2025 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

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1 Executive Summary

1.1 *Stock*

Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus*.

1.2 *Catches*

Retained catches have not occurred since 1998/99. Bycatch has been limited in recent years. Bycatch mortality in the crab (e.g., Tanner crab, snow crab) fisheries that incidentally take PIBKC was 0 t in 2024/25; the average discard mortality over the past five years in these fisheries was 0 t. Most bycatch mortality for PIBKC occurs in the BSAI groundfish fixed gear (pot and hook-and-line) fisheries (5-year average: 0.033 t) and trawl fisheries (5-year average: 0.061 t). In 2024/25, the estimated PIBKC bycatch mortality was 0.029 t in the groundfish fixed gear fisheries and 0 t in the groundfish trawl fisheries. Total fishing mortality in 2024/25 was 0.029 t, while the 5-year average was 0.094 t.

1.3 *Stock biomass*

Based on 5-year running average results from the NMFS EBS Shelf Survey (the time series for PIBKC starts in 1975), estimates of stock biomass were largest in the late 1970s (72,132 t), decreased by an order of magnitude by 2000 (to 3,936 t), and decreased by another order of magnitude by

2015 (577.0 t). Average biomass over the last five years is 277.6 t. Biomass continues to fluctuate at low abundances in all size classes; any short-term trends are questionable because the survey estimates exhibit large uncertainties due to the patchiness of catches. 2023 was the first year in which the NMFS EBS bottom trawl survey failed to catch any mature male crab within the Pribilof Islands stock area.

1.4 *Recruitment*

Recruitment indices (e.g., immature males < 120 mm CL) from the EBS trawl survey are not well understood for PIBKC. Juveniles may not be well-assessed by the survey due to their use of untrawlable habitat, but abundance in the survey has remained consistently low over at least the past 10 years. Immature females have not been caught in the survey since 2018. Two immature males were caught in 2023, but none in 2022.

1.5 *Management performance*

Management quantities related to stock biomass for PIBKC, B and B_{MSY}, are based on mature male biomass-at-mating (MMB-at-mating). The Minimum Stock Size Threshold (MSST) is defined as $\frac{1}{2}B_{MSY}$: if current B is above the MSST, the stock is not overfished. Management quantities related to fishing mortality are based on total catch (retained + discards) mortality. If total catch mortality is less than the overfishing limit (OFL), then overfishing is not occurring. As summarized in Tables A and B, current B (74.99 t) is below the MSST determined in this assessment (2,073 t) and consequently the stock is overfished. Total catch mortality in 2022/23 (0.029 t) was less than the OFL (1.160 t) so overfishing did not occur in 2024/25.

Table A. Management performance (in metric tons).

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2022/23	2,100	180	closed	0	0.25	1.16	0.87
2023/24	2,073	61	closed	0	0.091	1.16	0.87
2024/25	2,073	75	closed	0	0.03	1.16	0.87
2025/26	–	162	closed	–	–	1.16	0.87
2026/27	–	162	closed	–	–	1.16	0.87
2027/28	–	162	closed	–	–	1.16	0.87
2028/29	–	162	closed	–	–	1.16	0.87

Table B. Management performance (in millions of pounds).

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC
2022/23	4.63	0.397	closed	0	0.0006	0.0026	0.0019
2023/24	4.5705	0.1346	closed	0	0.0002	0.0026	0.0019
2024/25	4.5705	0.1653	closed	0	0.000063	0.0026	0.0019
2025/26	–	0.3582	closed	–	–	0.0026	0.0019
2026/27	–	0.3582	closed	–	–	0.0026	0.0019
2027/28	–	0.3582	closed	–	–	0.0026	0.0019
2028/29	–	0.3582	closed	–	–	0.0026	0.0019

Notes: Based on data available to the Crab Plan Team at the time of the assessment for the crab fishing year.

1.6 *Basis for the 2025/26 OFL*

The value of B_{MSY} used to determine stock status is based on Tier 4 considerations. Here, the average estimated MMB-at-mating over the disjoint time period [1980/81-1984/85, 1990/91-1997/98] is used as a proxy for B_{MSY}. The annual MMB-at-mating time series is estimated using a spatiotemporal species distribution model (SDM) fit to haul-level survey CPUE to reduce the inter-annual variability and large uncertainties associated with design-based estimates of MMB at the time of the survey. Subsequently, the model-estimated time series is projected forward to the time at which mating occurs (Feb. 15, by convention) while taking into account intervening natural and fishing mortality. Using this approach, the B_{MSY} proxy was determined to be 4,146 t. The estimated current MMB-at-mating is 74.99 t. The ratio of current MMB-at-mating to B_{MSY} is less than the value of the F_{OFL} Control Rule parameter β (0.25), so directed fishing is not allowed. The MMB-at-mating for 2025/26 is 162.5 t, projected from the SDM estimate of 2025 survey MMB to the time of mating (Feb. 15, 2025) based on natural mortality, assumptions regarding discard mortality in 2025/26, and the F_{OFL} control rule.

As per the rebuilding plan (Foy et al. 2014), the OFL is based on a Tier 5 calculation of average bycatch mortalities between 1999/2000 and 2005/06, which is a time period thought to adequately reflect the conservation needs associated with this stock and to acknowledge existing non-directed catch mortality. Using this approach, the OFL was determined to be 1.160 t for 2025/26.

Table C. Basis for the OFL (in metric tons).

Year	Tier	B_{MSY}	B	B/B_{MSY}	γ	Years to define B_{MSY}	M	P*
2021/22	4c	4,099	180	0.044	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2022/23	4c	4,200	180	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2023/24	4c	4,200	181	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2024/25	4c	4,200	181	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2025/26	4c	4,146	162	0.039	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer

Table D. Basis for the OFL (in millions of pounds).

Year	Tier	B_{MSY}	B	B/B_{MSY}	γ	Years to define B_{MSY}	M	P*
2021/22	4c	9.037	0.398	0.044	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2022/23	4c	9.259	0.398	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2023/24	4c	9.259	0.399	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2024/25	4c	9.259	0.399	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2025/26	4c	9.1411	0.3582	0.039	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer

1.7 *Probability density function for the OFL*

Not applicable for this stock.

1.8 *ABC*

The ABC was calculated using a 25% buffer on the OFL, as in assessments since 2015 (Stockhausen 2015). Thus, the ABC is 0.870 t (= 0.75 x 1.160 t).

1.9 *Rebuilding analyses results summary*

The stock has been declared as overfished since 2002; a rebuilding plan was implemented in 2004 and revised in 2014. The revised rebuilding plan does not have a target rebuild date and NMFS cannot predict when, or if, rebuilding will occur. The 2025/26 stock assessment shows this stock is still overfished. The causes of the continued low abundance and failure to recover are not well-understood, but are thought to be predominantly due to environmental changes that inhibit recruitment. Weems et al. (2025) suggest that larval supply, not changes in benthic habitat, is limiting juvenile recruitment. In May 2024, the Assistant Regional Administrator made the determination that the progress of the PIBKC stock towards rebuilding is "consistent with expectations""[1].

2 Summary of Major Changes

2.1 Management

In 2002, NMFS notified the NPFMC that the PIBKC stock was overfished. A rebuilding plan was implemented in 2003 that included the closure of the stock to directed fishing until the stock was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the Crab FMP and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015 (NPFMC 2023). Amendment 103 closed the Pribilof Islands Habitat Conservation Zone (PIHCZ) to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amended the prior rebuilding plan to incorporate new information on the likely rebuilding timeframe for the stock, taking into

[1] May 6, 2024, NMFS Memorandum: "Review of Progress for the Pribilof Islands Blue King Crab Rebuilding Plan" by Gretchen Harrington, Assistant Regional Administrator for Sustainable Fisheries

account environmental conditions and the status and population biology of the stock. No pot fishing for Pacific cod has occurred within the PIHCZ since 2015/16.

Full assessments for the PIBKC have been conducted on a biennial (odd years) basis since 2019. The 2021 assessment (Stockhausen 2021) was conducted in May, prior to the 2021 NMFS EBS shelf survey and the completion of the crab year (July 1-June 30). The timing of the assessment was subsequently changed to September in 2023 in order to be able to incorporate the current year's EBS shelf survey and bycatch data for the complete crab year (Stockhausen 2023a). This assessment also incorporates the current year's (2025) EBS shelf survey.

2.2 2. Input data

Retained and discard catch time series were updated with data from the crab and groundfish fisheries for 2022/23-2024/25. Abundance and biomass data for PIBKC were added for the 2024-2025 NMFS EBS Shelf Bottom Trawl Surveys.

2.3 3. Assessment methodology

In 2017, PIBKC moved to a triennial schedule for full assessments following stock prioritization (Stockhausen 2017). In 2018, a partial assessment was conducted (Stockhausen 2018) to determine whether overfishing occurred in the previous year. However, the NMFS Alaska Regional Office (AKRO) noted a biennial requirement to review the rebuilding status for PIBKC and that the assessment and rebuilding review should occur on the same schedule. Consequently, the 2019 and 2021 assessments were full assessments (Stockhausen 2019, 2021). The timing for the 2021 full assessment was changed from September to May to try to reduce the Fall workload of the author, the Crab Plan Team, and the Council's Science and Statistical Committee. This change required the use of several estimates for quantities used in the assessment model, including survey MMB in the year of the assessment as well as retained catch and bycatch quantities in the fishery year prior to the assessment. The NMFS EBS Shelf Survey is typically conducted annually in June-August, so biomass estimates from the survey in the year of the assessment were not available for the 2021 assessment, and a value projected by a random walk model used to estimate the survey MMB time series was used as a substitute to calculate MMB-at-mating for the 2021 assessment year. The directed fishery was closed in 2021/22, so there was no retained catch or bycatch associated with it. However, the Tanner crab (*Chionoecetes bairdi*), snow crab (*C. opilio*), and groundfish fisheries were still being prosecuted at the time the 2021 assessment was conducted, necessitating the use of estimates for the bycatch in these fisheries. To avoid these complications, the assessment was moved back to September for the 2023 and subsequent assessments, including this assessment.

The methodology this year is generally similar to that in the 2023 assessment. However, the 2023 assessment used a random walk time series model based on the R software `rema` package to reduce the variance in the time series of design-based estimates of area-integrated mature male biomass from the NMFS EBS shelf survey whereas this assessment uses a spatiotemporal random effects species distribution model based on the `sdmTMB` R package to estimate the time series. This change was motivated by the fact that no mature males caught in the 2023 and 2024 surveys, which introduced observed zero's into the design-based survey MMB time series and proved problematic for the `rema` approach. The Tier 4 approach used in this assessment for status determination is identical to that adopted by the CPT and SSC in 2015 and used in subsequent assessments (Stockhausen 2015, 2016, 2017, 2019, 2021, 2023a).

2.4 4. Assessment results

Overfishing did not occur in 2024/25 because total catch mortality (0.029 t) was less than the OFL (1.160 t). B_{MSY} decreased from the previous assessment (4,196 t) to 4,146 t while the projected MMB-at-mating for 2025/26 decreased from the previous assessment (180.5 t) to 162.5 t. Stock status did not change: the stock remains in Tier 4c. The stock remains overfished and a directed fishery is prohibited in 2025/26. The OFL (based on average catch), the author-recommended ABC buffer, and the ABC are identical to last year's values (1.160 t, 0.25, and 0.870 t, respectively).

3 Responses to SSC and CPT Comments

3.1 Remarks pertinent to this assessment

3.1.1 CPT comments May 2025:

CPT comment

The CPT agreed with the author on both model choice (model "tw-ar") and methodology (sdmTMB) for the final assessment in September, noting that the use of a spatiotemporal model to estimate MMB across space and time is preferable to more arbitrary `rema` approaches for dealing with zero data, and result in more defensible estimates of MMB in 2023 and 2024 given continued declines in PIBKC population estimates.

Author response

The `sdmTMB` R package has been used in this assessment to fit spatiotemporal random effects models to haul-level observations of CPUE for MMB at the time of the survey and calculate area-integrated estimates of survey MMB.

CPT comment

The corner stations should remain in the pre-2024 survey time series for PIBKC.

Author response

These stations have been kept.

CPT comment

Use `crabpack` estimates of survey biomass for 1979.

Author response

Done.

CPT comment

Refer to "Model-based indices" (2025 May CPT agenda item) documents for NSRKC, Tanner crab and snow crab sdmTMB models for suitable diagnostics to report for PIBKC models for September.

Author response

Diagnostics reported for sdmTMB models include predictive skill scores, RMSE, and MAE from k-fold cross-validation, DHARMa residuals statistics, and Moran's I.

CPT comment

…with respect to the sdmTMB analyses, the CPT requests: 1) Accounting for land when creating a spatial grid and mesh; 2) exploring different mesh sizes; 3) including predictive skill scores; and 4) exploring MCMC residuals in addition to `DHARMa` residuals

Author response

1) Model results for evaluation meshes with barriers representing land and the shelf edge were evaluated in addition to those for meshes without barriers. The recommended model uses an evaluation mesh with barriers.
2) Several different techniques and resolutions for constructing evaluation meshes were considered; most proved unsatisfactory but a comparison of results from models fit using meshes constructed using a k-means algorithm with 40, 60, and 80 nodes is provided.

3) mean predictive skill from *k*-fold cross-validation (k=10) is the main basis for selecting the recommended `sdmTMB` model.
4) time constraints did not allow exploration of MCMC residuals in addition to `DHARMa` residuals.

3.1.2 SSC comments June 2025:

SSC Comment

The SSC concurs with the author and CPT recommended application of the `sdmTMB` R package for this Tier 4 assessment.

Author response

See responses to May 2025 CPT comments above.

SSC Comment

The SSC agreed with the author and CPT's recommendations to maintain the corner stations in the surveys pre-2024 for future assessments, as they provide historical data for estimates of abundance/biomass and size compositions.

Author response

Done.

SSC Comment

The SSC concurs with the CPT's and author's recommendation to bring forward the model and approach that uses a Tweedie distribution with a first-order autoregressive spatiotemporal model in `sdmTMB` for final specification in September 2025. The SSC also concurs with all CPT recommendations to improve and provide the appropriate diagnostics for the `sdmTMB` model.

Author response

Done.

SSC Comment

The SSC notes that a historical retrospective is different from a within model retrospective and requests that crab assessments include a plot comparing the model-estimated time series of mature male biomass from the current assessment with the time series from the ten previous assessments (i.e., historical retrospective).

Author response

The requested plot has been provided using assessments from the last 10 *years* (Figure 52). Because PIBKC is assessed on a biennial basis, the plot does not include results from before 2015.

SSC Comment

The SSC recommended that the CPT provide GMACS version updates in each CPT report with information on changes between versions and that authors clearly identify which GMACS versions were used and a brief summary of the effects of version changes on the assessment.

Author response

The PIBKC assessment does not use GMACS.

SSC Comment

The SSC recommends that each crab SAFE chapter include a clear description of the buffers used in harvest specification over the most recent five years, as a basis for comparing the current year's buffer recommendations.

Author response

Noted. A 25% buffer has been used in harvest specifications since 2014 and is also recommended for this year.

3.1.3 CPT comments Setember 2023:

none

3.1.4 SSC comments October 2023:

none

3.1.5 CPT comments May 2023:

CPT comment

The CPT agreed (following the author's recommendation) with the change to use the **rema** R package for the assessment.

Author response

The *rema* R package, which underwent a favorable Center for Independent Experts (CIE) review during 2023, has been used to fit the random walk model to design-based estimates of MMB at the time of the survey.

3.1.6 SSC comments June 2023:

SSC Comment

The SSC concurs with the author and CPT recommended application of the **rema** R package for this Tier 4 assessment.

Author response

See Section 3.1.5.

SSC Comment

The SSC also looks forward to the SAFE section on rebuilding in September as the rebuilding plan nears its second decade.

Author response

The revised (2014) rebuilding plan does not have a target rebuild date and NMFS cannot predict when or if rebuilding will occur (NPFMC 2023). There is no new and unexpected information that would significantly alter the rebuilding expectations. The recent trajectory of the time series of MMB-at-survey time provides no evidence of an increasing trend. Further, survey size compositions provide no evidence for recent recruitment to the stock. The failure of the EBS shelf survey to catch any mature males this year does not raise the level of concern for this stock above what it has been in the recent past; the survey does not target blue king crab and the result is consistent with sampling a population at low (but non-zero) abundance. The causes of the continued low abundance and failure to recover are not well understood, but are thought to be predominantly due to environmental changes that inhibit recruitment. In April 2022, the last time a determination of overfished status was made was made, the Regional Administrator determined that PIBKC was "not making inadequate progress" towards rebuilding.

Sept 2025: In May 2024, the Assistant Regional Administrator made the determination that the progress toward rebuilding was as "expected".

3.1.7 CPT comments September 2022:

None

3.1.8 SSC comments October 2022:

None

3.1.9 CPT comments May 2022:

None

3.1.10 SSC comments June 2022:

None

3.1.11 CPT comments September 2021:

None

3.1.12 SSC comments October 2021:

None

3.1.13 CPT comments May 2021:

CPT Comment

The CPT discussed the SAFE stock specification table with respect to PIBKC being a biennial assessment and whether the assessment should be brought back to a September CPT meeting cycle in order to fully account for any bycatch that occurs through the end of June. The advantages of an assessment review in September are that the most recent survey and bycatch data through the end of the June fishing year would be available, and there would be no need to revise the assessment with the final catches. The disadvantage is that it would add incrementally to the September workload, both for the assessment author and CPT. It was noted that the September workload has been reduced during odd years by shifting the SMBKC assessment to a biennial cycle. Therefore the CPT recommends that future PIBKC assessments (starting in 2023) should be conducted for September meetings.

Author response

As recommended, this assessment was moved to September 2023.

CPT Comment

The CPT recommends exploring VAST for the PIBKC assessment.

Author response

As the CPT itself noted, "using VAST may be problematic when very small numbers of animals are caught at only a handful of stations (as with PIBKC)" and "biomass estimates from VAST may not be reliable, and estimated confidence intervals may be even less so". Consequently, this request was given a low priority (potential VAST applications in the Tanner crab assessment were addressed instead) and has not yet been addressed.

September 2025: `sdmTMB`, a spatiotemporal GLMM for species distribution modeling similar to VAST is used in this (2025) assessment to generate model-based indices of mature male survey biomass.

CPT Comment

The CPT recommends "…exploring smoothing the survey point-estimate CVs (e.g., apply median CV for all years)".

Author response

The random walk model implemented using the *rema* R package incorporates the annual variability in survey point estimates in a statistically-appropriate manner. Consequently, this recommendation has not been addressed.

3.1.14 SSC comments June 2021:

SSC comment (general)

Crab assessments should generally follow the default groundfish practice of projecting the current year's catches if one or more fisheries are incomplete at the time of the assessment.

Author response

Now that the PIBKC assessment is again conducted for September/October, this is no longer an issue for this assessment.

SSC Comment

The SSC supports the CPT recommendation to move the timing of the PIBKC assessment back to September for the CPT.

Author response

As recommended, this assessment was conducted for the September 2023 meeting.

SSC comment

The SSC looks forward to the report on the blue king crab stock structure template in the near future.

Author response

Staff capacity has not permitted progress on this request.

4 Introduction

4.1 Stock

Pribilof Islands blue king crab (PIBKC), *Paralithodes platypus*.

4.2 Distribution

Blue king crab are anomurans in the family Lithodidae, which also includes the red king crab (*Paralithodes camtschaticus*) and golden or brown king crab (*Lithodes aequispinus*) in Alaska. Blue king crab are found in widely-separated populations across the North Pacific (Figure 1). In the western Pacific, blue king crab occur off Hokkaido in Japan and isolated populations have been observed in the Sea of Okhotsk and along the Siberian coast to the Bering Straits. In North America, they are found in the Diomede Islands, Point Hope, outer Kotzebue Sound, King Island, and the outer parts of Norton Sound. In the remainder of the Bering Sea, they are found in the waters off St. Matthew Island and the Pribilof Islands. In more southerly areas, blue king crab are found in the Gulf of Alaska in widely-separated populations that are frequently associated with fjord-like bays (Figure 1). The insular distribution of blue king crab relative to the similar but more broadly distributed red king crab is likely the result of post-glacial-period increases in water temperature that have limited the distribution of this cold-water adapted species (Somerton 1985). Factors that may be directly responsible for limiting the distribution include the physiological requirements for reproduction, competition with the more warm-water adapted red king crab, exclusion by warm-water predators, or habitat requirements for settlement of larvae (Armstrong et al. 1985, 1987; Somerton 1985).

4.3 Stock structure

The stock structure of blue king crab in the North Pacific is largely unknown. Stoutamore (2014) found significant genetic divergence between all sites comparing genetic samples collected from sites in Southeast Alaska, the Pribilof Islands, St. Matthew Island, Little Diomede, Chaunskaya Bay, Shelikhov Gulf, and the western Bering Sea, with Southeast Alaska exhibiting the highest divergence from the other sites. Allele frequencies from the Pribilofs and St. Matthew (and Little Diomede) grouped together more closely than with other sites based on Principal Components Analysis. Temporal changes were significant between samples collected in the Pribilofs and at St. Matthew in the early 1990s and ones collected during 2006-2011, although there was no evidence these changes were due to recent population bottlenecks. Stoutamore (2014) suggested that this apparent genetic drift could be a consequence of the large decreases in abundance at these locations since the early 1980s.

The potential for species interactions between blue king crab and red king crab as a cause for PIBKC shifts in abundance and distribution was addressed in a previous assessment (Foy 2013). Foy (2013) compared the spatial extent of both species in the Pribilof Islands from 1975 to 2009 and found that, in the early 1980's when red king crab first became abundant, blue king crab males and females dominated the stations (numbering between 1 and 7) where the species co-occurred in the Pribilof Islands District. Spatially, the stations with co-occurrence were broadly distributed around the Pribilof Islands. In the 1990's, the red king crab population increased substantially as the blue king crab population decreased. During this time period, the number of stations with co-occurrence remained around a maximum of 8, but they were equally dominated by both blue king crab and red king crab—suggesting a direct overlap in distribution at the scale of a survey station. During this time period, the stations dominated by red king crab were dispersed around the Pribilof Islands. Between 2001 and 2009 the blue king crab population decreased dramatically while the red king crab population fluctuated. The number of stations dominated by blue king crab in 2001-2009 was similar to that for stations dominated by red king crab for both males and females, suggesting continued competition for similar habitat. The only stations dominated by blue king crab in the latter period were to the north and east of St. Paul Island. Although blue king crab protection measures also afford protection for the red king crab in this region, red king crab stocks continue to fluctuate (more so than simply accounted for by the uncertainty in the survey).

During the years when the fishery was active (1973-1989, 1995-1999), PIBKC were managed by the Alaska Department of Fish and Game (ADF&G) under the Bering Sea king crab Registration Area Q Pribilof District ((Bowers et al. 2008); Figure 2). In the Pribilof District, blue king crab occupy the waters adjacent to and northeast of the Pribilof Islands (Armstrong et al. 1987). For assessment purposes, the Pribilof District as shown in Figure 2, with the addition of a 20 nm mile strip to the east of the District (bounded by the dotted red line in Figure 2), is considered to define the stock boundary for PIBKC.

4.4 Life History

Blue king crab are similar in size and appearance, except for color, to the more widespread red king crab, but are typically biennial spawners with lesser fecundity and somewhat larger sized (ca. 1.2 mm) eggs (Somerton and MacIntosh 1983; Jensen et al. 1985; Somerton and MacIntosh 1985; Jensen and Armstrong 1989; Selin and Fedotov 1996; Stevens 2006a). Blue king crab fecundity increases with size, from approximately 100,000 embryos for a 100-110 mm carapace length (CL) female to approximately 200,000 for a female >140-mm CL (Somerton and MacIntosh 1985). Blue king crab have a biennial ovarian cycle with embryos developing over a 12- or 13-month period depending on whether or not the female is primiparous or multiparous, respectively (Stevens 2006a). Armstrong et al. (1985) and Armstrong et al. (1987), however, estimated the embryonic period for Pribilof blue king crab at 11-12 months, regardless of previous reproductive history. Somerton and MacIntosh (1985) estimated embryo development at 14-15 months. It may not be possible for large female blue king crab to support the energy requirements for annual ovary development, growth, and egg extrusion due to limitations imposed by their habitat, such as poor quality or low abundance of food or reduced feeding activity due to cold water (Armstrong et al. 1987; Jensen and Armstrong 1989). Both the large size reached by Pribilof Islands blue king crab and the generally high productivity of the Pribilof area, however, argue against such environmental constraints. Stoutamore (2014) found no genetic evidence to support a hypothesis for two genetically-distinct strains extruding and hatching eggs on alternate years. Development of the fertilized embryos occurs in the egg cases attached to the pleopods beneath the abdomen of the female crab and hatching occurs February through April (Stevens 2006b). After larvae are released, large female Pribilof blue king crab will molt, mate, and extrude their clutches the following year in late March through mid-April (Armstrong et al. 1987). Stoutamore (2014) found strong genetic evidence for a single-paternity mating system.

Female crab require an average of 29 days to release larvae, and release an average of 110,033 larvae (Stevens 2006b). Larvae are pelagic and pass through four zoeal larval stages that last about 10 days each, with length of time being dependent on temperature: the colder the temperature the slower the development and vice versa (Stevens et al. 2008). Stage I zoeae must find food within 60 hours as starvation reduces their ability to capture prey (Paul and Paul 1980) and successfully molt. Zoeae consume phytoplankton, the diatom *Thalassiosira* spp. in particular, and zooplankton. The fifth larval stage is the non-feeding (Stevens et al. 2008) and transitional glaucothoe stage in which the larvae take on the shape of a small benthic crab but retain the ability to swim by using their extended abdomen as a tail. This is the stage at which the larvae search for appropriate settling substrate and, upon finding it, molts to the first juvenile stage and henceforth remains benthic. The larval stage is estimated to last for 2.5 to 4 months and larvae metamorphose and settle during July through early September (Armstrong et al. 1987; Stevens et al. 2008). Weems et al. (2025) suggest that larval supply is the main factor limiting recruitment in the Pribilof Islands.

Blue king crab molt frequently as juveniles, growing a few mm in size with each molt. Unlike red king crab juveniles, blue king crab juveniles are not known to form pods. Female king crab typically reach sexual maturity at approximately five years of age, while males may reach maturity at six years of age (NPFMC 2003). Female size at 50% maturity for Pribilof blue king crab is estimated to be 96-mm CL and size at maturity for males, estimated from chela height relative to carapace length, is estimated to be 108-mm CL (Somerton and MacIntosh 1983). Skip molting occurs with increasing probability for males larger than 100 mm CL (NMFS 2005).

Longevity is unknown for this species due to the absence of hard parts retained through molts with which to age crabs. Estimates of 20 to 30 years in age have been suggested (Blau 1997). Natural mortality for male Pribilof blue king crab has been estimated at 0.34-0.94 with a mean of 0.79 (Otto and Cummiskey 1990) and a range of 0.16 to 0.35 for Pribilof and St. Matthew Island stocks combined (Zheng et al. 1997). An annual natural mortality of 0.2 yr^{-1} for all king crab species was originally adopted in the federal crab fishery management plan for the BSAI areas (Siddeek et al. 2002). This was subsequently revised and a rate of 0.18 yr^{-1} is currently used for PIBKC.

4.5 Management history

The blue king crab stock in the Pribilof District is currently overfished and the directed fishery has been closed since 1999/2000 (Bowers et al. 2011; NPFMC 2014a; Stockhausen 2021). Bottom trawl gear and pot fishing for Pacific cod are currently excluded from the Pribilof Islands Habitat Conservation Zone (PIHCZ, Figure 3) to minimize bycatch of PIBKC in the groundfish fisheries. Fishing for Tanner crab and snow crab is also prohibited within annual area closures implemented by ADF&G that generally incorporate the PIHCZ.

The blue king crab fishery in the Pribilof District began in 1973 with a reported catch of 580 t by eight vessels (Table 1; Figure 4). Landings increased during the 1970s and peaked at a harvest of 5,000 t in the 1980/81 season (Table 1; Figure 4), with an associated increase in effort to 110 vessels (Bowers et al. 2008). The fishery occurred September through January, but usually lasted less than six weeks (Otto and Cummiskey 1990; Bowers et al. 2008). The fishery was male only, and legal size was >165-mm carapace width (NPFMC 1994). State guideline harvest levels (GHL) were 10 percent of the estimated abundance of mature males or 20 percent of the estimated number of legal males (Bowers et al. 2008).

Pribilof Islands blue king crab occasionally occur as bycatch in the eastern Bering Sea snow crab fishery, the western Bering Sea Tanner crab fishery, the Bering Sea hair crab (*Erimacrus isenbeckii*) fishery, and the Pribilof red and blue king crab fisheries. In addition, blue king crab are taken as bycatch in groundfish fisheries by both fixed and trawl gear, primarily those targeting Pacific cod, flathead sole and yellowfin sole (Tables 3-6).

Amendment 21a to the BSAI Groundfish FMP prohibited the use of non-pelagic trawl gear in the Pribilof Islands Habitat Conservation Area (subsequently renamed the Pribilof Islands Habitat Conservation Zone in Amendment 43; Figure 3), which the amendment also established (NPFMC

1994). The amendment went into effect January 20, 1995 and protects the majority of crab habitat in the Pribilof Islands area from the impact of bottom contact trawl gear.

Declines in the PIBKC stock after 1995 resulted in a closure of directed fishing from 1999 to the present. The stock was declared overfished in September 2002, and ADF&G developed a rebuilding harvest strategy as part of the NPFMC comprehensive rebuilding plan for the stock. The rebuilding plan also included the closure of the stock to directed fishing until it was rebuilt. In 2009, NMFS determined that the PIBKC stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. Subsequently, Amendment 43 to the King and Tanner Crab Fishery Management Plan (FMP) and Amendment 103 to the BSAI Groundfish FMP to rebuild the PIBKC stock were adopted by the Council in 2012 and approved by the Secretary of Commerce in early 2015. Amendment 103 closes the Pribilof Islands Habitat Conservation Zone (Figure 3) to pot fishing for Pacific cod to promote bycatch reduction on PIBKC. Amendment 43 amends the prior rebuilding plan to incorporate new information on the likely rebuilding time frame for the stock (> 50 years), considering environmental conditions and the status and population biology of the stock (NPFMC 2014a).

5 Data

5.1 Summary of new information

The time series of retained and discarded catch in the crab fisheries was updated for 2023/24 and 2024/25 from ADF&G data (B. Daly, ADF&G, pers. comm.): there was no retained catch and no observed (and thus no expanded) bycatch in the previous two years. Similarly, the time series of PIBKC bycatch in the groundfish fisheries was updated for the past two crab years using data served by AKFIN from the AKRO's Catch-in-Areas database: total (expanded) bycatch was 0.432 t and total mortality was 0.091 t in 2023/24 and 0.143 t and 0.029 t in 2024/25.

The survey MMB time series and related data for PIBKC were updated with results from the 2024 and 2025 NMFS EBS shelf bottom trawl surveys. Design-based estimates of survey MMB were 0 t in 2024 and 0.203 t in 2025. The corresponding numbers of mature males caught in the survey were 0 and 2.

5.2 Crab fisheries

5.2.1 Retained catch

The directed fishery has been closed since 1999/2000. Historical retained catch data (Table 1, Figure 4) were obtained from Bowers et al. (2011). Retained catch data start in 1973, reaching a maximum of 4,976 t in 1980/1981 before dropping precipitously. In the 1995/96 to 1998/99 seasons, blue king crab and red king crab were fished under the same Guideline Harvest Level (GHL). Total allowable catch (TAC) for the directed fishery has been set at zero since 1999/2000; there will be no retained catch allowed during the 2025/26 crab fishing season.

5.2.2 Bycatch and discard mortality

Estimates for annual bycatch of PIBKC in the crab fisheries is provided by ADF&G for sublegal males (< 138 mm CL), legal males (≥ 138 mm CL), and females based on data collected by onboard observers in the snow crab and Tanner crab fisheries (aggregated across fisheries in Table 2 and Figure 4), although data may be incomplete for some of these fisheries. Prior to 1998/99, observer data exist only for catcher-processor vessels, so discarded catch before this date are not included here. Catch weight was calculated by first determining the mean weight for crabs in the three categories (legal non-retained, sublegal, and female). The average weight for each category was then calculated from length frequency tables, where the carapace length (z, in mm) was converted to weight (w, in g) using the following equation:

$$w = \alpha \cdot z^{\beta} \tag{1}$$

Values for the length-to-weight conversion parameters α and β were applied across the time period (males: $\alpha = 0.000508$, $\beta = 3.106409$; females: $\alpha = 0.02065$, $\beta = 2.27$; Daly et al. (2014)). Average weights ($\overline{W}$) for each category were calculated using the following equation:

$$\overline{W} = \frac{\sum w_z \cdot n_z}{\sum n_z} \tag{2}$$

where w_z is crab weight-at-size z (i.e., carapace length) using Equation 1, and n_z is the number of crabs observed at that size in the category. Finally, estimated total non-retained weights for each crab fishery were the product of average weight ($\overline{W}$), CPUE (numbers/observed pot) based on observer data, and total effort (pot lifts) in each crab fishery.

As in the previous assessment (Stockhausen 2023a), a 20% handling mortality rate was applied to the bycatch estimates to calculate discard mortality on PIBKC in these pot fisheries. In assessments prior to 2017, a handling mortality rate of 50% was applied to bycatch in the pot fisheries. The revised value used here is now consistent with the rates used in other king crab assessments (e.g., Zheng 2016). Estimates of bycatch and discard mortality (Table 2 and Figure 4) reached a maximum of 1.950 t for discard mortality by 1999/00, after which they decline to near zero, with an average over the last five years for discard mortality of only 0 t.

For 2024/25, discard mortality in the crab fisheries was 0 t (Ben Daly, ADF&G, pers. comm. July 31, 2025).

5.3 Bycatch in the groundfish fisheries

Bycatch estimates of PIBKC in the groundfish fisheries are based on groundfish observer data sampling expanded to total catch. Historical estimates beginning in 1996 are available to 2009 from AKFIN using results from the old Catch Accounting System database. This data is limited in its spatial resolution to NMFS statistical areas, which do not conform to the PIBKC stock area. As with previous assessments, estimates of blue king crab bycatch in the groundfish fisheries from NMFS statistical area 513 are assumed to account for bycatch within the PIBKC stock area. More recent estimates, 2008-present, are available from AKFIN using results from the AKRO's Catch-In-Areas database, which provides standardized spatial resolution using ADF&G statistical areas (among other improvements over the older Catch Accounting System). In 2019, the algorithm used by AKFIN to expand observer data was changed from one based on retained groundfish catch weight to the one currently used by AKRO, which is based on total groundfish catch weight. This was applied retroactively to data from calendar year 2017 forward, affecting estimates for crab starting in crab year 2016.

Here, bycatch in the groundfish fisheries during 1991/92-2024/25 is documented. The data were downloaded from AKFIN on July 16, 2025 for the current assessment. In order to apply gear-specific discard mortality rates to the bycatch data, trawl gear types (pelagic and non-pelagic) have been aggregated as "trawl" gear, while hook-and-line (longline) and pot gear have been aggregated as "fixed" gear. As in previous assessments, discard mortality rates of 0.2 and 0.8 have subsequently been applied by gear type (fixed and trawl, respectively) to the estimated bycatch biomass to estimate fishing-related mortality for the discarded crab (Stockhausen 2023a). Since 2009/10, the maximum annual bycatch of PIBKC in the groundfish fisheries was 1.552 t in 2015/16, while the maximum total discard mortality was 0.795 t in 2015/16. In contrast, the average bycatch over the last 5 years is 0.240 t, while the average discard mortality is 0.094 t.

5.3.1 Bycatch by gear type

Annual estimates of bycatch abundance, biomass, and discard mortality of PIBKC in the groundfish fisheries are presented in Table 3 and Figures 5 and 6 by (aggregated) gear type. In general, trawl gear takes more PIBKC than fixed gear, and with higher mortality, although exceptions occur (e.g., 2011/12, 2013/14, and 2014/15). The average mortality on PIBKC taken by trawl gear over the last five years is 0.061 t while that taken by fixed gear is 0.033 t.

5.3.2 Bycatch by target type

Annual estimates of bycatch abundance, biomass, and discard mortality of PIBKC in the groundfish fisheries are presented by groundfish target type in Tables 4-6 and Figure 7. Groundfish targets with less than 10 kg bycatch over the 2009/10-2024/25 period have been dropped. PIBKC is primarily taken as bycatch in fisheries targeting flathead sole, yellowfin sole, northern rock sole, and Pacific cod. Although the Pacific cod fishery accounted for the highest bycatch of PIBKC (in 2015) across the time series, it generally ranks below the other fisheries as a source of mortality because the bycatch occurs primarily with fixed gear.

5.3.3 Spatial patterns of bycatch

Spatial patterns of PIBKC bycatch, by ADF&G stat area, in the groundfish fisheries are illustrated by gear type in Figures 8 and 9. Bycatch taken with trawl gear tends to be concentrated along and to the northeast of the eastern boundary of the Habitat Conservation Zone (non-pelagic trawl gear is excluded from the Zone), although 2012 was an exception in which bycatch was concentrated along the western edge of the Zone. In contrast, bycatch taken by fixed gear is typically dispersed along the shelf edge, although it was concentrated within and near the Habitat Conservation Zone (Figure 3) in 2015/16.

5.4 Catch-at-length

No catch-at-length data is used in the assessment.

5.5 Survey data

5.6 NMFS EBS bottom trawl shelf survey

Time series of annual estimates of area-swept abundance and biomass, as well as size composition data, are available for PIBKC from the summer NMFS EBS Shelf Bottom Trawl Survey based on the stock area first defined in the 2013 assessment (Foy 2013), which includes the Pribilof District and a 20 nm strip adjacent to the eastern edge of the District (Figure 2). The adjacent area was added as a result of the 2015 rebuilding plan and the concern that crab outside the Pribilof District were not being accounted for in the assessment. The survey has been conducted annually since 1975, with the exception of 2020. In 2020, the survey was not conducted due to issues associated with the global COVID-19 pandemic.

The standardized EBS bottom trawl survey is based on a systematic design with a fixed sampling station at the center of each 37.04 × 37.04 km (20 × 20 nautical mile) grid square (Lauth and Nichol 2013). In the area surrounding the Pribilof Islands, high-density "corner stations" were sampled from 1982-2023 to better assess local blue king crab concentrations, but these were dropped in 2024 as part of efforts to improve overall survey efficiency (Figure 10). Since 1982, the survey has used standard 83-112 Eastern otter trawls, which have 25.3-m (83 ft) headropes and 34.1-m (112 ft) footropes, to sample crab and groundfish species at the stations within the Pribilof District, augmented by a column of 9 stations to the east of the District (indicated by the dashed red line in Figure 2) to better encompass the stock limits. The standard tow is nominally 30 minutes on bottom at a tow speed of 3 knots (~1.5 nmi distance), but net mensuration gear is used to more accurately assess time and distance "on bottom" as well as net width to provide a precise estimate of area swept. The net mensuration gear also allows the collection of depth and temperature data. Details of the NMFS bottom trawl protocols established by the National Oceanic and Atmospheric Administration can be found in (Stauffer 2004).

For each tow, all crab were removed from the catch, sorted by species and sex, and a total catch weight was obtained for each species (e.g., Zacher et al. 2023). All blue king crab were sampled for biological characteristics, including sex, carapace length (to 1 mm prior to 2016, to 0.1 mm since), weight, shell condition, and egg color, egg condition, and clutch size for females. Male crab were characterized as immature, mature, sublegal, and legal based on the size categories in Table 7. Females were characterized as immature or mature based on abdominal flap morphology and egg presence (Zacher et al. 2023).

Biomass estimates were calculated using weight-size relationships developed by the AFSC's Kodiak Laboratory (the same as those applied to fishery data: Equation 1; Zacher et al. (2023)) applied to individual male and female crab. Individual crab weights were calculated and summed within the legal male, sublegal male, mature, and immature size categories for each sex caught at a station. Total biomass was estimated by averaging crab density (biomass /area swept) from all stations within the area-augmented Pribilof District and multiplying by the total area (Zacher et al. 2023).

Forty-five stations were included in survey strata for PIBKC in 1975, increasing to 86 by 1983 and remaining essentially constant until 2024, at which point the number of stations decreased to 70 when the "high density" stations were dropped (Tables 8 and 9). In the early 1980s, males were found at up to 38 of these stations and females were found at up to 24. This decreased in the 1990s when males occurred in a maximum of 22 stations, with females occurring at a maximum of 15 stations. Since 2010, the maximum number of stations at which males were caught is 9, with a median of 5, while females were caught at a maximum of 8 stations, with a median of 4. In similar fashion, the number of males caught declined from a maximum of 858 in 1975 to a since-2010 maximum of 22; for females, the corresponding numbers are 343 (in 1981) and 24. In most years, more mature crab were caught than immature, although there were exceptions (e.g., 1989 for both sexes). In 2024, no blue king crab were caught in any category. In 2025, no immature/sublegal males or immature females were caught. A single mature/legal male was caught at each of two stations in 2025 while three mature females were caught at a single station (Tables 8 and 9).

Annual survey abundance and biomass for PIBKC have declined precipitously over the course of the 45 year time series (Tables 10-15 and Figures 11-22). On decadal scales, mean survey abundance and biomass have declined for males from 12.703 million crab and 28.41 thousand t in the 1970s to 0.224 million crab and 0.402 thousand t in the 2010s. Similarly, mean survey abundance and biomass have declined for females from 4.332 million crab and 3.949 thousand t in the 1970s to 0.128 million crab and 0.115 thousand t in the 2010s. Dampened oscillations in survey abundance and biomass have occurred on roughly decadal scales for this stock, with maxima exhibited at the start of the time series for males, followed by a decline to low values in the mid-to-late 1980s, an increase to a relative maximum in the early 1990s, followed by a decline to consistent low values since 1999 (a "blip" with large confidence intervals in 2005 was the exception). Females show a similar pattern, but lagged perhaps 5 years or so (without a "blip" in 2005). In 2019, apparent increases observed in mature and legal male biomass estimates relative to 2018 were attributed primarily to an abbreviated, but "still valid," tow that may have had the effect of artificially increasing the CPUE calculated for the affected station (Zacher et al. 2020).

One feature that characterizes survey-based estimates of abundance and biomass for PIBKC is the large uncertainty (cv on the order of 0.5-1) associated with the estimates, which complicates the interpretation of sometimes large interannual swings in estimates of abundance (Tables 12 and 13, Figures 11-16) and biomass (Tables 14 and 15, Figures 17-22). Estimated total abundance of male PIBKC from the NMFS EBS bottom trawl survey declined from ~24 million crab in 1975, the first year of the "standardized" survey, to ~150,000 in 2016 (the lowest estimated abundance since 2004, which was the minimum for the time series. Following a general decline to a low-point in 1985 (~500,000 males), abundance increased by a factor of 10 in the early 1990s, then generally declined (with small-amplitude oscillations superimposed) to the present. Estimated female abundance generally followed a similar trend, spiking at 180 million crab in 1980, from ~13 million crab in 1975 and only ~1 million in 1979, then returned to more typical levels in 1981 (~6 million crab). More recently, abundance has fluctuated around 200,000 females. Estimated biomass for both males and females has followed trends similar to those in abundance.

Size frequencies across the entire time series are shown by sex in Figures 23-25. Based on patterns for crab > 50 mm CL, a single recruitment event starting in 1988 is evident in Figure 24, with a second possible event starting in 2005. However, these plots provide little evidence of recent recruitment.

The small numbers of crab caught in recent surveys make it difficult to draw firm conclusions regarding spatial patterns (Figures 26-29). Examining decadaly-averaged patterns, however, there appears to have been a fairly strong contraction in range from extending beyond the PIHCZ in the 1980s to contained within the PIHCZ currently. The current spatial pattern of PIBKC abundance is centered fairly compactly within the Pribilof District to the east of St. Paul Island and north of St. George Island, within a 60 nm radius of St. Paul.

6 Analytic Approach

6.1 History of modeling approaches

A catch survey analysis was used to assess the stock in the past (Zheng et al. 1997), but it is no longer in use. In October 2013, the SSC concurred with the CPT that the PIBKC stock falls under Tier 4 for status determination (SSC 2013). Stock status is determined by comparing current B to the Minimum Stock Size Threshold (MSST), where B is current MMB at the time of mating (by convention, MMB on Feb 15) and the MSST is $\frac{1}{2}B_{MSY}$. For a Tier 4 stock, it is not possible to determine B_{MSY} and MSST directly. Instead, time-averaged MMB-at-mating is used as a proxy for B_{MSY}, where the averaging is over a time period assumed to be representative of the stock being fished at an average rate near F_{MSY} such that the stock is fluctuating around B_{MSY}. However, MMB-at-mating is not directly observed. Instead, estimates of MMB at the time of the NMFS EBS Shelf Survey are combined with estimates of natural mortality (M), retained catch mortality (RM), and discard catch mortality of crab taken as bycatch in the directed fishery and other fisheries (DM). The current modeling approach uses M for king crab (0.18), and annual estimates of RM and DM to project design-based estimates of MMB at the time of the survey (July 1, by convention) forward to the time of mating.

The sampling-related uncertainty associated with annual design-based estimates of MMB from the survey is extremely large for PIBKC; thus, different approaches have been used to provide a "smoothed" version of MMB at the time of the survey from which to project forward to estimate MMB-at-mating. In the 2013 and 2014 assessments (Foy 2013; Stockhausen 2014), inverse-variance (IV) averaging was used to smooth the annual survey biomass estimates. In the 2015 assessment (Stockhausen 2015), an AD Model Builder (Fournier et al. 2016) state space/random effects random walk (SS/RE RW) model was developed to estimate annual survey MMB to use in estimating B_{MSY}. One advantage of the SS/RE RW model over the IV approach was that it provided an estimate of process error in the MMB time series. Other advantages included handling missing data and providing a method to project uncertainty. An updated version of the SS/RE RW model utilizing the `rema` R package (R Core Team 2022; Sullivan 2022) used in Tier 5 groundfish assessments was reviewed and endorsed by the CPT and SSC during their May and June, 2023 meetings CPT (2023). The 2023 assessment used the `rema` implementation of the SS/RE RW (Stockhausen 2023a). In 2023 and 2024, the survey failed to catch any mature male PIBKC, resulting in zeros in the design-based estimates of survey MMB for those years. While the `rema` model could deal with years in which the survey was not conducted (i.e., "missing data") in a statistically sound manner, it's treatment of observed zeros in the design-based time series was strictly ad hoc. For the 2023 assessment, the observed 2023 value of zero survey MMB was treated as an "NA", or "missing data", as if the 2023 survey had not been conducted. This became more problematic when the 2024 survey also failed to catch any mature male PIBKC as well. At its May 2025 meeting (CPT 2025), the CPT reviewed several suggestions by the author (Stockhausen 2025b) on alternative approaches to deal with the observed zeros and recommended adopting a spatiotemporal modeling approach using the `sdmTMB` R package (Anderson et al. 2024) to fit a one-step autoregressive (AR1) spatiotemporal model to survey CPUE data and subsequently calculate a time series of survey MMB. The SSC concurred with the CPT's recommendation (SSC 2025) and eighteen models of the type recommended were evaluated by the author (Stockhausen 2025a). Of the models evaluated, the author selected the one with the best predictive skill based on k-fold cross-validation, "ar1S_nullT_logDepth_km080b", to provide the required survey MMB time series.

Since 2017, PIBKC assessments have been conducted on an odd-year biennial schedule. The assessment timing was moved from September to May prior to the 2021 assessment, which required that several data inputs to the model (assessment year MMB at the time of the survey and retained catch and bycatch values from the crab fishery year prior to the assessment year) be estimated in some fashion. This proved to be unsatisfactory, resulting in the assessment timing moved back to September for the 2023 and subsequent assessments, with the result that this assessment uses complete 2024/25 catch and 2025 survey data without any extrapolation.

6.2 Model Description

6.2.1 MMB at the time of the survey

`rema` SS/RE RW time series modeling approach

As noted above, a SS/RE RW time series modeling approach based on the `rema` R package was used to estimate survey MMB in the 2023 assessment. To apply this method, survey MMB in year y, MMB^s_y, is calculated from haul-level survey data by first calculating haul-level MMB, $MMB^s_{y,h}$, using:

$$MMB^s_{y,h} = \sum_z w_z \cdot P_z \cdot n^s_{y,h,z} \tag{3}$$

where w_z is male weight at size z (mm CL), P_z is the probability of maturity at size z, and $n^s_{y,h,z}$ is the number of males caught (expanded for sub-sampling) at size z in survey haul h in year y. For PIBKC, P_z is a knife-edge function, with all males larger than 119 mm CL regarded as mature (Table 7). Haul-level $MMB^s_{y,h}$ is then expanded to survey-level MMB^s_y using standard design-based area-swept calculations (Wakabayashi et al. 1985).

The SS/RE RW model is a statistical approach that models annual log-scale changes in "true" survey MMB as a random walk process using

$$p(< ln(MMB^s_y) > | < ln(MMB^s_{y-1}) >) \sim N(0, \phi^2) \tag{4}$$

as the state equation, where $< ln(MMB^s_y) >$ is the estimated "true" ln-scale survey MMB in year y, $p(x|\theta)$ denotes the probability of x conditional on θ, $N(\mu, v)$ indicates the normal distribution with mean μ and variance v, and ϕ^2 represents the estimated (ln-scale) process error variance. The associated observation equation is

$$ln(MMB^s_y) =< ln(MMB^s_y) > +\eta_y, \text{ where } \eta_y \sim N(0, {\sigma^s_y}^2) \tag{5}$$

where MMB_y^s is the design-based ("observed") survey MMB in year y, η_y represents normally-distributed ln-scale observation error, and ${\sigma_y^s}^2$ is the ln-scale design-based survey MMB variance in year y. The MMB_y^s's and σ_y^s's are observed quantities, while the $< ln(MMB_s) >$'s are estimated parameters regarded as random effects in the likelihood function. The process error variance ϕ^2 is parameterized on the ln-scale using $\phi^2 = exp(2 \cdot \lambda)$, where λ is an estimated fixed effect parameter.

Parameter estimates are obtained by minimizing the joint negative log-likelihood objective function

$$\Lambda = \sum_y \left[ln(2\pi\phi) + \left(\frac{< ln(MMB_y^s) > - < ln(MMB_{y-1}^s) >}{\phi} \right)^2 \right] + \sum_y \left(\frac{ln(MMB_y^s) - < ln(MMB_y^s) >}{\sigma_y^s} \right)^2 \tag{6}$$

and integrating out the random effects using the Laplace approximation.

One drawback associated with the SS/RE RW model described here is that the observed survey MMB is fit on a natural log scale, which cannot accommodate zeros as observations (the natural log of zero is negative infinity). This was not an issue for the PIBKC assessment prior to 2023 but, became an issue in the 2023 assessment because the design-based estimate of survey MMB for 2023 was zero. Following the Groundfish Plan Team's currently accepted method for dealing with zeros in a time series, the zero was treated as a "NA" (i.e., as missing data rather than as an observed value), hence this approach is subsequently referred to as "0's as NAs".

`sdmTMB`

`sdmTMB` (Anderson et al. 2024) is an R package that fits spatial and spatiotemporal Generalized Linear Mixed Effects Models (GLMMs)) using Template Model Builder (TMB), R-INLA, and Gaussian Markov random fields. One common application of this framework is to create species distribution models (SDMs) from species abundance data collected across space and (possibly) through time, although its principal advantage here is that it can also estimate stock-level time series by integrating estimated spatially-explicit patterns of abundance or biomass across space. Where the `rema` models fit survey-level biomass, the `sdmTMB` models fit haul-level survey CPUE. A simple way to think about an `sdmTMB` model is that it provides a way to interpolate survey observations across space and time, taking into account both population variability across space and time as well as variability inherent to the sampling process itself. While several preliminary `sdmTMB` model configurations involving different statistical assumptions were presented to the CPT in May, the CPT subsequently recommended (which the SSC supported) to proceed with models based on a Tweedie distribution, with spatiotemporal random effects having an AR1 (one-step autoregressive) temporal error structure. The Tweedie distribution (Tweedie 1984) is a compound Poisson-gamma distribution that allows observed absences (zeros) in the data, incorporating a single linear predictor (rather than two in the case of two-stage models like the delta-gamma) while estimating a parameter that reflects the degree of mixing between the underlying Poisson and gamma distributions. (Thorson et al. 2021) recommend using the Tweedie distribution for spatiotemporal models by default, particularly when it is not possible to compare the scale of model-derived indices with those from design-based estimators (although comparison is possible in this case). Predictive likelihood scores obtained using k-fold cross-validation were used to rank 18 `sdmTMB` spatiotemporal model configurations based on a Tweedie distribution with log-link to the haul-level survey CPUE for MMB from 1975-2024 (Stockhausen 2025a); only the model ranked as "best" was used here to fit the 1975-2025 dataset.

Briefly, the models considered can be expressed as

$$\mathbb{E}[o_{s,t}] = \mu_{s,t},$$
$$\mu_{s,t} = f^{-1}\left(\alpha \cdot s[ln(d_{s,t})] + \beta \cdot \gamma_t + \delta \cdot \omega_s + \epsilon_{s,t}\right)$$

where $o_{s,t}$ represents the observed mature male survey CPUE at position s in year t; $\mathbb{E}[\cdot]$ is the expectation operator; $\mu_{s,t}$ is the mean at s,t; f represents the link function (the natural log in all cases here); α, β, and δ are 1 or 0 to turn on/off, respectively, a smooth function of depth ($s[ln(d_{s,t})]$), temporally-varying random intercepts (γ_t), or spatially-varying random effects (ω_s). $\epsilon_{s,t}$ represents the spatiotemporal random effects terms included in all the models.

Spatiotemporal random effects were included in all the models with an AR1 temporal covariance structure such that

$$\delta_{t=1} \sim \text{MVNormal}(0, \Sigma_\epsilon),$$
$$\delta_{t>1} = \rho\delta_{t-1} + \sqrt{1-\rho^2}\epsilon_t,\ \epsilon_t \sim \text{MVNormal}\left(0, \Sigma_\epsilon\right)$$

where Σ_ϵ is a spatial covariance matrix, ρ is the correlation coefficient, and the ϵ_t represents temporally iid spatial random effects with the same spatial covariance structure as $\delta_{t=1}$.

In some models, depth was included as a covariate with the effect estimated as a smooth, main effects function of $ln(d_s)$ using the "s" function from the `mgcv` R package (Wood 2017). Temporally-static spatial random fields were also included in some models as a Gaussian Markov random field (GMRF), ω_s,

$$\omega_s \sim \text{MVNormal}(0, \sigma_\omega^2 Q_\omega^{-1})$$

where Q_ω is a sparse precision matrix and σ_ω^2 is the marginal variance. Temporal random effects (random intercepts) were included in some models as random intercepts, γ_t, that followed a first-order autoregressive process, with

$$\gamma_{t=1} \sim \text{Normal}\left(0, \sigma_\gamma^2\right),$$
$$\gamma_{t>1} \sim \left(\rho_\gamma \gamma_{t-1}, \sqrt{1-\rho_\gamma^2}\sigma_\gamma^2\right)$$

where the first time step has a mean zero prior and ρ_γ is the correlation between subsequent time steps.

In addition to alternative statistical models, various spatial meshes used in the model fitting process Figure 30 and spatial correlation barriers associated with the Pribilof Islands and the continental shelf edge were considered.

The model yielding the best average predictive likelihood score, "ar1S_nullT_logDepth_km080b", was the one that included a smooth function of ln-scale depth as a fixed effect and a time-invariant spatial GMRF (but not an AR1 temporal component) in addition to the spatiotemporal AR1 GMRF. and was fit using the 80-knot k-means evaluation mesh with spatial correlation barriers (Stockhausen 2025a).

The evaluation mesh is used to fit a `sdmTMB` model to CPUE data, with spatiotemporal random effects estimated at each mesh node for each time step. However, the evaluation mesh is generally at a coarser scale than that of the data to improve model stability and convergence times. Following model estimation, a "prediction grid" can be used to predict spatiotemporal patterns of species abundance/biomass at much finer spatial resolutions than the evaluation grid. Subsequently, area-integrated indices of species abundance or biomass can be obtained by integrating the predicted densities across the area of interest. Here, three prediction grids were evaluated as the basis for area-integrated indices of PIBKC mature male survey biomass (MMSB) to determine an estimate for terminal year MMSB (Figure 31). The spatial resolution was the same (5 km) for all three grids, but the coverage relative to the NMFS survey grid and the continental shelf differed: grid 0 covered the Pribilof District as defined by NMFS survey strata, extending across the Pribilof Islands and beyond the shelf edge in some areas; grid 1 extended to the shelf edge (500 m depth) and excluded the Pribilof Islands; and grid 2 was limited to depths < 500 m within the NMFS survey strata and excluded the Pribilof Islands. All three grids extend slightly beyond the *k*-means 40 evaluation mesh, while prediction grid 0 extends slightly beyond the *k*-means 60 mesh (Figure 31), which proved problematic when estimating the MMSB indices using these combinations of evaluation mesh and prediction grid.

6.2.2 MMB-at-mating

Annual estimates of MMB-at-mating (MMB_y^{am}) are calculated from the SS/RE RW estimates of MMB at the time of the annual NMFS EBS bottom trawl survey by accounting for natural and fishing mortality from the time of the survey to mating (nominally February 15 of the following year). Given the SS/RE RW estimates $< MMB_y^s >$ of MMB at the time of the survey in year y, MMB_y^{am} was calculated from MMB_y^s, MMB_y^{bf} (MMB just before the fisheries), and MMB_y^{af} (MMB just after the fisheries, which are assumed to occur instantaneously as a simplification), using:

$$MMB_y^{bf} = < MMB_y^s > \cdot e^{-M \cdot t_{sf}} \tag{7}$$

$$MMB_y^{af} = MMB_y^{bf} - RM_y - DM_y^{MM} \tag{8}$$

$$MMB_y^{am} = MMB_y^{af} \cdot e^{-M \cdot t_{fm}} \tag{9}$$

where M is natural mortality, RM_y is retained catch mortality on MMB in the directed fishery in year y, DM_y^{MM} is discard mortality on mature males (**not** on all crab) in all fisheries in year y, t_{sf} is the time between the survey and the fishery, t_{fm} is the time between the fishery and mating.

6.3 Model Selection and Evaluation

6.3.1 `rema` model estimates for MMB at the time of the survey

All three `rema` models for survey MMB achieved acceptable maximum gradients and are considered to have converged (Table 16). Estimated process errors, ϕ, are similar between the three SS/RE RW models and appear reasonable (Table 17). Given that the Tweedie parameter is limited to the range [1,2], the confidence interval associated with its estimate indicates the parameter may not be well-estimated (Table 17). The MCMC results for the ln-scale process error (i.e., λ), the ln-scale terminal survey year, and the arithmetic-scale terminal year survey biomass (Figures 32-37) do not indicate any issues with the non-Tweedie models. MCMC results were not produced for the model using the Tweedie option (MCMC for the Tweedie option is known to take a long time for some models; Jane Sullivan, AFSC, pers. comm.).

The SS/RE RW models appear to fit the survey MMB data well through most of the time series, but the "zeros as NAs" and "Tweedie" models do not fit the declining trend in the data during the final two years (Tables 18-21; Figures 38-39). One-step-ahead (OSA) residuals are shown in Figures 40 and 41 for the non-"Tweedie" models; OSAs for the `rema` model are considered an improved method over Pearson's residuals for assessing model fit. The OSA residuals are slightly negative.

6.4 `sdmTMB` index for PIBKC mature male survey biomass

The NMFS EBS bottom trawl survey captured no mature male PIBKC in 2023 and 2024, introducing problematic zeros into the area-expanded, design-based survey MMB time series that the `rema` model is used to smooth. To better address this issue, the CPT and SSC concurred with the author's suggestion (Stockhausen 2025b) that using a spatiotemporal model such as provided by the `sdmTMB` (Anderson et al. 2024) R package would be a statistically-preferable approach to estimating the survey MMB time series (SSC 2025; CPT 2025). `sdmTMB` provides the ability to statistically model and estimate trends and variability in stock biomass through space and time given spatially-explicit data such as the NMFS EBS bottom trawl survey provides.

6.4.1 Methods

`sdmTMB` is an `R` package (R Core Team 2022; Anderson et al. 2024) that fits spatiotemporal Generalized Linear Mixed Effects Models (GLMMs) using Template Model Builder [TMB; Kristensen et al. (2016)], R-INLA(Lindgren and Rue 2015), and Gaussian Markov random fields. One common application is to create species distribution models (SDMs) from species abundance data collected across space and through time, although its principal advantage here is that it can also estimate stock-level time series by integrating estimated spatially-explicit patterns of abundance or biomass across space. A simple way to think about an `sdmTMB` model is that it provides a way to interpolate survey observations across space and time, taking into account both population variability across space and time as well as variability inherent to the sampling process itself.

Based on CPT and SSC recommendations following the May 2025 CPT Meeting(SSC 2025; CPT 2025), an analysis was conducted using the 1977-2024 EBS shelf survey data (prior to availability of the 2025 survey data) to select a suitable `sdmTMB` model to use to fit the 1975-2025 survey data and estimate a model-based time series for PIBKC survey MMB (Appendix A). The "best" model that fit haul-level mature male survey CPUE from that analysis (labelled "ar1ST_nullT_logDepth_km080b" in the appendix) was a spatiotemporal generalized mixed model (GLMM) which used a Tweedie error model with a log link, a k-means mesh with 80 nodes that included correlation barriers for the Pribilof Islands and the continental shelf (Figure 42), and estimated: 1) spatiotemporal random effects with a first-order autoregresssive (AR1) temporal dependence; 2) spatial (only) random effects; 3) no temporal-only random effects; and 4) a smooth function of ln-transformed bottom depth as a main term. The Tweedie distribution is a compound Poisson-gamma distribution that incorporates a single linear predictor but estimates an additional parameter that reflects the degree of mixing between an underlying presence/absence Poisson distribution and a conditional, presence-only gamma distribution (Tweedie 1984). (Thorson et al. 2021) recommend using the Tweedie distribution for spatiotemporal models by default, particularly when it is not possible to compare with scale from design-based estimators (although comparison is possible in this case).

