Preliminary Arrowtooth Flounder Bridging Model to CEATTLE

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Background

- Arrowtooth Flounder (Atheresthes stomias, ATF)
- Area: Gulf of Alaska (GOA)
- Tier/Cycle: 3a on four year cycle from prioritization
- Platform: Automatic Differentiation Model Builder (ADMB)
- Model: 19.0, same model structure since 2015 (ADMB model)
- Status: Not subject to overfishing, currently overfished, or approaching overfished
- See Shotwell et al., 2021 for more details

Plan Team or SSC Recommendations

- Collection of recommendations since 2019 from PT and SSC
- Recommend investigation of the following elements:
  - Recent lower recruitment trends and relationship to environmental conditions in the GOA, including the development of an ESP
  - Lack of fit in female survey age and fishery length compositions, including interactions between female natural mortality and selectivity
  - Incorporation of predation mortality estimates from the GOA CEATTLE model
  - Update growth and age-length conversion matrices

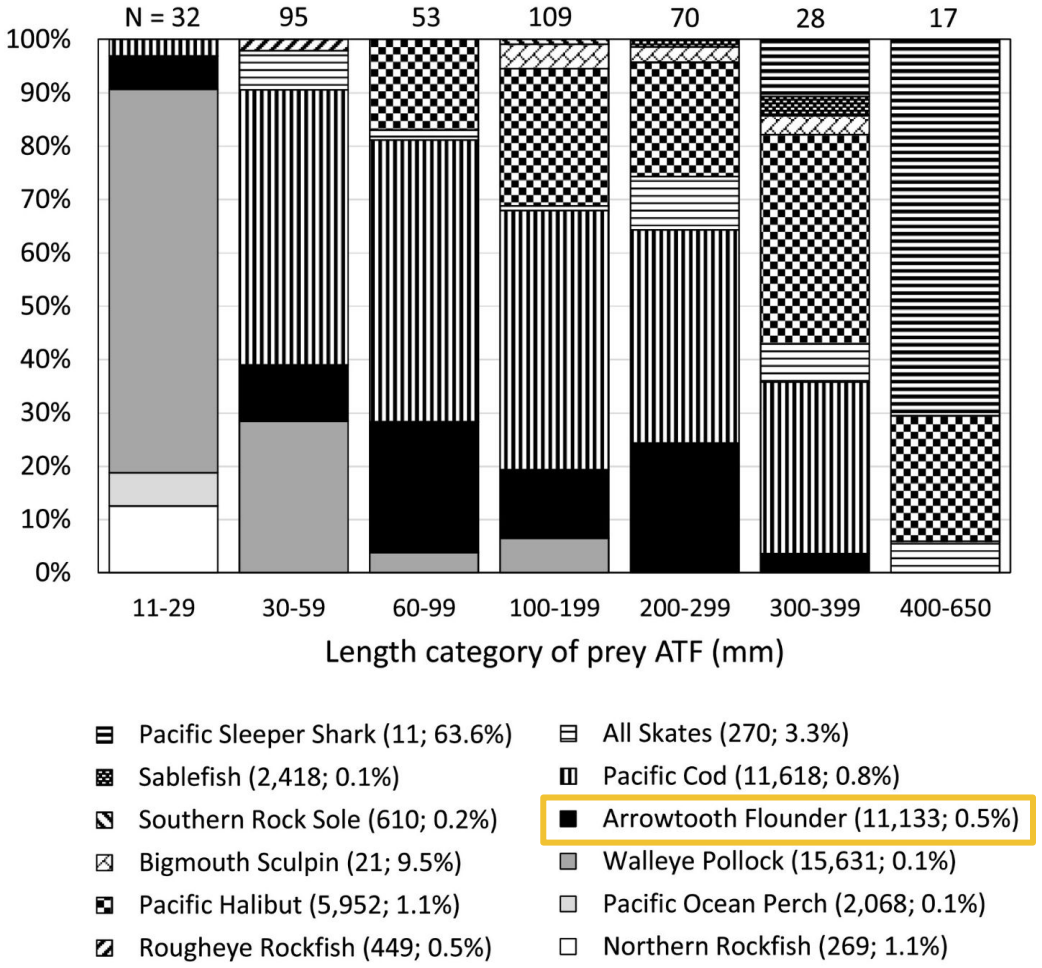
Goals

Begin to address the PT/SSC recommendations by:

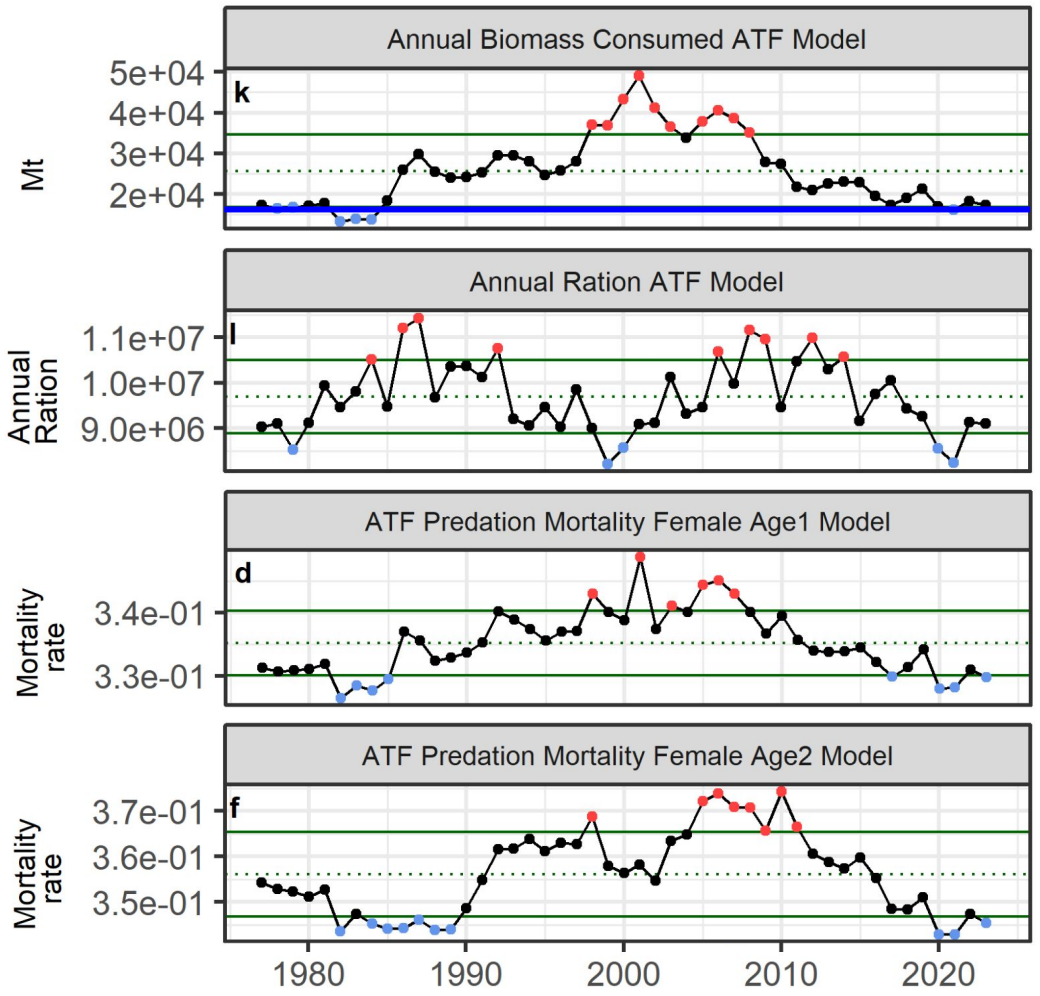
1. Updating the current ADMB model to TMB to potentially improve parameter estimation
2. Accounting for both the impacts of cannibalism and fishery removals in the population dynamics assessment model used for GOA ATF

