Impacts of spatiotemporal index standardization on the Norton Sound red king crab stock assessment

Crab Plan Team, September 2025

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Design- vs. model-based indices in stock assessment

Potential drawbacks of using design-based indices:

- inflated temporal variability in abundance estimates due to failure to account for spatial dependence
- biased results when sampling deviates from survey design

Potential benefits of using model-based indices:

- reduced variability of abundance estimates by accounting for spatial variation in survey catch, incorporating habitat variables; reduced uncertainty in assessment model outputs
- robustness to changes in survey effort (Yalcin et al. 2023)
- improved predictive ability (northern shrimp, Cao et al. 2017; witch flounder, Chen et al. 2024)

Norton Sound red king crab and model-based indices

Outline:

Stock, surveys, background

Modeling approach, evaluation, diagnostics

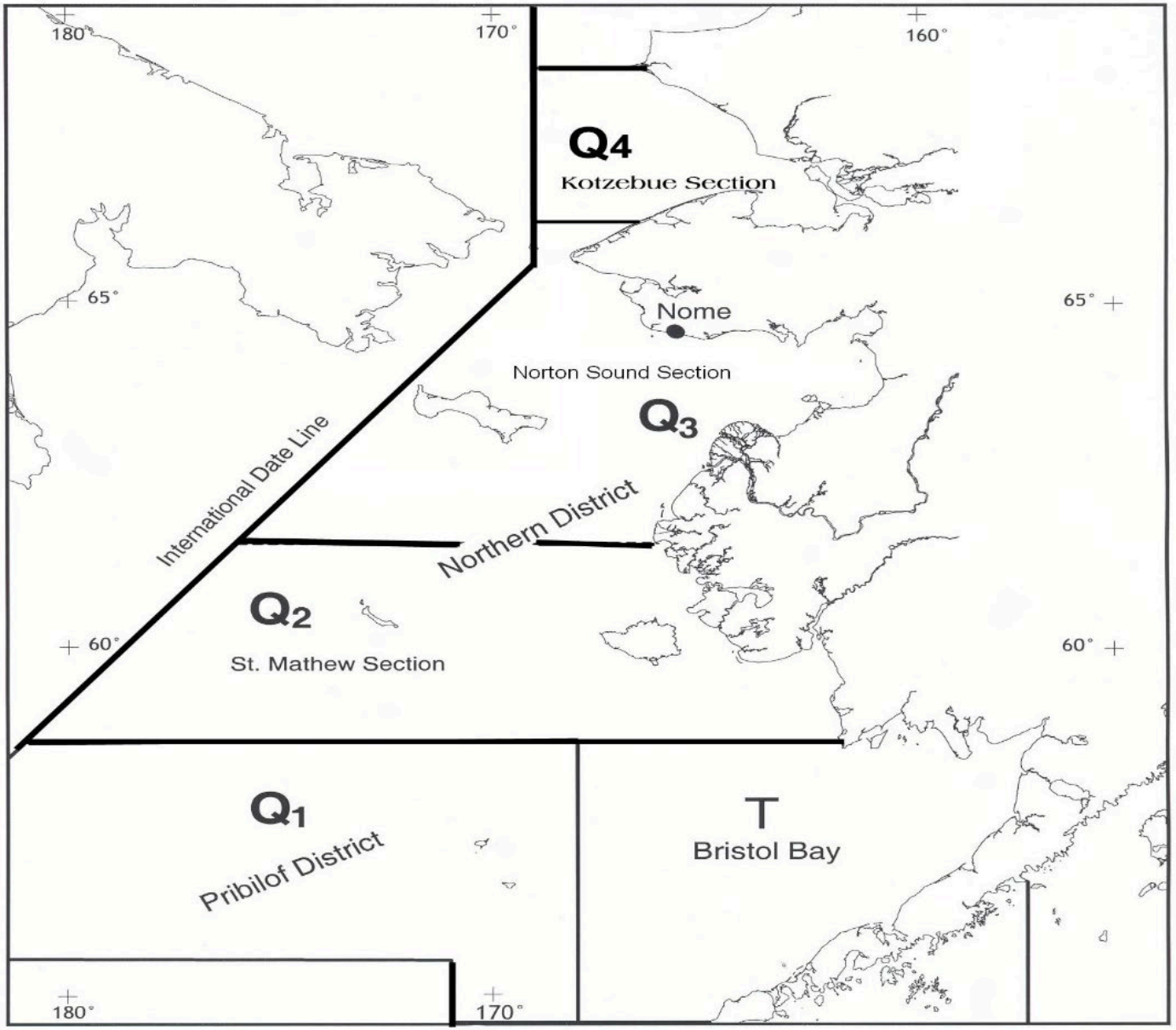
Prediction grids and spatial predictions

Indices, comparison to design-based indices

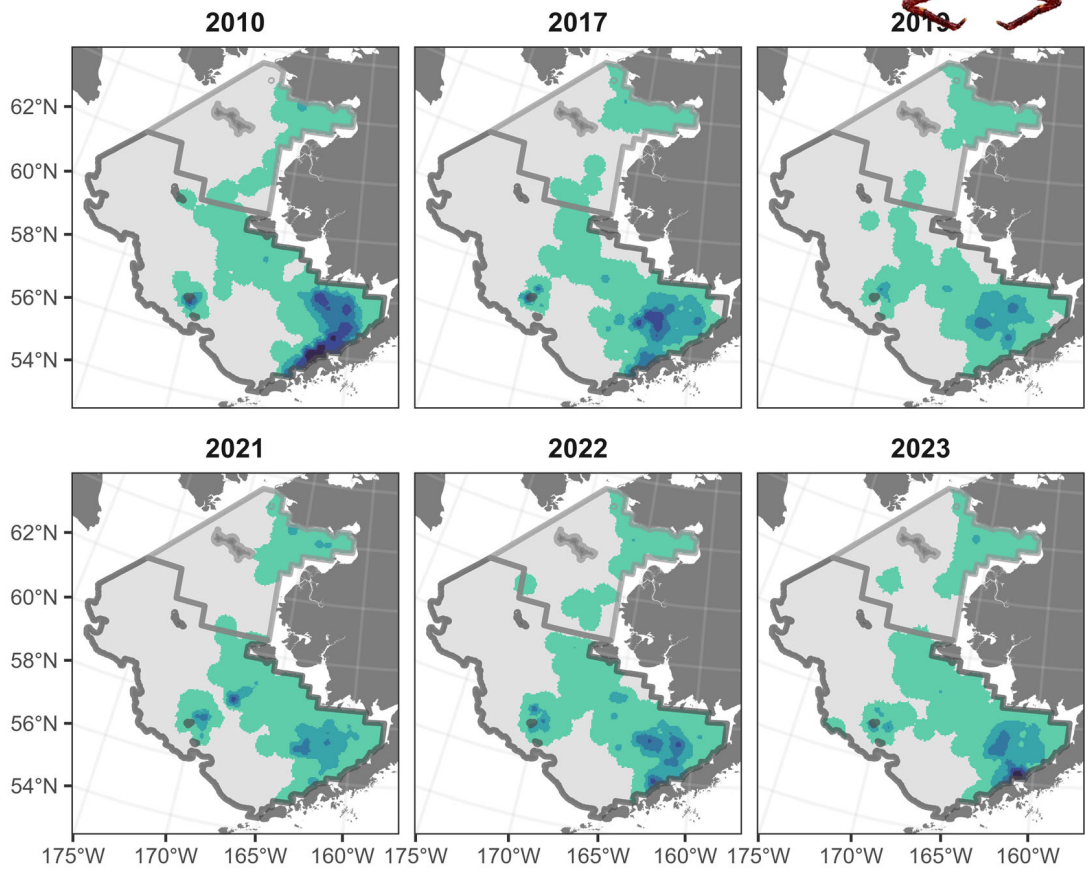
Impacts on stock assessment model output of using model-based index

Future work and feedback

Norton Sound red king crab stock



Norton Sound red king crab stock



Markowitz et al. (2023) Northern Bering Sea groundfish and crab trawl survey highlights. NOAA Community Report.

ALASKA DEPARTMENT OF FISH AND GAME

Trawl surveys

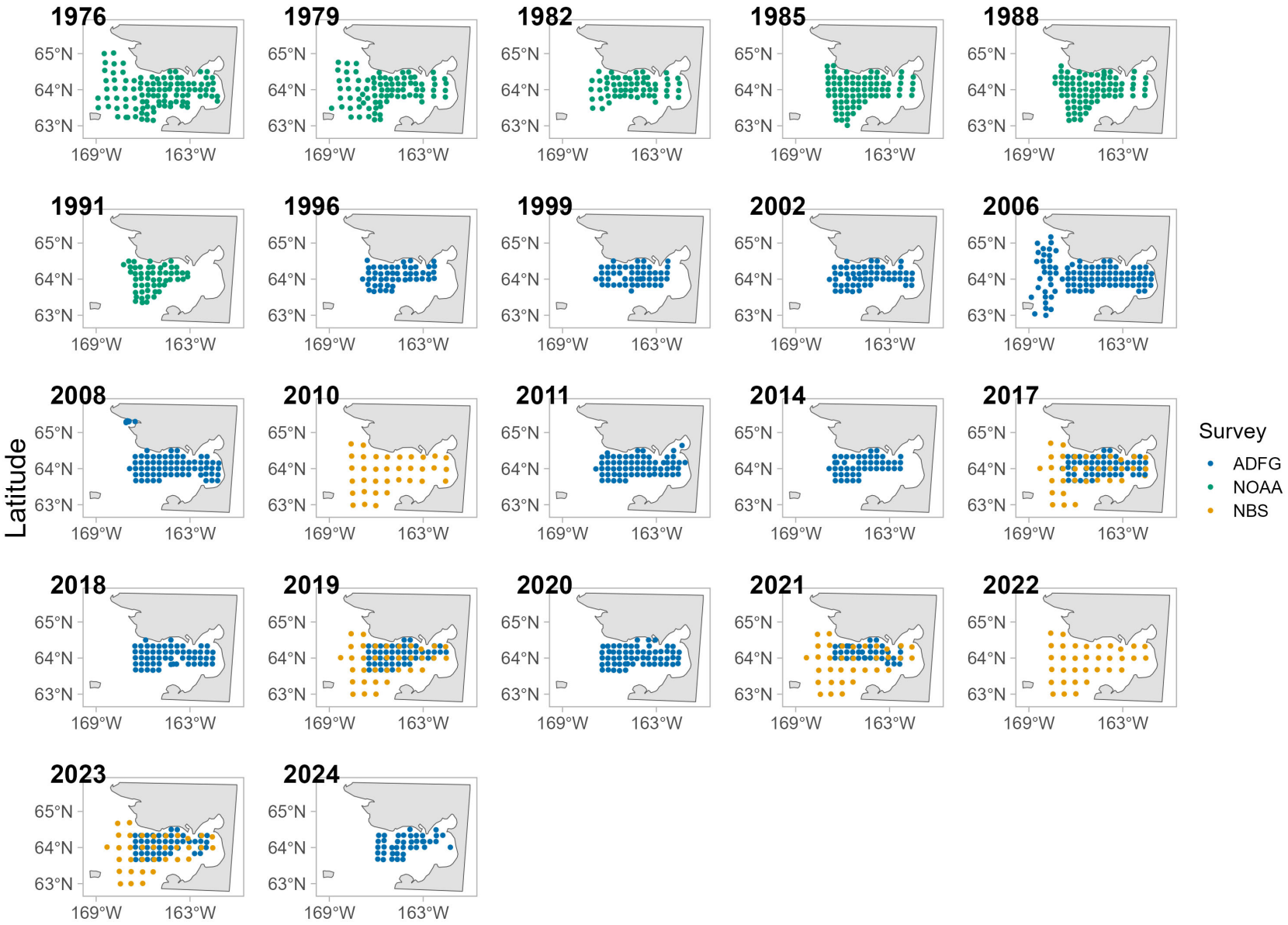
Survey	Years	Grid	Gear	Net width	Tow length	Stations (median)
NOAA NS	1976-1991	10 nm	83-112	50 ft	1.3-1.7 nm	53-104 (78.5)
ADF&G	1996-2024	10 nm	400	40 ft	1.0 nm	39-100 (54.5)
NOAA NBS	2010-2025	20 nm	83-112	50 ft	1.3-2.5 nm	34-35 (35)

NOAA NBS survey occurred in 2025

ADF&G survey expected to occur in 2026

Only including males $\geq$ 64 mm in carapace length

Survey areas sampled



Results from May 2025

Developed survey-specific model-based indices:

- ADF&G survey: delta-gamma model with year and depth
- NOAA NS survey: delta-lognormal model with year and depth
- NOAA NBS survey: Tweedie model with year only

Using these model-based indices in the assessment model led to

- stronger positive retrospective patterns
- similar or poorer fits to most data sources in the model

Combining surveys into a single model-based index identified as next step

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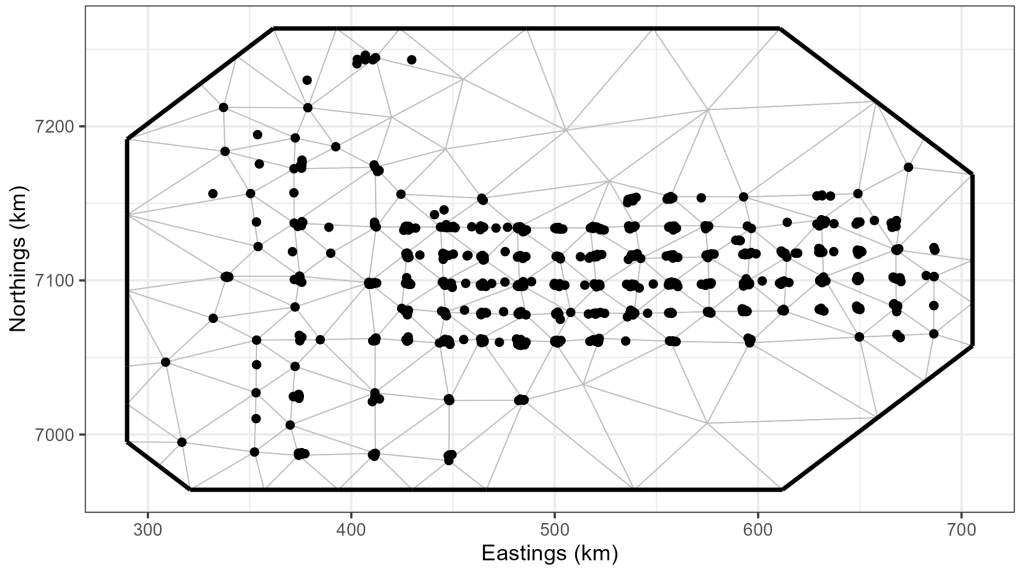
Modeling approach

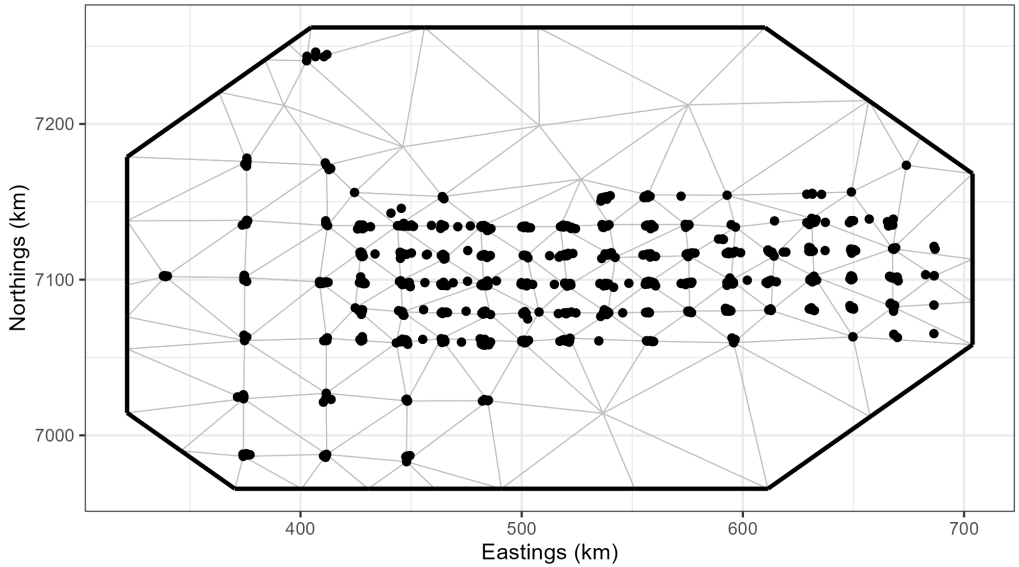
Fit geostatistical GLMMs with spatiotemporally correlated random effects using **sdmTMB**

