Rose v rho

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Contents

Comparison of Rose and Rho-adjusted Approaches

This document compares two ways to address stock assessments exhibiting retrospective problems in terms of stock status and catch advice. The Rose approach uses an ensemble of models that change the input data to remove the retrospective problem in different ways. It requires a fair amount of computing time to explore many options. The rho-adjusted approach modifies the terminal year estimates based on the Mohn's rho values. It has the challenge of a discontinuity at the end of the time series. This document walks the reader through two examples using Georges Bank Yellowtail Flounder and White Hake. These examples are provided for demonstration purposes only and should not be considered to provide guidance on the assessment of either stock.

Georges Bank Yellowtail Flounder Example

Background

The Georges Bank yellowtail flounder (GBYT) stock has been plagued by a strong retrospective pattern for many years. In 2014 a benchmark assessment was conducted that rejected the anayltical modeling (then in VPA) in favor of an index-based approach due to the strong retrospective pattern. The data from the current index-based assessment was input to a statistical catch at age model (ASAP) for this demonstration and still exhibits a strong retrospective pattern with a 5 year Mohn's rho for spawning stock biomass of 2.14.

This assessment uses data from 1973-2018 for ages 1-6+ with three surveys providing tuning information. Recent survey values have been near or at time series lows. Recent quotas are well below historical catch amounts (hundreds of tons compared to tens of thousands of tons) with discards in the scallop fishery contributing a major source of the catch (discards were greater than landings in two recent years). This stock has not responded to recent low catches and continues to decline despite low quotas being set. Both missing catch and increased natural moratality have been explored previously as an explanation for the strong retrospective patterns in this stock assessment. However, the magnitude of the missing catch or amount of change required in M needed to remove the retrospective pattern was considered too large by review panels. The rho-adjustment approach was used in years prior to the VPA being rejected.

Removing the GBYT retro

There are an infinite number of ways to remove a retrospective pattern by changing the input data. This demonstration focuses on a limited set of combinations. Either the catch or natural mortality rate is increased in recent years. The change from original to modified values can happen suddenly from one year to the next

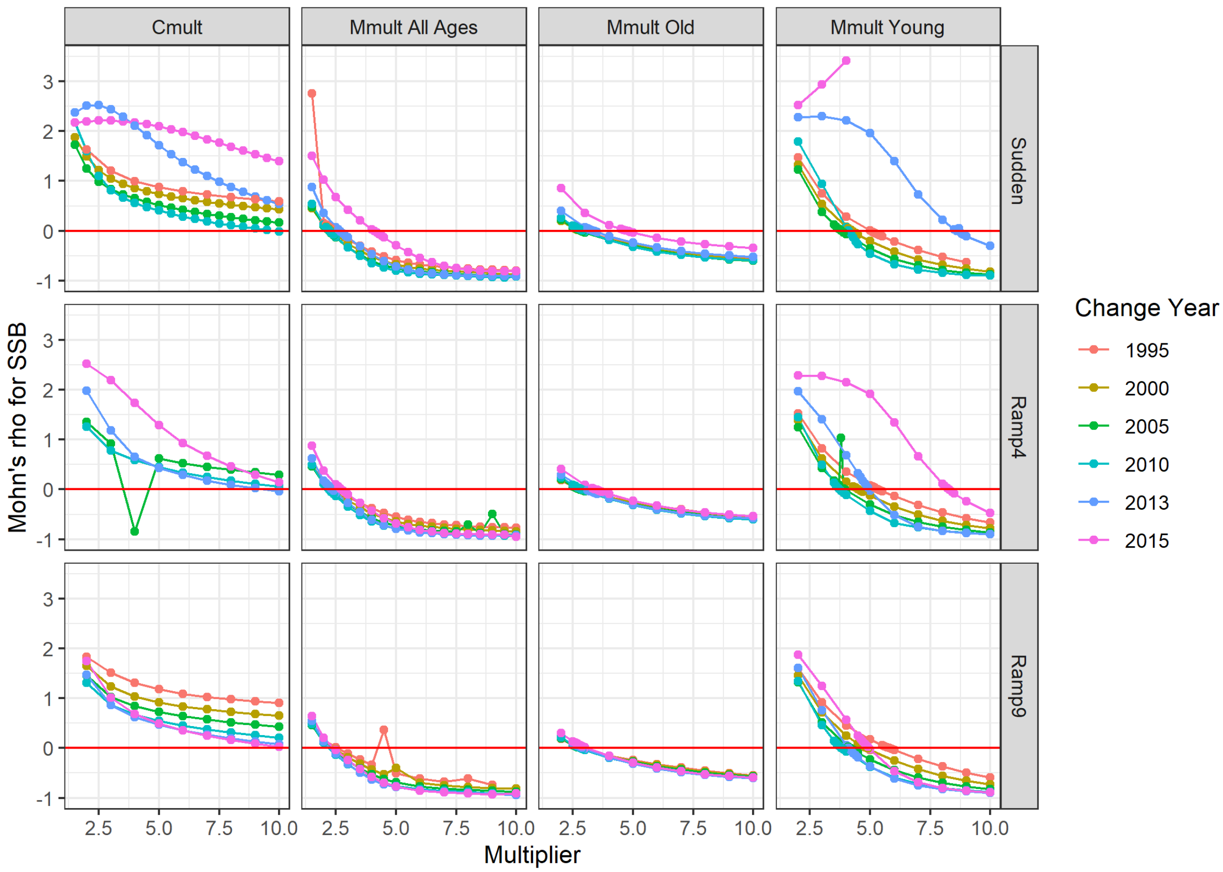


Figure 1: Examination of ways to remove the retrospective pattern

or with a linear ramp of 4 or 9 years. When natural mortality is modified, the increase can occur across all ages, only young ages (ages 1-3 in this case), or only old ages (ages 4-6+) in this case. The timing of the change was examined for years 1995, 2000, 2005, 2010, 2013, and 2015 being the first year of fully changed catch or natural mortality. The catch or natural mortality was modified by multiplication across all ages for catch or according the age range in the natural mortality scenario. This resulted in a total of 12 scenarios with 6 change years as possible ways to remove the retrospective pattern. For each scenario, a range of multipliers was applied to find the multiplier (to the nearest 0.1) that removed the retrospective pattern. Just over one thousand ASAP runs were conducted when searching for the multipliers that removed the retrospective pattern.

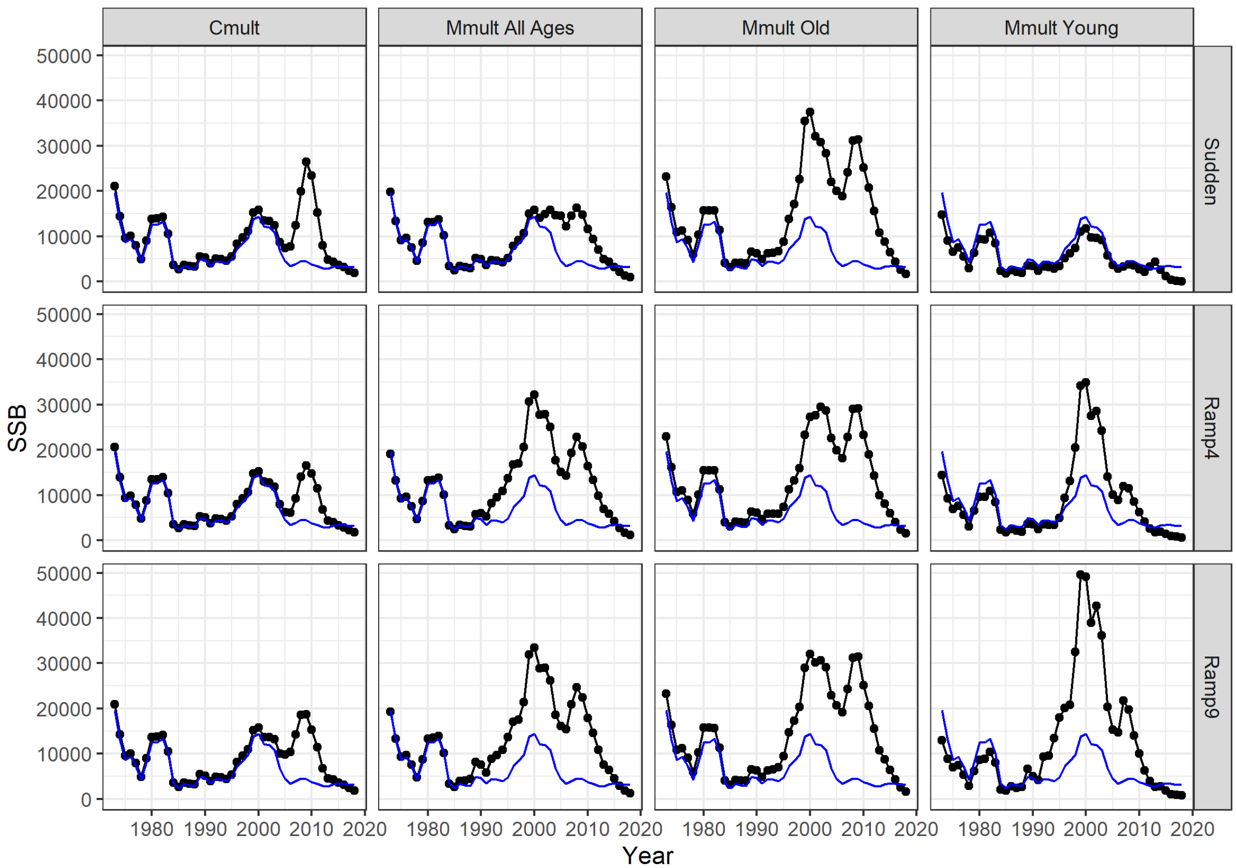
The plot shows that for most scenarios and change years, it was possible to find a multiplier less than 10 that removed the retrospective pattern (ssbrho = 0). However, there were some combinations that were unable to reduce the retrospective pattern sufficiently (e.g., many of the Cmult cases). There were also the occasional "blips" in the pattern of Mohn's rho for spawning stock biomass as the multiplier changed (e.g., Cmult-Ramp4-2005) due to one or more of the peels producting a dramatically different estimate of SSB. This means an automated system of finding a multiplier may not work well. Instead, an iterative approach was used with an initial large step size for the multipliers examined that was further refined.

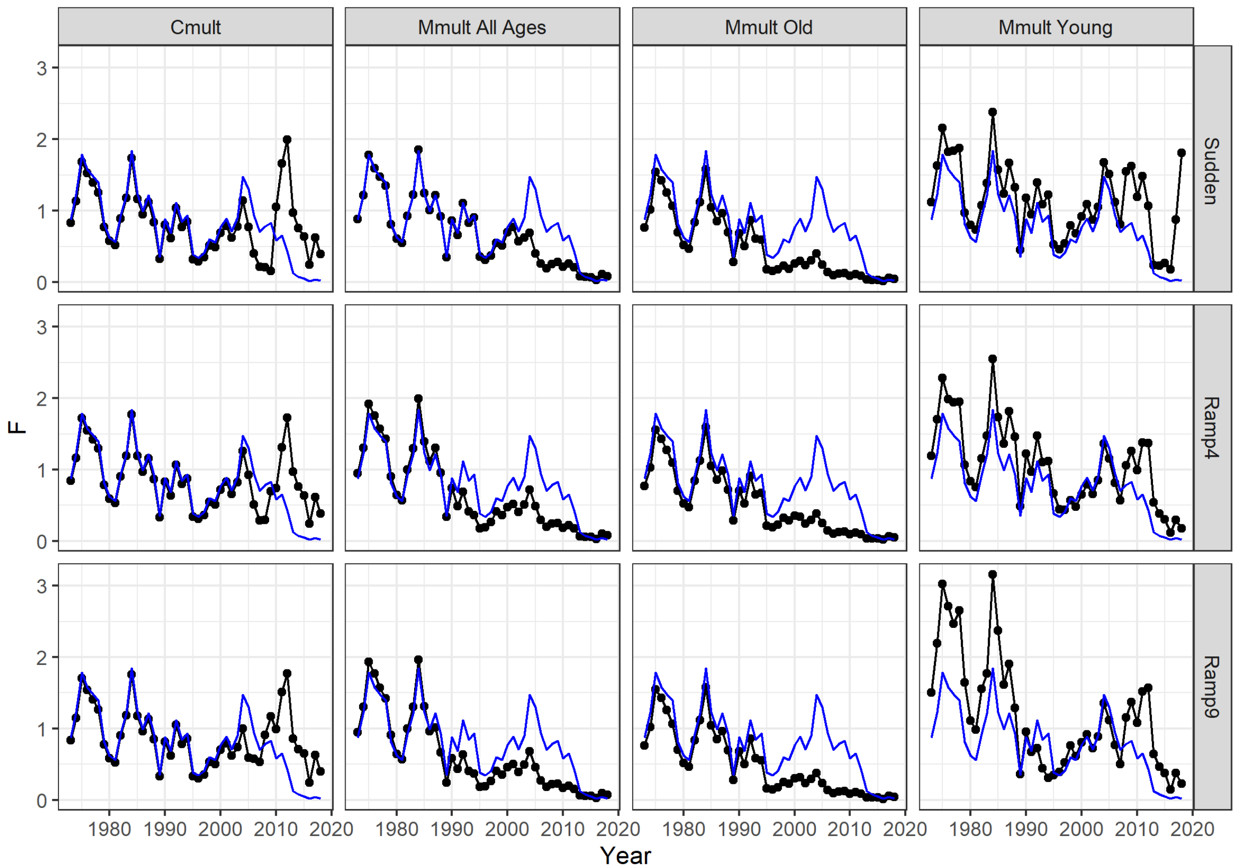
To allow the greatest diversity of models in the Rose approach, the change year with the lowest absolute value of Mohn's rho for SSB for each scenario was selected as shown below.

