

Método de Zhou 2013

PCOM Posterior-focused catch-only method S. Zhou, Modificado por Elson Leal y María José Zúñiga para sardina austral Aysen, CBA 2021

This method requires time series of catch data only. However, some life history parameters, M , L_{inf} , k , T_{max} , $T_{maturation}$, will improve the performance. Also, a rough guess of maximum depletion level $D = B_{end}/K$ will be helpful. This example is for single catch series

Modelo

```
library(knitr) # para generar reporte Rmarkdown
library(stringr)
library(reshape)
library(dplyr)
library(ggplot2)
library(ggthemes) # para ggplot
library(patchwork) # para unir gráficos de ggplot
library(strucchange) # libreria utilizada para análisis de quiebres

getwd()

## [1] "/Users/mariajosezunigabasualto/MJZ/CTP2022/SARDINAAUSTRAL_AYSEN/PRIMER_INFORME"

#####
# model
#####
BDM=function(K,dep,b,C,r){ ### biomass dynamics model
  B=err.B=rep(NA,length(C))
  B[1]=b*K;b1=B[1]
  for(i in 2:length(B)){
    B[i]=max(min(B[i-1]+r*B[i-1]*(1-B[i-1]/K)-C[i-1],K),0)
    # err.B[i]=ifelse(!is.na(U[i-1]&U[i]) & B[i]>0, (B[i-1]/B[i]-U[i-1]/U[i]^2,NA)
  }
  if(all(B>C) & all(B<=K)){
    abs(B[length(B)]-dep*K)
    # if(any(U>0)){((B[length(B)]-dep*K)/K)^2 +sum(err.B,na.rm=T)} else ((B[length(B)]-dep*K)/K)^2
  } else {10^5}
}
```

Simulación

Ingresa datos de captura

```
#
#####
# input catch data and r range for sautral XI stock
#####
#C=c(4033,5318,4163,7547,5097,3853,653,1352,1839,4488)
#C=c(4033,5318,4163,7547,5097,3853,653,1352,1839,3600)
C=c(4033,5318,4163,7547,5097,3853,653,1352,1839,3600)
yr=seq(2012,2021)
r.lci=0.85;
r.uci=1.2
#####
# search through K grids, with specific range for K1 follow
#####
N1=100
K1=exp(seq(log(max(C)),log(max(C)*50),l=N1))
#####
# genera los valores de la deplecion
#####
dep=round(seq(0.1,0.8,0.05),2)
nd=length(dep)
r1=obj1=matrix(0,N1,nd) #matriz que almacena los output de las funciones
b=1#Si (C[1]/max(C)<0.5, (0.5+0.9)/2 (0.3+0.6)/2);b=0.5
# ciclo
for(j in 1:nd){
  for(i in 1:N1){
    out=optimize(BDM,K=K1[i],b=b,C=C,dep=dep[j],
      interval=c(r.lci-.05,r.uci+.05))
    r1[i,j]=out$min
    obj1[i,j]=out$obj
  }
}

#####
#
#vLinf=58.95;vk=0.28;Tmax=10;Tmat=NA;T=17
#M=vector()
#M[1]=exp(1.44-0.982*log(Tmax))
#M[2]=1.65/Tmat
#M[3]=exp(1.2-0.17*log(vLinf)+log(vk))
#M[4]=1.82*vk
#M[5]=exp(-0.0152-0.279*log(vLinf)+0.6543*log(vk)+0.463*log(T))
#w=0.87 #para teleost y w=0.41 para chondrithys
#r.mean=2*mean(M,na.rm=T)*w
#r.sd=sd(M,na.rm=T)
#r.backup=r
#r[r > r.mean+2*r.sd | r < r.mean-2*r.sd]=NA

#####
r1.backup=r1 ;# r1=r1.backup
r1[obj1 > K1*0.01]=NA
```

```

r1[r1 > r.uci | r1 < r.lci]=NA
#####
kr=as.data.frame(cbind(K1,r1))
colnames(kr)=c('k',dep)
all=cbind(K1,stack(kr[,2:nd+1]))#antes nd+1
colnames(all)=c("k","r","ind")

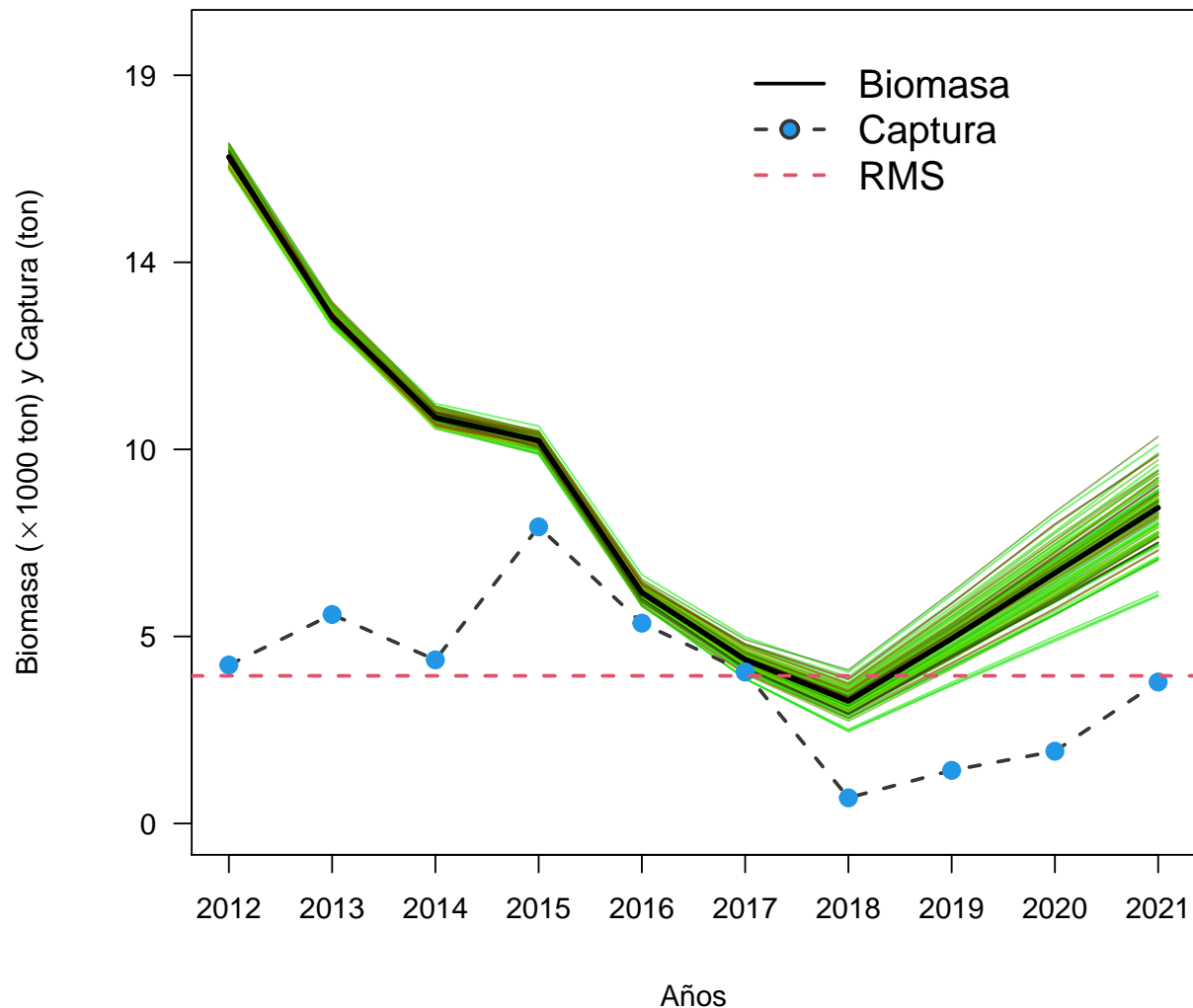
all$d=as.numeric(as.character(all$ind))
all=all[,c(1,2,4)]
all=all[!is.na(all[,2]),]
all$msy=all[,1]*all[,2]/4

#####
# estimate reference points
#####
#cutoff=ifelse(tail(C,1)/max(C)<=0.5,0.5,0.8)
all2      =all[!is.na(all$r) & all$d <= 0.50,]#cutoff,assume upper depeltion=0.50
quan1     =apply(all2,2,quantile)
k25       =quan1[,1][2]
k75       =quan1[,1][4]
r25       =quan1[,2][2]
r75       =quan1[,2][4]
msy.media=quan1[,4][3]
all13     =all2[all2$k>k25 & all2$k<k75 & all2$r>r25 & all2$r<r75,]
para      =list(k25=k25,k75=k75,r25=r25,r75=r75)

