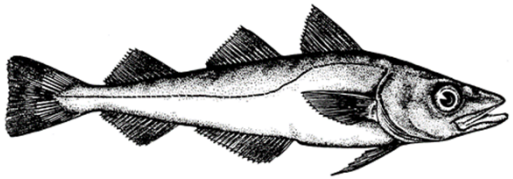
GOA Pollock



Cole Monnahan, Grant Adams
2026 November Plan Team
cole.monnahan@noaa.gov

Collaborators: Bridget E. Ferriss, S. Kalei Shotwell, Zack Oyafuso, Mike Levine, Denise McKelvey

Author's <u>2027 ABC = 155,551 t</u>

- Increase of 17% from 2026 (2024 SAFE)
- 2028 ABC decreases to 106,221 t (-31%)
- B38.5 in 2027
- No reduction from max ABC.

Changes (cumulative) to model:

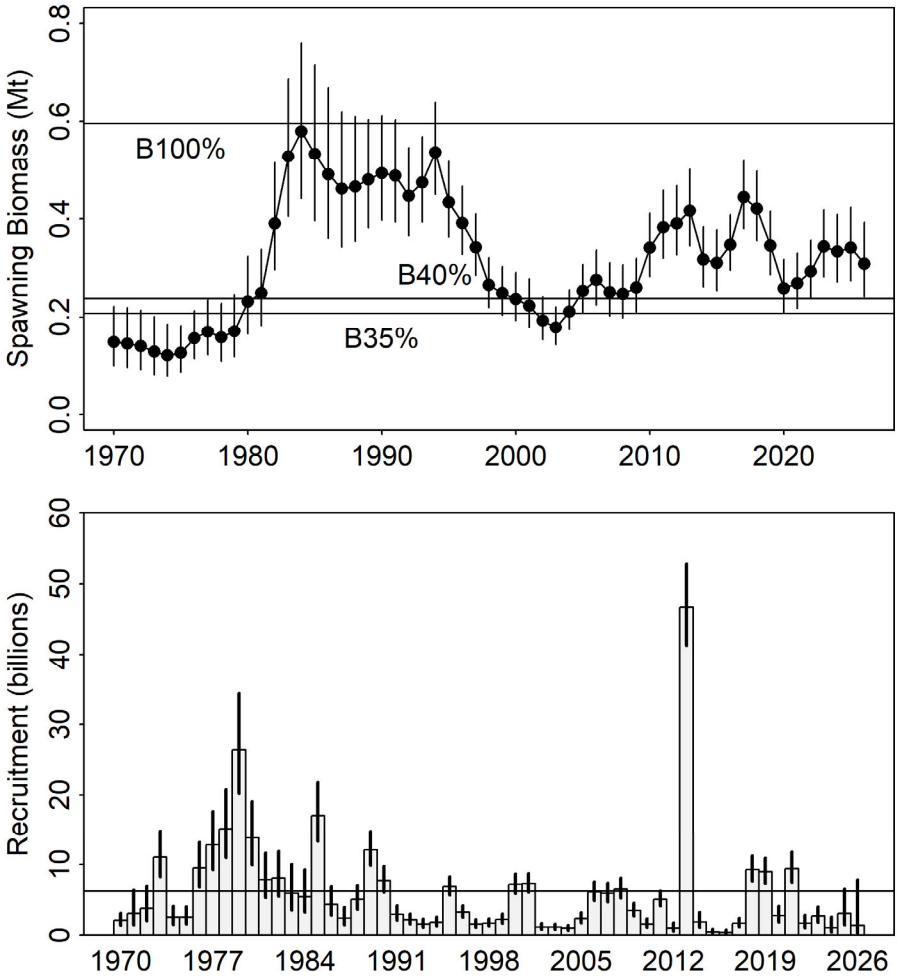
- 26a: Rceattle bridge with σ_R estimated
- **26b: 26a + DSEM module on recruitment (author recommended)**

Concerns:

- Very poor fit to NMFS bottom trawl index
- Poor recent recruitment, and large 2017, 2018 & 2020 cohorts aging out

Positives:

- Better retrospective pattern

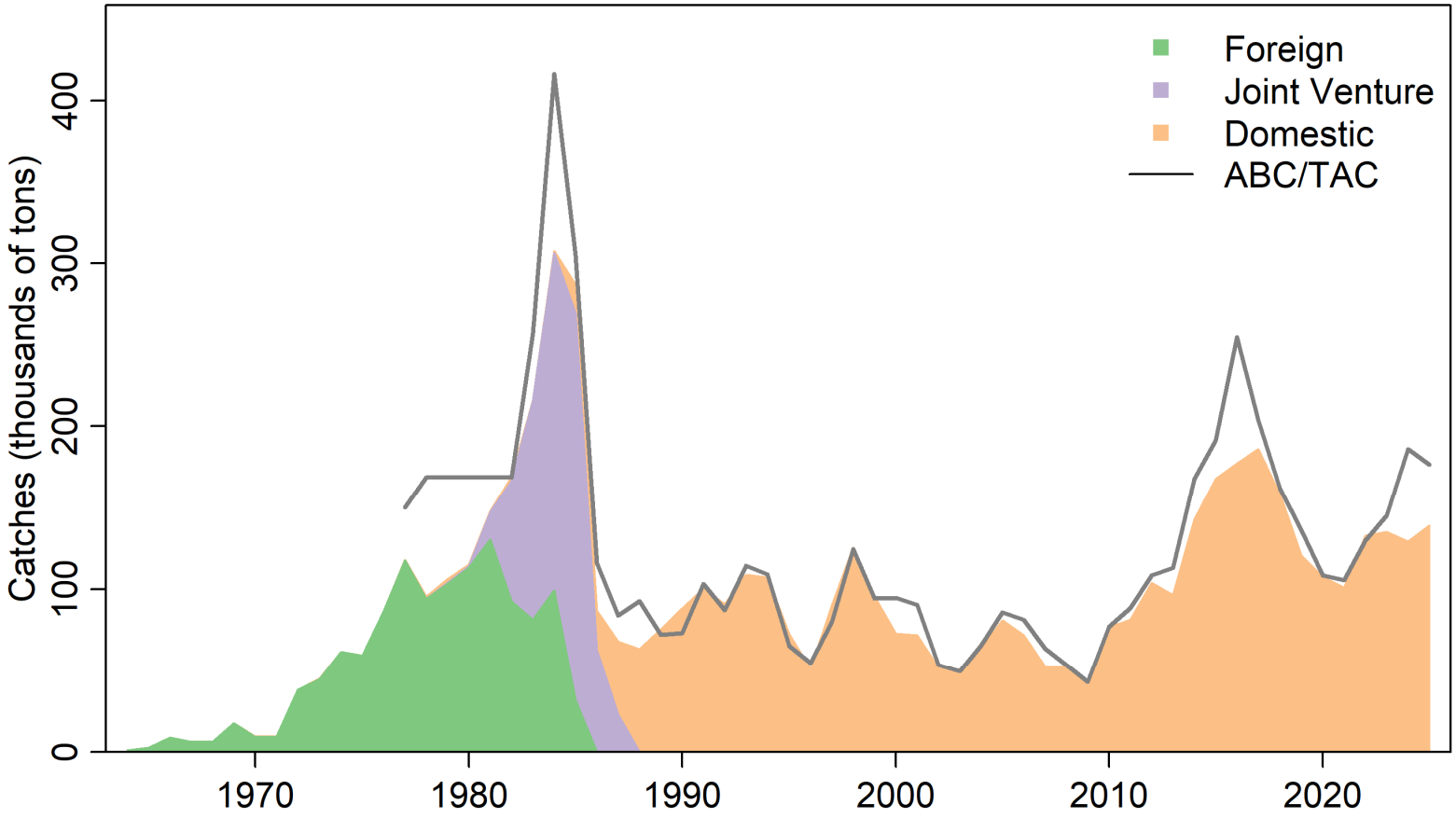


Model overview

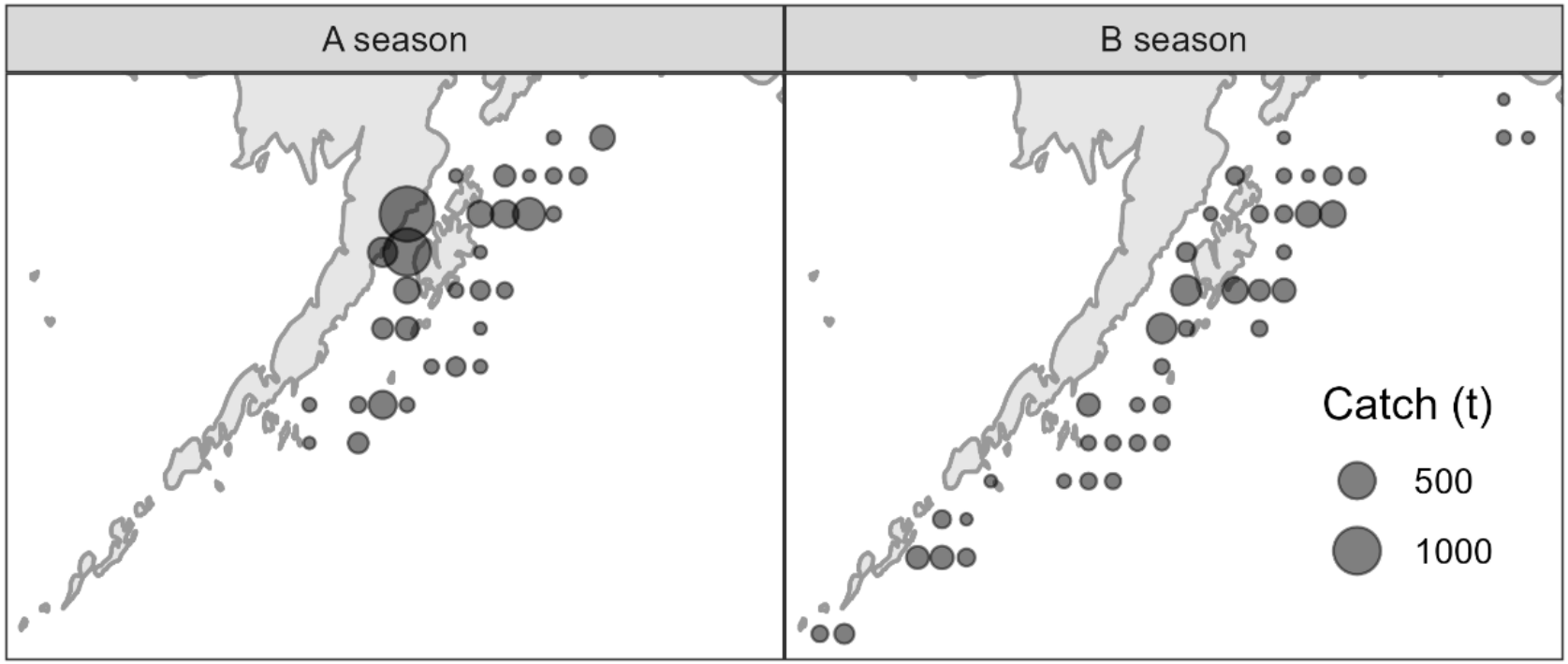
- Single-sex, single fishery, ages 1-10+
- Empirical weight at age
  - No internal length dynamics, all age-based processes
  - Length comps converted via specified matrices
- Fishery selectivity is double logistic
- Time-varying (RW) initial slope/intercept
- Fitted to 4 surveys:
  - NMFS winter (Shelikof) + summer (coast wide) acoustic
  - NMFS and ADF&G summer bottom trawl
- Time-varying catchability for Shelikof and ADF&G
- Prior on NMFS BT catchability sets scale and stabilizes model