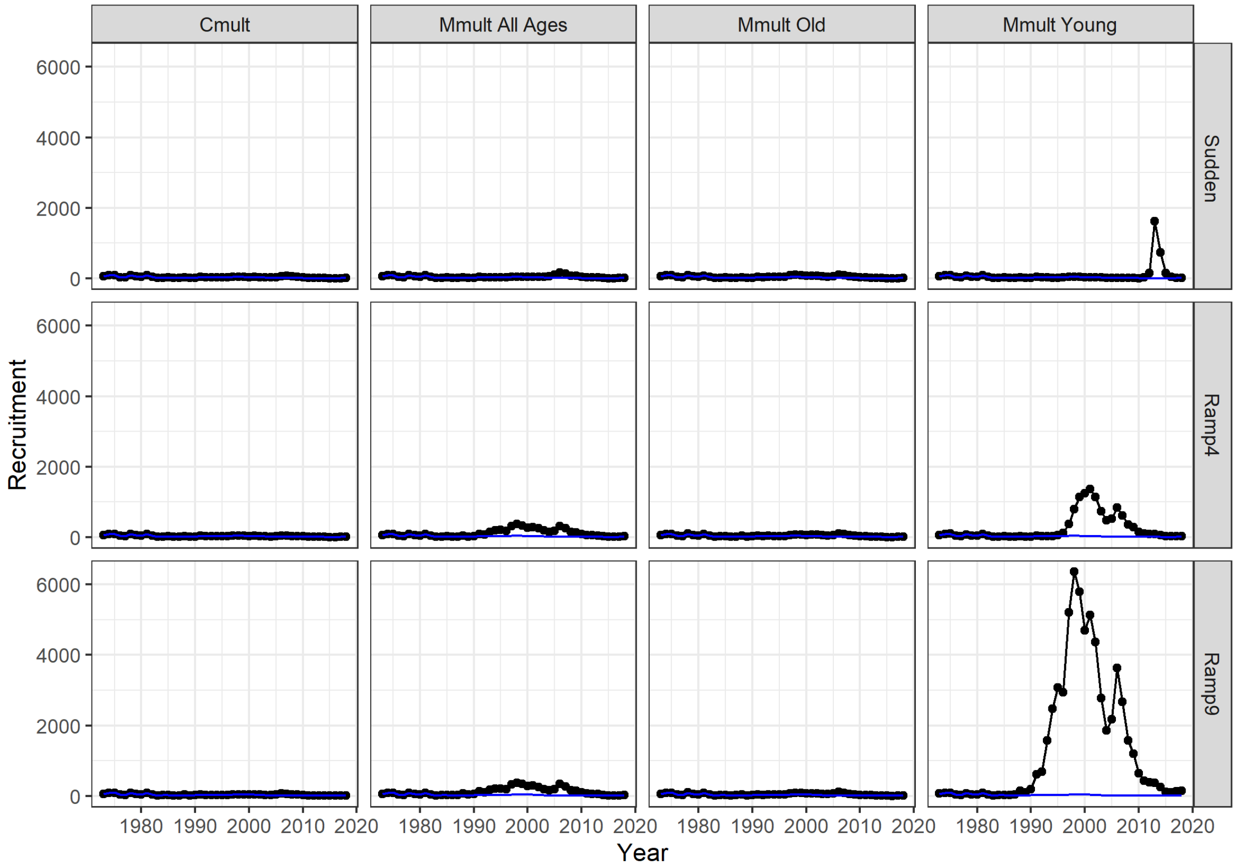
```
##              scenario change.year ramp cmult mmult       ssbrho
## 1       Sudden Cmults        2010    0    10   1.0 -0.013028268
## 2        Ramp4 Cmults        2013    4     9   1.0  0.022195777
```

```
## 3          Ramp9 Cmults        2015     9     10    1.0   0.026836550
## 4         Sudden Mmults        2005     0      1    2.2   0.003792029
## 5          Ramp4 Mmults        1995     4      1    2.5  -0.000568356
## 6          Ramp9 Mmults        1995     9      1    2.5   0.016738500
## 7     Old Sudden Mmults        2000     0      1    2.8   0.002620500
## 8      Old Ramp4 Mmults        2005     4      1    2.8  -0.002240719
## 9      Old Ramp9 Mmults        2005     9      1    2.8   0.000721171
## 10 Young Sudden Mmults        2013     0      1    8.6   0.000652003
## 11  Young Ramp4 Mmults        2000     4      1    4.5   0.003387530
## 12  Young Ramp9 Mmults        1995     9      1    5.8  -0.000370662
```

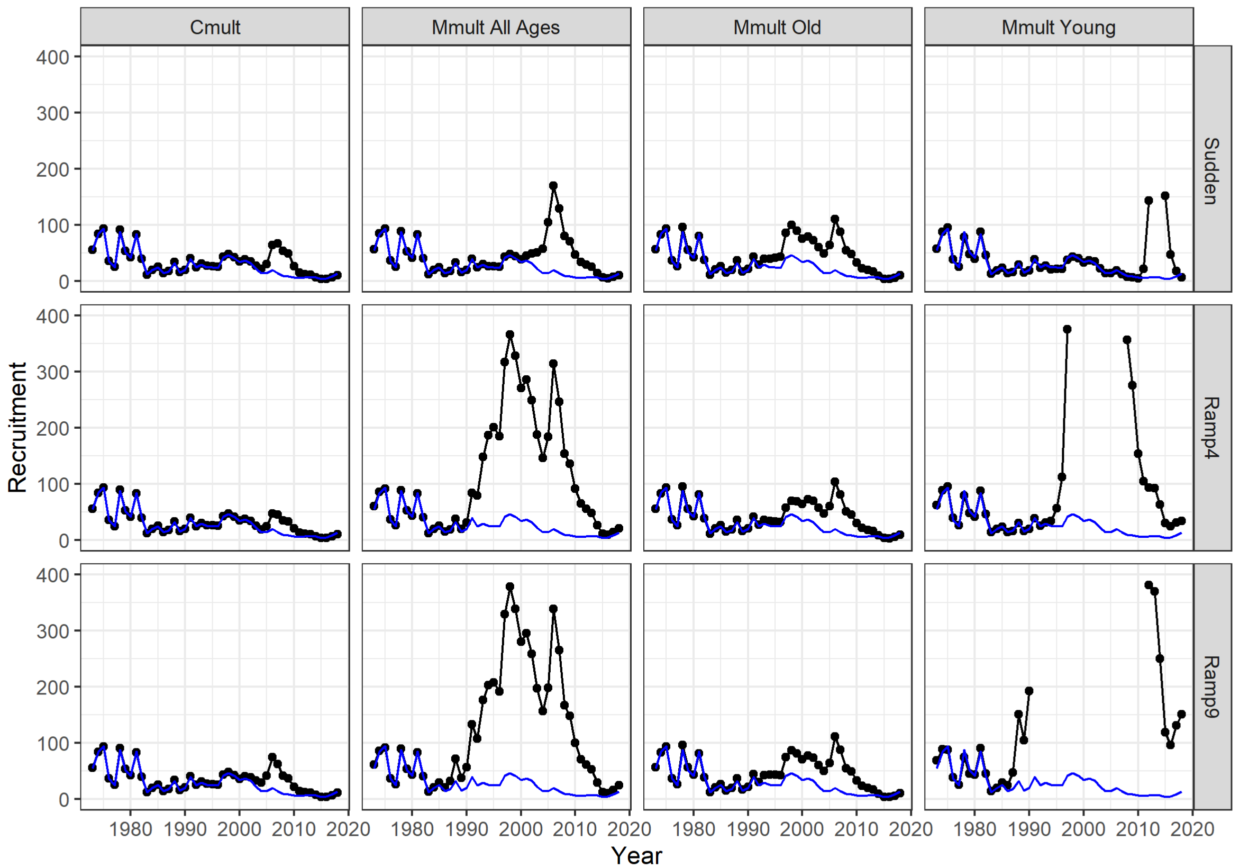
These 12 scenarios all removed the retrospective pattern, but produced quite different estimates of SSB, F, and recruitemnt. In the plots below, the units are SSB in metric tons, F is the mean fishing mortality rate on ages 5-6+, and Recruitment in millions of fish. The solid blue line in each plot is the base case run.




Cmult
Mmult All Ages
Mmult Old
Mmult Young
Sudden
Ramp4
Ramp9
F
Year
0
1
2
3
1980
1990
2000
2010
2020



The natural mortality multipliers applied to young ages produced much higher recruitment estimates than any of the other scenarios. Limiting the range of recruitments plotted allows the other scenarios to be compared to the base case.



Of course, a Mohn's rho for SSB of zero is not the only diagnostic that should be considered in the Rose approach. Fits to the indices, parameter estimates at bounds or unbelievable values, fits to age composition data, etc. should all be considered. The table below provides a link to a pdf showing the model fits and results for each scenario. These can be compared to the base run.

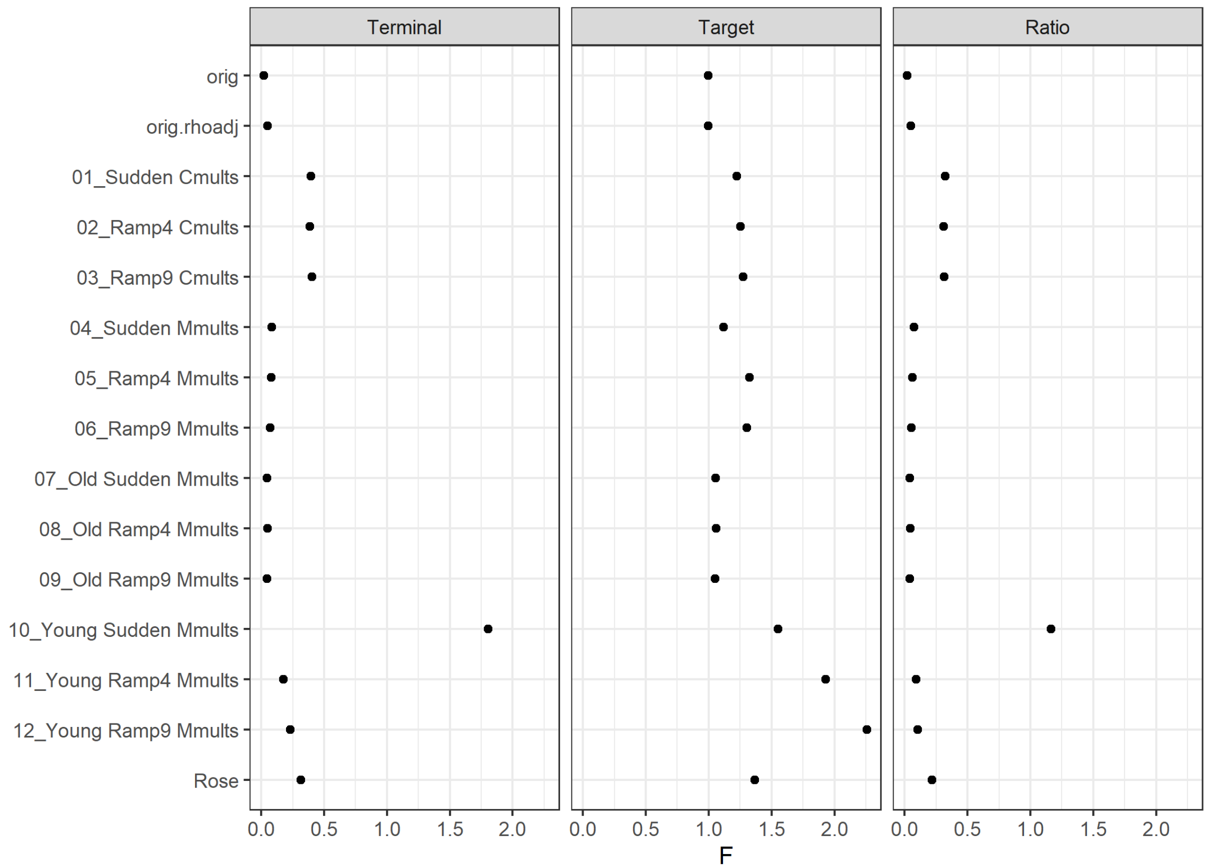
Ramp	Cmult	Mmult All Ages	Mmult Old	Mmult Young
Sudden	1	4	7	10
Ramp4	2	5	8	11
Ramp9	3	6	9	12

Despite some troubling diagnostics for some scenarios, all 12 scenarios were kept for this demonstration. Actual application of the Rose approach would spend a lot of time evaluating which scenarios had good enough diagnostics to be considered in the ensemble approach. This consideration would be done before the catch advice was calculated to prevent picking scenarios to include based on the catch advice.