Model diagnostics applied here include `sdmTMB`'s "sanity" check on convergence and variance parameter reasonableness, DHARMa residuals tests using the `DHARMa` R package (Hartig 2022), examination of plots of spatial residuals, and a test for spatial autocorrelation in the latter residuals using the `spdep` R package and a permutation test for Moran's I statistic (Bivand 2022).

After examining results from the model diagnostics, model-based predictions of survey CPUE for mature males were calculated at all haul locations and across the three fine-scale spatial prediction grids Figure 43 for each year in 1975-2025. As noted previously, the spatial resolution of the three prediction grids is 5 km, but they differ slightly in areal coverage depending on how they match up with the EBS shelf survey grid and the 500 m contour at the shelf break. Subsequently, each set of predictions was areally-integrated by year with bias correction to obtain a time series of model-based survey MMB and associated 80% confidence intervals.

6.4.2 Results

The fitted sdmTMB model converged and passed all `sdmTMB` "sanity" checks (Table 23). Standard model results are presented in Table 24. The spatial correlation falls to ~1/e after ~200 km, or about five survey grid cells. The Tweedy parameter is close to 1, indicating the mixture of Poisson and gamma distributions is very similar to the former. The spatiotemporal AR1 coefficient is 0.78, indicating fairly high autocorrelation between years. The coefficient scaling the main-effects smooth function of ln-scale depth, β, does not appear to be extremely well-determined because its value is relatively small and 0 is well within its associated confidence interval. The smooth function itself (Figure 44) resembles a step function with depth, where the effect is positive for bottom depths less than ~100 m and negative for deeper areas. The uncertainty increases dramatically with depths > 150 m, reflecting the lack of catch data from deeper areas.

Using the `DHARMa R` package (Hartig 2022), predicted haul-level CPUE for mature males tended to be slightly larger than the observed values across most of the range of the predicted values (Figure 45). The results failed tests for uniformity, outliers, and dispersion, but these can be overly sensitive when the number of observations is large; no year-specific patterns were evident in the residuals with respect to the predictions. The residuals did not exhibit any strong spatial correlations in most years (Figures 46 and 47, Table 25), and only four years failed the Moran's I test for autocorrelation.

Compared with the `rema` model from the previous section (6.3.1), the survey MMB indices derived from the sdmTMB model exhibited comparable estimates and slightly smaller confidence intervals (Figures 48-48, Table 26). This is not unexpected given that the `rema` model fits to spatially-aggregated data using the design-based estimates whereas the `sdmTMB` model is capturing both the spatial and temporal variability in the haul-level data. Interestingly, the confidence intervals for the `sdmTMB` index are much smaller than those of the `rema` model at the start of the time series but are somewhat larger at the end, presumably reflecting the spatial contraction of the stock over time and the spatial variability in where mature males were caught as abundance declined. At the end of the time series, where the design-based estimates are "hard" zeros, the `rema` estimates simply "coast" through 2023 and 2024 while the sdmTMB estimates are substantially lower, but non-zero.

The `sdmTMB` model provides a more statistically sound basis for "filling in the zeros" in the NMFS EBS bottom trawl survey data for mature male PIBKC biomass than does the `rema` model considered in the previous section (6.3.1) mainly because it treats them as actual observations and does not simply ignore them, as treating them as NA's (i.e., unknown) does. Thus, an sdmTMB-derived time series for survey MMB will be used in subsequent sections to derive the MMB-at-mating time series and determine B_{MSY}, current B, and stock status. The index derived using prediction grid 1 was selected to go forward with because, of the three grids considered, it most closely aligns to the stock area.

6.4.3 MMB-at-mating

MMB-at-mating was estimated using results from the `sdmTMB` model for MMB at the time of the survey (as per CPT and SSC recommendations (SSC 2025; CPT 2025)). Estimated MMB-at-mating was highest at the start of the time series (1975/76; 22,718 t) and declined rapidly until 1985/86 (643 t), after which it increased slowly, reaching a lower peak in 1993/94 (2,673 t) (Table 27, Figure 51). A subsequent decline started in 1995/1996. Since 2004/05, MMB-at-mating has fluctuated at a very low level (~50-400 t). Following the initial period of large catches and concurrent high survey biomass in 1975/76-1984/85, fishing mortality has had little effect on the estimated MMB-at-mating since 1985/86. Estimated MMB-at-mating for 2024/25 is 75 t. MMB-at-mating in the last two years has been at its lowest levels in the time series.

The time series of MMB-at-mating estimated in this assessment, although similar in overall pattern to those from previous assessments, differs somewhat in detail from those time series (Figure 52) due to the (first) use in this assessment of `sdmTMB` to determine the time series of survey MMB.

7 Calculation of the OFL

7.1 Tier Level:

In 2013 the CPT and SSC designated PIBKC as a Tier 4 for status determination, defined by Amendment 24 to the Fishery Management Plan for the Bering Sea/Aleutian Islands King and Tanner Crabs (NPFMC 2008a), based on data availability.

7.2 Parameters and stock sizes

Parameters and stock sizes to determine the Tier 4 status are listed in Table 28.

7.3 OFL specification

7.3.1 Stock status level

The minimum stock size threshold (MSST) for Tier 4 stocks is specified as $\frac{1}{2}B_{MSY}$ (or a proxy thereof, $B_{MSY_{proxy}}$). If B drops below the MSST, the stock is considered to be overfished. The stock status level is based on the ratio of "current" spawning stock biomass (B) to B_{MSY}. Maximum Sustainable Yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. The fishing mortality that, if applied over the long-term, would result in MSY is F_{MSY}. B_{MSY} is the long-term average stock size when fished at F_{MSY}, and is based on mature male biomass at the time of mating (MMB_{mating}), which serves as a proxy for egg production. MMB_{mating} is used as a basis for B_{MSY} because of the complicated female crab life history, unknown sex ratios, and male-only fishery.

Although B_{MSY} cannot be calculated for a Tier 4 stock, a proxy value ($B_{MSY_{proxy}}$) is defined as the average biomass over a specified time period that satisfies the conditions under which B_{MSY} would occur (i.e., equilibrium biomass yielding MSY under an applied F_{MSY}). The time period for establishing $B_{MSY_{proxy}}$ is assumed to be representative of the stock being fished at an average rate near F_{MSY} and fluctuating around B_{MSY}. The SSC has previously endorsed using the time periods 1980-84 and 1990-97 to calculate $B_{MSY_{proxy}}$ for PIBKC to avoid time periods of low abundance possibly caused by high fishing pressure (Figure 53). Alternative time periods (e.g., 1975 to 1979) have also been considered, but these were rejected (Foy 2013). Considerations for choosing the averaging time period include the following:

Production potential

1) Between 2006 and 2013 the stock appeared to be below a threshold for responding to increased production based on the lack of response of the adult stock biomass to slight fluctuations in recruitment (male crab 120-134 mm; Figure 20 in Foy (2013)). The stock appears to have remained below this (unknown) threshold to the present.

2) An estimate of surplus production using the equation

$$ASP_t = MMB_{t+1} - MMB_t + C_t$$

where C_t denotes total catch mortality in year t suggested that meaningful surplus production existed only in the late 1970s and early 1980s, while minor surplus production in the early 1990s may have led to the increases in biomass observed in the late 1990s.

3) Although climate regime shifts where temperature and current patterns change are likely to impact blue king crab larval dispersal and subsequent juvenile crab distribution, no apparent trends in production before or after 1978 were observed (Foy 2013). There are few empirical data to identify trends that may indicate a production shift.

Exploitation rates

Exploitation rates fluctuated during the open fishery periods from 1975 to 1987 and 1995 to 1998 (Figure 20 in Foy (2013)) while total catch increased until 1980, then decreased until the fishery was closed in 1987 (Figure 4). Following the re-opening of the fishery in 1995, total catch declined annually until the fishery was closed again in 1999. The current $F_{MSY_{proxy}} = M$ is 0.18 yr^{-1}, so time periods with greater exploitation rates should not be considered to represent periods with average rates of fishery removals.

Recruitment

After increases in exploitation rates in the late 1980s and 1990s, estimates of ln(recruits/MMB) dropped, suggesting that recruitment rates were not sufficient to sustain exploitation rates at the levels of $F_{MSY_{proxy}} = M$ (Foy 2013).

7.3.2 Basis for the OFL

In Tier 4, the "total catch OFL" and the "retained catch OFL" are calculated by applying the F_{OFL} to all crab at the time of the fishery (total catch OFL) or to the legal portion of the stock (retained catch OFL). The stock status level (a, b or c) is based on the ratio of B to $B_{MSY_{proxy}}$, and determines the F_{OFL} based on the Tier 4 F_{OFL} Control Rule (Figure 54) as described in the following table:

The Tier 4 F_{OFL} Control Rule (see also Figure 54).

Level	$B/B_{MSY_{proxy}}$	F_{OFL}
a.	$B/B_{MSY_{proxy}} > 1.0$	$F_{OFL} = \gamma \cdot M$
b.	$\beta < B/B_{MSY_{proxy}} \leq 1.0$	$F_{OFL} = \gamma \cdot M[(B/B_{MSY_{proxy}} - \alpha)/(1-\alpha)]$
c.	$B/B_{MSY_{proxy}} \leq \beta$	$F_{directed} = 0,\ F_{OFL} \leq F_{MSY}$

When $B/B_{MSY_{proxy}}$ is greater than 1 (Stock Status Level a), $F_{OFL_{proxy}}$ is given by the product of a scalar (γ, nominally equal to 1.0) and M. When $B/B_{MSY_{proxy}}$ is less than 1 and greater than the critical threshold β (=0.25) (Stock Status Level b), the scalar α (= 0.1) determines the slope of the non-constant portion of the control rule for $F_{OFL_{proxy}}$. When the ratio $B/B_{MSY_{proxy}}$ drops below β (Stock Status Level c), directed fishing mortality is set to zero. Values for α and β (0.1 and 0.25, respectively) are based on a sensitivity analysis of the effects on $B/B_{MSY_{proxy}}$ (NMFS 2008). Because the stock is overfished when $B <$ MSST, the stock *may* be overfished when the stock is level "b" but it is certainly overfished when the level is "c" .

In this assessment, $B_{MSY_{proxy}}$ is the average of MMB_{mating} over the years {1980:1984,1990:1997} (see Figure 53), i.e., 4,146 t. Because MMB-at-mating for 2024/25 is 74.99 t, the current stock status ratio is 0.0180866 and the stock is "overfished". The Tier level is Tier 4c.

7.3.3 Basis for MMB-at-mating

The basis for projecting MMB from the survey to the time of mating for years prior to the assessment year is discussed in detail the Model Description section above (Section 6.2.2). For the assessment year, 2025/26, the fishery has not yet occurred so RM and DM are unknown. The amount of fishing mortality depends on the (as yet-to-be-determined) overfishing limit, so an iterative procedure is used to estimate MMB-at-mating. This procedure involves:

1. "guess" a value for F_{OFL}, the directed fishing mortality rate that yields OFL ($F_{OFL_{max}} = \gamma \cdot M$ is used)
2. determine the OFL corresponding to fishing at F_{OFL} using the following equations:

- $MMB_f = MMB_s \cdot e^{-M \cdot t_{sf}}$
- $RM_{OFL} = \left(1 - e^{-F_{OFL}}\right) \cdot MMB_s \cdot e^{-M \cdot t_{sf}}$
- $DM_{OFL} = \theta \cdot \frac{MMB_f}{p_{male}}$
- $OFL = RM_{OFL} + DM_{OFL}$

3. project MMB-at-mating from the "current" survey MMB and the OFL:
   - $MMB_m = \left[MMB_{f_y} - \left(RM_{OFL} + p_{male} \cdot DM_{OFL}\right)\right] \cdot e^{-M \cdot t_{fm}}$
4. use the harvest control rule to determine the F_{OFL} corresponding to the projected MMB-at-mating.
5. update the "guess" in 1. for the result in 4.
6. repeat steps 2-5 until the process has converged, yielding self-consistent values for F_{OFL} and B.

In this procedure, p_{male} is the fraction of discard mortality on males (taken to be 0.5). Note that this procedure determines the OFL for the assessment year as well as the (projected) MMB-at-mating. Also note that, while the retained mortality RM_{OFL} is based on the F_{OFL}, the discard mortality DM_{OFL} is assumed to be proportional to the MMB at the time of the fishery, with proportionality constant $\frac{\theta}{p_{male}}$.

The value of MMB at the time of the survey for the / fishing year is 181 t, Table 28). The constant θ was determined by the average ratio of discard mortality on MMB (DM_{MMB}) to MMB at the time of the fishery (MMB_f) over a recent time interval:

$$\theta = \frac{1}{N} \sum_y \frac{DM_{MMB_y}}{MMB_{f_y}}$$

where the sum is over the last N years. The value for θ used for this assessment is 7.3026734×10^{-4}, based on averaging over the last 3 years (Table 28).

7.3.4 Specification of F_{OFL}, OFL and other applicable measures

The iterative calculations to determine the Tier 4 F_{OFL}, OFL, and related measures are described in the previous section. Parameters for the calculations are listed in Table 28. The results are given in Table 29. Projected MMB-at-mating for crab fishery year 2025/26 is 162.5 t and the associated status ratio is 0.0392. Consequently, the stock is projected to be in Tier 4c, with $F_{OFL} = 0$ (directed fishing is prohibited). The resulting Tier 4 OFL would be 0.252 t.

The following tables summarize the basis for the OFL for the fishing years 2021/22 to 2025/26 (repeating Tables C and D in the Executive Summary).

Basis for the OFL (biomass units in metric tons).

Year	Tier	B_{MSY}	B	B/B_{MSY}	γ	Years to define B_{MSY}	M	P*
2021/22	4c	4,099	180	0.044	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2022/23	4c	4,200	180	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2023/24	4c	4,200	181	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2024/25	4c	4,200	181	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2025/26	4c	4,146	162	0.039	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer

Basis for the OFL (biomass units in millions of lbs).

Year	Tier	B_{MSY}	B	B/B_{MSY}	γ	Years to define B_{MSY}	M	P*
2021/22	4c	9.037	0.398	0.044	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2022/23	4c	9.259	0.398	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2023/24	4c	9.259	0.399	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2024/25	4c	9.259	0.399	0.043	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer
2025/26	4c	9.1411	0.3582	0.039	1	1980/81-1984/85; 1990/91-1997/98	0.18	25% buffer

7.3.5 Specification of the retained catch portion of the total catch OFL

The retained portion of the total catch OFL for this stock is 0 t.

7.3.6 Recommendations

No alternative models were considered for this assessment: the methods used to determine stock status are the same as those used in the previous assessment. Based on this Tier 4 approach, and similar to conclusions reached in recent assessments, MMB-at-mating remains at historically low levels such that the stock is in Tier 4c, requiring that the directed fishery be closed and that F_{OFL} be set such that it is less than F_{MSY}. The rebuilding analysis (NMFS 2008) concluded that an OFL of 1.16 t (0.0026 million lbs), corresponding to a current fishing mortality rate of roughly 0.006 yr^{-1}, would be consistent with this requirement on F_{OFL} while allowing for a minimal amount of bycatch such that fisheries for other crab or groundfish targets could be be prosecuted. The author recommends continuing to use this approach.

8 Calculation of the ABC

To calculate an Annual Catch Limit (ACL) to account for scientific uncertainty in the OFL, an acceptable biological catch (ABC) control rule was developed such that ACL=ABC. For Tier 3 and 4 stocks, the ABC is set below the OFL by a proportion based on a predetermined probability that the ABC would exceed the OFL (P*). Currently, P* is set at 0.49 and represents a proportion of the OFL distribution that accounts for within-assessment uncertainty (σ_w) in the OFL to establish the maximum permissible ABC (ABC$_{max}$). Any additional uncertainty to account for uncertainty outside of the assessment methods is considered as a recommended ABC below ABC$_{max}$. For the PIBKC stock, the SSC has approved a constant buffer of 25% to the OFL (NPFMC 2014b).

8.1 Specification of the probability distribution of the OFL used in the ABC

The OFL was set based on a Tier 5 calculation of average catch mortalities between 1999/2000 and 2005/06 to adequately reflect the conservation needs with this stock and to acknowledge the existing non-directed catch mortality. As such, the OFL does not have an associated probability distribution.

8.2 List of variables related to scientific uncertainty considered in the OFL probability distribution

None. The OFL is based on a Tier 5 calculation and does not have an associated probability distribution. However, compared to other BSAI crab stocks, the uncertainty associated with the estimates of stock size and OFL for Pribilof Islands blue king crab is very high due to insufficient data and the small spatial extent of the stock relative to the survey sampling density. The coefficient of variation (cv) for the design-based estimate of survey MMB for the most recent survey (2025) is 0.7037, and has ranged between 0.17 and 1.00. The corresponding cv for the RW model-estimated MMB is 0.5415.

8.3 List of additional uncertainties considered for alternative σ_b applications to the ABC

No alternative σ_b applications were considered, but several sources of uncertainty are not included in the measures of uncertainty reported as part of the stock assessment:

- Natural mortality is pre-specified, not estimated. Survey catchability is essentially treated as 1, and not estimated.
- F_{MSY} is assumed to be equal to $\gamma \cdot M$ when applying the OFL control rule, where the proportionality constant γ is assumed to be equal to 1.0 and M is assumed to be known.
- B_{MSY} is assumed to be equivalent to average mature male biomass. However, stock biomass has fluctuated greatly and targeted fisheries only occurred from 1973-1987 and 1995-1998, so considerable uncertainty exists with this estimate of B_{MSY}.

8.4 Recommendations

For 2025/26 $F_{directed} = 0$ and the total catch OFL is based on the catch biomass that would address the conservation needs for this stock while acknowledging the existing non-directed catch mortality. In this case, the ABC based on a 25% buffer of the average catch between 1999/2000 and 2005/2006 would be 0.870 t. The following tables repeat the information in Tables A and B.

Management performance (in metric tons).

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC	yr
2022/23	2,100	180	closed	0	0.25	1.16	0.87	2022
2023/24	2,073	61	closed	0	0.091	1.16	0.87	2023
2024/25	2,073	75	closed	0	0.03	1.16	0.87	2024
2025/26	–	162	closed	–	–	1.16	0.87	2025
2026/27	–	162	closed	–	–	1.16	0.87	2026
2027/28	–	162	closed	–	–	1.16	0.87	2027
2028/29	–	162	closed	–	–	1.16	0.87	2028

Management performance (in millions of lbs).

Year	MSST	Biomass	TAC	Retained Catch	Total Catch Mortality	OFL	ABC	yr
2022/23	4.63	0.397	closed	0	0.0006	0.0026	0.0019	2022
2023/24	4.5705	0.1346	closed	0	0.0002	0.0026	0.0019	2023
2024/25	4.5705	0.1653	closed	0	0.000063	0.0026	0.0019	2024
2025/26	–	0.3582	closed	–	–	0.0026	0.0019	2025
2026/27	–	0.3582	closed	–	–	0.0026	0.0019	2026
2027/28	–	0.3582	closed	–	–	0.0026	0.0019	2027
2028/29	–	0.3582	closed	–	–	0.0026	0.0019	2028

9 Rebuilding Analyses

A revised rebuilding analysis was submitted to the U.S. Secretary of Commerce in 2014 because NMFS determined that the stock was not rebuilding in a timely manner and would not meet the rebuilding horizon of 2014. The Secretary approved the plan in 2015, as well as the two amendments that implement the revised plan (Amendment 43 to the King and Tanner Crab Fishery Management Plan and Amendment 103 to the BSAI Groundfish Fishery Management Plan). These amendments impose a closure to all fishing for Pacific cod with pot gear in the Pribilof Islands Habitat Conservation Zone. This measure was designed to protect the main concentration of the stock from the fishery with the highest observed rates of bycatch (NPFMC 2014a). The area has been closed to trawling since 1995.

The causes of the continued low abundance and failure to recover are not well-understood, but are thought to be predominantly due to environmental changes that inhibit recruitment. Weems et al. (2025) suggest that larval supply, not changes in benthic habitat, is limiting juvenile recruitment. Reum et al. (2020) recently developed a qualitative network model that describes important biological interactions that may influence the productivity of PIBKC and found that, under a scenario of no projected climate change, predicted increases in PIBKC were reliable only when stock enhancement was implemented in a PIBKC hatchery-program scenario. However, when environmental trends were accounted for, stock enhancement could not counteract the adverse impacts of climate, which had an overall negative effect on BKC. They concluded that a stock enhancement program for PIBKC may be a necessary, but not sufficient, requirement for rebuilding to occur.

The revised (2014) rebuilding plan does not have a target rebuild date and NMFS cannot predict when or if rebuilding will occur (Harrington 2024). There is no new and unexpected information that would significantly alter the rebuilding expectations. The recent trajectory of the time series of MMB-at-survey time provides no evidence of an increasing trend. Further, survey size compositions provide no evidence for recent recruitment to the stock. The failure of the EBS shelf survey to catch any mature males this year does not raise the level of concern for this stock above what it has been in the recent past; the survey does not target blue king crab and the result is consistent with sampling a population at low (but non-zero) abundance. The causes of the continued low abundance and failure to recover are not well understood, but are thought to be predominantly due to environmental changes that inhibit recruitment. In May 2024, NMFS determined that "…the rebuilding progress for PIBKC is consistent with the expectations outlined in the rebuilding plan, current environmental conditions that inform stock status, the current condition of the stock, and the estimated rebuilding time."[2]

10 Data Gaps and Research Priorities

One rationale for using a `rema`-based model is that it generally takes less time to run a model, although convergence issues leading to long run times have been known to occur. With the spatial mesh used here (Figure 42), run times were on the order of an hour or so, which is not prohibitive under the compressed time frame required to produce this stock assessment report. However, selection from among several candidate models should involve assessing model predictive skill, which is prohibitive in this context. Thus, as long as selection among alternative models has occurred prior to August (i.e., prior to conclusion of the current year's survey), deriving model-based indices of survey MMB using an sdmTMB model is the recommended workflow. However, if this can not be the case, use of `rema` models should be reconsidered in light of the time constraints on crab stock assessments.

Given the large CVs associated with the survey abundance and biomass estimates for PIBKC, assessment of this species might benefit from additional surveys using alternative gear at finer spatial resolution. Data from the ADFG Pribilof Islands Pot Survey were recently provided to the author by Ben Daly (ADFG) but a full analysis of the data has not been conducted yet. Other data gaps include stock-specific natural mortality rates and a lack of understanding regarding processes apparently preventing successful recruitment to the Pribilof District.

11 Acknowledgments

I would like to acknowledge the particular contributions to this assessment made by all personnel contributing to the planning and execution of the (and previous) NMFS EBS shelf bottom trawl survey(s). Ben Daly (ADF&G) for providing crab fishery catch information and ADFG pot survey data (which, while unable to be used here due to time constraints, will contribute to future assessments). Caitlin Stark (ADFG) provided some useful examples of workflow for `sdmTMB` analyses. Ebett Siddon (AFSC) contributed ecosystem information to the PIBKC Risk Table (Stockhausen and Siddon 2025). Sandra Lowe (AFSC Seattle) provided a helpful review of a first draft of this document.

[2]May 6, 2024, NMFS Memorandum: "Review of Progress for the Pribilof Islands Blue King Crab Rebuilding Plan" by Gretchen Harrington, Assistant Regional Administrator for Sustainable Fisheries

References

Anderson, S.C., Ward, E.J., English, P.A., Barnett, L.A.K., and Thorson, J.T. 2024. sdmTMB: An R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. bioRxiv **2022.03.24.485545**. doi:10.1101/2022.03.24.485545.

Armstrong, D.A., Armstrong, J.L., Jensen, G.C., Palacios, R., and Williams, G. 1987. Distribution, abundance, and biology of blue king and Korean hair crabs around the Pribilof Islands. U.S. Dep. Commer., NOAA.

Armstrong, D.A., Armstrong, J.L., Palacios, R., Jensen, G.C., and Williams, G. 1985. Early life history of juvenile blue king crab, *Paralithodes platypus*, around the Pribilof Islands. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA.

Bivand, R. 2022. R packages for analyzing spatial data: A comparative case study with areal data. Geographical Analysis **54**(3): 488–518. doi:10.1111/gean.12319.

Blau, F.S. 1997. Alaska king crabs: Wildlife notebook series. Alaska Department of Fish and Game. Available from http://www.adfg.state.ak.us/pubs/notebook/shellfsh/kingcrab.php.

Bowers, F.R., Schwenzfeier, M., Coleman, S., Failor-Rounds, B.J., Milani, K., Herring, K., Salmon, M., and Albert, M. 2008. Annual Management Report for the Commercial and Subsistence Shellfsh Fisheries of the Aleutian Islands, Bering Sea and the Westward Region's Shellfsh ObserverProgram, 2006/07. Alaska Department of Fish and Game, Juneau, AK.

Bowers, F., Schwenzfeierand, M., Herring, K., Salmon, M., Fitch, H., Alas, J., and Baechler, B. 2011. Annual management report for the commercial and subsistence shellfish fisheries of the Aleutian Islands, Bering Sea, and the Westward Region's Shellfish Observer Program, 2009/2010. Alaska Department of Fish and Game.

CPT. 2023. Crab Plan Team report. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=4ace502c-f13b-411f-8301-978c09746e6a.pdf&fileName=C1%20CPT%20Report%20May%202023.pdf.

CPT. 2025. Crab Plan Team report. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=b3bf30f5-19b7-463e-a862-633fe323f9c0.pdf&fileName=C2%20CPT%20Report%20May%202025.pdf.

Daly, B., Armistead, C., and Foy, R. 2014. The 2014 Eastern Bering Sea Continental Shelf Bottom Trawl Survey: Results for Commercial Crab Species. NOAA. Available from https://apps-afsc.fisheries.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-282.pdf.

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnussona, A., Maunder, M.N., Nielsen, A., and Sibert, J. 2016. AD model builder: Using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. **27**(1).

Foy, R.J. 2013. 2013 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2013 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2013.pdf.

Foy, R.J., Miller, S., Stram, D., Fey, M., Lewis, S., Gasper, J.R., and Harrington, G.A. 2014. Final Environmental Assessment for proposed amendment 43 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs and proposed amendment 103 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands To prevent overfishing and rebuild Pribilof Islands blue king crab. National Marine Fisheries Service.

Available from https://repository.library.noaa.gov/view/noaa/18186/noaa_18186_DS1.pdf.

Harrington, G.(Assistant.R.A. for S.F. 2024, May. Review of Progress for the Pribilof Islands Blue King Crab Rebuilding Plan. {Internal Memo}, National Marine Fisheries Service Sustainable Fisheries Division.

Hartig, F. 2022. DHARMa: Residual diagnostics for hierarchical (multi-level / mixed) regression models. Available from http://florianhartig.github.io/DHARMa/.

Jensen, G.C., and Armstrong, D. 1989. Biennial reproductive cycle of blue king crab, *Paralithodes platypus*, at the Pribilof Islands, Alaska, and comparison to a congener, *P. camtschatica*. Canadian Journal of Fisheries and Aquatic Sciences **46**(6): 932–940.

Jensen, G.C., Armstrong, D.A., and Williams, G. 1985. Reproductive biology of the blue king crab, *Paralithodes platypus*, in the Pribilof Islands. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA.

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H., and Bell, B.M. 2016. TMB: Automatic differentiation and Laplace approximation. Journal of Statistical Software **70**(5): 1–21. doi:10.18637/jss.v070.i05.

Lauth, R.R., and Nichol, D.G. 2013. Results of the 2012 eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. National Oceanic; Atmospheric Administration (NOAA). Available from https://apps-afsc.fisheries.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-256.pdf.

Lindgren, F., and Rue, H. 2015. Bayesian spatial modelling with R-INLA. Journal of Statistical Software **63**(19): 1–25. Available from http://www.jstatsoft.org/v63/i19/.

NMFS. 2005. APPENDIX F.3. ESSENTIAL FISH HABITAT ASSESSMENT REPORT for the Bering Sea and Aleutian Islands King and Tanner Crabs. NOAA Fisheries, Juneau, AK.

NMFS. 2008. Final Environmental Assessment for Amendment 24 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs to Revise Overfishing Definitions. National Marine Fisheries Service. Available from https://repository.library.noaa.gov/view/noaa/18139/noaa_18139_DS1.pdf.

NPFMC. 1994. Environmental Assessment/RegulatoryImpact Review/Initial Regulatory Flexibility analysis for Amendment 21a to the Fishery Management Plan for Bering Sea and Aleutian Island Groundfish. NMFS Alaska Region, PO Box 21668, Juneau, AK 99802-1668.

NPFMC. 2003. Environmental assessment for Amendment 17 to the Fishery Management Plan for the King and Tanner crab fsheries in the Bering Sea/Aleutian Islands: a rebuilding plan for the Pribilof Islands blue king crab stock. North Pacific Fishery Management Council, Anchorage, AK.

NPFMC. 2014a. Final Environmental Assessment for proposed Amendment 43 to the Fishery Management Plan for Bering Sea/Aleutian Island King and Tanner Crabs and proposed Amendment 103 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK.

NPFMC. 2014b. Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands. 2014 Final Crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=84a80bf9-a465-4e91-8da7-b84e414c0e3e.pdf&fileName=C3%20CRAB%20SAFE%202014_reduced.pdf.

NPFMC. 2023. BSAI Crab Fishery Management Plan Amendment Summaries. North Pacific Fishery Management Council, 1007 West Third, Suite 400, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/Publications/Crab_Amendment_Summaries.pdf.

Otto, R.S., and Cummiskey, P.A. 1990. Growth of adult male blue king crab (*Paralithodes platypus*).

In Proceedings of the International Symposium on King and Tanner crabs. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA. p. 633.

Paul, A.J., and Paul, J.M. 1980. The effect of early starvation on later feeding success of king crab zoeae. Journal of Experimental Marine Biology and Ecology **44**: 247–251.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

Reum, J.C.P., McDonald, P.S., Long, W.C., Holsman, K.K., Divine, L., Armstrong, D., and Armstrong, J. 2020. Rapid assessment of management options for promoting stock rebuilding in data-poor species under climate change. Conservation Biology **34**(3): 611–621. Blackwell Publishing Ltd. doi:https://doi.org/10.1111/cobi.13427.

Selin, N.I., and Fedotov, P.A. 1996. Vertical distribution and some biological characteristics of the blue king crab *Paralithodes platypus* in the northwestern Bering Sea. Marine Biology **22**: 386–390.

Siddeek, M., Watson, L.J., Blau, S.F., and Moore, H. 2002. Estimating natural mortality of king crabs from tag recapture data. *Edited by* A. Paul, E. Dawe, R. Elner, G. Jamieson, G. Kruse, R. Otto, B. Sainte-Marie, T. Shirley, and D.(eds). Woodby. University of Alaska Sea Grant, P.O. Box 755040 205 O'Neill Bldg. Fairbanks AK 99775-5040 USA, [URL:http://www.uaf.edu/seagrant/]. pp. 25–75.

Somerton, D.A. 1985. The disjunct distribution of blue king crab, *Paralithodes platypus*, in Alaska: Some hypotheses. *In* Proceedings of the international king crab symposium. University of Alaska Sea Grant, PO Box 755040 203 O'Neill Bldg. Fairbanks AK 99775-5040 USA.

Somerton, D.A., and MacIntosh, R.A. 1983. The size at sexual maturity of blue king crab, *Paralithodes platypus*, in Alaska. Fishery Bulletin **81**(3): 621–628.

Somerton, D., and MacIntosh, R.A. 1985. Reproductive biology of the female blue king crab *Paralithodes platypus* near the Pribilof Islands, Alaska. Journal of Crustacean Biology **5**: 365–376.

SSC. 2013. Report of the Scientific And Statistical Committee to the North Pacific Fishery Management Council. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=3745f797-357c-4d23-a671-f5f142eba04c.pdf&fileName=SSC%20Minutes.pdf.

SSC. 2023. Scientific and Statistical Committee Final Report to the North Pacific Fishery Management Council. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=6e92b161-ea7f-4a57-97fd-45b3ff4aaff0.pdf&fileName=SSC%20Report%20June%202023_FINAL.pdf.

SSC. 2025. Scientific and Statistical Committee Final Report to the North Pacific Fishery Management Council. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=4079a528-23d0-4f90-82f8-a235c18052d5.pdf&fileName=SSC%20Report%20June%202025_FINAL.pdf.

Stauffer, G.A. 2004. NOAA protocols for groundfish bottom trawl surveys of the Nation's fishery resources. U.S. National Oceanic; Atmospheric Administration (NOAA).

Stevens, B.S. 2006a. Embryo development and morphometry in the blue king crab *Paralithodes platypus* studied by using image and cluster analysis. Journal of Shellfsh Research **25**(2): 596–576.

Stevens, B.S. 2006b. Timing and duration of larval hatching for blue king crab *Paralithodes platypus* Brandt, 1850, held in the laboratory. Journal of Crustacean Biology **26**(4): 495–502.

Stevens, B.S., Persselin, S.L., and Matweyou, J.A. 2008. Survival of blue king crab *Paralithodes platypus* Brandt, 1850, larvae in cultivation: Effects of diet, temperature and rearing density. Aquaculture Research **39**: 390–397.

Stockhausen, W.T. 2014. 2014 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2014 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=84a80bf9-a465-4e91-8da7-b84e414c0e3e.pdf&fileName=C3%20CRAB%20SAFE%202014_reduced.pdf.

Stockhausen, W.T. 2015. 2015 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2015 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2015.pdf.

Stockhausen, W.T. 2016. 2016 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2016 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2016CrabSAFE_final.pdf.

Stockhausen, W.T. 2017. 2017 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2017 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/CrabSAFE2017.pdf.

Stockhausen, W.T. 2018. 2018 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2018 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2018/SAFE_2018_Complete.pdf.

Stockhausen, W.T. 2019. 2019 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2019 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2019/SAFE_2019_Complete.pdf.

Stockhausen, W.T. 2021. 2021 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2021 final crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 83. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=6b1606ce-3b55-4273-935a-8ec90b8d5295.pdf&fileName=5%20Priblof%20Island%20Blue%20King%20Crab%20SAFE.pdf.

Stockhausen, W.T. 2023a. 2023 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2023 Final Crab SAFE.

North Pacific Fishery Management Council, Anchorage, AK. p. 112. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=05baad65-e92f-4998-8655-a076b17b7af3.pdf&fileName=Priblof%20Island%20Blue%20King%20Crab%20SAFE.pdf.

Stockhausen, W.T. 2023b. PIBKC: Random effects model comparisons. North Pacific Fishery Management Council, Juneau, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=5b0ede20-15e1-44fa-9931-35a952b76c50.pdf&fileName=PIBKC%202023%20Proposed%20model%20runs.pdf.

Stockhausen, W.T. 2025a. Appendix A: sdmTMB Model Selection to Estimate PIBKC mature male biomass from the NMFS EBS survey. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/Meeting/Details/3097.

Stockhausen, W.T. 2025b. 2025 PIBKC assessment considerations. North Pacific Fishery Management Council, Juneau, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=753c6ba1-2567-468a-b6eb-faa77ec3e4a3.pdf&fileName=PIBKC2025-05.pdf.

Stockhausen, W.T., and Siddon, E. 2025. Appendix B: Draft Risk Table for the 2025 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/Meeting/Details/3097.

Stoutamore, J.L. 2014. Population genetics and mating structure of blue king crab (*Paralithodes platypus*). Master's thesis, University of Alaska, Fairbanks, Fairbanks, AK. Available from http://hdl.handle.net/11122/4547.

Sullivan, J. 2022. rema: A generalized framework to fit the random effects (RE) model, a state-space random walk model developed at the Alaska Fisheries Science Center (AFSC) for apportionment and biomass estimation of groundfish and crab stocks. Available from https://github.com/JaneSullivan-NOAA/rema, https://afsc-assessments.github.io/rema/.

Thorson, J.T., Cunningham, C.J., Jorgensen, E., Havron, A., Hulson, P.-J.F., Monnahan, C.C., and von Szalay, P. 2021. The surprising sensitivity of index scale to delta-model assumptions: Recommendations for model-based index standardization. Fisheries Research **233**: 105745. doi:https://doi.org/10.1016/j.fishres.2020.105745.

Tweedie, M.C.K. 1984. An index which distinguishes between some important exponential families. *In* Statistics: Applications and new directions. Proceedings of the Indian Statistical Institute Golden Jubilee International Conference. *Edited by* J.K. Ghosh and J. Roy. Indian Statistical Institute, Calcutta. pp. 579--604.

Wakabayashi, K., Bakkala, R.G., and Alton, M.S. 1985. Methods of the U.S.-Japan demersal trawl surveys. *In* Results of cooperative U.S.-Japan groundfish investigations in the Bering Sea during May-August 1979. *Edited by* K. Wakabayashi. Int. North Pac. Fish. Comm. Bull. pp. 7–29.

Weems, J.D., Long, W.C., Divine, L.M., and Eckert, G.L. 2025. Blue king crab (paralithodes platypus) and red king crab (p. Camtschaticus) juvenile settlement to nearshore nursery habitats of saint paul island, pribilof islands, alaska. Canadian Journal of Fisheries and Aquatic Sciences **82**: 1–21. doi:10.1139/cjfas-2024-0227.

Wood, S.N. 2017. Generalized Additive Models: An introduction with R. *In* 2nd edition. Chapman; Hall/CRC.

Zacher, L.S., Richar, J.I., Fedewa, E.J., Ryznar, E.R., and Litzow, M.A. 2023. The 2022 eastern and northern Bering Sea continental shelf trawl surveys: Results for commercial crab species. U.S. National Oceanic; Atmospheric Administration (NOAA). doi:https://doi.org/10.25923/r6px-9707.

Zacher, L.S., Richar, J.I., and Foy, R.J. 2020. The 2019 eastern and northern Bering Sea continental shelf trawl surveys: Results for commercial crab species. U.S. National Oceanic; Atmospheric Administration (NOAA). doi:https://doi.org/10.25923/8jdb-5p39.

Zheng, J. 2016. 2016 Stock Assessment and Fishery Evaluation Report for the bristol bay red king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2016 final crab SAFE. North Pacific Fishery Management Council. Available from https://www.npfmc.org/wp-content/PDFdocuments/resources/SAFE/CrabSAFE/2016CrabSAFE_final.pdf.

Zheng, J., Murphy, M.C., and Kruse, G.H. 1997. Application of a catch-survey analysis to blue king crab stocks near Pribilof and St. Matthew Islands. Alaska Fishery Research Bulletin **4**(1): 62–74.

Tables

List of Tables

Table 1. Retained catch and average CPUE (number of legal males/pot lift) of PIBKC in the directed pot fishery, 1973-1998/99. The directed fishery has been closed since the 1999/2000 fishing season. NA: not applicable (no directed fishery)

crab year	number	biomass (t)	avg. cpue (num. legal crab/pot lift)
1973/74	174,420	579	26
1974/75	908,072	3,224	20
1975/76	314,931	1,104	19
1976/77	855,505	2,999	12
1977/78	807,092	2,929	8
1978/79	797,364	2,901	8
1979/80	815,557	2,719	10
1980/81	1,497,101	4,976	9
1981/82	1,202,499	4,119	7
1982/83	587,908	1,998	5
1983/84	276,364	995	3
1984/85	40,427	139	3
1985/86	76,945	240	3
1986/87	36,988	117	2
1987/88	95,130	318	2
1988/89	0	0	NA
1989/90	0	0	NA
1990/91	0	0	NA
1991/92	0	0	NA
1992/93	0	0	NA
1993/94	0	0	NA
1994/95	0	0	NA
1995/96	190,951	628	5
1996/97	127,712	425	4
1997/98	68,603	232	3
1998/99	68,419	234	3
1999/00	0	0	NA

Table 2. Bycatch catch of PIBKC in the directed and other crab fisheries, as estimated from crab observer data. A discard mortality rate of 0.2 was applied to obtain discard mortalities. Units are t.

crab year	females	sublegal males	legal males	catch total catch	discard mortality
1996/97	0.000	0.807	0.000	0.807	0.161
1997/98	0.000	0.000	0.000	0.000	0.000
1998/99	3.715	0.467	2.295	6.477	1.295
1999/00	1.969	4.291	3.493	9.752	1.950
2000/01	0.000	0.000	0.000	0.000	0.000
2001/02	0.000	0.000	0.000	0.000	0.000
2002/03	0.000	0.000	0.000	0.000	0.000
2003/04	0.000	0.000	0.000	0.000	0.000
2004/05	0.000	0.000	0.000	0.000	0.000
2005/06	0.050	0.000	0.000	0.050	0.010
2006/07	0.104	0.000	0.000	0.104	0.021
2007/08	0.136	0.000	0.000	0.136	0.027
2008/09	0.000	0.000	0.000	0.000	0.000
2009/10	0.000	0.000	0.000	0.000	0.000
2010/11	0.000	0.186	0.000	0.186	0.037
2011/12	0.000	0.000	0.000	0.000	0.000
2012/13	0.000	0.000	0.000	0.000	0.000
2013/14	0.000	0.000	0.000	0.000	0.000
2014/15	0.000	0.000	0.000	0.000	0.000
2015/16	0.102	0.230	0.000	0.333	0.067
2016/17	0.000	0.000	0.000	0.000	0.000
2017/18	0.064	0.000	0.000	0.064	0.013
2018/19	0.000	0.101	0.000	0.101	0.020
2019/20	0.000	0.000	0.000	0.000	0.000
2020/21	0.000	0.000	0.000	0.000	0.000
2021/22	0.000	0.000	0.000	0.000	0.000
2022/23	0.000	0.000	0.000	0.000	0.000
2023/24	0.000	0.000	0.000	0.000	0.000
2024/25	0.000	0.000	0.000	0.000	0.000

Table 3. Bycatch of PIBKC in the groundfish fisheries, by gear type. Biomass and (discard) mortality are in kilograms. Number of vessels and bycatch in numbers are only available after 2008/09. Discard mortality rates of 0.2 and 0.8 for fixed and trawl gear, respectively, were applied to obtain discard mortalities.

			fixed			trawl
year	number	biomass	mortality	number	biomass	mortality
1991/92	*NA*	67	13	*NA*	6199	4959
1992/93	*NA*	879	176	*NA*	60791	48633
1993/94	*NA*	0	0	*NA*	34232	27385
1994/95	*NA*	35	7	*NA*	6856	5485
1995/96	*NA*	108	22	*NA*	1284	1028
1996/97	*NA*	31	6	*NA*	67	54
1997/98	*NA*	1462	292	*NA*	130	104
1998/99	*NA*	19800	3960	*NA*	79	64
1999/00	*NA*	795	159	*NA*	20	16
2000/01	*NA*	116	23	*NA*	23	19
2001/02	*NA*	833	167	*NA*	29	24
2002/03	*NA*	71	14	*NA*	297	238
2003/04	*NA*	345	69	*NA*	227	181
2004/05	*NA*	816	163	*NA*	2	1
2005/06	*NA*	353	71	*NA*	1339	1071
2006/07	*NA*	138	28	*NA*	74	59
2007/08	*NA*	3993	799	*NA*	132	106
2008/09	*NA*	141	28	*NA*	473	379
2009/10	87	216	43	193	207	165
2010/11	16	44	9	35	56	45
2011/12	54	112	22	8	7	6
2012/13	72	170	34	340	669	535
2013/14	41	65	13	0	0	0
2014/15	65	144	29	0	0	0
2015/16	352	744	149	257	808	646
2016/17	63	93	19	524	455	364
2017/18	2	4	1	265	378	303
2018/19	24	38	8	398	466	373
2019/20	10	18	4	226	522	418

(continued)

year	number	biomass	fixed mortality	number	biomass	trawl mortality
2020/21	5	7	1	0	0	0
2021/22	22	30	6	46	109	87
2022/23	126	215	43	91	266	213
2023/24	260	425	85	0	7	5
2024/25	92	143	29	0	0	0

Table 4. Bycatch (numbers of crab) of PIBKC in the groundfish fisheries, by target type (avalable only after 2008/09). Discard mortality rates were not applied.

year	Flathead Sole number	Pacific Cod number	Pollock - bottom number	Rock Sole - BSAI number	Yellowfin Sole - BSAI number
2009/10	54	87	20	0	119
2010/11	35	14	0	0	0
2011/12	0	62	0	0	0
2012/13	12	72	0	0	328
2013/14	0	41	0	0	0
2014/15	0	64	0	0	0
2015/16	58	351	0	0	199
2016/17	0	63	0	432	92
2017/18	95	2	0	0	170
2018/19	0	24	97	0	300
2019/20	0	10	0	55	170
2020/21	0	5	0	0	0
2021/22	0	22	0	0	46
2022/23	0	126	0	23	68
2023/24	0	260	0	0	0
2024/25	0	91	0	0	0

Table 5. Bycatch (biomass, in kg) of PIBKC in the groundfish fisheries, by target type (avalable only after 2008/09). Discard mortality rates were not applied.

year	Flathead Sole biomass	Pacific Cod biomass	Pollock - bottom biomass	Rock Sole - BSAI biomass	Yellowfin Sole - BSAI biomass
2009/10	71	216	7	0	129
2010/11	56	42	0	0	0
2011/12	0	119	0	0	0
2012/13	24	170	0	0	645
2013/14	0	64	0	0	0
2014/15	0	143	0	0	0
2015/16	147	742	0	0	661
2016/17	0	91	0	368	87
2017/18	227	4	0	0	151
2018/19	0	38	23	0	442
2019/20	0	18	1	189	332
2020/21	0	7	0	0	0
2021/22	0	30	0	0	109
2022/23	0	215	0	106	160
2023/24	0	425	0	0	6
2024/25	0	141	0	0	0

Table 6. Discard mortality (in kg) of PIBKC in the groundfish fisheries, by target type.Discard mortality rates of 0.2 and 0.8 for fixed and trawl gear, respectively, were applied to obtain discard mortalities.

year	Flathead Sole mortality	Pacific Cod mortality	Pollock - bottom mortality	Rock Sole - BSAI mortality	Yellowfin Sole - BSAI mortality
2009/10	57	43	5	0	103
2010/11	45	8	0	0	0
2011/12	0	28	0	0	0
2012/13	19	34	0	0	516
2013/14	0	13	0	0	0
2014/15	0	29	0	0	0
2015/16	117	148	0	0	529
2016/17	0	18	0	294	70
2017/18	182	1	0	0	121
2018/19	0	8	19	0	354
2019/20	0	4	1	151	265
2020/21	0	1	0	0	0
2021/22	0	6	0	0	87
2022/23	0	43	0	84	128
2023/24	0	85	0	0	5
2024/25	0	28	0	0	0

Table 7. Size groups for various male components of the PIBKC stock used here. Female maturity is based on abdominal flap morphology and egg presence.

sex	size.range	category
male	< 120 mm CL	immature male
male	> 119 mm CL	mature male
male	< 135 mm CL	sublegal male
male	> 134 mm CL	legal male

Table 8. Sample sizes (number of survey hauls, number hauls where crab were caught, number of crab caught) for male population components in the NMFS EBS trawl survey in the Pribilof District.

year	survey number of hauls	immature males non-0 hauls	immature males no. crab	mature males non-0 hauls	mature males no. crab	sublegal males non-0 hauls	sublegal males no. crab	legal males non-0 hauls	legal males no. crab	all males non-0 hauls	all males no. crab
1975	45	11	305	13	553	11	530	13	328	13	858
1976	59	3	105	11	91	9	122	10	74	12	196
1977	58	7	56	10	129	9	73	9	112	10	185
1978	58	8	60	11	130	10	112	10	78	12	190
1979	58	2	2	14	90	8	25	13	67	14	92
1980	70	10	41	21	133	12	64	21	110	21	174
1981	84	19	99	36	184	23	128	36	155	38	283
1982	84	19	70	35	114	21	84	31	100	38	184
1983	86	15	47	32	93	18	74	29	66	35	140
1984	86	10	27	20	37	17	37	16	27	25	64
1985	86	3	4	14	24	8	13	11	15	14	28
1986	86	1	1	13	26	2	2	13	25	13	27
1987	86	5	34	15	50	6	38	14	46	16	84
1988	85	5	52	5	12	5	52	5	12	9	64
1989	86	8	160	4	11	8	160	4	11	10	171
1990	86	8	90	10	59	11	126	7	23	14	149
1991	85	16	92	19	103	20	129	14	66	22	195
1992	86	12	89	14	73	13	119	12	43	17	162
1993	85	12	75	19	96	15	115	17	56	21	171
1994	86	8	32	18	68	12	51	18	49	19	100
1995	86	7	66	18	177	15	118	14	125	19	243
1996	86	7	32	19	87	11	54	19	65	20	119
1997	86	7	25	17	65	10	39	16	51	19	90
1998	85	12	56	20	56	15	66	17	46	21	112
1999	86	7	9	13	34	9	18	11	25	15	43
2000	85	4	9	16	40	9	20	13	29	16	49
2001	86	3	5	6	28	4	9	5	24	7	33
2002	86	0	0	6	12	1	1	6	11	6	12
2003	86	2	2	7	14	3	3	7	13	9	16

(continued)

year	survey number of hauls	immature males non-0 hauls	immature males no. crab	mature males non-0 hauls	mature males no. crab	sublegal males non-0 hauls	sublegal males no. crab	legal males non-0 hauls	legal males no. crab	all males non-0 hauls	all males no. crab
2004	85	3	5	3	3	5	7	1	1	6	8
2005	84	3	54	2	5	3	54	2	5	4	59
2006	86	4	7	3	3	4	8	2	2	6	10
2007	86	4	14	2	6	4	17	2	3	4	20
2008	86	2	13	1	1	2	13	1	1	3	14
2009	86	5	16	3	15	5	27	3	4	5	31
2010	86	2	6	5	8	3	10	4	4	5	14
2011	86	0	0	3	9	2	2	2	7	3	9
2012	86	1	9	4	13	1	14	4	8	4	22
2013	86	1	3	2	6	2	5	2	4	3	9
2014	86	3	5	2	5	3	5	2	5	4	10
2015	86	2	4	8	13	6	10	5	7	9	17
2016	86	4	5	3	3	5	7	1	1	5	8
2017	86	2	4	4	4	3	5	3	3	5	8
2018	86	4	6	3	3	4	6	3	3	5	9
2019	86	5	8	3	3	5	8	3	3	6	11
2021	86	1	1	5	9	3	4	4	6	5	10
2022	86	0	0	2	2	0	0	2	2	2	2
2023	86	2	2	0	0	2	2	0	0	2	2
2024	70	0	0	0	0	0	0	0	0	0	0
2025	70	0	0	2	2	0	0	2	2	2	2

Table 9. Sample sizes (number of survey hauls, number hauls where crab were caught, number of crab caught) for female population components in the NMFS EBS trawl survey in the Pribilof District.

	survey	immature females		mature females		all females	
	number	non-0	no.	non-0	no.	non-0	no.
year	of hauls	hauls	crab	hauls	crab	hauls	crab
1975	45	0	0	9	265	9	265
1976	59	3	81	4	11	7	92
1977	58	2	9	5	136	7	145
1978	58	1	1	8	107	9	108
1979	58	2	3	4	22	6	25
1980	70	3	6	11	337	14	343
1981	84	13	31	20	202	33	233
1982	84	5	35	23	264	28	299
1983	86	6	15	17	288	23	303
1984	86	6	24	14	145	20	169
1985	86	7	15	8	28	15	43
1986	86	2	2	8	106	10	108
1987	86	5	22	7	36	12	58
1988	85	5	38	8	20	13	58
1989	86	8	131	9	40	17	171
1990	86	5	75	9	90	14	165
1991	85	9	36	11	126	20	162
1992	86	4	66	9	76	13	142
1993	85	5	45	13	89	18	134
1994	86	3	8	12	271	15	279
1995	86	3	38	11	220	14	258
1996	86	7	13	10	213	17	226
1997	86	4	17	11	137	15	154
1998	85	8	29	11	107	19	136
1999	86	0	0	10	155	10	155
2000	85	0	0	13	74	13	74
2001	86	1	1	9	93	10	94
2002	86	1	1	6	66	7	67
2003	86	4	4	7	69	11	73

(continued)

year	survey number of hauls	immature females non-0 hauls	immature females no. crab	mature females non-0 hauls	mature females no. crab	all females non-0 hauls	all females no. crab
2004	85	3	5	3	4	6	9
2005	84	1	43	5	15	6	58
2006	86	4	6	3	22	7	28
2007	86	3	7	2	9	5	16
2008	86	3	19	4	24	7	43
2009	86	3	9	3	29	6	38
2010	86	5	9	4	15	9	24
2011	86	1	1	2	2	3	3
2012	86	1	1	5	15	6	16
2013	86	2	2	4	8	6	10
2014	86	1	1	3	4	4	5
2015	86	0	0	4	11	4	11
2016	86	4	5	7	19	11	24
2017	86	4	5	4	10	8	15
2018	86	1	1	3	6	4	7
2019	86	0	0	2	11	2	11
2021	86	0	0	3	12	3	12
2022	86	0	0	4	7	4	7
2023	86	0	0	1	7	1	7
2024	70	0	0	0	0	0	0
2025	70	0	0	1	3	1	3

Table 10. Summary statistics for trawl survey abundance by decade, in millions.

												decade
		1970		1980		1990		2000		2010		2020
category	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
immature females	1.685	7.369	0.7645	2.636	0.756	2.177	0.3201	2.2681	0.05116	0.1656	0.00000	0.00000
mature females	6.978	13.880	21.3116	182.903	3.008	5.047	0.7272	1.6975	0.20400	0.3594	0.11164	0.22932
all females	4.332	13.880	11.0381	182.903	1.882	5.047	0.5236	2.2681	0.12758	0.3594	0.05582	0.22932
immature males	4.030	8.476	1.3213	3.515	1.237	2.450	0.3257	1.9813	0.09662	0.1945	0.01053	0.03322
mature males	8.673	15.288	1.8942	7.842	1.619	3.102	0.2274	0.7251	0.12712	0.2722	0.05399	0.17362
sublegal males	6.348	14.712	1.6675	4.331	1.791	3.349	0.3850	1.9813	0.13763	0.3026	0.02231	0.07831
legal males	6.355	11.769	1.5480	6.244	1.065	2.186	0.1681	0.5276	0.08610	0.1642	0.04222	0.11475
all males	12.703	23.764	3.2155	10.575	2.856	4.371	0.5531	2.0733	0.22373	0.4668	0.06452	0.19306

Table 11. Summary statistics for trawl survey biomass by decade, in 1,000s t.

												decade
		1970		1980		1990		2000		2010		2020
category	mean	max	mean	max	mean	max	mean	max	mean	max	mean	max
immature females	1.111	4.968	0.3149	0.8008	0.3763	1.118	0.09232	0.4773	0.02422	0.08408	0.000000	0.00000
mature females	6.787	13.154	24.4680	211.6037	2.9518	5.408	0.81884	1.8163	0.20584	0.41163	0.125969	0.26241
all females	3.949	13.154	12.3914	211.6037	1.6640	5.408	0.45558	1.8163	0.11503	0.41163	0.062984	0.26241
immature males	3.802	8.341	0.7711	2.0838	0.9836	2.004	0.13309	0.3258	0.07633	0.16471	0.007783	0.02392
mature males	24.612	42.618	5.7347	23.5529	4.0885	8.360	0.65383	2.0913	0.32571	0.64394	0.143889	0.40462
sublegal males	7.896	19.378	1.3954	4.9581	1.9477	3.567	0.23745	0.5649	0.14687	0.34967	0.029205	0.12211
legal males	20.518	40.366	5.1104	20.6786	3.1245	6.787	0.54947	1.7457	0.25518	0.45898	0.122467	0.29751
all males	28.414	46.395	6.5058	25.6367	5.0721	9.328	0.78692	2.2047	0.40204	0.80865	0.151672	0.41962

Table 12. Estimated annual abundance (millions of crab) of male PIBKC population components from the NMFS EBS trawl survey.

	immature males		mature males		sublegal males		legal males		all males	
year	est.	cv	est.	cv	est.	cv	est.	cv	est.	cv
1975	8.476	0.567	15.288	0.502	14.712	0.479	9.051	0.501	23.764	0.466
1976	4.960	0.954	4.782	0.445	5.729	0.882	4.012	0.471	9.742	0.589
1977	4.216	0.457	13.044	0.743	5.491	0.440	11.769	0.771	17.260	0.625
1978	2.421	0.502	6.141	0.496	4.639	0.419	3.923	0.616	8.562	0.428
1979	0.079	0.704	4.108	0.326	1.170	0.449	3.017	0.310	4.187	0.324
1980	2.733	0.466	7.842	0.408	4.331	0.458	6.244	0.420	10.575	0.400
1981	2.099	0.324	3.834	0.180	2.688	0.317	3.246	0.177	5.934	0.207
1982	1.371	0.281	2.354	0.181	1.654	0.255	2.071	0.188	3.725	0.172
1983	1.031	0.357	1.851	0.186	1.561	0.309	1.321	0.170	2.882	0.220
1984	0.518	0.397	0.771	0.225	0.730	0.290	0.558	0.247	1.288	0.212
1985	0.068	0.598	0.428	0.281	0.226	0.340	0.270	0.294	0.496	0.269
1986	0.019	1.000	0.480	0.305	0.039	0.698	0.460	0.313	0.499	0.298
1987	0.622	0.834	0.903	0.414	0.695	0.748	0.830	0.416	1.525	0.434
1988	1.238	0.842	0.238	0.509	1.238	0.842	0.238	0.509	1.476	0.708
1989	3.515	0.588	0.240	0.624	3.515	0.588	0.240	0.624	3.755	0.585
1990	2.450	0.596	1.470	0.626	3.349	0.596	0.572	0.538	3.920	0.578
1991	1.920	0.373	2.014	0.363	2.697	0.332	1.238	0.444	3.935	0.343
1992	2.436	0.588	1.935	0.420	3.217	0.520	1.154	0.453	4.371	0.475
1993	1.484	0.520	1.876	0.310	2.245	0.432	1.114	0.300	3.359	0.339
1994	0.639	0.374	1.294	0.341	0.998	0.343	0.935	0.345	1.933	0.332
1995	1.147	0.889	3.102	0.600	2.062	0.744	2.186	0.615	4.249	0.675
1996	0.719	0.625	1.712	0.281	1.162	0.547	1.269	0.263	2.431	0.334
1997	0.467	0.525	1.201	0.294	0.736	0.464	0.933	0.284	1.669	0.342
1998	0.949	0.458	0.967	0.246	1.119	0.414	0.797	0.253	1.917	0.309
1999	0.160	0.373	0.617	0.334	0.324	0.388	0.453	0.345	0.777	0.327
2000	0.164	0.563	0.725	0.296	0.361	0.385	0.528	0.297	0.889	0.312
2001	0.093	0.645	0.522	0.710	0.169	0.595	0.446	0.744	0.615	0.690
2002	0.000	0.000	0.225	0.473	0.018	1.000	0.207	0.495	0.225	0.473
2003	0.045	0.717	0.229	0.389	0.061	0.589	0.214	0.402	0.274	0.341
2004	0.088	0.590	0.048	0.563	0.120	0.460	0.016	1.000	0.136	0.417
2005	1.981	0.964	0.092	0.712	1.981	0.964	0.092	0.712	2.073	0.921

(continued)

	immature males		mature males		sublegal males		legal males		all males	
year	est.	cv	est.	cv	est.	cv	est.	cv	est.	cv
2006	0.138	0.495	0.056	0.564	0.155	0.503	0.038	0.699	0.194	0.419
2007	0.246	0.717	0.110	0.854	0.302	0.644	0.054	0.745	0.356	0.639
2008	0.234	0.928	0.018	1.000	0.234	0.928	0.018	1.000	0.252	0.862
2009	0.268	0.631	0.249	0.732	0.448	0.697	0.068	0.588	0.516	0.676
2010	0.101	0.841	0.130	0.486	0.167	0.728	0.065	0.482	0.232	0.608
2011	0.000	0.000	0.166	0.792	0.036	0.698	0.129	0.868	0.166	0.792
2012	0.195	1.000	0.272	0.797	0.303	1.000	0.164	0.678	0.467	0.879
2013	0.076	1.000	0.104	0.862	0.112	0.745	0.069	0.804	0.181	0.644
2014	0.091	0.591	0.092	0.710	0.091	0.591	0.092	0.710	0.183	0.566
2015	0.076	0.766	0.234	0.367	0.185	0.525	0.125	0.446	0.309	0.408
2016	0.094	0.517	0.056	0.563	0.131	0.458	0.019	1.000	0.150	0.488
2017	0.068	0.773	0.091	0.503	0.087	0.637	0.072	0.589	0.159	0.456
2018	0.110	0.572	0.056	0.563	0.110	0.572	0.056	0.563	0.166	0.521
2019	0.155	0.485	0.071	0.575	0.155	0.485	0.071	0.575	0.226	0.462
2021	0.019	1.000	0.174	0.495	0.078	0.600	0.115	0.568	0.193	0.516
2022	0.000	0.000	0.035	0.698	0.000	0.000	0.035	0.698	0.035	0.698
2023	0.033	0.699	0.000	0.000	0.033	0.699	0.000	0.000	0.033	0.699
2024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2025	0.000	0.000	0.062	0.702	0.000	0.000	0.062	0.702	0.062	0.702

Table 13. Estimated annual abundance (millions of crab) of female PIBKC population components from the NMFS EBS trawl survey.