```

Figura biomasa

```
#####
nsim=100
#GRAFICA LA BIOMASA
par(mar=c(5,5.5,1,1),cex.axis=1.3,cex.lab=1.3)
out1=sim1(k25=k25,k75=k75,r25=r25,r75=r75,C=C,yr=yr,nsim=nsim,msy=msy.media)
```



```
#####
#EXTRAE DATOS DE INTERES PARA LA INCERTIDUMBRE
#####
F2Fmsy =as.data.frame(out1[8]);
B2Bmsy =as.data.frame(out1[9])
quant =function(x)quantile(x,c(0.2,0.8))

dat.out =data.frame(year=yr,
                     B2Bmsy.med=apply(B2Bmsy,1,median),
                     quan1.B=apply(B2Bmsy,1,quant)[1,],
                     quan3.B=apply(B2Bmsy,1,quant)[2,],
```

```

F2Fmsy.med=apply(F2Fmsy,1,median),
quan1.F=apply(F2Fmsy,1,quant)[1,],
quan3.F=apply(F2Fmsy,1,quant)[2,])

BF2msy.end = data.frame(t(rbind(B2Bmsy[length(yr),],F2Fmsy[length(yr),])))
colnames(BF2msy.end)=c("B2Bmsy","F2Fmsy")
#kable(BF2msy.end)
#
out1.backup=out1 #out1=out1.backup
sp=out1[1:5]
sp=as.data.frame(sp) # summary(sp)
colnames(sp)=c("k","r","msy","Bend","Depletion")
BendD=apply(sp,2,quantile)
#####
#FINAL RESULT
#####
tabla<-cbind(quan1[,c(1,2,4)],BendD[,4:5])
write.csv2(tabla,"tabla1.csv",row.names=FALSE)
kable(tabla)

```

	k	r	msy	Bend	Depletion
0%	16634.15	0.8534279	3692.060	5785.155	0.3417133
25%	16634.15	0.8614773	3726.883	7380.686	0.4359569
50%	16969.38	0.8861789	3757.632	8031.823	0.4744178
75%	17304.61	0.9106092	3786.803	8410.411	0.4967800
100%	17304.61	0.9178450	3816.893	9843.053	0.5814022

```

Bioma <-apply(out1.backup[[6]],1,quantile)
#note: Bmsy = k/2, Blim = k/4
B.sim =data.frame(out1[6])
BF =t(apply(B.sim,1,quantile))
BF =cbind(BF,C/BF)
BRP =c(quan1[3,1]/2,quan1[3,2]/2)
fs =data.frame(cbind(BF[,c(8,3)],yr)) # F y Biomasa media
#GRAFICA BIOMASA V/S CPUE
#plot(yr,BF[,3],type="b",ylab="Biomasa and CPUE")
#par(new=T)
#plot(yr,U,type="b",col=2,axes=F,xlab="",ylab="")
#

