Apportionment simulations

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# General information

Sablefish apportionment of ABC to management regions has been fixed at 2013 ratios since 2014. An objective of the analyses presented here is to examine pros and cons of a suite of sablefish ABC apportionment methods. This document presents the apportionment simulation work to date. This is a work in progress and we are seeking feedback on OM and EM set up, alternative performance metrics that would be useful in making apportionment method recommendations, and any other suggestions for simulation and model performance. Bonus points if you can suggest better ways to graph things.

These apportionment simulation analyses contain two primary components, a 6-area operating model (OM) and a 1-area estimation model (EM). The OM is spatial so that potential spatial dynamics in fleet or fish behavior (via catchability, selectivity, and fish movement) may be simulated. The OM simulates data in two periods - a deterministic conditioning period which occurs for years 1977-2018 and is the same across simulations, and a stochastic forward projecting portion which runs for years 2019-2023. The EM is similar to the EM used for sablefish management, but begins in 1977 instead of 1960, does not include length compositions, and does not fit a trawl survey. After the conditioning period data is generated in the OM, the OM population is sampled, and simulated data from the OM is combined into a single area dataset which is passed to the EM.

In the forward projecting period, the OM-EM is iterative, looping through years. The order of operations for year y are: OM - Read in previous year’s apportioned ABC by area, estimate the F required to catch ABC for each area, apply F and M to OM population, move fish between areas, sample the population for fishery and longline survey abundance indices and for longline survey and fixed gear fishery age compositions, build the .dat file and pass it to the EM in ADMB, run the EM and get an estimate of the next year’s ABC (then repeat for the next year).

At present for each apportionment method we examine, we are running 5 simulations covering years 1977-2023. For November, we hope to present results for 100 (or more) simulated datasets each looping over years 2019-2049 (30 years for forward looping years).

There are some inherent assumptions in this simulation we would like to present up front: 1) we assume ABC=TAC and 100% of apportioned ABC is caught in each region 2) we do not correct for whale depredation in the ABC or survey index 3) recruitment occurs at age 2 and recruitment is split equally between males and females

# Alternative apportionment scenarios

In the analyses presented in this document we examine X apportion methods: Equal, Fixed, Equilibrium, NPFMC, Exp\_survey\_wt, Exp\_fishery\_wt, Non-Exp\_NPFMC, Partial\_fixed, Age\_based, All\_to\_one.  
The future plan is to examine this suite:  
1 - Equal (Each region receives 1/6 of the ABC)  
2 - Fixed (The apportionment proportions from the 2013 assessment that have been applied as fixed proportions for 2014-2018)  
3 - Equilibrium (Based on the stationary distribution of the movement rates)  
4 - NPFMC (5-yr exponentially weighted moving average of fishery and survey indices; survey weight is 2x fishery weight)  
5 - Exp\_survey\_wt (Similar to ‘NPFMC’ option but using survey index only)  
6 - Exp\_fishery\_wt (Similar to ‘NPFMC’ option but using fishery index only)  
7 - Non-Exp\_NPFMC (A 5-yr moving average of fishery and survey indices)  
8 - Partial\_fixed (BS and AI receive 10% of the ABC each, WG, CG, WY, and EY are apportioned based on NPFMC method)  
9 - Age\_based (Based on the proportions of fish at age of 50% maturity in each area - i.e. areas with greater proportion of fish at age of 50% maturity or greater will be apportioned a greater proportion of ABC)  
10 - All\_to\_one (all apportionment to one area - for research purposes of showing extremes ONLY)

# Conditioning period

The OM model set up begins by establishing initial numbers at age for each area in 1976. Initial N for 1976 is input as the 2018 management EM totaly abundance estimated for 1977. This is split into 6 spatial areas using the proportion of abundance by area from the longline survey abundance estimate and split into initial age and sex proportions using proportion by sex and age from 2018 management EM for 1976 numbers at age. Numbers at age are conveted to biomass at age using the age-weight relationship as described in the sablefish 2018 SAFE report.

OM conditioning period is deterministic and the same for all simulation iterations. Movement is specified between 6 and the OM is set up to accomodate age-based movement at present movement is un-varying over ages. The OM conditioning period is deterministic, with recruitment from the EM read in, catch, read in and the F which generated that catch estimated and applied to the population.

Movement rates used in the OM are externally generated and based on the Hanselman et al. 2015 “Move it or lose it…” paper. The model described in the paper was re-run for `r n.area’ and those movement values are input.