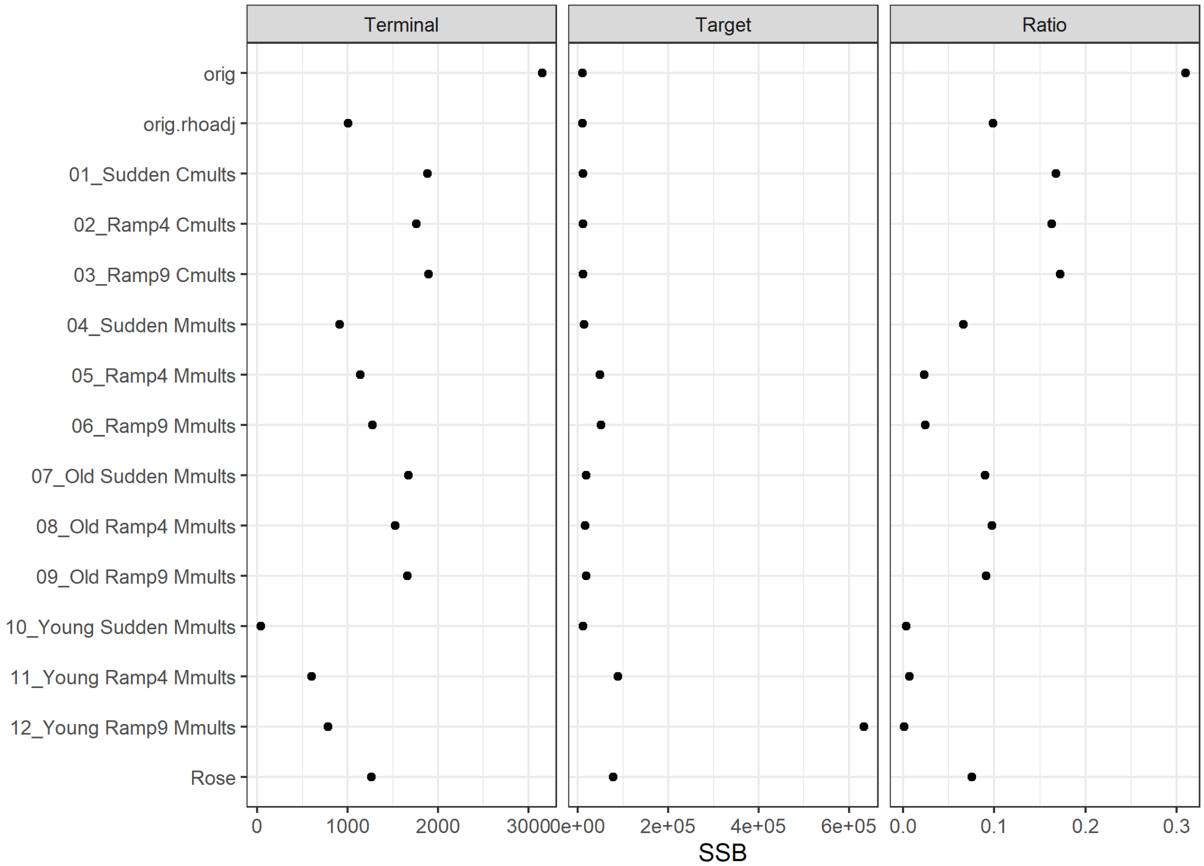
GBYT Reference Points and Status

For the sake of simplicity, F40%SPR (the F that reduces spawning stock biomass per recruit to 40% of unexploited) was selected as the fishing mortality reference point. Of note, the natural mortality rate used in the calculation of F40% was the original value of 0.4, not a value at the end of the time series with M multipliers. This is because the time periods associated with the change in M are too short for the fish population to have evolved characteristics associated with this new M (see Legault and Palmer 2016 for more details). The weights and maturity at age were the same across all scenarios, only the fishery selectivity differed. The most recent time block (2008-2018) was used for the fishery selectivity for each run. Due to the relatively high M of 0.4 and the selectivity being to the right of the maturity ogive for all runs, the F40 values were quite high. As seen above, most runs estimated a much lower F value in the terminal year of the assessment, resulting in the F status being well below 1. However, there is one scenario (Young Sudden Mmults) that has a terminal year F of nearly 2 that is above the target F for that scenario. This one scenario has a strong influence on the Rose estimates. The terminal year SSB was always well below the target SSB, resulting in ratios well below 0.5 (the overfished definition in the US is typically half of SSBmsy or an SSBmsy proxy). For GBYT, the Rose status is the same as the rho-adjusted status with both estimating higher F ratios and lower SSB ratios compared to the original run. The changes in F and SSB ratios were greater for the Rose approach compared to the rho-adjusted approach for GBYT.

```
##                  Scenario F_Terminal F_Target F_Ratio SSB_Terminal
## 1                    orig      0.020    0.997   0.020         3153
## 2             orig.rhoadj      0.050    0.997   0.051         1003
## 3        01_Sudden Cmults      0.396    1.222   0.324         1881
## 4         02_Ramp4 Cmults      0.386    1.255   0.308         1762
## 5         03_Ramp9 Cmults      0.402    1.275   0.315         1895
## 6        04_Sudden Mmults      0.082    1.119   0.073          914
## 7         05_Ramp4 Mmults      0.079    1.324   0.060         1140
## 8         06_Ramp9 Mmults      0.071    1.303   0.054         1275
## 9    07_Old Sudden Mmults      0.044    1.056   0.042         1674
## 10    08_Old Ramp4 Mmults      0.049    1.060   0.046         1528
## 11    09_Old Ramp9 Mmults      0.045    1.053   0.042         1662
## 12 10_Young Sudden Mmults      1.806    1.550   1.165           39
## 13  11_Young Ramp4 Mmults      0.175    1.931   0.091          601
## 14  12_Young Ramp9 Mmults      0.231    2.259   0.102          785
## 15                   Rose      0.314    1.367   0.219         1263
##    SSB_Target SSB_Ratio
## 1       10177     0.310
## 2       10177     0.099
## 3       11239     0.167
## 4       10817     0.163
## 5       11011     0.172
## 6       13782     0.066
## 7       48716     0.023
## 8       51689     0.025
## 9       18566     0.090
## 10      15712     0.097
## 11      18227     0.091
## 12      11942     0.003
## 13      88845     0.007
## 14     632838     0.001
## 15      77782     0.076
```

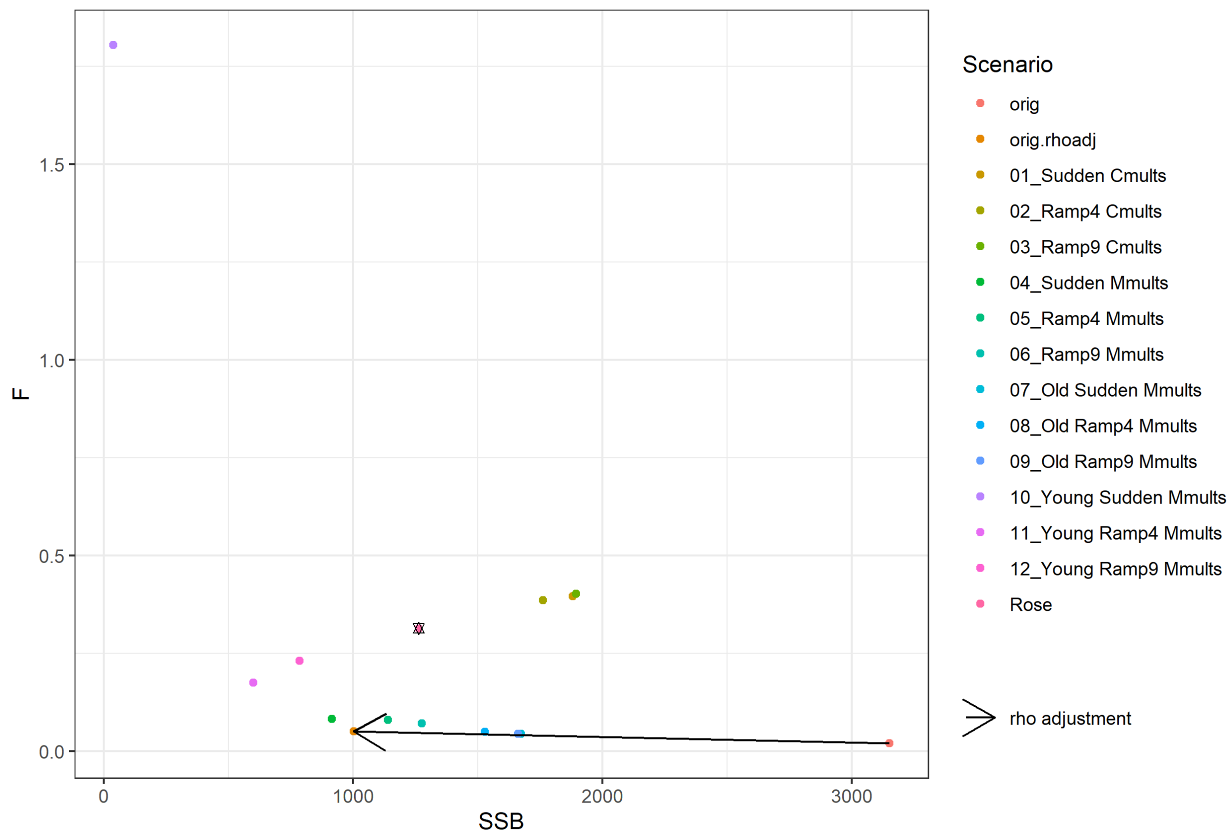


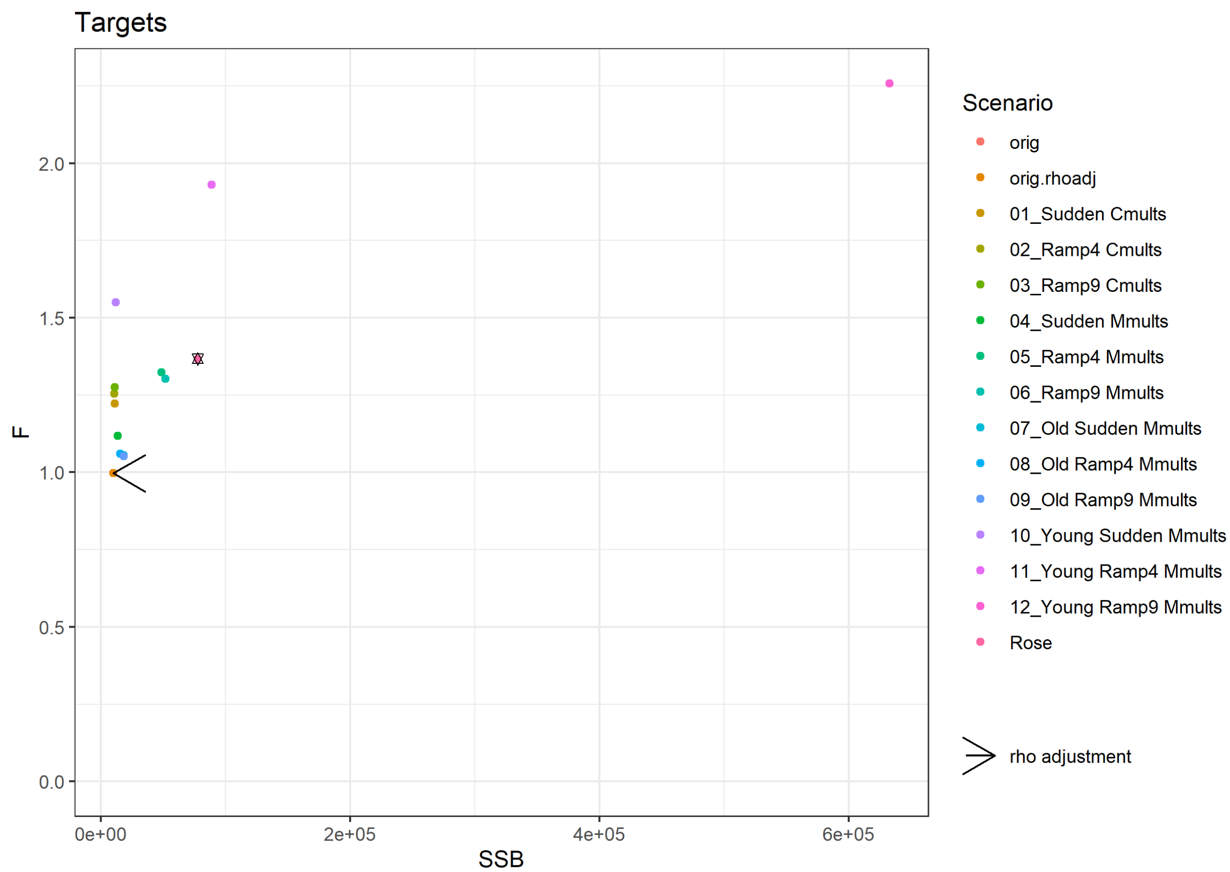
Terminal
Target
Ratio
orig
orig.rhoadj
01_Sudden Cmults
02_Ramp4 Cmults
03_Ramp9 Cmults
04_Sudden Mmults
05_Ramp4 Mmults
06_Ramp9 Mmults
07_Old Sudden Mmults
08_Old Ramp4 Mmults
09_Old Ramp9 Mmults
10_Young Sudden Mmults
11_Young Ramp4 Mmults
12_Young Ramp9 Mmults
Rose
0.0 0.5 1.0 1.5 2.0
F

