SCRS/2019/129 Collect. Vol. Sci. Pap. ICCAT, 76(1): 127-138 (2020)

EVALUATION OF CONSTANT HARVEST RATE AND INDEX-BASED CANDIDATE MANAGEMENT PROCEDURES FOR ATLANTIC BLUEFIN TUNA USING THE ABT_MSE R PACKAGE

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SUMMARY

Three candidate management procedures for Atlantic bluefin tuna are evaluated using the ABT_MSE package in R. The first procedure is based on constant harvest rate strategies for both the east and west stocks, with the target rates tuned to each operating model using terminal F multipliers that achieve median spawning biomass ratios in projections near 1.0. The second management procedure evaluated uses juvenile indices of abundance to predict future changes in allowable catches. The third procedure evaluates the ability to achieve SSB of the West stock at or above current estimates (measured by stock-of-origin indices of abundance in the MSE), a strategy that has been used by managers in the West Atlantic as an objective given uncertainty in spawning biomass estimates and associated benchmarks. Each procedure is evaluated against zero-catch and harvest at levels that produce MSY scenarios for comparison of trade-offs among strategies. The inference gained is based on the assumption that accurate indices of relative abundance are obtainable in the near future versus whether existing abundances accurately represent stock biomass.

RÉSUMÉ

Trois possibles procédures de gestion pour le thon rouge de l'Atlantique sont évaluées à l'aide du logiciel ABT_MSE dans R. La première procédure est basée sur des stratégies de taux de capture constants pour les stocks Est et Ouest, les taux cibles étant adaptés à chaque modèle opérationnel à l'aide des multiplicateurs de F terminal qui permettent d'obtenir la médiane des ratios de la biomasse reproductrice dans des projections proches de 1,0. La deuxième procédure de gestion évaluée utilise les indices d'abondance des juvéniles pour prédire les changements futurs des captures autorisées. La troisième procédure évalue la capacité à atteindre la SSB du stock occidental égale ou supérieure aux estimations actuelles (mesurées par les indices d'abondance du stock d'origine dans la MSE), une stratégie qui a été utilisée par les gestionnaires de l'Atlantique Ouest comme objectif étant donné l'incertitude des estimations de la biomasse reproductrice et des points de référence associés. Chaque procédure est évaluée par rapport à la prise zéro et à la ponction à des niveaux qui produisent des scénarios de PME permettant de comparer les différentes options entre les stratégies. L'inférence obtenue est basée sur l'hypothèse qu'il est possible d'obtenir des indices précis d'abondance relative dans un avenir proche, par opposition à la question de savoir si les abondances existantes représentent précisément la biomasse des stocks.

RESUMEN

Se evalúan tres procedimientos de ordenación candidatos para el atún rojo del Atlántico utilizando el paquete ABT_MSE en R. El primer procedimiento se basa en estrategias de tasa de captura constante tanto para el stock del este como el del oeste, con las tasas objetivo calibradas a cada modelo operativo utilizando multiplicadores de F terminal que logren la mediana de las ratios de la biomasa reproductora en las proyecciones cercanas a 1.0. El segundo procedimiento de ordenación evaluado utiliza índices de abundancia de juveniles para predecir cambios futuros en las capturas permisibles. El tercer procedimiento evalúa la capacidad de lograr SSB del stock occidental en o por encima de las estimaciones actuales (medida por los índices de abundancia del stock de origen en la MSE), una estrategia que ha sido usada por los gestores en el Atlántico occidental como un objetivo dada la incertidumbre

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en las estimaciones de la biomasa reproductora y en los elementos de referencia asociados. Cada procedimiento se evalúa respecto a la captura cero y la captura en niveles que producen escenarios de MSE para comparar las ventajas e inconvenientes entre las estrategias. La inferencia obtenida se basa en el supuesto de que en el futuro cercano son obtenibles índices de abundancia relativa precisos frente a si los índices de abundancia existentes representan de forma precisa la biomasa del stock.

KEYWORDS

Atlantic bluefin tuna, Management strategy evaluations, Candidate management procedures

1. Introduction

A management strategy evaluation (MSE) for Atlantic bluefin tuna has been under development by ICCAT and contracted technical experts for the last several years as part of the Atlantic-wide Research Programme for Bluefin Tuna. The MSE provides a flexible simulation framework to test alternative strategies for determining total allowable catches of Atlantic bluefin tuna in the East and West Atlantic. One of the strengths of the MSE is the alternative parameterizations of recruitment, natural mortality, and stock mixing (shown to have large effects on future sustainable catch projections from the stock assessments) programmed into the model. This flexibility allows for testing of how different procedures perform under alternative scenarios of stock biology and fisheries dynamics. The purpose of this report is to document preliminary strategies evaluated by the authors, to serve as a technical guide for group discussion, and for reference in future candidate management procedure development.

