Stock structure template for Bering Sea red king crab

Contributors: Katie Palof, Cody Szuwalski, Ben Daly, Hamachan Hamazaki

This stock structure template covers red king crab stocks in the Bering Sea which include - Bristol Bay red king crab (BBRKC), Pribilof Island red king crab (PIRKC), Norton Sound red king crab (NSRKC), Western Aleutian Island red king crab (WAIRKC), and Northern district red king crab (Figures 1 and 2). The first four populations are managed as separate stocks under Federal and State co-management as defined in the crab Federal fisheries management plan (FMP, https://www.npfmc.org/wp-content/PDFdocuments/fmp/Crab/CrabFMP.pdf).

Section 1: Genetic information

There have been a few studies focusing on red king crab genetics in Alaska waters. Two of the most recent ones both examine evolutionary linkages for red crab in Alaskan waters - including the Bering Sea, Aleutians, Gulf of Alaska and Southeast Alaska (Vulstek et al. 2013, Grant and Cheng 2012, Figure 3a). Genetically red crab populations in the Western Aleutians and Norton Sound are isolated from the rest of the Bering Sea. Three genetic clusters resulted in both studies: Norton Sounds and western Aleutian Islands, southeast Bering Sea and Gulf of Alaska, and southeast Alaska (Figure 3b).

The Western Aleutian Island red king crab and Norton Sound red king crab populations are currently considered isolated populations and are fished as such. Genetic studies confirm this separation.

The Bristol Bay red king crab population clusters genetically with PIRKC and the western Gulf of Alaska populations (GOA) - specifically Kodiak. The Bristol Bay stock does show some indication that it may have undergone a recent reduction in genetic diversity due to low population size using samples from 1989 and 2008, but this was not confirmed with both studies and may be an artifact of samples used.

Overall, genetics indicates that there has been multi-generational (in genetics terms which could be 100s of years) geneflow between BBRKC, PIRKC, and other red crab in the Southeast Bering Sea and GOA. However, they cannot rule out demographically independent populations since the genetic connectivity may occur due to ice-age refuge ancestry and not current population gene flow. The tools in these studies are not useful in determining contemporary genetic structure, and ocean currents patterns and their interaction with larvae likely prevent large-scale mixing between populations within the Bering Sea area – specifically those in the western Bering Sea vs. southeastern Bering Sea.

The conclusions from genetic studies are that NSRKC and WAIRKC are their own distinct populations due to genetic divergence and likely barriers in substantial geneflow, while the southern Bering Sea – BB, PI, and northern crab – are harder to determine current genetic linkage. More detailed genetic sampling and studies within the southern Bering Sea, paired with a seascape genetic study, may help understand the connectivity of these three stocks. Current studies underway using genome sequencing work for Bering Sea red king crab suggest PI and BB are separate stocks but no genetic information exists for the Northern unstratified crab (per comm. Carl St. John, PhD candidate Cornell University).

Section 2: Non-genetic information

Comparisons of size frequencies over time between Bristol Bay, Pribilof Islands, and Northern Unstratified (Figure 5 and 8) do not appear to have any substantial patterns. Comparisons between Bristol Bay and Northern Unstratified show similar trends over time for males and females (Figures 6 and 7), however the sample sizes in the North prevent statistical comparison. The differences in abundance between these two areas can be observed better when they are compared at the same scale as Bristol Bay in Figure 6b, 7b, and 9a,b.

Physical or oceanographic barriers exist in the Aleutian Islands near Samalga Pass and for Norton Sound in the northern Bering Sea. Within the southeastern Bering Sea (BB, PI and Northern) there are no physical barriers to population structure. Research on larval advection for Bristol Bay suggests that along with oceanographic currents, both timing of larval release and prevailing environmental conditions can affect recruitment potential. The ability for larvae to be carried outside Bristol Bay likely depends heavily on both of these factors and varies with environmental regimes (Daly et al. 2020).

Section 3: History of spatial management units for Bering Sea red king crab

Stock management boundaries were originally based on historic fishing grounds and associated navigable landmarks. These were established in the FMP for crab as Bristol Bay (BBRKC), Pribilof Island (PIRKC), Western Aleutian Island (WAIRKC), and Norton Sound (NSRKC). These areas encompassed the historic high density, fishable areas for red king crab in the Bering Sea, and still represent the majority of red king crab distribution today (Figures 9a, b).

Section 4: Summary and future work recommendations

This document summarizes current stock trends over the entire Bering Sea but focuses on the 3 stocks in the southeastern Bering Sea (PI, BB, and Northern crab) that were determined to be of interest in an earlier draft of this document. Data compiled for this document provides evidence that genetic and landscape data indicates separate stock structure for NSRKC and WAIRKC. Of the three stocks of interest the Northern district is the one with the least known about it since it is not part of a current stock assessment or stock as defined in the FMP.

Northern district red king crab data is collected during the summer eastern Bering Sea trawl survey and summarized in associated documents from this survey, typically the annual NOAA technical memo. Data on size compositions (Figures 6a, b and 7a,b), general distribution maps for the last five years from the survey (Figures 9a,b), and proportion of the biomass in the Northern area vs Bristol Bay (Figures 10a,b) are summarized in this document.

Northern area crab size composition trends are difficult to discern due to low sample sizes in the annual survey, however they appear to trend similarly to Bristol Bay in some years (Figures 6a, b and 7a, b). The size composition trends in figures 7a and 7b are graphed on the same scale and indicate the vast difference in sample size between these two areas. Similarities in size composition trends can occur for these stocks due to similarities in environmental conditions that contribute to successful recruitment events, and do not provide evidence for the presence or lack of stock structure.

The annual tech memo summarizes the density of red king crab caught in the summer NMFS Eastern Bering Sea trawl survey visually through maps that depict red king crab catch for size/sex groups. Maps of densities over the last five years for mature males and females (included here from the 2023 draft memo) suggest potential connectivity between the Northern area crab and the Bristol Bay population (Figures 9a, b). The extent of this connectivity is unknown due to lack of tagging, genetic or other studies that would determine if the Northern area crab are part of the same mating population as Bristol Bay. The proportion of red crab found in the Northern area has fluctuated over time and suggests a trend of more crab are in the Northern area in the last 15 years than previously seen (Figures 10a,b). However, the interannual variability of this proportion prevents a statistical significant conclusion that crab are moving north-ward. The current Bristol Bay stock assessment continues to track Northern area crab proportions as part of the annual stock assessment process.

Future work to assist in understanding the connectivity of the BB, PI and Northern district crab should include:

- Bering Sea specific genetic studies with increased sampling locations and genetic tools, potentially utilizing seascape genetic analysis.
- Analysis of oceanographic information for the area - current flow, temperature, etc. - to determine potential linkages.
- Tagging data -specifically between BB and the Northern district. A summary of data currently available and future tagging needs.