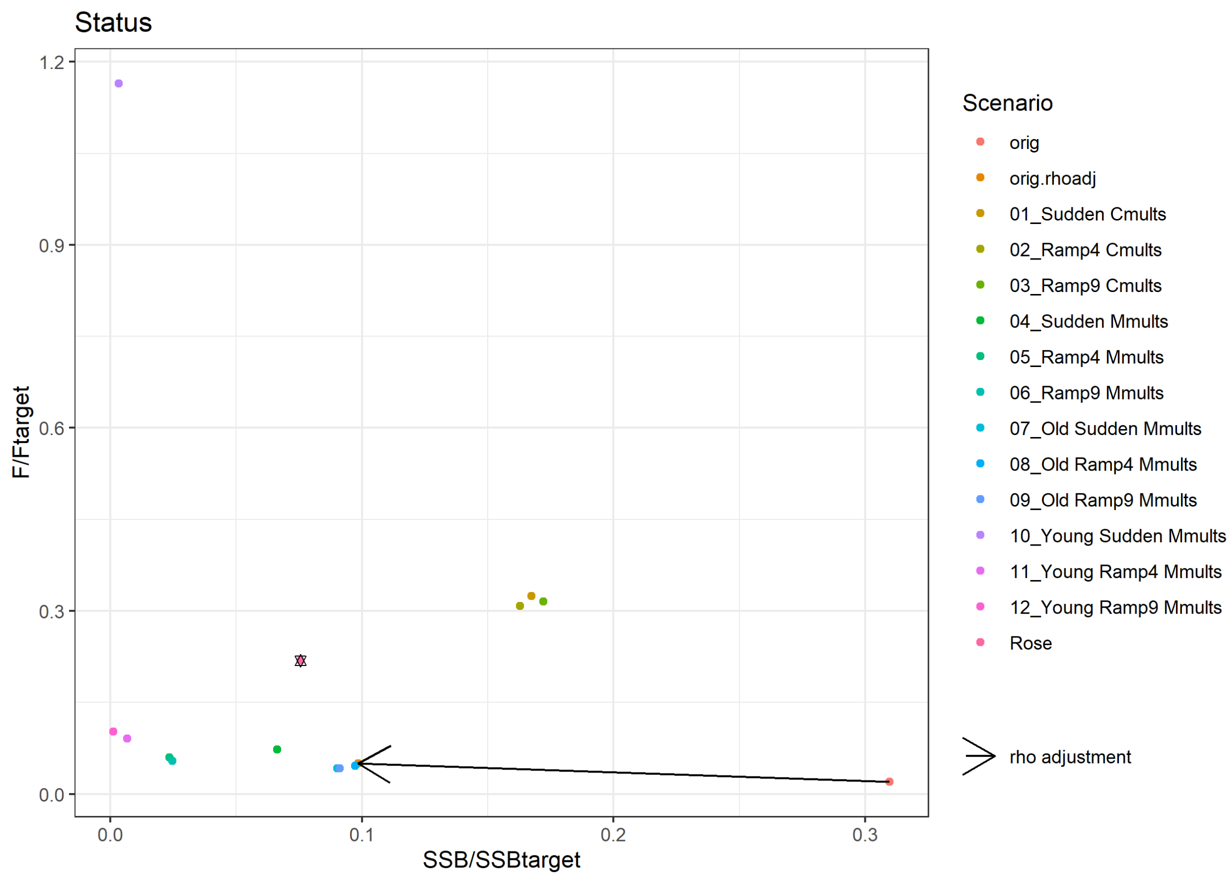


The Rose estimates are highlighted with a star symbol in the following three plots.

Terminal Year




Targets
F
2.0
1.5
1.0
0.5
0.0
0e+00
2e+05
4e+05
6e+05
SSB
Scenario
orig
orig.rhoadj
01_Sudden Cmults
02_Ramp4 Cmults
03_Ramp9 Cmults
04_Sudden Mmults
05_Ramp4 Mmults
06_Ramp9 Mmults
07_Old Sudden Mmults
08_Old Ramp4 Mmults
09_Old Ramp9 Mmults
10_Young Sudden Mmults
11_Young Ramp4 Mmults
12_Young Ramp9 Mmults
Rose
rho adjustment



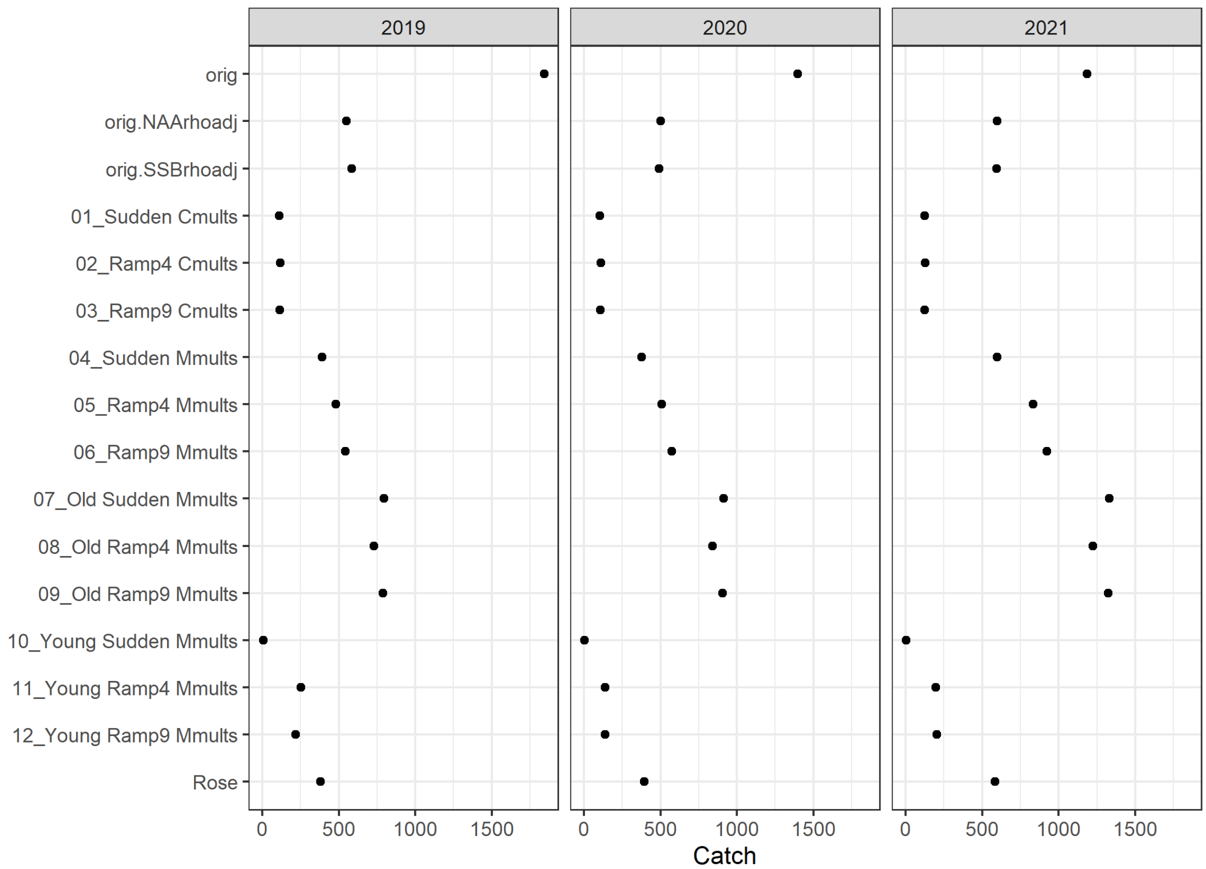
GBYT Catch Advice

Catch advice was based on applying the target F for each scenario for three years. Two approached were used to adjust the terminal year plus one numbers at age for the rho-adjusted catch advice. One case applied the Mohn's rho for SSB to all ages while the other case used the age-specific Mohn's rho values to adjust the numbers at age. The adjustment was calculated as Nadj = Norig / (1 + rho). The Rose scenarios that used catch multipliers had the output catch divided by the catch multipliers because this missing catch in the assessment would not be expected to be suddenly available to the fishery in terms of reported catch. The Rose scenarios that used M multipliers continued the M from the terminal year in the assessment because there is no reason to expect the natural mortality rate to suddenly return to its original value in the projections. If the M was decreased in the projections, there would be "bonus" amount of fish suddenly available to the fishery as catch and to help rebuilding.

The catch table and plot below shows the Rose approach providing lower catch advice than either rho-adjusted approach for GBYT in all three years.

```
##                Scenario X2019 X2020 X2021
## 1                  orig  1843  1398  1187
## 2         orig.SSBrhoadj   586   491   595
## 3         orig.NAArhoadj   549   500   600
## 4       01_Sudden Cmults   111   105   122
## 5        02_Ramp4 Cmults   117   110   127
## 6        03_Ramp9 Cmults   113   106   123
## 7       04_Sudden Mmults   392   375   599
## 8        05_Ramp4 Mmults   482   508   832
```

```
## 9          06_Ramp9 Mmults   542   572   922
## 10   07_Old Sudden Mmults   797   914  1331
## 11    08_Old Ramp4 Mmults   729   840  1224
## 12    09_Old Ramp9 Mmults   790   908  1324
## 13 10_Young Sudden Mmults     6     3     3
## 14  11_Young Ramp4 Mmults   252   139   197
## 15  12_Young Ramp9 Mmults   218   137   204
## 16                   Rose   379   393   584
```



White Hake example

Background

The white hake (WH) stock assessment was recently updated as part of a mangement track (local lingo meaning not a benchmark assessment). The stock exhibited a strong retrospective pattern based on 7 peels with Mohn's rho for SSB of 0.31. While strong, this is a much smaller retrospective pattern than the GBYT example above. Using the ICES standard of 5 peels, the Mohn's rho for SSB is 0.24, which still results in a strong retrospective pattern.

This assessment uses data from 1963-2018 for ages 1-9+ with two surveys providing tuning information. Recent survey values have been near the medians of the time series. Recent quotas are below historical catch amounts (low thousands of tons compared to high thousands of thousands of tons). This stock has been slowly increasing in abundance in responded to recent low catches. There has not been a reason suggested for this retrospective pattern. The rho-adjustment approach has been used in recent years to determine

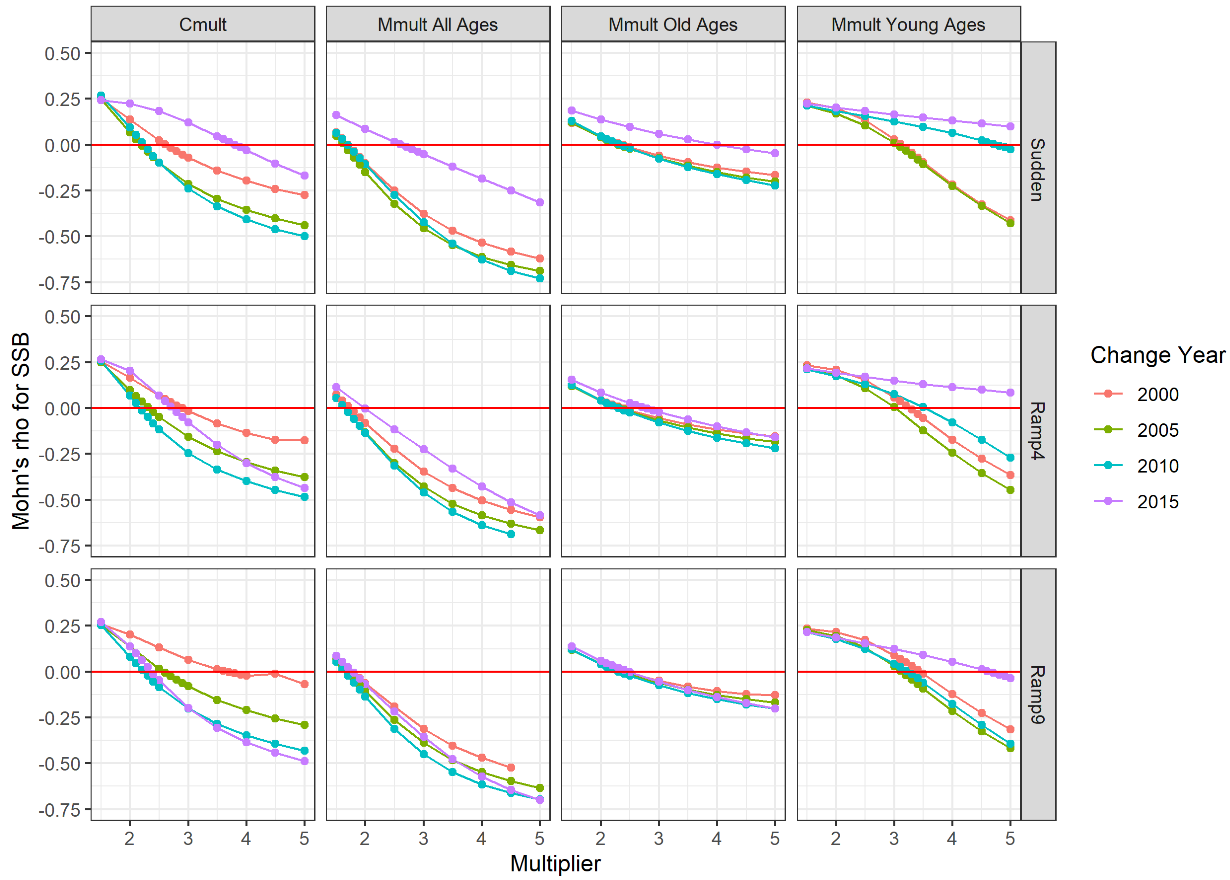


Figure 2: Examination of ways to remove the retrospective pattern

stock status and catch advice (based on a 7 year peel). This example uses a 5 year peel for consistency with the standard in ICES.