2. Methods and Results

Three candidate management procedures (CMPs) were evaluated using the ABT_MSE package in R. The first procedure is based on constant harvest rate (constU) strategies for both the east and west stocks. In the MSE, the indices of abundance are assumed to be proportional to vulnerable biomass, i.e. the base parameterization assumes time-invariant catchability. Therefore, a relative harvest rate for each stock can be calculated as follows:

$$harvest\ rate = catch/abundance$$

$$relative\ abundance = catchability * abundance$$

$$relative\ harvest\ rate\ (relU) = \frac{catch}{relative\ abundance}$$

Applying this approach, management procedures for east and west stocks are designed to apply a constant harvest rate strategy using removals of the stock and stock-of-origin indices of spawning biomass. For the West stock, the Gulf of Mexico larval survey is used, and for the East stock, the Mediterranean larval survey is used. Both indices are assumed to be proportional to the spawning biomasses of the individual stocks, and measured with observation error (i.e. the "Good_Obs" observation model was used for all trials). These scenarios were designed to evaluate the constU CMP performance under the assumption of unbiased indices of SSB. The goal was to determine how well a constant F strategy would perform when accurate measures of harvest rate (or accurate catches and relative SSB indices) are available to inform empirical CMPs.

To tune the constU CMP to each operating model (OM), a target rate was determined by searching a grid of hypothesized multipliers of the terminal relative harvest rates of East and West stocks. For each OM, a pair of terminal F multipliers were selected that achieved median spawning biomass ratios in a thirty-year projection near 1.0. In some cases when the stock trajectory showed a decline or increase at the 30-yr mark, the tuning parameters were modified to achieve a SSB ratio of 1.0 near the equilibrium point where biomass was relatively stable. While inherently not implementable, this 'OM-specific' tuning is useful for demonstrative purposes to show the divergence in F multipliers across the OMs. In practice a CMP does not know which OM is reality and only a single set of tuning parameters can be set; hence actual performance in implementation will vary across OMs. For instance, tuning to OM1 (3 and 5 multiplier on current exploitation rate) would achieve very different performance than OM15 (0.9 and 0.3 multipliers, respectively on East and West current exploitation rate).

The second CMP evaluated juvenile indices of abundance to predict future changes in allowable catches by stock area. The US rod and reel index is used as a West Atlantic fishery recruitment index to predict future changes in total allowable catch, with a time-lag of four years (ages 2-4 are sampled in survey, the fish enter major fisheries at 6-8 years old), and the GBYP aerial survey is used for the East Area juvenile abundance. Similar to the constU CMP, catchability is assumed to be constant (or calibrated when time-varying) in the juvenile indices. Additionally, the assumption of time-invariant migration rates are assumed, but not does not assume age-invariant migration rates. In these CMPs, the change in total allowable catch is based on the change in the index with the 4-year time lag.

The third procedure (W_rebuild) evaluates the strategy of achieving an SSB level of the West stock at or above current estimates (as measured by stock-of-origin indices of SSB abundance in the MSE) a strategy that has been used by managers in the West Atlantic as an objective given uncertainty in current stock biomass relative to biomass benchmarks. The CMP for the East stock in the W_rebuild scenario is the constU CMP described above for scenario 1.

Each procedure was evaluated against zero-catch and harvest at levels that produce MSY scenarios for comparison of trade-offs among strategies. All scenarios were evaluated with a maximum allowable change in TAC of 30% every three years. This allowed for moderate flexibility in the CMPs to respond to changes in stock biomass, under a defined level of fishery stability. The CMPs are designed to evaluate alternative values of %TAC change and quota periods, as needed in the future. R codes for the CMPs are pasted in **Appendix 1**.

The tuning parameters selected for each OM are listed in the **Table 1**. In some scenarios, the East stock SSB was tuned to a higher biomass ratio than 1.0 to allow for the West stock to achieve the target. CMP performance metrics are provided in **Table 2**. Figures 1 and 2 provide examples of MSE plots for operating models 1 and 13, for comparison of candidate management procedure performance under optimistic (high stock biomasses) and pessimistic (stock rebuilding) scenarios.