Table 1: Summary of available data on stock identification for Bering Sea red king crab

Factor and criterion	Justification
Harvest & Trends	
Fishing mortality (5-year average percent of Fabc or Fofl)	bbrkc – close to Fofl last 3 years fisher was open, fishery closed in 21/22 & 22/23 wairkc/pirkc - fishery closed.
Spatial concentration of fishery relative to abundance (Fishing is focused in areas << management areas)	Fishery in BBRKC typically occurs in the center of the stock boundaries (Figure 4)
Population trends (Different areas show different trend directions)	
Barriers & phenotypic characters	
Generation time (e.g., >10 years)	Unknown. Age to maturity estimated to be around 6 to 7 years
Physical limitations (Clear physical inhibitors to movement)	Norton Sound and Aleutian island chain. Biogeographical boundary at Samalga Pass attributes divergence between WAI population and southeastern Bering SEA (BB and PI)
Growth differences (Significantly different LAA, WAA, or LW parameters)	Growth differences exist in NS, not sure if we have information for other stocks
Age/size-structure (Significantly different size/age compositions)	Figure 5 shows comparison of size compositions for bbrkc, pirkc, and northern district crab.
Spawning time differences (Significantly different mean time of spawning)	Unknown.
Maturity-at-age/length differences (Significantly different mean maturity-at-age/ length)	BB and NS clear differences due to growth and size differences.
Morphometrics (Field identifiable characters)	Size at maturity differences between BB and NS
Meristics (Minimally overlapping differences in counts)	Unknown.
Behavior & movement	
Spawning site fidelity (Spawning individuals occur in same location consistently)	Unknown.
Mark-recapture data (Tagging data may show limited movement)	Recent and current tagging available for BBRKC stock, a summary of this work is needed.
Natural tags (Acquired tags may show movement smaller than management areas)	Unknown.
Genetics	
Isolation by distance (Significant regression)	Present when compared to all Alaska samples (including SE Alaksa, p <0.01). Just Bering Sea samples did not show significant IBD but there is some relationship (p=0.064).
Dispersal distance (<<Management areas)	Genetic data suggests gene flow between most of the Bering Sea – excluding NS and WAI red king crab which appear to be more genetically distinct.
Pairwise genetic differences (Significant differences between geographically distinct collections)	None significant within the southeastern Bering Sea.

References:

Daly, B., et al. 2020. Red king crab larval advection in Bristol Bay: Implications for recruitment variability. Fisheries Oceanography 29(6): 505-525.

Grant, W. S., and W. Cheng. 2012. Incorporating deep and shallow components of genetic structure into the management of Alaskan red king crab. Evolutionary Applications 5: 820-837.

Grant, W.S., et al. "Phylogeography of red king crab: implications for management and stock enhancement." King Crabs of the World, edited by Bradley Stevens, CRC Press, 2014, p.47-72.

Spencer, P. et al. 2010. Guidelines for determination of spatial management units for exploited populations in Alaskan groundfish fishery management plans. NPFMC Sept. 2010 plan team draft

Vulstek, S.C. et al. 2013. Spatio-Temporal population genetic structure and mating system of red king crab (*Paralithodes camtschaticus*) in Alaska. Journal of Crustacean Biology 33(5): 691-701.

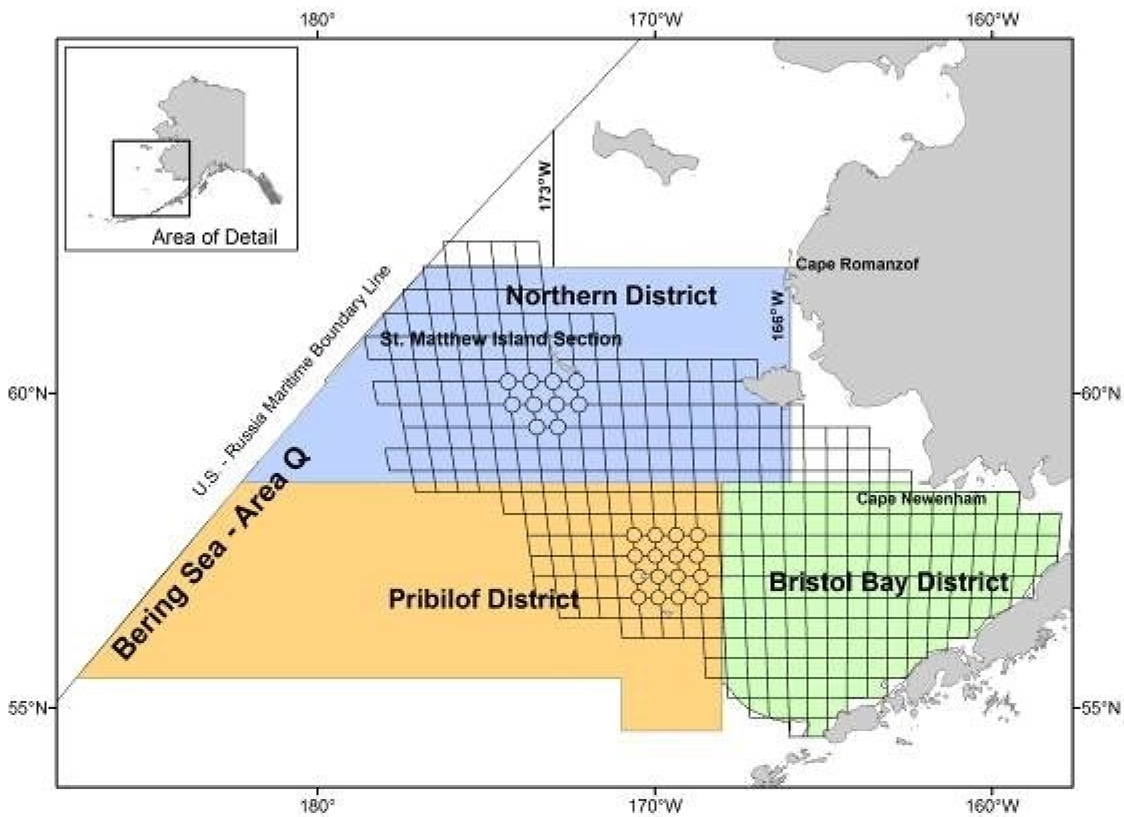

Figure 1. Bering Sea management areas (BBRKC, PIRKC, and Northern district), along with NMFS trawl survey stations. This figure does NOT include NSRKC or WAIRKC.

