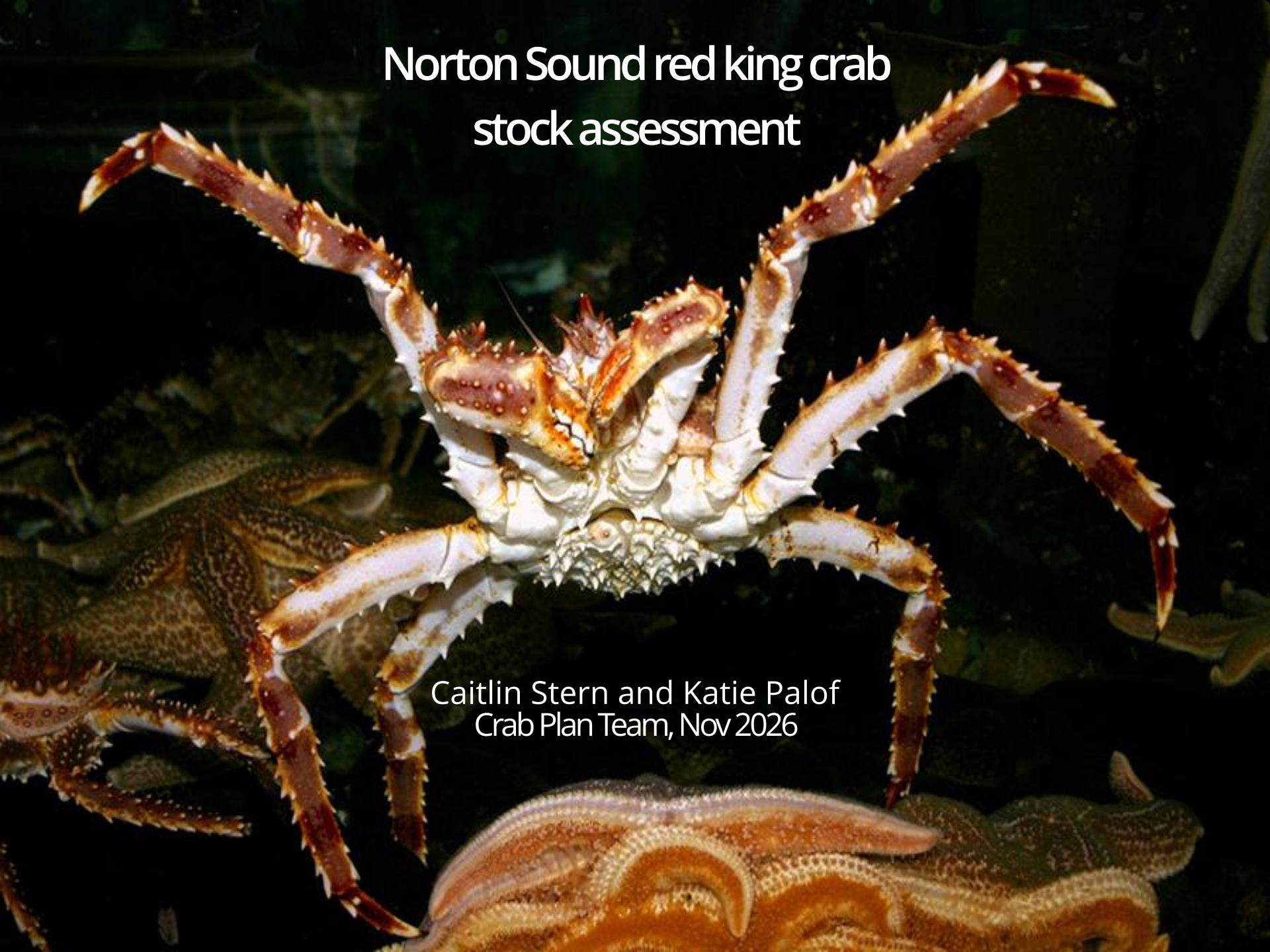
Norton Sound red king crab stock assessment



Caitlin Stern and Katie Palof
Crab Plan Team, Nov 2026

Topics

Fishery update

Priorities for the 2026 assessment cycle

Bridging analyses

Development of a model-based index (MBI)

Alternative models

Risk table and ABC buffer

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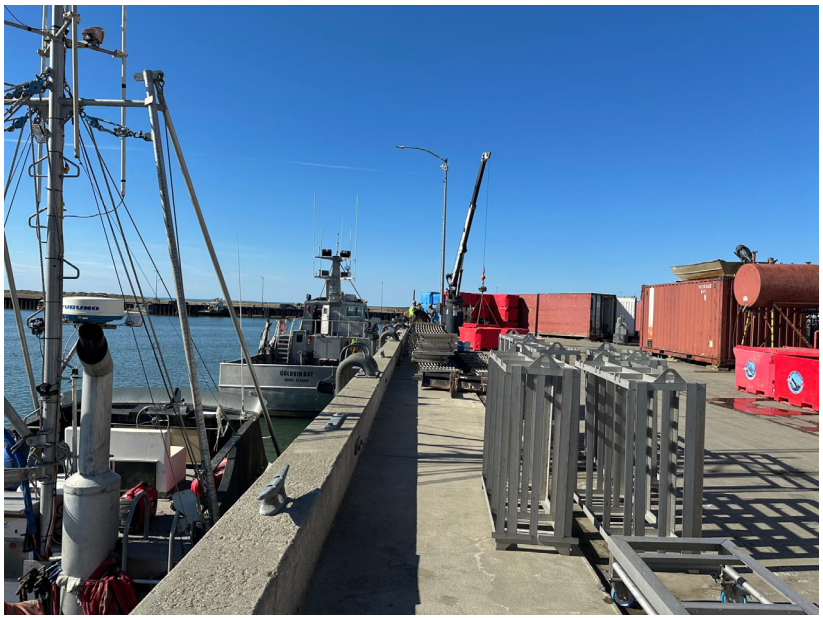
Risk table and ABC buffer

Norton Sound red king crab fisheries

Commercial: summer small vessel and winter through the ice

Subsistence: year-round





Super-exclusive since 1994

Not rationalized

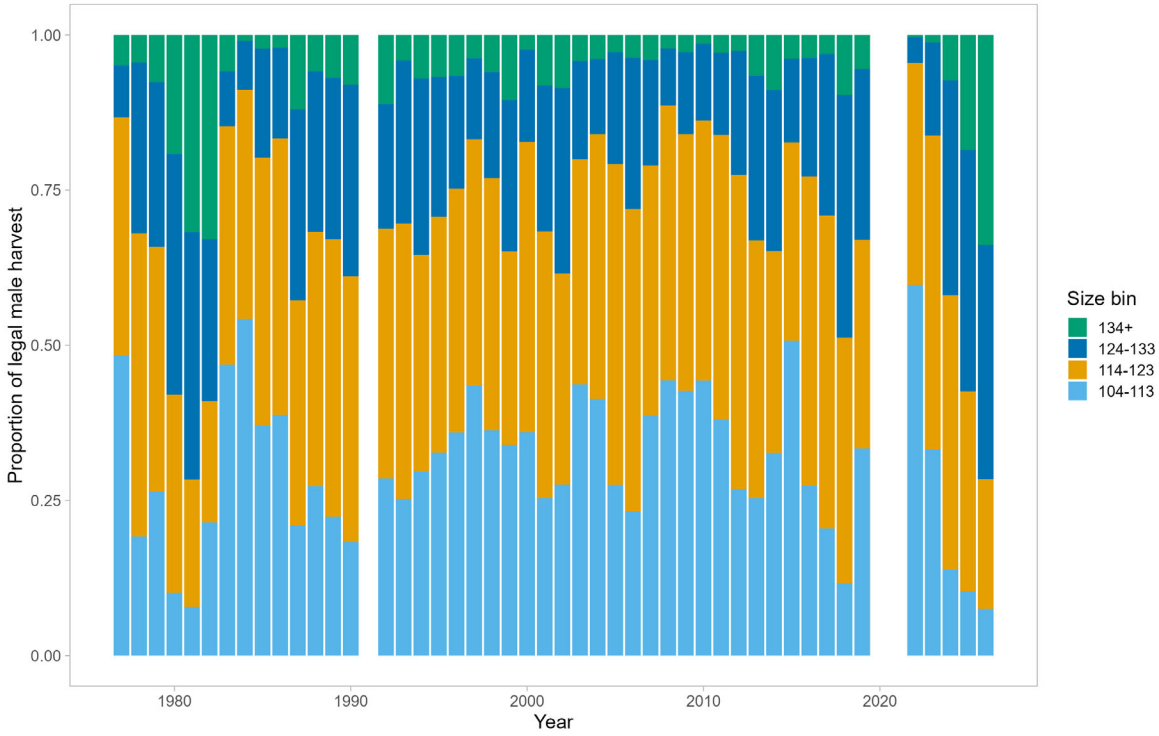
High % large males in 2026 catch

Average weight in summer commercial fishery (3.7 lb) highest in time series

34% of males retained in the summer commercial fishery were in largest size bin

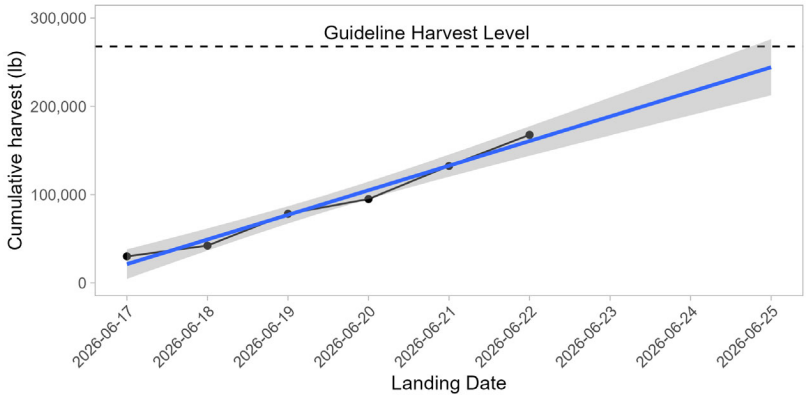
Most similar years: 1981 (32%) and 1982 (31%)

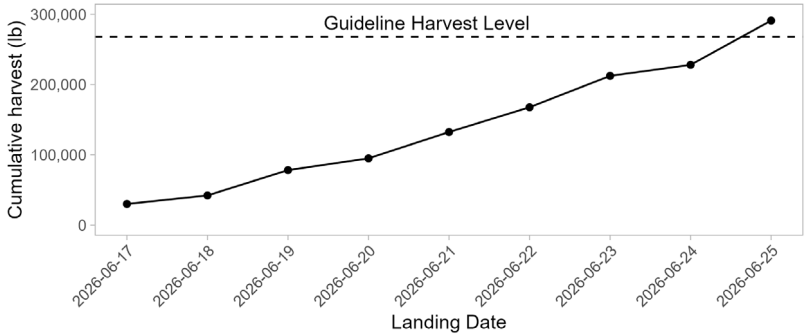
Reduced natural mortality? Changes in movement?



2026 summer commercial fishery







2026 fisheries summary



426,000 lb OFL

298,000 lb ABC

268,000 lb GHL

313,033 lb total retained catch, comm. fisheries

328,043 lb total retained catch, comm. and sub. fisheries

338,628 lb total including estimated discard mortality

GHL and ABC exceeded; OFL not exceeded so overfishing did not occur

ABC overage considerations



Stock concerns?

- model includes catch
- projections assume OFL taken

FMP guidance

- see Accountability Measures document
- revisit in buffer discussion

State has discretion to e.g. adjust harvest rate

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SSC and CPT comments

Present two model-based index versions, one including survey-station depth as a covariate and one excluding it, so the influence of depth on the index scale and the resulting reference points can be evaluated in the assessment.

Addressed here.

Assess whether depth and survey identity are correlated in the combined dataset to determine whether the depth covariate captures real bathymetric structure or partly absorbs a difference in scale between the two surveys.

We explored including an interaction between depth and survey identity in the spatiotemporal models to address this issue.

Size composition data should be incorporated into the MBI such that the previous issues with abundance in the largest size bin can be assessed

This is high priority for the next assessment cycle.

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Risk table and ABC buffer

Base model: 26.0 - May

- males $\geq$ 64 mm only, 8 size classes
- catch: winter com. retained, sub. retained, sub. total, summer com. retained
- relative abundance: 3 trawl surveys, standardized summer com. fishery CPUE in 3 time blocks
- size comps: winter com. retained, summer com. retained, summer com. discards, summer com. total, 3 trawl surveys, winter pot survey
- size-dependent M = 0.23 for males with CL $\leq$ 123 mm, est. for CL $>$ 123 mm (2 largest size bins)
- fishery selectivity: logistic for summer com., winter com., and subsistence
- pot survey selectivity: dome-shaped for winter pot survey
- trawl survey selectivity: only estimated for NOAA NS trawl survey, other trawl survey selectivities mirrored to that value. Estimate = 1 for all size classes
- survey catchability = 1 for ADF&G trawl survey, estimated for other trawl surveys and fishery CPUE indices
- GMACS version 2.20.34a

Bridging analyses

Model 26.0 - Nov: 26.0 - May transitioned to GMACS 2.20.44

Model 26.0 - updated: 26.0 - Nov with updated data

Updated data:

- winter commercial fishery: retained catch
- winter subsistence fishery: retained catch, total catch
- summer commercial fishery: retained catch, CPUE, size comps
- no new fishery-independent data available