Catch history

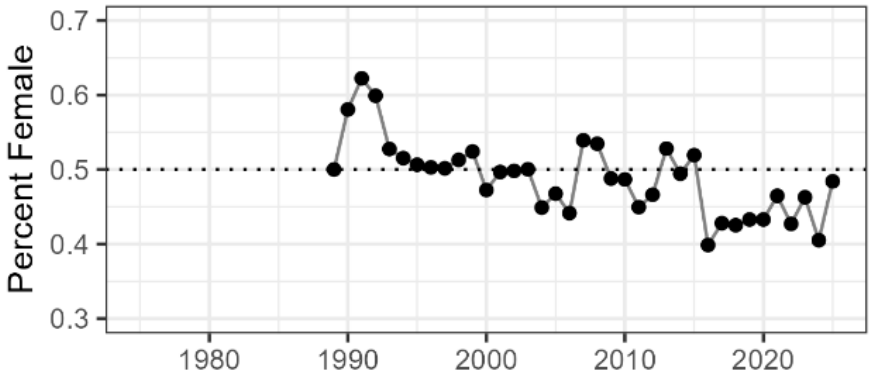
2026 projected catch = TAC = 129,749

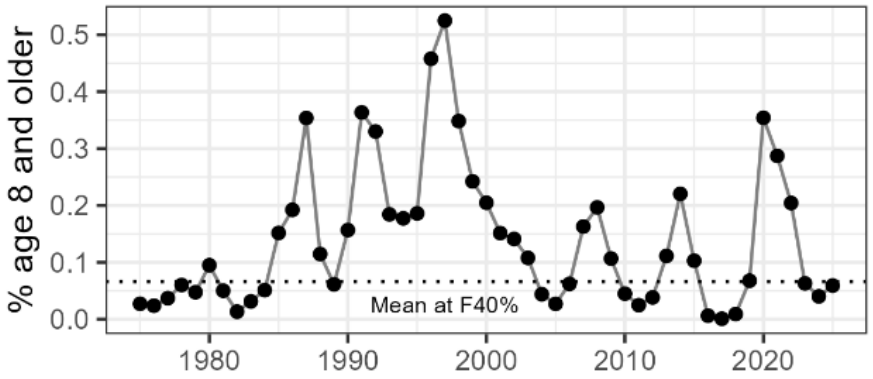


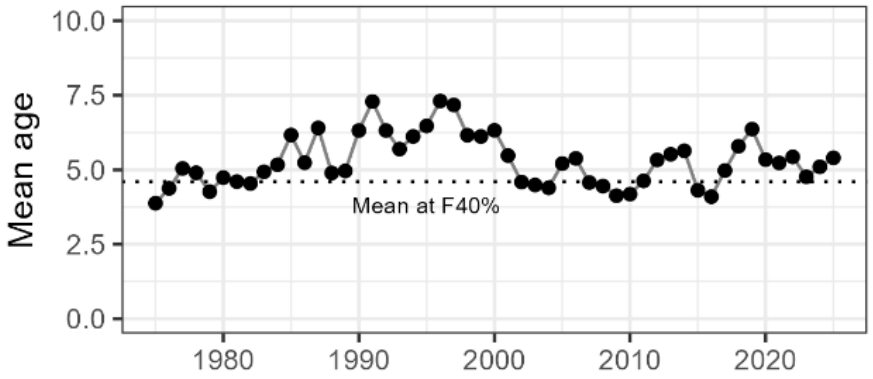
2025 fishery catch distribution

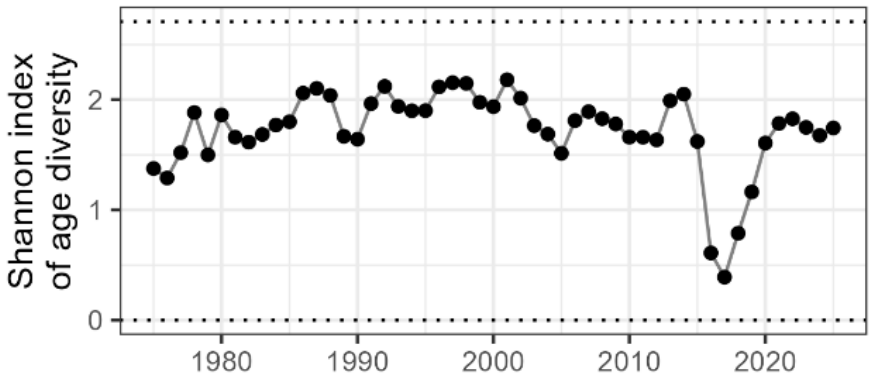


Fishery catch indicators









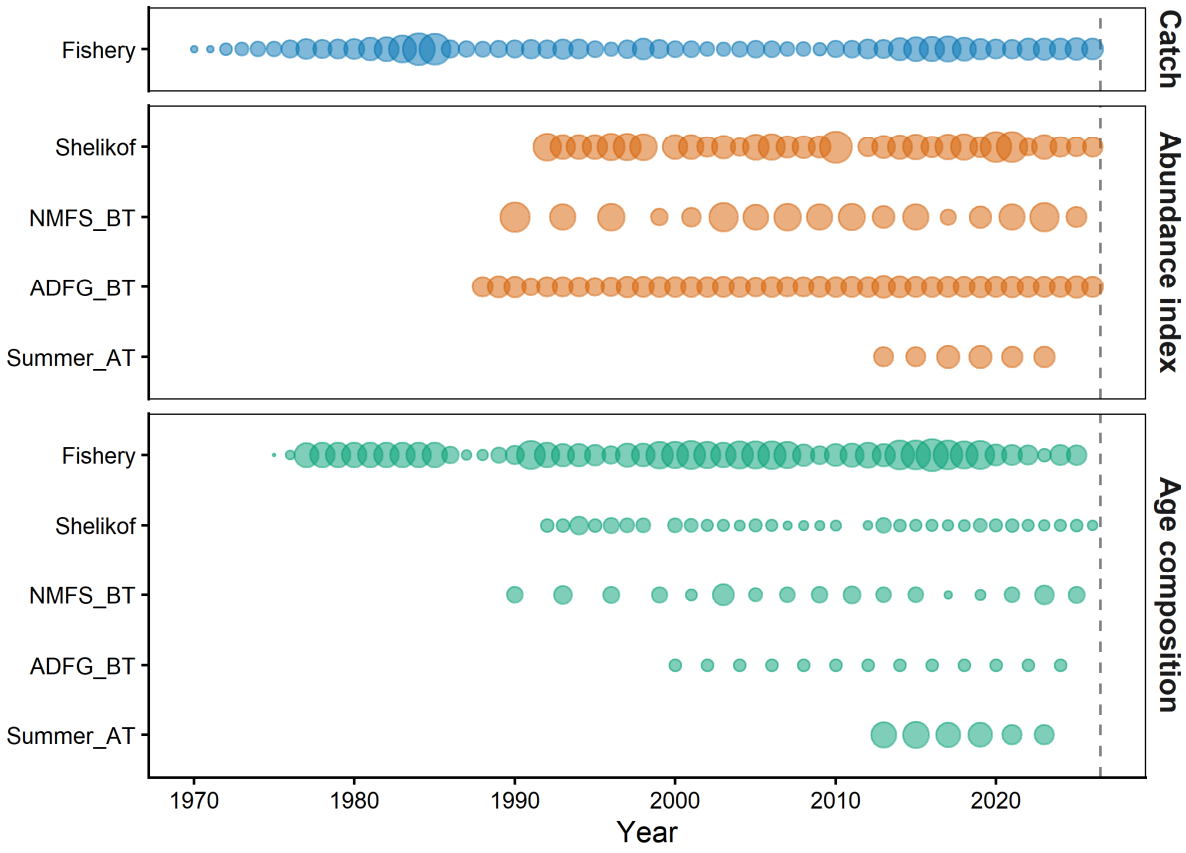
New data available in 2026

2026 was an “off” year in the GOA

- 2026 winter Shelikof acoustic survey (index and ages)
- 2025 NMFS BT ages
- 2026 ADF&G bottom trawl index

NMFS BT up 35% (2023 to 2025)
Shelikof down 35% from 2025
ADF&G down 27% from 2025

Summer AT discontinued in 2025



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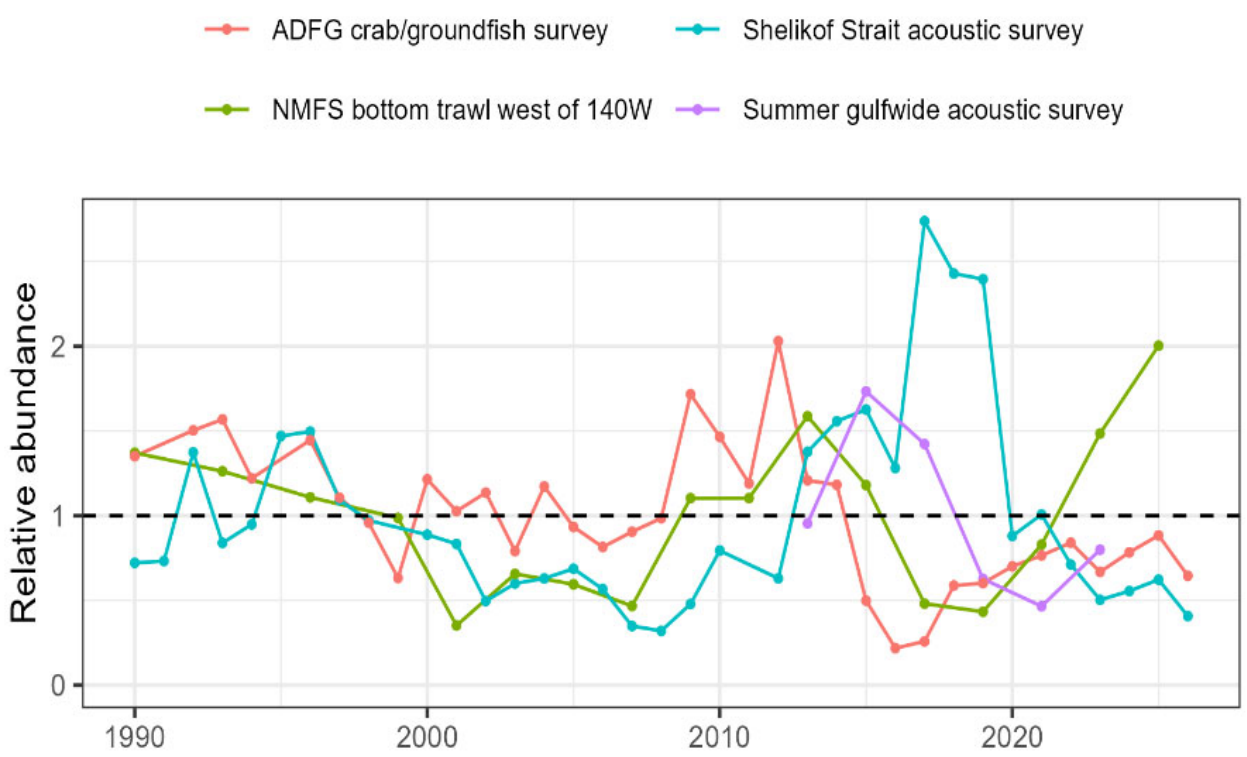
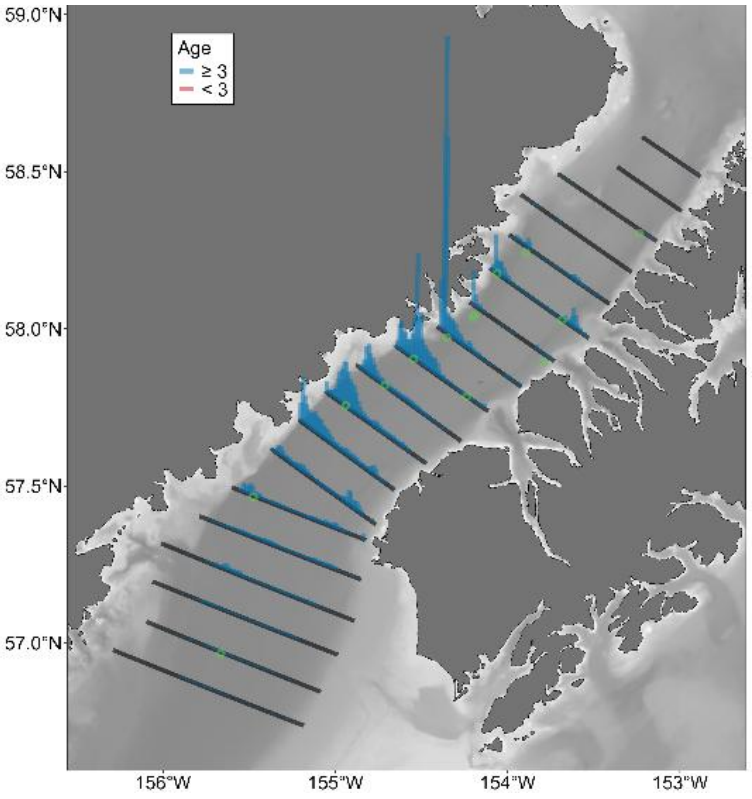
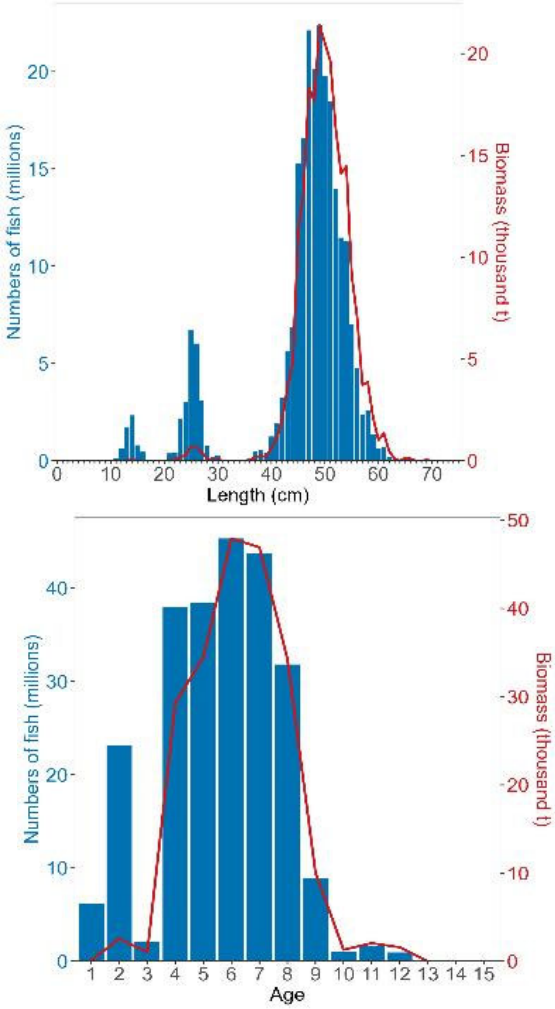


Winter acoustic results

- Shelikof interrupted due to inclement weather
- Missed south end of Strait
- No evidence of missed fish, using data as-is
- Plans to incorporate areas outside Shelikof into assessment in 2027





Thanks to D. McKelvey (MACE)

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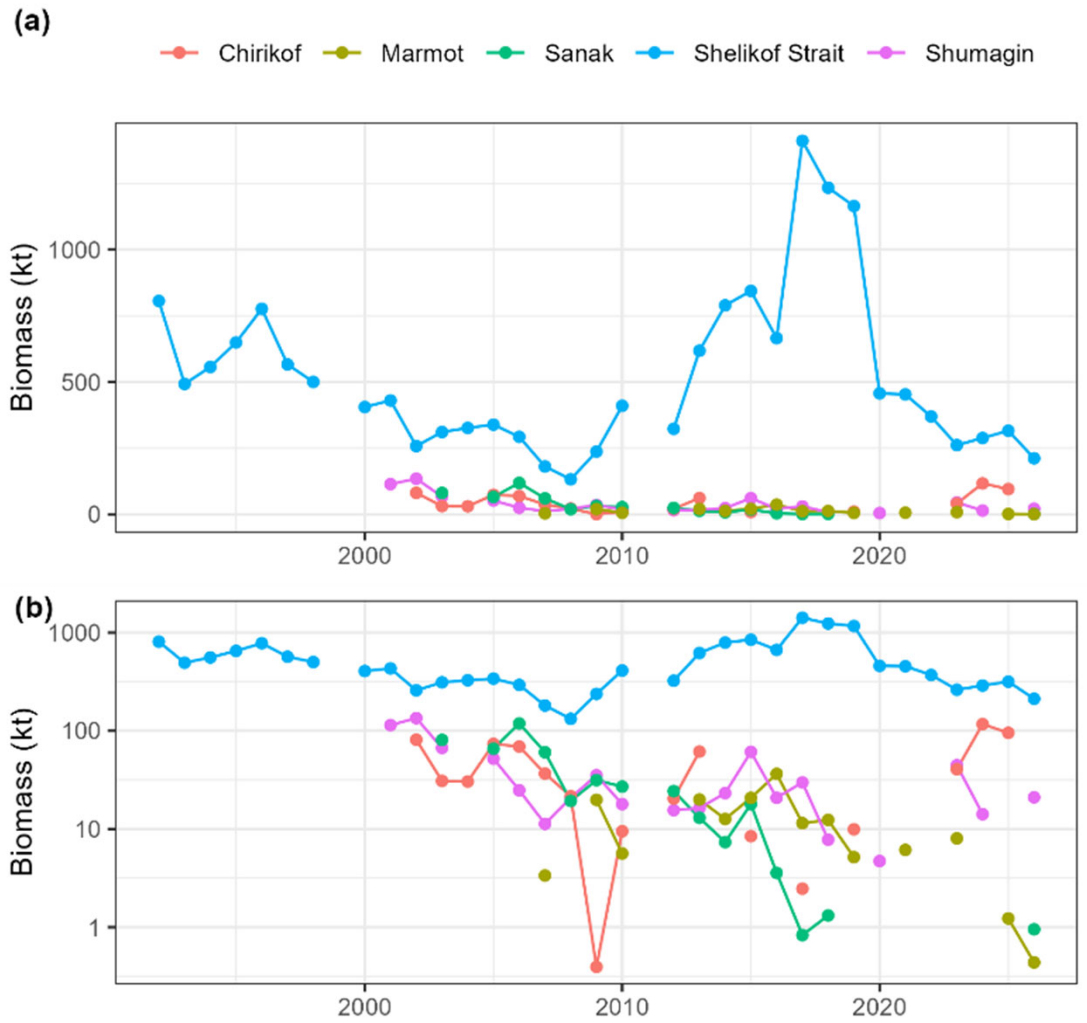
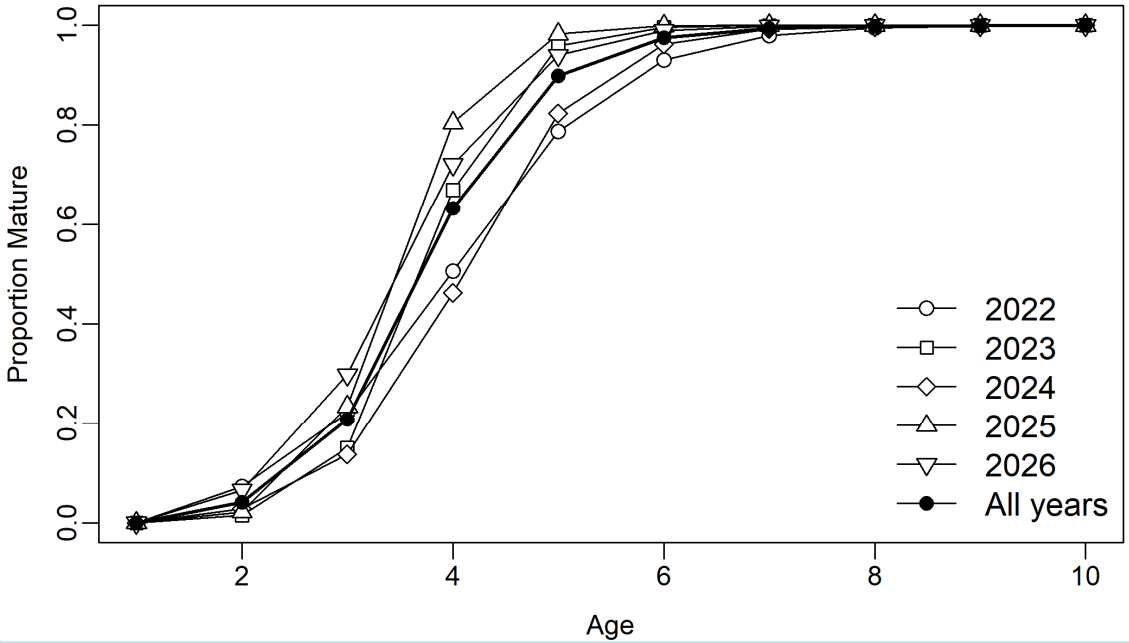
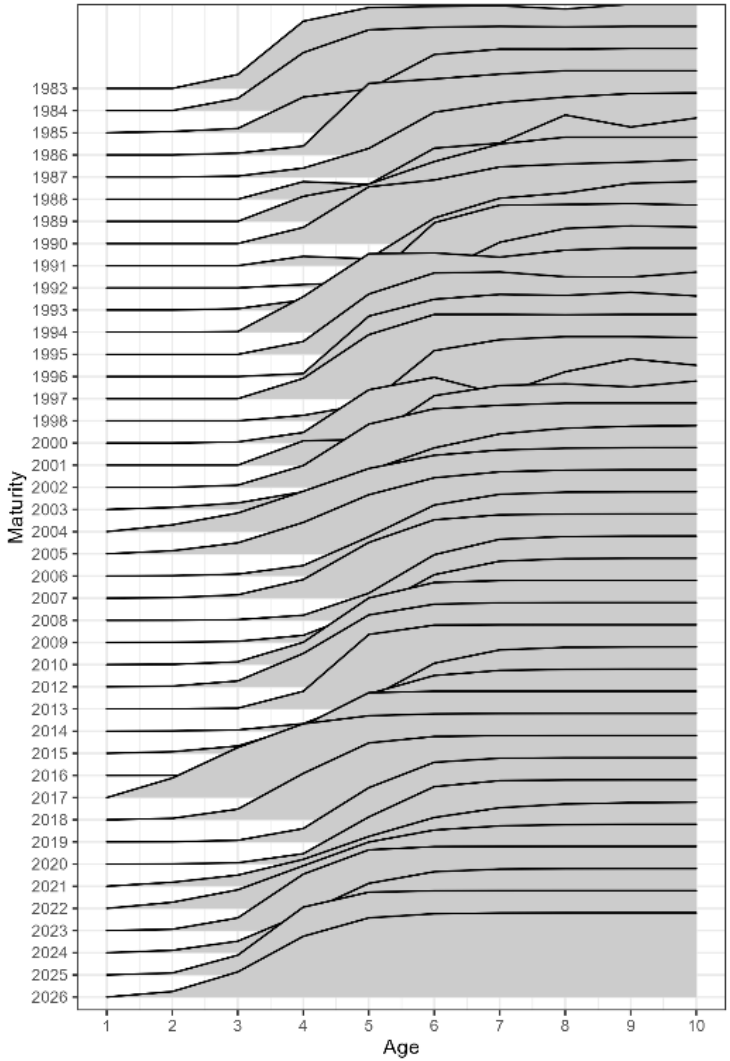


Maturity: recent estimates

Estimated from Shelikof data. Data after 2003 use local abundance weighting.

