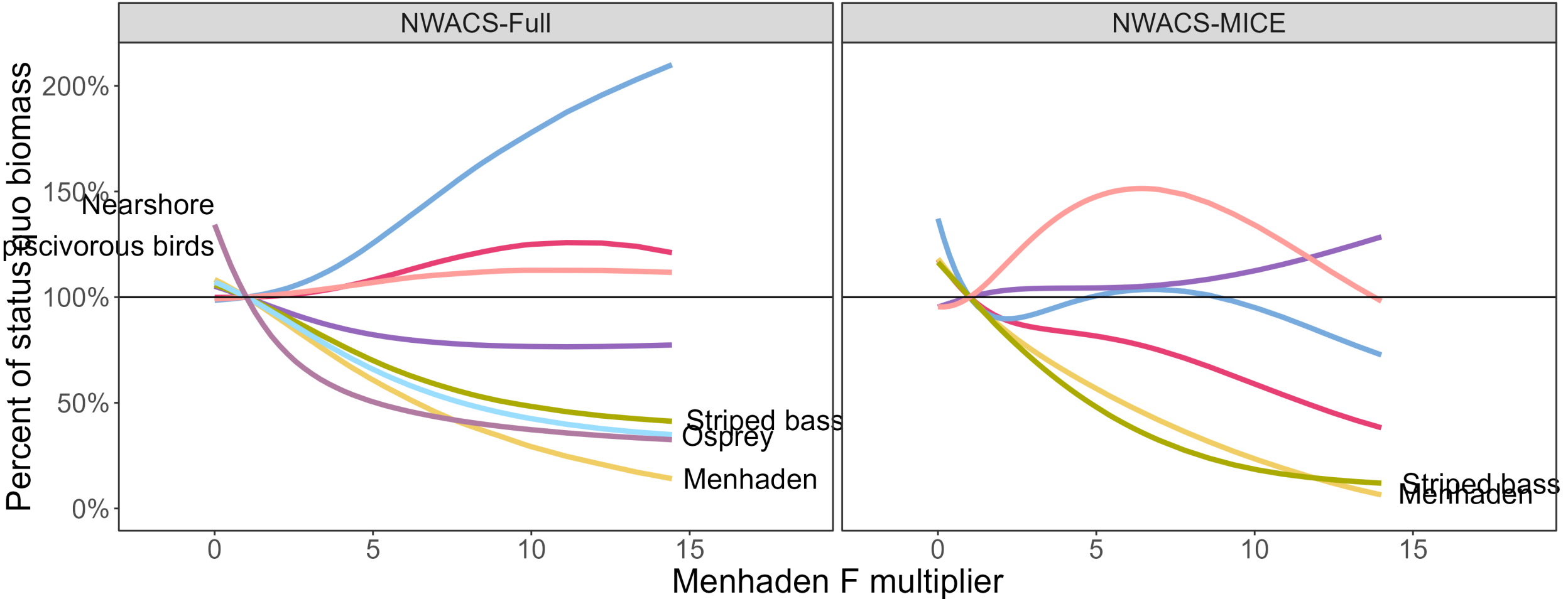
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Predator Responses to Menhaden F

- Striped bass were the most sensitive predator to increases in menhaden F; both models showed biomass declines at high F.
- Weakfish increased under higher F, though the shape of the response varied by model.
- Bluefish showed a positive response in FULL, but more nonlinear and negative in MICE.
- MICE predicted increases in dogfish and decreases in herring with rising F; FULL showed the opposite.
- These differences stem from structural features (e.g., seasonal egg production, prey switching, and vulnerability coefficients).

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- Atlantic herring
- Bluefish
- Striped bass
- Osprey
- Menhaden
- Spiny dogfish
- Weakfish
- Nearshore piscivorous birds

Management Implications and Ecological Resilience

- Results suggest that menhaden are **moderately sensitive** to changes in predator dynamics.
- Management has been conservative relative to both historical single-species targets and ERP thresholds.
- Even with higher F and lower biomass post-M revision, current TAC has low risk of exceeding ERP $F_{\text{THRESHOLD}}$.
- Generalist predator diets and a diverse forage base reduce dependency on menhaden alone.
- The ecosystem is not “wasp-waisted” like those cited in past global syntheses (e.g., Pikitch et al. 2012; Smith et al. 2011).