No concerning issues encountered in either bridging step

Model 26.0 - updated is considered the base model

Topics

Fishery update

Priorities for the 2026 assessment cycle

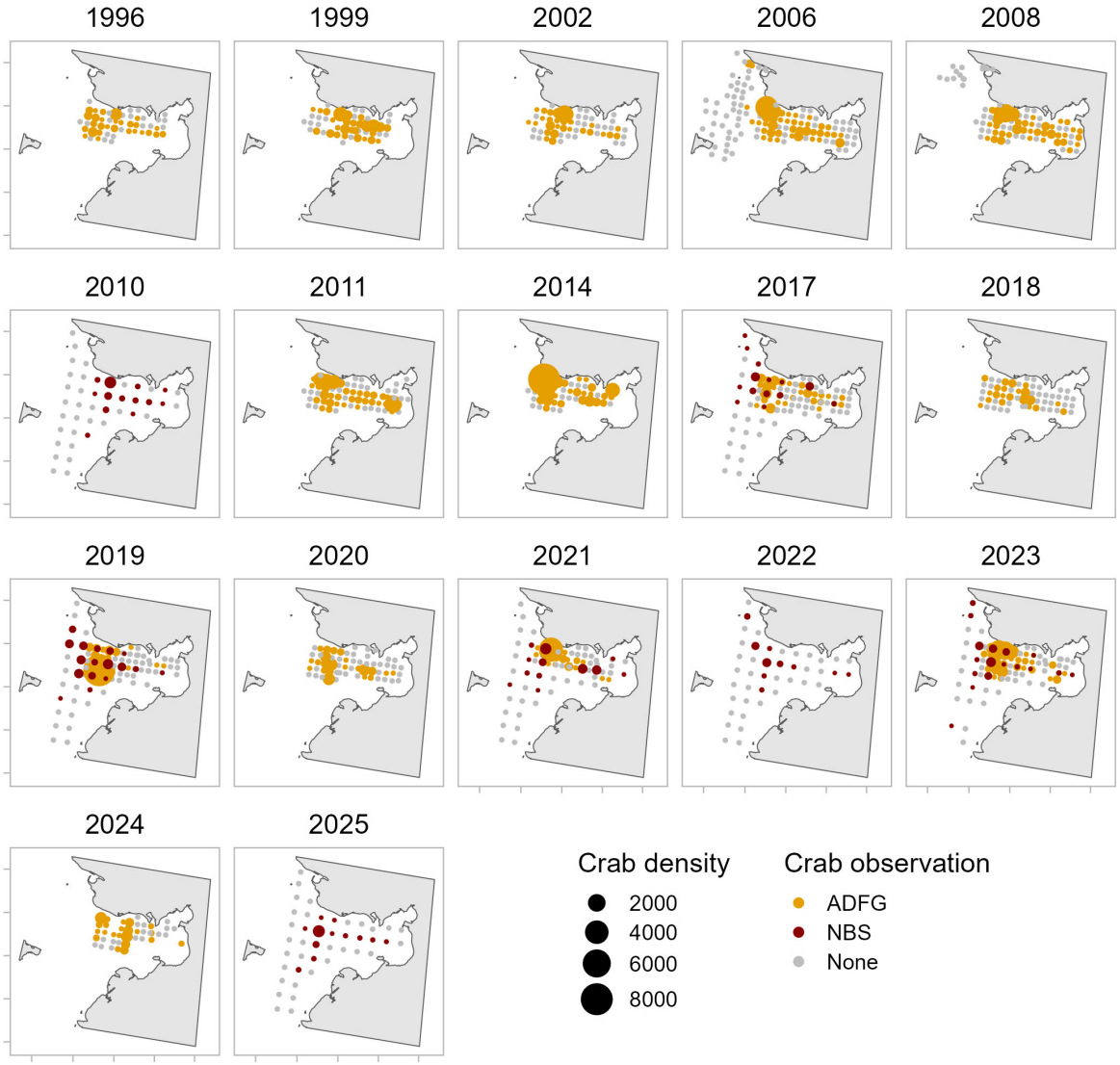
Bridging analyses

Development of a model-based index (MBI)

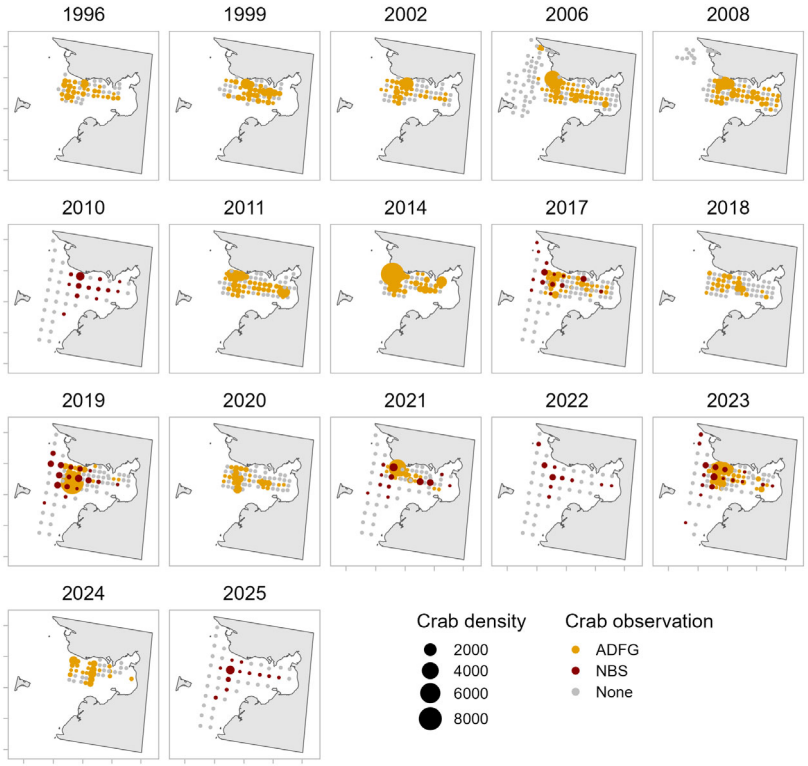
Alternative models

Risk table and ABC buffer

Spatiotemporal variation in sampling



Model-based index development



Survey sampling varies in space and time; spatiotemporal standardization is needed

Design-based ADF&G and NBS survey estimates calculate abundance over the area targeted for commercial harvest

Survey observations indicate that the stock range is likely larger

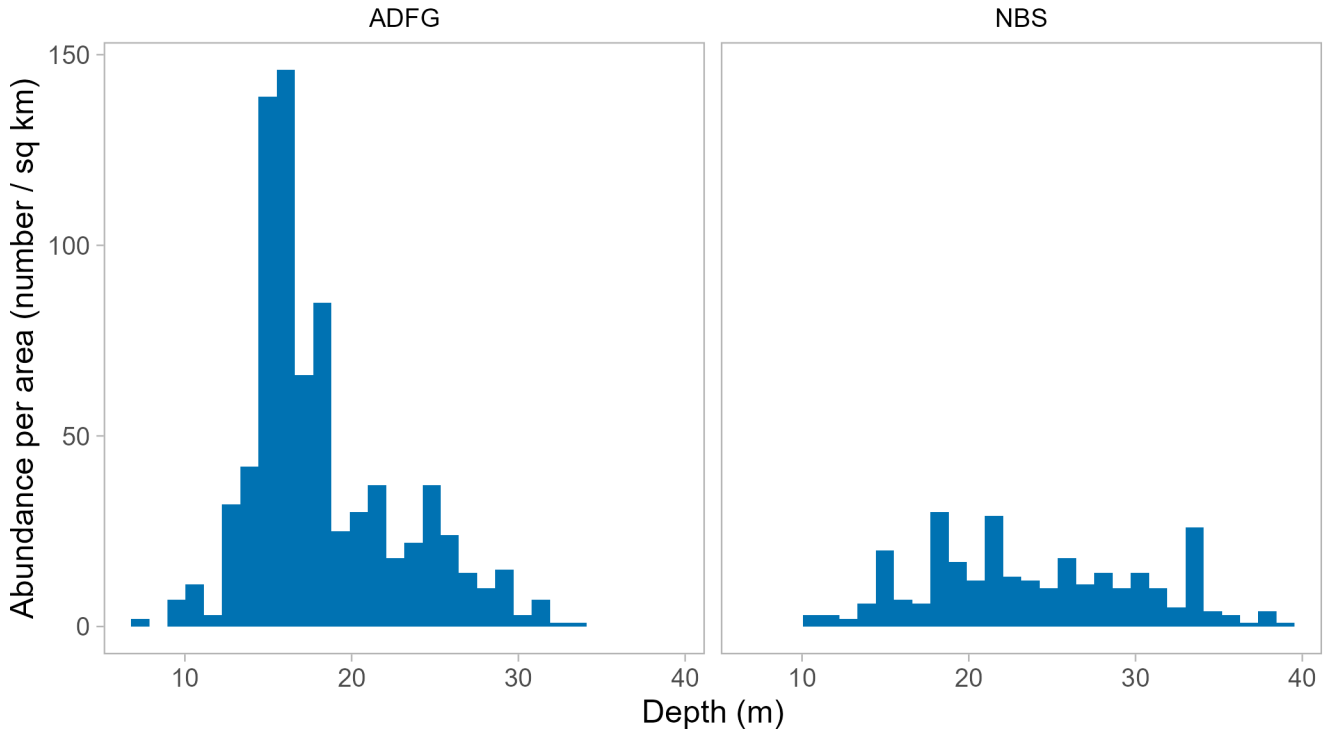
Accounting for spatiotemporal variation in survey catch expected to lead to more consistent abundance estimates

Model-based index standardization

Fit geostatistical GLMMs with spatiotemporally correlated random effects to survey data using sdmTMB

Fixed effects in all models: year, survey

Including depth: depth, depth * survey, s(depth, by = survey)

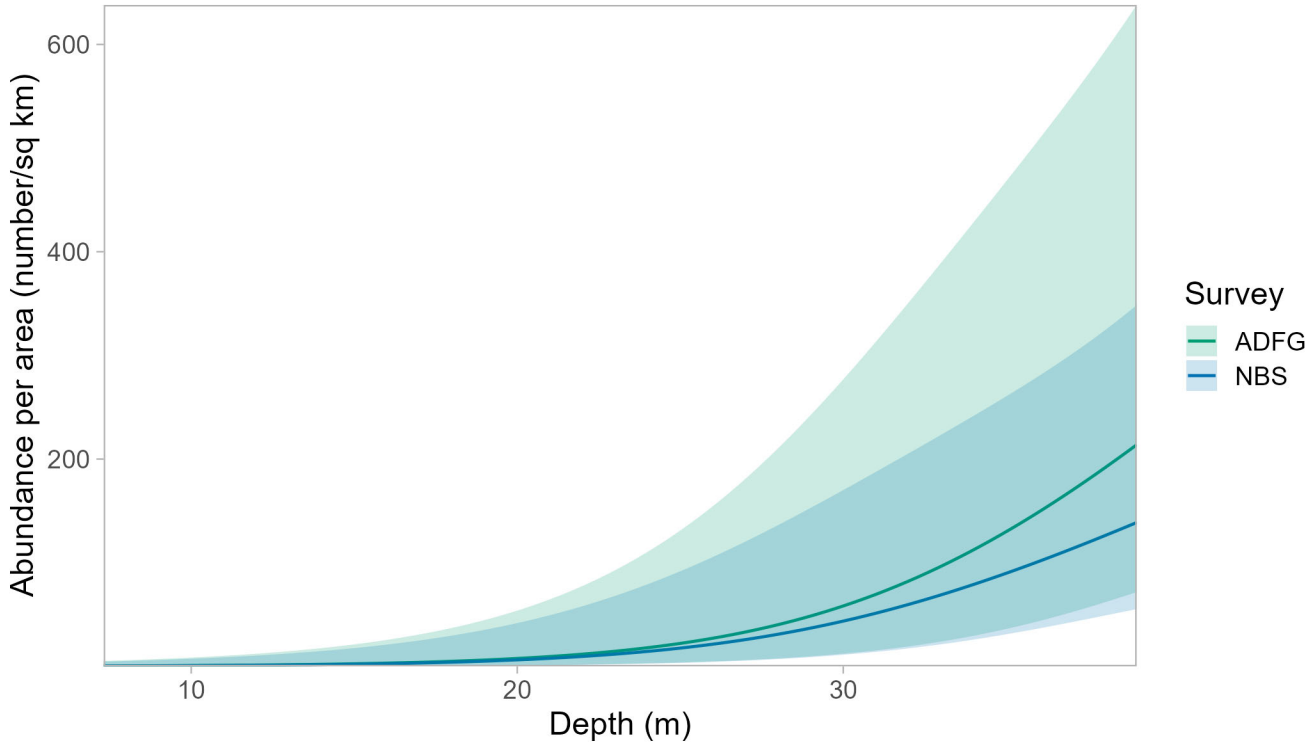


Model-based index standardization

Fit geostatistical GLMMs with spatiotemporally correlated random effects to survey data using sdmTMB

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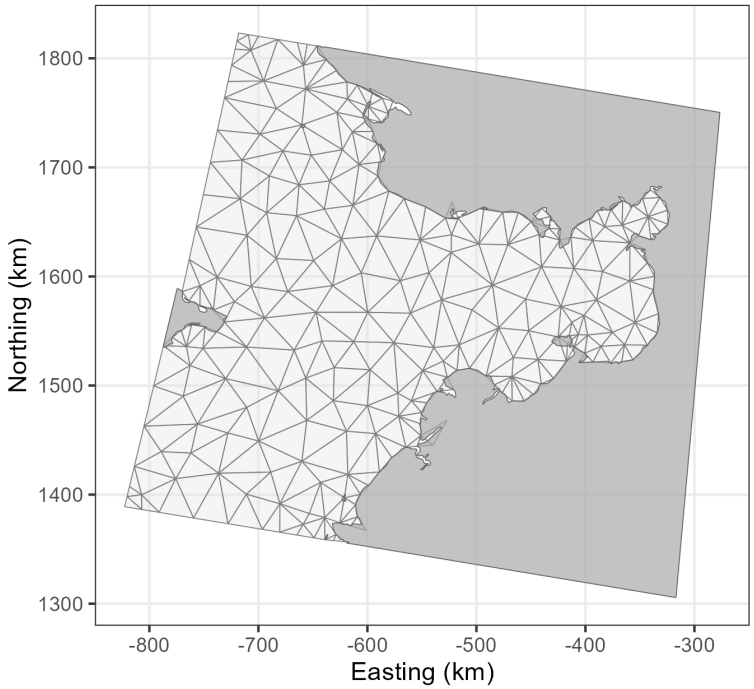
Model-based index standardization

Fit geostatistical GLMMs with spatiotemporally correlated random effects to survey data using sdmTMB