	immature females		mature females		all females	
year	est.	cv	est.	cv	est.	cv
1975	0.000	0.000	13.148	0.608	13.148	0.608
1976	7.369	0.966	0.769	0.513	8.138	1.479
1977	0.852	0.825	13.880	0.860	14.732	1.685
1978	0.061	1.000	5.927	0.662	5.988	1.662
1979	0.142	0.719	1.169	0.812	1.311	1.530
1980	0.781	0.774	182.903	0.977	183.684	1.752
1981	0.827	0.408	5.433	0.437	6.260	0.845
1982	0.876	0.514	7.837	0.648	8.713	1.163
1983	0.464	0.545	9.308	0.780	9.772	1.325
1984	0.465	0.516	2.769	0.380	3.234	0.896
1985	0.260	0.541	0.486	0.437	0.746	0.978
1986	0.037	0.698	2.102	0.898	2.139	1.596
1987	0.402	0.743	0.670	0.584	1.072	1.327
1988	0.898	0.869	0.465	0.479	1.363	1.348
1989	2.636	0.738	1.142	0.659	3.778	1.397
1990	2.177	0.910	2.046	0.547	4.223	1.457
1991	0.805	0.463	2.767	0.416	3.572	0.879
1992	1.797	0.927	2.150	0.494	3.947	1.421
1993	0.881	0.606	1.783	0.445	2.664	1.051
1994	0.145	0.574	5.047	0.443	5.192	1.017
1995	0.658	0.920	4.039	0.521	4.697	1.441
1996	0.276	0.418	5.046	0.484	5.322	0.902
1997	0.320	0.669	2.614	0.423	2.934	1.091
1998	0.500	0.431	1.830	0.443	2.330	0.874
1999	0.000	0.000	2.756	0.490	2.756	0.490
2000	0.000	0.000	1.363	0.463	1.363	0.463
2001	0.019	1.000	1.697	0.753	1.716	1.753
2002	0.019	1.000	1.222	0.794	1.241	1.794
2003	0.067	0.483	1.120	0.764	1.187	1.247
2004	0.098	0.634	0.070	0.603	0.168	1.237
2005	2.268	1.000	0.289	0.565	2.557	1.565

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(continued)

	immature females		mature females		all females	
year	est.	cv	est.	cv	est.	cv
2006	0.113	0.548	0.430	0.766	0.543	1.315
2007	0.122	0.728	0.166	0.899	0.288	1.627
2008	0.342	0.898	0.437	0.658	0.779	1.556
2009	0.152	0.612	0.477	0.818	0.629	1.429
2010	0.166	0.558	0.249	0.691	0.415	1.249
2011	0.018	1.000	0.037	0.698	0.055	1.698
2012	0.035	1.000	0.312	0.764	0.347	1.764
2013	0.045	0.704	0.150	0.627	0.195	1.331
2014	0.028	1.000	0.074	0.604	0.102	1.604
2015	0.000	0.000	0.202	0.655	0.202	0.655
2016	0.095	0.515	0.359	0.520	0.454	1.035
2017	0.105	0.501	0.244	0.624	0.349	1.125
2018	0.020	1.000	0.114	0.614	0.134	1.614
2019	0.000	0.000	0.297	0.828	0.297	0.828
2021	0.000	0.000	0.229	0.671	0.229	0.671
2022	0.000	0.000	0.121	0.617	0.121	0.617
2023	0.000	0.000	0.117	1.000	0.117	1.000
2024	0.000	0.000	0.000	0.000	0.000	0.000
2025	0.000	0.000	0.091	1.000	0.091	1.000

Table 14. Estimated annual biomass (1,000s t) of male PIBKC population components from the NMFS EBS trawl survey.

	immature males		mature males		sublegal males		legal males		all males	
year	est.	cv	est.	cv	est.	cv	est.	cv	est.	cv
1975	8.341	0.525	38.054	0.501	19.378	0.466	27.016	0.499	46.395	0.475
1976	4.129	0.944	14.059	0.451	5.539	0.811	12.649	0.468	18.188	0.452
1977	3.713	0.443	42.618	0.768	5.966	0.463	40.366	0.784	46.332	0.729
1978	2.765	0.509	17.370	0.558	6.618	0.412	13.517	0.642	20.135	0.506
1979	0.061	0.785	10.959	0.315	1.981	0.452	9.040	0.311	11.021	0.315
1980	2.084	0.492	23.553	0.430	4.958	0.464	20.679	0.446	25.637	0.417
1981	1.704	0.299	11.628	0.174	2.779	0.297	10.554	0.175	13.332	0.175
1982	1.152	0.232	7.389	0.187	1.647	0.217	6.893	0.192	8.541	0.175
1983	0.962	0.357	5.409	0.178	1.897	0.297	4.474	0.175	6.371	0.187
1984	0.130	0.362	2.216	0.229	0.521	0.268	1.824	0.247	2.345	0.222
1985	0.039	0.733	1.055	0.267	0.338	0.374	0.755	0.283	1.094	0.263
1986	0.004	1.000	1.505	0.303	0.035	0.897	1.473	0.307	1.508	0.302
1987	0.191	0.783	2.923	0.411	0.334	0.536	2.781	0.414	3.115	0.397
1988	0.170	0.707	0.842	0.529	0.170	0.707	0.842	0.529	1.012	0.457
1989	1.275	0.620	0.827	0.637	1.275	0.620	0.827	0.637	2.102	0.551
1990	2.004	0.661	3.078	0.600	3.567	0.665	1.514	0.515	5.082	0.610
1991	1.377	0.386	4.690	0.386	2.741	0.336	3.326	0.450	6.067	0.373
1992	1.801	0.512	4.391	0.423	3.157	0.446	3.035	0.446	6.192	0.432
1993	1.088	0.545	4.556	0.307	2.442	0.409	3.203	0.301	5.644	0.305
1994	0.619	0.388	3.410	0.345	1.224	0.350	2.806	0.351	4.029	0.343
1995	0.968	0.863	8.360	0.604	2.541	0.673	6.787	0.615	9.328	0.629
1996	0.745	0.605	4.641	0.269	1.512	0.524	3.873	0.265	5.386	0.279
1997	0.381	0.545	3.233	0.276	0.849	0.451	2.765	0.271	3.614	0.294
1998	0.692	0.413	2.798	0.249	0.980	0.354	2.510	0.255	3.490	0.252
1999	0.161	0.402	1.729	0.337	0.464	0.414	1.426	0.347	1.890	0.333
2000	0.113	0.679	2.091	0.296	0.459	0.373	1.746	0.305	2.205	0.304
2001	0.087	0.764	1.599	0.735	0.225	0.628	1.461	0.759	1.686	0.733
2002	0.000	0.000	0.680	0.506	0.033	1.000	0.647	0.525	0.680	0.506
2003	0.019	0.984	0.702	0.400	0.050	0.723	0.671	0.411	0.721	0.390
2004	0.036	0.649	0.107	0.583	0.094	0.487	0.048	1.000	0.143	0.455
2005	0.326	0.942	0.344	0.710	0.326	0.942	0.344	0.710	0.670	0.589

(continued)

	immature males		mature males		sublegal males		legal males		all males	
year	est.	cv	est.	cv	est.	cv	est.	cv	est.	cv
2006	0.087	0.585	0.166	0.603	0.114	0.616	0.139	0.699	0.253	0.462
2007	0.197	0.737	0.306	0.798	0.298	0.632	0.206	0.734	0.503	0.661
2008	0.212	0.952	0.046	1.000	0.212	0.952	0.046	1.000	0.258	0.797
2009	0.254	0.680	0.497	0.713	0.565	0.740	0.187	0.604	0.751	0.698
2010	0.092	0.853	0.303	0.461	0.205	0.702	0.190	0.483	0.395	0.522
2011	0.000	0.000	0.461	0.843	0.062	0.705	0.399	0.886	0.461	0.843
2012	0.165	1.000	0.644	0.735	0.350	1.000	0.459	0.643	0.809	0.786
2013	0.015	1.000	0.250	0.797	0.075	0.824	0.190	0.752	0.265	0.754
2014	0.083	0.623	0.233	0.699	0.083	0.623	0.233	0.699	0.317	0.567
2015	0.082	0.747	0.622	0.394	0.275	0.494	0.428	0.458	0.703	0.395
2016	0.071	0.486	0.130	0.613	0.133	0.495	0.068	1.000	0.201	0.515
2017	0.046	0.767	0.255	0.514	0.076	0.599	0.224	0.573	0.300	0.470
2018	0.096	0.540	0.154	0.571	0.096	0.540	0.154	0.571	0.249	0.522
2019	0.115	0.542	0.206	0.604	0.115	0.542	0.206	0.604	0.321	0.504
2021	0.015	1.000	0.405	0.503	0.122	0.653	0.298	0.576	0.420	0.512
2022	0.000	0.000	0.112	0.702	0.000	0.000	0.112	0.702	0.112	0.702
2023	0.024	1.000	0.000	0.000	0.024	1.000	0.000	0.000	0.024	1.000
2024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2025	0.000	0.000	0.203	0.704	0.000	0.000	0.203	0.704	0.203	0.704

Table 15. Estimated annual biomass (1,000s t) of female PIBKC population components from the NMFS EBS trawl survey.

	immature females		mature females		all females	
year	est.	cv	est.	cv	est.	cv
1975	0.000	0.000	12.442	0.636	12.442	0.636
1976	4.968	0.972	0.824	0.532	5.792	1.504
1977	0.419	0.829	13.154	0.875	13.573	1.704
1978	0.076	1.000	6.416	0.725	6.492	1.725
1979	0.092	0.730	1.097	0.793	1.189	1.523
1980	0.699	0.865	211.604	0.984	212.303	1.849
1981	0.497	0.413	5.987	0.469	6.484	0.882
1982	0.553	0.572	8.824	0.678	9.377	1.250
1983	0.258	0.607	9.990	0.791	10.248	1.398
1984	0.015	0.688	3.070	0.381	3.085	1.069
1985	0.005	0.457	0.520	0.448	0.525	0.905
1986	0.011	0.727	2.420	0.901	2.431	1.628
1987	0.119	0.855	0.795	0.583	0.914	1.439
1988	0.190	0.788	0.528	0.491	0.718	1.279
1989	0.801	0.666	0.945	0.581	1.746	1.246
1990	1.118	0.928	1.810	0.508	2.928	1.436
1991	0.343	0.475	2.433	0.414	2.776	0.889
1992	0.802	0.961	1.848	0.480	2.650	1.441
1993	0.444	0.624	1.647	0.461	2.091	1.085
1994	0.087	0.570	4.806	0.447	4.893	1.016
1995	0.331	0.904	3.948	0.519	4.279	1.423
1996	0.177	0.415	5.408	0.502	5.585	0.917
1997	0.194	0.659	2.835	0.429	3.029	1.089
1998	0.267	0.425	1.914	0.441	2.181	0.866
1999	0.000	0.000	2.868	0.467	2.868	0.467
2000	0.000	0.000	1.462	0.460	1.462	0.460
2001	0.000	1.000	1.816	0.722	1.816	1.722
2002	0.000	1.000	1.401	0.776	1.401	1.776
2003	0.021	0.667	1.286	0.745	1.307	1.412
2004	0.025	0.821	0.098	0.597	0.123	1.418
2005	0.477	1.000	0.370	0.570	0.847	1.570

(continued)

	immature females		mature females		all females	
year	est.	cv	est.	cv	est.	cv
2006	0.038	0.602	0.538	0.760	0.576	1.362
2007	0.059	0.792	0.223	0.876	0.282	1.668
2008	0.222	0.901	0.450	0.635	0.672	1.537
2009	0.080	0.660	0.545	0.849	0.625	1.509
2010	0.084	0.578	0.310	0.660	0.394	1.238
2011	0.003	1.000	0.034	0.725	0.037	1.725
2012	0.009	1.000	0.229	0.660	0.238	1.660
2013	0.012	0.722	0.154	0.700	0.166	1.422
2014	0.016	1.000	0.091	0.605	0.107	1.605
2015	0.000	0.000	0.160	0.662	0.160	0.662
2016	0.050	0.490	0.354	0.493	0.404	0.983
2017	0.055	0.501	0.206	0.591	0.261	1.092
2018	0.013	1.000	0.108	0.725	0.121	1.725
2019	0.000	0.000	0.412	0.859	0.412	0.859
2021	0.000	0.000	0.262	0.632	0.262	0.632
2022	0.000	0.000	0.146	0.663	0.146	0.663
2023	0.000	0.000	0.119	1.000	0.119	1.000
2024	0.000	0.000	0.000	0.000	0.000	0.000
2025	0.000	0.000	0.102	1.000	0.102	1.000

Table 16. Maximum objective function gradient after SS/RE RW model optimization, by “zeros option”.

[H]

zeros option	max gradient
0’s as NAs	2.2e-14
small constant	3.4e-14
Tweedie	1.1e-11

Table 17. Maximum objective function gradient after SS/RE RW model optimization, by "zeros option".

	0's as NAs			small constant			Tweedie		
parameter	estimate	lci	uci	estimate	lci	uci	estimate	lci	uci
process_error	0.42	0.3347	0.5268	1.396	1.115	1.747	0.3903	0.3103	0.4909
tweedie_p	–	–	–	–	–	–	1.4854	1.2363	1.7420

Table 18. "Zeros as NAs" model fits to mature male survey biomass (in t). lci: lower confidence bound; uci: upper confidence bound; observed: design-based survey estimates; base: model results from last assessment; model: "Zeros as NAs" model results. Confidence intervals are 80 percent.

	value			lci			uci		
year	observed	base	model	observed	base	model	observed	base	model
1975	38054	27014	26546	20760	16993	16710	69754	42944	42172
1976	14059	20468	19983	8104	13798	13499	24391	30363	29580
1977	42618	22406	21038	17814	14440	13594	101958	34768	32558
1978	17370	19078	16929	8912	12779	11403	33852	28482	25134
1979	10959	17294	13397	7386	12456	9835	16262	24012	18251
1980	23553	16871	15404	13894	11983	10979	39925	23752	21612
1981	11628	11525	11389	9321	9451	9341	14507	14055	13887
1982	7389	7458	7446	5825	6068	6062	9373	9166	9145
1983	5409	5068	5062	4316	4150	4147	6778	6190	6179
1984	2216	2357	2361	1659	1852	1857	2959	2999	3002
1985	1055	1365	1371	754	1034	1040	1476	1801	1808
1986	1505	1559	1561	1030	1163	1166	2199	2090	2090
1987	2923	1917	1913	1761	1351	1351	4853	2720	2709
1988	842	1446	1454	446	965	972	1591	2167	2174
1989	827	1623	1632	392	1051	1060	1749	2505	2513
1990	3078	2604	2605	1513	1730	1735	6261	3920	3911
1991	4690	3787	3777	2910	2671	2668	7556	5369	5347
1992	4391	4164	4157	2612	2942	2942	7382	5895	5874
1993	4556	4319	4315	3100	3202	3203	6694	5826	5813
1994	3410	4025	4027	2220	2923	2929	5240	5541	5536
1995	8360	4898	4880	4091	3331	3329	17086	7201	7155
1996	4641	4366	4359	3309	3310	3308	6509	5758	5743
1997	3233	3322	3321	2284	2530	2533	4575	4361	4356
1998	2798	2703	2702	2043	2088	2089	3833	3498	3493
1999	1729	1981	1983	1136	1460	1464	2631	2688	2686
2000	2091	1827	1824	1443	1355	1354	3031	2464	2456
2001	1599	1259	1257	689	833	834	3710	1904	1894
2002	680	785	785	369	532	533	1254	1158	1156
2003	702	548	548	428	383	384	1150	785	784

(continued)

		value			lci			uci	
year	observed	base	model	observed	base	model	observed	base	model
2004	107	284	286	53	184	186	214	437	439
2005	344	268	269	152	171	172	780	421	421
2006	166	228	229	81	145	146	339	356	357
2007	306	232	233	125	144	145	753	374	375
2008	46	214	215	16	129	131	134	353	354
2009	497	294	294	219	187	187	1130	463	461
2010	303	321	321	173	215	215	532	479	478
2011	461	370	369	180	232	233	1180	588	585
2012	644	395	394	277	247	247	1496	631	628
2013	250	344	344	102	216	216	615	549	547
2014	233	337	337	104	217	218	524	522	520
2015	622	390	388	382	270	269	1011	563	560
2016	130	251	251	63	166	167	267	379	379
2017	255	234	235	137	157	157	473	350	350
2018	154	206	206	78	135	136	303	314	314
2019	206	218	218	101	139	140	421	342	341
2020	NA	238	238	NA	140	141	NA	405	402
2021	405	261	260	220	166	168	743	410	404
2022	112	201	201	50	116	122	252	348	333
2023	NA	201	202	NA	92	107	NA	436	380
2024	NA	–	202	NA	–	103	NA	–	397
2025	203	–	202	90	–	106	457	–	387

Table 19. "Small constant" model fits to mature male survey biomass (in t; 1975-2019). lci: lower confidence bound; uci: upper confidence bound; observed: design-based survey estimates; base: model results from last assessment; model: "small constant" model results. Confidence intervals are 80 percent.

	value			lci			uci		
year	observed	base	model	observed	base	model	observed	base	model
1975	38054	27014	34833	20760	16993	19558	69754	42944	62038
1976	14059	20468	16124	8104	13798	9660	24391	30363	26914
1977	42618	22406	31635	17814	14440	15183	101958	34768	65913
1978	17370	19078	17732	8912	12779	9761	33852	28482	32212
1979	10959	17294	11529	7386	12456	7894	16262	24012	16837
1980	23553	16871	21202	13894	11983	12993	39925	23752	34596
1981	11628	11525	11654	9321	9451	9371	14507	14055	14493
1982	7389	7458	7406	5825	6068	5862	9373	9166	9357
1983	5409	5068	5361	4316	4150	4292	6778	6190	6696
1984	2216	2357	2225	1659	1852	1678	2959	2999	2951
1985	1055	1365	1094	754	1034	790	1476	1801	1515
1986	1505	1559	1519	1030	1163	1055	2199	2090	2186
1987	2923	1917	2586	1761	1351	1609	4853	2720	4158
1988	842	1446	959	446	965	539	1591	2167	1706
1989	827	1623	988	392	1051	513	1749	2505	1906
1990	3078	2604	2813	1513	1730	1502	6261	3920	5266
1991	4690	3787	4525	2910	2671	2887	7556	5369	7092
1992	4391	4164	4409	2612	2942	2722	7382	5895	7141
1993	4556	4319	4504	3100	3202	3114	6694	5826	6515
1994	3410	4025	3592	2220	2923	2386	5240	5541	5405
1995	8360	4898	7030	4091	3331	3751	17086	7201	13174
1996	4641	4366	4650	3309	3310	3351	6509	5758	6453
1997	3233	3322	3257	2284	2530	2329	4575	4361	4553
1998	2798	2703	2774	2043	2088	2043	3833	3498	3766
1999	1729	1981	1785	1136	1460	1198	2631	2688	2661
2000	2091	1827	2049	1443	1355	1433	3031	2464	2931
2001	1599	1259	1472	689	833	725	3710	1904	2989
2002	680	785	727	369	532	416	1254	1158	1269
2003	702	548	634	428	383	399	1150	785	1009
2004	107	284	146	53	184	79	214	437	273
2005	344	268	277	152	171	137	780	421	558
2006	166	228	184	81	145	97	339	356	347
2007	306	232	233	125	144	109	753	374	496

(continued)

		value			lci			uci	
year	observed	base	model	observed	base	model	observed	base	model
2008	46	214	99	16	129	42	134	353	235
2009	497	294	366	219	187	180	1130	463	743
2010	303	321	318	173	215	189	532	479	535
2011	461	370	444	180	232	205	1180	588	959
2012	644	395	537	277	247	261	1496	631	1107
2013	250	344	288	102	216	136	615	549	613
2014	233	337	272	104	217	136	524	522	545
2015	622	390	541	382	270	342	1011	563	858
2016	130	251	166	63	166	88	267	379	315
2017	255	234	234	137	157	133	473	350	412
2018	154	206	166	78	135	91	303	314	306
2019	206	218	206	101	139	108	421	342	394

Table 20. "Small constant" model fits to mature male survey biomass (in t; 2020-2023). lci: lower confidence bound; uci: upper confidence bound; observed: design-based survey estimates; base: model results from last assessment; model: "small constant" model results. Confidence intervals are 80 percent.

	value			lci			uci		
year	observed	base	model	observed	base	model	observed	base	model
2020	*NA*	238.3904	257.2118	*NA*	140.2626	67.2982	*NA*	405.1686	983.0569
2021	404.6204	260.8362	320.8567	220.2023	165.8087	180.4136	743.4874	410.3256	570.6281
2022	112.1007	200.5591	53.9348	49.7997	115.5261	26.4056	252.3422	348.1805	110.1644
2023	0.0100	200.5591	0.2593	0.0025	92.3354	0.0697	0.0402	435.6288	0.9639
2024	0.0100	–	0.2701	0.0025	–	0.0738	0.0402	–	0.9892
2025	202.7218	–	65.2565	89.9264	–	29.0391	456.9973	–	146.6443

Table 21. "Tweedie" model fits to mature male survey biomass (in t). lci: lower confidence bound; uci: upper confidence bound; observed: design-based survey estimates; base: model results from last assessment; model: "Tweedie" model results. Confidence intervals are 80 percent.

		value			lci			uci	
year	observed	base	model	observed	base	model	observed	base	model
1975	38054	27014	26717	20760	16993	17678	69754	42944	40376
1976	14059	20468	20987	8104	13798	13828	24391	30363	31853
1977	42618	22406	21435	17814	14440	14526	101958	34768	31632
1978	17370	19078	16926	8912	12779	11505	33852	28482	24902
1979	10959	17294	13727	7386	12456	9847	16262	24012	19137
1980	23553	16871	15482	13894	11983	11522	39925	23752	20801
1981	11628	11525	11300	9321	9451	9319	14507	14055	13702
1982	7389	7458	7388	5825	6068	6029	9373	9166	9053
1983	5409	5068	5012	4316	4150	4147	6778	6190	6059
1984	2216	2357	2391	1659	1852	1861	2959	2999	3072
1985	1055	1365	1461	754	1034	1059	1476	1801	2016
1986	1505	1559	1606	1030	1163	1188	2199	2090	2171
1987	2923	1917	2033	1761	1351	1485	4853	2720	2783
1988	842	1446	1742	446	965	1093	1591	2167	2774
1989	827	1623	1959	392	1051	1193	1749	2505	3217
1990	3078	2604	2728	1513	1730	1817	6261	3920	4097
1991	4690	3787	3740	2910	2671	2723	7556	5369	5137
1992	4391	4164	4047	2612	2942	2912	7382	5895	5624
1993	4556	4319	4227	3100	3202	3171	6694	5826	5635
1994	3410	4025	4034	2220	2923	2904	5240	5541	5605
1995	8360	4898	4838	4091	3331	3458	17086	7201	6769
1996	4641	4366	4277	3309	3310	3294	6509	5758	5554
1997	3233	3322	3271	2284	2530	2501	4575	4361	4277
1998	2798	2703	2659	2043	2088	2072	3833	3498	3413
1999	1729	1981	1972	1136	1460	1445	2631	2688	2691
2000	2091	1827	1783	1443	1355	1353	3031	2464	2349
2001	1599	1259	1225	689	833	831	3710	1904	1804
2002	680	785	799	369	532	537	1254	1158	1189
2003	702	548	591	428	383	415	1150	785	842

(continued)

	value			lci			uci		
year	observed	base	model	observed	base	model	observed	base	model
2004	107	284	377	53	184	228	214	437	623
2005	344	268	314	152	171	192	780	421	514
2006	166	228	265	81	145	158	339	356	446
2007	306	232	268	125	144	160	753	374	446
2008	46	214	272	16	129	159	134	353	465
2009	497	294	319	219	187	207	1130	463	491
2010	303	321	324	173	215	216	532	479	485
2011	461	370	358	180	232	231	1180	588	554
2012	644	395	386	277	247	252	1496	631	589
2013	250	344	350	102	216	217	615	549	565
2014	233	337	354	104	217	226	524	522	556
2015	622	390	411	382	270	298	1011	563	566
2016	130	251	284	63	166	182	267	379	443
2017	255	234	245	137	157	161	473	350	372
2018	154	206	214	78	135	135	303	314	340
2019	206	218	221	101	139	139	421	342	351
2020	NA	238	243	NA	140	148	NA	405	400
2021	405	261	268	220	166	180	743	410	399
2022	112	201	219	50	116	127	252	348	378
2023	0	201	212	NA	92	111	NA	436	405
2024	0	–	205	NA	–	103	NA	–	408
2025	203	–	198	90	–	100	457	–	391

Table 22. Brief description of the sdmTMB model, “ar1S_nullT_logDepth_km080b”.

model	distribution type	link	spatiotemporal	spatial	temporal	covariates	mesh
sdmTMB	Tweedie	log	AR(1)	on	off	log(bottom depth)	k=80 means w/ barriers

Table 23. Results from `sdmTMB` "sanity" function for the sdmTMB model. "sanity" checks that 1) the minimizer exited correctly; 2) all fixed-effects gradients were very small; 3) the hessian was positive-definite; 4) the eigenvalues were not extremely large or small; 5) no standard errors were unreasonably large; 6) no fixed-effect standard errors were unreasonably large; 7) no variance parameters are extremely large or small; 8) the spatial range parameter is not extremely large.

finished	minimizer	gradients	hessian	eigenvalues	se magnitude	fixed effects NAs	sigmas	range
true	ok	ok	ok	ok	ok	no NAs	ok	ok

Table 24. Summary model results. Confidence intervals are 95%.

term	estimate	lower CI	upper CI	description
β	0.27	-3.63	4.17	coefficient for smooth function of ln(depth)
ϕ	0.15	0.12	0.18	dispersion parameter
p_{TW}	1.15	1.12	1.18	Tweedie mixing parameter
Matern range	194.44	164.24	230.20	spatial correlaton range
σ_o	66.57	48.58	91.23	spatial std. dev.
ρ	0.78	0.68	0.85	spatiotemporal AR1 correlation
σ_E	47.39	35.46	63.33	spatiotemporal marginal AR1 SD

Table 25. Significant Moran's I values for the scaled DHARMa residuals, by year, based on Monte-Carlo permutation statistics. p-values < 0.05 were taken as indicating significant spatial autocorrelation. Values in other years were not significant

year	statistic	p value
2000	0.0709579	0.043956
2001	0.0644789	0.047952
2012	0.0745767	0.025974
2013	0.0988919	0.016983
2021	0.0645912	0.044955

Table 26. Design- and model-based estimates of survey MMB.

	design-based			rema			sdmTMB E			sdmTMB 0			sdmTMB 1			
year	value	lwr	upr	value	lwr	upr	value	lwr	upr	value	lwr	upr	value	lwr	upr	value
1975	38,054	20,760	69,754	26,546	16,710	42,172	24,477	21,988	27,247	26,295	21,284	32,487	26,388	21,351	32,613	26,278
1976	14,059	8,104	24,391	19,983	13,499	29,580	9,921	8,467	11,625	15,362	11,893	19,845	15,450	11,957	19,963	15,319
1977	42,618	17,814	101,958	21,038	13,594	32,558	27,329	24,564	30,405	19,807	16,181	24,244	19,890	16,242	24,357	19,819
1978	17,370	8,912	33,852	16,929	11,403	25,134	11,609	10,016	13,457	11,234	8,885	14,204	11,304	8,939	14,293	11,229
1979	10,959	7,386	16,262	13,397	9,835	18,251	7,862	6,610	9,350	22,555	16,058	31,680	22,618	16,099	31,777	22,527
1980	23,553	13,894	39,925	15,404	10,979	21,612	15,816	13,975	17,901	19,729	16,182	24,055	19,792	16,230	24,135	19,700
1981	11,628	9,321	14,507	11,389	9,341	13,887	10,761	9,416	12,298	12,698	9,792	16,467	12,717	9,812	16,482	12,600
1982	7,389	5,825	9,373	7,446	6,062	9,145	6,956	5,913	8,184	9,860	6,700	14,510	9,827	6,687	14,442	9,717
1983	5,409	4,316	6,778	5,062	4,147	6,179	5,139	4,284	6,164	6,124	4,347	8,629	6,110	4,345	8,590	6,028
1984	2,216	1,659	2,959	2,361	1,857	3,002	2,041	1,568	2,657	2,134	1,522	2,992	2,150	1,537	3,007	2,094
1985	1,055	754	1,476	1,371	1,040	1,808	1,045	744	1,466	927	648	1,326	965	675	1,381	920
1986	1,505	1,030	2,199	1,561	1,166	2,090	1,345	991	1,824	1,116	805	1,548	1,157	834	1,605	1,113
1987	2,923	1,761	4,853	1,913	1,351	2,709	2,217	1,737	2,830	1,869	1,406	2,485	1,915	1,440	2,548	1,870
1988	842	446	1,591	1,454	972	2,174	703	474	1,044	621	411	939	655	433	990	619
1989	827	392	1,749	1,632	1,060	2,513	690	461	1,032	545	361	822	580	384	875	543
1990	3,078	1,513	6,261	2,605	1,735	3,911	2,665	2,061	3,447	1,937	1,453	2,580	1,985	1,490	2,644	1,928
1991	4,690	2,910	7,556	3,777	2,668	5,347	4,373	3,553	5,381	3,327	2,628	4,211	3,395	2,682	4,297	3,309
1992	4,391	2,612	7,382	4,157	2,942	5,874	4,023	3,259	4,967	2,796	2,198	3,555	2,852	2,243	3,628	2,790
1993	4,556	3,100	6,694	4,315	3,203	5,813	3,961	3,230	4,857	2,923	2,323	3,678	2,984	2,371	3,755	2,916
1994	3,410	2,220	5,240	4,027	2,929	5,536	3,188	2,544	3,996	2,298	1,804	2,929	2,354	1,847	3,000	2,296
1995	8,360	4,091	17,086	4,880	3,329	7,155	7,694	6,498	9,110	4,433	3,638	5,403	4,500	3,693	5,484	4,428
1996	4,641	3,309	6,509	4,359	3,308	5,743	4,059	3,339	4,934	3,054	2,468	3,780	3,115	2,516	3,856	3,045
1997	3,233	2,284	4,575	3,321	2,533	4,356	2,871	2,289	3,599	2,223	1,745	2,832	2,269	1,782	2,891	2,214
1998	2,798	2,043	3,833	2,702	2,089	3,493	2,492	1,958	3,173	1,947	1,500	2,529	1,982	1,527	2,572	1,935
1999	1,729	1,136	2,631	1,983	1,464	2,686	1,626	1,211	2,184	1,255	923	1,705	1,289	949	1,751	1,245
2000	2,091	1,443	3,031	1,824	1,354	2,456	1,746	1,323	2,305	1,335	996	1,791	1,371	1,022	1,838	1,331
2001	1,599	689	3,710	1,257	834	1,894	1,417	1,010	1,988	789	553	1,126	823	577	1,174	786
2002	680	369	1,254	785	533	1,156	634	400	1,006	427	267	681	456	286	728	423
2003	702	428	1,150	548	384	784	679	431	1,069	429	272	677	463	293	731	427
2004	107	53	214	286	186	439	167	78	357	124	59	258	152	73	318	122
2005	344	152	780	269	172	421	284	151	533	175	93	327	205	110	383	173

(continued)

	design-based			rema			sdmTMB E			sdmTMB 0			sdmTMB 1			
year	value	lwr	upr	value	lwr	upr	value	lwr	upr	value	lwr	upr	value	lwr	upr	value
2006	166	81	339	229	146	357	189	90	398	121	58	251	151	73	315	120
2007	306	125	753	233	145	375	258	131	509	140	71	277	173	88	340	139
2008	46	16	134	215	131	354	113	45	282	75	31	183	107	44	261	74
2009	497	219	1,130	294	187	461	423	241	741	247	139	439	285	160	505	246
2010	303	173	532	321	215	478	339	184	624	220	119	406	261	141	483	217
2011	461	180	1,180	369	233	585	466	268	812	256	144	454	298	168	530	253
2012	644	277	1,496	394	247	628	582	354	954	356	214	595	402	241	670	354
2013	250	102	615	344	216	547	236	123	453	210	110	399	258	135	492	208
2014	233	104	524	337	218	520	226	119	431	183	97	347	222	117	421	182
2015	622	382	1,011	388	269	560	499	313	797	400	249	642	442	276	710	398
2016	130	63	267	251	167	379	166	80	346	132	64	270	168	82	345	130
2017	255	137	473	235	157	350	227	117	439	162	85	309	199	104	380	160
2018	154	78	303	206	136	314	153	73	319	144	68	302	184	87	387	142
2019	206	101	421	218	140	341	205	101	416	165	82	332	208	103	420	163
2020	NA	NA	NA	238	141	402	–	–	–	287	66	1,255	328	76	1,417	285
2021	405	220	743	260	168	404	329	184	590	227	127	406	265	148	473	225
2022	112	50	252	201	122	333	109	47	258	79	34	181	113	49	262	77
2023	NA	NA	NA	202	107	380	40	12	134	36	11	113	68	20	226	35
2024	NA	NA	NA	202	103	397	40	11	142	50	15	173	83	24	292	49
2025	203	90	457	202	106	387	134	51	349	143	54	379	181	69	476	141

Table 27. Components in the calculation of the MMB-at-mating time series, as well as MMB-at-mating calculated for the last assessment. Fishing mortality is only on mature males. All values are in t.

year	MMB at survey	MMB before fishery	fishing mortality	MMB after fishery	MMB-at-mating	last assmt
1975	26387.81	25226.68	$1.104e+03$	24122.68	22717.89	23281.7
1976	15449.60	14769.77	$2.999e+03$	11770.77	11085.30	15603.4
1977	19889.63	19014.44	$2.929e+03$	16085.44	15148.70	17414.6
1978	11303.67	10806.28	$2.901e+03$	7905.28	7444.91	14444.2
1979	22618.26	21623.00	$2.719e+03$	18904.00	17803.11	13009.6
1980	19791.95	18921.05	$4.976e+03$	13945.05	13132.95	10502.9
1981	12716.66	12157.10	$4.119e+03$	8038.10	7570.00	6497.2
1982	9827.35	9394.92	$1.998e+03$	7396.92	6966.16	4833.1
1983	6109.79	5840.94	$9.950e+02$	4845.94	4563.74	3626.1
1984	2150.18	2055.56	$1.390e+02$	1916.56	1804.95	1991.0
1985	965.04	922.58	$2.400e+02$	682.58	642.83	1002.7
1986	1156.90	1106.00	$1.170e+02$	989.00	931.40	1293.6
1987	1915.47	1831.19	$3.180e+02$	1513.19	1425.06	1426.5
1988	654.73	625.92	$0.000e+00$	625.92	589.47	1302.0
1989	579.87	554.36	$0.000e+00$	554.36	522.07	1461.0
1990	1984.67	1897.34	$0.000e+00$	1897.34	1786.85	2344.5
1991	3394.89	3245.51	$2.486e+00$	3243.02	3054.16	3407.0
1992	2852.49	2726.97	$2.440e+01$	2702.57	2545.18	3726.1
1993	2983.53	2852.25	$1.369e+01$	2838.55	2673.25	3875.6
1994	2353.77	2250.20	$2.746e+00$	2247.45	2116.57	3620.8
1995	4500.09	4302.08	$6.285e+02$	3673.55	3459.62	3817.6
1996	3114.73	2977.67	$4.250e+02$	2552.64	2403.99	3530.6
1997	2269.49	2169.63	$2.322e+02$	1937.43	1824.60	2771.9
1998	1981.80	1894.59	$2.365e+02$	1658.12	1561.56	2210.5
1999	1289.04	1232.32	$7.862e-01$	1231.54	1159.82	1783.0
2000	1370.65	1310.33	$2.097e-02$	1310.31	1234.01	1645.1
2001	823.02	786.80	$9.507e-02$	786.71	740.89	1133.5
2002	456.10	436.03	$1.261e-01$	435.90	410.52	706.6
2003	463.13	442.75	$1.252e-01$	442.62	416.85	493.7
2004	152.42	145.71	$8.217e-02$	145.63	137.15	255.2
2005	204.90	195.88	$5.711e-01$	195.31	183.94	241.2
2006	151.50	144.83	$4.334e-02$	144.79	136.35	204.9
2007	172.61	165.01	$4.523e-01$	164.56	154.98	208.5
2008	106.70	102.01	$2.035e-01$	101.81	95.88	192.2
2009	284.57	272.04	$1.043e-01$	271.94	256.10	264.6
2010	261.07	249.58	$2.695e-02$	249.55	235.02	288.8
2011	298.49	285.36	$1.401e-02$	285.34	268.73	332.7
2012	401.67	383.99	$2.845e-01$	383.71	361.36	355.3

(continued)

year	MMB at survey	MMB before fishery	fishing mortality	MMB after fishery	MMB-at-mating	last assmt
2013	257.55	246.22	$6.464e-03$	246.21	231.87	309.7
2014	221.89	212.12	$1.447e-02$	212.11	199.76	303.2
2015	442.31	422.85	$3.975e-01$	422.45	397.85	350.4
2016	167.78	160.40	$1.914e-01$	160.21	150.88	225.4
2017	198.69	189.95	$1.516e-01$	189.80	178.74	210.9
2018	183.83	175.74	$1.901e-01$	175.55	165.33	185.1
2019	208.11	198.95	$2.106e-01$	198.74	187.17	196.0
2020	327.61	313.20	$7.560e-04$	313.20	294.96	214.6
2021	264.55	252.91	$4.648e-02$	252.86	238.14	234.8
2022	112.89	107.92	$1.278e-01$	107.79	101.52	180.4
2023	67.87	64.88	$4.526e-02$	64.84	61.06	–
2024	83.31	79.64	$1.431e-02$	79.63	74.99	–
2025	180.61	172.66	–	–	–	–

Table 28. Values required to determine the Tier 4 OFL.

	quantity	value	units	description
1	MMB_s	181	t	current survey MMB
2	B_{MSY}	4,146	t	Tier 4 B_{MSY} proxy
3	θ	0.00073	–	mean MMB exploitaion ratio
4	M	0.18	$year^{-1}$	assumed natural mortality
5	γ	1	–	control rule parameter
6	α	0.1	–	control rule parameter
7	β	0.25	–	control rule parameter
8	t_{sf}	0.25	years	time from survey to fishery
9	t_{fm}	0.333	years	time from survey to fishery

Table 29. Results from the Tier 4 OFL determination. RM_{OFL} = retained catch portion of the OFL, DM_{OFL} = discard mortality portion of the OFL used to determine B ("current") MMB-at-mating for 2025/26.

	quantity	units	value
1	B	t	162
2	B_{MSY}	t	4,146
3	stock status	–	overfished
4	F_{OFL}	$year^{-1}$	0
5	RM_{OFL}	t	0
6	DM_{OFL}	t	0.252
7	OFL	t	0.252

Figures

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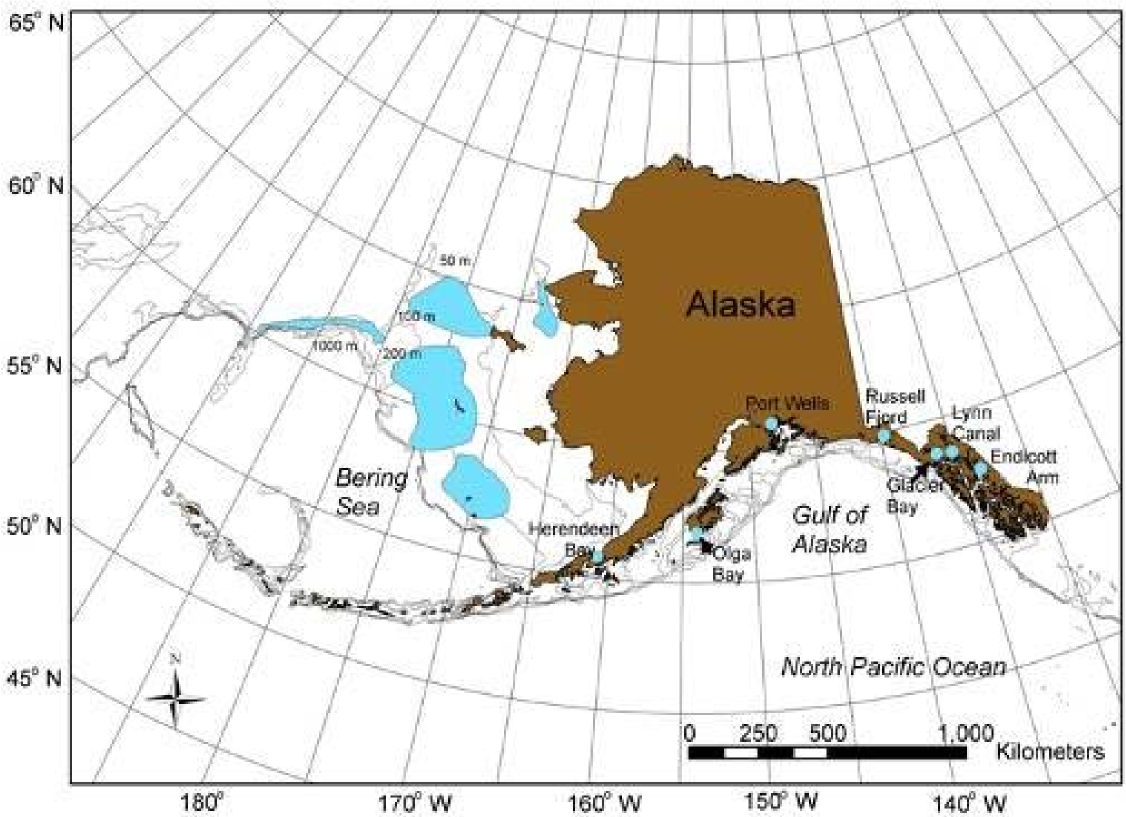

Figure 1. Distribution of blue king crab, *Paralithodesplatypus*, in Alaskan waters.

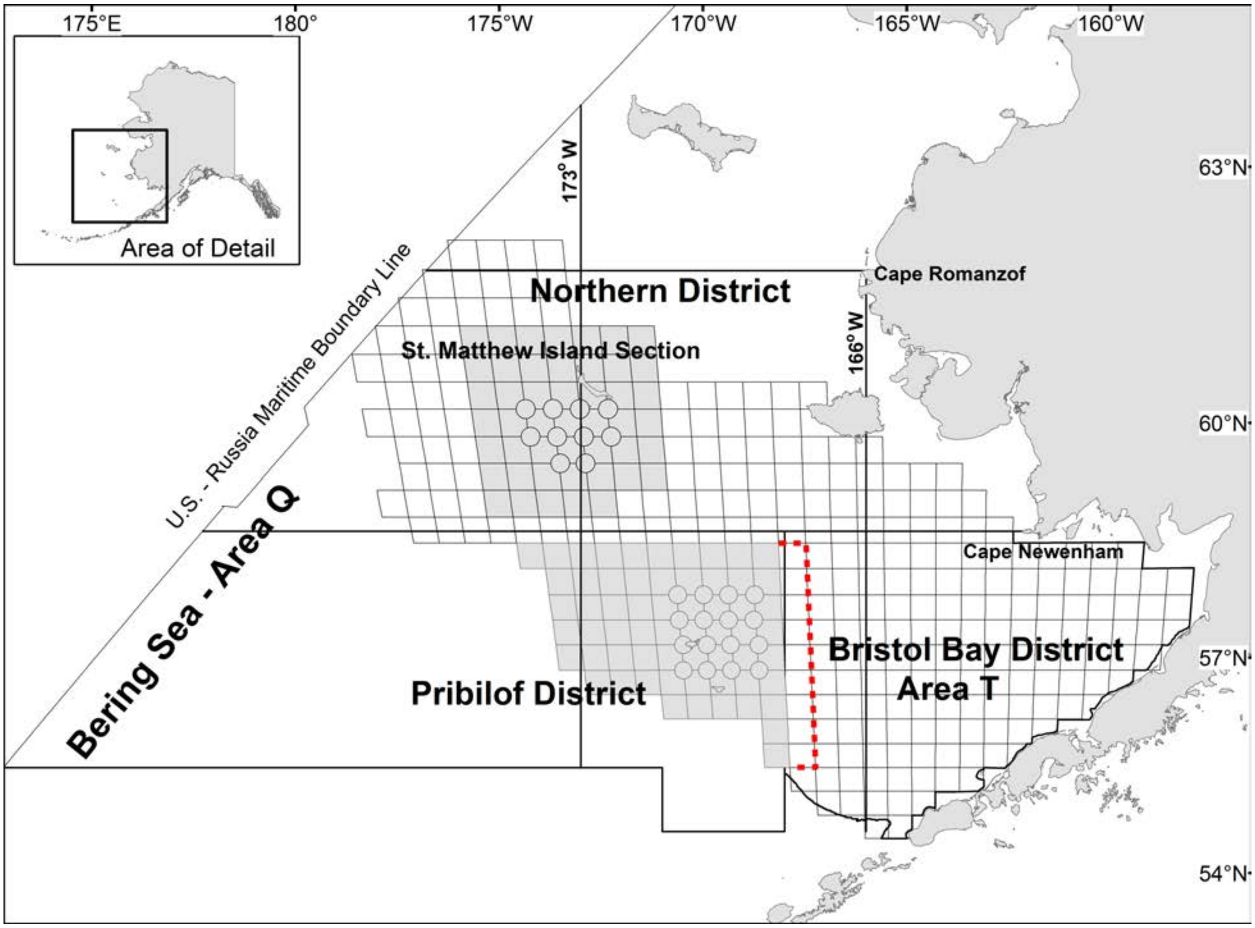

Figure 2. Map of the ADF&G King Crab Registration Area Q (Bering Sea), showing (among others) the Pribilof District, which constitutes the stock boundary for PIBKC. The figure also indicates NMFS EBS Shelf survey grid (squares and circles), the original area used to calculate survey biomass and fishery catch data (shded in grey) in the Pribilof District, and the additional 20nm strip (red dotted line) added in 2013.

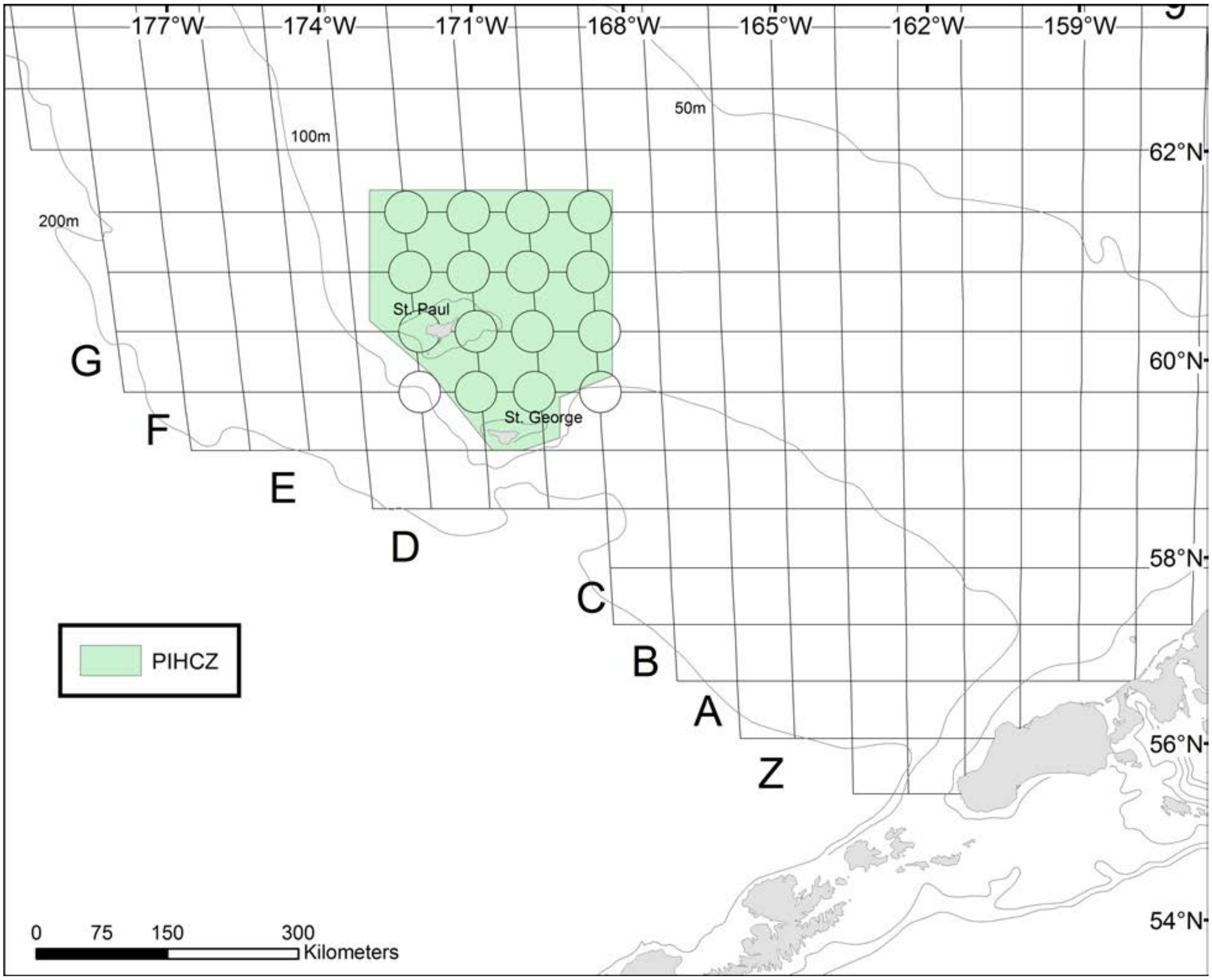

Figure 3. The shaded area shows the Pribilof Islands Habitat Conservation Zone (PIHCZ). Trawl fishing is prohibited year-round in this zone (as of 1995), as is pot fishing for Pacific cod (as of 2015). Also shown is a portion of the NMFS annual EBS bottom trawl survey grid (squares and circles).

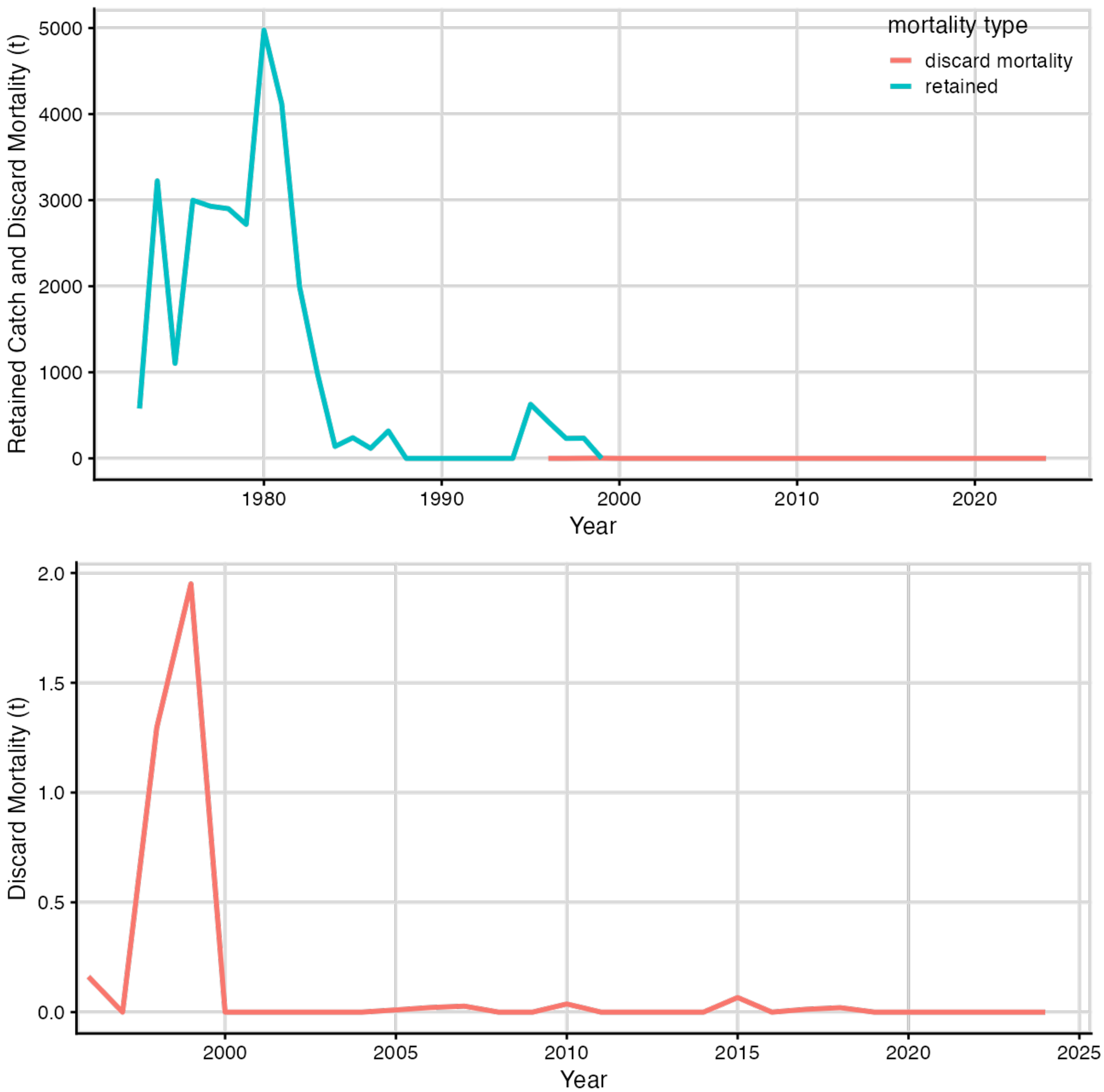

Figure 4. Retained catch and discard mortality, in t, for PIBKC in the crab fisheries. A discard mortality rate of 0.2 was used to convert bycatch biomass to mortality. The lower plot shows discard mortality in the crab fisheries on an expanded y-axis scale to show annual details.

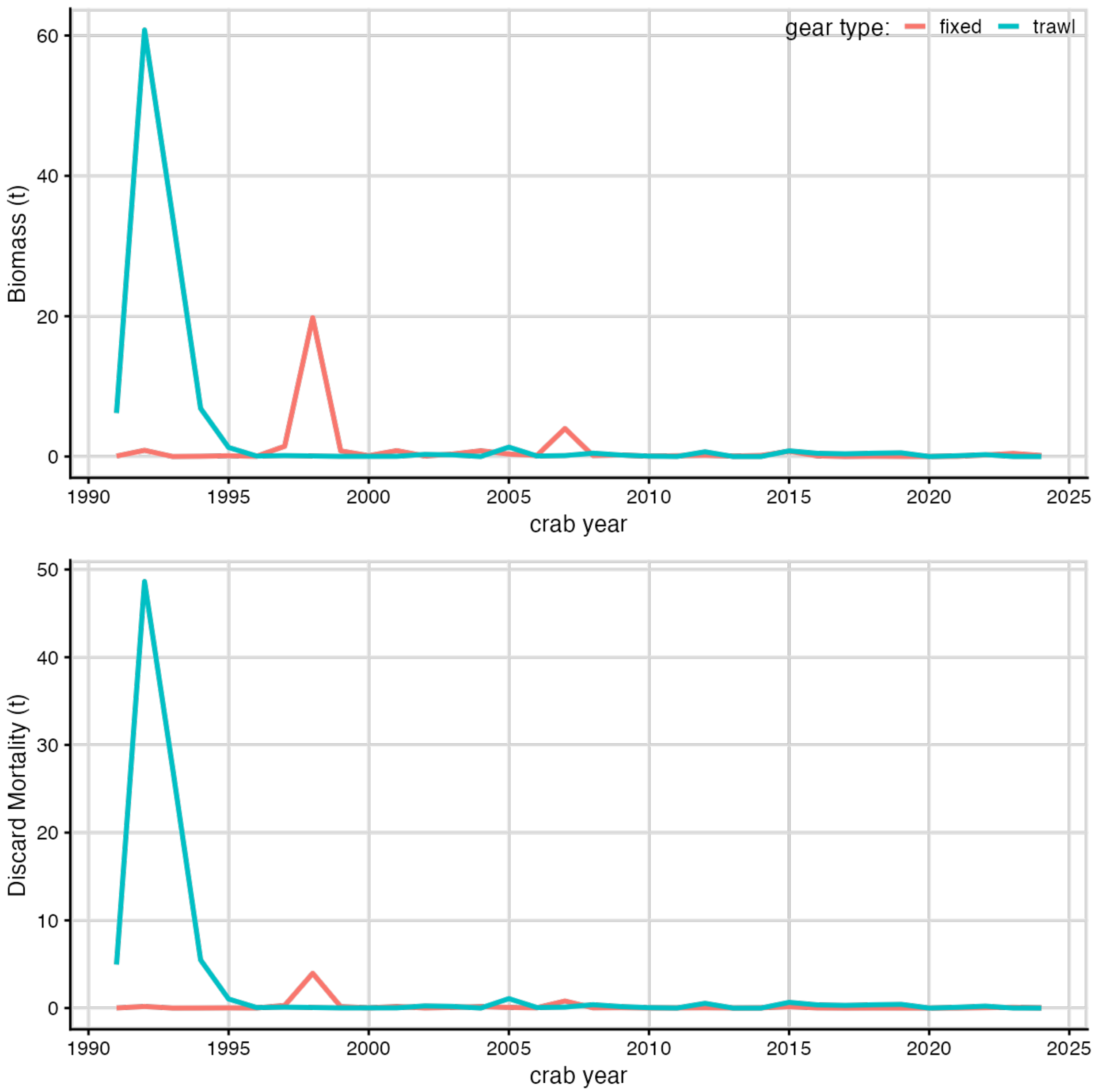

Figure 5. Upper plot: Bycatch of PIBKC in the groundfish fisheries since 1991/92 by gear type (no mortality applied). Lower plot: Discard mortality of PIBKC in the groundfish fisheries since 1991/92 by gear type. Gear-specific discard mortality rates of 0.2 and 0.8 were applied to bycatch from fixed and trawl gear, respectively

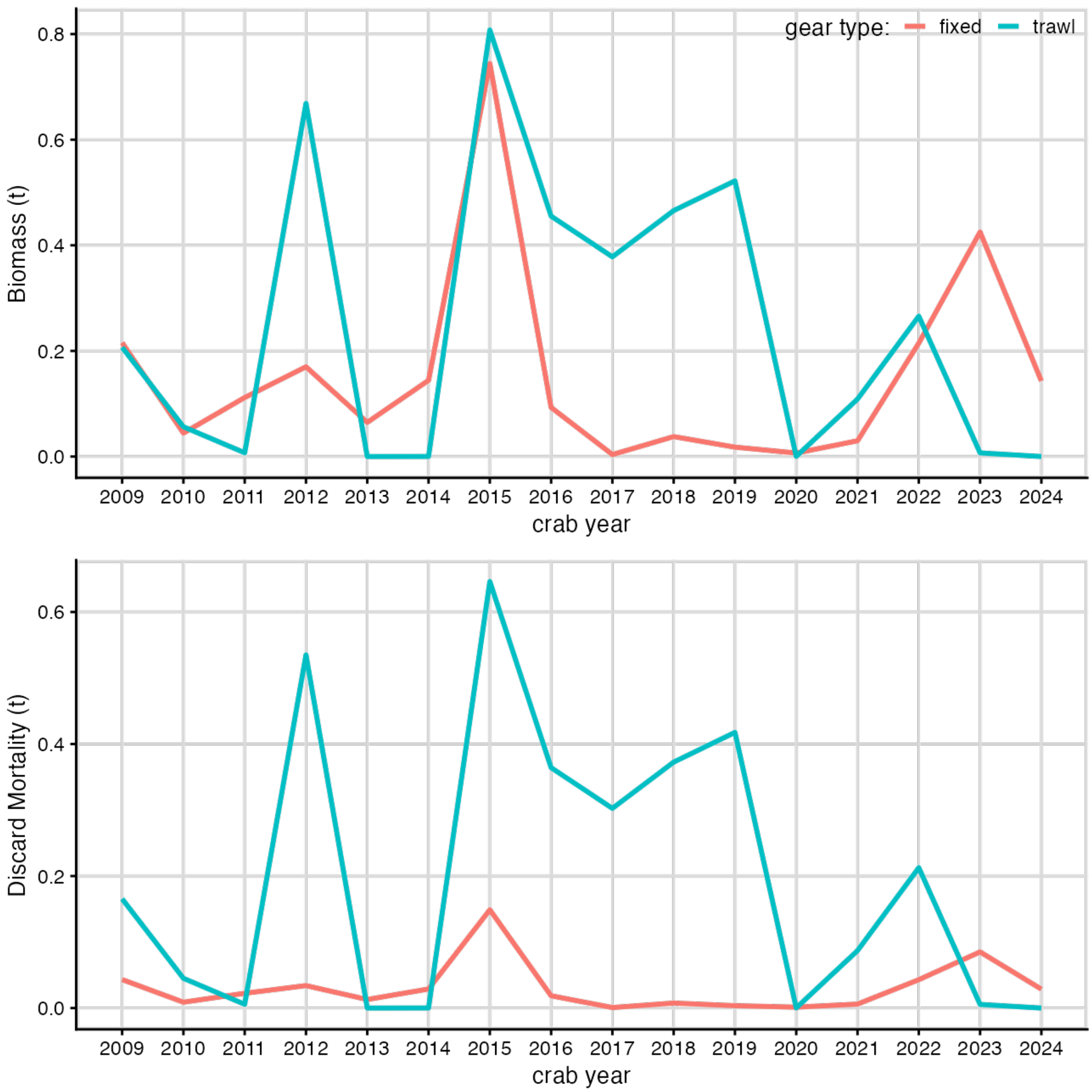

Figure 6. Upper plot: Bycatch of PIBKC in the groundfish fisheries since 2009/10 by gear type (no mortality applied). Lower plot: Discard mortality of PIBKC in the groundfish fisheries since 2009/10 by gear type. Gear-specific discard mortality rates of 0.2 and 0.8 were applied to bycatch from fixed and trawl gear, respectively

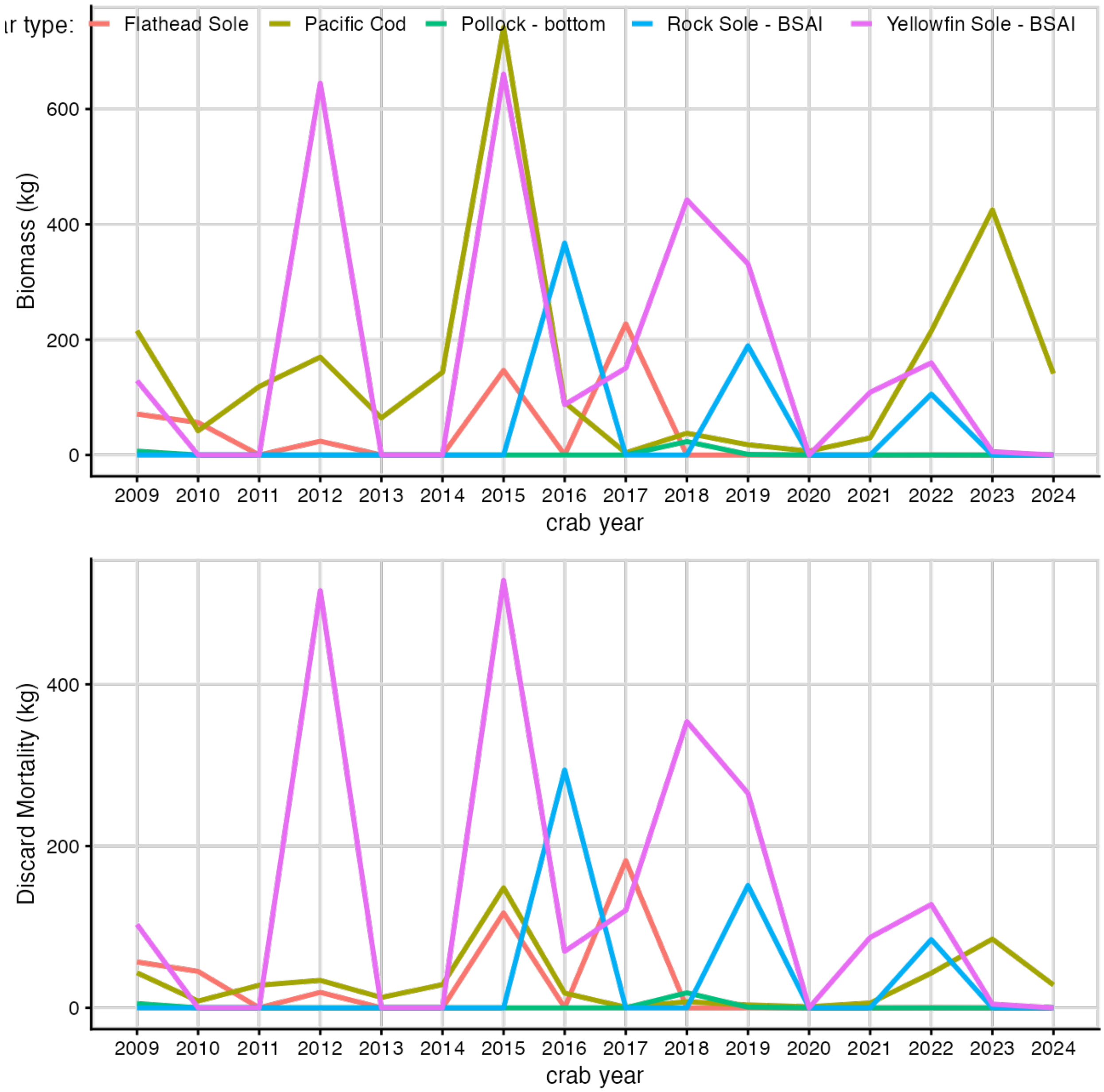

Figure 7. Upper plot: Bycatch (kg) of PIBKC in the groundfish fisheries since 2009/10 by target type (no mortality applied). Lower plot: Discard mortality (kg) of PIBKC in the groundfish fisheries since 2009/10 by target type. Gear-specific discard mortality rates of 0.2 and 0.8 were applied to bycatch from fixed and trawl gear, respectively

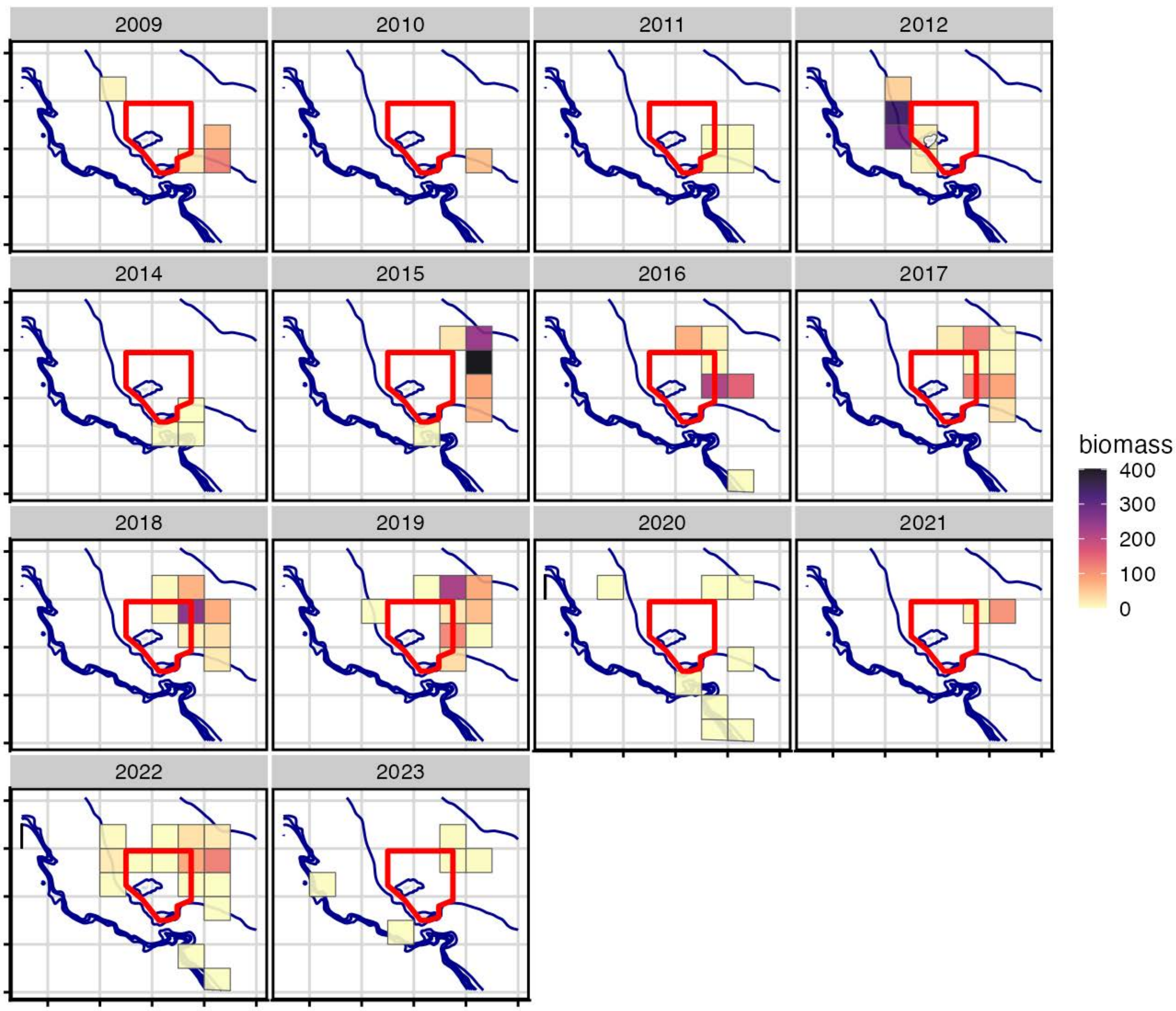

Figure 8. Estimated bycatch of PIBKC in the groundfish trawl gear fisheries by ADF&G stat area, expanded from groundfish observer reports. Red line: boundary of the PIHCZ.

