Attempt of stock assessment of the Indian Ocean swordfish by production models based on the Bayesian model averaging method

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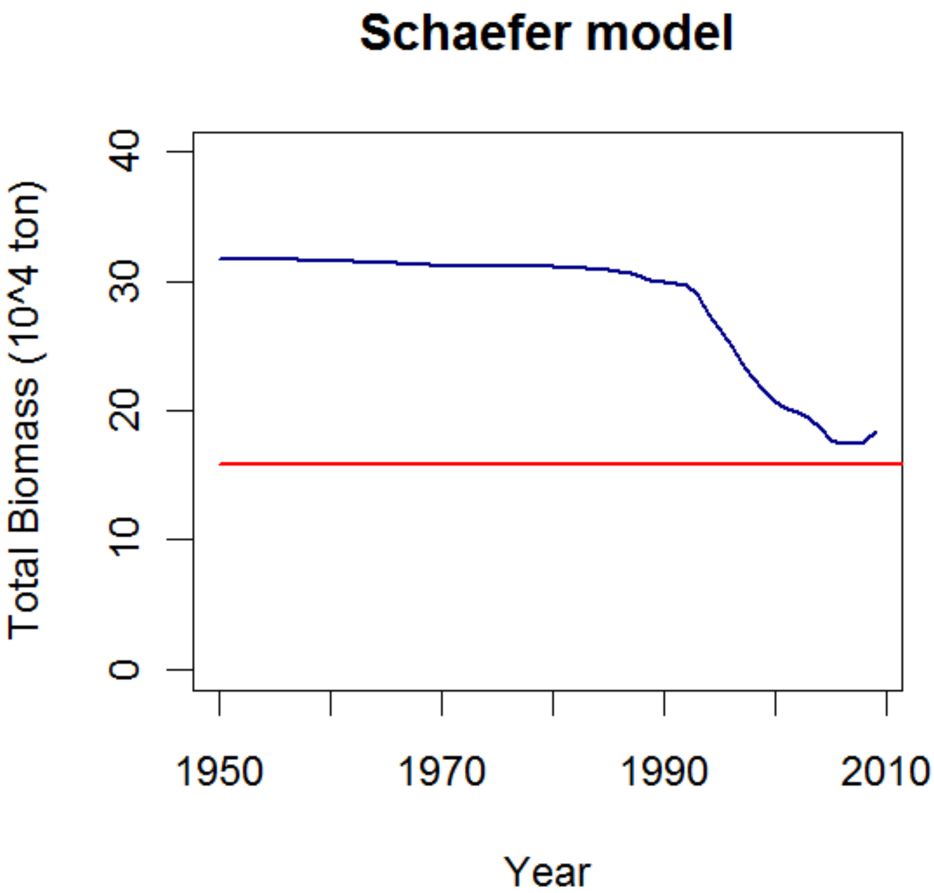
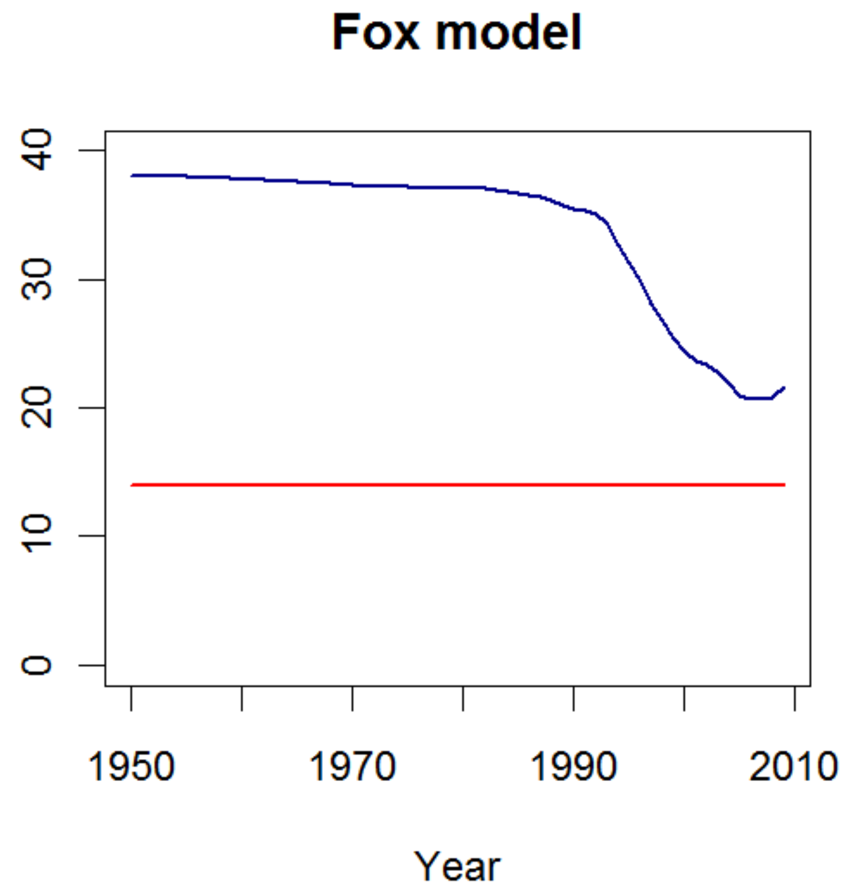
Motivation (model uncertainty)





