Stock-recruitment analysis for Atnarko sockeye

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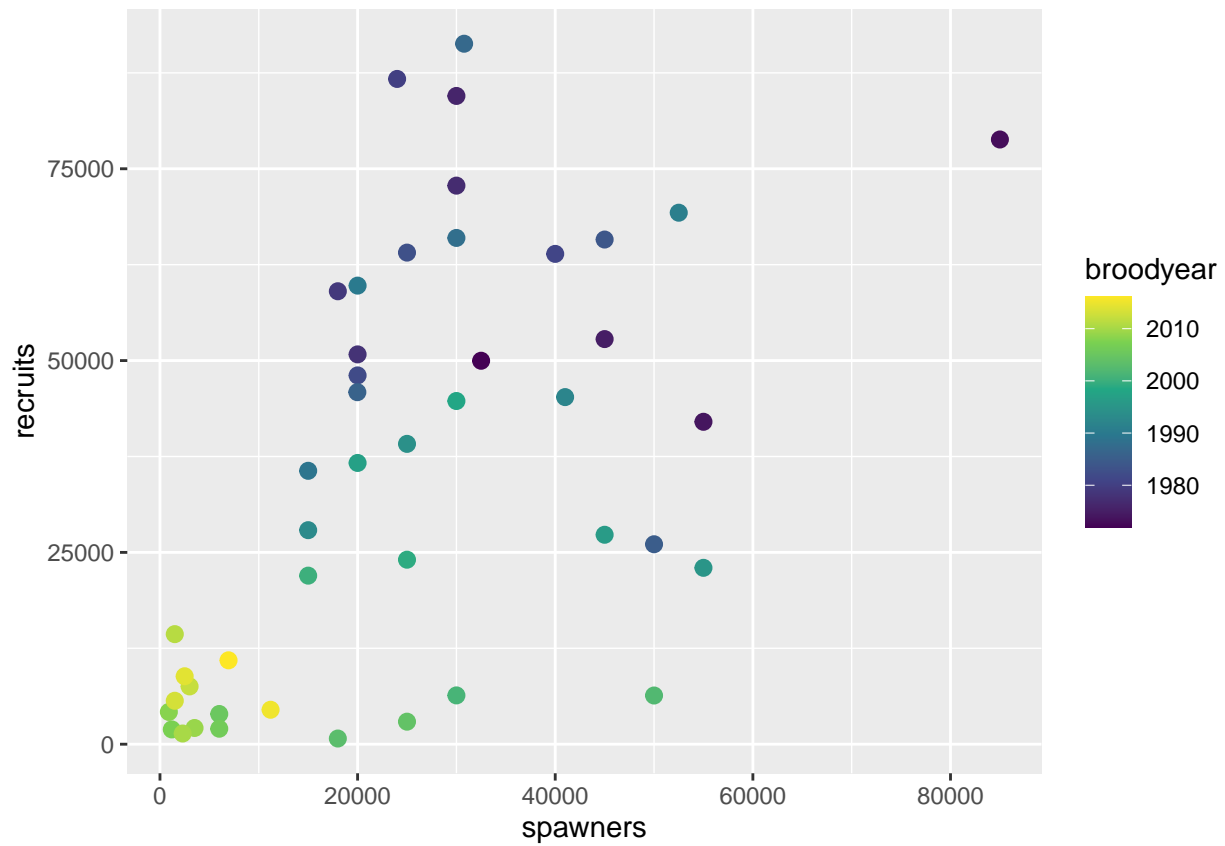Plot recruits as a function of escapement, by brood year.

Figure 1. Recruitment as a function of spawner escapement for Atnarko sockeye from brood year cohorts 1972 to 2016.

We will use the Atnarko sockeye stock-recruitment time-series to compare 8 different stock-recruitment model forms that represent time-invariant (models 1 & 2), time-varying (models 3 - 5), or regime-shift (models 6 - 8) model types.

Model 1 - Static Ricker curve

Model 2 - Autocorrelated Ricker curve

Model 3 - Time-varying productivity Ricker curve

Model 4 - Time-varying capacity Ricker curve

Model 5 - Time-varying prod. & cap. Ricker curve

Model 6 - Regime-shift productivity Ricker curve

Model 7 - Regime-shift capacity Ricker curve

Model 8 - Regime-shift prod. & cap. Ricker curve

We start by competing each of these models in their accuracy in predicting productivity (log Recruits per Spawner) 1-year ahead using an iterative cross-validation approach (implemented with functions from samEst), starting from the 16th brood cohort and onwards. Note, for this analysis we have adjusted the default priors on stock capacity from samEst to be more informative for Atnarko sockeye based on a capacity prior estimate from Atlas et al. 2022 (). We set the expected capacity to be ~18000, with 1 standard deviation (on the log scale) ranging from 6600 to 43000.

Using the out-of-sample log-likelihood estimates, we can compare the Bayesian model weights for each model set. First finding the highest likelihood prediction window (ie 1-year back parameters, last 3-year average of parameters, or last 5-year average of parameters). We can assess model weights using the full predictive dataset, or dropping the 10/20% of hardest to assess years as the full model likelihoods may be highly influenced by the most challenging to predict observations.

```
##    m1    m2    m3    m4    m5    m6    m7  m8_1
## 0.000 0.747 0.000 0.252 0.000 0.000 0.000 0.000


##    m1    m2    m3    m4    m5    m6    m7  m8_1
## 0.000 0.447 0.001 0.000 0.000 0.027 0.521 0.004


##    m1    m2    m3    m4    m5    m6    m7  m8_1
## 0.018 0.009 0.000 0.000 0.001 0.744 0.224 0.005
```

Using the 1-year out-of-sample predictive accuracy from 1987 to 2016, the best supported model was the static model with autocorrelated residuals (model 4), with regime-shift capacity (model 4) and regime-shift productivity having the next highest level of support based on the 90% and 80% highest accuracy observations, respectively.