In these simulations, indices of abundance were assumed proportional to abundances of spawning biomass and juveniles for each stock or area with observation error (observation model = Good_Obs), and therefore the inference gained is based on the assumption that accurate indices of relative abundance are obtainable in the near future, and not informative for evaluating whether existing abundances accurately represent stock biomasses. The MSE simulations highlight the importance of accurate abundance indices in empirical management strategies, similar to the stock assessment models used to provide current management advice.

Table 1. Constant harvest rate management procedure tuning parameters to scale operating model terminal harvest rates to the target that produces a spawning biomass ratio of 1.0 for each stock.

Operating model	East_TermF_Mult	West_TermF_Mult
OM1	3	5
OM2	2.5	6
OM3	1.5	4.5
OM4	2.7	2
OM5	2	1
OM6	0.8	1
OM7	3.4	12
OM8	2.8	15
OM9	1.2	5
OM10	2.4	7
OM11	2.3	18
OM12	0.8	2.2
OM13	2.5	0.5
OM14	0.5	0.5
OM15	0.9	0.3

Table 2. Select performance metrics for each candidate management procedure by operating model. The metrics are calculated for the 30-year projection period.

	East Atlantic				West Atlantic			
Operating Model 1	AveCatch	PrOverfishing	PrOverfished	SSB/SSBmsy	AveCatch	PrOverfishing	PrOverfished	SSB/SSBmsy
ZeroC-ZeroC	2.7	0.0	0.0	3.2	0.2	0.0	0.0	2.9
UMSY-UMSY	49.4	3.3	0.0	1.3	5.2	43.3	0.0	1.3
ConstU_E-ConstU_W	50.5	5.0	6.7	1.1	4.7	26.7	8.3	1.2
E_JuvAerial-W_JuvRR	37.1	0.0	0.0	1.8	1.4	0.0	0.0	2.3
ConstU_E-W_Rebuild	50.9	5.0	0.0	1.2	1.8	0.0	0.0	1.9
Operating Model 2								
ZeroC-ZeroC	2.7	0.0	0.0	2.5	0.2	0.0	0.0	2.4
UMSY-UMSY	34.9	21.7	18.3	1.3	6.0	35.0	0.0	1.4
ConstU_E-ConstU_W	39.6	11.7	0.0	1.1	6.6	35.0	5.0	1.1
E_JuvAerial-W_JuvRR	34.1	0.0	0.0	1.4	2.0	0.0	0.0	1.9
ConstU_E-W_Rebuild	39.9	10.0	0.0	1.2	1.8	0.0	0.0	1.9
Operating Model 3								
ZeroC-ZeroC	2.7	0.0	0.0	2.9	0.2	0.0	0.0	2.9
UMSY-UMSY	41.0	21.7	35.0	0.5	10.5	5.0	15.0	0.9
ConstU_E-ConstU_W	30.8	0.0	1.7	1.1	4.8	0.0	0.0	1.8
E_JuvAerial-W_JuvRR	34.7	15.0	10.0	0.8	1.8	0.0	0.0	2.2
ConstU_E-W_Rebuild	30.8	0.0	1.7	1.1	3.2	0.0	0.0	2.1
Operating Model 4								
ZeroC-ZeroC	2.7	0.0	0.0	3.0	0.2	0.0	0.0	3.1
UMSY-UMSY	47.4	1.7	0.0	1.2	3.2	25.0	3.3	1.2
ConstU_E-ConstU_W	52.8	13.3	16.7	1.0	3.1	35.0	21.7	1.0
E_JuvAerial-W_JuvRR	37.0	0.0	0.0	1.7	1.5	0.0	0.0	2.0
ConstU_E-W_Rebuild	53.1	13.3	15.0	1.0	1.9	3.3	0.0	1.4
Operating Model 5								
ZeroC-ZeroC	2.7	0.0	0.0	2.5	0.2	0.0	0.0	2.1
UMSY-UMSY	34.7	28.3	11.7	1.3	2.4	35.0	35.0	1.0
ConstU_E-ConstU_W	36.7	3.3	0.0	1.3	2.2	10.0	18.3	1.1
E_JuvAerial-W_JuvRR	34.9	0.0	0.0	1.3	2.0	5.0	10.0	1.1
ConstU_E-W_Rebuild	36.7	3.3	0.0	1.3	1.8	0.0	0.0	1.2
Operating Model 6								
ZeroC-ZeroC	2.7	0.0	0.0	2.7	0.2	0.0	0.0	3.2
UMSY-UMSY	41.1	10.0	26.7	0.7	6.8	1.7	10.0	1.0
ConstU_E-ConstU_W	22.8	0.0	0.0	1.6	5.3	8.3	0.0	1.7
E_JuvAerial-W_JuvRR	36.2	10.0	5.0	1.0	1.9	0.0	0.0	2.1
ConstU_E-W_Rebuild	22.8	0.0	0.0	1.6	3.7	0.0	0.0	2.1
Operating Model 7								
ZeroC-ZeroC	2.7	0.0	0.0	3.2	0.2	0.0	0.0	3.0
UMSY-UMSY	47.1	1.7	0.0	1.2	10.9	70.0	0.0	1.4
ConstU_E-ConstU_W	52.2	11.7	16.7	1.0	7.6	18.3	3.3	1.3
E_JuvAerial-W_JuvRR	37.0	0.0	0.0	1.8	1.4	0.0	0.0	2.7
ConstU_E-W_Rebuild	52.8	11.7	15.0	1.1	1.8	0.0	0.0	2.4
Operating Model 8								
ZeroC-ZeroC	2.7	0.0	0.0	2.6	0.2	0.0	0.0	2.5
UMSY-UMSY	35.4	15.0	18.3	1.3	12.7	45.0	0.0	1.4
ConstU_E-ConstU_W	40.8	5.0	0.0	1.2	9.4	21.7	0.0	1.4
E_JuvAerial-W_JuvRR	34.2	0.0	0.0	1.5	2.0	0.0	0.0	2.2
ConstU_E-W_Rebuild	41.2	5.0	0.0	1.3	1.8	0.0	0.0	2.2