```

Sensibilidad

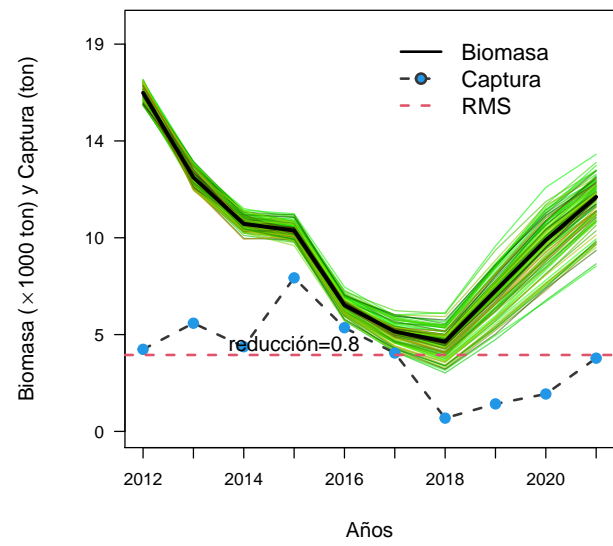
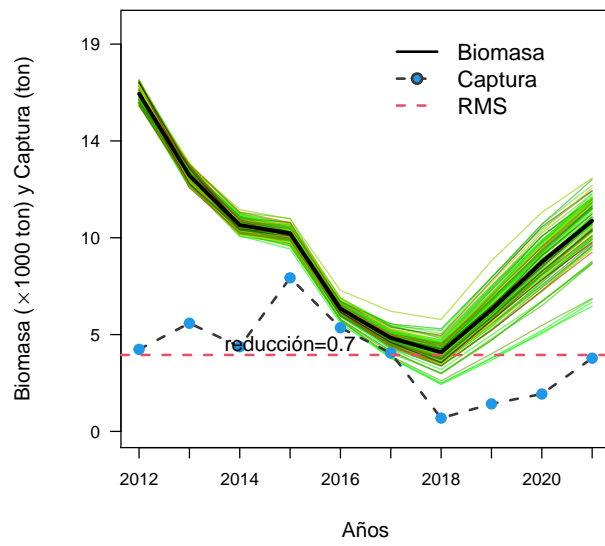
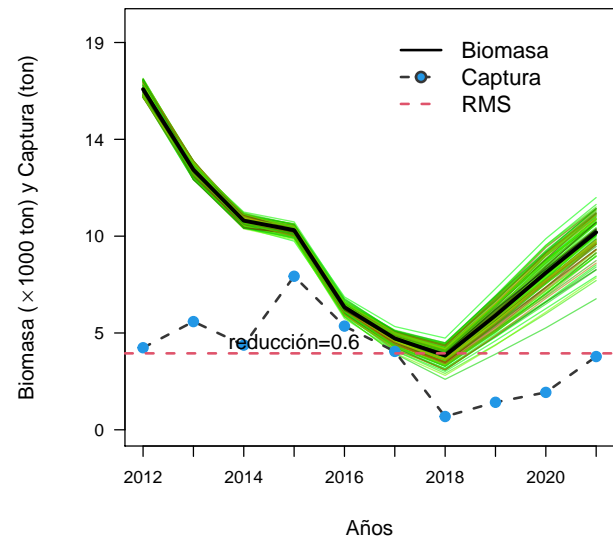
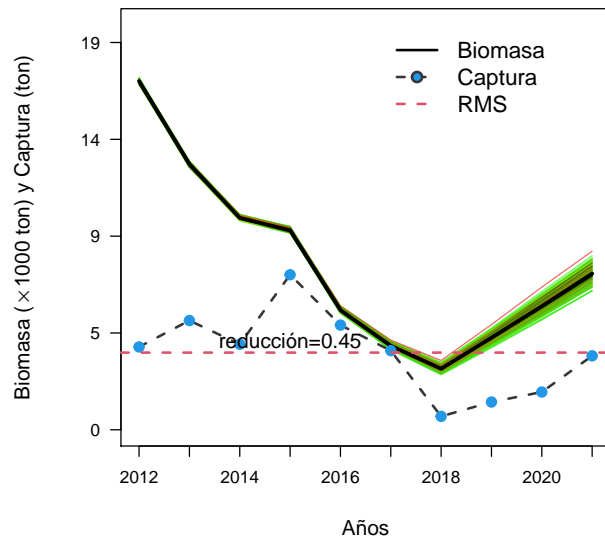
```
#####
# sensitivity to assumed upper depletion (if needed) #
#####
med.out=low.out=up.out=matrix(NA,nrow=4,ncol=6)
d.l=c(0.45,0.6,0.7,0.8) # assumed upper depletion levels
layout(matrix(1:4,ncol=2,byrow=T),widths=c(1,1),heights=c(1,1))
for(i in 1:4){
  all2=all[!is.na(all$r) & all$d <= d.l[i],]
  quan1=apply(all2,2,quantile)
  k25=quan1[,1][2]
  k75=quan1[,1][4]
  r25=quan1[,2][2]
  r75=quan1[,2][4]
  msy.median=quan1[,4][3]
  nsim=100
  #####
  #Figura
  par(mar=c(5,5.5,1,1),cex.axis=1.3)
  out1=sim1(k25=k25,k75=k75,r25=r25,r75=r75,C=C,yr=yr,nsim=nsim,msy=msy.media)
  tex=paste("reducción=",d.l[i],sep="")
  text(2015,round(para$k25,0)*0.26,tex,cex=1.2,xpd=T)
  #####
  # Tablas
  sp = out1[1:5]
  sp = as.data.frame(sp) # summary(sp)
  colnames(sp)= c('k','r','msy','Bend','D')
  BendD = apply(sp,2,quantile)

  med.out[i,] =(c(quan1[3,],BendD[3,4:5]))
  low.out[i,] =(c(quan1[2,],BendD[1,4:5]))
  up.out[i,] =(c(quan1[4,],BendD[5,4:5]))

  med.out[,3] =t(d.l)
  low.out[,3] =t(d.l)
  up.out[,3] =t(d.l)

  colnames(med.out)=c("k","r","d.upper","msy","Bend","D")
  colnames(low.out)=c("k","r","d.upper","msy","Bend","D")
  colnames(up.out)=c("k","r","d.upper","msy","Bend","D")

  kable(med.out)
  kable(low.out)
  kable(up.out)
  #####
}
```



