A CANDIDATE MANAGEMENT PROCEDURE FOR BLUEFIN TUNA

A.R. Hanke[1]

SUMMARY

A candidate management procedure for bluefin tuna is evaluated.

RÉSUMÉ

Le présent document évalue une procédure de gestion possible pour le thon rouge.

RESUMEN

Se evalúa un procedimiento de ordenación candidato para el atún rojo.

KEYWORDS

Management procedure, MSE, bluefin tuna

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1. Introduction

A management strategy evaluation framework developed for Bluefin tuna (ABTMSE version 2.7.0) was used to test the performance of a management procedure (MP) developed following consultation with stakeholders in the Canadian Bluefin tuna fishery. The single DFO MP and several constant catch MPs applied in the western stock management area were evaluated against a single constant catch scenario for the east.

2. Method

A constant catch MP (CurEC100) was developed for the eastern stock that attempted to set the TAC according to the management recommendations for 2016 through 2020. In each MSE run, a 3 year management cycle for setting TACs is assumed. A 3 year interval on TAC updates resulted in a TAC being repeated until the next update. The consequence of this was that the desired TACS for the eastern stock of 23,155 MT in year one (2017) followed by 28,200 and 36,000 MT in years 2 and 3 with 36,000 MT thereafter were rather 23,155 MT for years 1 to 3 and 28,200 thereafter.

The DFO western MP (DFO7_40_10) uses index 7 (GOM_LAR_SUV) to predict stock status and derive a TAC recommendation. Healthy, cautious, critical and super critical zones are defined by the reference values 1.0, 0.4 and 0.1. The stock status at the conclusion of a management cycle is determined by comparing the ratio of the index value at the end of a cycle to a base value of the index. The base value is the mean of the index values in the last 3 years of the historical period.

In addition to an evaluation of status based on the index, the MP also determines the trend in the index over the most recent 4 years in order. The magnitude and direction of the trend affects the TAC recommendation conditional on stock status and comprise the control rules.

These control rules are as follows:

1. When the stock is in the healthy zone and the trend is positive, the TAC is increased by a scalar of 0.3 applied to the magnitude of the trend. Thus a slope of 1.0 increases the TAC by 30%. Otherwise, if the trend is negative there is no adjustment in the TAC.

2. When the stock is in the cautious zone and the trend is negative, the TAC is decreased by a scalar of 0.1 applied to the magnitude of the trend. Thus a slope of -1.0 decreases the TAC by 10%. Otherwise, if the trend is positive there is no adjustment in the TAC.

3. When the stock is in the critical zone, the TAC is decreased by a scalar of 0.1 applied to the magnitude of the trend 50%. In the event that the status falls below the critical zone, the TAC is set to 0.

In mathematical terms the MP works as follows:

$$I_{base} = \sum_{y=2012}^{2015} I_y/4$$

$$I_{ratio} = I_n/I_{base}$$

$$\beta = I_j - \alpha/Y_j, \qquad j = y_{n-3}, \dots, y_n$$

Healthy Zone

$$I_{ratio} \geq 1 \ \wedge \ \beta \geq 0, \qquad TAC_{y_{n+1}} = (1 + \beta \times 0.3) \times TAC_{y_n}$$

$$I_{ratio} \geq 1 \ \wedge \ \beta < 0, \qquad TAC_{y_{n+1}} = TAC_{y_n}$$

Cautious Zone

$$I_{ratio} < 1 \ \wedge \ I_{ratio} \geq 0.4 \ \wedge \ \beta < 0, \qquad TAC_{y_{n+1}} = \ (1 + \beta \times 0.1) \times TAC_{y_n}$$

$$I_{ratio} < 1 \ \wedge \ I_{ratio} \geq 0.4 \ \wedge \ \beta \geq 0, \qquad TAC_{y_{n+1}} = \ TAC_{y_n}$$

Critical Zone A

$$I_{ratio} < 0.4 \ \wedge \ I_{ratio} \geq 0.1 \,, \qquad TAC_{y_{n+1}} = \ 0.5 \times TAC_{y_n}$$

Critical Zone B

$$I_{ratio} < 0.1 \,, \qquad TAC_{y_{n+1}} = \ 0$$

The remaining MPs are all constant catch scenarios which reflect the current TAC set by ICCAT and alternatives of 1x, 1.5x and 2x increases (CurC100, CurC150, CurC200).

For all runs a perfect implementation model is assumed but with bad observations and the MPs are all run against the example OM which may be identical to OM_1 but with only 12 simulations. Each MSE run is followed by a series of plots that:

1. Compare the catch by area to the TAC by area,

2. Describe B/B_{MSY} and F/F_{MSY},

3. Evaluate performance against objectives and

4. Provide a series of diagnostic plots that are views of the SSB, SSBa, TAC, Cobs, C, D, Iobs and Bt vectors from the dset and MSE objects created following each MSE run.

Note that the diagnostic plots are based on the results from simulation 1 only whereas the other plots capture the variability in the responses from all 12 simulations.

3. Results

The MSE outputs for DFO MP show the median (black) and mean (coloured) value of the simulations. The grey or pink envelope represents the 97.5 and 2.5 percentiles of the simulations. In these runs there are only 16 simulations so the full uncertainty of the MP performance is likely not captured.

In the performance metric plot:

1. PBLIM determines the probability that the stock biomass is below B_{LIM} over the projected 30 year time period. B_{LIM} is .1*B_{MSY} and performance <5% is preferred.

2. PRK determines the probability that BFMSY, over the 30 year projected time period. Performance < 10% is preferred.

3. PRK determines the probability that BFMSY, over the 30 year projected time period. Performance < 10% is preferred.

4. C2750_2130 determines the probability that the catch is at least 2750 MT in years 21 to 30. Performance > 60% is preferred. pp = 2 = West.

5. C2750_1130 determines the probability that the catch is at least 2750 MT in years 11 to 30. Performance > 60% is preferred. pp = 2 = West.

6. T2750_2130 determines the probability that the TAC is at least 2750 MT in years 21 to 30. Performance > 60% is preferred. pp = 2 = West.

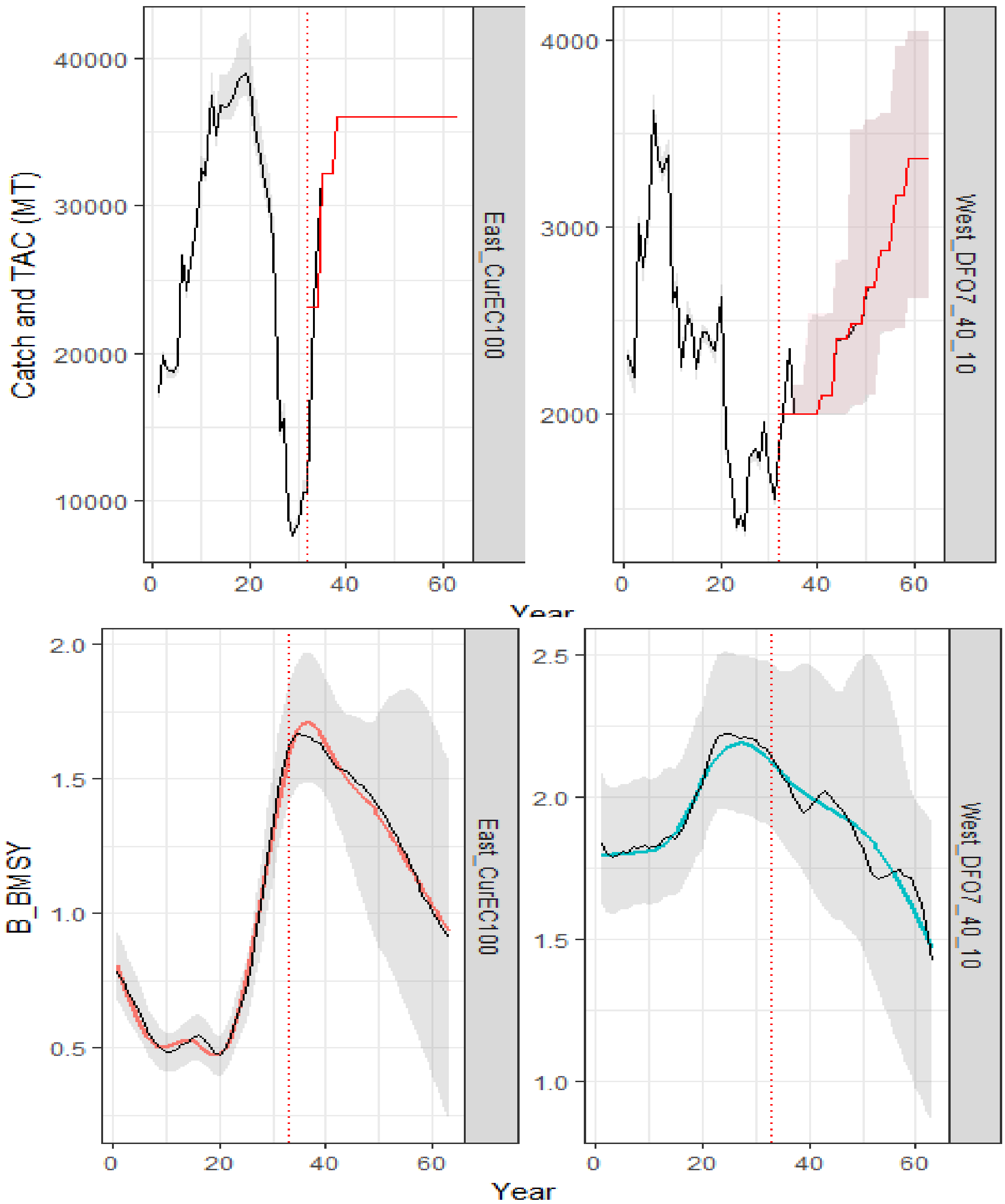
7. T2750_1130 determines the probability that the catch is at least 2750 MT in years 11 to 30. Performance > 60% is preferred. pp = 2 = West.

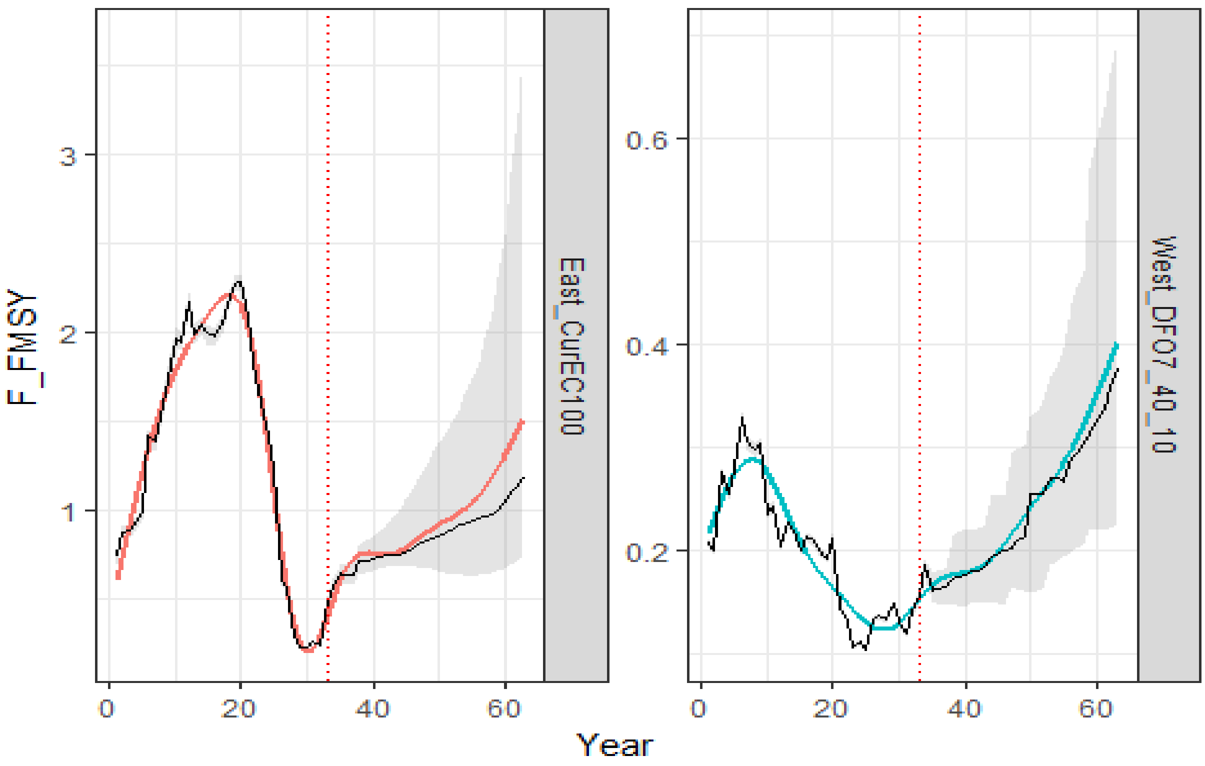
8. AVC10 determines if the annual change in yield over the 30 year projected time period is less than 10%. Performance > 60% is preferred.

