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APPLICATION OF A BAYESIAN SURPLUS PRODUCTION MODEL TO PRELIMINARY DATA FOR SOUTH ATLANTIC ALBACORE

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SUMMARY

The Bayesian Surplus Production (BSP) model that was applied to the South Atlantic albacore stock in 2011 was updated using an additional two years of catch data, and the CPUE data set that was produced at the 2012 data meeting. The same informative priors were used, as well as an alternative prior for r that was less informative. The alternative models were used to predict the probability of the stock achieving a biomass above B_{MSY} under a range of management scenarios. Kobe plots were also produced. Estimates of current status were dependent on which method was used to weight the CPUE data points.

RÉSUMÉ

Le modèle bayésien de production excédentaire (BSP) qui a été appliqué au stock de germon de l'Atlantique Sud en 2011 a été mis à jour à l'aide des données de capture de deux années supplémentaires, ainsi que du jeu de données de CPUE qui avait été produit à la réunion de préparation des données de 2012. Les mêmes priors informatifs ont été utilisés ainsi qu'un prior alternatif pour r qui était moins informatif. Les modèles alternatifs ont été utilisés afin de prédire la probabilité que le stock atteigne une biomasse supérieure à B_{PME} selon divers scénarios de gestion. Des diagrammes de Kobe ont également été élaborés. Les estimations de l'état actuel dépendaient du type de méthode utilisée pour pondérer les points de données de la CPUE.

RESUMEN

Se actualizó el modelo de producción excedente bayesiano (BSP) que se aplicó al stock de atún blanco del Atlántico sur en 2011 utilizando dos años adicionales de datos de captura y el conjunto de datos de CPUE que se realizó en la reunión de preparación de datos de 2012. Se utilizaron las mismas distribuciones previas informativas, así como una distribución previa alternativa para r que era menos informativa. Los modelos alternativos se utilizaron para predecir la probabilidad de que el stock alcance una biomasa por encima de Brms en un rango de escenarios de ordenación. Se realizaron también diagramas de Kobe. Las estimaciones del estado actual del stock dependían del método utilizado para ponderar los puntos de datos de CPUE.

KEYWORDS

Catch/effort, Mathematical models, Stochastic models, Stock assessment, Population dynamics

1. Introduction

The Bayesian Surplus Production Model (BSP, McAllister et al. 2001, 2003, Babcock 2007, Babcock 2012), was used in the 2011 assessment of South Atlantic and Mediterranean albacore (Anonymous 2012). The model requires input data on catches, which do not need to be separated by fleet, as well as at least one index of abundance, such as a catch per unit of effort (CPUE) series. In addition, it is possible to use available biological information about albacore to set up a Bayesian informative prior probability density function for the rate of population increase (*r*); this constrains the model to estimate parameter values that are biologically plausible. Informative priors can also be used to constrain the value of the carrying capacity (*K*), and the starting biomass ratio (*Bo/K*). Either a Schaefer model or a generalized production model can be used. The model can also be used to make projections, and estimate the probability of the stock staying above a management target such as the biomass that supports maximums sustainable yield (B_{msy}). The model includes measurement error in CPUE, but not process error. Catches are assumed to be known without error. If the model is used with uninformative priors it should give similar results to an ASPIC model with the same data.

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2. Methods

Catch data are available in the ICCAT Task I database from 1956 through 2011 for South Atlantic albacore (**Figure 1a**). The CPUE indices from the 2012 data preparatory meeting (Anonymous 2013) were used, from the Taiwanese longline, Uruguayan longline, and Japanese longline (early and late). Four series that were used in the 2011 assessment (Japanese intermediate, Brazil, and South Africa, early and late) were not used, following the recommendation of data preparatory meeting. Data were available from at least one series for every year between 1959 and 2011 (**Figure 1b**).