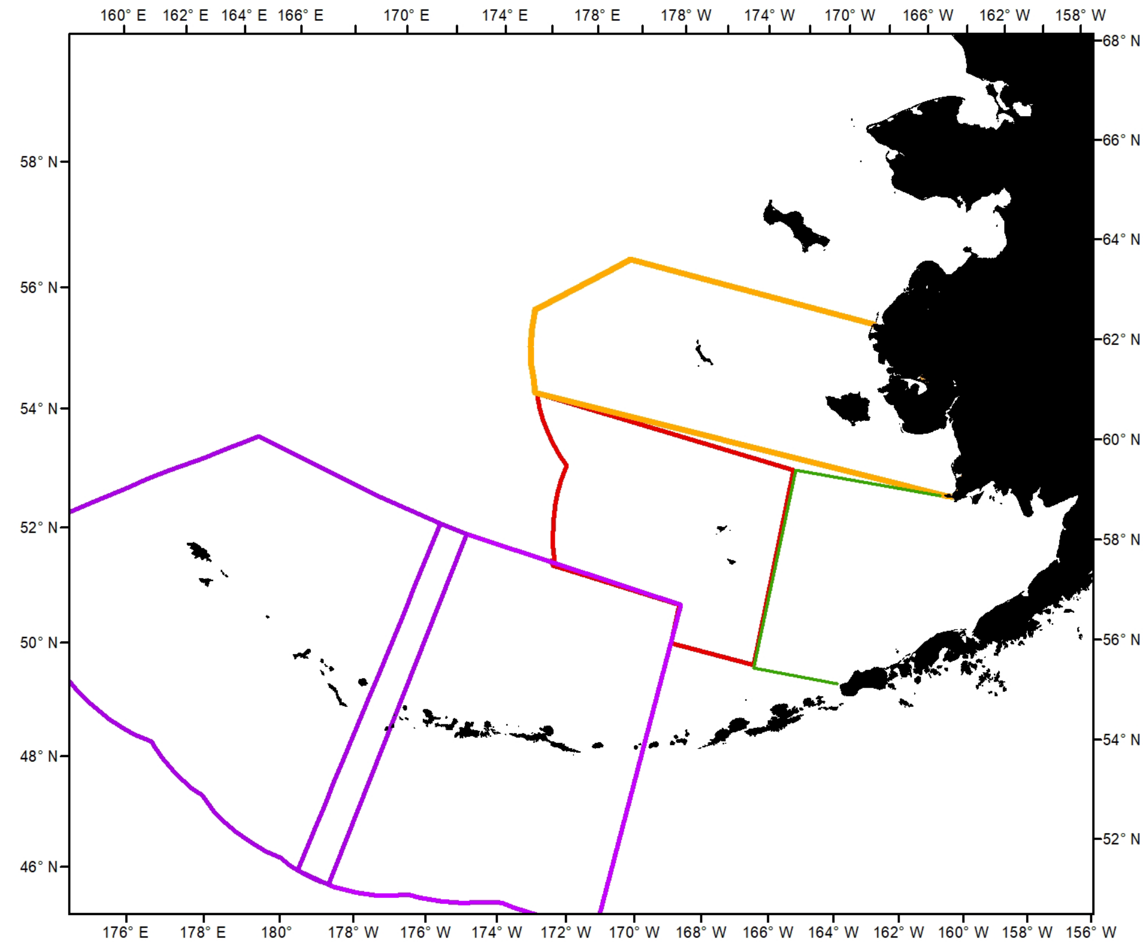

Figure 2. High level overview of some Bering Sea management areas (BBRKC - green, PIRKC - red, Northern district - yellow, WAIRKC – purple; source: Ben Daly).

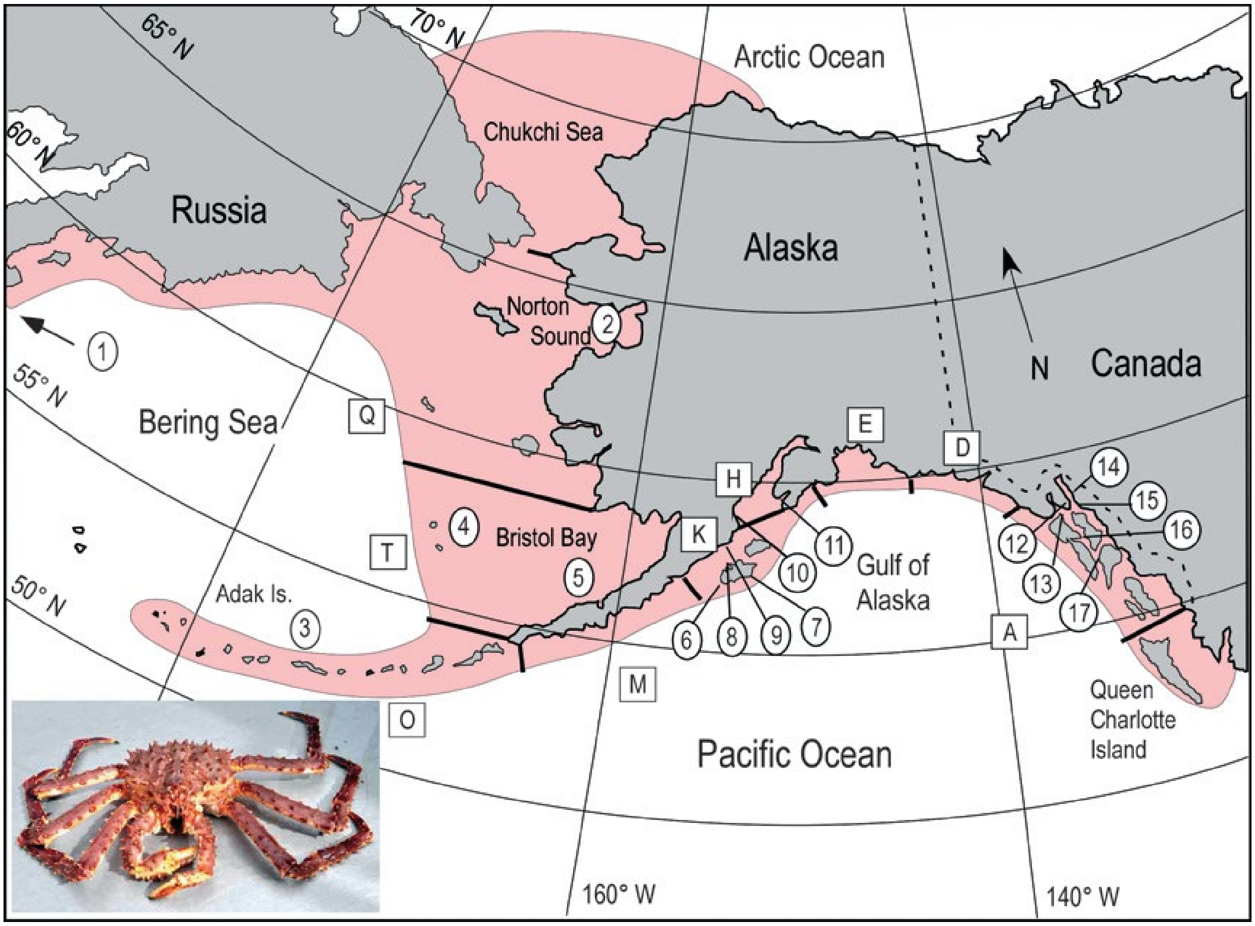

FIgure 3a. Map of the Bering Sea and Gulf of Alaska showing the geographic distribution of red king crab (red) and locations of samples. Numbers in ovals represent sample locations, and letters in squares represent State of Alaska harvest management areas (registration areas). Thick lines indicate management area boundaries (Source: Grant and Cheng 2012).

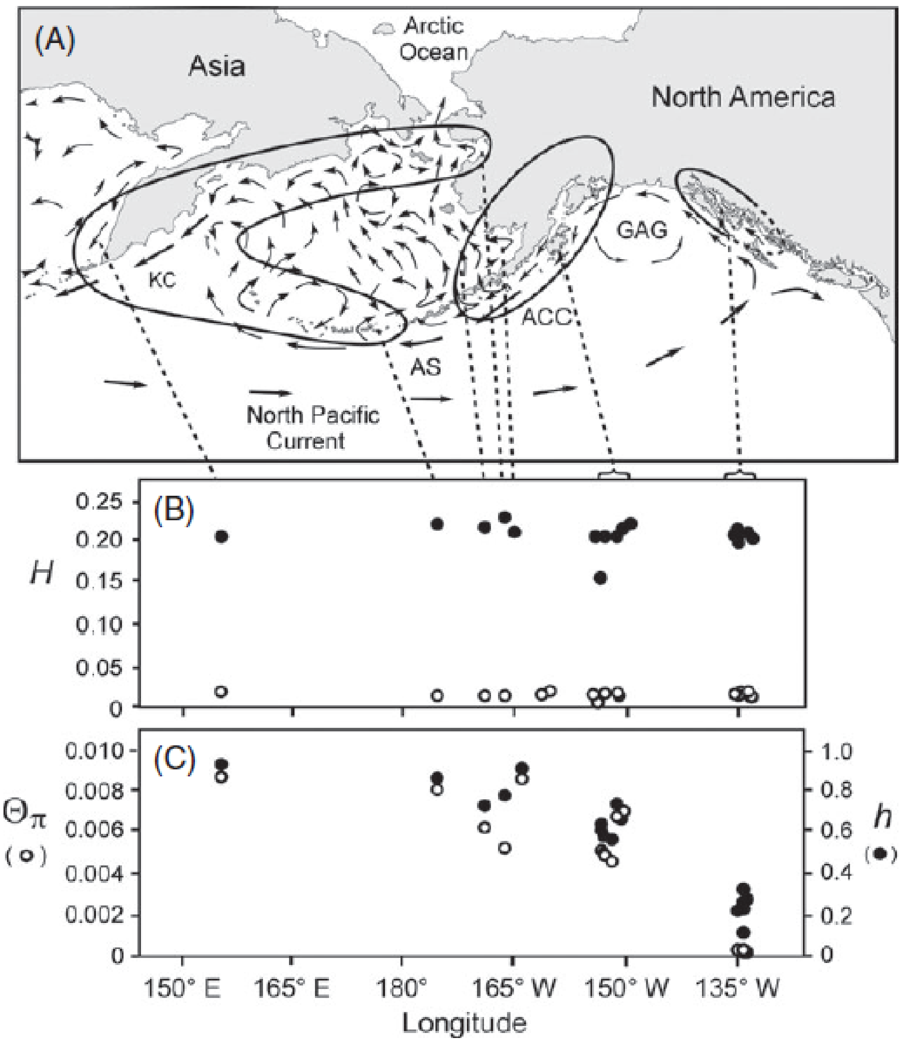

Figure 2 (a) Map of the North Pacific Ocean and Bering Sea showing generalized current patterns and three major population groups of red king crabs. (b) Average heterozygosity of 15 single nucleotide polymorphisms (closed circles) and average heterozygosity of 38 allozyme loci (open circles). (c) Mitochondrial DNA haplotype diversity (closed circles) and nucleotide diversity (open circles). KC, Kamchatka Current; AS, Alaska Stream; ACC, Alaska Coastal Current; and GAG, Gulf of Alaska Gyre.