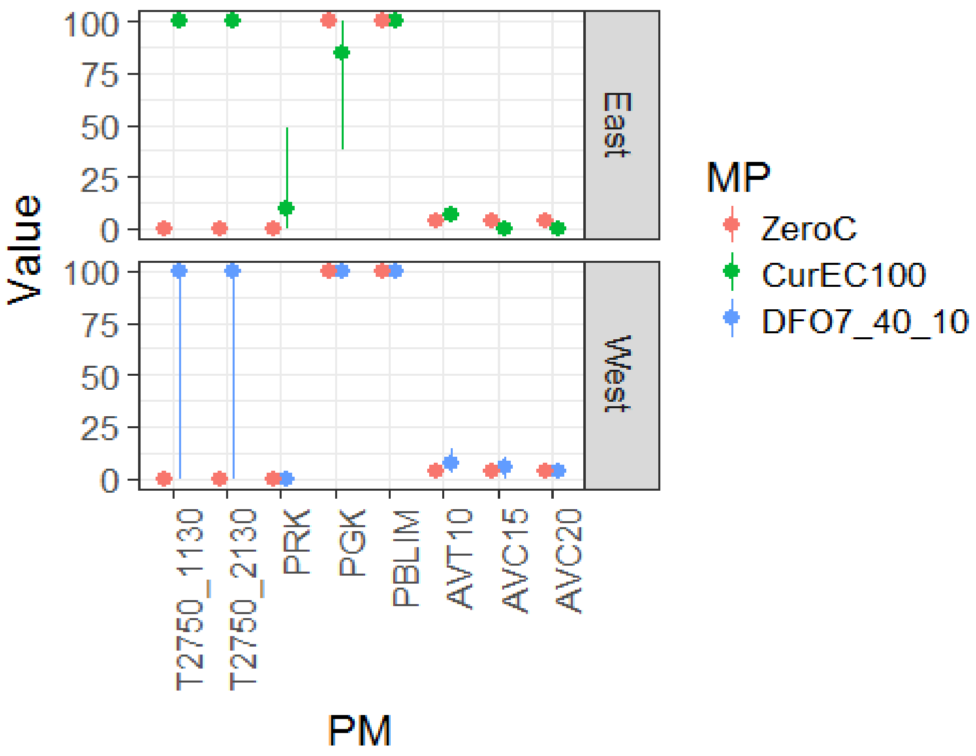
9. AVC15 determines if the annual change in yield over the 30 year projected time period is less than 15%. Performance > 60% is preferred.

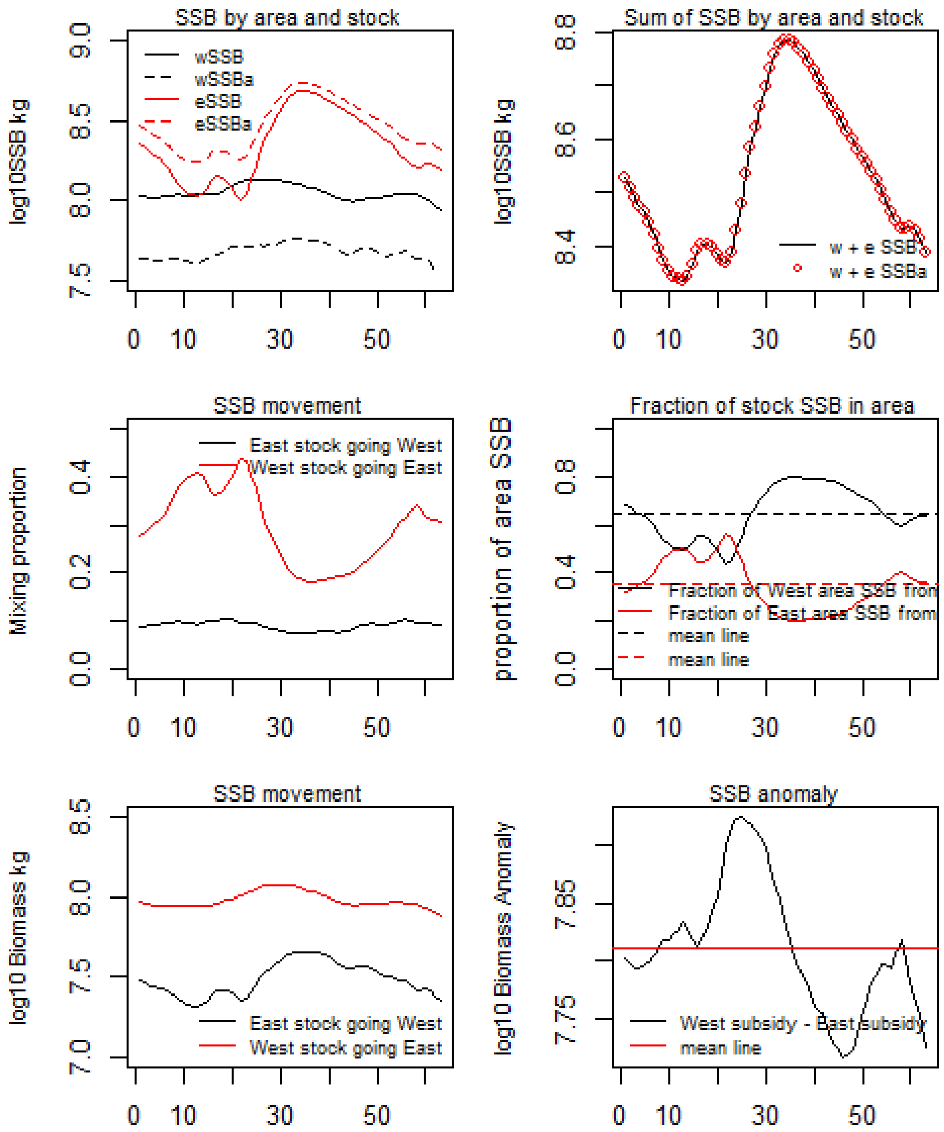
10. AVC20 determines if the annual change in yield over the 30 year projected time period is less than 20%. Performance > 60% is preferred.

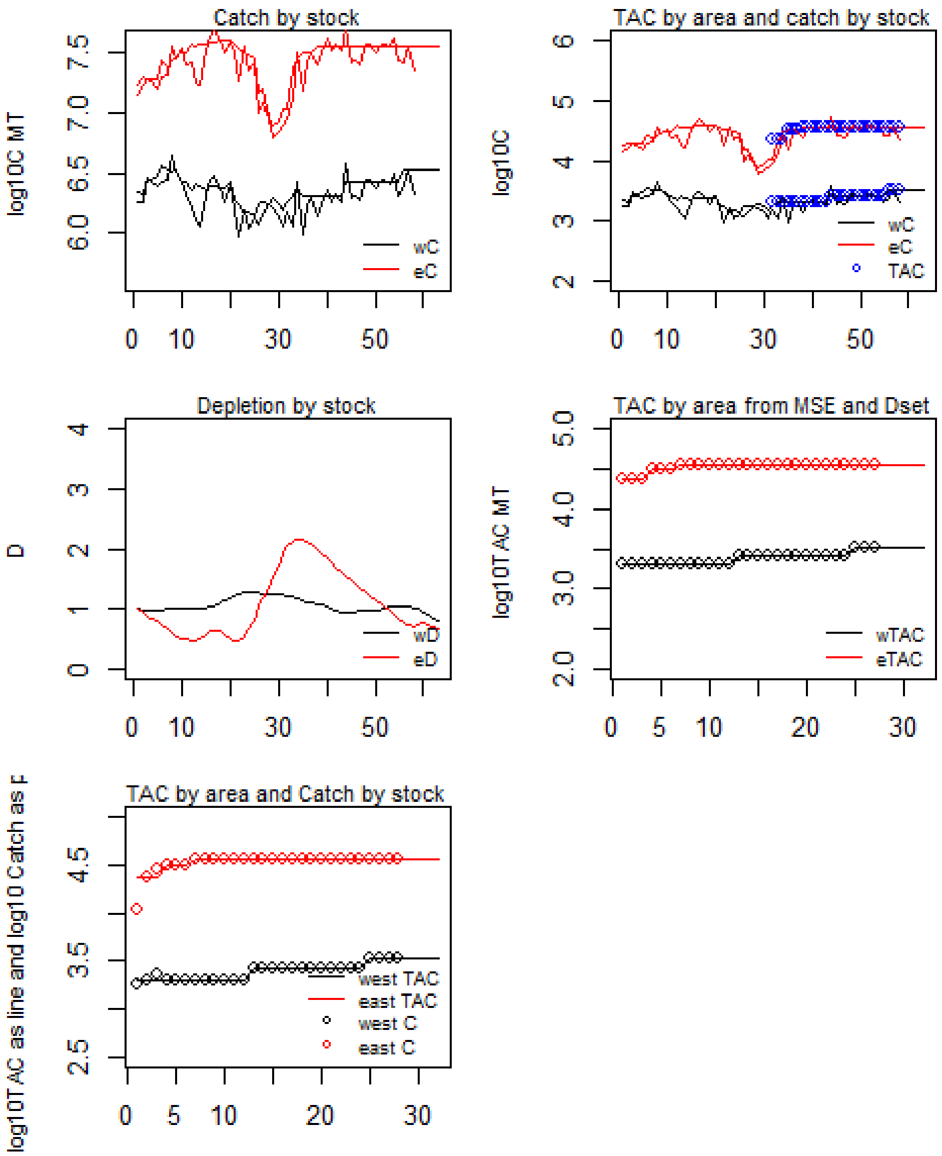
11. AVT10 determines the probability that the annual change in TAC over the 30 year projected time period is less than 10%. Performance > 60% is preferred.

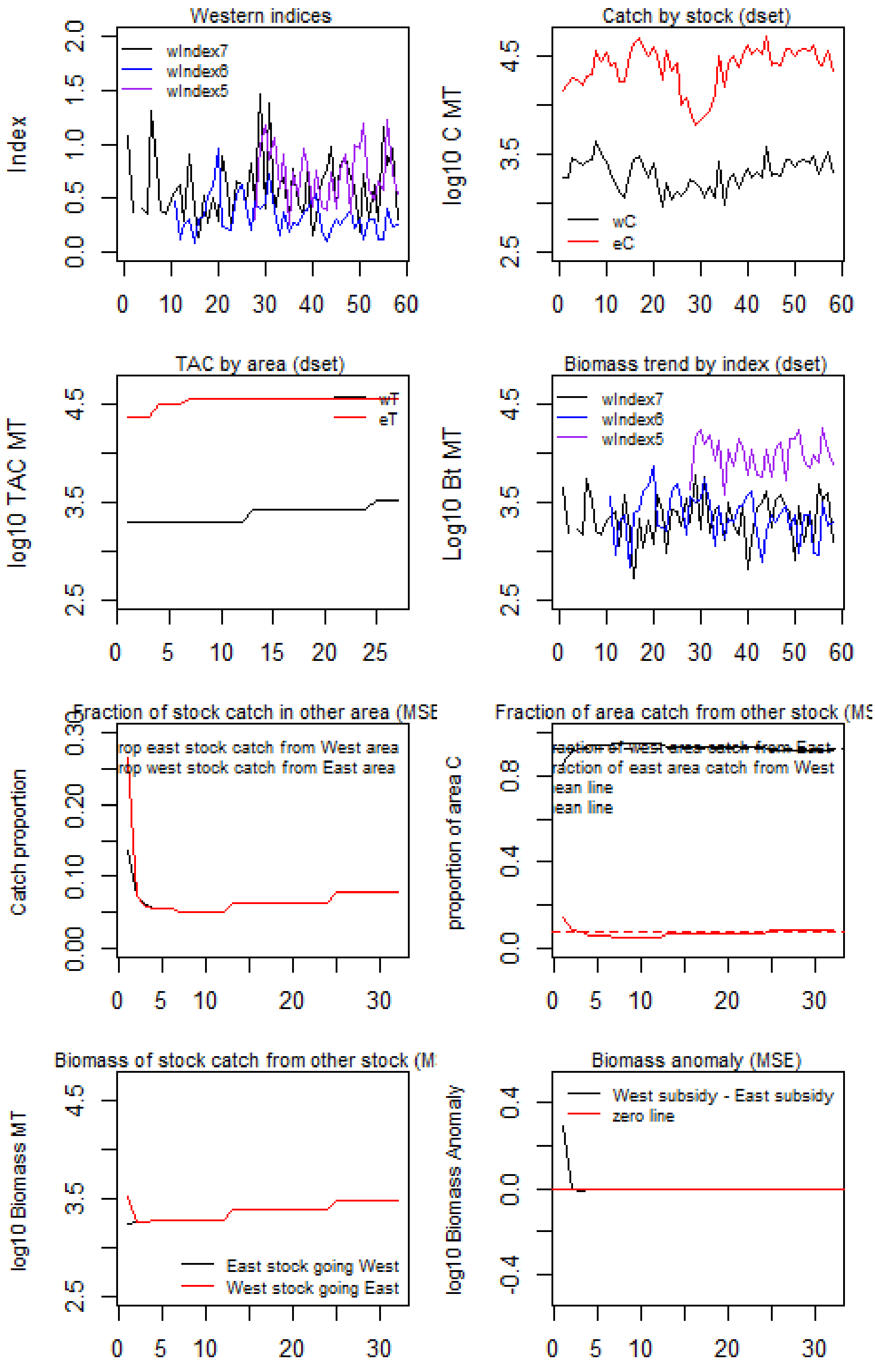

Catch and TAC (MT)
East_CurEC100
West_DFO7_40_10
Year
B_BMSY
East_CurEC100
West_DFO7_40_10
Year