Table 2. Continued.

	East Atlantic				West Atlantic			
Operating Model 9	AveCatch	PrOverfishing	PrOverfished	SSB/SSBmsy	AveCatch	PrOverfishing	PrOverfished	SSB/SSBmsy
ZeroC-ZeroC	2.7	0.0	0.0	2.9	0.2	0.0	0.0	3.0
UMSY-UMSY	38.9	10.0	38.3	0.5	16.2	16.7	11.7	1.0
ConstU_E-ConstU_W	25.3	0.0	0.0	1.4	8.0	5.0	0.0	1.9
E_JuvAerial-W_JuvRR	34.3	10.0	10.0	0.9	1.6	0.0	0.0	2.6
ConstU_E-W_Rebuild	25.4	0.0	0.0	1.5	2.7	0.0	0.0	2.6
Operating Model 10								
ZeroC-ZeroC	2.7	0.0	0.0	2.9	0.2	0.0	0.0	3.3
UMSY-UMSY	43.3	0.0	0.0	1.2	6.3	66.7	0.0	1.3
ConstU_E-ConstU_W	48.7	6.7	16.7	1.0	6.3	33.3	10.0	1.1
E_JuvAerial-W_JuvRR	37.3	0.0	0.0	1.6	1.5	0.0	0.0	2.7
ConstU_E-W_Rebuild	49.3	6.7	15.0	1.0	1.9	0.0	0.0	2.3
Operating Model 11								
ZeroC-ZeroC	2.7	0.0	0.0	2.5	0.2	0.0	0.0	2.7
UMSY-UMSY	37.4	15.0	11.7	1.3	13.8	45.0	0.0	1.5
ConstU_E-ConstU_W	40.1	0.0	0.0	1.3	9.5	20.0	0.0	1.7
E_JuvAerial-W_JuvRR	35.3	0.0	0.0	1.5	2.0	0.0	0.0	2.4
ConstU_E-W_Rebuild	40.4	0.0	0.0	1.4	1.8	0.0	0.0	2.4
Operating Model 12								
ZeroC-ZeroC	2.7	0.0	0.0	2.6	0.2	0.0	0.0	3.4
UMSY-UMSY	37.0	3.3	30.0	0.7	10.0	16.7	5.0	1.1
ConstU_E-ConstU_W	22.6	0.0	0.0	1.5	6.9	10.0	0.0	1.9
E_JuvAerial-W_JuvRR	36.2	16.7	13.3	0.8	1.7	0.0	0.0	2.7
ConstU_E-W_Rebuild	22.7	0.0	0.0	1.5	3.0	0.0	0.0	2.6
Operating Model 13								
ZeroC-ZeroC	2.7	0.0	0.0	3.0	0.2	6.7	23.3	2.7
UMSY-UMSY	48.4	1.7	0.0	1.2	1.8	6.7	80.0	1.0
ConstU_E-ConstU_W	52.7	10.0	15.0	1.0	1.5	6.7	91.7	0.9
E_JuvAerial-W_JuvRR	37.1	0.0	0.0	1.7	1.6	16.7	46.7	1.4
ConstU_E-W_Rebuild	52.5	10.0	15.0	1.0	2.1	46.7	100.0	0.8
Operating Model 14								
ZeroC-ZeroC	2.7	0.0	0.0	2.4	0.2	10.0	63.3	1.4
UMSY-UMSY	34.6	28.3	15.0	1.3	1.0	30.0	100.0	0.6
ConstU_E-ConstU_W	22.3	0.0	0.0	1.8	1.4	40.0	100.0	0.7
E_JuvAerial-W_JuvRR	34.8	0.0	0.0	1.3	2.0	70.0	100.0	0.4
ConstU_E-W_Rebuild	22.3	0.0	0.0	1.8	1.8	55.0	100.0	0.6
Operating Model 15								
ZeroC-ZeroC	2.7	0.0	0.0	2.7	0.2	0.0	20.0	2.9
UMSY-UMSY	42.5	15.0	26.7	0.7	4.4	0.0	36.7	0.9
ConstU_E-ConstU_W	26.0	0.0	0.0	1.5	2.5	0.0	23.3	1.8
E_JuvAerial-W_JuvRR	36.3	11.7	5.0	1.0	2.1	0.0	23.3	1.5
ConstU_E-W_Rebuild	25.9	0.0	0.0	1.5	4.2	3.3	25.0	1.4