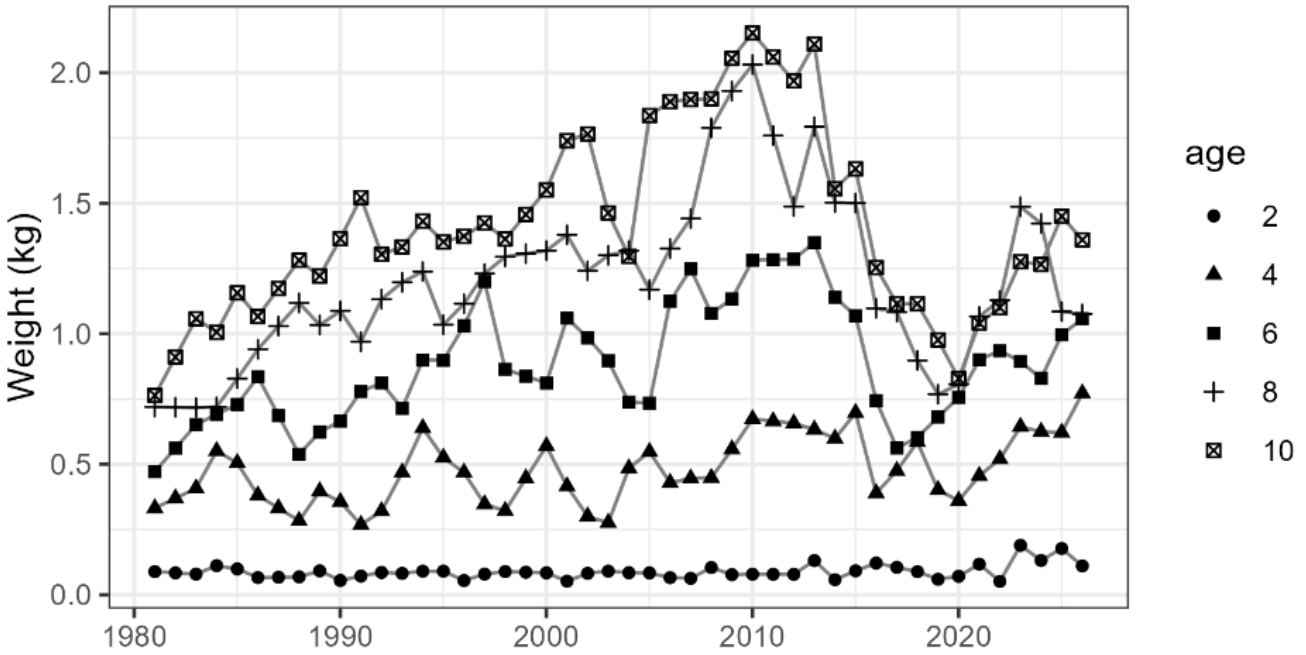
Long-term average (1983-2026) used in projections





Spawning weight at age (WAA)

- WAA from Shelikof survey
- Declined from 2012 to 2020
- Increasing again
- 5-year average used for projections



Key parameters estimated externally

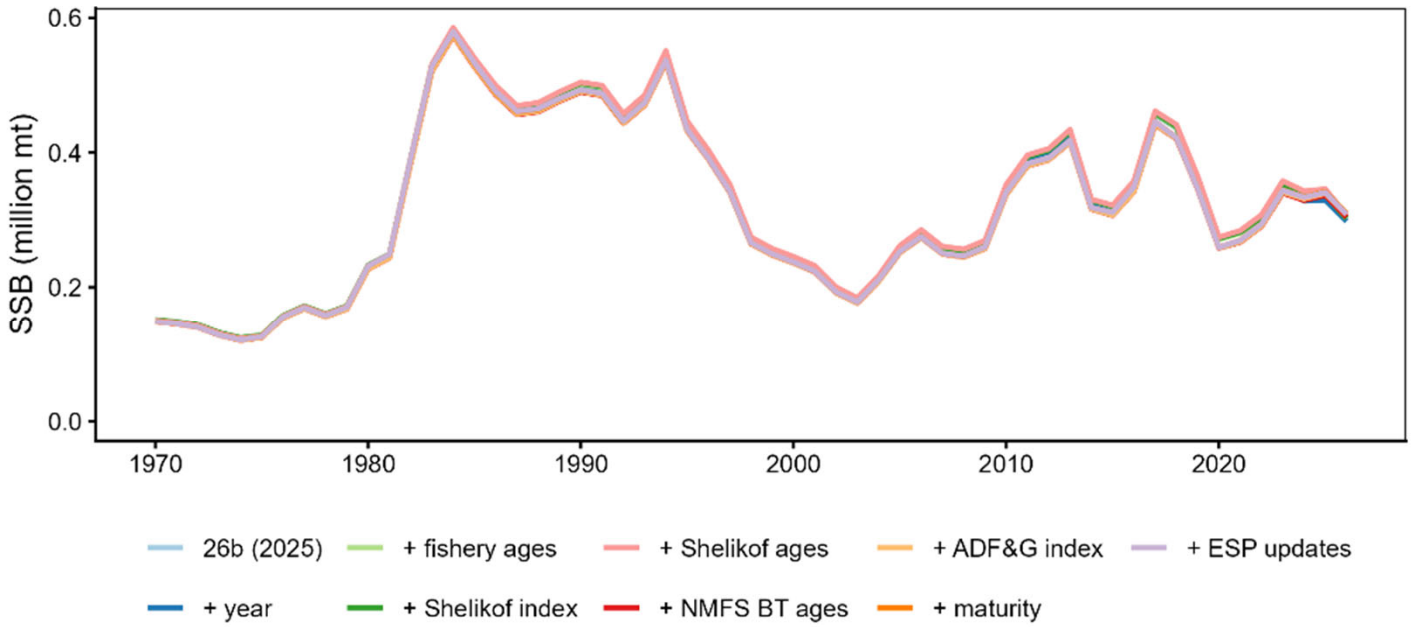
- Natural mortality: age-specific
- Fishery WAA
  - Data used through 2025
  - A RE model used for 2026 and projections
- Spawning WAA
  - Annual data exclusively from Shelikof Strait
  - 5-year average for projections (2021-2026)
- Population WAA
  - Projections use average of last 3 NMFS BT surveys
- Proportion mature at age
  - Long-term (1983-present) average used throughout

Parameters estimated internally

Population process modeled	Number of parameters	Estimation details
Mean recruitment	1	Estimated in log space
Recruitment deviations	Years 1970-2026 = 57	Estimated as log deviances from the log mean with all years constrained by random deviation process error of 1.3.
Natural mortality	Age-specific= 10	Not currently estimated in the model
Fishing mortality	Years 1970-2026 = 57	Estimated as log deviances from the log mean
Mean fishery selectivity	4	Slope parameters estimated on a log scale, intercept parameters on an arithmetic scale
Annual changes in fishery selectivity	2 * (No. years-1) = 112	Estimated as deviations from mean selectivity and constrained by random walk process error
Mean survey catchability	No. of surveys = 4	Catchabilities estimated on a log scale.
Annual changes in survey catchability	(No. years-1) = 56	Annual catchability for winter acoustic surveys and ADF&G surveys estimated as deviations from mean catchability and constrained by random walk process error
Covariate smoothing on catchability link for Shelikof survey	AR(1) process error and correlation, and effect size (3), as well as annual random effects (57)	The random effects are integrated out and not included in the total here.
Survey selectivity	8 (2 each for the Shelikof and summer acoustic surveys, and the NMFS and ADF&G BT surveys)	Slope parameters estimated on a log scale.
Overdispersion for Dirichlet-multinomial age composition	Fishery (1) and surveys (4)	Estimated in log space
DSEM time-series	Process SDs (11) and AR(1) correlations (10)	Estimated in natural space
DSEM partial effects	No. causal relationships assumed (9)	Estimated in natural space
DSEM random effects	No. of variables times no. of years = 902	Represent the latent states of all variables in all years. The random effects are integrated out and not included in the total here.
Total	234 fixed effects (1015 random effects)	

Sequential addition of data

- Track 2026 accepted model (26b) changes as new data are added
- Very stable trend and scale



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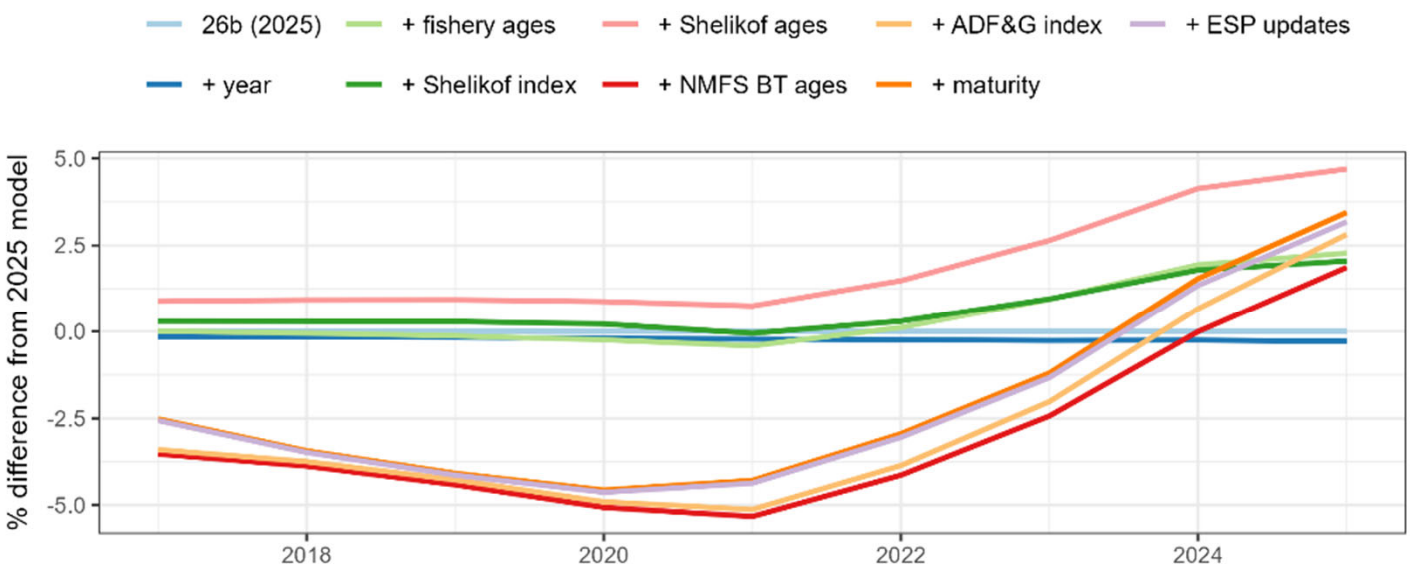
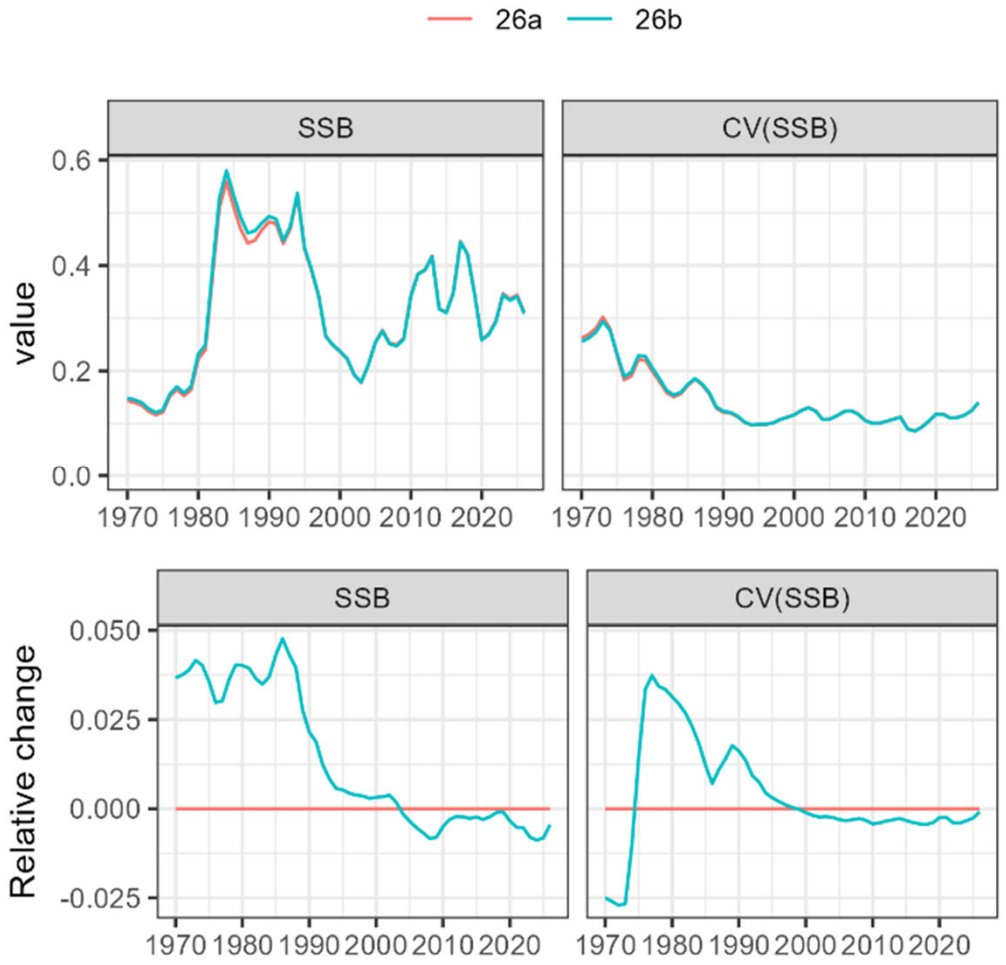
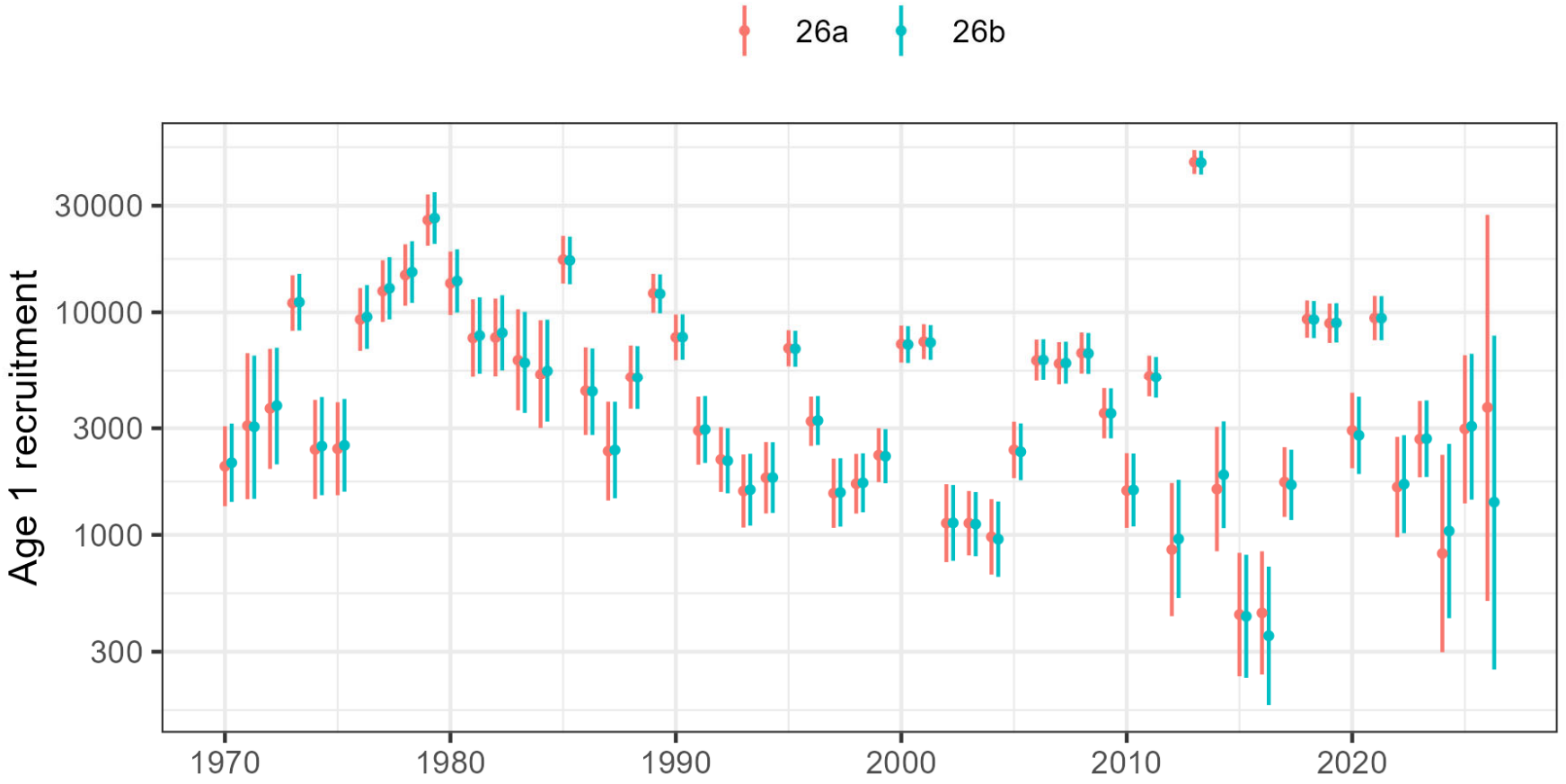


