FLash:::fwd for stock projection

Laurence Kell

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Introduction

An important part of stock assessment is setting future management regulations, e.g. based on catches, effort or selectivity. Therefore often a stock or population (i.e. a projection) hmay be required after an assessment for a range of catches to allow managers to decide upon a TAC or within an MSE for a management measure set by an MP.

The precautionary approach[^books_be] requires harvest control rules (HCRs) to trigger pre-agreed conservation and management action. This requires limit reference points to set boundaries that constrain harvesting within safe biological limits within which stocks can produce the maximum sustainable yield (MSY) and targets to ensure that management objectives are met.

The performance of HCRs, i.e. how well they meet management objectives should be evaluated, ideally using Management Strategy Evaluation (MSE) where the HCRs is tested as part of a Management Procedure (MP). Where an MP is the combination of the data collection regime stock assessment procedure and the setting of managment regulations. HCRs can be modelled using the fwd method of FLR; see the MSE document for examples of simulation testing.

fwd takes objects descibing historical stock status and assumptions about future dynamics(e.g. growth, maturity, natural mortality and recruitment dynamics), then performs a projection for future options e.g. for catches, fishing mortality.

Libraries

```
library(FLCore)
library(FLash)
library(FLBRP)
library(ggplotFL)
```

In the following examples we use the ple4 FLSock object

```
data(ple4)
```

Methods

The main method is fwd which is used to make future projections, e.g. to evaluate different management options such as Total Allowable Catches (TACs) once a stock assessment has been conducted or for simulating a Harvest Control Rule (HCR) as part of a Management Strategy Evaluation (MSE).

fwdWindow sets up future dynamics of the FLStock object and fwdControl that sets up the target options in the projections. fwdControl is very flexible but can be tricky to set up so there are a variety of methods for standard tasks, e.g. simulating a Harvest Control Rule (HCR) or running projections for F, catch and biomass target.

fwdWindow

To perform a projection requires making assumptions about future processes such as growth and recruitment and any management effects on selectivity. This requires extending an FLStock object using fwdWindow and an FLBRP object. In this way projections and equilibrium dynamics and reference points are consistent.

```
stk=fwdWindow(ple4,end=2020,eql)
```

If recruitment is based on a stock recruitment relationship, this can be obtained by fitting to the historic time series.

```
sr   =as.FLSR(ple4,model="bevholt")
sr   =fmle(sr,control=list(silent=TRUE))
```

Then used to estimate the expected equilibrium dynamics

```
eql=FLBRP(ple4,sr=sr)
eql=brp(eql)

plot(eql)+theme(legend.position="bottom")
```

Future stock parameters

```
ggplot(FLQuants(eql,"m","mat","stock.wt","catch.sel"))+
  geom_line(aes(age,data))+
  facet_wrap(~qname,scale="free_y")
```

Projecting

We first show how simple projections (e.g. for F and catch) can be performed. Later we show how a variety of HCRs can be simulated.

Simulate fishing at $F_{0.1}$, first create an FLQuant with the target Fs

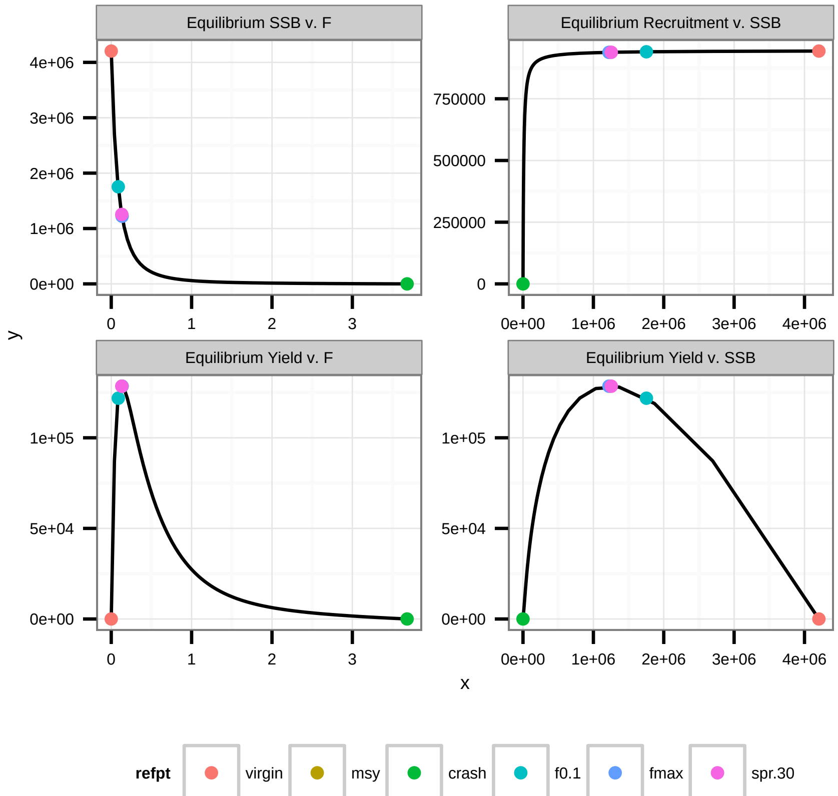


Figure 1: Equilibrium Dynamics

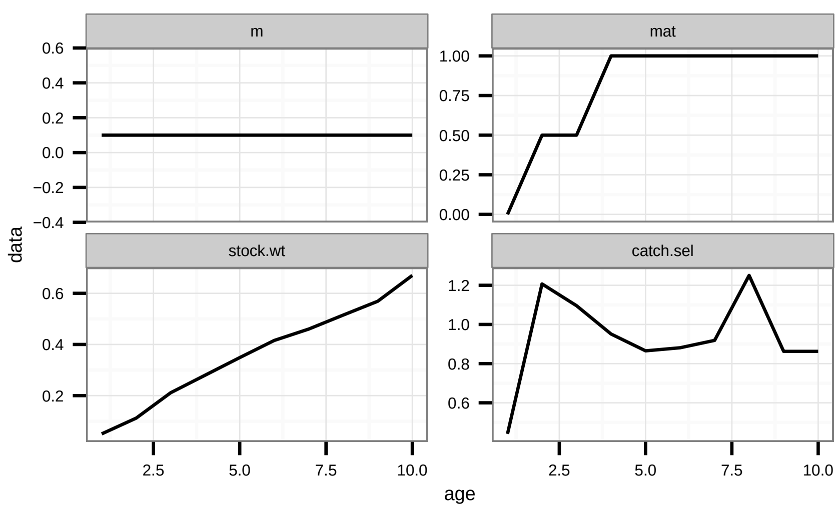


Figure 2: Stock Parameters in future projection

```
F0.1=FLQuant(refpts(eql)["f0.1","harvest",drop=T],
             dimnames=list(year=2009:2020))
```