AIC = -54.23

AIC = -54.48

Solutions

- Choose "the best model" anyway
  (do not consider any model selection uncertainty)
- Sensitivity tests (a lot of scenarios)
- Consider a worst case scenario
  (invoking "precautional approach"!)
- Integrated risk assessment through averaging
  (weights in averaging are given according to the strength of evidence of models)

Model averaging

How do you average?

$K = \omega_{Schaefer} * K_{Schaefer} + \omega_{Fox} * K_{Fox}$

$MSY = \omega_{Schaefer} * MSY_{Schaefer} + \omega_{Fox} * MSY_{Fox}$

. . .

How do you assess the weights? (Bayesian method)

A priori

P(Schaefer model is correct) = 0.5 (even)

Update using the information on data (posterior)

P(Schaefer model is correct | Data) = 0.6 = $\omega_{Schaefer}$

Objectives

- To introduce an approach of "model averaging" for the assessment and management
- To show some preliminary results including Kobe 1 plot when applying the averaging
- To hear any comments
  (even critical comments are welcomed!)

Basic dynamics and models

Population dynamics

$$P_t = \left\{ P_{t-1} + P_{t-1} f(P_{t-1}) - C_{t-1} \right\} e^{u_t}, \quad u_t \sim N(0, \tau^2)$$

process error

$$f(P_t) = r(1 - P_t / K)$$

$$f(P_t) = r(\log K - \log P_t)$$

Observation model

$$I_t = \tilde{I}_t e^{u_t}, \quad u_t \sim N(0, cv_t^2)$$

sampling error

$$\tilde{I}_t = qP_t e^{v_t}, \quad v_t \sim N(0, cv_{add}^2)$$

model error

$$\log I_t \sim N(\log qP_t,\ cv_t^2 + cv_{add}^2)$$

Initial investigation via ML estimation based on Japanese data only

1. Model errors other than sampling errors in standardized CPUE estimates?
   (cv_add=0 or not => the answer was clear "YES")

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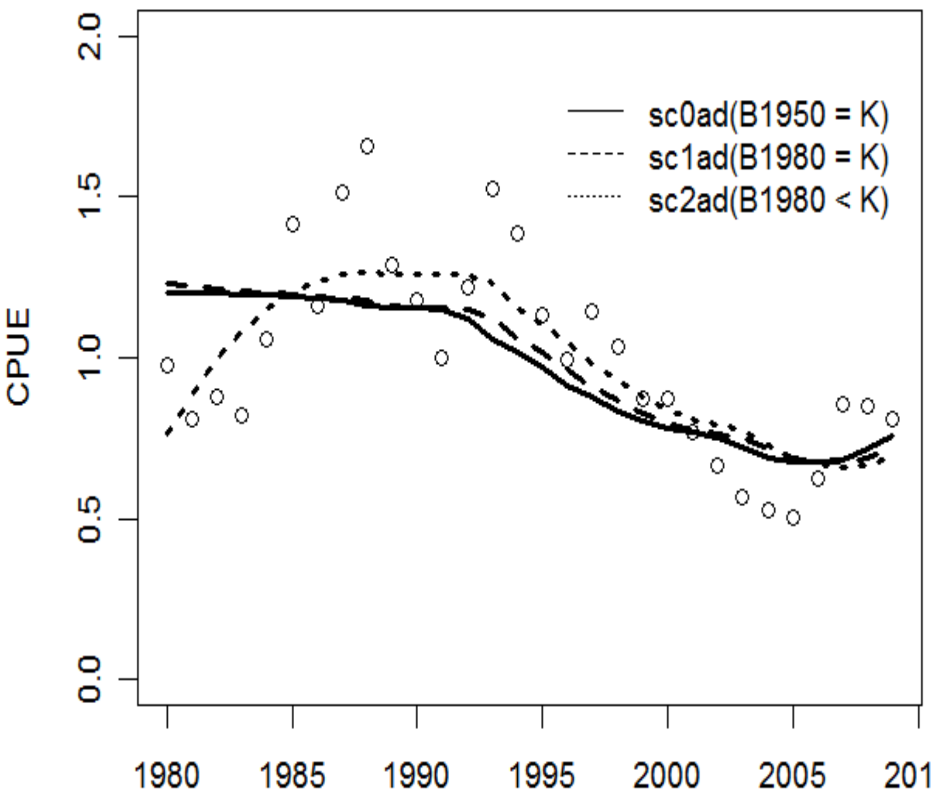
2. Depletion level in the initial year considered
   (P1950 = K or P1980=K or ….?)