Modeling approach

SPDE mesh without depth information (114 vertices)



SPDE mesh with depth information (93 vertices)



Model specification and convergence

Fit geostatistical GLMMs with spatiotemporally correlated random effects using **sdmTMB**

Estimated spatiotemporal random fields as independent and identically distributed (IID)

Combined data set: ADF&G and NOAA NBS survey time series

Predictors: year + survey identity OR year + survey identity + depth

Distributions: Tweedie, delta-gamma, delta-lognormal

All 6 models converged

Model diagnostics

Q-Q plots

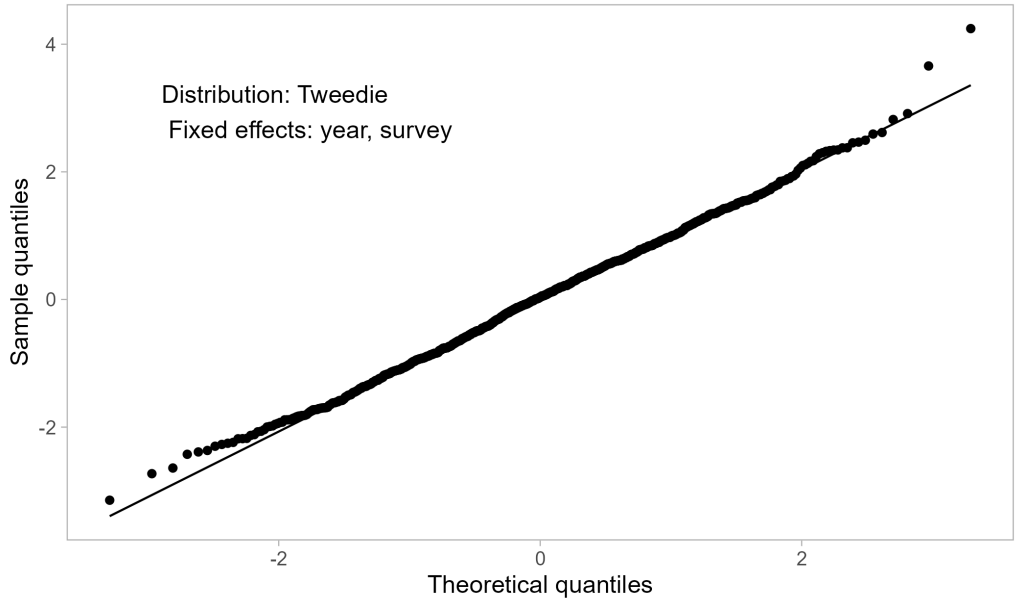
Moran's I clustering analysis

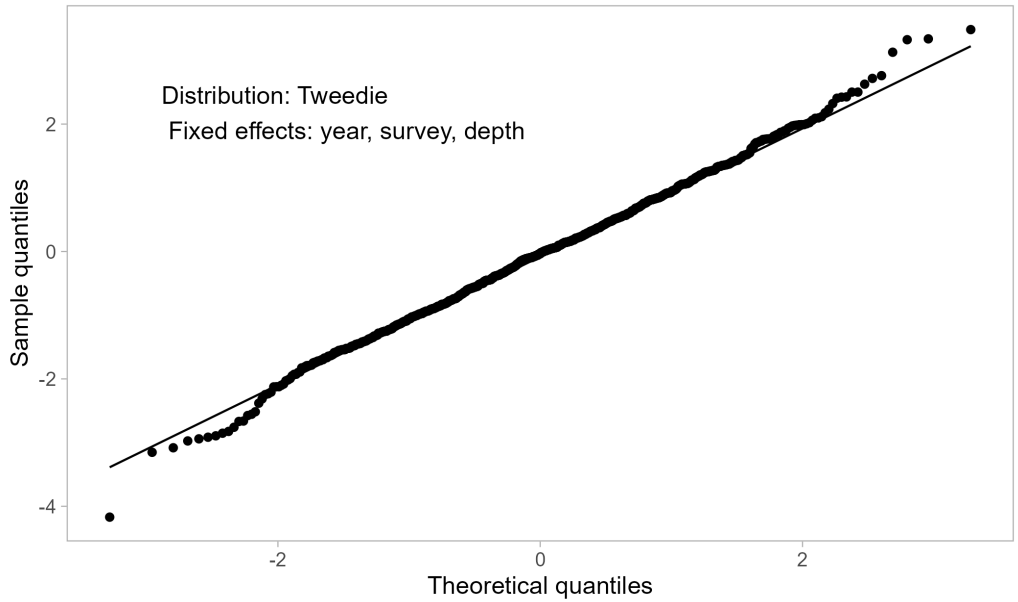
- Tests for spatial patterns in residuals; positive statistic values indicate spatial autocorrelation
- Monte Carlo sims of Moran's I; null hypothesis that the residual values were randomly distributed in space
- Moran's I statistic for each year is an overall score of clustering for the spatial residuals across the spatial domain

Model predictive skill: predictive ability of the model for new observations

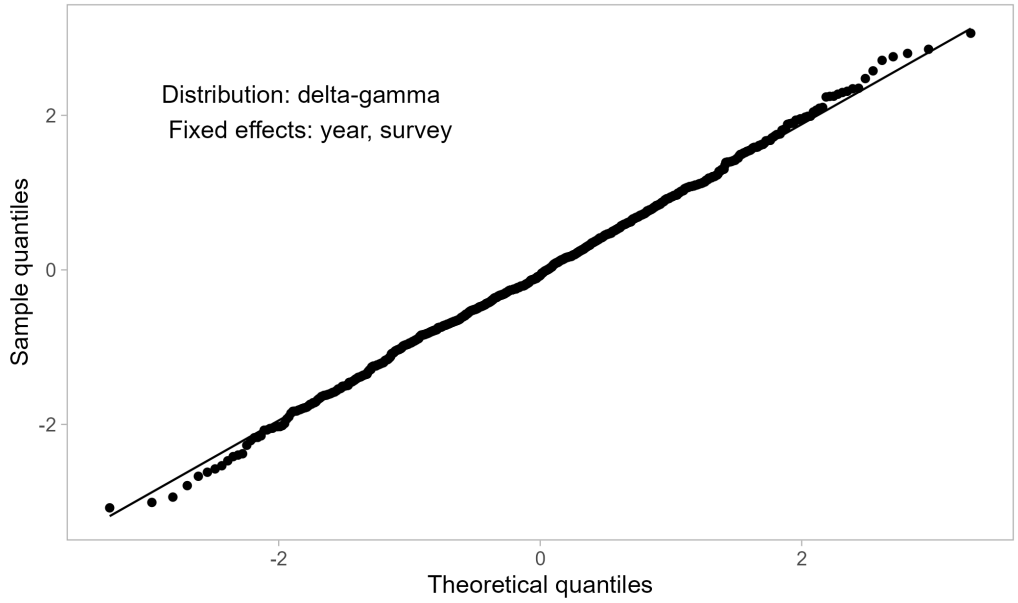
- cross validation using sdmTMB_cv()
- 10 randomly arranged folds for each model

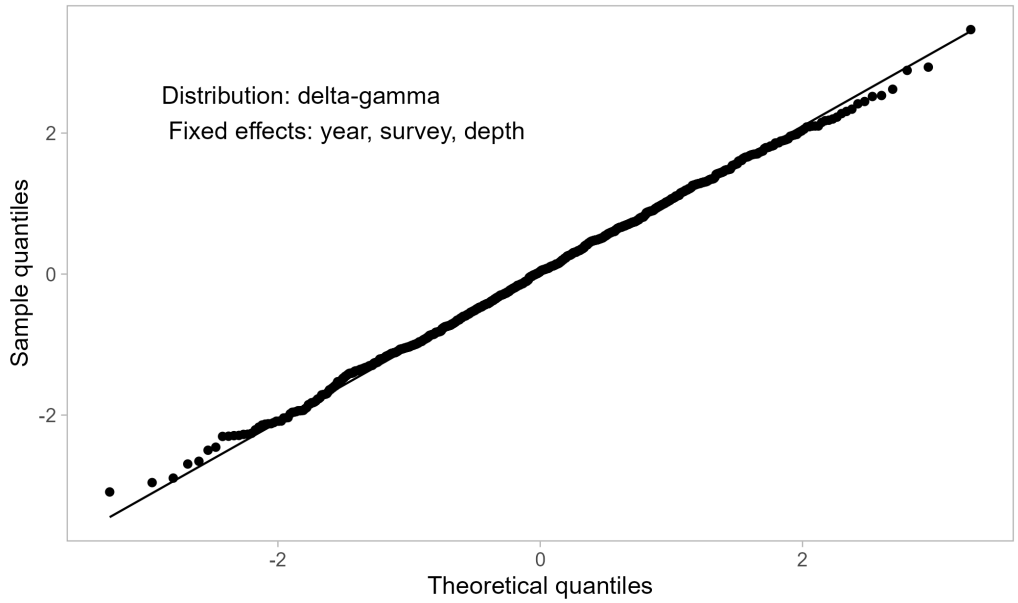
Q-Q plots: Tweedie



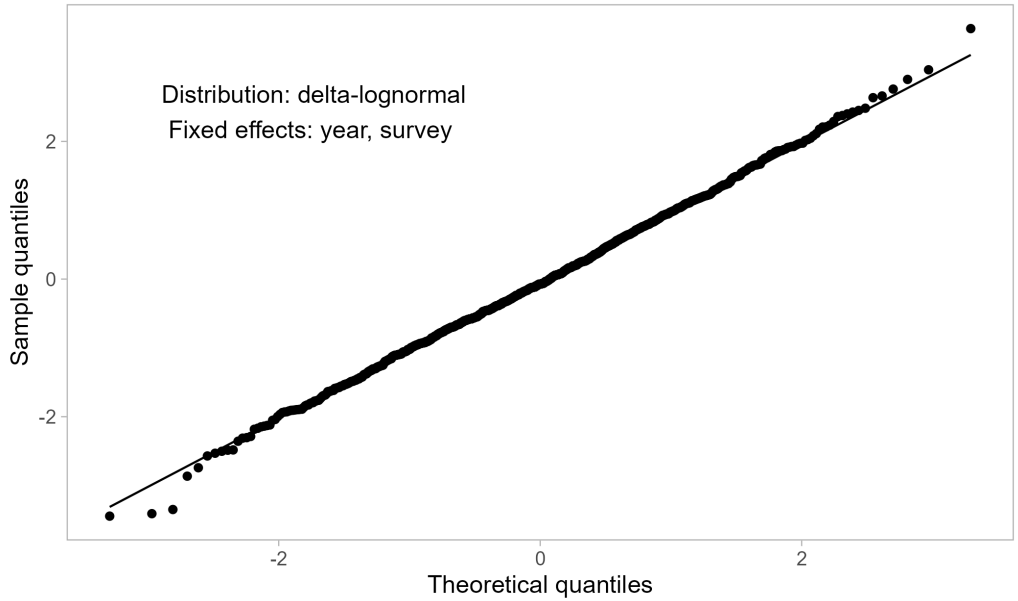


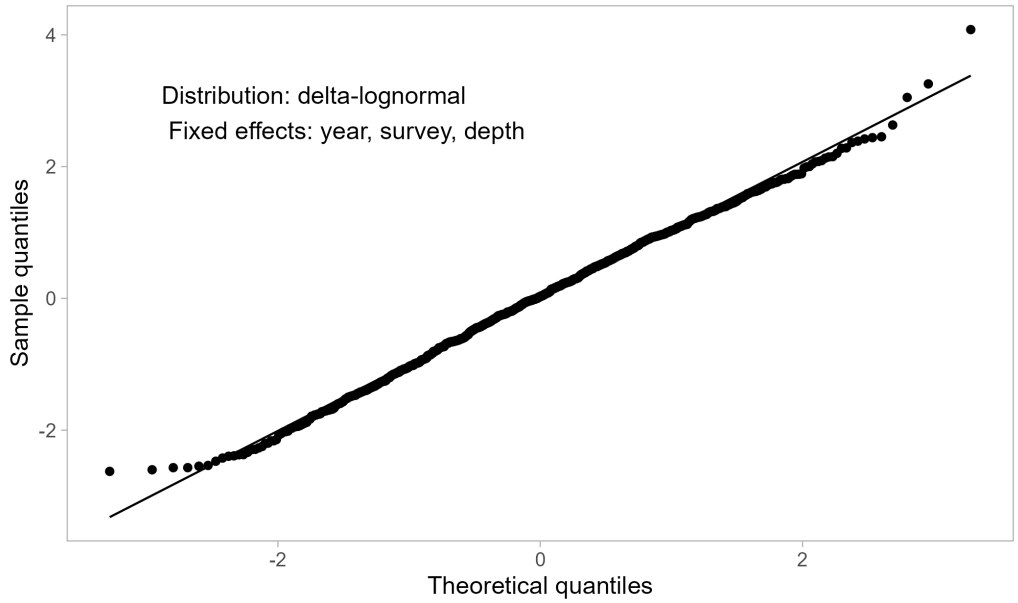
Q-Q plots: delta gamma





Q-Q plots: delta lognormal





Moran's I analysis: Tweedie

Distribution	Fixed effects	Year	Moran's I statistic	p-value
Tweedie	year, survey	1996	0.016	0.224
Tweedie	year, survey	1999	0.003	0.315
Tweedie	year, survey	2002	-0.116	0.993
Tweedie	year, survey	2006	0.135	0.003
Tweedie	year, survey	2008	0.018	0.223
Tweedie	year, survey	2010	-0.079	0.793
Tweedie	year, survey	2011	-0.045	0.725
Tweedie	year, survey	2014	0.027	0.185
Tweedie	year, survey	2017	-0.018	0.562
Tweedie	year, survey	2018	0.002	0.297
Tweedie	year, survey	2019	-0.059	0.858
Tweedie	year, survey	2020	-0.077	0.889
Tweedie	year, survey	2021	-0.074	0.934
Tweedie	year, survey	2022	0.000	0.274
Tweedie	year, survey	2023	0.019	0.200
Tweedie	year, survey	2024	-0.001	0.257

Moran's I analysis: Tweedie

Distribution	Fixed effects	Year	Moran's I statistic	p-value
Tweedie	year, survey, depth	1996	0.053	0.087
Tweedie	year, survey, depth	1999	0.173	0.005
Tweedie	year, survey, depth	2002	-0.022	0.465
Tweedie	year, survey, depth	2006	0.040	0.120
Tweedie	year, survey, depth	2008	-0.010	0.430
Tweedie	year, survey, depth	2010	0.082	0.056
Tweedie	year, survey, depth	2011	0.037	0.142
Tweedie	year, survey, depth	2014	-0.056	0.709
Tweedie	year, survey, depth	2017	0.062	0.065
Tweedie	year, survey, depth	2018	-0.002	0.370
Tweedie	year, survey, depth	2019	0.011	0.270
Tweedie	year, survey, depth	2020	-0.079	0.917
Tweedie	year, survey, depth	2021	-0.026	0.605
Tweedie	year, survey, depth	2022	0.014	0.211
Tweedie	year, survey, depth	2023	0.037	0.109
Tweedie	year, survey, depth	2024	0.021	0.196

Moran's I analysis: delta gamma

Distribution	Fixed effects	Year	Moran's I statistic	p-value
delta gamma	year, survey	1996	-0.049	0.693
delta gamma	year, survey	1999	-0.019	0.452
delta gamma	year, survey	2002	0.000	0.336
delta gamma	year, survey	2006	0.048	0.090
delta gamma	year, survey	2008	0.005	0.313
delta gamma	year, survey	2010	0.113	0.015
delta gamma	year, survey	2011	0.028	0.195
delta gamma	year, survey	2014	0.021	0.182
delta gamma	year, survey	2017	-0.060	0.886
delta gamma	year, survey	2018	-0.039	0.646
delta gamma	year, survey	2019	-0.010	0.445
delta gamma	year, survey	2020	-0.043	0.682
delta gamma	year, survey	2021	-0.077	0.945
delta gamma	year, survey	2022	-0.061	0.651
delta gamma	year, survey	2023	-0.034	0.692
delta gamma	year, survey	2024	-0.036	0.508

