Spatiotemporal model-based indices of abundance for Norton Sound red king crab

Crab Plan Team, May 2025

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Norton Sound red king crab and model-based indices

SSC and CPT concerns:

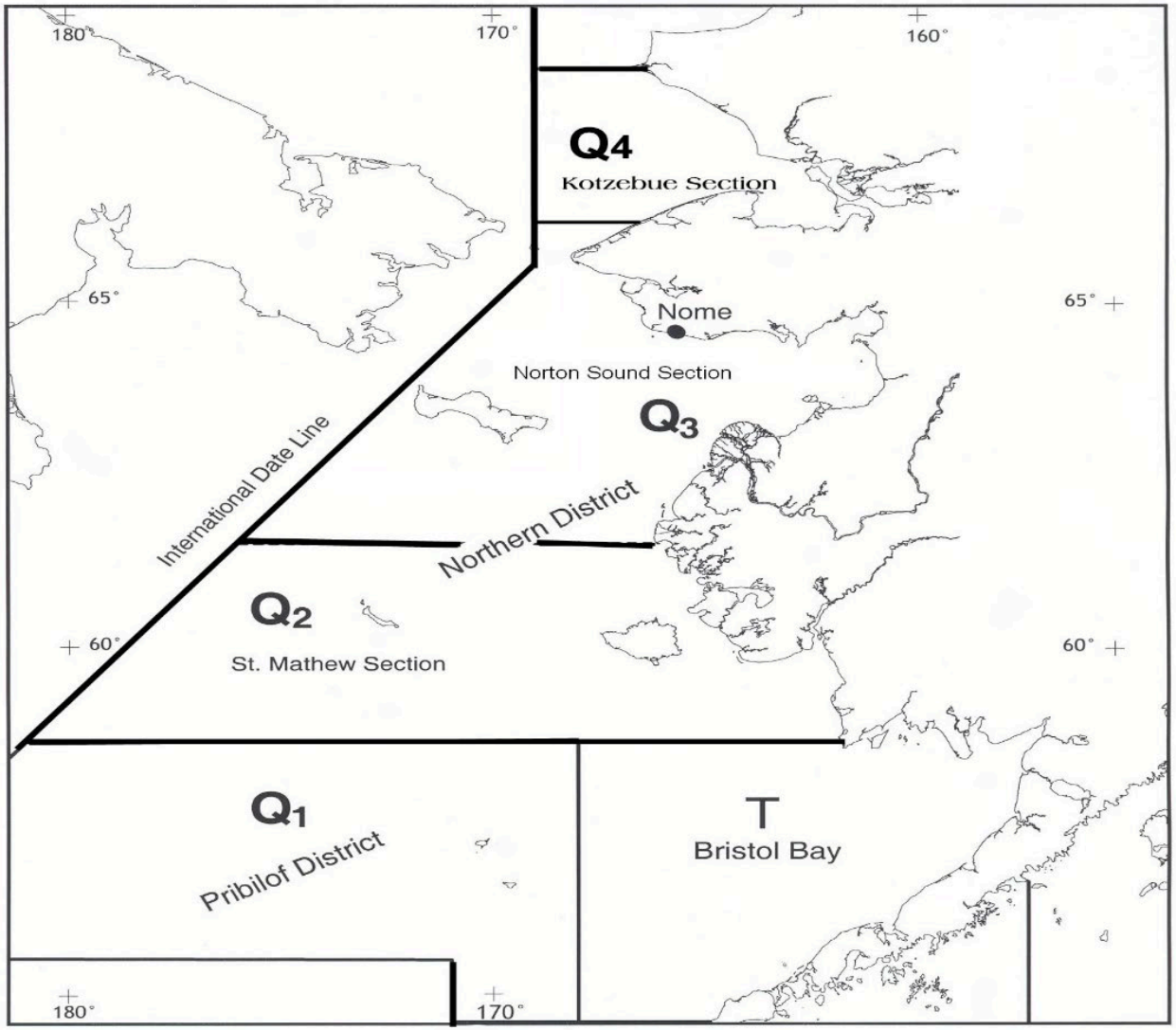
- consistency of area over which abundance is estimated
- sufficient diagnostics for evaluating spatiotemporal models

Outline:

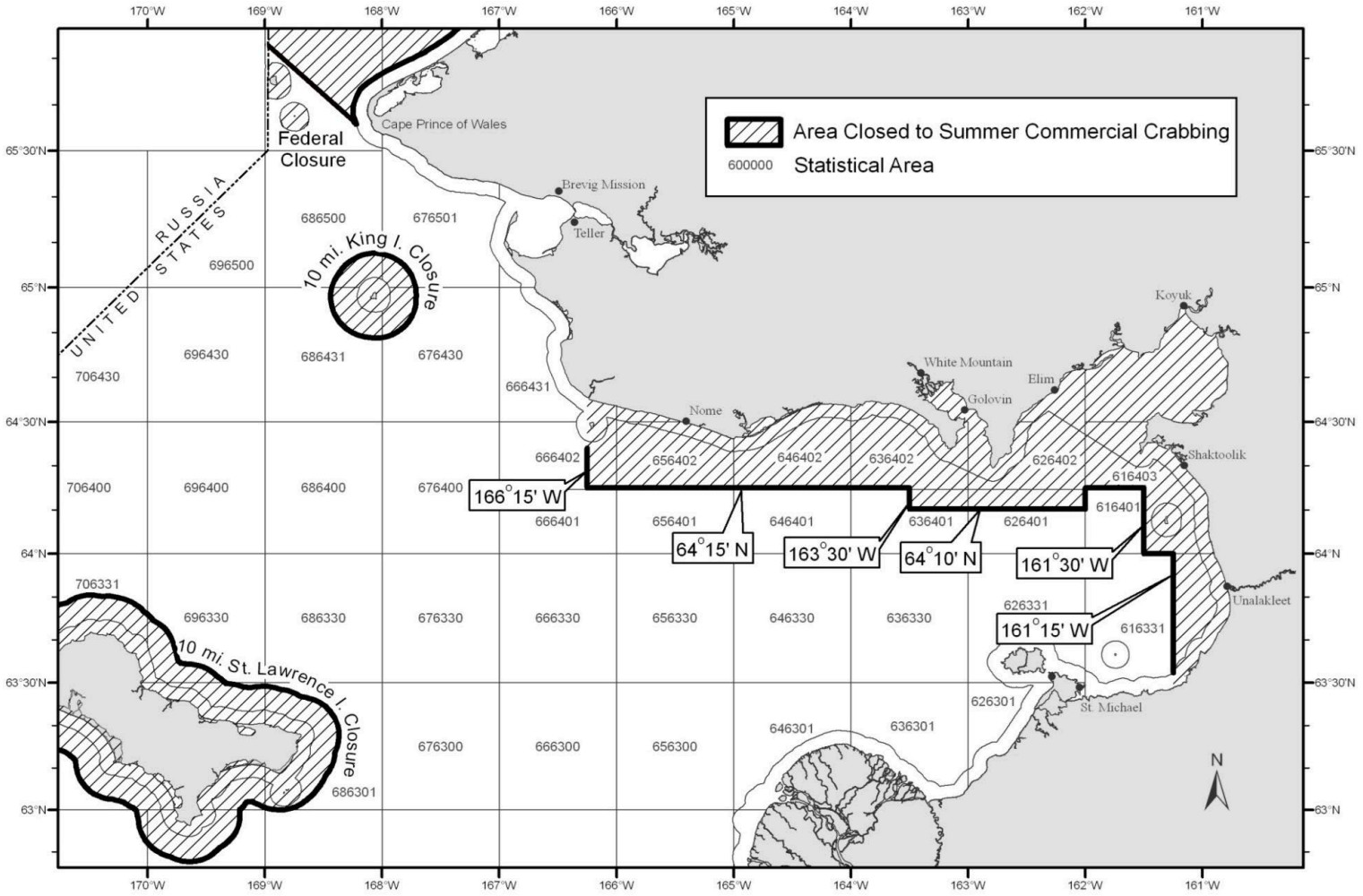
- stock and surveys
- modeling approach
- model evaluation and diagnostics
- model-based vs. design-based indices
- future work

Feedback: area over which to estimate abundance

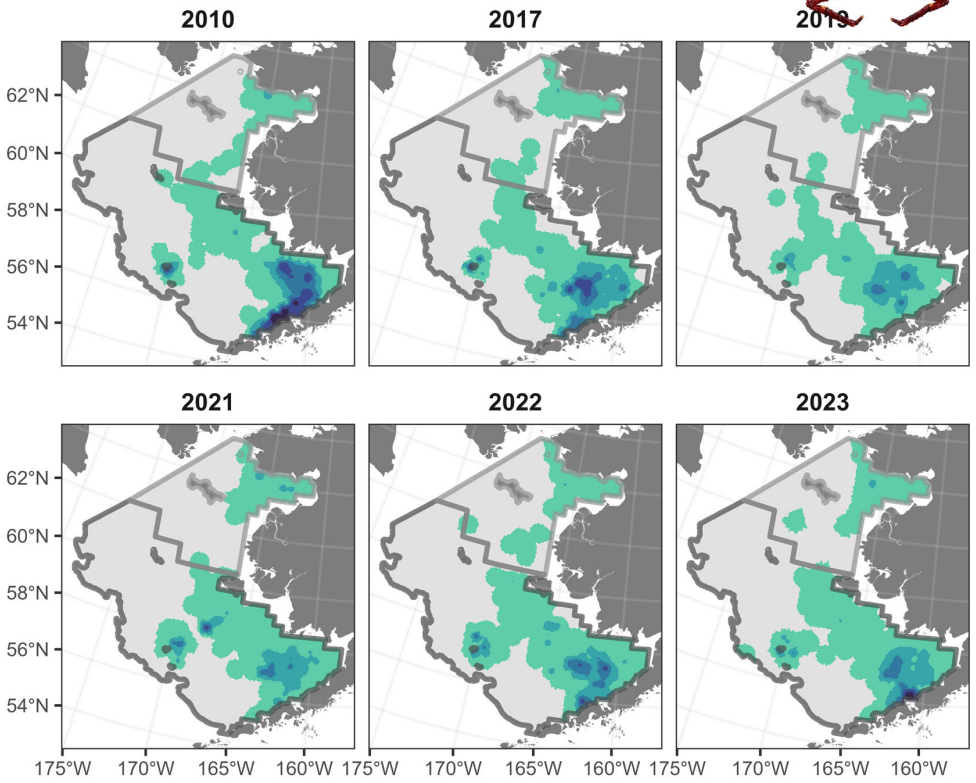
Norton Sound red king crab stock



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.

Red king crab
Weight CPUE (kg/km²)

No catch >0–3 >3–9 >9–19 >19–40 >40–82

Trawl surveys

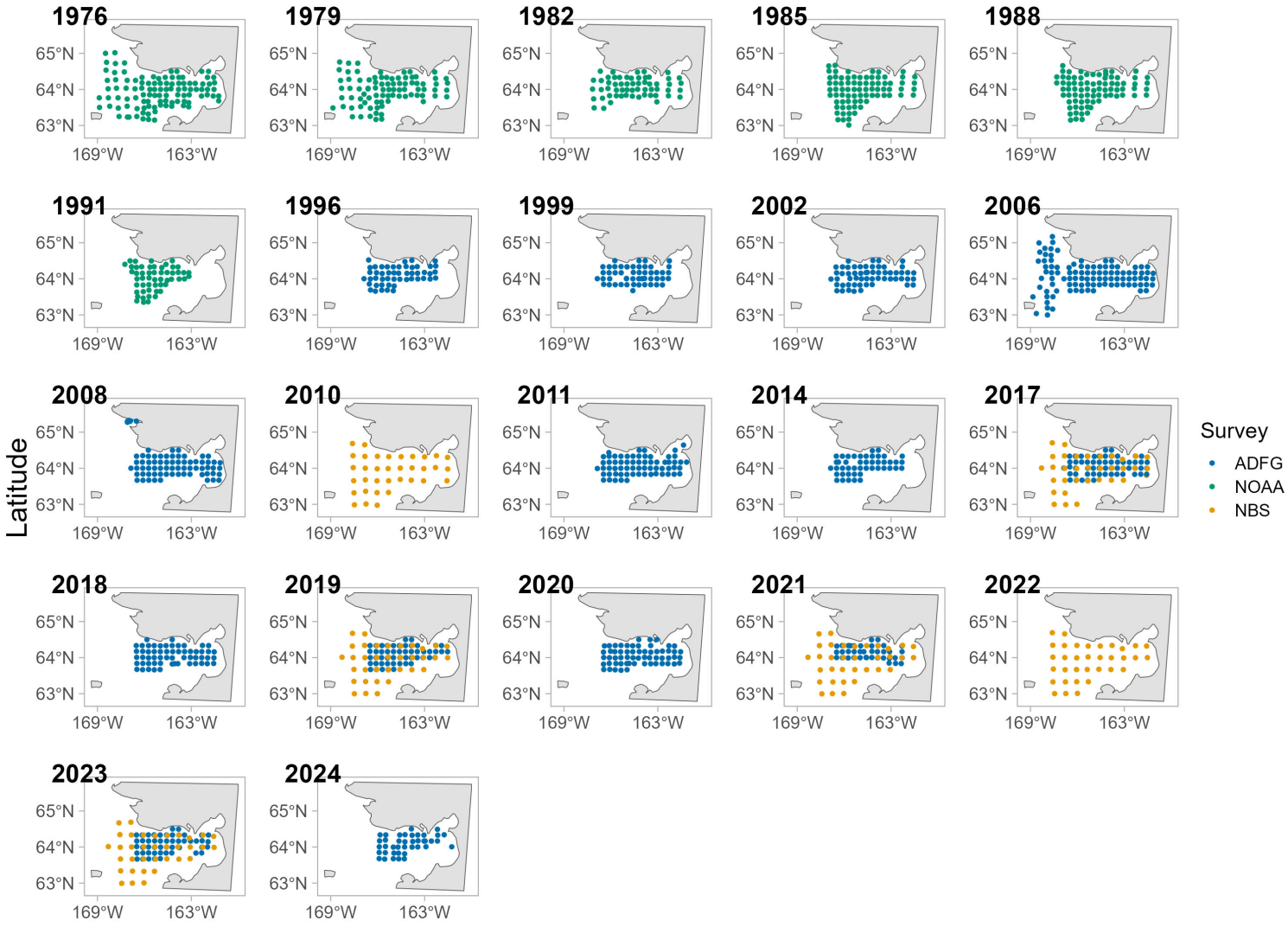
Survey	Years	Grid	Gear	Net width	Tow length	Stations (median)
NOAA NS	1976-1991	10 nm	83-112	50 ft	1.3-1.7 nm	53-104 (78.5)
ADF&G	1996-2024	10 nm	400	40 ft	1.0 nm	39-100 (54.5)
NOAA NBS	2010-2023	20 nm	83-112	50 ft	1.3-2.5 nm	34-35 (35)

All surveys use Eastern Otter trawl gear

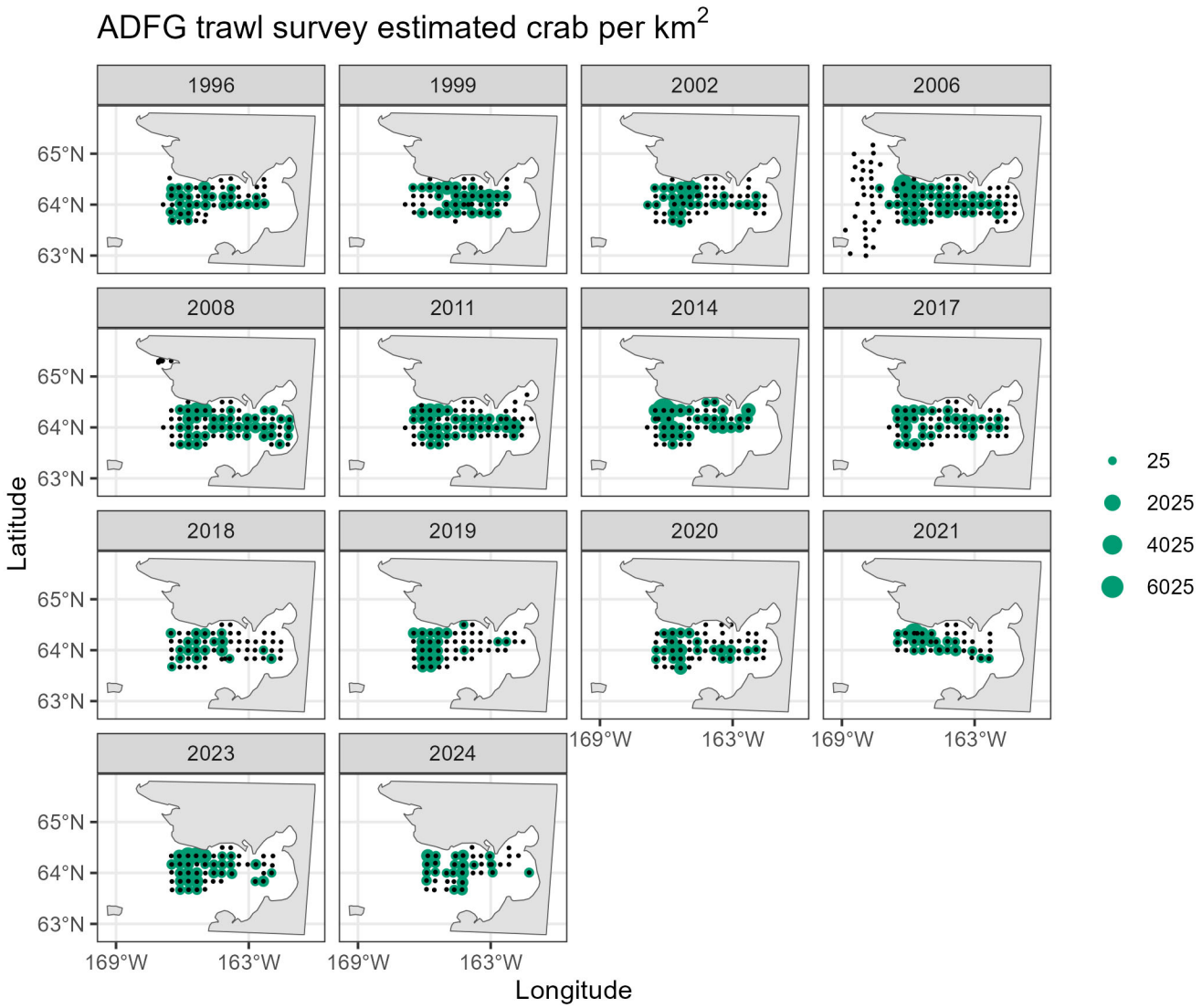
ADF&G and NOAA NBS surveys expected to occur in 2025