Initial investigation via ML estimation based on Japanese data only

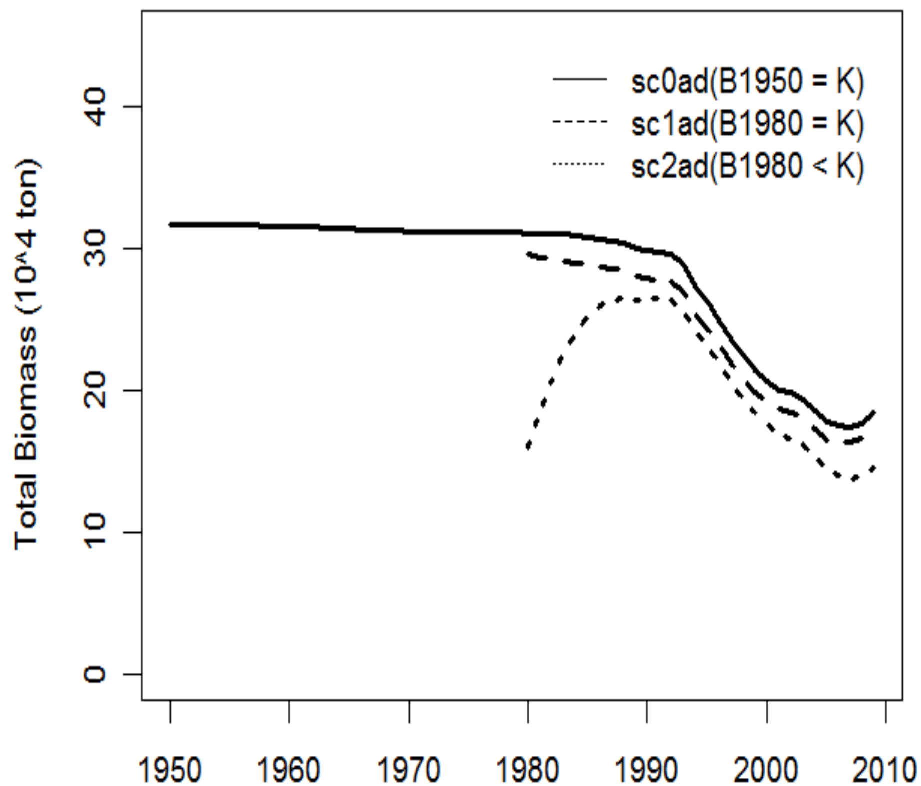
Run	sc0ad		sc1ad		sc2ad	
Initial year	1950		1980		1980	
Initial depletion	B1950 = K		B1980 = K		B1980 < K	
	Estimate	SE	Estimate	SE	Estimate	SE
r	0.373	0.282	0.407	0.307	0.393	0.110
K	31.75	19.55	29.67	18.80	28.56	6.20
q	0.039	0.025	0.041	0.028	0.048	0.011
D1950	1.000					
D1980	0.981	0.002	1.000		0.561	0.085
D2009	0.581	0.074	0.589	0.075	0.511	0.058
cv_add	0.214	0.028	0.216	0.028	0.179	0.023
#parameters	4		4		5	
AIC	-54.23		-53.68		-62.83	