Then project forward, note that sr is also required and that recruitment is determininistic.

```
stk=fwd(stk,f=F0.1,sr=sr)
```

```
plot(FLStocks("Historic"=ple4,"F0.1"=stk))
```

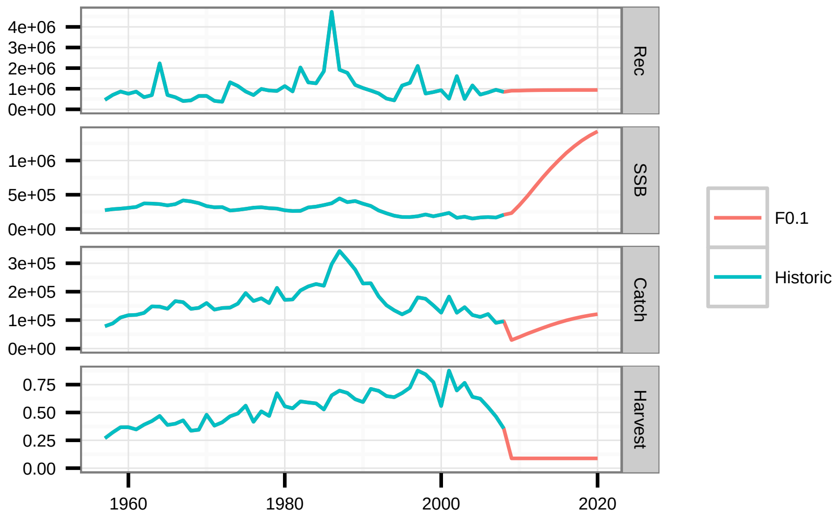


Figure 3: Projection for $F_{0.1}$

It is possible to project for different Fs i.e. alternative reference points

```
library(plyr)
```

```
dimnames(refpts(eql))$refpt
```

```
[1] "virgin" "msy"    "crash"  "f0.1"
[5] "fmax"   "spr.30" "mey"
```

```
refs=refpts(eql)[c("msy","f0.1","fmax","spr.30"),"harvest",drop=T]
```

```
targetF=FLQuants(mlply(data.frame(refs),
                       function(refs)
                           FLQuant(refs,dimnames=list(year=2009:2020))))
```

```
names(targetF)=names(refs)
```

```
names(targetF)[]="f"
```

```
stks=fwd(stk,targetF,sr=sr)

plot(stks)
```

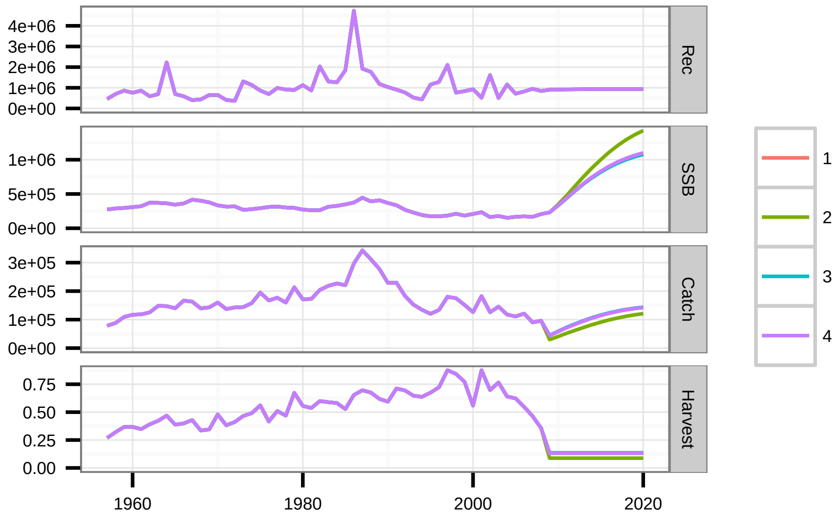


Figure 4: Comparision of projections for different F reference points

or different multipliers of F_{MSY}

```
msyTargets=FLQuants(mlply(seq(0,2,.25),
                       function(x)
                           FLQuant(x*refs["msy"],dimnames=list(year=2009:2020))))

names(msyTargets)[]="f"

stks=fwd(stk,msyTargets,sr=sr)

plot(stks)
```

Catch projections are done in a similar way e.g. for MSY

```
refpts(eql)["msy"]

An object of class "FLPar"
     quantity
refpt harvest    yield      rec
  msy 1.3378e-01 1.2850e+05 9.3821e+05
     quantity
refpt ssb        biomass    revenue
  msy 1.2351e+06 1.3923e+06         NA
     quantity
refpt cost       profit
```

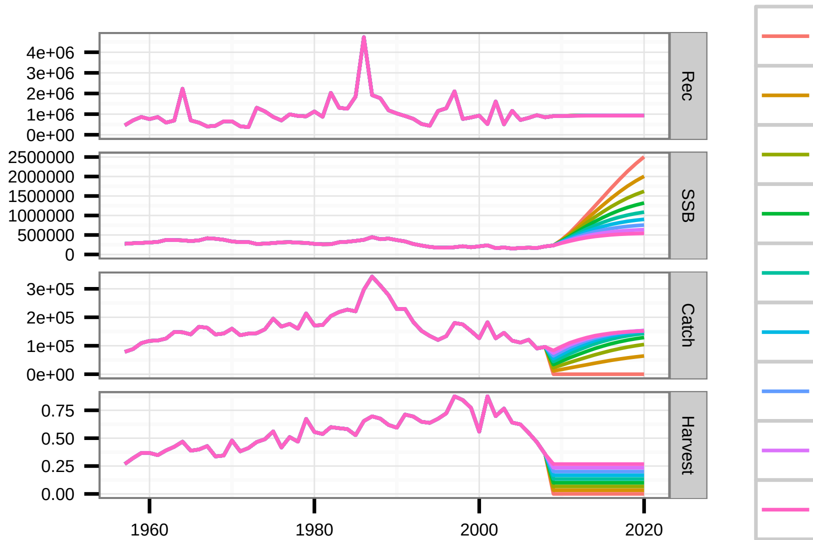


Figure 5: Comparison of projections for different Fs

```
  msy         NA          NA
units:  NA
```

```
refpts(eql)["msy",c("harvest","yield")]
```

```
An object of class "FLPar"
     quantity
refpt harvest    yield
  msy 1.3378e-01 1.2850e+05
units:  NA
```

```
msy=FLQuant(c(refpts(eql)["msy","yield"]),dimnames=list(year=2009:2020))
```

```
stks=fwd(stk,catch=msy,sr=sr)
```

```
plot(stks)
```

Compare F and Catch projections, e.g. for MSY and F_{MSY}

```
msys=FLQuants("f"    =targetF[[2]],
              "catch"=msy)
stks=fwd(stk,msys,sr=sr)
```

```
plot(stks)
```

If the projected catch is high you could simulate high Fs, however, there will be a cap of effort and capacity so in practice such high Fs may not be realised. Therefore there is a constraint on F.