F_FMSY
East_CurEC100
West_DFO7_40_10
Year

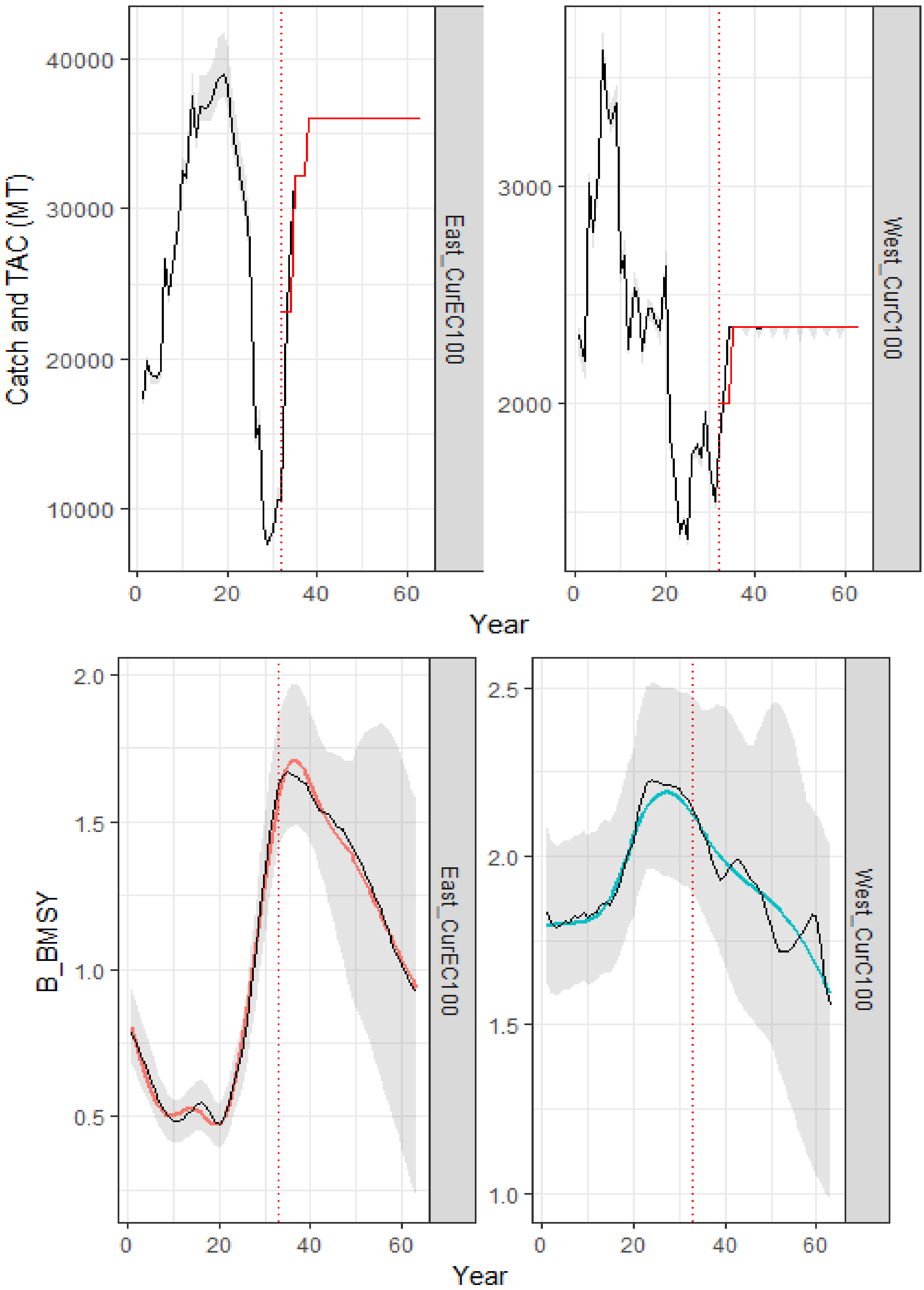

Value
East
West
MP
ZeroC
CurEC100
DFO7_40_10
T2750_1130
T2750_2130
PRK
PGK
PBLIM
AVT10
AVC15
AVC20
PM

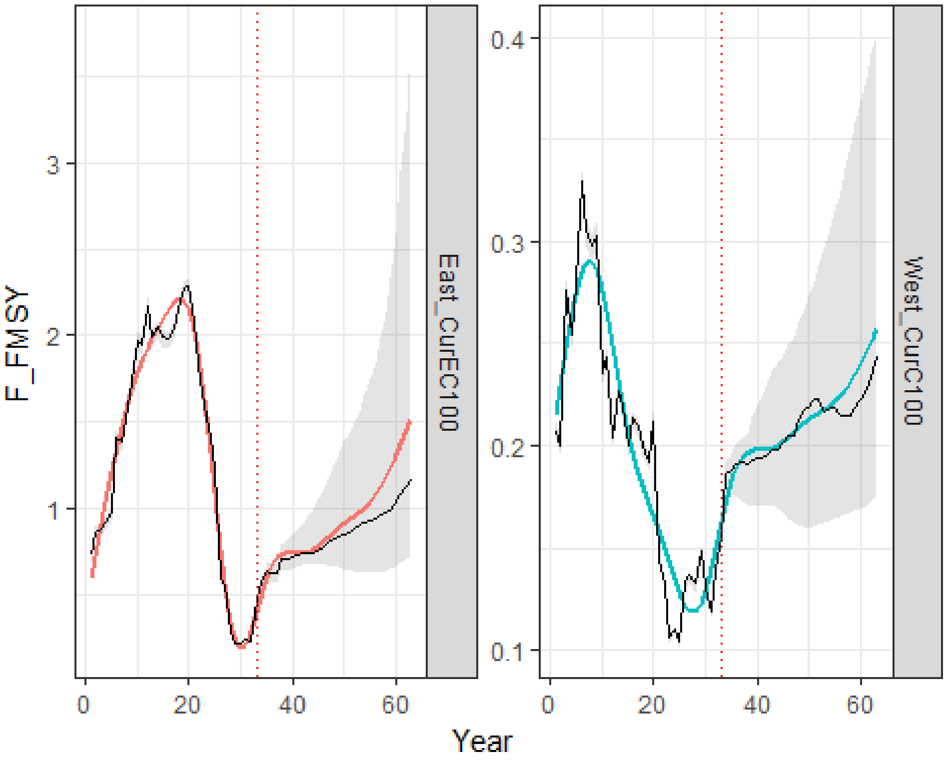

SSB by area and stock
log10SSB kg
wSSB
wSSBa
eSSB
eSSBa
Sum of SSB by area and stock
log10SSB kg
w + e SSB
w + e SSBa
SSB movement
Mixing proportion
East stock going West
West stock going East
Fraction of stock SSB in area
proportion of area SSB
mean line
mean line
SSB movement
log10 Biomass kg
East stock going West
West stock going East
SSB anomaly
log10 Biomass Anomaly
West subsidy - East subsidy
mean line


Catch by stock
log10C MT
wC
eC
TAC by area and catch by stock
log10C
wC
eC
TAC
Depletion by stock
D
wD
eD
TAC by area from MSE and Dset
log10TAC MT
wTAC
eTAC
TAC by area and Catch by stock
log10TAC as line and log10 Catch as p
west TAC
east TAC
west C
east C

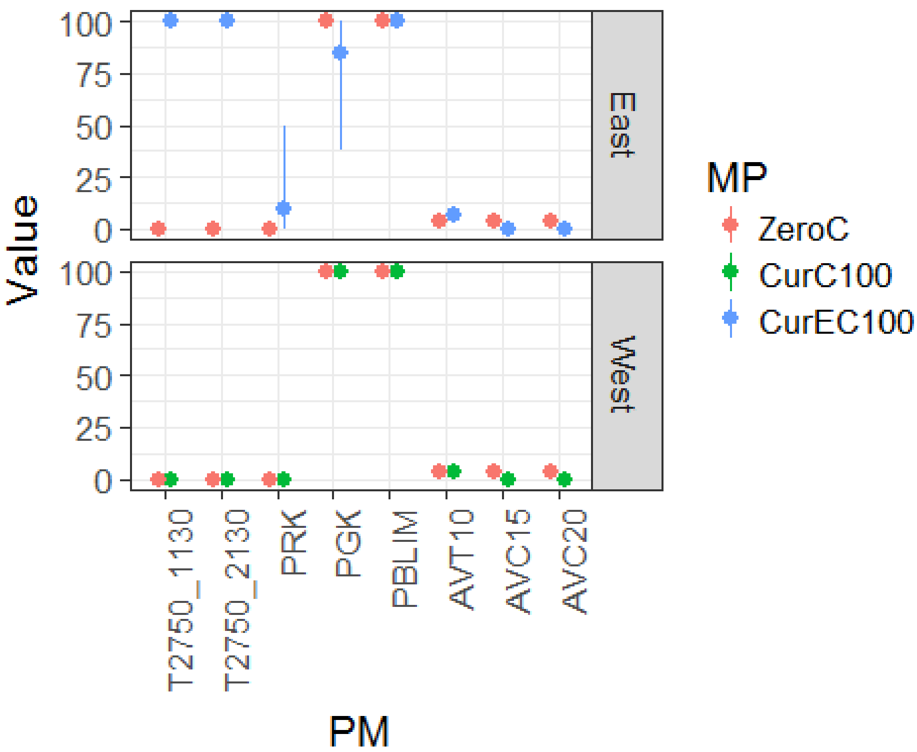

Western indices
Index
wIndex7
wIndex6
wIndex5
Catch by stock (dset)
log10 C MT
wC
eC
TAC by area (dset)
log10 TAC MT
wT
eT
Biomass trend by index (dset)
Log10 Bt MT
wIndex7
wIndex6
wIndex5
Fraction of stock catch in other area (MSE
Catch proportion
rop east stock catch from West area
rop west stock catch from East area
Fraction of area catch from other stock (MS
proportion of area C
raction of east area catch from West
ean line
ean line
Biomass of stock catch from other stock (M
log10 Biomass MT
East stock going West
West stock going East
Biomass anomaly (MSE)
log10 Biomass Anomaly
West subsidy - East subsidy
zero line

Current catch for both stocks.