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

Survey areas sampled



Survey abundance by station



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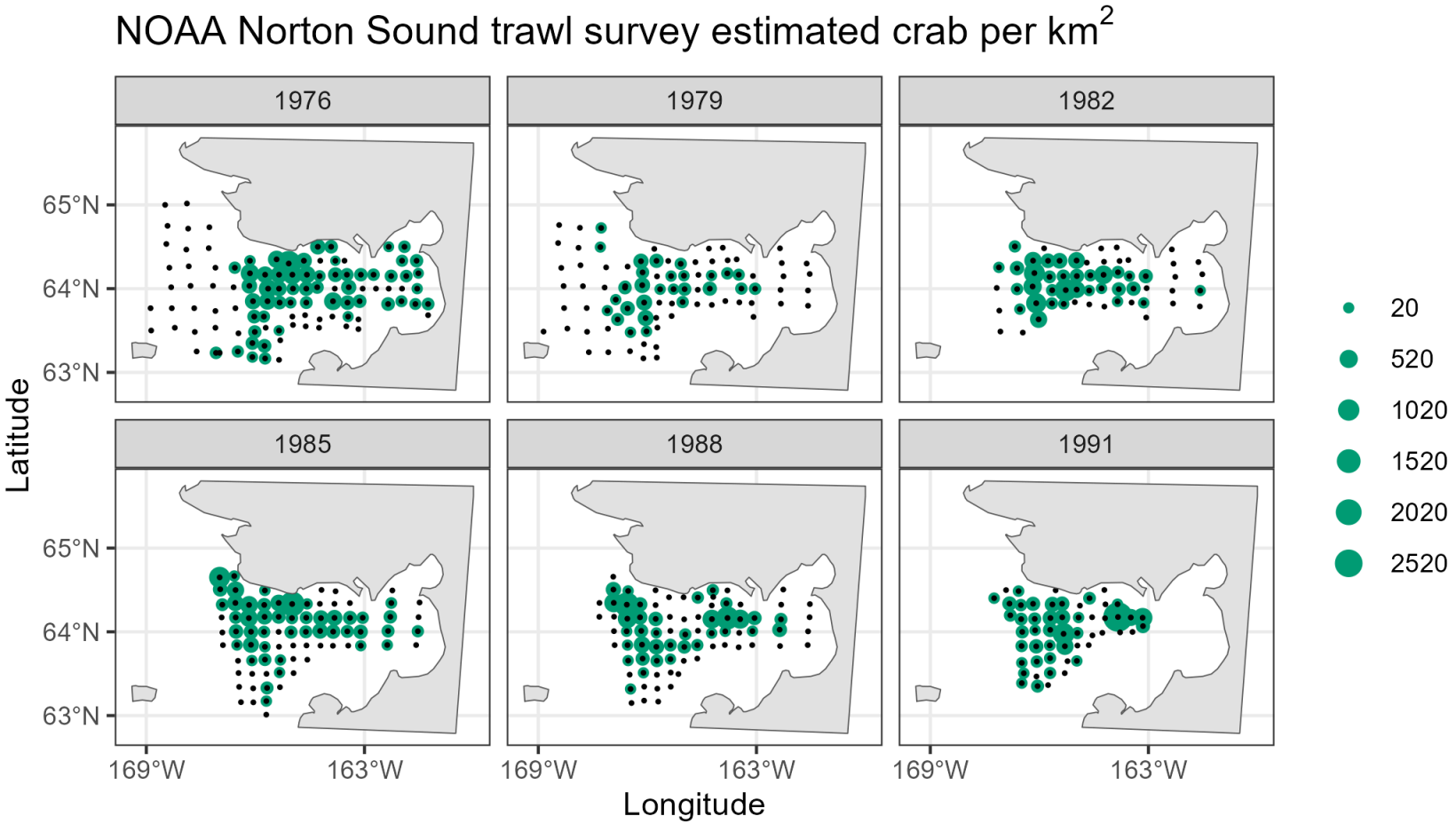
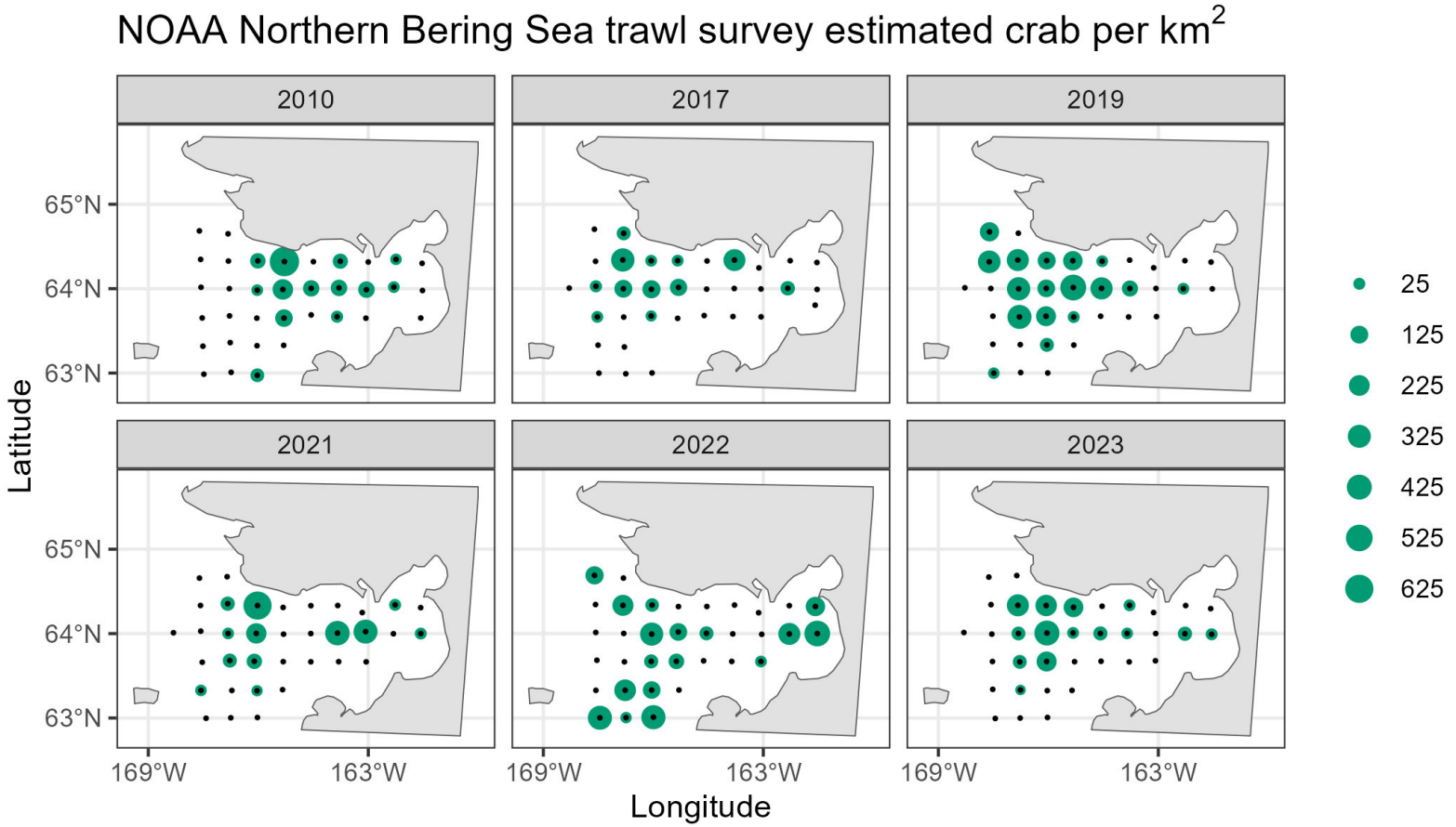


Survey abundance by station



Design-based abundance estimates

From the 2024 NSRKC SAFE:

"The fundamental issue regarding NSRKC assessment is a lack of clearly defined spatial boundaries"

"Abundance of the 1976-1991 NMFS trawl survey is standardized to 7600 nm^2 …whereas that of ADF&G survey is unexpanded, with coverage ranging from 4700–5200 nm^2 "

"The standardized ADF&G trawl survey area is a fraction of Norton Sound where NSRKC lives and can be subject to fisheries…using the "Total abundance" would be more appropriate."

- Matching ADF&G survey design-based abundance estimates may not be desirable
- A consistent definition of the area over which to estimate abundance is needed

Outline

Stock and surveys

Modeling approach, evaluation, diagnostics

Prediction grids and spatial predictions

Indices, comparison to design-based indices

Future work and feedback

Modeling approach

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

Constructed triangulation meshes using make_mesh() and add_barrier_mesh()

Ensured that the number of mesh vertices was lower than the number of data points

Model specification

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

Predictors: year or year + survey station depth

Model structures:

- Tweedie with a log link
- delta-gamma with a logit link for the binomial distribution and a log link for the gamma distribution
- delta-lognormal with a logit link for the binomial distribution and a log link for the lognormal distribution.

Model convergence

Evaluated convergence using sdmTMB function sanity_check()

ADF&G survey converged models:

- Tweedie with a year effect only
- Tweedie with year and depth effects
- delta-gamma with year and depth effects

NOAA NBS trawl survey converged models:

- Tweedie with a year effect only
- Tweedie with year and depth effects

All six NOAA Norton Sound trawl survey models converged

Model predictive skill

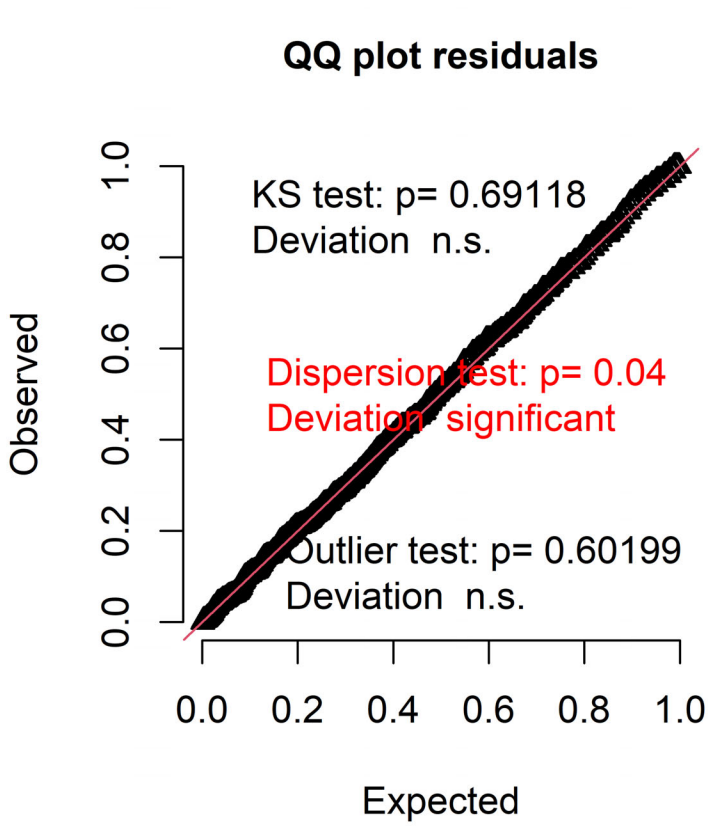
Model predictive skill: predictive ability of the model for new observations

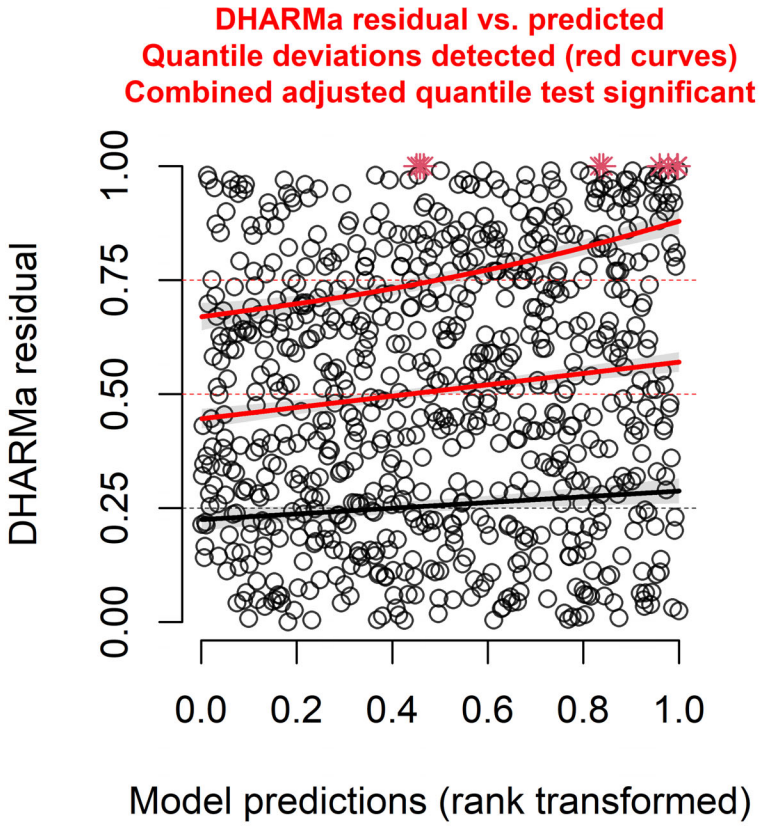
- cross validation using sdmTMB_cv()
- 10 randomly arranged folds for each model

Models with best predictive skill:

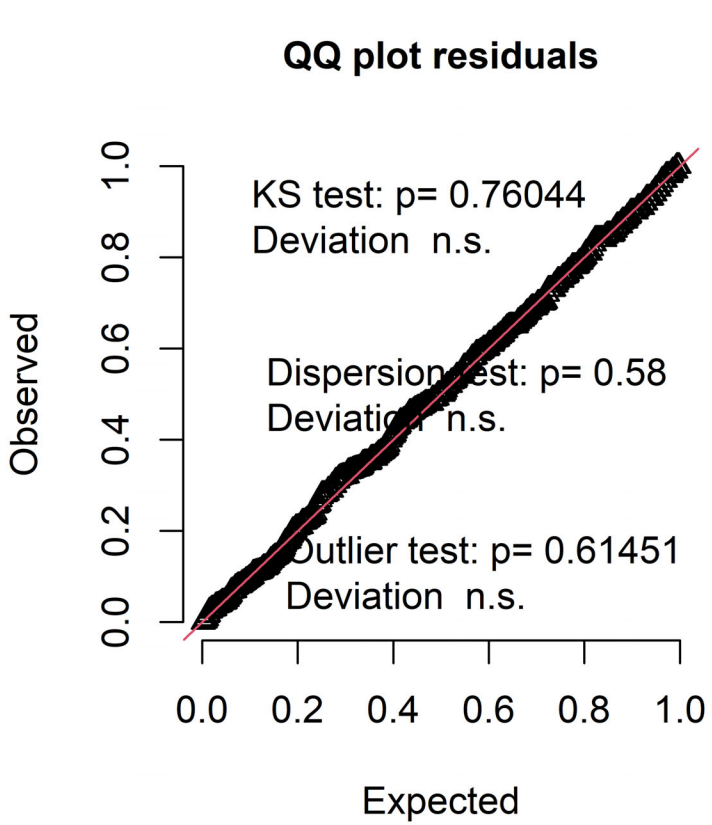
- ADF&G survey: delta-gamma model with year and depth
- NOAA NS survey: delta-lognormal model with year and depth
- NOAA NBS survey: Tweedie model with year only

