Pacific Cod in the Bering Sea: A Transboundary Stock Assessment Summary

1. Introduction and Context

Pacific cod (*Gadus macrocephalus*) support major commercial fisheries across the North Pacific and are a critical resource for both the United States and Russia. Historically, stock assessments were conducted independently on either side of the international boundary, which limited understanding of the transboundary dynamics that shape the stock. Recent efforts have integrated data from the Eastern and Northern Bering Sea (EBS and NBS), western Gulf of Alaska (WGOA), and Western Bering Sea (WBS) within a single assessment framework, representing a major step forward in monitoring this transboundary population.

Cod in the Bering Sea exhibit strong spatial connectivity and sensitivity to environmental drivers. Genetic and tagging studies support the conclusion that fish move across the U.S.–Russia boundary and that the WBS is closely linked to the EBS, NBS, and WGOA. Climate variability, particularly the extent of the cold pool and warming bottom temperature anomalies, influences cod distribution, recruitment, and availability.

This document summarizes the first two-area stock assessment for Pacific cod in the Bering Sea, integrating U.S. and WBS survey and fishery data, and contrasting a two-area model with a single-area sensitivity run.

2. Methods

The assessment combined multiple data sources: U.S. and WBS bottom trawl surveys, fishery catches, and length and age compositions. WBS data included fishery catches and survey length compositions, though no WBS age data were available. U.S. surveys provided both length and age data, with strong time series coverage.

Model-based indices were developed using the R package sdmTMB. These spatiotemporal models applied a Tweedie distribution to accommodate zero-inflated, continuous biomass-per-unit-effort data. A barrier mesh (~300 knots) incorporating U.S.–Russia coastlines was constructed, and spatially varying coefficients accounted for cold-pool extent and survey-specific structure. Two index sets were produced: one from U.S.-only data (EBS, NBS, WGOA) and one combining U.S. and WBS data.

Stock Synthesis was configured in two ways: (1) a two-area model allowing movement between the U.S. waters and WBS, and (2) a single-area model using the combined indices as a sensitivity test. The two-area model was emphasized in interpretation. Exploitation trends and Schaefer surplus production fits were also examined.

3. Results

3.1 Biomass indices (sdmTMB)

The sdmTMB indices revealed consistent long-term dynamics but highlighted important differences among regions. In the EBS, results with and without WBS data were nearly identical, showing declines in the late 1980s and 2000s followed by rebuilding in the 2010s. In the NBS, WBS data produced smoother biomass trajectories and constrained uncertainty. The WGOA remained stable at relatively low biomass. The WBS index, only available when WBS data were included, displayed pronounced variability wi...

3.2 Stock Synthesis fits

The two-area Stock Synthesis model provided strong fits to survey biomass indices and fishery length compositions. U.S. indices were closely matched with narrow confidence intervals, while Russian indices exhibited larger residuals and uncertainty. Length composition fits were satisfactory overall, though deviations were more evident in the Russian survey.

3.3 Growth

Growth parameter estimates differed sharply by area. U.S. cod attained larger asymptotic lengths with narrow confidence intervals, while WBS cod showed smaller asymptotic sizes and very wide uncertainty. To stabilize estimation, LAmin was fixed for WBS. This lack of age–length data for Russia reduced the model’s ability to resolve year-class structure and propagated uncertainty into recruitment and movement estimates.

3.4 Recruitment

Recruitment patterns were dominated by the U.S. regions, with episodic strong year classes. In contrast, WBS recruitment was highly variable and difficult to distinguish from immigration, given the uncertainty in growth parameters. Recruitment success showed positive associations with cold-pool extent and was negatively impacted by warming bottom temperatures, consistent with known ecological drivers of cod distribution.

3.5 Biomass and Spawning Biomass

Total biomass and spawning stock biomass (SSB) displayed peaks in the early 1980s, mid-2000s, and early 2010s. The two-area model produced higher and more variable SSB compared to the combined model. Biomass trajectories tracked environmental fluctuations, with declines aligning with warm periods and reduced cold pools.

3.6 Exploitation

Fishing mortality (F = Z–M) peaked in the 1980s before declining under modern management. U.S. exploitation remained relatively stable thereafter, while WBS exploitation fluctuated sharply, reflecting both local variability and immigration from U.S. stocks. Catch vs. biomass plots showed density-dependent patterns, and Schaefer surplus production fits provided diagnostic MSY reference points.

3.7 Movement

The two-area model estimated substantial inter-regional movement of age-3+ cod, with net flows consistently into the WBS. Largest transfers occurred during the mid-1980s and early 2010s, exceeding 400–500 thousand t in some years. Correlation analyses indicated that U.S. biomass was the primary driver of flows into the WBS, while WBS biomass had little influence. However, these results remain uncertain due to poorly estimated growth and recruitment in the WBS.

4. Discussion and Conclusions

This two-area assessment highlights the transboundary dynamics of Pacific cod in the Bering Sea. U.S. regions (EBS, NBS, WGOA) provide the backbone of production, while the WBS functions as a recipient area, sustained by immigration. The WBS also exhibits its own episodic variability, but uncertainty in growth and recruitment estimation limits confidence in these dynamics.

Environmental drivers, especially cold-pool extent and bottom temperature, strongly influence biomass, recruitment, and distribution. Exploitation patterns differ by region, with U.S. fisheries showing stability and WBS fisheries reflecting greater variability and reliance on inflows. Movement estimates underscore the interconnected nature of these systems, though quantitative estimates remain uncertain.

The most pressing data gap is the absence of Russian age–length data. This deficiency undermines estimates of growth, recruitment, and movement, and limits the ability to distinguish local production from immigration. Addressing this gap should be a top priority for future collaborative research. Expanded biological sampling in the WBS, joint analyses, and continued incorporation of environmental covariates are essential for improving future assessments and ensuring sustainable management of this shared ...