We'll proceed by fitting and visualizing these three models to the full dataset.
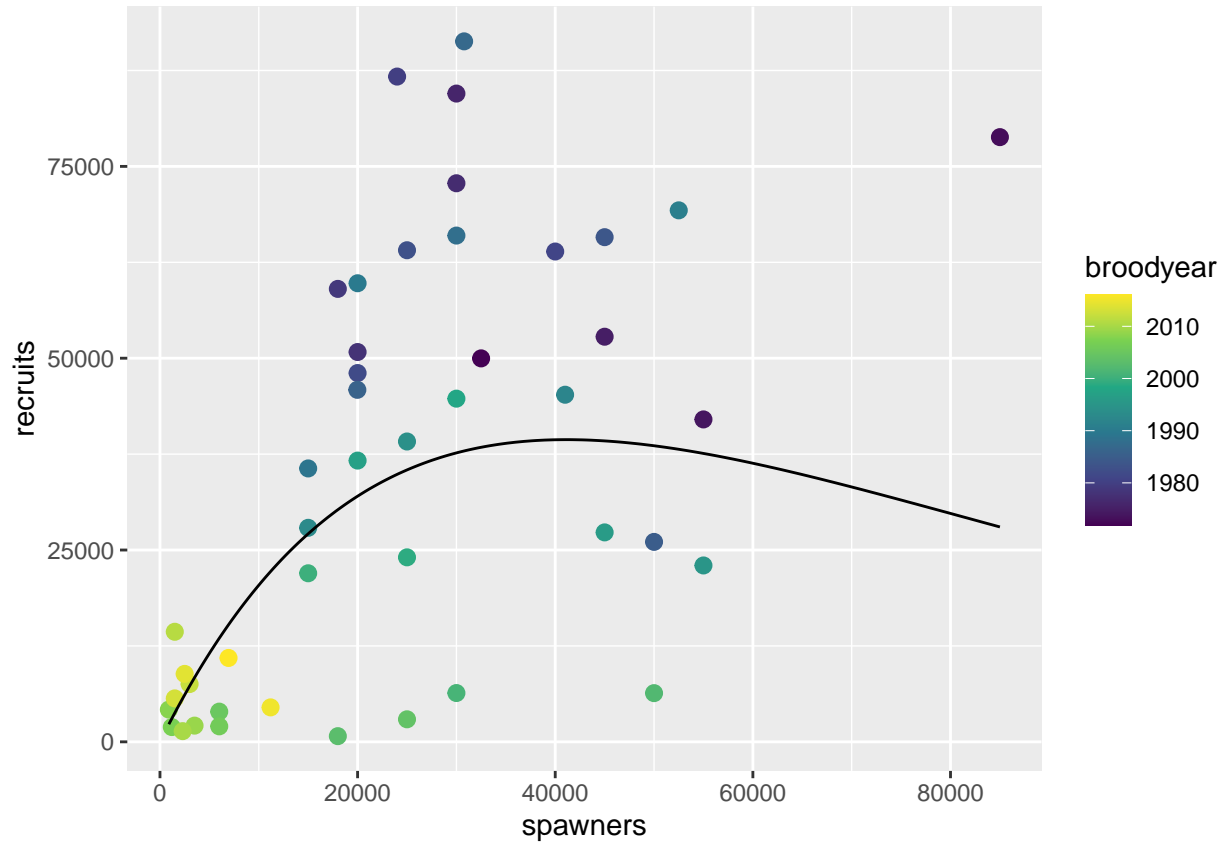
Figure 2a. Predicted stock-recruitment functions for Atnarko sockeye, with observations coloured by brood cohort year, from the top-rated model (Ricker curve with autocorrelated residuals) for the full predictive window from 1987 to 2016.
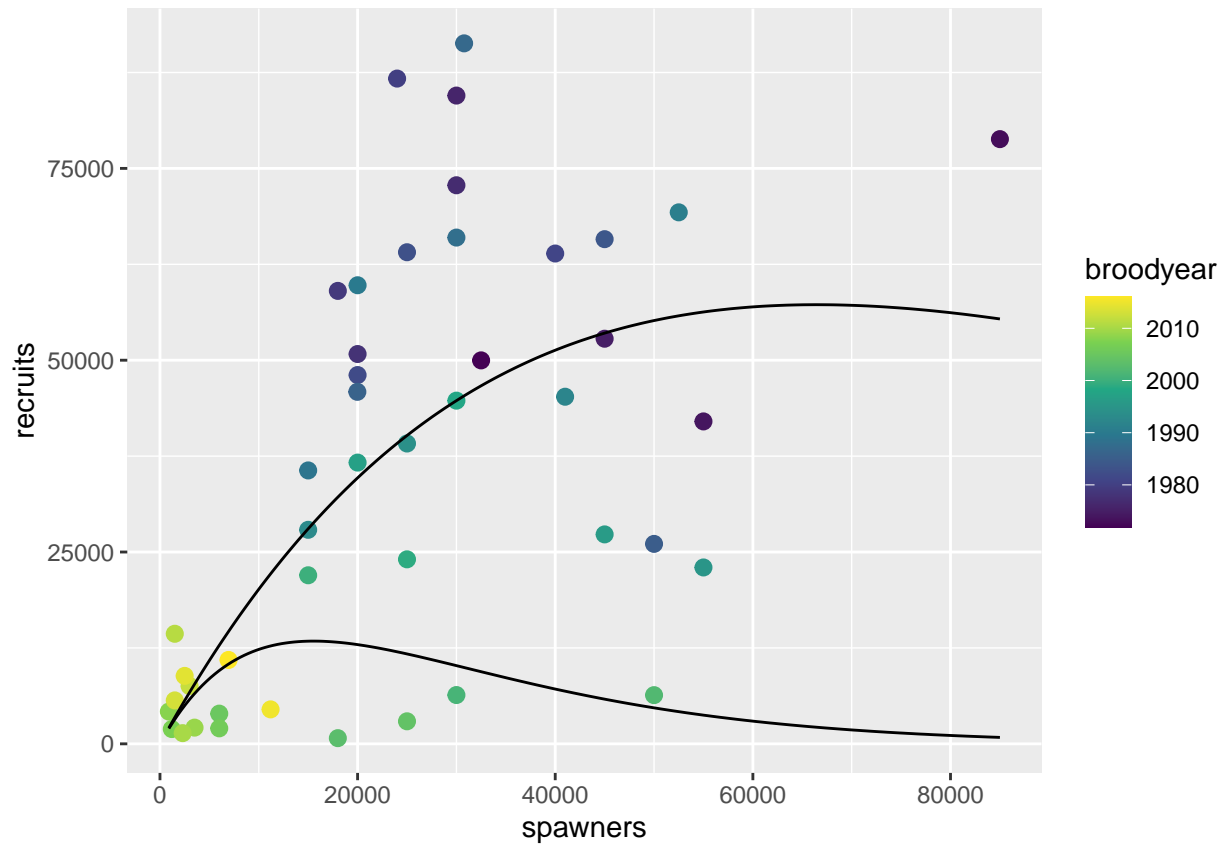
Figure 2a. Predicted stock-recruitment functions for Atnarko sockeye, with observations coloured by brood cohort year, from