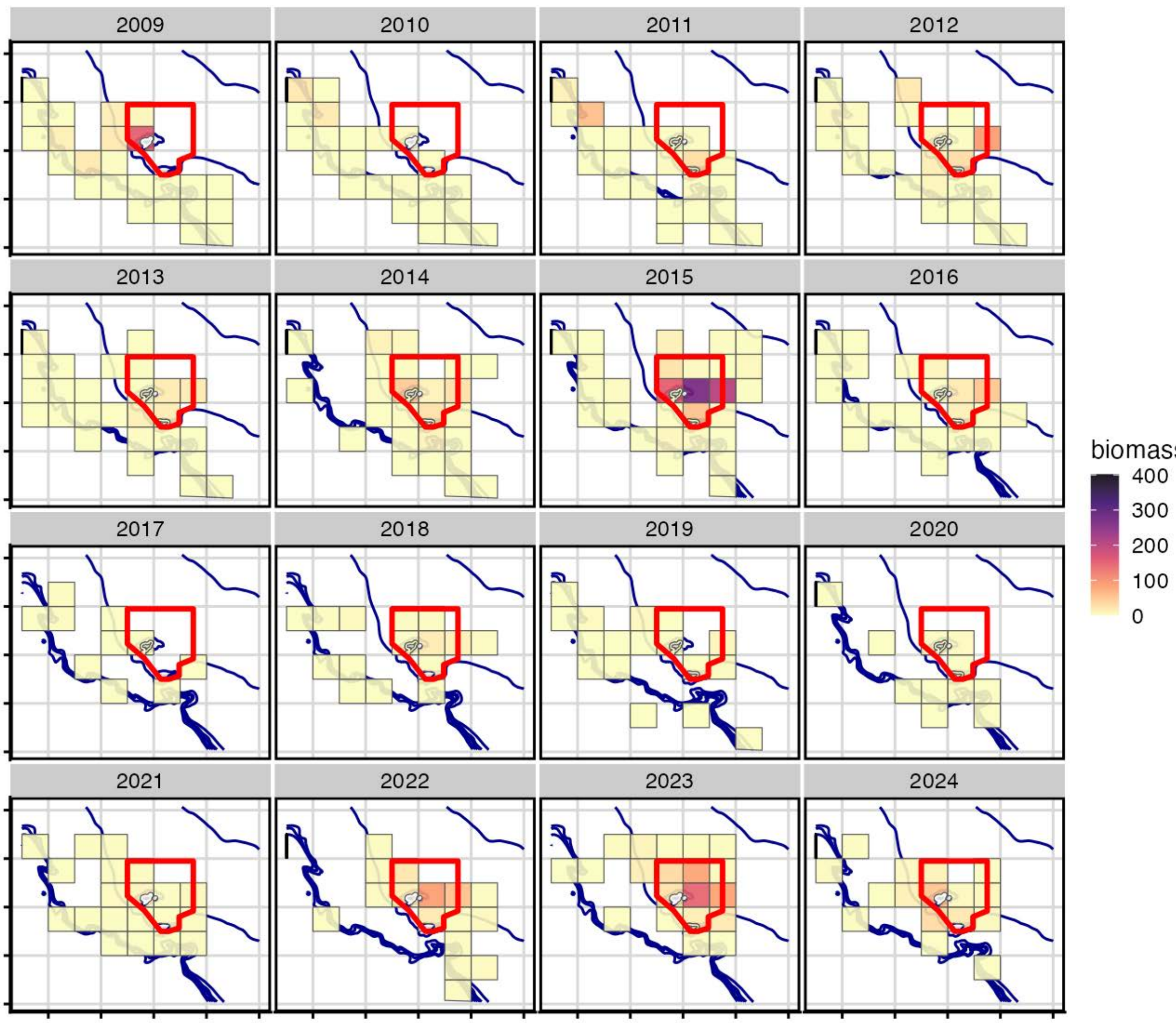

Figure 9. Estimated bycatch of PIBKC in the groundfish fixed gear fisheries by ADF&G stat area, expanded from groundfish observer reports. Red line: boundary of the PIHCZ.

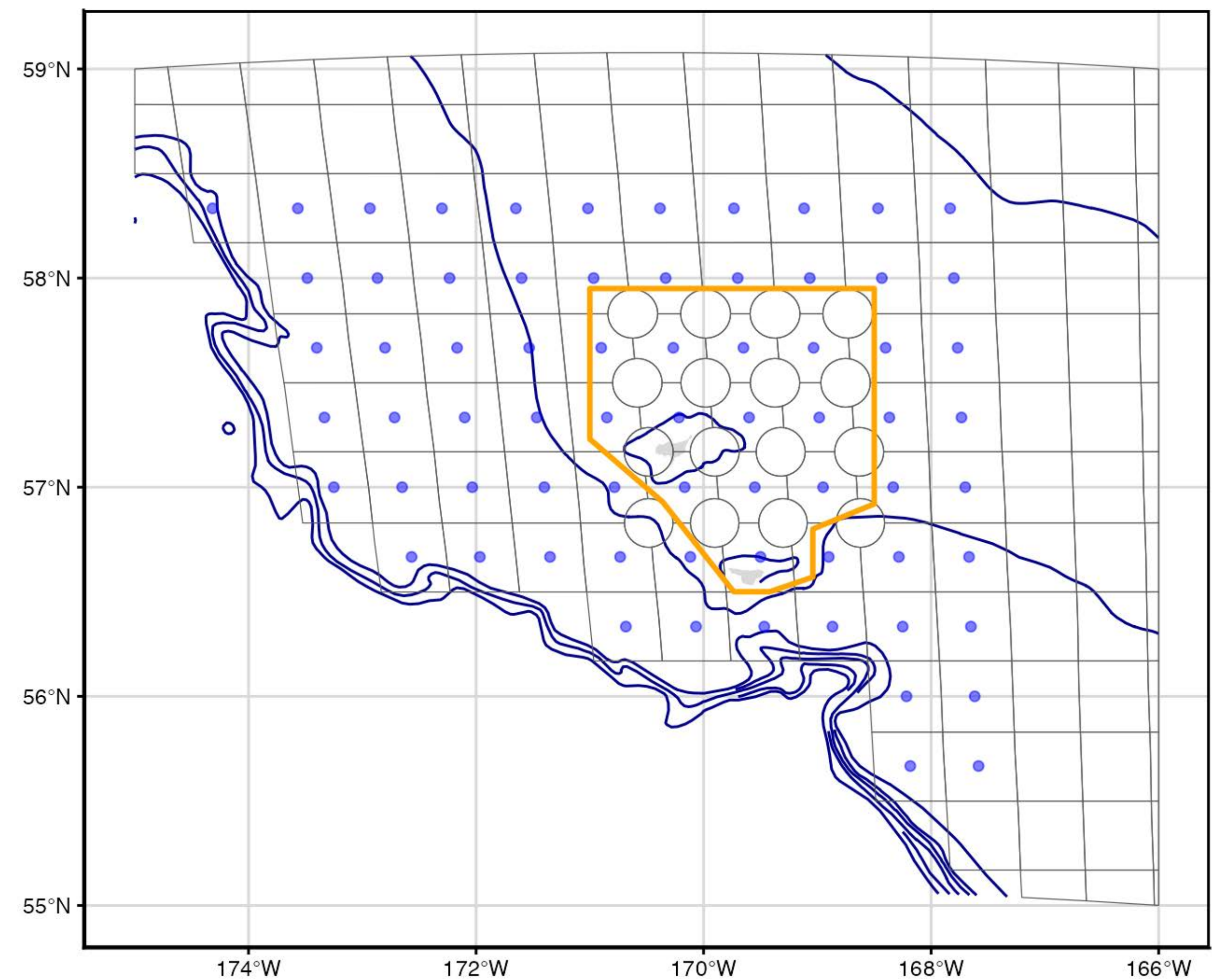

Figure 10. NMFS EBS Shelf Survey stations in the Pribilof District (large dots), the survey station grid (thin black lines), and the Pribilof Islands Habitat Conservation Zone (orange outline).

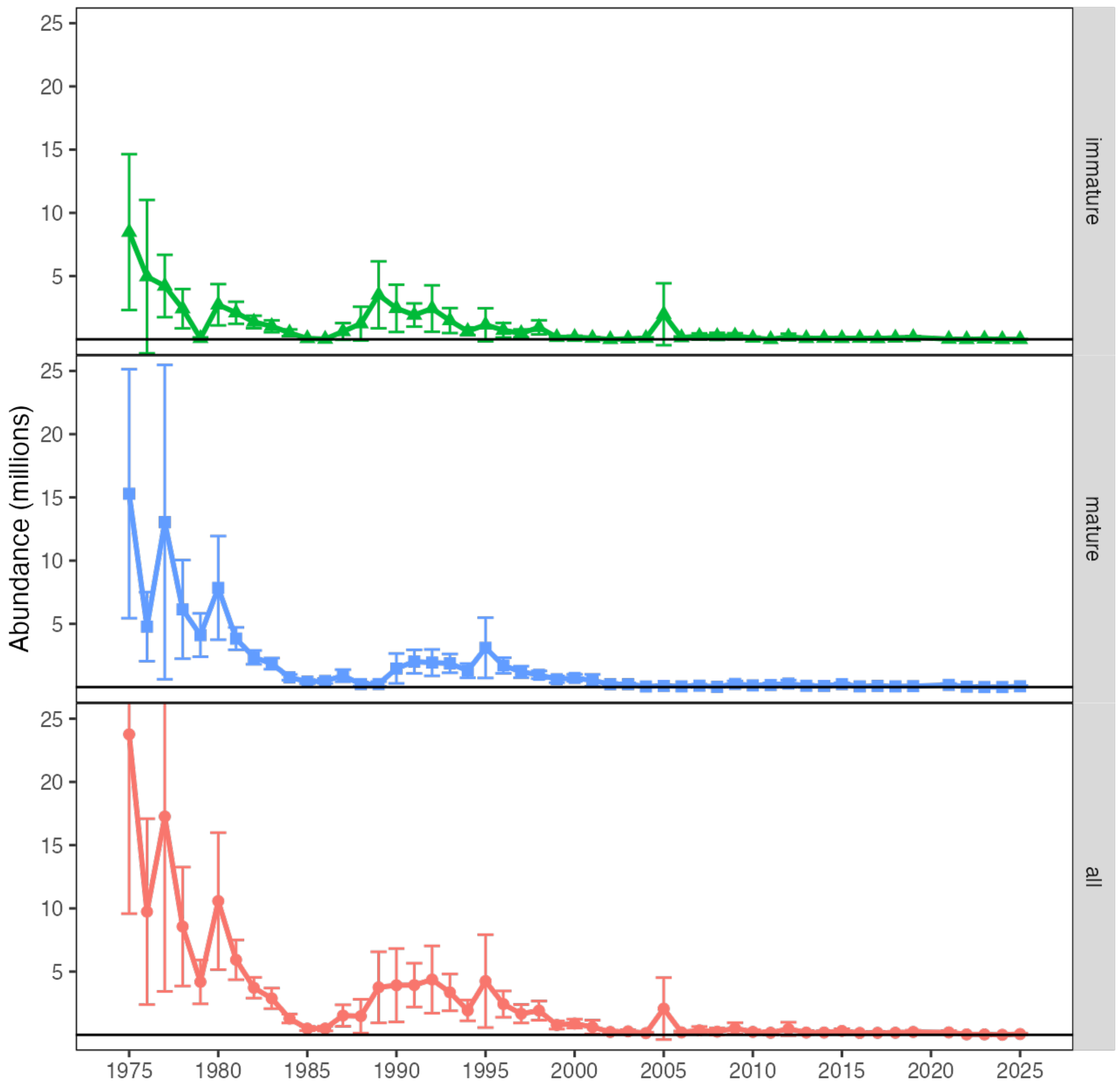

Figure 11. NMFS survey abundance time series for male PIBKC, by maturity category.

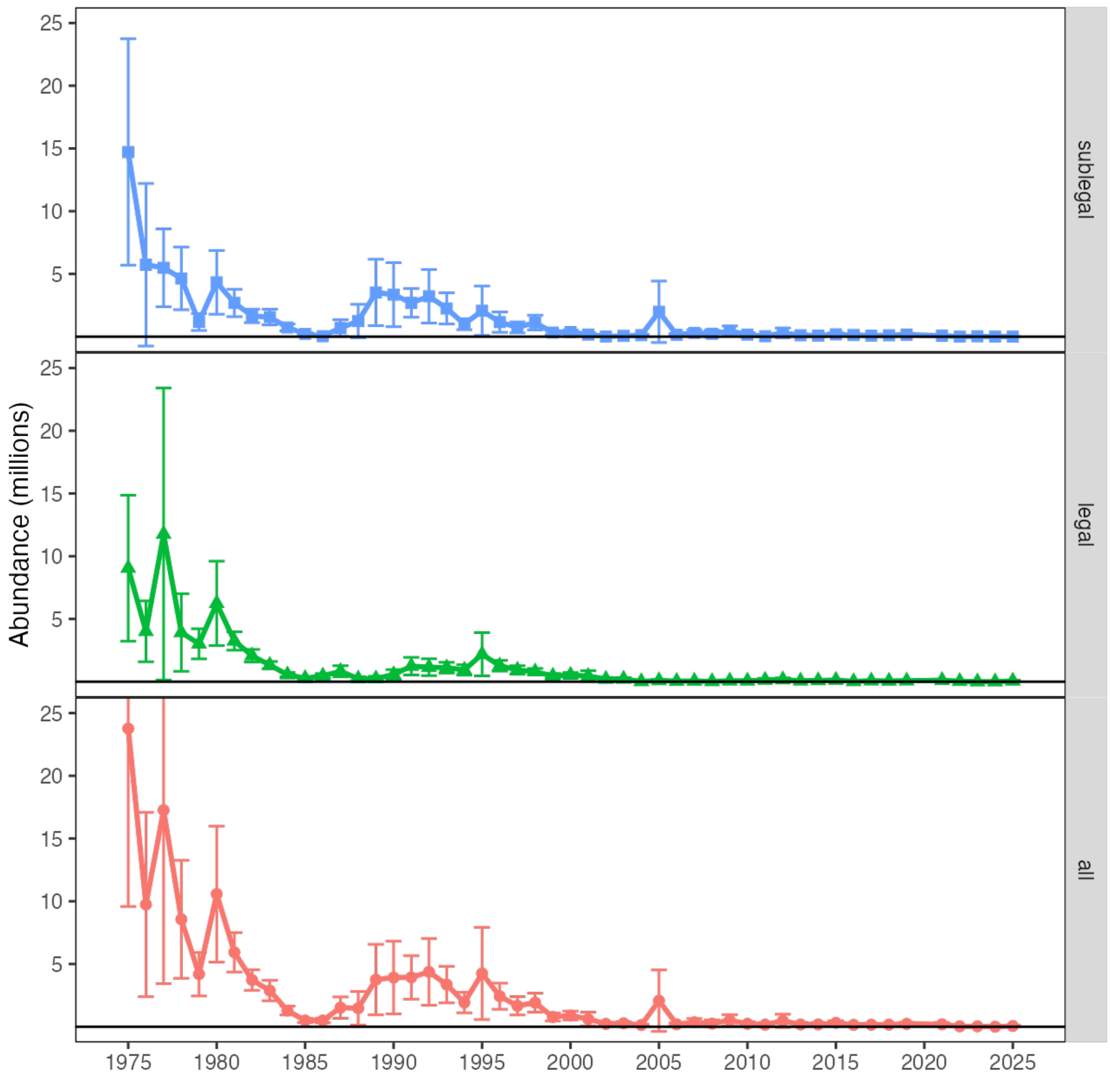

Figure 12. NMFS survey abundance time series for male PIBKC, by fishery category.

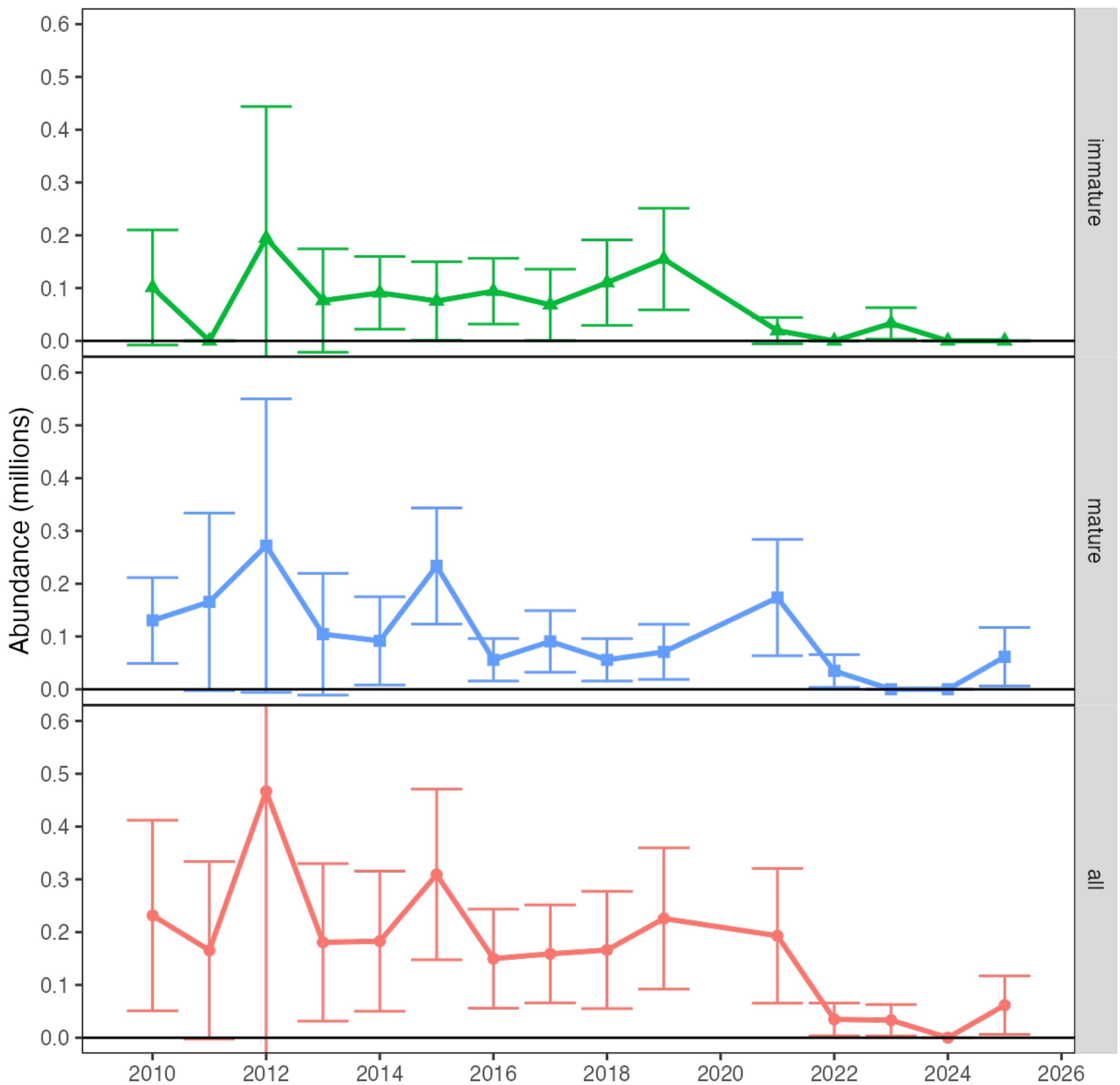

Figure 13. NMFS survey abundance time series for male PIBKC, by population category, from 2010.

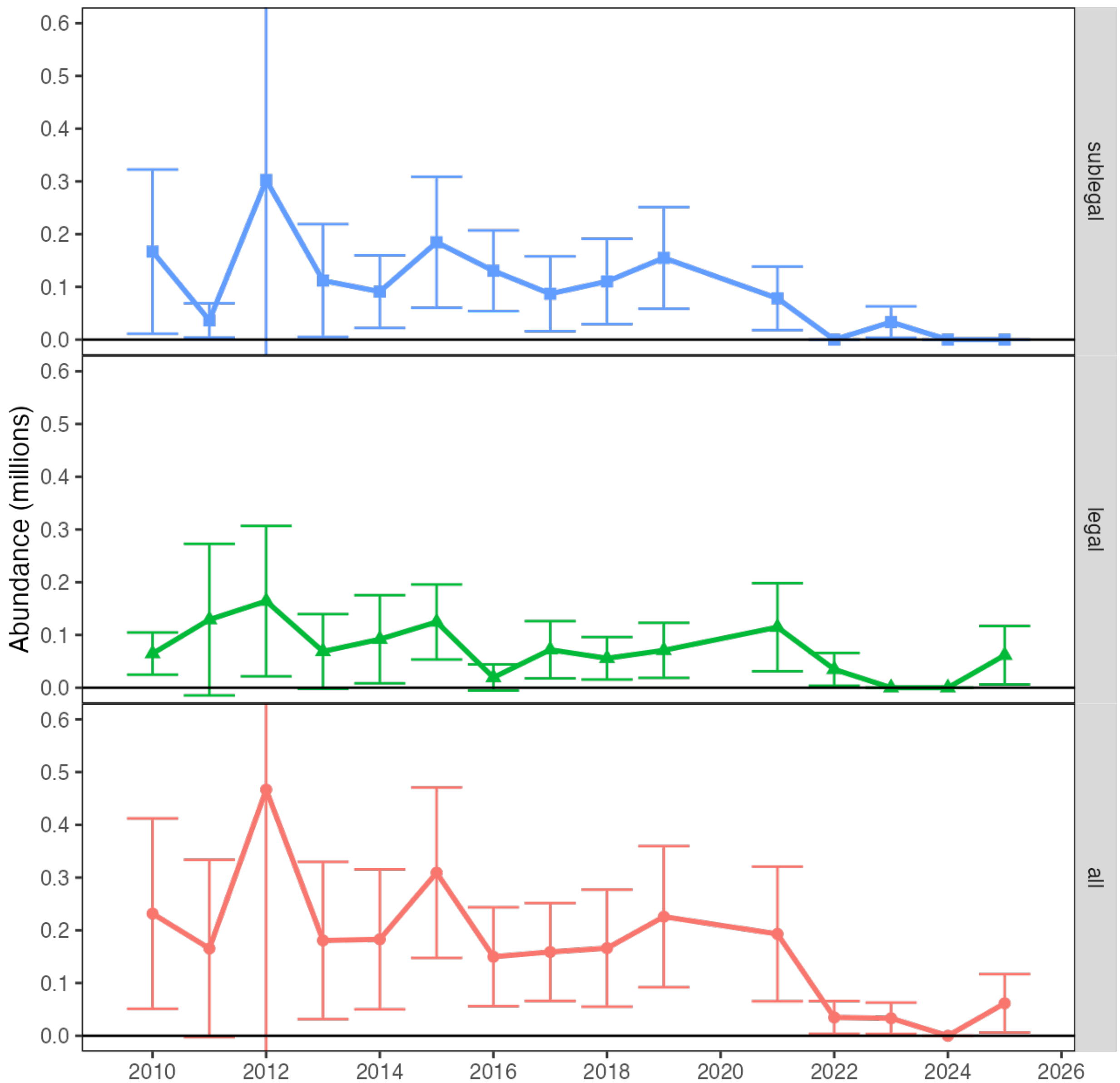

Figure 14. NMFS survey abundance time series for male PIBKC, by fishery category, from 2010.

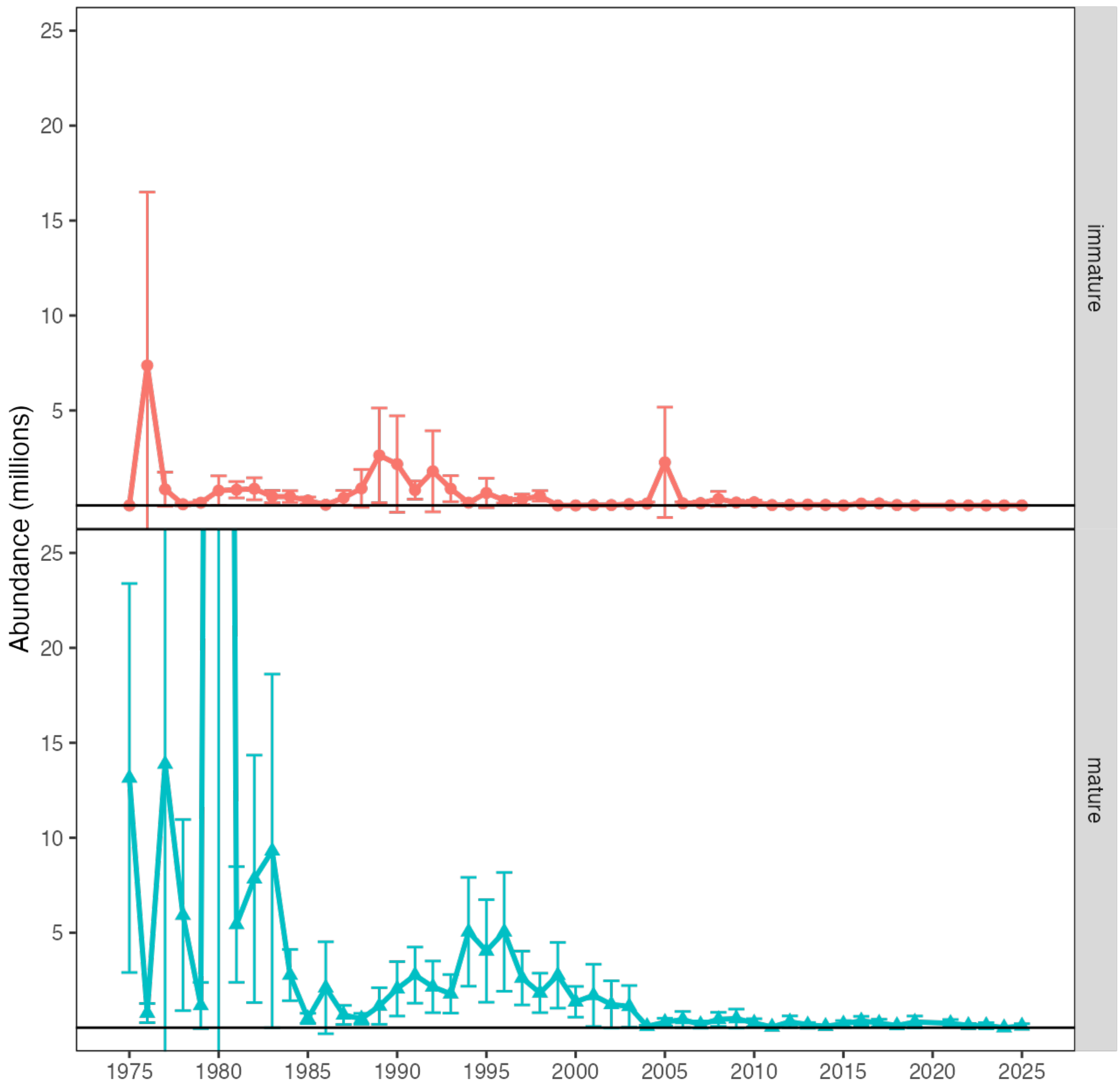

Figure 15. NMFS survey abundance time series for female PIBKC, by population category. The values for mature and all females for 1980 are off-scale to better show details of remaining values.

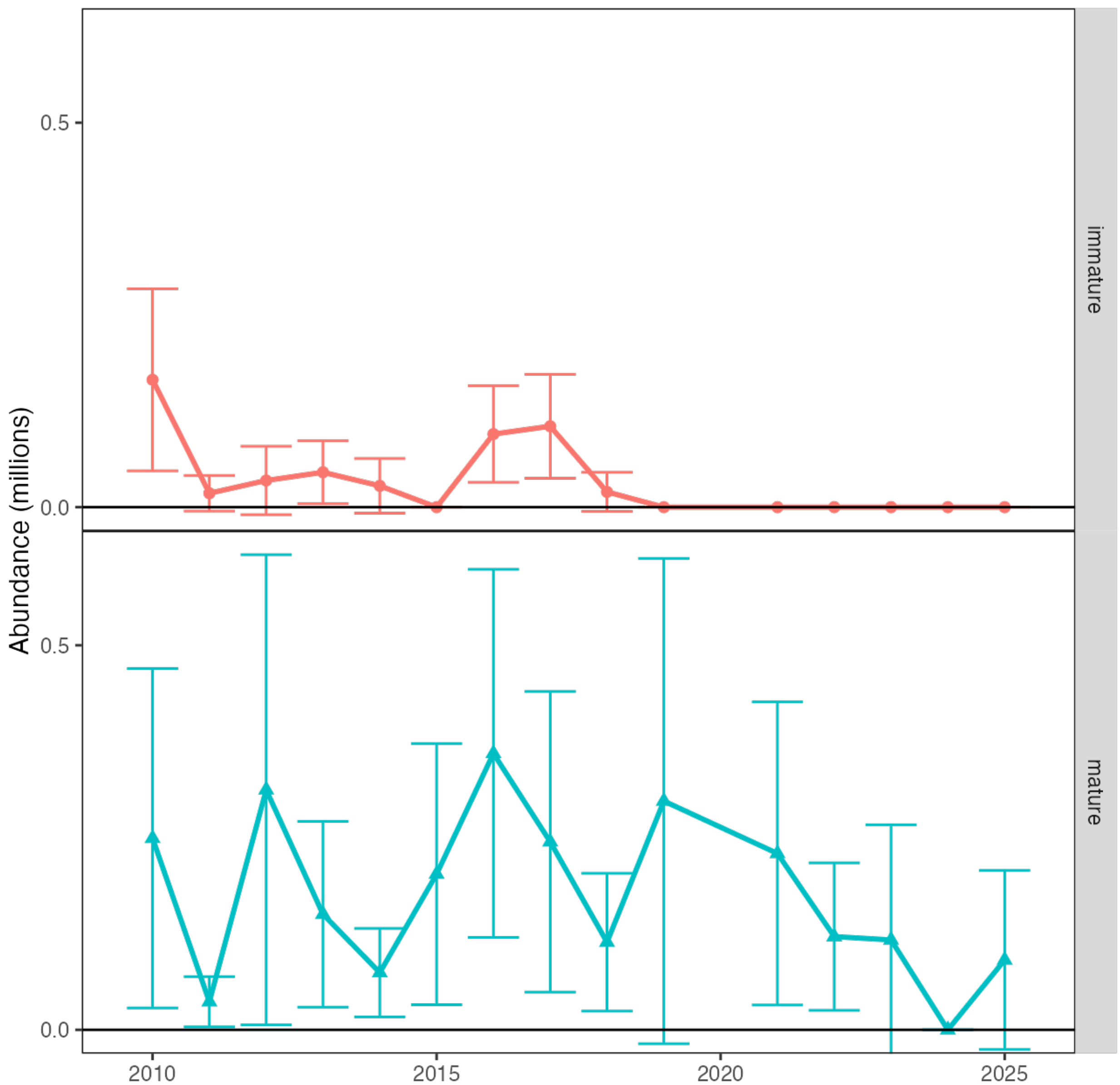

Figure 16. NMFS survey abundance time series for female PIBKC, by population category, from 2010.

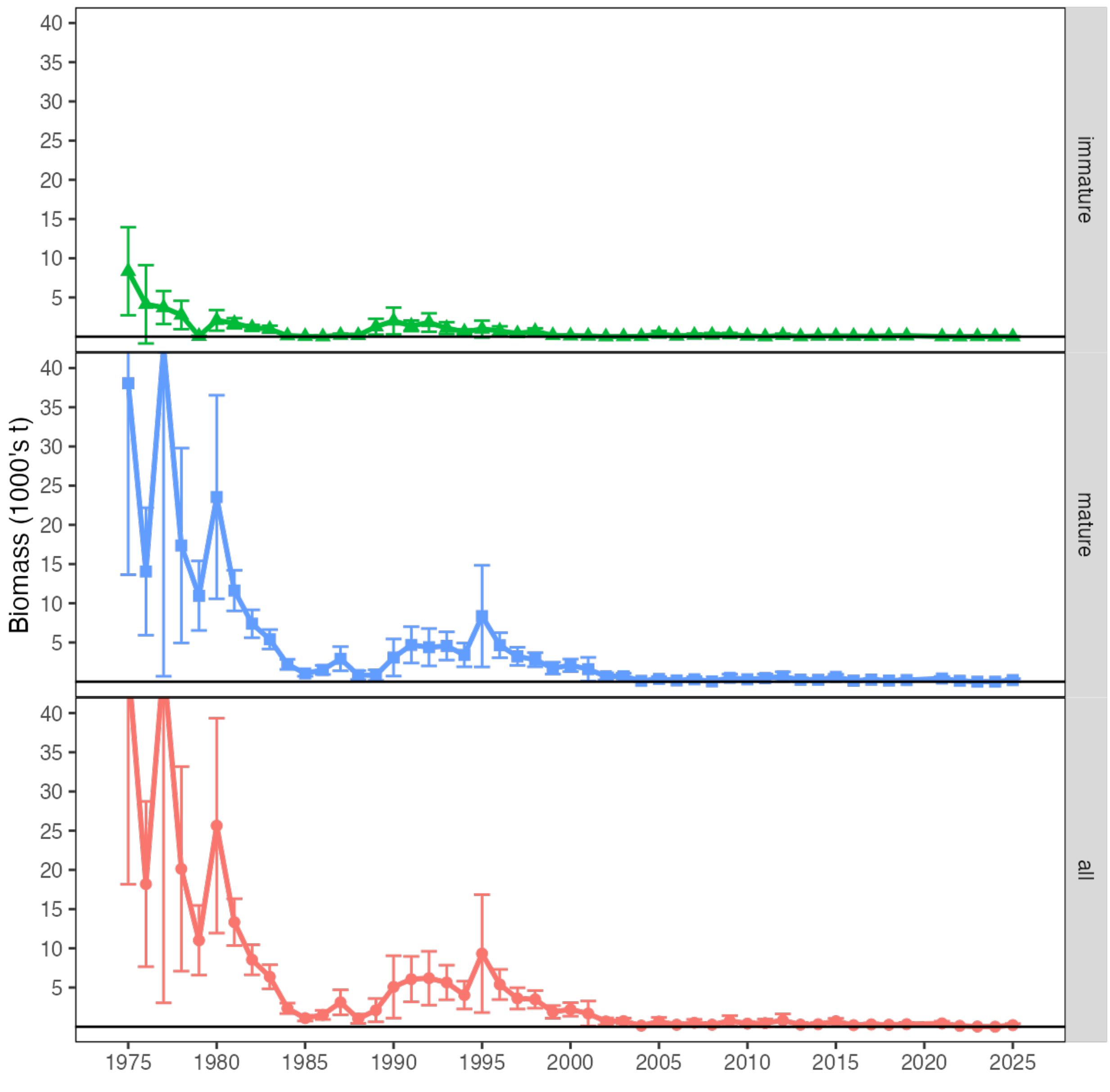

Figure 17. NMFS survey biomass time series for male PIBKC, by maturity category.

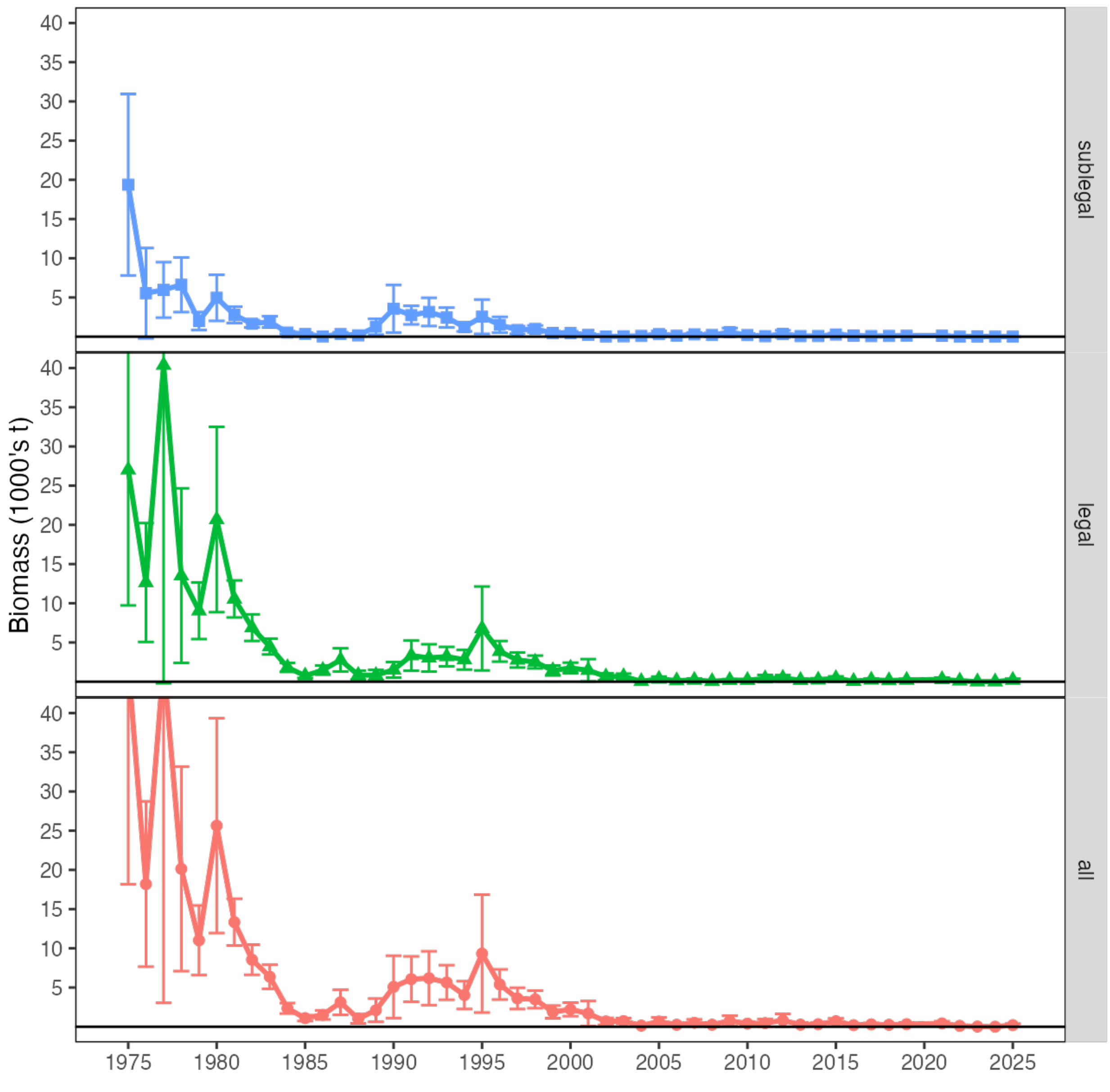

Figure 18. NMFS survey biomass time series for male PIBKC, by fishery category.

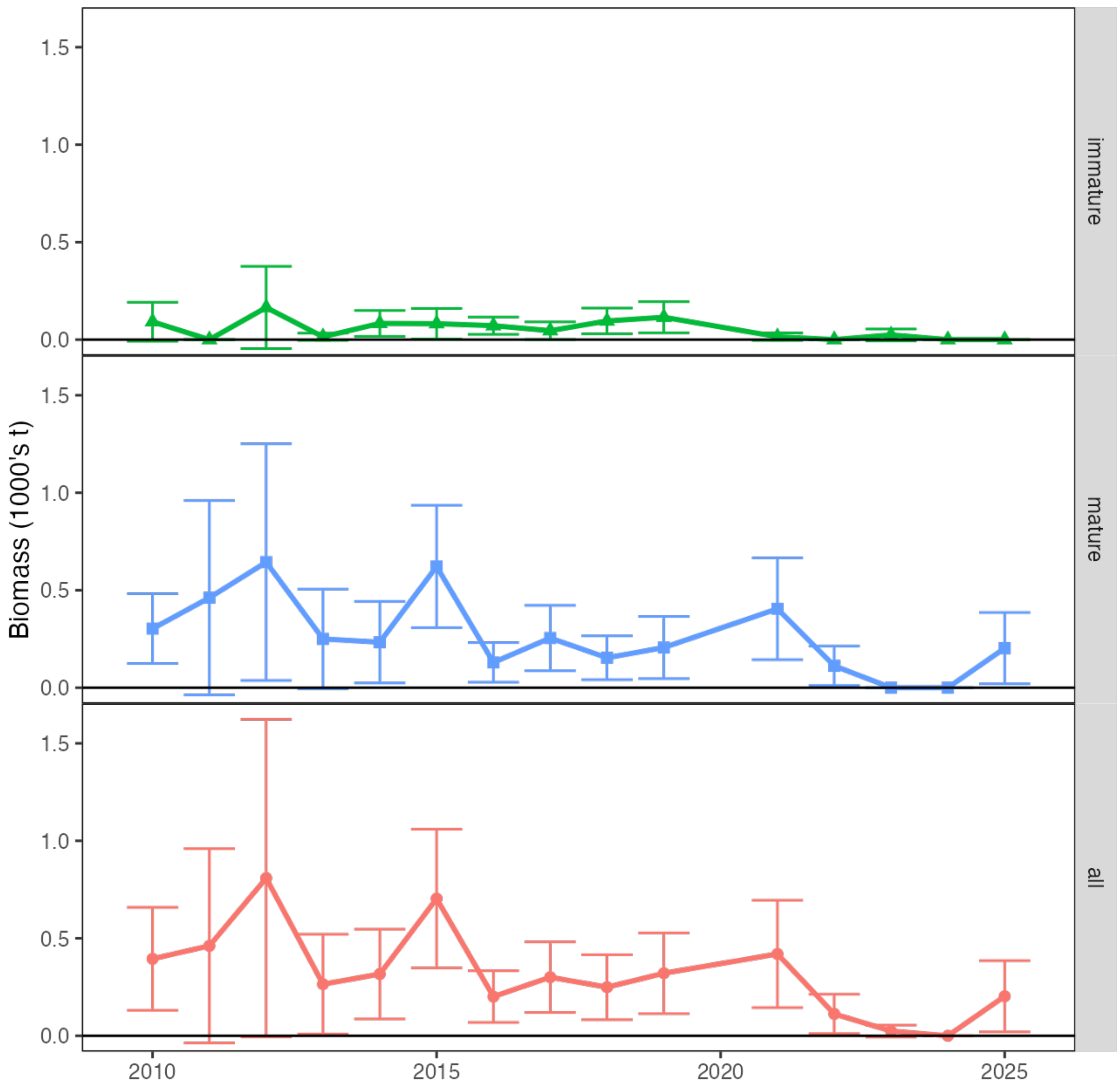

Figure 19. NMFS survey biomass time series for male PIBKC, by maturity category, from 2010.

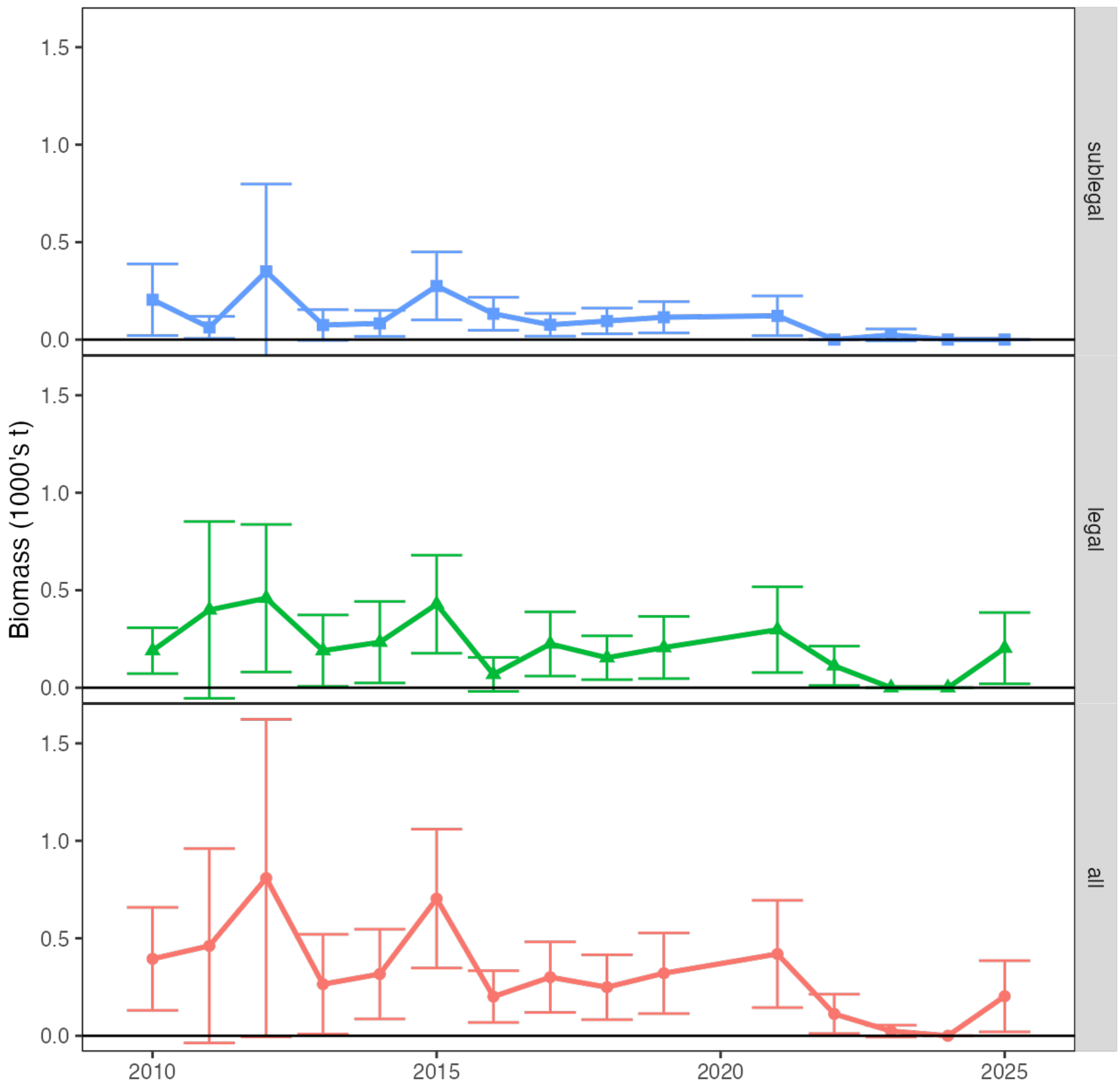

Figure 20. NMFS survey biomass time series for male PIBKC, by fishery category, from 2010.

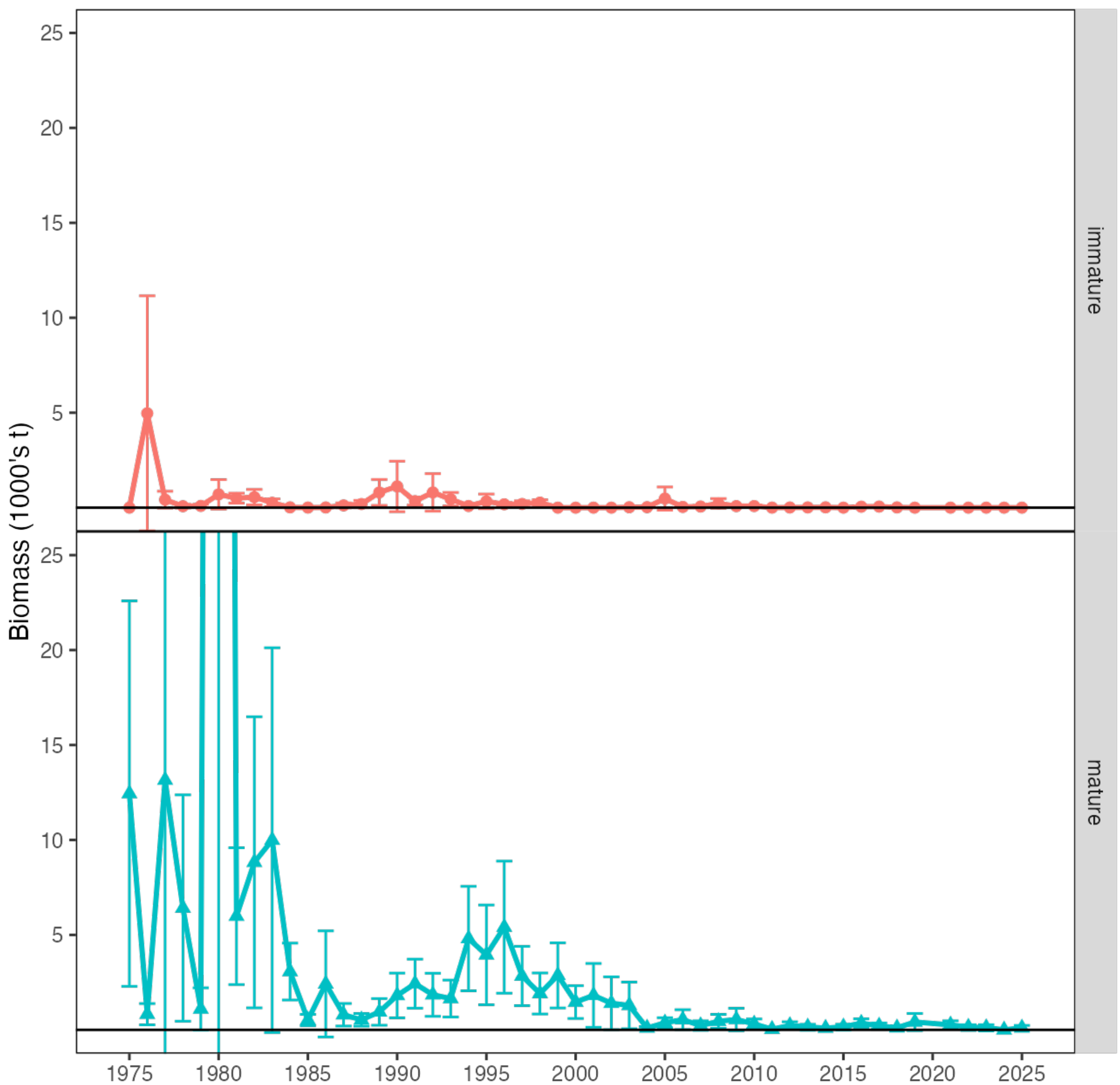

Figure 21. NMFS survey biomass time series for female PIBKC, by population category. The values for mature and all females for 1980 are off-scale to better show details of remaining values.

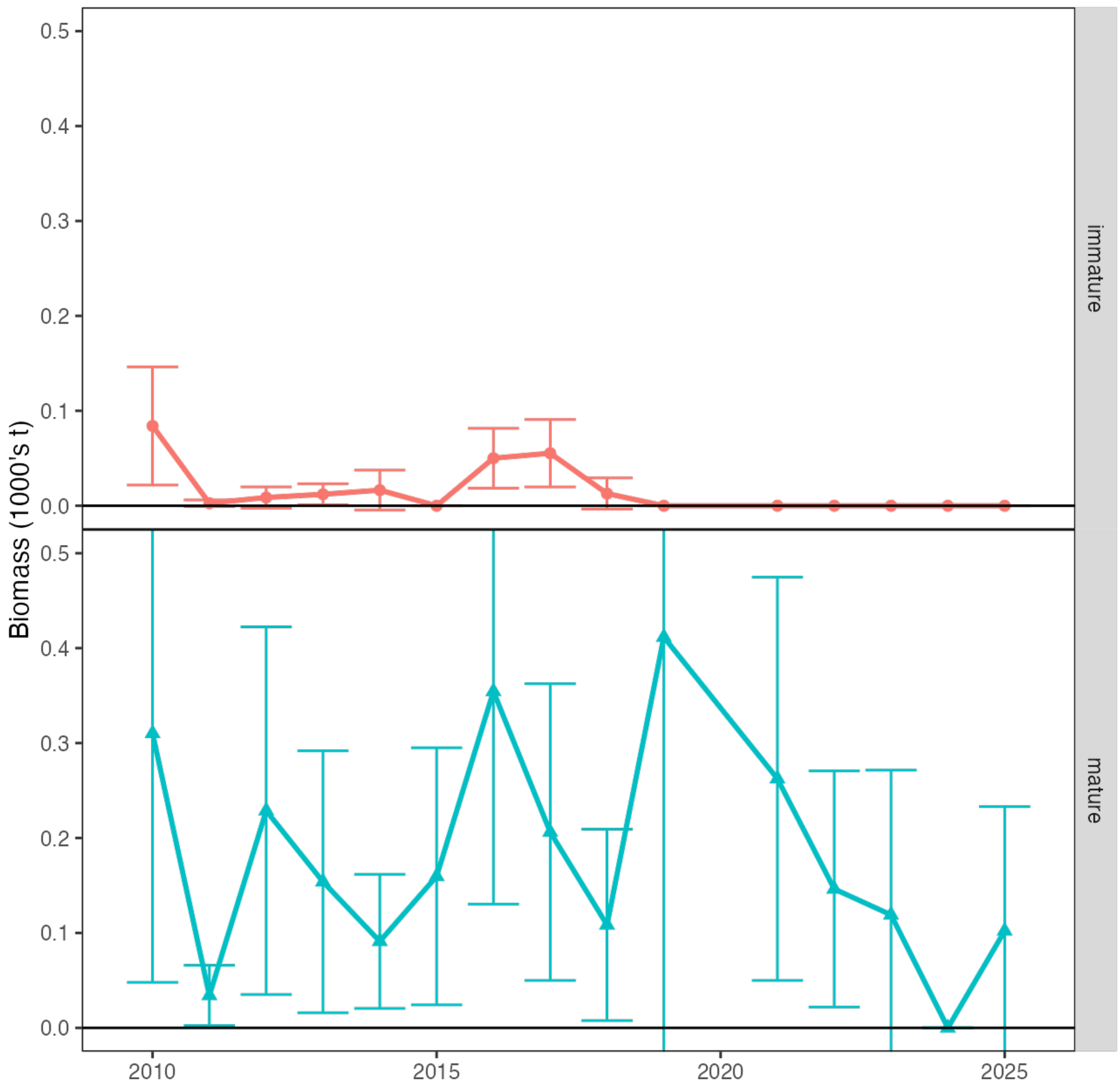

Figure 22. NMFS survey biomass time series for female PIBKC, by population category, from 2010.