Model alternatives

- Very small impacts to SSB between alternative models



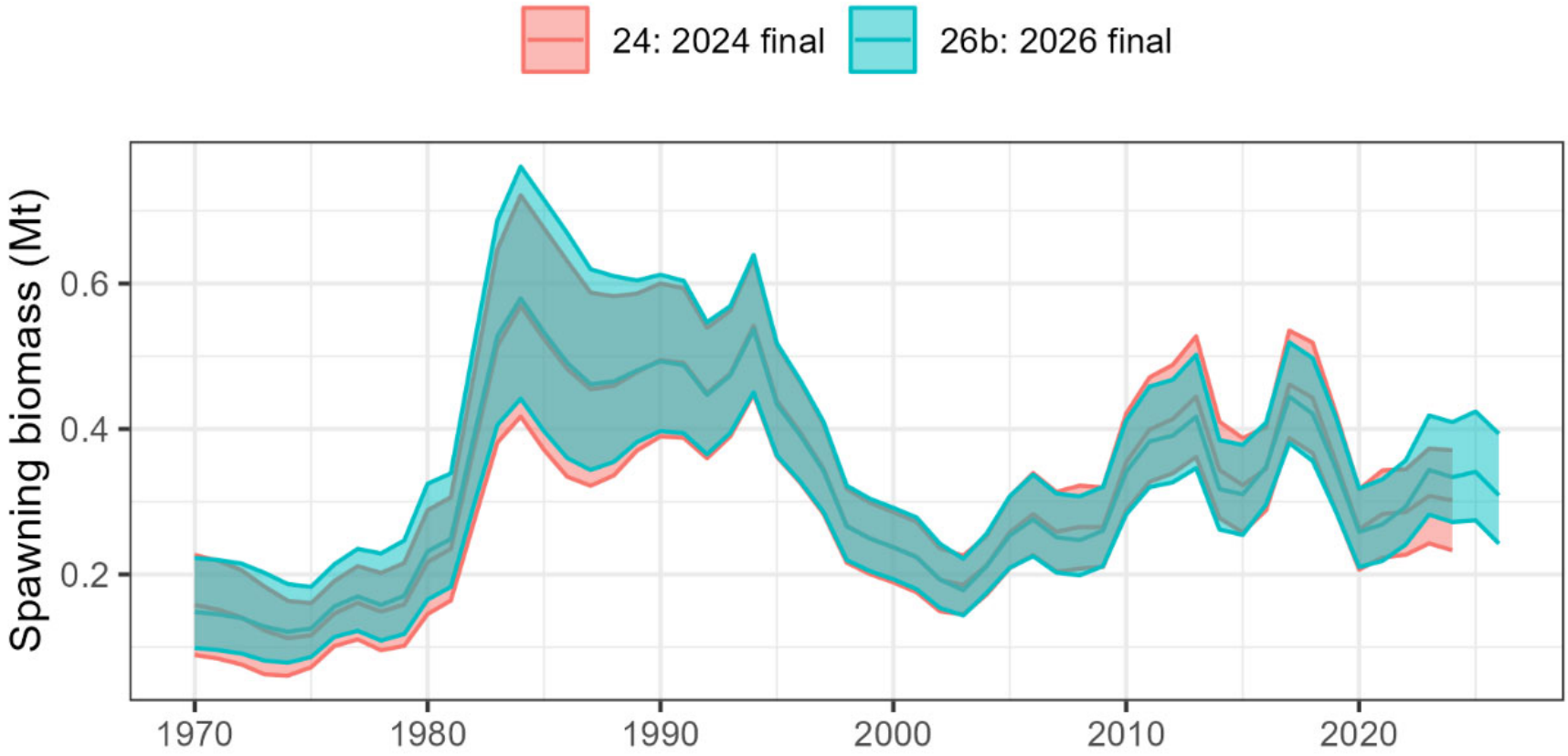
Model alternatives: Recruitment estimates



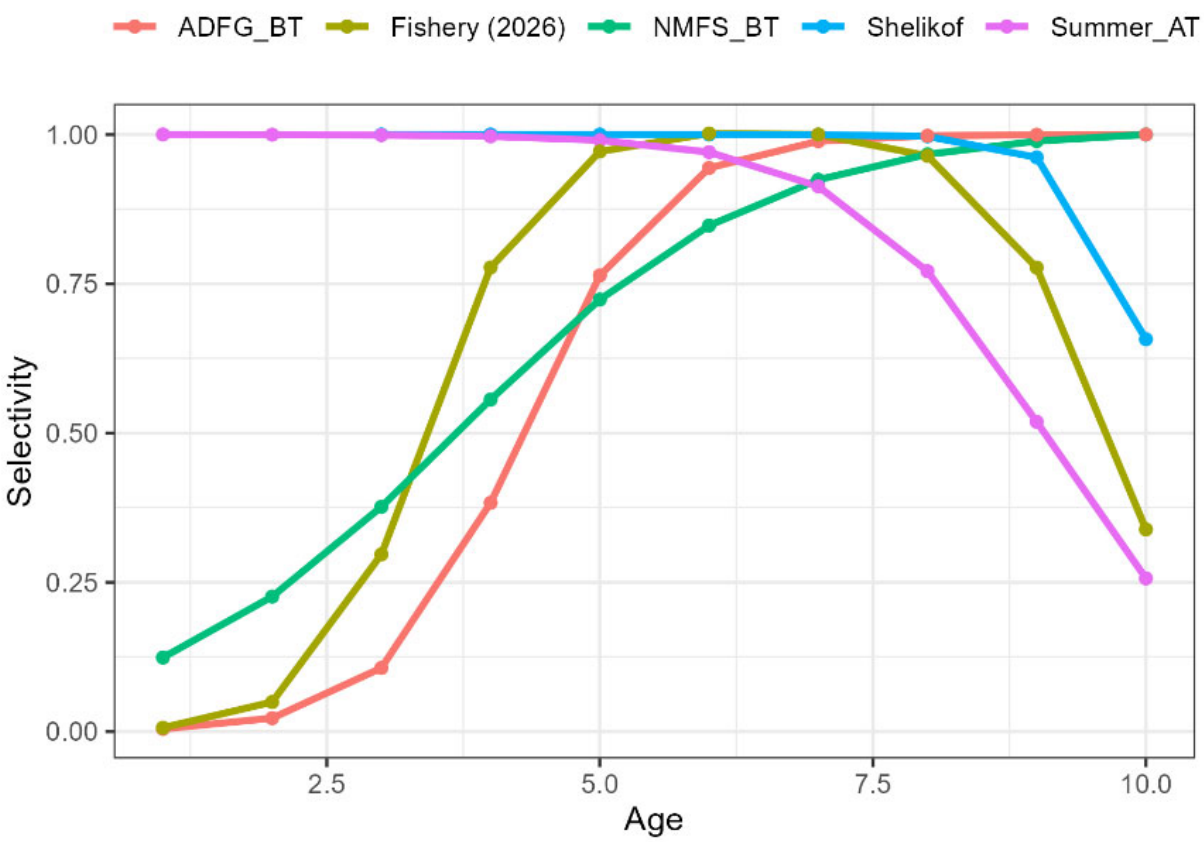
Model alternatives: management advice

Model Version	2027 SSB (t)	B100	FOFL	FABC	2027 OFL	2027 ABC
26a	228,897	592,000	0.345	0.289	180,640	155,778
26b	228,801	596,000	0.346	0.291	180,370	155,551