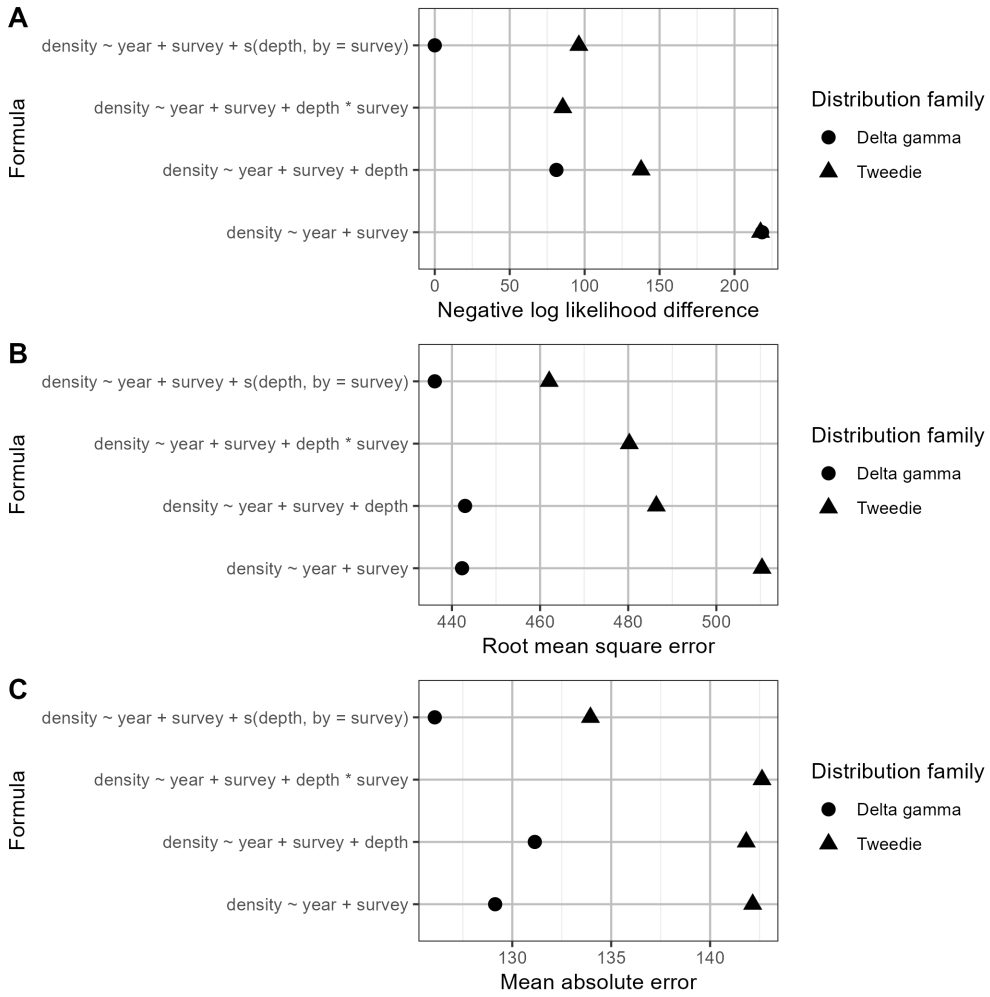
Fixed effects in all models: year, survey

Including depth: depth, depth * survey, s(depth, by = survey)

Distribution families: Tweedie, delta gamma, delta lognormal



Model selection

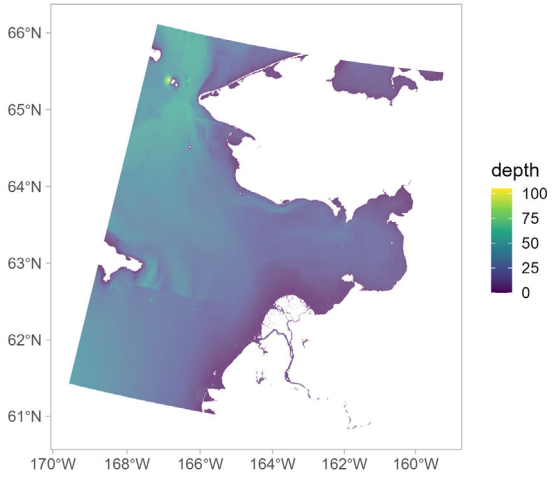


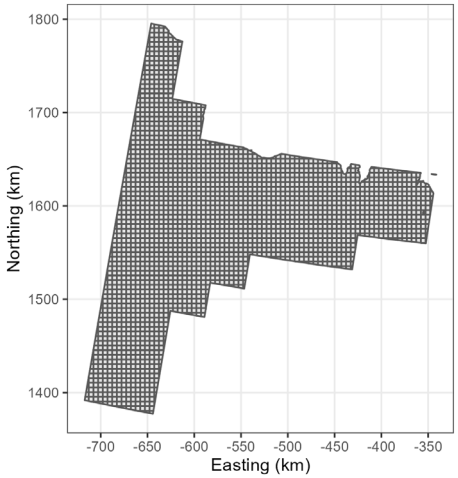
Model selection

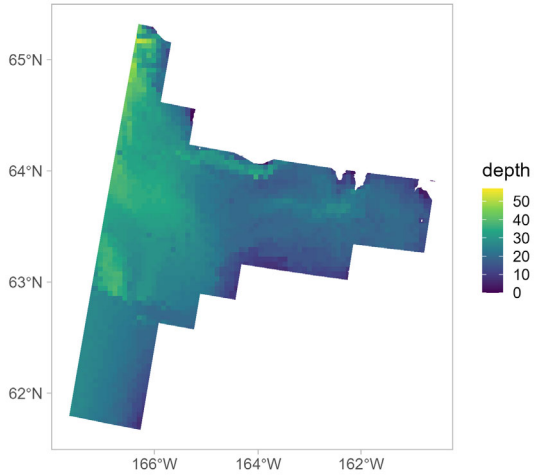
Model without depth: delta gamma distribution. Similar NLL, RMSE and MAE substantially lower.

Model with depth: delta gamma distribution, density ~ year + survey + s(depth, by = survey). Lowest NLL, RMSE, and MAE.

Prediction grid

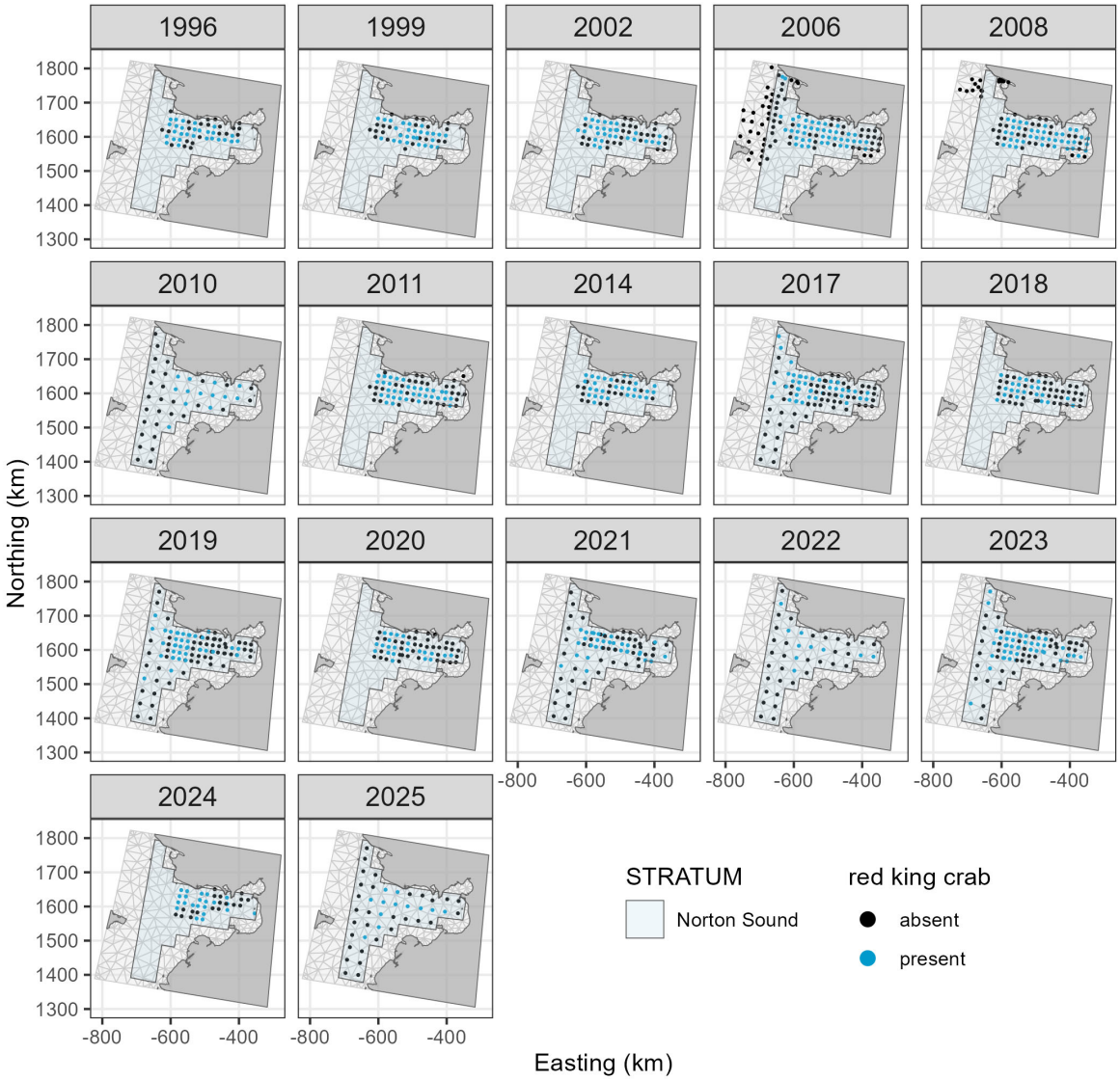




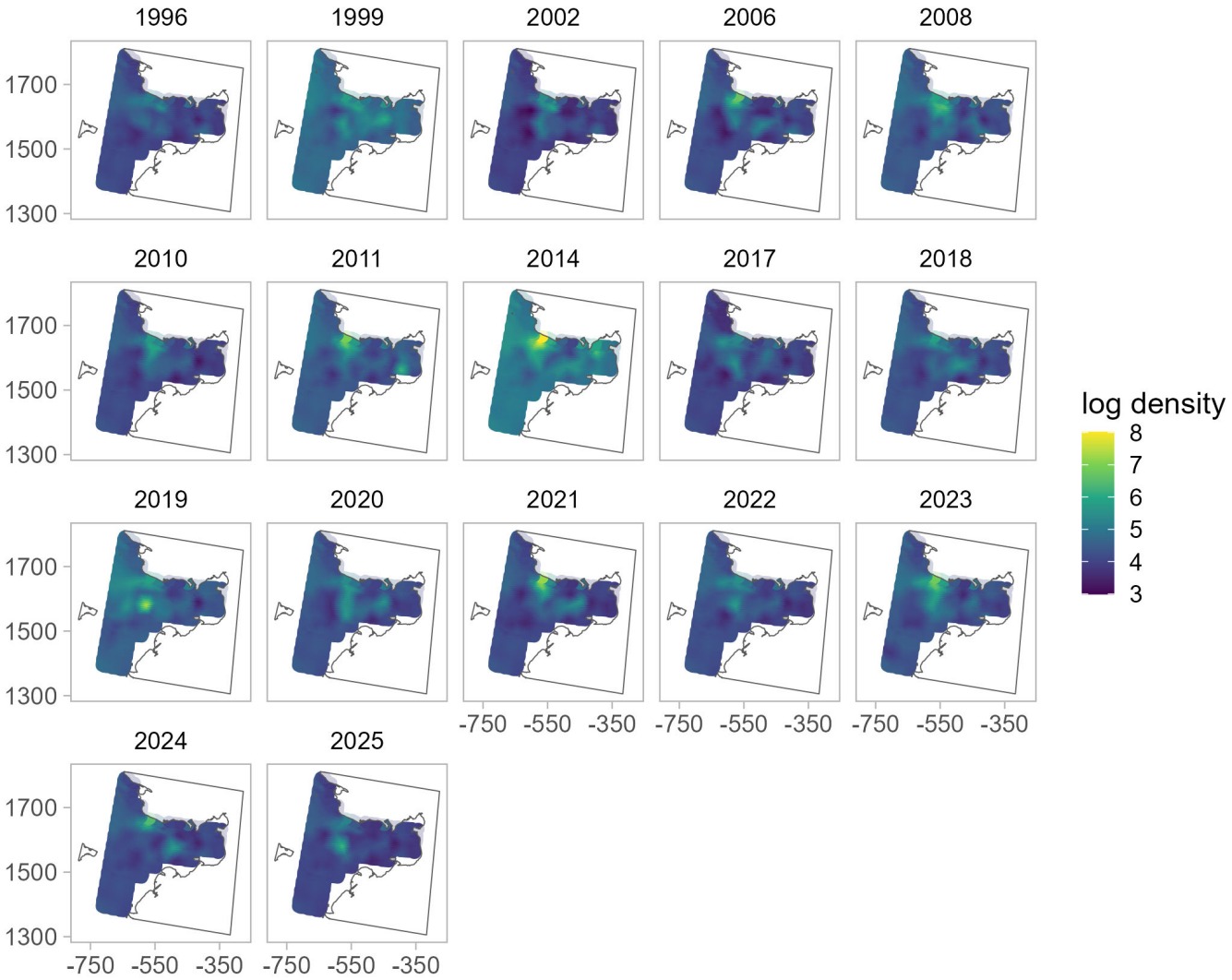


Depth information added to prediction grid for models that included depth

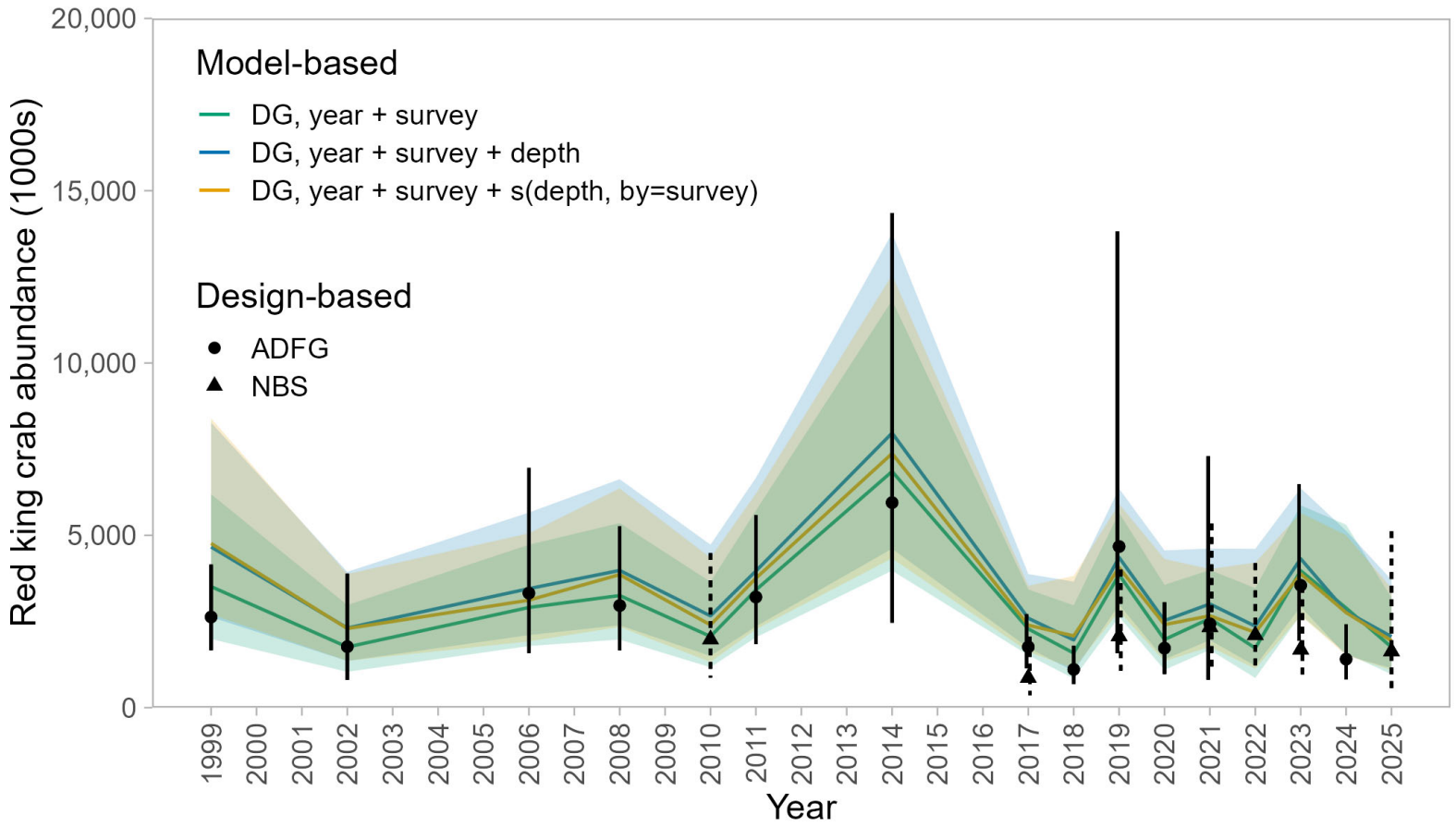
Prediction grid and stock range



Spatial predictions - positive catch



Model-based vs. design-based indices



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Risk table and ABC buffer

Alternative models

26.1: 26.0 with a model-based index of abundance. Catchability for the MBI fixed at 1.