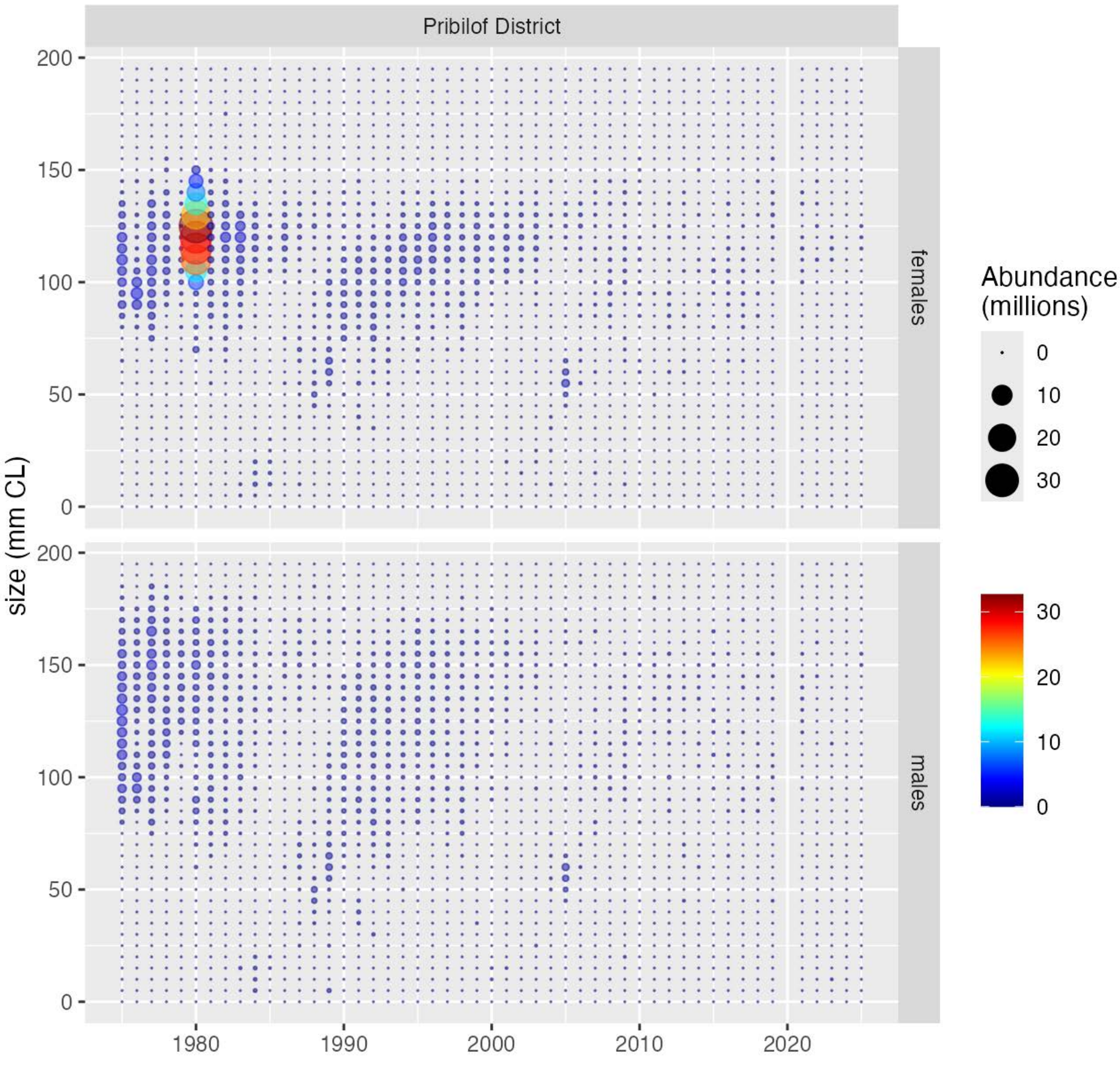

Figure 23. Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex, over the entire survey period. The survey was not conducted in 2020.

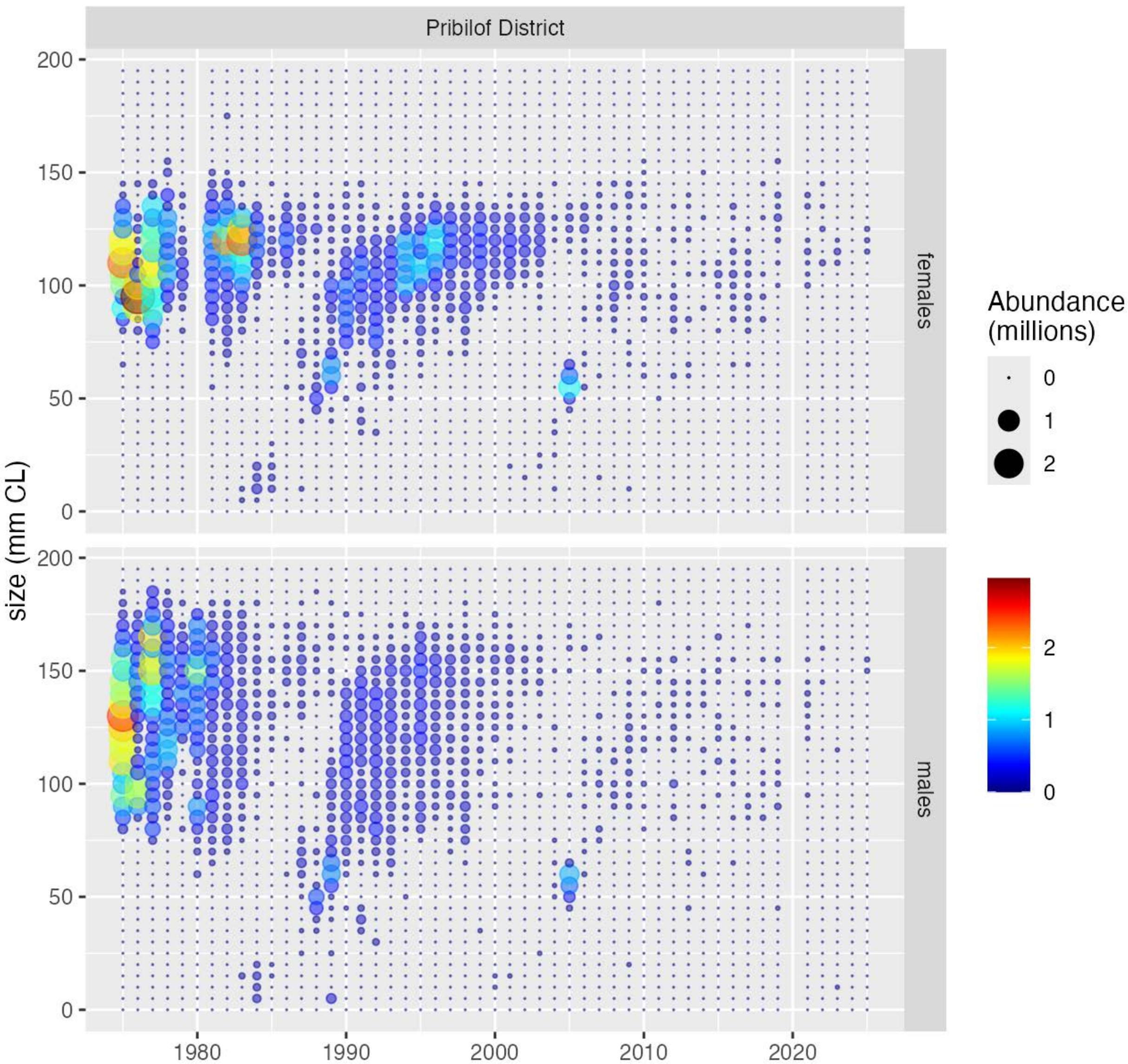

Figure 24. Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex, over the entire survey period, except that females in 1980 have been removed to show detail. The survey was not conducted in 2020.

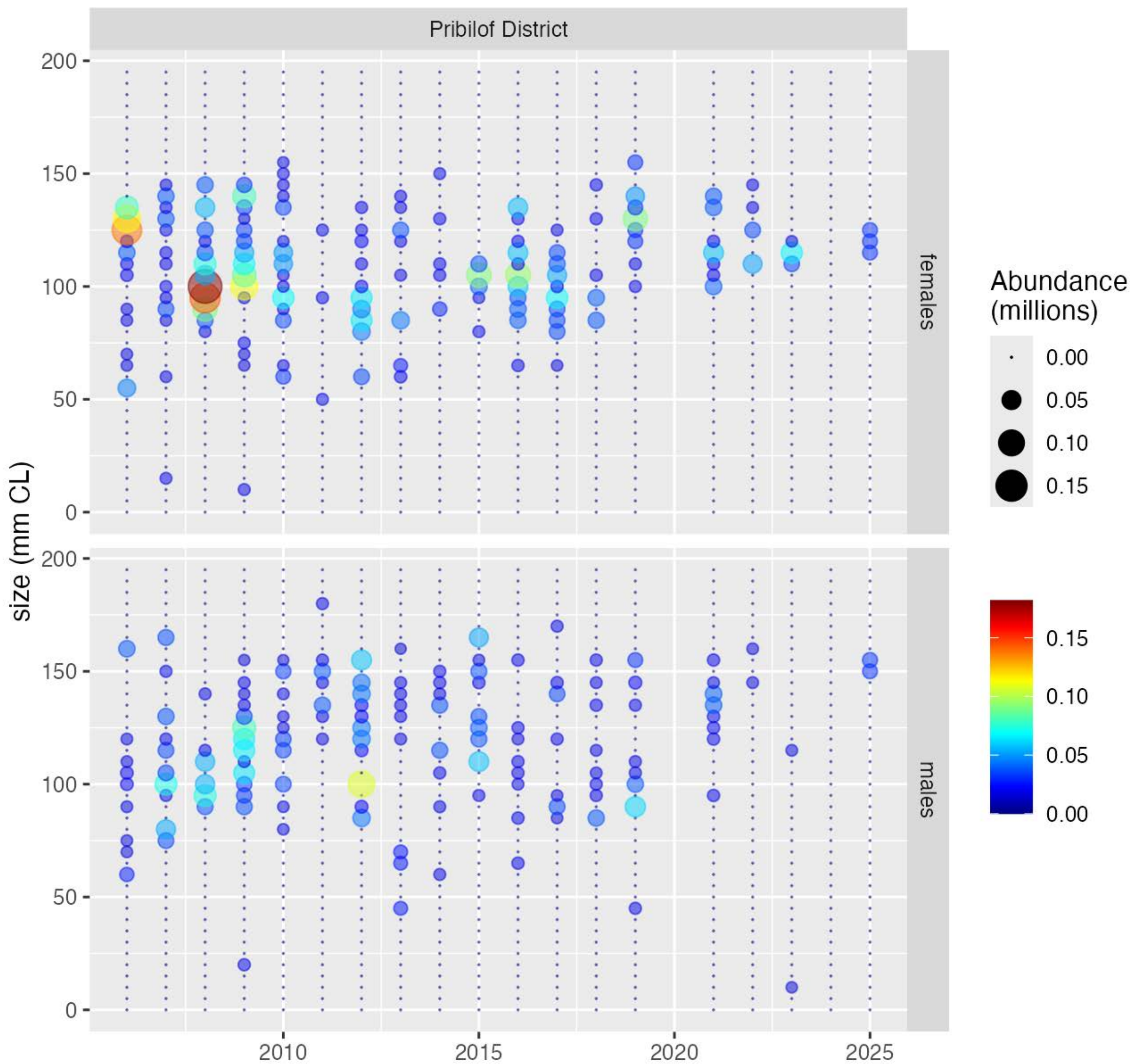

Figure 25. Annual size compositions for PIBKC in the NMFS EBS trawl survey, by sex, since 2006. The survey was not conducted in 2020.

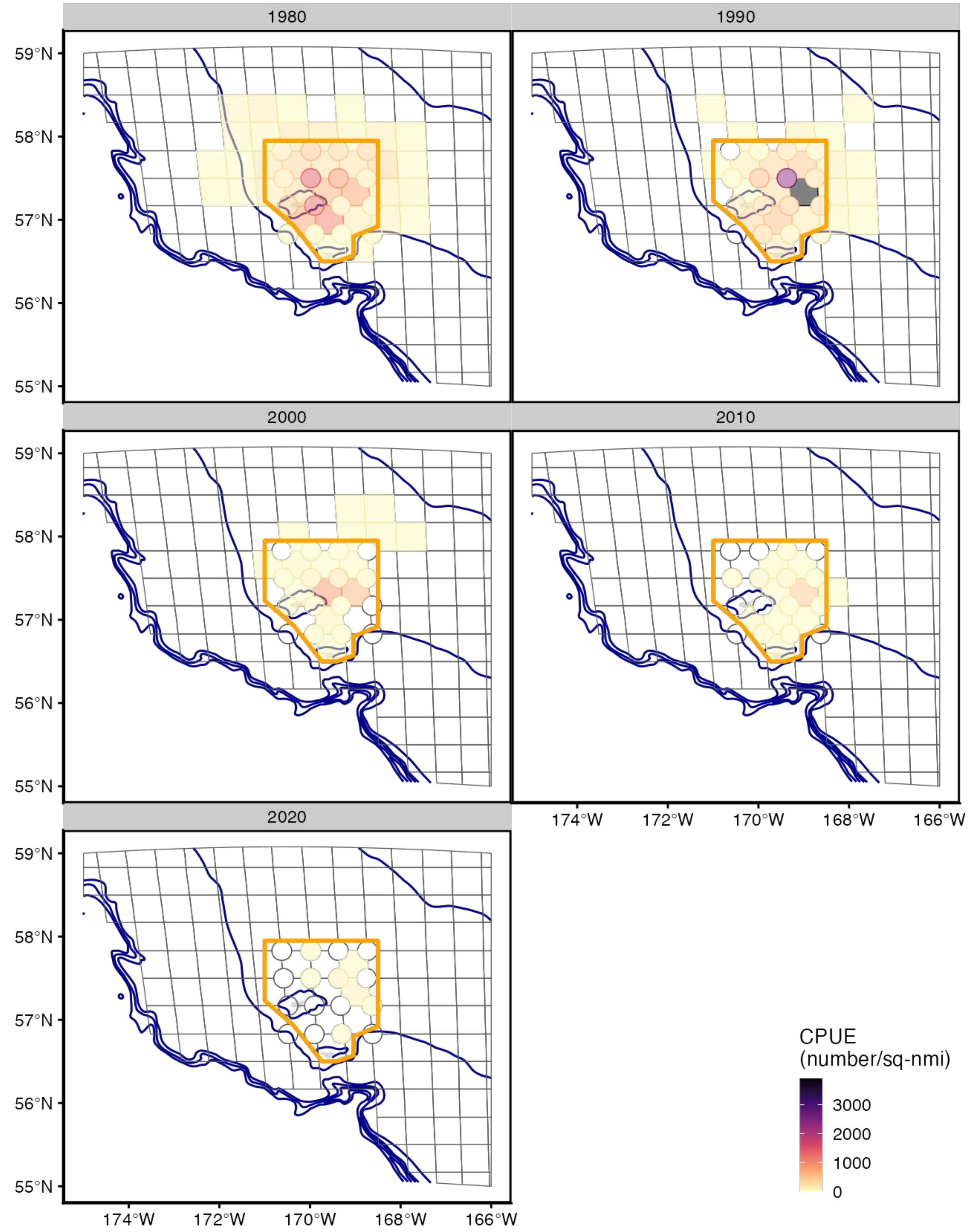

Figure 26. Decadal-average abundance CPUE (number/sq-nmi) by for male PIBKC in the NMFS EBS trawl survey.

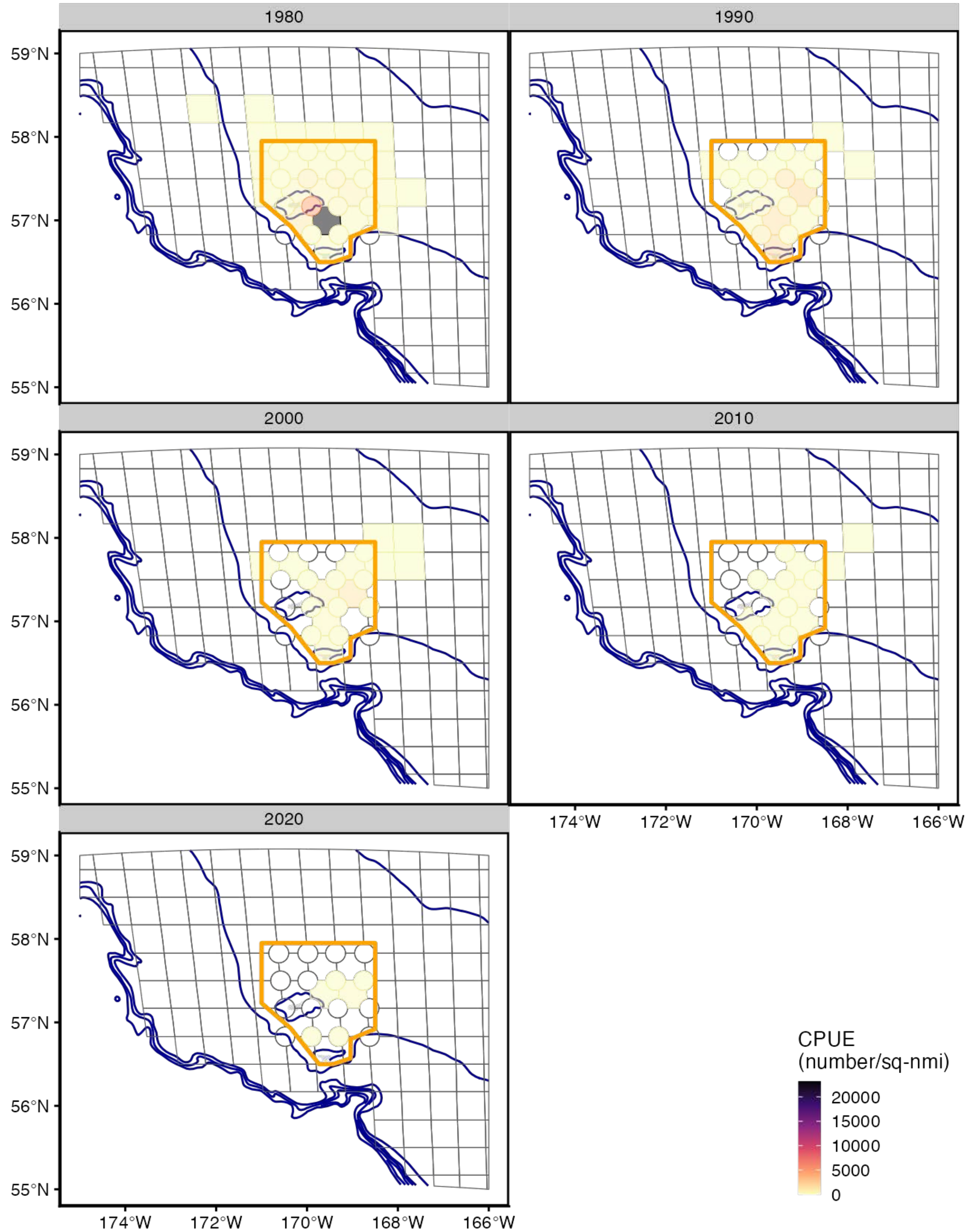

Figure 27. Decadal-average abundance CPUE (number/sq-nmi) by for female PIBKC in the NMFS EBS trawl survey.

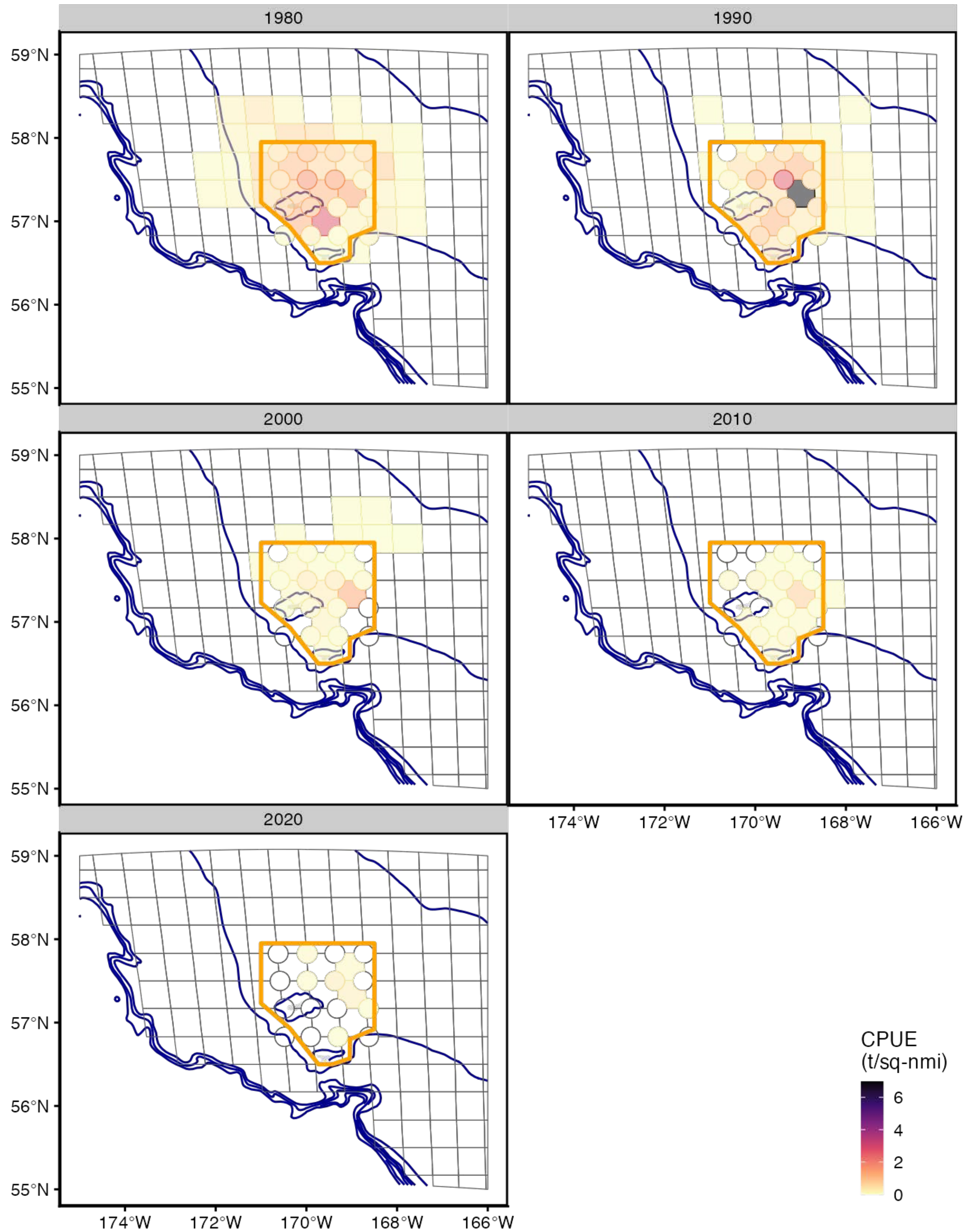

Figure 28. Decadal-average biomass CPUE (t/sq-nmi) by for male PIBKC in the NMFS EBS trawl survey.

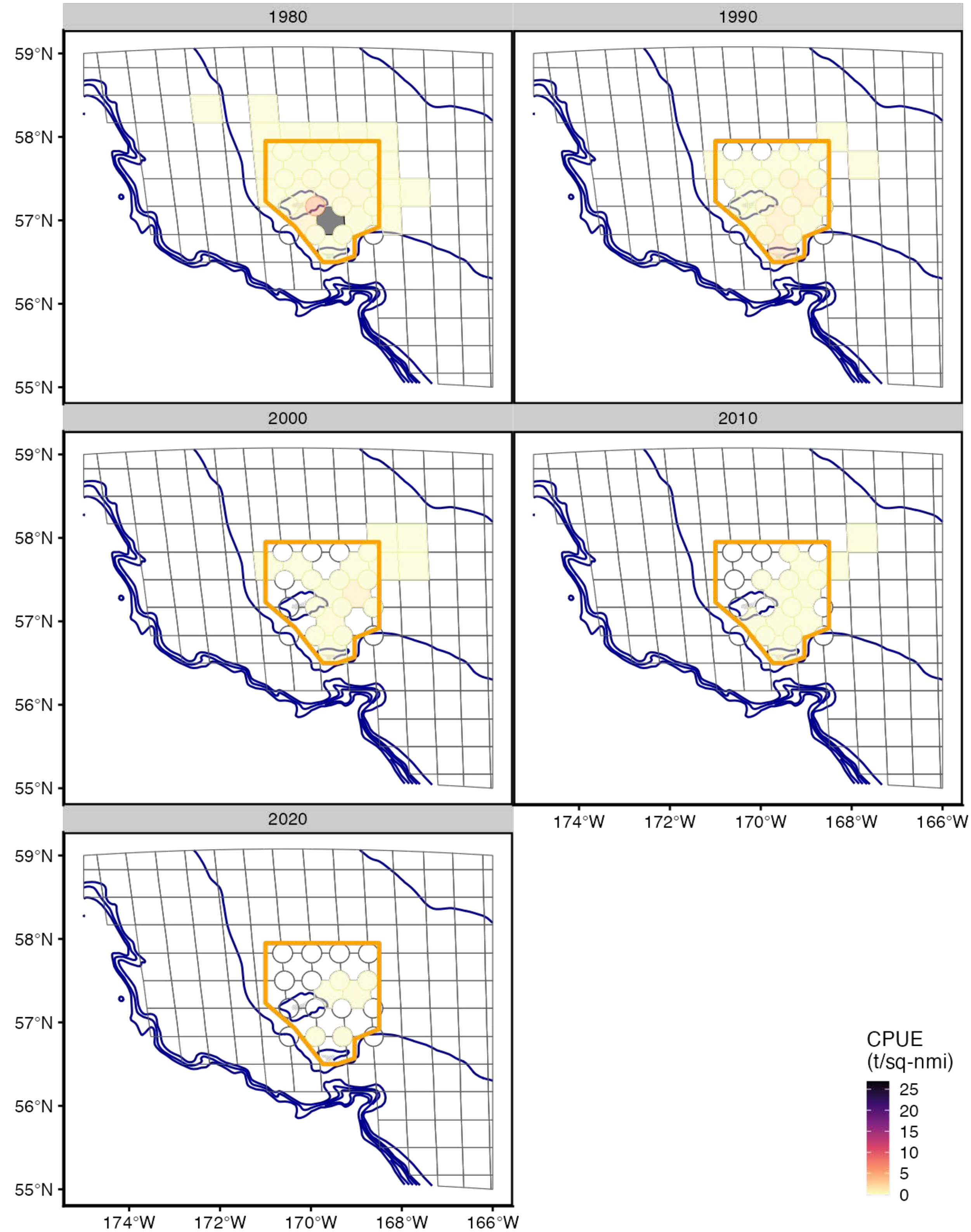

Figure 29. Decadal-average biomass CPUE (t/sq-nmi) by for female PIBKC in the NMFS EBS trawl survey.

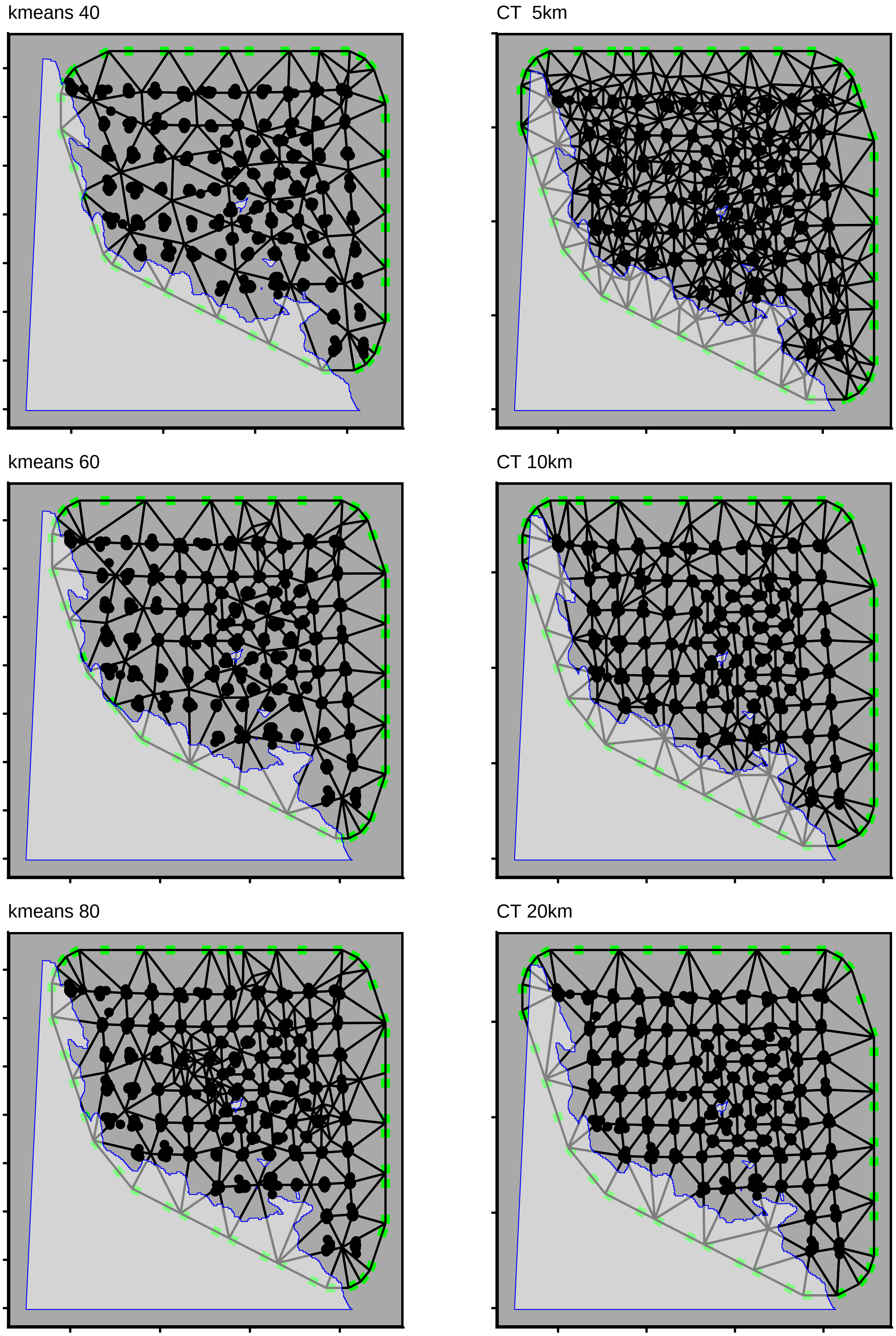

Figure 30. The triangular SPDE evaluation meshes considered while developing the sdmTMB models. For each, the sdmTMB function “make_mesh” was applied to the NMFS survey haul-level CPUE data for MMB (black dots). “kmeans” (left column) or “CT” (right-hand column) indicate the method used; the value indicates the number of allowd knots (kmeans) or the minimum distance allowed between nodes (CT). The green dots indicate

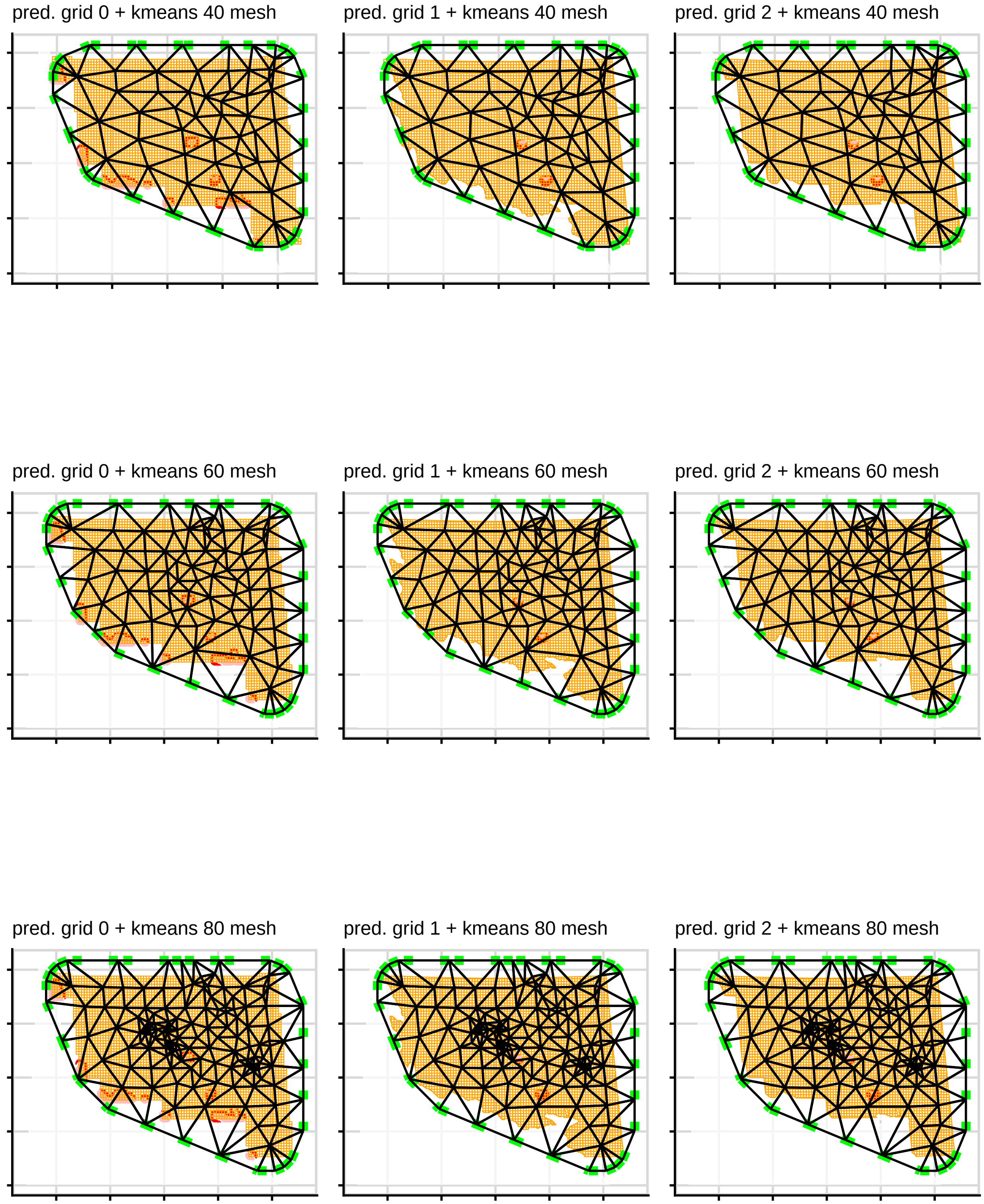

Figure 31. Three prediction grids evaluated (each compared with the "kmeans" evaluation grids). Each prediction grid (orange squares) uses a 5 km grid cell size but covers a slightly different area: grid 0 covers the Pribilof District as defined by NMFS survey strata, and extends across the Pribilof Islands and beyond the shelf edge in some areas (darker orange); grid 1 extends to the shelf edge (500 m depth) and excludes the Pribilof Islands;

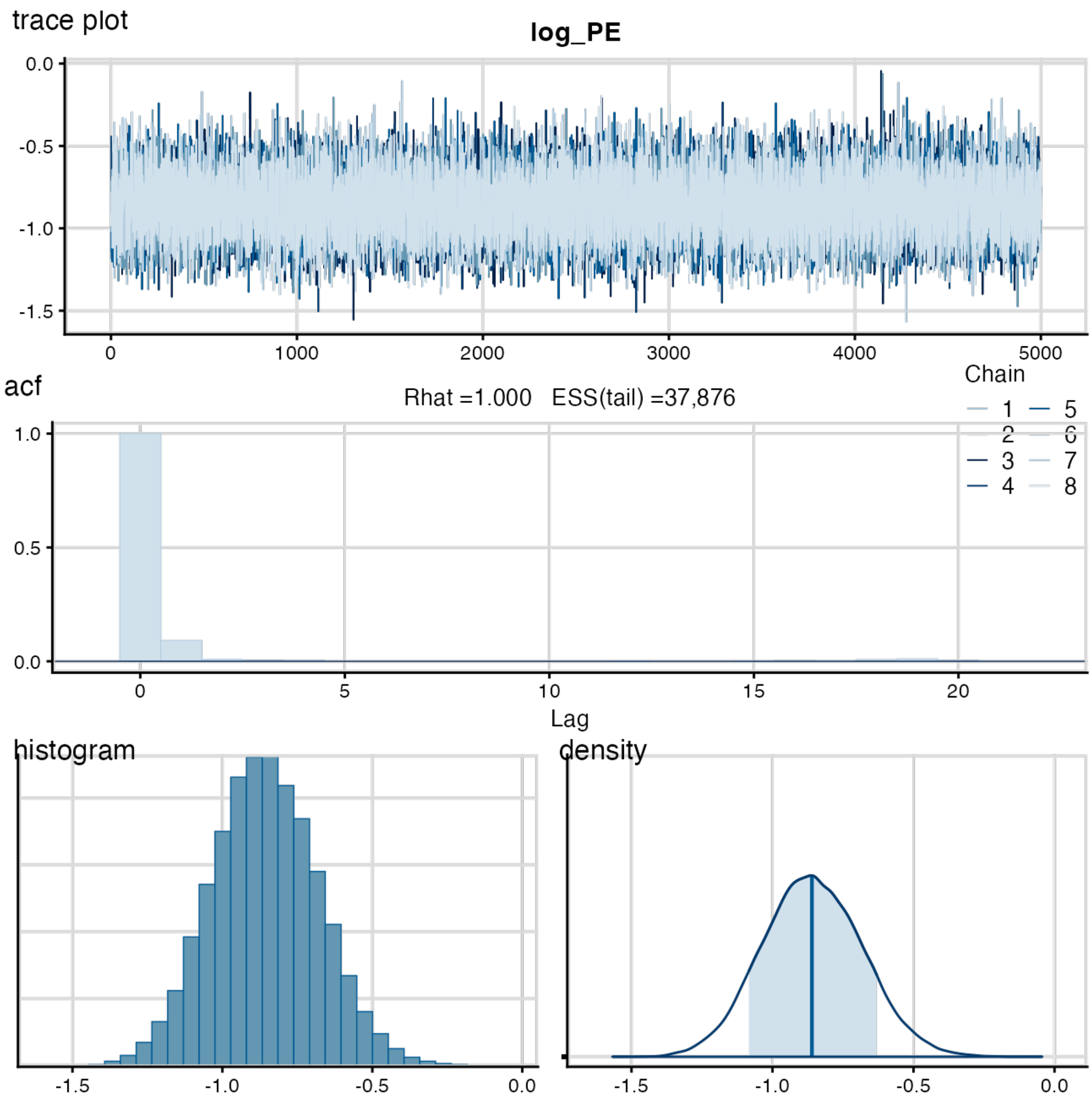

Figure 32. MCMC diagnostics for the ln-scale process error parameter from the "zeros as NAs" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

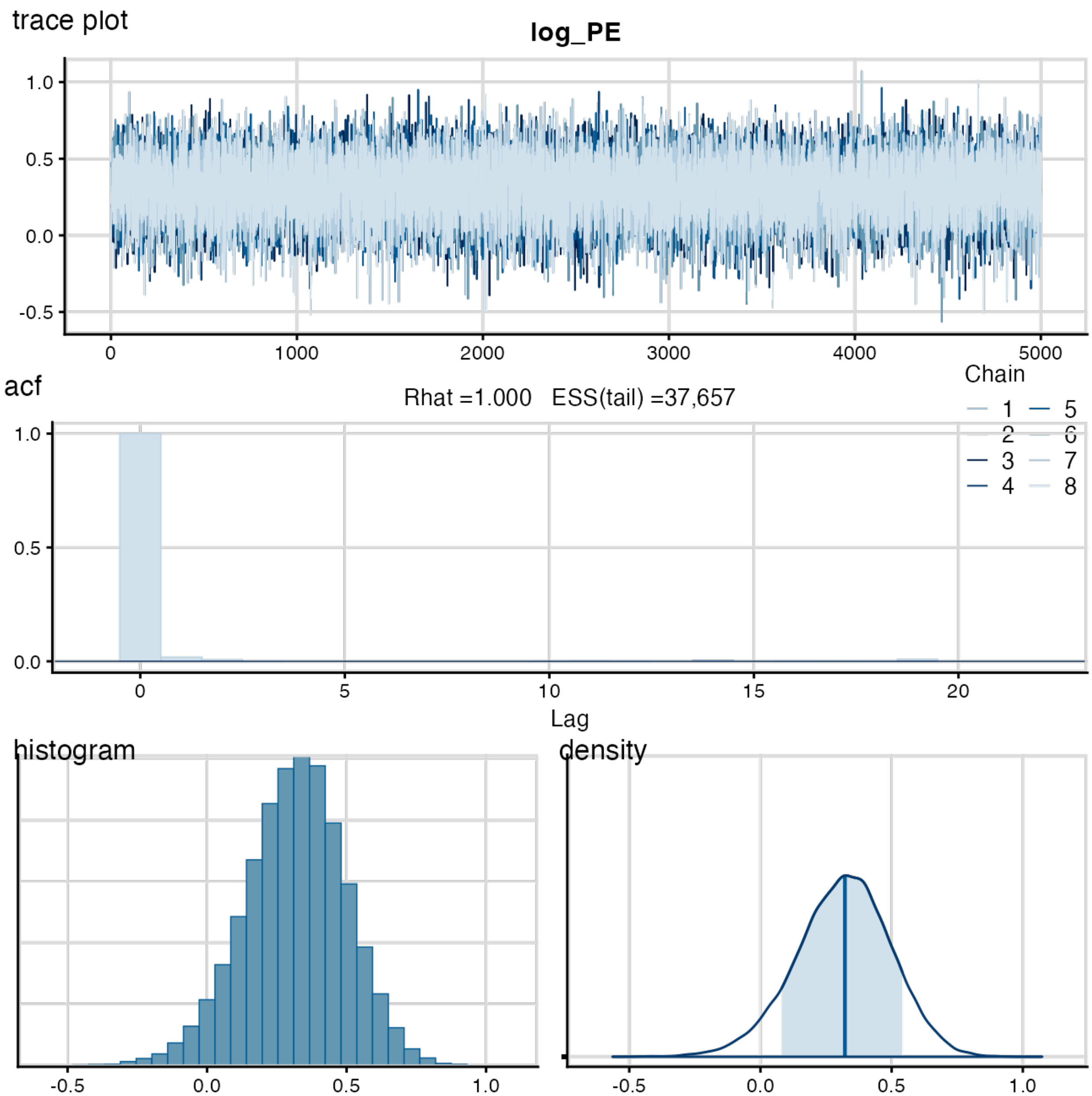

Figure 33. MCMC diagnostics for the ln-scale process error parameter from the "small constant" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

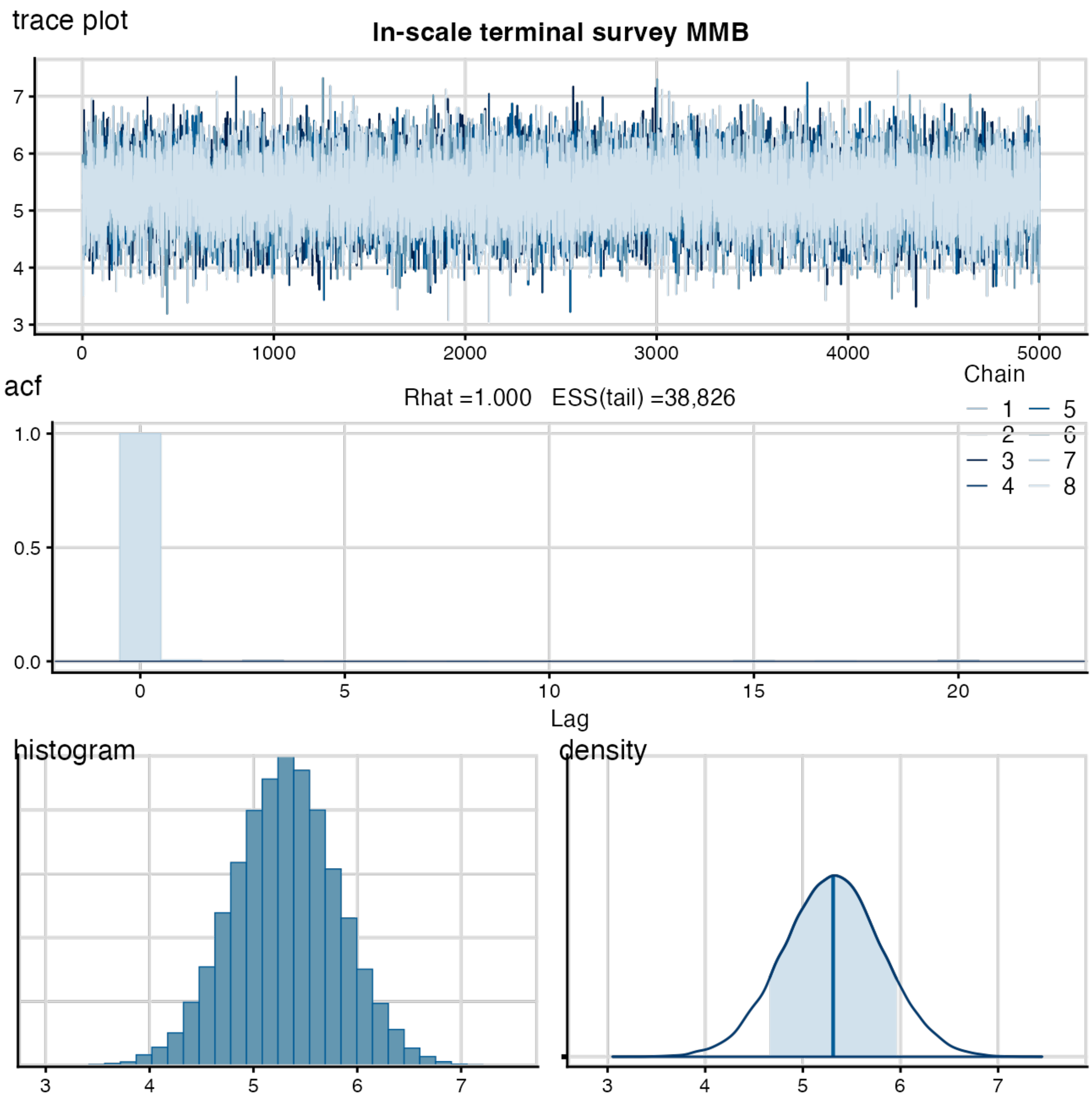

Figure 34. MCMC diagnostics for the ln-scale terminal year survey MMB from the "zeros as NAs" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

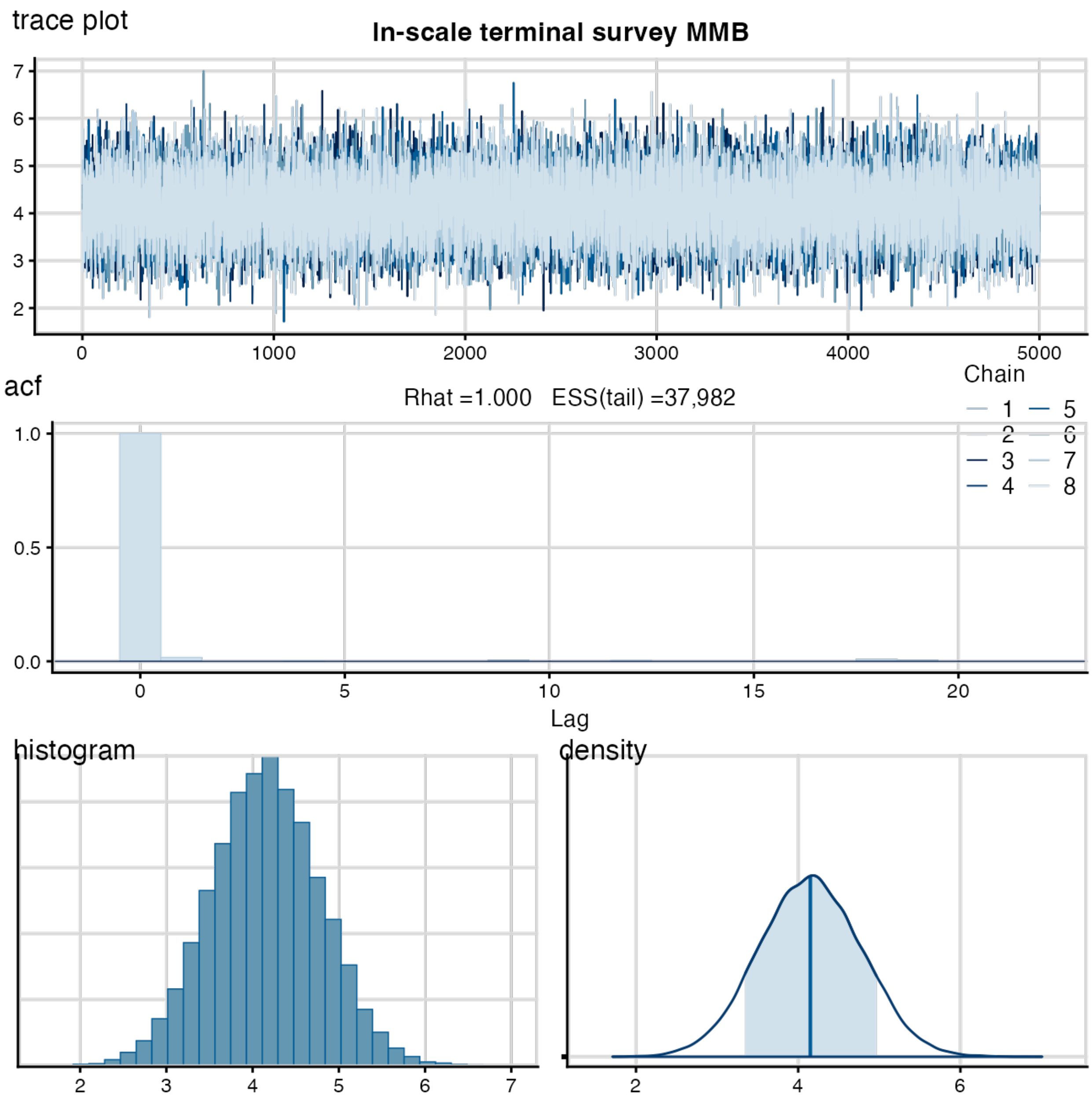

Figure 35. MCMC diagnostics for the ln-scale terminal year survey MMB from the "small constant" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

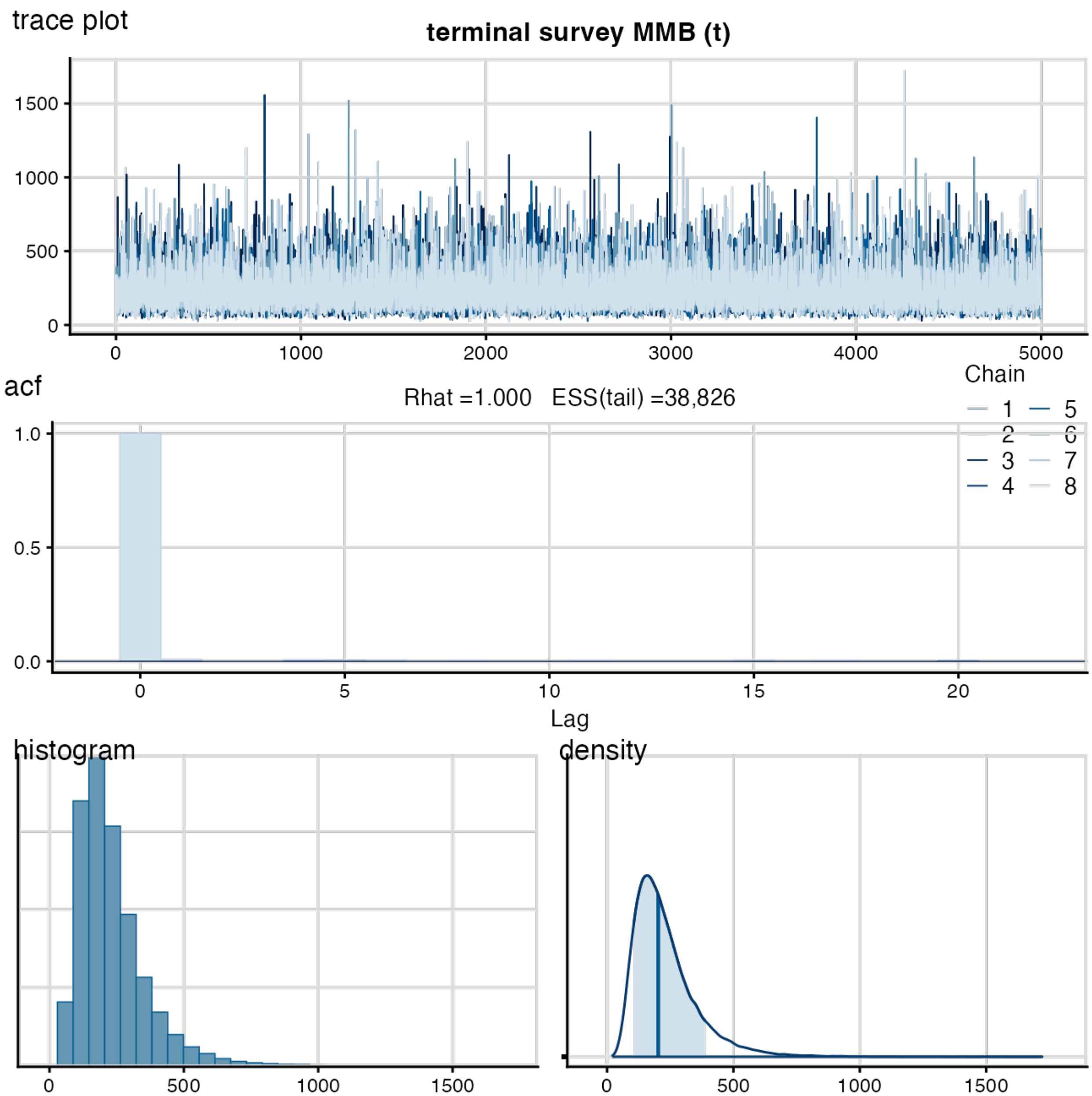

Figure 36. MCMC diagnostics for the terminal year survey MMB from the "zeros as NAs" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

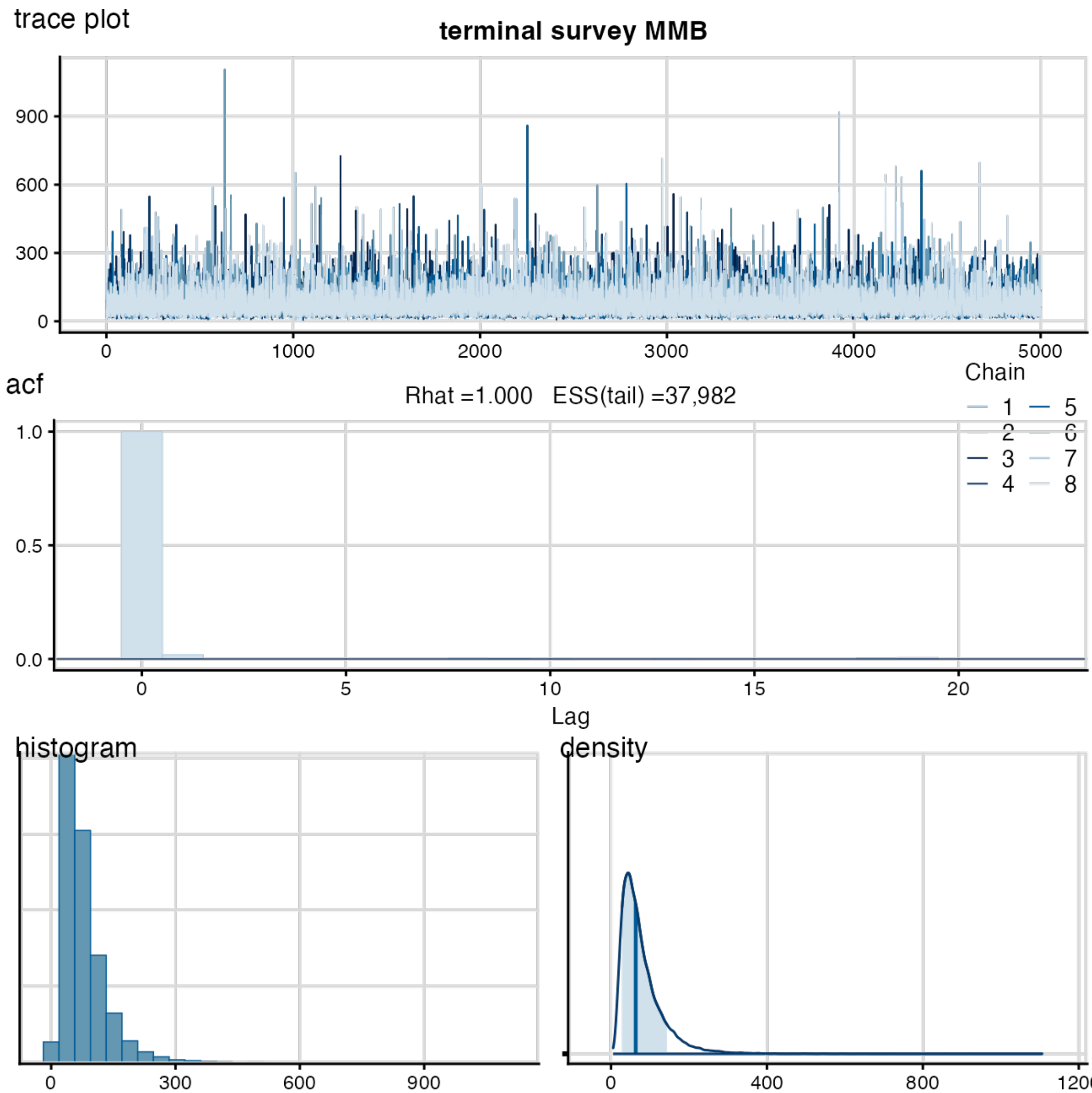

Figure 37. MCMC diagnostics for the terminal year survey MMB from the "small constant" model. Top row: trace plot; center row: autocorrelation plot; bottom row: histogram (left) and estimated posterior density with median (vertical line) and 80 percent confidence interval (shading). rHat (<1.05) and ESS (>100) are measures of acceptable MCMC mixing.

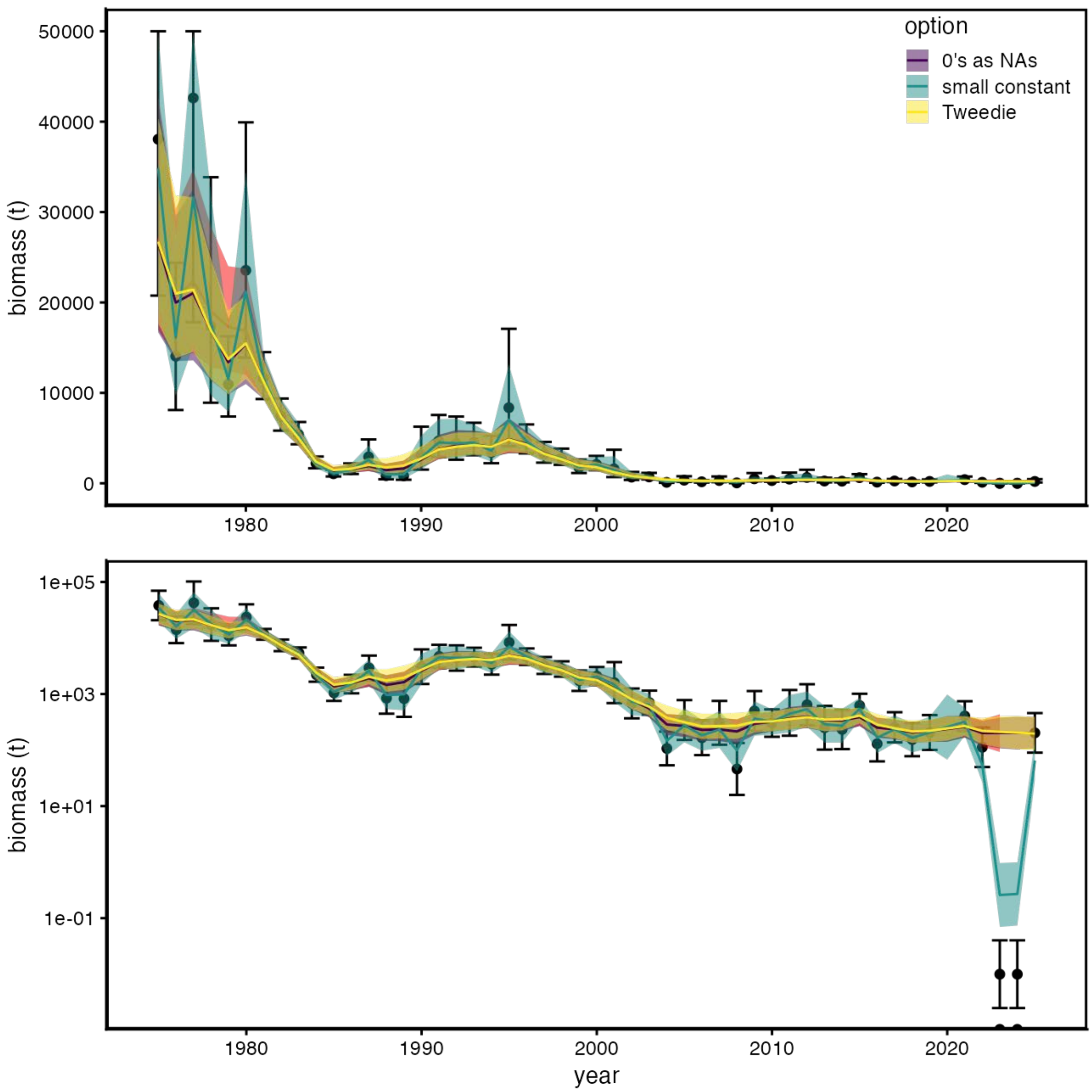

Figure 38. Results for the random walk model fits to mature survey biomass. Design-based estimates: points and error bars; last assessment: red line + red shading; current assessment: indicated colored lines + shading. Upper plot: arithmetic scale; lower plot: log-scale. Confidence intervals are 80 percent.