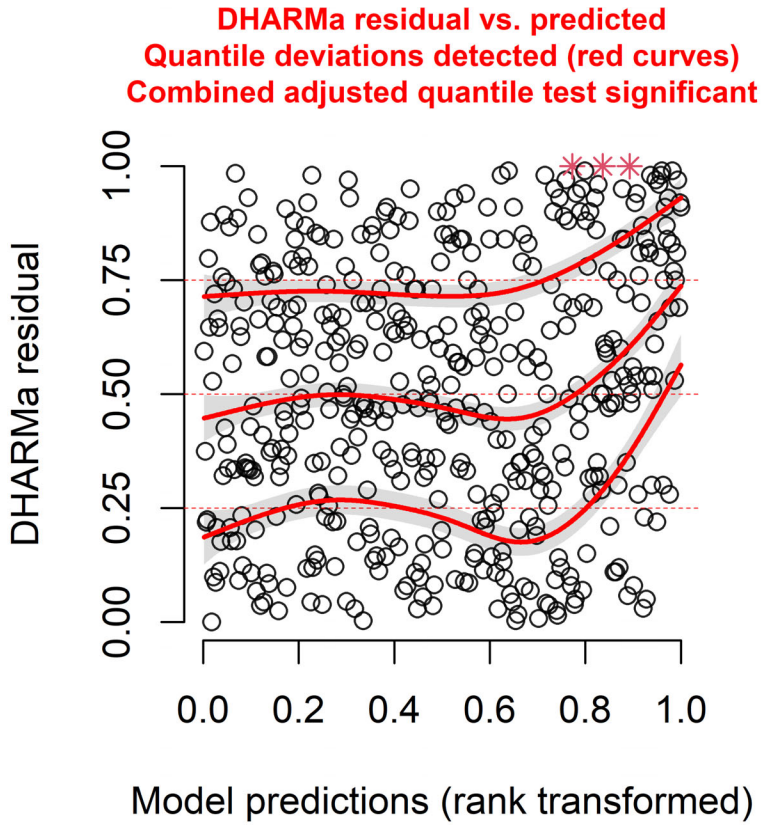
Model diagnostics: ADF&G survey



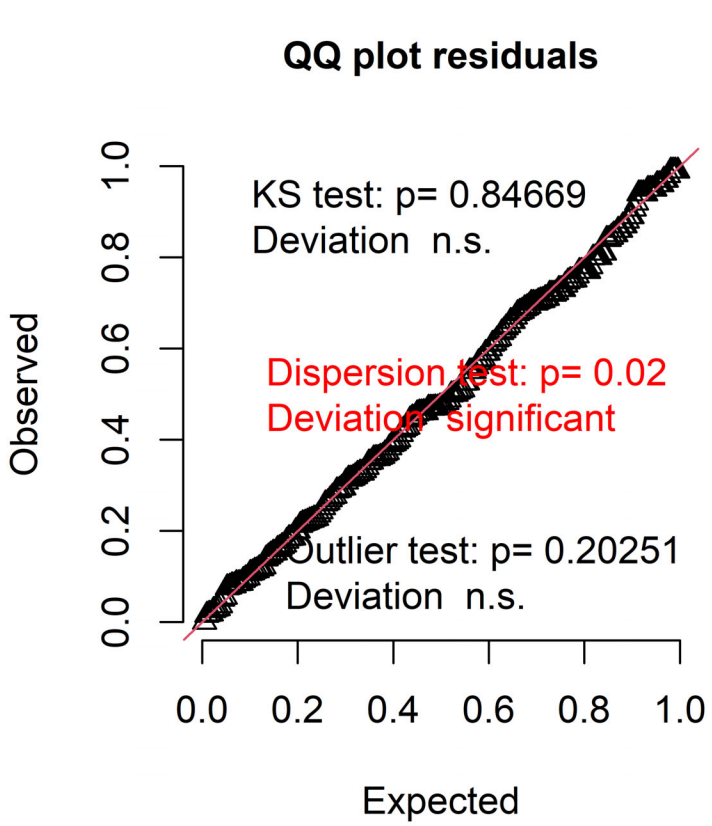


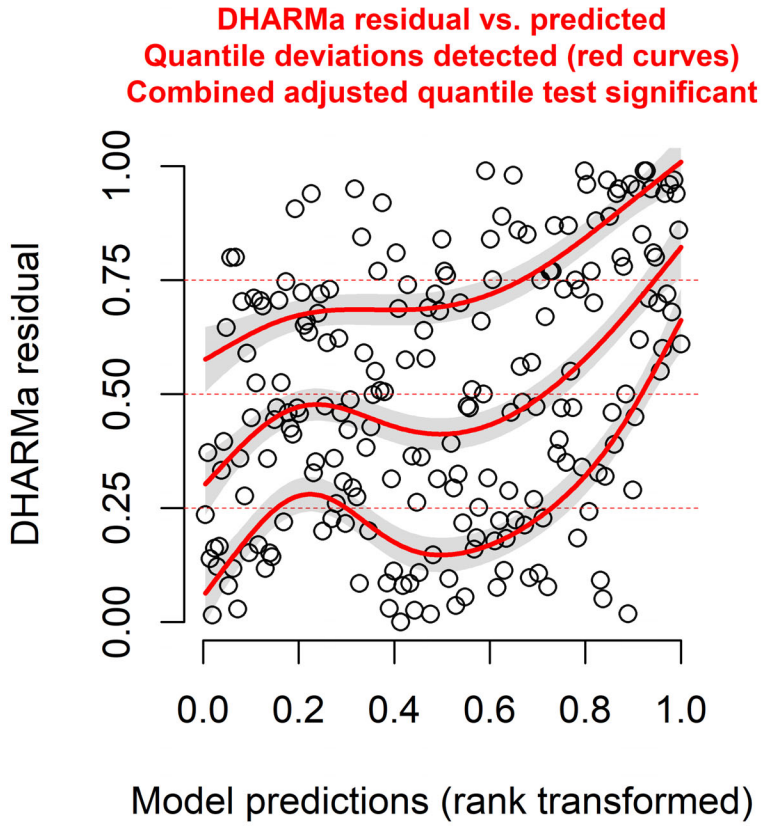
Model diagnostics: NOAA NS survey





Model diagnostics: NOAA NBS survey





Model diagnostics summary

Survey	Model	Effects	Log-likelihood	Kolmogorov-Smirnov	Quantiles	Dispersion	Outliers	Zero inflation
ADF&G	Tweedie	year	-3,069	0.415	<0.01	0.02	0.38	0.88
ADF&G	Tweedie	year, depth	-3,026	0.473	<0.01	0.62	0.30	0.76
ADF&G	DG	year, depth	-2,985	0.691	<0.01	0.04	0.60	0.96
NOAA NS	Tweedie	year	-1,791	0.574	<0.01	<0.01	0.61	0.84
NOAA NS	DG	year	-1,703	0.537	<0.01	0.94	0.87	0.52
NOAA NS	DL	year	-1,648	0.717	<0.01	0.22	0.31	0.44
NOAA NS	Tweedie	year, depth	-1,732	0.312	<0.01	<0.01	0.61	0.92
NOAA NS	DG	year, depth	-1,706	0.062	<0.01	0.82	0.24	0.18
NOAA NS	DL	year, depth	-1,642	0.760	<0.01	0.58	0.61	0.72
NOAA NBS	Tweedie	year	-662	0.847	<0.01	0.02	0.20	0.42
NOAA NBS	Tweedie	year, depth	-1,124	0.613	<0.01	<0.01	0.80	0.82

Moran's I clustering analysis

Tests for spatial patterns in residuals

Applied across each year of the time series for each survey

- 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
- positive Moran's I statistic values indicate spatial autocorrelation; negative values indicate negative spatial autocorrelation
- p-values < 0.05 indicate significant clustering of spatial residuals

Moran's I analysis: ADF&G survey

Survey	Model	Year	Moran's I statistic	p-value
ADF&G	DG, year + depth	1996	-0.01	0.38
ADF&G	DG, year + depth	1999	0.02	0.23
ADF&G	DG, year + depth	2002	-0.02	0.49
ADF&G	DG, year + depth	2006	0.06	0.09
ADF&G	DG, year + depth	2008	0.00	0.32
ADF&G	DG, year + depth	2011	-0.05	0.74
ADF&G	DG, year + depth	2014	-0.01	0.36
ADF&G	DG, year + depth	2017	0.02	0.18
ADF&G	DG, year + depth	2018	0.06	0.09
ADF&G	DG, year + depth	2019	0.10	0.02
ADF&G	DG, year + depth	2020	-0.03	0.60
ADF&G	DG, year + depth	2021	0.02	0.19
ADF&G	DG, year + depth	2023	-0.05	0.72
ADF&G	DG, year + depth	2024	0.03	0.17

Moran's I analysis: NOAA NS survey

Survey	Model	Year	Moran's I statistic	p-value
NOAA NS	DL, year + depth	1976	0.125	0.002
NOAA NS	DL, year + depth	1979	0.051	0.088
NOAA NS	DL, year + depth	1982	-0.014	0.425
NOAA NS	DL, year + depth	1985	0.134	0.006
NOAA NS	DL, year + depth	1988	0.039	0.124
NOAA NS	DL, year + depth	1991	-0.022	0.476

Two years with significant spatial autocorrelation

Moran's I analysis: NOAA NBS survey

Survey	Model	Year	Moran's I statistic	p-value
NOAA NBS	Tweedie, year	2010	0.05	0.09
NOAA NBS	Tweedie, year	2017	0.02	0.16
NOAA NBS	Tweedie, year	2019	0.05	0.09
NOAA NBS	Tweedie, year	2021	-0.02	0.38
NOAA NBS	Tweedie, year	2022	-0.04	0.55
NOAA NBS	Tweedie, year	2023	0.06	0.08

No years with significant clustering of spatial residuals

Outline

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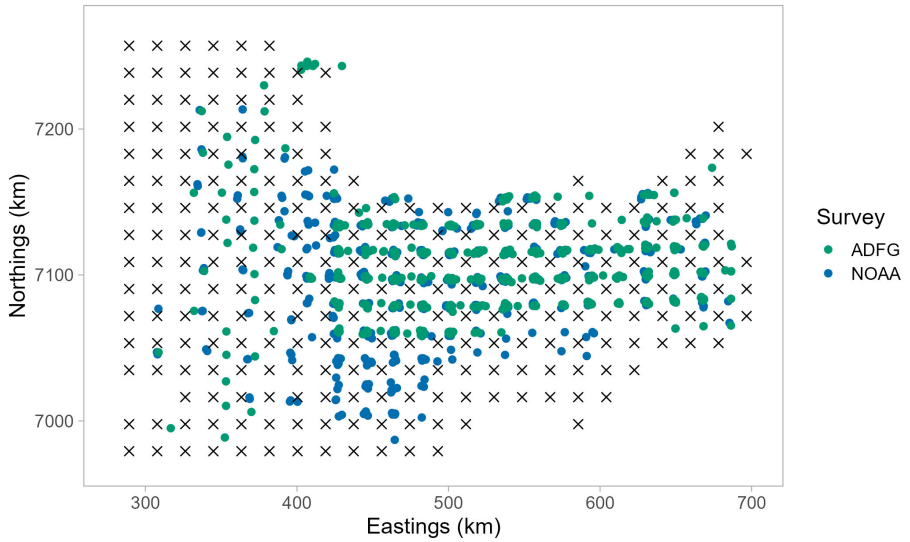
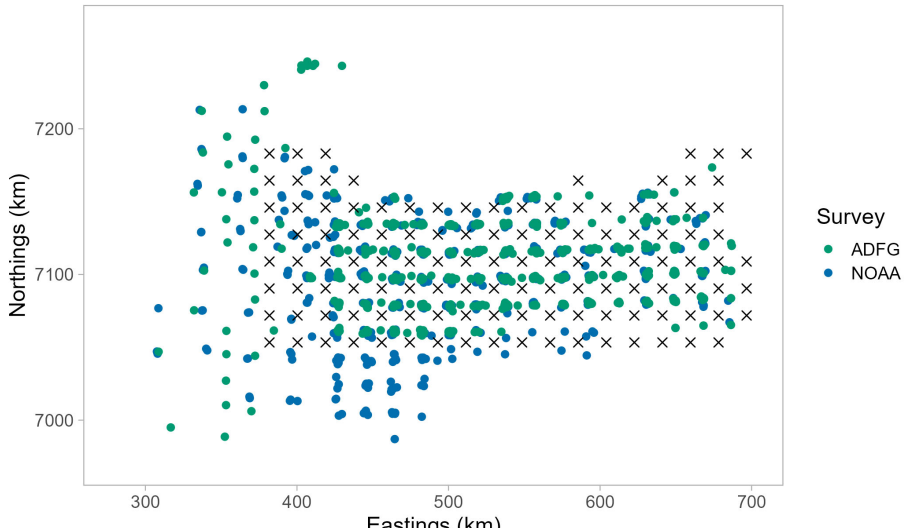
Indices, comparison to design-based indices