Moran's I analysis: delta gamma

Distribution	Fixed effects	Year	Moran's I statistic	p-value
delta gamma	year, survey, depth	1996	0.065	0.076
delta gamma	year, survey, depth	1999	0.040	0.130
delta gamma	year, survey, depth	2002	0.127	0.006
delta gamma	year, survey, depth	2006	-0.049	0.768
delta gamma	year, survey, depth	2008	0.013	0.264
delta gamma	year, survey, depth	2010	0.058	0.090
delta gamma	year, survey, depth	2011	-0.047	0.741
delta gamma	year, survey, depth	2014	0.140	0.016
delta gamma	year, survey, depth	2017	0.016	0.224
delta gamma	year, survey, depth	2018	-0.050	0.709
delta gamma	year, survey, depth	2019	-0.076	0.955
delta gamma	year, survey, depth	2020	-0.097	0.977
delta gamma	year, survey, depth	2021	-0.111	0.995
delta gamma	year, survey, depth	2022	-0.063	0.674
delta gamma	year, survey, depth	2023	-0.069	0.925
delta gamma	year, survey, depth	2024	0.009	0.208

Moran's I analysis: delta lognormal

Distribution	Fixed effects	Year	Moran's I statistic	p-value
delta lognormal	year, survey	1996	-0.06	0.79
delta lognormal	year, survey	1999	0.01	0.27
delta lognormal	year, survey	2002	0.00	0.30
delta lognormal	year, survey	2006	0.02	0.22
delta lognormal	year, survey	2008	0.08	0.04
delta lognormal	year, survey	2010	0.02	0.19
delta lognormal	year, survey	2011	-0.09	0.95
delta lognormal	year, survey	2014	0.02	0.22
delta lognormal	year, survey	2017	-0.01	0.42
delta lognormal	year, survey	2018	0.06	0.08
delta lognormal	year, survey	2019	0.11	0.01
delta lognormal	year, survey	2020	-0.06	0.82
delta lognormal	year, survey	2021	-0.09	0.96
delta lognormal	year, survey	2022	-0.02	0.33
delta lognormal	year, survey	2023	0.04	0.08
delta lognormal	year, survey	2024	-0.03	0.45

Moran's I analysis: delta lognormal

Distribution	Fixed effects	Year	Moran's I statistic	p-value
delta lognormal	year, survey, depth	1996	-0.04	0.62
delta lognormal	year, survey, depth	1999	0.07	0.07
delta lognormal	year, survey, depth	2002	0.04	0.13
delta lognormal	year, survey, depth	2006	0.00	0.32
delta lognormal	year, survey, depth	2008	0.10	0.02
delta lognormal	year, survey, depth	2010	0.13	0.02
delta lognormal	year, survey, depth	2011	0.01	0.26
delta lognormal	year, survey, depth	2014	0.11	0.03
delta lognormal	year, survey, depth	2017	0.02	0.19
delta lognormal	year, survey, depth	2018	0.00	0.36
delta lognormal	year, survey, depth	2019	0.09	0.02
delta lognormal	year, survey, depth	2020	-0.01	0.45
delta lognormal	year, survey, depth	2021	-0.07	0.93
delta lognormal	year, survey, depth	2022	0.00	0.27
delta lognormal	year, survey, depth	2023	0.01	0.28
delta lognormal	year, survey, depth	2024	-0.09	0.91

Cross-validation analysis

Distribution	Fixed effects	Log-likelihood	RMSE	MAE
Tweedie	year, survey	-3788	622	142
Tweedie	year, survey, depth	-3745	856	154
delta lognormal	year, survey	-3536	439	126
delta lognormal	year, survey, depth	-3505	445	129
delta gamma	year, survey	-3752	439	123
delta gamma	year, survey, depth	-3702	445	126

Cross-validation analysis

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Tweedie	year, survey	-3788	622	142
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delta lognormal	year, survey	-3536	439	126
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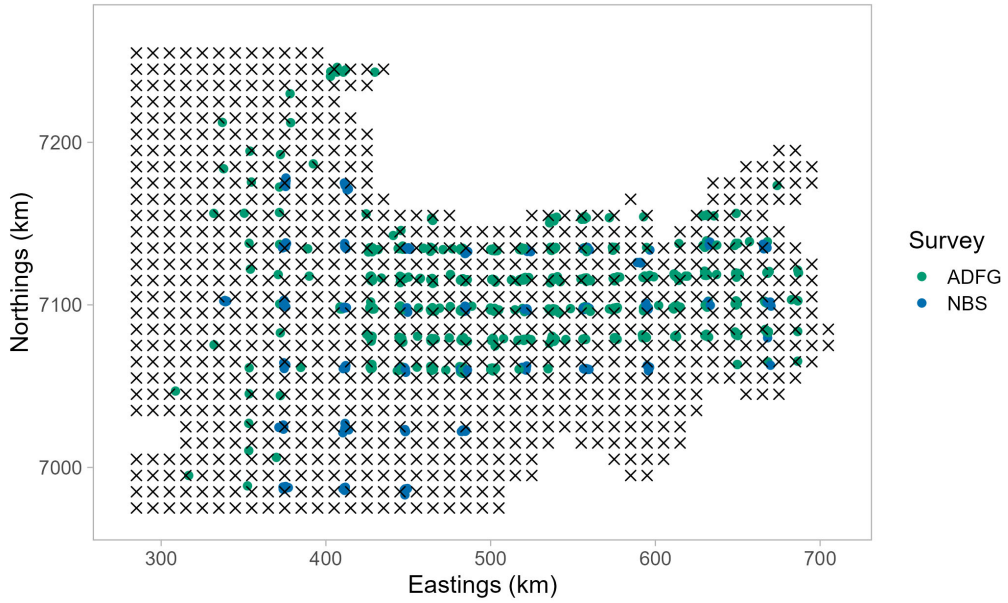
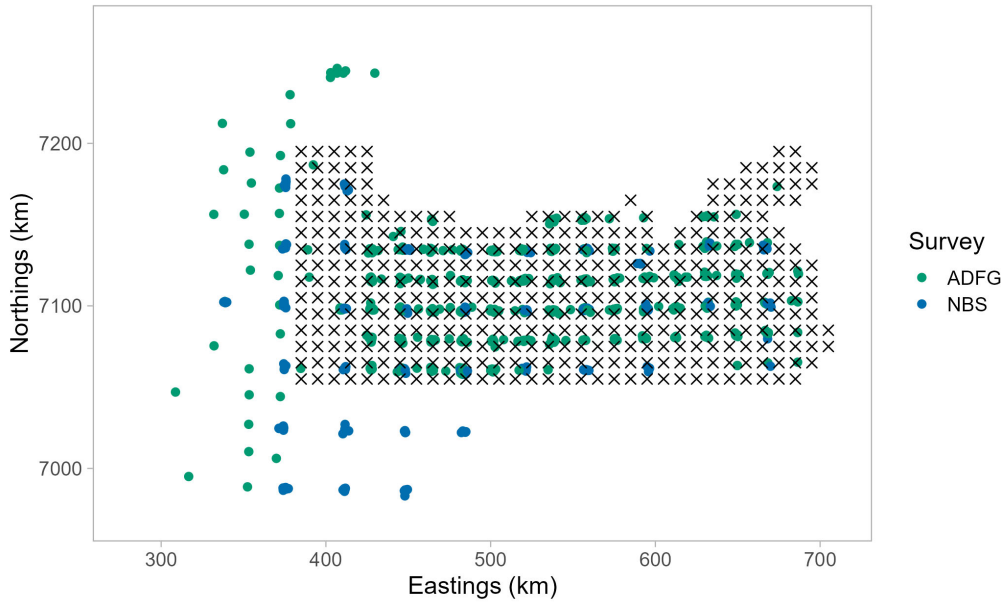
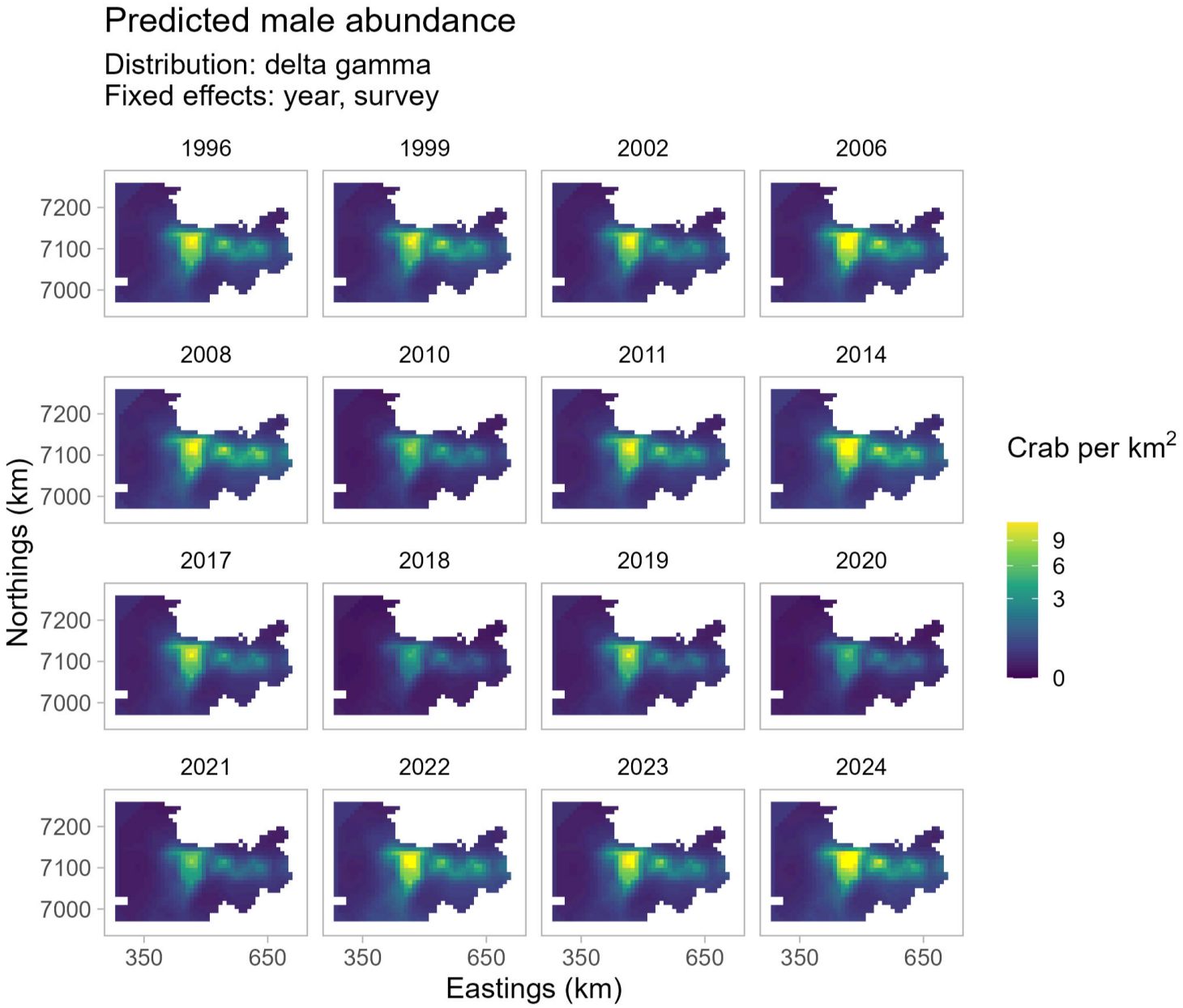
Prediction grids