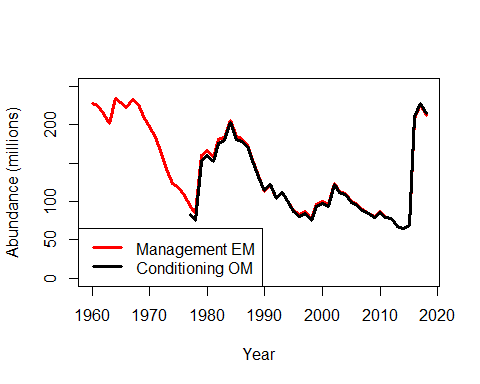
## To EY To WY To CG To WG To BS To AI  
## From EY 0.744367 0.076350 0.149227 0.026232 0.002098 0.001726  
## From WY 0.137189 0.191575 0.478710 0.152110 0.021954 0.018462  
## From CG 0.108443 0.193604 0.486216 0.162973 0.026394 0.022370  
## From WG 0.037484 0.120964 0.320461 0.290733 0.122029 0.108328  
## From BS 0.005357 0.031088 0.092290 0.215184 0.627622 0.028460  
## From AI 0.002495 0.014990 0.045060 0.113111 0.046442 0.777902

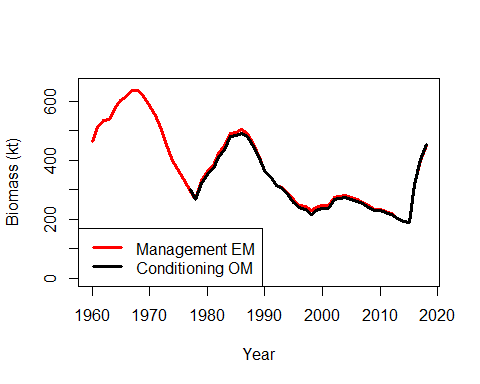
See the Appendix for OM equations.

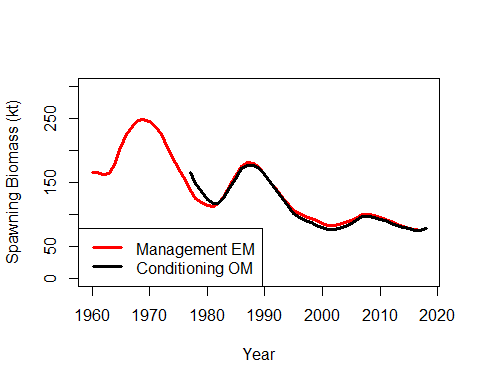
# Conditioning period validation

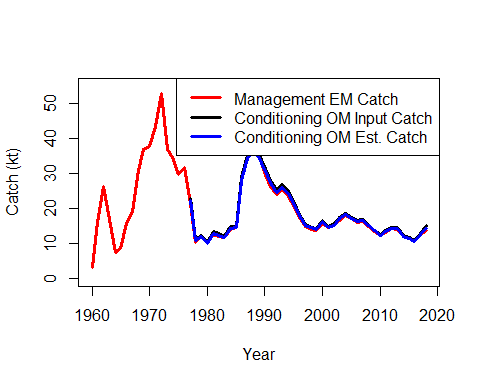
The figures and tables below are presented to show the ability of the spatial (with movement) OM conditioning period to match the current EM historical data and to further describe the methods for setting up the OM. In general, the conditioning period matches very well to the EM. However some differences exist due to movement and spatial OM parameters which differ from the management EM. Because this isn’t a full MSE, alternative states of nature and alternative realities are not the focus.

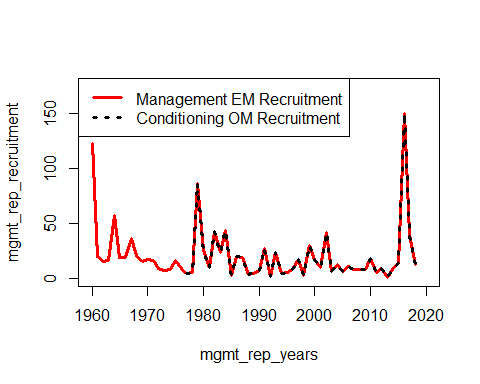
Abundance in numbers (millions of fish, summed over areas) generated from the OM matches the Management model EM.



Biomass (kt, summed over areas) generated from the OM matches the Management model EM. 

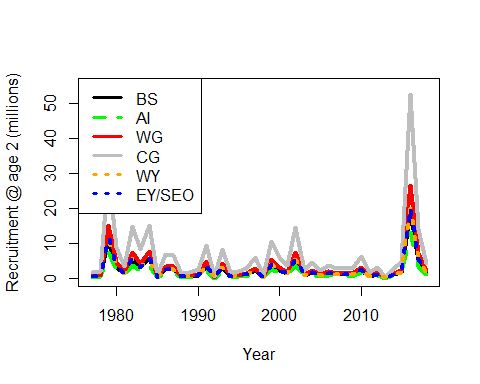
Spawning biomass (kt, summed over areas) generated from the OM matches the Management model EM. 

OM catch was designed to match EM observed catch. An F-solving function in the OM takes input catch and estimates the fishing mortality required to take that catch, using OM numbers at age and selectivity. The estimated F rate is then used in the generating abundance for the OM. 