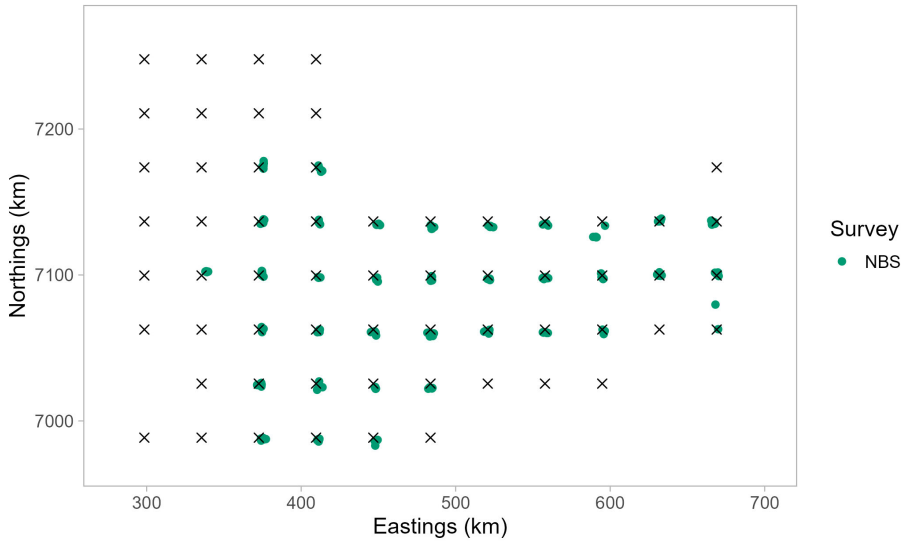
Future work and feedback

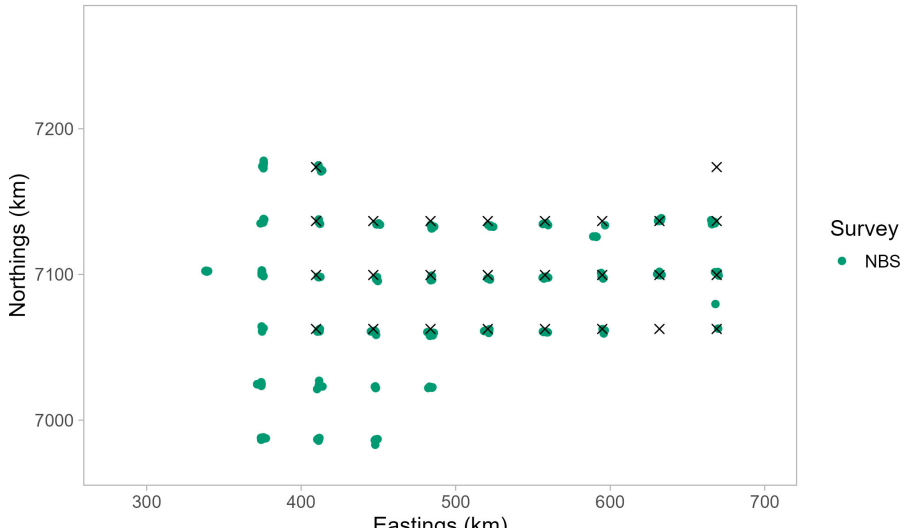
Prediction grids



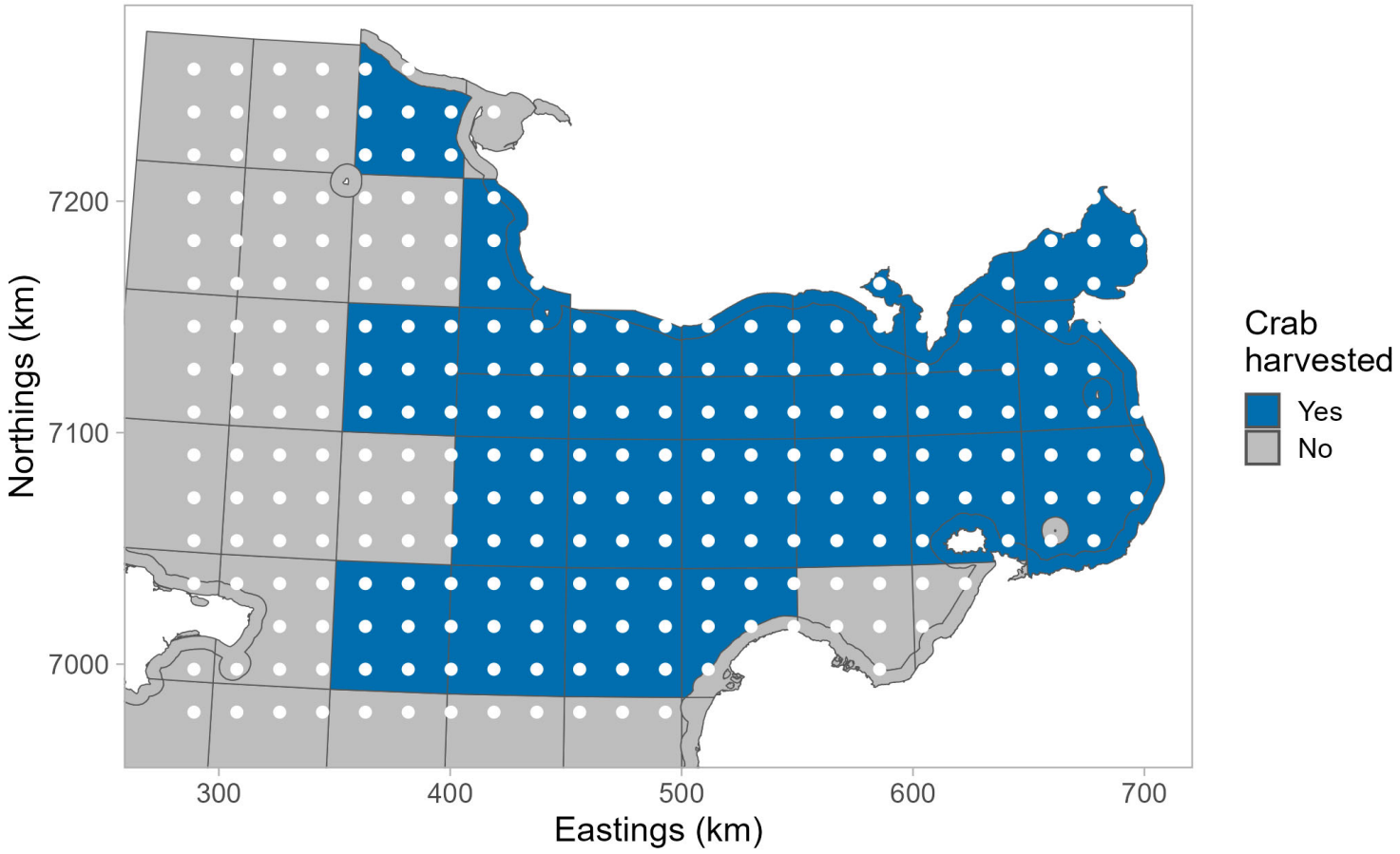


Prediction grids





Harvest information



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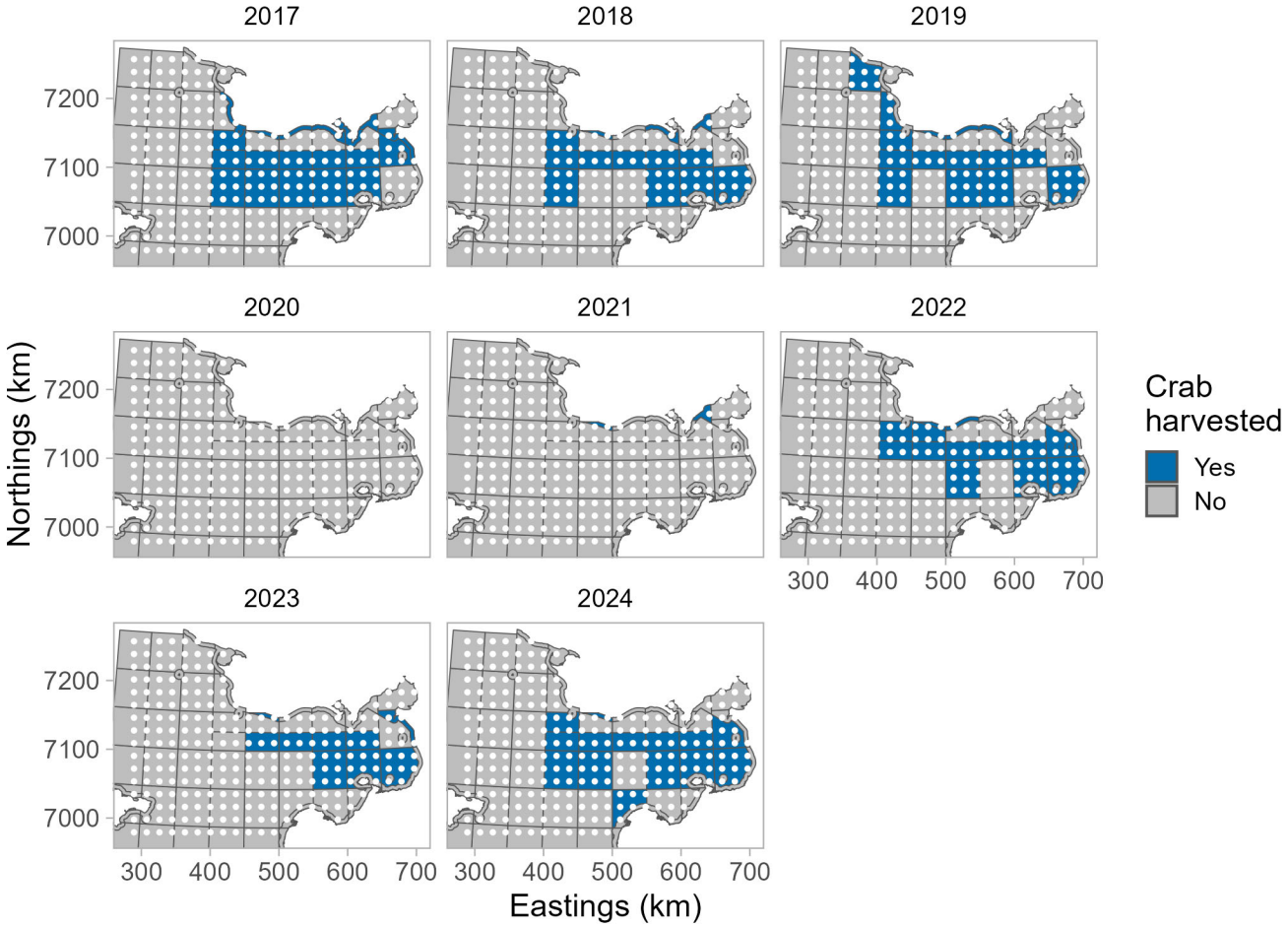

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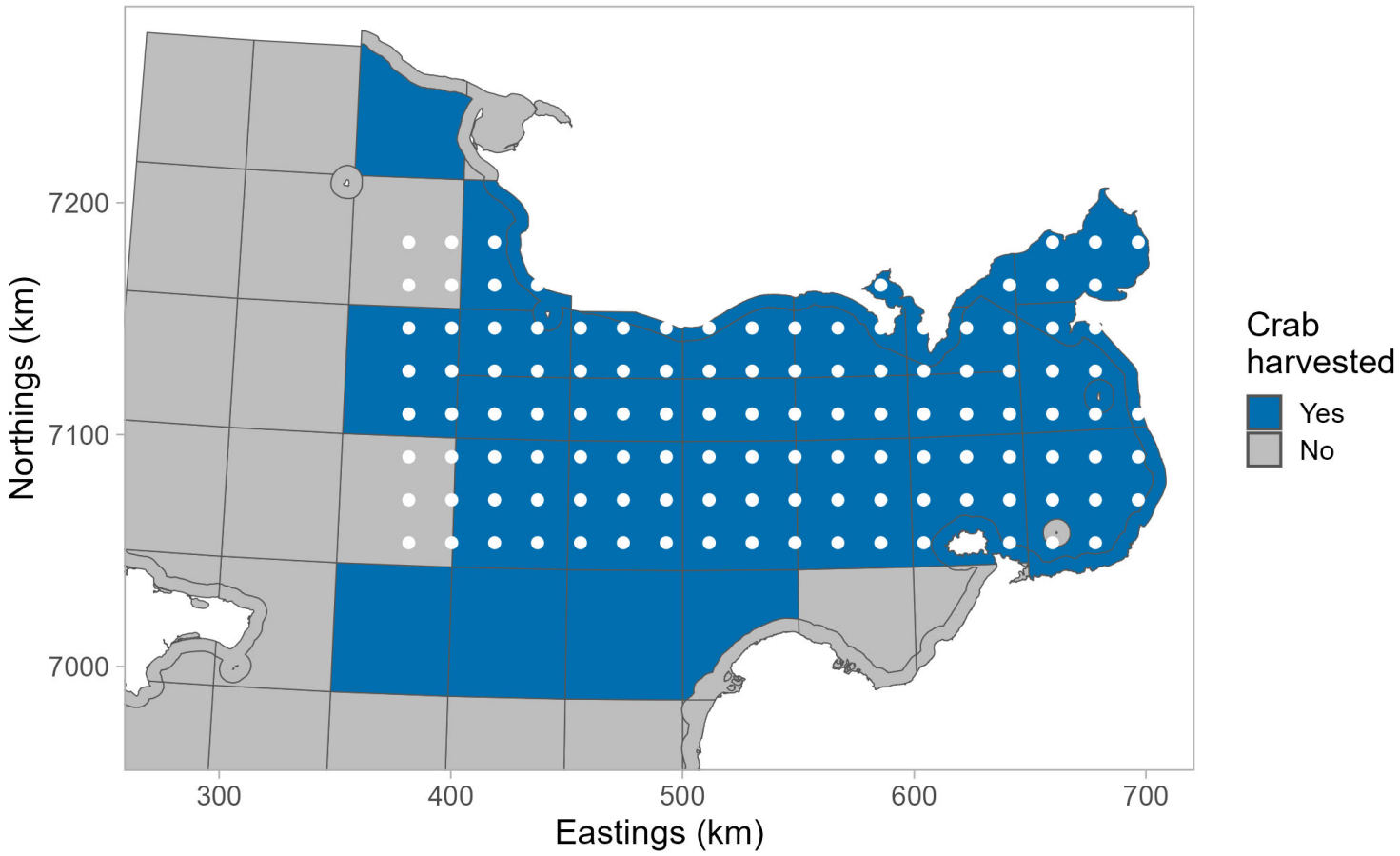

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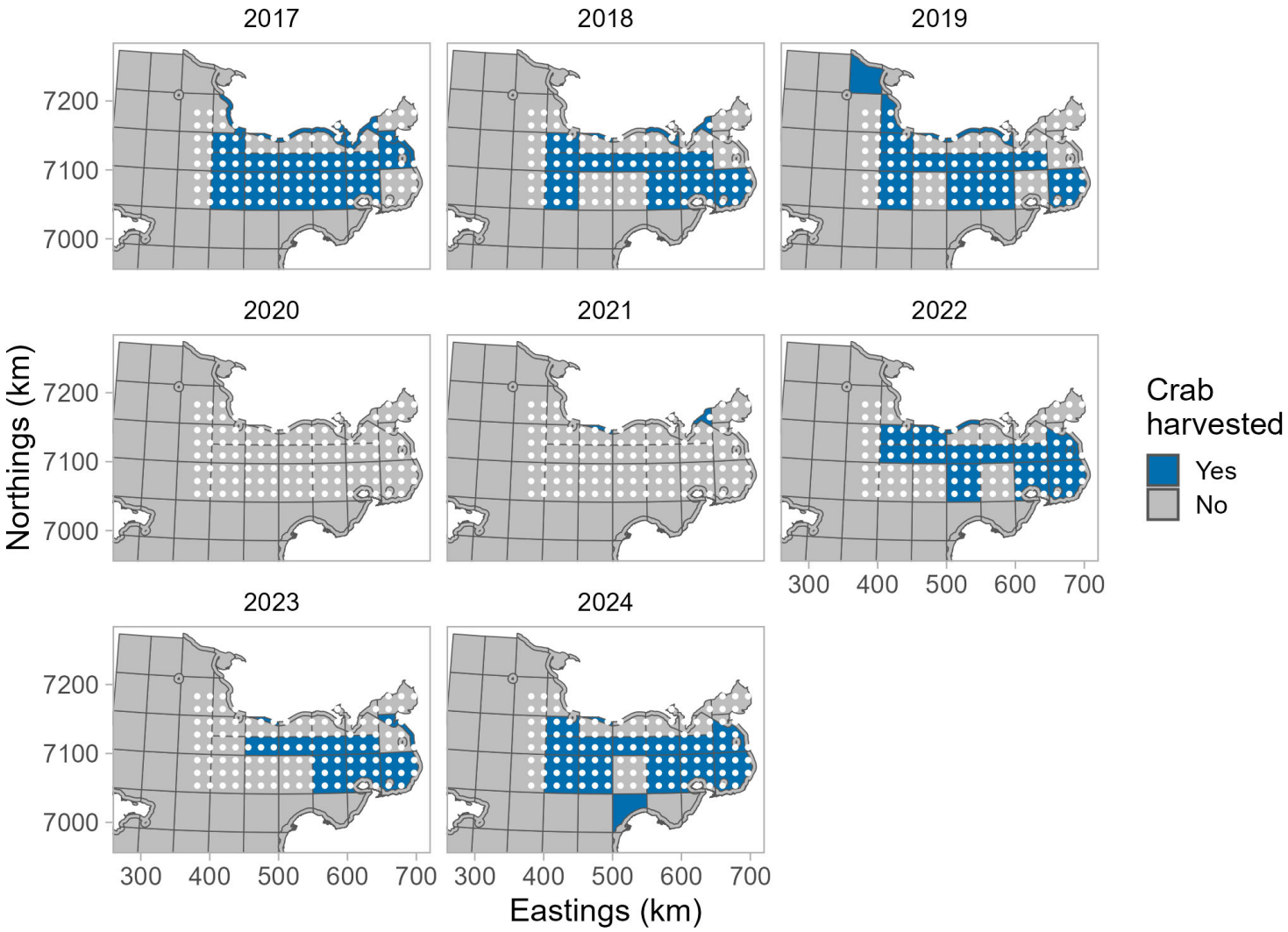
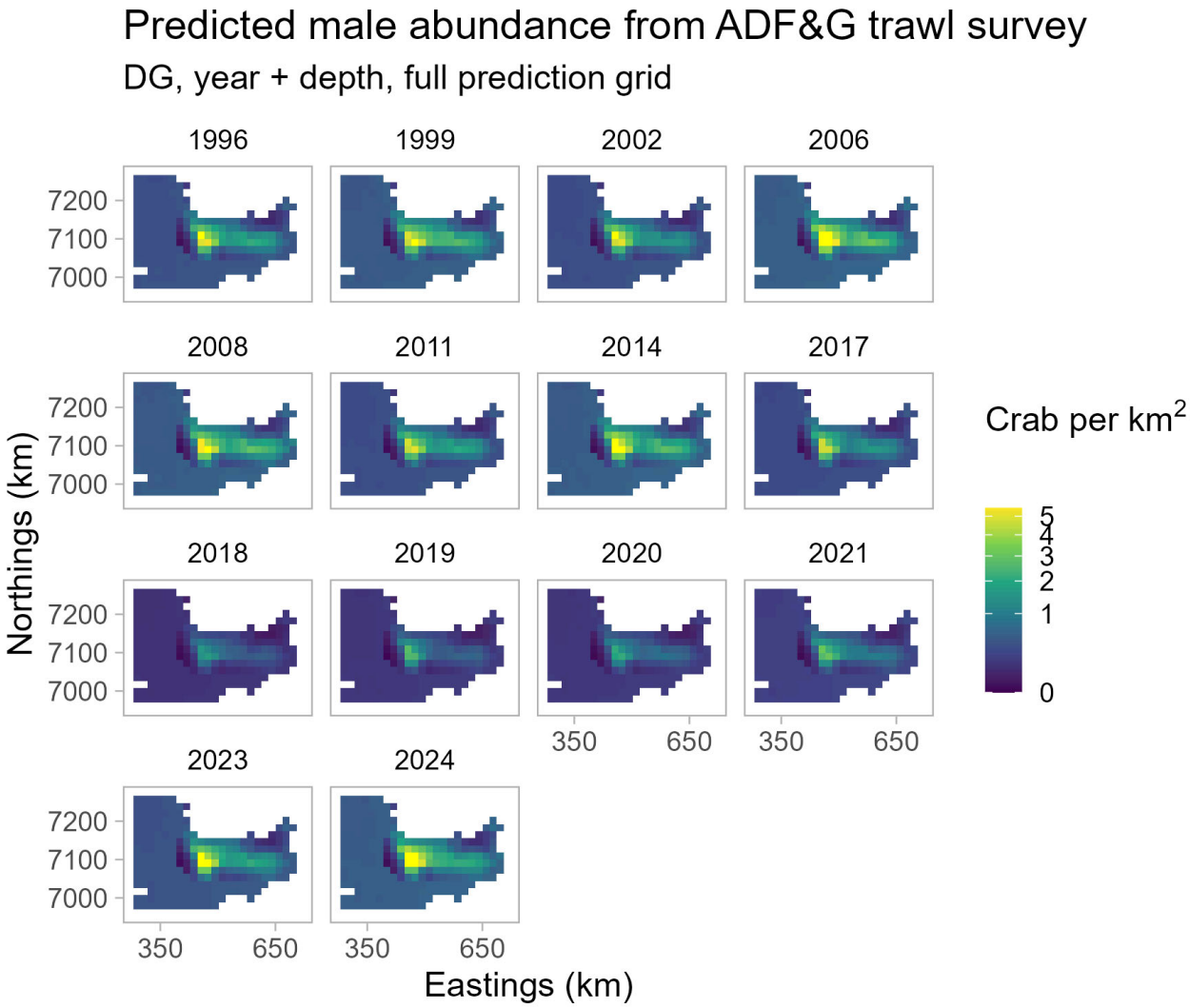
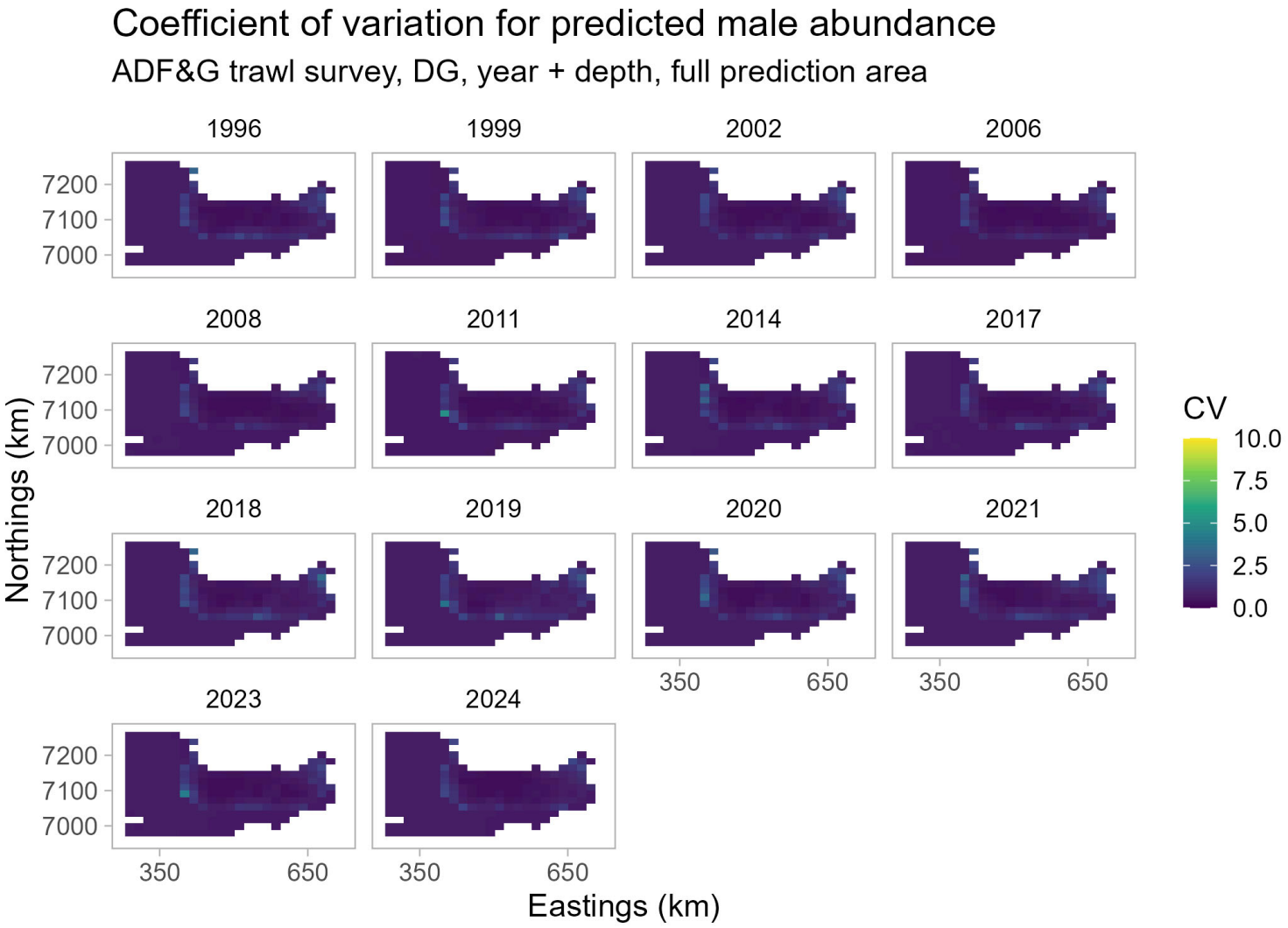