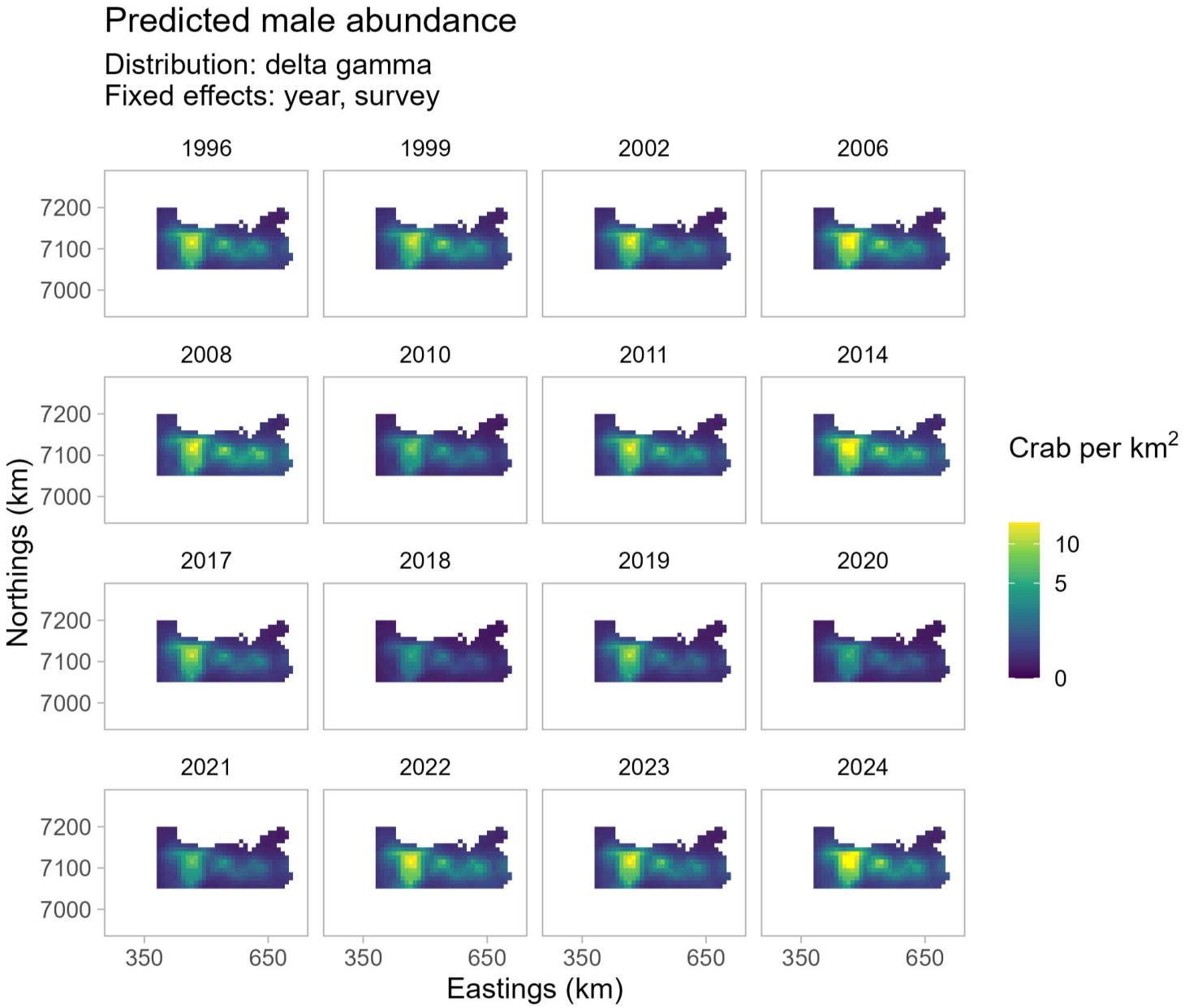




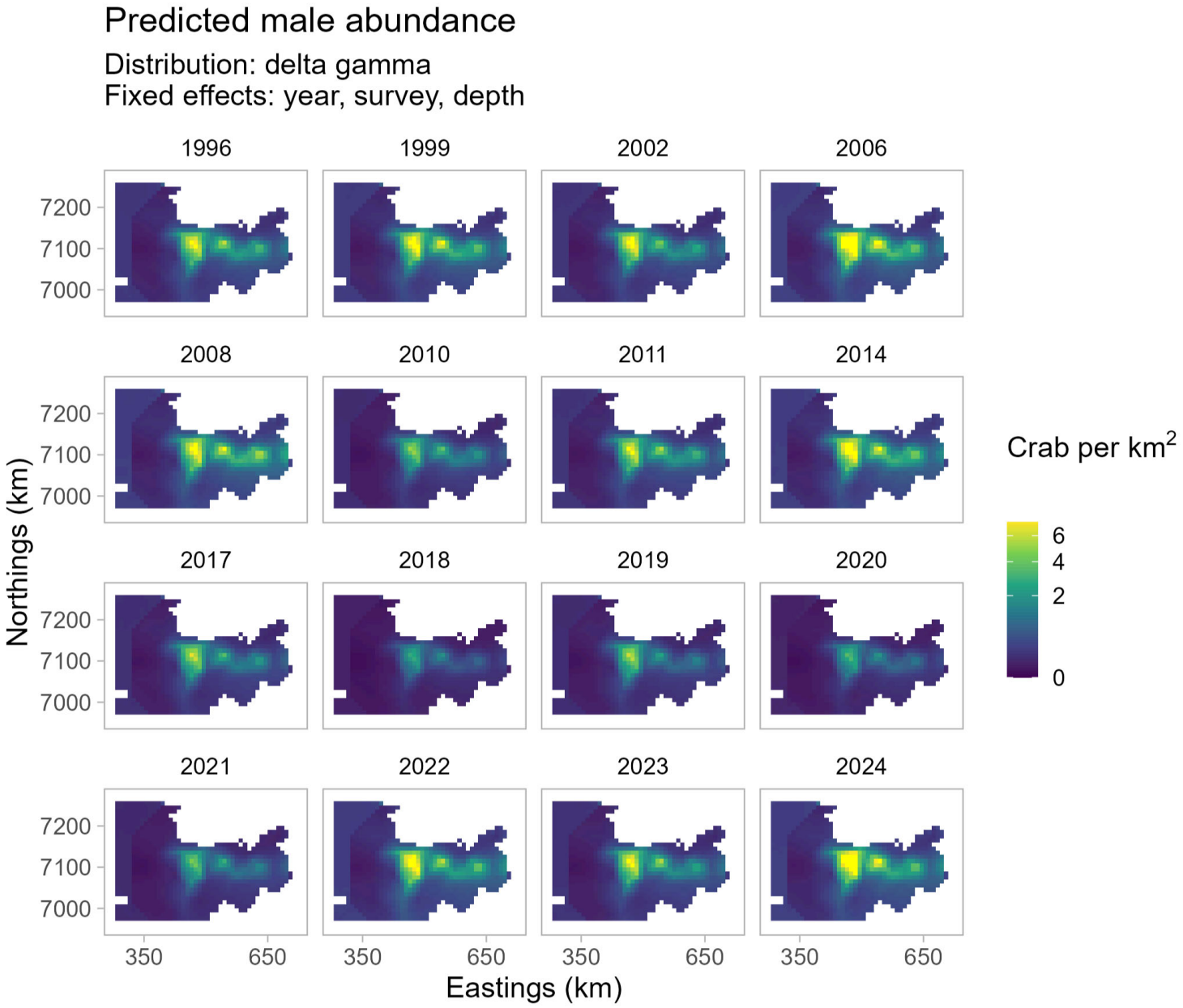
delta gamma, year + survey



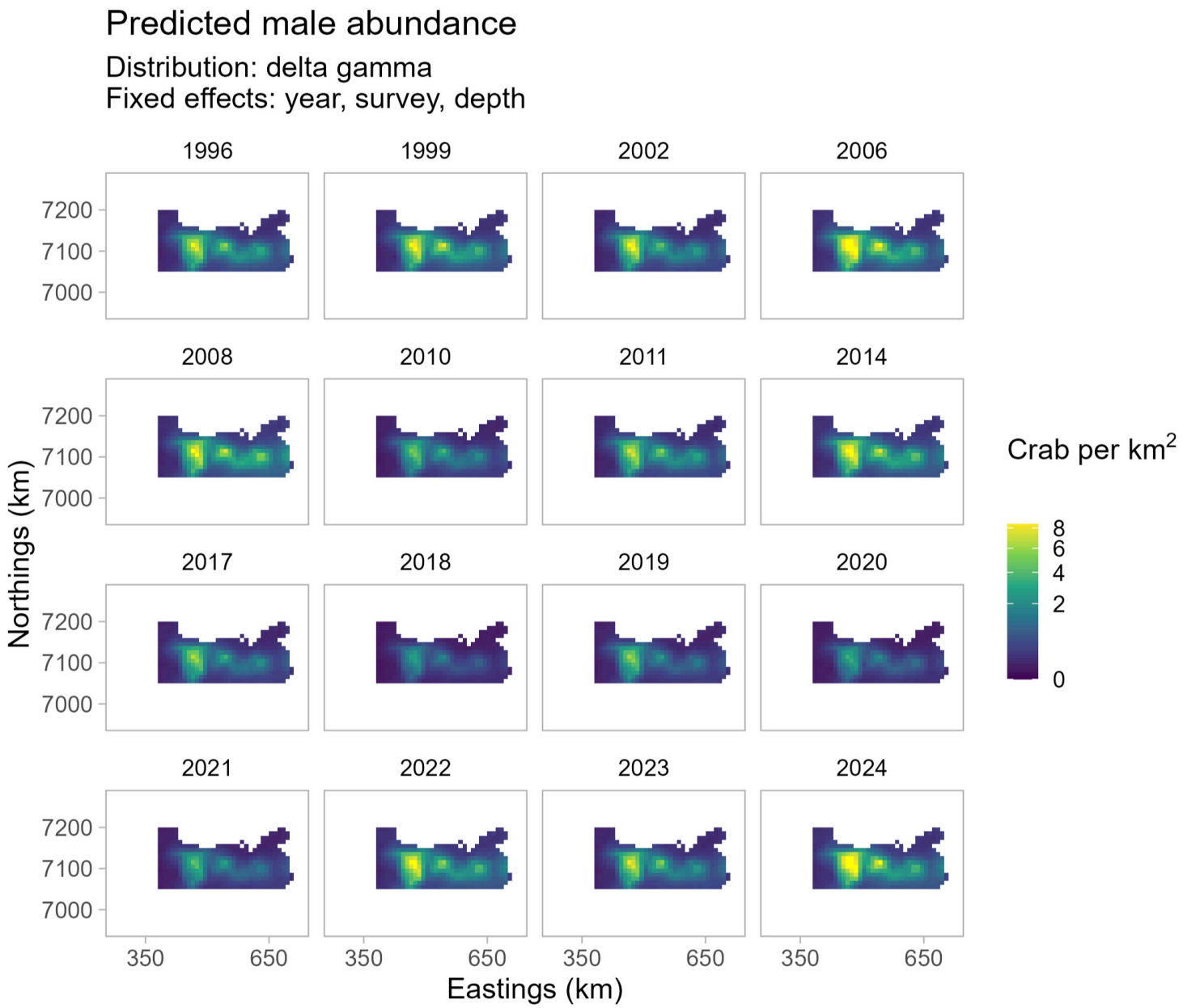
delta gamma, year + survey, small grid



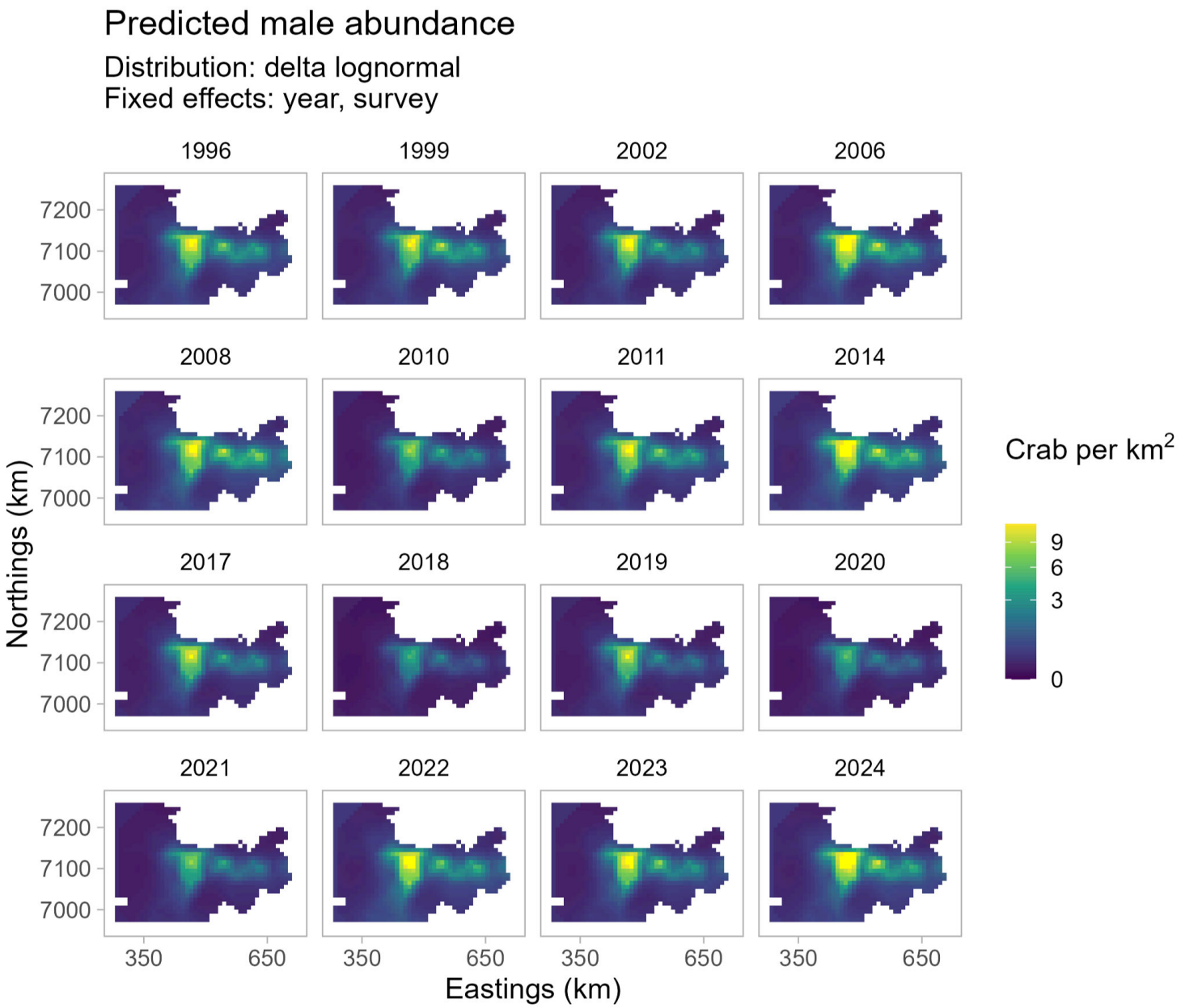
delta gamma, year + survey + depth



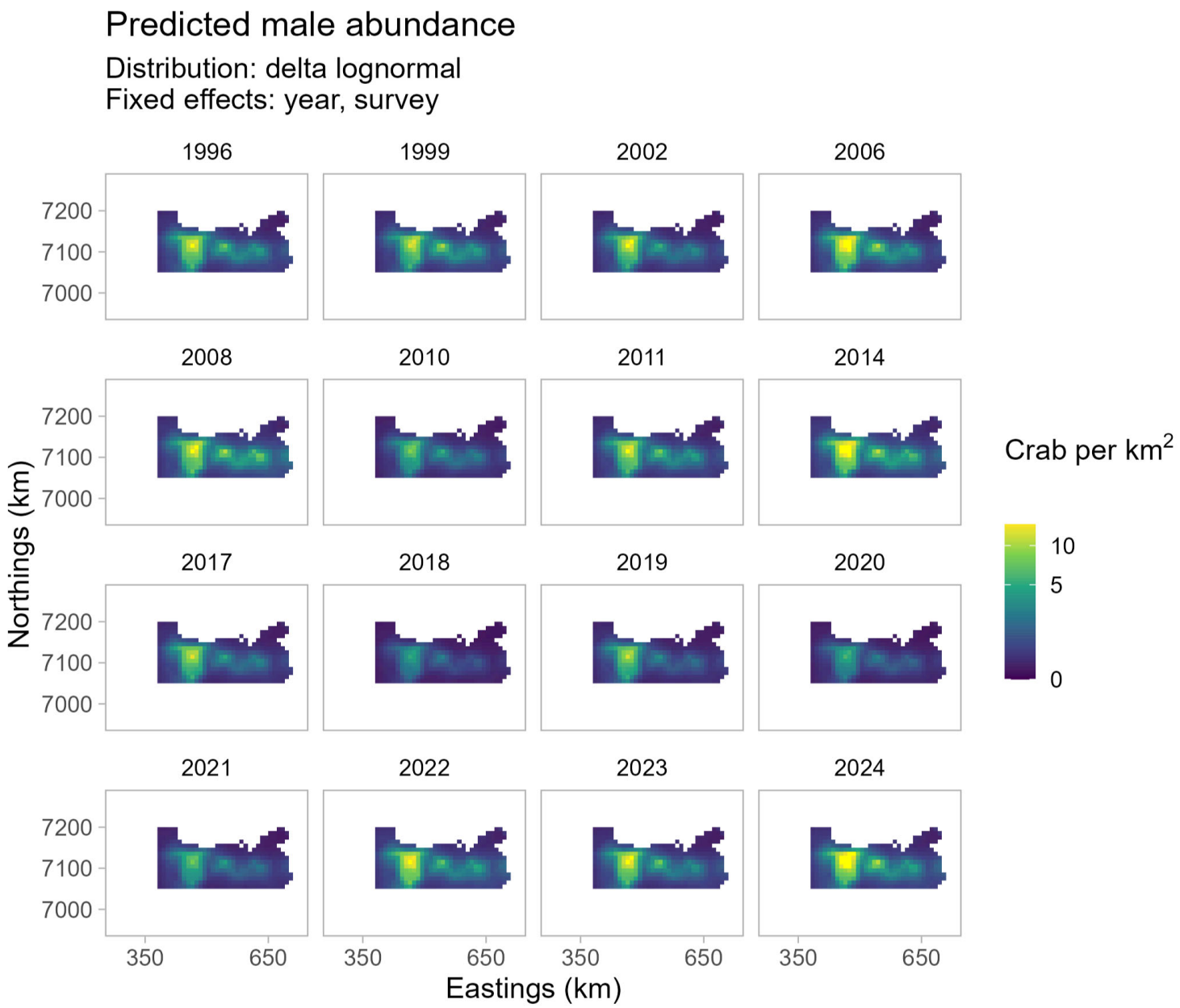
DG, year + survey + depth, small grid



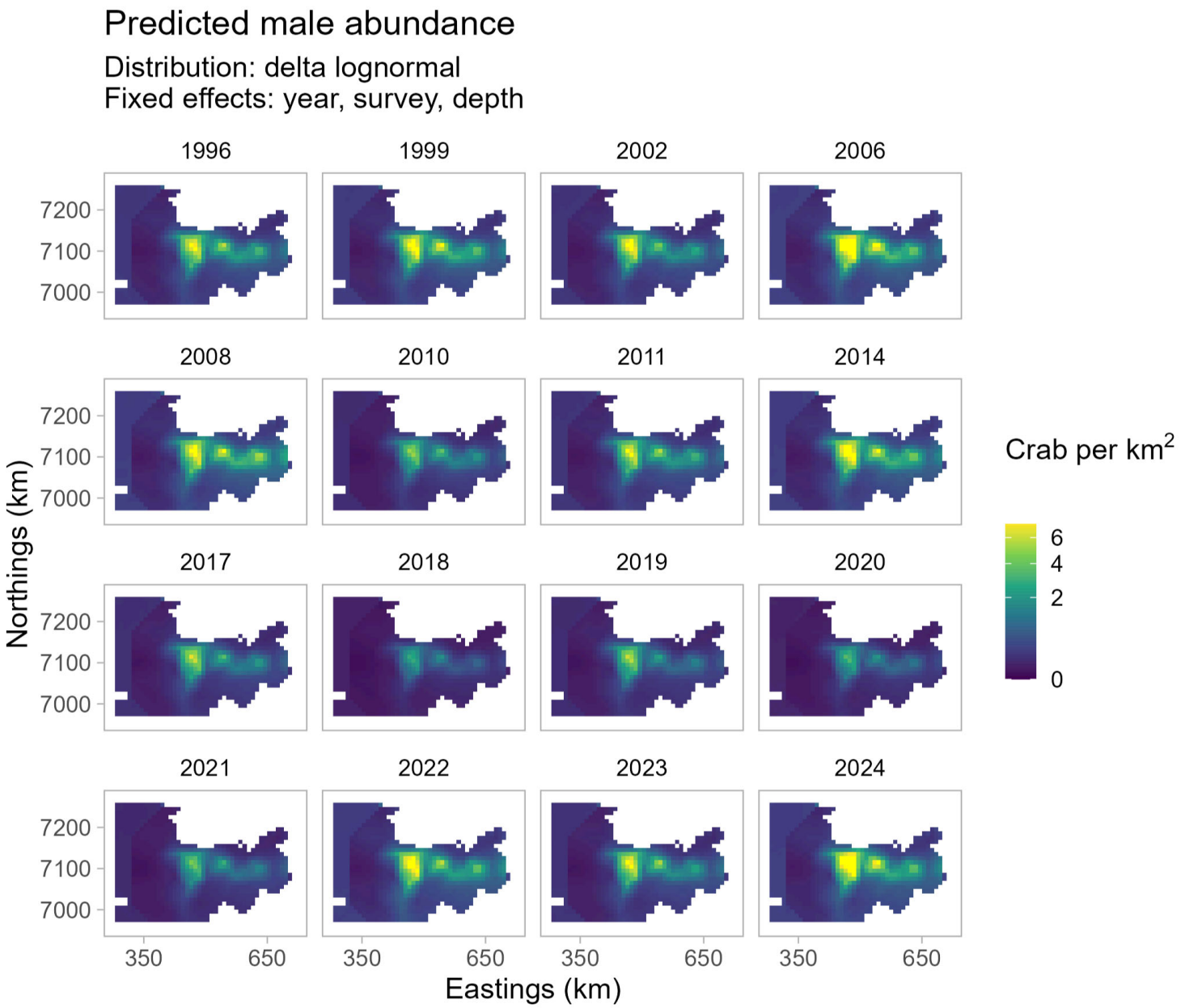