26.2: 26.0 with a model-based index of abundance. Catchability estimated for the MBI.

26.1.nd and 26.2.nd: model-based index without depth

26.1.d and 26.2.d: model-based index with depth

Model results

- Model convergence
- Catchability, selectivity
- Fishing mortality, natural mortality
- Fits to time series: catch, indices, size comps
- Recruitment, MMB
- Retrospectives, projections
- Reference points

Model convergence

Maximum likelihood estimate (MLE) identified by jittering

Model	% of 200 jitter runs that ran successfully	% successful runs that had min. objective function value	Max. gradient at MLE
26.0.up	63	85	-0.0000009
26.1.d	66	83	-0.0000039
26.1.nd	60	87	-0.0000217
26.2.d	58	89	-0.0000052
26.2.nd	60	91	-0.0000241

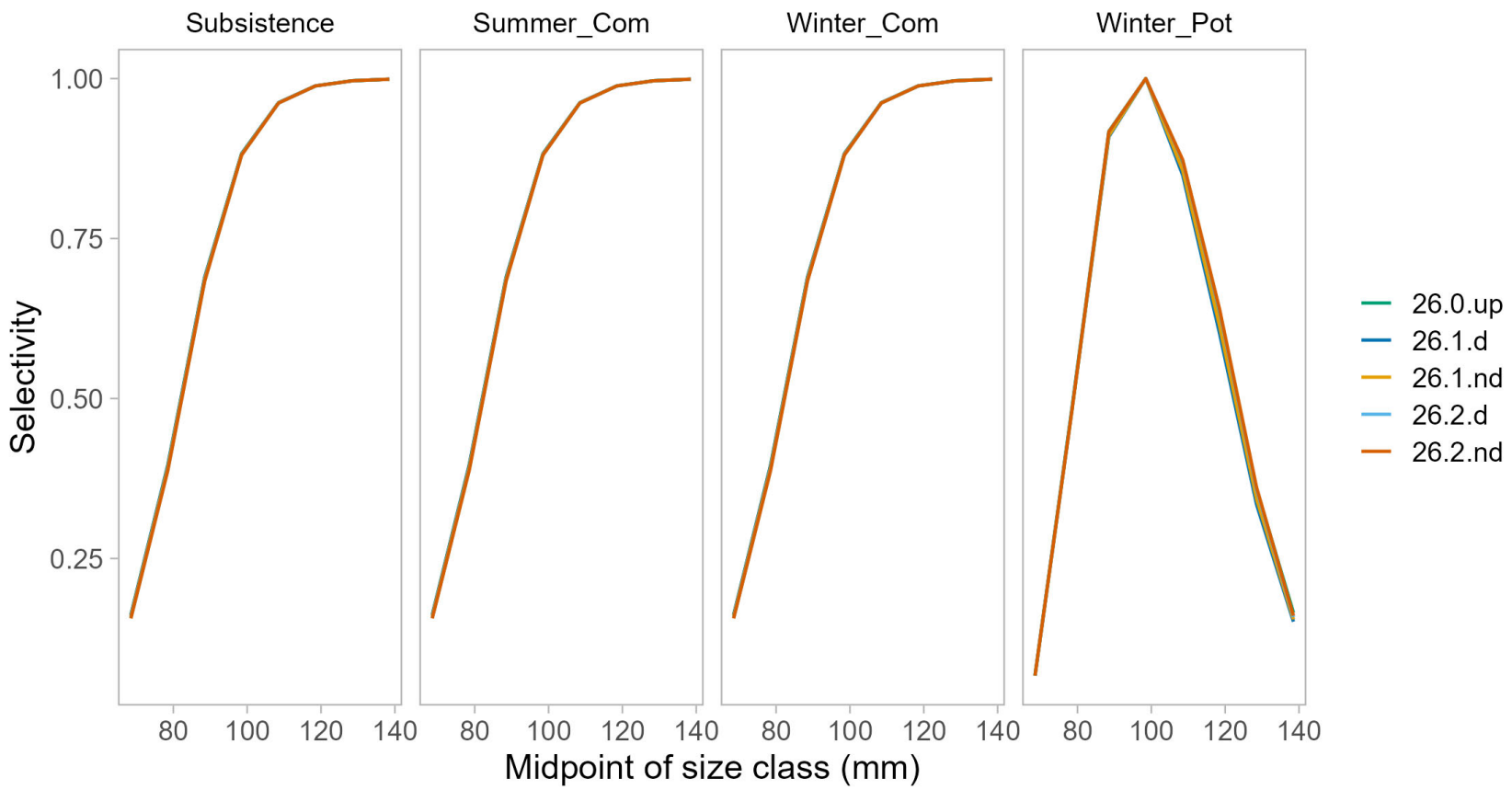
Catchability

Estimated $q > 1$ for model-based index; further investigation needed

Index	26.0.up	26.1.nd	26.1.d	26.2.nd	26.2.d
Historical survey	0.8348	0.6977	0.6243	0.8699	0.8641
ADFG survey	1.0000				
NBS survey	0.6854				
Model-based		1.0000	1.0000	1.4419	1.6858
CPUE series 1	0.0008	0.0007	0.0006	0.0009	0.0009
CPUE series 2	0.0014	0.0012	0.0010	0.0016	0.0016
CPUE series 3	0.0011	0.0009	0.0008	0.0013	0.0014