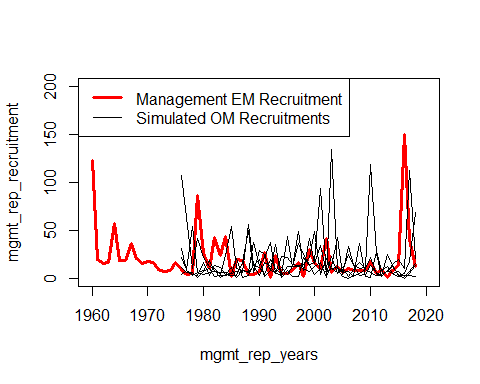
OM recruitment was designed to match EM recruitment. Mgmt EM recruitment values (in numbers) for 1977-2018 are read in and split into 6 areas based on the proportion of age-2 sablefish in the longline survey in each area, and split equally between males and females.  
**N**(h,y,a,m,i) = Rec.Proportion(m) x 0.5 x **Recruitment**(y-1),  
where h, y, a, m, and i are subscripts for sex, year, age, area, and simulation, respectively. This figure shows management EM recruitment and OM recruitment (summed over areas). 

The values for age-2 proportions by area (for order BS, AI, WG, CG, WY, EY/SEO) from the longline surevey are:

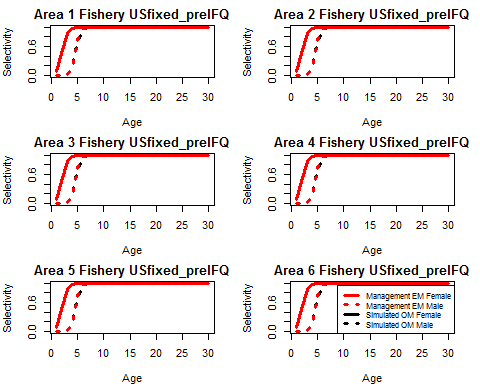
0.14, 0.07, 0.14, 0.43, 0.14, 0.09.

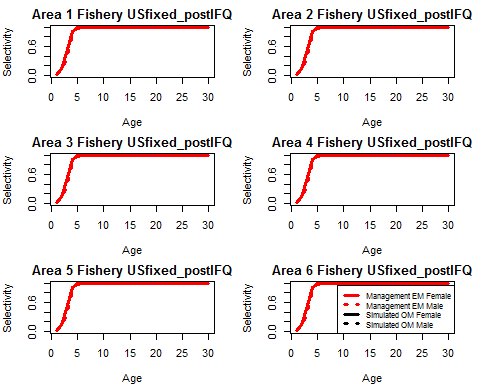


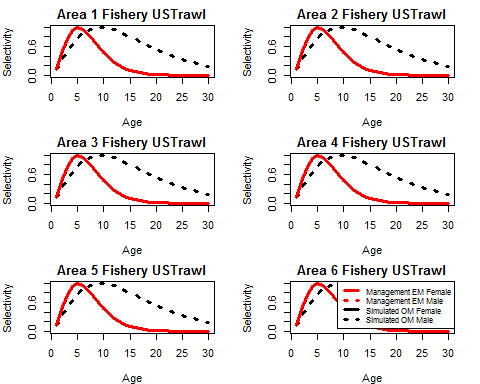
Recruitment for the forward projecting period is the same across apportionment simulations and does not have a stock recruitment relationship. Recruitment for n.years x n.sims is drawn once (from a multinomial distribution) and used for all apportionment methods. Mean recruitment (average log-recruitment) and recruitment standard deviation for the multinomial is from the management EM. Recruitment in each year is divided into OM spatial areas based on the mean proportion of age-2 (recruitment age) sablefish in each area from the longline survey for 1977-2018.

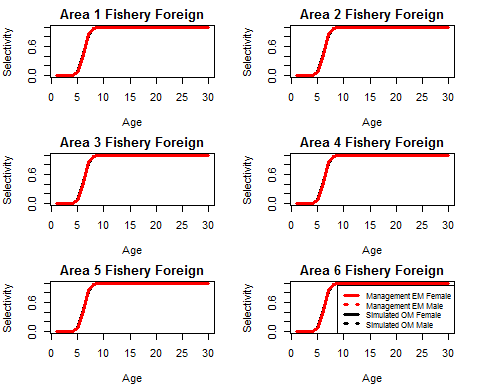
For comparison, the conditioning period recruitment draws for 5 compared to management EM estimated recruitment is shown here, though note that these values are NOT USED in the conditioning period. 

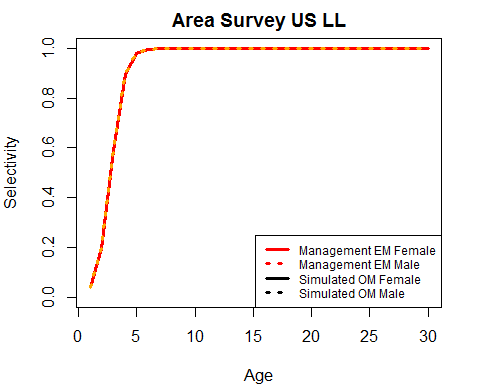
## Selectivity in OM

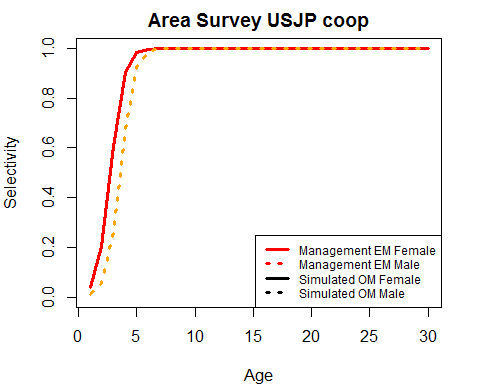
The following figures show selectivity at age for the OPM - these are used for all years of the OM, not just the conditioning period.  
US fixed gear pre IFQ selectivity  