Initial investigation via ML estimation based on Japanese data only

CPUE



Biomass

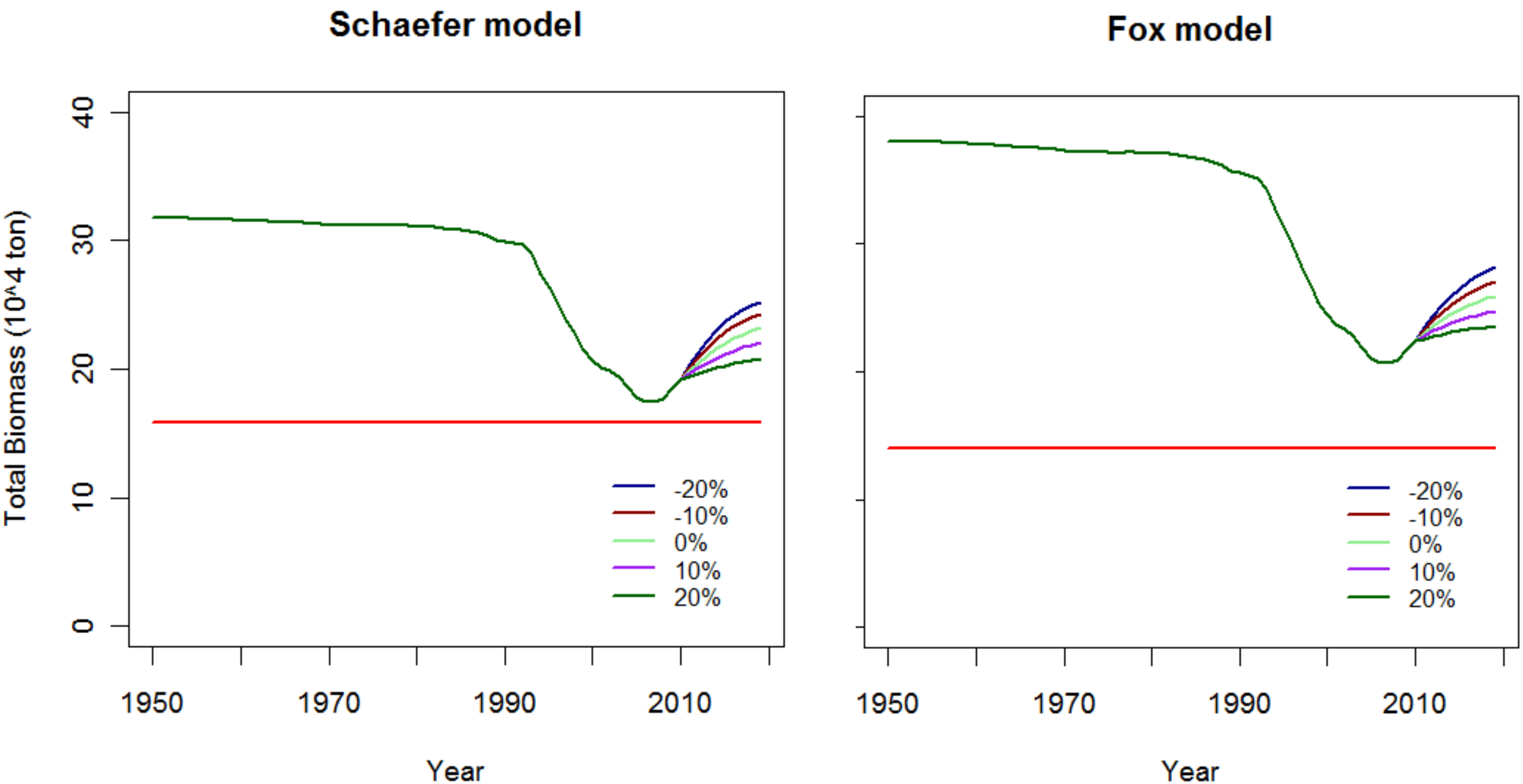


We assume the population level in 1950 as the virgin stock and use the catch since 1950

Initial investigation via ML estimation based on Japanese data only

1. Observation errors other than sampling errors in standardized CPUE estimates?
   (cv_add=0 or not => the answer was clear "YES")
2. Depletion level in the initial year considered
   (P1950 = K or P1980=K or ....? => Ass. P1950 = K)
3. Variants in the production model
   (Schaefer and Fox, already shown, somewhat different results)