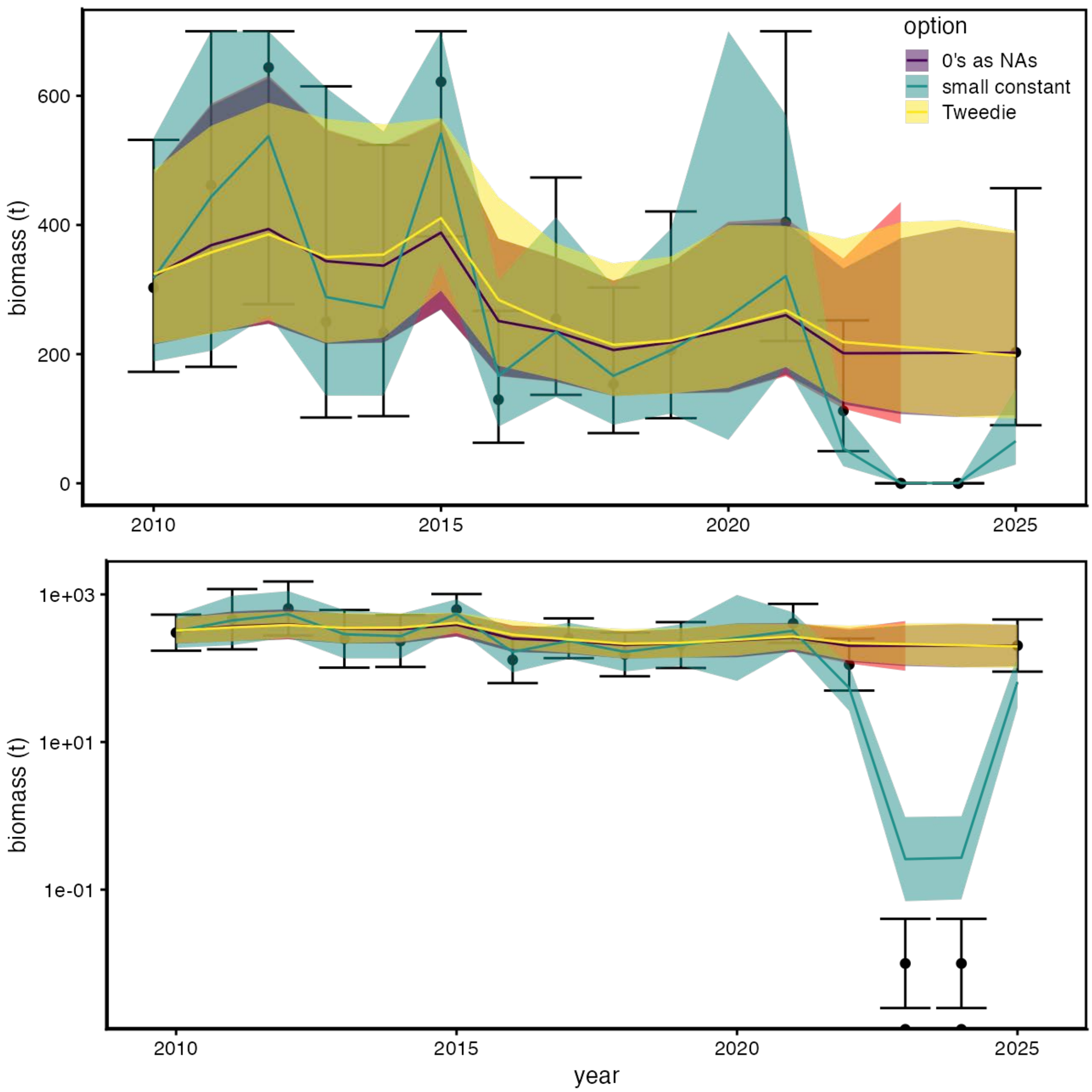

Figure 39. Results for the random walk model fits to mature survey biomass, showing recent time period. Design-based estimates: points and error bars (to 700 t); last assessment: red line + red shading; current assessment: indicated colored lines + shading. Upper plot: arithmetic scale; lower plot: log-scale. Confidence intervals are 80 percent.

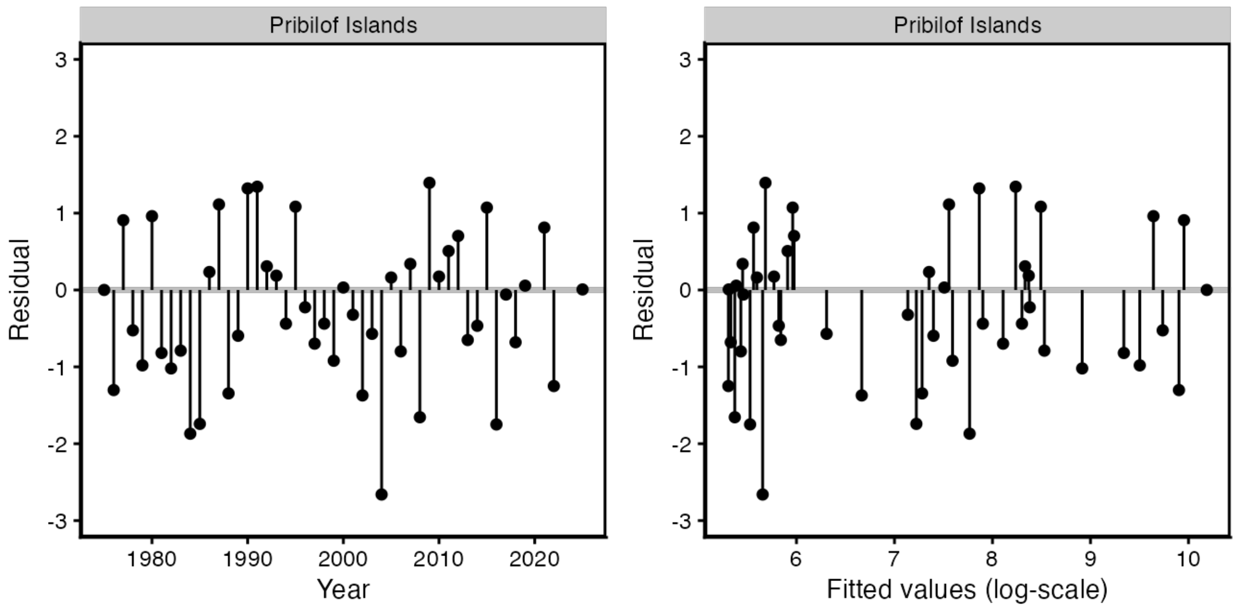

Figure 40. One-step-ahead (OSA) residual diagnostic plots for the "zeros as NAs" random walk model. Upper left: OSA residuals vs. year; Upper right: OSA residuals vs. fitted values; Lower left: histogram and kernel density of the OSA residuals; Lower right: qqplot for the OSA residuals;

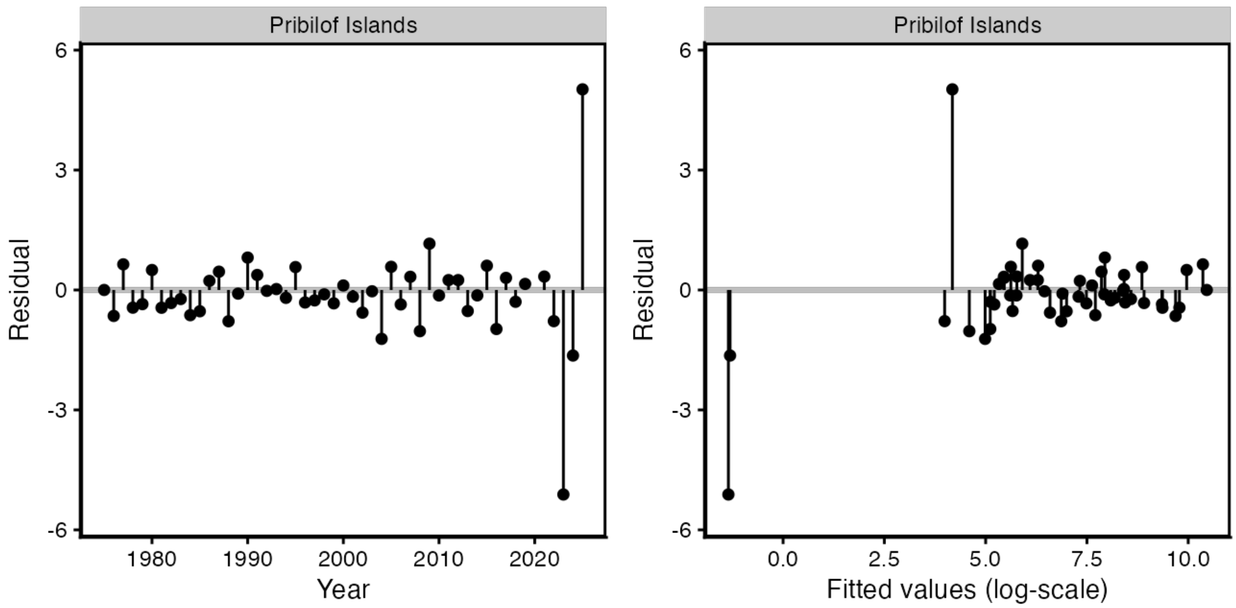

Figure 41. One-step-ahead (OSA) residual diagnostic plots for the "small constant" random walk model. Upper left: OSA residuals vs. year; Upper right: OSA residuals vs. fitted values; Lower left: histogram and kernel density of the OSA residuals; Lower right: qqplot for the OSA residuals;

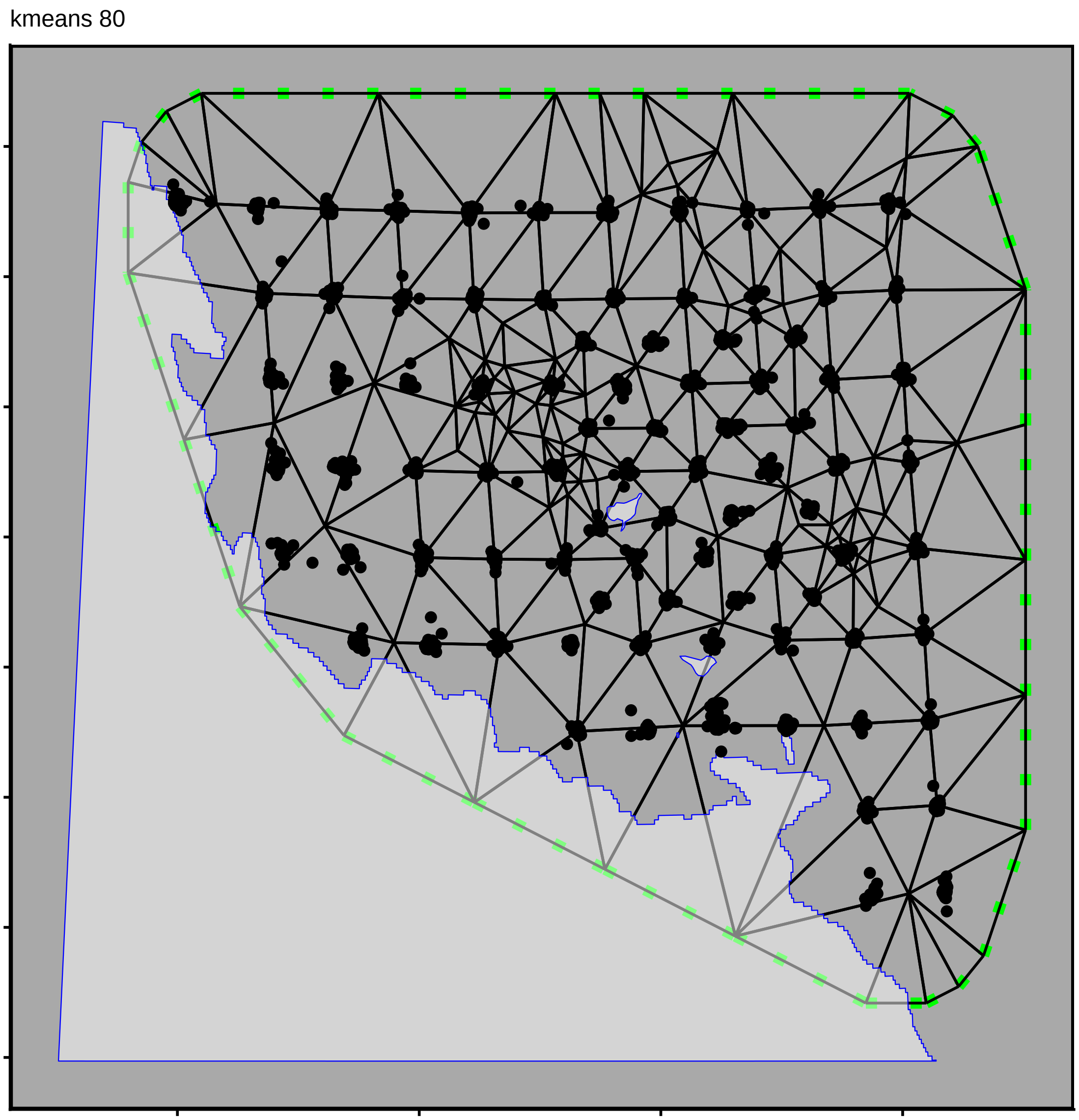

Figure 42. The triangular SPDE evaluation mesh used for the sdmTMB model "ar1S_nullT_logDepth_km080b". For each, the sdmTMB function "make_mesh" was applied to the NMFS survey haul-level CPUE data for MMB (black dots). "kmeans" (left column) or "CT" (righthand column) indicate the method used; the value indicates the number of allowd knots (kmeans) or the minimum distance allowed between nodes (CT). The green dots indicate the boundary vertices, the segments indicate triangle edges. The light gray polygons (with blue outlines) were used to create interpolation barriers representing the shelf edge and the Pribilof Islands.

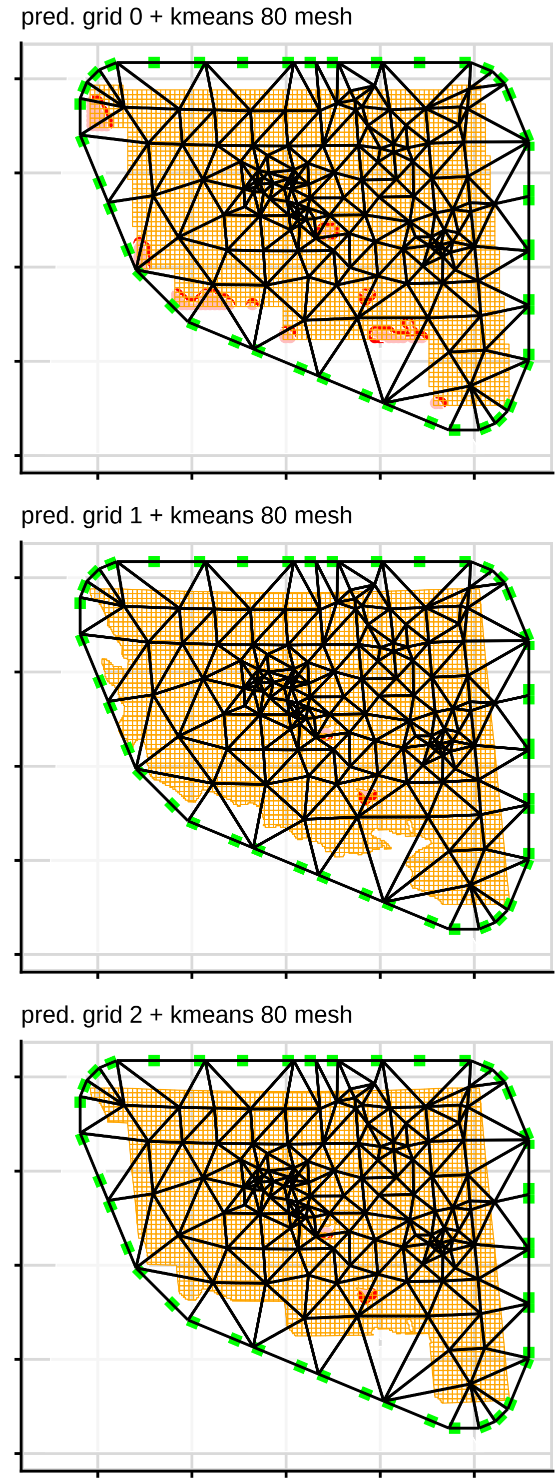

Figure 43. Three prediction grids evaluated (each compared with the “kmeans” 80 evaluation grid). Each prediction grid (orange squares) uses a 5 km grid cell size but covers a slightly different area: grid 0 covers the Pribilof District as defined by NMFS survey strata, and extends across the Pribilof Islands and beyond the shelf edge in some areas (darker orange); grid 1 extends to the shelf edge (500 m depth) and excludes the Pribilof Islands; and grid 2 is limited to depths < 500 m within the Pribilof District and excludes the Pribilof Islands.

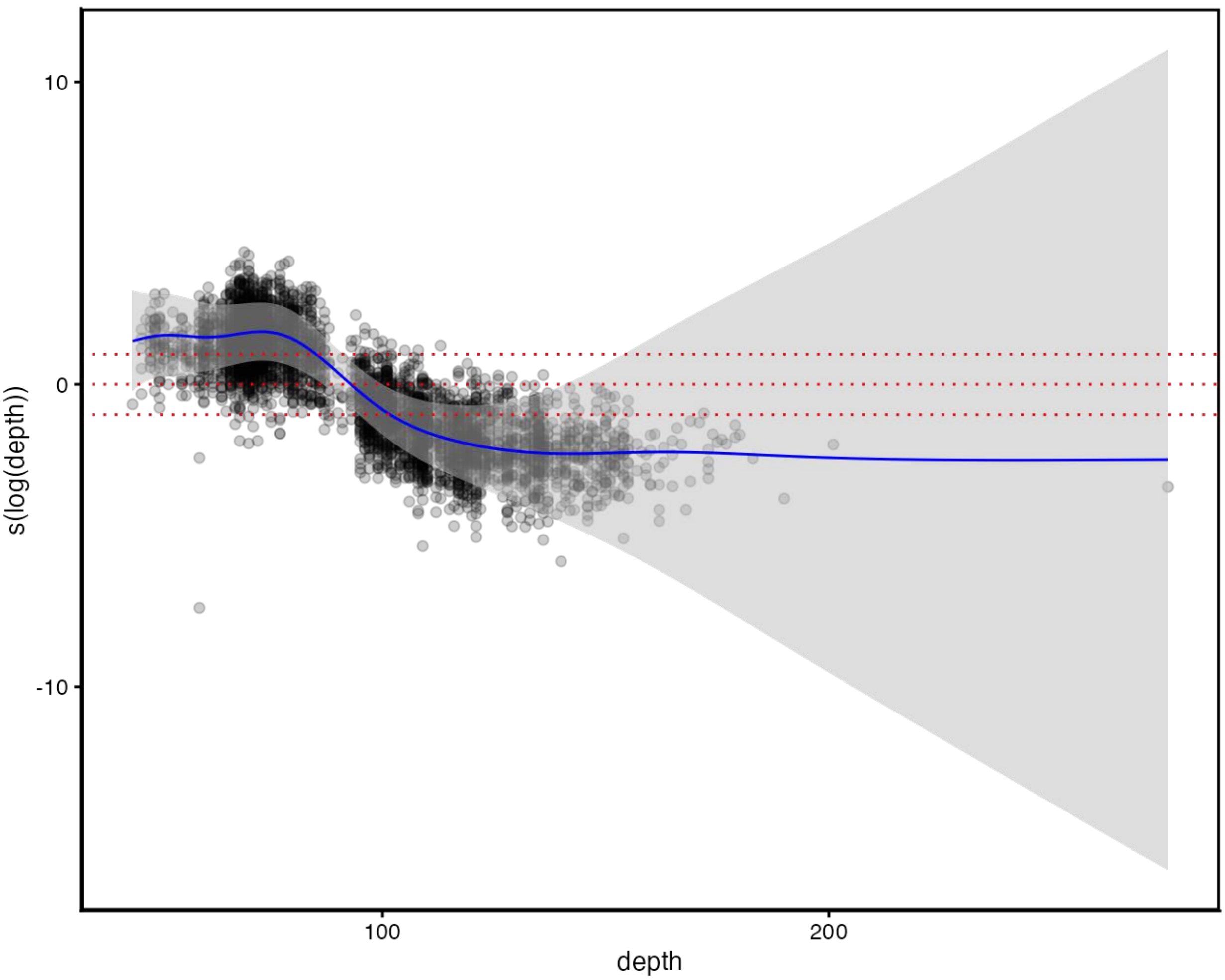

Figure 44. Estimated smooth function of ln(bottom depth) as a main effect covariate, on the link (ln) scale. Line: estimated effect; shading: 95% confidence intervals; points: residuals; horiontal dotted lines are plotted at link-scale values of -1, 0, and 1.

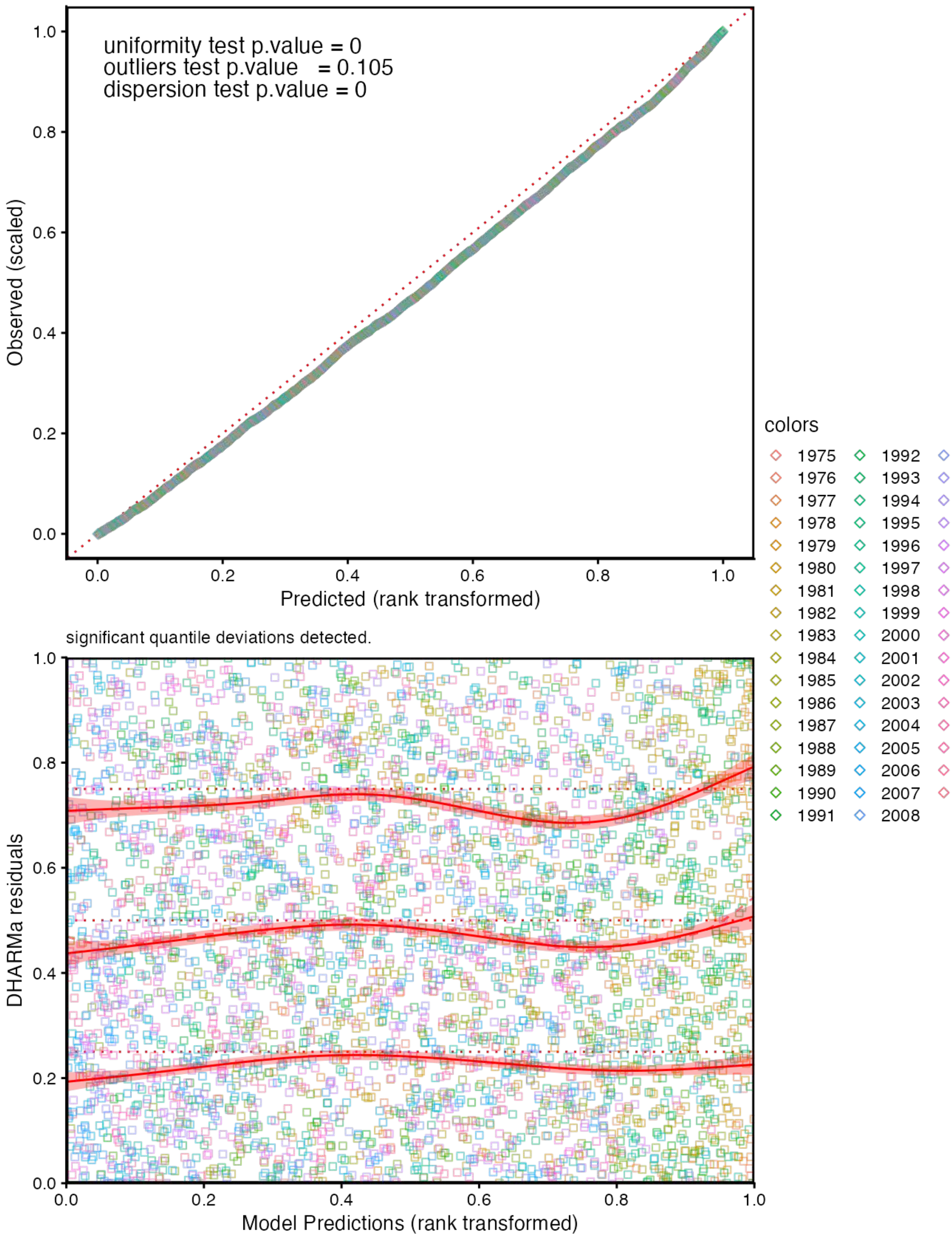

Figure 45. DHARMa diagnostic plots. Upper plot: QQ plot for scaled observations vs. rank-transformed predictions. dotted line indicates ideal behavior. Lower plot: quantiles for simulated residuals vs. rank-transformed predictions, dotted lines indicate theoretical 0.25, 0.5, and 0.75 quantiles, solid lines and shaded areas indicate smoothed trends of quantiles of simulated residuals across the ranked predictions. Symbol colors indicate associated survey year.

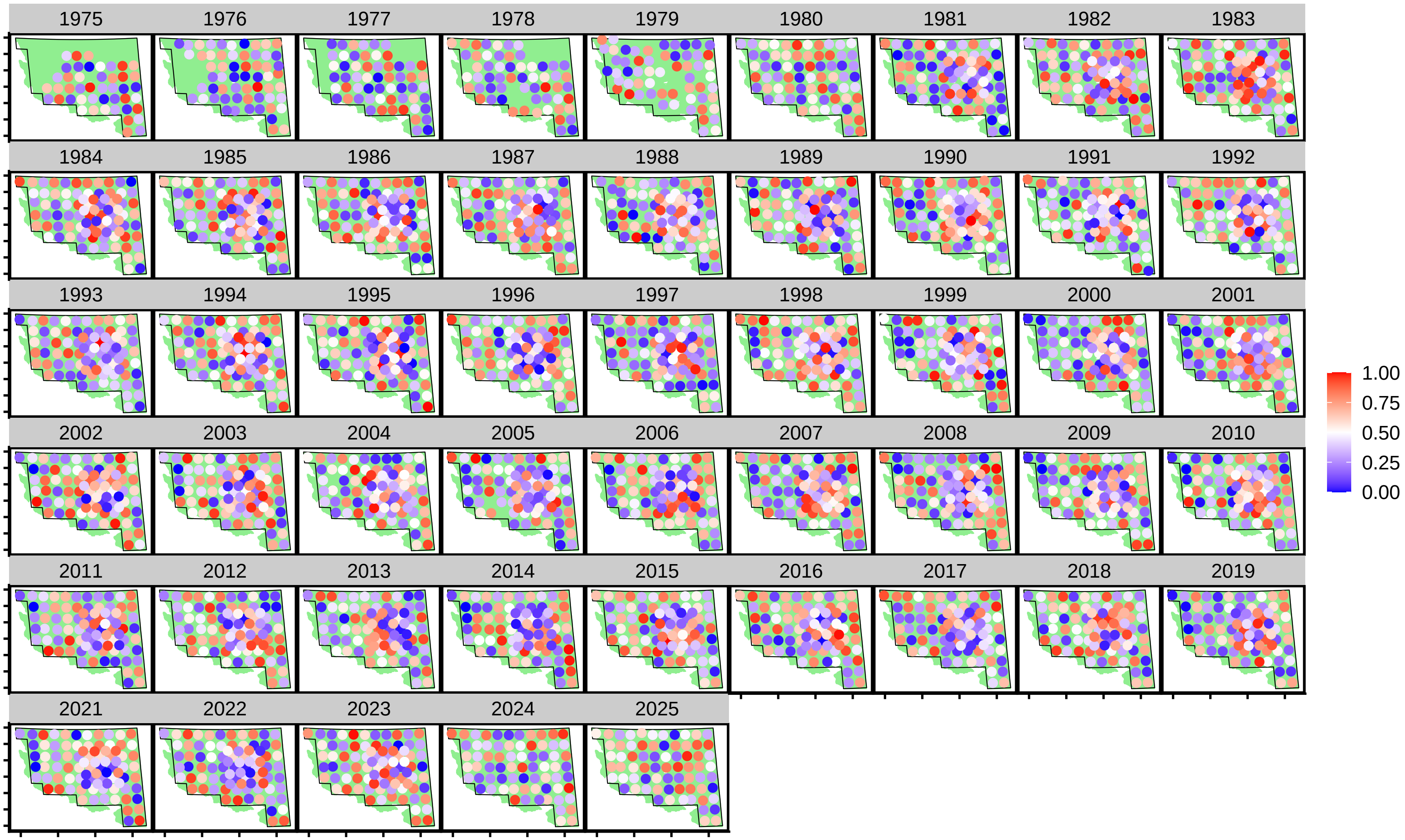

Figure 46. DHARMa scaled residuals (0 to 1) by haul location and year.

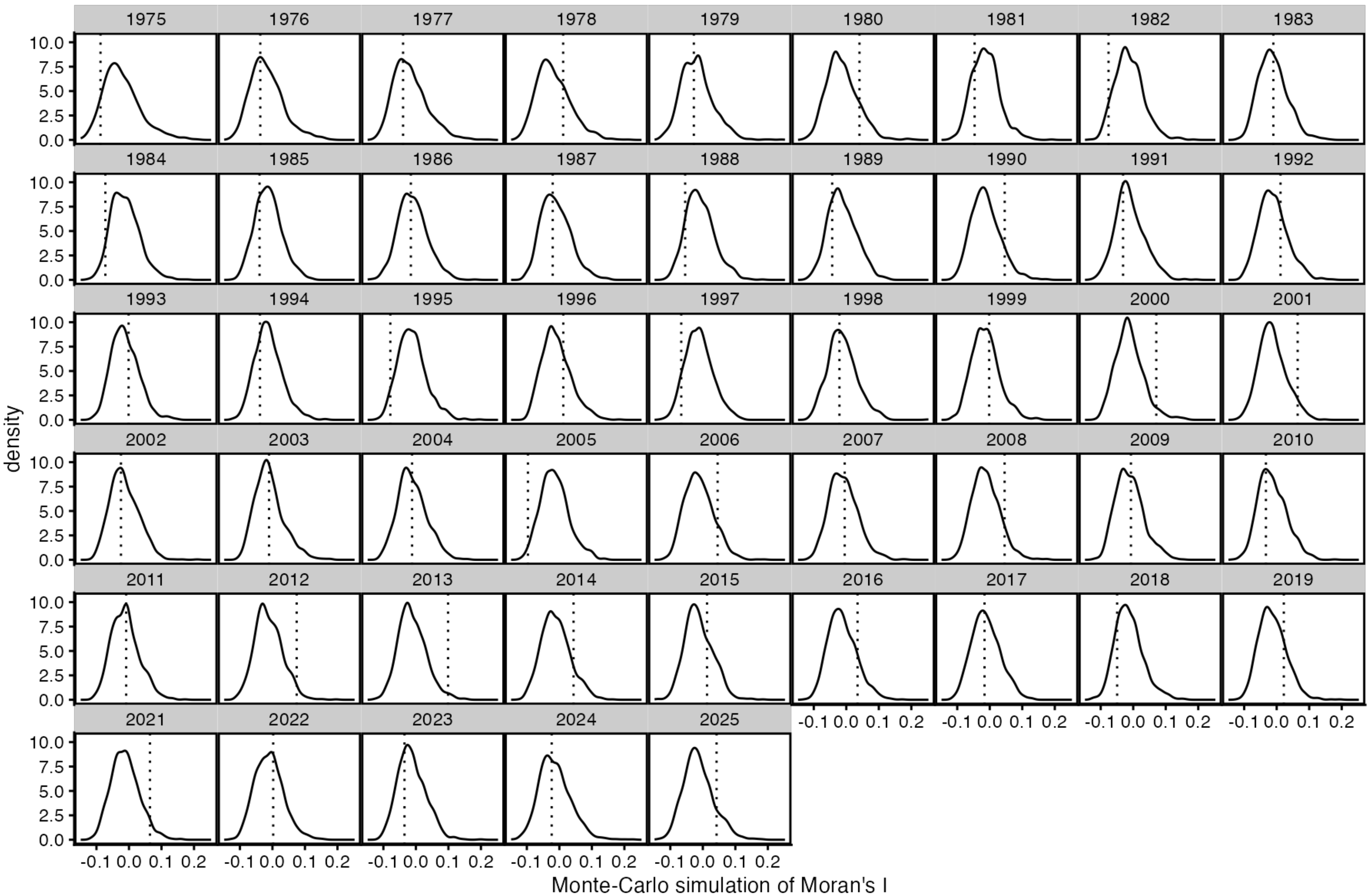

Figure 47. Monte-Carlo (permutation) simulation results for Moran's I, which tests for spatial autocorrelation, by year. Solid line: distribution of statistic under null hypothesis of no spatial autocorrelation. Dotted vertical line: value of realized statistic.

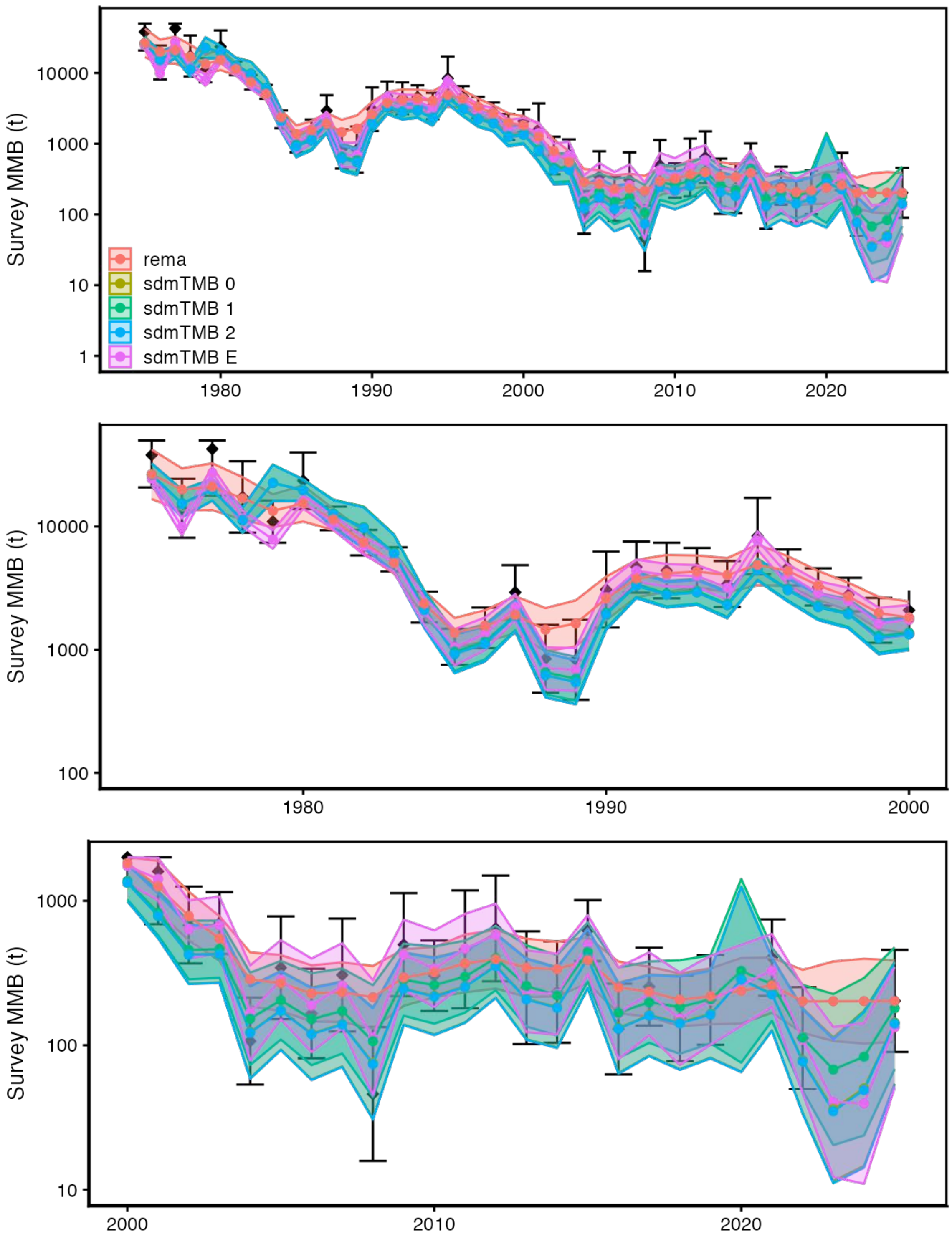

Figure 48. Comparison of `sdmTMB` and `rema` model-based indices (colored points, lines, and regions) and design-based indices (black dots and error bars). The last character of the "sdmTMB"-labelled indices indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations ("E") used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals, as do the error bars.Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

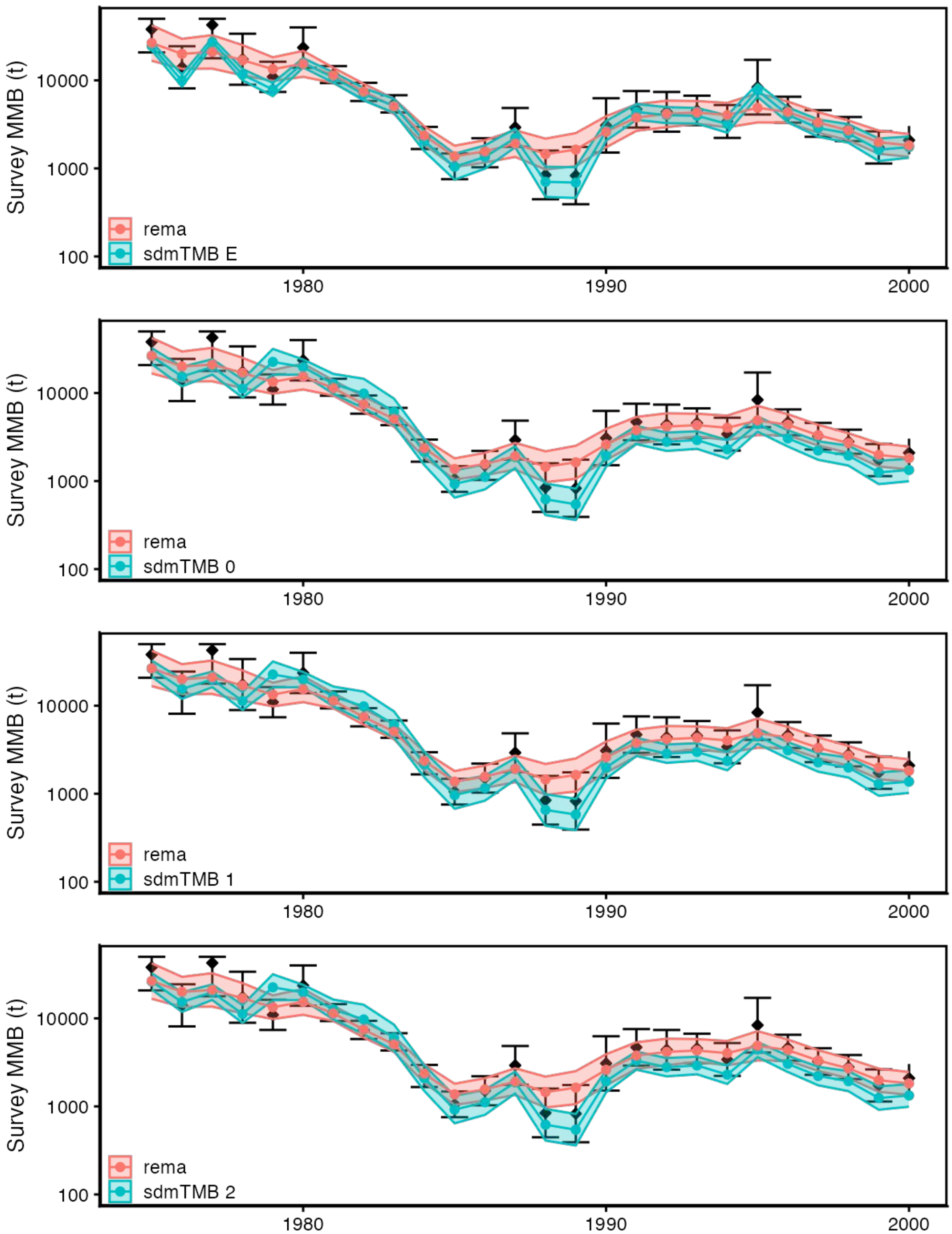

Figure 49. Comparison of `sdmTMB` and `rema` model-based indices (colored points, lines, and regions) and design-based indices (black dots and error bars) for 1975-2000 (to show detail better). The last character of the "sdmTMB"-labelled indices indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations ("E") used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals, as do the error bars.

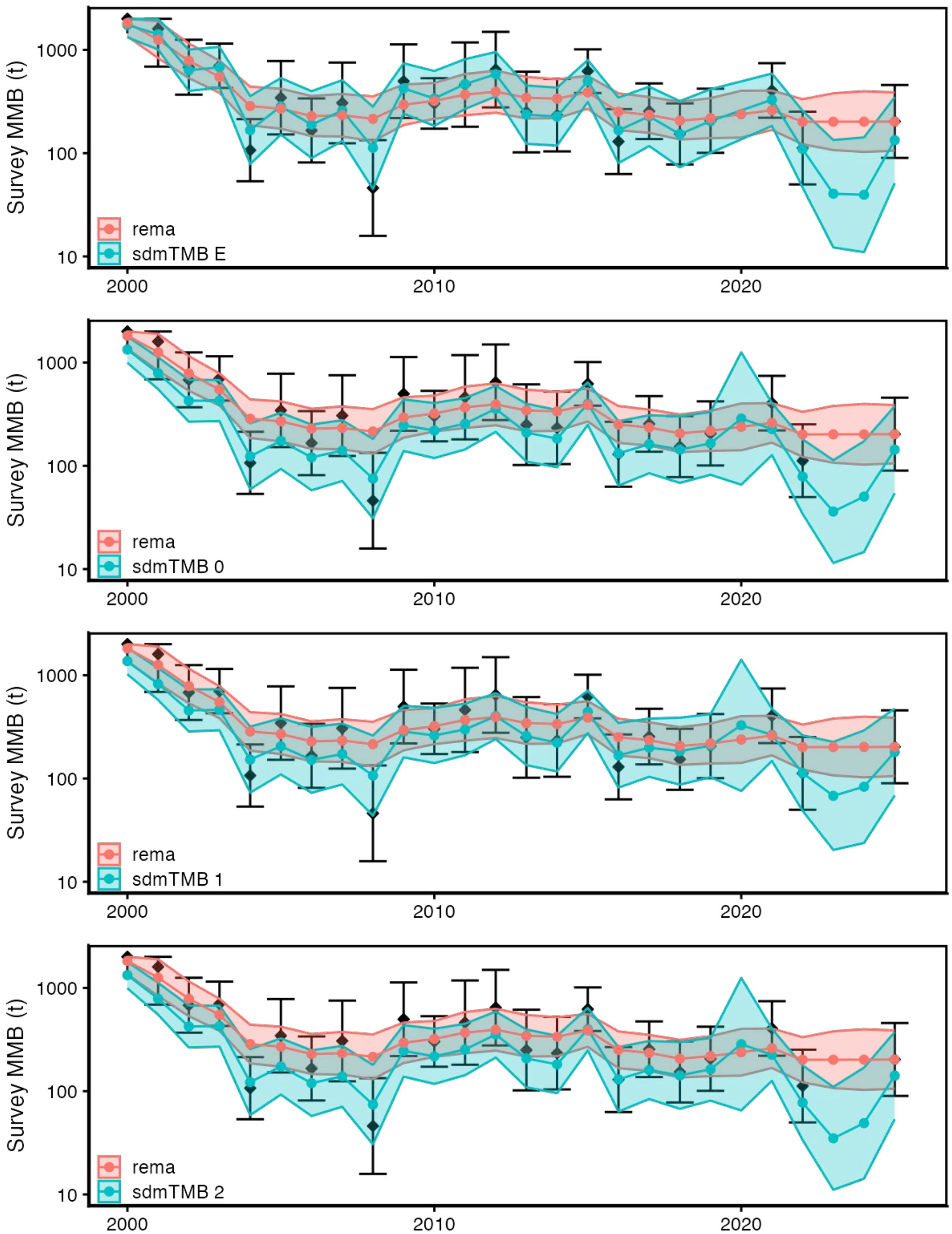

Figure 50. Comparison of `sdmTMB` and `rema` model-based indices (colored points, lines, and regions) and design-based indices (black dots and error bars) for 2000-current year (to show detail better). The last character of the "sdmTMB"-labelled indices indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations ("E") used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals, as do the error bars.

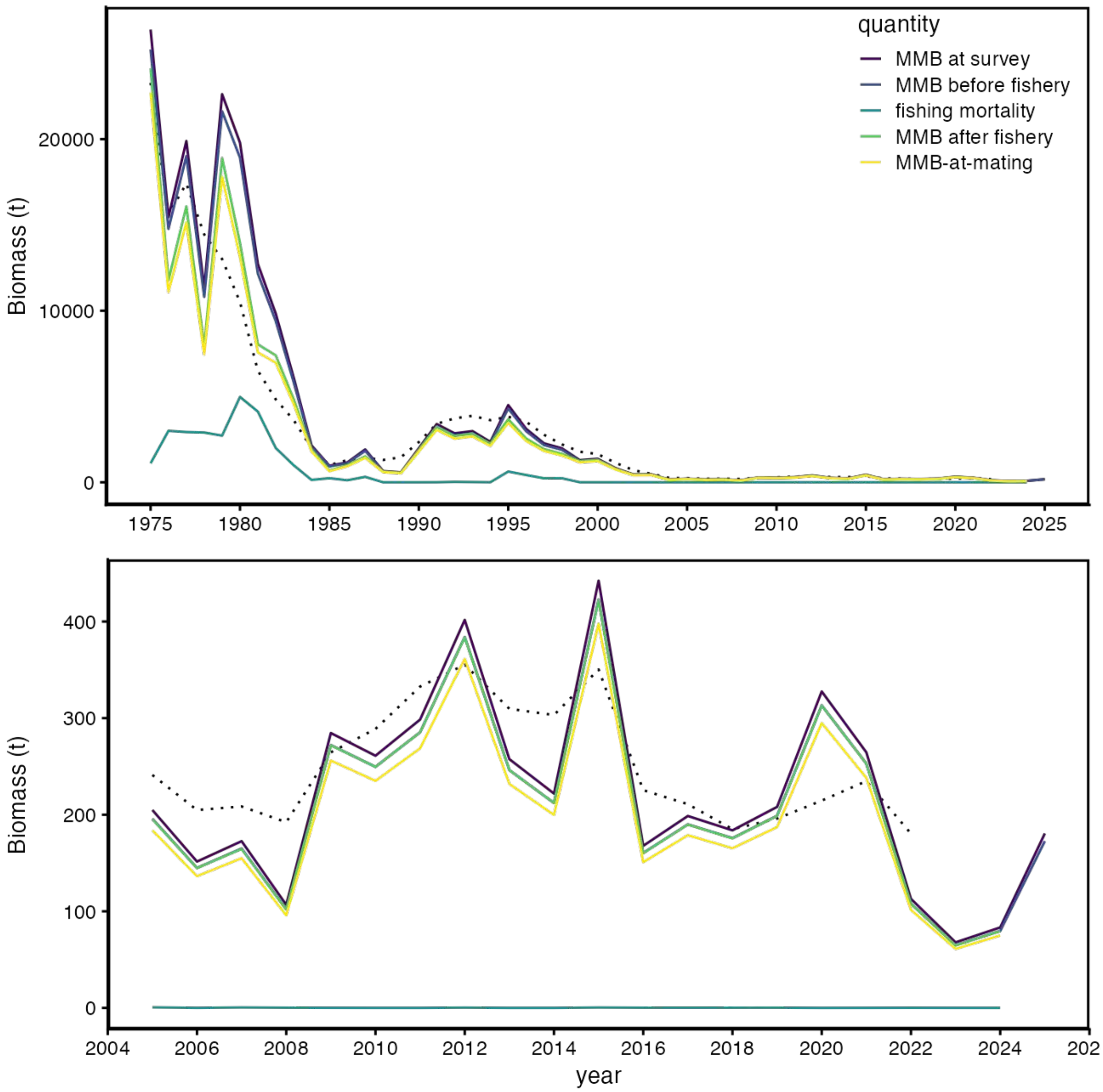

Figure 51. Estimated MMB-at-mating. Upper plot: full time series. Lower plot: detail for 2005/06+. Dotted line is estimated time series from last assesment.

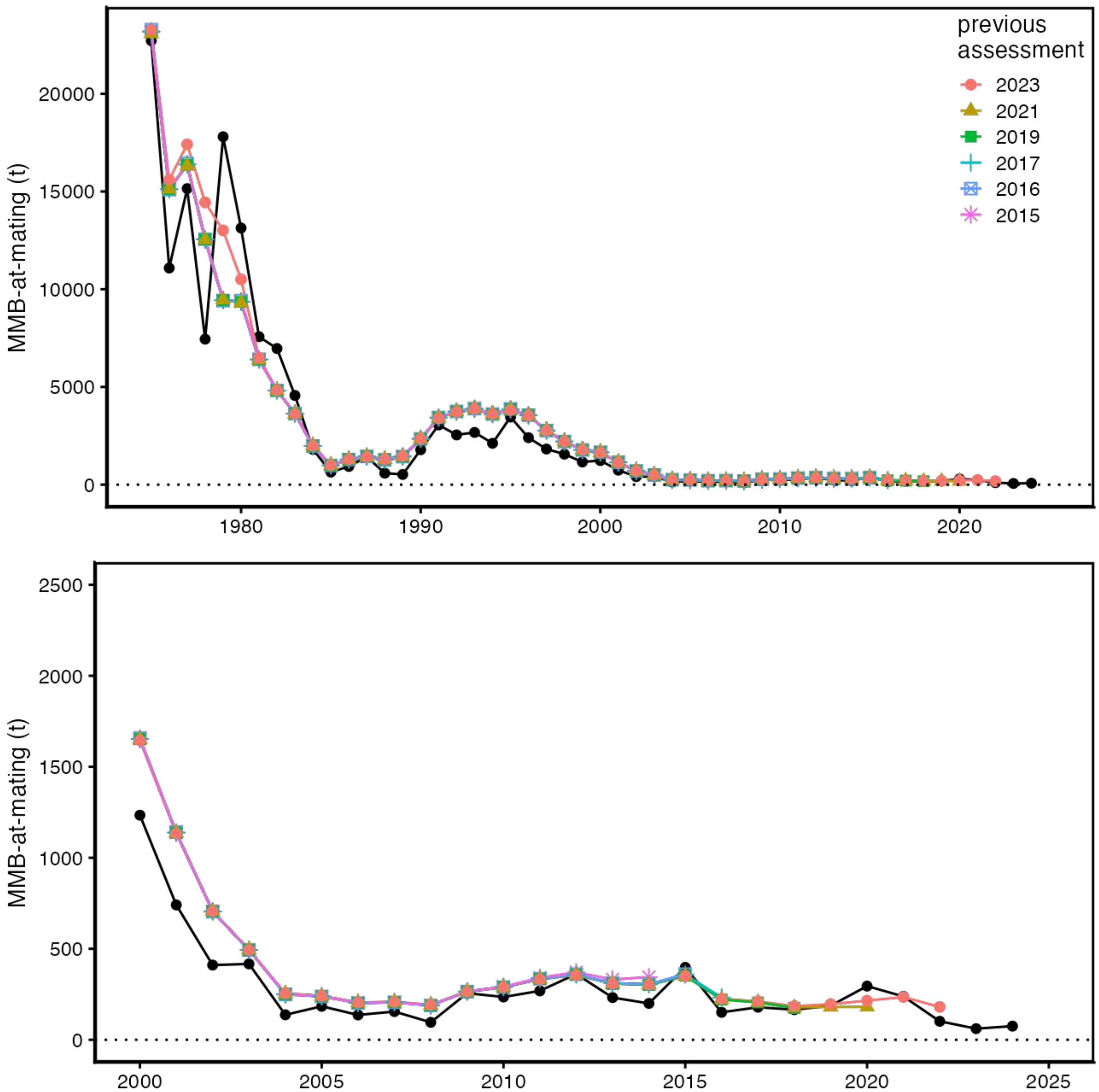

Figure 52. Comparison of the estimated MMB-at-mating time series from the current assessment (bllack line/symbols) and values from previous assessments (colored lines/symbols).

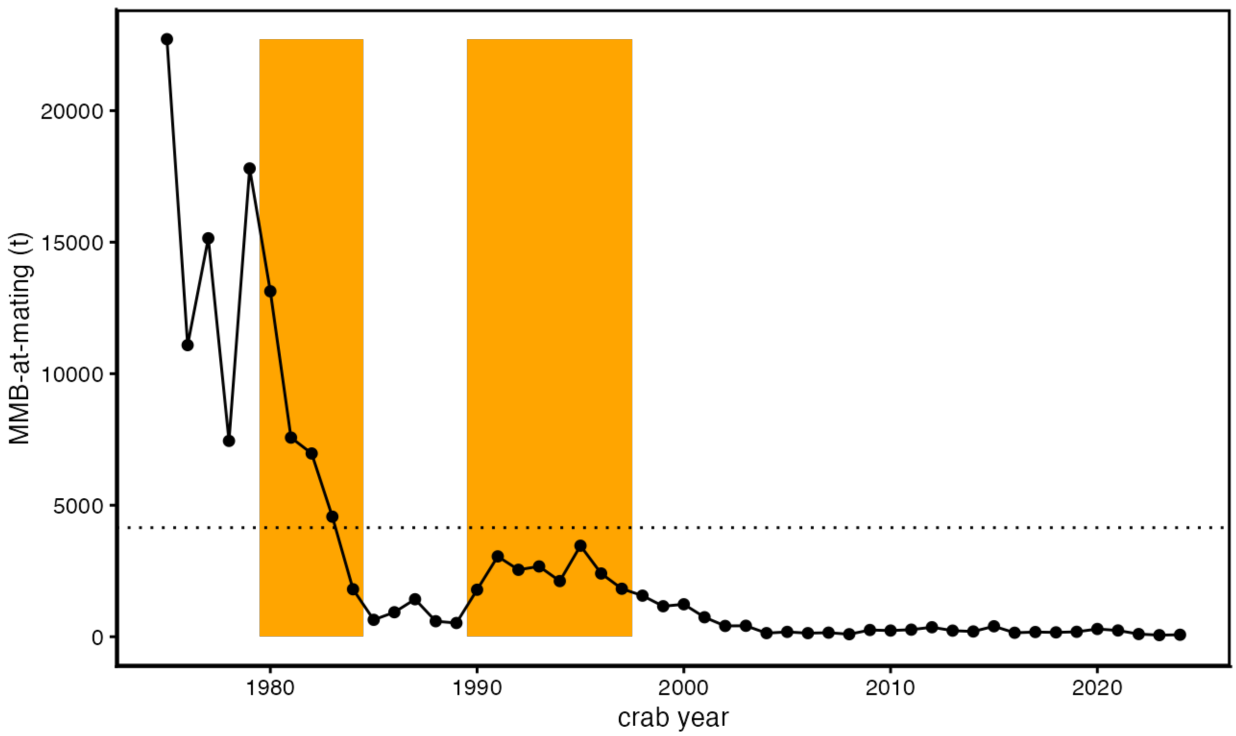

Figure 53. Time frame and time series to determine the Tier 4 B_{MSY}. Line and points: MMB-at-mating time series. Grey fill: time frame used for averaging to determine B_{MSY}. Dotted line: B_{MSY}.

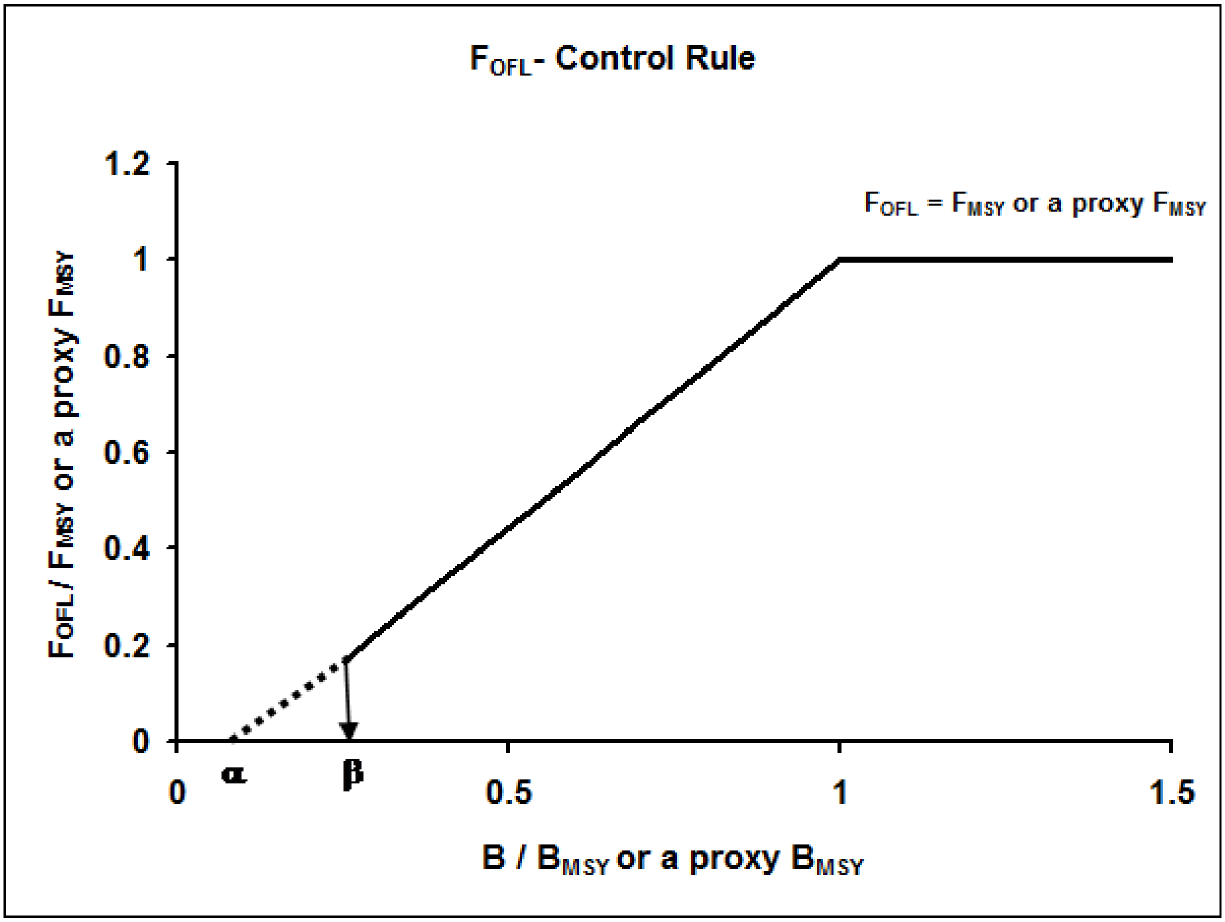

Figure 54. F_{OFL} Control Rule for Tier 4 stocks under Amendment 24 to the BSAI King and Tanner Crabs fshery management plan. Directed fshing mortality is set to 0 below ($\beta = 0.25$).

Appendix A: sdmTMB Model Selection to Estimate PIBKC mature male biomass from the NMFS EBS survey

William T. Stockhausen

2025-08-28

0.1 `sdmTMB` Models for PIBKC mature male biomass

The NMFS EBS bottom trawl survey captured no mature male PIBKC in 2023 and 2024, introducing observed zeros into the design-based survey time series for Pribilof Islands blue king crab mature male biomass (PIBKC MMB). The `rema` R package (R Core Team 2022; Sullivan 2022) has been used in previous assessments (e.g., Stockhausen (2023)) to fit a random effects first-order autoregressive (AR1) time series model to this time series to provide model-based estimates of the time series and terminal year survey MMB, but because `rema` fits the time series progression on the log-scale, the observed zeros are problematic because they become negative infinities when transformed to that scale. Several *ad hoc* approaches to dealing with the observed zeros while retaining the `rema` framework were presented to the CPT and SSC at their May and June (respectively) 2025 meetings (Stockhausen (2025)), but all were rejected in favor of deriving the model-based survey MMB time series based on spatiotemporal species distribution models (SDMs) using the `sdmTMB` `R` package (R Core Team 2022; Anderson et al. 2024).

`sdmTMB` is an `R` package that fits spatial and spatiotemporal Generalized Linear Mixed Effects Models (GLMMs) using Template Model Builder [TMB; Kristensen et al. (2016)], R-INLA (Lindgren and Rue 2015), and Gaussian Markov random fields. One common application of this framework is to create spatially-explicit species distribution models (SDMs) from species abundance data collected across space and (possibly) through time, although its principal advantage here is that it can also estimate stock-level time series by integrating estimated spatially-explicit patterns of abundance or biomass across space. A simple way to think about an `sdmTMB` model is that it provides a way to interpolate observations across space and time, taking into account both stochastic population variability across space and time as well as variability inherent to the sampling process itself. While several preliminary `sdmTMB` model configurations involving different statistical assumptions were presented to the CPT in May, it subsequently recommended (which the SSC supported) proceeding with models based on a Tweedie distribution, with spatiotemporal random effects having an AR1 error structure. The Tweedie distribution (Tweedie 1984) is a compound Poisson-gamma distribution that allows observed absences (zeros) in the data, incorporating a single linear predictor (rather than two in the case of two-stage models like the delta-gamma) while estimating a parameter that reflects the degree of mixing between the underlying Poisson and gamma distributions. (Thorson et al. 2021) recommend using the Tweedie distribution for spatiotemporal models by default, particularly when it is not possible to compare the scale of model-derived indices with those from design-based estimators (although comparison is possible in this case).