the top-rated model (regime-shift capacity) for the 90% highest log-likelihood years.
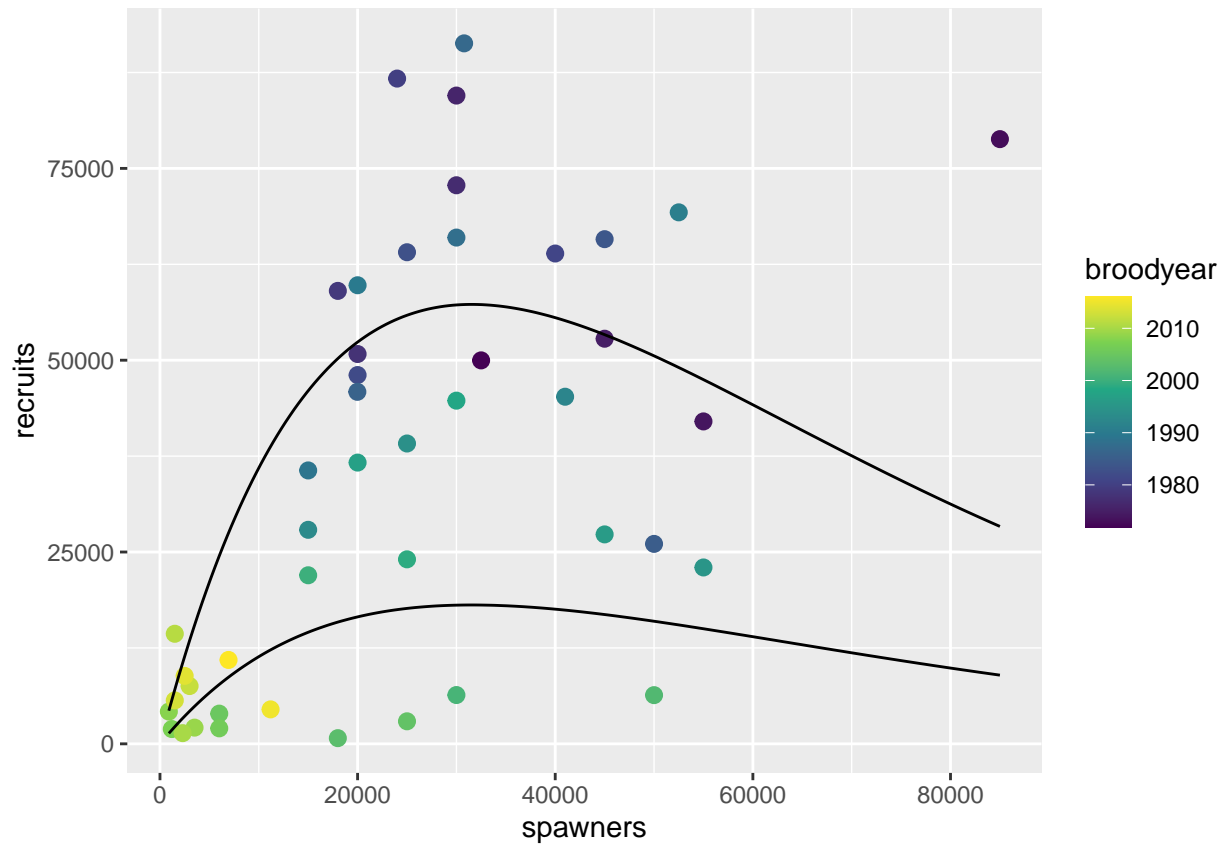
Figure 2c. Predicted stock-recruitment functions for Atnarko sockeye, with observations coloured by brood cohort year, from the top-rated model (regime-shift productivity) for the 80% highest log-likelihood years.
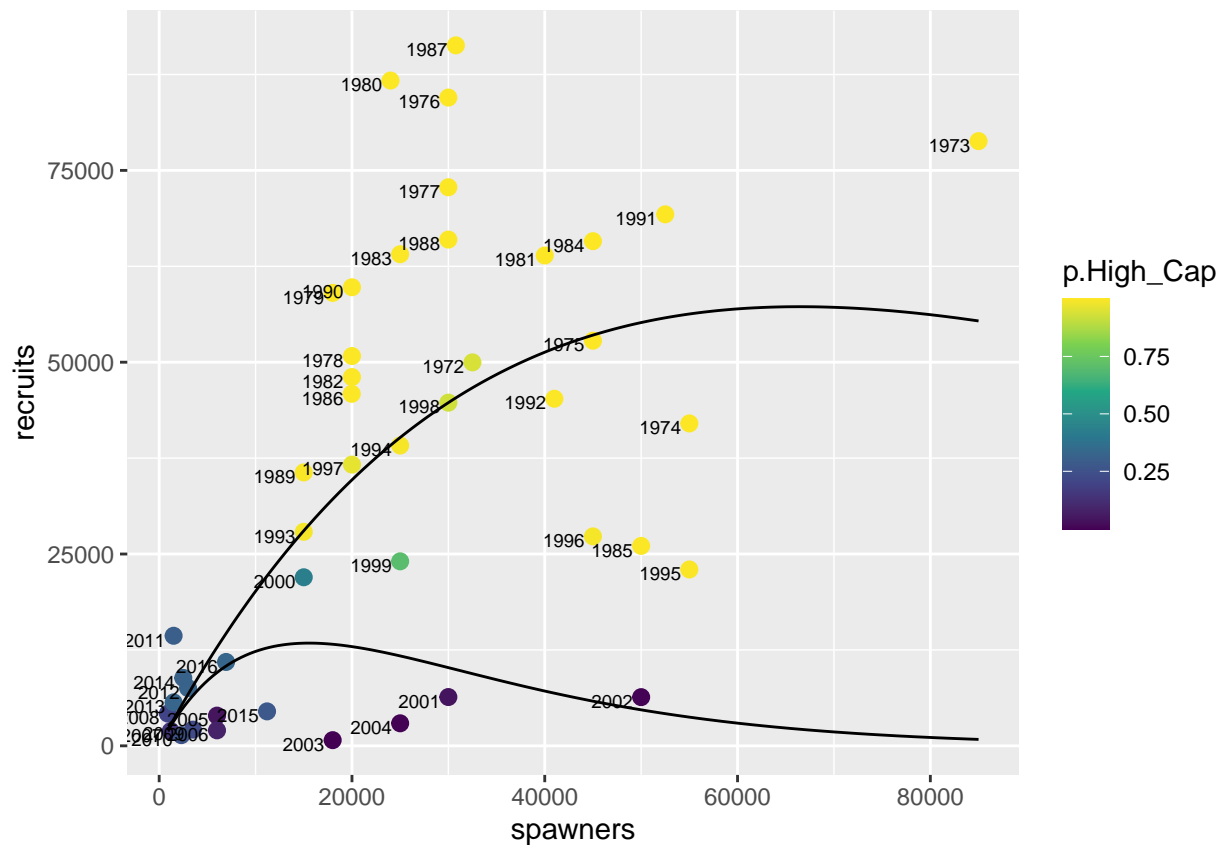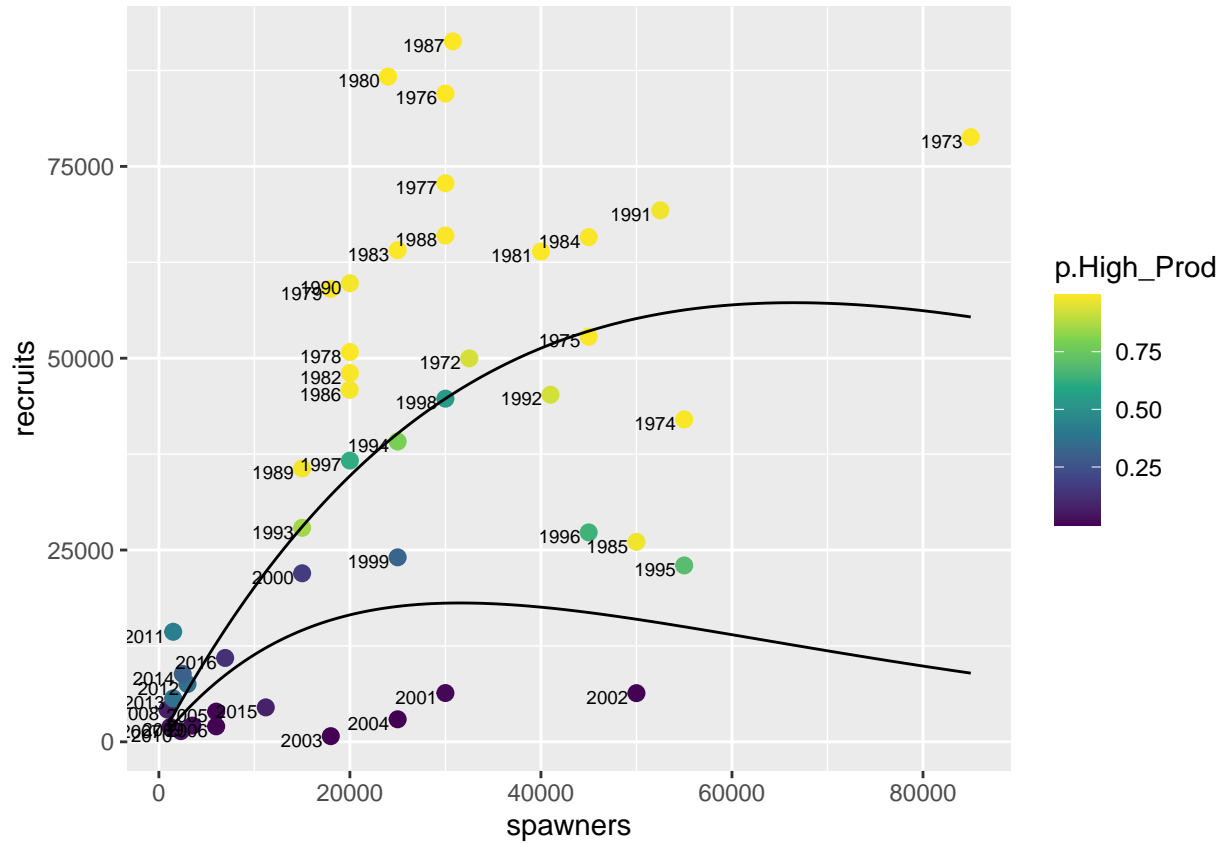
Figure 3a. Predicted stock-recruitment functions for Atnarko sockeye for each regime (high and low