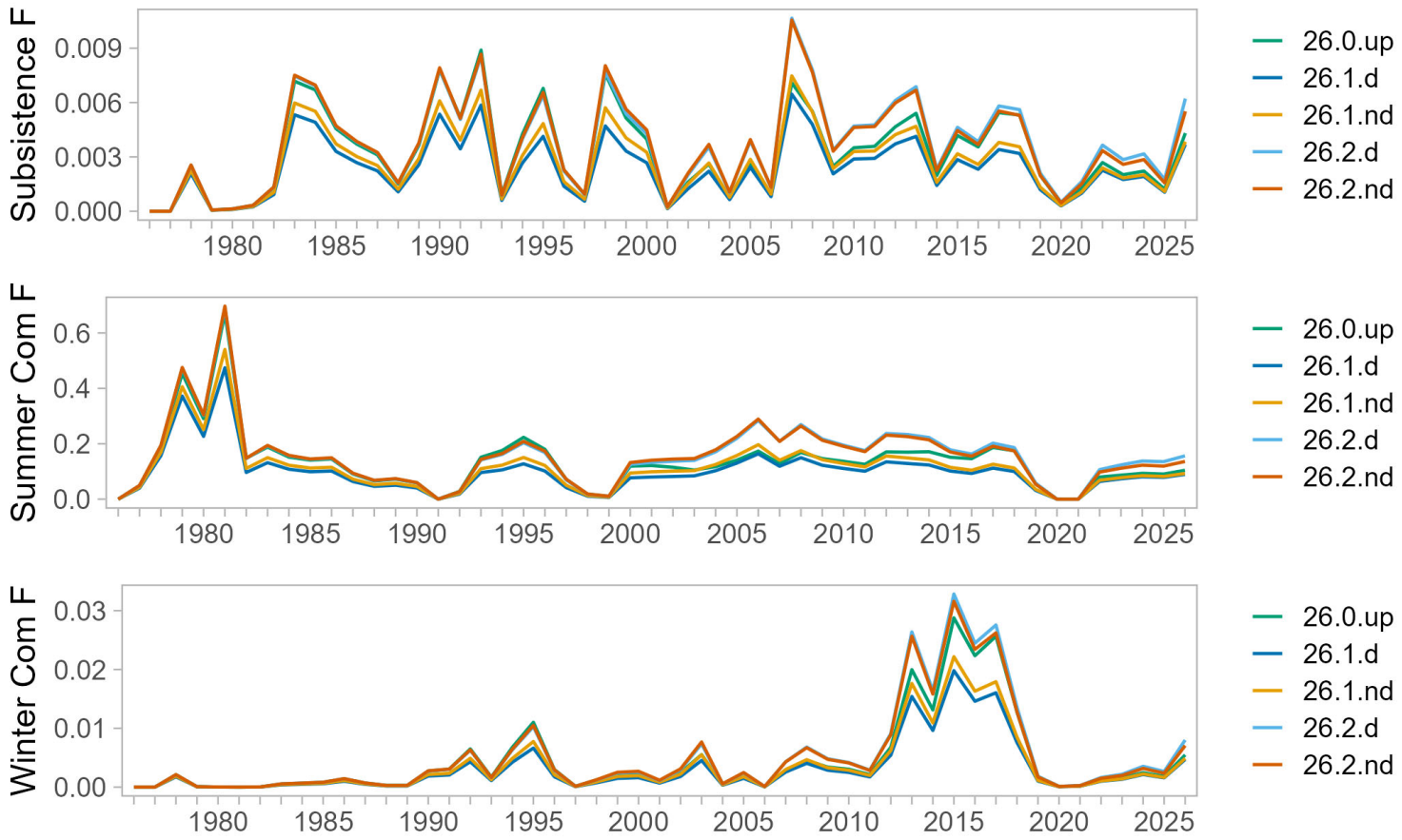
Selectivity

Selectivity parameter estimates similar across models



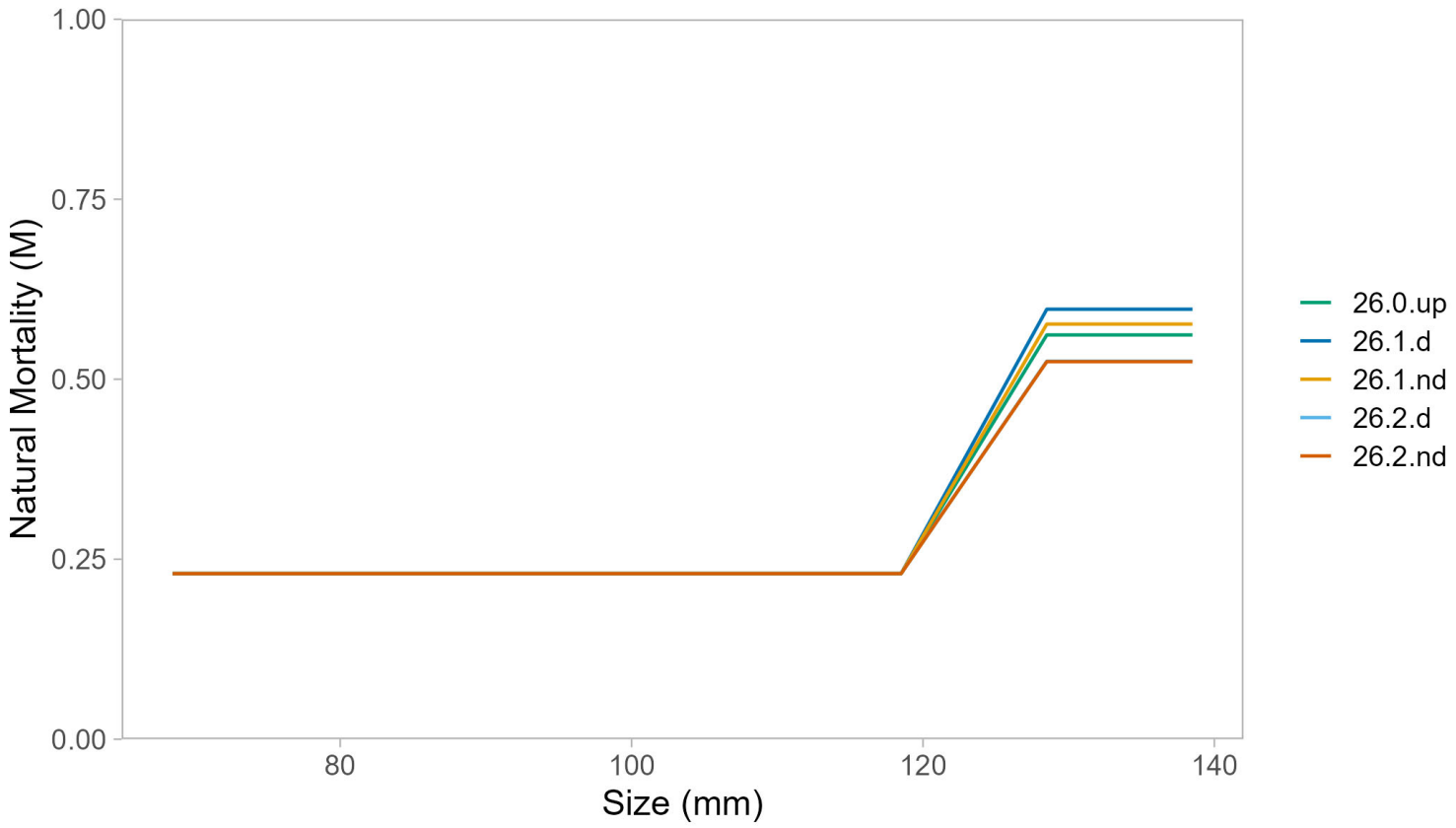
Fishing mortality

Fishing mortality estimates lower when MBI used with fixed *q*



Natural mortality

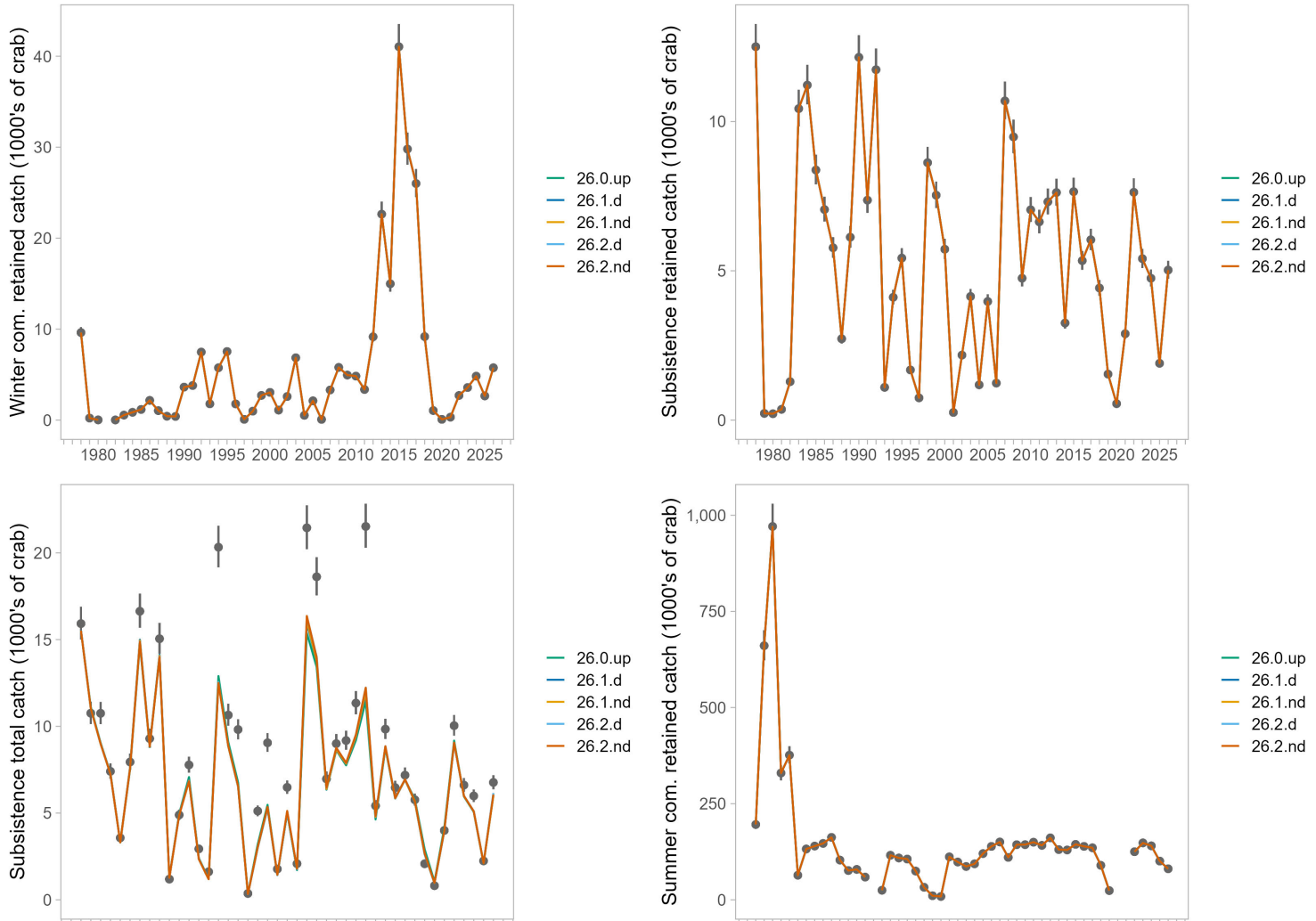
M for large males higher when MBI used with fixed *q*



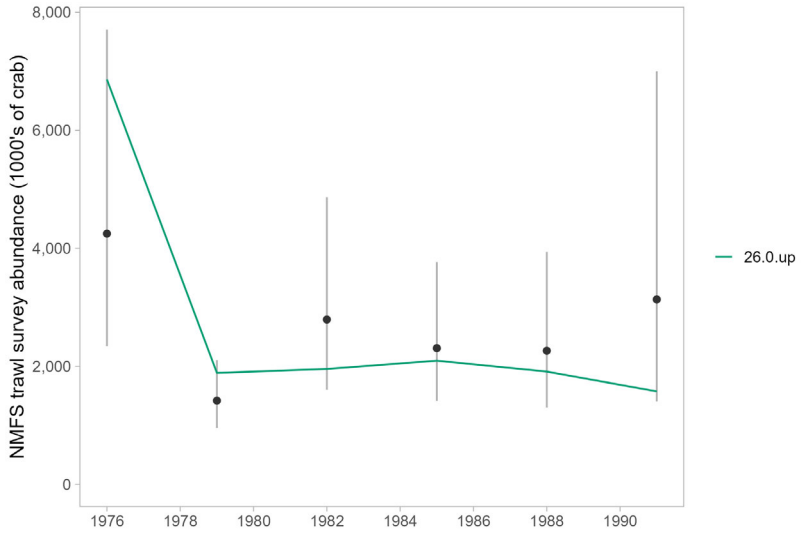
M = 0.23 for males $\leq$ 123 mm CL

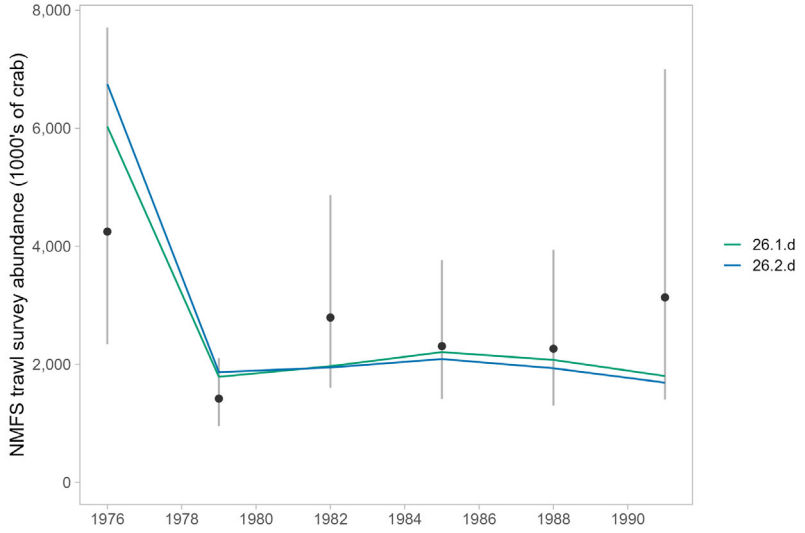
Fits to fishery catch data

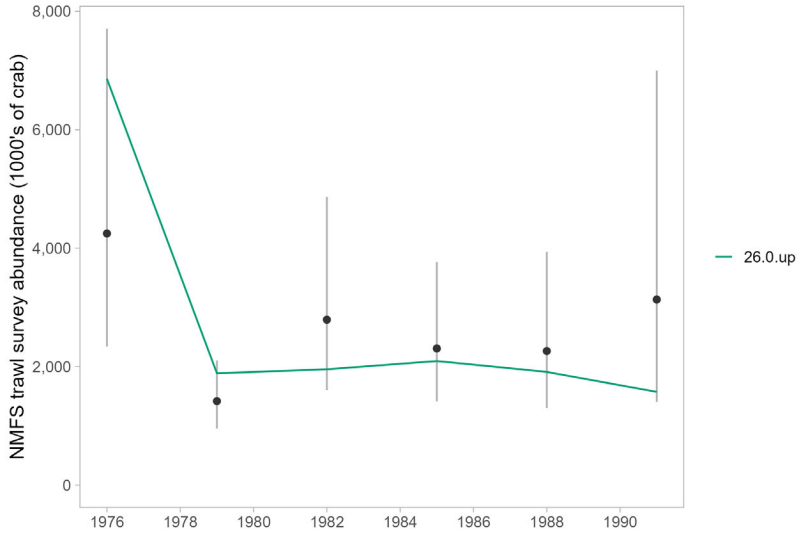
Fits to catch data similar across models



Fits to NOAA NS survey index



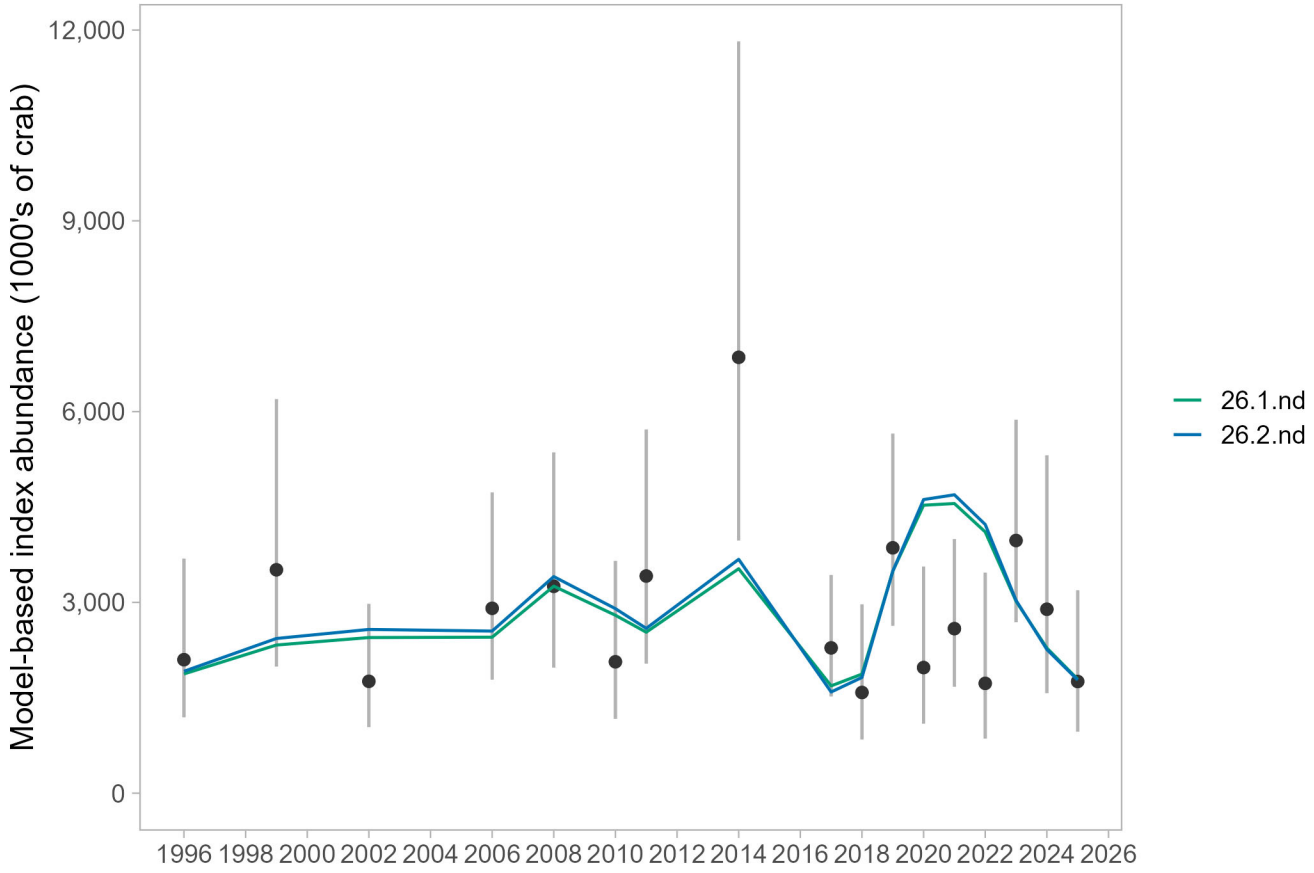




Fit to historical index best when MBI used with fixed *q*, depth included (26.1.d)

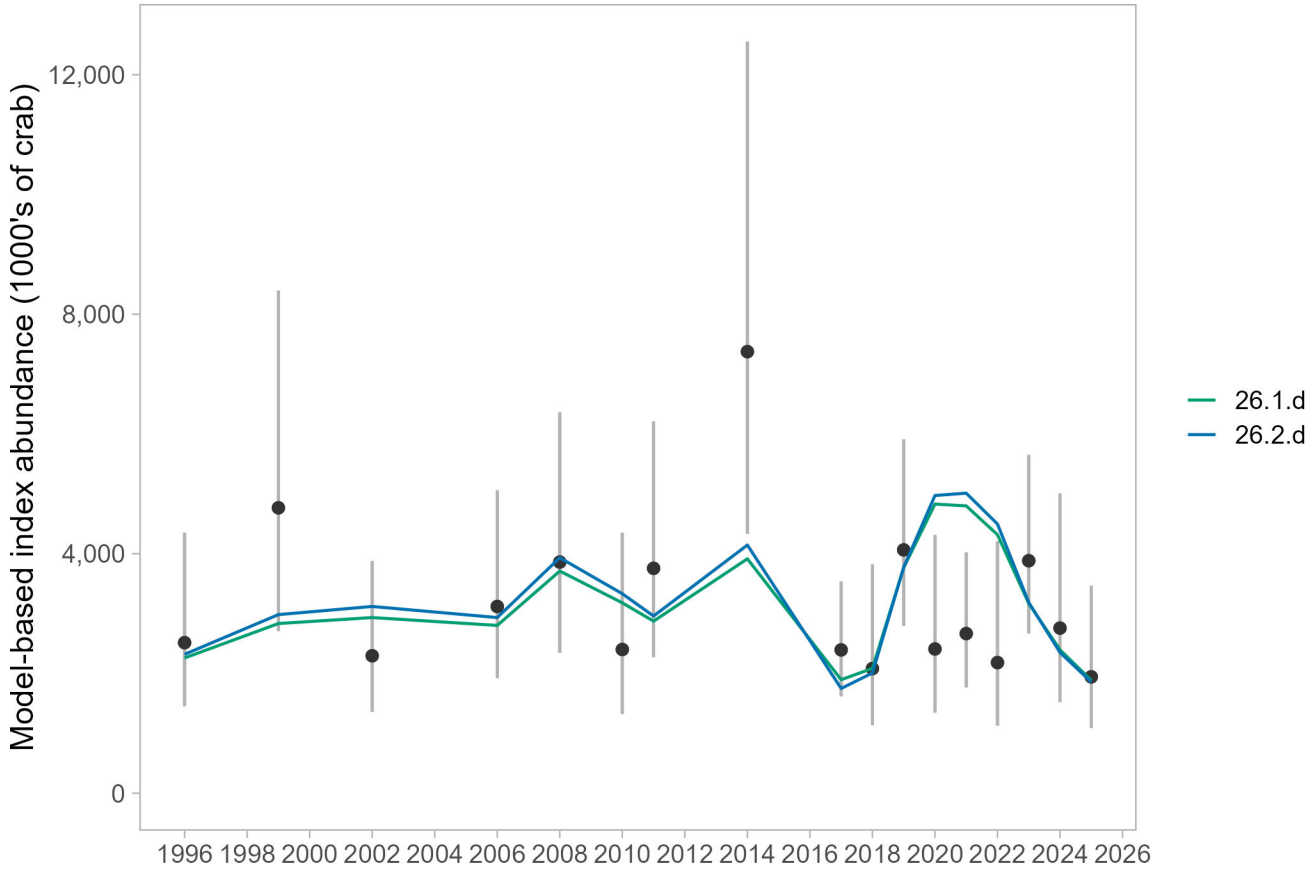
Fits to MBI without depth

Fit to MBI without depth best when *q* fixed



Fits to MBI with depth

Fit to MBI with depth best when *q* fixed



Fits to CPUE indices

1977-1992:

- base model fits best
- of MBI models, model without depth and with estimated *q* fits best

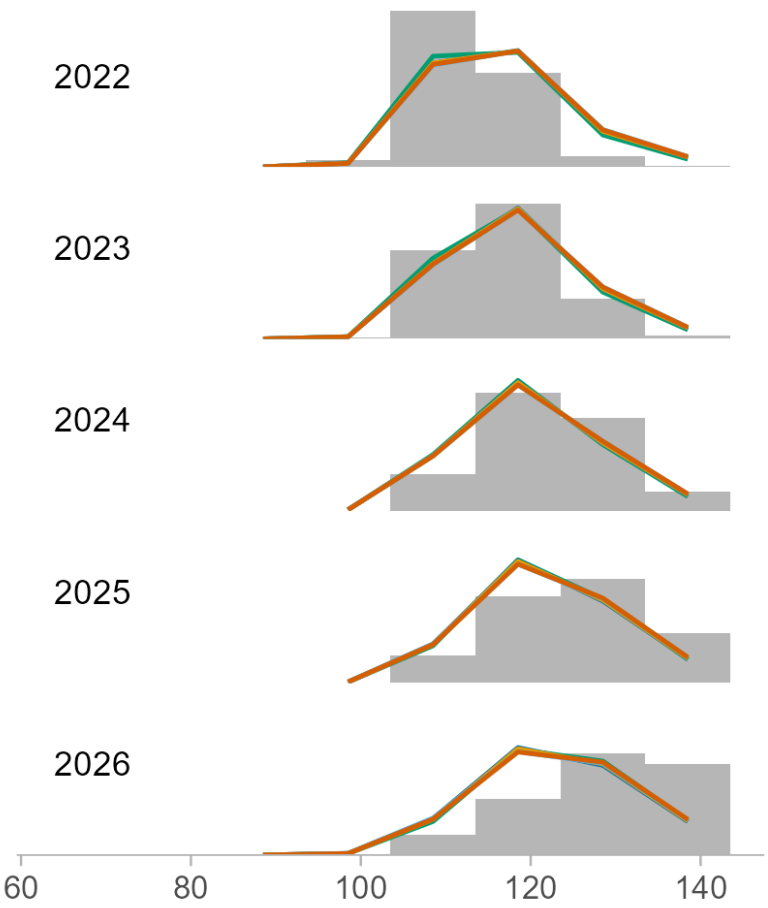
1993-2006: model using MBI with depth included and *q* fixed fits best

2007-2026:

- base model fits best
- of MBI models, model without depth and with estimated *q* fits best

Estimated *q* low for all three series in all models

Fits to size composition time series

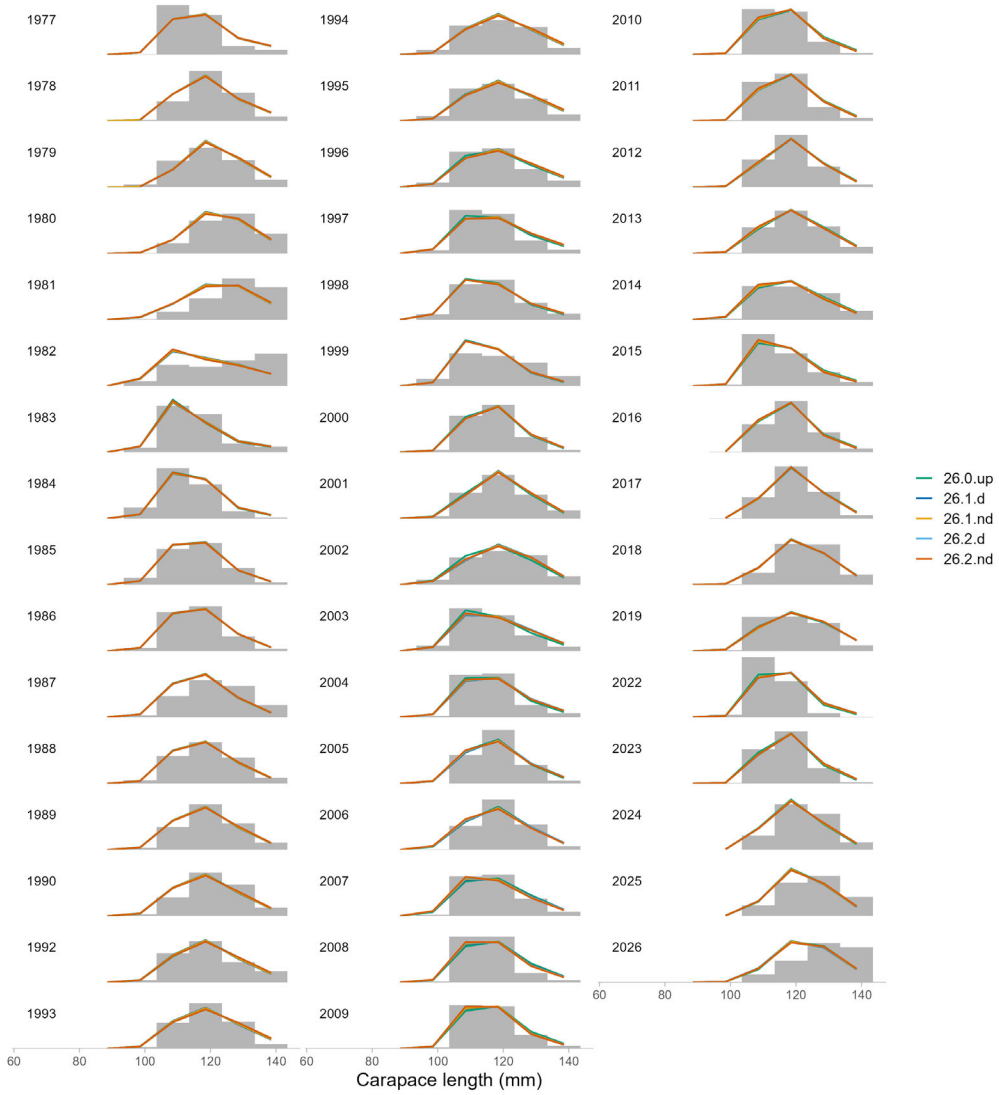


Overall, fits to size composition time series similar across models, including base model

All models had difficulties fitting the atypically high relative abundance of large males in the summer commercial fishery retained catch size compositions in 2025 and 2026

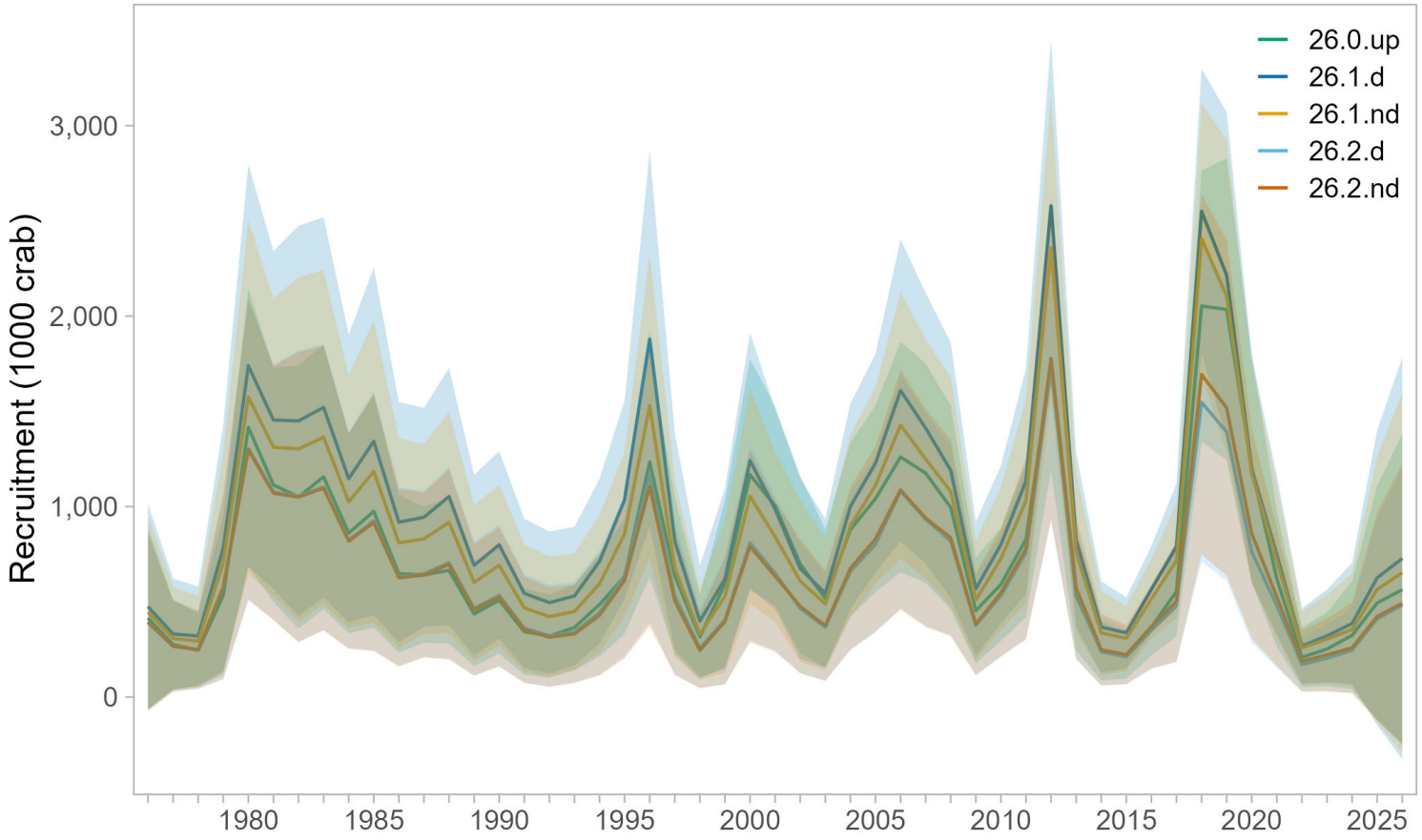
The most similar retained catch size compositions are from 1980-1982

Fits to size comps - summer retained



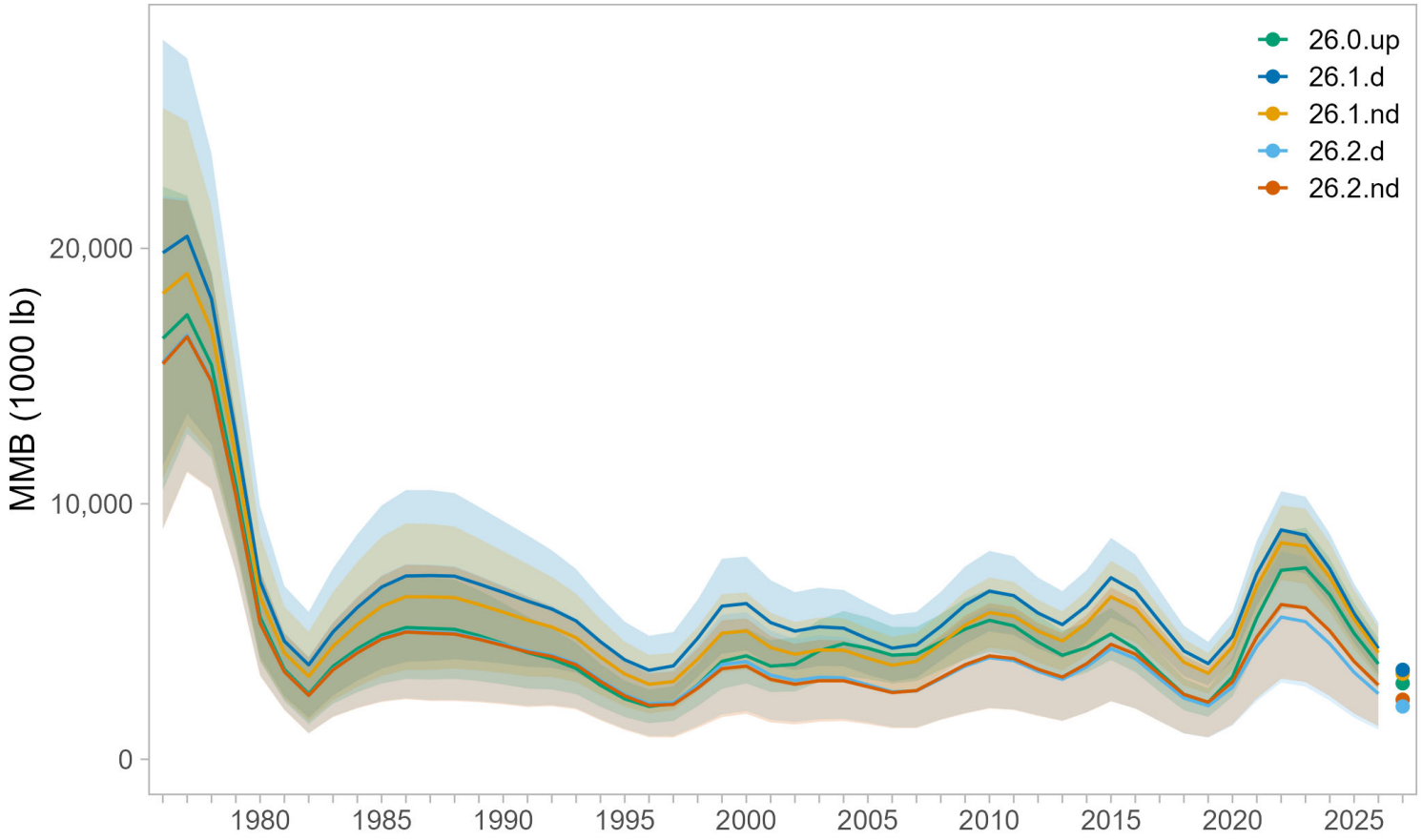
Recruitment

Recruitment may be trending up but uncertainty is high
Survey data needed to better track pseudo-cohort progression