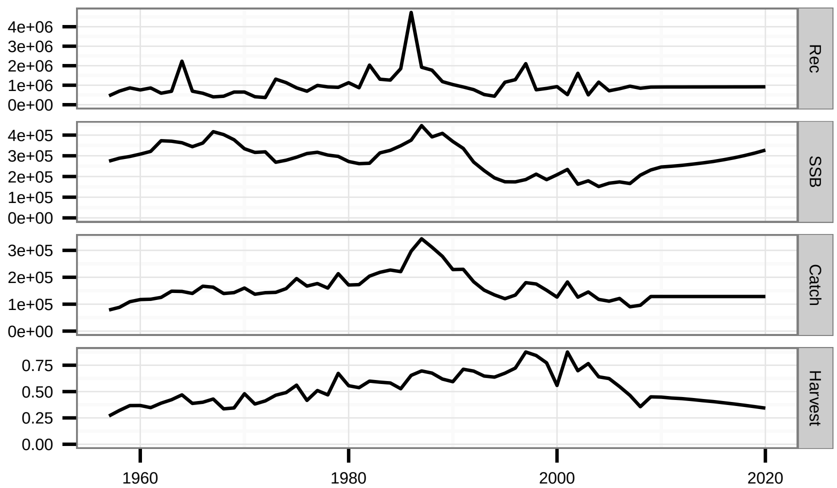


Figure 6: Comparioson of catch Projections

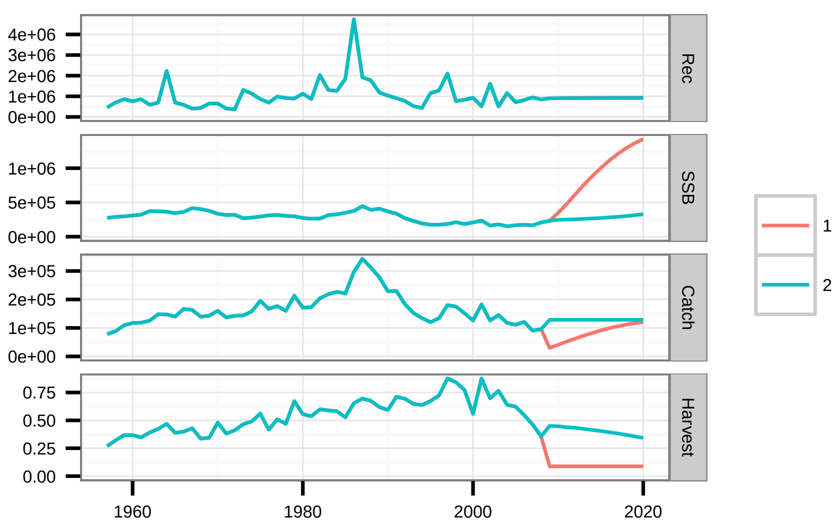
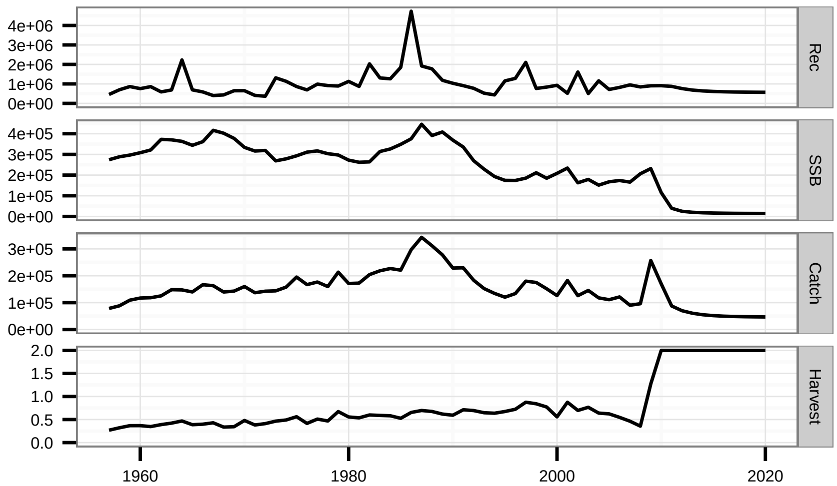


Figure 7: Comparison of Catch and F projections

```
catch=FLQuant(c(refpts(eql)["msy","yield"])*2,
                          dimnames=list(year=2009:2020))

stk=fwd(stk,catch=catch,sr=sr)

plot(stk)
```

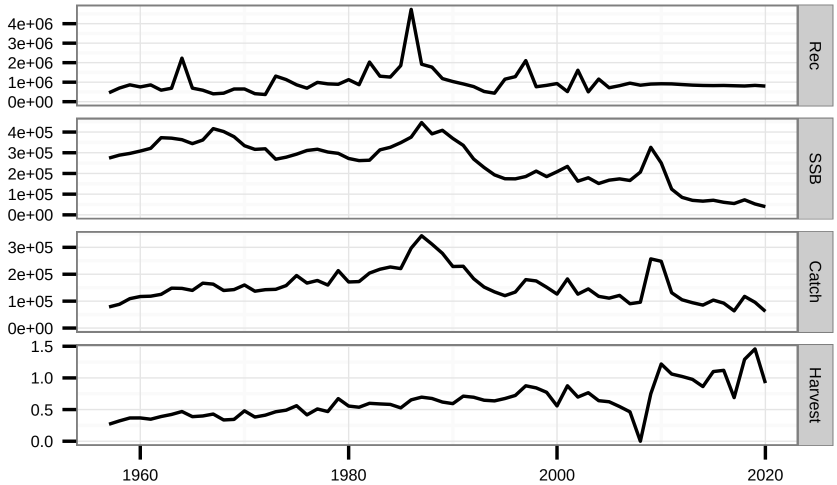


i.e. maxF, this allows an upper limit to be set on F
This can also be used to model capacity