capacity regimes), with observations coloured by the median probability of being in the 'High Capacity' regime (Yellow indicating high probability and purple low probability, respectively).
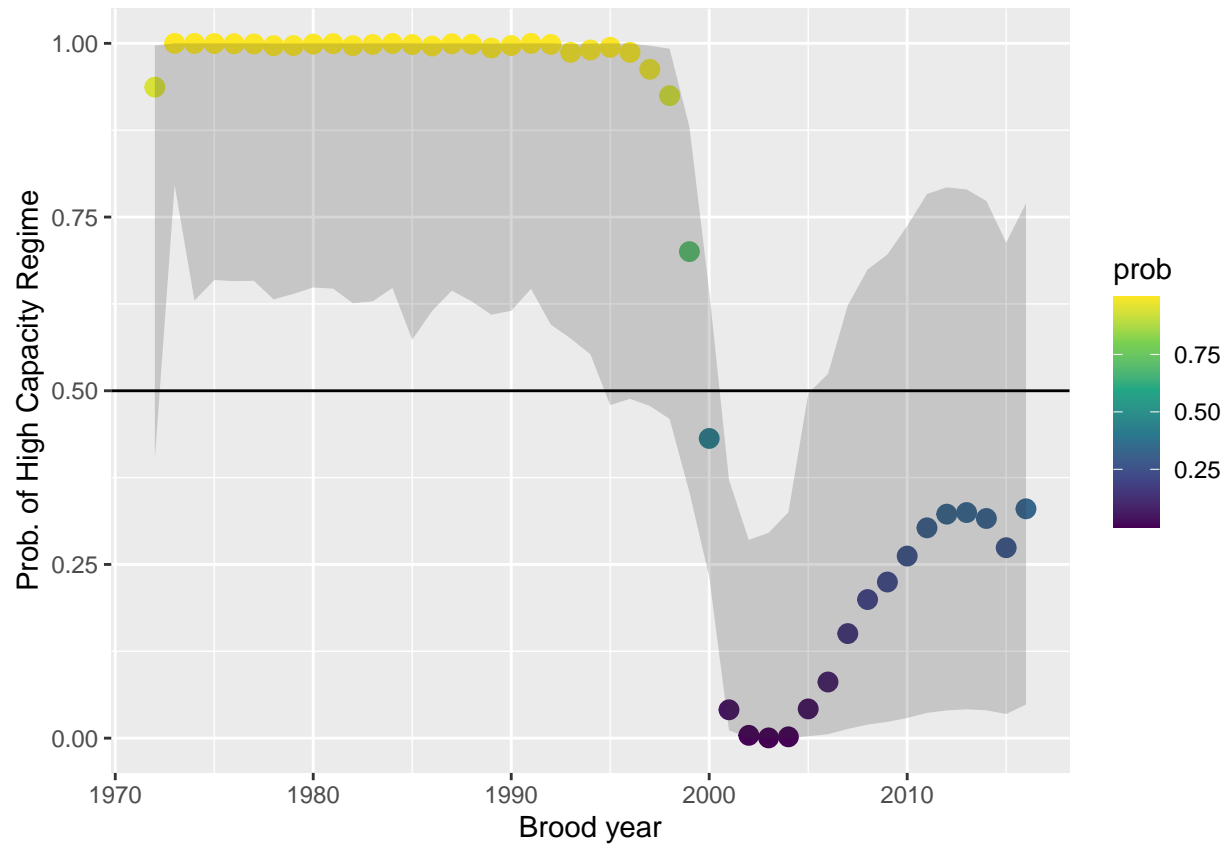
Figure 3b. Predicted stock-recruitment functions for Atnarko sockeye for each regime (high and low productivity regimes), with observations coloured by the median probability of being in the 'High Productivity' regime (Yellow indicating high probability and purple low probability, respectively).