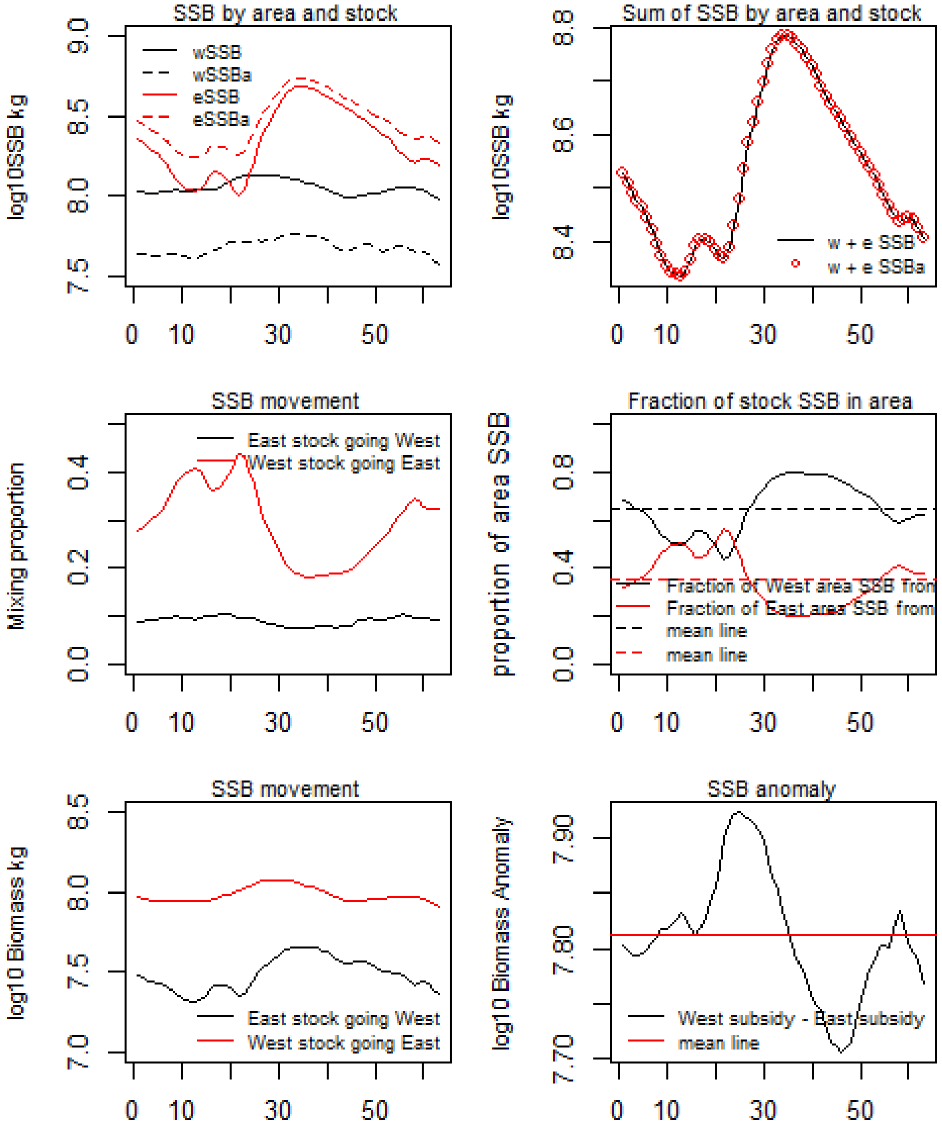


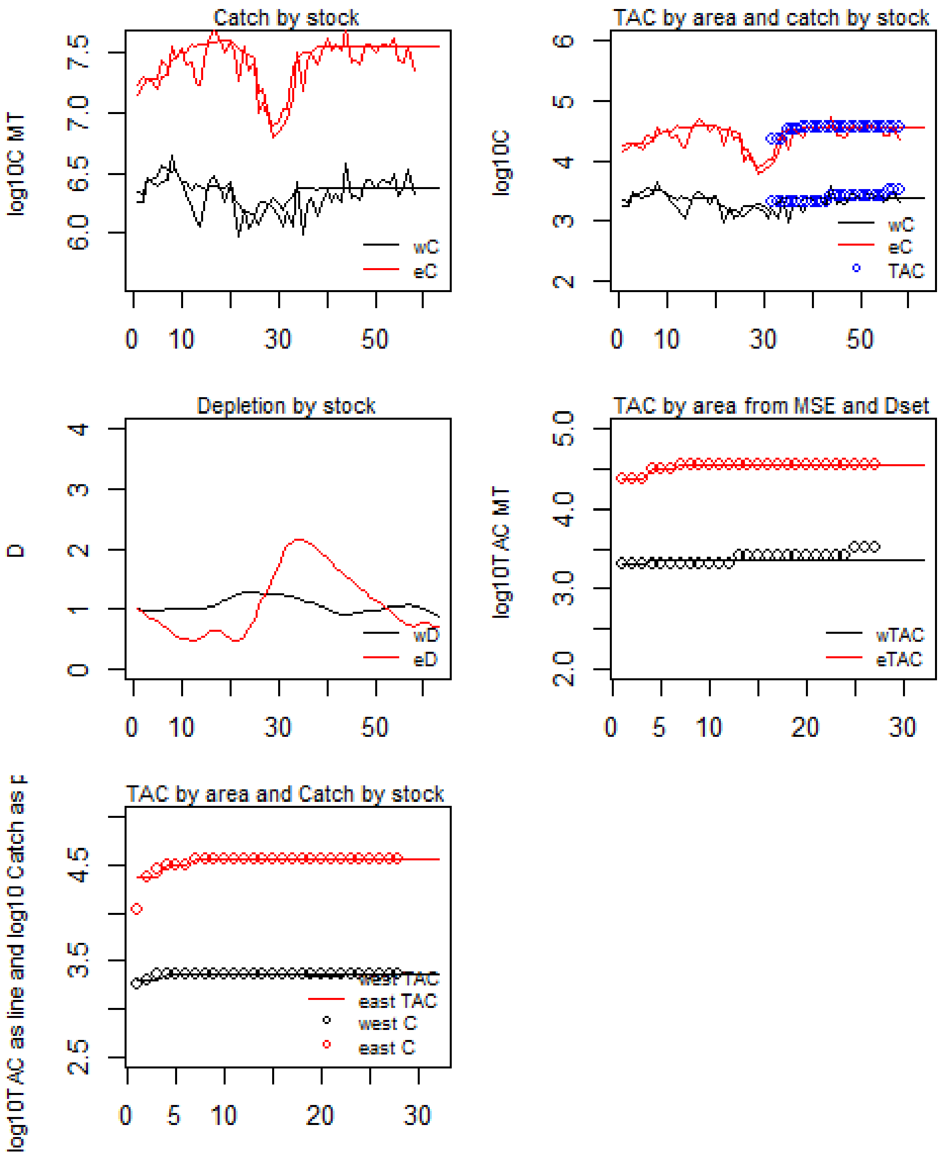


F_FMSY
East_CurEC100
West_CurC100
Year

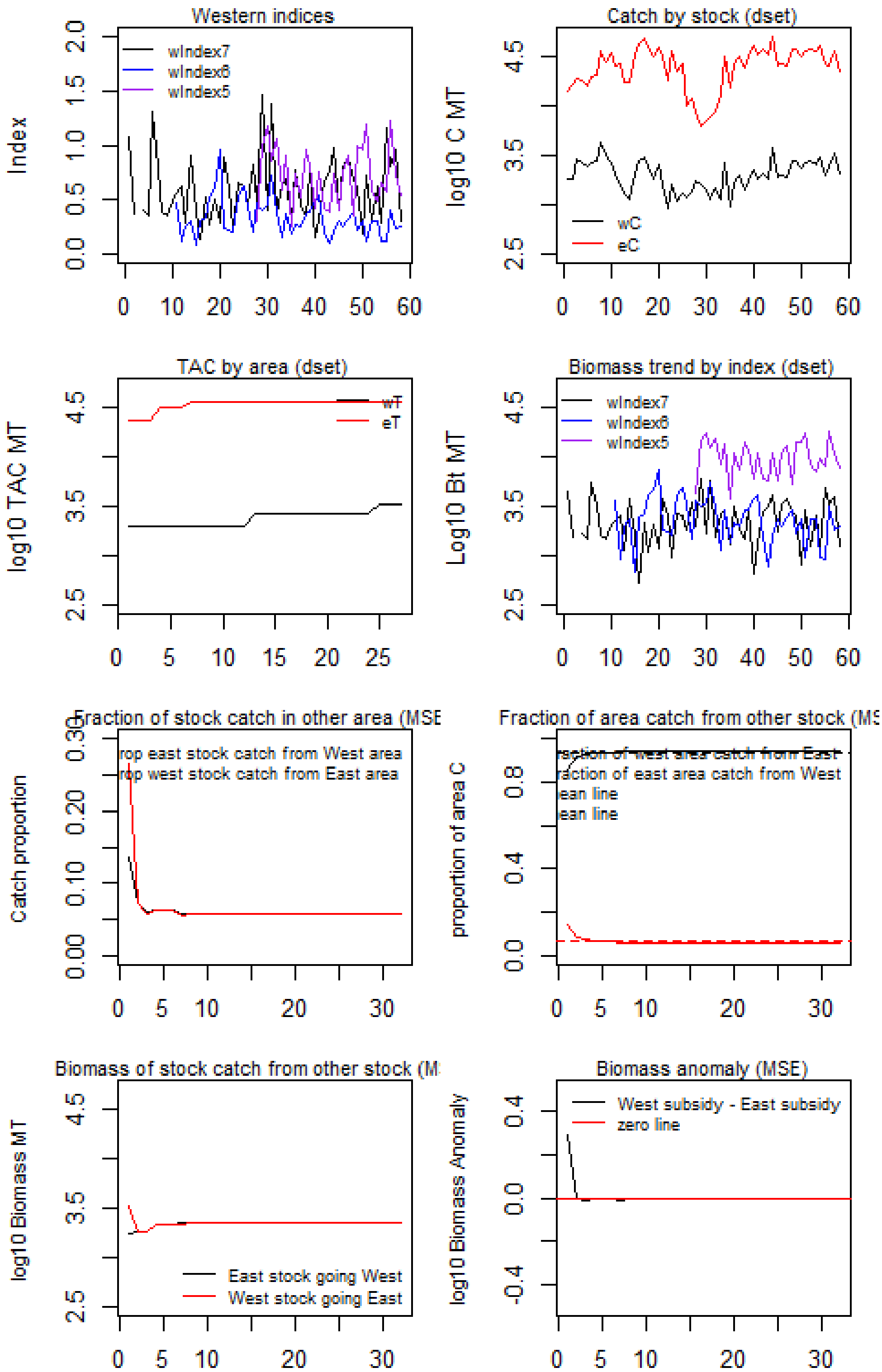


Value
East
West
MP
ZeroC
CurC100
CurEC100
T2750_1130
T2750_2130
PRK
PGK
PBLIM
AVT10
AVC15
AVC20
PM

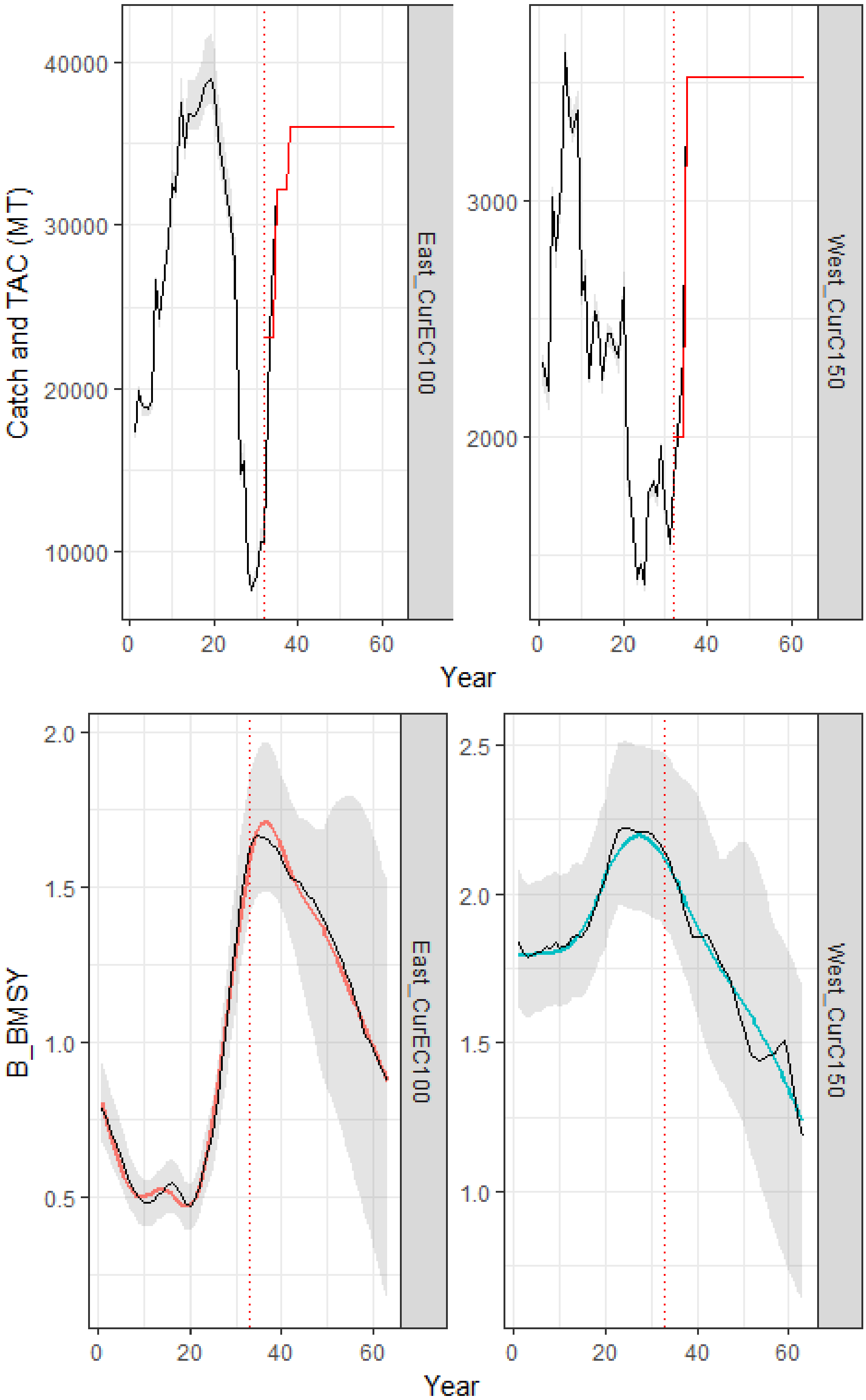

SSB by area and stock
log10SSB kg
wSSB
wSSBa
eSSB
eSSBa
Sum of SSB by area and stock
log10SSB kg
w + e SSB
w + e SSBa
SSB movement
Mixing proportion
East stock going West
West stock going East
Fraction of stock SSB in area
proportion of area SSB
Fraction of West area SSB from
Fraction of East area SSB from
mean line
mean line
SSB movement
log10 Biomass kg
East stock going West
West stock going East
SSB anomaly
log10 Biomass Anomaly
West subsidy - East subsidy
mean line

