We built a simulation model for three fisheries that are linked by cross-fishery participation. The fisheries are loosely based off of Dungeness crab, Chinook salmon and groundfish on the U.S. West Coast. Crab and salmon populations are modeled with random recruitment pulses each year and no across-year survival. This is reasonable for crab, as populations on the U.S. west coast display no stock-recruit relationship and nearly all legal-sized males are caught every year. Salmon populations are almost entirely of hatchery origin, so availability to the fishery depends mainly on hatchery production and ocean survival rates. After being available to the fishery, salmon return to their natal streams to spawn and die, so the available biomass in one year is independent of the previous year. [Ole ?: are the same fish available from year to year?] Unlike crab and salmon, groundfish are much longer-lived and therefore subject to depletion across years. Therefore, we modeled the groundfish population using a delay-difference model with a Beverton-Holt stock-recruit relationship and approximately parameterized the growth, mortality, and recruitment dynamics based on Sablefish.

Costs of fishing are divided into annual fixed costs that are automatically incurred every year (e.g., permits, boat and gear maintenance) and weekly variable costs that are only incurred if a vessel chooses to fish for a particular species in a given week (e.g., fuel, bait, labor). Fixed costs are constant for all participants, but variable costs vary by vessel according to a lognormal distribution in order to mimic variability in fishing skill. This allows for individual vessels to make different decisions through the season as to whether a particular population is profitable in a given week. Given fixed costs and the coefficient of variation for variable costs, we solved for the mean variable cost that led to zero profits in a year of average recruitment strength for the marginal (5th percentile) fisher who might be considering entry into the fishery. For groundfish, we furthermore forced the cost structure to lead the population to equilibrate at 40% of unfished biomass (the management target). Because we force no profitability on average, our assumption that annual participation in the fishery and permit costs are stable is reasonable. To avoid monte carlo error during the root-finding phase, these vessel-specific variable costs are assigned based on quantiles from the inverse lognormal cumulative density function. For actual simulations, these costs are drawn randomly, but held constant over time. For simplicity, this variable cost calculation is done independently for each fishery (i.e., vessels do not have other fishing options during the calculations), and is based on a fleet consisting of the same number of vessels as hold permits for the fishery in the baseline scenario.

Fishers are assumed to have perfect knowledge of the available biomass each week, and catchability is held constant, with no interference among vessels. Prices are also held constant for groundfish and salmon, so fishers also have perfect knowledge of the revenue and profit they will earn in a week for those populations. A demand function was built for the crab population to 1) better mimic the high level of depletion that occurs and 2) increase the temporal overlap between the realized crab and salmon fisheries. Prices for crab go up linearly once overall weekly catches fall below X% of average recruitment. Fishers use the prices paid for crab in the previous week to calculate expected revenue and profit for the upcoming week. In the first week of the year, X happens. Based on this information, each week each vessel calculates their expected profits (expected revenue – variable costs) for each fishery that is open and for which they hold a permit, and either fish in the most profitable fishery or, if no fishery is profitable, do not fish that week. For a given vessel holding multiple permits, variable costs across fisheries are correlated.