delta lognormal, year + survey



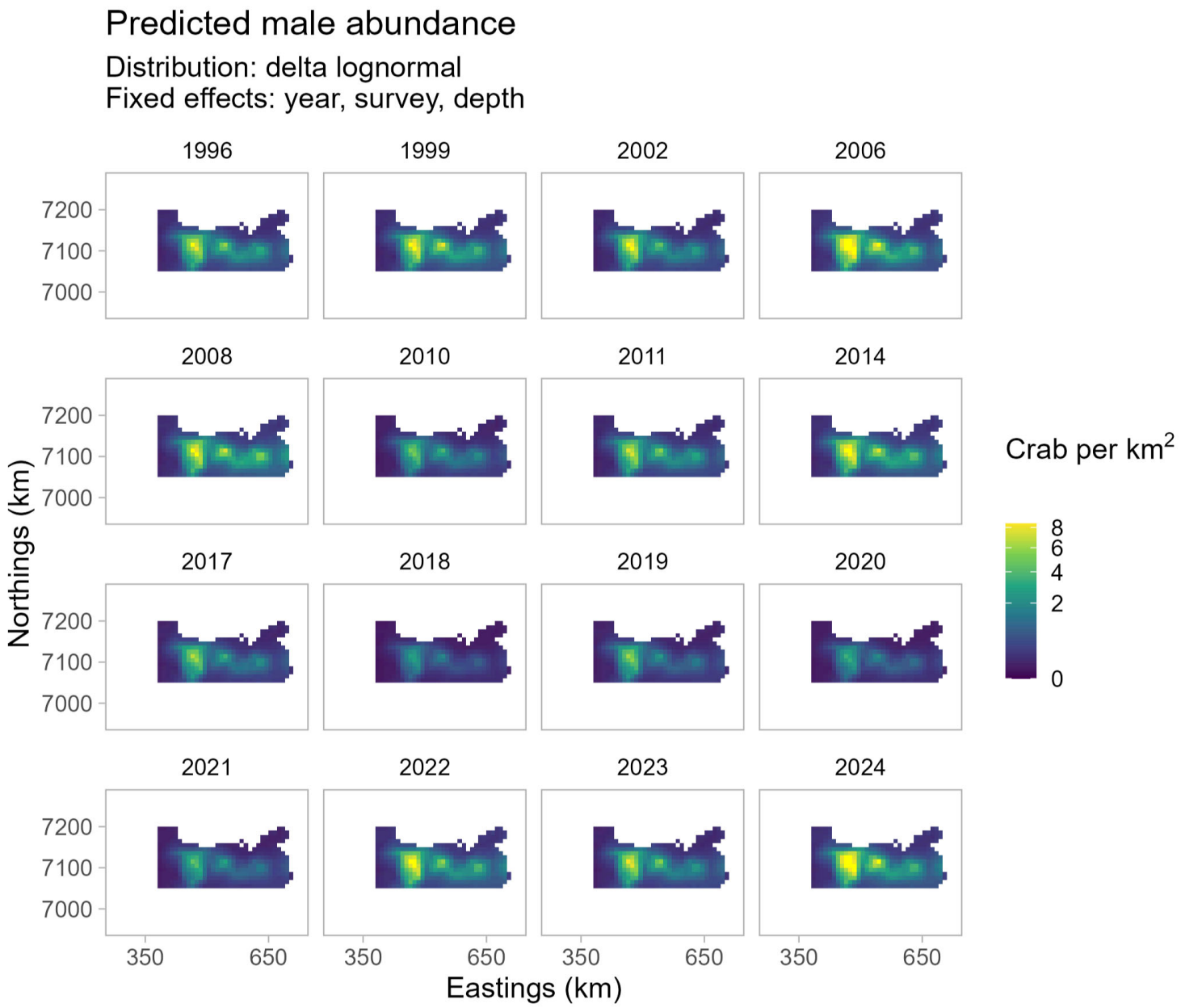
delta lognormal, year + survey, small



delta lognormal, year + survey + depth



DL, year + survey + depth, small



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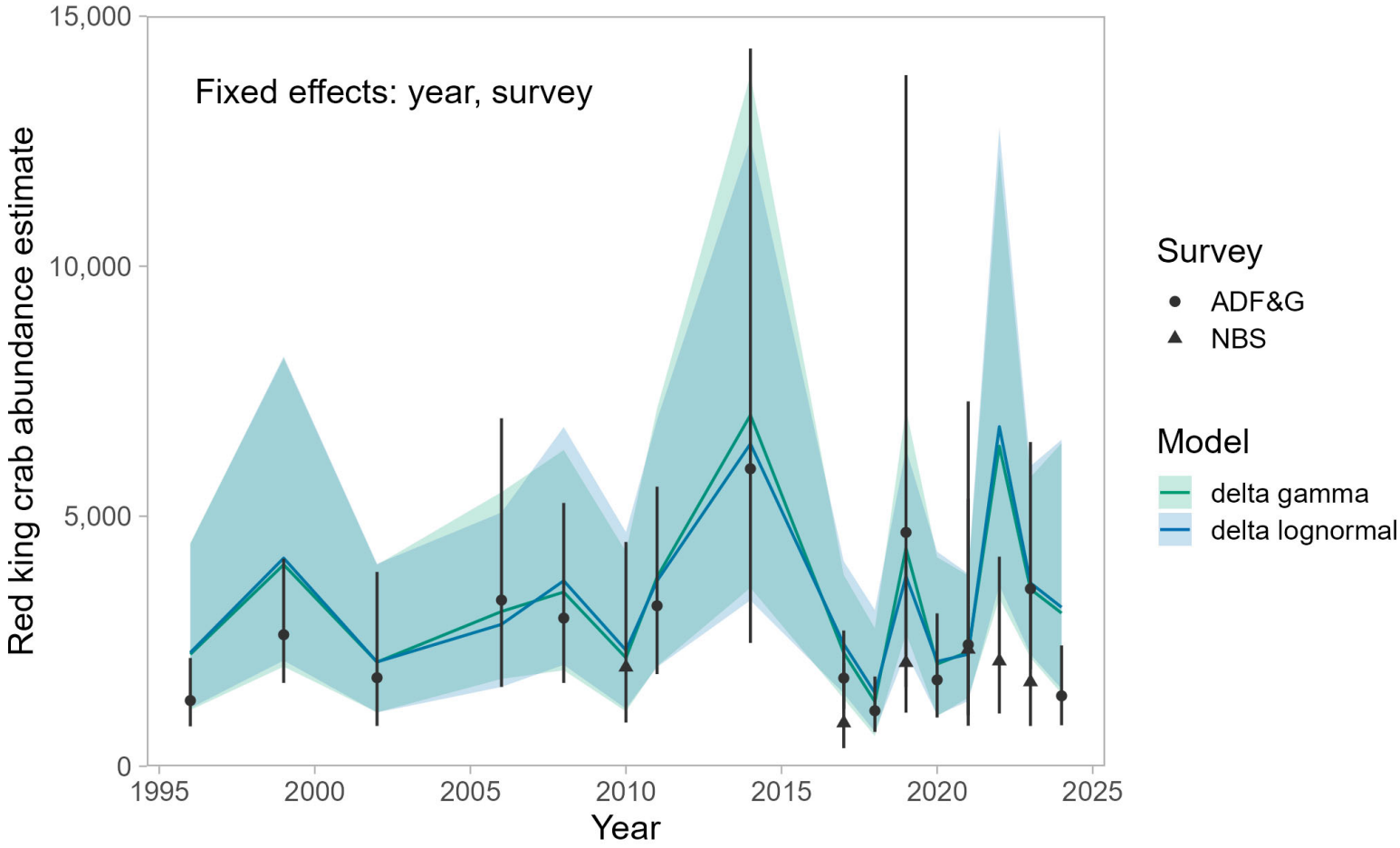
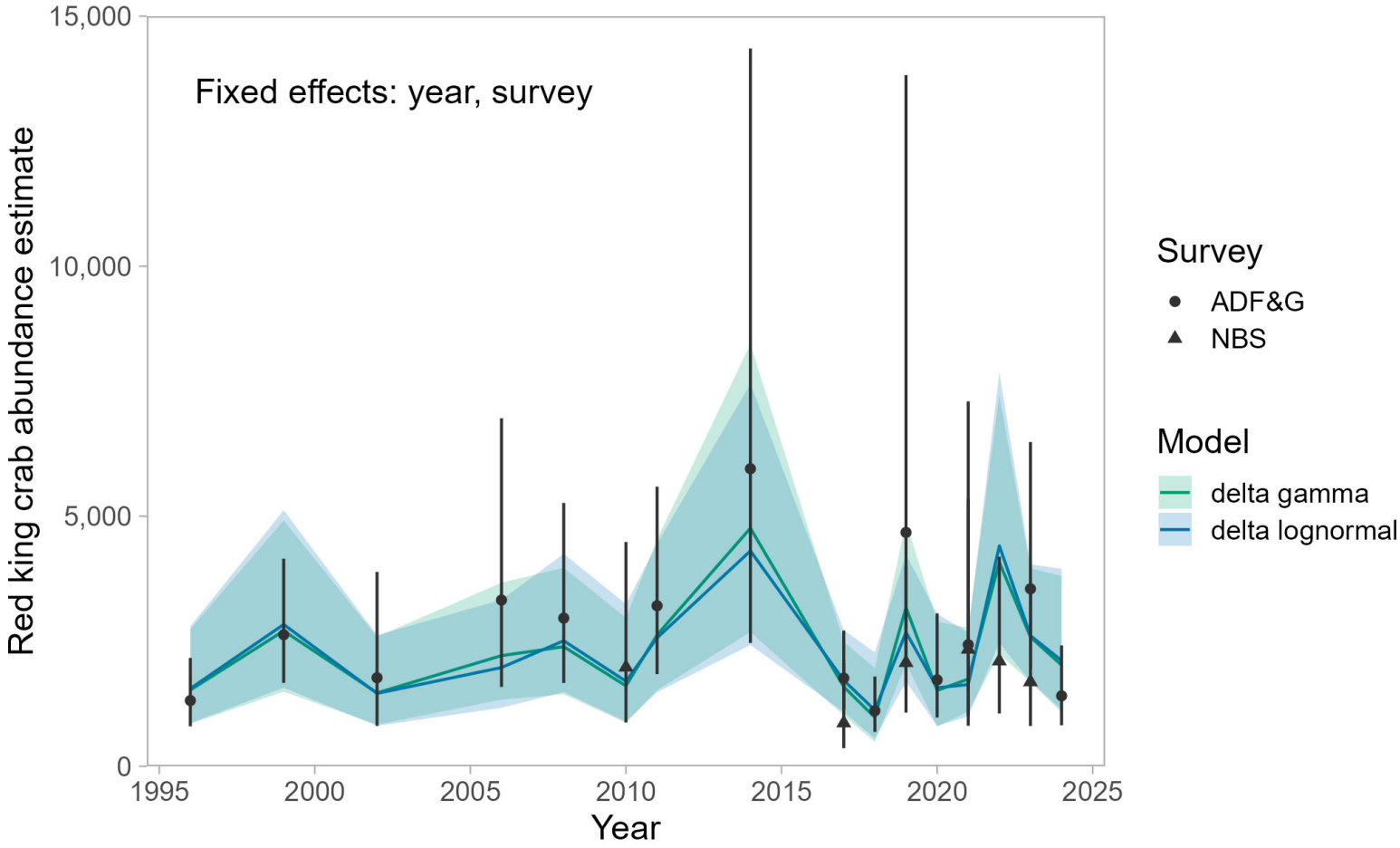
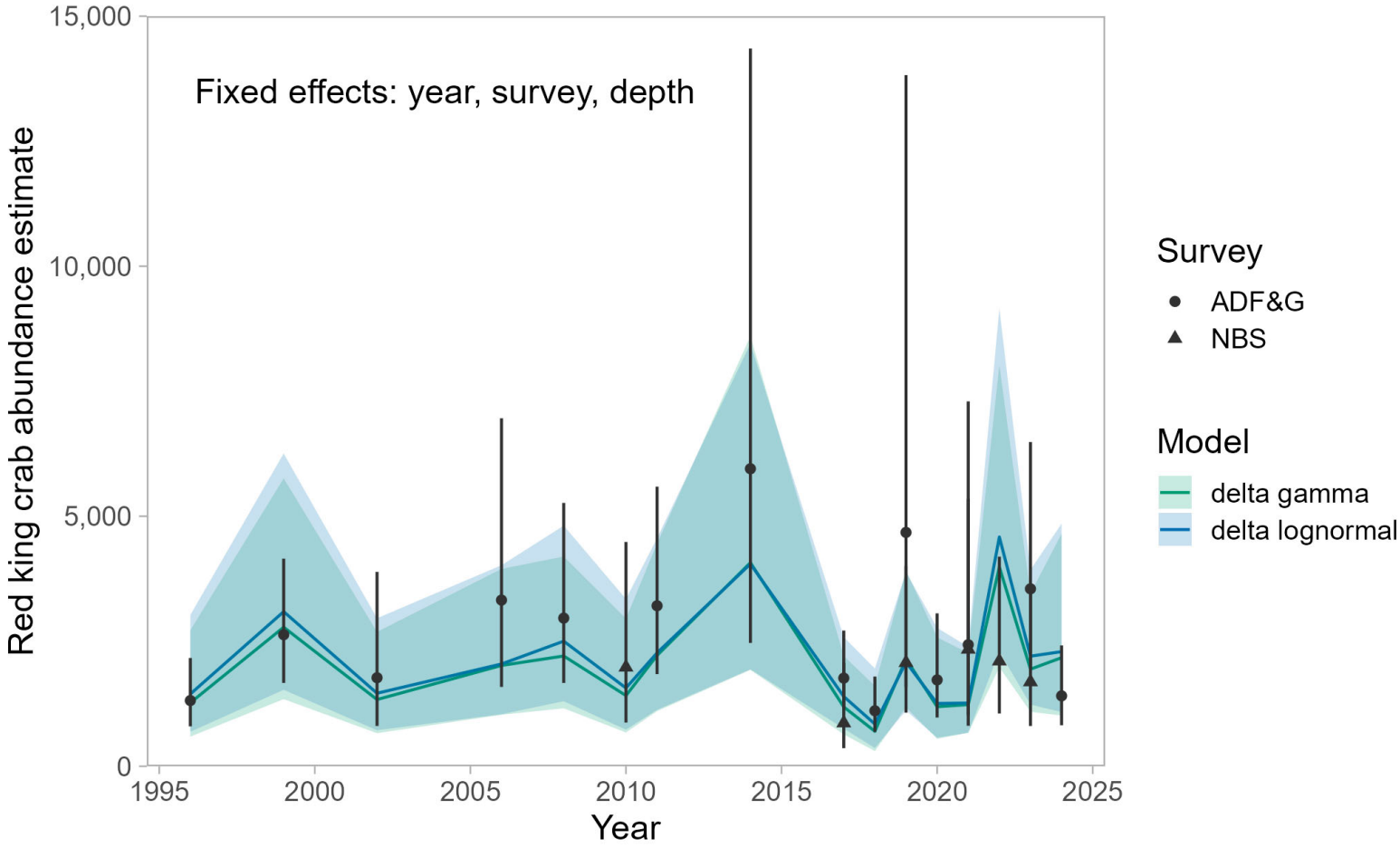
Indices: year + survey, large grid