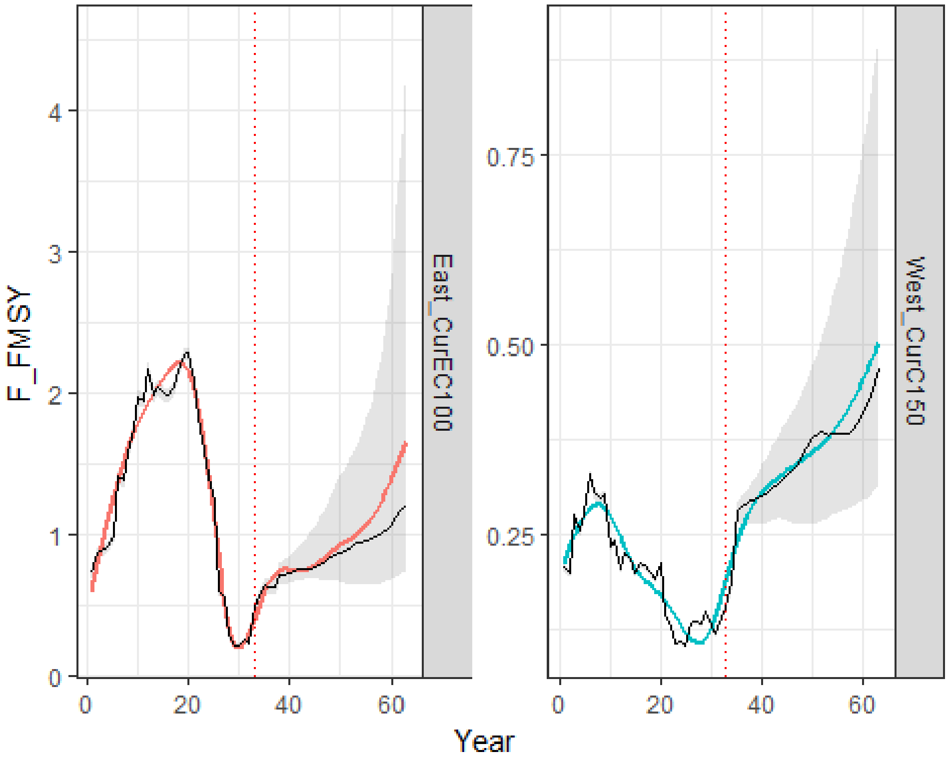


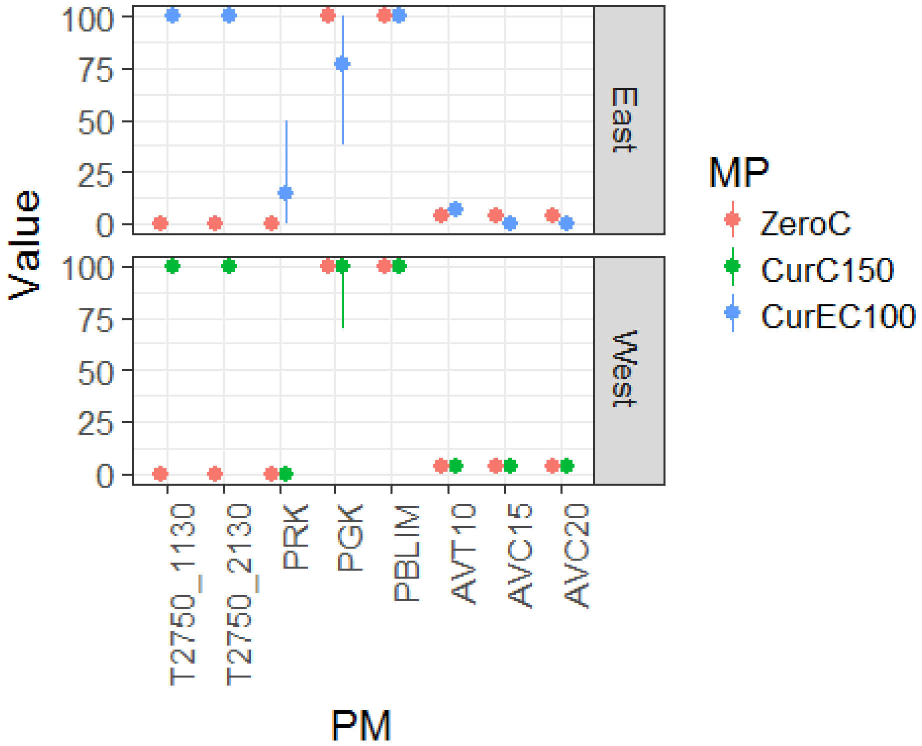
Catch by stock
log10C MT
6.0
6.5
7.0
7.5
0
10
30
50
wC
eC
TAC by area and catch by stock
log10C
2
3
4
5
6
0
10
30
50
wC
eC
TAC
Depletion by stock
D
0
1
2
3
4
0
10
30
50
wD
eD
TAC by area from MSE and Dset
log10T AC MT
2.0
3.0
4.0
5.0
0
5
10
20
30
wTAC
eTAC
TAC by area and Catch by stock
log10T AC as line and log10 Catch as p
2.5
3.5
4.5
0
5
10
20
30
west TAC
east TAC
west C
east C

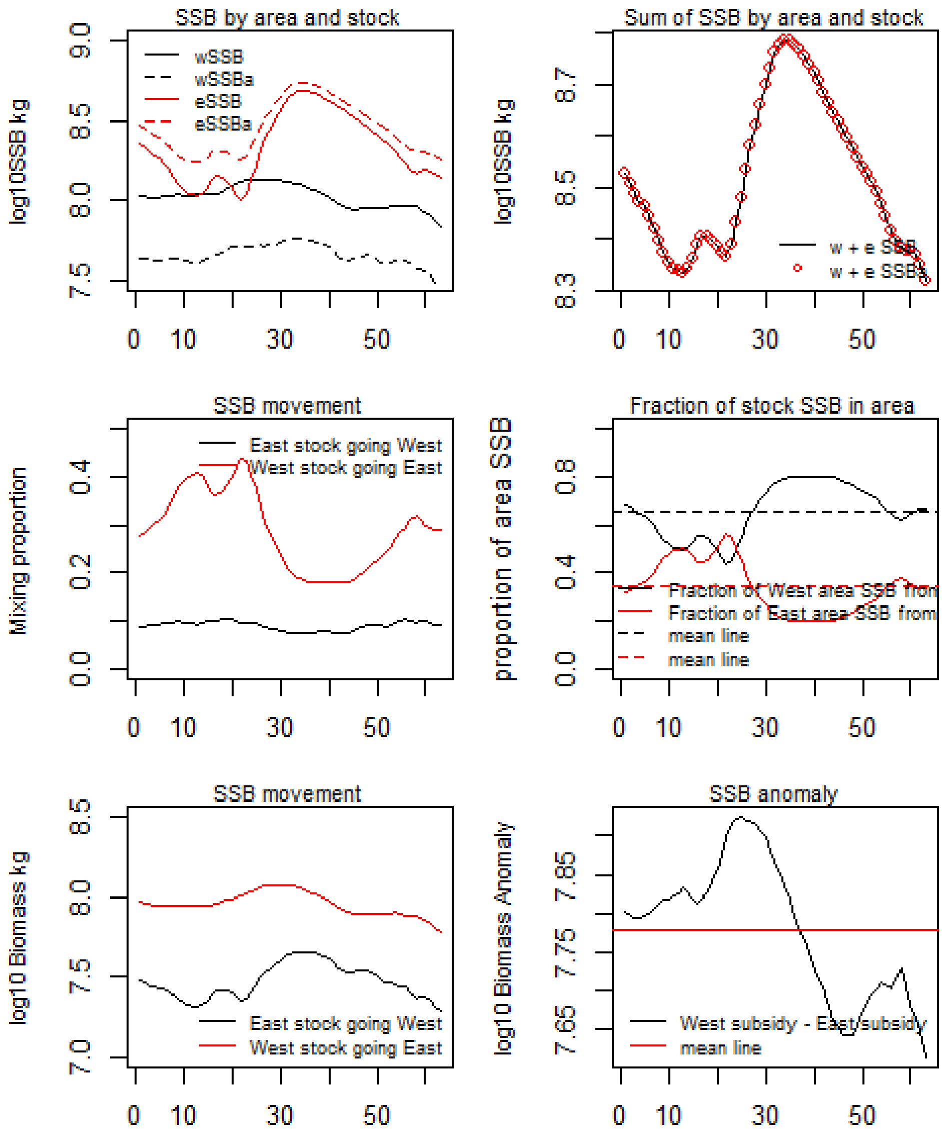

Western indices
Index
wIndex7
wIndex6
wIndex5
Catch by stock (dset)
log10 C MT
wC
eC
TAC by area (dset)
log10 TAC MT
wT
eT
Biomass trend by index (dset)
Log10 Bt MT
wIndex7
wIndex6
wIndex5
Fraction of stock catch in other area (MSE
Catch proportion
rop east stock catch from West area
rop west stock catch from East area
Fraction of area catch from other stock (MS
proportion of area C
raction of east area catch from West
ean line
ean line
Biomass of stock catch from other stock (M
log10 Biomass MT
East stock going West
West stock going East
Biomass anomaly (MSE)
log10 Biomass Anomaly
West subsidy - East subsidy
zero line