Justification

- Template Model Builder
  - Based on ADMB but can estimate time-varying parameters as random effects
  - Current assessment does not estimate recruitment variance parameter
- Cannibalism
  - Doyle et al., 2018 found non-trivial amount of cannibalism on small to medium size ATF
  - Adams et al., 2022 estimated 27-37 kt of ATF consumed by predators in the multispecies model, most were ATF
  - Fishery 1.2-37 kt of ATF, average 17 kt



Preliminary ESP Mini



- Biomass ATF consumed by cannibalism exceeds catch in many years (blue line = average of catch at 17 kt)
- ATF ration is cyclical but high (average = 9.7 mmt), emphasizing role of ATF in ecosystem
- Predation mortality for females and males is higher than fixed estimates in current assessment model
- Predation mortality for age 1 is lower than for age 2 across all years
- Predation mortality is more variable for age 2 than age 1 (possibly habitat related)

Methods

- Platform: CEATTLE or Climate-Enhanced, Age-based model with Temperature-specific Trophic Linkages and Energetics
  - From Holsman et al., 2016 and expanded for groundfish in the GOA using TMB by Adams et al., 2022
  - Links single-species age-structured models through predation mortality
  - Conditioned on the temperature-dependent bioenergetic demand and diet-based prey-selectivity patterns of predators
  - Can be run in single-species mode or multi-species mode
- Data: uses the same inputs as the ADMB operational assessment
  - Addition of diet and bioenergetics from AFSC stomach sampling program and bottom temperature data from Climate Forecast System Reanalysis (Hulson et al., 2023)

Data

Source	Data	Years
AFSC GOA bottom trawl survey	Survey biomass and standard error	1984,1987,1990,1993,1996,1999,2001,2003, 2005,2007,2009,2011,2013,2015,2017,2019,2021
	Age composition	1984,1987,1990,1993,1996,1999,2001,2003, 2005,2007,2009,2011,2013,2015,2017,2019
	Diet composition	1990,1993,1996,1999,2001,2003,2005,2007,2009 2011,2013,2015
Holsman and Aydin (2015)	Bioenergetic demand	1990,1993,1996,1999,2001,2003,2005,2007,2009 2011,2013,2015
Fishery	Catch Biomass	1977 - 2019,**2020-2023**
	Length composition	1977 - 1993, 1995-2020

Models

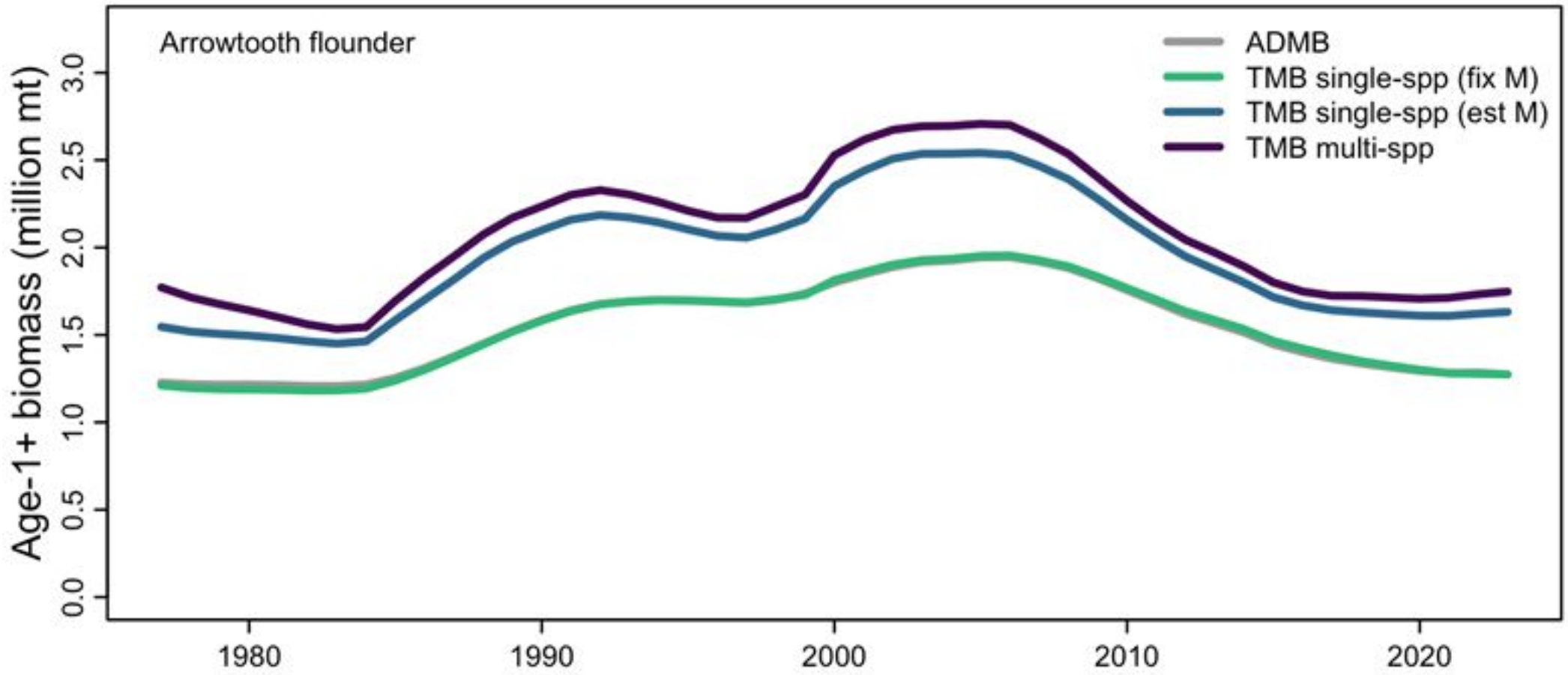
1. ADMB model: current operational single-species ADMB based assessment from the 2021 SAFE (Shotwell et al., 2021) with updated catch to 2023
2. TMB single-spp (species) fixed natural mortality (*M*) model using CEATTLE *
3. TMB single-spp (species) estimated sex-specific *M* model using CEATTLE
4. TMB multi-spp (species) model using CEATTLE that estimates sex-, age-, and time-varying *M* due to cannibalism from ATF (*M2*) and sex-specific residual mortality (*M1*)