US fixed gear post IFQ  


US trawl fish  


US fixed gear foreign  


US longline survey - OM selectivity not spatial 

USJP ll coop survey  


## OM sampling for abundance indices, age comps

Need some text here describing the index sampling code (sampling N or B, combining over areas for input to EM, CVs)

Need some text here describing the age comp sampling code…

# EM specifications

For 2019 onward, the EM is run at every annual step using data ‘sampled’ from the OM population. As a reminder the order of operations for year y are: OM - Read in previous year’s apportioned ABC by area (from the EM), estimate the F required to catch ABC for each area, apply F and M to OM population, move fish between areas, sample the population for fishery and longline survey abundance indices and for longline survey and fixed gear fishery age compositions, build the .dat file and pass it to the EM in ADMB, run the EM and get an estimate of the next year’s ABC (then repeat for the next year).

# Forward looping model output

## Convergence

First, we look at the proportion of years within a simulation and apportionment scenario which converged.

For these simulations, a model was considered ‘converged’ for a given year if the max gradient component was < 0.001. The proportion of sims which converged for each years for each apportionment method are:

## Equal Fixed Equilibrium NPFMC Exp\_survey\_wt Exp\_fishery\_wt  
## 44 0.4 0.4 0.4 0.4 0.4 0.4  
## 45 0.4 0.4 0.4 0.4 0.8 0.4  
## 46 0.2 0.2 0.4 0.4 0.2 0.4  
## 47 0.2 0.4 0.2 0.2 0.2 0.4  
## 48 0.6 0.6 0.0 0.6 0.4 0.4  
## Non-Exp\_NPFMC Partial\_fixed Age\_based All\_to\_one  
## 44 0.4 0.4 0.4 0.4  
## 45 0.6 0.0 0.4 0.2  
## 46 0.2 0.6 0.2 0.4  
## 47 0.0 0.2 0.2 0.4  
## 48 0.6 0.8 0.6 0.6

The proportion of years which converged for each sims and apportionment method are:

## Equal Fixed Equilibrium NPFMC Exp\_survey\_wt Exp\_fishery\_wt  
## sim1 0.4 0.6 0.2 0.6 0.6 0.6  
## sim2 0.6 0.2 0.2 0.6 0.6 0.4  
## sim3 0.4 0.4 0.4 0.6 0.4 0.6  
## sim4 0.0 0.2 0.0 0.2 0.2 0.0  
## sim5 0.4 0.6 0.6 0.0 0.2 0.4  
## Non-Exp\_NPFMC Partial\_fixed Age\_based All\_to\_one  
## sim1 0.6 0.6 0.8 0.4  
## sim2 0.4 0.6 0.6 0.8  
## sim3 0.4 0.6 0.2 0.6  
## sim4 0.2 0.0 0.0 0.2  
## sim5 0.2 0.2 0.2 0.0

Finally, the overall proportion of years x sims that converged for each apportionment method are below. Note that for now, all models (converged or not) are included in the following output figures and performance metric calculations.

## [1] 0.36  
## [1] 0.4  
## [1] 0.28  
## [1] 0.4  
## [1] 0.4  
## [1] 0.4  
## [1] 0.36  
## [1] 0.4  
## [1] 0.36  
## [1] 0.4

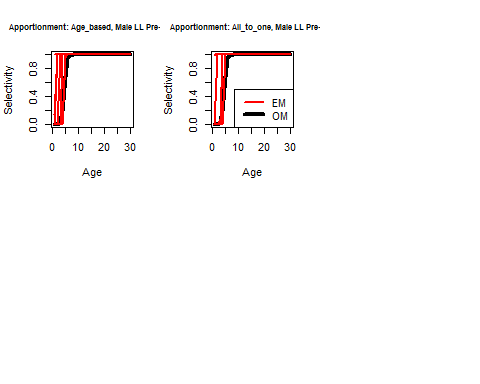
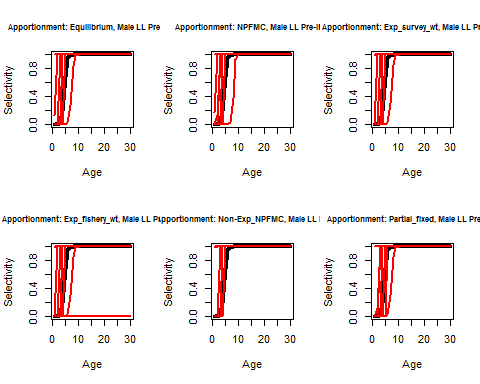
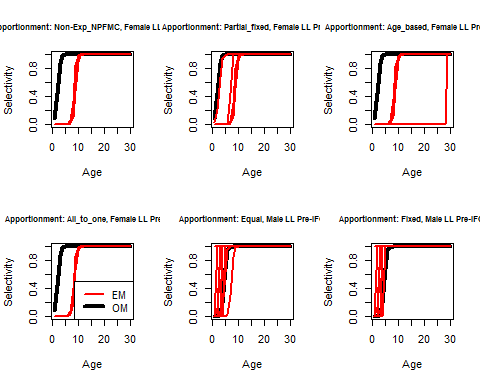
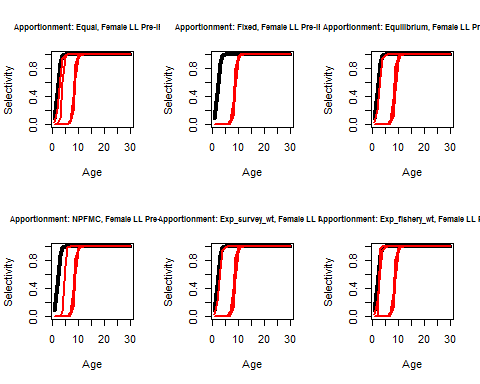
## Objective function values