Mature male biomass

MMB trending down, following progression of 2019 pseudo-cohort through population



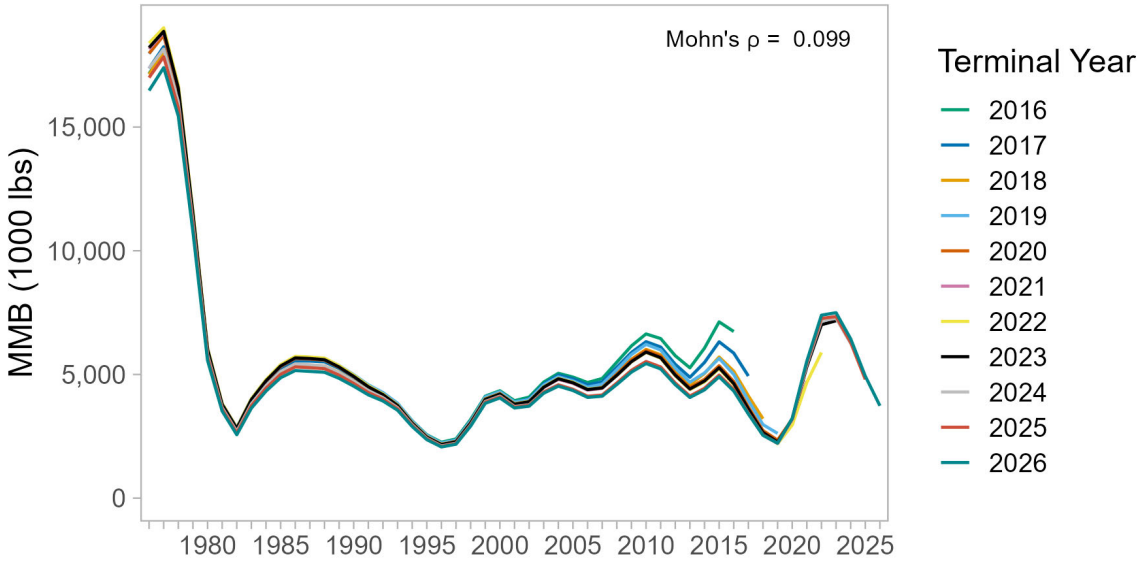
Retrospective analyses

Mohn's ρ for accepted model was 0.126 (Nov 2025 SAFE)

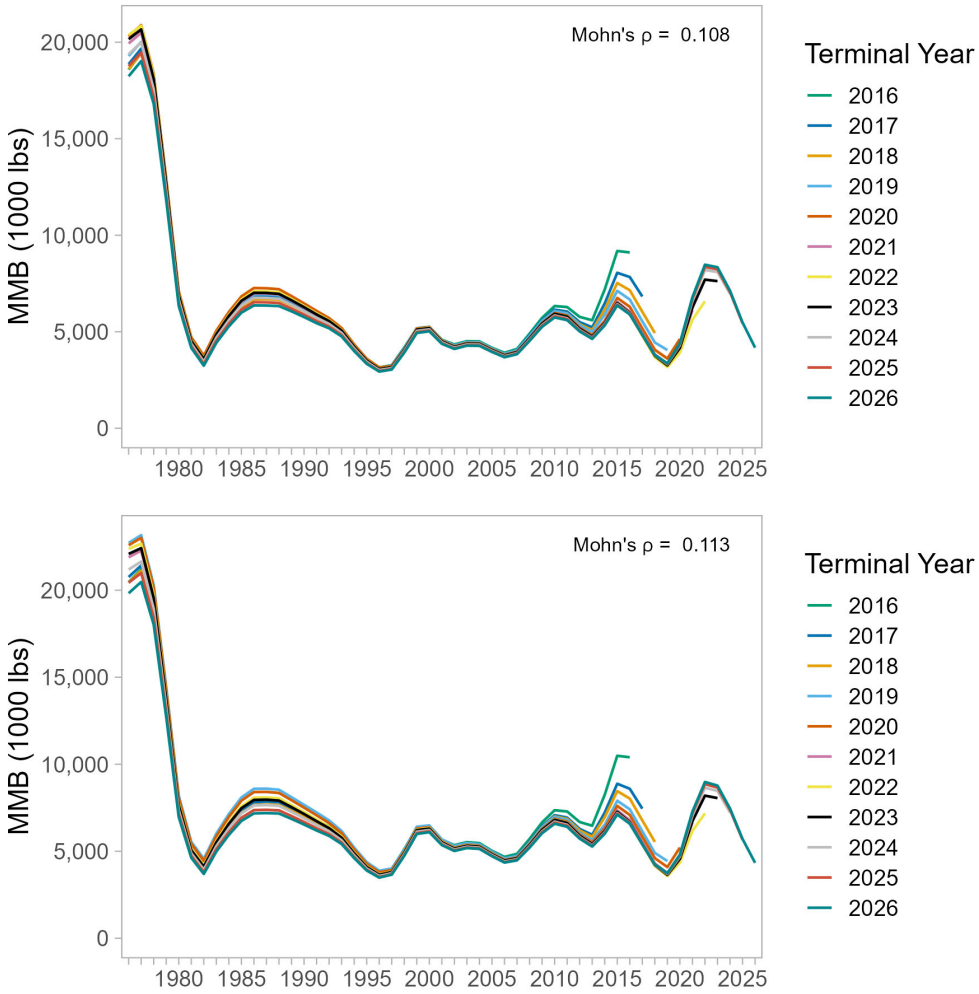
All models here show improved ability to estimate stock biomass in the terminal year

Model	Mohn's ρ
26.0.up	0.099
26.1.nd	0.108
26.1.d	0.113
26.2.nd	-0.007
26.2.d	-0.023

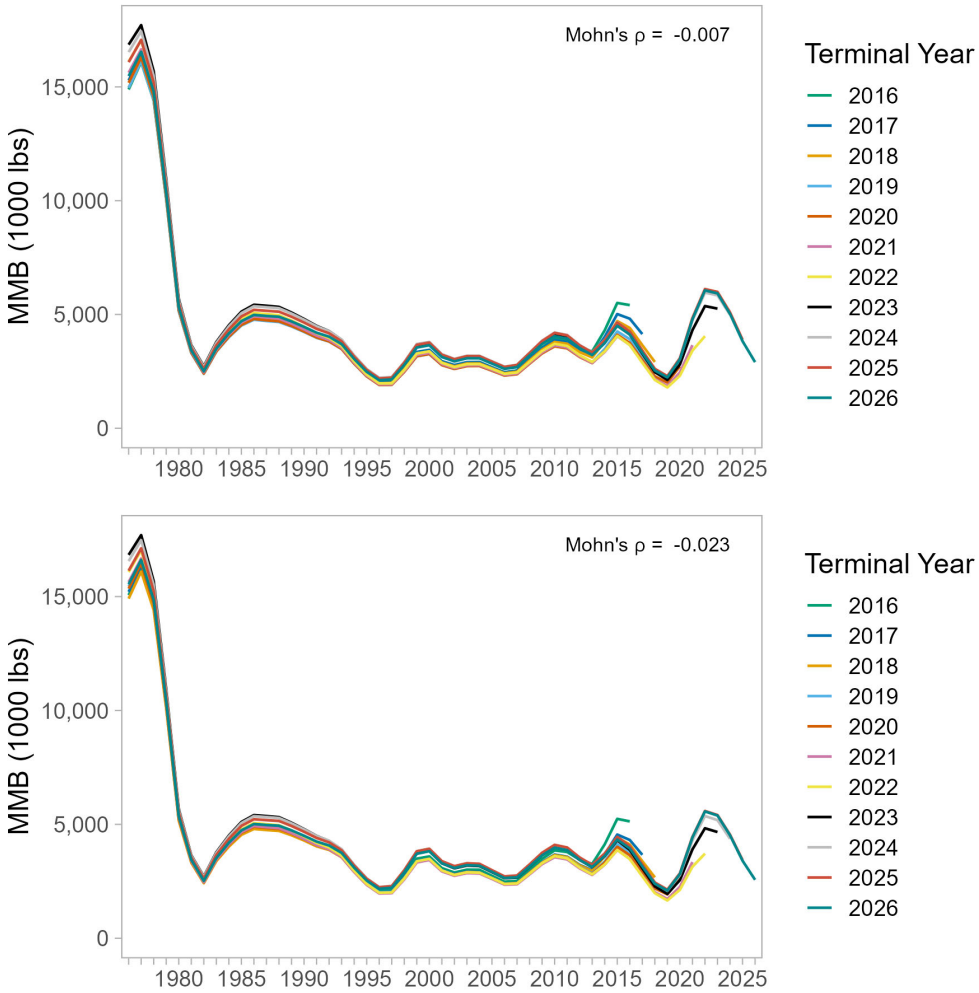
Retrospective analysis - 26.0



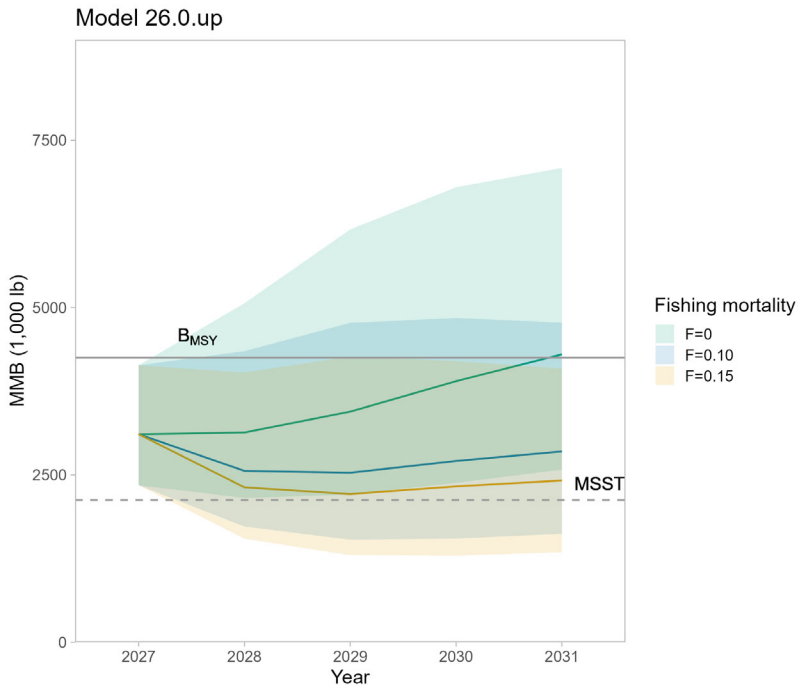
Retrospective analysis - 26.1.nd, 26.1.d



Retrospective analysis - 26.2.nd, 26.2.d

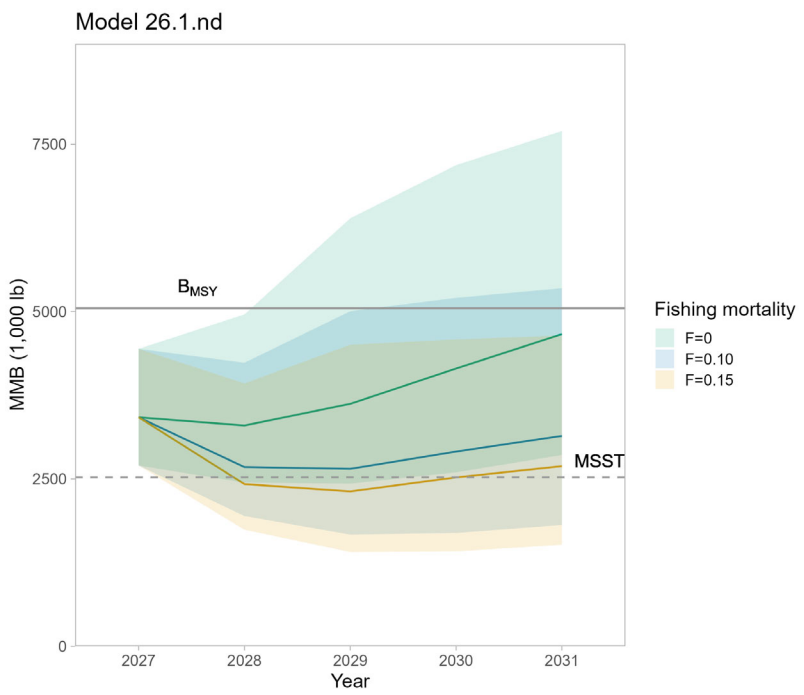


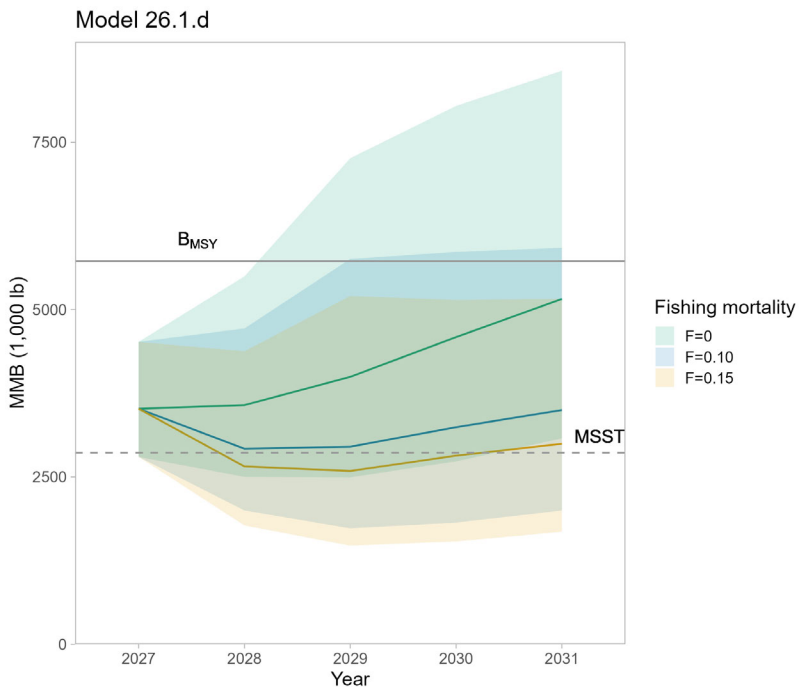
Projections



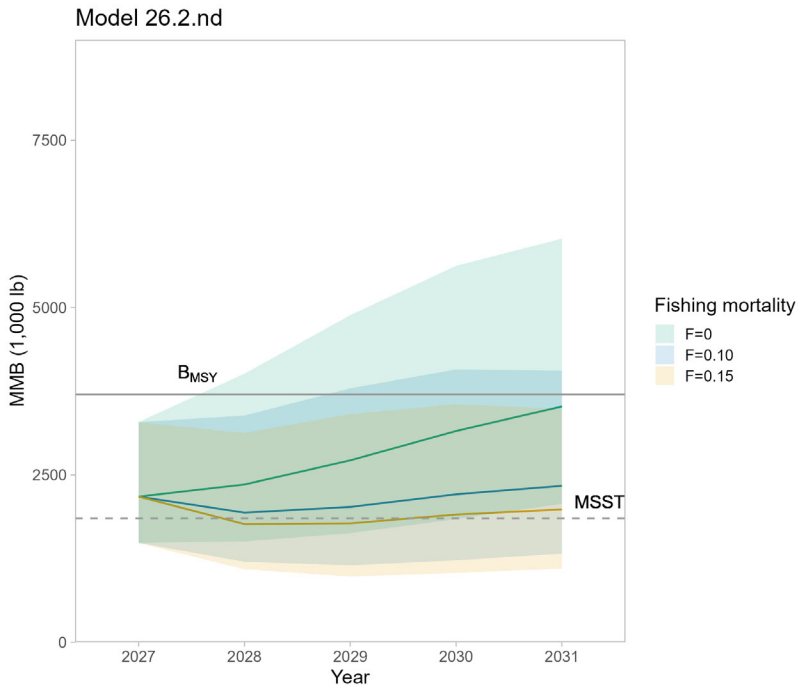
At typical recent fishing mortality rates, all models project a decline in MMB followed by stabilization and increase