Removing the White Hake retro

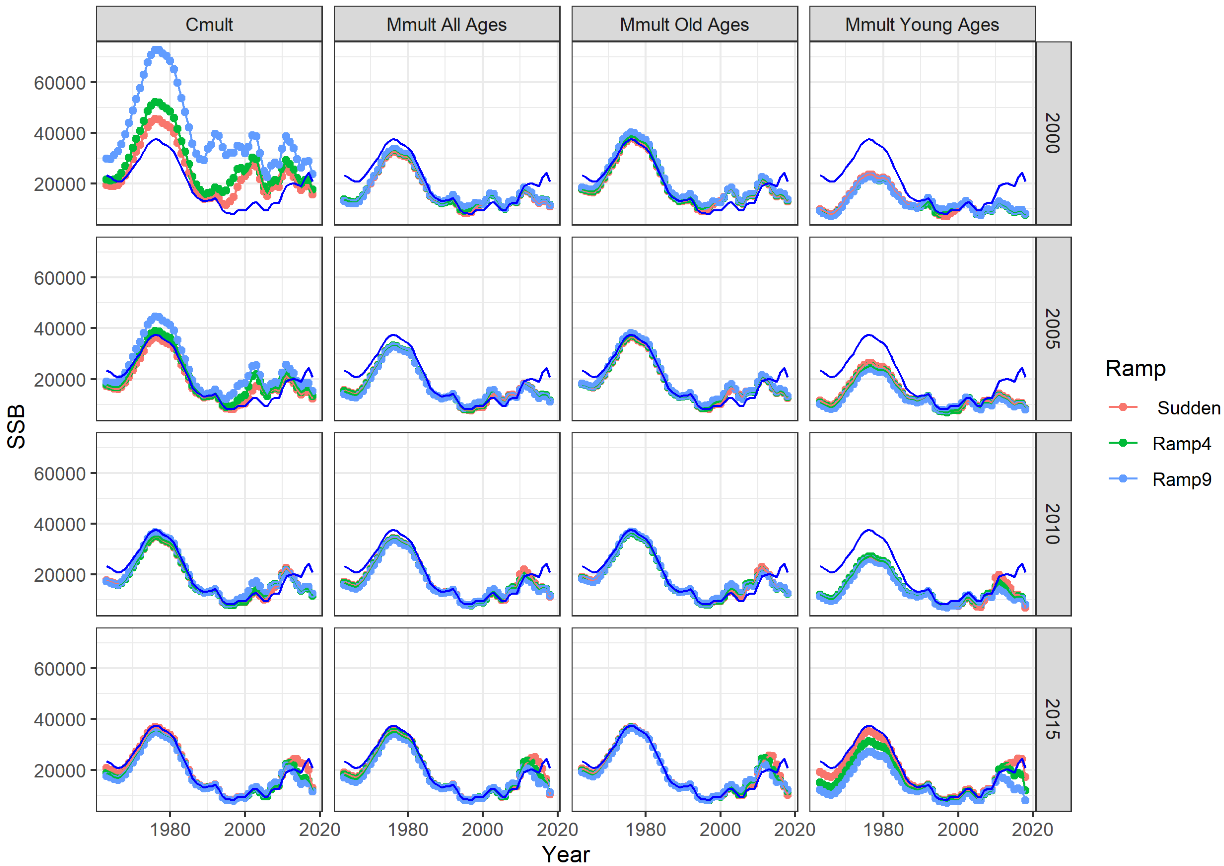
For white hake, a systematic approach to removing the retrospective pattern was also applied. Either the catch or natural mortality rate is increased in recent years. The change from original to modified values can happen suddenly from one year to the next or with a linear ramp of 4 or 9 years. When natural mortality is modified, the increase can occur across all ages, only young ages (ages 1-4 in this case), or only old ages (ages 6-9+ in this case). The timing of the change was examined for years 2000, 2005, 2010, and 2015 being the first year of fully changed catch or natural mortality. The catch or natural mortality was modified by multiplication across all ages for catch or according the age range in the natural mortality scenario. This resulted in a total of 12 scenarios with 4 change years as possible ways to remove the retrospective pattern. For each scenario, a range of multipliers was applied to find the multiplier (to the nearest 0.1) that removed the retrospective pattern. A total of 555 ASAP runs were done to find these best multipliers for the 48 combinations.

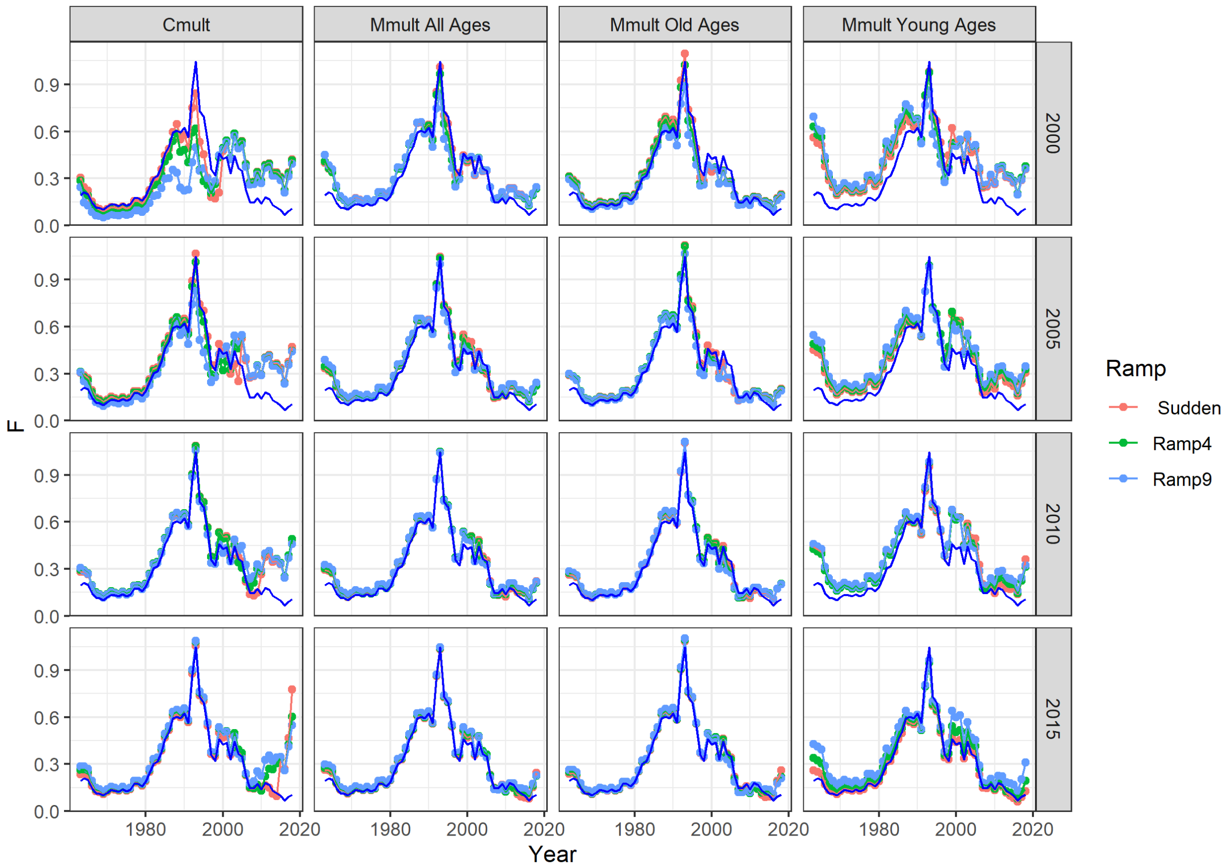
The plot shows that for all scenarios and change years, it was possible to find a multiplier less than 5 that removed the retrospective pattern (ssbrho within -0.013 to 0.100) as shown below.

```
##               scenario change.year ramp cmult mmult        ssbrho
## 1        Sudden Cmults        2000    0   2.6   1.0  2.031043e-03
```

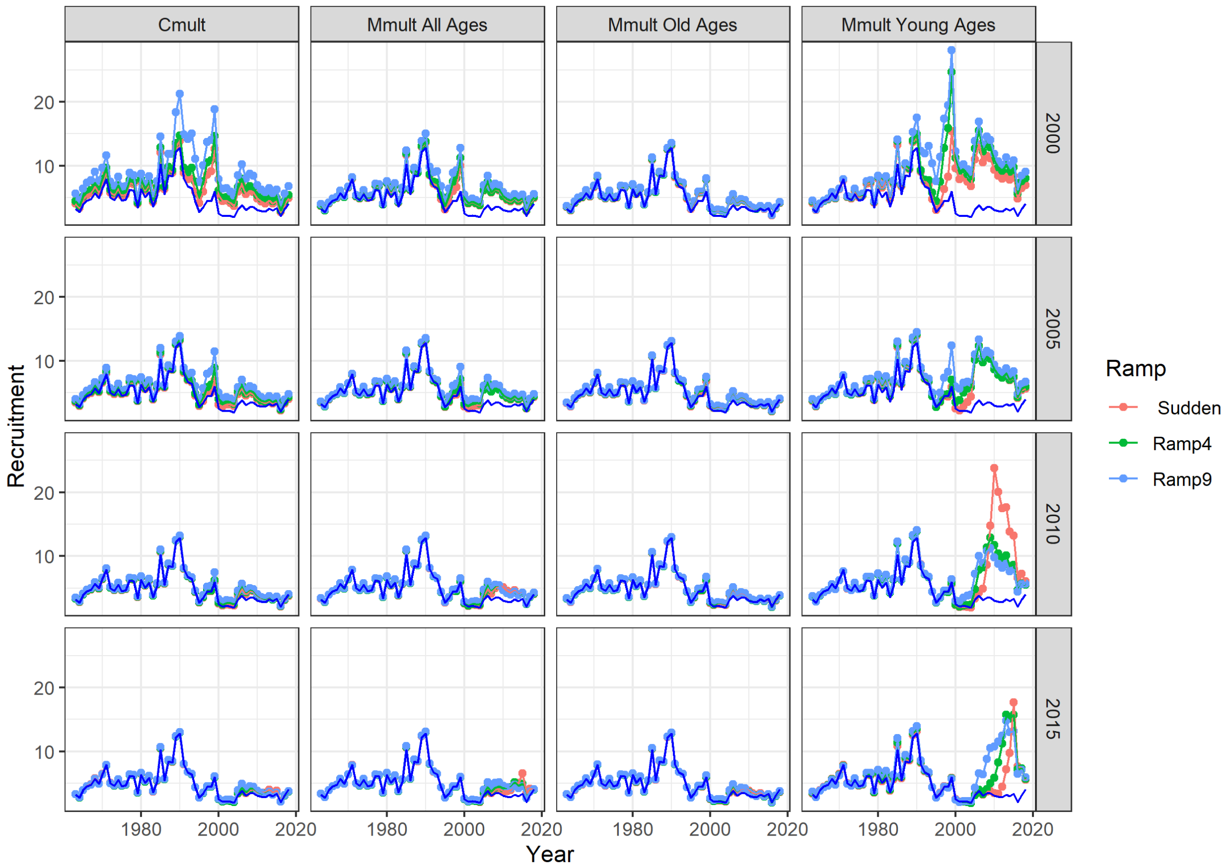
```
## 2        Sudden Cmults        2005    0   2.2   1.0 -5.749937e-03
## 3        Sudden Cmults        2010    0   2.2   1.0  1.263940e-02
## 4        Sudden Cmults        2015    0   3.8   1.0 -7.381923e-04
## 5         Ramp4 Cmults        2000    4   2.9   1.0 -3.714917e-04
## 6         Ramp4 Cmults        2005    4   2.3   1.0  5.353923e-03
## 7         Ramp4 Cmults        2010    4   2.2   1.0 -1.286194e-02
## 8         Ramp4 Cmults        2015    4   2.7   1.0  8.507758e-03
## 9         Ramp9 Cmults        2000    9   3.7   1.0 -2.507874e-03
## 10        Ramp9 Cmults        2005    9   2.6   1.0 -5.248440e-03
## 11        Ramp9 Cmults        2010    9   2.2   1.0  9.342529e-03
## 12        Ramp9 Cmults        2015    9   2.4   1.0 -1.311846e-02
## 13       Sudden Mmults        2000    0   1.0   1.7 -8.902172e-04
## 14       Sudden Mmults        2005    0   1.0   1.6  8.972259e-03
## 15       Sudden Mmults        2010    0   1.0   1.7 -4.247748e-03
## 16       Sudden Mmults        2015    0   1.0   2.6  1.866134e-03
## 17        Ramp4 Mmults        2000    4   1.0   1.7  1.120698e-02
## 18        Ramp4 Mmults        2005    4   1.0   1.6  1.736520e-02
## 19        Ramp4 Mmults        2010    4   1.0   1.6  1.567103e-02
## 20        Ramp4 Mmults        2015    4   1.0   2.0 -2.630471e-03
## 21        Ramp9 Mmults        2000    9   1.0   1.8 -7.365206e-03
## 22        Ramp9 Mmults        2005    9   1.0   1.7 -5.623246e-03
## 23        Ramp9 Mmults        2010    9   1.0   1.6  1.596233e-02
## 24        Ramp9 Mmults        2015    9   1.0   1.8 -7.179721e-03
## 25   Old Sudden Mmults        2000    0   1.0   2.4 -5.152670e-03
## 26   Old Sudden Mmults        2005    0   1.0   2.3  4.763059e-05
## 27   Old Sudden Mmults        2010    0   1.0   2.3  3.841934e-03
## 28   Old Sudden Mmults        2015    0   1.0   4.0 -9.001123e-04
## 29    Old Ramp4 Mmults        2000    4   1.0   2.4 -2.067572e-03
## 30    Old Ramp4 Mmults        2005    4   1.0   2.3  2.691638e-03
## 31    Old Ramp4 Mmults        2010    4   1.0   2.3 -3.449542e-04
## 32    Old Ramp4 Mmults        2015    4   1.0   2.8 -2.998194e-03
## 33    Old Ramp9 Mmults        2000    9   1.0   2.4 -4.300485e-04
## 34    Old Ramp9 Mmults        2005    9   1.0   2.3  5.002606e-03
## 35    Old Ramp9 Mmults        2010    9   1.0   2.3  3.334432e-04
## 36    Old Ramp9 Mmults        2015    9   1.0   2.5 -2.511824e-03
## 37 Young Sudden Mmults        2000    0   1.0   3.1  4.331702e-03
## 38 Young Sudden Mmults        2005    0   1.0   3.0  8.995993e-03
## 39 Young Sudden Mmults        2010    0   1.0   4.7  4.105428e-03
## 40 Young Sudden Mmults        2015    0   1.0   5.0  1.000542e-01
## 41  Young Ramp4 Mmults        2000    4   1.0   3.3 -7.746503e-03
## 42  Young Ramp4 Mmults        2005    4   1.0   3.0  5.469336e-03
## 43  Young Ramp4 Mmults        2010    4   1.0   3.5  6.017076e-03
## 44  Young Ramp4 Mmults        2015    4   1.0   5.0  8.554970e-02
## 45  Young Ramp9 Mmults        2000    9   1.0   3.4  1.018337e-02
## 46  Young Ramp9 Mmults        2005    9   1.0   3.1  5.570539e-03
## 47  Young Ramp9 Mmults        2010    9   1.0   3.2  5.156175e-03
## 48  Young Ramp9 Mmults        2015    9   1.0   4.6  2.712598e-03
```