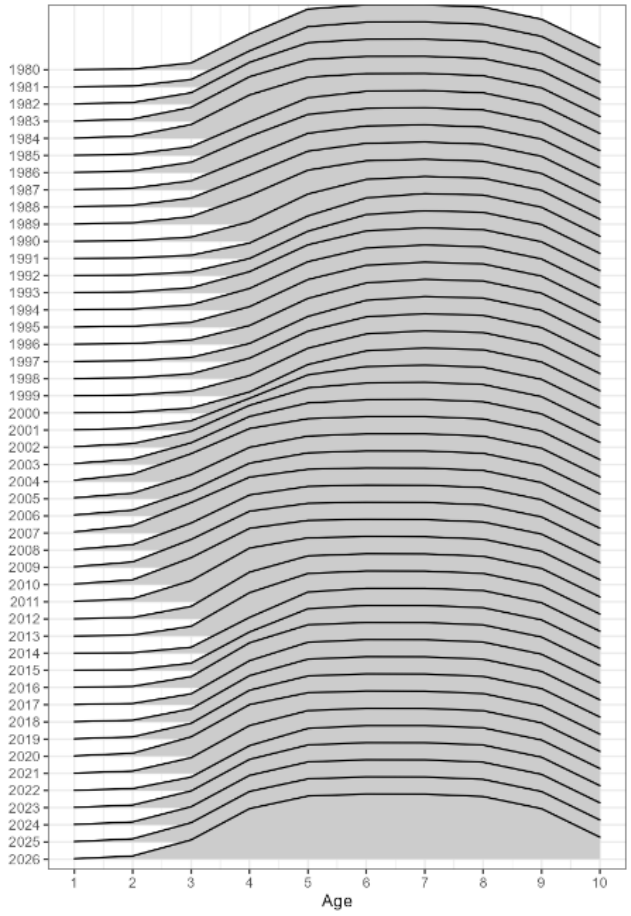
Final model compared to last year



Selectivity

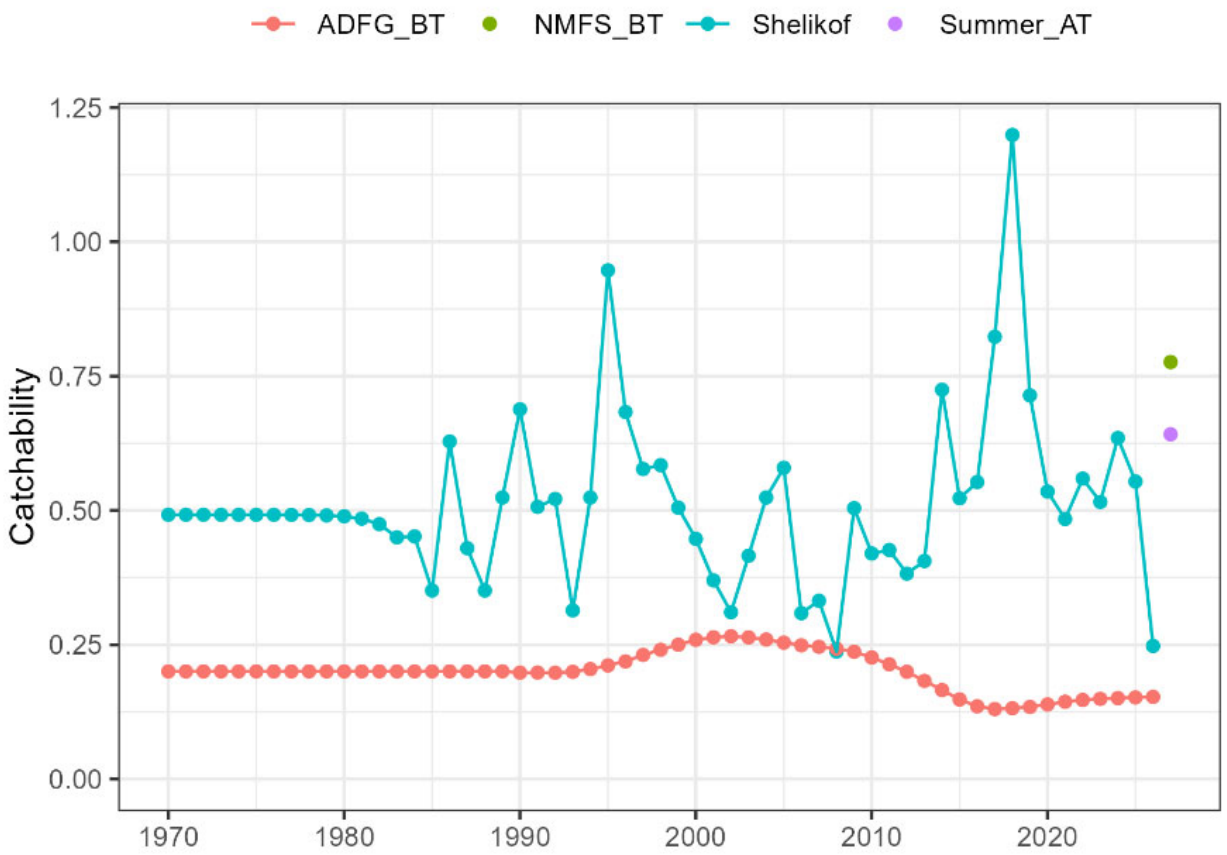


Fishery selectivity: double logistic with time-varying ascending limb



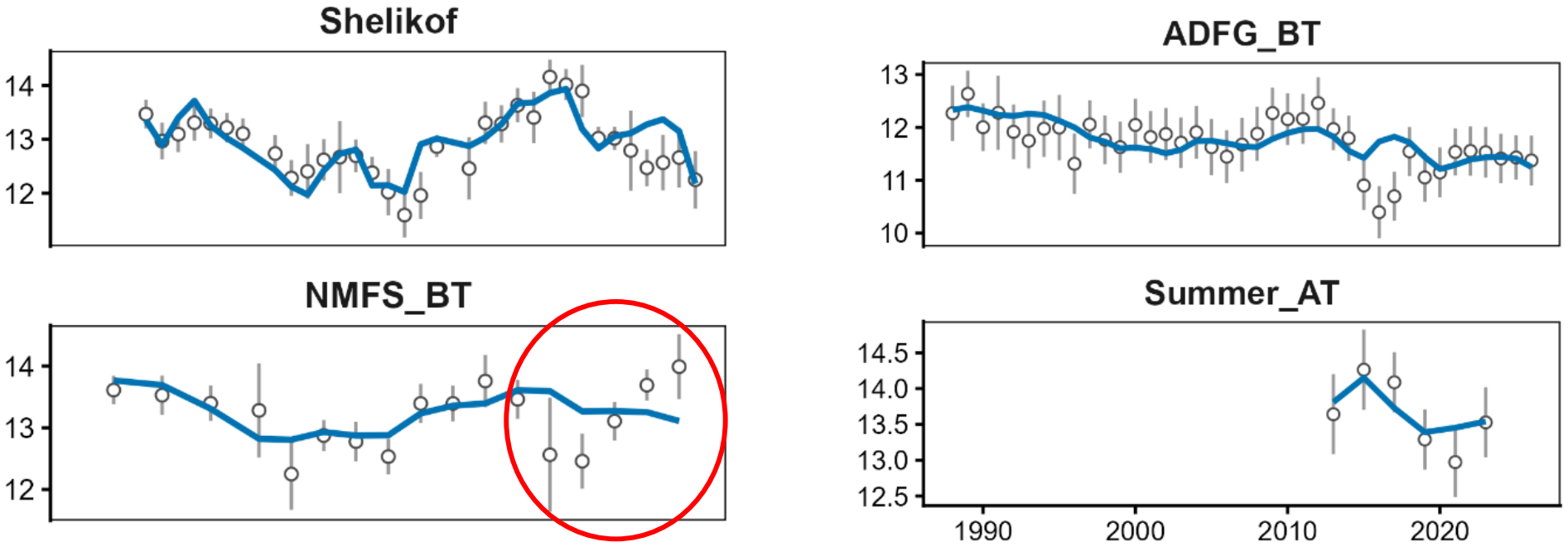
Estimates of catchability

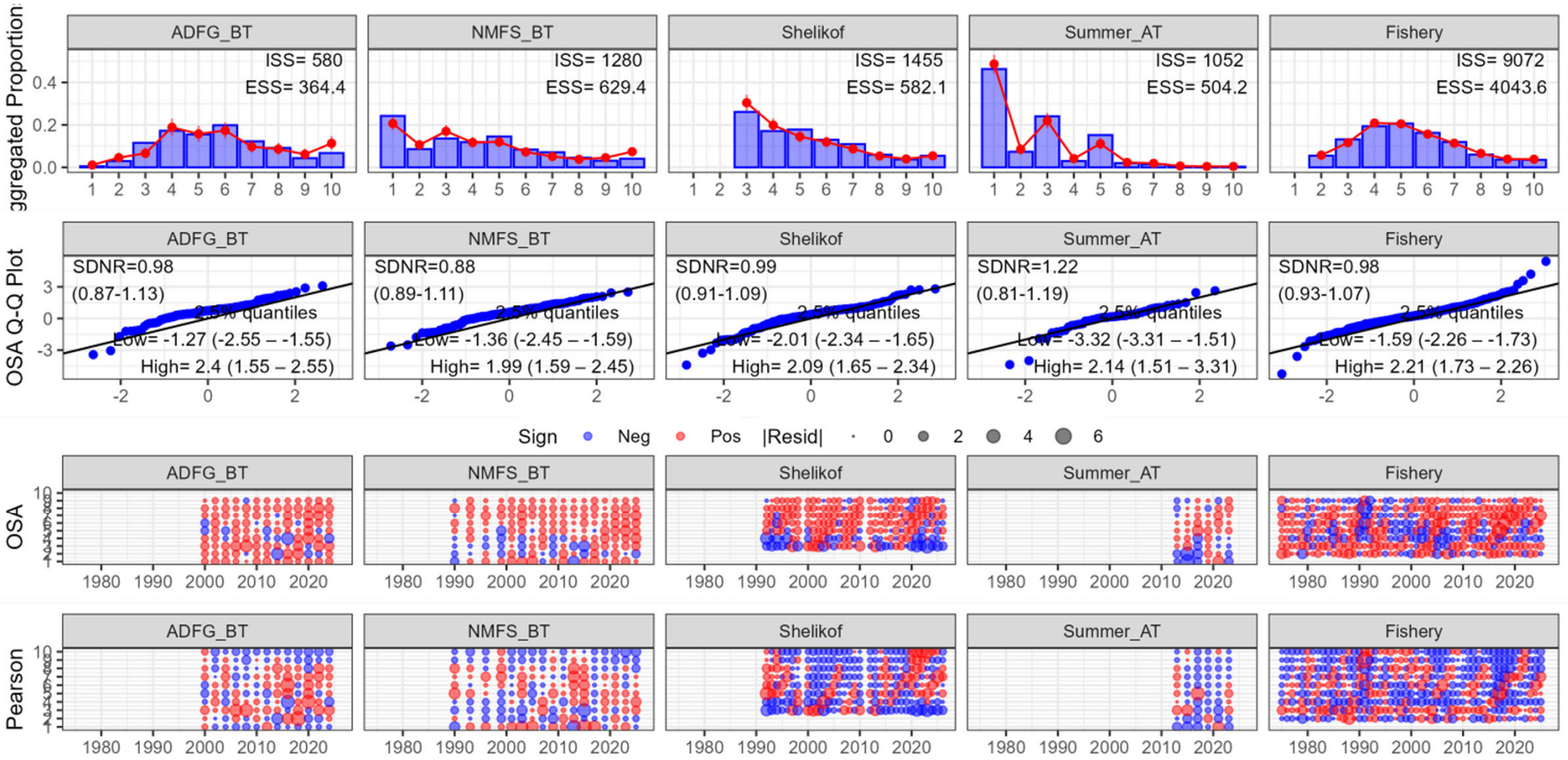
- Shelikof driven by timing covariate (Rogers et al. 2024)
  - Logit proportion mature
  - Smoothed w/ AR(1) internally
- ADF&G a highly constrained RW (penalized ML)



Index fits

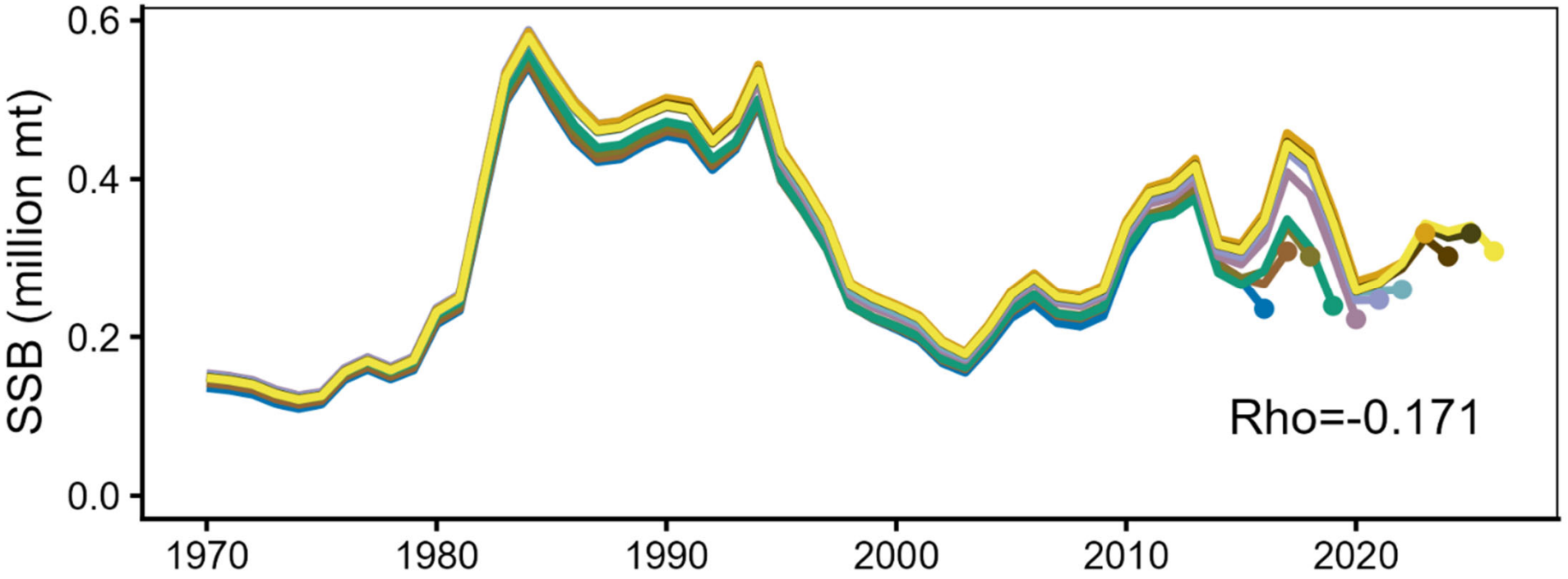
- Improved Shelikof fits (q-link); poor NMFS BT




ADFG_BT
ISS= 580
ESS= 364.4
NMFS_BT
ISS= 1280
ESS= 629.4
Shelikof
ISS= 1455
ESS= 582.1
Summer_AT
ISS= 1052
ESS= 504.2
Fishery
ISS= 9072
ESS= 4043.6
ggregated Proportion
OSA Q-Q Plot
SDNR=0.98
(0.87-1.13)
2.5% quantiles
Low= -1.27 (-2.55 – -1.55)
High= 2.4 (1.55 – 2.55)
SDNR=0.88
(0.89-1.11)
2.5% quantiles
Low= -1.36 (-2.45 – -1.59)
High= 1.99 (1.59 – 2.45)
SDNR=0.99
(0.91-1.09)
2.5% quantiles
Low= -2.01 (-2.34 – -1.65)
High= 2.09 (1.65 – 2.34)
SDNR=1.22
(0.81-1.19)
2.5% quantiles
Low= -3.32 (-3.31 – -1.51)
High= 2.14 (1.51 – 3.31)
SDNR=0.98
(0.93-1.07)
2.5% quantiles
Low= -1.59 (-2.26 – -1.73)
High= 2.21 (1.73 – 2.26)
Sign Neg Pos |Resid| 0 2 4 6
OSA
Pearson

Retrospective patterns

- Rho not significant (null range -0.2 to 0.3)

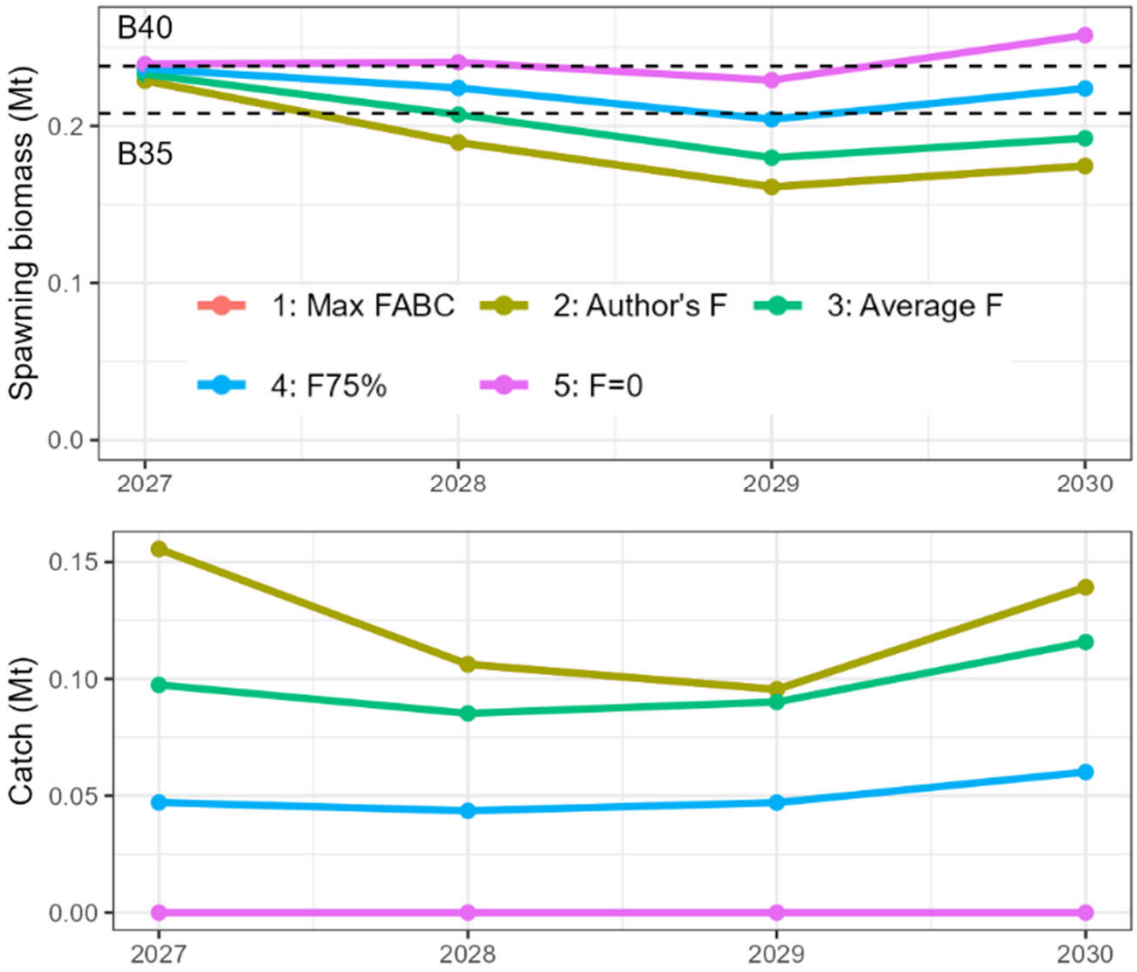


Projections: an aside

- In 2023 there was an issue in the projections
- 2023 SSB was 14% lower in “proj” than the assessment due to differences in spawning WAA (annual vs 5-year average)
- Starting in 2024 “spmR” was configured to start in next year, bypassing this issue (Thanks to J. Ianelli)

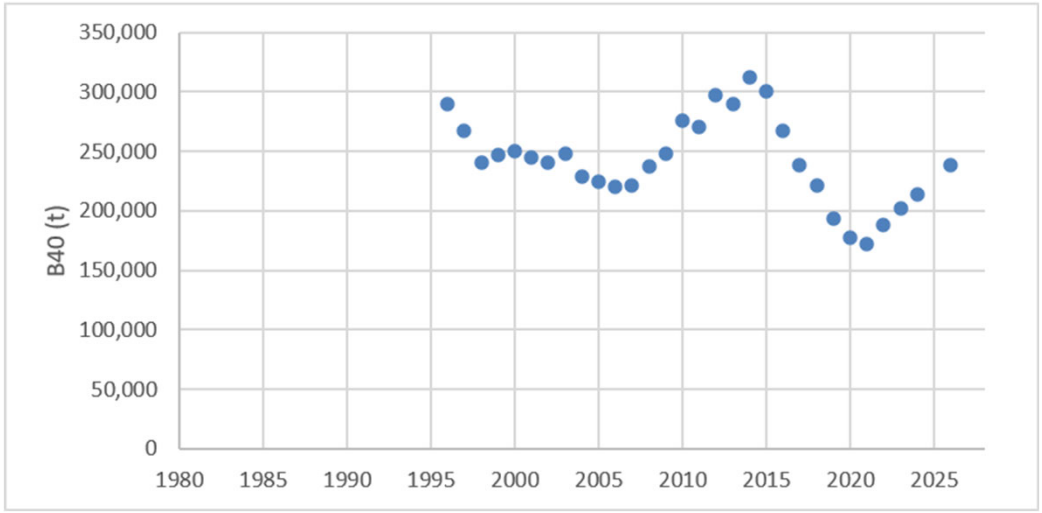
Projections in 2026

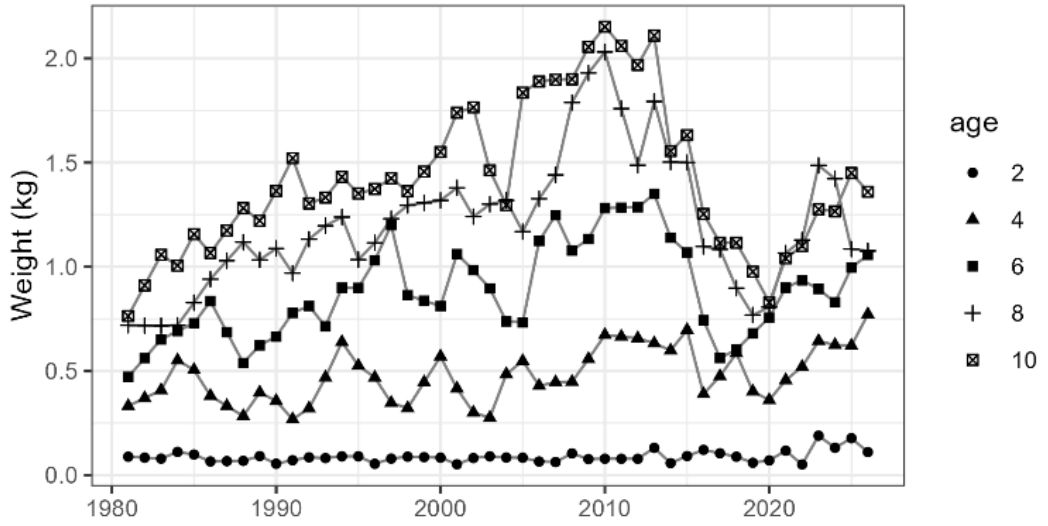
- GOA pollock has substantial time-varying quantities (WAA, maturity)
- What to use for SPR?... Ongoing challenge