Predicted abundance



Predicted abundance CV's



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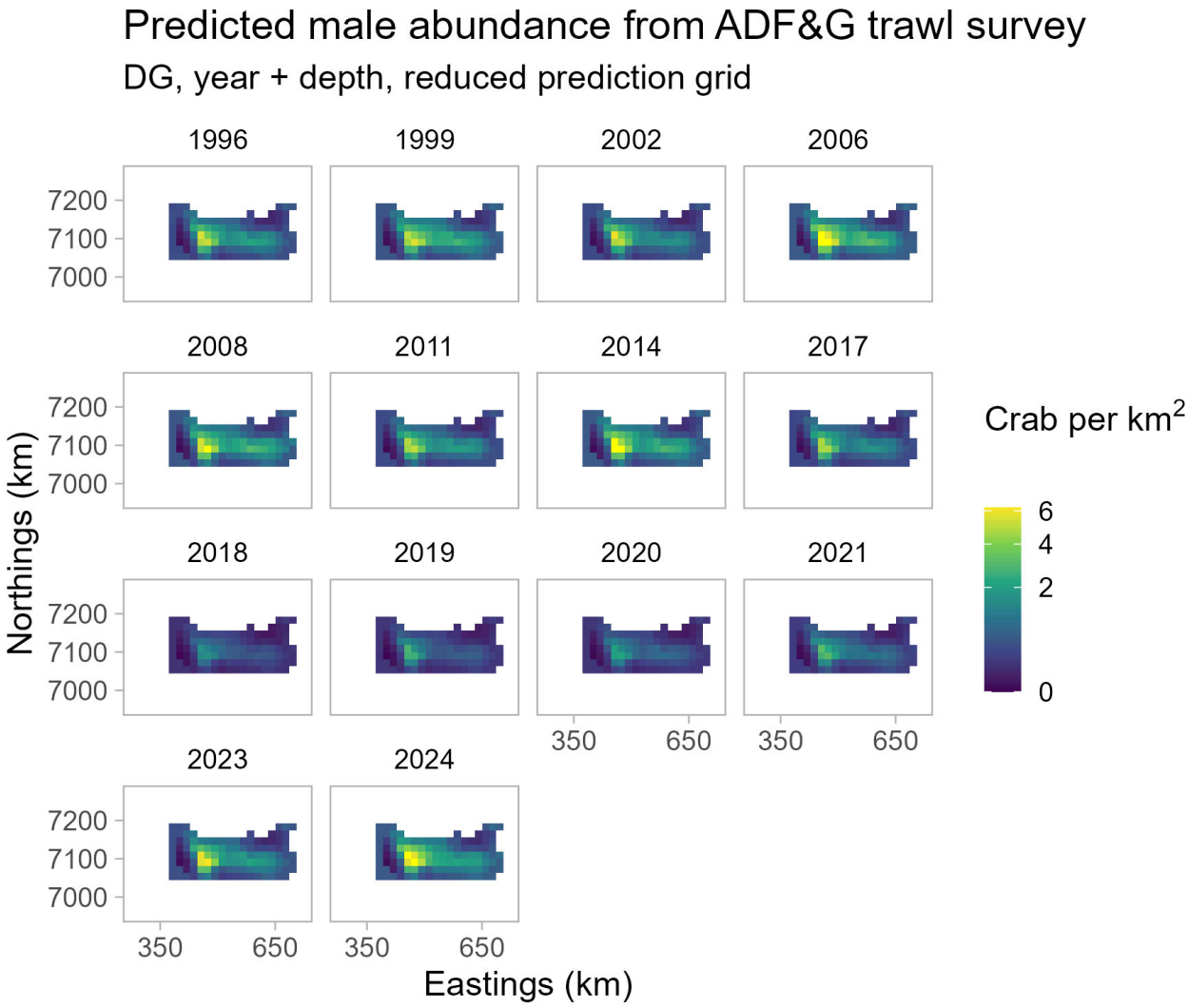

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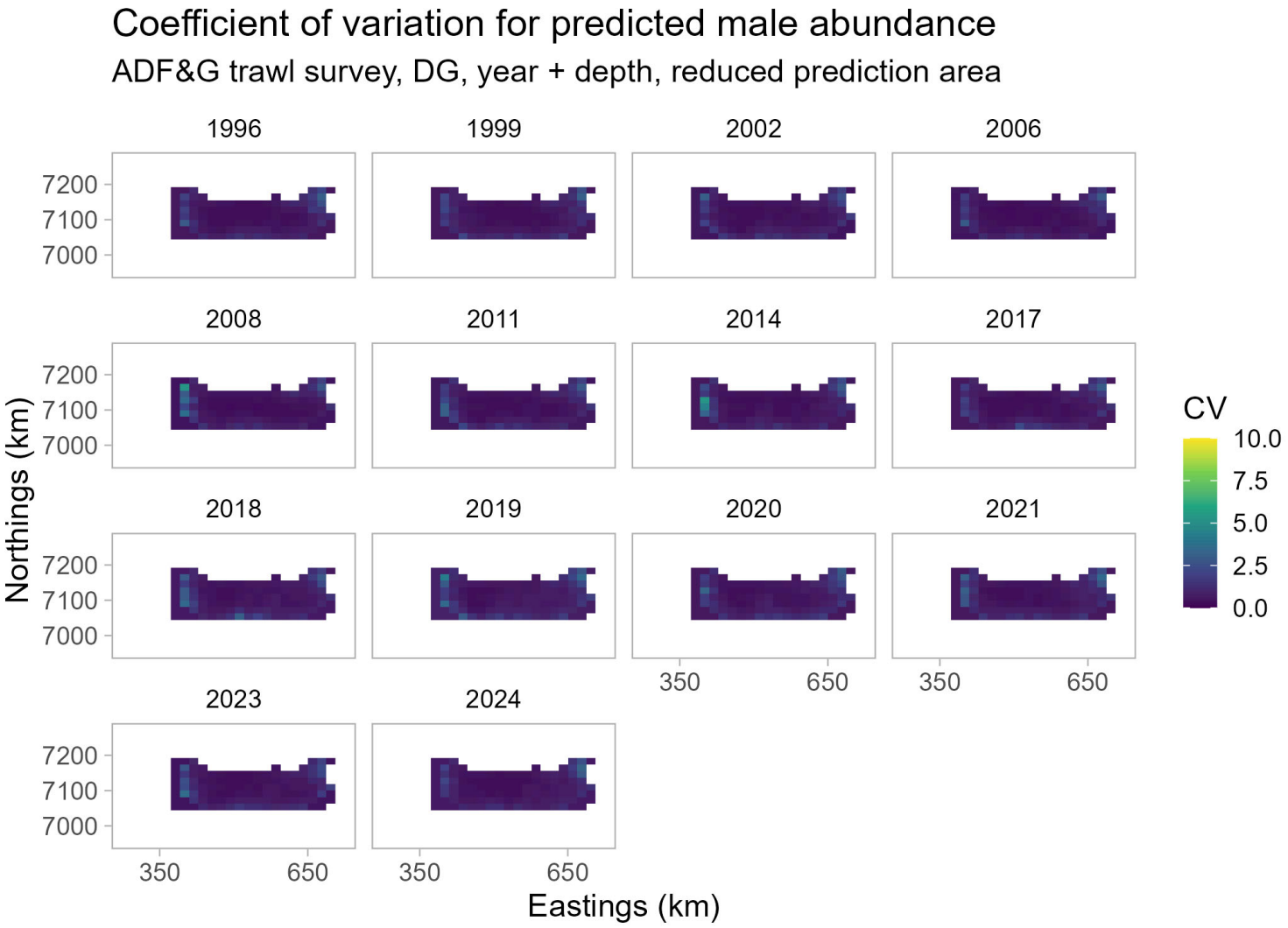

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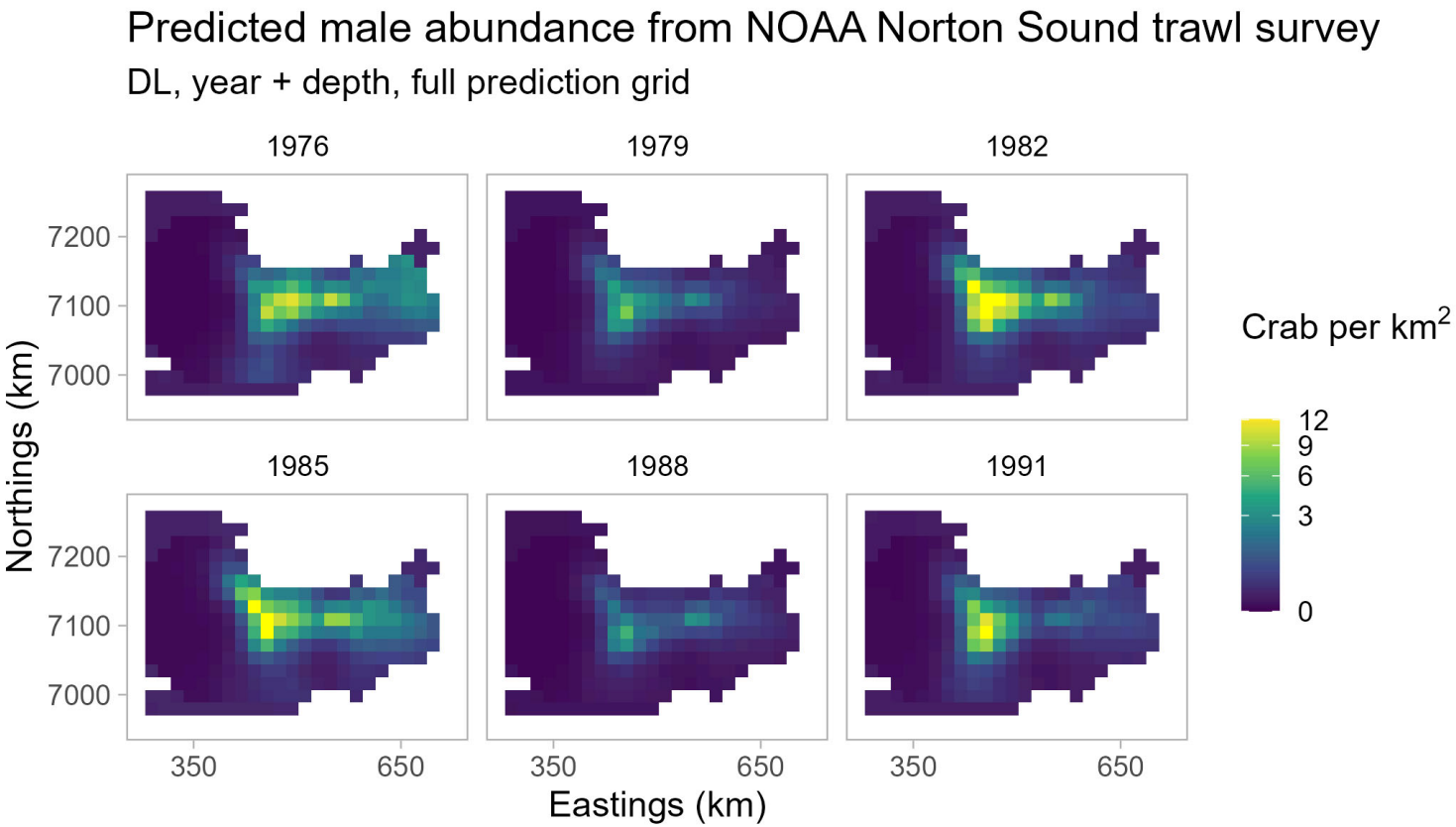