*Note: extensive bridging appendix between Model 1 and 2, almost no difference

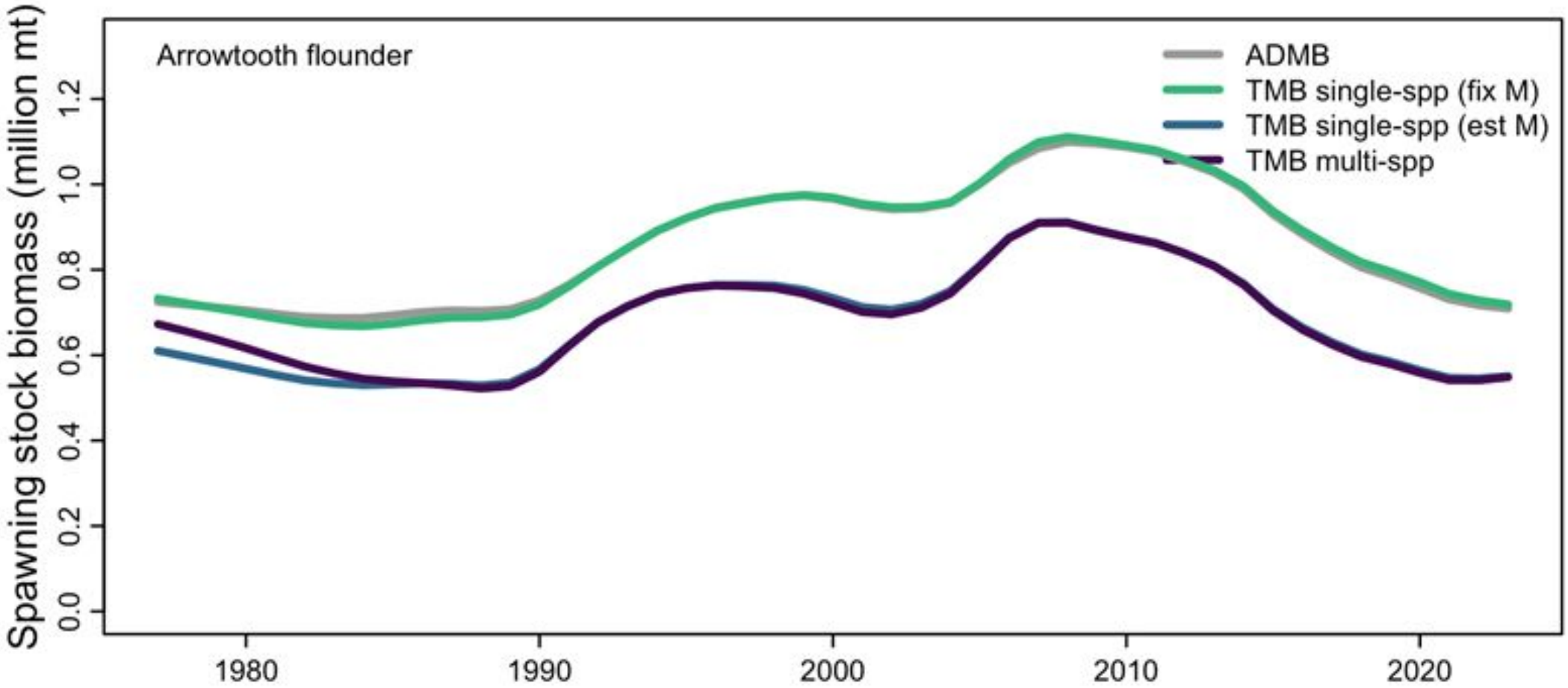
Results

- ADMB (model 1) and CEATTLE single spp fixed M (model 2) have very similar trends
- Single spp CEATTLE that estimated *M* (model 3) and multi-spp CEATTLE model (model 4) have similar trends and higher estimates of recruitment and biomass
  - Model 3 estimated *M* higher for both males and females than fixed values used in Models 1 & 2
  - Models 3 & 4 had lower estimates of SSB due to higher estimates of mortality for older fish
  - Model 4 higher estimates of total M only impacted younger age-classes (age 1-8)