Figure 4. Estimated probabilities of each brood year cohort being in the 'high capacity' regime state from 1972 to 2016, conversely, low probabilities indicate a high probability of being in a 'low capacity' regime state. Shaded area represents the 90% confidence intervals in the state probabilities.
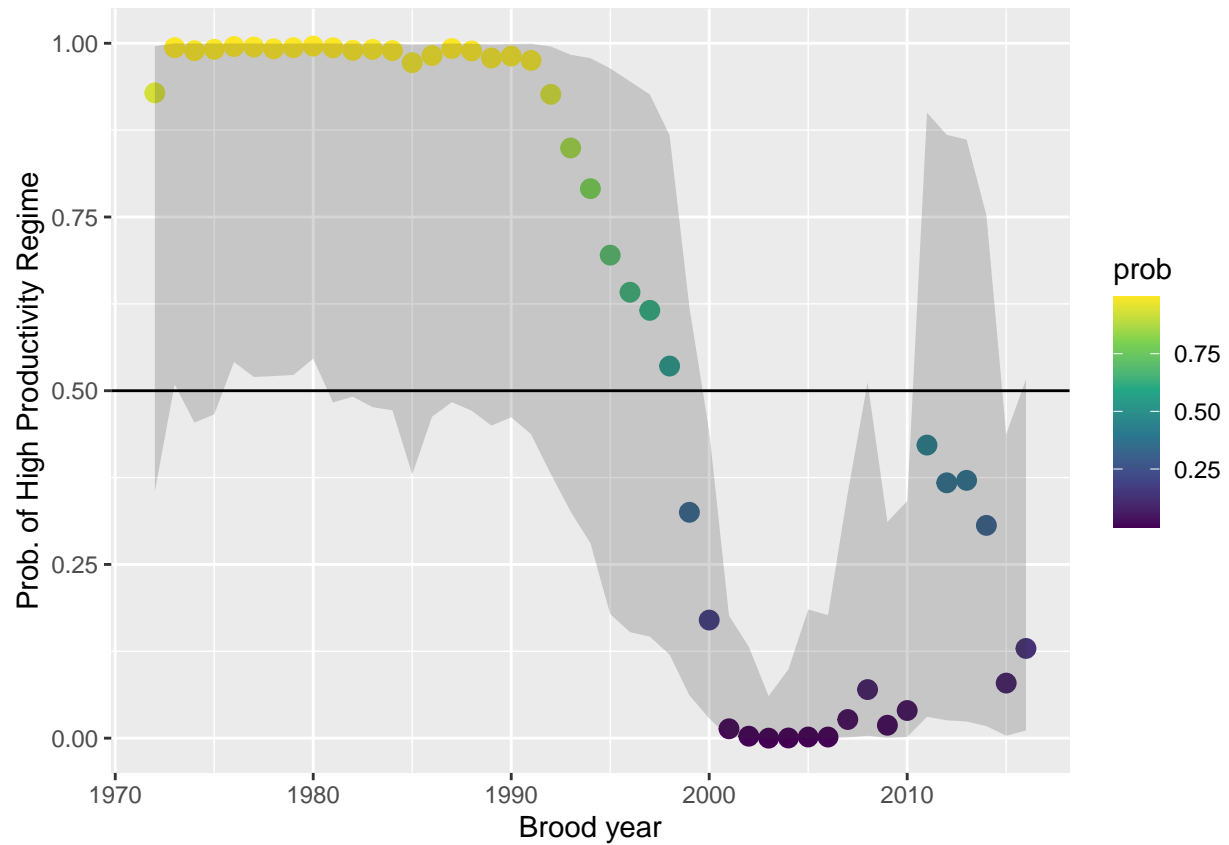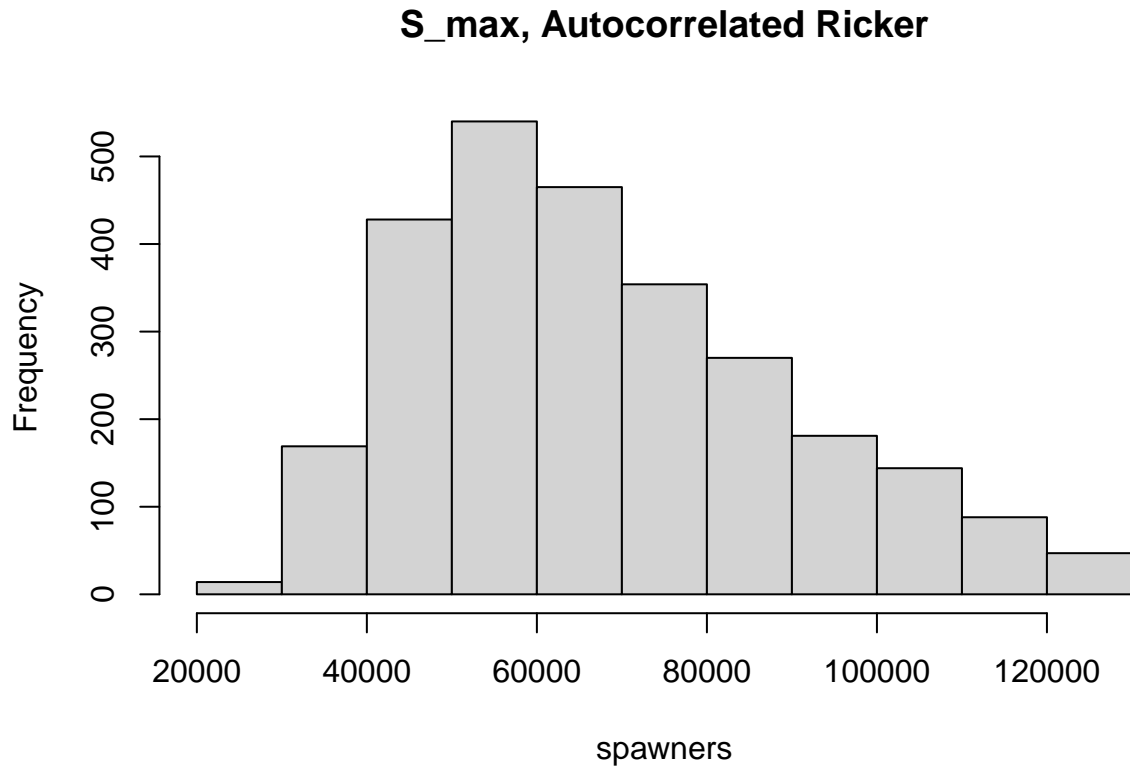
Figure 4. 1) Estimated probabilities of each brood year cohort being in the 'high productivity' regime state from 1972 to 2016, conversely, low probabilities indicate a high probability of being in a 'low productivity' regime state. 2) Shaded area represents the 90% confidence intervals in the state probabilities.
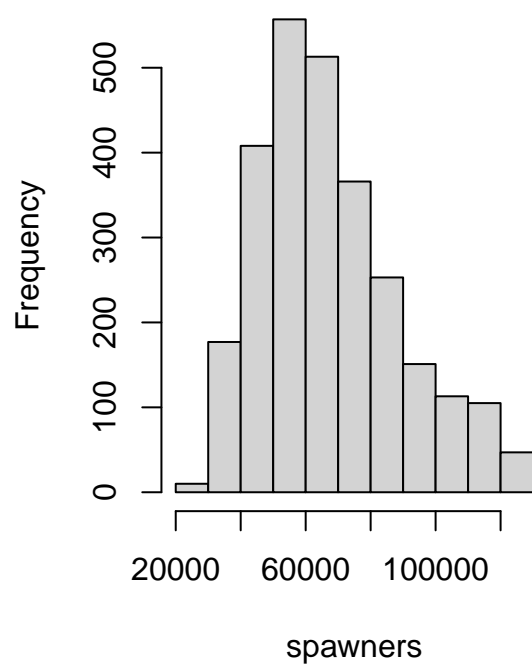
Reference points

