# Standard vs. State-Space model

The biggest difference between standard and state-space model is a treatment of spawner and recruit and SR model.  
Standard model considers that spawners and recruit are observed and independent quantity, and SR model is a primary process that generates SR relationship. However, except few cases (e.g., pink salmon) recruit is not observed and independent. Recruit is a reconstructed from run size and run age composition over multiple years. State-space model, on the other hand, considers that SR model is a latent process that generates observed quantities of that produces run, and run age composition. As such, state-space model constructs and estimates entire process that generate annual run by age as follows: \* Spawner generates recruits (via SR model process) \* A portion of recruit return at an age \* Multiple ages

# Bayesian State-Space Model

A Bayesian state-space spawner-recruit model consists of process sub-model and likelihood sub-model. The process sub-model creates observed quantities: Annual run size by age (or run size and run by age proportion), harvest, and escapement. The likelihood sub-model fits the model predicted quantities to observed quantities.

## Process sub-model

**NOTE** Here **t** indicates brood year, and **y** indicates annual calendar year. Spawners of brood year t () produces brood year recruits (). The is produced based on Ricker of Beverton-Holt SR function

Turning recruit to annual run, the number of fish returning in calendar year y () is harvested by fisheries

and the remaining fish will become spawners

The relation between brood year (t) and calender year (y) is as follows

From Brood year perspective, recruits of brood year t () will return to natal stream in multiple ages classes (a) (a: } in brood year t+a {a: }

and

where is a **maturity schedule** or a proportion of recruit of brood year t that will return in year t+a at age a.

From Calender year perspective, fish returning in calendar year y () consists of multiple ages from to

The age a fish returning in calendar year y (() is a recruit from spawners of the year y-a () that corresponds to the recruit of brood year t spawners that return in brood year a+t.

For instance an age 4 fish returning in a calendar year y=1 (1980) is an recruit from a spawner of calendar year -3 (y= 1-4)(1976) that corresponds to a recruit of brood year t=1 (1976) that returns as age 4 in brood year 5 (t=1+4).

### Maturity schedule

The maturity schedule was modeled to be Dirichlet distribution,implemented by generating independent random variables from a gamma distribution .

## Observation Submodel

Observation submodels consist of run, harvest, escapement sizes, and run age composition.

Run, harvest, escapement sizes are assumed to have lognormal distribution with mean is model log of predicted size, and sigma is observed cv.

**Run**

where

**Harvest**

where

**Escapement**

where

**Run age composition**  
Run age composition is assumed to have a multinomial distribution.

where and