The biomass in the first year of the fishery, relative to the carrying capacity *K*, was given an informative lognormal prior with a mean of 0.9 and a log standard deviation of 0.1 implying that the population was close to unfished in the first year of the fishery. The prior for *K* was uniform in log space. An informative prior for the intrinsic rate of population increase r was developed as shown in Babcock (2012) and the 2011 Assessment. Briefly, the value of *r* can be calculated as (Myers 1997, 1999):

(1) $$(e^r)^a - S(e^r)^{a-1} - \tilde{\alpha} = 0$$

where a is the age at 50% maturity, *S* is the annual survival rate of spawners and $\tilde{\alpha}$ is maximum number of spawners produced per spawner per year after a lag of a years, a parameter related to the steepness of the stock recruit curve. A prior for r was calculated based on informative priors for a, S and $\tilde{\alpha}$, using Monte Carlo simulation (Babcock and McAllister 2003, Anonymous 2003, Babcock 2012). Annual survival *S* was calculated from a prior for natural mortality rate *M* that was normal, with a mean of 0.3, a standard deviation of 0.1 between zero and 1.0. Median age at maturity was 5.5, with a range from 4 to 7. Monte Carlo draws from these distributions were used to calculate *r* using equation (1). The empirical distribution was approximated by a *t* distribution with mean 0.2, variance 0.025 and df 10, which was used as a prior in the BSP model. To examine the effect of this prior on the results, a prior with 10 times the variance was also used.

As in the 2011 assessment, CPUE data points were weighted either equally or by the relative amount of catch taken by each fleet (**Table 1**). When catch weighting was used, the only CPUE indices with a strong influence on the results were the Japanese longline early series, and the Chinese Taipei series (**Figure 1c**).

All model variations were fitted using the BSP software, version 1, using the priors as an importance function for the sampling importance resampling (SIR) algorithm. Projections were conducted the fishing mortality rate at MSY, and total allowable catch (TAC) at 20000, 25000, 30000 and 35000. Results were plotted using R, and Kobe plots were produced using the kobe package (Kell 2012).

3. Results

All three models (equal weighting, catch weighting, or equal weighting with a less informative prior) fit a general declining trend through the CPUE data with a flat or increasing trend over the last decade (**Figure 2**). The model with catch weighting estimated a larger carrying capacity (**Table 2, Figure 3**). In general, *K* had a very broad posterior distribution with some probability of values up to the upper limit of *K*, especially for the run with catch weighting. A higher upper limit of *K* would probably give a higher estimated posterior mean of *K* for this run (SA 5). The posterior mean of *r* was close to the prior mean of 0.2, even when a less informative prior was used for *r* (SA 6). There was a strong negative correlation between *r* and *K* (**Figure 4**).

Although all three models estimated a decline in biomass and an increase in fishing mortality rate over time, the models with equal weighting found that the population was probably overfished and experiencing overfishing, while the model with catch weighting found that the population was probably not overfished or experiencing overfishing (**Figure 5, Figure 6**).

Given a TAC around the level of the current harvest, the models with equal weighing projected that the median population would continue to decline, and the model with catch weighting projected that the median population would increase (**Table 3, Figure 7**).

4. Discussion

The results of this analysis were similar to the 2011 assessment results in that the equal weighting scenario found that the population was overfished and experiencing overfishing, and the catch weighting scenario found that the population was not overfished but was experiencing overfishing. The results were fairly uncertain, as would be expected given that the CPUE data show a general declining trend. In such "one-way-trip" data sets, there is often strong correlation between *r* and *K* and both parameters are poorly estimated. The informative prior for *r* reduced the variance of both *r* and *K*, but made little difference in the estimate of current status (compare SA4 and SA 6 in **Table 1**).

The results were more sensitive to how the CPUE data points were weighted then to the informative priors (compare SA4 and SA 5 in **Table 1**). The difference in results is caused by the fact that the different CPUE series have somewhat different trends in recent years. Sensitivity analyses with a wider range of weightings would be worthwhile.

Acknowledgements

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Table 1. Model specification for South Atlantic albacore BSP model.

Model	Prior *Bo/K*	Prior *K*	Prior *r*	Weights
SA 4	logormal(μ=0.9, ln(σ)=0.1), 0.1-1.5	log(K) uniform 100-2000000	t(μ=0.2, σ^2=0.025, df=10), 0.1-1.5	equal
SA 5	logormal(μ=0.9, ln(σ)=0.1), 0.1-1.5	log(K) uniform 100-2000000	t(μ=0.2, σ^2=0.025, df=10), 0.1-1.5	catch
SA 6	logormal(μ=0.9, ln(σ)=0.1),0.1-1.5	log(K) uniform 100-2000000	t(μ=0.2, σ^2=0.25, df=10), 0.1-1.5	equal

Table 2. Results of BSP model runs South Atlantic (SA) albacore.