Figure 3b. Genetic groupings and generalized current patterns (Source: FIgure 2 from Grant and Cheng 2012) .

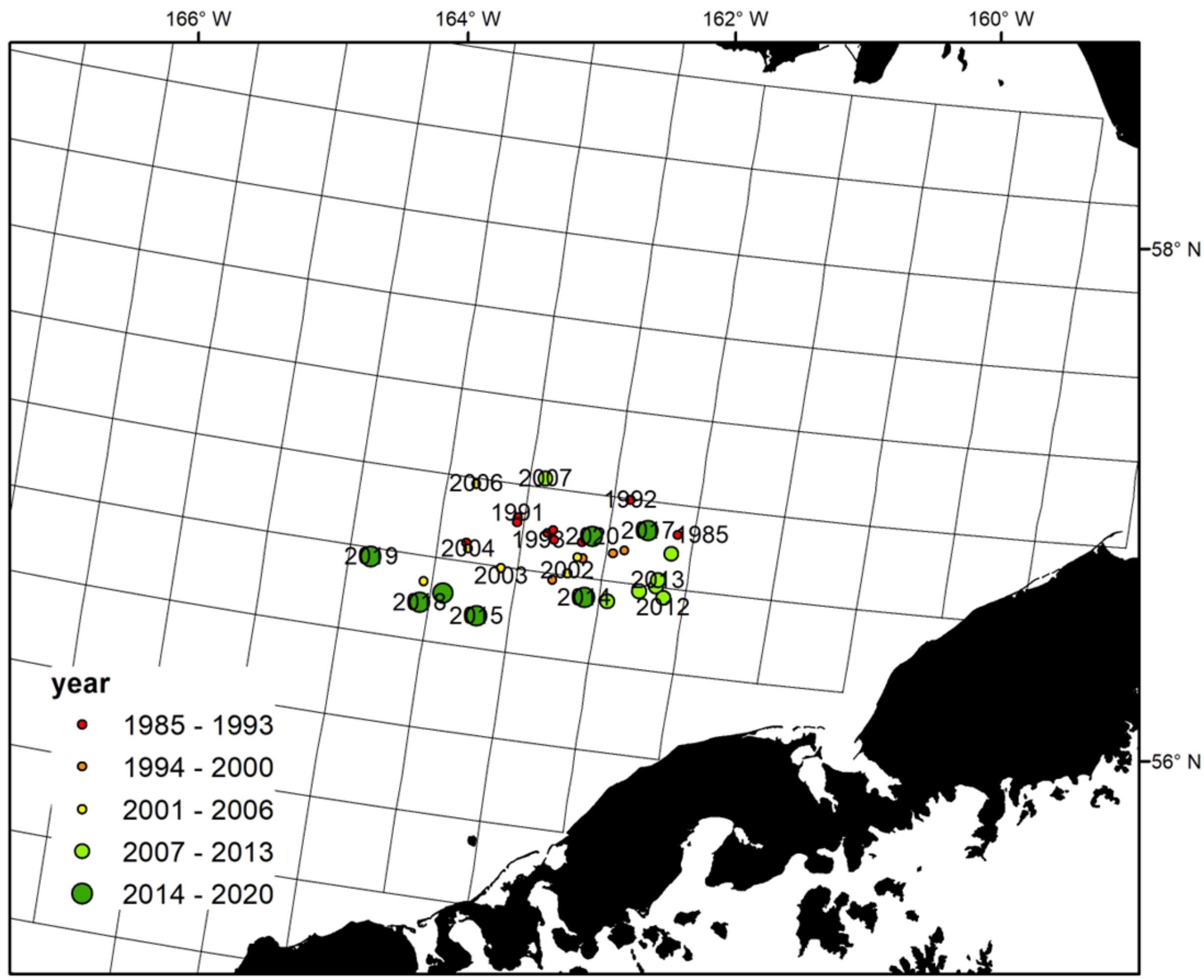

Figure 4. BBRKC weighted centers of catch over time, fishery was closed in 2021/22 and 2022/23 seasons (Source: September 2022 CPT presentation by B.Daly, ADF&G).