The objective function values for each sim and year iteration of the EM were:

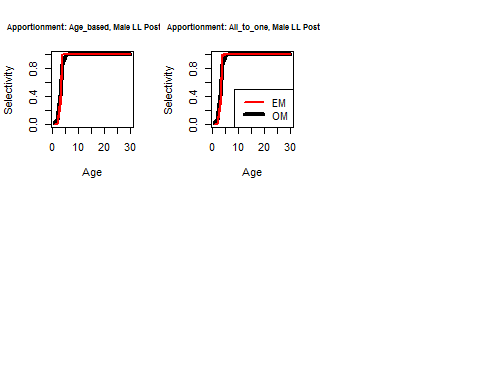
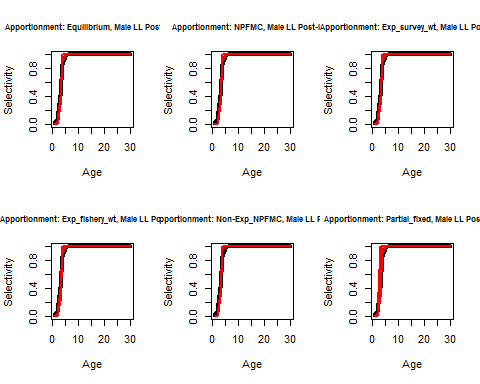
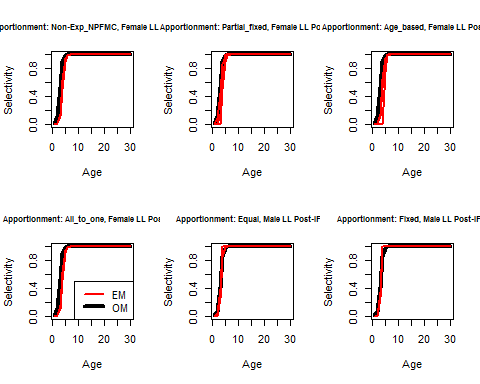
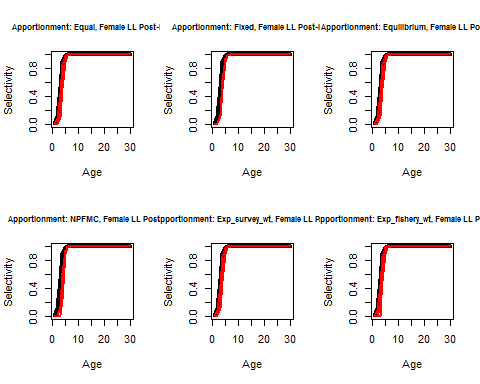
## , , Equal  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -0.0000588425 -5.002515e-04 -0.1114358804 -1.565683e-02 -5.462403e-02  
## 2020 -0.1711267791 -2.352240e+02 -0.0004903277 -1.424260e-01 -4.685718e-04  
## 2021 -0.0016039665 -3.958859e-04 -0.0036569916 -1.515154e-01 -3.545966e-03  
## 2022 -0.0028540182 -2.873269e-04 -0.0016408857 -9.526442e+04 -3.945922e+04  
## 2023 -0.0002587136 -1.244336e-03 -0.0002527210 -1.787121e-03 -5.969226e-04  
##   
## , , Fixed  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -5.884250e-05 -0.0005002515 -1.114359e-01 -1.565683e-02 -0.0546240298  
## 2020 -2.156656e-03 -0.0052923003 -1.005406e-03 -4.859275e-05 -0.0006240986  
## 2021 -4.194042e+02 -0.0045446718 -2.470349e+02 -5.666150e-02 -0.0002796996  
## 2022 -4.219408e-04 -0.0042472086 -2.880815e-04 -4.405258e-03 -0.3391307113  
## 2023 -8.467430e-04 -0.0010265679 -8.460666e-04 -2.183964e-03 -0.0008468262  
##   
## , , Equilibrium  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -5.884250e-05 -5.002515e-04 -1.114359e-01 -0.015656826 -0.0546240298  
## 2020 -3.338591e-03 -5.295256e+02 -2.939833e-04 -0.005658683 -0.0004782359  
## 2021 -1.854234e+04 -3.611837e-02 -6.901262e-05 -0.004175531 -0.0007159913  
## 2022 -1.537156e-03 -1.151842e-03 -2.854774e+05 -0.001247335 -0.0002822302  
## 2023 -1.418133e-03 -3.176075e-03 -5.923186e-01 -0.315454588 -0.0656343754  
##   
## , , NPFMC  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -0.0000588425 -5.002515e-04 -0.1114358804 -1.565683e-02 -0.054624030  
## 2020 -0.0034911485 -2.404925e-04 -0.0005745636 -7.754583e-03 -0.006289662  
## 2021 -0.0052762836 -2.812761e-04 -0.0001644875 -1.594318e-01 -0.306315037  
## 2022 -0.0001857676 -4.356957e+02 -0.0011719821 -8.402179e+04 -0.140567686  
## 2023 -0.0008917862 -1.200120e-03 -0.0002879256 -4.653037e-04 -0.002918762  
##   
## , , Exp\_survey\_wt  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -0.0000588425 -5.002515e-04 -1.114359e-01 -0.0156568261 -0.0546240298  
## 2020 -0.0006658576 -6.935921e-05 -1.642855e-04 -0.0000591542 -0.0010906146  
## 2021 -0.1825001349 -4.552051e-04 -1.059896e-03 -0.0066911539 -0.0011132112  
## 2022 -0.0064103354 -5.921514e-03 -9.732952e+04 -0.0020053922 -0.0008874129  
## 2023 -0.0009346248 -1.187517e+00 -3.811431e-04 -0.3265318175 -0.0078861237  
##   
## , , Exp\_fishery\_wt  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -5.884250e-05 -5.002515e-04 -1.114359e-01 -0.015656826 -0.0546240298  
## 2020 -7.497428e-04 -1.805369e-01 -7.151262e-04 -0.207926365 -0.0041544150  
## 2021 -2.426779e+02 -4.151258e+04 -1.419359e-05 -0.003245074 -0.0002079746  
## 2022 -4.970970e-04 -4.264499e+04 -3.211909e-03 -0.001936422 -0.0005991049  
## 2023 -2.201807e-03 -1.395365e-04 -1.251387e-04 -0.164503764 -0.0343159119  
##   
## , , Non-Exp\_NPFMC  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -0.0000588425 -0.0005002515 -1.114359e-01 -0.0156568261 -0.0546240298  
## 2020 -0.0007987790 -0.0003293111 -1.308312e-03 -0.0118868755 -0.0004064038  
## 2021 -0.1343284407 -0.0019932199 -8.904567e-05 -0.0016348807 -0.0014277261  
## 2022 -0.0011309379 -0.0017057300 -3.649328e-03 -0.2209628410 -0.0045821272  
## 2023 -0.0007386557 -0.0035902839 -9.826183e-05 -0.0003785028 -0.0022661485  
##   
## , , Partial\_fixed  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -5.884250e-05 -5.002515e-04 -1.114359e-01 -0.015656826 -5.462403e-02  
## 2020 -4.871366e-03 -4.062802e+02 -4.037630e-02 -0.320794226 -2.594817e-01  
## 2021 -7.787899e-04 -2.881734e-04 -1.904134e-04 -0.020220105 -2.548833e-03  
## 2022 -1.736536e-03 -4.038590e-02 -5.741341e-04 -0.008073304 -4.269784e+03  
## 2023 -5.828405e-05 -8.057106e-04 -5.408892e-05 -0.014038450 -6.762442e-05  
##   
## , , Age\_based  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -5.884250e-05 -5.002515e-04 -1.114359e-01 -1.565683e-02 -5.462403e-02  
## 2020 -1.688109e-04 -1.202854e-03 -6.116118e-01 -1.040090e-01 -6.811989e-05  
## 2021 -6.799677e-05 -5.572855e+02 -5.545557e+02 -1.026201e+04 -1.959764e-01  
## 2022 -2.945448e-03 -1.509938e-04 -1.679006e-03 -2.373984e-02 -1.214910e-03  
## 2023 -8.853563e-05 -6.455272e-04 -3.386729e-04 -1.278029e-03 -5.907330e-02  
##   
## , , All\_to\_one  
##   
## sim1 sim2 sim3 sim4 sim5  
## 2019 -0.0000588425 -5.002515e-04 -0.1114358804 -1.565683e-02 -0.054624030  
## 2020 -0.0021814190 -2.356941e+02 -0.0004167178 -9.965906e-02 -0.018687433  
## 2021 -0.0022986096 -4.980876e-04 -0.0001189827 -4.674719e-02 -0.001578120  
## 2022 -0.0042129404 -2.595430e-04 -0.0167007011 -8.306524e-05 -0.002858089  
## 2023 -0.0002615313 -2.594910e-04 -0.0003293504 -5.309692e-03 -0.001892195