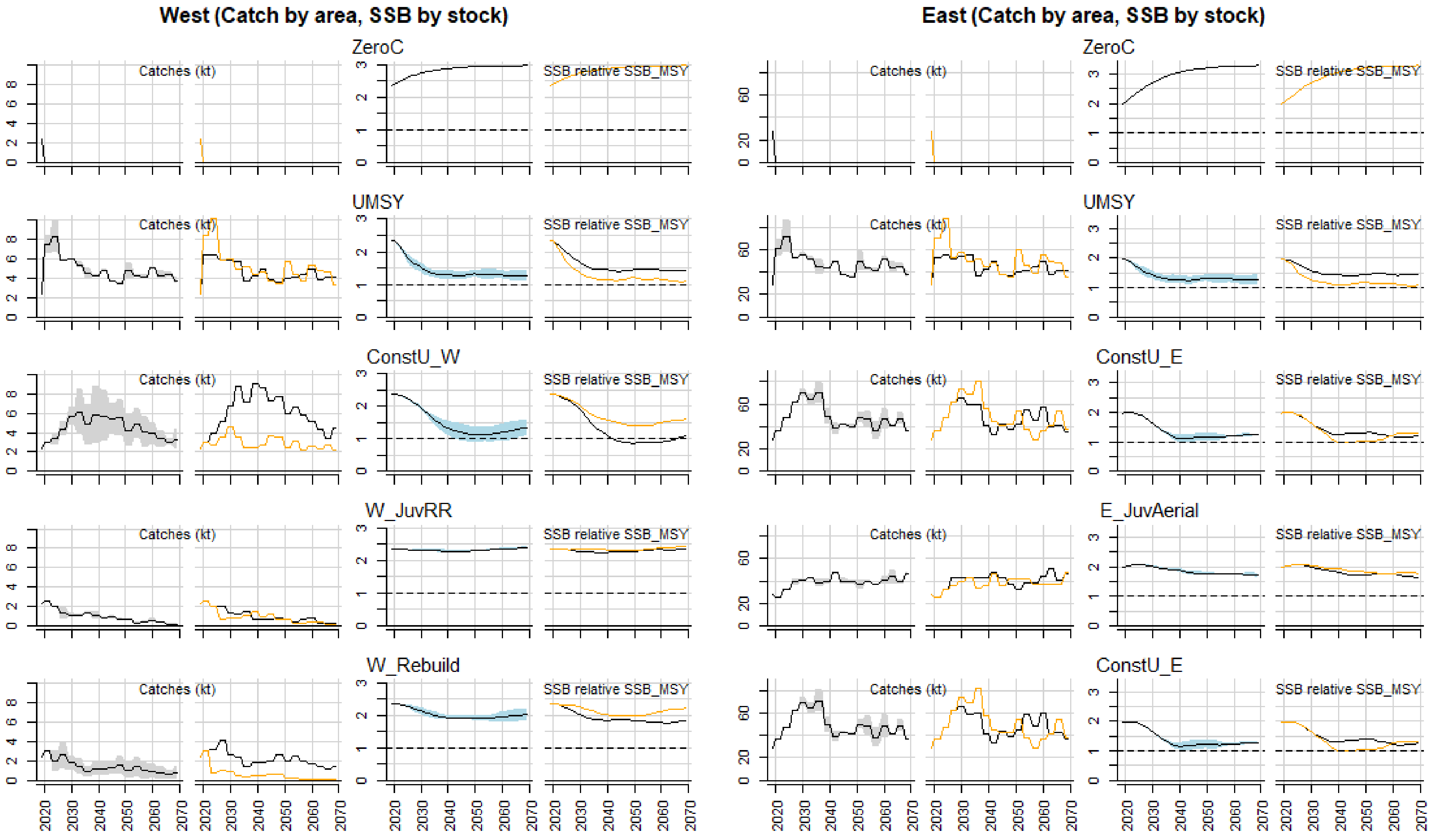

Figure 1. MSE plots for operating model 1, for comparison of alternative candidate management procedures under an optimistic scenario of high stock biomass relative to SSB_MSY.