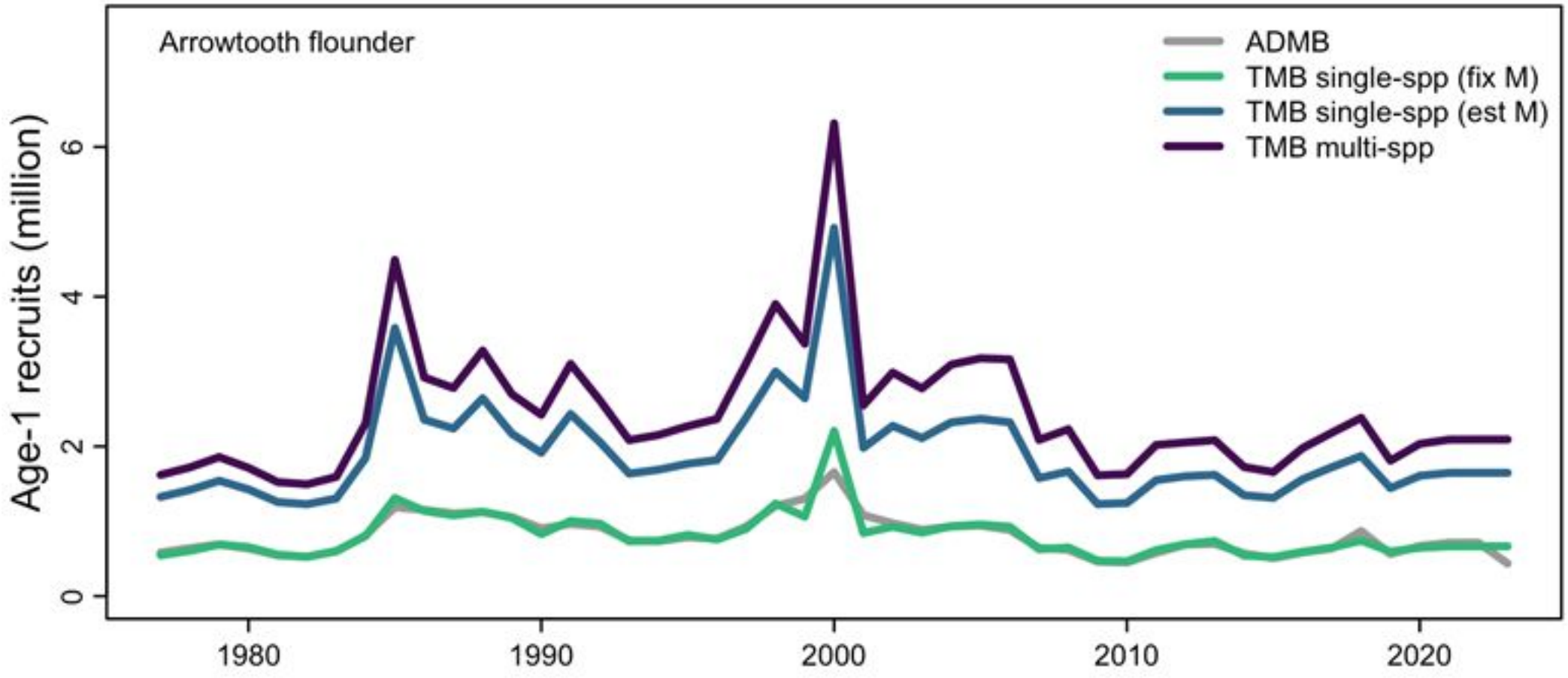
Results - Total Biomass



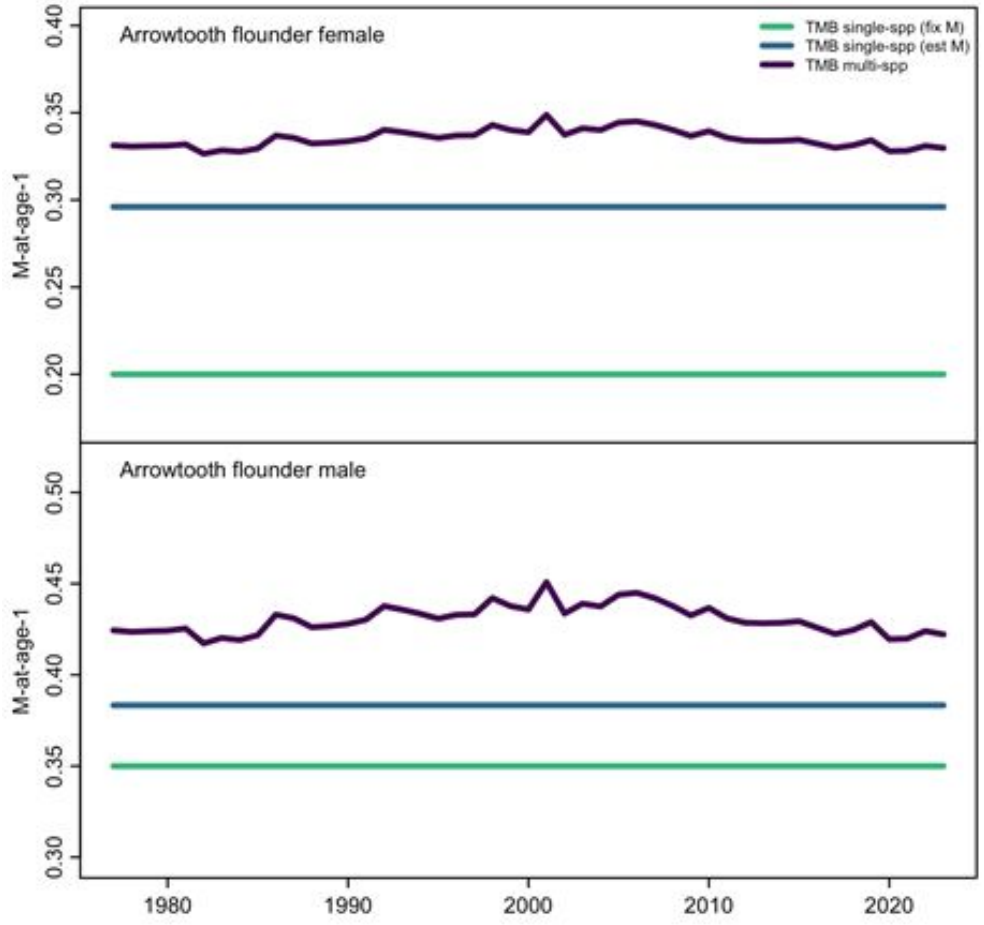
Results - Spawning Stock Biomass

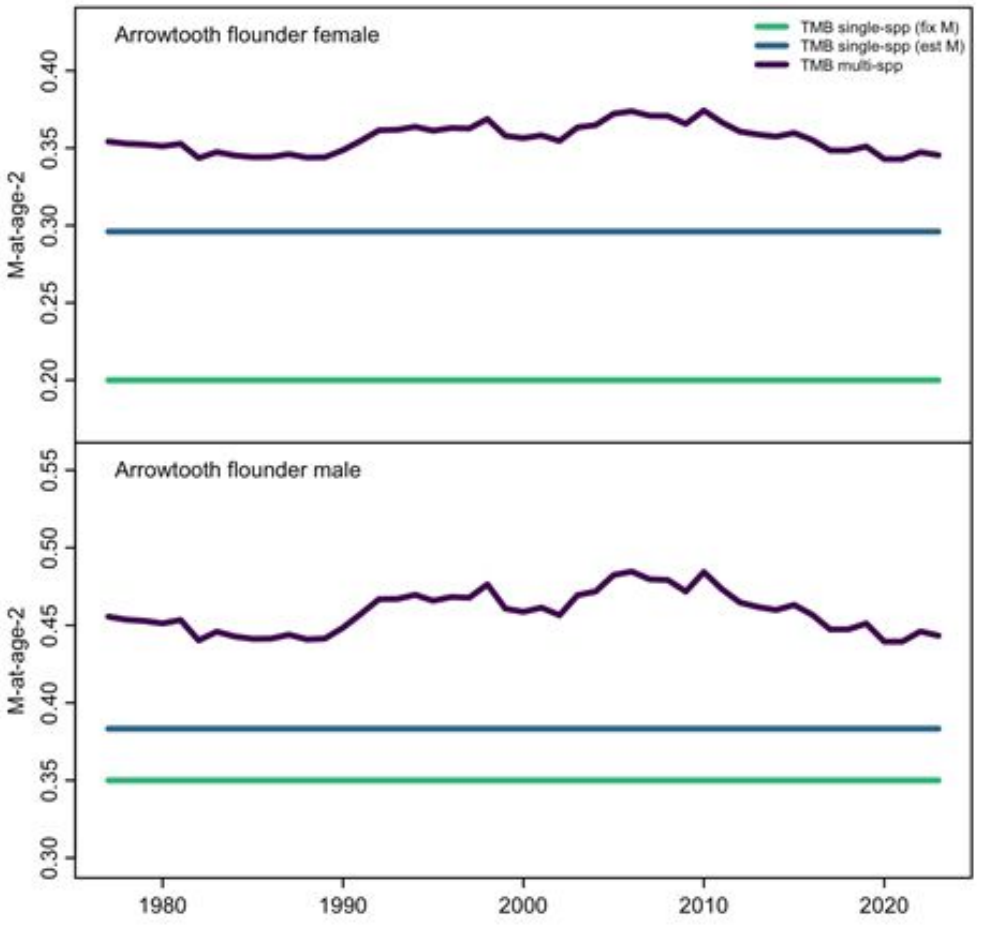


Results - Recruitment

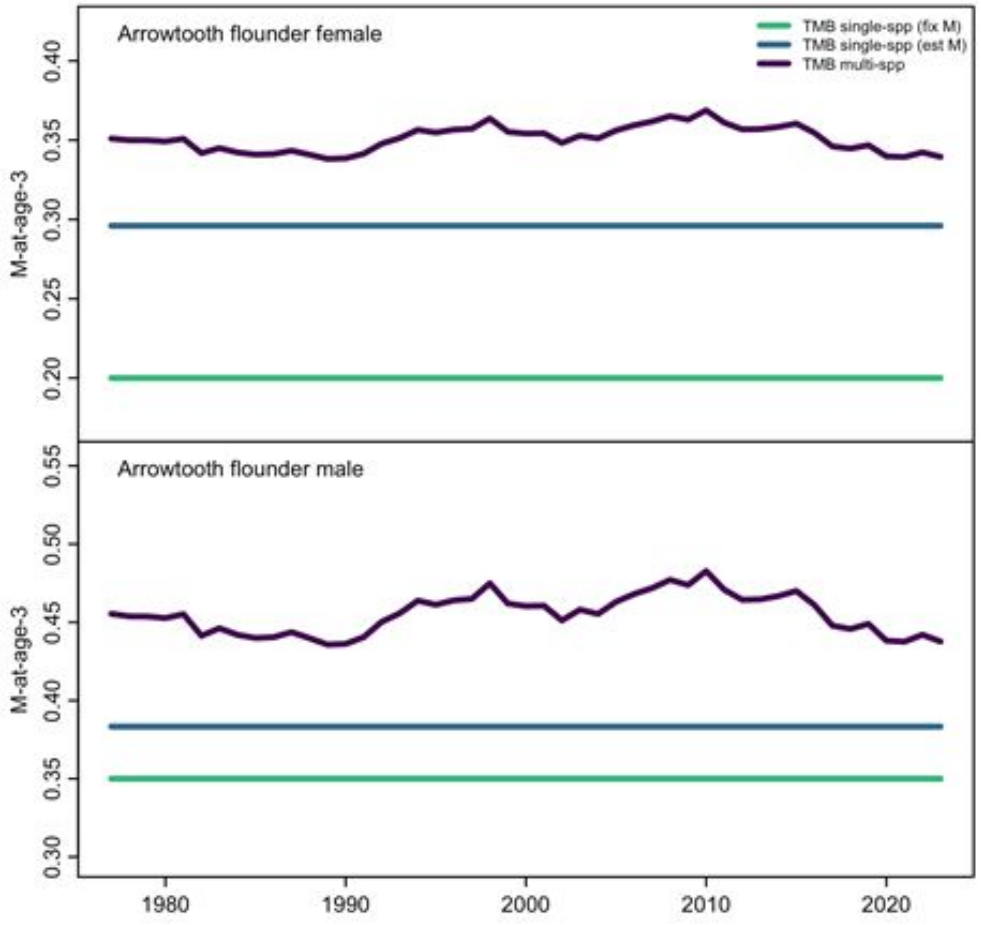


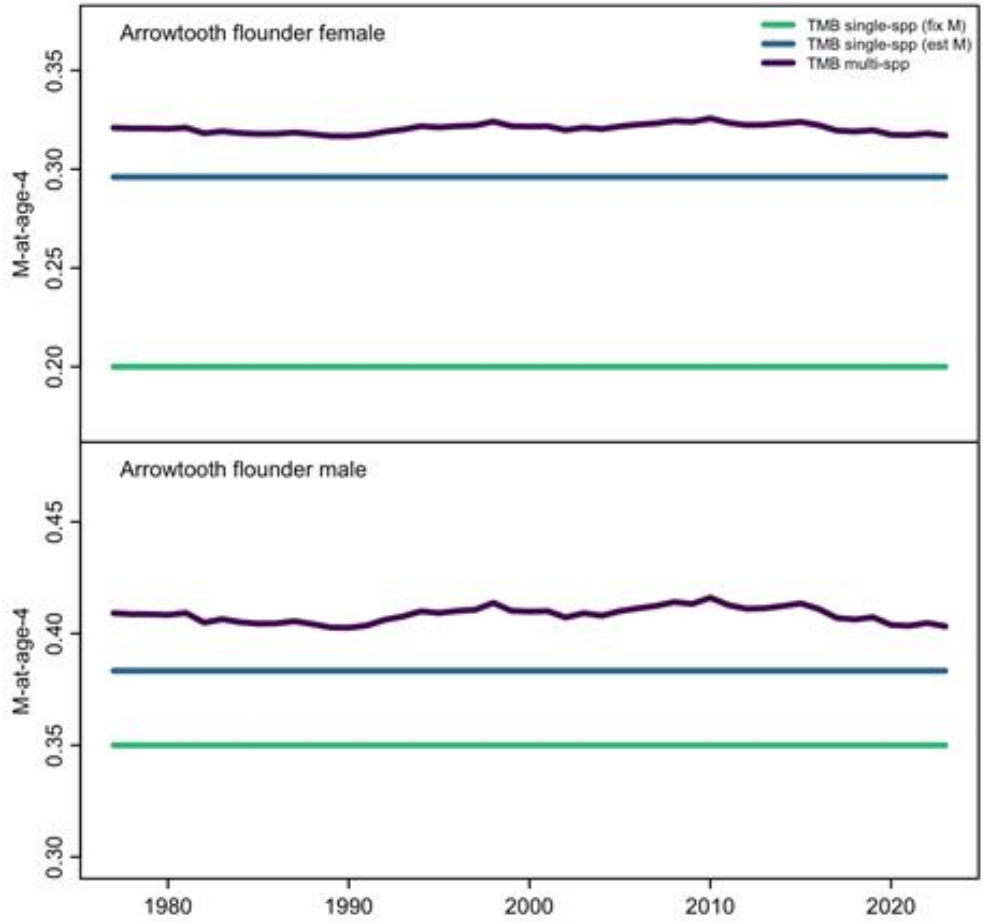
Results - Total Natural Mortality Age 1, 2