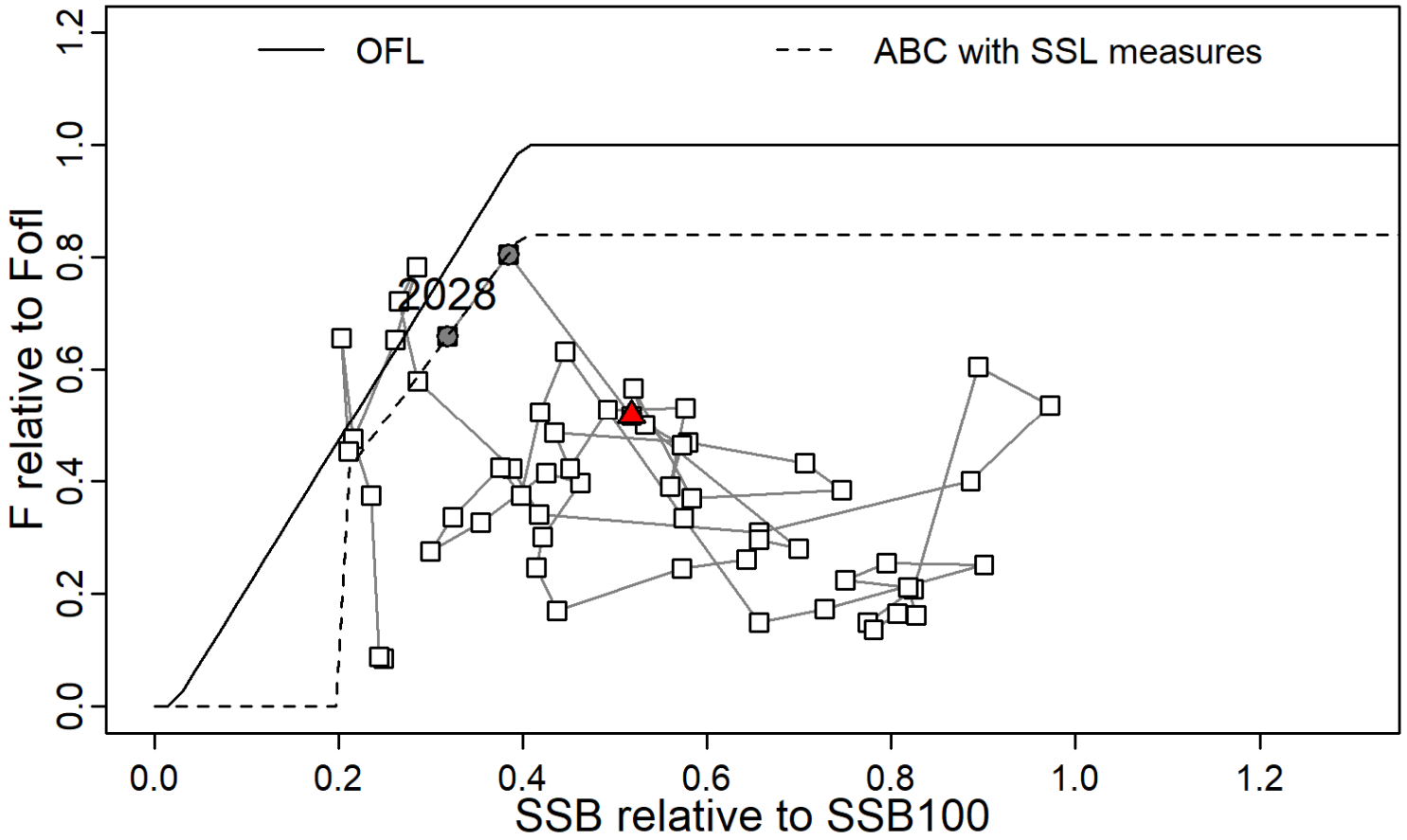
Projections in 2026

- GOA pollock has substantial time-varying quantities (WAA, maturity)
- What to use for SPR?... Ongoing challenge
- But creates large variation in B40 etc.





Status trends



Risk table: overview

Summary and ABC recommendation

Assessment-related considerations	*Population dynamics considerations*	*Ecosystem considerations*	*Fishery Performance considerations related to the health of the stock*
Level 1: Normal	Level 1: Normal	Level 1: Normal	Level 1: Normal

- Assessment concerns: poor fit to NMFS BT index, some misfit to age compositions
- No reduction from maxABC is recommended

Model 26b: Justification & Validation of DSEM

- PT and SSC asked for more validation
- End of results, questions?

A scientific framework for ecosystem-linked assessments

Incorporating ecosystem, environmental, and climate information into assessments and fisheries management is a key NMFS goal:

- NOAA Fisheries Climate Science Strategy (NCSS; Link et al., 2015)
- Ecosystem-based Fisheries Management Road Map (NMFS 2016)
- Next Generation Stock Assessment Enterprise (Lynch et al. 2018).

- This is also a long-term goal of the ESP (Shotwell et al. 2022)
- But few AFSC, and only 8/232 (3.4%) of US stocks, directly link a covariate (Karp and Vieser 2024).

A scientific framework for ecosystem-linked assessments

Karp and Vieser (2024) identified barriers to meeting goals:

- Limited data, model capabilities, and agency capacity to do the work
- Limited mechanistic understanding of the system
- Institutional inertia

Our proposal and vision to meet national goals:

- Formalize structural-causal models as a **scientific** framework to build mechanistic understanding from observational data
- Use ESPs as the framework to collate relevant data and form **a diverse science team to develop mechanistic hypotheses**.
- DSEM-integrated assessments as a **statistical** tool to incorporate mechanistic hypotheses into fisheries management

Limited mechanistic understanding of the system

Grace (2024) defines *Causal Knowledge Analysis*, as an "evaluation and compilation of existing evidence indicative of causal content and the features of mechanisms."

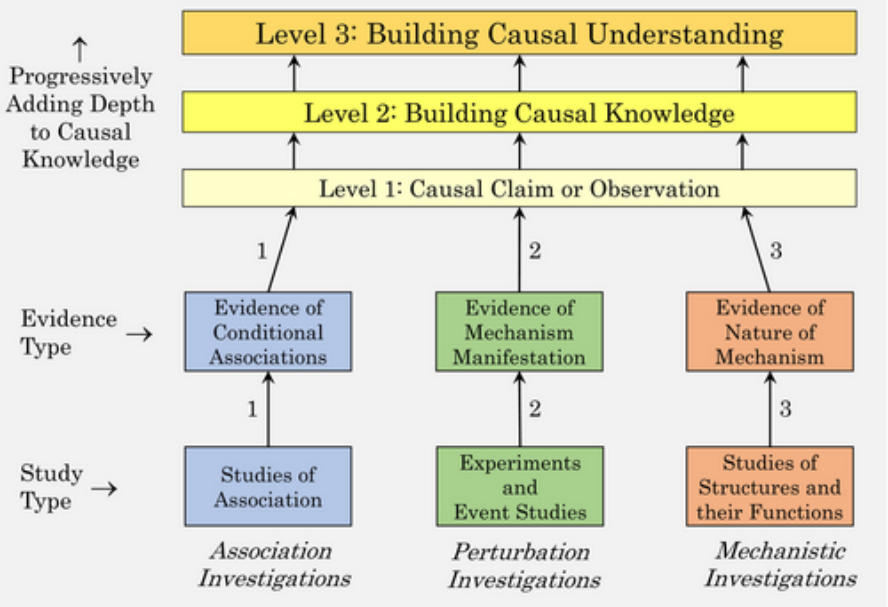


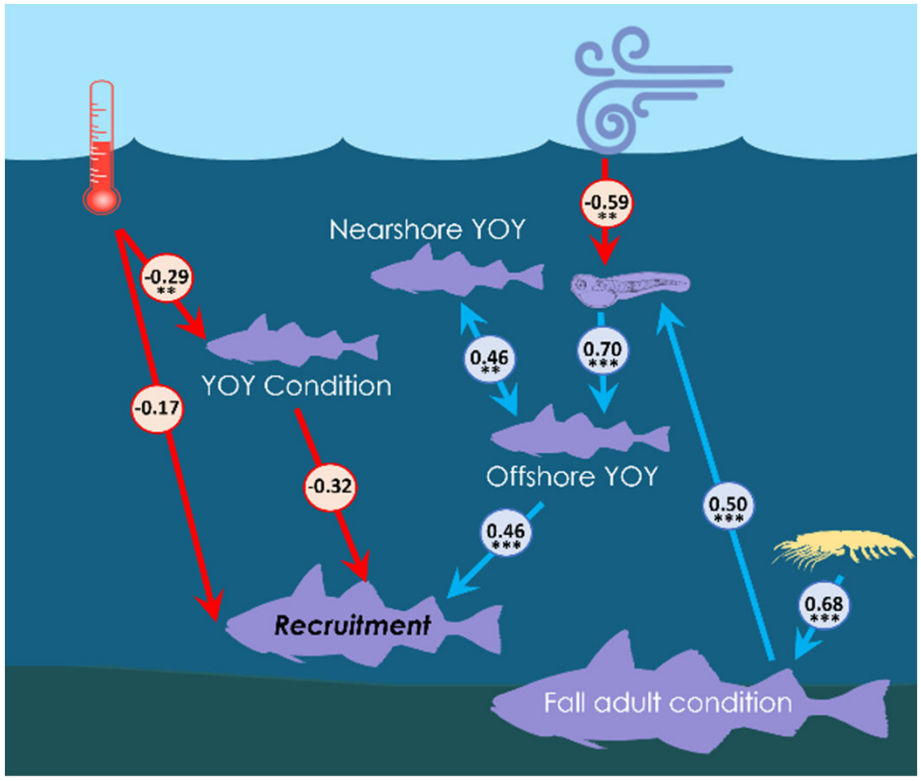
FIGURE 4 Open in figure viewer | PowerPoint

Representation of the Integrative Causal Investigation Paradigm. Two of the most important features of this paradigm meant to be conveyed here are (1) directing attention to the long-term goal of building causal knowledge and understanding across multiple studies and (2) recognizing the essential role of mechanistic investigations in establishing causal knowledge.

Grace (2024) *An integrative paradigm for building causal knowledge*

Model 26b: DSEM linkage details

- Model 26b is based on Champagnat et al. (2026)
  - DAGs built by team of experts
- Incorporates 8 ESP variables directly into the assessment
- We used mean recruitment for management this year