Variable	SA 4	SA 5	SA 6
K (1000)	648.23(0.57)	784.85(0.56)	595.54(0.69)
r	0.20(0.63)	0.22(0.62)	0.26(0.75)
MSY (1000)	22.16(0.25)	35.15(0.80)	22.99(0.36)
Bcur (1000)	224.66(0.64)	471.74(0.78)	210.38(0.71)
Binit (1000)	600.12(0.57)	725.53(0.56)	550.90(0.69)
Bcur/Binit	0.39(0.34)	0.64(0.39)	0.42(0.35)
Ccur/MSY	1.20(0.45)	0.94(0.57)	1.19(0.52)
Bcur/Bmsy	0.72(0.34)	1.17(0.38)	0.77(0.35)
Fcur/Fmsy	1.98(0.77)	1.22(1.41)	1.91(0.89)

Table 3. Decision table for South Atlantic albacore.

		SA 4		SA 5		SA 6	
Horizon	Policy	E(Bfin/ Bmsy)	P(Bfin> Bmsy)	E(Bfin/ Bmsy)	P(Bfin> Bmsy)	E(Bfin/ Bmsy)	P(Bfin> Bmsy)
10-year	HR=1*HRmsy	0.83	0.14	0.97	0.63	0.85	0.21
	TAC=20000	0.77	0.34	1.23	0.71	0.87	0.43
	TAC=25000	0.56	0.17	1.10	0.62	0.65	0.29
	TAC=30000	0.36	0.05	0.97	0.52	0.41	0.07
	TAC=35000	0.20	0.01	0.83	0.41	0.19	0.01
15-year	HR=1*HRmsy	0.86	0.14	0.96	0.63	0.87	0.21
	TAC=20000	0.78	0.40	1.24	0.72	0.89	0.49
	TAC=25000	0.49	0.18	1.07	0.62	0.59	0.30
	TAC=30000	0.23	0.03	0.89	0.47	0.28	0.04
	TAC=35000	0.10	0.01	0.72	0.36	0.09	0.01
25-year	HR=1*HRmsy	0.90	0.14	0.96	0.63	0.91	0.21
	TAC=20000	0.78	0.46	1.24	0.74	0.89	0.53
	TAC=25000	0.40	0.20	1.03	0.62	0.52	0.32
	TAC=30000	0.11	0.02	0.79	0.42	0.13	0.02
	TAC=35000	0.04	0.01	0.58	0.31	0.04	0.01