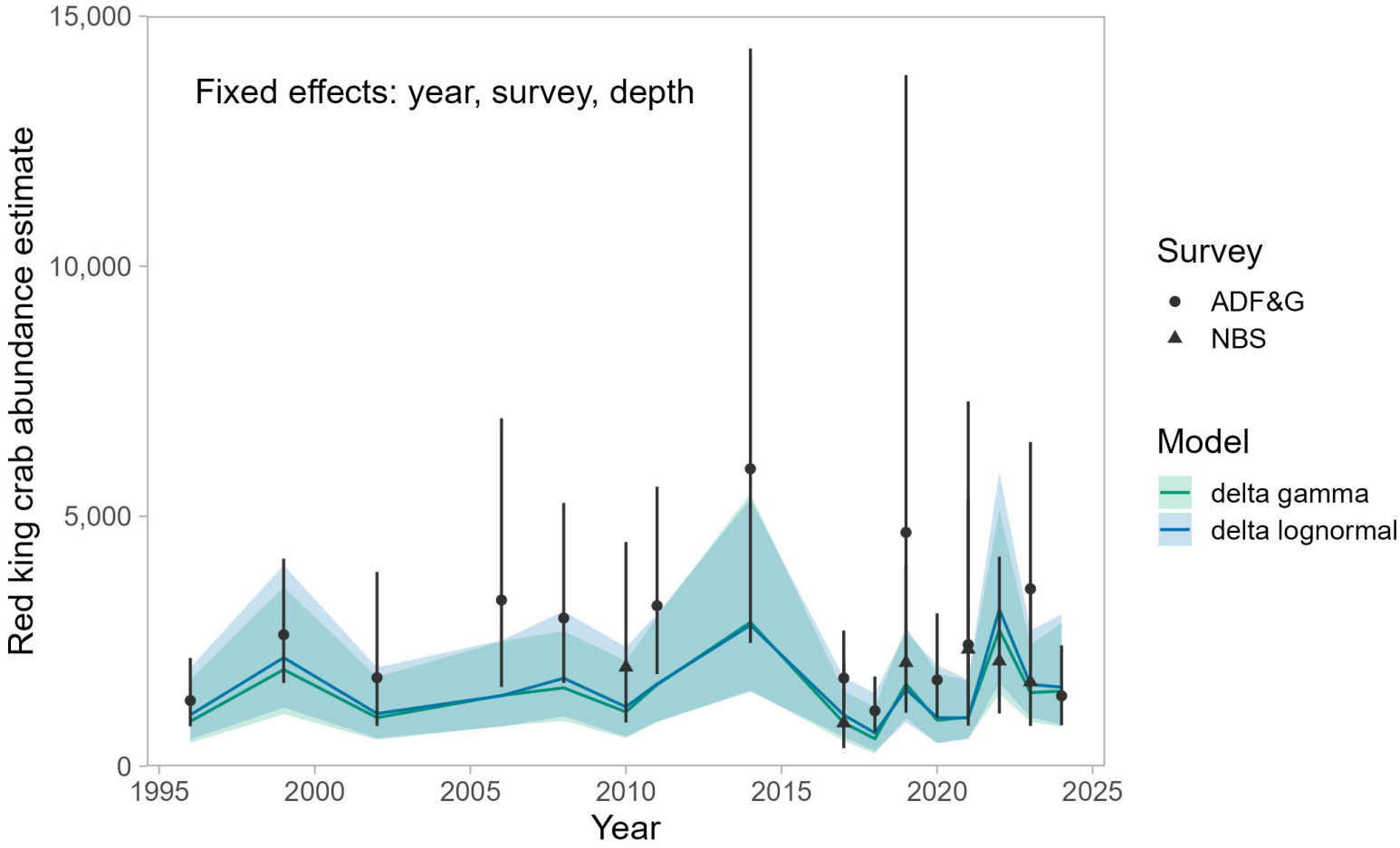
Indices: year + survey, small grid



Indices: year + survey + depth, large



Indices: year + survey + depth, small



Model- vs. design-based indices

- overall, model-based indices appear to have reduced variability compared to design-based
- accounting for depth seems to reduce further variability
- using the smaller prediction grid seems to lead to reduced abundance estimates
- index chosen to use in the stock assessment model: delta gamma, depth included, large grid

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Stock assessment models

24.0b6: 3 design-based survey indices of abundance (NOAA Norton Sound, ADF&G, and NOAA NBS)

24.0b6a: 1 design-based survey index of abundance (NOAA Norton Sound), 1 model-based index of abundance

24.0b6b: 1 model-based index of abundance

All models also include indices of abundance based on standardized fishery CPUE, broken into three time periods

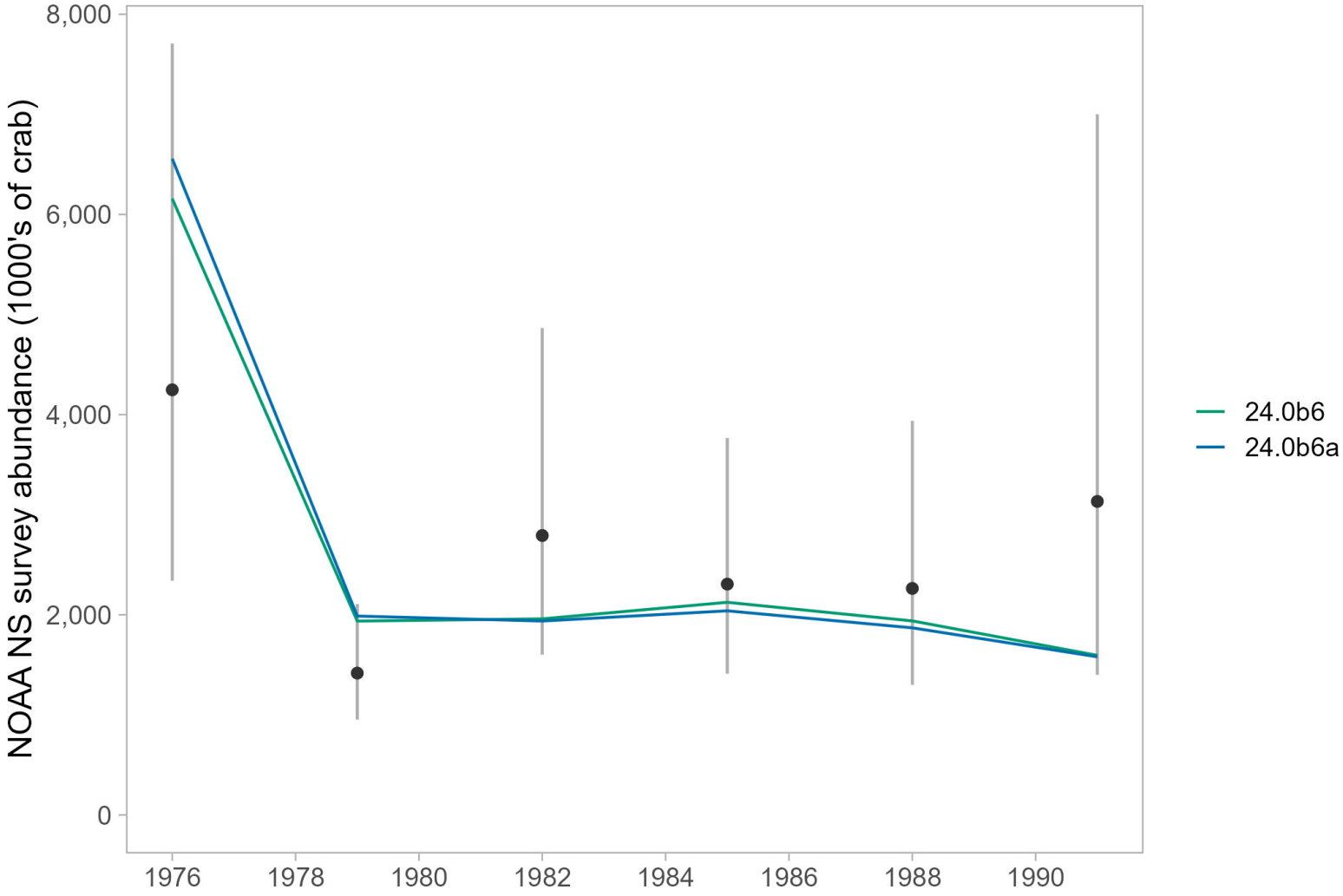
Model fits: likelihood components

Component	24.0b6	24.0b6a	24.0b6b
Winter comm. retained catch	-119.04	-119.04	-119.04
Subsistence retained catch	-121.63	-121.63	-121.63
Subsistence total catch	0.00	0.00	0.00
Summer comm. retained catch	-116.44	-116.44	-116.44
Model-based index	NA	-3.88	-3.36
NMFS trawl survey 1976-1991	-3.31	-2.60	NA
ADF&G trawl survey	-4.04	NA	NA
NOAA NBS survey	-5.41	NA	NA
Pot CPUE 1977-1992	-2.98	-3.13	-3.01
Pot CPUE 1993-2006	-5.06	-0.48	-0.46
Pot CPUE 2007-2024	-11.33	-1.93	-1.91

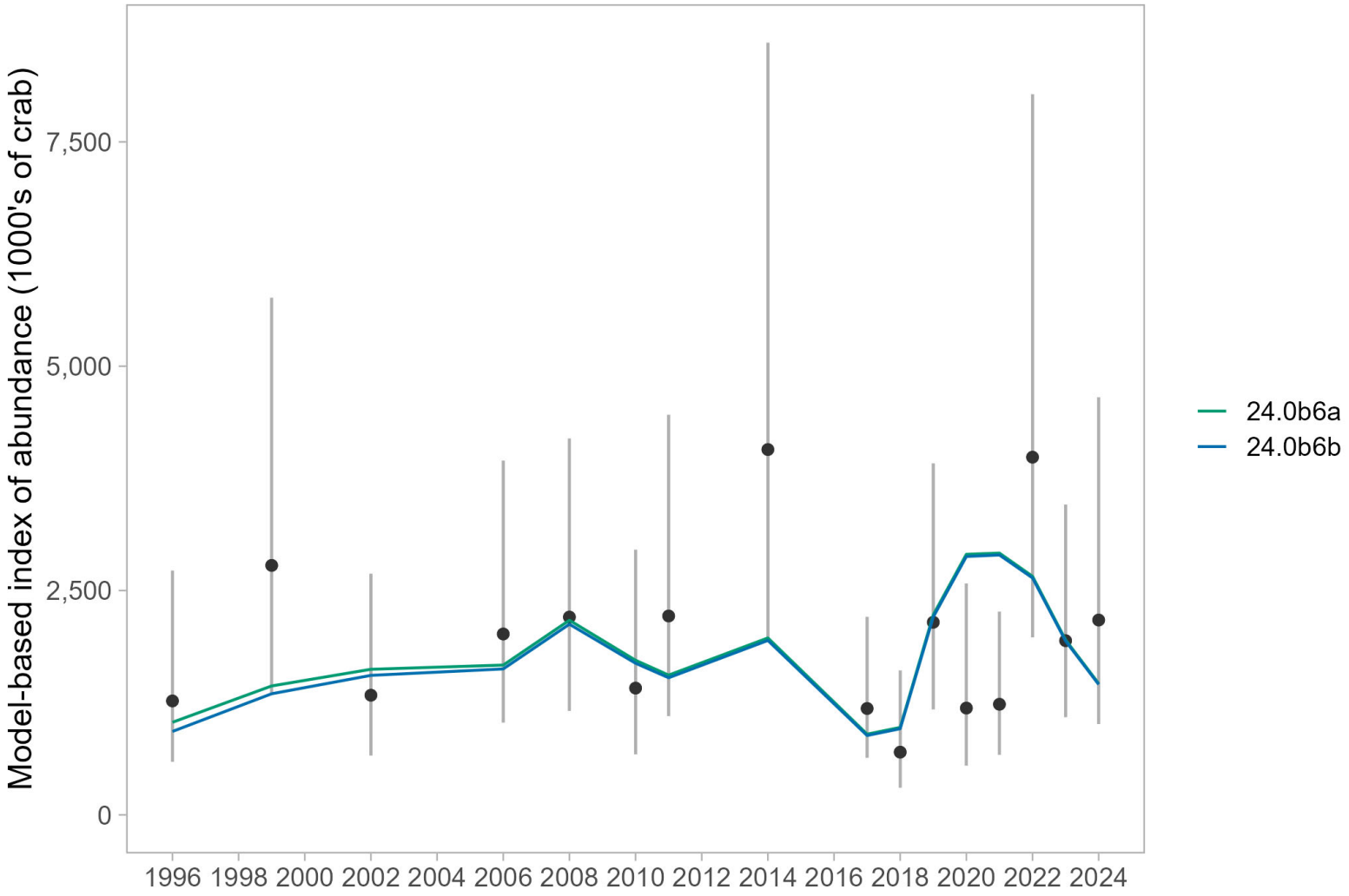
Model fits: likelihood components

Component	24.0b6	24.0b6a	24.0b6b
Winter com. retained size comp.	50.97	50.81	50.72
Summer com. retained size comp.	703.56	703.41	702.71
Summer com. discard size comp.	279.74	279.79	279.81
Summer com. total size comp	216.62	216.75	216.77
NMFS trawl survey size comp.	317.70	316.94	316.53
ADF&G trawl survey size comp.	282.76	282.25	281.74
NBS trawl survey size comp.	157.33	157.08	156.99
Winter pot survey size comp.	613.77	611.96	612.64
Recruitment deviations	51.15	51.02	50.61
Prior	95.49	94.38	93.67
Total	4182.64	4198.18	4199.09
Total estimated parameters	226.00	225.00	224.00