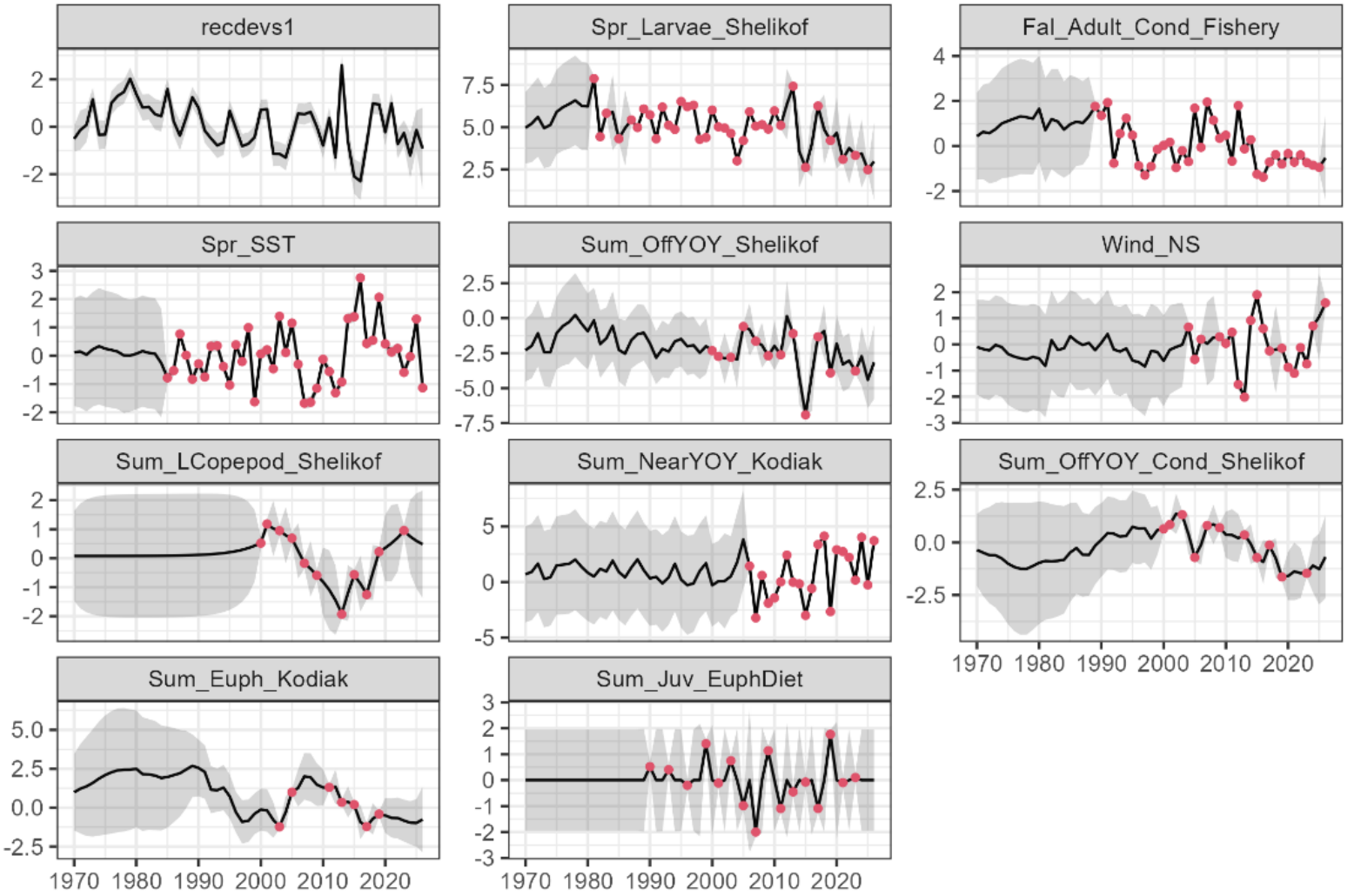


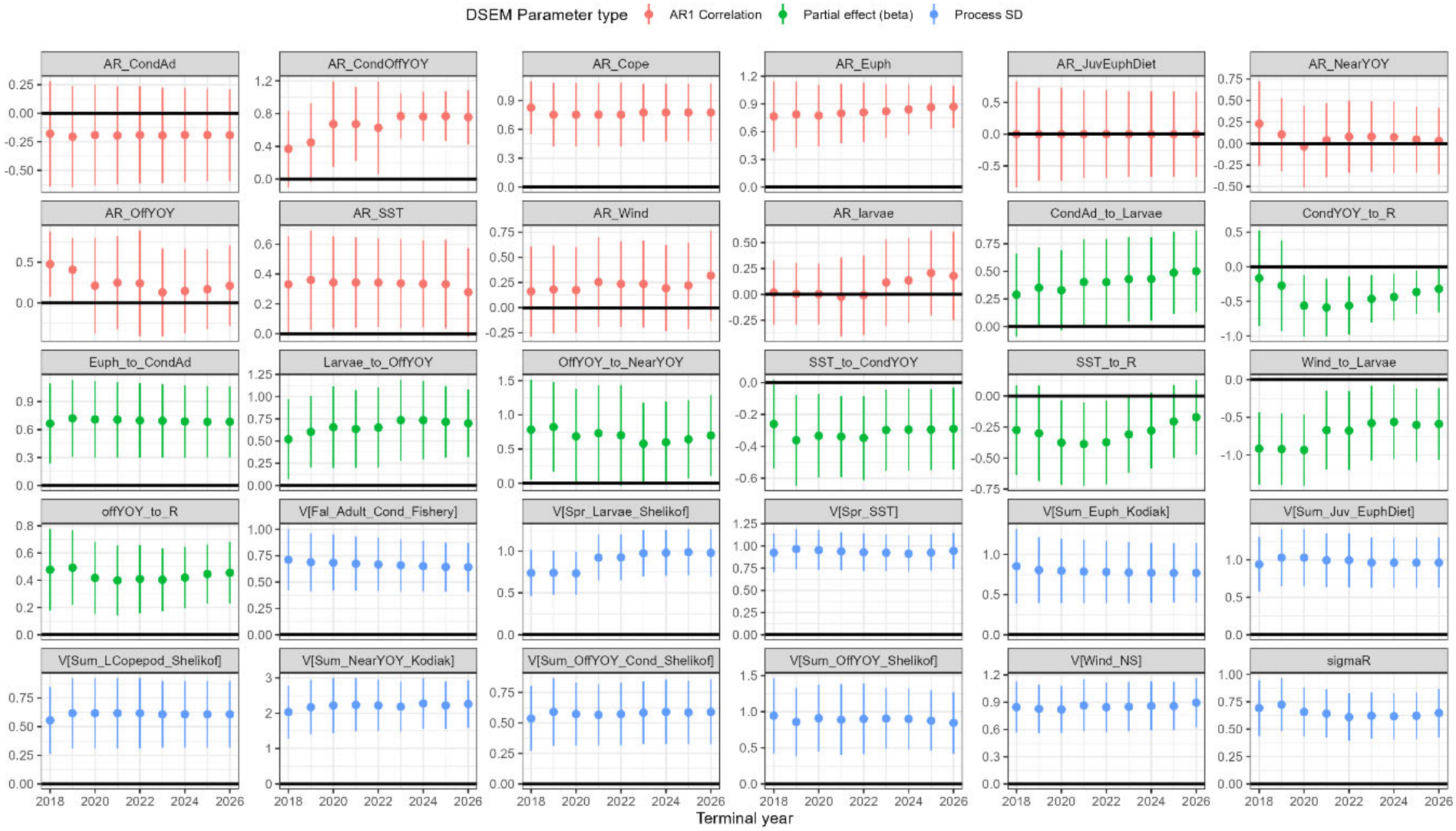
Causal Models as a Scientific Framework for Next-Generation Ecosystem and Climate-Linked Stock Assessments

J. Champagnat[1,2] | C. C. Monnahan[3] | J. Y. Sullivan[4] | James T. Thorson[3] | S. K. Shotwell[4] | L. Rogers[3] | A. E. Punt[1]

Model 26b: Justification & Validation of DSEM

- *The SSC supports the continued development of the DSEM approach and considers integration of ecosystem information directly into the assessment a promising avenue for improving recruitment estimation and prediction for this stock*
- *The SSC agrees with the use of average recruitment in projections for this assessment cycle*
- PT/SSC asked for more analysis to justify the DSEM model
  - Are parameter estimates stable over time? **[Yes]**
  - How much better does it predict recruitment? **[31% better]**
  - How much do projected recruits impact projected biomass and SSB? **[Very little]**
  - Sensitivity to removal of variables **[Unclear, need more guidance]**


recdevs1
Spr_Larvae_Shelikof
Fal_Adult_Cond_Fishery
Spr_SST
Sum_OffYOY_Shelikof
Wind_NS
Sum_LCopepod_Shelikof
Sum_NearYOY_Kodiak
Sum_OffYOY_Cond_Shelikof
Sum_Euph_Kodiak
Sum_Juv_EuphDiet
1970 1980 1990 2000 2010 2020


DSEM Parameter type
AR1 Correlation
Partial effect (beta)
Process SD
AR_CondAd
AR_CondOffYOY
AR_Cope
AR_Euph
AR_JuvEuphDiet
AR_NearYOY
AR_OffYOY
AR_SST
AR_Wind
AR_larvae
CondAd_to_Larvae
CondYOY_to_R
Euph_to_CondAd
Larvae_to_OffYOY
OffYOY_to_NearYOY
SST_to_CondYOY
SST_to_R
Wind_to_Larvae
offYOY_to_R
V[Fal_Adult_Cond_Fishery]
V[Spr_Larvae_Shelikof]
V[Spr_SST]
V[Sum_Euph_Kodiak]
V[Sum_Juv_EuphDiet]
V[Sum_LCopepod_Shelikof]
V[Sum_NearYOY_Kodiak]
V[Sum_OffYOY_Cond_Shelikof]
V[Sum_OffYOY_Shelikof]
V[Wind_NS]
sigmaR
2018
2020
2022
2024
2026
Terminal year

Skill testing via leave-future-out analysis

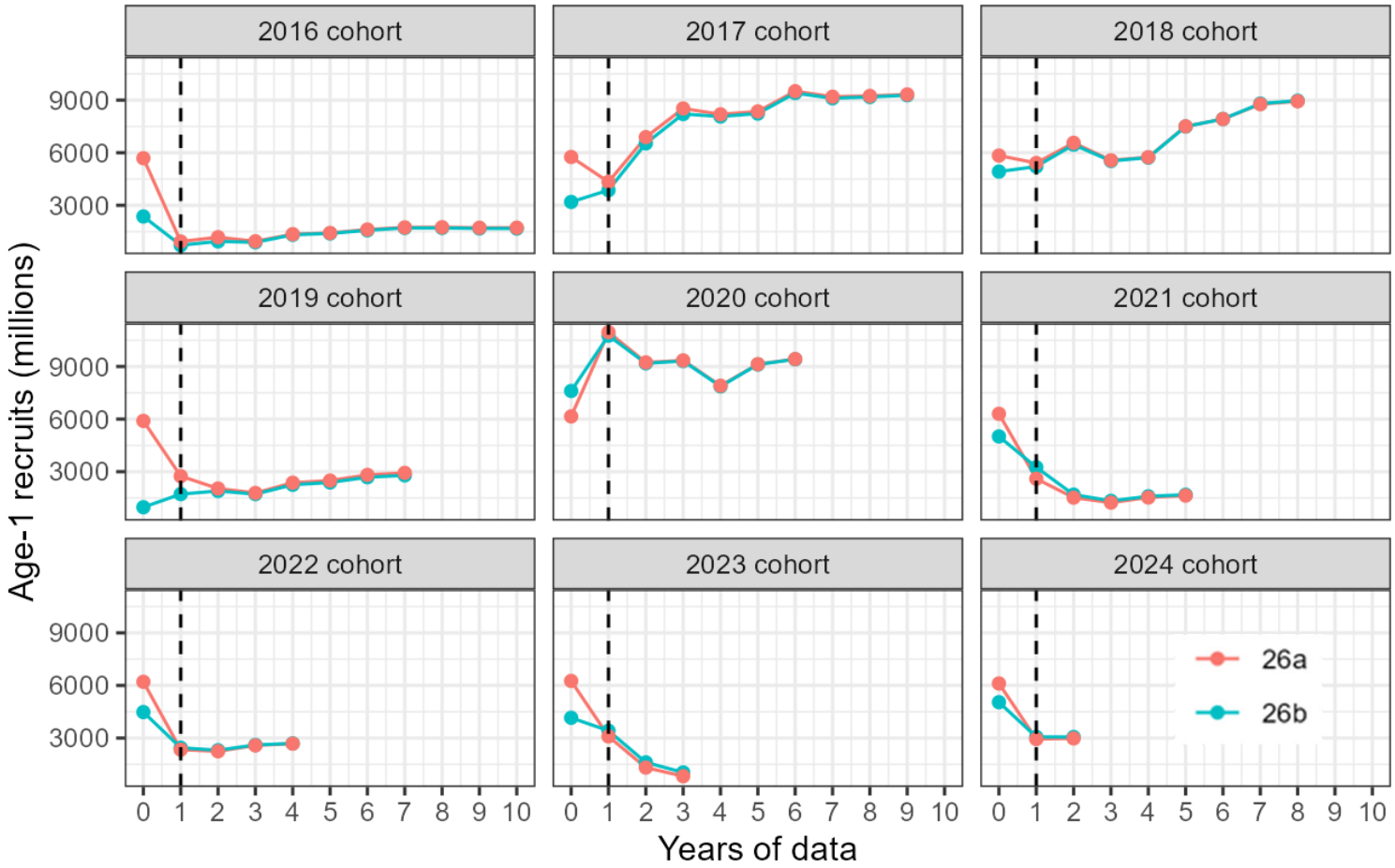
Did a retrospective, projecting recruitment one year ahead using either mean (26a) or or DSEM (26b)

Used full-data recruitment as baseline to compare

Peeling done by year, not actual data availability

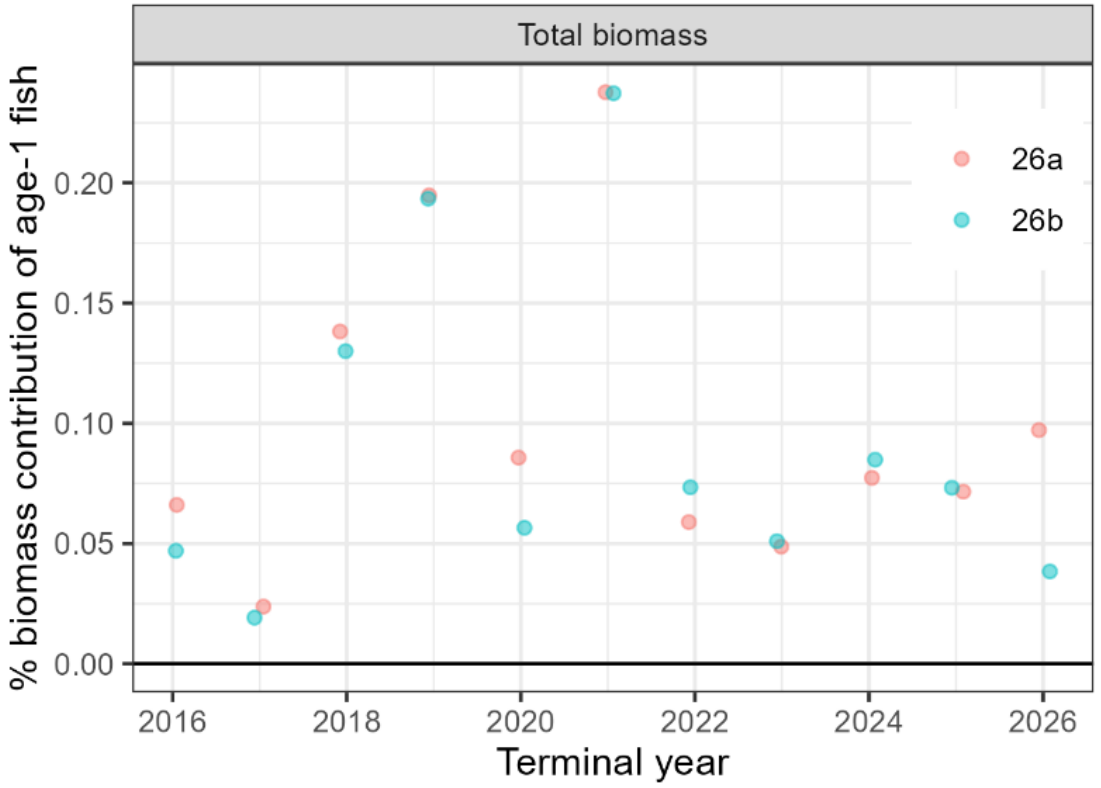
Calculated mean absolute error across peels. **26b was 31% smaller.**

Thanks to Grant Adams for configuring Rceattle to do this



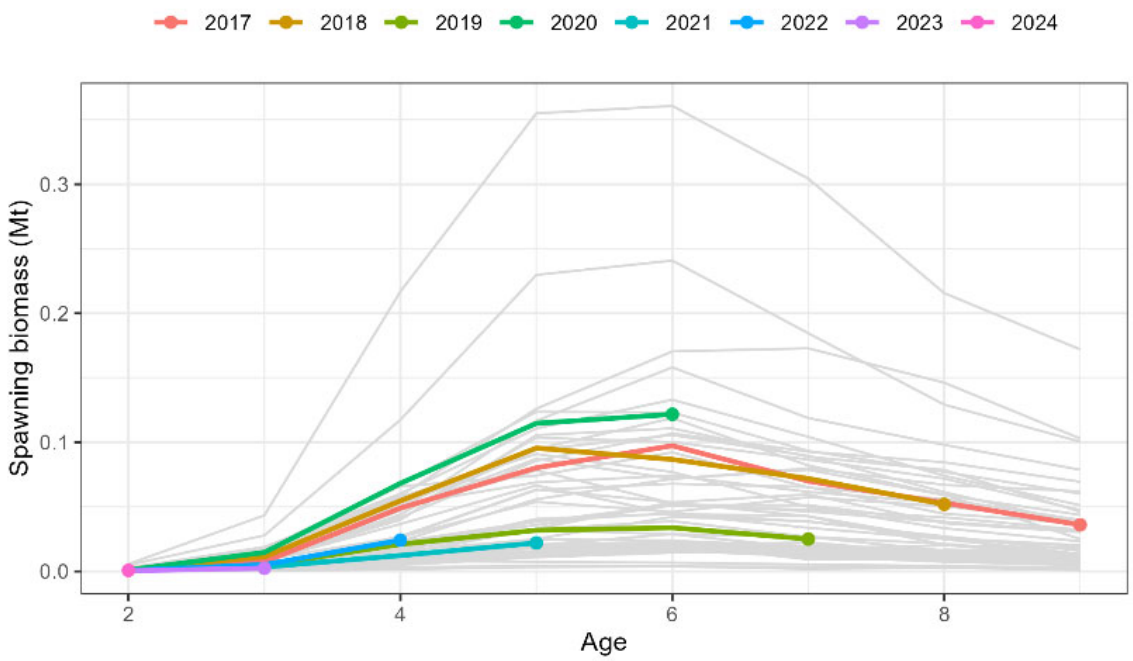
Age-1 contribution to total biomass

For several projection years, report the proportions of total biomass and SSB attributable to the terminal-year age-1 recruitment estimate in Model 26b, and compare them with results under the status quo mean-recruitment assumption in Model 26a.



Age-1 contribution to spawning biomass

For several projection years, report the proportions of total biomass and SSB attributable to the terminal-year age-1 recruitment estimate in Model 26b, and compare them with results under the status quo mean-recruitment assumption in Model 26a.