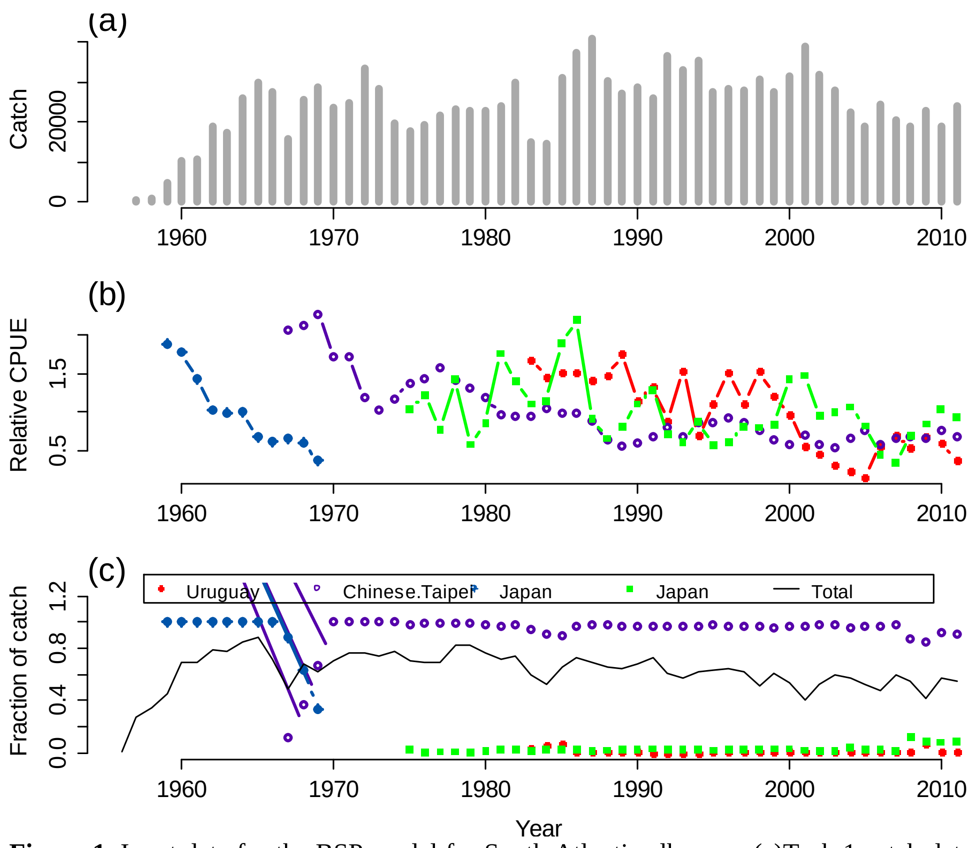

Figure 1. Input data for the BSP model for South Atlantic albacore: (a)Task 1 catch data, (b) CPUE series each divided by its mean, and (c) the relative weights assigned to each series by catch weighting. The solid line in part (c) is the fraction of the total catch from fleets for which indices are available.

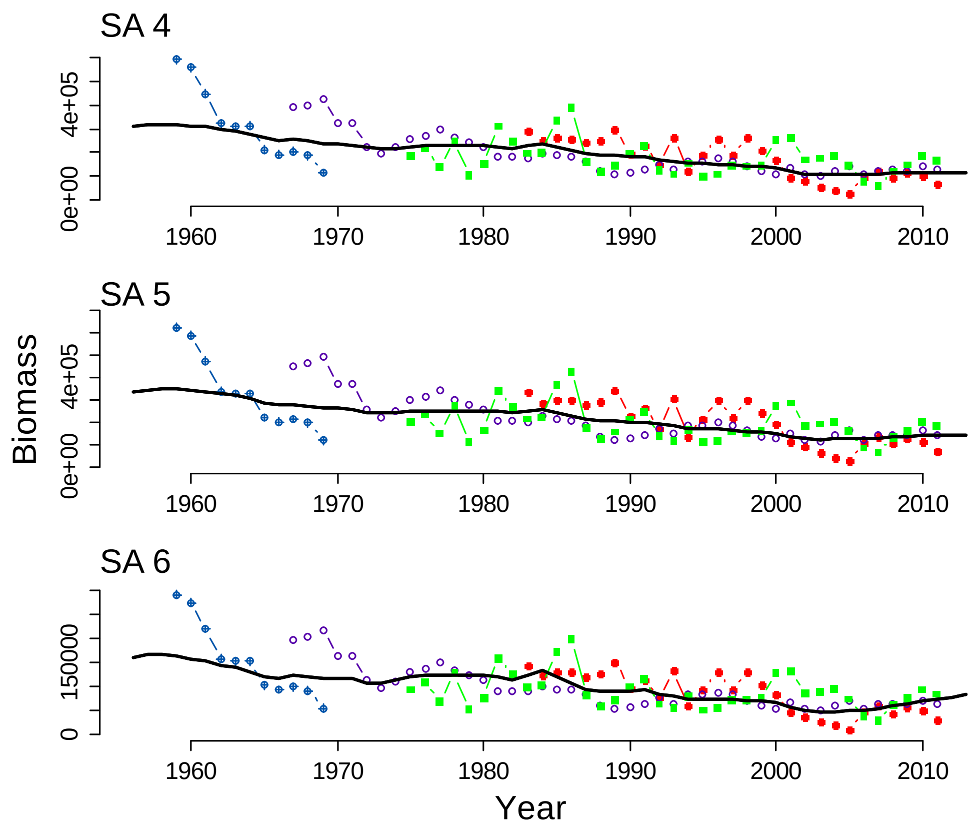

Figure 2. CPUE fits for South Atlantic albacore at the mode of the posterior distribution of the parameters for runs defined in **Table 1.**