S_max: Histogram of the estimated spawner escapement that maximizes recruitment. Note that esitmates are truncated here (for visual purposes) at the 90% upper estimate to remove extremely high estimates on the tails of the parameters for each regime.
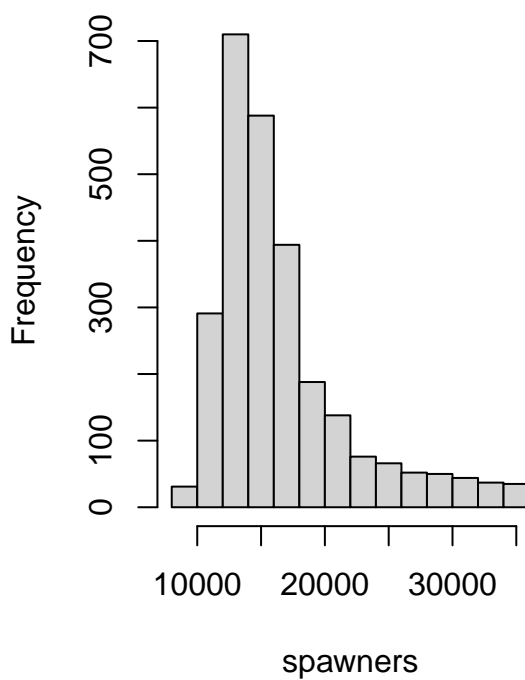