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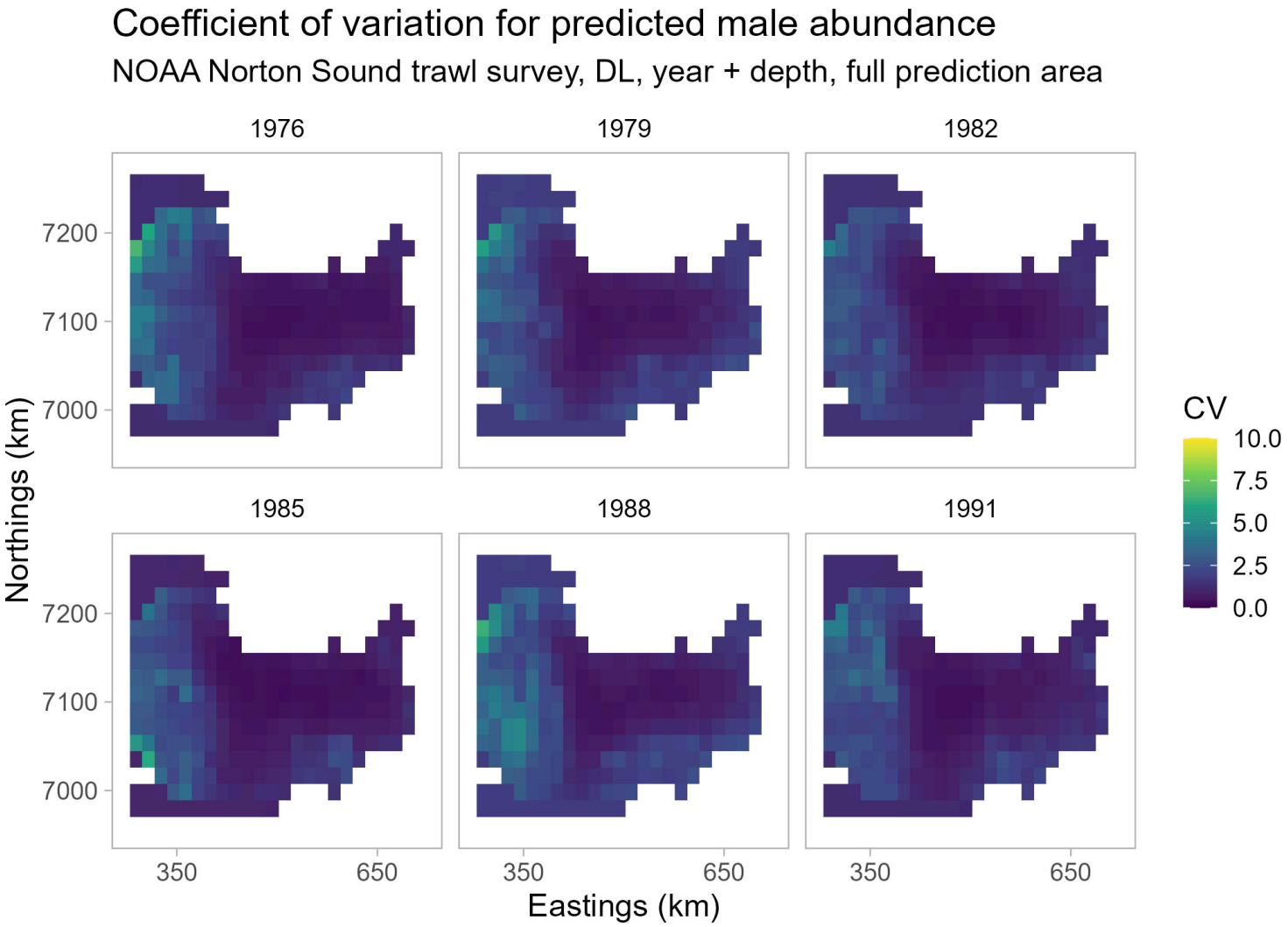

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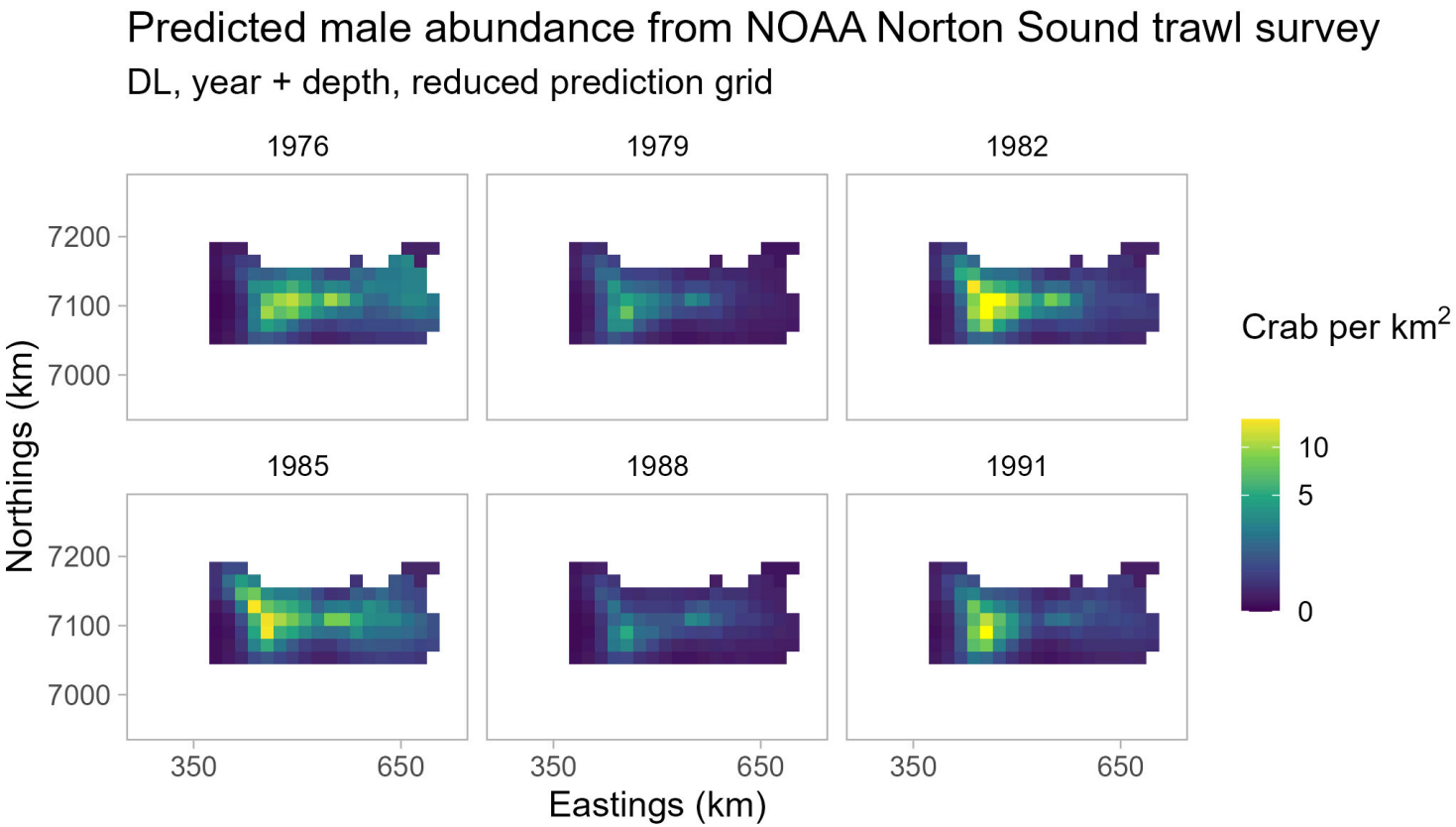

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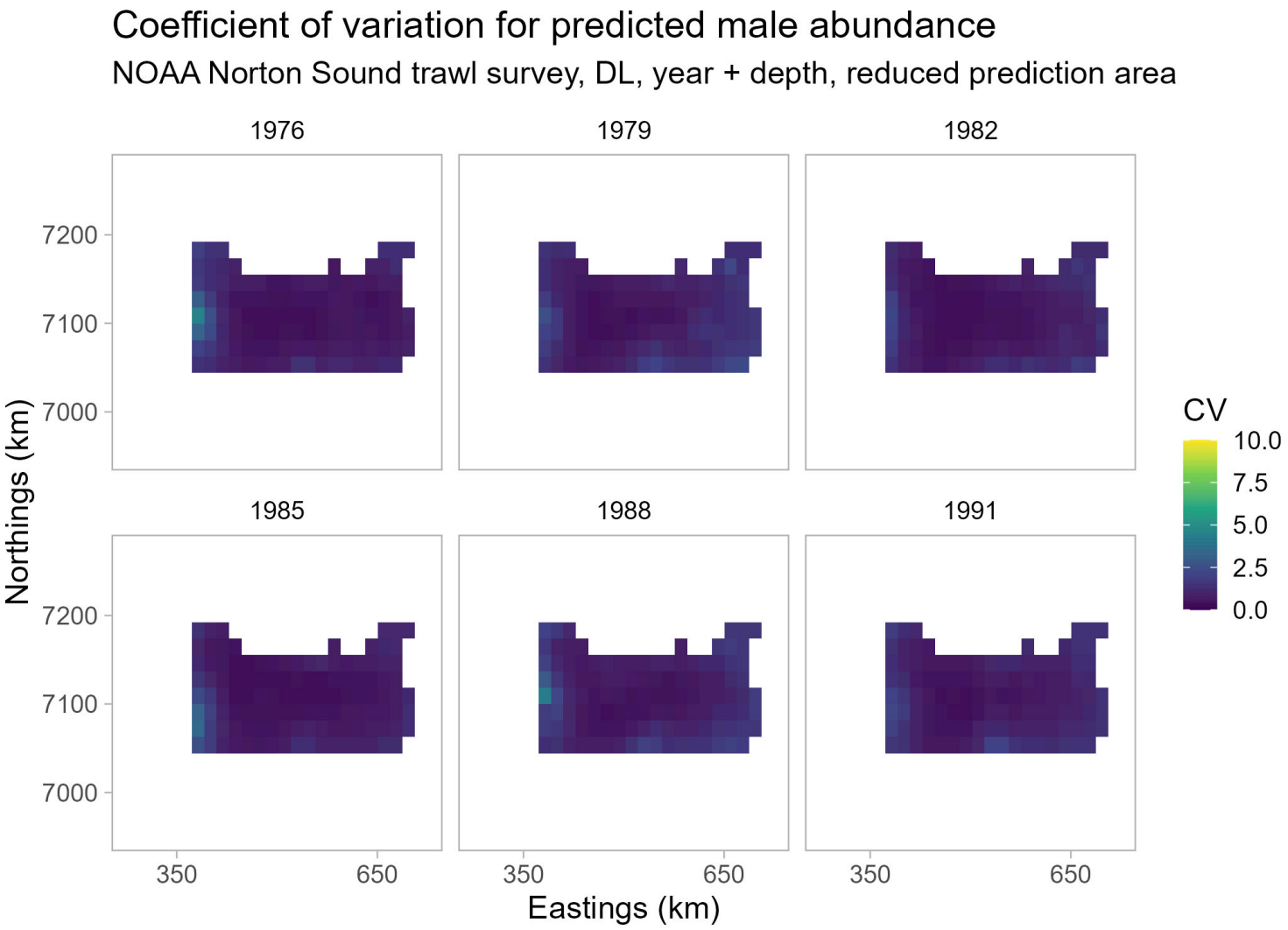

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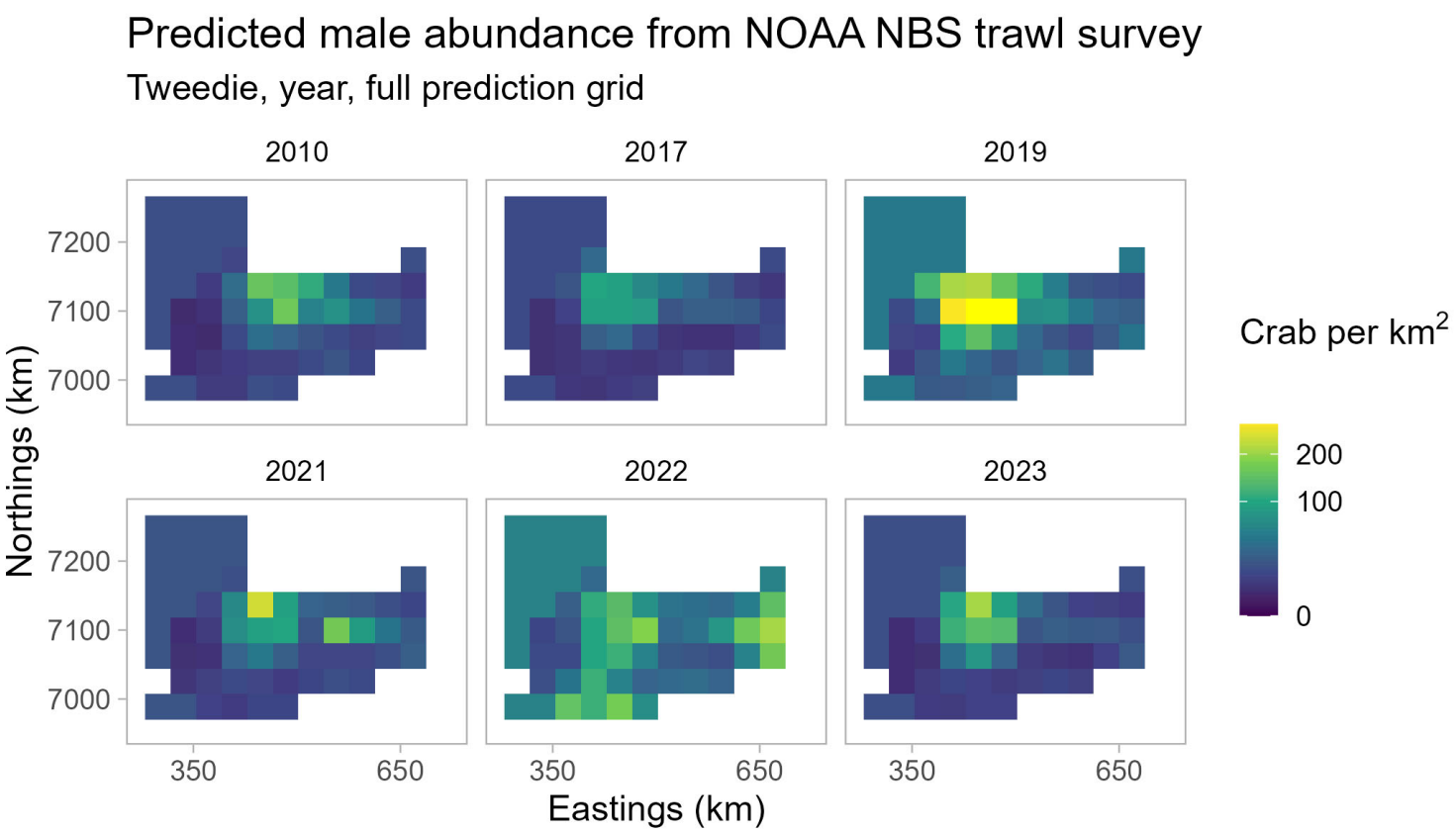

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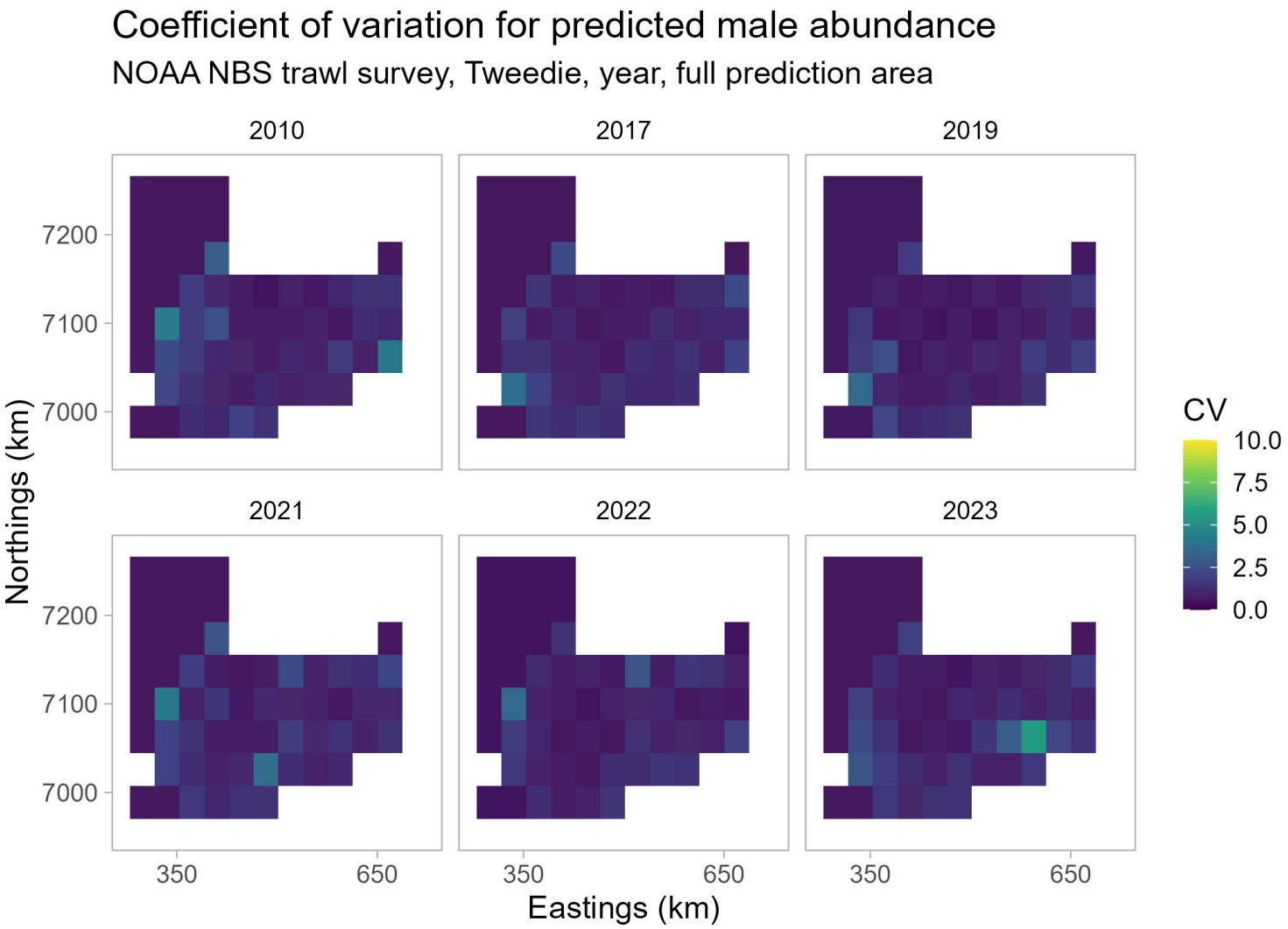