Initial investigation via ML estimation based on Japanese data only



Initial investigation via ML estimation based on Japanese data only

1. Observation errors other than sampling errors in standardized CPUE estimates?
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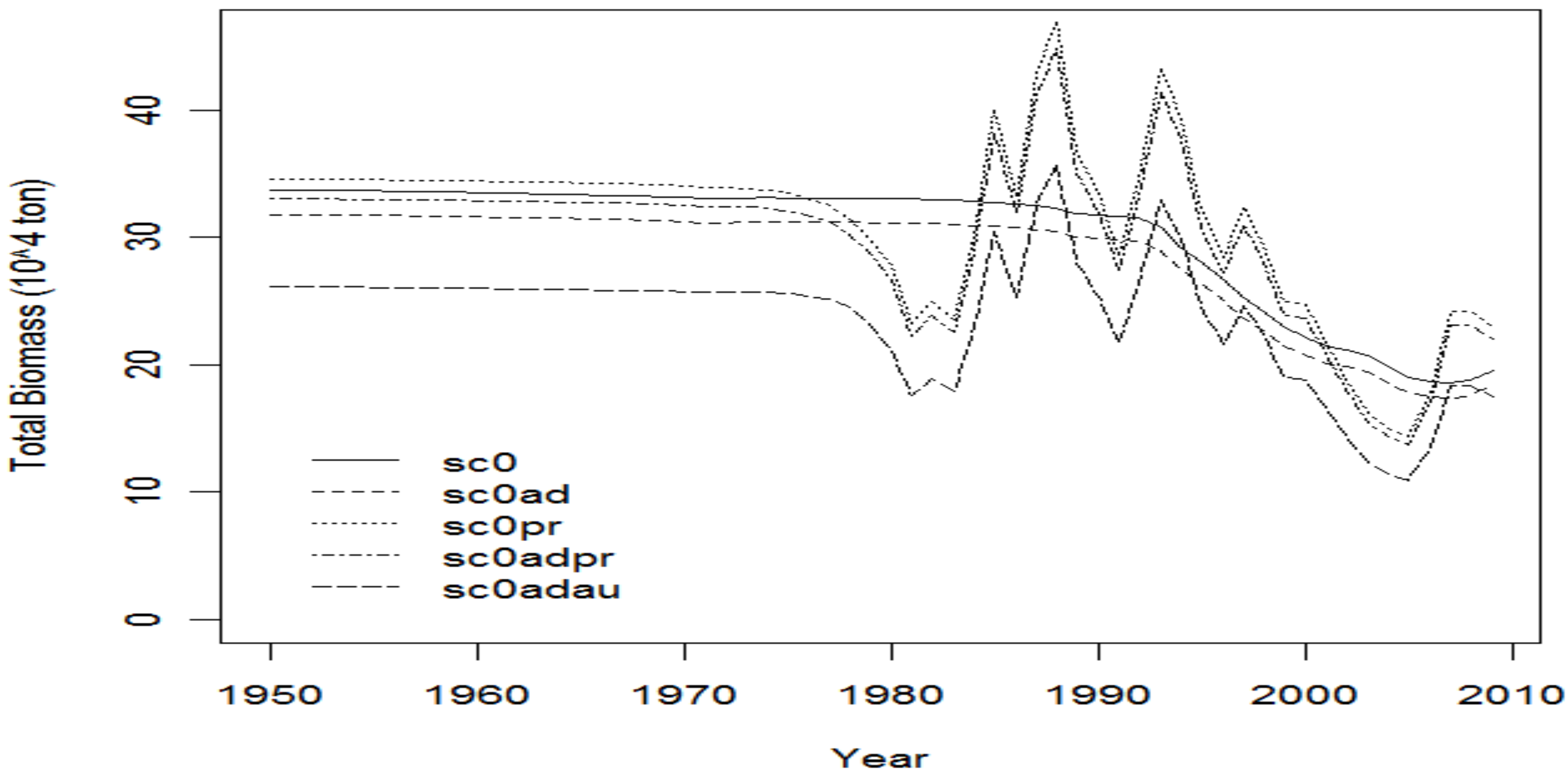
2. Depletion level in the initial year considered
   (P1950 = K or P1980=K or ....? => Ass. P1950 = K)
3. Variants in the production model
   (Schaefer and Fox, already shown, somewhat differ)
4. Incorporation of process error
   (Maximization of an integrated likelihood function via ADMB-RE => We did not distinguish the process error and model error.)