Results - Total Natural Mortality Age 3, 4



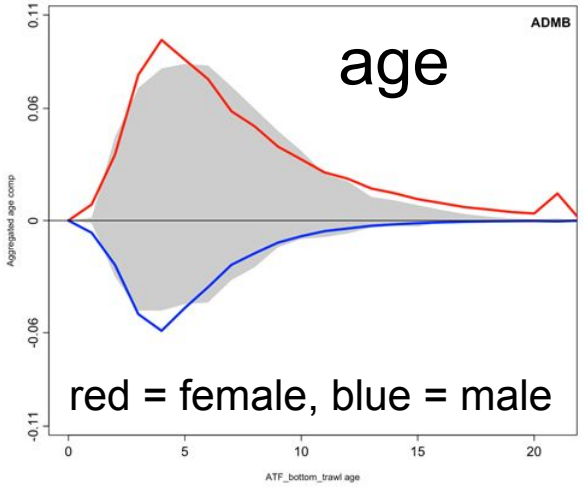


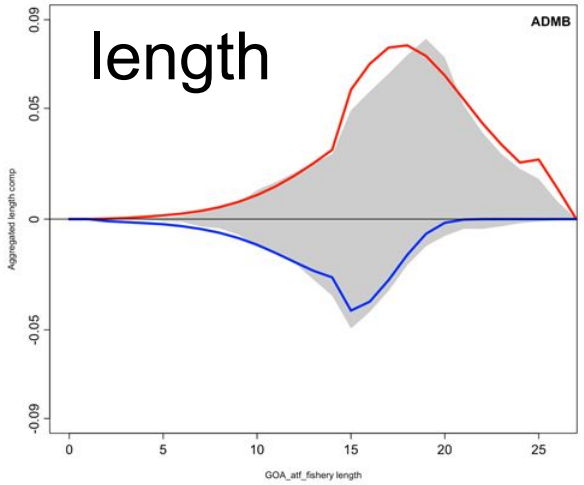
Results - Likelihood and Fit

- Single spp that estimated *M* (model 3) had lowest -lnL and multi-spp (model 4) had lower -lnL than models that fixed *M*
- Models that estimated *M* had improved fits to survey biomass, survey age composition, and fishery length composition data
- Models with fixed *M* (1, 2) had similar pearson and OSA residuals, models that estimated *M* (3, 4) had smaller OSA residuals
- All models had a positive trend for the female 1979 cohort from survey age data and all fit the plus length bin for males poorly