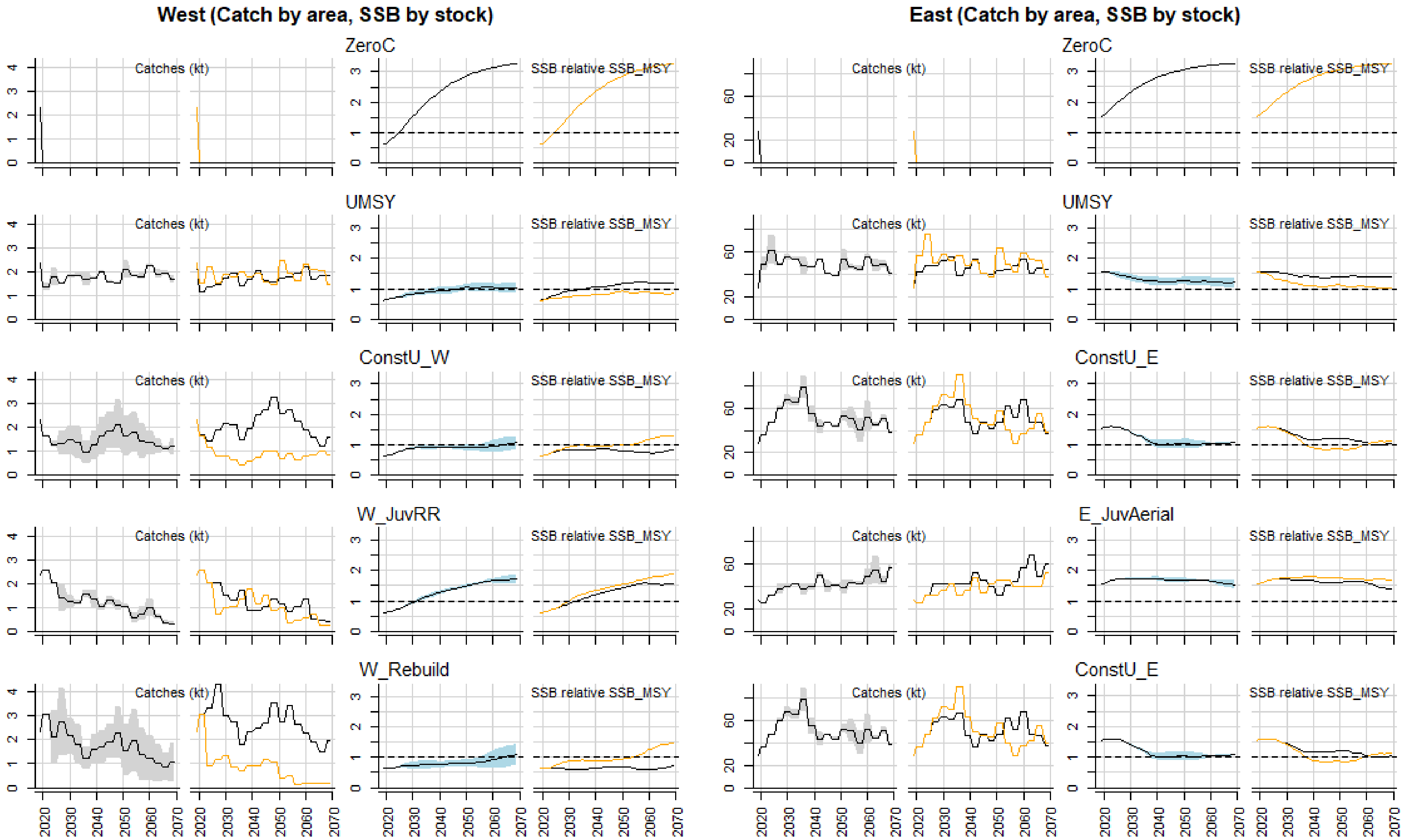

Figure 2. MSE plots for operating model 13. For comparison of alternative candidate management procedures under a west stock rebuilding scenario.