S_max, Autocorrelated Ricker

This figure corresponds to the top-ranked model (autocorrelated Ricker) for the full predictive samples from 1987 to 2016.
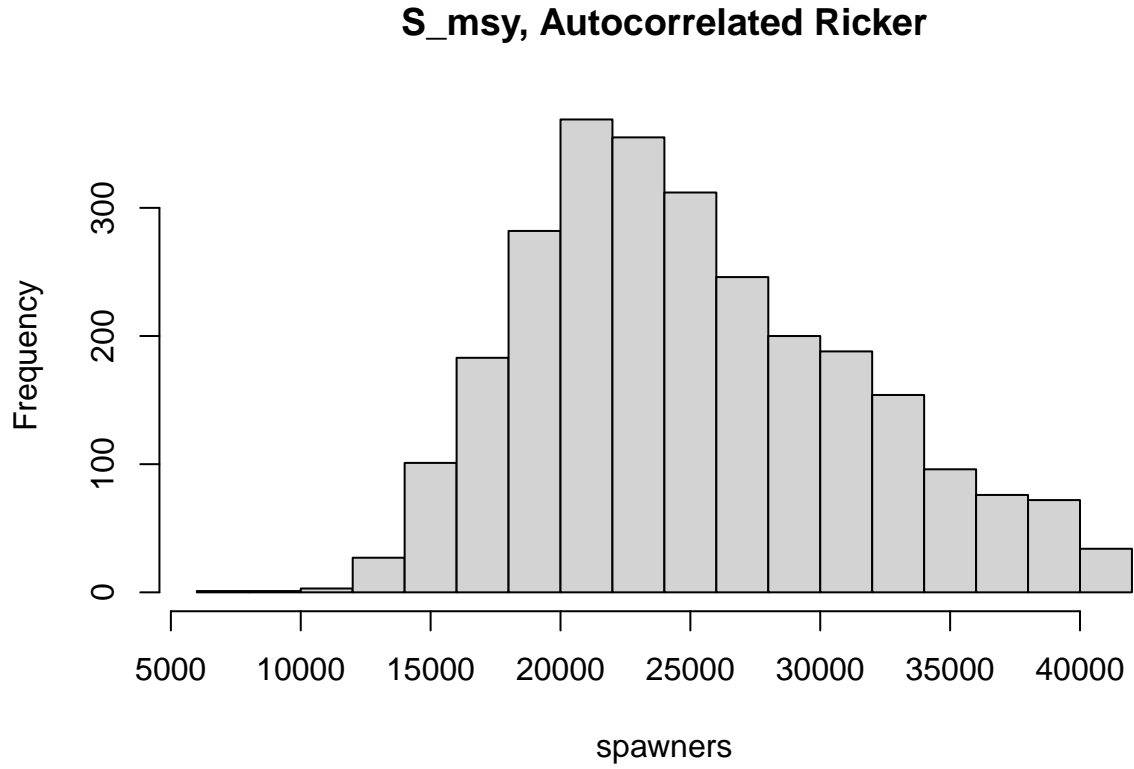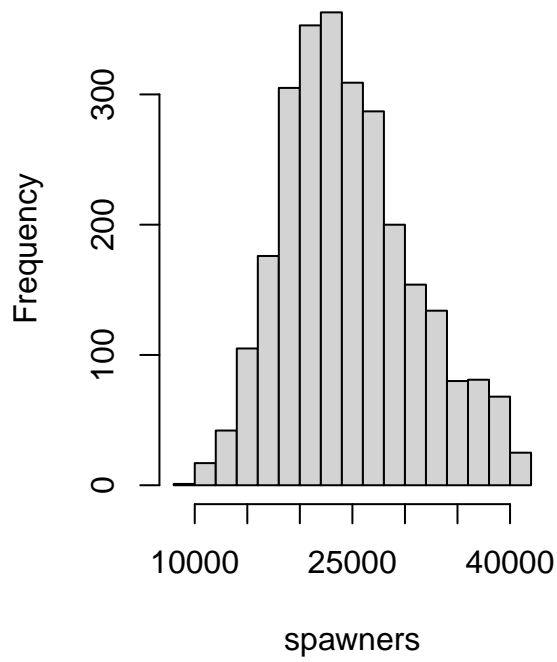
This figure corresponds to the top-ranked model (regime-shift beta) for the 90% highest predictive accuracy years - indicating the S_max differences in each regime.

S_{msy}: Histogram of the estimated spawner escapement that would produce (theoretical) maximum sustainable yield (MSY). Note that esitmates are truncated here (for visual purposes) at the 90% upper estimate to remove extremely high estimates on the tails of the parameters for each regime.
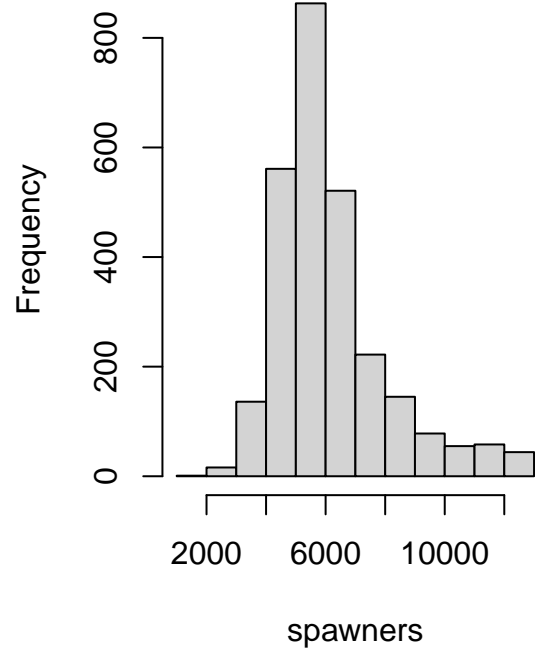
S_msy, Autocorrelated Ricker

This figure corresponds to the top-ranked model (autocorrelated Ricker) for the full predictive samples from 1987 to 2016.
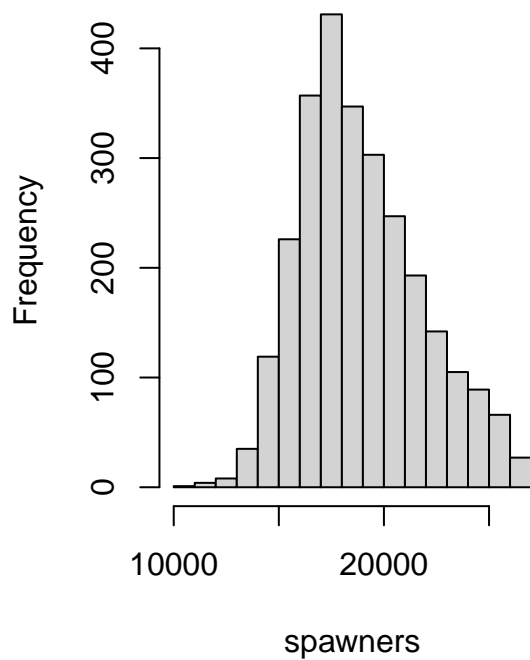
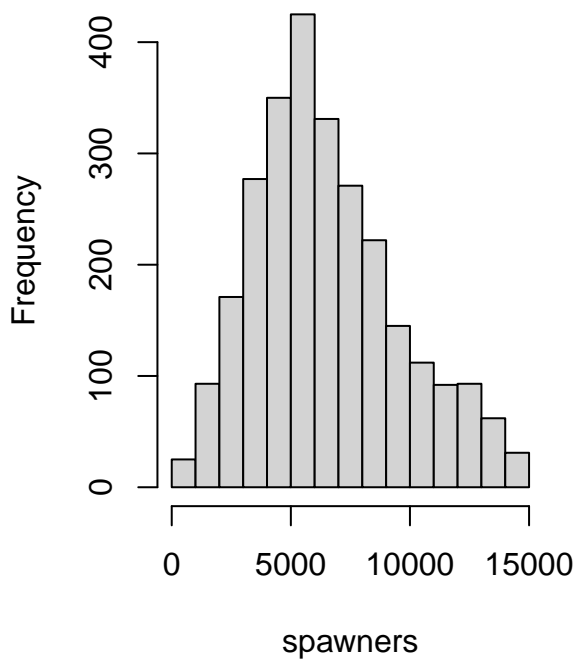**S_msy, High Capacity Regime**

