

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)
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")

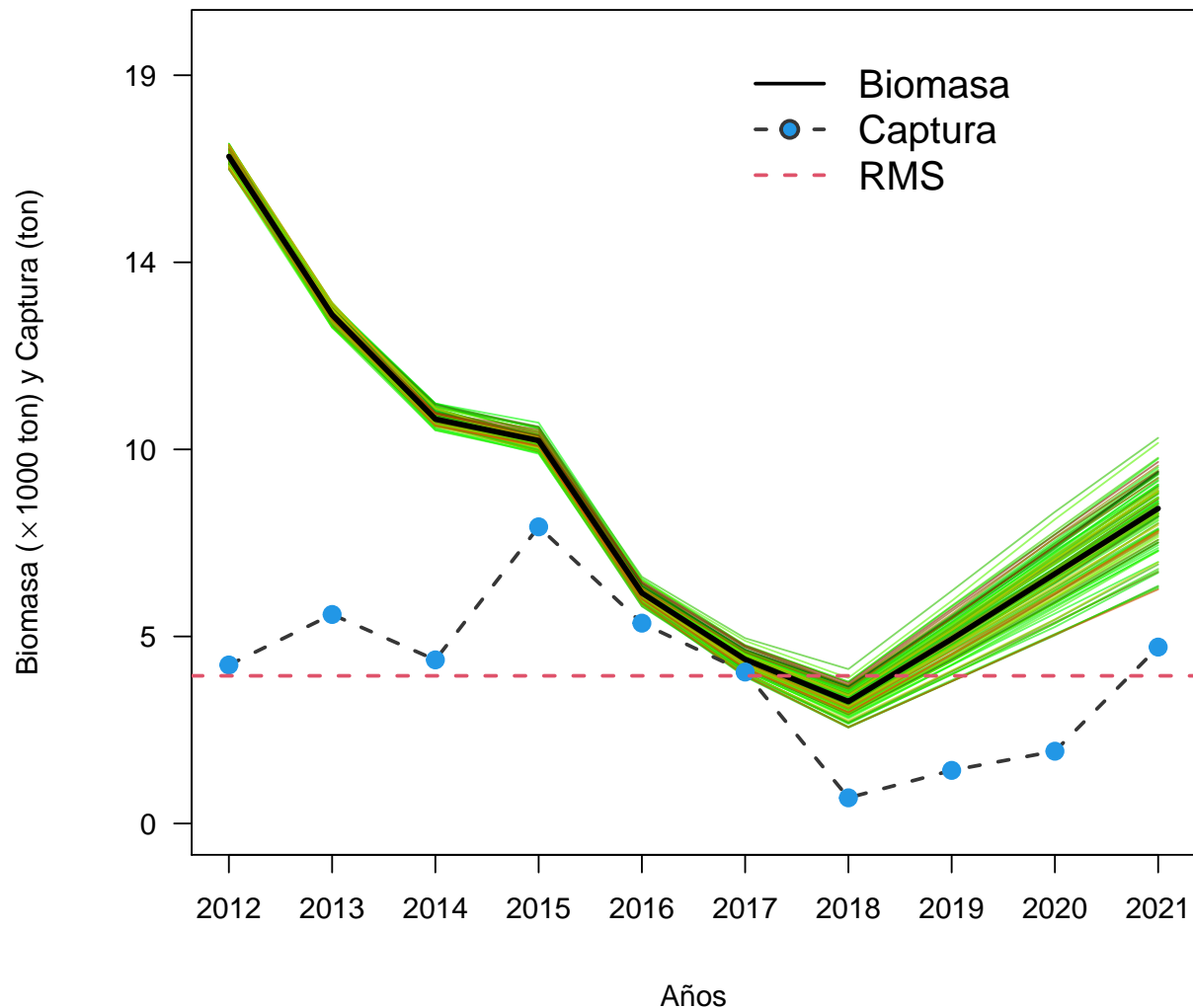
all$d=as.numeric(as.character(all$ind))
all=all[,c(1,2,4)]
all=all[!is.na(all[,2]),]
all$msy=all[,1]*all[,2]/4

#####
# 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]
all3      =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	5955.795	0.3509165
25%	16634.15	0.8614773	3726.883	7417.435	0.4370366
50%	16969.38	0.8861789	3757.632	8014.236	0.4722002