Since the original retrospective pattern was not as strong for white hake as it was for GBYT, the estimates of SSB, F, and recruitemnt did not vary as much. In the plots below, the units are SSB in metric tons, F is the mean fishing mortality rate on ages 6-9+, and Recruitment in millions of fish. The solid blue line in each plot is the base case run.


Cmult
Mmult All Ages
Mmult Old Ages
Mmult Young Ages
2000
2005
2010
2015
SSB
60000
40000
20000
1980
2000
2020
Year
Ramp
Sudden
Ramp4
Ramp9



Cmult
Mmult All Ages
Mmult Old Ages
Mmult Young Ages
2000
2005
2010
2015
F
0.0
0.3
0.6
0.9
1980
2000
2020
Year
Ramp
Sudden
Ramp4
Ramp9



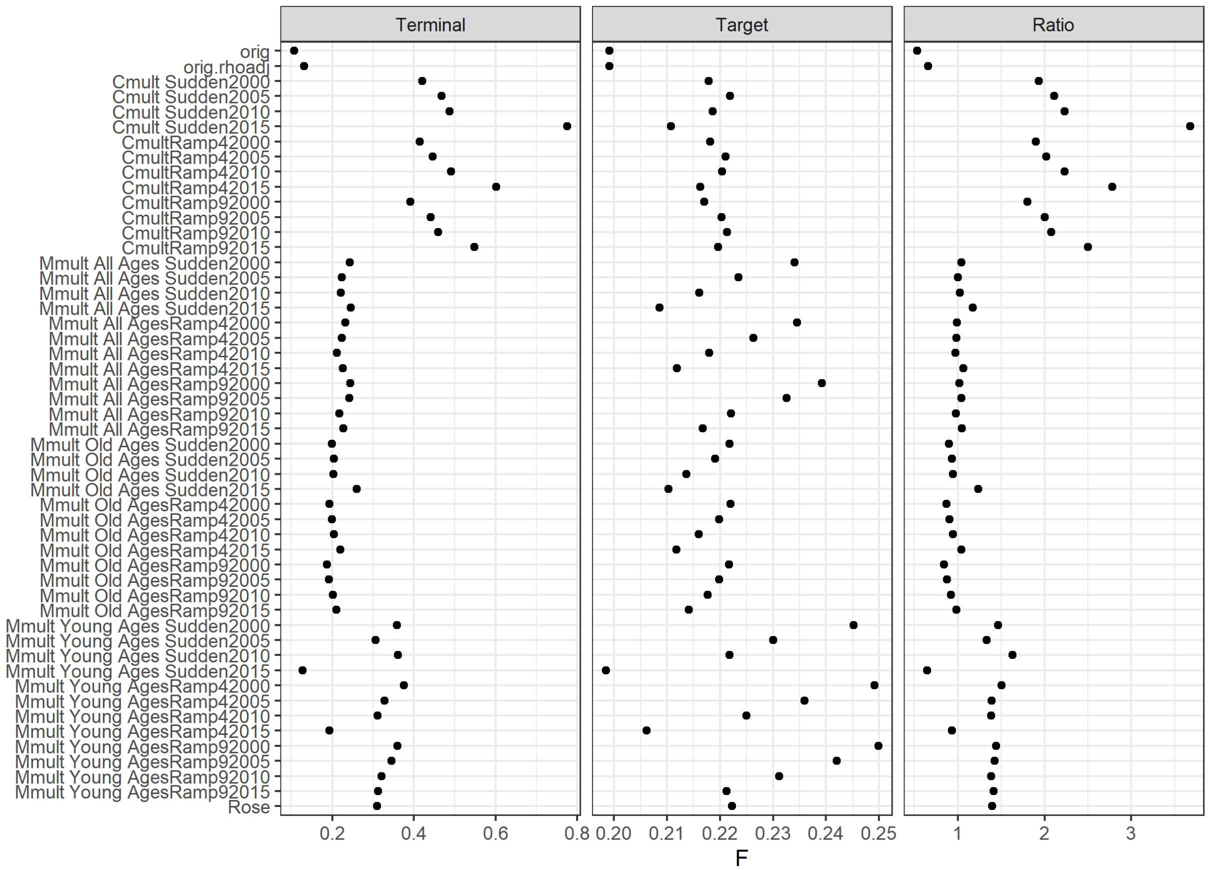
Of course, a Mohn's rho for SSB of zero is not the only diagnostic that should be considered in the Rose approach. Fits to the indices, parameter estimates at bounds or unbelievable values, fits to age composition data, etc. should all be considered. The 48 pdf files for the best runs can be found in the White-Hake/Rose/saved directory with (hopefully) informative filenames. These can be compared to the base run. For this example, all 48 runs were included in the Rose approach without consideration of other diagnostics.

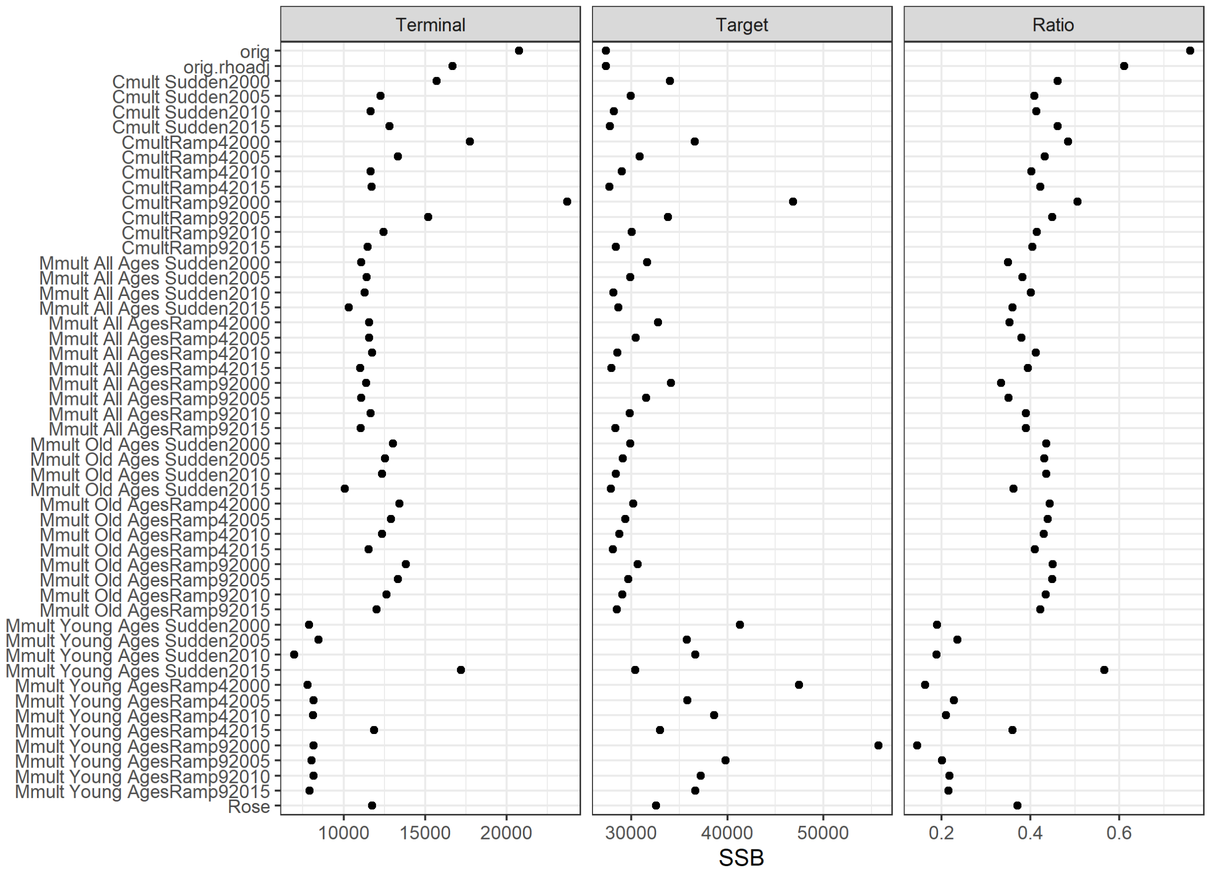
White Hake Reference Points and Status

For the sake of simplicity, F40%SPR (the F that reduces spawning stock biomass per recruit to 40% of unexploited) was selected as the fishing mortality reference point. Of note, the natural mortality rate used in the calculation of F40% was the original value of 0.2, not a value at the end of the time series with M multipliers. This is for the same reason noted above for GBYT. The weights and maturity at age were the same across all scenarios, only the fishery selectivity differed. The most recent time block (2008-2018) was used for the fishery selectivity for each run. The terminal year F is well below the target for the original run and the rho-adjusted run while most of the Rose scenarios and the Rose value are above 1. The rho-adjustment moves the F and F ratio in the same direction as the Rose approach, but not as far. The terminal year SSB is reduced by the rho adjustment but has a ratio that is above 0.5 while most of the Rose scenarios and the Rose value for the SSB ratio are below 0.5. Patterns can be seen within the groups of four change years for each scenario with more recent chagne years having lower F and SSB targets but inconsistent patterns for terminal year F and SSB, casuing the ratios to not follow strong patterns. These patterns in F targets can only be caused by changes in the selectivity of the fishery over time because the other inputs to the F40%SPR calculation are the same. The patterns in SSB targets can also be impacted by the recruitment estimates in the recent 10 years, which vary among the scenarios quite a bit (see plots above). For white hake, the rho-adjustment moved the F and SSB in the direction of the Rose estimates, but not as far as the Rose estimates, which is the same as in the GBYT example above.