Appendix 1

R code for the candidate management procedures tested

```
Run_MSE=function(SSBIndexE,SSBIndexW,JuvIndexE,JuvIndexW,deltaTAC_E,deltaTAC_W,tuneE,tuneW,O
Mnum,Obs_model,OMid)
{
##########################################################
#1. CONSTANT HARVEST RATE TARGETS, WITH TAC CHANGE LIMITS
##########################################################

ConstU_E <<-
function(x,dset,IndexNo=SSBIndexE,yrs4mean=3,target_yr=52,deltaE=deltaTAC_E,multiplierE=tuneE)
	{
	min_delta=(1-deltaE)
	max_delta=(1+deltaE)
	target_yrs=target_yr-(yrs4mean-1):0
	targetI=mean(dset$Iobs[x,IndexNo,target_yrs],na.rm=TRUE)
	targetC=mean(dset$Cobs[x,target_yrs],na.rm=TRUE)
	targetU=targetC/targetI
	lastyr=dim(dset$Iobs)[3]
	datayrs=lastyr-(yrs4mean-1):0
	curI=mean(dset$Iobs[x,IndexNo,datayrs],na.rm=TRUE)
	curC=mean(dset$Cobs[x,datayrs],na.rm=TRUE)
	curU=curC/curI
	delta_ratio=multiplierE*targetU/curU
	oldTAC = dset$MPrec[x]
	if(delta_ratio>.95&delta_ratio<1.05)
		{
		TAC=oldTAC
		}
	if(delta_ratio<.950001)
		{
		TAC=max(oldTAC*delta_ratio,oldTAC*min_delta)
		}
	else
		{
	TAC=min(oldTAC*delta_ratio,oldTAC*max_delta)
		}
	}
class(ConstU_E)<<-"MP"

ConstU_W <<-
function(x,dset,IndexNo=SSBIndexW,yrs4mean=3,target_yr=52,deltaW=deltaTAC_W,multiplierW=tuneW)
	{
	min_delta=(1-deltaW)
	max_delta=(1+deltaW)
	target_yrs=target_yr-(yrs4mean-1):0
	targetI=mean(dset$Iobs[x,IndexNo,target_yrs],na.rm=TRUE)
	targetC=mean(dset$Cobs[x,target_yrs],na.rm=TRUE)
	targetU=targetC/targetI
	lastyr=dim(dset$Iobs)[3]
	datayrs=lastyr-(yrs4mean-1):0
	curI=mean(dset$Iobs[x,IndexNo,datayrs],na.rm=TRUE)
	curC=mean(dset$Cobs[x,datayrs],na.rm=TRUE)
	curU=(curC/curI)
	delta_ratio=multiplierW*targetU/curU
	oldTAC = dset$MPrec[x]
	if(delta_ratio>.95&delta_ratio<1.05)
		{
```

```
			TAC=oldTAC
			}
		if(delta_ratio<.950001)
			{
			TAC=max(oldTAC*delta_ratio,oldTAC*min_delta)
			}
		else
			{
		TAC=min(oldTAC*delta_ratio,oldTAC*max_delta)
			}
		}
class(ConstU_W)<<-"MP"

###############################################################################
#2. JUVENILE INDEX CMP WITH APPROPRIATE TIME LAG OF RECRUITMENT TO FISHERIES
###############################################################################

E_JuvAerial <<- function(x,dset,IndexNo=JuvIndexE,yrs4mean=3,deltaE=deltaTAC_E)
		{
		lastyr = dim(dset$Iobs)[3]
		datayrs = lastyr-(yrs4mean+1):(2*yrs4mean)
		curI = mean(dset$Iobs[x,IndexNo,datayrs],na.rm=TRUE)
		targ_yrs = lastyr-(2*yrs4mean+1):(3*yrs4mean)
		targI = mean(dset$Iobs[x,IndexNo,targ_yrs],na.rm=TRUE)
		delta_ratio = curI/targI
		oldTAC = dset$MPrec[x]
		if(delta_ratio>0.95&delta_ratio<1.05)
			{
			TAC=oldTAC
			}
		else
			{
		TAC = min(oldTAC*delta_ratio,(1+deltaE)*oldTAC)
			}
		}
class(E_JuvAerial) <<- "MP"


W_JuvRR <<- function(x,dset,IndexNo=JuvIndexW,yrs4mean=3,deltaW=deltaTAC_W)
		{
		lastyr = dim(dset$Iobs)[3]
		datayrs = lastyr-(yrs4mean+1):(2*yrs4mean)
		curI = mean(dset$Iobs[x,IndexNo,datayrs],na.rm=TRUE)
		targ_yrs = lastyr-(2*yrs4mean+1):(3*yrs4mean)
		targI = mean(dset$Iobs[x,IndexNo,targ_yrs],na.rm=TRUE)
		delta_ratio = curI/targI
		oldTAC = dset$MPrec[x]
		if(delta_ratio>0.95&delta_ratio<1.05)
			{
			TAC=oldTAC
			}
		else
			{
		TAC = min(oldTAC*delta_ratio,(1+deltaW)*oldTAC)
			}
		}
class(W_JuvRR) <<- "MP"

#########################################################################################
```