Estimated trajectories with/without the process errors



Bayesian model averaging

Bayesian estimation

Parameter estimation

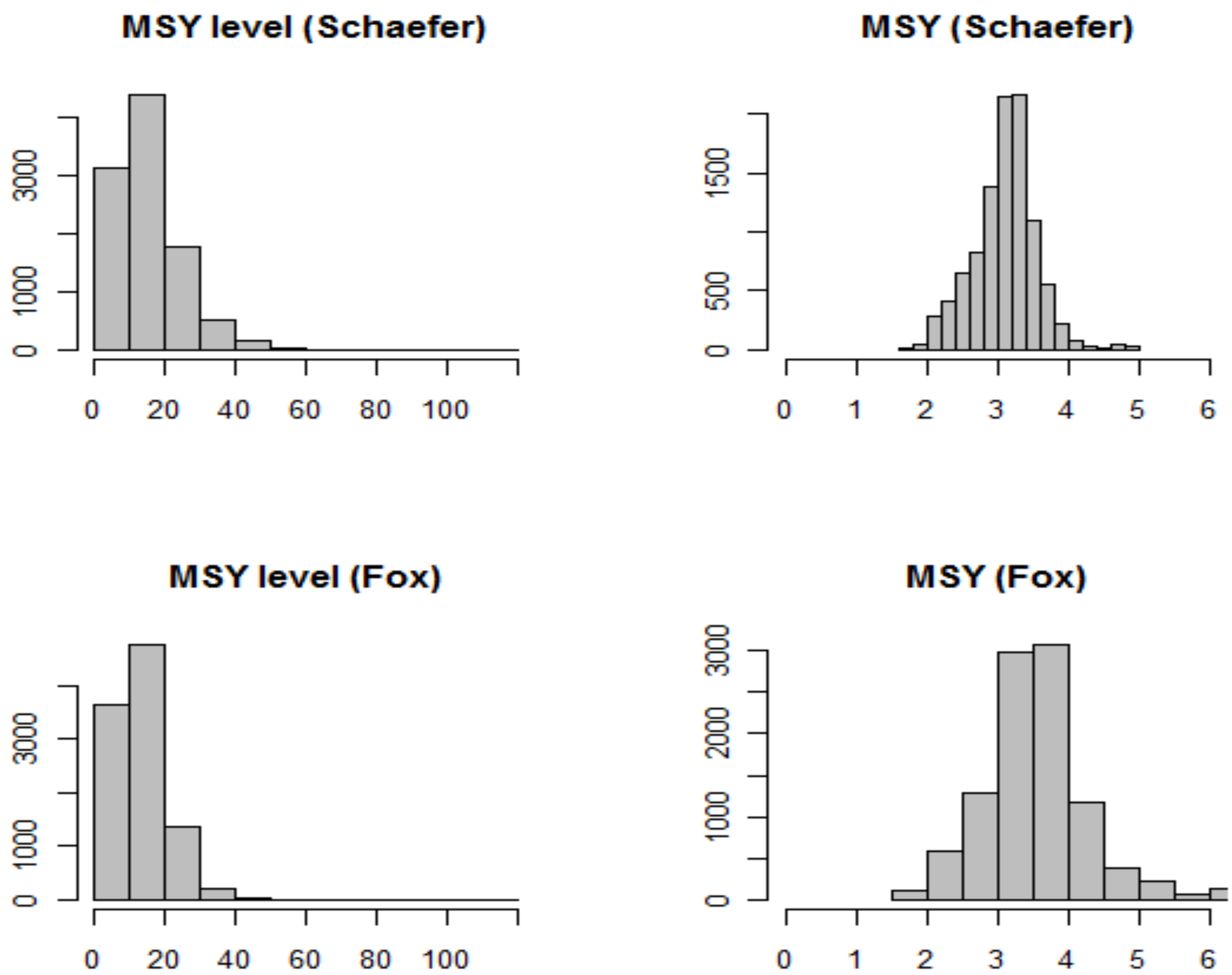
Prior distribution: flat prior for all the parameters

Posterior distribution given the data

Sampling and Importance Resampling (no MCMC)

- proposal dist is an asymptotic distribution of ML estimates for logarithms of parameters
- considered a Jacobian for the transformation

Posterior distributions



Computing model probabilities and marginal likelihood by "Importance Sampling"

$$P(Model_{SC} \mid Data) = \frac{f(Data \mid Model_{SC})}{f(Data \mid Model_{SC}) + f(Data \mid Model_{FX})}$$

$$P(Model_{FX} \mid Data) = 1 - P(Model_{SC} \mid Data)$$

$$\begin{aligned}
& f(Data \mid Model) \\
&= \int f(Data, \theta \mid Model)\pi(\theta \mid Model)\, d\theta \\
&= \int \frac{f(Data, \theta \mid Model)\pi(\theta \mid Model)}{g(\theta)} g(\theta) d\theta \\
&\approx \sum \frac{f(Data, \theta_i^* \mid Model)\pi(\theta_i^* \mid Model)}{g(\theta_i^*)}, \qquad \theta_i^* \sim g(\theta)
\end{aligned}$$

Posterior model probabilities

$$\omega_{Schaefer} = P(Model_{SC} \mid Data)$$
$$\omega_{Fox} = P(Model_{FX} \mid Data)$$