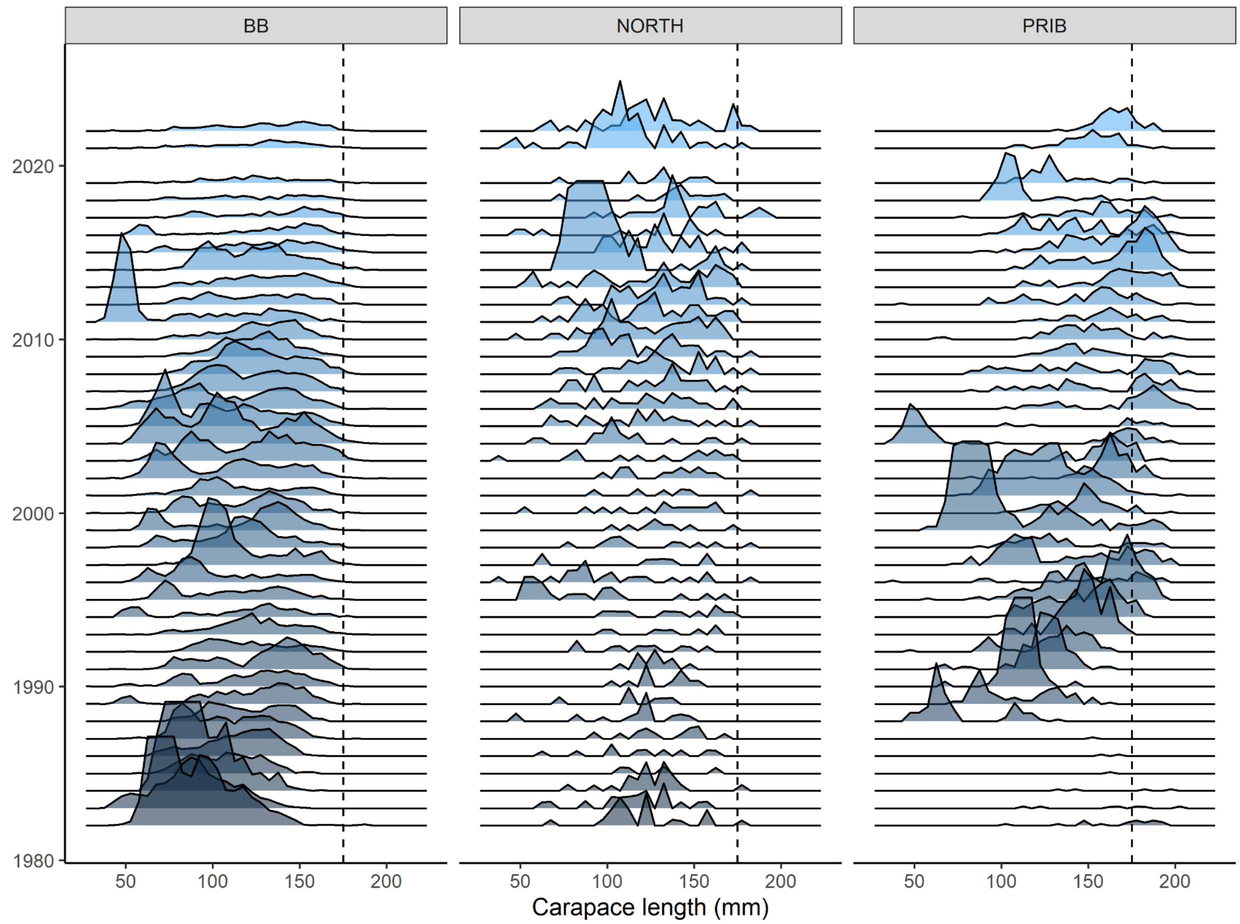

Figure 5. Density size composition comparisons over time for BBRKC, Northern district, and PIRKC (Source: provided by Cody Szuwalski).

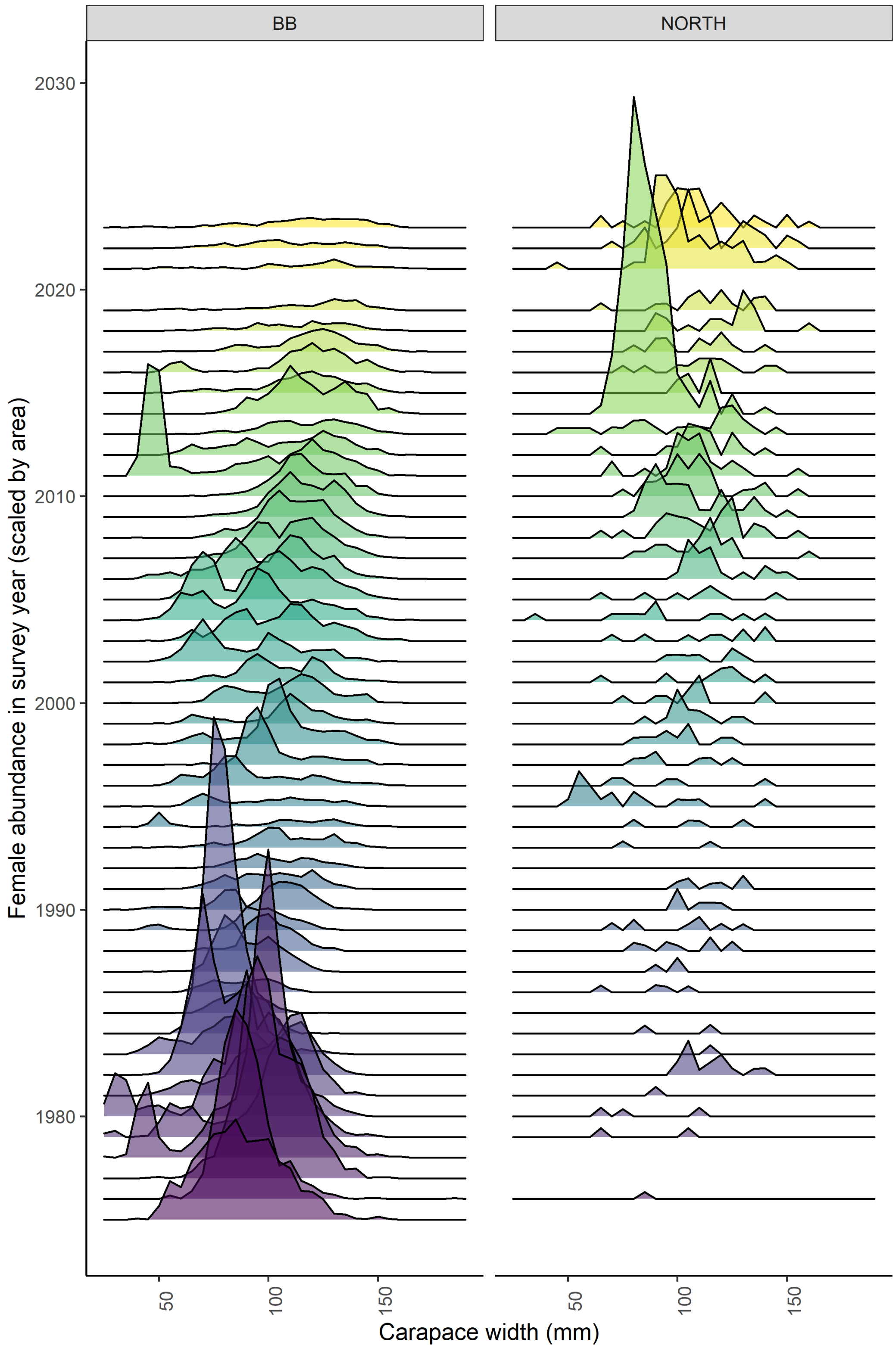

Figure 6a. Female size composition for BBRKC and Northern area over all years. Panels are not on the same scale.