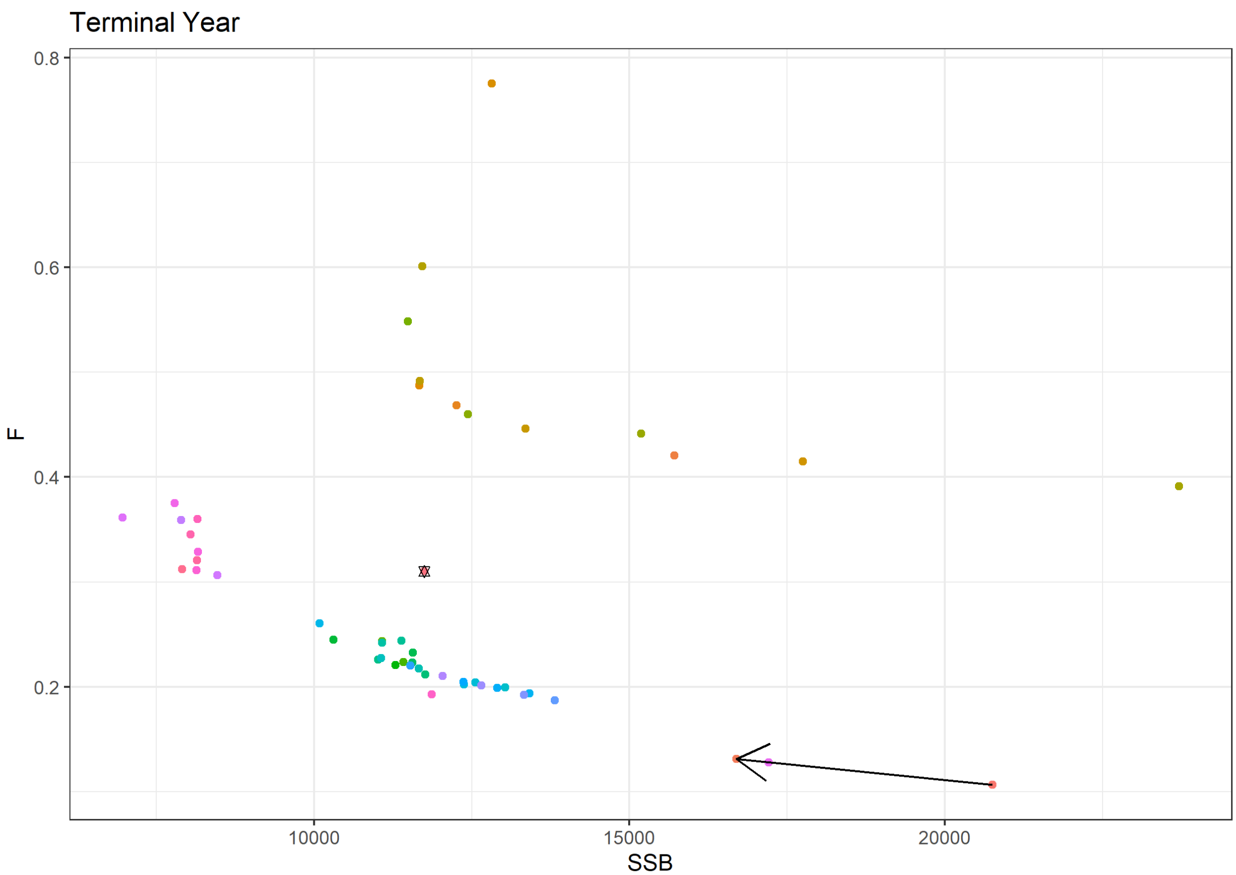
```
##                        Scenario F_Terminal F_Target F_Ratio SSB_Terminal
## 1                          orig      0.107    0.199   0.535        20757
## 2                   orig.rhoadj      0.131    0.199   0.658        16692
## 3              Cmult Sudden2000      0.421    0.218   1.931        15710
## 4              Cmult Sudden2005      0.468    0.222   2.111        12255
## 5              Cmult Sudden2010      0.488    0.219   2.230        11667
## 6              Cmult Sudden2015      0.775    0.211   3.679        12815
## 7                CmultRamp42000      0.415    0.218   1.902        17747
## 8                CmultRamp42005      0.446    0.221   2.018        13348
## 9                CmultRamp42010      0.491    0.220   2.230        11674
## 10               CmultRamp42015      0.601    0.216   2.779        11713
## 11               CmultRamp92000      0.391    0.217   1.803        23716
## 12               CmultRamp92005      0.441    0.220   2.003        15183
## 13               CmultRamp92010      0.460    0.221   2.077        12440
## 14               CmultRamp92015      0.549    0.220   2.497        11483
## 15   Mmult All Ages Sudden2000      0.243    0.234   1.040        11077
## 16   Mmult All Ages Sudden2005      0.224    0.223   1.001        11420
## 17   Mmult All Ages Sudden2010      0.221    0.216   1.022        11293
## 18   Mmult All Ages Sudden2015      0.245    0.209   1.174        10304
## 19     Mmult All AgesRamp42000      0.233    0.235   0.992        11568
## 20     Mmult All AgesRamp42005      0.223    0.226   0.986        11561
## 21     Mmult All AgesRamp42010      0.212    0.218   0.972        11765
## 22     Mmult All AgesRamp42015      0.226    0.212   1.066        11018
## 23     Mmult All AgesRamp92000      0.244    0.239   1.019        11388
## 24     Mmult All AgesRamp92005      0.242    0.233   1.040        11075
## 25     Mmult All AgesRamp92010      0.217    0.222   0.979        11657
## 26     Mmult All AgesRamp92015      0.227    0.217   1.049        11064
## 27   Mmult Old Ages Sudden2000      0.200    0.222   0.900        13026
## 28   Mmult Old Ages Sudden2005      0.204    0.219   0.931        12556
## 29   Mmult Old Ages Sudden2010      0.202    0.214   0.948        12373
## 30   Mmult Old Ages Sudden2015      0.260    0.210   1.238        10083
## 31     Mmult Old AgesRamp42000      0.194    0.222   0.872        13414
## 32     Mmult Old AgesRamp42005      0.199    0.220   0.905        12900
## 33     Mmult Old AgesRamp42010      0.205    0.216   0.947        12366
## 34     Mmult Old AgesRamp42015      0.220    0.212   1.039        11526
## 35     Mmult Old AgesRamp92000      0.187    0.222   0.845        13816
## 36     Mmult Old AgesRamp92005      0.192    0.220   0.874        13327
## 37     Mmult Old AgesRamp92010      0.201    0.218   0.924        12649
## 38     Mmult Old AgesRamp92015      0.210    0.214   0.983        12034
## 39 Mmult Young Ages Sudden2000      0.359    0.245   1.463         7893
## 40 Mmult Young Ages Sudden2005      0.307    0.230   1.333         8463
## 41 Mmult Young Ages Sudden2010      0.361    0.222   1.630         6961
## 42 Mmult Young Ages Sudden2015      0.128    0.198   0.645        17206
## 43   Mmult Young AgesRamp42000      0.375    0.249   1.506         7787
## 44   Mmult Young AgesRamp42005      0.329    0.236   1.393         8159
## 45   Mmult Young AgesRamp42010      0.311    0.225   1.384         8137
## 46   Mmult Young AgesRamp42015      0.193    0.206   0.935        11868
## 47   Mmult Young AgesRamp92000      0.360    0.250   1.440         8149
## 48   Mmult Young AgesRamp92005      0.345    0.242   1.426         8044
## 49   Mmult Young AgesRamp92010      0.321    0.231   1.387         8143
## 50   Mmult Young AgesRamp92015      0.312    0.221   1.411         7907
## 51                        Rose      0.310    0.222   1.395        11744
##    SSB_Target SSB_Ratio
## 1       27330     0.759
```

```
## 2        27330      0.611
## 3        34012      0.462
## 4        29962      0.409
## 5        28194      0.414
## 6        27756      0.462
## 7        36613      0.485
## 8        30889      0.432
## 9        29032      0.402
## 10       27707      0.423
## 11       46838      0.506
## 12       33821      0.449
## 13       30037      0.414
## 14       28407      0.404
## 15       31671      0.350
## 16       29887      0.382
## 17       28152      0.401
## 18       28662      0.360
## 19       32775      0.353
## 20       30432      0.380
## 21       28547      0.412
## 22       27901      0.395
## 23       34111      0.334
## 24       31523      0.351
## 25       29854      0.390
## 26       28351      0.390
## 27       29887      0.436
## 28       29093      0.432
## 29       28395      0.436
## 30       27868      0.362
## 31       30213      0.444
## 32       29370      0.439
## 33       28772      0.430
## 34       28102      0.410
## 35       30665      0.451
## 36       29700      0.449
## 37       29073      0.435
## 38       28499      0.422
## 39       41327      0.191
## 40       35787      0.236
## 41       36676      0.190
## 42       30384      0.566
## 43       47471      0.164
## 44       35814      0.228
## 45       38653      0.211
## 46       32989      0.360
## 47       55768      0.146
## 48       39813      0.202
## 49       37233      0.219
## 50       36670      0.216
## 51       32570      0.372
```

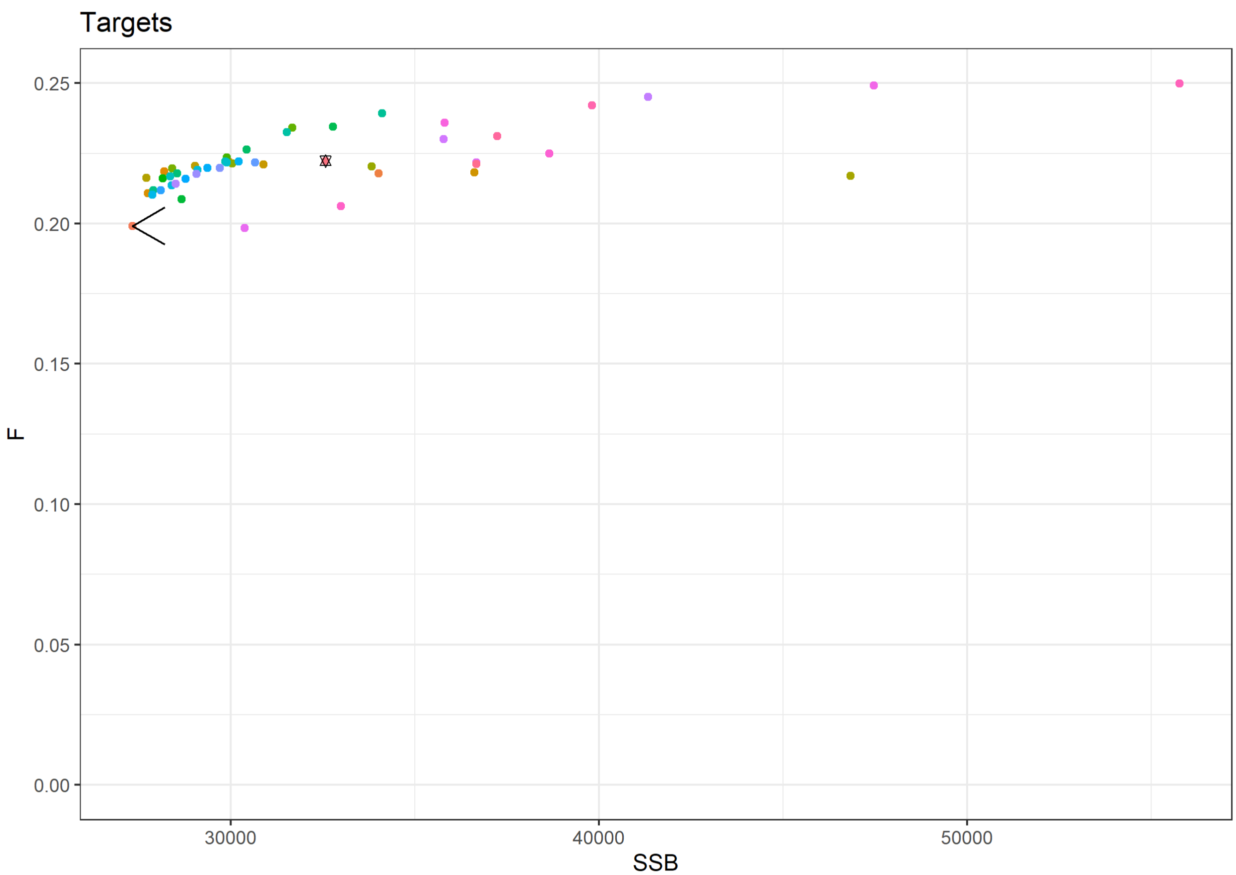

Terminal
Target
Ratio
orig
orig.rhoadj
Cmult Sudden2000
Cmult Sudden2005
Cmult Sudden2010
Cmult Sudden2015
CmultRamp42000
CmultRamp42005
CmultRamp42010
CmultRamp42015
CmultRamp92000
CmultRamp92005
CmultRamp92010
CmultRamp92015
Mmult All Ages Sudden2000
Mmult All Ages Sudden2005
Mmult All Ages Sudden2010
Mmult All Ages Sudden2015
Mmult All AgesRamp42000
Mmult All AgesRamp42005
Mmult All AgesRamp42010
Mmult All AgesRamp42015
Mmult All AgesRamp92000
Mmult All AgesRamp92005
Mmult All AgesRamp92010
Mmult All AgesRamp92015
Mmult Old Ages Sudden2000
Mmult Old Ages Sudden2005
Mmult Old Ages Sudden2010
Mmult Old Ages Sudden2015
Mmult Old AgesRamp42000
Mmult Old AgesRamp42005
Mmult Old AgesRamp42010
Mmult Old AgesRamp42015
Mmult Old AgesRamp92000
Mmult Old AgesRamp92005
Mmult Old AgesRamp92010
Mmult Old AgesRamp92015
Mmult Young Ages Sudden2000
Mmult Young Ages Sudden2005
Mmult Young Ages Sudden2010
Mmult Young Ages Sudden2015
Mmult Young AgesRamp42000
Mmult Young AgesRamp42005
Mmult Young AgesRamp42010
Mmult Young AgesRamp42015
Mmult Young AgesRamp92000
Mmult Young AgesRamp92005
Mmult Young AgesRamp92010
Mmult Young AgesRamp92015
Rose
0.2 0.4 0.6 0.8
0.20 0.21 0.22 0.23 0.24 0.25
1 2 3
F