Menhaden Life History and Recruitment Dynamics

- Menhaden experience the highest predation mortality at ages 0–1, while the fishery targets ages 2+.
- Recruitment success, rather than adult abundance, determines menhaden availability to predators.
- Environmental variability, more than spawning biomass, drives recruitment, aligning with Hilborn et al. (2017) and Buchheister et al. (2016).
- Life history traits (e.g., early maturity, high fecundity, year-round spawning) buffer against environmental and fishing pressures.
- Most individuals spawn at least once before entering peak fishery selectivity.

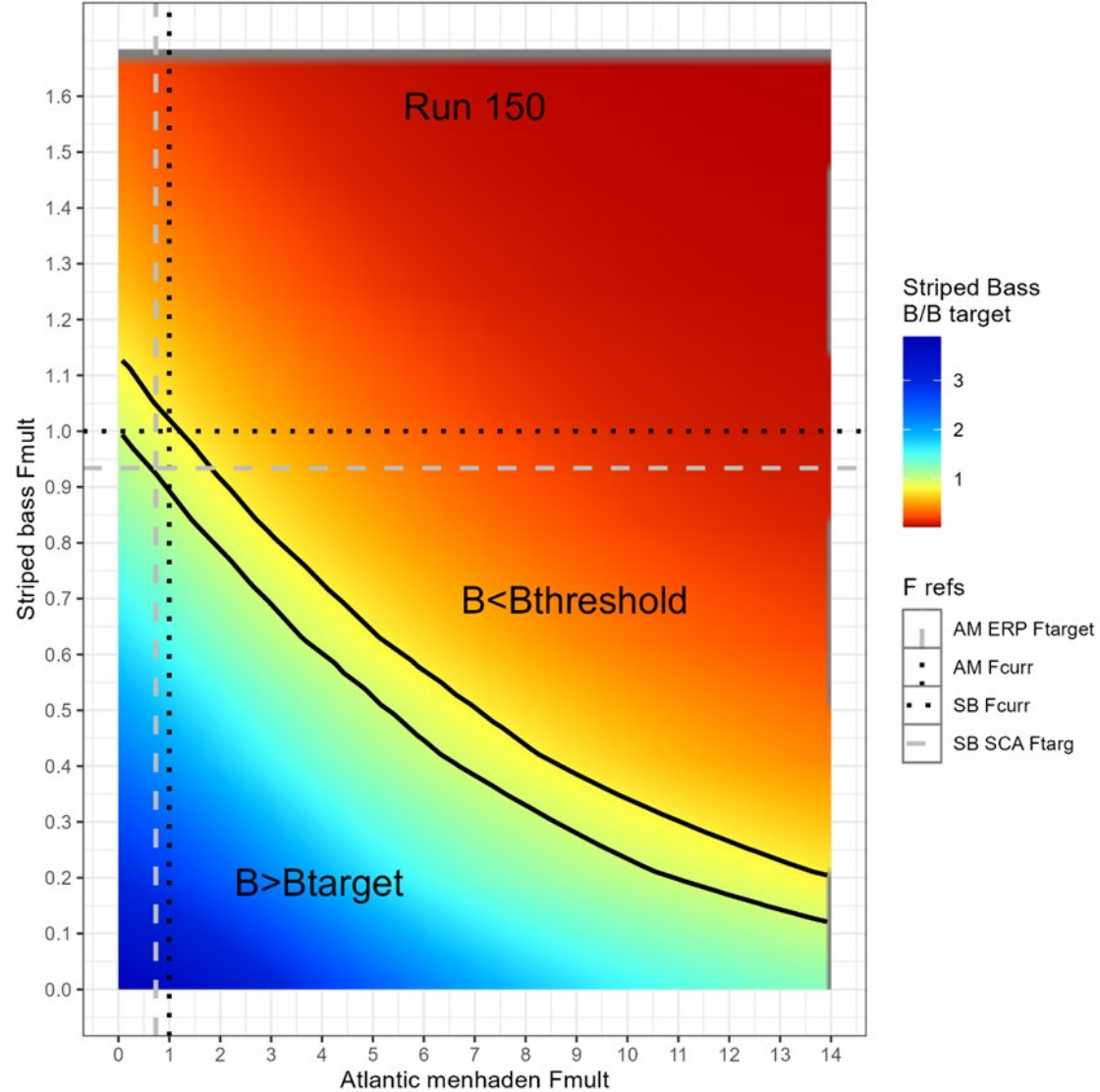
Spatial Considerations and Modeling Needs

- Current ERP models operate at a coastwide level and use seasonal overlap as a proxy for spatial structure.
- Key fine-scale interactions (e.g., predator-prey overlap in the Chesapeake Bay) are not explicitly modeled.
- Spatial effects are known to influence predator foraging success and localized prey depletion.
- Full spatial modeling remains a top priority for future assessments, managers, and stakeholders.