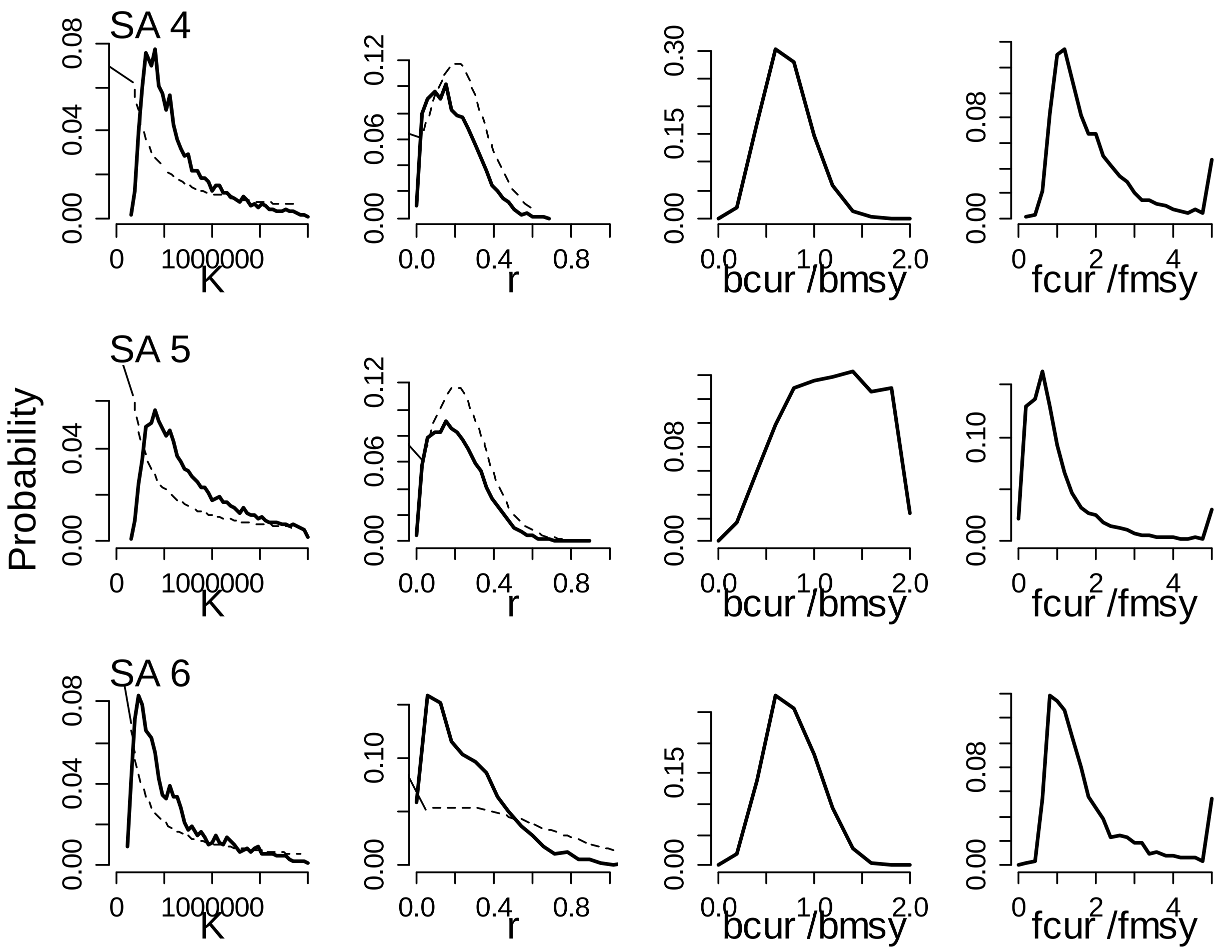

Figure 3. Posterior and prior probability density functions of *K* and *r*, and posterior densities of current B/B_{msy} and F/F_{msy} for South Atlantic albacore, for runs defined in **Table 1.**