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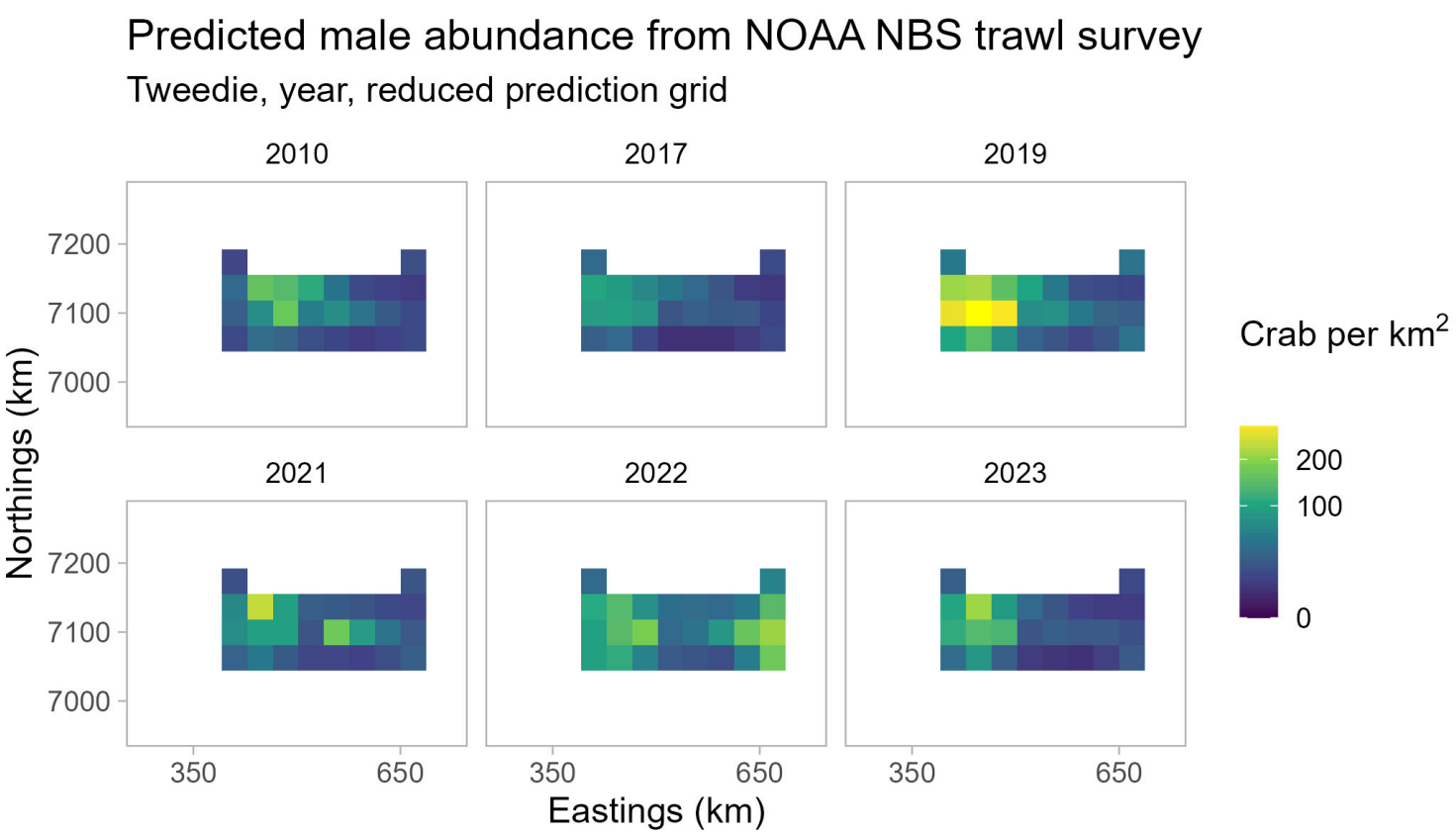

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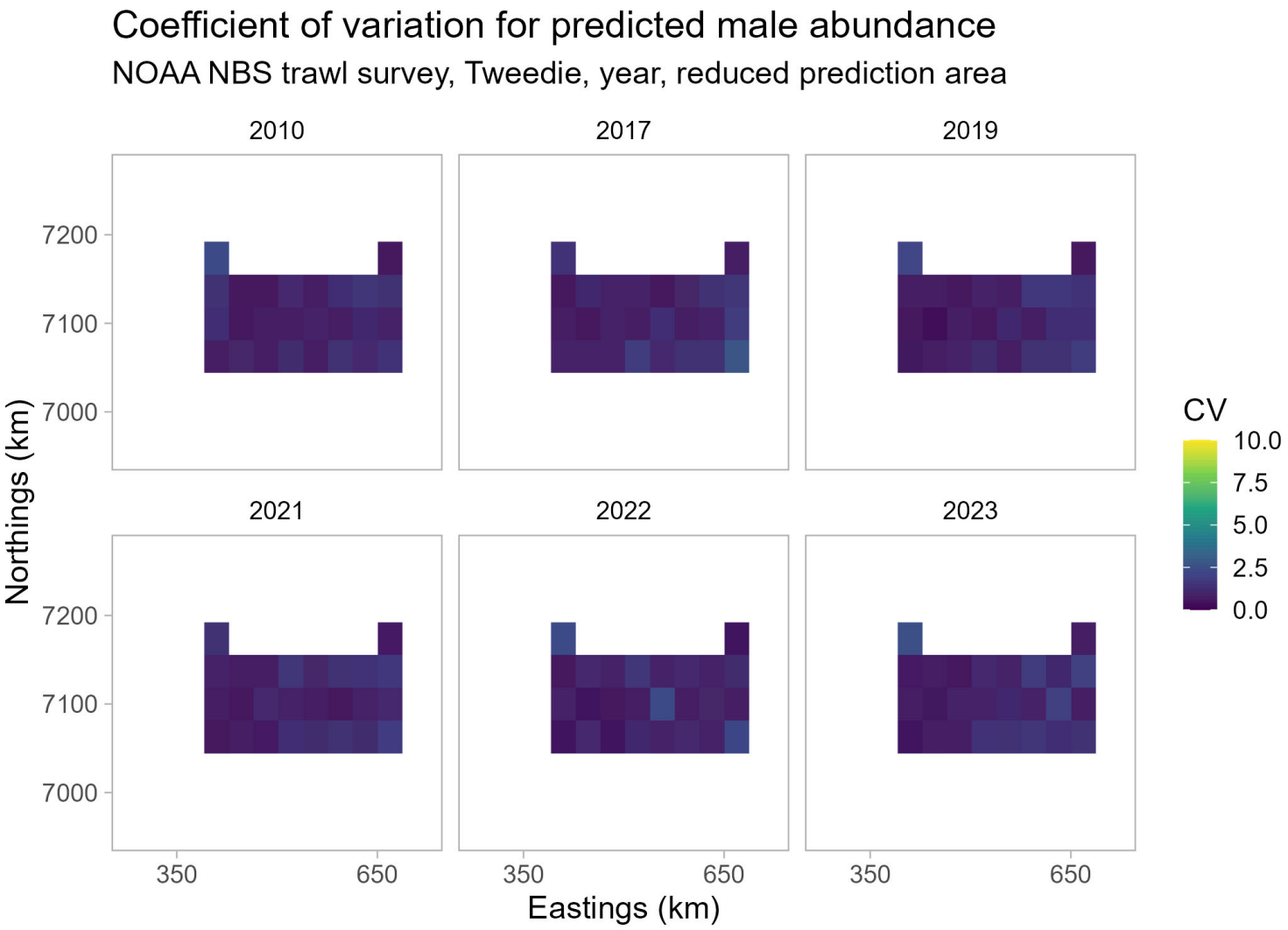

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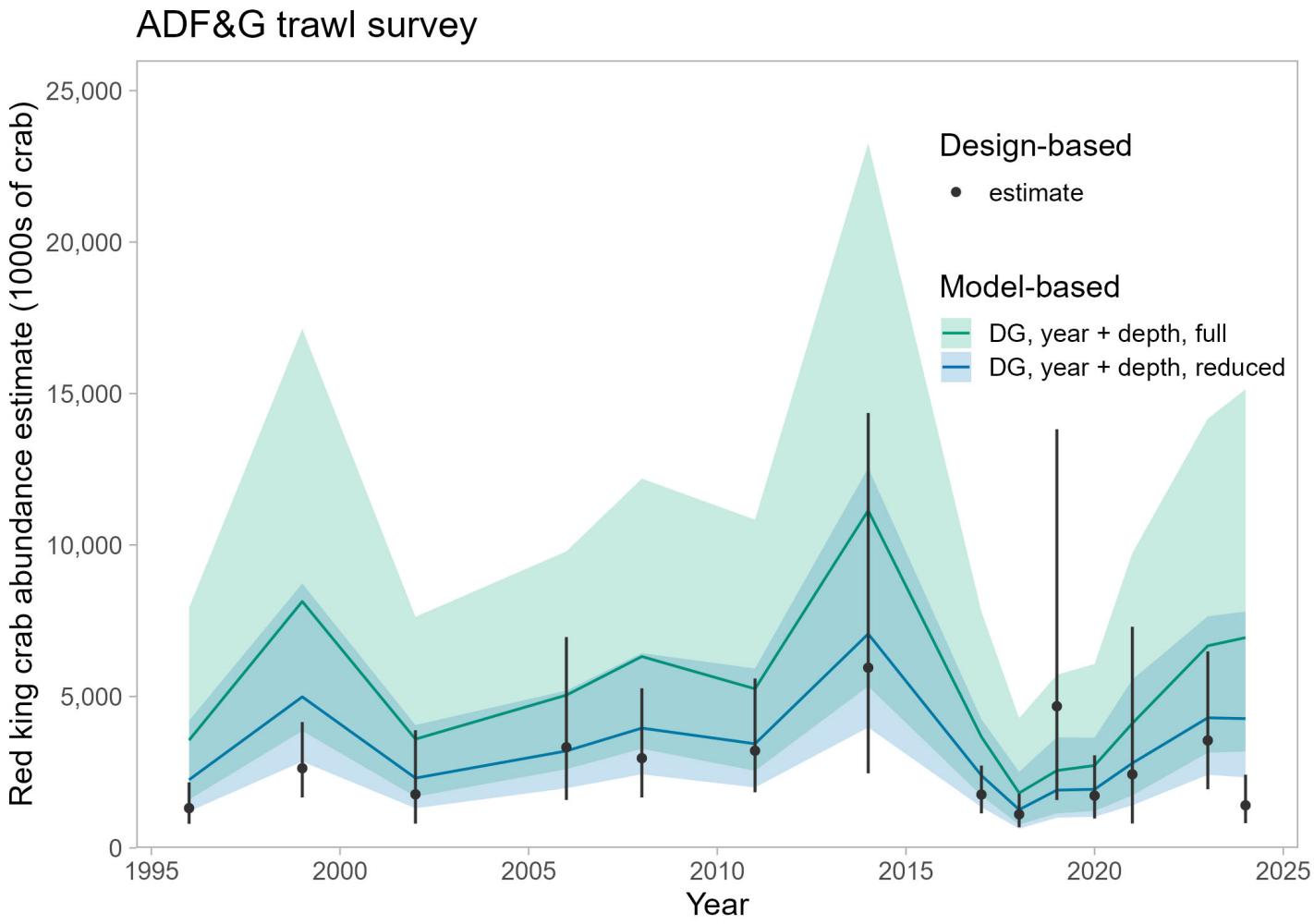
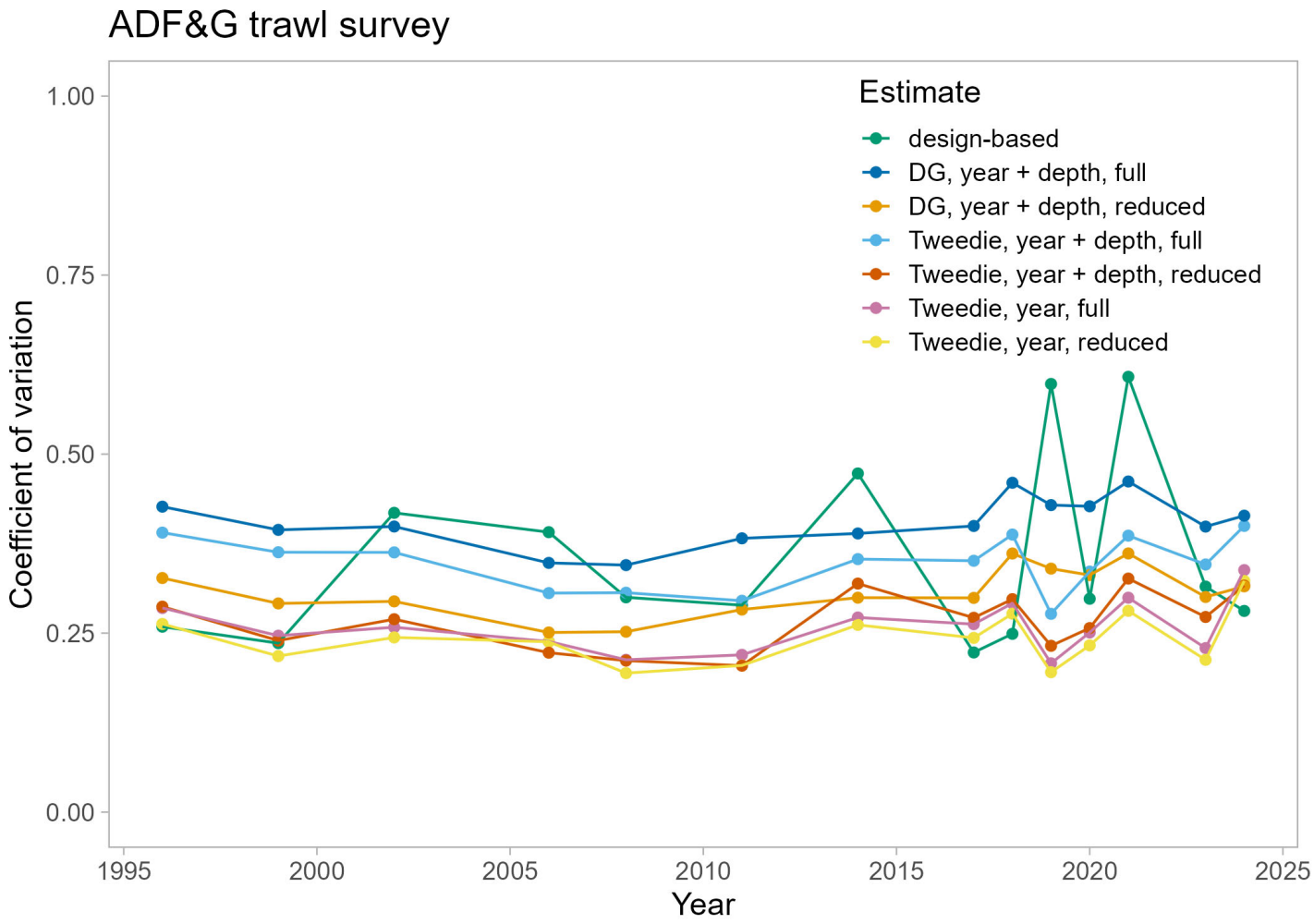
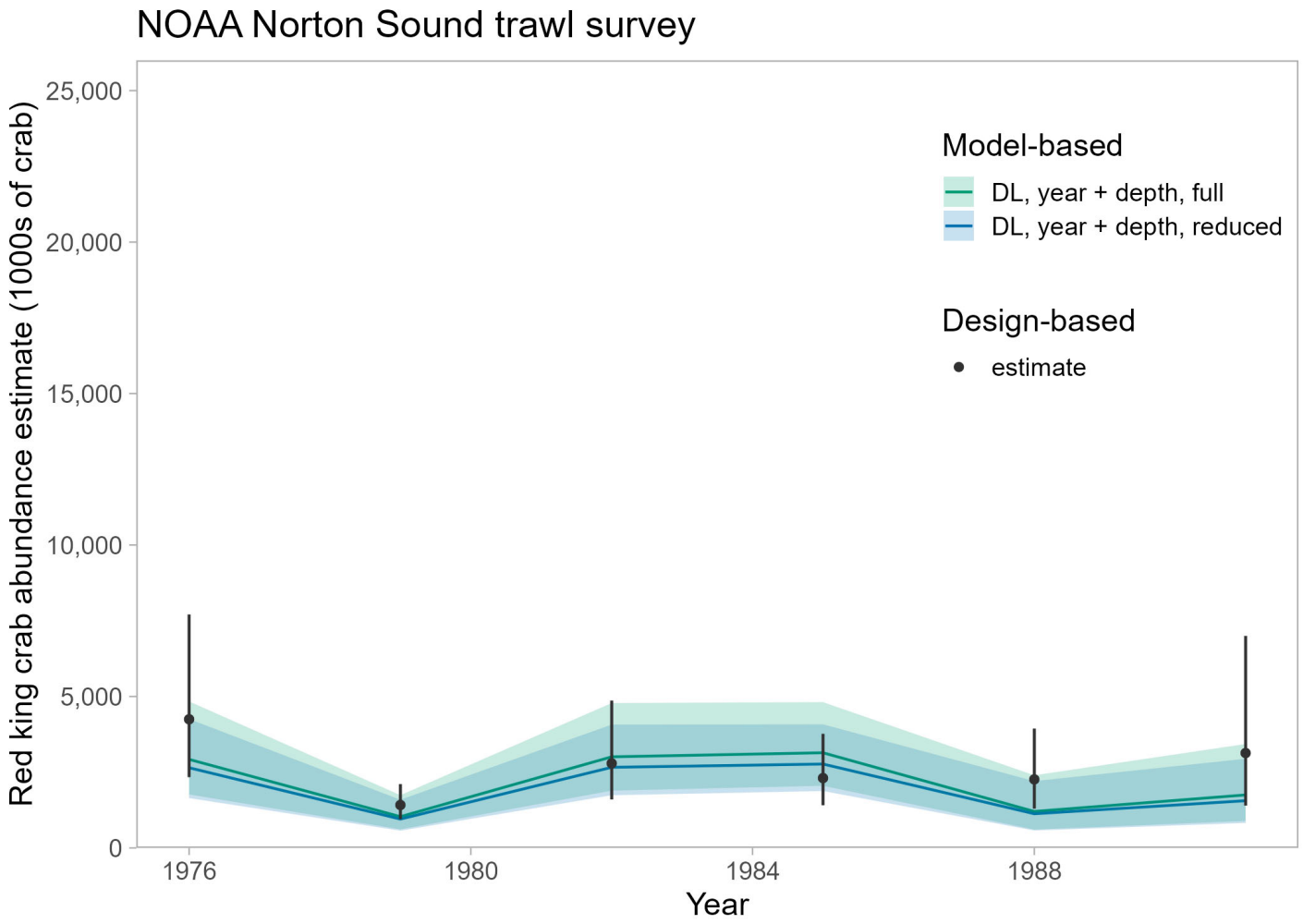
Indices: ADF&G survey