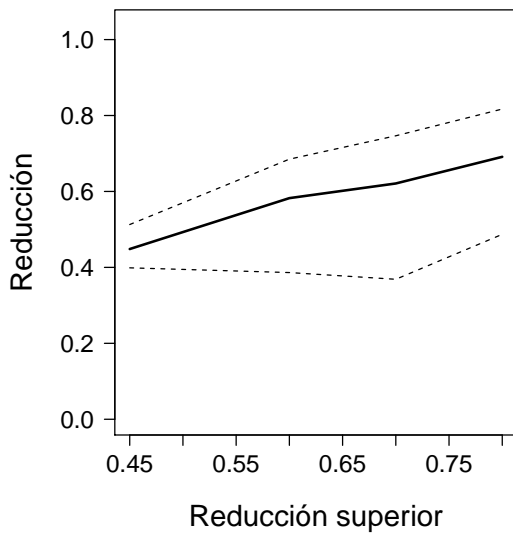
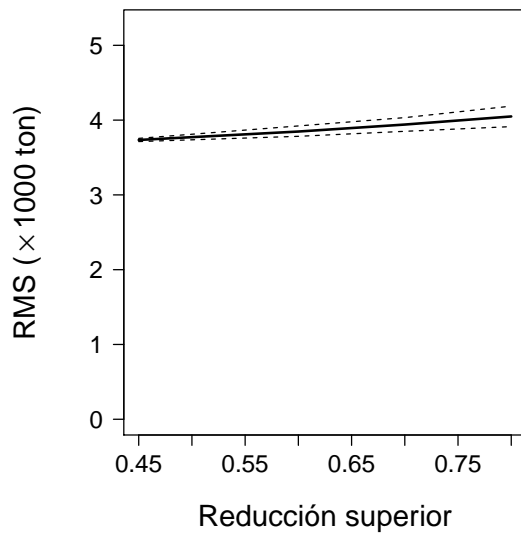
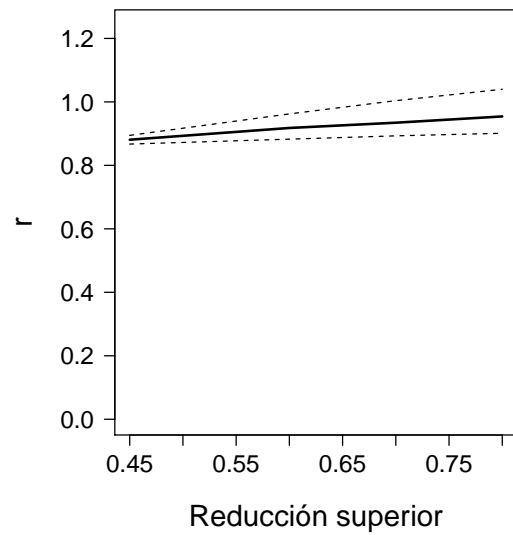
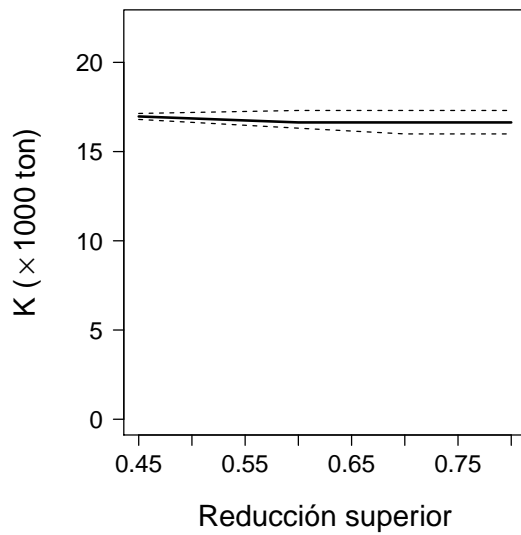
```
#####
# parameters as a function of assumed upper depletion level
#####
#name3<-paste(getwd(),"/Figuras/Fig3_Zhou2013_sensitivity.png",sep="")
#png(file=name3,width=900,height=1000)
layout(matrix(1:4,ncol=2,byrow=T),widths=c(1,1),heights=c(1,1))
par(mar=c(5.6,6.7,4,4),cex.axis=1.4)

plot(med.out[,3],med.out[,1]/1000,ylim=c(0,max(med.out[,1]/1000*1.3)),type='l',lwd=2,xlab='',ylab='',las=1)
lines(low.out[,3],low.out[,1]/1000,lty=2);lines(up.out[,3],up.out[,1]/1000,lty=2)
mtext(expression(paste('K (',"%%"1000 ton)')),side=2,line=3.8,cex=1.4)
mtext("Reducción superior",side=1,line=3.6,cex=1.4)

plot(med.out[,3],med.out[,2],ylim=c(0,max(med.out[,2]*1.3)),type='l',lwd=2,xlab='',ylab='',las=1)
mtext('r',side=2,line=3.8,cex=1.4)
mtext("Reducción superior",side=1,line=3.6,cex=1.4)
lines(low.out[,3],low.out[,2],lty=2);lines(up.out[,3],up.out[,2],lty=2)

plot(med.out[,3],med.out[,4]/1000,ylim=c(0,max(med.out[,4]/1000*1.3)),type='l',lwd=2,xlab='',ylab='',las=1)
lines(low.out[,3],low.out[,4]/1000,lty=2);lines(up.out[,3],up.out[,4]/1000,lty=2)
mtext(expression(paste('RMS (',"%%"1000 ton)')),side=2,line=3.8,cex=1.4)
mtext("Reducción superior",side=1,line=3.6,cex=1.4)

plot(med.out[,3],med.out[,6],ylim=c(0,max(med.out[,6]*1.5)),type='l',lwd=2,xlab='',ylab='',las=1)
lines(low.out[,3],low.out[,6],lty=2);lines(up.out[,3],up.out[,6],lty=2)
mtext("Reducción",side=2,line=3.8,cex=1.4)
mtext("Reducción superior",side=1,line=3.6,cex=1.4)
```

```
#dev.off()
```

```
#####
# GRAFICA DIAGRAMA DE FASE
#####
library(MASS)

K      <- med.out[1,1]
mc.dat <- BF2msy.end
Bmrs   <- tabla[3,1]/2 #BMRS
Fmrs   <- tabla[3,2]/2 #FMRS
Fest   <- C/Bioma[3,]  #F anual
Y1     <- Fest/Fmrs;
X1     <- Bioma[3,]/Bmrs
```

```

Z1      <-Bioma[3,]/K
#h=rep(0.13,4)
z<-kde2d(mc.dat[,1],mc.dat[,2],n=100,
lims=c(range(c(0,max(X1))),range(c(0,max(Y1)*1.7))))
est<-z$z/max(z$z);z$z<-est
#Bmrs=43590;Fmrs=0.3515;Fest=C/Bioma[3,]
#Y1<-Fest/Fmrs;X1<-Bioma[2,]/Bmrs
#
soli<-cbind(yr,round(Bioma[3,],0),round(Fest,2),round(Z1,2),round(X1,2),round(Y1,2))
colnames(soli)<-c("year","BT","Fest","B_Bo","Brel","Frel")

kable(soli)