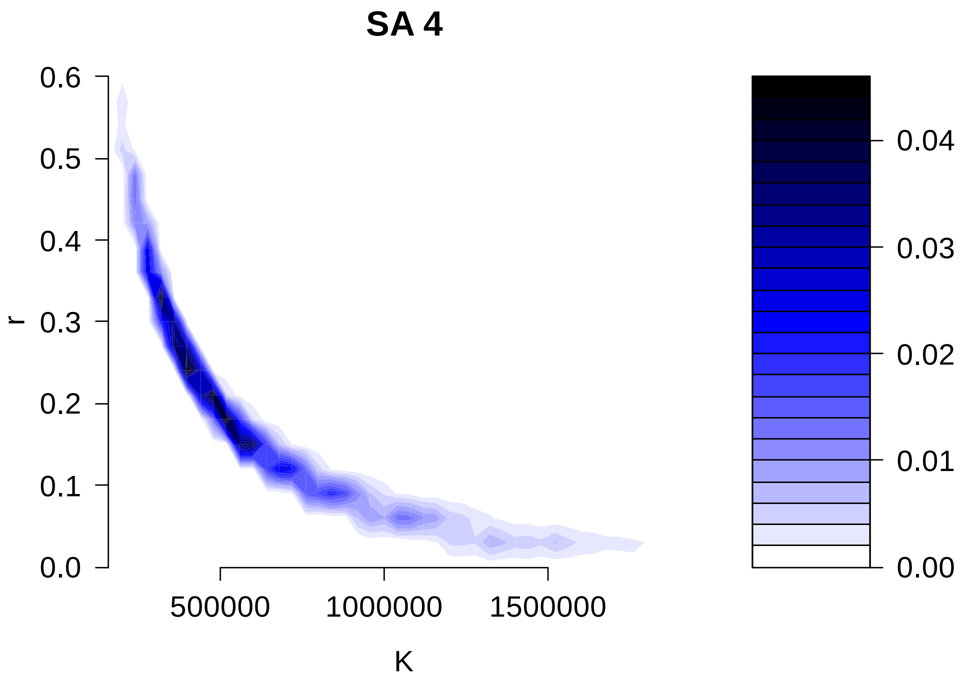

Figure 4. Joint posterior for *r* and *K* for the run with equal weighting and baseline priors.