Index CV's: ADF&G survey



Indices: NOAA Norton Sound survey



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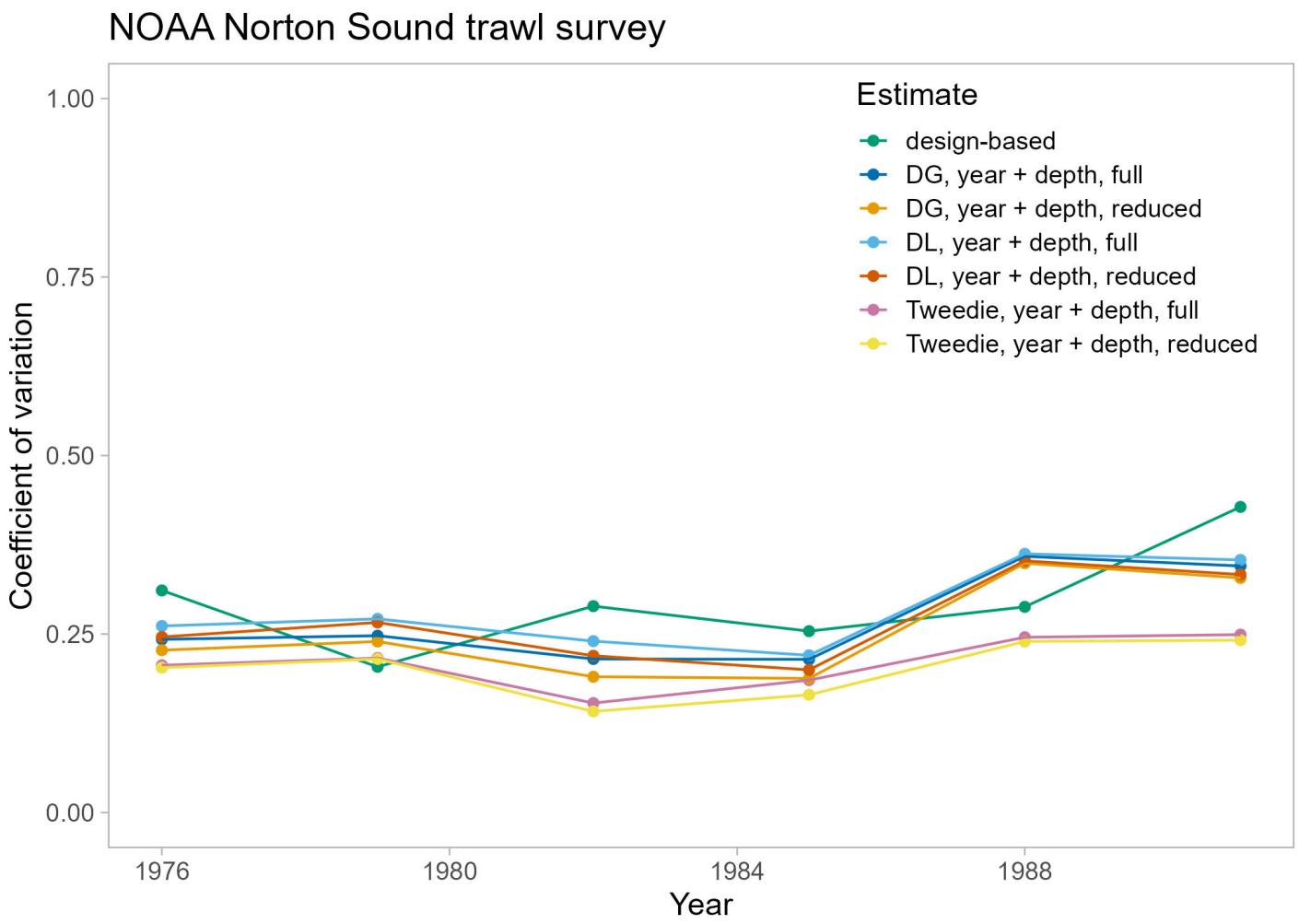

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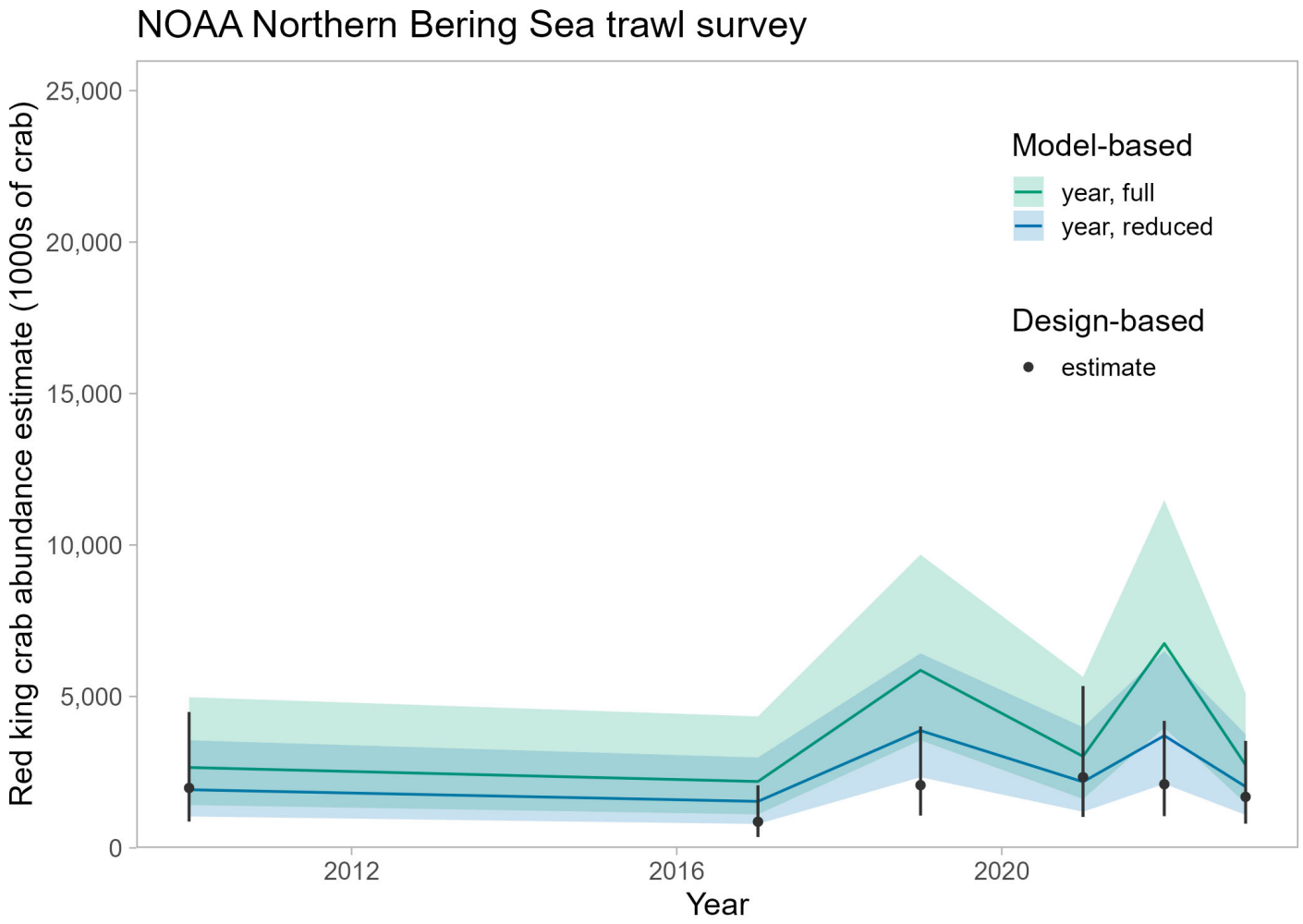

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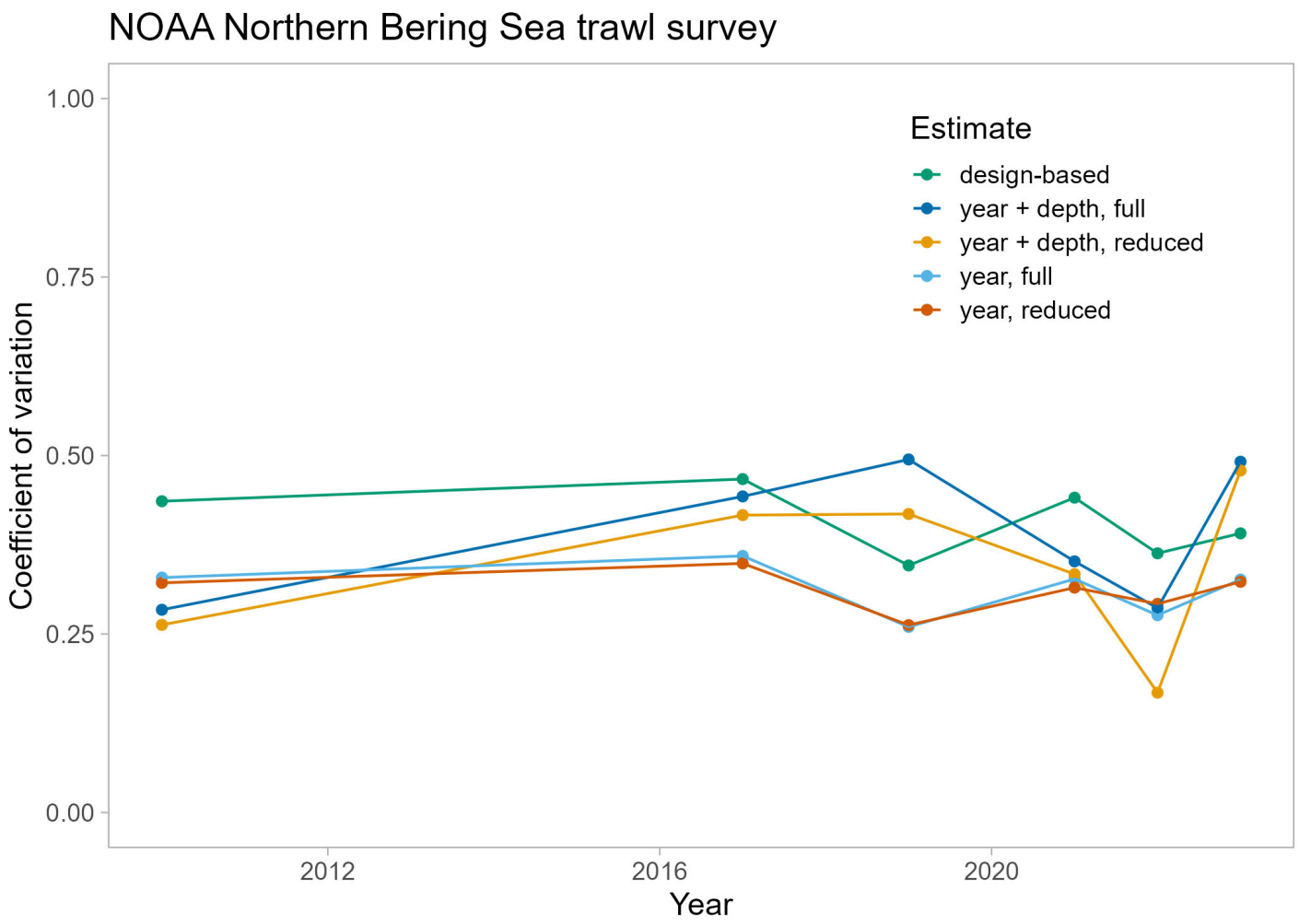

Model- vs. design-based indices

Survey	Model	Effects	Prediction grid	Ratio	TimeOut	Magnitude	CV Ratio
ADF&G	delta-gamma	year + depth	full	1.89	0.50	11.46	1.15
ADF&G	delta-gamma	year + depth	reduced	1.22	0.21	3.64	0.87
NOAA NS	delta-lognormal	year + depth	full	0.81	0.17	-0.47	0.96
NOAA NS	delta-lognormal	year + depth	reduced	0.73	0.33	-0.83	0.91
NOAA NBS	Tweedie	year	full	2.10	0.50	5.58	0.77
NOAA NBS	Tweedie	year	reduced	1.38	0.00	0.00	0.76

Ratio: time series mean of MBI / time series mean of DBI

TimeOut: proportion of years with MBI outside 95% CI of DBI ("outside years")

Magnitude: sum across outside years of magnitude of MBI relative to DBI

CVRatio: time series mean of MBI CV / DBI CV

Model- vs. design-based indices

Takeaways:

- model-based indices are standardized and use consistent prediction areas
- model-based index abundance estimates are higher than design-based for ADF&G and NOAA NBS surveys but lower for NOAA NS survey
- model-based index abundance estimates are higher when predicting over the full than the reduced area
- CV's are relatively similar for model-based and design-based indices, and actually higher for model-based for ADF&G survey index predicting over the full area

Future work and feedback

SSC and CPT concerns:

- consistency of area over which abundance is estimated
- sufficient diagnostics for evaluating spatiotemporal models

Next steps:

- use model-based indices in stock assessment models
- combine survey data to produce a single index of abundance
- develop model-based indices for survey size comps

Feedback: which prediction area to use? (stock identification)

Thanks!

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