75%	17304.61	0.9106092	3786.803	8520.308	0.5020181
100%	17304.61	0.9178450	3816.893	9811.489	0.5780947

```

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

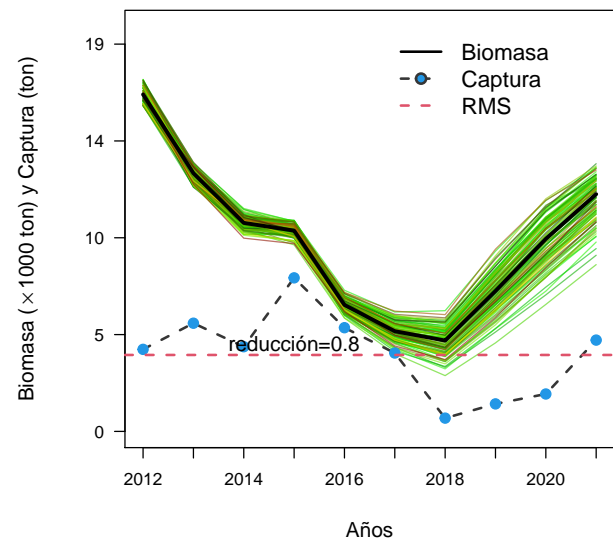
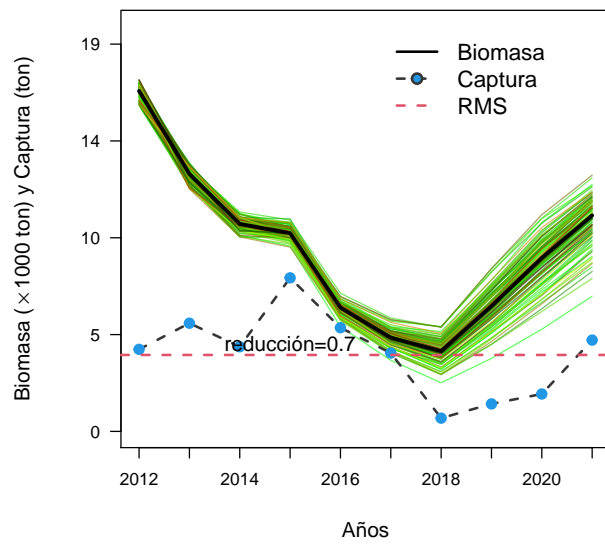
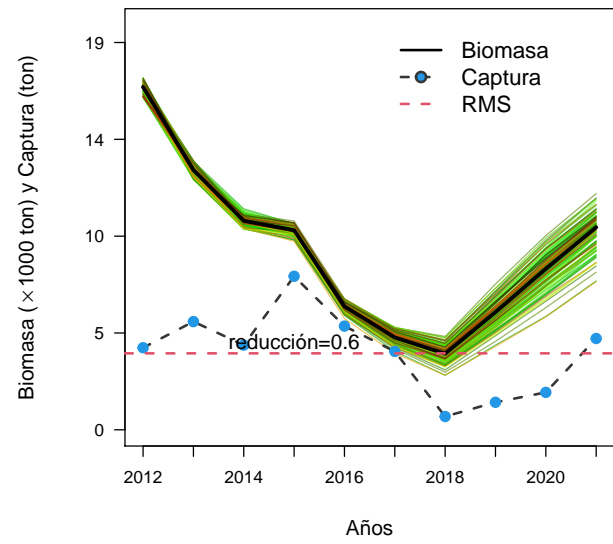
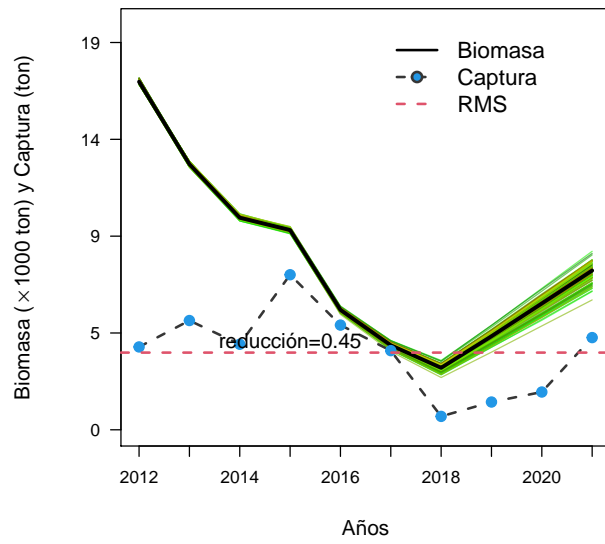
```
#####
# sensitivity to assumed upper depletion (if needed) #
#####
med.out=low.out=up.out=matrix(NA,nrow=4,ncol=6)
d.l=c(0.45,0.6,0.7,0.8) # assumed upper depletion levels