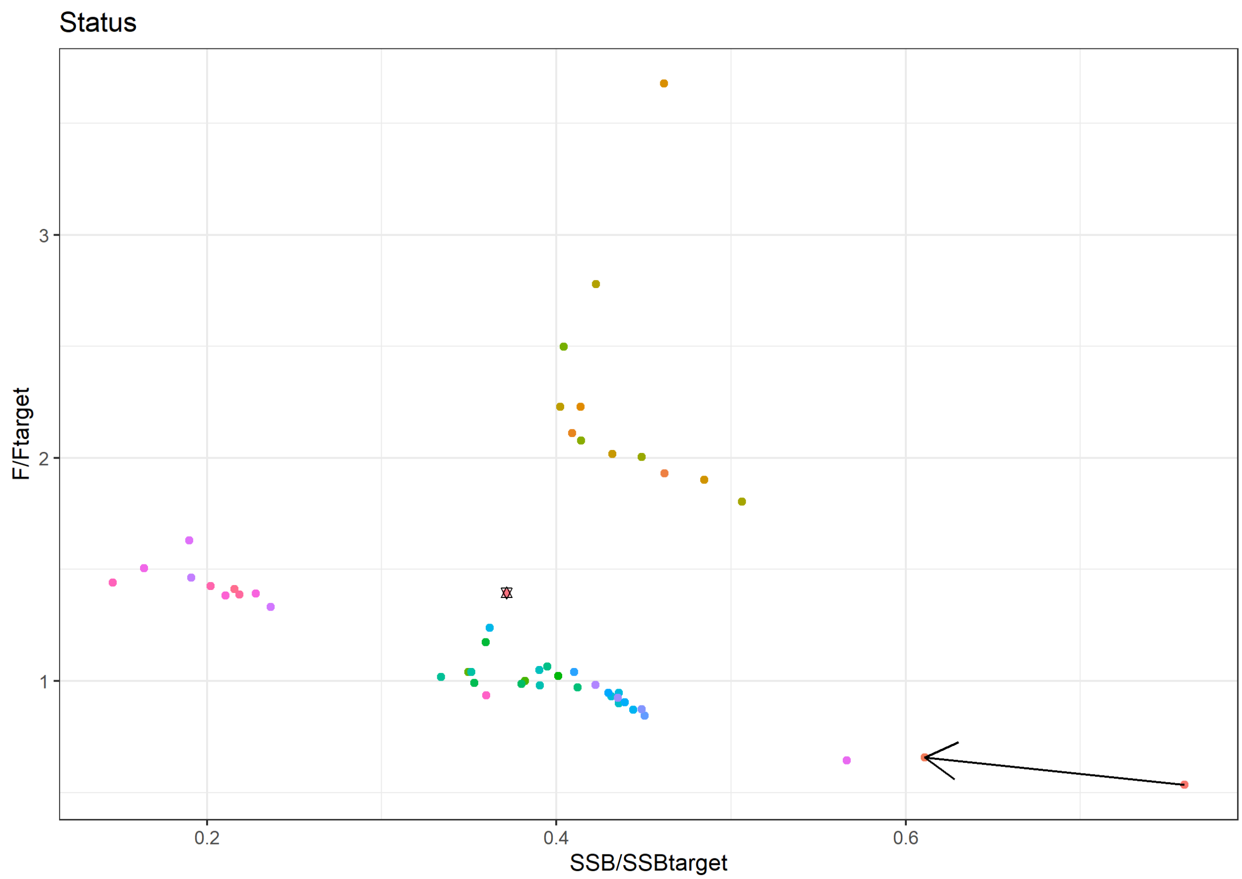
The Rose estimates are highlighted with a star symbol in the following three plots.



Terminal Year
0.8
0.6
0.4
0.2
F
10000
15000
20000
SSB



Targets
0.25
0.20
0.15
0.10
0.05
0.00
F
30000
40000
50000
SSB



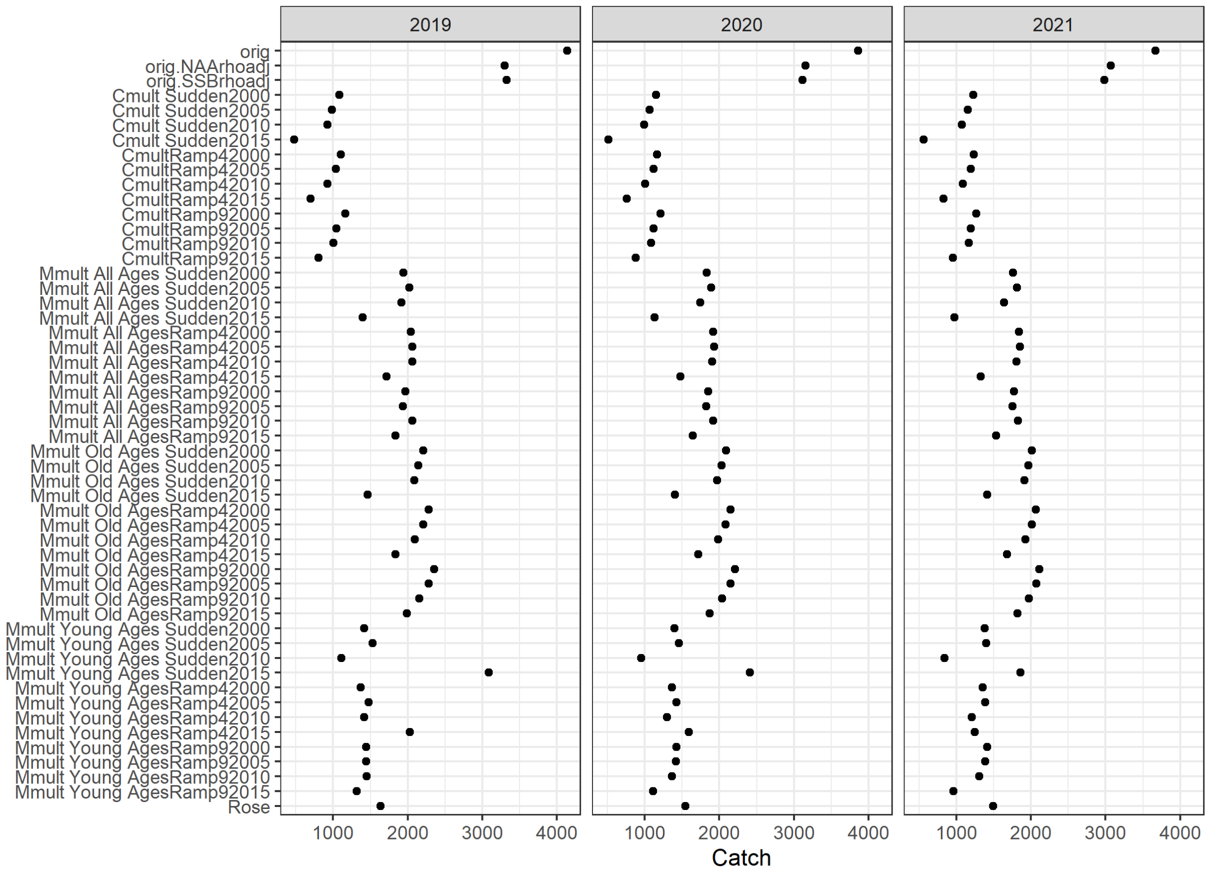
White Hake Catch Advice

Catch advice was based on applying the target F for each scenario for three years. Two approached were used to adjust the terminal year plus one numbers at age for the rho-adjusted catch advice. One case applied the Mohn's rho for SSB to all ages while the other case used the age-specific Mohn's rho values to adjust the numbers at age. The adjustment was calculated as Nadj = Norig / (1 + rho). The Rose scenarios that used catch multipliers had the output catch divided by the catch multipliers because this missing catch in the assessment would not be expected to be suddenly available to the fishery in terms of reported catch. The Rose scenarios that used M multipliers continued the M from the terminal year in the assessment because there is no reason to expect the natural mortality rate to suddenly return to its original value in the projections. If the M was decreased in the projections, there would be "bonus" amount of fish suddenly available to the fishery as catch and to help rebuilding.

The catch table and plot below shows the Rose approach providing lower catch advice than either rho-adjusted approach for white hake in all three years. This is the same result as for GBYT above.

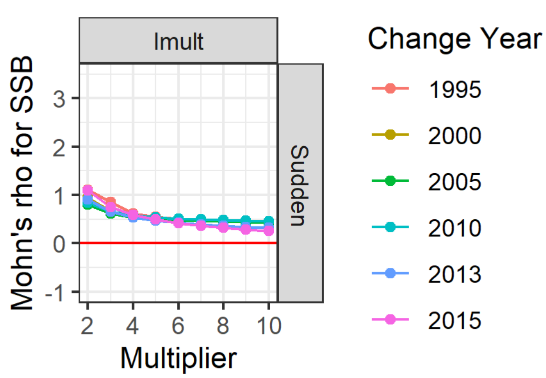
```
##                         Scenario X2019 X2020 X2021
## 1                           orig  4137  3863  3672
## 2                 orig.SSBrhoadj  3327  3116  2985
## 3                 orig.NAArhoadj  3298  3156  3069
## 4               Cmult Sudden2000  1085  1153  1226
## 5               Cmult Sudden2005   987  1068  1152
## 6               Cmult Sudden2010   921   992  1071
## 7               Cmult Sudden2015   476   514   563
## 8                 CmultRamp42000  1102  1165  1233
```

```
## 9              CmultRamp42005  1038  1116  1196
## 10             CmultRamp42010   925  1004  1088
## 11             CmultRamp42015   698   756   825
## 12             CmultRamp92000  1161  1211  1266
## 13             CmultRamp92005  1044  1118  1194
## 14             CmultRamp92010  1005  1084  1167
## 15             CmultRamp92015   805   877   956
## 16   Mmult All Ages Sudden2000  1941  1832  1762
## 17   Mmult All Ages Sudden2005  2022  1892  1810
## 18   Mmult All Ages Sudden2010  1917  1744  1639
## 19   Mmult All Ages Sudden2015  1397  1132   971
## 20     Mmult All AgesRamp42000  2041  1919  1840
## 21     Mmult All AgesRamp42005  2060  1933  1851
## 22     Mmult All AgesRamp42010  2065  1905  1806
## 23     Mmult All AgesRamp42015  1718  1478  1328
## 24     Mmult All AgesRamp92000  1969  1851  1774
## 25     Mmult All AgesRamp92005  1937  1824  1751
## 26     Mmult All AgesRamp92010  2062  1919  1828
## 27     Mmult All AgesRamp92015  1833  1646  1530
## 28   Mmult Old Ages Sudden2000  2211  2088  2013
## 29   Mmult Old Ages Sudden2005  2143  2028  1966
## 30   Mmult Old Ages Sudden2010  2091  1969  1913
## 31   Mmult Old Ages Sudden2015  1460  1403  1413
## 32     Mmult Old AgesRamp42000  2281  2148  2063
## 33     Mmult Old AgesRamp42005  2207  2085  2014
## 34     Mmult Old AgesRamp42010  2098  1983  1927
## 35     Mmult Old AgesRamp42015  1833  1719  1681
## 36     Mmult Old AgesRamp92000  2353  2207  2115
## 37     Mmult Old AgesRamp92005  2285  2151  2070
## 38     Mmult Old AgesRamp92010  2155  2036  1971
## 39     Mmult Old AgesRamp92015  1987  1870  1821
## 40 Mmult Young Ages Sudden2000  1414  1397  1382
## 41 Mmult Young Ages Sudden2005  1530  1456  1400
## 42 Mmult Young Ages Sudden2010  1110   952   844
## 43 Mmult Young Ages Sudden2015  3084  2409  1862
## 44   Mmult Young AgesRamp42000  1372  1364  1355
## 45   Mmult Young AgesRamp42005  1474  1426  1388
## 46   Mmult Young AgesRamp42010  1418  1296  1210
## 47   Mmult Young AgesRamp42015  2027  1589  1250
## 48   Mmult Young AgesRamp92000  1441  1427  1413
## 49   Mmult Young AgesRamp92005  1446  1416  1390
## 50   Mmult Young AgesRamp92010  1450  1368  1306
## 51   Mmult Young AgesRamp92015  1316  1112   957
## 52                        Rose  1633  1542  1491
```

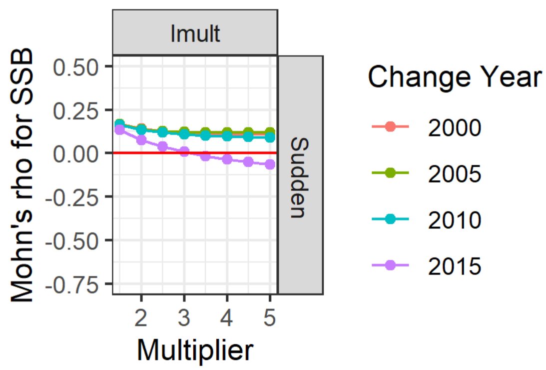


Food for thought

During the WKFORBIAS meeting, survey catchability changes were suggested as an additional means of removing the retrospective pattern. To have control over the search process, index multipliers were applied to the data, similar to the catch and natural mortality multipliers. However, initial explorations were not successful with none of the sudden change year multipliers reducing the Mohn's rho for SSB close enough to zero for GBYT.



Only one of the four change years was able to reduce the Mohn's rho for SSB to zero for White Hake.



The use of index multiplier does not appear to be an easy way to remove retrospective patterns. More research is needed to determine how survey catchabilty can be more easily incorporated in the Rose approach.

In both stocks, the rho-adjusted approach and Rose approach the F status point was increased and the SSB status point was decreased relative to the original run. The change due to the Rose approach was greater than from the rho-adjusted approach in both cases. Similarly, in both stocks the catch advice provided by both approaches as lower than the original run and the catch advice from the Rose approach was lower than the catch advice provided by the rho-adjustment.

As seen in the GBYT example, the Rose approach can be influenced by one scenario that is quite different from the others. This influence could be reduced by using some other measure of central tendancy of the scenarios, such as the median or a trimmed mean. It would be better to make this decision before applying the Rose approach to eliminate any concern about basing the decision on the results.

The rho-adjusted approach does not impact the reference points in these examples because only the terminal year is adjusted. There is not a standard approach used to link the terminal year adjusted values back to the rest of the time series, resulting in a sudden discontinuity in the time series. This is one of the major concerns expressed with using the rho-adjusted approach. Another concern is that rho-adjusting the terminal year F and N does not necessarily result in the same catch that was originally predicted.

Approach	Pros	Cons
Rose	All models in ensemble have no retro	Long run times
Rose	Addresses model structure uncertainty	Potential stacking the deck
Rho	Easy and quick to compute	Discontinuity in time series
Rho	Does not require identifying source of retro	Ad hoc adjustment