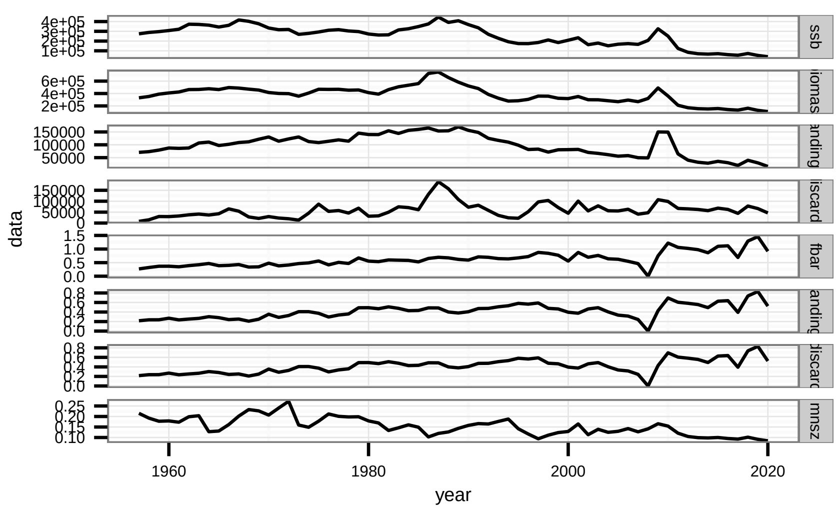
```
capacity=FLQuant(1,dimnames=list(year=2009:2020))
q       =rlnorm(1,FLQuant(0,dimnames=list(year=2009:2020)),.2)
maxF    =q*capacity

stk=fwd(stk,catch=catch,sr=sr,maxF=maxF)

plot(stk)
```

A variety of quantities can be considered in projections as well as catch and F, i.e. ssb, biomass, landings, discards, f, f.catch, f.landings, f.discards, effort, costs, revenue, profit, mnsz.

```
f.landings=function(x) apply((harvest(x)*
                   landings.n(x)/
                   catch.n(x))[ac( range(stk)["minfbar"]:range(stk)["maxfbar"])],2,mean)
f.discards=function(x) apply((harvest(x)*
                   landings.n(x)/
                   catch.n(x))[ac( range(stk)["minfbar"]:range(stk)["maxfbar"])],2,mean)
mnsz     =function(x) apply(stock.n(x)*stock.wt(x),2,sum)/
                       apply(stock.n(x),2,sum)
```



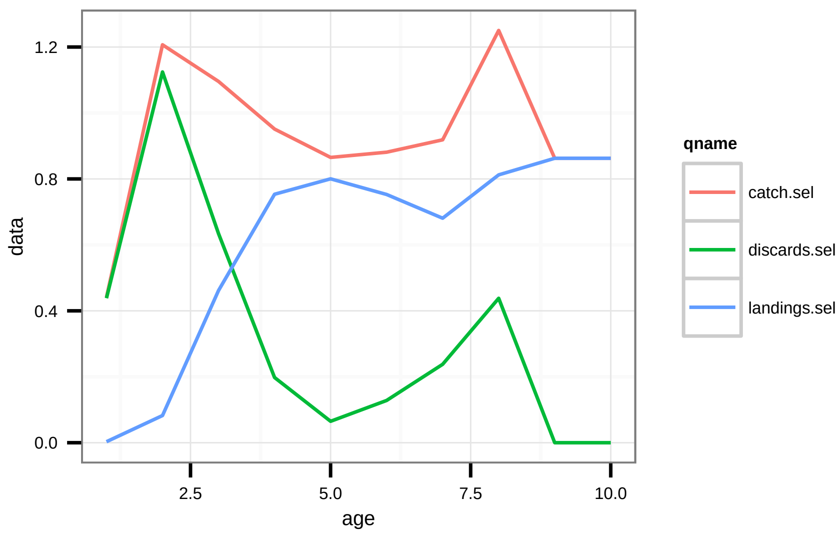

```
flqs=FLQuants(stk,"ssb", "biomass"=stock,
                  "landings", "discards", "fbar",
                  "f.landings", "f.discards","mnsz")

#             effort, costs, revenue, profit, .

ggplot(flqs)+
  geom_line(aes(year,data))+
  facet_grid(qname~.,scale="free_y")
```



Selection pattern

Management has two main options, i.e. setting effort (as in the examples above) or relative F-at-age by changing the selection pattern. The selection pattern-at-age of landings is that of the catch less discards e.g.

```
ggplot(FLQuants(eql,"catch.sel","discards.sel","landings.sel"))+
  geom_line(aes(age,data,col=qname))
```



In the FLStock object there are therefore 3 selection pattern components, and unfortunate three ways of calculating each. fwd uses computeCatch to re-estimate the catch.n, landings.n and discards.n before calculating future selection patterns.

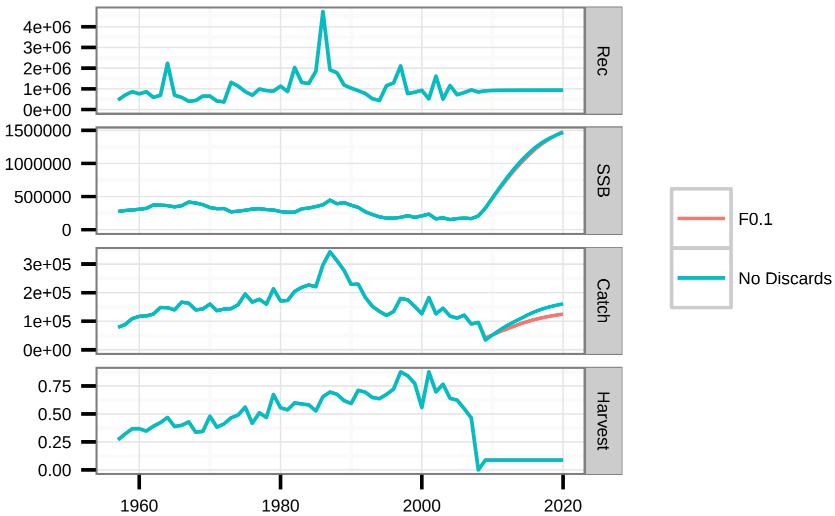
```
catch(stk)<-computeCatch(stk)
```

In fwd the selection patterns are then calculated as harvest*discards.n/catch.n, harvest*landings.n/catch.n and discards.sel+landings.sel

Simulation of gears that get rid of discarding can be done by

```
noDiscards=stk
discards.n(noDiscards)[,ac(2009:2020)]=0
catch.n(   noDiscards)[,ac(2009:2020)]<-landings.n(noDiscards)[,ac(2009:2020)]
catch(noDiscards)<-computeCatch(noDiscards)

## Note adjustment of harvest
harvest(noDiscards)[,ac(2009:2020)]=harvest(stk)[,ac(2009:2020)]*
  landings.n(stk)[,ac(2009:2020)]/catch.n(stk)[,ac(2009:2020)]
```

```
noDiscards=fwd(noDiscards,f=F0.1,sr=sr)
stk       =fwd(stk,       f=F0.1,sr=sr)

plot(FLStocks("No Discards"=noDiscards,"F0.1"=stk))
```



Non stationarity

Non stationarity is seen in many biological processes, what happens if future fecundity decreases?