layout(matrix(1:4,ncol=2,byrow=T),widths=c(1,1),heights=c(1,1))
for(i in 1:4){
  all2=all[!is.na(all$r) & all$d <= d.l[i],]
  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)
  #####
}
```



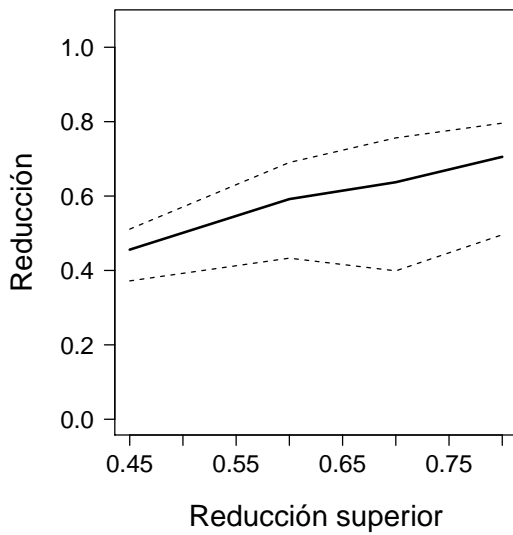
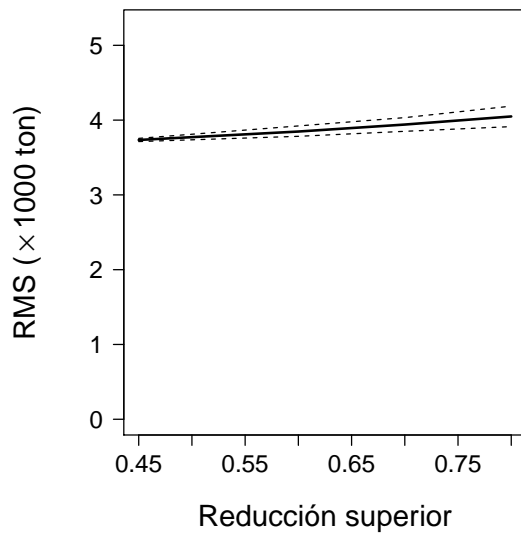
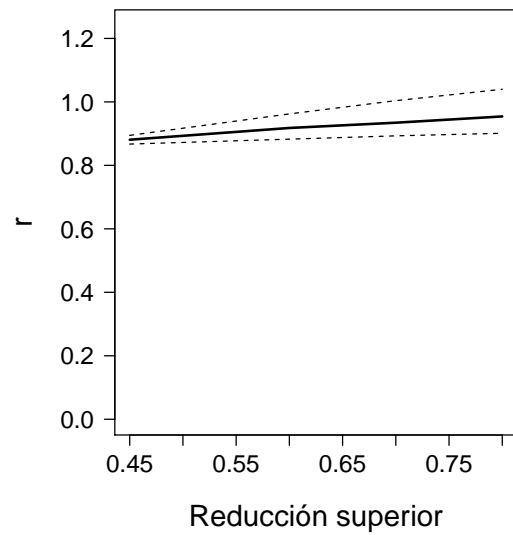
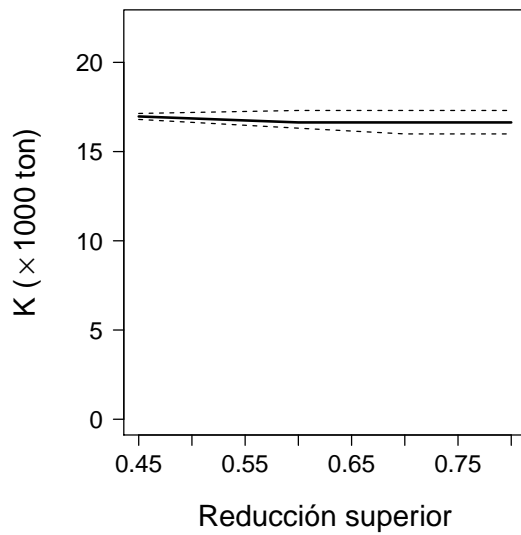
```
#####
# parameters as a function of assumed upper depletion level
#####
#name3<-paste(getwd(),"/Figuras/Fig3_Zhou2013_sensitivity.png",sep="")