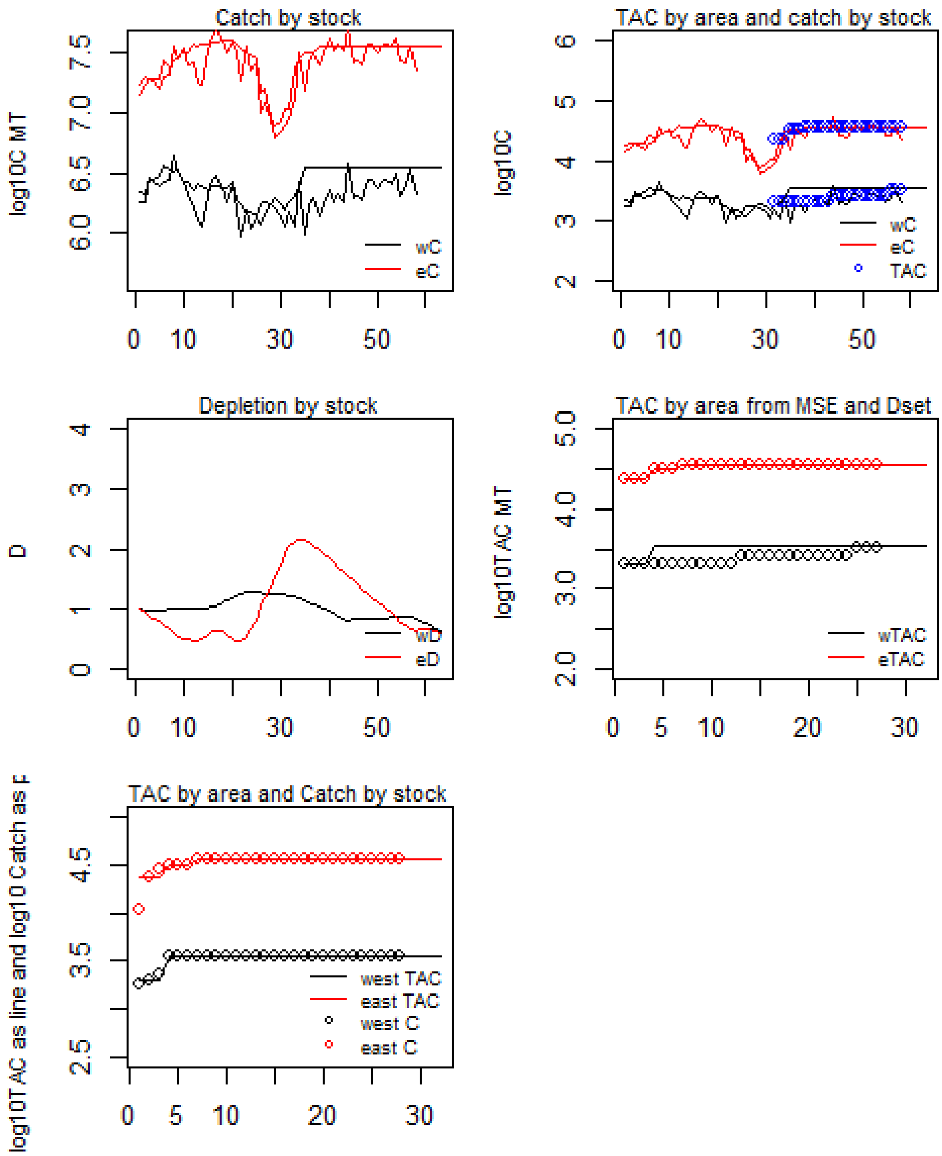
Catch for the western stock is 50% higher than current.



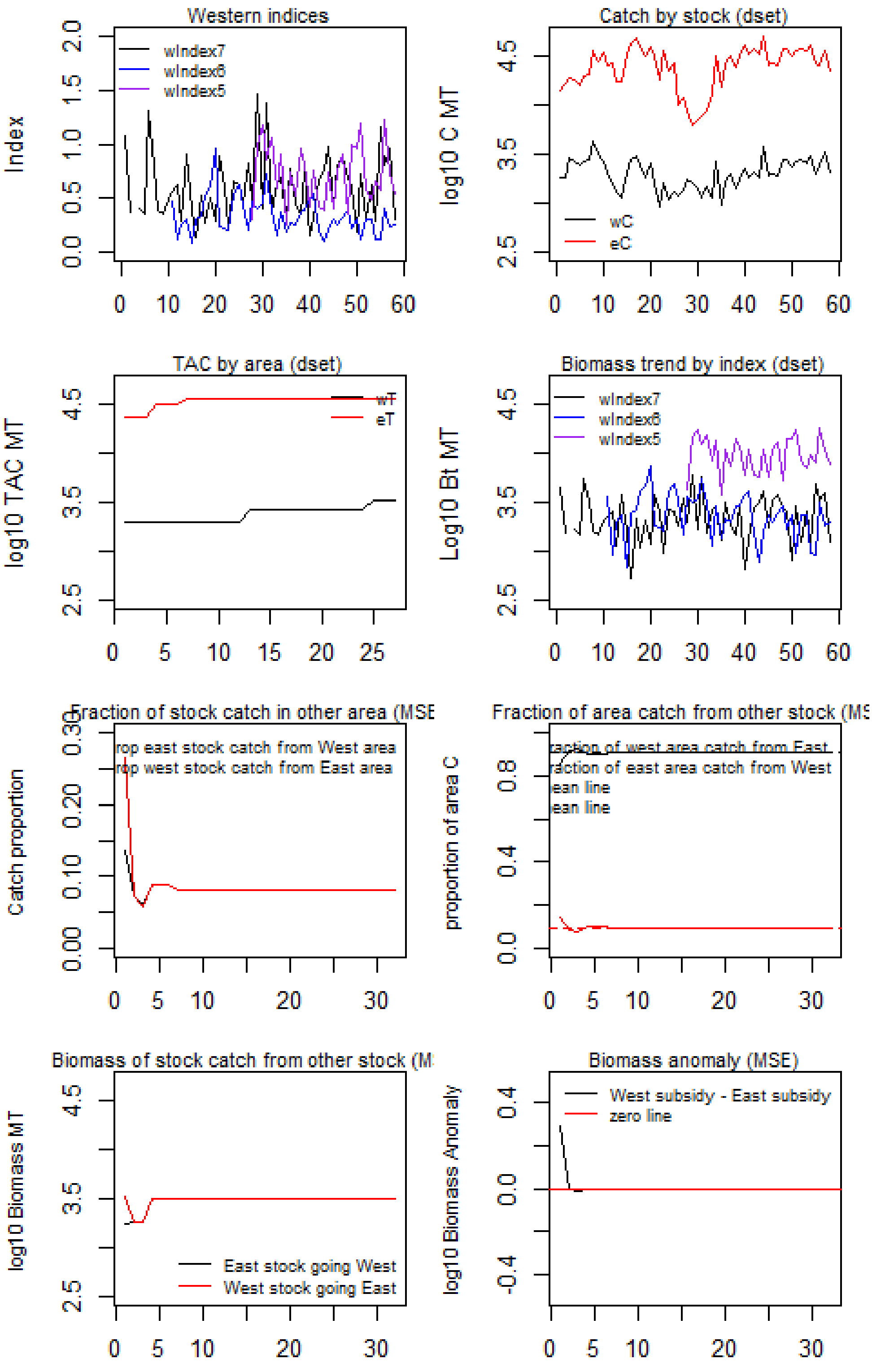

F_FMSY
4
3
2
1
0
East_CurEC100
0.75
0.50
0.25
West_CurC150
0
20
40
60
Year


Value
100
75
50
25
0
East
West
T2750_1130
T2750_2130
PRK
PGK
PBLIM
AVT10
AVC15
AVC20
PM
MP
ZeroC
CurC150
CurEC100

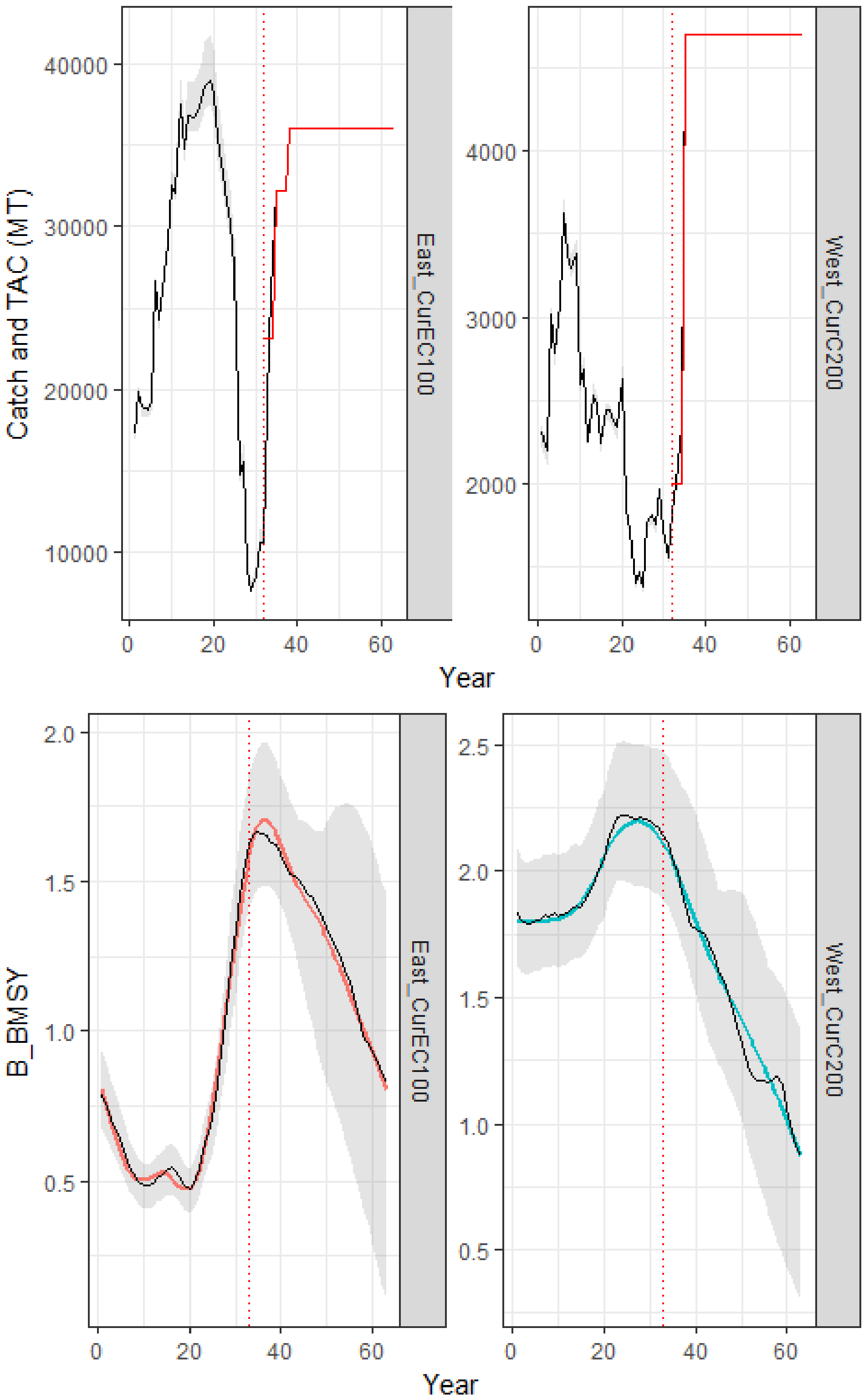

SSB by area and stock
log10SSB kg
9.0
8.5
8.0
7.5
wSSB
wSSBa
eSSB
eSSBa
0
10
30
50
Sum of SSB by area and stock
log10SSB kg
8.7
8.5
8.3
w + e SSB
w + e SSBa
SSB movement
Mixing proportion
0.4
0.2
0.0
East stock going West
West stock going East
Fraction of stock SSB in area
proportion of area SSB
0.8
0.4
0.0
Fraction of West area SSB fron
Fraction of East area SSB from
mean line
mean line
SSB movement
log10 Biomass kg
8.5
8.0
7.5
7.0
East stock going West
West stock going East
SSB anomaly
log10 Biomass Anomaly
7.85
7.75
7.65
West subsidy - East subsidy
mean line

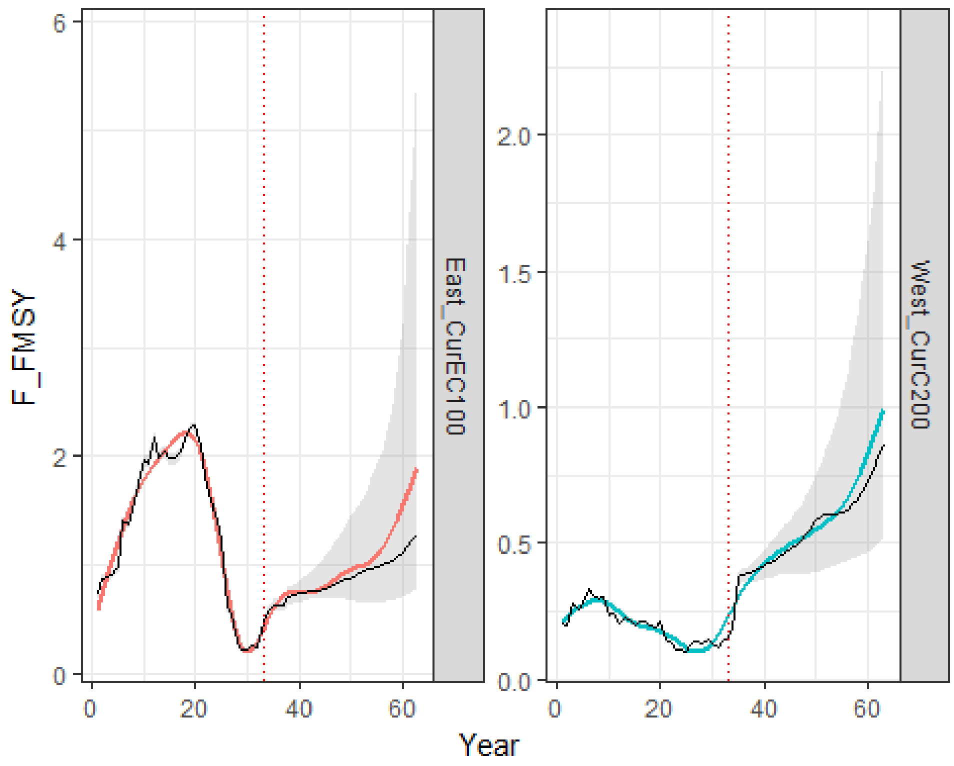


Catch by stock
log10C MT
wC
eC
TAC by area and catch by stock
log10C
wC
eC
TAC
Depletion by stock
D
wD
eD
TAC by area from MSE and Dset
log10TAC MT
wTAC
eTAC
TAC by area and Catch by stock
log10TAC as line and log10 Catch as p
west TAC
east TAC
west C
east C