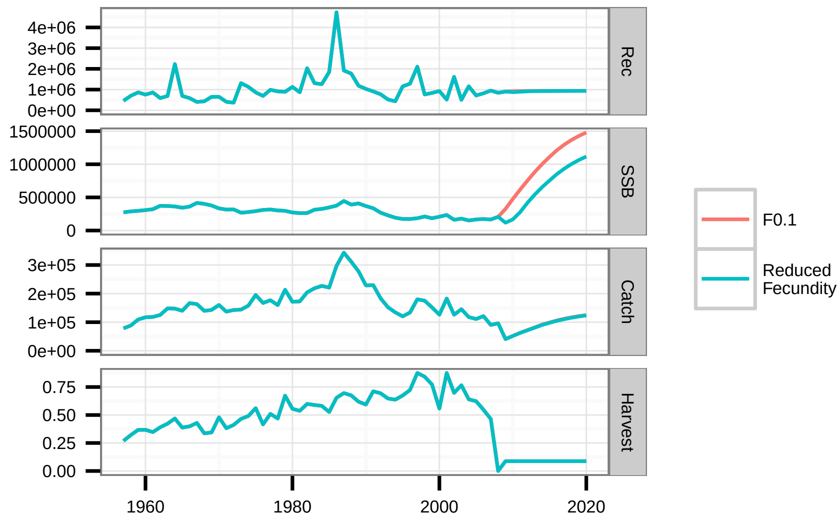
```
poorFec=stk
mat(poorFec)[1:5,ac(2009:2020)]=c(0,0,0,0,.5)

poorFec=fwd(poorFec,f=F0.1,sr=sr)

plot(FLStocks("Reduced \nFecundity"=poorFec,"F0.1"=stk))
```

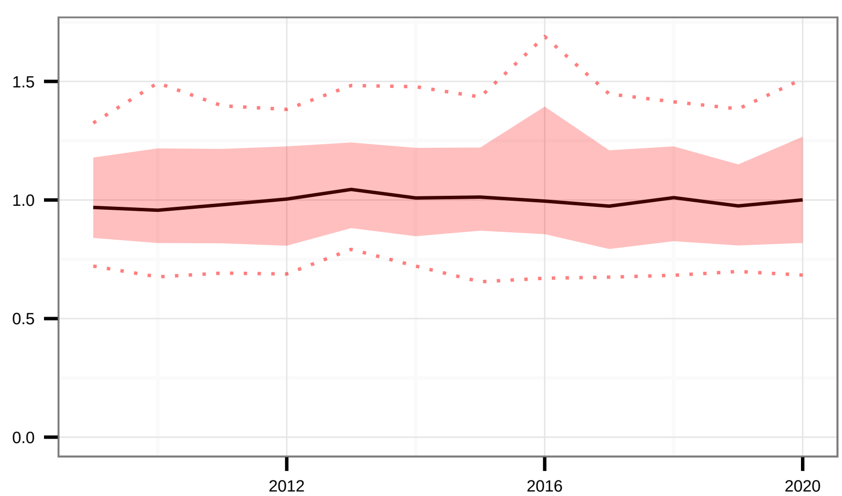
Or there is a regime shift in the stock recruitment relationship?

Stochasticity

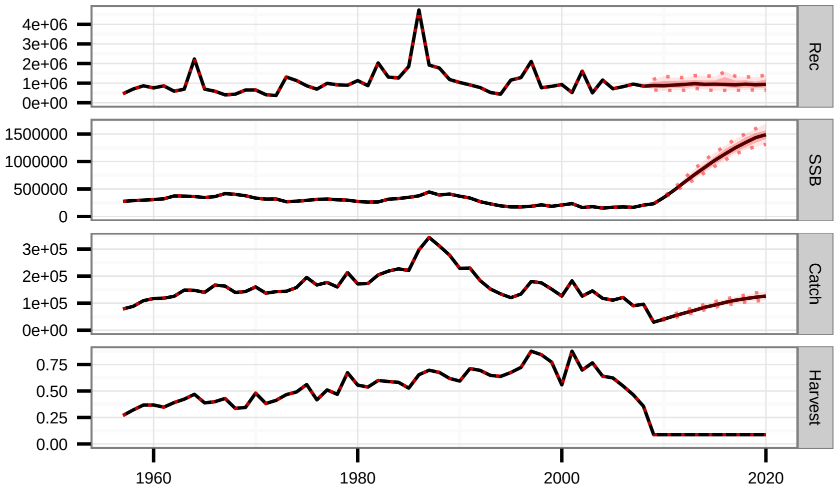
Monte Carlo simulations based on future recruitment

```
srDev=rlnorm(100,FLQuant(0,dimnames=list(year=2009:2020)),0.3)
plot(srDev)
```


4e+06
3e+06
2e+06
1e+06
0e+00
Rec
1500000
1000000
500000
0
SSB
3e+05
2e+05
1e+05
0e+00
Catch
0.75
0.50
0.25
0.00
Harvest
1960
1980
2000
2020
F0.1
Reduced Fecundity


1.5
1.0
0.5
0.0
2012
2016
2020

```
load("/tmp/flash.RData")
stk  =fwdWindow(stk,end=2020,eql)
stk  =fwd(stk,f=F0.1,sr=sr,sr.residuals=srDev)
plot(stk)
```



Harvest Control Rules

```
load("/tmp/flash.RData")
source('~/Desktop/flr/git/FLash/R/hcr.R')

hvt=hcr(stk,refpts(eql)["msy"])
hvt

$hvt
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2008
  all 0.0013378

units:  t*NA

$ssb
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
```

```
age   2008
  all 206480

units:  t
```

```
tac(stk,eql,hvt[[1]])
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2008
  all 431.74

units:  NA NA
```

fwdControl

fwdControl

target

trgtArray

effort

effArray

blocks

fwdControl is a more flexible but fiddly way of setting up projections. For example to replicate the $F_{0.1}$ projection above requires setting up a fwdControl object.