```

year	BT	Fest	B_Bo	Brel	Frel
2012	16956	0.24	1.00	2.00	0.54
2013	12882	0.41	0.76	1.52	0.93
2014	10328	0.40	0.61	1.22	0.91
2015	9741	0.77	0.57	1.15	1.75
2016	5869	0.87	0.35	0.69	1.96
2017	4169	0.92	0.25	0.49	2.09
2018	3119	0.21	0.18	0.37	0.47
2019	4701	0.29	0.28	0.55	0.65
2020	6373	0.29	0.38	0.75	0.65
2021	8032	0.45	0.47	0.95	1.01

```
kable(rbind(Bmrs,Fmrs))
```

Bmrs	8484.6911038
Fmrs	0.4430894

```

#library(rJava)                                ## PROBLEMAS CON ESTO
#library(xlsx)
write.csv2(soli,"tabla2.csv",row.names=FALSE)
#DEFINE LAS AREAS DE LOS POLIGONOS
cols<-c("#696969","#A8A8A8","#DEDEDE")
ini<-c(-0.09);
xmax<-max(X1)*1.35;
ymax<-max(Y1)*1.22;
xmin<-(0.08)
pol1<-matrix(c(0.9,ini,0.9,1.1,xmax,1.1,xmax,0.75,1.25,0.75,1.25,ini),
ncol=2,byrow=T)
pol2<-matrix(c(1.25,ini,1.25,0.75,xmax,0.75,xmax,ini),ncol=2,byrow=T)
pol3<-matrix(c(xmax,1.1,xmax,ymax,0.9,ymax,0.9,1.1),ncol=2,byrow=T)
pol4<-matrix(c(0.5,ini,0.9,ini,0.9,ymax,0.5,ymax),ncol=2,byrow=T)
pol5<-matrix(c(-0.07,ini,0.5,ini,0.5,ymax,-0.07,ymax),ncol=2,byrow=T)

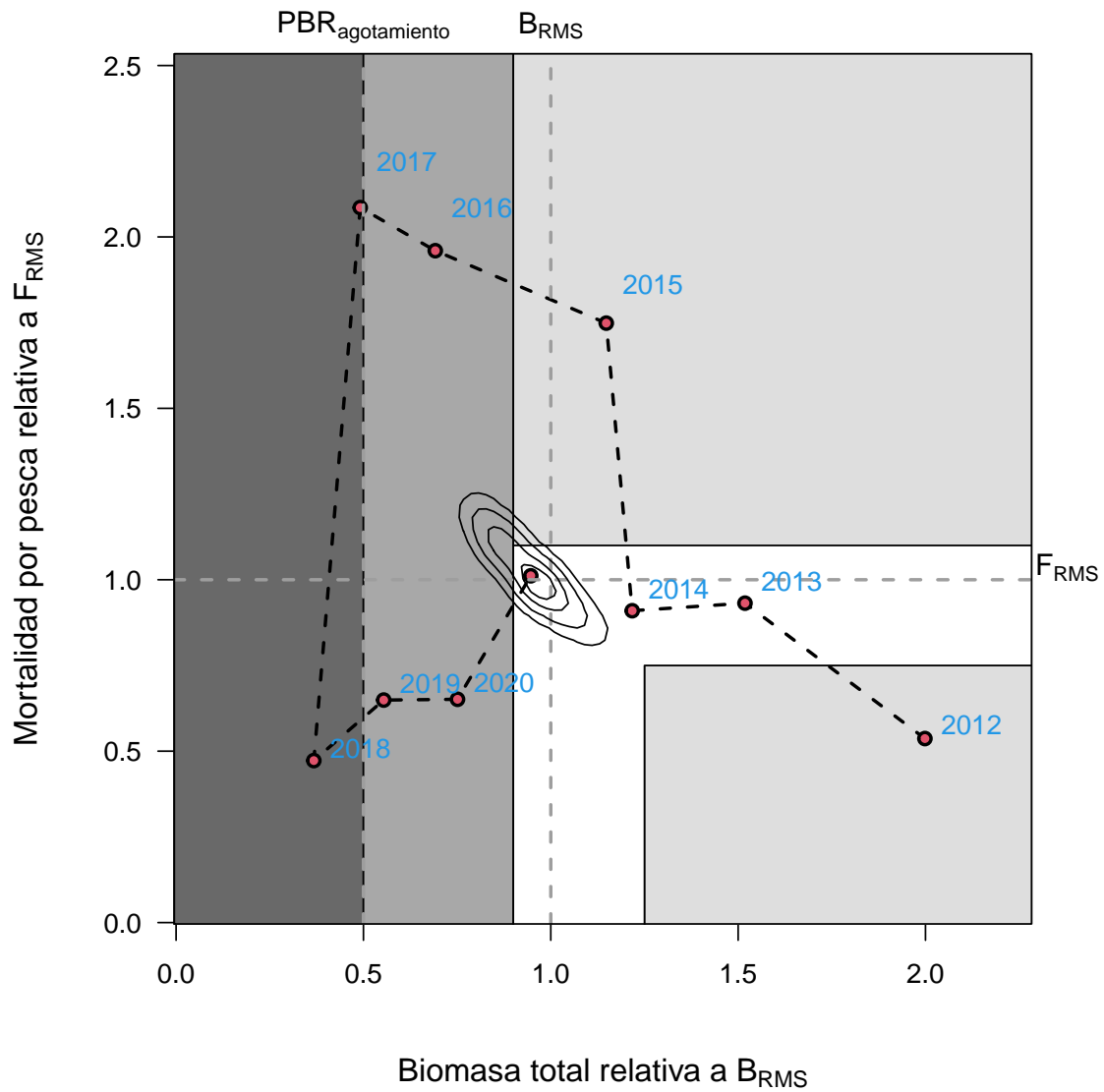
#name4<-paste(getwd(),"/Figuras/Fig4_Zhou2013_fase.png",sep="")
#png(file=name4,width=1200,height=1000)
par(mar=c(6.1,6.5,4.8,4.8),cex.axis=1,cex.lab=1)
plot(X1,Y1,col=0,xlab="",ylab="",yaxt="n",xlim=c(xmin,max(X1)*1.1),
ylim=c(0.09,max(Y1)*1.17))