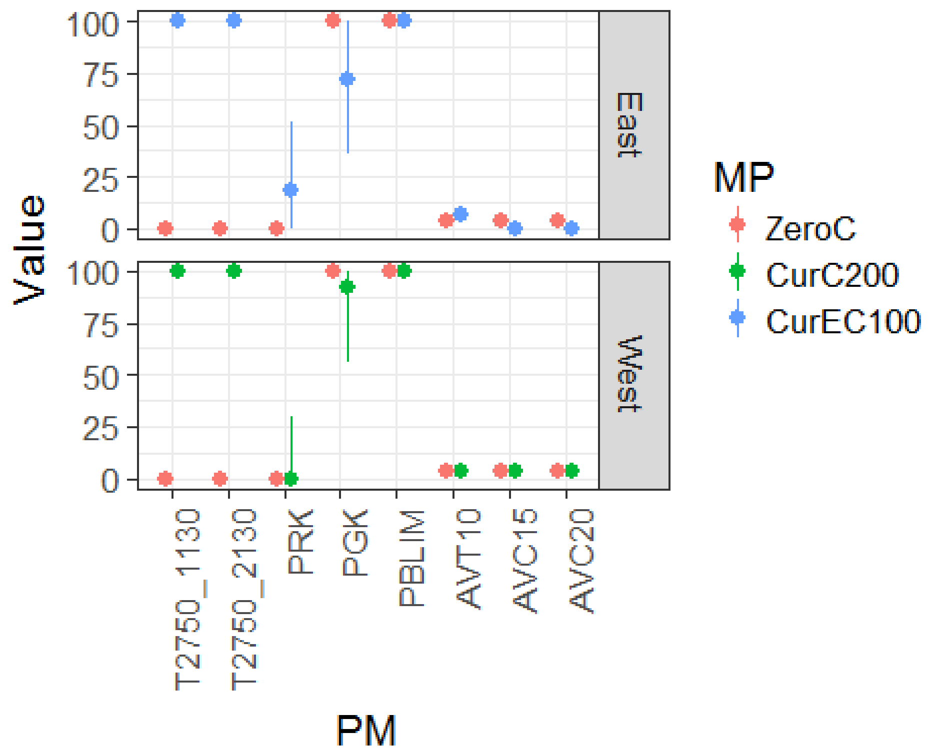

Western indices
Index
wIndex7
wIndex6
wIndex5
Catch by stock (dset)
log10 C MT
wC
eC
TAC by area (dset)
log10 TAC MT
wT
eT
Biomass trend by index (dset)
Log10 Bt MT
wIndex7
wIndex6
wIndex5
Fraction of stock catch in other area (MSE
Catch proportion
rop east stock catch from West area
rop west stock catch from East area
Fraction of area catch from other stock (MS
proportion of area C
raction of west area catch from East
raction of east area catch from West
ean line
ean line
Biomass of stock catch from other stock (M
log10 Biomass MT
East stock going West
West stock going East
Biomass anomaly (MSE)
log10 Biomass Anomaly
West subsidy - East subsidy
zero line

Catch for the western stock is 100% higher than current.





F_FMSY
Year
East_CurEC100
West_CurC200
0
2
4
6
0.0
0.5
1.0
1.5
2.0
0
20
40
60



Value
PM
East
West
MP
ZeroC
CurC200
CurEC100
0
25
50
75
100
T2750_1130
T2750_2130
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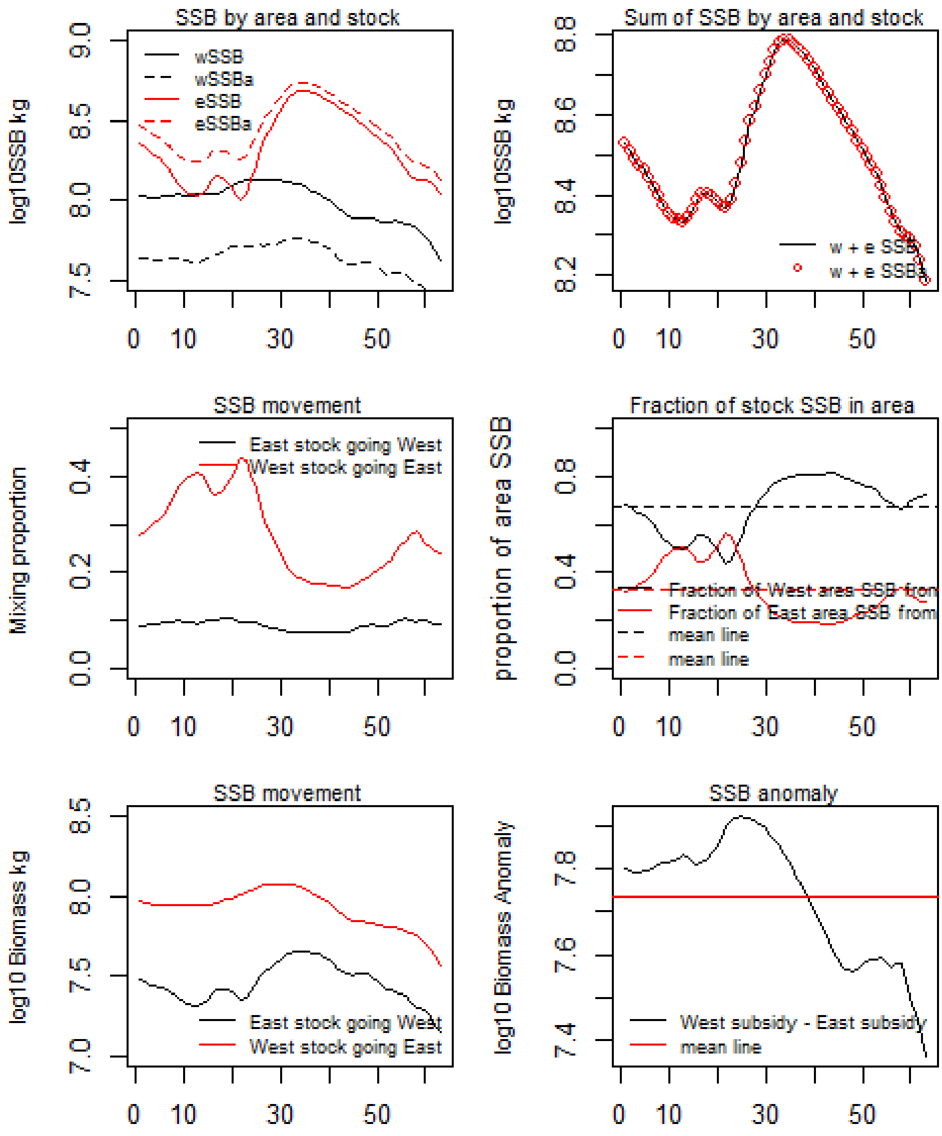
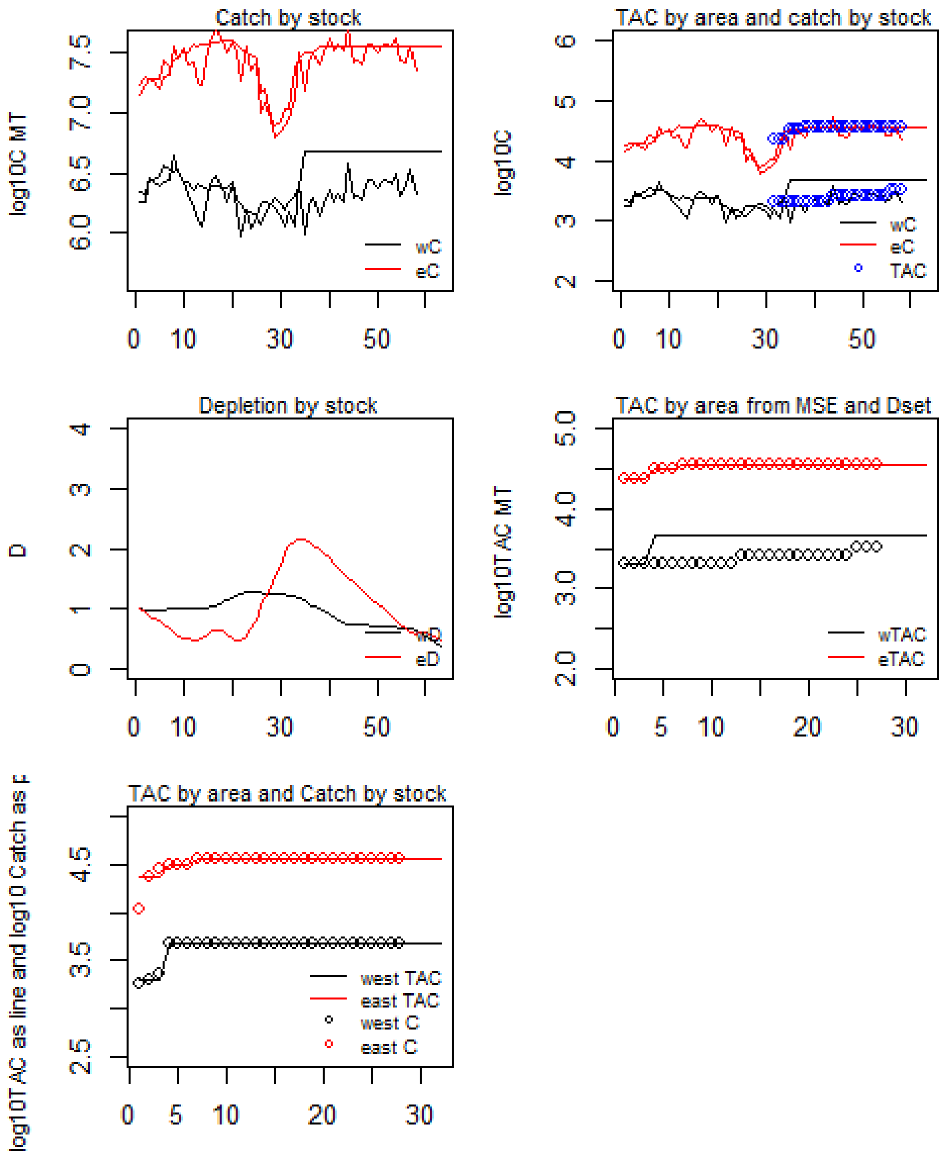
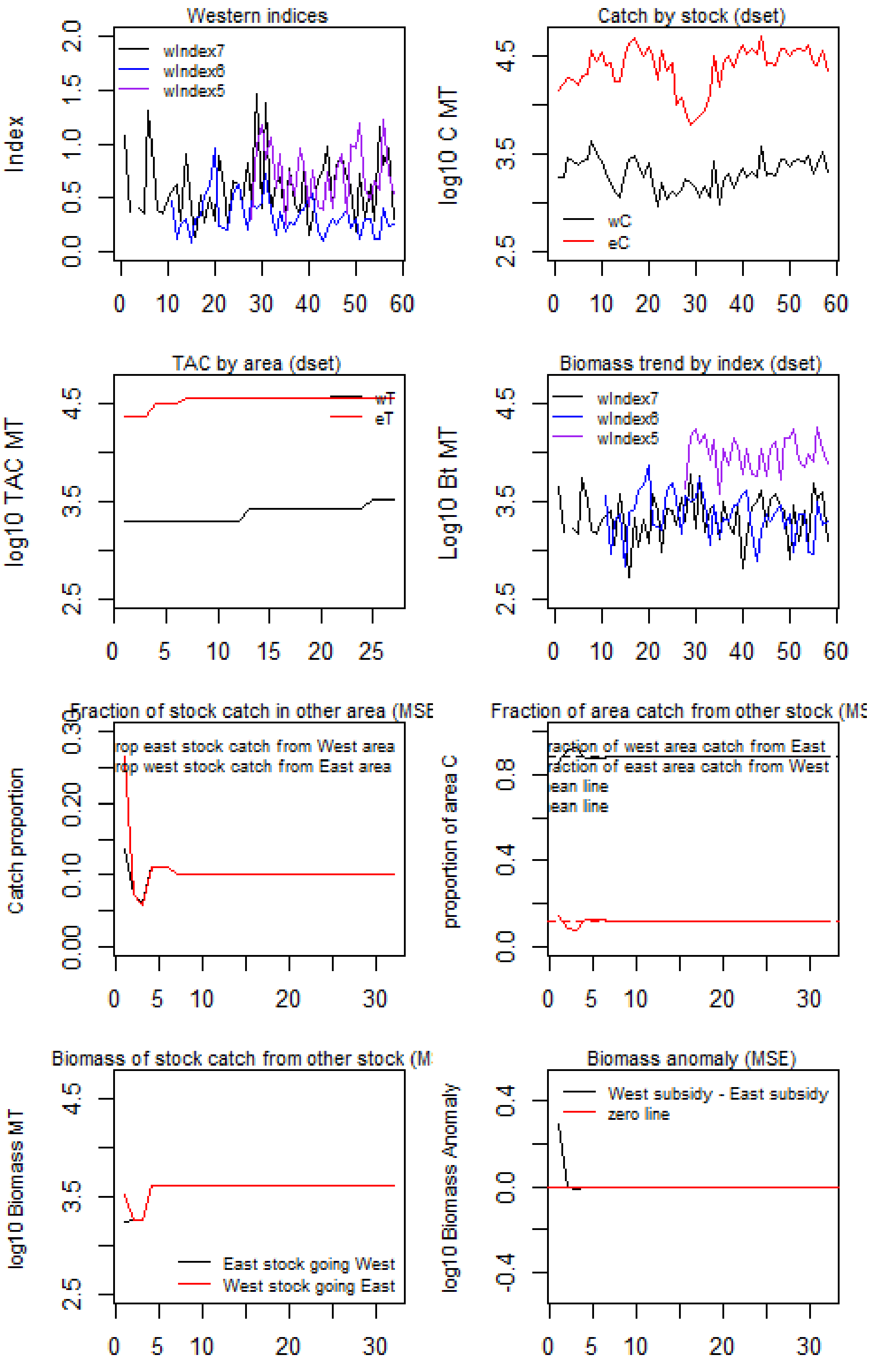
PGK
PBLIM
AVT10
AVC15
AVC20


