**GOA Pacific Cod Risk Table 2022**

***Ecosystem Considerations***

Appendix 2.1 provides a detailed look at environmental/ecosystem considerations specific to this stock within the ecosystem and socioeconomic profile (ESP). Broad-scale information on environmental and ecosystem considerations are provided by the Gulf of Alaska Ecosystem Status Report (GOA ESR; Ferriss et al., 2022). The text below summarizes ecosystem information related to GOA Pacific cod provided from both the ESP and GOA ESR.

**Environmental Processes:** Thermal conditions for 2022 and predicted 2023 are within known optimal ranges for Pacific cod life history stages: spawning (20m - 290m, 1°C - 7°C), egg (20m - 200m, 3°C - 6°C), larvae (0m - 45m, 5°C - 6°C). Spring temperatures at depth were cooler than average (Seward Line, Danielson 2022) and there were no heatwave events during the spawning period (Appendix 2.1: Spawning Heatwave GOA Model by S. Barbeaux), which are beneficial to spawning conditions. However, summer bottom temperatures were above average in the central GOA (47.9 m and 103.4 m) and western GOA (41.9 m and 64.07 m) (Appendix 2.1: Summer Temperature Bottom GOA Model by M. Wang), in alignment with above average bottom temperatures at the shelf edge (longline survey, Siwicke), along the Seward Line (Seward Line survey, Danielson 2022) and off Kodiak (ADF&G, Worton 2022). Warm summer temperatures at depth can potentially adversely influence adult growth and feeding conditions. However, the habitat suitability index developed at GAK 1 of the Seward line was above average suggesting suitable habitat for Pacific cod (Appendix 2.1: Winter Spring Pacific Cod Spawning Habitat Suitability GAK1 Model by L. Rogers). Fall surface temperatures continue to be above average (Satellite, Lemagie 2022), at a time critical to overwinter survival of age-0 cod. Mesoscale eddy kinetic energy in the Kodiak region decreased to below average, implying slightly reduced retention in the area and reduced cross-shelf transport to suitable nearshore nursery environments (Cheng 2022; Appendix 2.1: Annual Eddy Kinetic Energy Kodiak Satellite by W. Cheng). Survival of the age-0 year class has moderate potential for success, with above average CPUE in western GOA beach seine (Appendix 2.1: Summer Pacific Cod CPUE YOY Nearshore Kodiak Survey by B. Laurel and M. Litzow), above average spring chl-a & zooplankton biomass and slightly later than average peak spring bloom (Appendix 2.1: Spring Chlorophyll a Peak WCGOA Satellite by M. Callahan), lower than average eddy kinetic energy, and summer/fall surface temperatures have been above average. 2023 surface temperatures are predicted to be average to cooler than average, in alignment with winter La Niña conditions and a negative Pacific Decadal Oscillation (Bond 2022).

**Prey:** Foraging conditions for juveniles and adults were average (zooplankton) to above average (forage fish) in 2022. Limited information on biomass of calanoid copepod and euhausiids in 2022 indicate average availability (Seward Line, Hopcroft 2022, zooplanktivorous seabird reproductive success, Drummond 2022 and Hatch 2022, AFSC SECM survey Icy Strait, Fergusson 2022). Forage fish were above average across the GOA (planktivorous seabird reproductive success, Drummond 2022 and Hatch 2022, herring, Hebert 2022 and Pegau 2022, Appendix 2.1: Annual Common Murre Reproductive Success Chowiet Survey by S. Zador). Tanner crab around Kodiak continue to increase (ADF&G trawl survey, Worton 2022) and shrimp have been increasing around Chirikof, Yakutat, and southeastern GOA regions, but declining around Kodiak from 2017-2021 (AFSC Bottom Trawl Survey, Palsson 2021). Biomass trends for other prey, including polychaetes and other invertebrates, are unknown. Pacific cod condition indices were above average (with the exception of CGOA longline data, a divergence potentially due to small sample size) indicating success at meeting energetic demands.

**Predators and Competitors:** There is no cause to suspect increased predation pressure on Pacific cod. In general predators of Pacific cod (including Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin) appear to be stable or at relatively low population levels. The most recent data available suggest that Steller sea lion trends have stabilized (eastern GOA) or continued to be at low levels (western GOA) in the Gulf of Alaska. Pacific halibut, large Pacific cod (representing cannibalistic predation) are estimated at low biomass. In general, apex fish predators in the GOA are at relatively low abundances (including cod and arrowtooth flounder, although sablefish are increasing in abundance) (Whitehouse 2021). Planktivorous juvenile cod may experience increased levels of competition from recent strong sablefish year classes, especially the 2019 larger than expected year class (D. Goethel, pers. comm.), although decreased competition from low, even year pink salmon returns.

*Summary for Environmental/Ecosystem Considerations*

* Moderate to below average thermal conditions for adults and larvae (but within known thermal ranges), improved habitat suitability, and below average larval retention with mesoscale eddies
* Above average juvenile and adult cod prey base and above average Pacific cod condition indices
* Potentially unchanged, low levels of predation and competition, with exception of competition from recent large year classes of sablefish

The GOA population persists at low levels since the 2014-2016 and 2019 marine heatwave periods. The large 2020 year class was observed in high numbers as age-1s in 2021 surveys, and environmental conditions remain cautiously favorable for them to persist. The 2022 year class has mixed signals for success, with cooler ocean temperatures in the early spring but warm summer and fall temperatures during a period essential to overwinter survival, and an above average prey base. Together, the most recent data available suggest an ecosystem risk Level 1 – Normal: “No apparent environmental/ecosystem concerns.”

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