```

```

axis(2,las=1)
polygon(pol5,col=cols[1],border=1);polygon(pol4,col=cols[2],border=1)
polygon(pol3,col=cols[3],border=1);polygon(pol2,col=cols[3],border=1)
polygon(pol1,col="white",border="black")
#points(mc.dat[,1],mc.dat[,2],pch=21,bg="#B5B5B5",cex=0.9,col=1)
lines(X1,Y1,lty=2,col=1,lwd=2)
lines(X1,Y1,type="p",bg=2,pch=21,cex=1,lwd=2)
abline(v=1,lty=2,col=8,lwd=2);abline(h=1,lty=2,col=8,lwd=2)
abline(v=0.5,lty=2,col=8,lwd=2)
contour(z,drawlabels=FALSE,levels=c(0.1,0.25,0.5,0.75),add=TRUE)
text(0.5,max(Y1)*1.29,expression(PBR[paste("agotamiento")]),cex=1.1,
pos=1,xpd=T)
text(1,max(Y1)*1.29,expression(B[paste("RMS")]),cex=1.1,pos=1,xpd=T)
text(max(X1)*1.19,1.11,expression(F[paste("RMS")]),cex=1.1,pos=1,xpd=T)
mtext(expression(paste("Biomasa total relativa a ",B[paste("RMS")],sep="")),
side=1,line=4.2,cex=1.2)
mtext(expression(paste("Mortalidad por pesca relativa a ",F[paste("RMS")],
sep="")),side=2,line=3.8,cex=1.2)
#a2<-which(yr%in%seq(2015,1994,by=-2))==TRUE)
a2<-c(1,2,3,4,5,6,7,8,9)
text(X1[a2],Y1[a2]*1.06,yr[a2],cex=1,pos=4,col=4)
#text(1.10,0.83,"Plena Explotación",cex=1.6,pos=4,col=1,lwd=2)
#text(1.56,0.31,"Sub Explotación",cex=1.6,pos=4,col=1,lwd=2)
#text(1.33,1.51,"Sobrepesca",cex=1.6,pos=4,col=1,lwd=2)
#text(0.58,0.67,"Sobre",cex=1.6,pos=4,col=1,lwd=2)
#text(0.52,0.51,"Explotación",cex=1.6,pos=4,col=1,lwd=2)
#text(0.68,1.18,"Sobre-explotación y Sobrepesca",cex=1.6,pos=4,lwd=2,srt=90)
#text(0.23,1.18,"Colapso y/o Agotamiento",cex=1.6,pos=4,lwd=2,srt=90)
box()

```



#dev.off()