SSB by area and stock
log10SSB kg
wSSB
wSSBa
eSSB
eSSBa
Sum of SSB by area and stock
log10SSB kg
w + e SSB
w + e SSBa
SSB movement
Mixing proportion
East stock going West
West stock going East
Fraction of stock SSB in area
proportion of area SSB
Fraction of West area SSB fron
Fraction of East area SSB from
mean line
mean line
SSB movement
log10 Biomass kg
East stock going West
West stock going East
SSB anomaly
log10 Biomass Anomaly
West subsidy - East subsidy
mean line


Catch by stock
log10C MT
wC
eC
TAC by area and catch by stock
log10C
wC
eC
TAC
Depletion by stock
D
wD
eD
TAC by area from MSE and Dset
log10TAC MT
wTAC
eTAC
TAC by area and Catch by stock
log10TAC as line and log10 Catch as p
west TAC
east TAC
west C
east C


Western indices
wIndex7
wIndex6
wIndex5
Index
Catch by stock (dset)
wC
eC
log10 C MT
TAC by area (dset)
wT
eT
log10 TAC MT
Biomass trend by index (dset)
wIndex7
wIndex6
wIndex5
Log10 Bt MT
Fraction of stock catch in other area (MSE
rop east stock catch from West area
rop west stock catch from East area
Catch proportion
Fraction of area catch from other stock (MS
raction of west area catch from East
raction of east area catch from West
ean line
ean line
proportion of area C
Biomass of stock catch from other stock (M
East stock going West
West stock going East
log10 Biomass MT
Biomass anomaly (MSE)
West subsidy - East subsidy
zero line
log10 Biomass Anomaly

```
# Candidate management procedures and performance metrics
# A.R. Hanke, Feb. 28, 2018

###########################
### Performance metrics          ###
###########################

# PRK determines the probability that B<BMSY & F>FMSY, over the
# 30 year projected time period. Performance < 10% is preferred.
PRK =
function (MSE, pp = 1)
{apply(MSE@F_FMSY[, , pp, MSE@nyears + 1:30] > 1 &
        MSE@B_BMSY[,, pp, MSE@nyears + 1:30] < 1, 1:2, mean) * 100}

class(PRK)<-'PM'

# PGK determines the probability that B>BMSY & F<FMSY, over the
# 30 year projected time period. Performance > 60% is preferred.
# ***This PM function already exists!***

#TAC[nsim x MP x stock x proyear]
#C[MP x nsim x nstocks x nyears]

# C2750_2130 determines the probability that the catch is at least 2750 MT
# in years 21 to 30. Performance > 60% is prefered. pp = 2 = West.
C2750_2130 =
  function (MSE, pp = 2)
    {apply(MSE@C[, , pp, MSE@nyears + 21:30]>=2750000, 1:2, mean)*100}

class(C2750_2130)<-'PM'

# C2750_1130 determines the probability that the catch is at least 2750 MT
# in years 11 to 30. Performance > 60% is preferred. pp = 2 = West.
C2750_1130 =
  function (MSE, pp=2 )
    {apply(MSE@C[, , pp, MSE@nyears + 21:30]>=2750000, 1:2, mean)*100}

class(C2750_1130)<-'PM'

# T2750_2130 determines the probability that the TAC is at least 2750 MT
# in years 21 to 30. Performance > 60% is preferred. pp = 2 = West.
T2750_2130 =
  function (MSE, pp = 2)
  {apply(MSE@TAC[, , pp, 2 + 21:30]>=2750000, c(2,1), mean)*100}

class(T2750_2130)<-'PM'

# T2750_1130 determines the probability that the catch is at least 2750 MT
# in years 11 to 30. Performance > 60% is preferred. pp = 2 = West.
T2750_1130 =
  function (MSE, pp=2 )
  {apply(MSE@TAC[, , pp, 2 + 21:30]>=2750000, 2:1, mean)*100}

class(T2750_1130)<-'PM'


# PBLIM determines the probability that the stock biomass is below BLIM over
# the projected 30 year time period. Blim is .1*BMSY and performance <5% is preferred.
PBLIM =
  function(MSE, pp=1, lim = .1)
```

```
  {apply(MSE@B_BMSY[, , pp, MSE@nyears + 1:30]>lim, 1:2, mean)*100}

class(PBLIM)<-'PM'

# AVC10 determines if the annual change in yield over the 30 year projected time
# period is less than 10%. Performance > 60% is preferred.
AVC10 =
function (MSE, pp = 1)
 { ind1 <- MSE@nyears + 1:(MSE@proyears - 1)
  ind <- MSE@nyears + 2:MSE@proyears
  C <- MSE@C[, , pp, ]
  C[C == 0] <- tiny
  apply((abs(C[, , ind] - C[, , ind1])/C[, , ind1])>.1, 1:2,
      sum, na.rm = T)/length(ind) * 100}

class(AVC10) = 'PM'

# AVC15 determines if the annual change in yield over the 30 year projected time
# period is less than 15%. Performance > 60% is preferred.
AVC15 =
 function (MSE, pp = 1)
 { ind1 <- MSE@nyears + 1:(MSE@proyears - 1)
 ind <- MSE@nyears + 2:MSE@proyears
 C <- MSE@C[, , pp, ]
 C[C == 0] <- tiny
 apply((abs(C[, , ind] - C[, , ind1])/C[, , ind1])>.15, 1:2,
     sum, na.rm = T)/length(ind) * 100}

class(AVC15) = 'PM'

# AVC20 determines if the annual change in yield over the 30 year projected time
# period is less than 20%. Performance > 60% is preferred.
AVC20 =
 function (MSE, pp = 1)
 { ind1 <- MSE@nyears + 1:(MSE@proyears - 1)
 ind <- MSE@nyears + 2:MSE@proyears
 C <- MSE@C[, , pp, ]
 C[C == 0] <- tiny
 apply((abs(C[, , ind] - C[, , ind1])/C[, , ind1])>.2, 1:2,
     sum, na.rm = T)/length(ind) * 100}

class(AVC20) = 'PM'

# AVT10 determines the probability that the annual change in TAC over the 30 year projected time
# period is less than 10%. Performance > 60% is preferred.
AVT10 =
 function (MSE, pp = 2)
 { ind1 <- 2 + 1:(MSE@proyears - 1)
 ind <- 2 + 2:MSE@proyears
 T <- MSE@TAC[, , pp, ]
 T[T == 0] <- tiny
 apply((abs(T[, , ind] - T[, , ind1])/T[, , ind1])>.1, 2:1,
     sum, na.rm = T)/(MSE@proyears-1) * 100}

class(AVT10) = 'PM'
```

```
##############################
### Management Procedures              ###
##############################

# Constant catch that is 100% greater than current catch
CurC200 =
  function(x,dset){
    dset$curTAC[x] * 2
  }

class(CurC200) = 'MP'
environment(CurC200) <- asNamespace('ABTMSE')

# Eastern Recommended TAC. Current TAC recommendations, where last TAC held constant.
CurEC100 =
  function(x,dset){
    ny <- length(dset$Cobs[x, ])

    if(ny == 33) TAC = 23155000 # 2017
    if(ny == 34) TAC = 28200000 # 2018
    if(ny == 34) TAC = 32240000 # 2019
    if(ny == 35) TAC = 36000000 # 2020
    if(ny > 35)  TAC = 36000000
    TAC
    }

class(CurEC100) = 'MP'
environment(CurEC100) <- asNamespace('ABTMSE')

# By default DFO7_40_10 adjusts the TAC using index 7 (GOM_LAR_SUV).
# Adjustments are a function of the value of rat relative to references
# points (.1, .4 and 1 times I_dat/I_msy and the slope of the indicator.
#
# Other indices can be selected by changing the index ID.

DFO7_40_10 =
  function (x, dset, yrsmth = 4, lim = c(0.1, 0.4, 1), alp = c(0.5, 0.1, 0.3),
          IndexID = 7,
          I_base = c(7.237943e+00, 1.000000e-01, 3.384223e+01,
                   2.323167e+04, 1.917647e+00, 1.020295e+00,
                   5.455633e-01))
  { ny <- length(dset$Cobs[x, ])   # number of years of data
  ind <- (ny - (yrsmth - 1)):ny    # subset of years used in HCR
  yind <- 1:yrsmth                 # index of ind
  I_dat = dset$Iobs[x,IndexID,ind] # Index values for last yrsmth years
  I_msy = I_base[IndexID]/10        # assumes B/Bmsy=2 and I~B
  T_dat = dset$TAC[x, ]            # TAC

# slope of index over last yrsmth years
slope = coef(lm(scale(y,center = F) ~ scale(x, center = F),
               data=data.frame(x=yind, y=I_dat)))[2]

  #  slpadj = 180*atan(slope)/pi/45 # adjust to TAC increase based on trend

  TAC = T_dat[length(T_dat)]
  rat = I_dat[length(I_dat)]/I_msy

  # Healthy Zone rules
  if (rat >= lim[3]& sign(slope)<0)
    OFL = TAC
```

```
  if (rat >= lim[3]& sign(slope)>=0)
    OFL = (1+slope*alp[3])*TAC

  # Cautious Zone rules
  if (rat < lim[3] & rat >=lim[2] & sign(slope)<0)
    OFL = (1+slope*alp[2])*TAC
  if (rat < lim[3] & rat >=lim[2] & sign(slope)>=0)
    OFL = TAC

  # Critical Zone rules
  if (rat < lim[2] & rat >=lim[1])
    OFL = alp[1]*TAC
  if (rat<lim[1])
    OFL = 0
  if(OFL<=0)
    OFL = 0
  OFL}

class(DFO7_40_10) = 'MP'
environment(DFO7_40_10) <- asNamespace('ABTMSE')

######################################
# Implementation models             #############
######################################

# Perfect implementation
Underage_0 =
  function (U, over = 0, maxU = 0.9)
  {
    U <- U * (1 + over)
    U[U > maxU] <- maxU
    U
  }

class(Underage_0) = "IE"

# Underage of 10%
Underage_10 =
function (U, over = -0.1, maxU = 0.9)
{
  U <- U * (1 + over)
  U[U > maxU] <- maxU
  U
}

class(Underage_10) = "IE"
```