## Selectivity

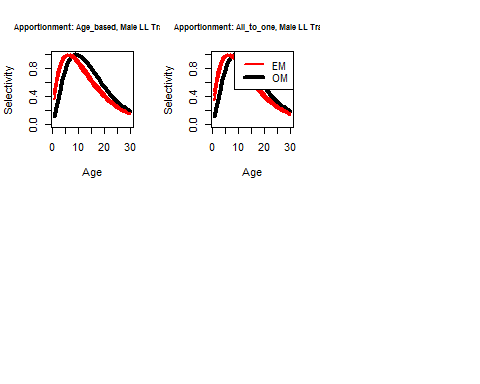
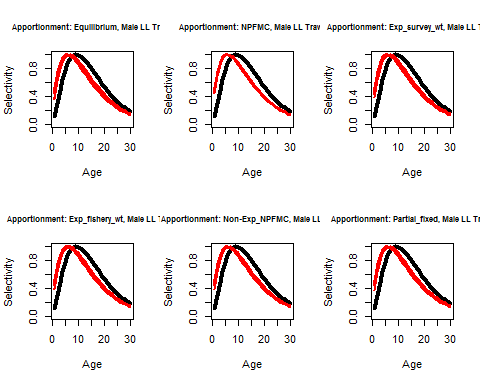
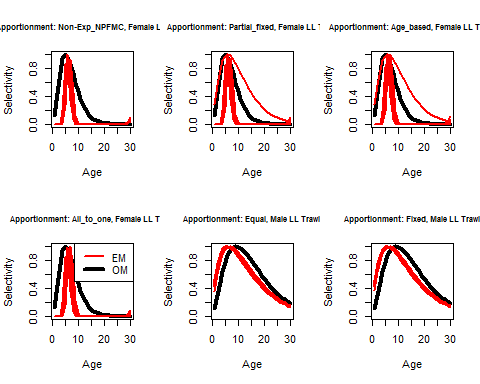
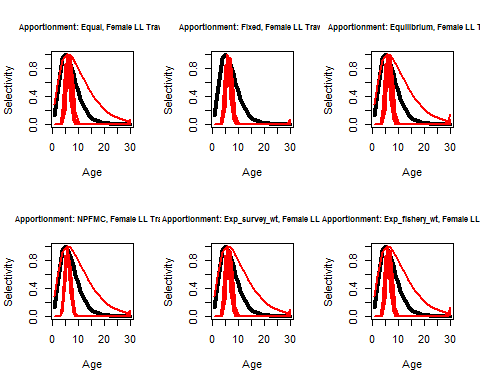
### Longline fishery Pre-IFQ

EM estimated selectivity for the longline fishery, Pre-IFQ years  


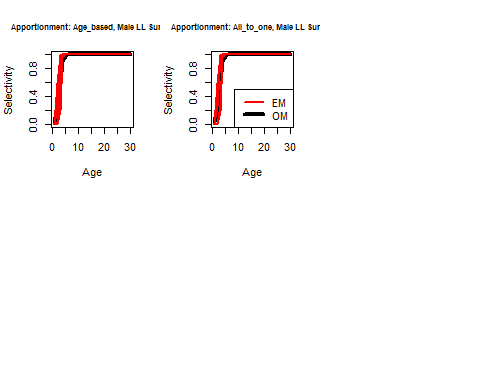
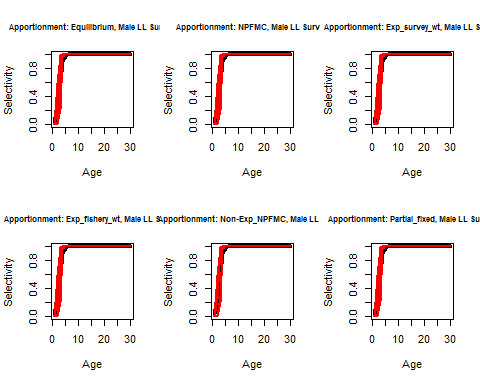
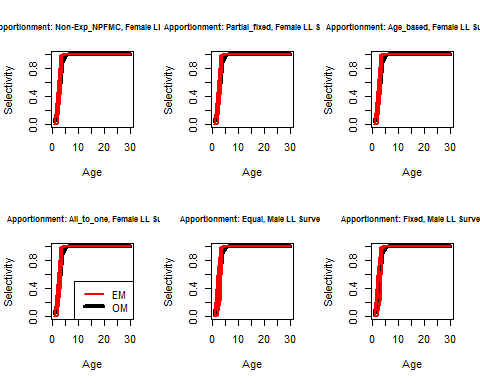
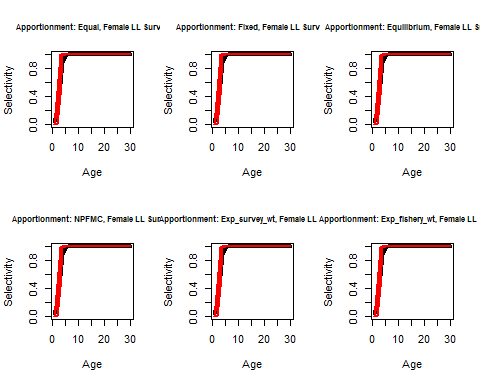
### Longline fishery Post-IFQ