Cálculo de CBA

```
#####
#CALCULO DE LA CBA PARA SARDINA AUSTRAL XI
#####
mata <-out1.backup[1:5];
mm <-length(mata)
mato <-vector()

for(p in 1:mm){
  mato <-cbind(mato,mata[[p]])}
mate <-as.data.frame(mato)
colnames(mate)<-c("k","r","msy","Bend","Depletion")

yy <-length(yr)
prob <-c(0.6666667,1.00,1.25) # ponderadores de Frms
ss <-dim(sp)
yrs_pro <-seq(yr[yy],yr[yy]+11,by=1) # años de proyección
yyp <-length(yrs_pro)

BT=CT=array(NA,c(length(prob),ss[1],length(yrs_pro)))

BT[, ,1] <-Bioma[3,yy]
CT[, ,1] <-C[yy]
Fi <-Fmrs*prob

# y = Frms ponderados
# n = número de simulaciones
# m = años de proyección

for(y in 1:length(Fi)){
  for(n in 1:ss[1]){
    ki=sp$k[n] # parámetro K simulado
    ri=sp$r[n] # parámetro r simulado
    for(m in 1:(yyp-1)){ # PROYECCIÓN
      if(m==1){
        CT[y, ,1]=C[yy]} # igual a la captura del último año
      else {
        CT[y,n,m]=BT[y,n,m]*Fi[y]} # captura proyectada
        BT[y,n,m+1]=BT[y,n,m]+ri*BT[y,n,m]*(1-BT[y,n,m]/ki)-CT[y,n,m] # biomasa total proyectada
      if(m==(yyp-1)){
        CT[y,n,m+1]=BT[y,n,m+1]*Fi[y]}
    }
  }
}

#####
# GRAFICA LA CBA 2 PARA sardina austral
#####
FF <-formatC(Fi,format="f",digits=2)
BB <-expression(paste("Biomasa (mil t)",sep=""))
Binf <-tabla[2,1]/2
Bsup <-tabla[4,1]/2
rng1 <-range(BT[, ,],na.rm=T)
```

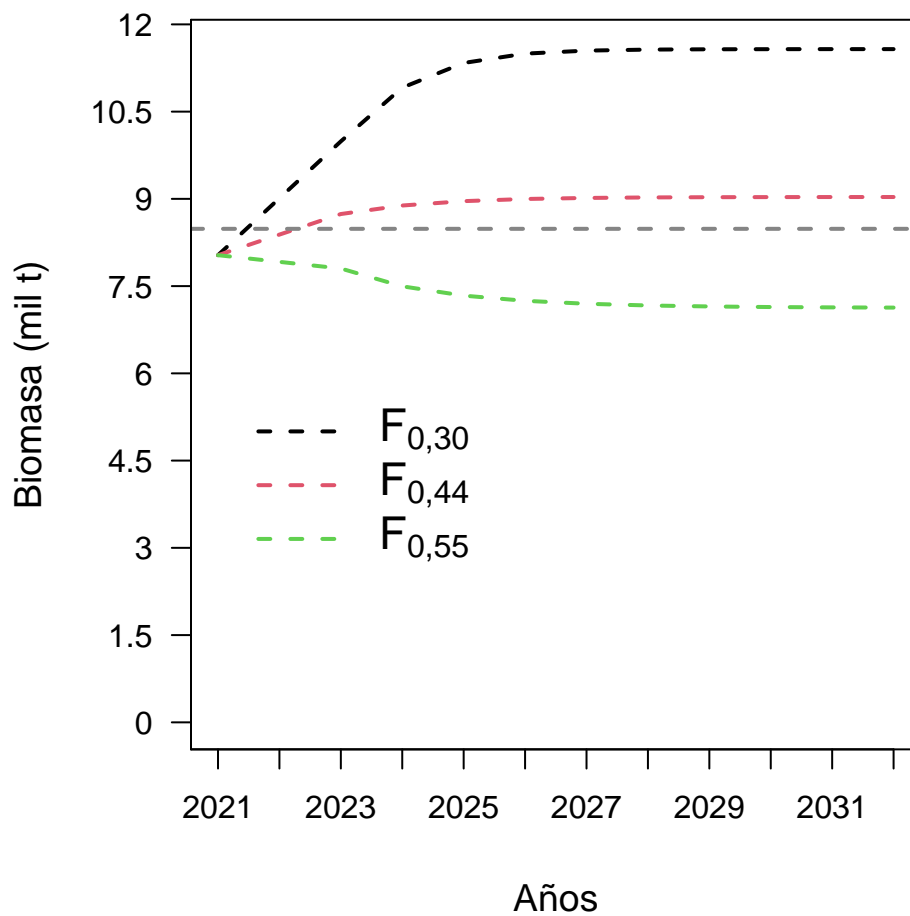
```

ax2 <-seq(0, rng1[2]*1.15, by=1500)
cols <- "#858585"
y1 <-length(yrs_pro)
xxxx<-matrix(ncol=3, nrow=11)

par(mar=c(5,5,1,1), cex.axis=1, cex.lab=1)
plot(yrs_pro[-2], seq(0, rng1[2]*1.15, le=(y1-1)), col=0, type="o", xlab="", ylab="", yaxt="n", ylim=c(0, rng1[2])

for(x in 1:length(Fi)){
  xxxx[,x]<-apply(BT[x,,], 2, quantile)[3, -2]
  lines(yrs_pro[-2], xxxx[,x], col=x, lty=2, lwd=2)
}
abline(h=Bmrs, lty=2, lwd=2, col=cols)
axis(2, at=ax2, labels=ax2/1000, las=1, cex=1)
mtext(BB, side=2, line=3.5, cex=1.2)
mtext("Años", side=1, line=3.4, cex=1.2)
legend(2021, rng1[2]*0.5, c(expression(F[paste("0,30")])), expression(F[paste("0,44")])),
expression(F[paste("0,55")])), lty=c(2,2,2,2,2), lwd=c(2,2,2,2,2), cex=1.4,
col=c(1,2,3), bty="n")