#3. SIMULATE THE WEST STRATEGY OF CONSTANT REBUILDING IN THE FACE OF UNCERTAINTY
```
####################################################################################

W_Rebuild <<- function(x,dset,IndexNo=SSBIndexW,yrs4mean=3,max_decrease=0.99,deltaW=deltaTAC_W)
	{
	lastyr = dim(dset$Iobs)[3]
	datayrs = lastyr-(yrs4mean-1):0
	curI = mean(dset$Iobs[x,IndexNo,datayrs],na.rm=TRUE)
	targ_yrs = lastyr-(2*yrs4mean-1):yrs4mean
	targI = mean(dset$Iobs[x,IndexNo,targ_yrs],na.rm=TRUE)
	delta_ratio = curI/targI
	oldTAC = dset$MPrec[x]
	if(delta_ratio<1)
		{
		TAC=max(oldTAC*delta_ratio,oldTAC*(1-max_decrease))
		}
	else
		{
	TAC = min(oldTAC*delta_ratio,oldTAC*(1+deltaW))
		}
	}
class(W_Rebuild) <<- "MP"

###########################################
#4. CONSTANT CATCH SCENARIOS FOR COMPARISON
###########################################

ConstC_E <<- function(x,dset,constC_E=quotaE)
	{
	TAC=constC_E*1000
	}
class(ConstC_E) <<- "MP"

ConstC_W <<- function(x,dset,constC_W=quotaW)
	{
	TAC=constC_W*1000
	}
class(ConstC_W) <<- "MP"


NOAA_MPs<<-list(
c('UMSY','UMSY'),
c('ConstU_E','ConstU_W'),
c('E_JuvAerial','W_JuvRR'),
c('ConstU_E','W_Rebuild'))#,
#c('ConstC_E','ConstC_W'))

MSE_MVPs<<-new('MSE',OM=OMnum,Obs=Obs_model,MPs=NOAA_MPs,interval=3)
windows(10,8)
plot(MSE_MVPs)
write.csv(getperf(MSE_MVPs),paste0(main_dir,"/Results/perf_metrics_",OMid,".csv"))
windows(9,8)
PPlot(MSE_MVPs)
windows(8,8)
Tplot(MSE_MVPs)
}

Run_MSE(
SSBIndexE = 3,                    #IndexNo to use for SSB of the East Stock
```

```
SSBIndexW = 7,                      #IndexNo to use for SSB of the West Stock
JuvIndexE = 4,                      #IndexNo to use for juvenile abundance of the East Stock
JuvIndexW = 6,                      #IndexNo to use for juvenile abundance of the West Stock
deltaTAC_E = 0.3,                   #Maximum allowable change in quota in the East
deltaTAC_W = 0.3,                   #Maximum allowable change in quota in the West
tuneE = 2.7,                        #Tuning parameter for East target constantF MP
tuneW = 2.0,                        #Tuning parameter for West target constantF MP
OMnum = OM_4d,                      #OM number for scenario
Obs_model = Good_Obs,               #Observation model for the OM
OMid = "OM_4d_delta30"              #OM label to save the performance metrics for each OM
)
RES= c(Br30(MSE_MVPs,pp=1)[3,1],Br30(MSE_MVPs,pp=2)[3,1])  #E and W
RES
```