#png(file=name3,width=900,height=1000)
layout(matrix(1:4,ncol=2,byrow=T),widths=c(1,1),heights=c(1,1))
par(mar=c(5.6,6.7,4,4),cex.axis=1.4)

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	16972	0.24	1.00	2.00	0.54
2013	12940	0.41	0.76	1.53	0.93
2014	10288	0.40	0.61	1.21	0.91
2015	9743	0.77	0.57	1.15	1.75
2016	5863	0.87	0.35	0.69	1.96
2017	4176	0.92	0.25	0.49	2.08
2018	3102	0.21	0.18	0.37	0.48
2019	4692	0.29	0.28	0.55	0.65
2020	6353	0.29	0.37	0.75	0.65
2021	8014	0.56	0.47	0.94	1.26

```
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)

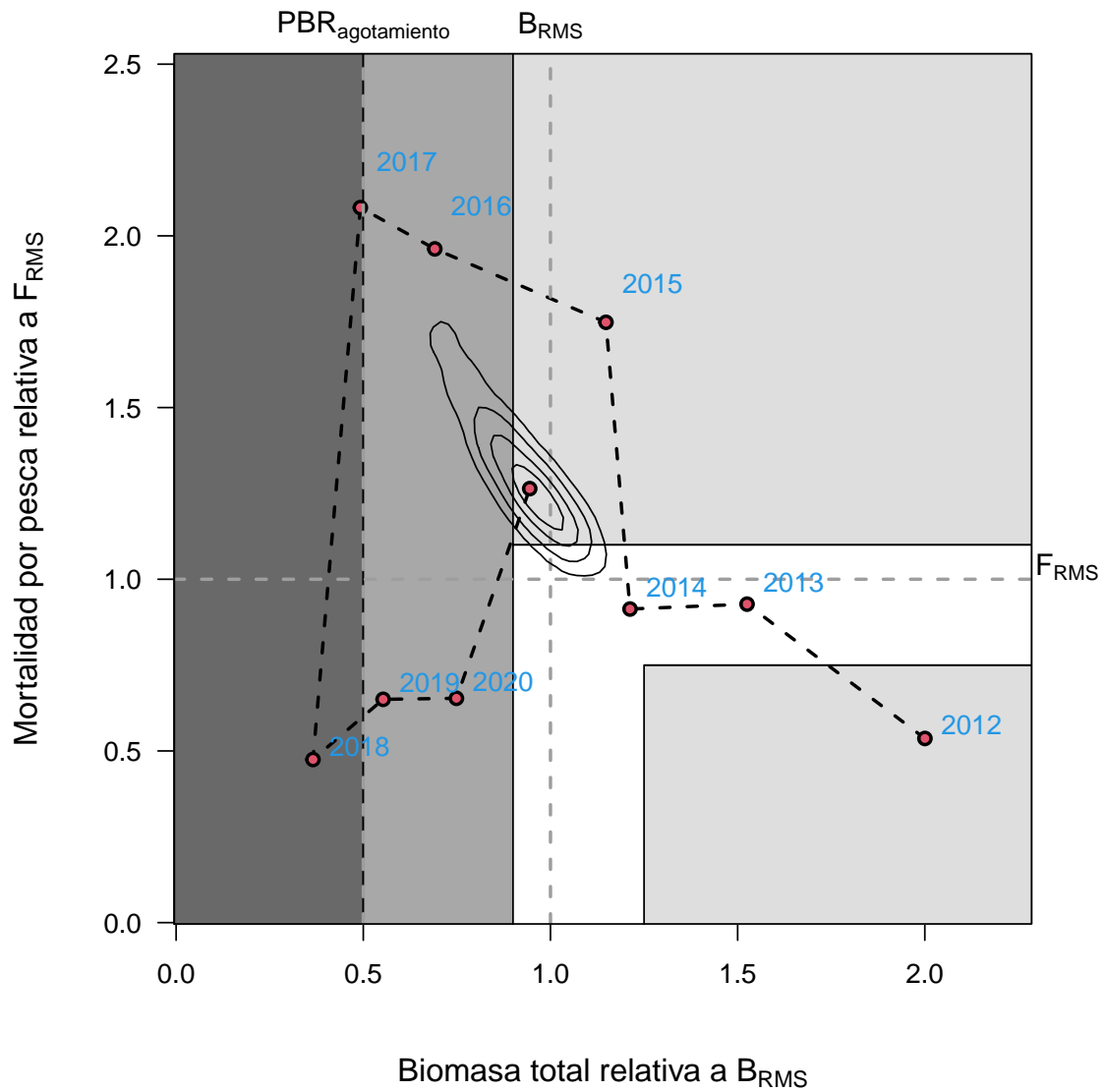
#name4<-paste(getwd(),"/Figuras/Fig4_Zhou2013_fase.png",sep="")
#png(file=name4,width=1200,height=1000)
par(mar=c(6.1,6.5,4.8,4.8),cex.axis=1,cex.lab=1)
plot(X1,Y1,col=0,xlab="",ylab="",yaxt="n",xlim=c(xmin,max(X1)*1.1),
ylim=c(0.09,max(Y1)*1.17))

```

```

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)
```

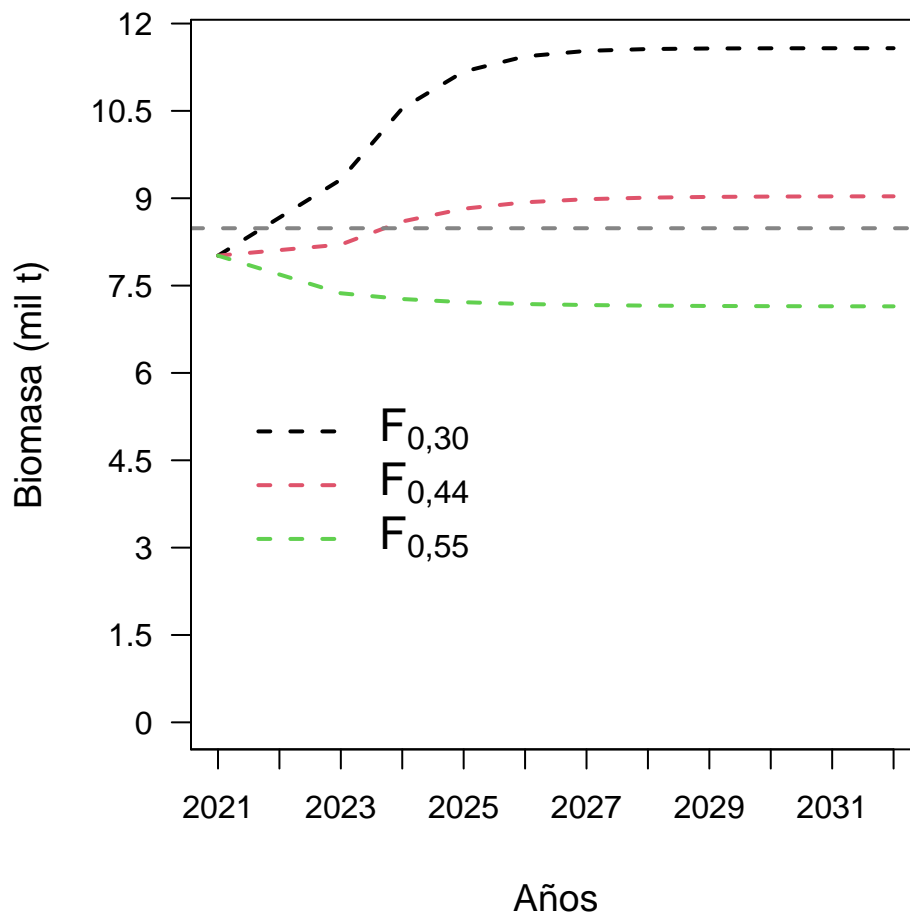
```

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
#####

```

```