This can be done using a constructor and a data.frame

```
ctrl=fwdControl(data.frame(year    =2009:2018,
                           val     =c(refpts(eql)["f0.1","harvest"]),
                           quantity="f"))
```

fwdControl is a class with 5 slots

```
slotNames(ctrl)
```

```
[1] "target"    "effort"    "trgtArray"
[4] "effArray"  "block"
```

For now we will concerntrate on just the target and trgtArray slots.

```
slotNames(ctrl)
```

```
[1] "target"    "effort"    "trgtArray"
[4] "effArray"  "block"
```

```
ctrl
```

```
Target
   year quantity min    val max
1  2009        f  NA 0.0876  NA
2  2010        f  NA 0.0876  NA
3  2011        f  NA 0.0876  NA
4  2012        f  NA 0.0876  NA
5  2013        f  NA 0.0876  NA
6  2014        f  NA 0.0876  NA
7  2015        f  NA 0.0876  NA
8  2016        f  NA 0.0876  NA
9  2017        f  NA 0.0876  NA
10 2018        f  NA 0.0876  NA


     min      val      max
  1        NA 0.087602       NA
  2        NA 0.087602       NA
  3        NA 0.087602       NA
  4        NA 0.087602       NA
  5        NA 0.087602       NA
  6        NA 0.087602       NA
  7        NA 0.087602       NA
  8        NA 0.087602       NA
  9        NA 0.087602       NA
  10       NA 0.087602       NA
```

target specifies the quantity for the projection (e.g. "f", "catch", "ssb", . . .) and the projection year. The projection can be a target by specifying it in val. While min and max specify bounds. For example if you want to project for a target F but also to check that SSB does not fall below an SSB limit.

An example with high F that decreases SSB a lot

```
target=fwdControl(data.frame(year=2009,val=0.8,quantity="f"))
stk   =fwdWindow(ple4,end=2010,eql)

stk=fwd(stk,ctrl=target,sr=eql)

fbar(stk)[,"2009"]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2009
  all 0.8

units:  f
```

```
ssb( stk)[,"2010"]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2010
  all 177289

units:  NA
```

Note that it is the end of year biomass that is constrained as in this case spawning is at Jan 1st and so fishing only has an effect of SSB next year

Constrain SSB so that it doesnt fall below 250000

```
target  <-fwdControl(data.frame(year=c(2009,2009),
                             val =c( 0.8,  NA),
                             min =c(NA,230000),
                             quantity=c("f","ssb")))
```

```
stk=fwd(stk,ctrl=target,sr=sr)
```

```
fbar(stk)[,"2009"]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2009
  all 0.52058

units:  f
```

```
ssb( stk)[,"2010"]
```

```
An object of class "FLQuant"
```

```
, , unit = unique, season = all, area = unique

     year
age   2010
  all 230000

units:  NA
```

If a stock spawns mid year so the adult population is affected by fishing then the SSB constraint is within year, e.g.

```
harvest.spwn(stk)[]=0.5

stk=fwd(stk,ctrl=target,sr=sr)

fbar(stk)[,  "2009"]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2009
  all 0.01302

units:  f
```

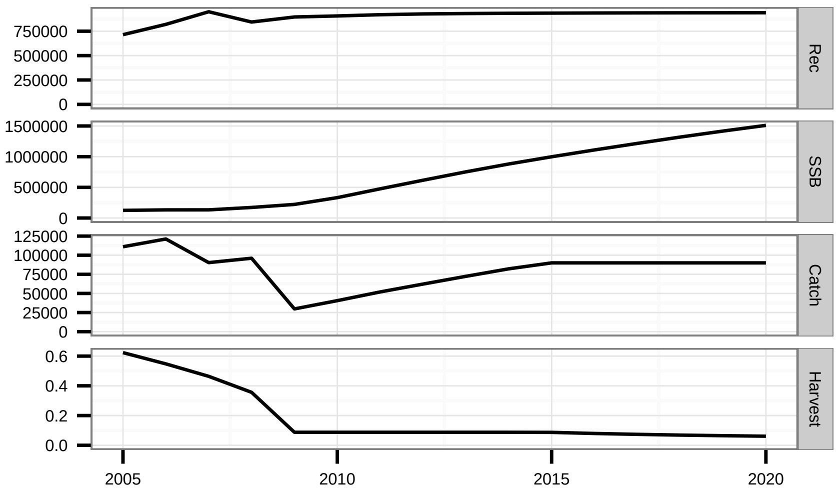
```
ssb( stk)[,c("2009","2010")]
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2009   2010
  all 230000 228391

units:  NA
```

Harvest Control Rules

```
msy  =refpts(eql)["msy", "yield"]
bmsy =refpts(eql)["msy", "ssb"]
f0.1 =refpts(eql)["f0.1","harvest"]
stk  =fwdWindow(stk,end=2020,eql)

#### constant catch with an upper F bound
ctrl=fwdControl(data.frame(year    =rep(2009:2020,each=2),
```

```
val      =rep(c(msy*0.7,NA),12),
  max      =rep(c(NA,f0.1),12),
quantity=rep(c("catch","f"),12)))
stk=fwd(stk,ctrl=ctrl,sr=sr)

plot(stk[,ac(2005:2020)])
```

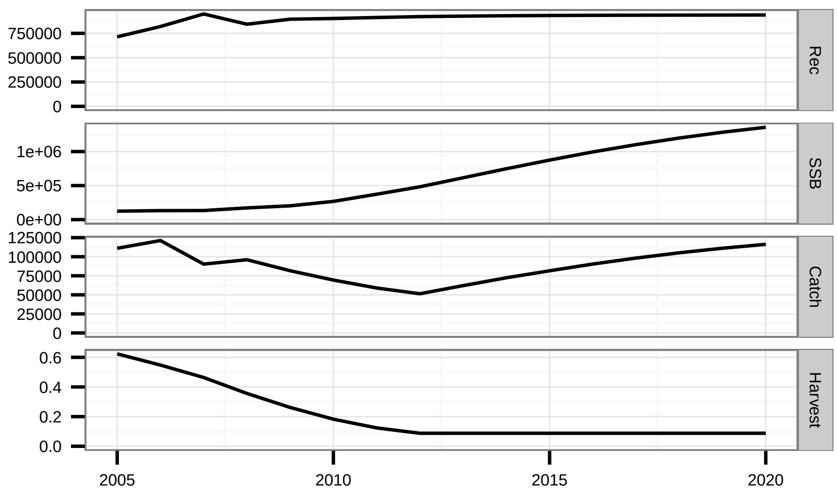


Reduce F to F0.1 but only let catch change by 15% a year

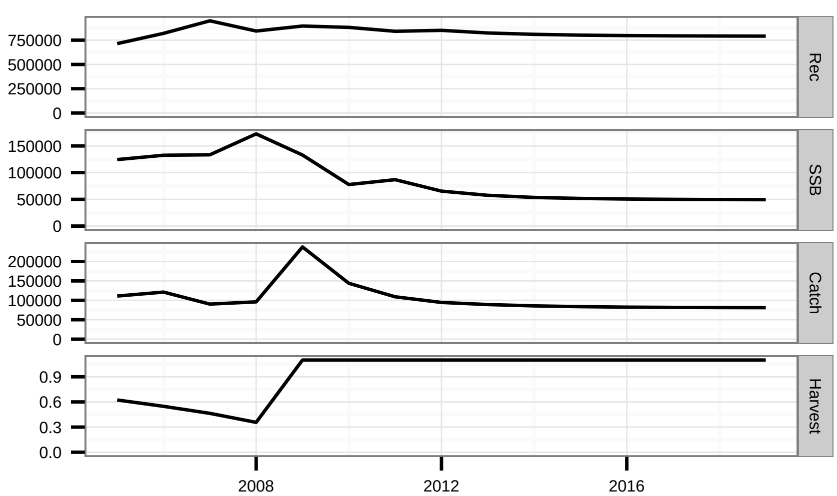
```
ctrl=fwdControl(data.frame(year    =rep(2009:2020,each=2),
                           rel.year=c(t(array(c(rep(NA,12),2008:2019),c(12,2)))),
                           val     =rep(c(f0.1,NA),12),
                           min     =rep(c(NA,0.85),12),
                           quantity=rep(c("f","catch"),12)))
stk=fwd(stk,ctrl=ctrl,sr=sr)

plot(stk[,ac(2005:2020)])
```