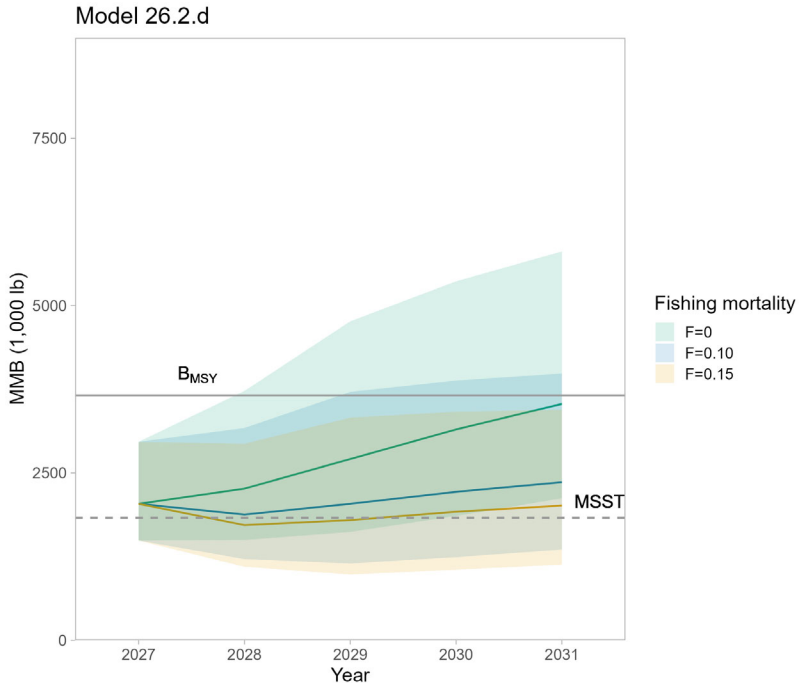
Projections for 26.1 models





Projections for 26.2 models





Comparison of model scenarios

Model-based index (MBI) of abundance

- combines ADF&G and NBS trawl survey data in one index
- standardizes spatiotemporally, addressing spatial and temporal variation in survey sampling effort
- addresses long-standing concerns about the comparability and spatial domain of the survey abundance estimates

Models 26.1.d and 26.2.d use MBI derived from a spatiotemporal model that included depth and had better out-of-sample predictive skill than model without depth

Models 26.2.nd and 26.2.d estimate q for MBI. Estimated catchabilities were > 1 and further investigation is needed

Model 26.1.d recommended for 2027 harvest specifications

Status and reference points

Status: not overfished, below B_{MSY}

Model	MMB	B_{MSY}	MMB/B_{MSY}	F_{OFL}	OFL	ABC	Units
26.0.up	1.349	1.929	0.699	0.153	0.142	0.100	1,000 t
26.1.nd	1.520	2.291	0.663	0.144	0.151	0.106	1,000 t
26.1.d	**1.588**	**2.597**	**0.612**	**0.131**	**0.143**	**0.100**	**1,000 t**
26.2.nd	1.057	1.680	0.630	0.135	0.099	0.070	1,000 t
26.2.d	0.937	1.660	0.565	0.119	0.077	0.054	1,000 t

Topics

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Bridging analyses

Development of a model-based index (MBI)

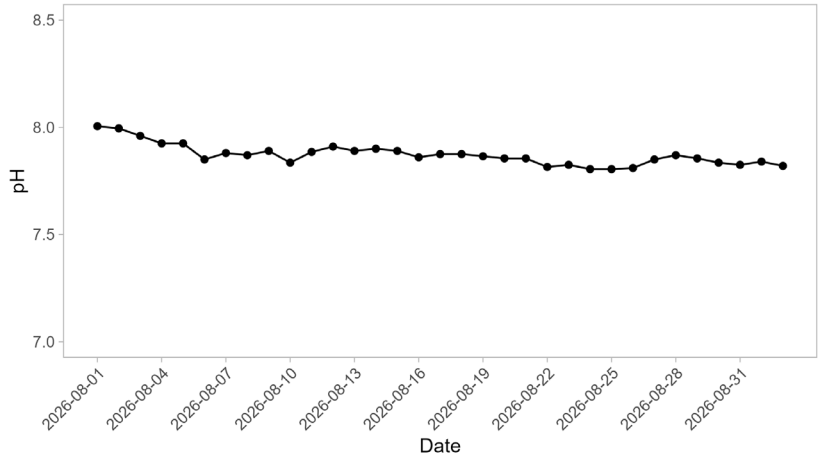
Alternative models

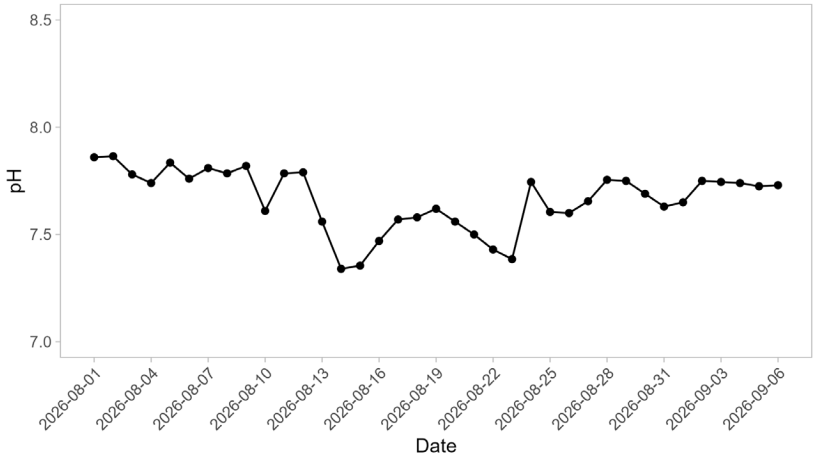
Risk table and ABC buffer

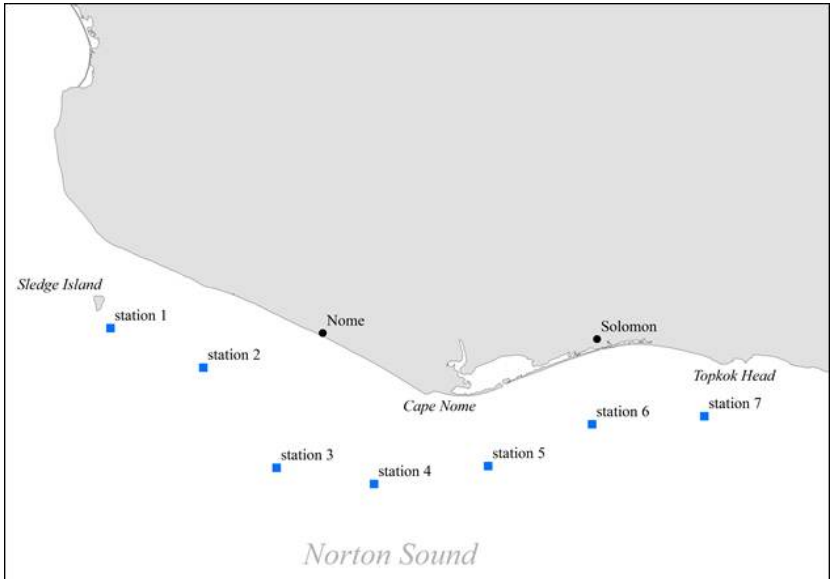
Risk table

	Assessment-related considerations	Population dynamics considerations	Environmental / ecosystem considerations	Fishery performance
	Level 2: increased concern	**Level 1: normal**	**Level 1: normal**	**Level 1: normal**
long term or persistent	M, size-at-maturity from other stocks. Discards model-estimated due to shortage of discard data. Impact of crab seasonal movement unknown. Area used for estimating abundance from survey may not capture full stock range. Overestimation of large crab addressed by estimating M.	Stock trends appear to be typical for the stock. Recruitment has been low but increasing since 2022.	General lack of mechanistic understanding of effects of ecosystem indicators on NSRKC survival and productivity. Modeled pH continues to decline.	Fishery-informed indicators are generally consistent with stable stock condition.
	no change	**no change**	**no change**	**no change**
current	Moving to a model using a spatiotemporally standardized index of abundance for would address concerns about mismatch between stock range and area used for estimating abundance.	Mean weight in summer commercial fishery retained catch highest in time series. % of males in retained catch in largest size bin highest in time series (34%); previously > 20% only in 1981, 1982.	Both modeled and measured pH in Norton Sound were low in 2026, which could negatively impact juvenile survivorship.	ABC exceeded in 2026 following larger than expected catch between fishery closure annoucement and closure.

pH in Norton Sound in 2026







Data collected by Jen Bell (ADF&G)

ABC buffer

- recommend 30% buffer for 2027 harvest specifications
- 30% buffer in 2023-2026
- concerns included retrospective pattern in MMB, lack of information about discards, size-dependent *M*
- retrospective pattern in MMB improved
- increased uncertainty due to lack of fishery-independent survey data in 2026
- poor fit to 2026 summer commercial fishery size comps

Reference points

Model	MMB	B_{MSY}	MMB/B_{MSY}	F_{OFL}	OFL	ABC	Units
26.0.up	1.35	1.93	0.70	0.153	0.142	0.100	1,000 t
26.1.nd	1.52	2.29	0.66	0.144	0.151	0.106	1,000 t
26.1.d	**1.59**	**2.60**	**0.61**	**0.131**	**0.143**	**0.100**	**1,000 t**
26.2.nd	1.06	1.68	0.63	0.135	0.099	0.070	1,000 t
26.2.d	0.94	1.66	0.56	0.119	0.077	0.054	1,000 t

Model	MMB	B_{MSY}	MMB/B_{MSY}	F_{OFL}	OFL	ABC	Units
26.0.up	2.97	4.25	0.70	0.153	0.314	0.220	million lb
26.1.nd	3.35	5.05	0.66	0.144	0.333	0.233	million lb
26.1.d	**3.50**	**5.72**	**0.61**	**0.131**	**0.316**	**0.221**	**million lb**
26.2.nd	2.33	3.70	0.63	0.135	0.219	0.153	million lb
26.2.d	2.07	3.66	0.56	0.119	0.171	0.119	million lb



Future work

- develop model-based estimation of size compositions
- review, document, and update CPUE standardization methods
- add winter subsistence total catch and summer subsistence catch data



Thanks!



Executive summary tables

Table 1: Status and catch specifications (1,000 t) for the recommended model, 26.1.d.

Year	MSST	Biomass (MMB_{mating})	GHL	Retained catch	Total catch	OFL	ABC	Model
2022/22	0.95	2.42	0.15	0.15	0.16	0.30	0.18	21.0
2023/23	1.20	2.40	0.178	0.192	0.201	0.292	0.204	21.0
2024/24	1.00	2.50	0.219	0.209	0.215	0.332	0.233	21.0
2025/25	0.98	2.15	0.186	0.164	0.168	0.284	0.199	24.0
2026/26	1.00	1.56	0.130	0.149	0.154	0.193	0.135	25.0a2
2027/27	1.30	1.59				0.143	0.100	26.1.d

Table 2: Status and catch specifications (million lb) for the recommended model, 26.1.d.

Year	MSST	Biomass (MMB_{mating})	GHL	Retained catch	Total catch	OFL	ABC	Model
2022/22	2.08	5.33	0.34	0.34	0.36	0.67	0.40	21.0
2023/23	2.65	5.29	0.392	0.425	0.444	0.643	0.450	21.0
2024/24	2.2	5.52	0.483	0.460	0.474	0.733	0.513	21.0
2025/25	2.16	4.72	0.410	0.361	0.369	0.628	0.440	24.0
2026/26	2.21	3.43	0.268	0.328	0.339	0.426	0.298	25.0a2
2027/27	2.86	3.50				0.315	0.221	26.1.d

Executive summary tables

Table 3: Basis for the OFL (1,000 t) from the recommended model, 26.1.d.

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2022/22	4a	1.90	2.42	1.3	0.18	1980-2021	0.18
2023/23	4a	1.98	2.40	1.2	0.18	1980-2022	0.18
2024/24	4a	2.02	2.50	1.2	0.18	1980-2023	0.18
2025/25	4a	1.96	2.15	1.09	0.18	1980-2024	0.18
2026/26	4b	2.00	1.56	0.78	0.17	1980-2025	0.23
2027/27	4b	2.60	1.59	0.61	0.13	1980-2026	0.23

Table 4: Basis for the OFL (million lb) from the recommended model, 26.1.d.

Year	Tier	B_{MSY}	Biomass (MMB_{mating})	B/B_{MSY}	F_{OFL}	Basis for B_{MSY}	Natural mortality
2022/22	4a	4.17	5.33	1.3	0.18	1980-2021	0.18
2023/23	4a	4.37	5.29	1.2	0.18	1980-2022	0.18
2024/24	4a	4.45	5.52	1.2	0.18	1980-2023	0.18
2025/25	4a	4.33	4.72	1.09	0.18	1980-2024	0.18
2026/26	4b	4.42	3.43	0.78	0.17	1980-2025	0.23
2027/27	4b	5.72	3.50	0.61	0.13	1980-2026	0.23