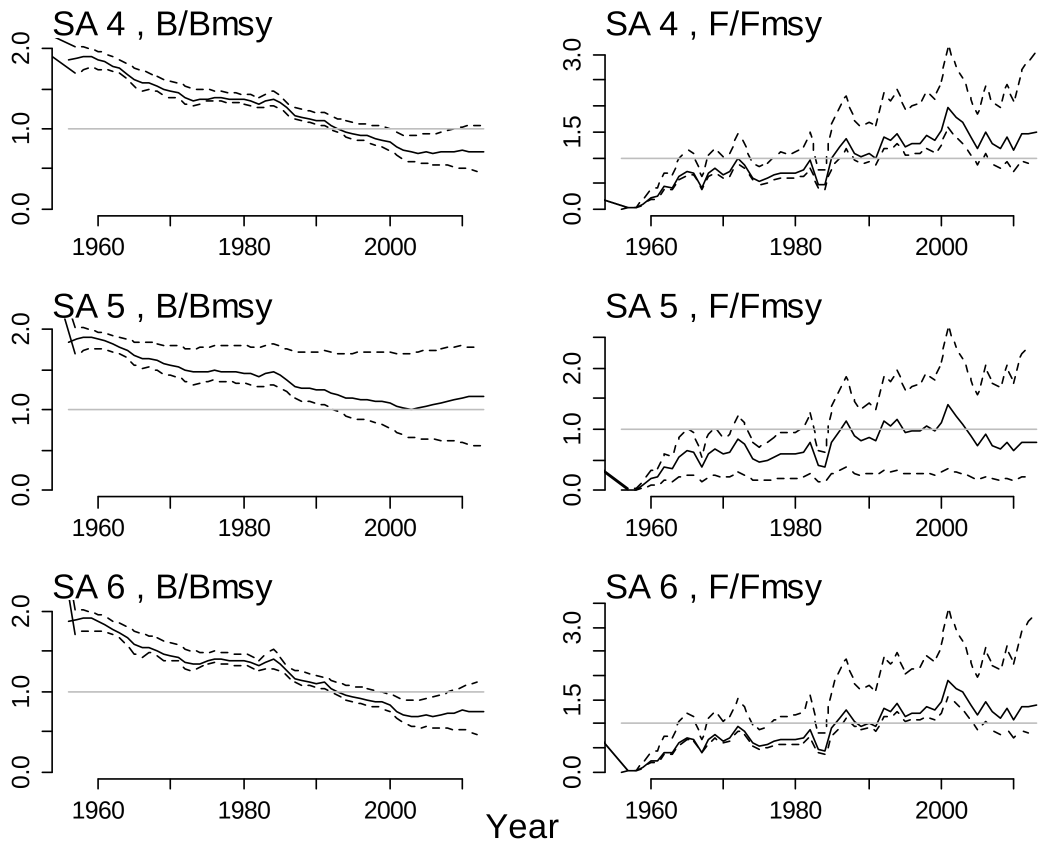

Figure 5. Biomass and fishing mortality rate trajectories for south Atlantic albacore with equal (top) or catch (bottom) weighting.

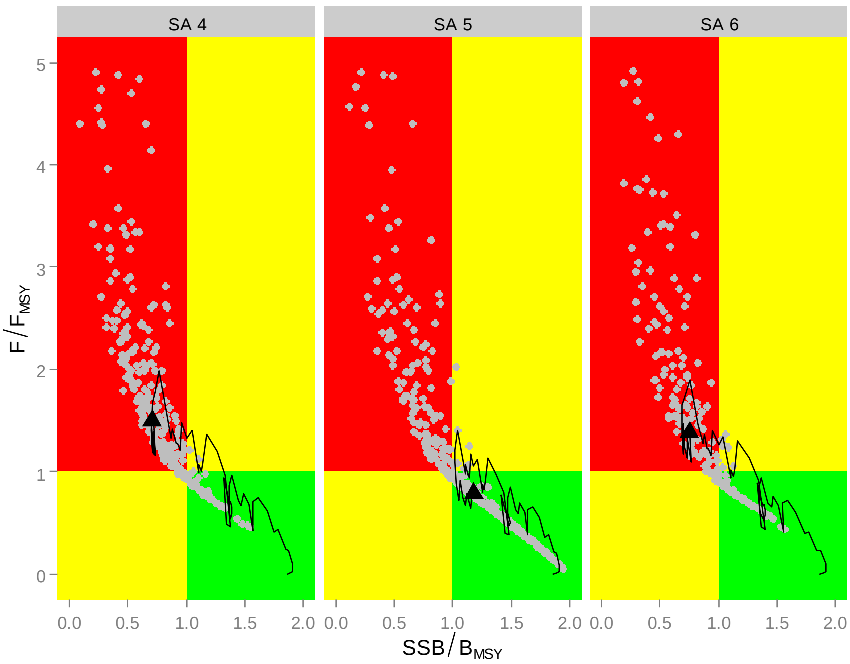

Figure 6. Phase plot for south Atlantic albacore, in Kobe format. Grey dots are a sample from the posterior distribution in 2013; black line is the median trajectory from 1956 to 2013, and black triangle is the current median. F/Fmsy values greater than 5 are not shown.