10% SSB increase

```
ctrl=fwdControl(data.frame(year    =rep(2009:2020,each=2),
                           rel.year=c(t(array(c(2008:2019,rep(NA,12)),c(12,2)))),
                           max     =rep(c(f0.1,NA),12),
                           val     =rep(c(NA,1.1),12),
                           quantity=rep(c("ssb","f"),12)))
stk=fwd(stk,ctrl=ctrl,sr=sr)

plot(stk[,ac(2005:2019)])

hcrF=function(iYr,SSB,Bpa,Blim,Fmin,Fmax){
    val =pmin(Fmax,Fmax-(Fmax-Fmin)*(Bpa-SSB)/(Bpa-Blim))
```



750000
500000
250000
0
Rec
1e+06
5e+05
0e+00
SSB
125000
100000
75000
50000
25000
0
Catch
0.6
0.4
0.2
0.0
Harvest
2005
2010
2015
2020



750000
500000
250000
0
Rec
150000
100000
50000
0
SSB
200000
150000
100000
50000
0
Catch
0.9
0.6
0.3
0.0
Harvest
2008
2012
2016

```
    trgt=fwdTarget(year=iYr+1,quantity="f",valueval)

    return(trgt)}
```

Recover stock to target SSB level corresponding to the 1980s in 2020 with a constant F strategy

```
load("/tmp/flash.RData")
stk=fwdWindow(stk,end=2020,eql)

ssbTarget = mean(ssb(stk)[,ac(1970:1989)])

## function to minimise
f<-function(x,stk,ssbTarget,ctrl,sr){

       # set target F for all years
       ctrl@target[,   "val"] =x
       ctrl@trgtArray[,"val",]=x

       # project
       stk=fwd(stk,ctrl=ctrl,sr=sr)

       # Squared Difference
       return((ssb(stk)[,ac(range(stk)["maxyear"])]-ssbTarget)^2)}

## control object
ctrl=fwdControl(data.frame(year=2009:2020,val=.5,rel=2008,quantity="f"))

xmin=optimize(f, c(0.1, 1.0), tol = 0.0000001, stk=stk, ssbTarget=ssbTarget,
              ctrl=ctrl, sr=eql)
ctrl=fwdControl(data.frame(year=2009:2020,val=xmin$minimum,rel=2008,quantity="f"))

stk     =fwd(stk,ctrl=ctrl,sr=eql)

# update catch slot
catch(stk) = computeCatch(stk)

# Have we reached the target?
ssbTarget
```

```
[1] 322339
```

```
ssb(stk)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique
```

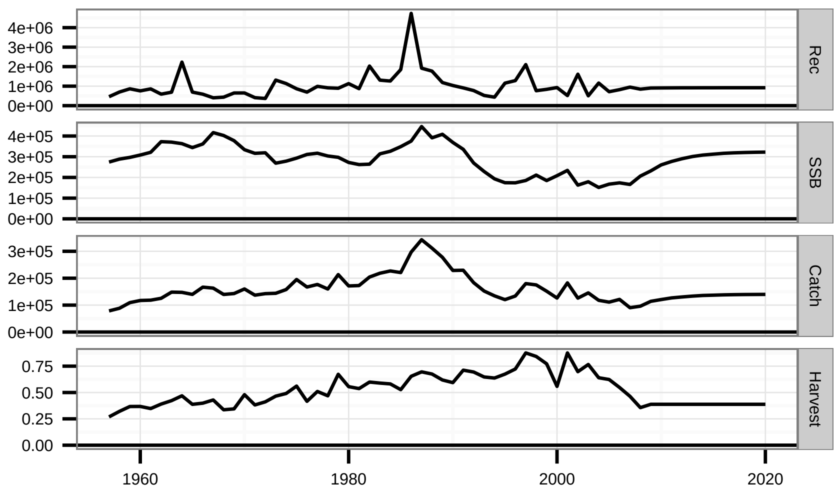
```
     year
age   1957   1958   1959   1960   1961
  all 274205 288540 296825 308164 321354
     year
age   1962   1963   1964   1965   1966
  all 372863 370373 363077 344013 361549
     year
age   1967   1968   1969   1970   1971
  all 416563 402521 377432 333933 316343
     year
age   1972   1973   1974   1975   1976
  all 319062 268714 278648 293136 310954
     year
age   1977   1978   1979   1980   1981
  all 316929 303433 297122 272416 262061
     year
age   1982   1983   1984   1985   1986
  all 263998 314021 326341 348675 375392
     year
age   1987   1988   1989   1990   1991
  all 445855 391254 408489 368969 335747
     year
age   1992   1993   1994   1995   1996
  all 269528 228668 193093 174408 173903
     year
age   1997   1998   1999   2000   2001
  all 185308 211327 184733 208393 234078
     year
age   2002   2003   2004   2005   2006
  all 162725 179158 151508 167531 173783
     year
age   2007   2008   2009   2010   2011
  all 166061 206480 231522 260641 277268
     year
age   2012   2013   2014   2015   2016
  all 290401 300924 308029 312489 316464
     year
age   2017   2018   2019   2020
  all 318754 320424 321560 322339

units:  NA

# At what level of constant F
```

```
fbar(stk)
```

```
An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   1957    1958    1959    1960   
  all 0.26857 0.32106 0.36734 0.36796
     year
age   1961    1962    1963    1964   
  all 0.34756 0.39012 0.42276 0.46878
     year
age   1965    1966    1967    1968   
  all 0.38796 0.39896 0.42923 0.33621
     year
age   1969    1970    1971    1972   
  all 0.34457 0.47965 0.38206 0.41158
     year
age   1973    1974    1975    1976   
  all 0.46551 0.49072 0.56113 0.41641
     year
age   1977    1978    1979    1980   
  all 0.51007 0.46862 0.67312 0.55555
     year
age   1981    1982    1983    1984   
  all 0.53705 0.59912 0.58934 0.58159
     year
age   1985    1986    1987    1988   
  all 0.52695 0.65386 0.69596 0.67530
     year
age   1989    1990    1991    1992   
  all 0.61895 0.59361 0.71195 0.69443
     year
age   1993    1994    1995    1996   
  all 0.64752 0.63741 0.67444 0.72301
     year
age   1997    1998    1999    2000   
  all 0.87588 0.84233 0.77264 0.55795
     year
age   2001    2002    2003    2004   
  all 0.87567 0.69763 0.76597 0.64015
     year
age   2005    2006    2007    2008   
  all 0.62343 0.54764 0.46392 0.35631
```

```
     year
age   2009    2010    2011    2012
  all 0.38813 0.38813 0.38813 0.38813
     year
age   2013    2014    2015    2016
  all 0.38813 0.38813 0.38813 0.38813
     year
age   2017    2018    2019    2020
  all 0.38813 0.38813 0.38813 0.38813

units:  f
```

```
plot(stk)+
  geom_hline(aes())
```