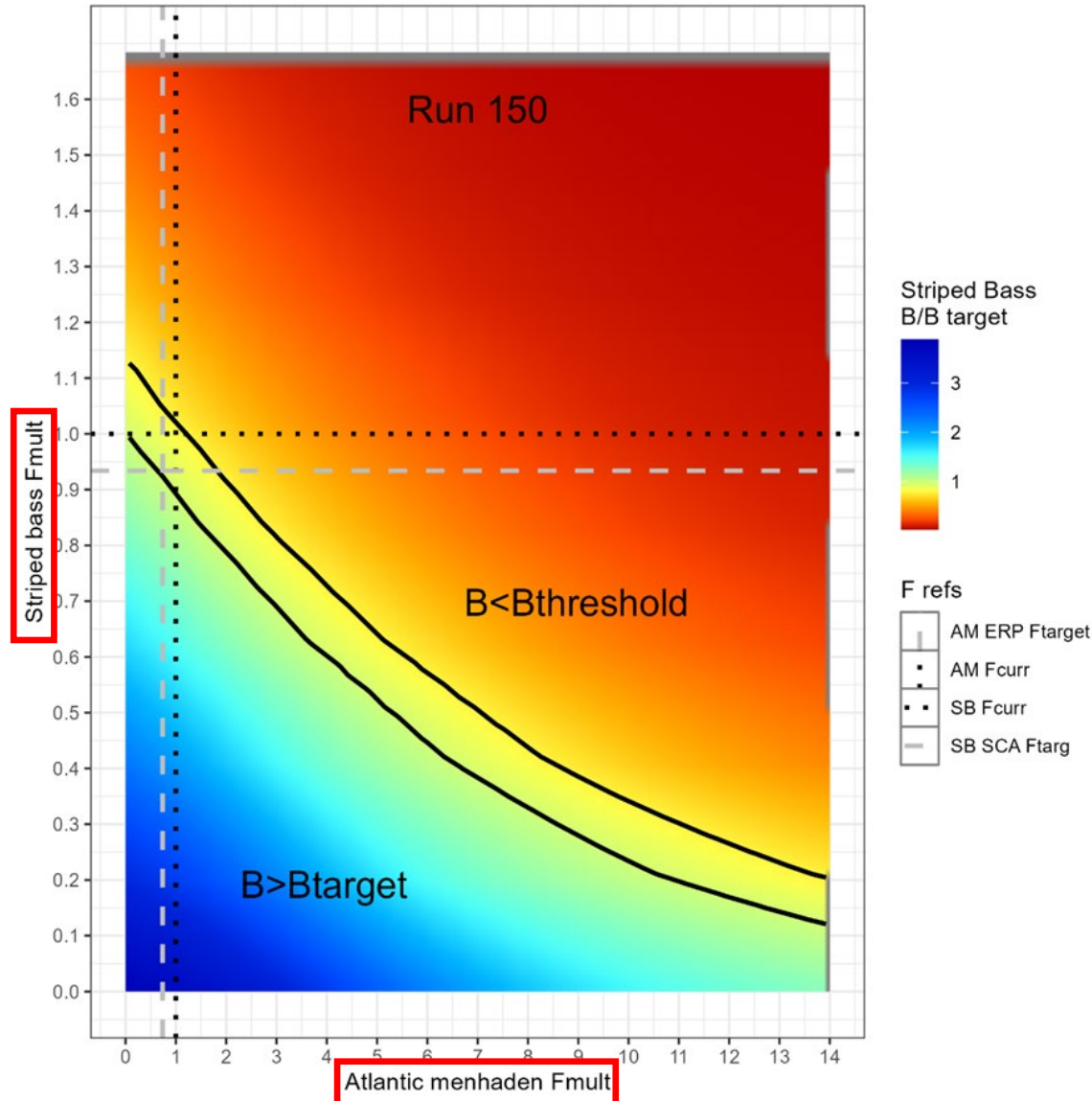
Management Advice and Trade-off Evaluation