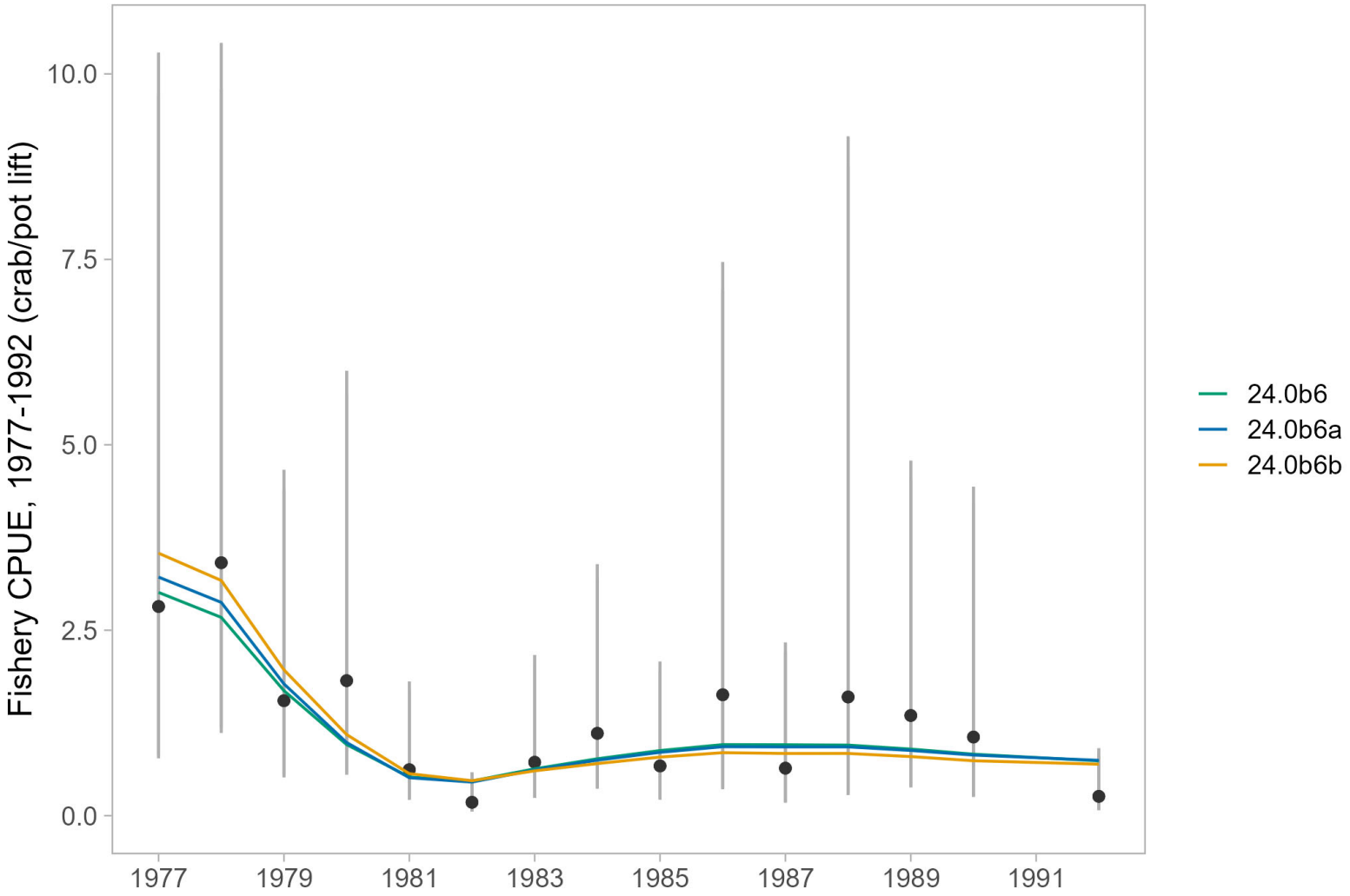
Model fits: design-based index



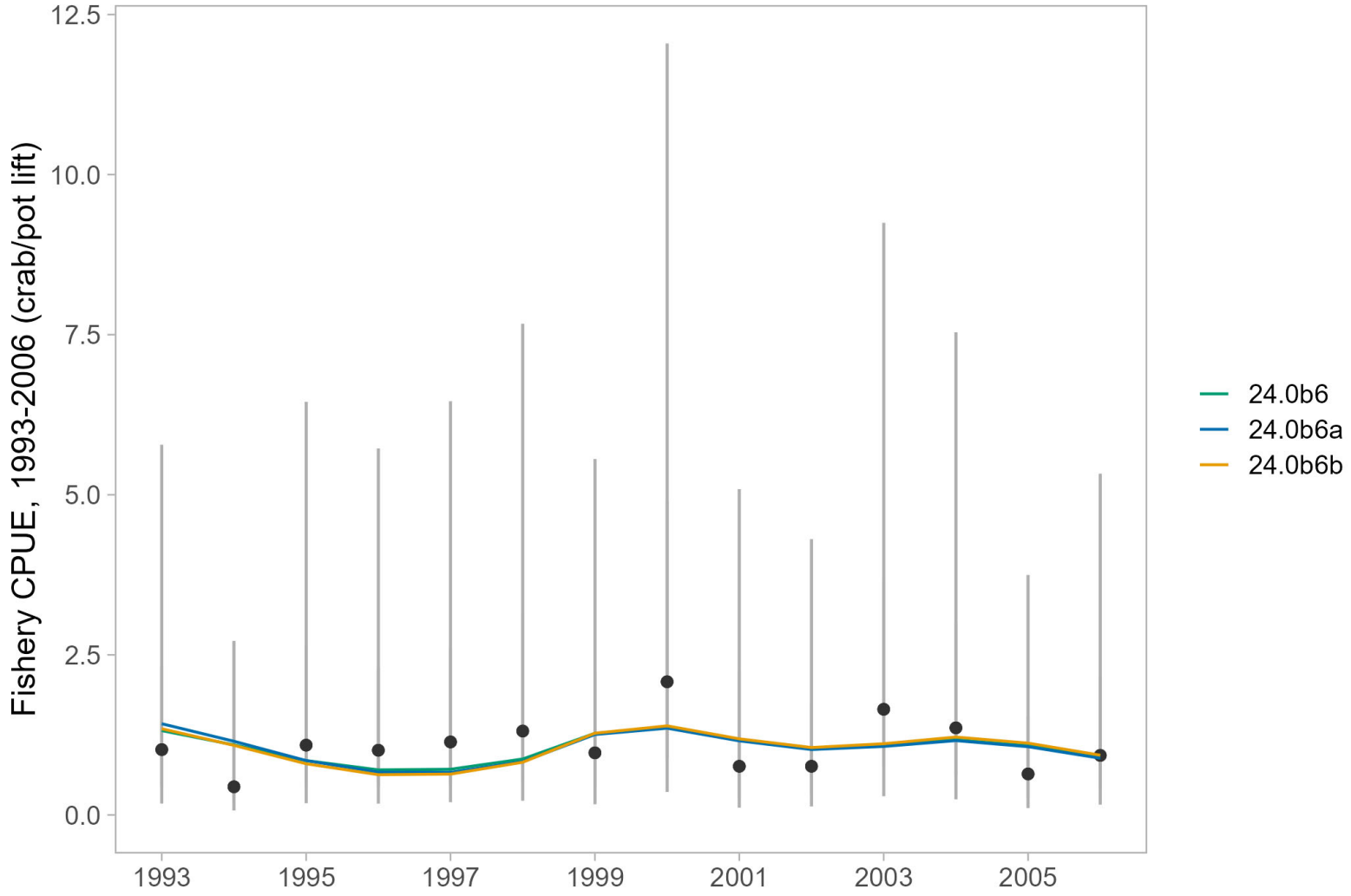
Model fits: model-based index



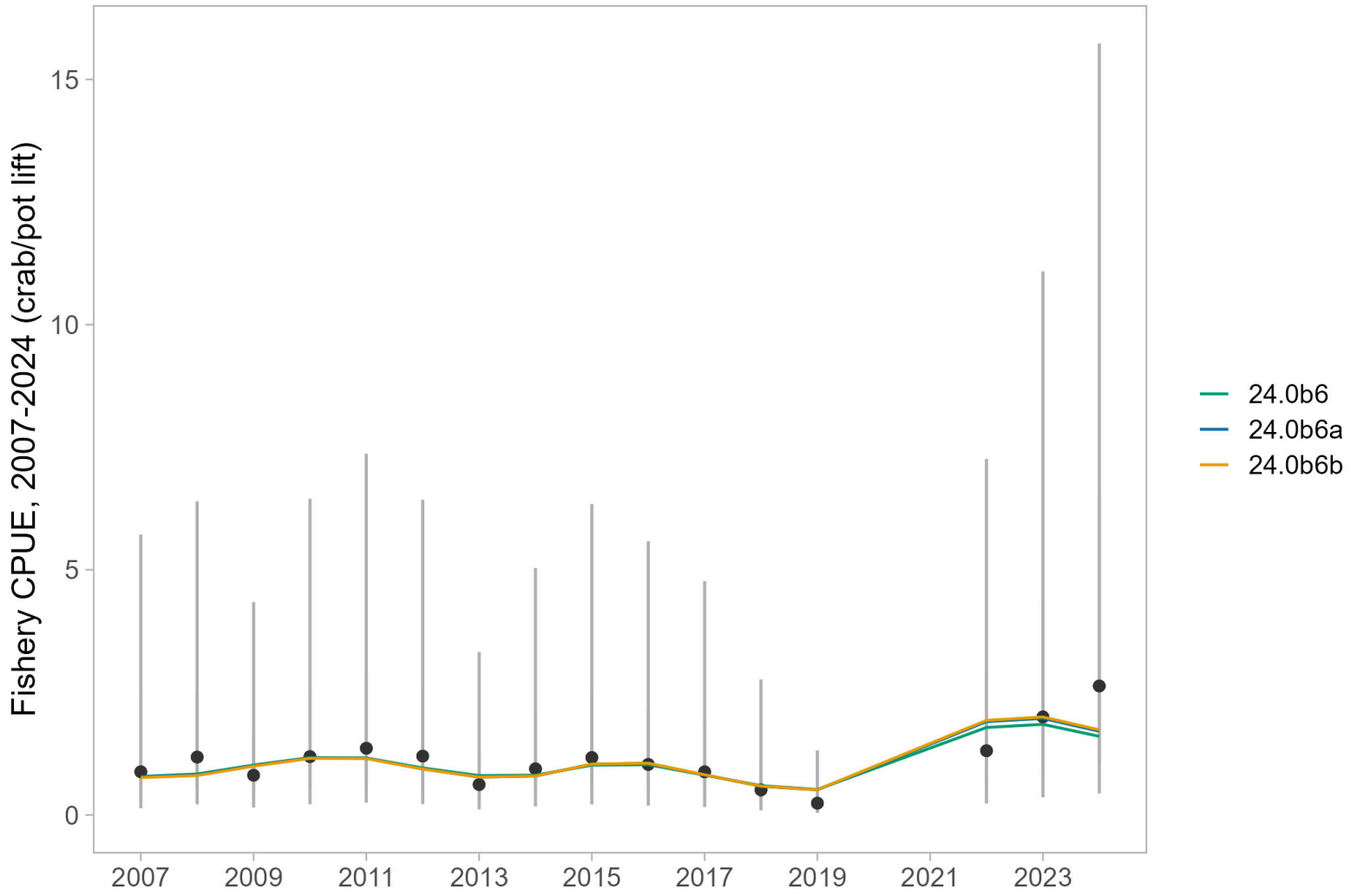
Model fits: CPUE index 1977-1992



Model fits: CPUE index 1993-2006



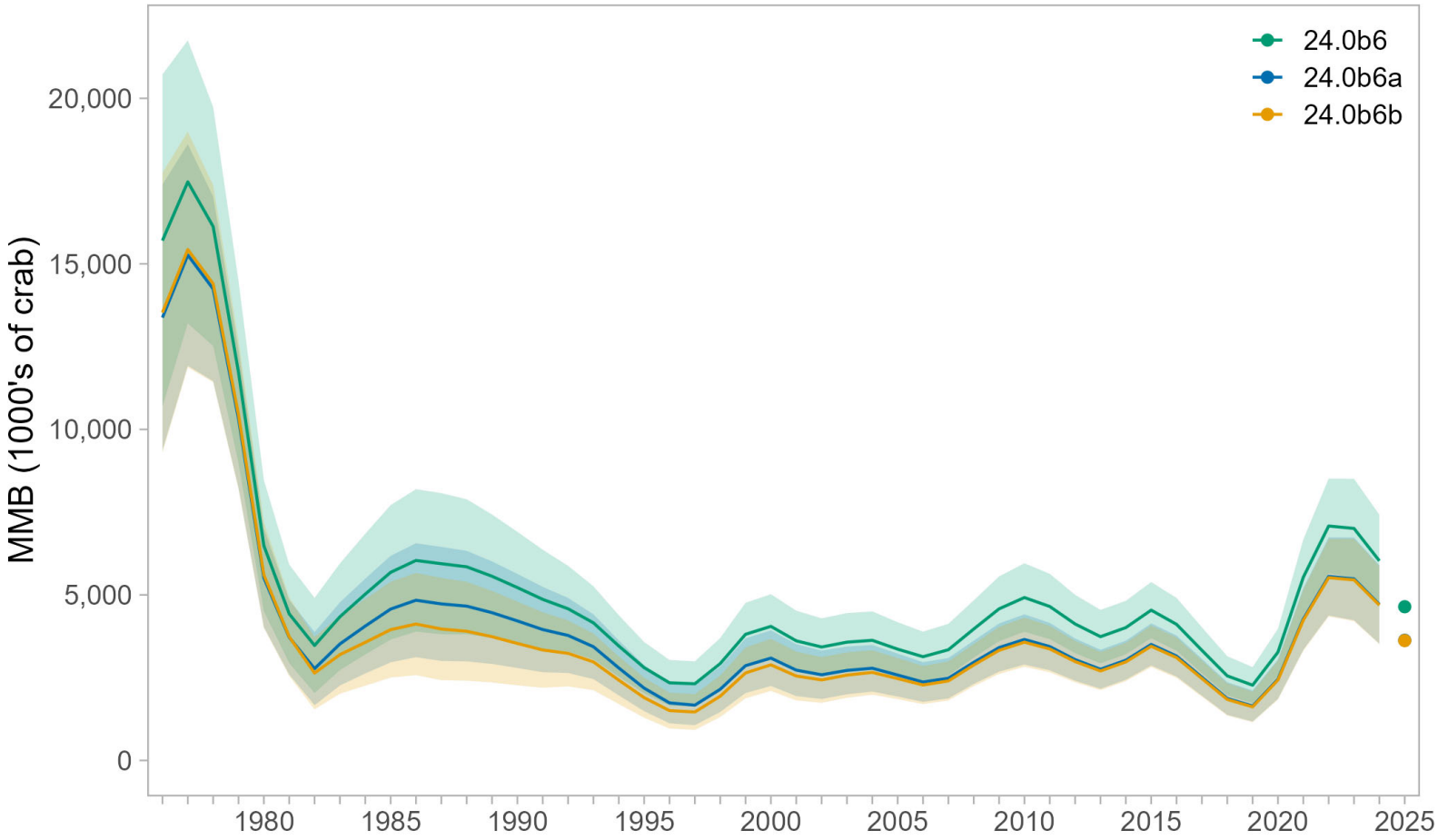
Model fits: CPUE index 2007-2024



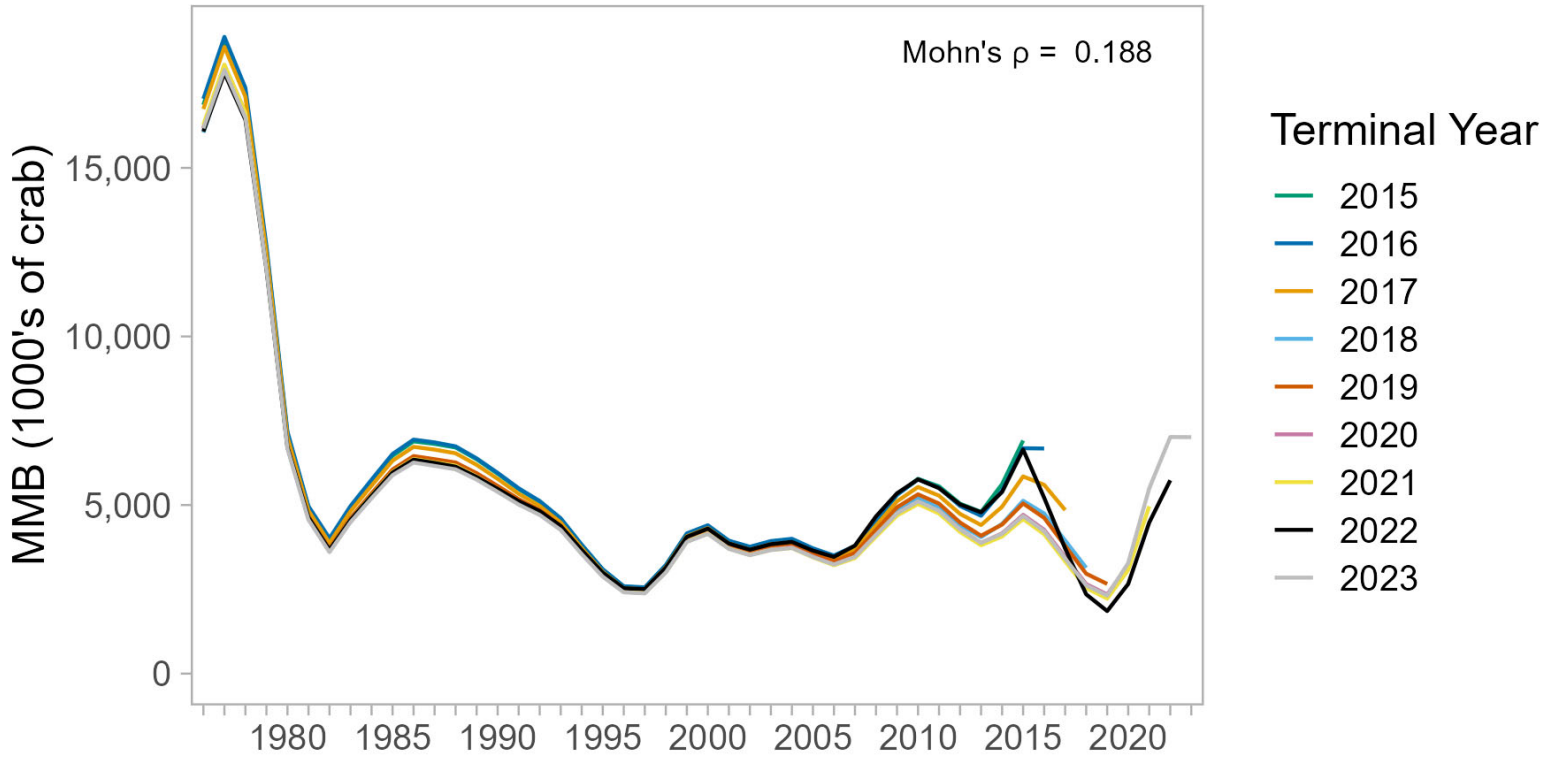
Catchability

	24.0b6	24.0b6a	24.0b6b
Model-based index	NA	1.000	1.000
ADFG survey	1.000	NA	NA
NOAA NS survey	0.743	0.906	NA
NOAA NBS survey	0.700	NA	NA
CPUE 1	0.001	0.001	0.001
CPUE 2	0.001	0.002	0.002
CPUE 3	0.001	0.002	0.002