0.2 Methods

Here, 18 different `sdmTMB` model configurations were examined (Table 1). Based on the CPT recommendation, only models with ln-scale spatiotemporal random effects modeled as Tweedie AR1 distributions were considered. Other "axes" of model construction included whether strictly spatial random effects were estimated, whether strictly temporal random effects were estimated, whether a smoothly-varying function of haul depth was estimated, the grid used to predict survey catch per unit effort (CPUE in [biomass]/[unit area]) across the management area for PIBKC, the spatial "mesh" (e.g., grid) used to estimate the model spatiotemporal and spatial random effects, and whether barriers (e.g., the Pribilof Islands) were included the estimation mesh.

0.2.1 Statistical models

All of the models examined here can be expressed as

$$\begin{aligned}\mathbb{E}[o_{s,t}] &= \mu_{s,t}, \\ \mu_{s,t} &= f^{-1}\left(\alpha \cdot s[ln(d_{s,t})] + \beta \cdot \gamma_t + \delta \cdot \omega_s + \epsilon_{s,t}\right)\end{aligned}$$

where $o_{s,t}$ represents the observed survey CPUE at position s in year t; $\mathbb{E}[\cdot]$ is the expectation operator; $\mu_{s,t}$ is the mean at s,t; f represents the link function (the natural log in all cases here); α, β, and δ are 1 or 0 to turn on/off, respectively, a smooth function of depth ($s[ln(d_{s,t})]$), temporally-varying random intercepts (γ_t), or spatially-varying random effects (ω_s). $\epsilon_{s,t}$ represents the spatiotemporal random effects terms included in all the models.

Depth is included as a covariate in models with the "covariate" column value listed as "ln(depth)", with the effect estimated as a smooth, main effects function of $ln(d_s)$ using the "s" function from the `mgcv` R package. Spatial random fields are included in models with the "spatial" column value listed as "on". The random field, ω_s, is a Gaussian Markov random field with

$$\omega_s \sim \text{MVNormal}(0, \sigma_\omega^2 Q_\omega^{-1})$$

where Q_ω is a sparse precision matrix and σ_ω^2 is the marginal variance. Temporal random effects (random intercepts) are included in models with the "temporal" column value listed as "AR1". The random temporal intercepts, γ_t, follow a first-order autoregressive process, with

$$\begin{aligned}\gamma_{t=1} &\sim \text{Normal}\left(0, \sigma_\gamma^2\right), \\ \gamma_{t>1} &\sim \left(\rho_\gamma \gamma_{t-1}, \sqrt{1-\rho_\gamma^2}\sigma_\gamma^2\right)\end{aligned}$$

where the first time step is given a mean zero prior and ρ_γ is the correlation between subsequent time steps. The spatiotemporal random effects included in all the models were estimated using an AR1 temporal covariance structure such that

$$\begin{aligned}\delta_{t=1} &\sim \text{MVNormal}(0, \Sigma_\epsilon), \\ \delta_{t>1} &= \rho\delta_{t-1} + \sqrt{1-\rho^2}\epsilon_t,\ \epsilon_t \sim \text{MVNormal}\left(0, \Sigma_\epsilon\right)\end{aligned}$$

where Σ_ϵ is a spatial covariance matrix, ρ is the correlation coefficient, and the ϵ_t are temporally iid spatial random effects with the same spatial covariance structure as $\delta_{t=1}$.

0.2.2 Evaluation meshes

Six triangular stochastic partial differential equation (SPDE) meshes, based on two mesh construction strategies ("kmeans" and "cutoff") and three sizes per strategy, were originally considered for model evaluation (Figure 1). However, preliminary tests with the "cutoff" meshes (labelled "CT" in the figure) proved unsatisfactory, with sdmTMB models either failing to converge or taking a prohibitive amount of time. The majority of models evaluated here used the "kmeans" mesh with 80 knots, although the "best" 80-knot model was also evaluated at 40 and 60 knots to partially explore the influence of mesh size on results.

0.2.3 Prediction grids

The evaluation mesh is used to fit a `sdmTMB` model to CPUE data, with spatiotemporal random effects estimated at each mesh node for each time step. However, the evaluation mesh is generally at a coarser scale than that of the data to improve model stability and convergence times. Following model estimation, a "prediction grid" can be used to predict spatiotemporal patterns of species abundance/biomass at much finer spatial resolutions than the evaluation grid. Subsequently, area-integrated indices of species abundance or biomass can be obtained by integrating the predicted densities across the area of interest. Here, three prediction grids were evaluated as the basis for area-integrated indices of PIBKC mature male survey biomass (MMSB) to determine an estimate for terminal year MMSB (Figure 2). The spatial resolution was the same (5 km) for all three grids, but the coverage relative to the NMFS survey grid and the continental shelf differed: grid 0 covered the Pribilof District as defined by NMFS survey strata, extending across the Pribilof Islands and beyond the shelf edge in some areas; grid 1 extended to the shelf edge (500 m depth) and excluded the Pribilof Islands; and grid 2 was limited to depths $<$ 500 m within the NMFS survey strata and excluded the Pribilof Islands. All three grids extend slightly beyond the kmeans 40 evaluation mesh, while prediction grid 0 extends slightly beyond the kmeans 60 mesh (Figure 2), which proved problematic when estimating the MMSB indices using these combinations of evaluation mesh and prediction grid.

0.2.4 Model evaluation

All models were estimated using `sdmTMB`'s 'sdmTMB' function by fitting the 1975-2024 NMFS EBS haul-level MMSB CPUE dataset for PIBKC using restricted maximum likelihood and adding 2020, the year the EBS survey was not conducted due to Covid-19, as an "extra" year. Models were first evaluated using `sdmTMB`'s 'sanity' function, which checks for issues with model convergence, hessian inversion, and the estimated size of the variances related to the various random effects components.

Models which passed `sdmTMB`'s sanity check were then subjected to a k-fold out-of-sample cross-validation procedure and subsequently ranked using the average out-of-sample predictive skill, with "k" chosen as 10. For each model, the cross-validation procedure randomly split the haul-level CPUE data into 10 "folds" of similar size, with approximately 10% of the data selected as the out-of-sample evaluation set and the remaining 90% of the data used as the training set. The evaluation data were selected across the 10 folds without replacement, so each datum featured in an evaluation set once. For each fold, the model was fit to the training data and used to predict the out-of-sample evaluation data. The out-of-sample log-likelihood score, root mean square error

(RMSE), and mean absolute error (MAE) were then calculated for each fold for a given model. The models were then ranked by the mean (negative) log-likelihood score (smaller being better) and the five "best" models were selected for further examination.

For the five "best" models, residuals were checked without regard to spatial pattern for uniformity, outliers, dispersion, and quantile behavior using the `DHARMa` R package's (Hartig 2022). They were then checked for spatial correlation by examining annual maps of the residuals for patterns and using the Moran's I test function ("moran.mc") in the `spdep` R package (Pebesma and Bivand 2023) to test for spatial autocorrelation in the residuals each year. Finally, aggregated biomass indices were calculated for each of these models using the three prediction grids and `sdmTMB`'s "get_index" function and the resulting time series compared.

0.3 Results

0.3.1 Model checks

Three models either failed to finish or failed the `sdmTMB`'s sanity checks Table 2. The remaining models passed all of the checks.

0.3.2 Cross-validation

Based on the 10-fold cross-validation, the best model in terms of out-of-sample predictive performance was `ar1S_nullT_logDepth_km080b`, based on all three cross-validation statistics (Table 3, Figures 3-5). Model `ar1s_nullT_logDepth_km040b` failed to converge during the cross-validation tests.

0.3.3 DHARMa residuals

All of the remaining models were tested for deviations from uniformity, significant dispersion, presence of outliers, and quantile bias and nonlinearity using the `DHARMa` R package. All of the models passed the outliers test at the $p > 0.05$ level of significance, but none passed the other tests at the same level (Table 4). Standard `DHARMa` residual plots are illustrated in Figures 6-10 for the top five models ranked on the average cross-validation score (lowest score is best).

0.3.4 Spatial residuals and statistics

Spatial plots of residuals scaled to range from 0 to 1 are illustrated in 5-year time blocks for the five "best" models ranked on the average cross-validation score (lowest score is best) are illustrated in Figures 11-20. The distributions associated with the null hypothesis of Moran's I test for spatial autocorrelation were very similar across models and years while the values of the statistics were different (Figure 21). The distributions were determined using 1000 randomly-drawn permutations of the residuals for each model for each year; the statistic for each model and year was determined from the "observed" spatial pattern of residuals. Two of the models failed the Moran's I test for spatial correlation in a couple of years (Table 5), but this was not unexpected given the number of years for which the statistic was calculated.

0.3.5 Fixed effects (smoothed covariates)

Three of the "best" models contained a smooth function of log-scale haul depth as a fixed effects covariate (Figures 22-24). The estimated smooth function has an amplifying effect at depths shallower than ~100 m and a diminishing effect at greater depths, with the uncertainty increasing dramatically at depths greater than ~150 m due to a lack of observations at greater depths.

0.3.6 Biomass indices

The biomass indices calculate using the evaluation grid and the three prediction grids are illustrated for the five "best" models in Figures 25-29. The results are generally similar across models and grids, with the notable exceptions that 1) the estimates for 1979 differs substantially between the evaluation grid and the three prediction grids for all five models, and 2) the results using prediction grid 1 for models (except the "best" model) that include log depth as a covariate. Using the evaluation grid to generate the biomass index results in estimates almost equivalent to the design-based values (not shown) and the spatial pattern of haul locations in 1979 was unique among survey years, so differences are not surprising. As noted previously, prediction grid 1 extended to the shelf edge (500 m depth) and excluded the Pribilof Islands. The inclusion of depths up to 500 m led to obviously poor estimates for the biomass indices when using this grid with models "r1S_nullT_logDepth_km060b" and "r1S_nullT_logDepth_km080", but not with the "best" model r1S_nullT_logDepth_km080b.

0.3.7 Model and biomass index selection

Based on the analysis presented, Model "ar1S_nullT_logDepth_km080b" appears to be the "best" of the 18 models considered. Although the indices based on prediction grid 1 were poor for two of the models that included a smooth function of log depth as a fixed effect, this was not the case for "ar1S_nullT_logDepth_km080b". Because prediction grid 1 best represents the shelf area within the Pribilof District, the mature male survey biomass index based on Model "ar1S_nullT_logDepth_km080b" and prediction grid 1 is considered the "best" index to use to calculate MMB-at-mating in the Tier 4 status determination for PIBKC.

References

Anderson, S.C., Ward, E.J., English, P.A., Barnett, L.A.K., and Thorson, J.T. 2024. sdmTMB: An R package for fast, flexible, and user-friendly generalized linear mixed effects models with spatial and spatiotemporal random fields. bioRxiv **2022.03.24.485545**. doi:10.1101/2022.03.24.485545.

Hartig, F. 2022. DHARMa: Residual diagnostics for hierarchical (multi-level / mixed) regression models. Available from http://florianhartig.github.io/DHARMa/.

Kristensen, K., Nielsen, A., Berg, C.W., Skaug, H., and Bell, B.M. 2016. TMB: Automatic differentiation and Laplace approximation. Journal of Statistical Software **70**(5): 1–21. doi:10.18637/jss.v070.i05.

Lindgren, F., and Rue, H. 2015. Bayesian spatial modelling with R-INLA. Journal of Statistical Software **63**(19): 1–25. Available from http://www.jstatsoft.org/v63/i19/.

Pebesma, E., and Bivand, R.S. 2023. Spatial data science with applications in R. Chapman & Hall. Available from https://r-spatial.org/book/.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

Stockhausen, W.T. 2023. 2023 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands blue king crab fisheries of the Bering Sea and Aleutian Islands regions. *In* Stock Assessment and Fishery Evaluation Report for the KING AND TANNER CRAB FISHERIES of the Bering Sea and Aleutian Islands regions 2023 Final Crab SAFE. North Pacific Fishery Management Council, Anchorage, AK. p. 112. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=05baad65-e92f-4998-8655-a076b17b7af3.pdf&fileName=Priblof%20Island%20Blue%20King%20Crab%20SAFE.pdf.

Stockhausen, W.T. 2025. 2025 PIBKC assessment considerations. North Pacific Fishery Management Council, Juneau, AK. Available from https://meetings.npfmc.org/CommentReview/DownloadFile?p=753c6ba1-2567-468a-b6eb-faa77ec3e4a3.pdf&fileName=PIBKC2025-05.pdf.

Sullivan, J. 2022. rema: A generalized framework to fit the random effects (RE) model, a state-space random walk model developed at the Alaska Fisheries Science Center (AFSC) for apportionment and biomass estimation of groundfish and crab stocks. Available from https://github.com/JaneSullivan-NOAA/rema, https://afsc-assessments.github.io/rema/.

Thorson, J.T., Cunningham, C.J., Jorgensen, E., Havron, A., Hulson, P.-J.F., Monnahan, C.C., and von Szalay, P. 2021. The surprising sensitivity of index scale to delta-model assumptions: Recommendations for model-based index standardization. Fisheries Research **233**: 105745. doi:https://doi.org/10.1016/j.fishres.2020.105745.

Tweedie, M.C.K. 1984. An index which distinguishes between some important exponential families. *In* Statistics: Applications and new directions. Proceedings of the Indian Statistical Institute Golden Jubilee International Conference. *Edited by* J.K. Ghosh and J. Roy. Indian Statistical Institute, Calcutta. pp. 579--604.

Tables

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Table 1. Brief description of the models examined here. All models fit to mature male survey CPUE in t/sq. km., assumed a Tweedie error distribution with log link, and estimated spatiotemporal random effects with a temporal AR1 structure.

name	spatial	temporal	covariate	evaluation mesh	barriers
onS_ar1T_noCovar_km080	on	AR1	none	kmeans 80	no
onS_offT_noCovar_km080	on	off	none	kmeans 80	no
offS_ar1T_noCovar_km080	off	AR1	none	kmeans 80	no
offS_offT_noCovar_km080	off	off	none	kmeans 80	no
onS_ar1T_logDepth_km080	on	AR1	ln(depth)	kmeans 80	no
onS_offT_logDepth_km080	on	off	ln(depth)	kmeans 80	no
offS_ar1T_logDepth_km080	off	AR1	ln(depth)	kmeans 80	no
offS_offT_logDepth_km080	off	off	ln(depth)	kmeans 80	no
onS_ar1T_noCovar_km080b	on	AR1	none	kmeans 80	yes
onS_offT_noCovar_km080b	on	off	none	kmeans 80	yes
offS_ar1T_noCovar_km080b	off	AR1	none	kmeans 80	yes
offS_offT_noCovar_km080b	off	off	none	kmeans 80	yes
onS_ar1T_logDepth_km080b	on	AR1	ln(depth)	kmeans 80	yes
onS_offT_logDepth_km080b	on	off	ln(depth)	kmeans 80	yes
offS_ar1T_logDepth_km080b	off	AR1	ln(depth)	kmeans 80	yes
offS_offT_logDepth_km080b	off	off	ln(depth)	kmeans 80	yes
onS_offT_logDepth_km040b	on	off	ln(depth)	kmeans 40	yes
onS_offT_logDepth_km060b	on	off	ln(depth)	kmeans 60	yes

Table 2. Summary table for model checks using sdmTMB's 'sanity'function. For models that finished running

name	finished	hessian	eigen values	minimizer	range	gradients	se magnitude	NAs	sigmas	all
onS_ar1T_noCovar_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_offT_noCovar_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_ar1T_noCovar_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_offT_noCovar_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_ar1T_logDepth_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_offT_logDepth_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_ar1T_logDepth_km080	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_offT_logDepth_km080	false	–	–	–	–	–	–	–	–	–
onS_ar1T_noCovar_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_offT_noCovar_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_ar1T_noCovar_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_offT_noCovar_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_ar1T_logDepth_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_offT_logDepth_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_ar1T_logDepth_km080b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
offS_offT_logDepth_km080b	true	not ok	ok	ok	ok	ok	not ok	some NAs	not ok	not ok
onS_offT_logDepth_km040b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok
onS_offT_logDepth_km060b	true	ok	ok	ok	ok	ok	ok	no NAs	ok	ok

Table 3. Summary statistics from the 10-fold cross-validation tests, randked by the negative out-of-sample predictive log-likelihood score. Model ar1s_nullT_logDepth_km040b failed to converge during the cross-validation tests and is not listed in the table.

model	-mean(log-likelihood)	mean(RMSE)	mean(MAE)
ar1S_nullT_logDepth_km080b	95.76340	0.2756831	0.0451916
offS_nullT_noCovar_km080b	99.95572	0.3323269	0.0483967
ar1S_nullT_logDepth_km060b	100.11473	0.3822746	0.0521069
offS_ar1T_noCovar_km080	108.38197	0.3215885	0.0475334
ar1S_nullT_logDepth_km080	110.54570	0.3506269	0.0496702
ar1S_nullT_noCovar_km080b	110.88060	0.3387133	0.0466871
ar1S_ar1T_noCovar_km080b	112.51754	0.3095588	0.0455972
offS_nullT_noCovar_km080	113.31247	0.3446132	0.0491336
offS_ar1T_noCovar_km080b	114.30084	0.4230001	0.0539670
offS_ar1T_logDepth_km080b	119.00278	0.3546071	0.0479412
ar1S_nullT_noCovar_km080	119.50918	0.3557230	0.0505758
offS_ar1T_logDepth_km080	126.04203	0.4012171	0.0507293
ar1S_ar1T_logDepth_km080b	129.57397	0.3449482	0.0483890
ar1S_ar1T_logDepth_km080	129.73837	0.3411131	0.0453765

Table 4. DHARMa statistical checks on the `sdmTMB` models. Checks with p-values < 0.05 were regarded as failing the test.

model	uniformity	dispersion	outliers	quantiles
onS_ar1T_noCovar_km080	0.003	0.000	0.801	0.001
onS_offT_noCovar_km080	0.004	0.000	0.380	0.001
offS_ar1T_noCovar_km080	0.010	0.000	1.000	0.001
offS_offT_noCovar_km080	0.023	0.000	0.449	0.003
onS_ar1T_logDepth_km080	0.026	0.000	0.380	0.002
onS_offT_logDepth_km080	0.006	0.000	0.531	0.000
offS_ar1T_logDepth_km080	0.007	0.000	1.000	0.004
onS_ar1T_noCovar_km080b	0.008	0.000	0.900	0.001
onS_offT_noCovar_km080b	0.004	0.000	0.258	0.001
offS_ar1T_noCovar_km080b	0.010	0.000	1.000	0.001
offS_offT_noCovar_km080b	0.038	0.000	0.900	0.009
onS_ar1T_logDepth_km080b	0.019	0.000	0.801	0.001
onS_offT_logDepth_km080b	0.006	0.000	0.900	0.000
offS_ar1T_logDepth_km080b	0.006	0.000	0.707	0.004
onS_offT_logDepth_km040b	0.247	0.092	0.614	0.048
onS_offT_logDepth_km060b	0.060	0.000	0.380	0.000

Table 5. Models which failed the permutation-based Moran's I in at least one year (p<0.05), with the year, statistic, and p-value determined by permutation.

name	year	statistic	p_value
tw_ar1ST_offS_ar1T_noCovar_km080	1979	0.115	0.024
tw_ar1ST_offS_ar1T_noCovar_km080	1992	0.087	0.017
tw_ar1ST_offS_ar1T_noCovar_km080	2005	0.099	0.012
tw_ar1ST_ar1S_nullT_logDepth_km080	2024	0.071	0.041
tw_ar1ST_ar1S_nullT_logDepth_km080b	2024	0.074	0.040

Figures

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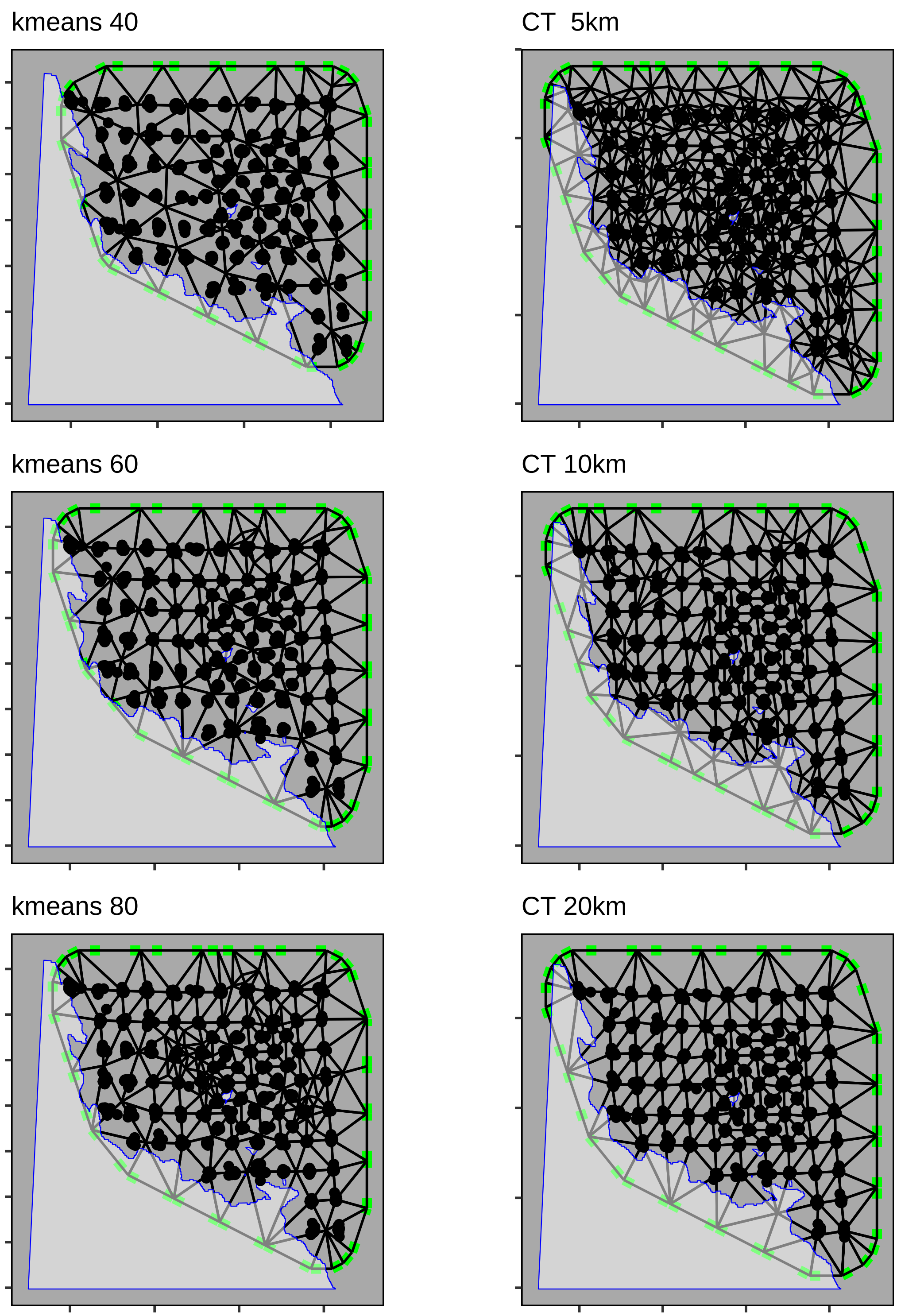

Figure 1. The triangular SPDE evaluation meshes considered while developing the sdmTMB models. For each, the sdmTMB function "make_mesh" was applied to the NMFS survey haul-level CPUE data for MMB (black dots). "kmeans" (left column) or "CT" (right-hand column) indicate the method used; the value indicates the number of allowd knots (kmeans) or the minimum distance allowed between nodes (CT). The green dots indicate the boundary vertices, the segments indicate triangle edges. The light gray polygons (with blue outlines) were used to create interpolation barriers representing the shelf edge and the Pribilof Islands.

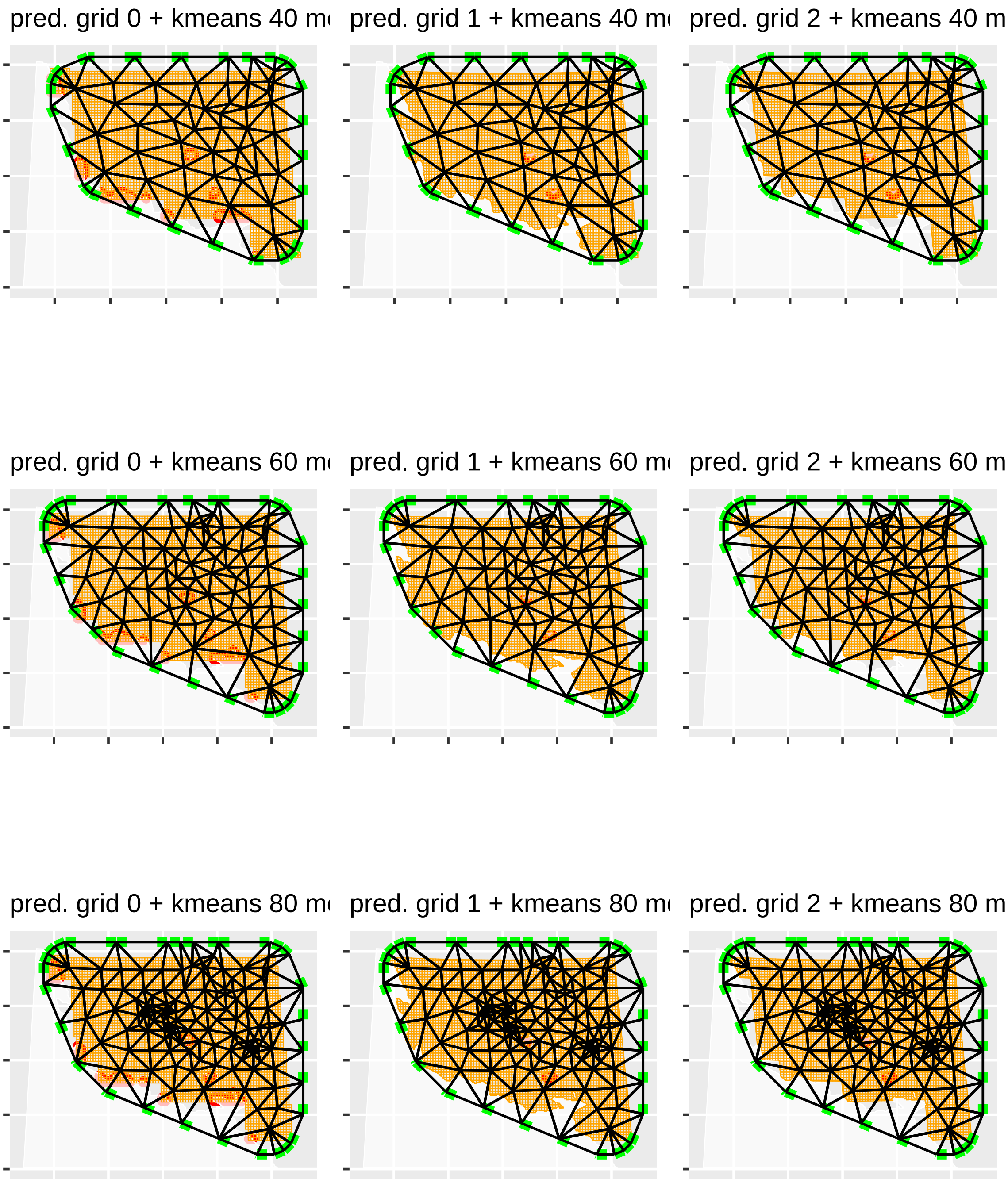

Figure 2. Three prediction grids evaluated (each compared with the "kmeans" evaluation grids). Each prediction grid (orange squares) uses a 5 km grid cell size but covers a slightly different area: grid 0 covers the Pribilof District as defined by NMFS survey strata, and extends across the Pribilof Islands and beyond the shelf edge in some areas (darker orange); grid 1 extends to the shelf edge (500 m depth) and excludes the Pribilof Islands; and grid 2 is limited to depths < 500 m within the Pribilof District and excludes the Pribilof Islands.

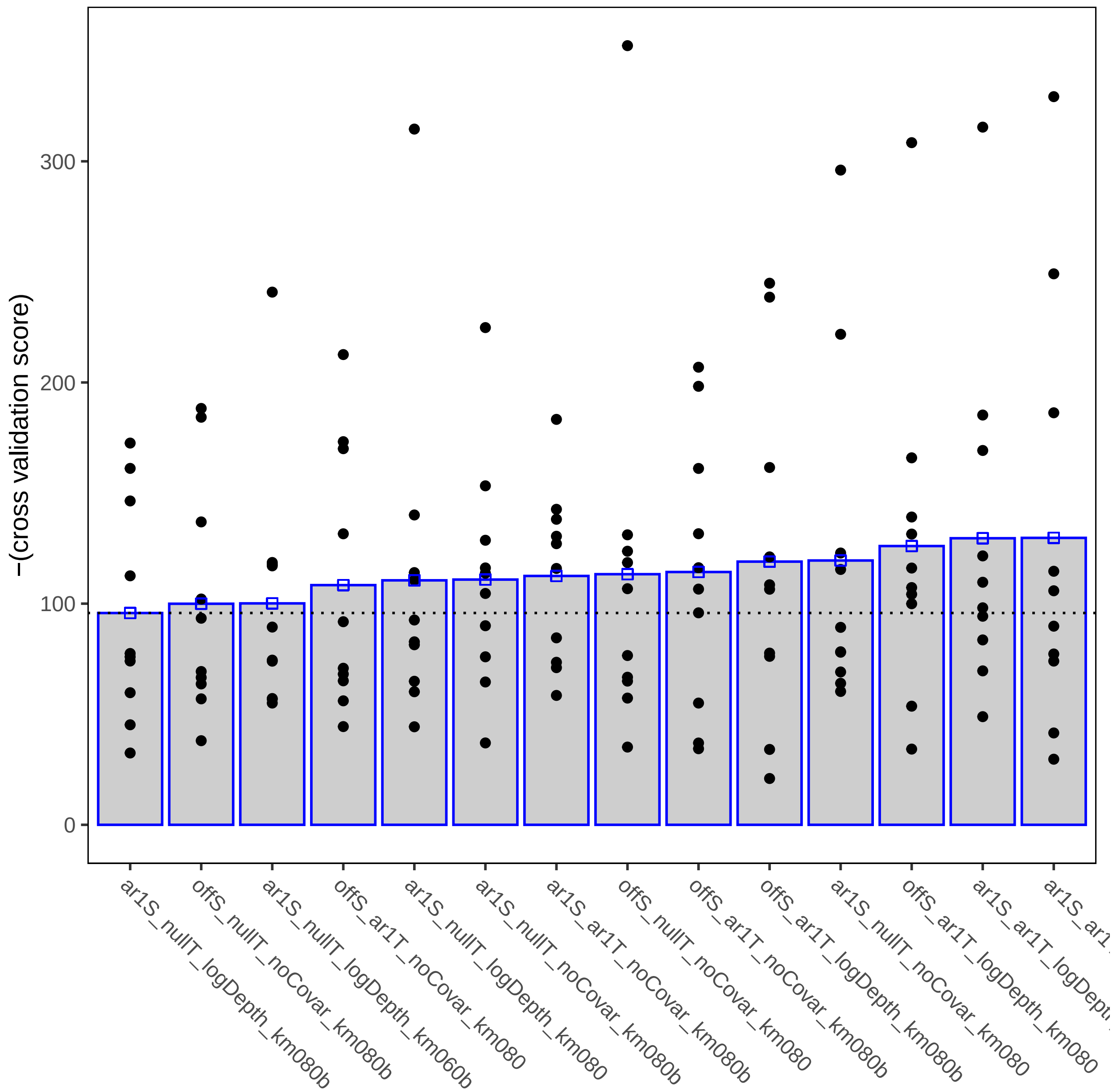

Figure 3. Results from cross-validation of the sdmTMB models, using 10 random folds/model. The cross-validation score for each run is the negative log-likelihood of the left out (out-of-sample) data. The model results are ordered by the average out-of-sample negative log likelihood, with the "best" model atken as the one with the lowest average negative log-likelihood.

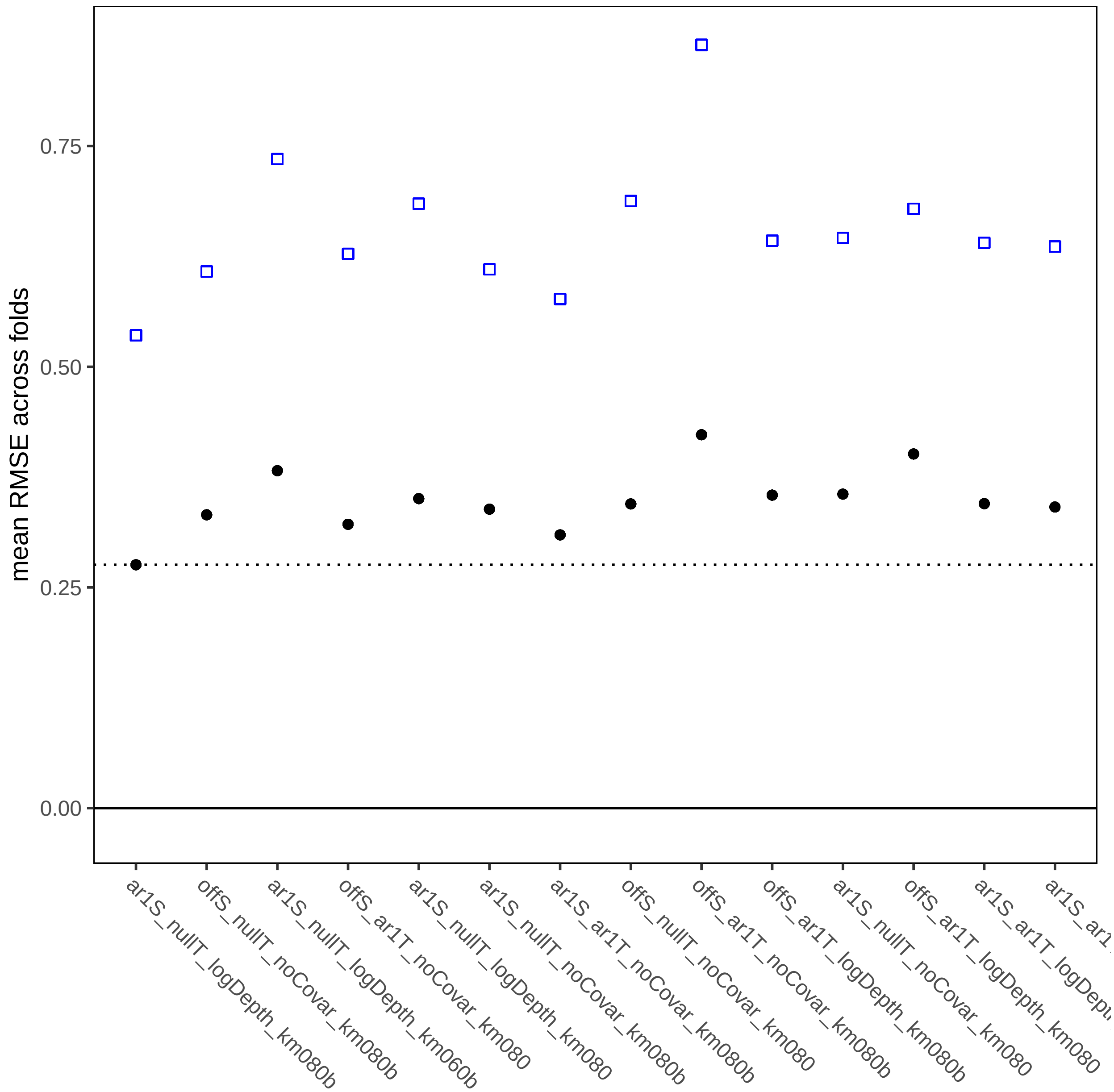

Figure 4. Mean (black symbols) and mean plus standard error (blue symbols) for root mean square errors (RMSEs) from the cross-validation of the sdmTMB models, using 10 random folds/model. The RMSE for each run was the RMSE for the out-of-sample data relative to the model predictions. The model results are ordered left-to-right as in Figure 3.

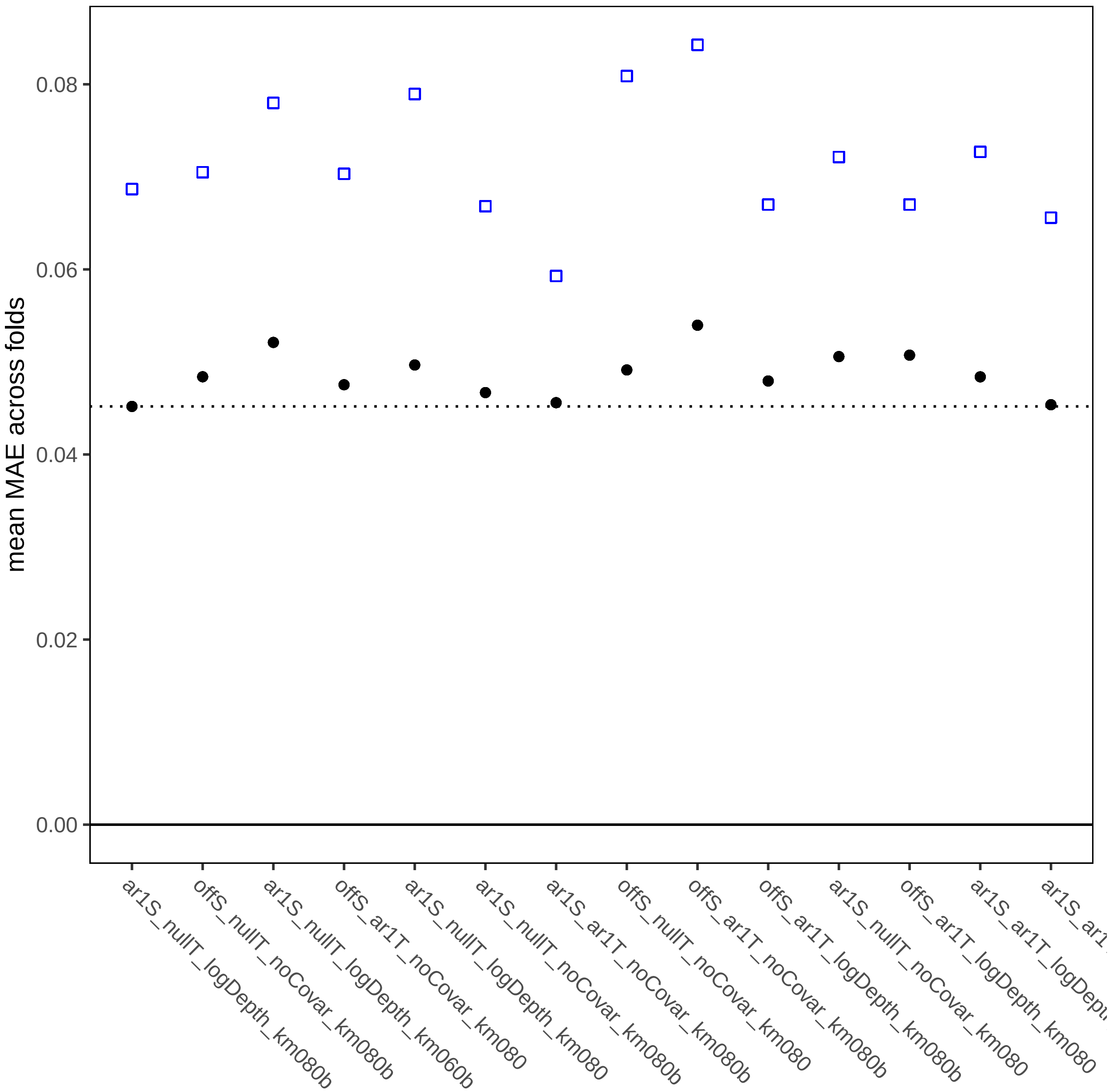

Figure 5. Mean (black symbols) and mean plus standard error (blue symbols) for mean absolute error (MAEs) from the cross-validation of the sdmTMB models, using 10 random folds/model. The MAE for each run was the MAE for the out-of-sample data relative to the model predictions. The model results are ordered left-to-right as in Figure 3.

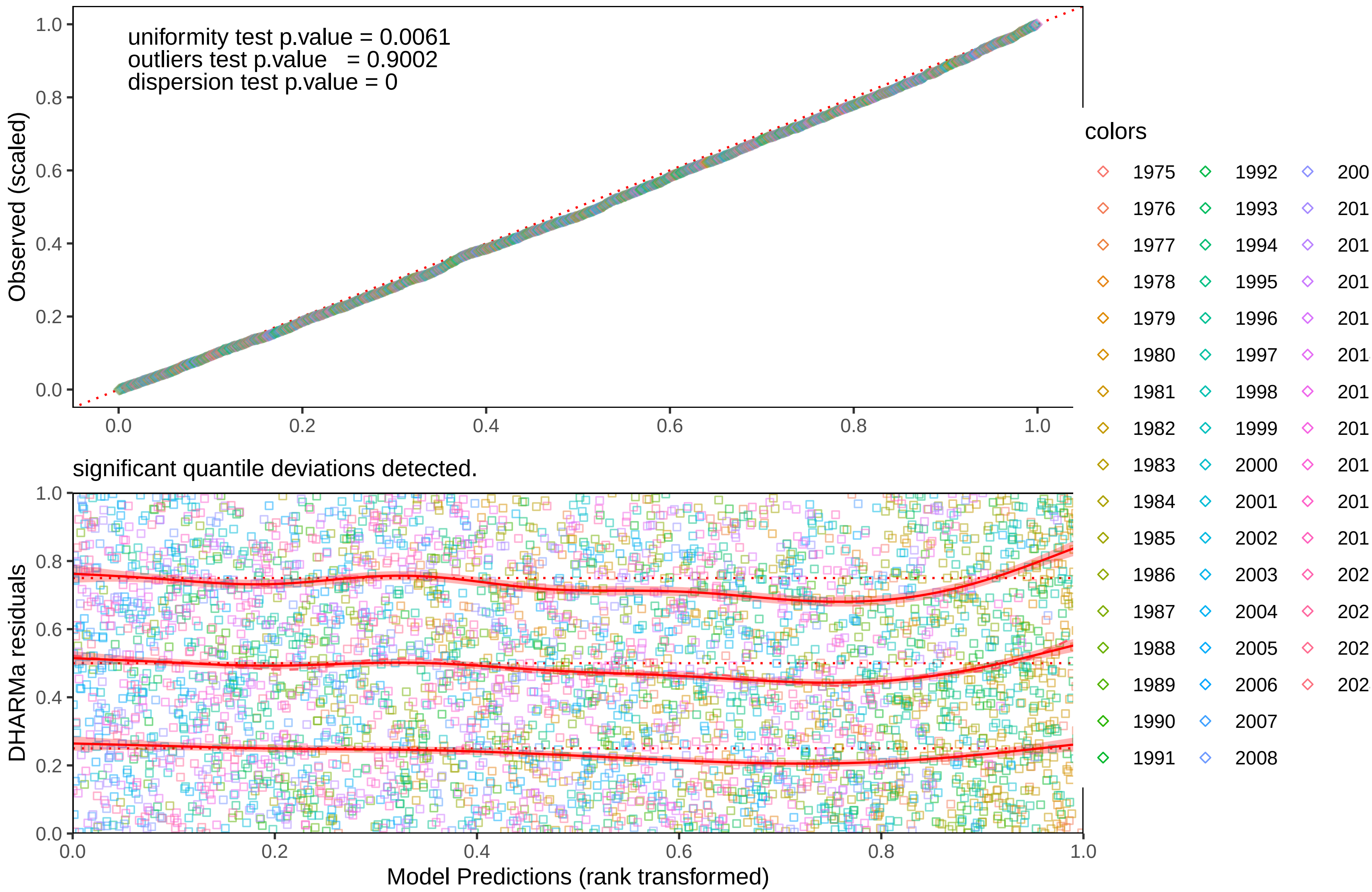

Figure 6. DHARMa residuals diagnostic plots for ar1S_nullT_logDepth_km080b.

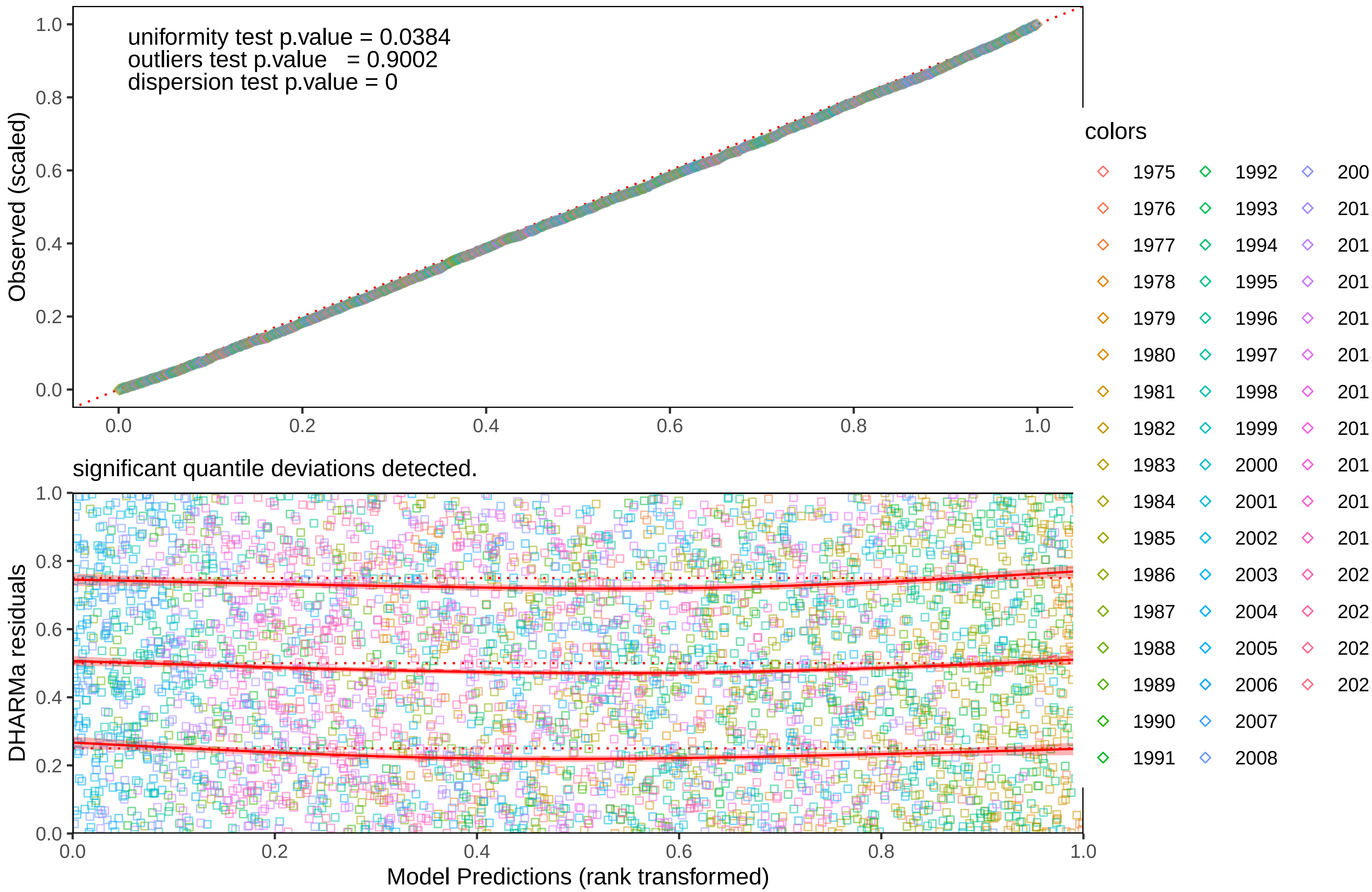

Figure 7. DHARMa residuals diagnostic plots for offS_nullT_noCovar_km080b.

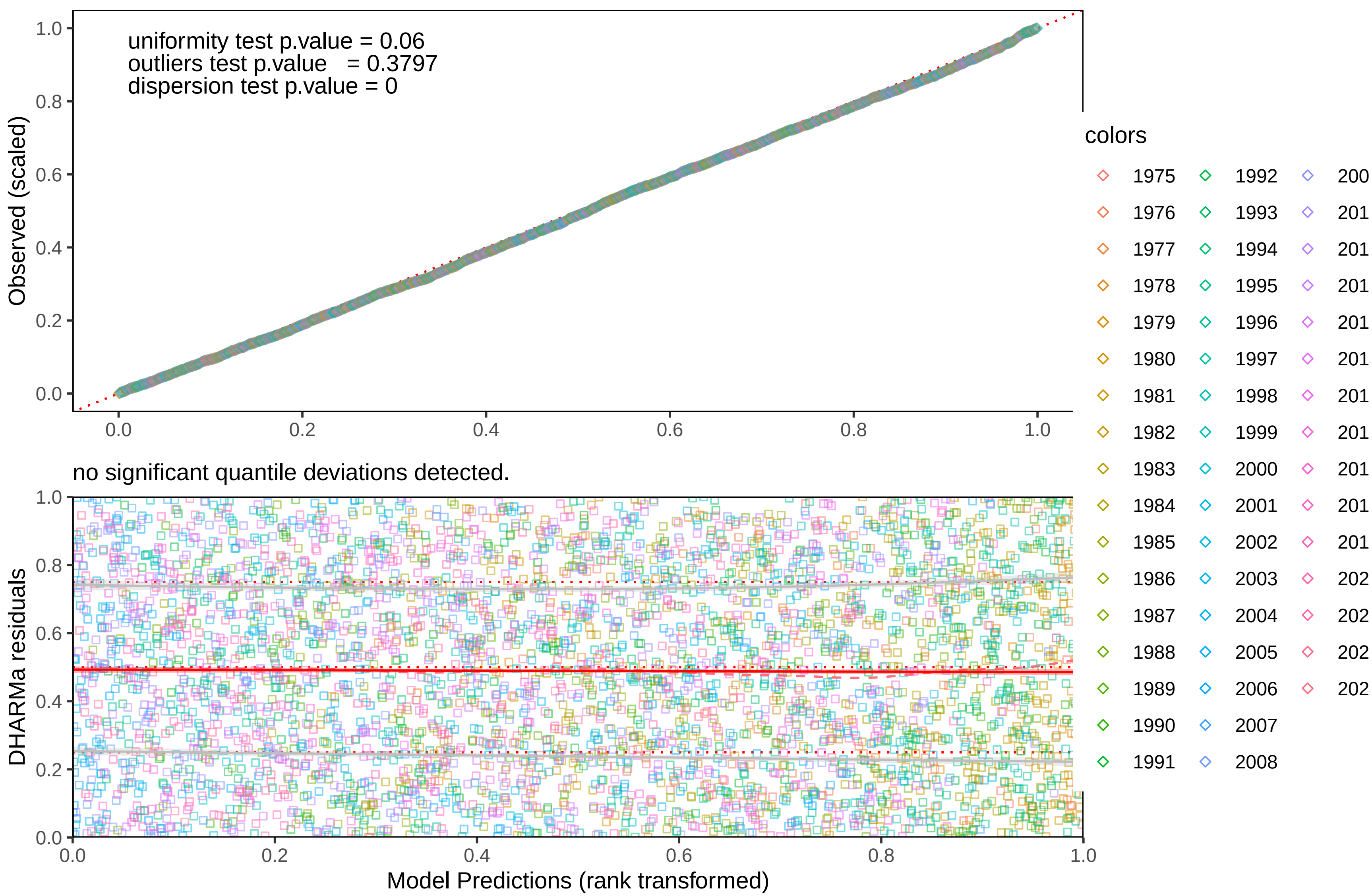

Figure 8. DHARMa residuals diagnostic plots for ar1S_nullT_logDepth_km060b.

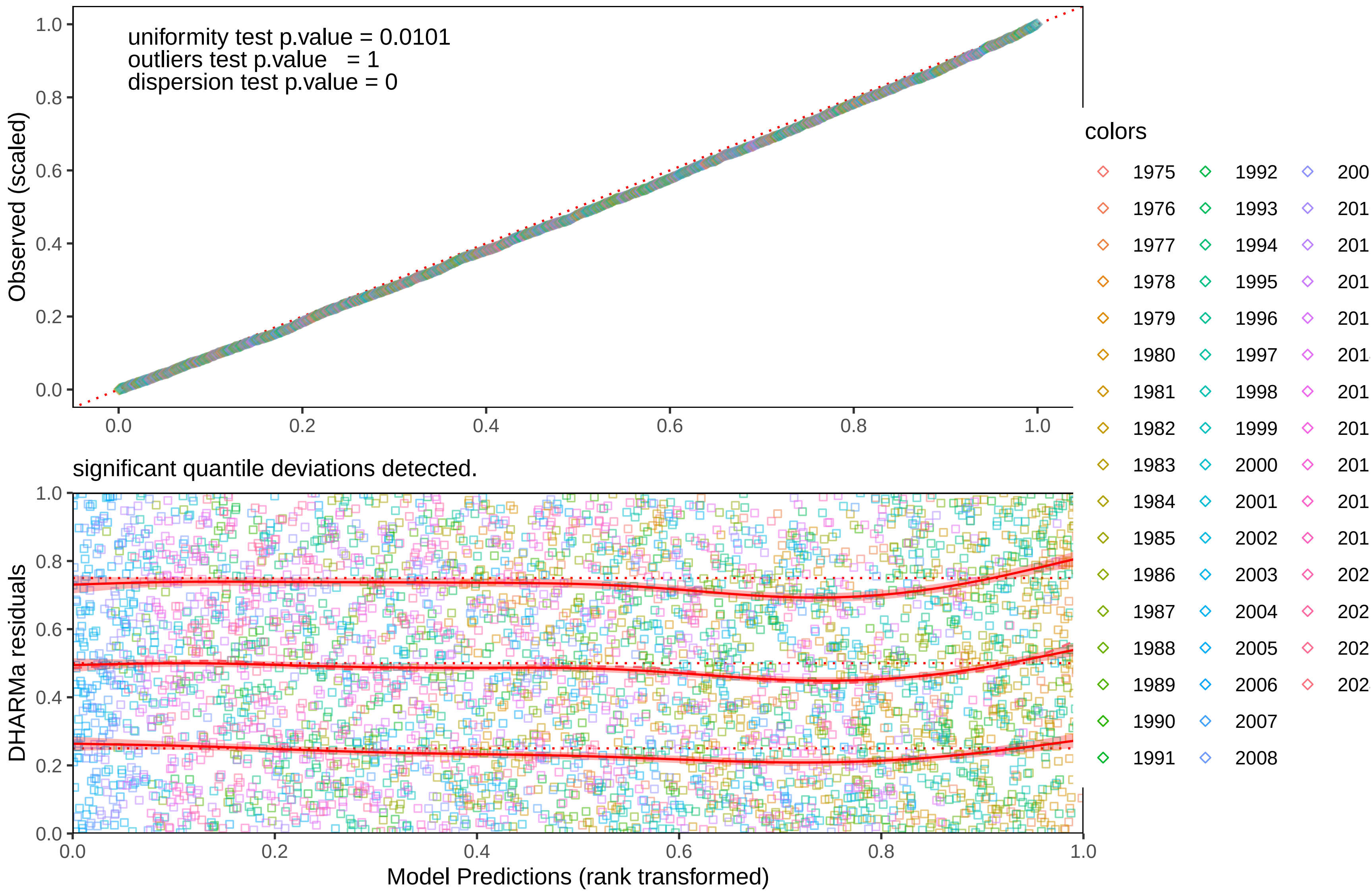

Figure 9. DHARMa residuals diagnostic plots for offS_ar1T_noCovar_km080.

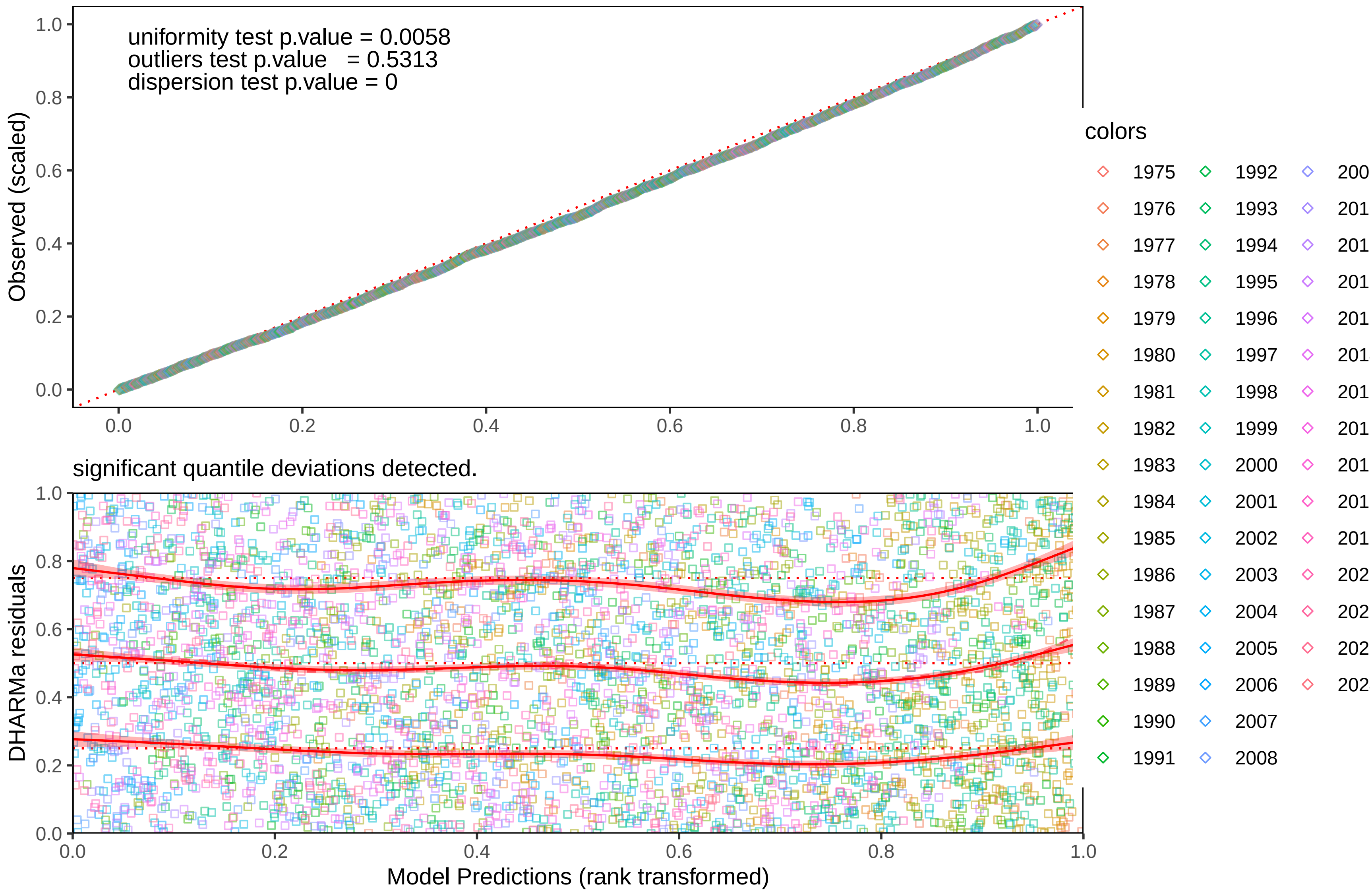

Figure 10. DHARMa residuals diagnostic plots for ar1S_nullT_logDepth_km080.

Figure 11. Scaled spatial residuals (0 to 1) in the 5-year time interval 1975-1979 by model for the five "best" models as ranked in the cross-validation exercise.

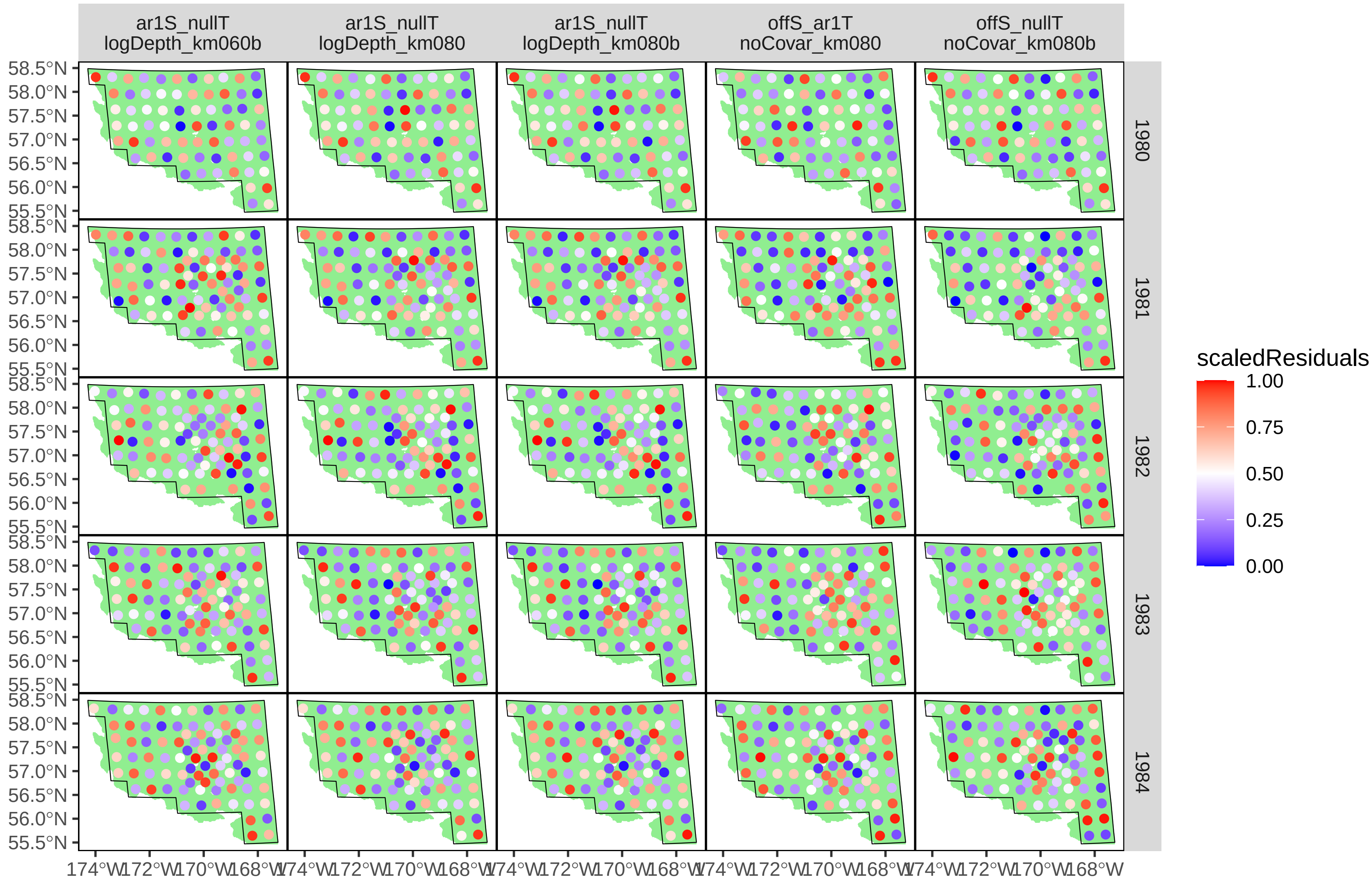

Figure 12. Scaled spatial residuals (0 to 1) in the 5-year time interval 1980-1984 by model for the five "best" models as ranked in the cross-validation exercise.