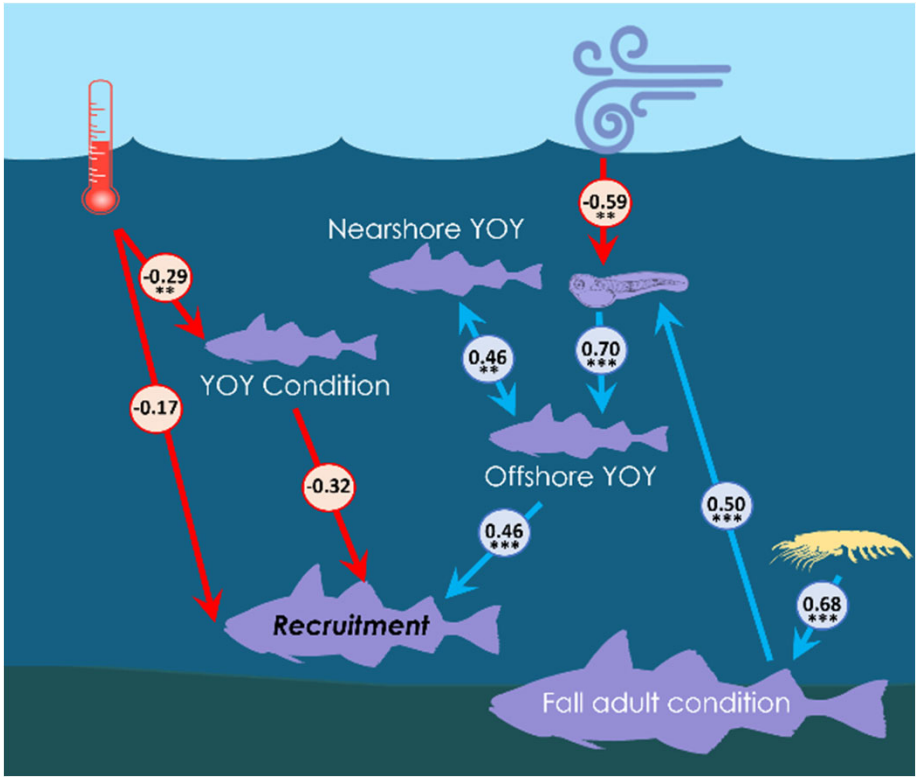
Age-0 maturity assumed 0 so left off.
Plus group left off for visual clarity

Sensitivity to dropping variables

Conduct sensitivity analyses that remove data streams informing the DAG to assess their relative influence and the consequences of discontinuing those streams.

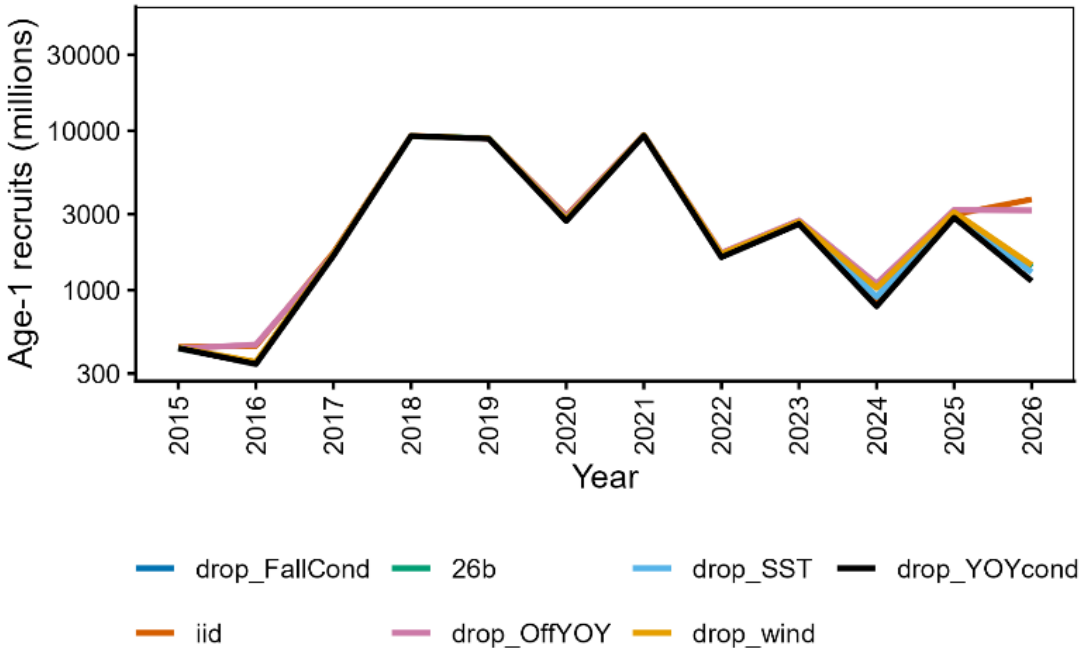
A dropped link means to **drop all links out of a variable**

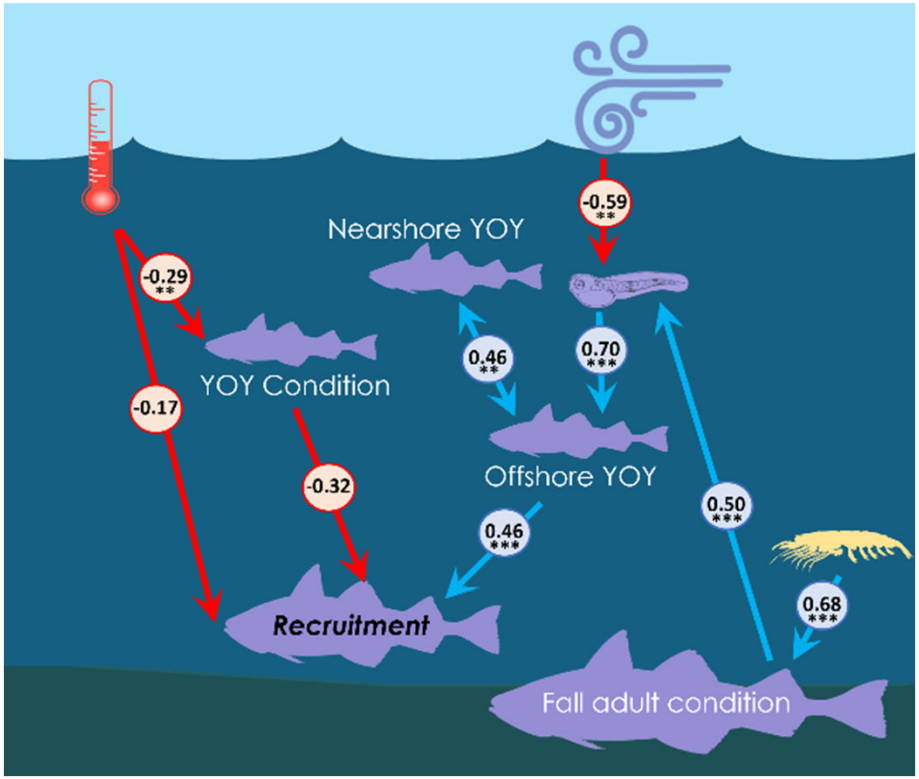
model	npars	deltaAIC	SigmaR
26b	234	0.0	0.65
drop_YOYcond	233	0.3	0.70
drop_SST	232	1.2	0.65
drop_wind	233	3.3	0.66
drop_FallCond	233	3.5	0.63
drop_OffYOY	233	9.5	0.84
iid	225	33.9	1.00



Does this address your concerns?

Sensitivity to dropping variables





Does this address your concerns?

Model 26b: Justification & Validation of DSEM

- Structural-causal models provide philosophical and scientific framework and used in other fields
- Statistical performance is very good, strong evidence of improved prediction of recruitment
- **Why not use this?**
- Can always take it out down the road.
- Plan to revisit set of DAGs in 2027

Overall concerns + discussion + research updates

- Poor NMFS BT fit, unlikely to be a simple answer but will know more in 2027
- Continued issues with scale without the NMFS BT, and data conflict
- Plus group too low? – **will explore for next year**
- Some issues in composition fits
  - Should I use time-varying age-based survey selectivity?
  - Growth variation + constant gear => variation in age-based selex
- **PT request**: *try to include additional surveyed areas not currently included in the winter survey index estimates*
  - Ongoing research. An analytical plan is in place, expect results 2027.

Status Summary for Gulf of Alaska Pollock in W/C/WYK Areas

Quantity/Status	As estimated or *specified in 2024* for: 2025	2026	As estimated or *recommended this* year for: 2027*	2028*
M (natural mortality)	0.300	0.300	0.300	0.300
Tier	3a	3a	3b	3b
Projected total (age 3+) biomass (t)	1,269,931	1,005,310	818,037	742,211
Projected female spawning biomass (t)	243,078	196,028	228,801	189,463
$B_{100\%}$	535,000	535,000	596,000	596,000
$B_{40\%}$	214,000	214,000	238,000	238,000
$B_{35\%}$	187,000	187,000	208,000	208,000
F_{OFL}	0.321	0.321	0.346	0.346
maxF_{ABC}	0.271	0.271	0.291	0.291
F_{ABC}	0.271	0.271	0.291	0.291
OFL (t)	210,111	153,971	**180,370**	123,876
*max*ABC (t)	181,022	133,075	155,551	106,221
ABC (t)	181,022	133,075	**155,551**	106,221
Status	As determined in 2024 for: 2023	2024	As determined *this* year for: 2026	2027
Overfishing	No	n/a	No	n/a
Overfished	n/a	No	n/a	No
Approaching overfished	n/a	No	n/a	No

*Projections are based on an estimated catch of 129,749 t for 2026 and estimates of 155,551 t and 106,221 t used in place of maximum permissible ABC for 2027 and 2028.

W/C/WYK BRDs

Year	Area	Season A BRD (t)	Season B BRD (t)	Total ABC (t)
2027	610	5,793	33,699	39,492
	620	52,642	15,879	68,521
	630	15,608	24,463	40,071
	640	3,577		3,577
2028	610	3,956	23,012	26,968
	620	35,948	10,844	46,792
	630	10,658	16,705	27,363
	640	2,443		2,443

Changes from 2025 BRDs

	BRD (t)		Percent	
Area	Season A	Season B	Season A	Season B
610	15	1,944	0.5%	4.2%
620	-9,038	-3,118	-0.2%	-0.3%
630	-2,542	-10,390	0.0%	-3.6%
640	-1,704		-0.6%	

Results for GOA pollock in SE (Tier 5)

Status Summary for Gulf of Alaska Pollock in the Southeast Outside Area

	As estimated or *specified last* in 2024 for:		As estimated or *recommended this* year for:	
Quantity/Status	2025	2026	2027	2028
M (natural mortality)	0.30	0.30	0.30	0.30
Tier	5	5	5	5
Biomass (t)	43,328	43,328	25,333	25,333
F_{OFL}	0.30	0.30	0.30	0.30
$maxF_{ABC}$	0.23	0.23	0.23	0.23
F_{ABC}	0.23	0.23	0.23	0.23
OFL (t)	12,998	12,998	7,600	7,600
*max*ABC (t)	9,749	9,749	5,700	5,700
ABC (t)	9,749	9,749	5,700	5,700
	As determined *last* year for:		As determined *this* year for:	
Status	2023	2024	2026	2027
Overfishing	No	n/a	No	n/a

Questions?

- Thanks!

Author's <u>2027 ABC = 155,551 t</u>

- Increase of 17% from 2026
- 2027 ABC decreases to 106,221 t (-31%)
- No reduction from max ABC

Changes (cumulative) to model:

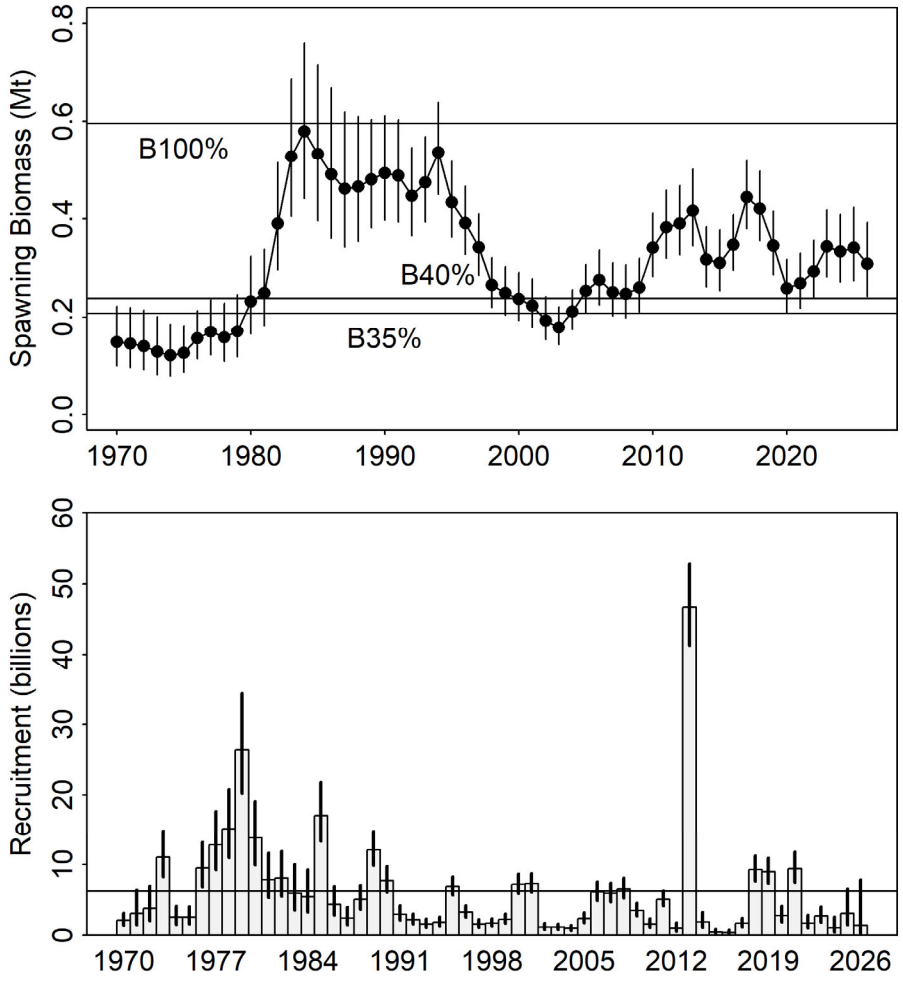
- 26a: Rceattle bridge with σ_R estimated
- **26b: 26a + DSEM module on recruitment (author recommended)**

Concerns:

- Poor fit to NMFS bottom trawl index
- Poor recent recruitment, above average 2017, 2018 & 2020 cohorts aging out

Positives:

- Better retrospective pattern



References

Champagnat, J., et al. (2026). "Causal Models as a Scientific Framework for Next-Generation Ecosystem and Climate-Linked Stock Assessments." Fish and Fisheries **27(4): 942-959.**

Karp, M., and J. Vieser. 2024. An Accounting of Approaches to Incorporate Environmental, Climate, and Ecosystem Impacts in Fishery Stock Assessments in the US from 2003-2023.

Grace, J. B. 2024. An integrative paradigm for building causal knowledge. Ecological Monographs 94:e1628.

Link, J. S., R. B. Griffis, and D. S. Busch. 2015. NOAA fisheries climate science strategy. NOAA Tech. Memo. NMFS-F/SPO-155, 70 p.

Lynch, P. D., R. D. Methot, and J. S. Link. 2018. Implementing a next generation stock assessment enterprise: an update to the NOAA Fisheries Stock Assessment Improvement Plan.

Monnahan, C. C., et al. (2021). "Incorporating vertical distribution in index standardization accounts for spatiotemporal availability to acoustic and bottom trawl gear for semi-pelagic species." ICES Journal of Marine Science **78(5): 1826-1839.**

NMFS (National Marine Fisheries Service). 2016. Ecosystem-based fisheries management road map. U.S. Dept. of Commerce, National Marine Fisheries Service Instruction 01-120-01. [Available at www.fisheries.noaa.gov/resource/document/ecosystem-based-fisheriesmanagement-road-map]

Shotwell, S. K., et al. (2023). "Introducing the Ecosystem and Socioeconomic Profile, a Proving Ground for Next Generation Stock Assessments." Coastal Management **51(5-6): 319-352.**

Thorson, J. T. and K. Kristensen (2026). "Ecological examples of nonstationarity, nonlinearity and statistical interactions in dynamic structural equation models." Methods in Ecology and Evolution **17(8): 2510-2523.**

Thorson, J. T., et al. (2024). "Dynamic structural equation models synthesize ecosystem dynamics constrained by ecological mechanisms." Methods in Ecology and Evolution **15(4): 744-755** McElreath, R. 2018. Statistical rethinking: A Bayesian course with examples in R and Stan. Chapman and Hall/CRC.

Rogers, L. A., C. C. Monnahan, K. Williams, D. T. Jones, and M. W. Dorn. 2024. Climate-driven changes in the timing of spawning and the availability of walleye pollock (*Gadus chalcogrammus) to assessment surveys in the Gulf of Alaska. ICES Journal of Marine Science. 10.1093/icesjms/fsae005.*

Thorson, J. T., A. G. Andrews III, T. E. Essington, and S. I. Large. 2024. Dynamic structural equation models synthesize ecosystem dynamics constrained by ecological mechanisms. Methods in Ecology and Evolution **15:744-755.**

Pearl, Judea. "Causal inference in statistics: An overview." (2009): 96-146.

Cohort contributions to spawning biomass

Age-1 are assumed 0 and left off.

Age 10+ excluded for visual clarity