S_msy, Low Capacity Regime

This figure corresponds to the top-ranked model (regime-shift capacity) for the 90% highest predictive accuracy years - indicating the S_msy differences in each regime.
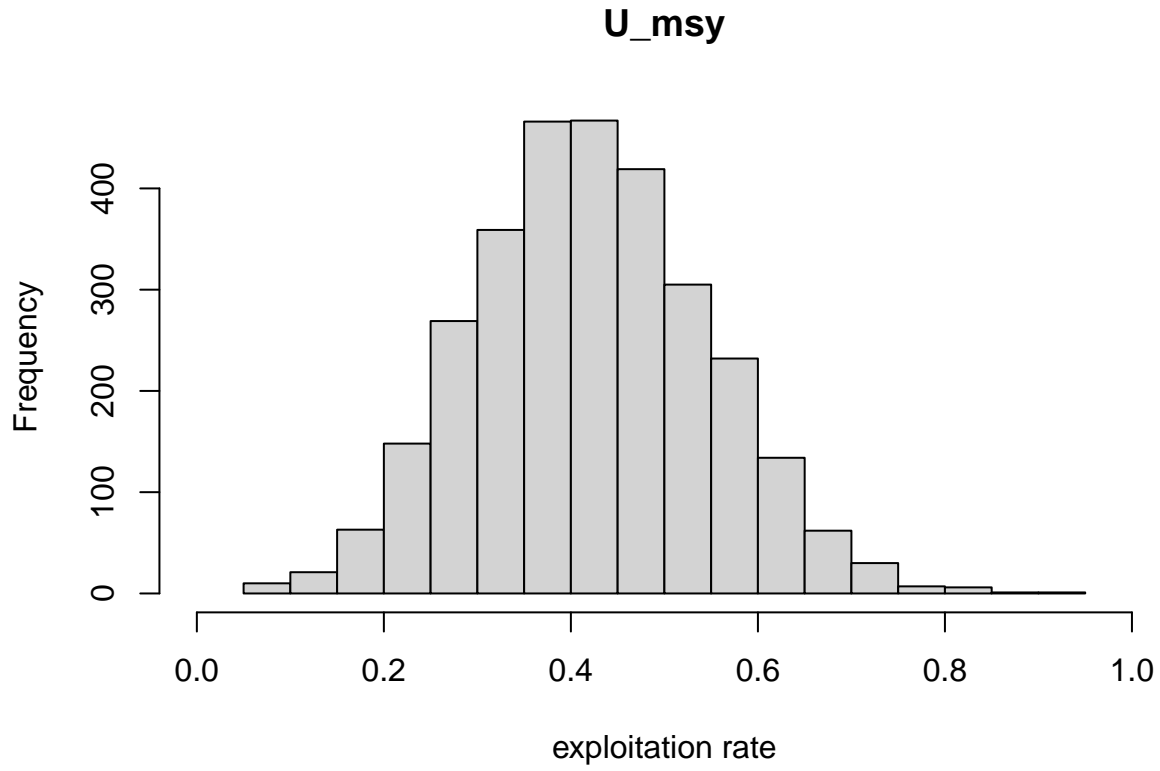
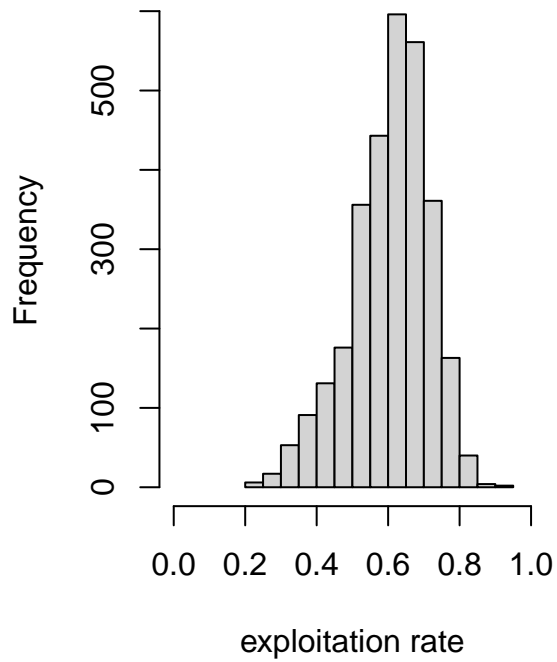**S_msy, High Productivity Regim** **S_msy, Low Productivity Regim**

This figure corresponds to the top-ranked model (regime-shift productivity) for the 90% highest predictive accuracy years - indicating the $S_m sy$ differences in each regime.

U_{msy}: The corresponding maximum sustainable annual exploitation rate is shared between both regimes, since it depends on the shared productivity parameter.
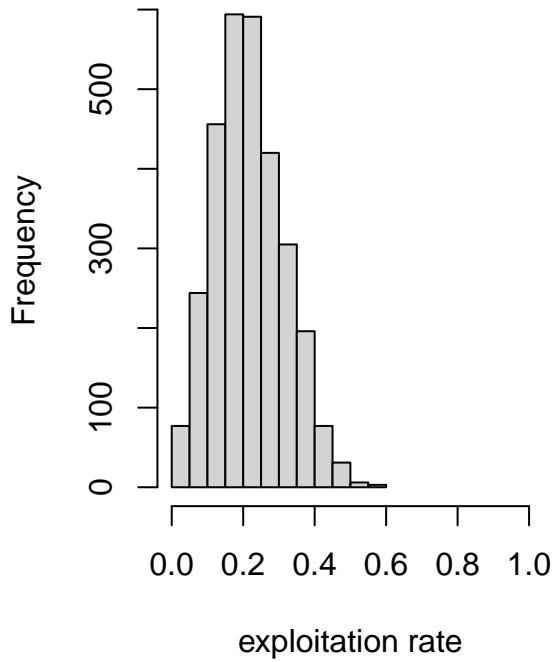
U_msy

This figure corresponds to $U_m sy$ from the top-ranked model (autocorrelated Ricker) for the full predictive samples from 1987 to 2016.

U_msy, High Productivity Regim   **U_msy, Low Productivity Regim**

This figure corresponds to U_msy from the top-ranked model (regime-shift productivity) for the 80% highest predictive accuracy years - indicating the U_msy differences in each regime.