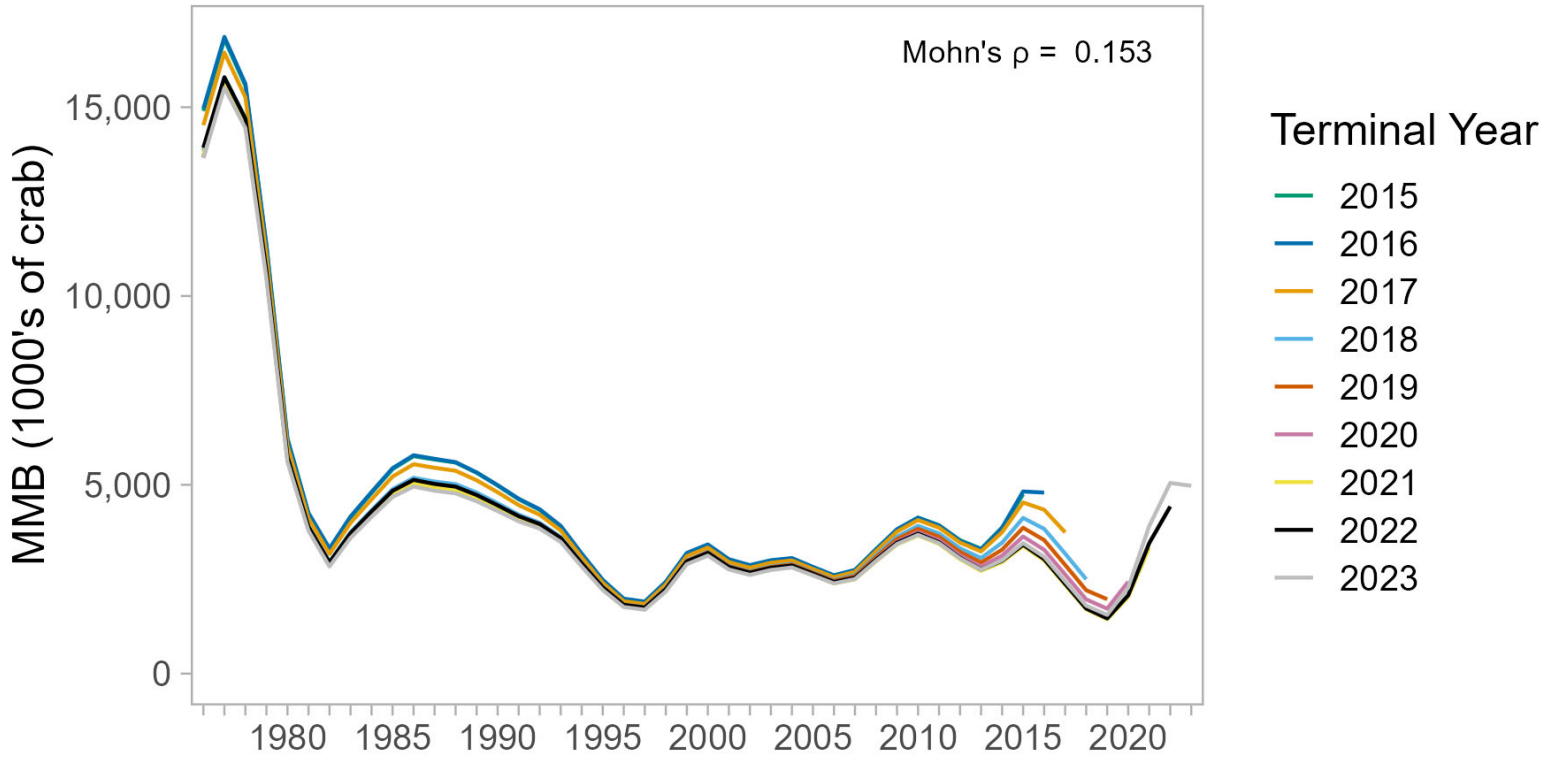
Mature Male Biomass



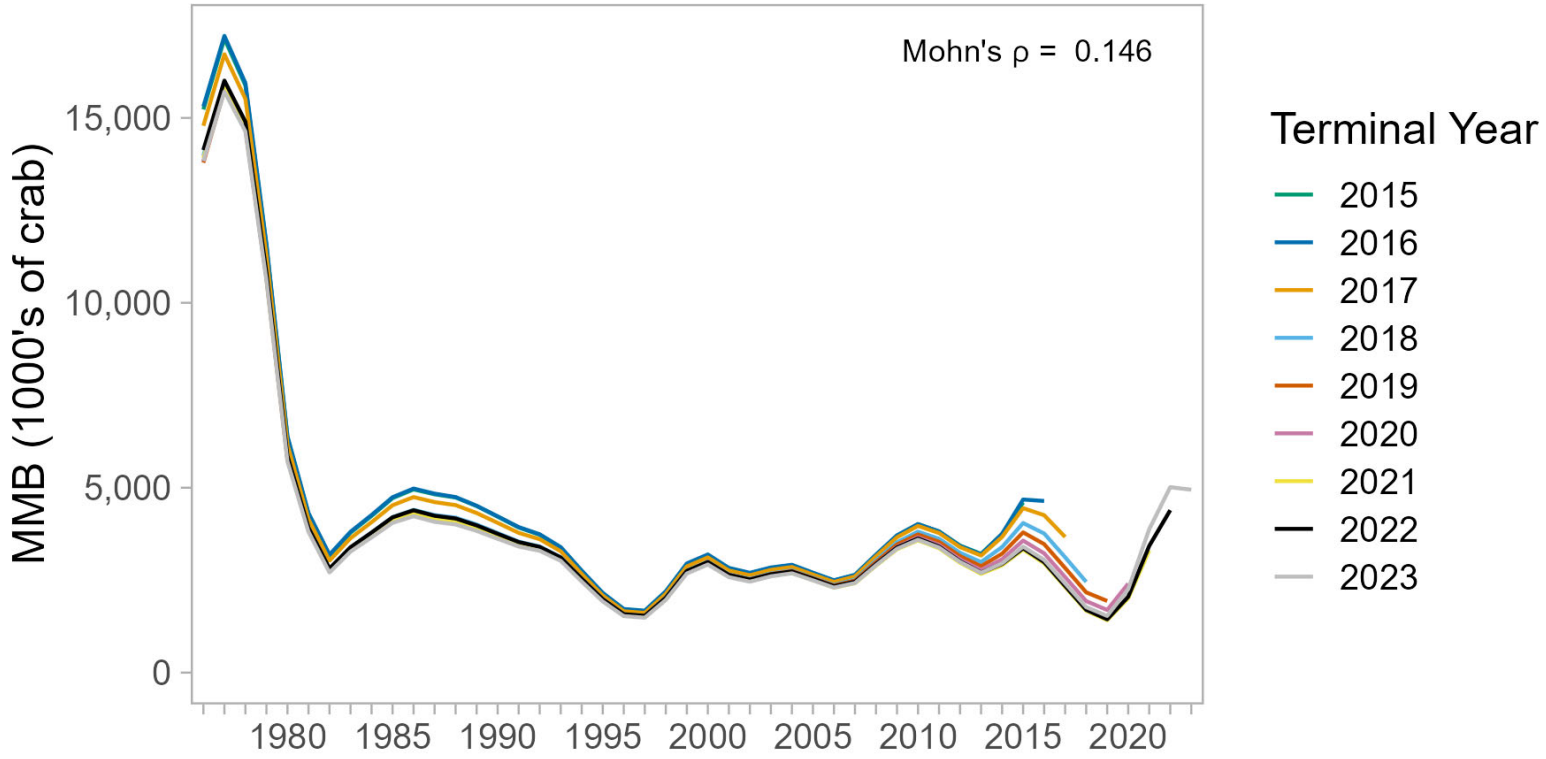
Retrospective analysis: design-based indices only



Retrospective analysis: design-based index + model-based index



Retrospective analysis: model-based index only



Management quantities

	24.0b6	24.0b6a	24.0b6b
MMB_{2024}	4642.49	3629.70	3619.51
B_{MSY}	4291.92	3342.25	3116.52
MMB/B_{MSY}	1.08	1.09	1.16
F_{OFL}	0.18	0.18	0.18
OFL_{2024}	577.32	455.91	457.09
ABC_{2024}	404.12	319.14	319.96

Effects on the stock assessment model output of using a model-based index

Takeaways:

Using the model-based index in the assessment model

- leads to reduced estimated scale of the population
- does not consistently improve fits
- leads to less extreme retrospective pattern in MMB
- may improve ability to predict biomass for the terminal year

Adding more years with both ADF&G and NBS surveys is a priority

Outline

Stock, surveys, background

Modeling approach, evaluation, diagnostics

Prediction grids and spatial predictions

Indices, comparison to design-based indices

Impacts on stock assessment model output of using model-based index

Future work and feedback

Future work and feedback

Feedback:

- how to use NOAA Norton Sound survey data
- estimating vs. fixing catchability for the model-based index
- analyses for comparing model performance with and without model-based indices

Next steps:

- explore effects of estimating catchability on stock assessment model output
- improve comparisons of model performance

Thanks!

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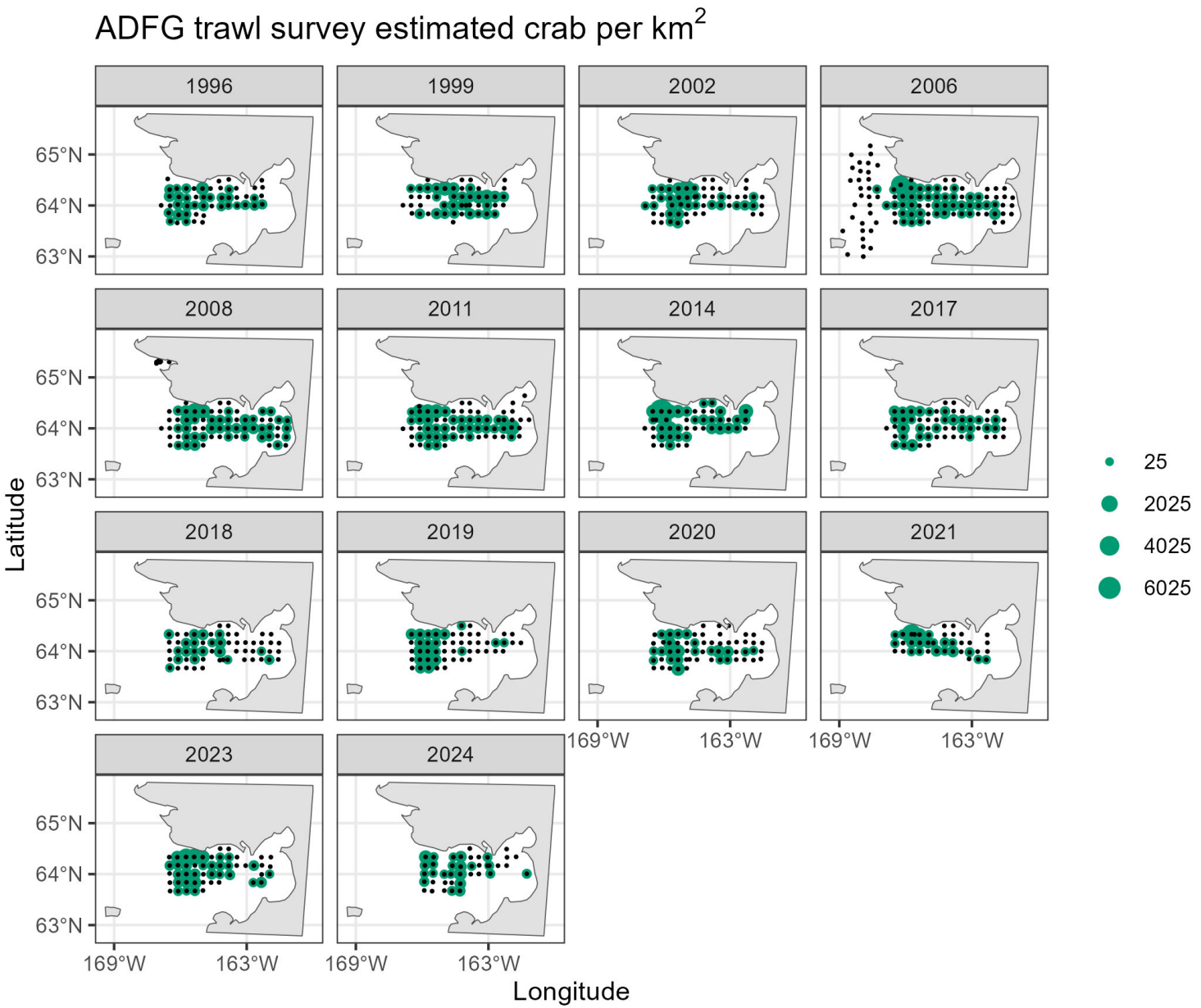
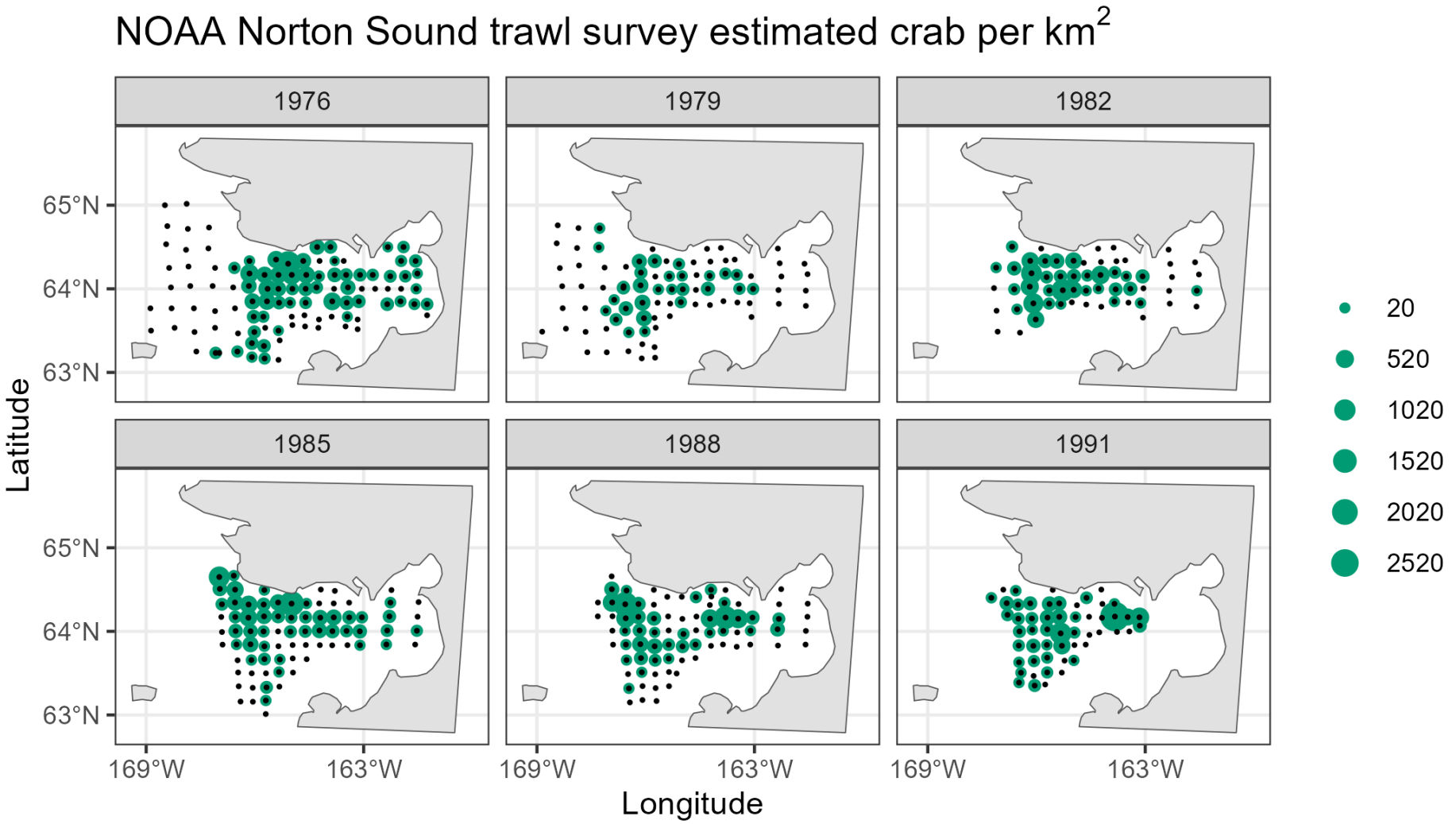
Survey abundance by station



Survey abundance by station



Survey abundance by station