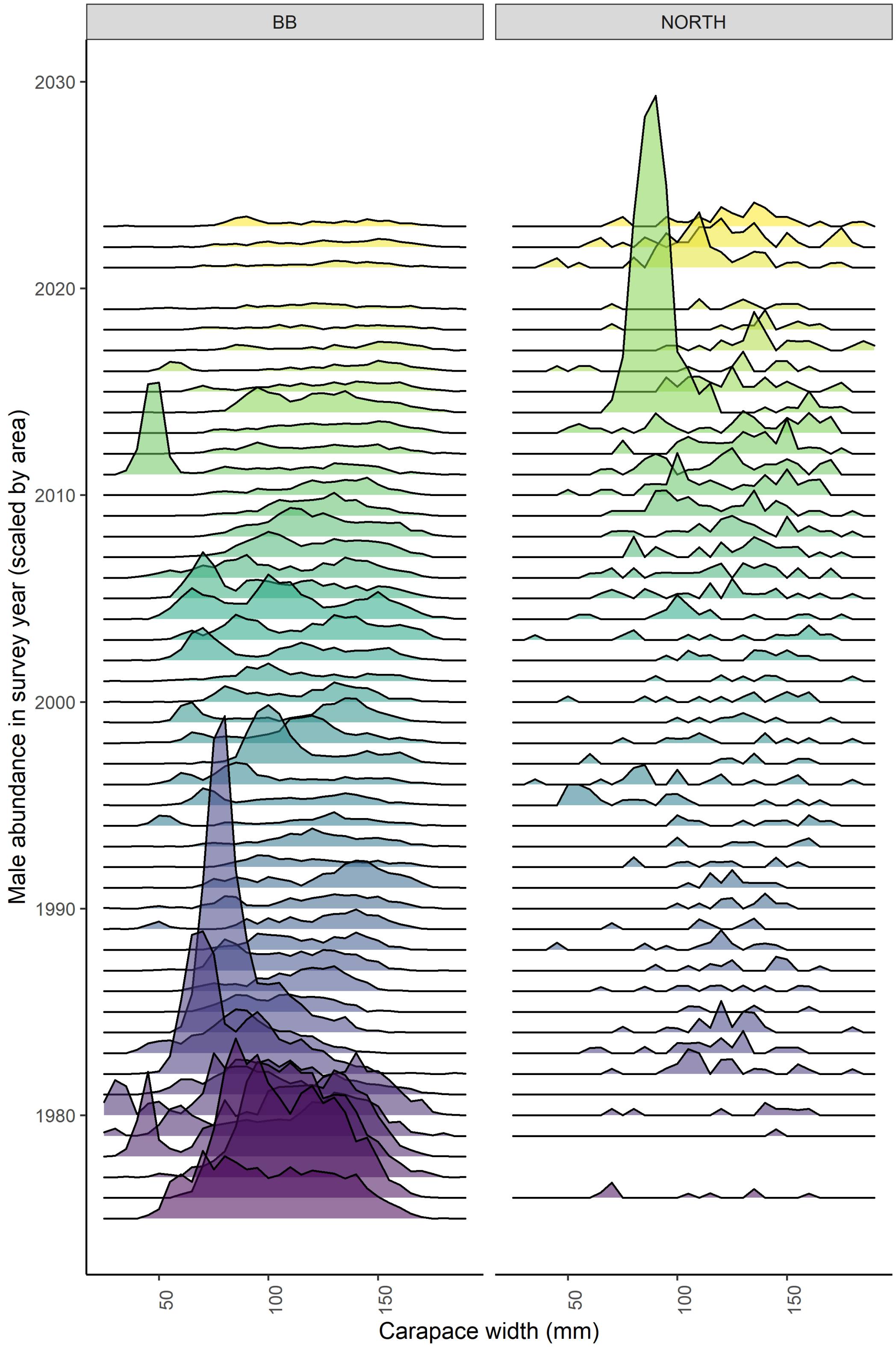

Figure 6b. Male size composition for BBRKC and Northern area over all years. Panels are not on the same scale.

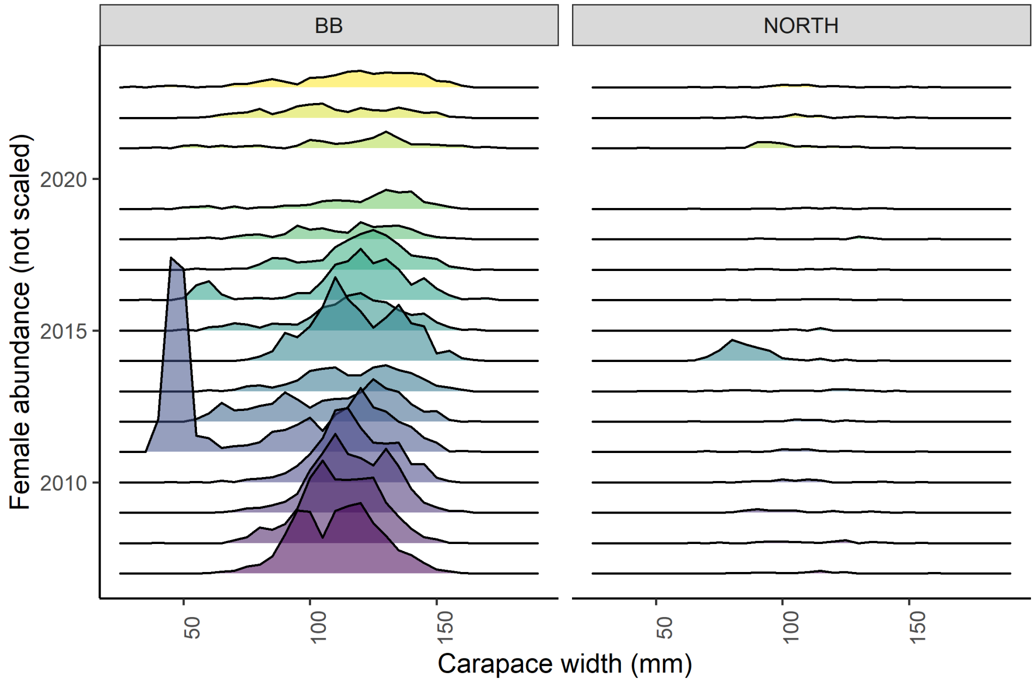

Figure 7a. Female size compositions since 2007 from NMFS trawl survey data. Panels are on the same scale (unlike Figures 6a and 6b).

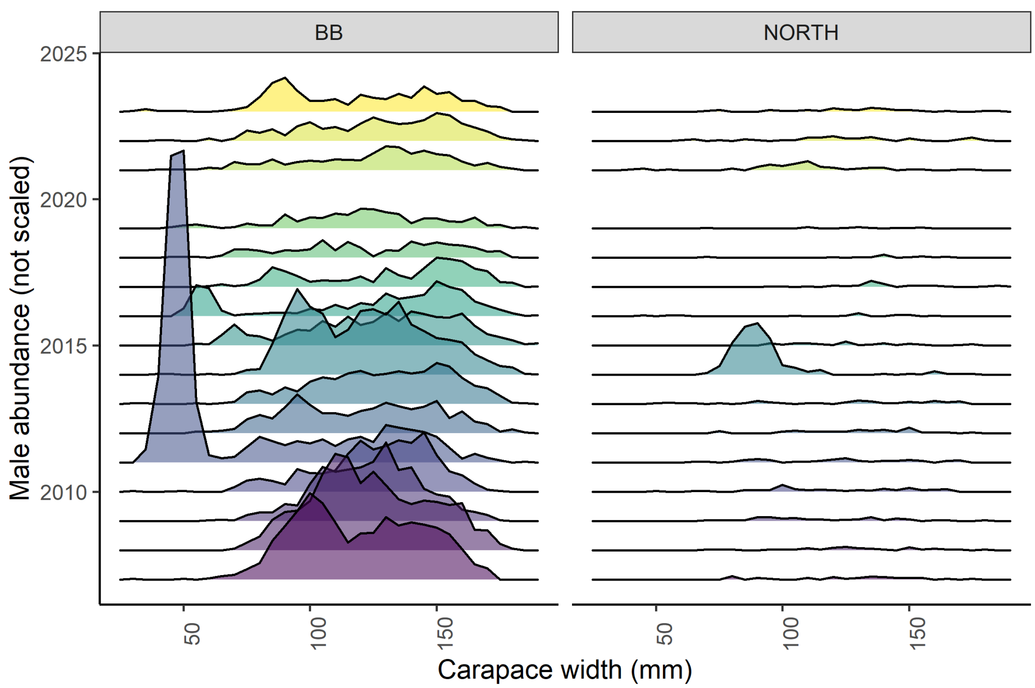

Figure 7b. Male size compositions since 2007 from NMFS trawl survey data. Panels are on the same scale (unlike Figures 6a and 6b).