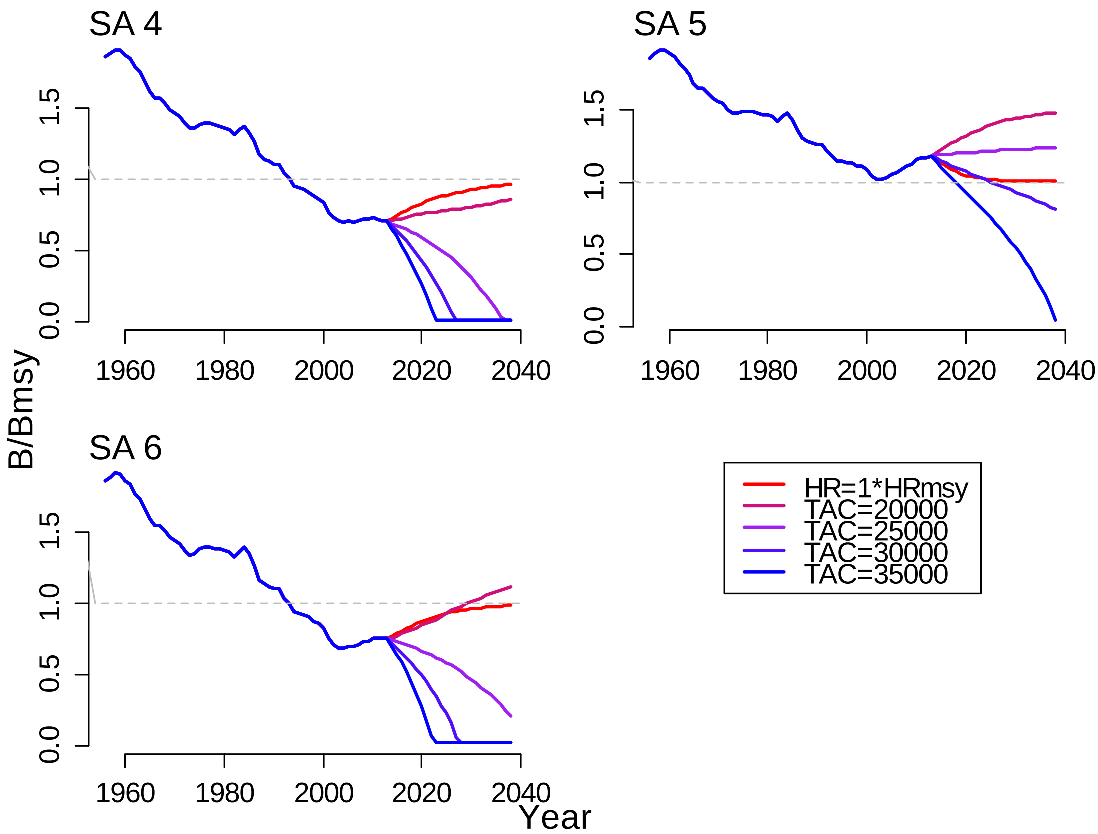

Figure 7. Median projections for south Atlantic albacore with varying management strategies.

Appendix 1

R code to produce the CPUE input file for weighting the data points by the catch in each fleet

```
library(lattice)
### File names and run descriptions
catfile="albSA2013cat1"
cpuefile="albSA2012cpue1"
fleetfile="fleetALB2011"
setwd("C:/ALB2013")
######### Read in catch and cpue data from BSP files
cat=read.csv(paste("program\\data\\",catfile,".csv",sep=""),header=F)
names(cat)=c("year","catch")
cat=cat[cat$year<=lastyrcat,]
cpue=read.csv(paste("program\\data\\",cpuefile,".csv",sep=""),header=F)
names(cpue)=c("index","year","mean","cv")
cpue2=cpue
nind=max(cpue$index)

######### Calculate catch weightings and reprint
#the fleet catch file must be a .csv file, with a column labelled year,
# and columns containing the catches by fleet.
fleetfile="fleetALB2012"
fleetcat=read.csv(paste("program\\data\\",fleetfile,".csv",sep=""),header=T
)
indices=c("Uruguay","Chinese.Taipei","Japan","Japan")
# "Indices" must contain the fleet names associated with each index,
#matching the fleet catch file
yr=fleetcat$year
a=match(indices,names(fleetcat))
a # must contain no NAs
fleetcat2=fleetcat[,a]
fleetcat2[is.na(fleetcat2)]=0
for(i in 1:nind) {
 x=match(yr,cpue$year[cpue$index==i])
 fleetcat2[is.na(x),i]=0
}
fleetcat3=fleetcat2
fleetcat3[fleetcat3>0]=1
a=table(indices)
a=a[a>1]
for(i in 1:length(a)) {
 b=as.matrix(fleetcat3[,!is.na(match(indices,names(a[i])))]) %*%
rep(1,a[i])
 for(j in which(b>1)) {
 d=which(!is.na(match(indices,names(a[i]))))
 d=d[fleetcat2[j,d]>0]
 fleetcat2[j,d]=fleetcat[j,names(a[i])]/b[j]
}}
x=as.matrix(fleetcat2) %*% rep(1,nind)
summary(x)
fleetcat2=fleetcat2/x
fleetcat2[fleetcat2<0.000000001]=NA
cpue3=cpue
for(i in 1:nind)
 cpue3$cv[cpue3$index==i]=round(1/sqrt(fleetcat2[!is.na(fleetcat2[,i]) &
fleetcat2[,i]>0,i]),4)

write.table(cpue3,file=paste("program\\data\\",fleetfile,"cpuewt.csv",sep="
"),sep=",",col.names=FALSE,row.names=FALSE)
```