- ERP WG supports continued use of BAM + NWACS-MICE to set harvest advice.
- BAM offers tactical advice; MICE quantifies ecosystem trade-offs and predator impacts.
- Surface plots enable managers to weigh predator and prey objectives.
- Translating between BAM and MICE introduces risk and uncertainty
- The ERP framework formalizes ecosystem trade-offs that were previously handled via ad hoc buffers.

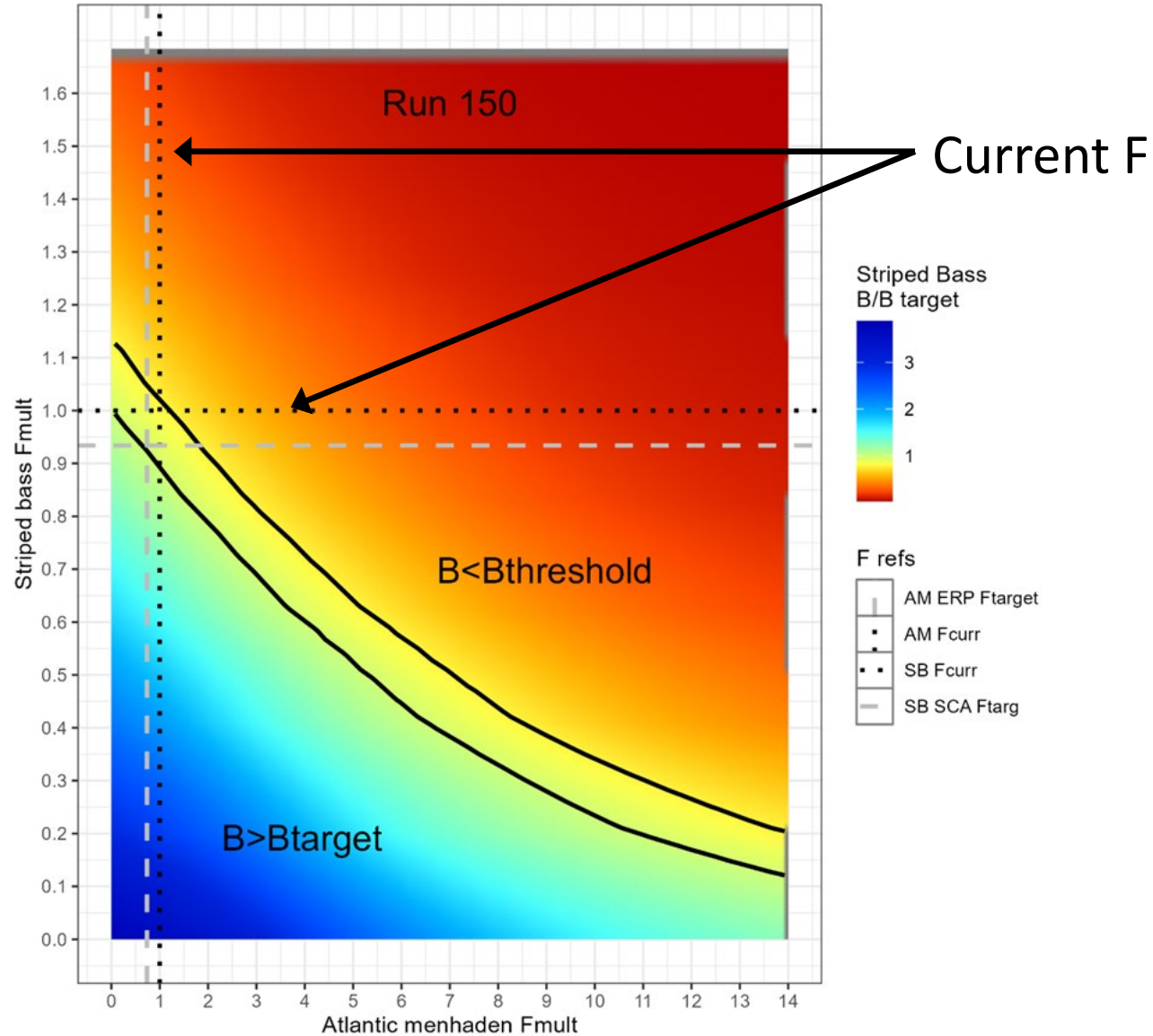
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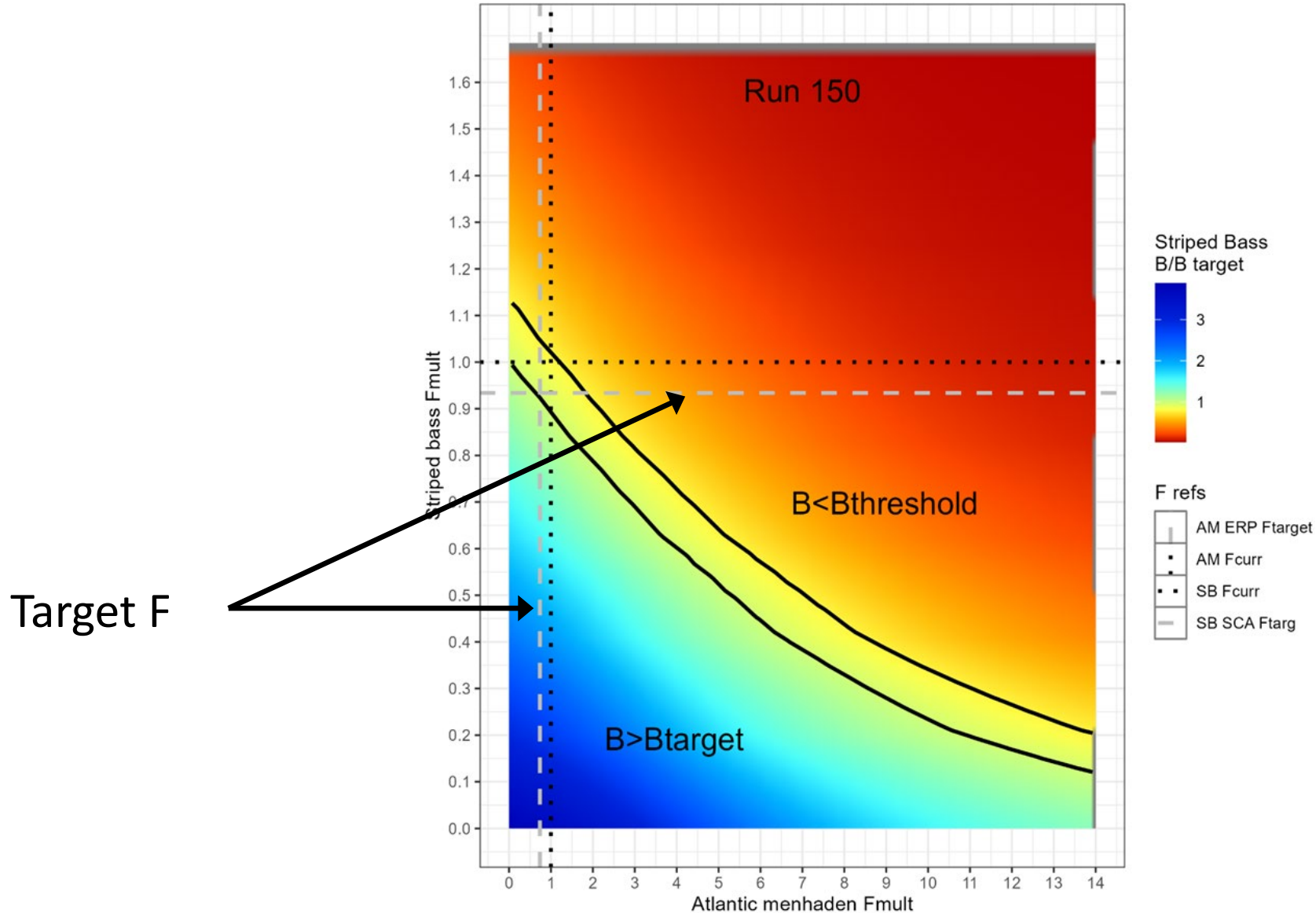
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