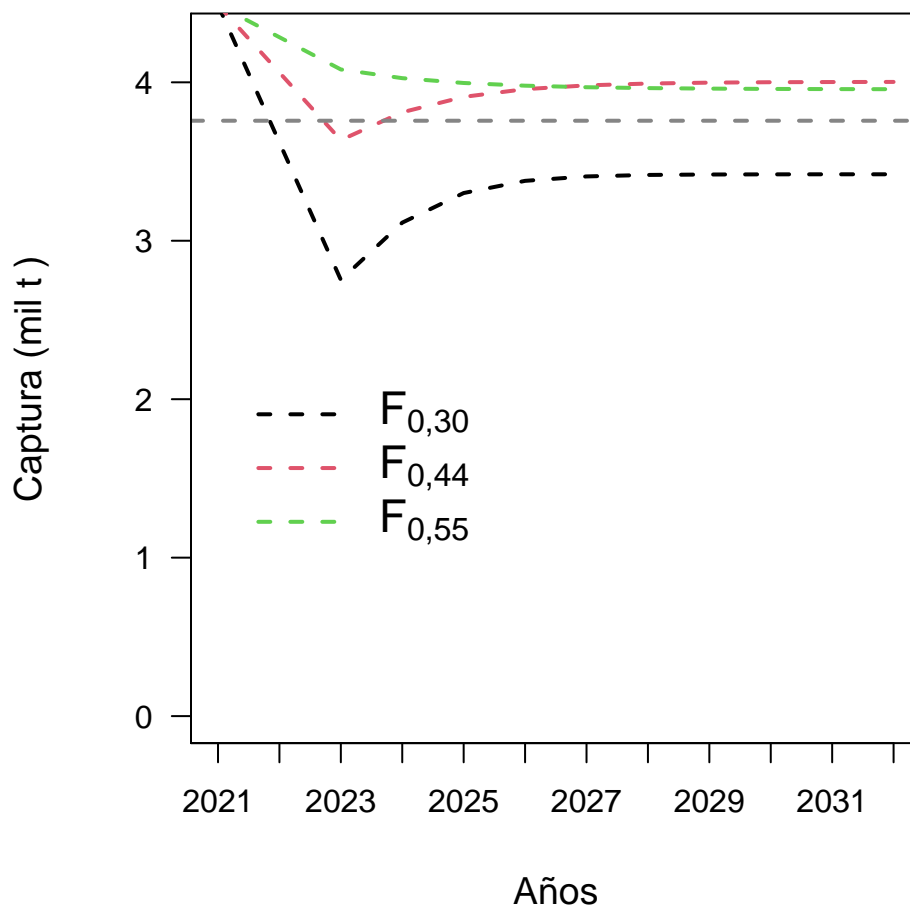
CC <-expression(paste("Captura (mil t)",sep=""))
MRS <-tabla[3,3] #50%
rng2 <-range(CT[,],na.rm=T)
ax3 <-seq(0,rng2[2]*1.15,by=1000)

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 2209.873 2213.901 2222.323 2226.953 2231.200
## 0.44 3314.810 3320.851 3333.484 3340.430 3346.799
## 0.55 4143.512 4151.063 4166.855 4175.537 4183.499

#####
# 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%	3297.362
25%	3328.960
50%	3346.799
75%	3366.987
97.5%	3396.586

#FIN