$K = \omega_{Schaefer} * K_{Schaefer} + \omega_{Fox} * K_{Fox}$

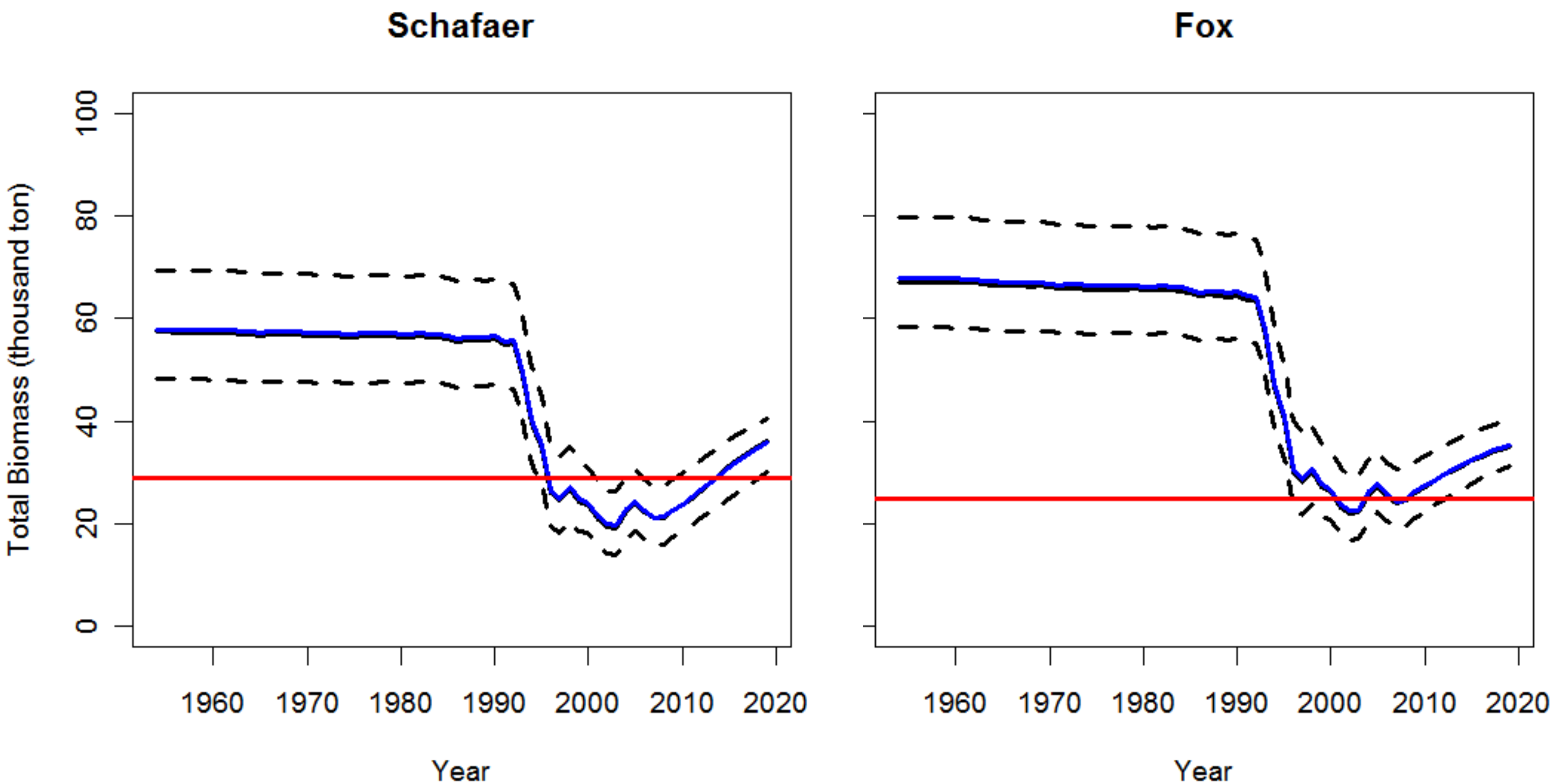
$MSY = \omega_{Schaefer} * MSY_{Schaefer} + \omega_{Fox} * MSY_{Fox}$

. . .