```



```

#####
# GRAFICA LA CAPTURA
#####

```

```

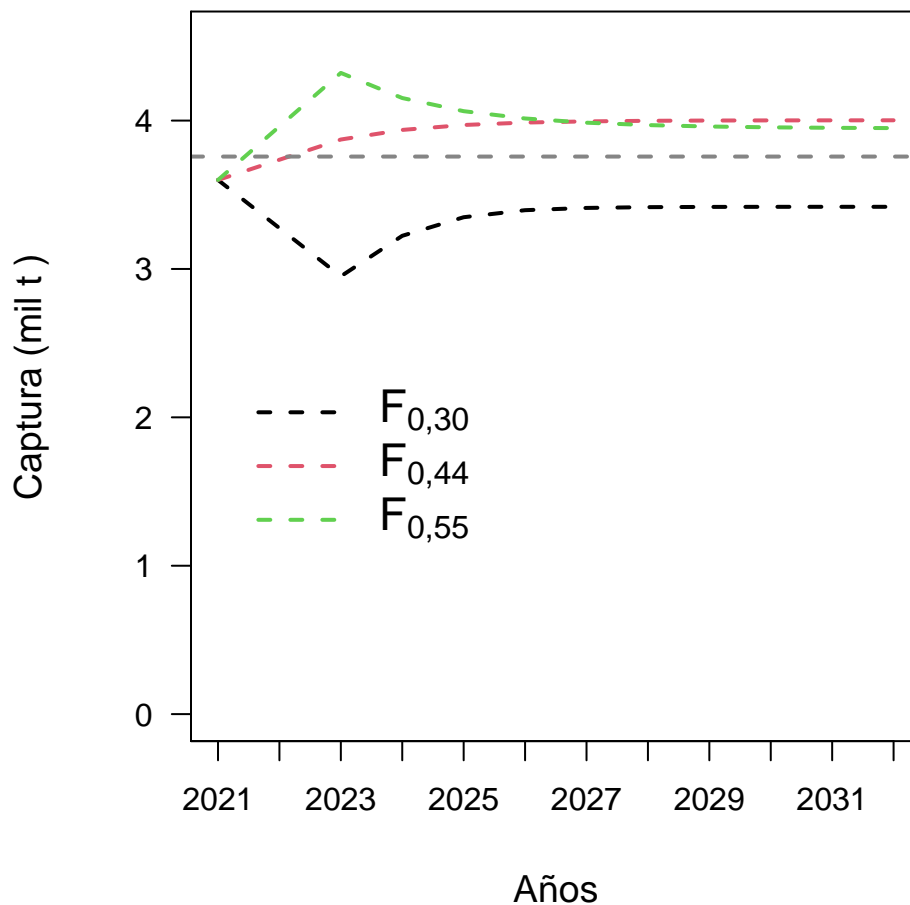
CC <-expression(paste("Captura (mil t)",sep=""))
MRS <-tabla[3,3] #50%
rng2 <-range(CT[,],na.rm=T)
ax3 <-seq(0,rng2[2]*1.15,by=1000)

xxxx<-matrix(ncol=3,nrow=11)

par(mar=c(5,5,1,1),cex.axis=1,cex.lab=1)
plot(yrs_pro[-2],seq(0,rng2[2]*1.15,le=11),col=0,type="o",xlab="",ylab="",yaxt="n",ylim=c(0,rng2[2]*0.9))

for(x in 1:length(Fi)){
  xxxx[,x]<-apply(CT[x,,],2,quantile)[3,-2]
  lines(yrs_pro[-2],xxxx[,x],col=x,lty=2,lwd=2)
}
abline(h=MRS,lty=2,lwd=2,col=cols)
axis(2,at=ax3,labels=sprintf("%0.0f",ax3/1000),las=1,cex=1.4)
mtext(CC,side=2,line=3.5,cex=1.2)
mtext("Años",side=1,line=3.4,cex=1.2)
legend(2021,rng2[2]*0.5,c(expression(F[paste("0,30")])),expression(F[paste("0,44")])),
expression(F[paste("0,55")])),lty=c(2,2,2,2,2),lwd=c(2,2,2,2,2),cex=1.4,
col=c(1,2,3),bty="n")

```



```
#####
# TABLA DE RESULTADOS CAPTURA 2021
#####
ct<-matrix(NA,length(Fi),5)
for(i in 1:length(Fi)){
  ct[i,]<-as.numeric(quantile(CT[i,,2],probs=c(.1,.2,.3,.4,.5))) # CT[i,,2] (el 2 representa 1 año de p
}
colnames(ct)<-c("10%", "20%", "30%", "40%", "50%")
rownames(ct)<-formatC(Fi,format="f",digits=2)
cat("\n")

print(ct)

##          10%      20%      30%      40%      50%
## 0.30 2477.292 2485.237 2489.657 2493.287 2498.381
## 0.44 3715.938 3727.855 3734.485 3739.931 3747.572
## 0.55 4644.923 4659.818 4668.107 4674.914 4684.465

#####
# TABLA DE RESULTADOS biomasa 2021
#####
bt<-matrix(NA,length(Fi),5)
for(i in 1:length(Fi)){
  bt[i,]<-as.numeric(quantile(BT[i,,2],probs=c(.1,.2,.3,.4,.5))) # CT[i,,2] (el 2 representa 1 año de p
}
colnames(bt)<-c("10%", "20%", "30%", "40%", "50%")
rownames(bt)<-formatC(Fi,format="f",digits=2)
cat("\n")
print(bt)

year<-seq(2012,2021)
bioHil<-c(NA,17712,12394,11186,6911,5161,4212,6108,7933,8592)

par(mar=c(5,5,1,1),cex.axis=1,cex.lab=1)
plot(year,c(soli[,2],bt[2,5]),type="o",pch=19,ylim=c(0,20000), xaxp=c(2012,2022,10),ylab="Biomasa total
lines(year,bioHil,type="o",col=2,pch=19)
legend(2017,16000,c("Hilborn y Mangel 1997","Zhou 2013"),
      bty="n",lwd=1,pch=19,col=c(2,1), title="Método de estimación")

#####
# RANGO CBA PARA PBR Al MRS (2) y EL 2021(2)
#####
rango<-quantile(CT[2,,2],prob=c(0.025,0.25,0.50,0.75,0.975))

kable(rango)
```

	x
2.5%	3700.132
25%	3731.443
50%	3747.572
75%	3769.867
97.5%	3803.888

#FIN