Results - Aggregated survey age & fishery length

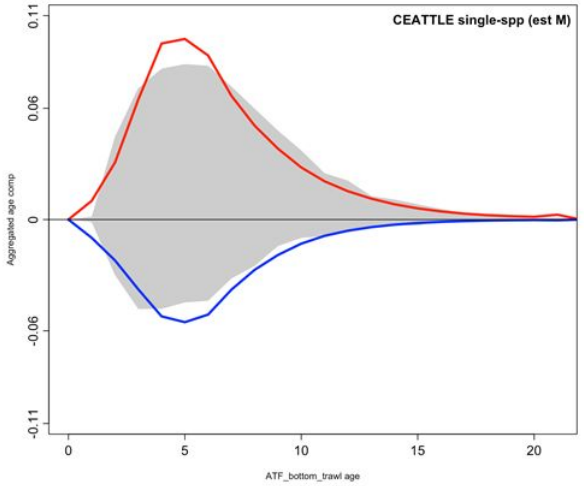
ADMB
Model 1

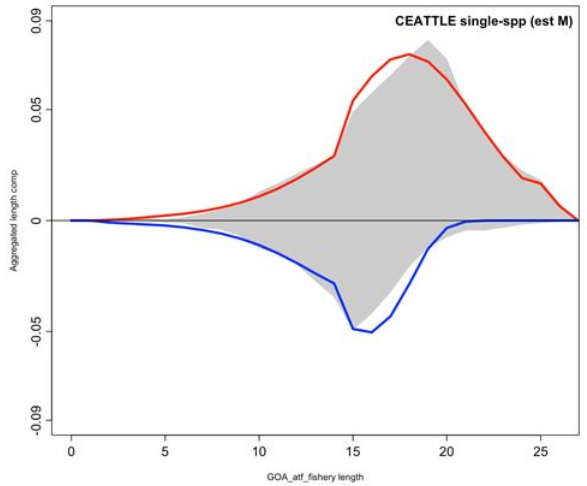




Kinks in older female ages and higher lengths

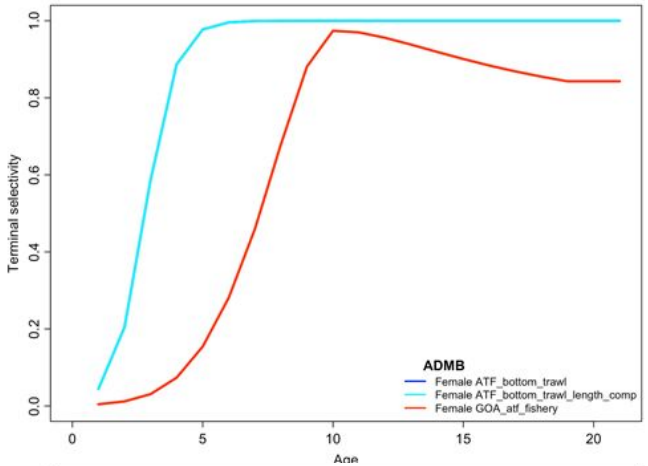
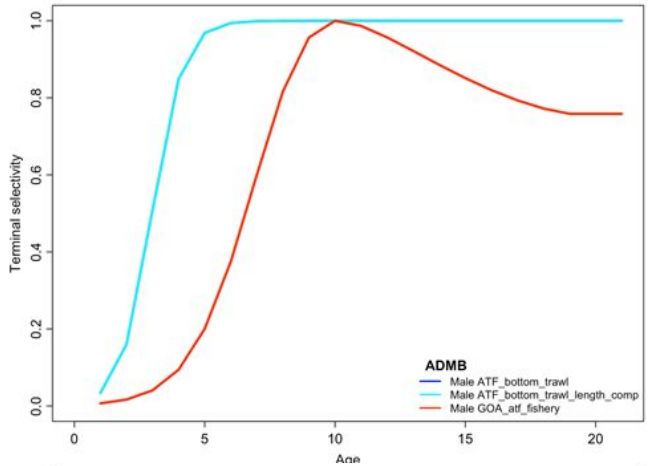
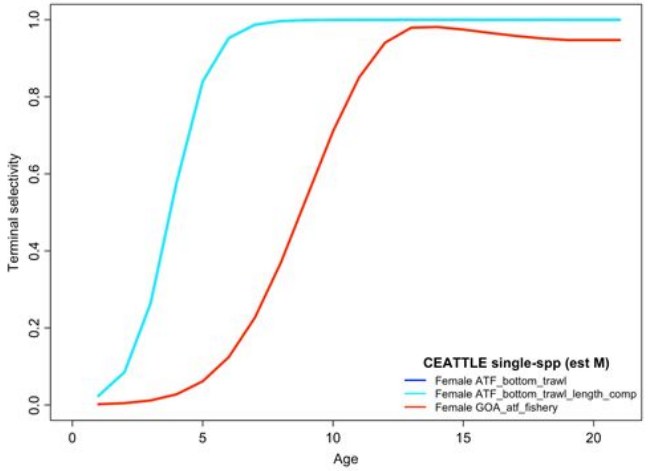
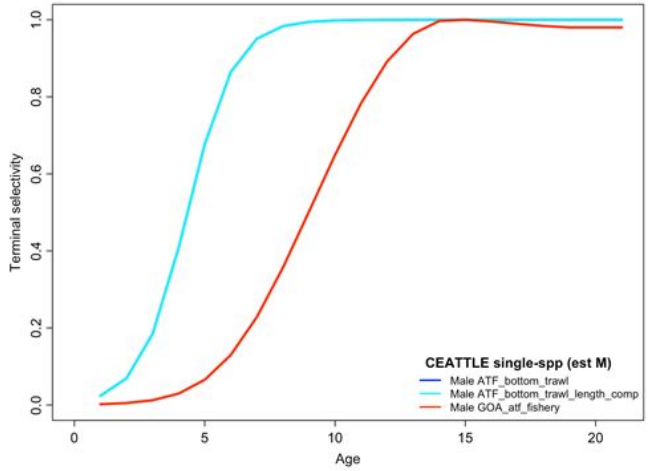
CEATTLE
Estimated M
Model 3



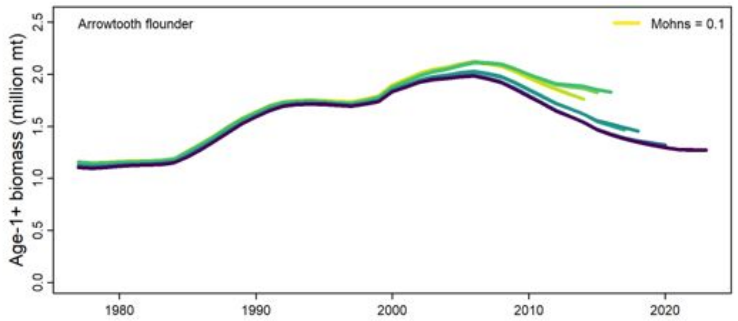
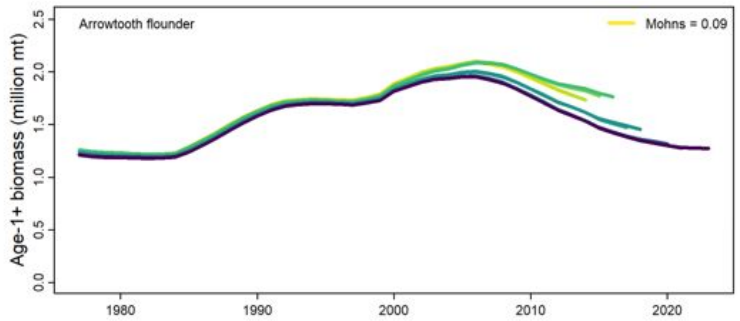
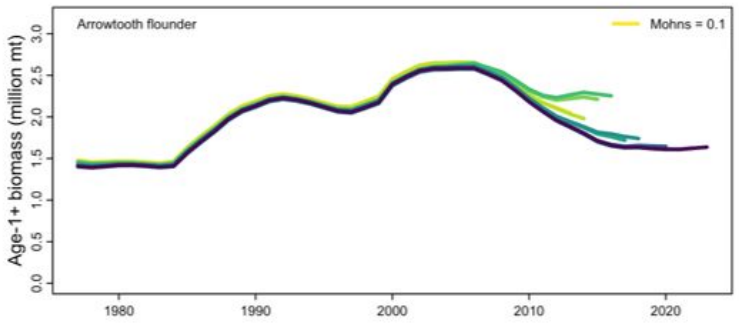
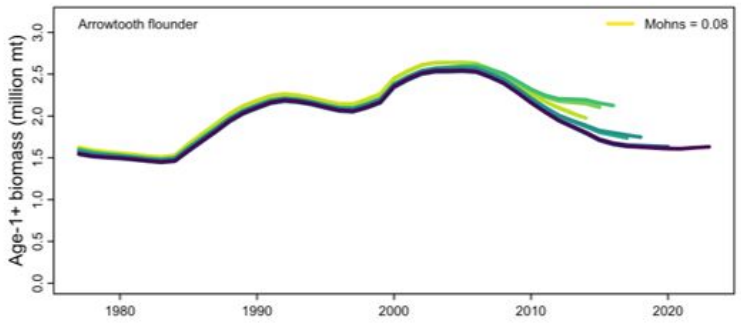