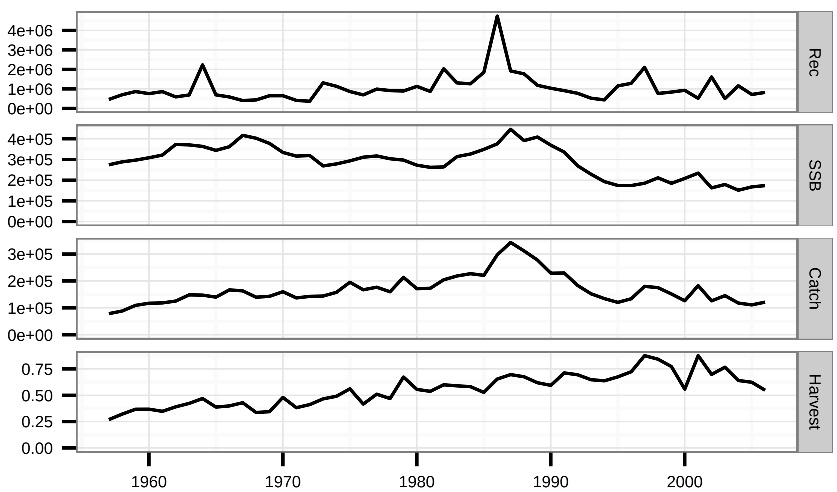
Recover stock to the desired SSB in 2006 with a constant Catch strategy Here val can be anything in the ctrl because it is overwritten in the optimisation loop

```
ctrl=fwdControl(data.frame(year=2009:2020,val=c(catch(stk)[,"2001"]),quantity="catch"))

xmin=optimize(f, c(100, 100000), tol = 0.0000001, stk=stk,
              ssbTarget=ssbTarget, ctrl=ctrl, sr=sr)
ctrl=fwdControl(data.frame(year=2009:2020,val=xmin$minimum,quantity="catch"))
stkC      =fwd(stk,ctrl=ctrl,sr=sr)

# Have we reached the target?
ssbTarget

[1] 322339
```

```
ssb(stkC)[,ac(2002:2020)]

An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2002   2003   2004   2005   2006
  all 162725 179158 151508 167531 173783
     year
age   2007   2008   2009   2010   2011
  all 166061 206480 231522 275100 317635
     year
age   2012   2013   2014   2015   2016
  all 369374 428468 493255 563472 639832
     year
age   2017   2018   2019   2020
  all 719045 801719 886464 972368

units:  NA

# At what level of constant catch
computeCatch(stkC)[,ac(2002:2020)]

An object of class "FLQuant"
, , unit = unique, season = all, area = unique

     year
age   2002   2003   2004   2005   2006
  all 125884 145390 117702 111060 121205
     year
age   2007   2008   2009   2010   2011
  all  90283  96040 100000 100000 100000
     year
age   2012   2013   2014   2015   2016
  all 100000 100000 100000 100000 100000
     year
age   2017   2018   2019   2020
  all 100000 100000 100000 100000

units:  NA NA

# And at what level of F
fbar(stkC)[,ac(2002:2006)]

An object of class "FLQuant"
, , unit = unique, season = all, area = unique
```

```
     year
age   2002    2003    2004    2005
  all 0.69763 0.76597 0.64015 0.62343
     year
age   2006
  all 0.54764

units:  f
```

```
# Update the catch slot
catch(stkC) = computeCatch(stkC)
# 'ave a butchers
plot(stkC[,ac(1957:2006)])
```




```
# Assessment up to and including 2001

# set courtship and egg laying in Autumn
stk@m.spwn[]      =0.66
stk@harvest.spwn[]=0.66

# assessment is in year 2002, set catch constraint in 2002 and a first guess for F in 2003
ctrl          =fwdControl(data.frame(year=2002:2003,val=c(85000,.5),quantity=c("catch","f")))
stk    =fwd(stk, ctrl=ctrl, sr=list(model="mean", params=FLPar(25000)))

# HCR specifies F=0.1 if ssb<100000, F=0.5 if ssb>300000
# otherwise linear increase as SSB increases
min.ssb=100000
max.ssb=300000
```

```
min.f  =0.1
max.f  =0.5

# slope of HCR
a.    =(max.f-min.f)/(max.ssb-min.ssb)
b.    =min.f-a.*min.ssb

# plot of HCR
plot(c(0.0,min.ssb,max.ssb,max.ssb*2),c(min.f,min.f,max.f,max.f),type="l",ylim=c(0,max.f*1.25),xlim=c(0,ma

## find F through iteration
t.    =999
i     =0
while (abs(ctrl@target[2,"val"]-t.)>10e-6 & i<50)
   {
   t.=ctrl@target[2,"val"]  ## save last val of F

   # calculate new F based on SSB last iter
   ctrl@target[2,"val"]    =a.*c(ssb(stk)[,"2003"])+b.
   ctrl@trgtArray[2,"val",]=a.*c(ssb(stk)[,"2003"])+b.
   stk=fwd(stk, ctrl=ctrl, sr=list(model="mean", params=FLPar(25000)))

   # 'av a gander
   points(c(ssb(stk)[,"2003"]),c(ctrl@target[2,"val"]),cex=1.25,pch=19,col=i)
   print(c(ssb(stk)[,"2003"]))
   print(c(ctrl@target[2,"val"]))
   i=i+1
   }

# F bounds
stk      =fwd(stk, ctrl=ctrl, sr=list(model="mean",params=FLPar(25000)))
plot(FLStocks(stk))
```

Examples

Targets

Limits

Relative targets and limits

Harvest Control Rules

Multi-annual management

Recovery Plans

Long-term plans

Technical measures

References