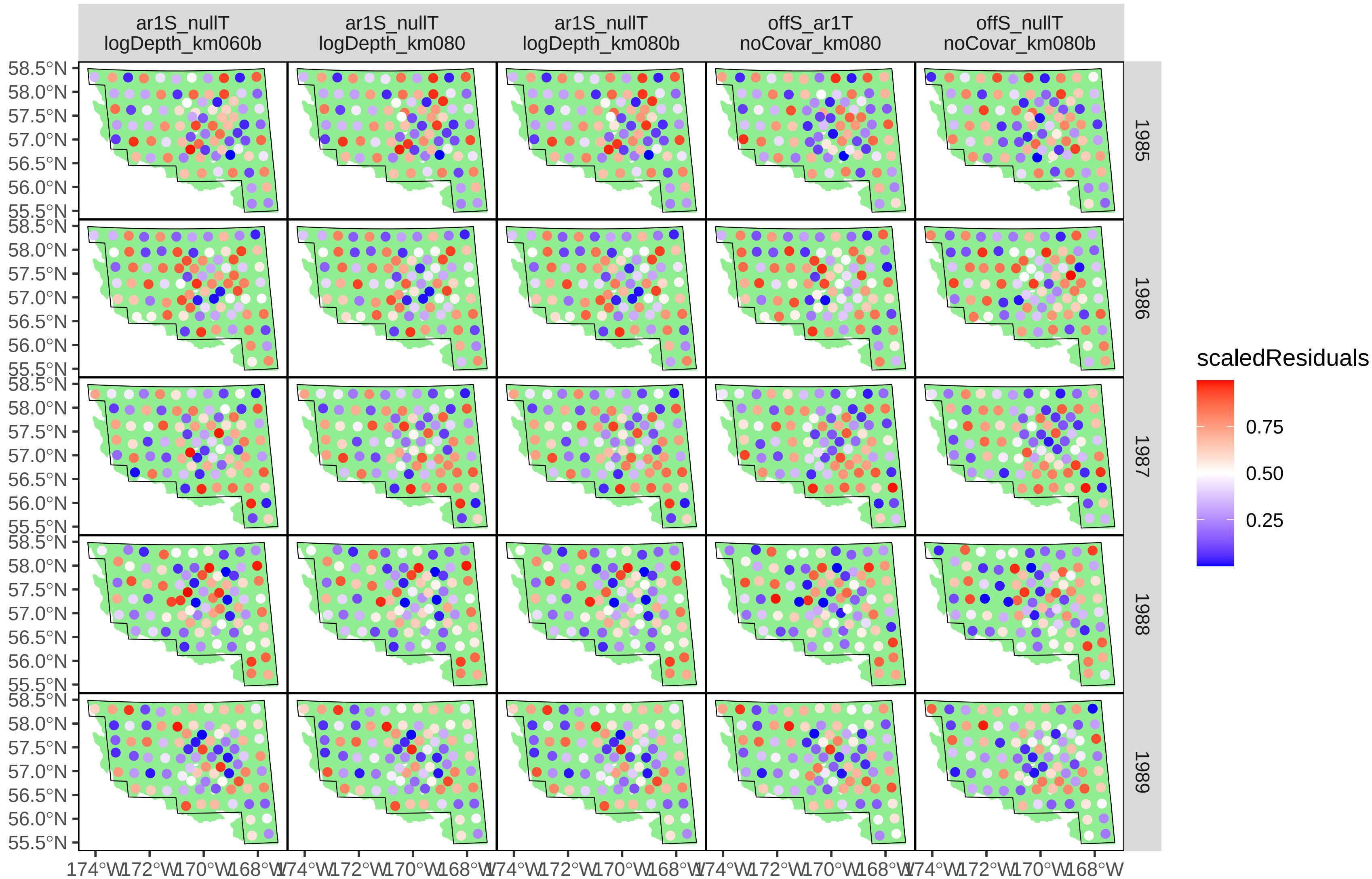

Figure 13. Scaled spatial residuals (0 to 1) in the 5-year time interval 1985-1989 by model for the five "best" models as ranked in the cross-validation exercise.

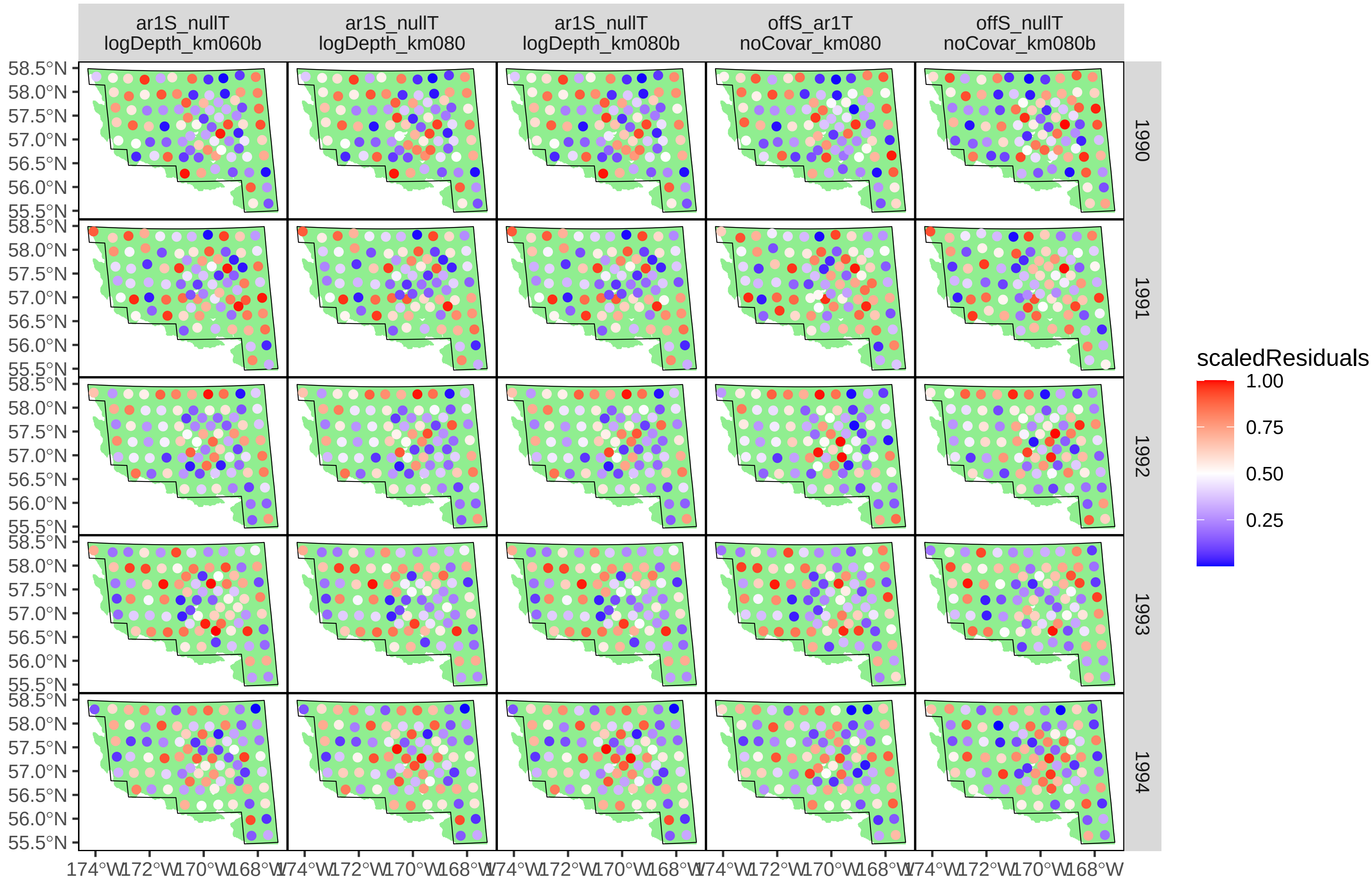

Figure 14. Scaled spatial residuals (0 to 1) in the 5-year time interval 1990-1994 by model for the five "best" models as ranked in the cross-validation exercise.

Figure 15. Scaled spatial residuals (0 to 1) in the 5-year time interval 1995-1999 by model for the five “best” models as ranked in the cross-validation exercise.

Figure 16. Scaled spatial residuals (0 to 1) in the 5-year time interval 2000-2004 by model for the five "best" models as ranked in the cross-validation exercise.

Figure 17. Scaled spatial residuals (0 to 1) in the 5-year time interval 2005-2009 by model for the five "best" models as ranked in the cross-validation exercise.

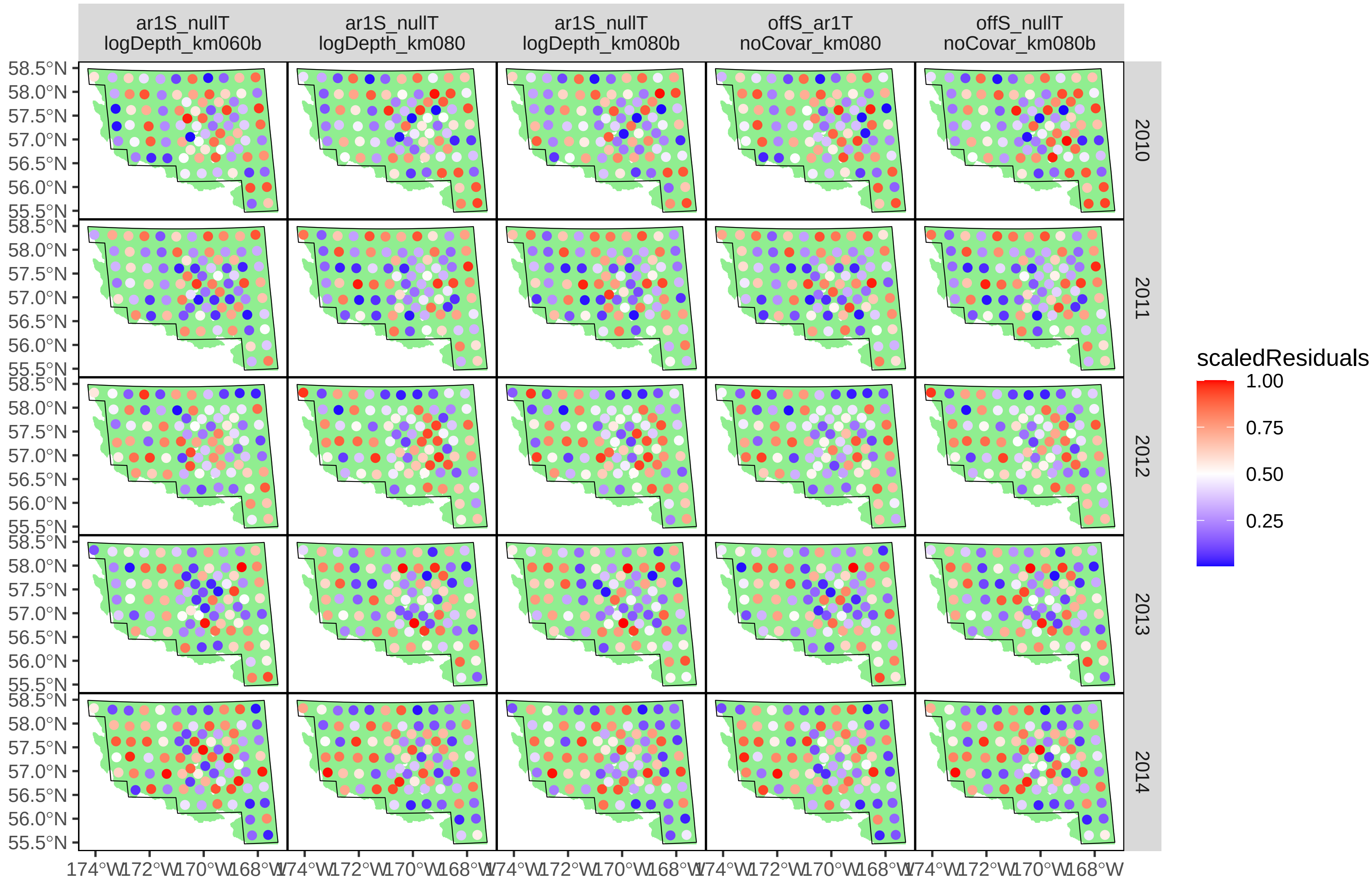

Figure 18. Scaled spatial residuals (0 to 1) in the 5-year time interval 2010-2014 by model for the five "best" models as ranked in the cross-validation exercise.

Figure 19. Scaled spatial residuals (0 to 1) in the 5-year time interval 2015-2019 by model for the five “best” models as ranked in the cross-validation exercise.

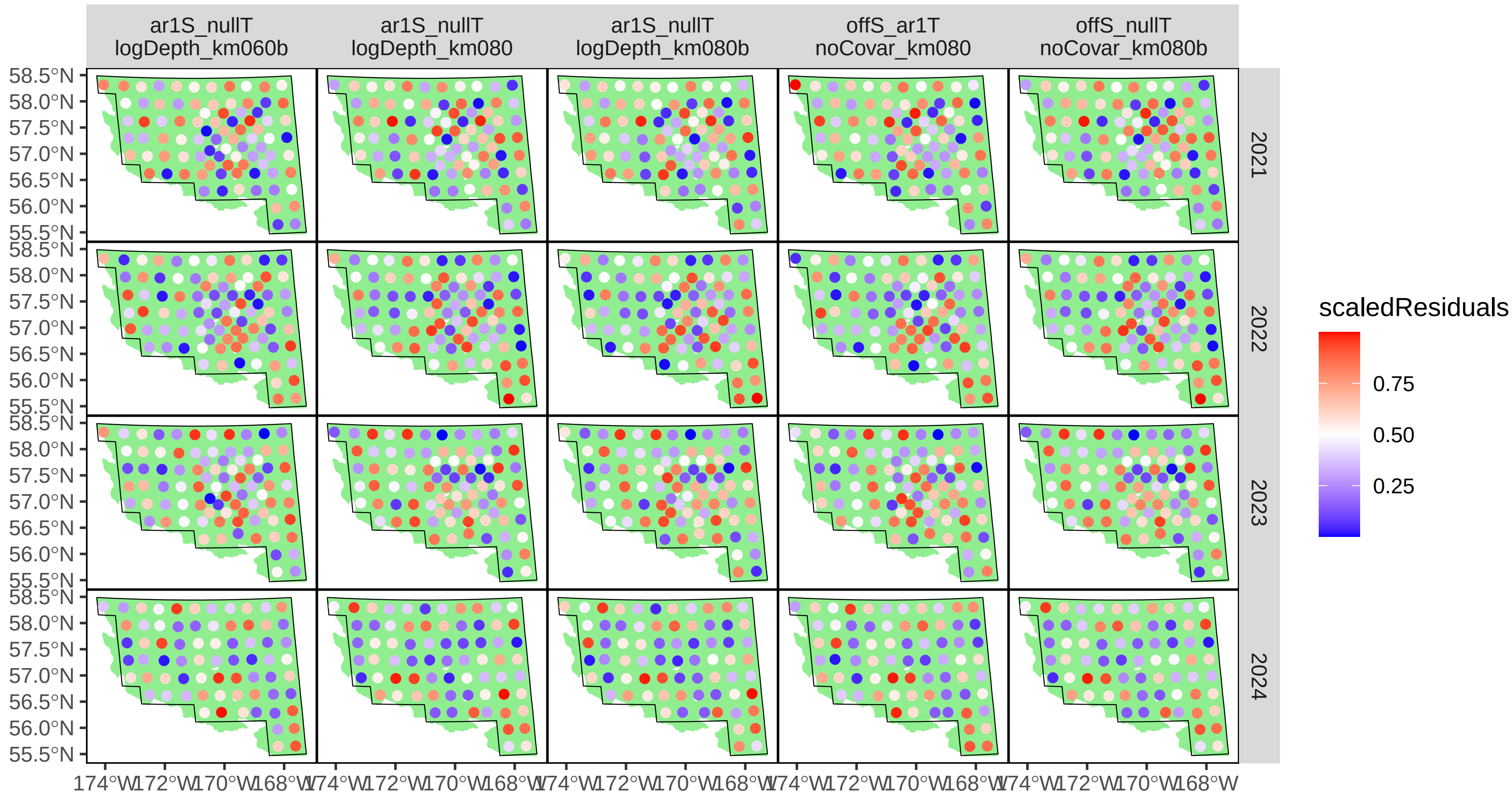

Figure 20. Scaled spatial residuals (0 to 1) in the 5-year time interval 2020-2024 by model for the five “best” models as ranked in the cross-validation exercise.

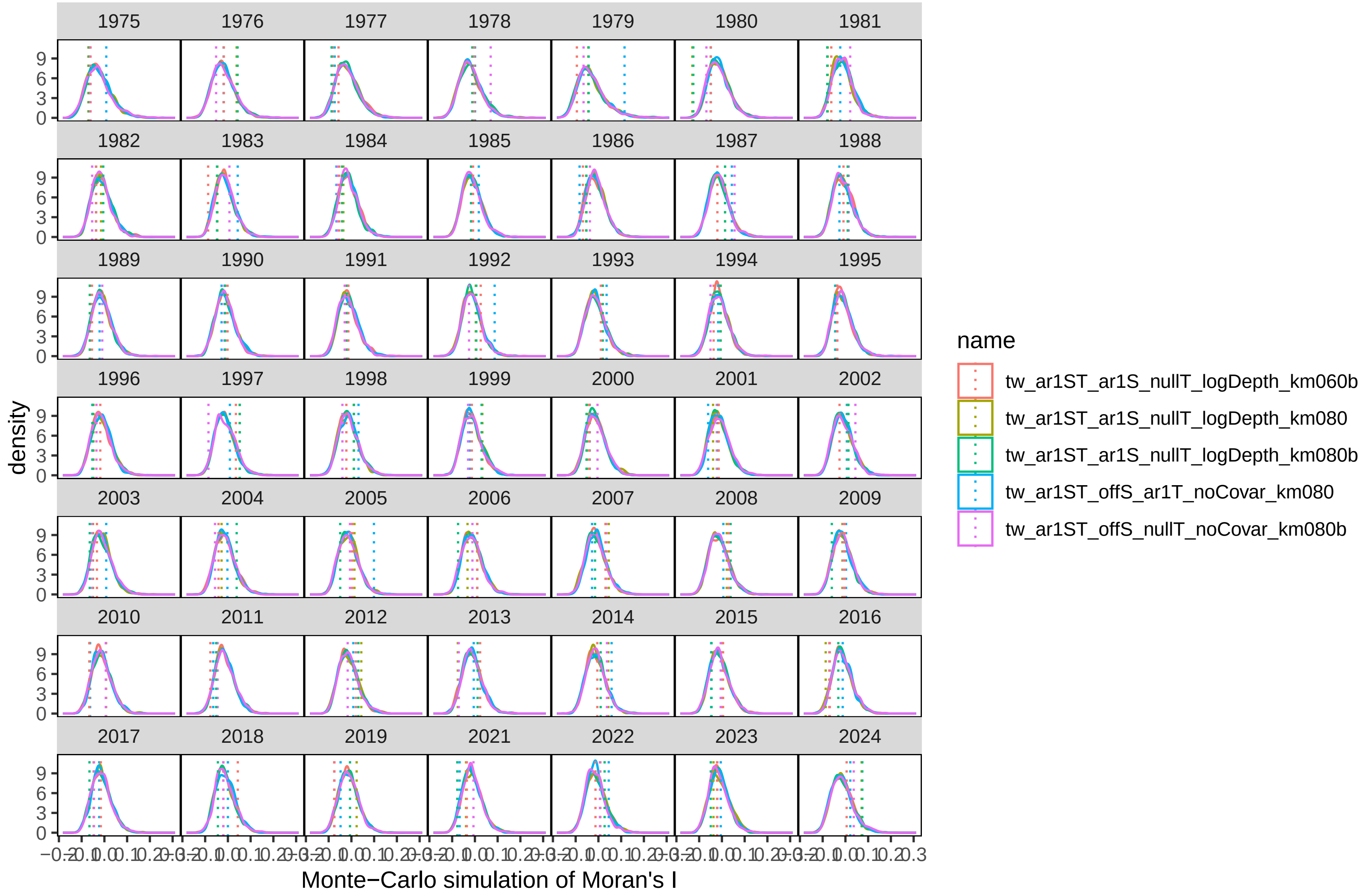

Figure 21. Null distributions (from permutation tests) and observed values of Moran's I statistic for spatial correlation.

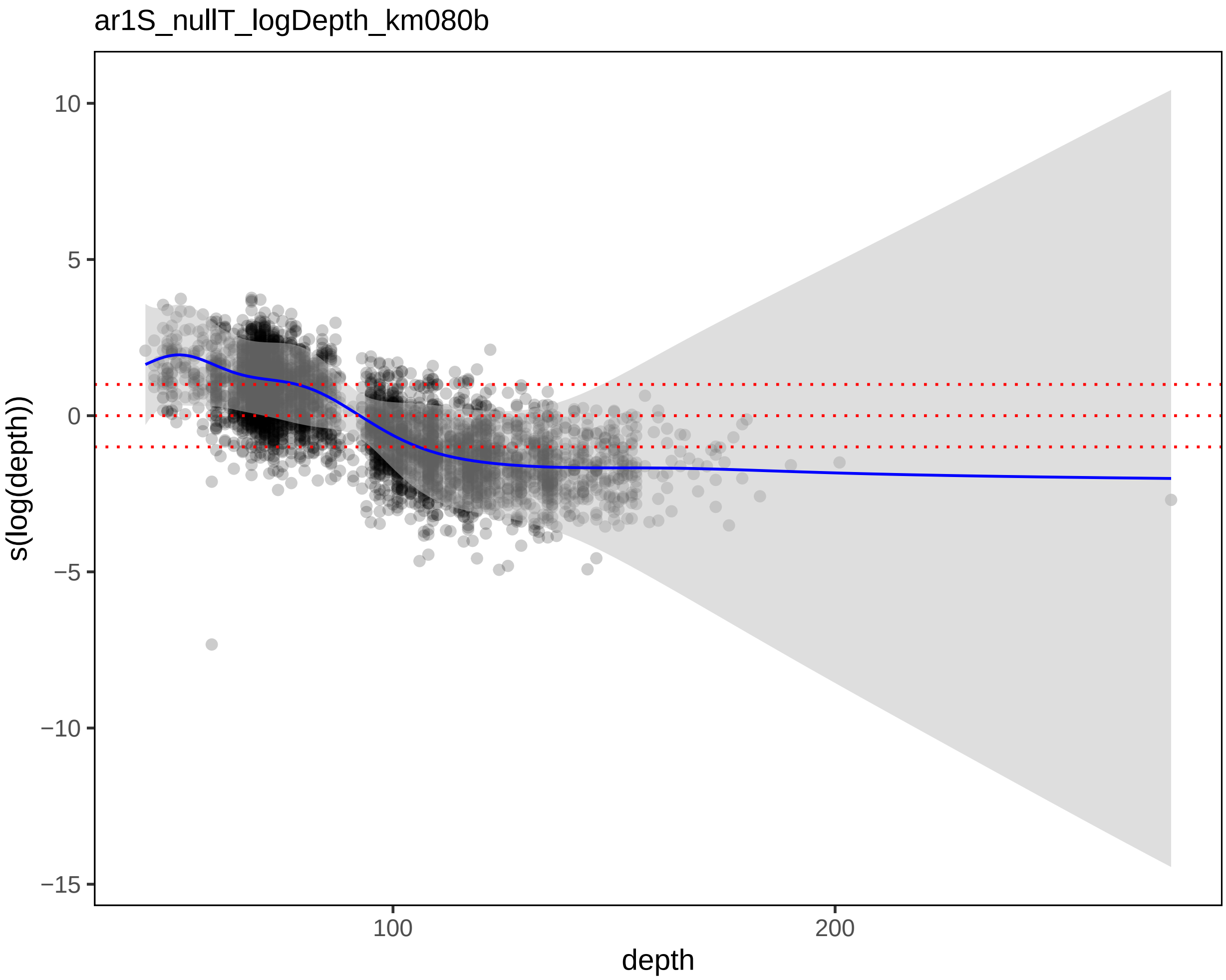

Figure 22. Estimated smooth function of ln(bottom depth) as a main effect covariate, on the link (ln) scale, for Model ar1S_nullT_logDepth_km080b. Line: estimated effect; shading: 95% confidence intervals; points: residuals; horiontal dotted lines are plotted at link-scale values of -1, 0, and 1.

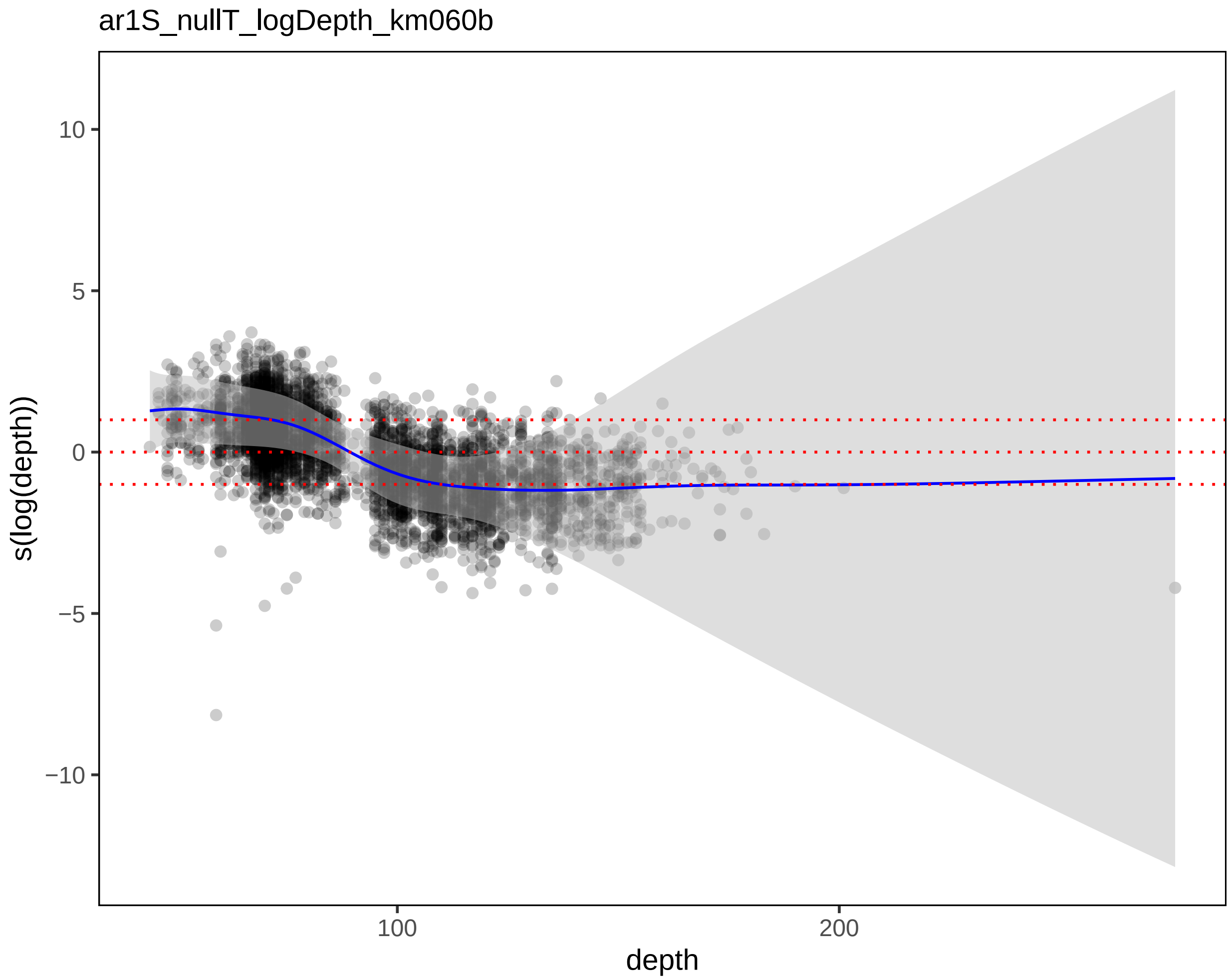

Figure 23. Estimated smooth function of ln(bottom depth) as a main effect covariate, on the link (ln) scale, for Model ar1S_nullT_logDepth_km060b. Line: estimated effect; shading: 95% confidence intervals; points: residuals; horiontal dotted lines are plotted at link-scale values of -1, 0, and 1.

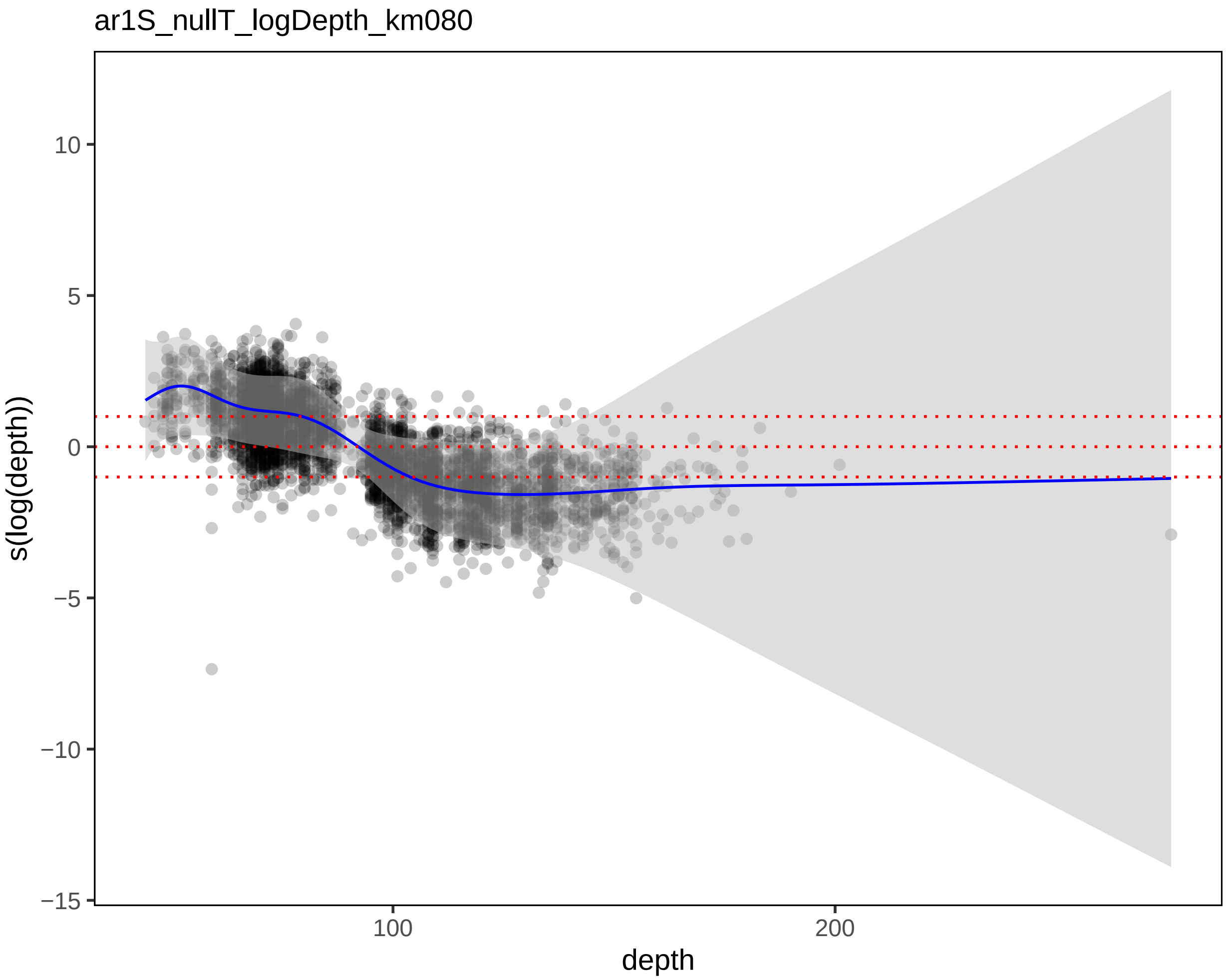

Figure 24. Estimated smooth function of ln(bottom depth) as a main effect covariate, on the link (ln) scale, for Model ar1S_nullT_logDepth_km080. Line: estimated effect; shading: 95% confidence intervals; points: residuals; horiontal dotted lines are plotted at link-scale values of -1, 0, and 1.

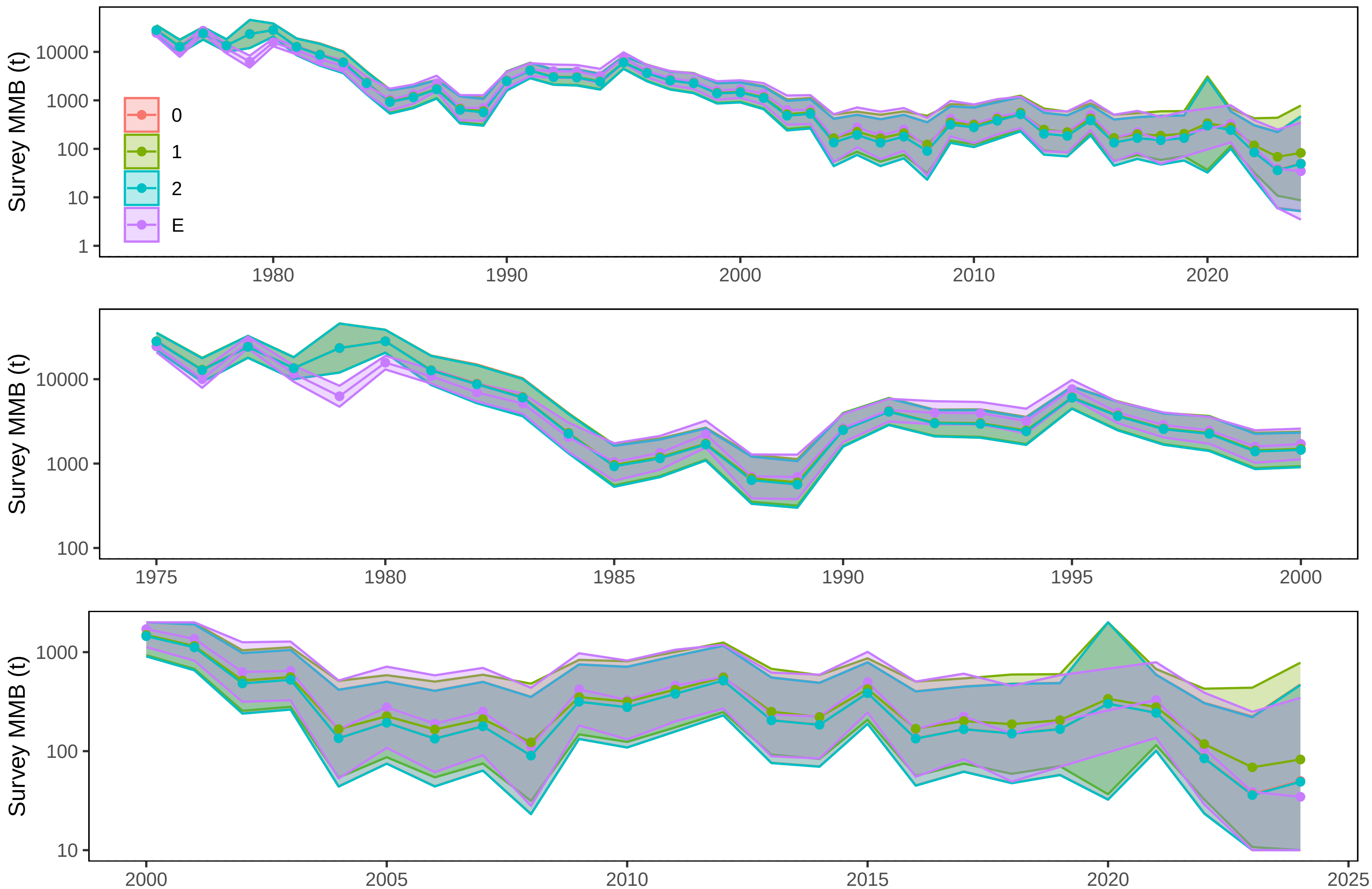

Figure 25. Comparison of `sdmTMB` model-based indices (colored points, lines, and regions) using different prediction grids for Model tw_ar1ST_ar1S_nullT_logDepth_km080b. The legend indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations ("E") used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals. Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

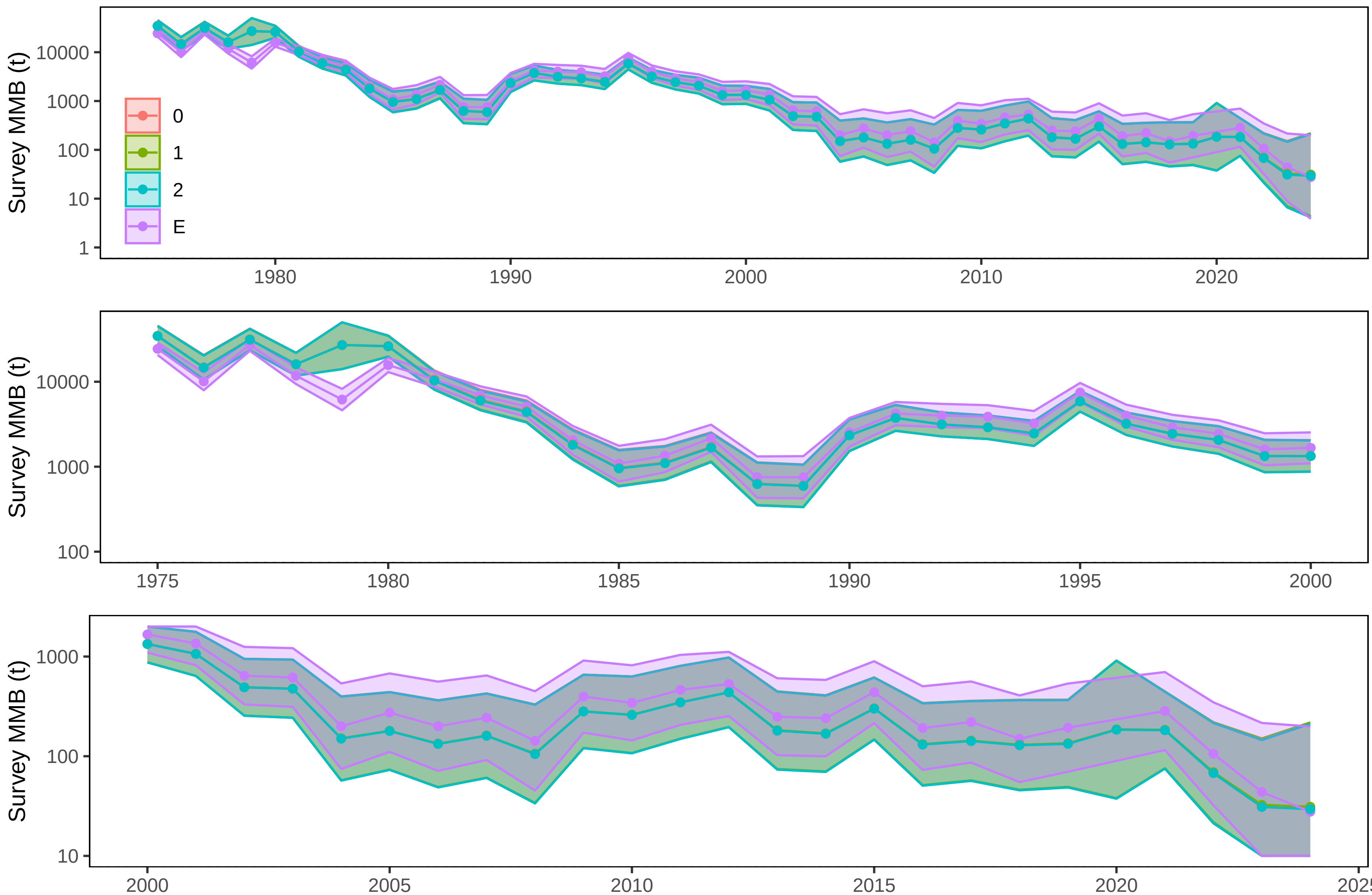

Figure 26. Comparison of `sdmTMB` model-based indices (colored points, lines, and regions) using different prediction grids for Model tw_ar1ST_offS_nullT_noCovar_km080b. The legend indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations (“E”) used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals. Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

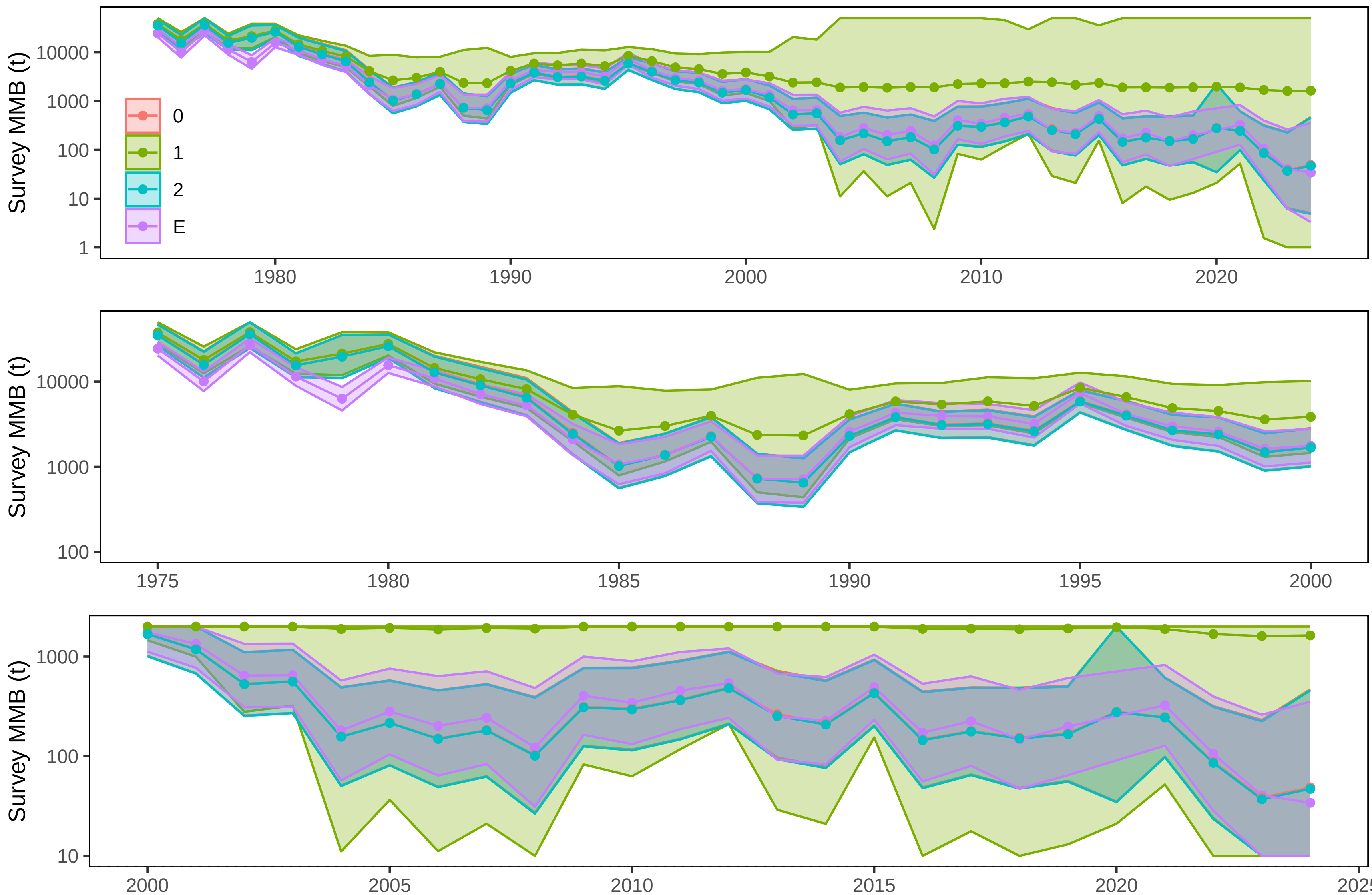

Figure 27. Comparison of `sdmTMB` model-based indices (colored points, lines, and regions) using different prediction grids for Model tw_ar1ST_ar1S_nullT_logDepth_km060b. The legend indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations (“E”) used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals. Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

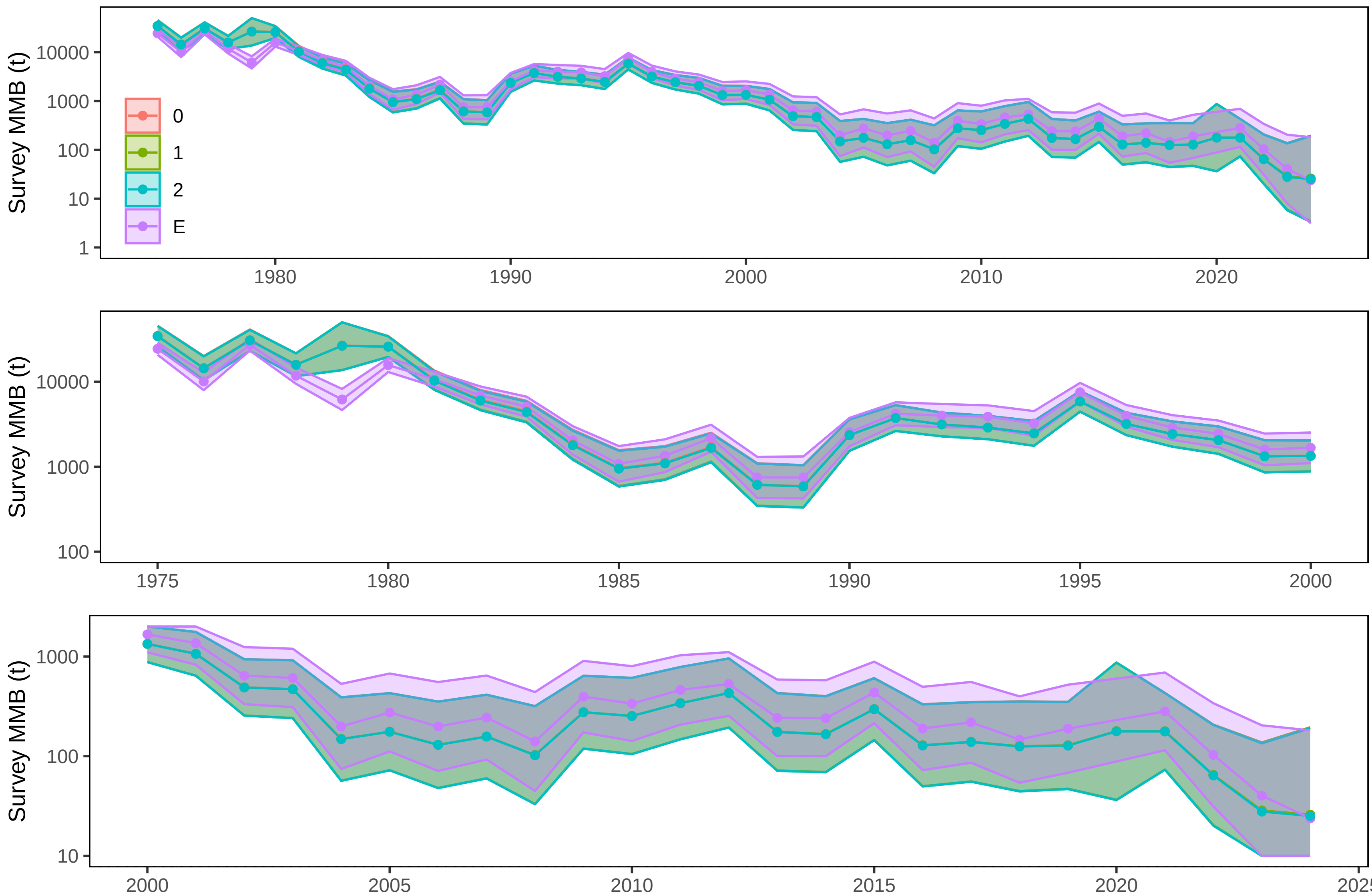

Figure 28. Comparison of sdmTMB model-based indices (colored points, lines, and regions) using different prediction grids for Model tw_ar1ST_offS_ar1T_noCovar_km080. The legend indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations ("E") used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals. Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

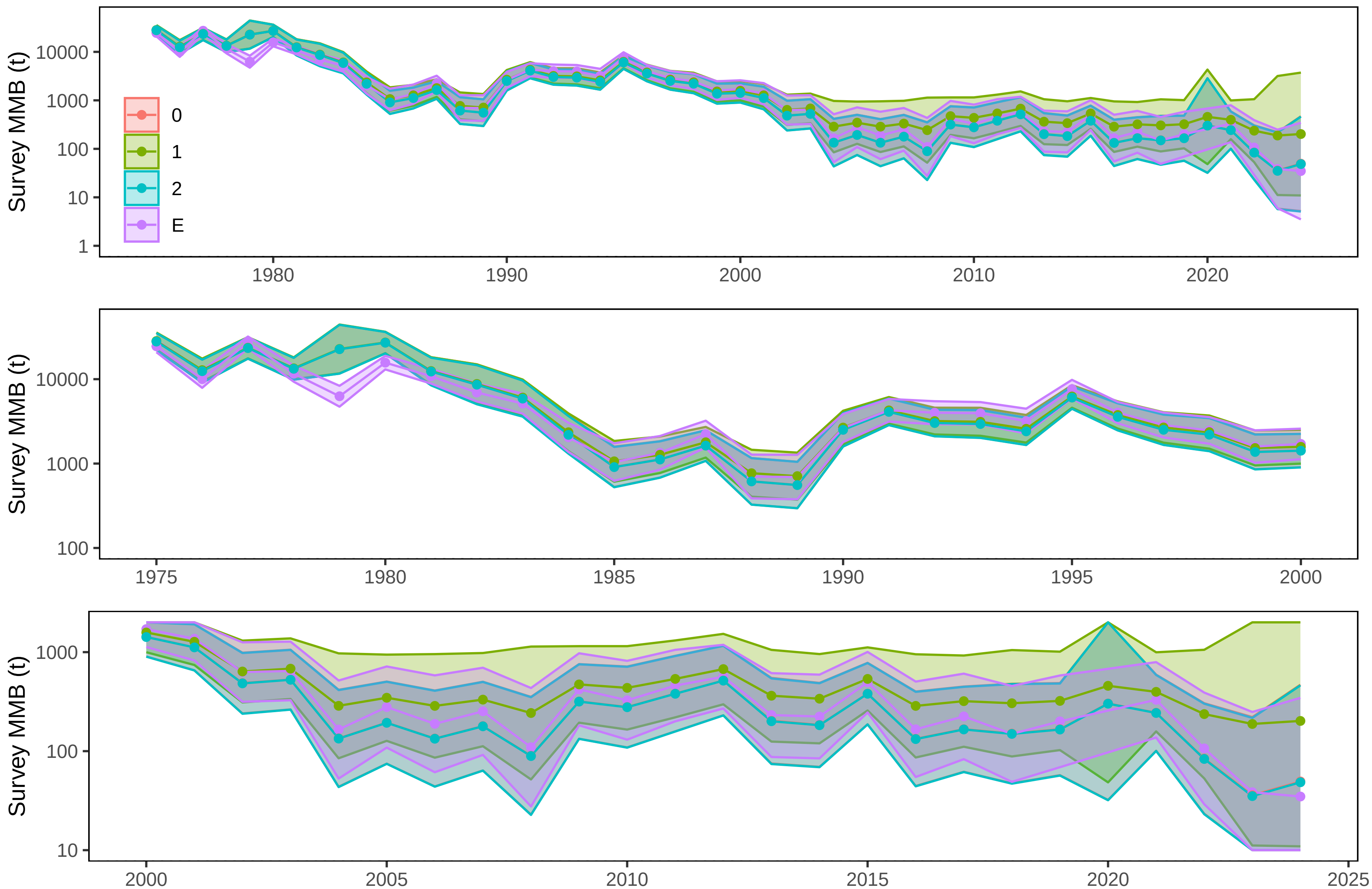

Figure 29. Comparison of `sdmTMB` model-based indices (colored points, lines, and regions) using different prediction grids for Model tw_ar1ST_ar1S_nullT_logDepth_km080. The legend indcates the fine scale prediction grid (0, 1, or 2) or the original haul locations (“E”) used to obtain the area-expanded survey MMB. The shaded areas represent 80% confidence intervals. Upper plot: full time series; middle plot: 1975-2000; lower plot: 2000-current year.

Appendix B: Draft Risk Table for the 2025 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions

William T. Stockhausen Elizabeth Siddon

2025-08-29

Introduction

In December 2018, the SSC recommended that all groundfish assessment authors use the risk table when determining whether to recommend an ABC lower than the maximum permissible. In June 2025, the SSC requested that a draft risk table be developed for the eastern Bering Sea Tanner crab stock. The following was used to complete the draft risk table, based on the template updated in 2023 to reflect only three levels of concern and implementing the SSC's December 2023 request regarding the labels for these levels:

	Assessment-related considerations	***Population dynamics considerations***	***Environmental/ecosystem considerations***	***Fishery Performance***
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Increased concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 3: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance considerations. Examples of the types of concerns that might be relevant in crab assessments include the following:

1. Assessment considerations—data-inputs: skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.
2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.
3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.
4. Fishery performance—fishery CPUE exhibits a contrasting pattern to the stock biomass trend, unusual spatial patterns of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

Summary and ABC Recommendation

It should be noted that a Ecosystem and Socioeconomic Profile (ESP) has not been created for PIBKC. The environmental/ecosystem conditions informing this table are derived from the from 2025 indicators, where available, or the 2024 Eastern Bering Sea Ecosystem Status Report (ESR; Siddon, 2024); the 2025 report has not been finalized.

The summarized results of the risk table for the Pribilof Islands blue king crab stock are in the table below. All scores are Level 1, suggesting no need to change the ABC buffer used in previous assessments. Consequently, the assessment author recommends that the overall risk level is the same as in 2024/25 and recommends using the previous ABC buffer (25%).

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	*Level 1: Normal*	*Level 1: Normal*	*Level 1: Normal*
No concerns regarding assessment methodology.	An ESP with stock-specific ecosystem indicators related to natural mortality, growth, and recruitment, has not been developed for this stock. Lack of larval supply to the Pribilof Islands area has been identified as a major factor limiting juvenile recruitment. However, these represent ongoing concerns.	Warm conditions with a reduced cold pool extent in 2024; forecast to be warm with delayed sea ice arrival in 2025. Corrosive bottom waters remain a concern for growth and survival. Overall, though, ecosystem concerns are minor with uncertain impacts on the stock.	An ESP with fishery-informed indicators has not been deeveloped for this stock: there is no directed fishery because the stock is overfished and under a rebuilding plan. Bottom trawl fishing and pot fishing for Pacific cod have been excluded from the Pribilof Islands Habitat Conservation Zone (PIHCZ) since 2005 and 2015, respectively. Area closures to Tanner crab and snow crab pot fisheries are implemented annually by ADF&G to avoid PIBKC bycatch; these generally incorporate the PIHCZ. Fishery performance concerns are minor for this stock.

Details

Assessment considerations

Risk Level 1: Normal

A spatiotemporal species distribution model to estimate a time series of mature male biomass from NMFS EBS bottom trawl survey data has been used this year for the first time to better handle recent surveys with no catches of mature males (Stockhausen 2025). Where comparable, the model-based index is consistent with estimates from previous assessments.

Population dynamics considerations

Risk Level 1: Normal

Stock biomass has fluctuated about historically low levels for the past 25 years, with no sign of increased recruitment. For much of that time, the stock has been under a federal rebuilding plan with the directed fishery closed and fishery exclusion zones have been implemented to minimize bycatch in other crab and groundfish fisheries. No indications of increased recruitment; larval supply may be the limiting factor to juvenile recruitment.

Environmental/Ecosystem considerations

Risk Level 1: Normal

Ecosystem indicators are organized into several categories to capture the scope of considerations available in the ESR reports:

- Distribution: December 2023 had significant along-shelf winds that could have driven offshore Ekman transport. March to May 2024 had weaker, but more sustained winds that also favored offshore transport (ESR: Hennon, 2024). Strong summer winds in 2024 resulted in a deep mixed layer (ESR: Hennon, 2024).
- Environmental Processes: During winter 2024-2025, the NPI was negative (ESR: Siddon, 2025) for the first time in 9 years, an indication of a stronger Aleutian Low Pressure System (ESR: Siddon, 2025). This means the Bering Sea was warm, stormy, and had less sea ice.
- Summer bottom trawl SSTs in the EBS were slightly cool, while mean bottom water temperature increased by 0.5°C from 2024 to 2025. The extent of the cold pool was below average and a 29% decrease from 2024 (ESR: Siddon, 2025).
- Sea ice is expected to arrive in the northern Bering Sea later in winter 2025/2026 than 2024/2025 due to comparatively low sea ice extent currently in the Chukchi Sea (ESR: Siddon, 2025 forecast will be updated for final ESR).
- The NMME ensemble forecasts as of today show moderate warm SST anomalies over much of the SEBS (<0.5°C) into fall 2025, except Bristol Bay shows anomalies up to +2 °C. The NBS is projected to have SSTs close to the historical mean (ESR: Siddon, 2025 forecast will be updated for final ESR).
- Bottom waters remained near threshold levels in 2024 that could negatively impact growth and survival, with the most corrosive bottom waters found in slope waters and over the northwest shelf (ESR: Pilcher, 2024).
- Prey: Diatom abundance anomalies, based on the Continuous Plankton Recorder, remained positive from 2023 to 2024 (ESR: Siddon, 2025), indicating above-average feeding conditions for pelagic crab stages in 2023 and 2024.
- Competitors: Over the southern shelf, motile epifauna (e.g., sea stars, brittle stars) biomass increased from 2023 to 2024 and remains above the long term mean (ESR: Siddon, 2024). Benthic forager (i.e., small-mouthed flatfish) biomass increased from 2023 to 2024, but remains below the time series mean, suggesting competition for prey resources remains low in 2024 (ESR: Siddon, 2024).
- Predators: Bristol Bay sockeye salmon run sizes were closer to the long-term average in 2023-2024 (ESR: Siddon, 2024), after multiple years of large run sizes, indicating a possible decline in predation pressure on larval crab.

Fishery performance

Risk Level 1: Normal

Fishery-informed indicators do not exist for PIBKC: there is no directed fishery because the stock is overfished and under a rebuilding plan. Bottom trawl fishing and pot fishing for Pacific cod have been excluded from the Pribilof Islands Habitat Conservation Zone (PIHCZ) since 2005 and 2015, respectively. Area closures to Tanner crab and snow crab pot fisheries are implemented annually by ADF&G to avoid PIBKC bycatch; these generally incorporate the PIHCZ. The OFL (1.16 t) was exceeded in 2015/16. Most bycatch mortality occurred in the hook-and-line fishery for Pacific cod and groundfish non-pelagic trawl fishery (1.018 t), with a smaller amount occurring in the Tanner crab fishery (0.166 t). Bycatch levels have subsequently decreased.

References

Please note that references for ESPs and ESRs use the citing convention specified in title pages of the ESP/ESR main report for individual contributions and the main report.

Stockhausen, W.T. 2025. 2025 Stock Assessment and Fishery Evaluation Report for the Pribilof Islands Blue King Crab Fisheries of the Bering Sea and Aleutian Islands Regions. North Pacific Fishery Management Council, Anchorage, AK. Available from https://meetings.npfmc.org/Meeting/Details/3097.

Hennon, T. 2024. Winds at the Shelf Break. In: Physical Environment Synthesis. In: Siddon, E. 2024. Ecosystem Status Report 2024: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.

Pilcher, D., J. Cross, N. Monacci, E. Kennedy, E. Siddon, and W.C. Long. 2024. Ocean Acidification. In: Siddon, E. 2024. Ecosystem Status Report 2024: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.

Siddon, E. 2024. Ecosystem Status Report 2024: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.

Siddon, E. 2025 (in press). Ecosystem Status Report 2025: Eastern Bering Sea, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.