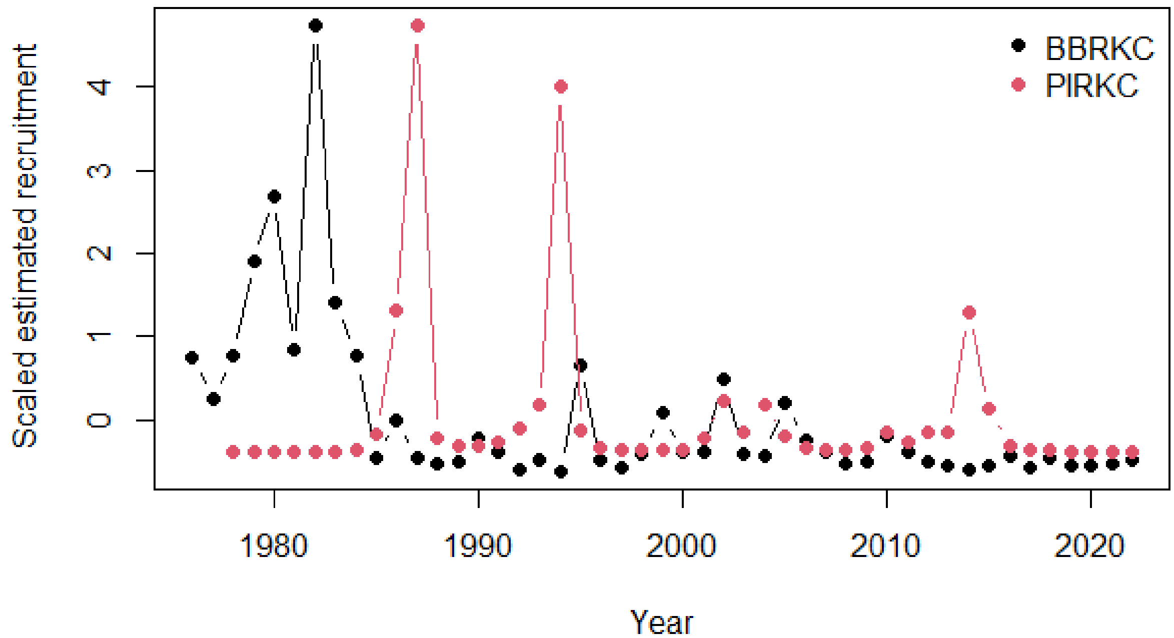

Figure 8. Scaled estimated recruitment from the stock assessments for BBRKC and PIRKC. PIRKC is advanced 2 years to account for the difference in size ranges modeled in each assessment. BBRKC starts at 67.5 mm carapace length; PIRKC starts at 37.5 mm carapace length (Source: provided by Cody Szuwalski).

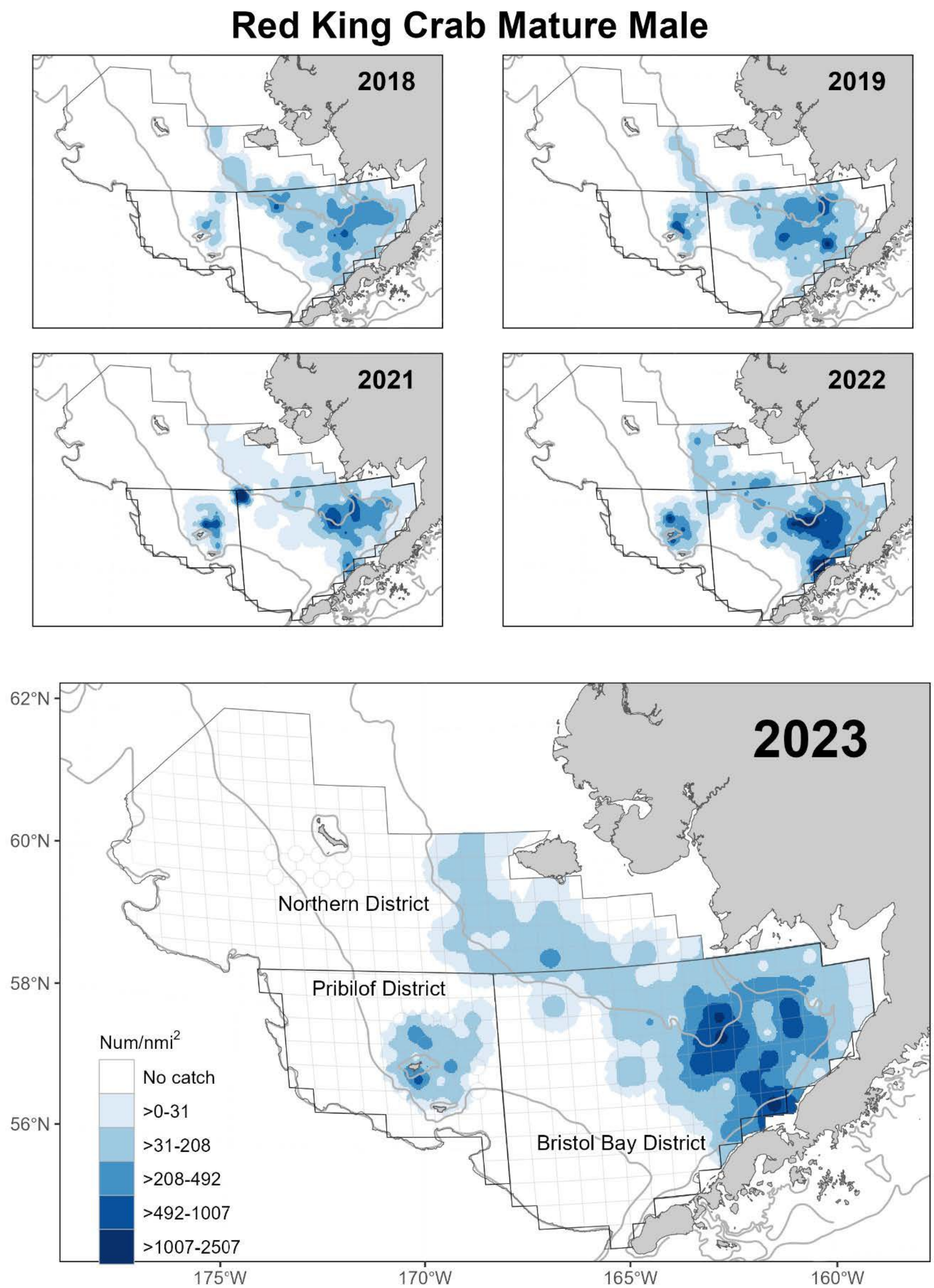

Figure 9a. Estimated total density of mature sized (>120 mm carapace length) male red king crab (*Paralithodes camtschaticus*) for the past five survey years. Outlined areas depict management districts (Source: NMFS draft tech memo for EBS crab, here). 2022 versions include the Northern Bering Sea survey and Norton Sound (see 2022 tech memo for that data).