### Trawl fishery



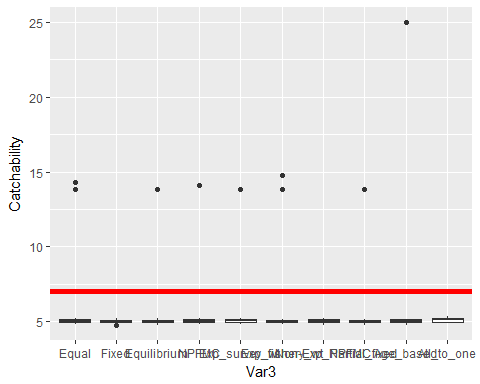
### Longline survey (US years)



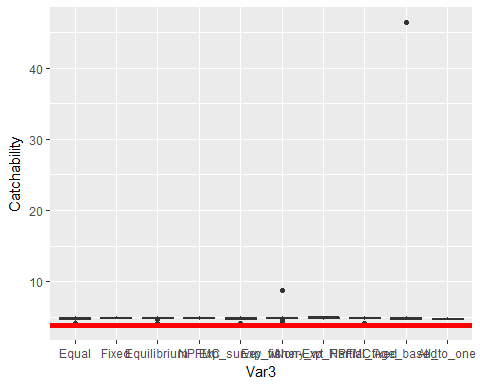
## Catchability

Catchability for the EM is shown below in boxplots. For each apportionment option (x axis) the box shows the median (thick line inside the box) and the 25th and 75th percentile interquartile range (box lower and upper border) of EM q estimates across all years and sims. The vertical bars represent the largest and smallest values within 1.5 times the interquartile range, and any values outside these ranges are shown as points. The dashed red line is the OM value of catchability.

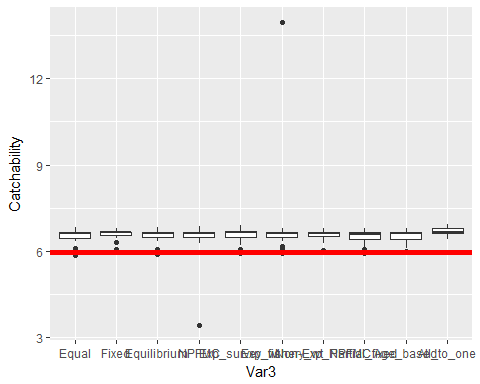
### Fixed gear fishery, foreign years



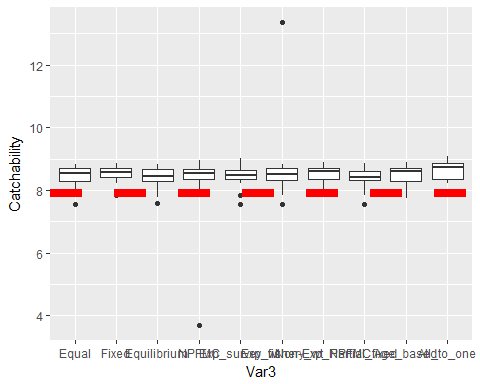
### Longline fishery Pre-IFQ

For the boxplots below, the dashed red line is OM q for BS, AI, and WG. The solid red line is OM q for CG, and the dotted line is OM q for WY and EY/SEO. 

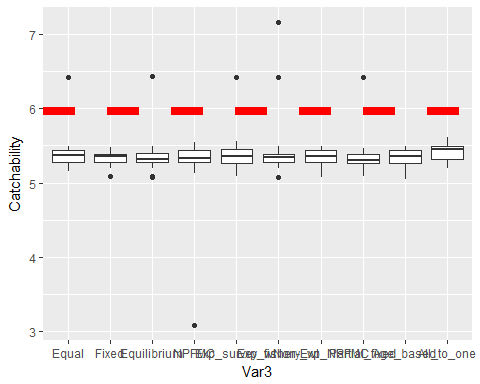
### Longline fishery Post-IFQ

For the boxplots below, the dashed red line is OM q for BS, AI, and WG. The solid red line is OM q for CG, and the dotted line is OM q for WY and EY/SEO.  


### Longline survey (US years)



### Longline survey (USJP years)



## Indices

### US longline fishery index (RPW)

### US longline survey index (RPN)

## Recruitment

## SSB time series

# Performance metrics

## stability for each apportionment option (over all areas summed, and by area) - mean and median absolute change in in ABC year to year and for all years

## How well do apportionment options track true biomass? Relative percent difference in OM biomass by area vs EM apportionment by area

## For each apportionment option, what is the proportion of years\*sims where EM F/F40<1?

## For each apportionment option, what is the proportion of years\*sims where EM B/B40<1? What is the mean and median depletion (SSBterminal year/B40) across sims for each year from EM? (plot it)

## mean and median age at harvest from EM (all areas combined) (and roughly mapped to size)

## mean and median catch/ABC for each area and overall