Better fit particularly in older ages and higher lengths

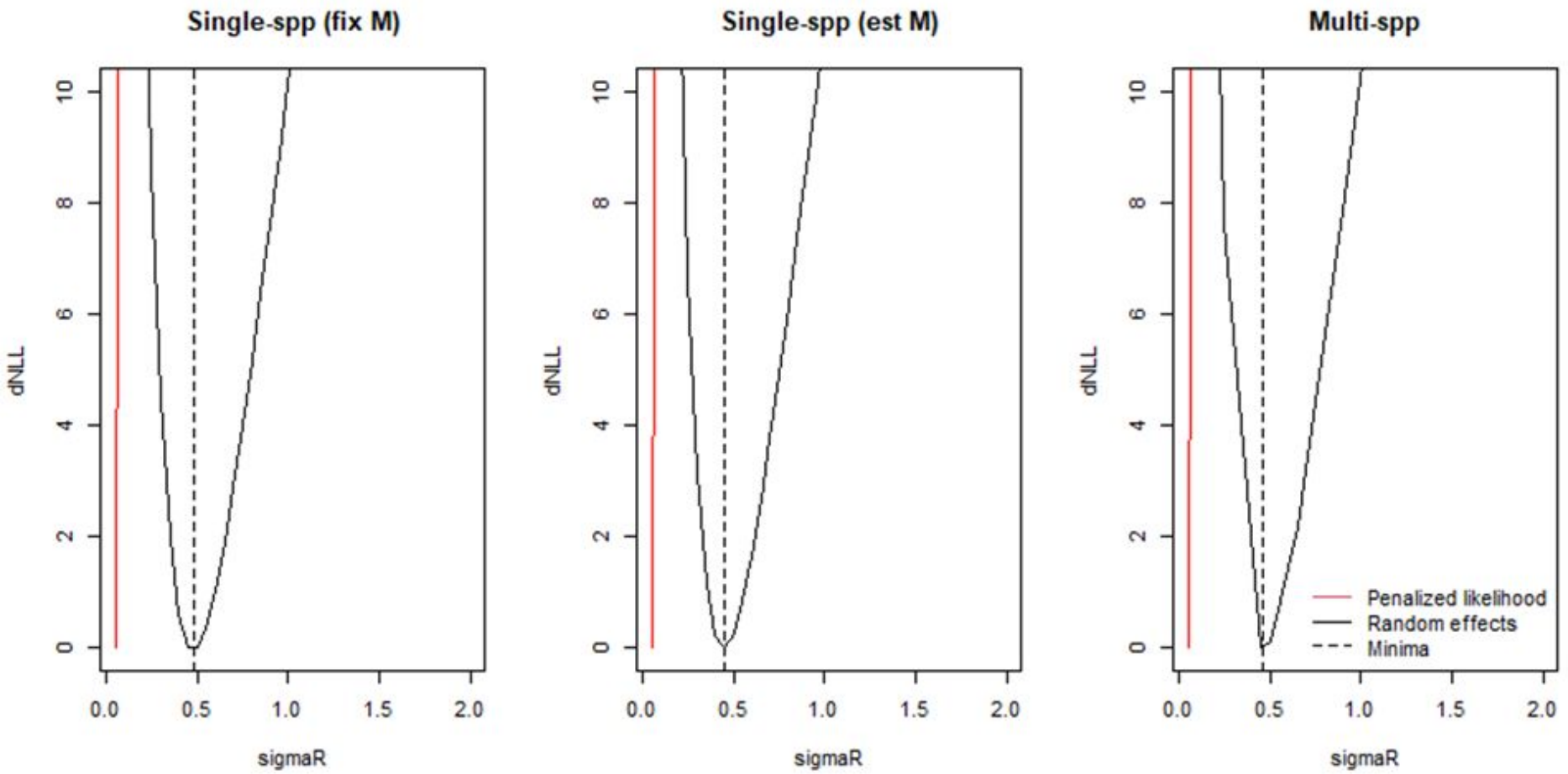
Results - Selectivity

	Female	Male	
ADMB Model 1			More dome-shaped in the fishery
CEATTLE Estimated M Model 3			More asymptotic in the fishery

Results - Retrospective

Model	Penalized likelihood	Marginalized likelihood
2. Single-spp fix M		
3. Single-spp est M		

Results - Sigma R Profile



Recommendations

- Move the stock assessment model to Template Model Builder
  - Better treatment of recruitment deviates as random effects
  - Explicitly estimates the associated variance parameter
- Estimate sex-specific, but age- and time-invariant natural mortality
- Update the growth transition matrices and aging error matrices
- Update diet data and use the multi-species model to inform age- and (possibly) time-varying mortality
- Explore model sensitivity to assumptions of catchability

Discussion

1) Cannibalism appears to be a significant source of mortality in the model, is it worth including, or just track it in ESP?
2) What models should we bring forward for next September? Sufficient bridging to move to TMB/CEATTLE?
3) Are there any elements that we are missing that the Plan Team would like us to include?
4) Are there other ideas on how to use the multi-species model to inform decisions?

Thank You!

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