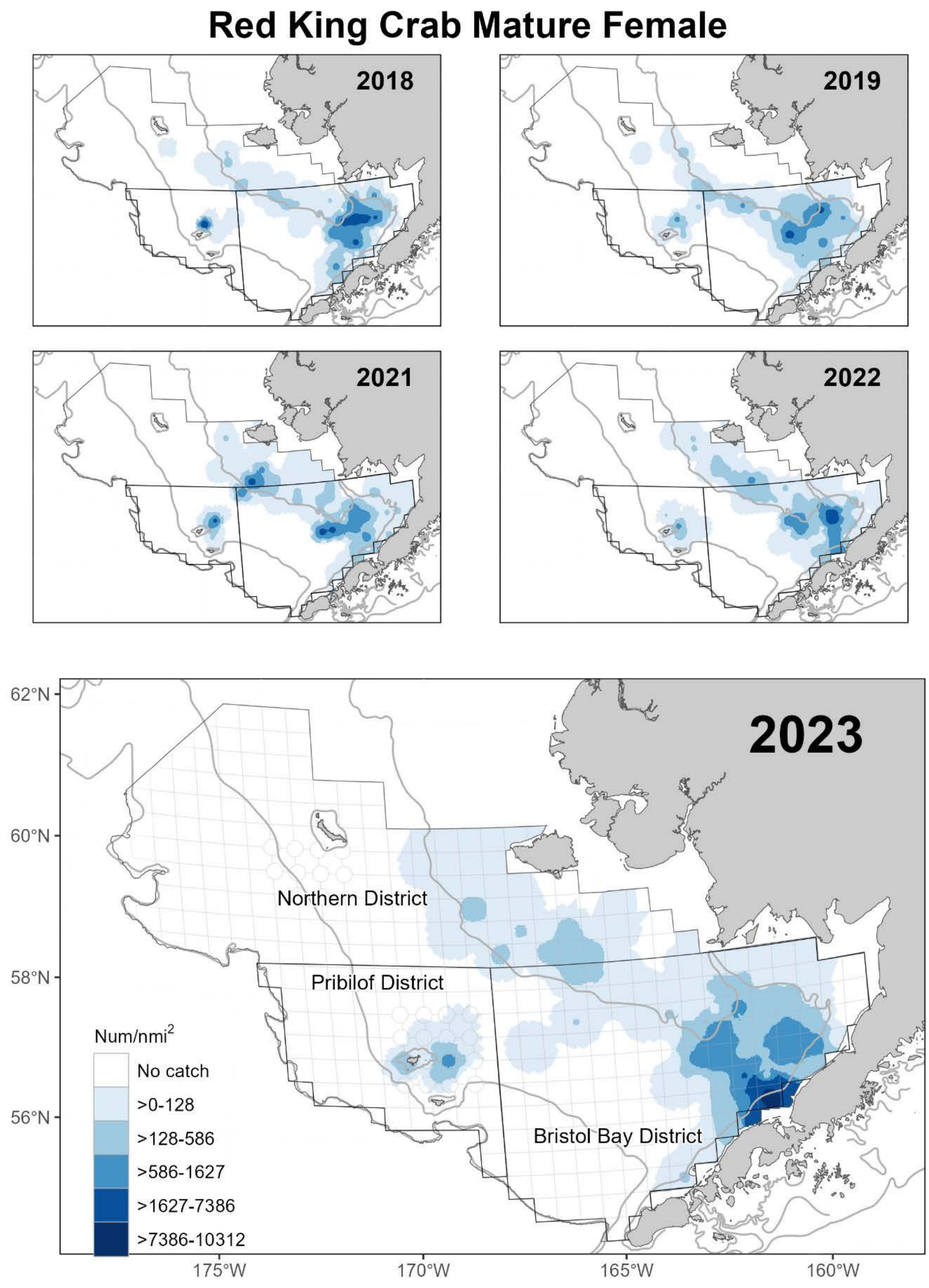

Figure 9b. Estimated total density of mature female red king crab (*Paralithodes camtschaticus*) for the past five survey years. Outlined areas depict management districts (Source: NMFS draft tech memo for EBS crab, here). 2022 versions include the Northern Bering Sea survey and Norton Sound (see 2022 tech memo for that data).

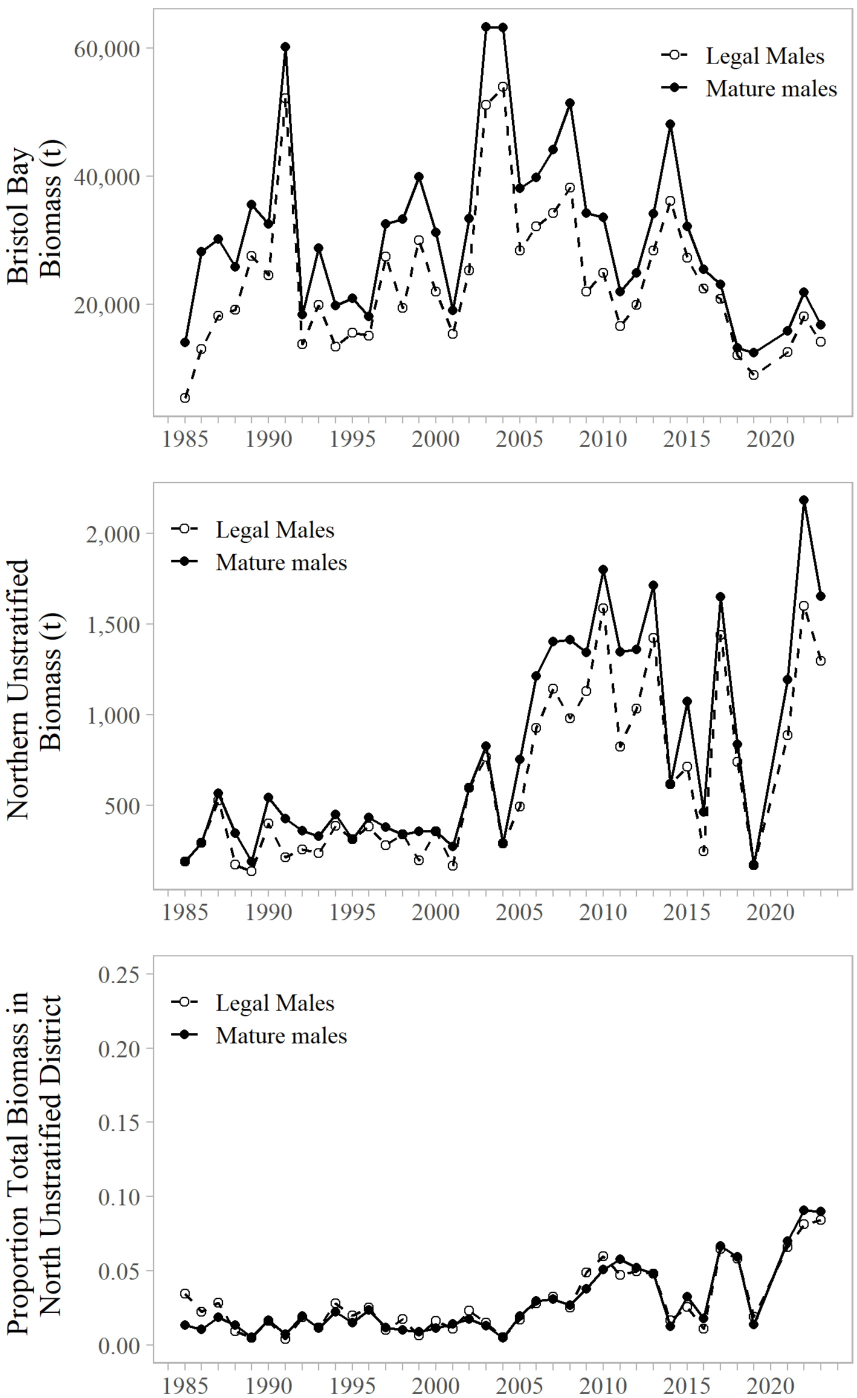

Figure 10a. Comparison of male distribution between Bristol Bay and Northern crab using NMFS survey data. Note: panels 1 and 2 do not have the same scale. There are far fewer crab in the Northern Unstratified area.

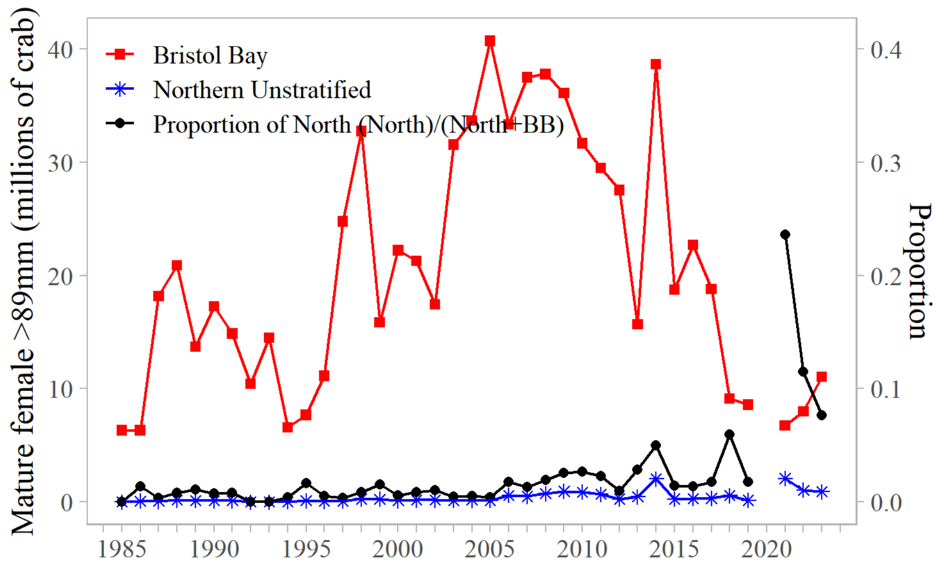

Figure 10b. Comparison of mature female (> 89 mm carapace length) distribution between Bristol Bay and Northern area crab using NMFS annual trawl survey data. Note: there are far fewer crab in the Northern Unstratified area.