and so on

Results for SW Region

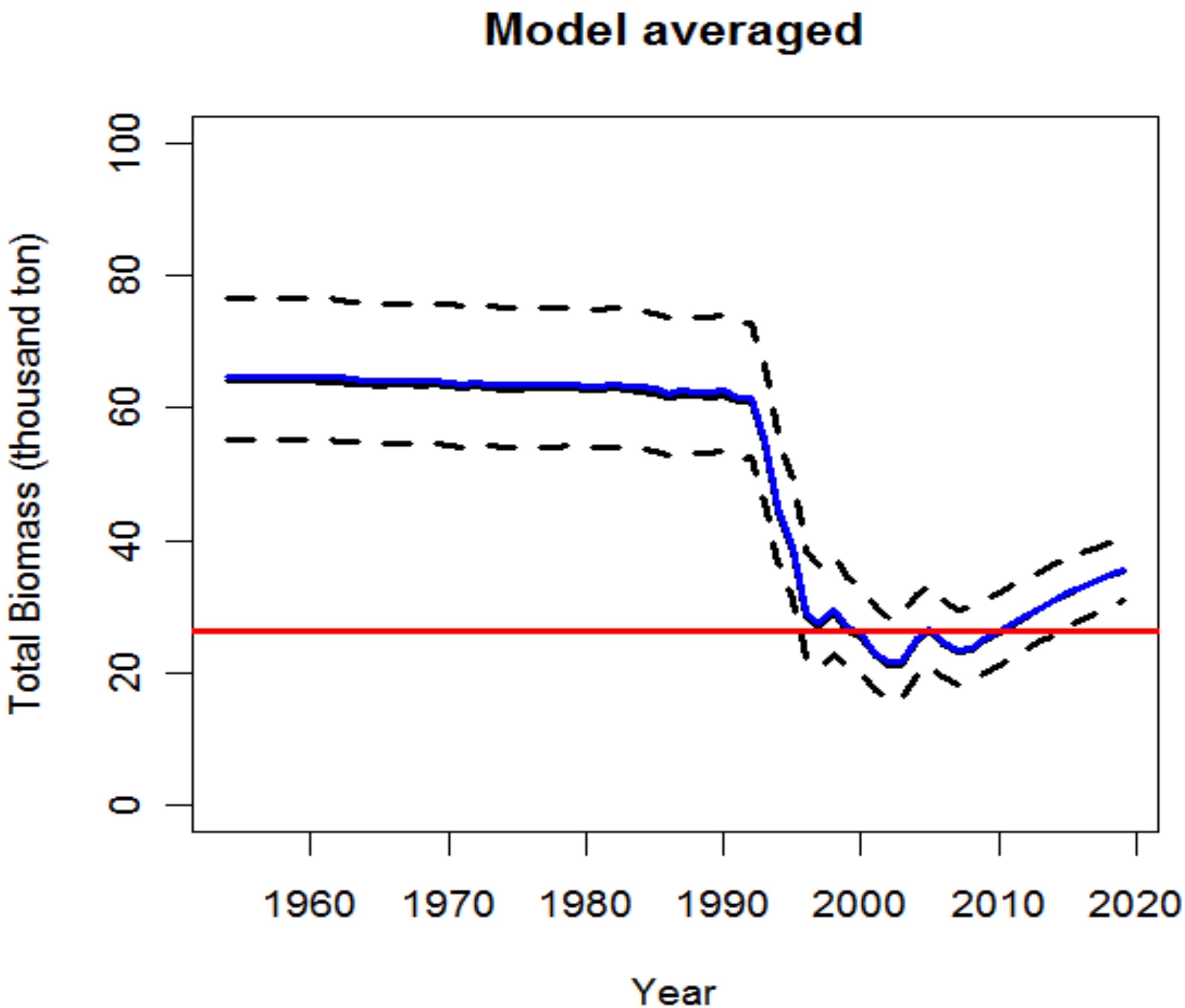
Results for SW (1) Model specific



$$\omega_{Schaefer} = P(Model_{SC} \mid Data) = 0.308$$

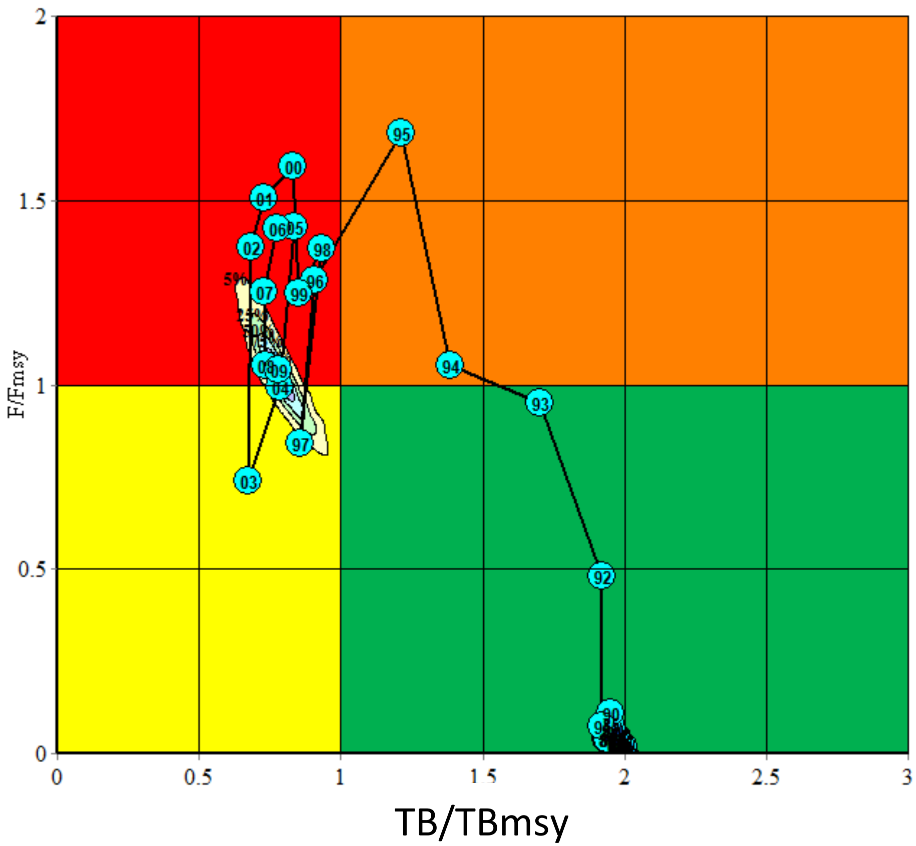
$$\omega_{Fox} = P(Model_{FX} \mid Data) = 0.692$$

Results for SW (2) Model averaging

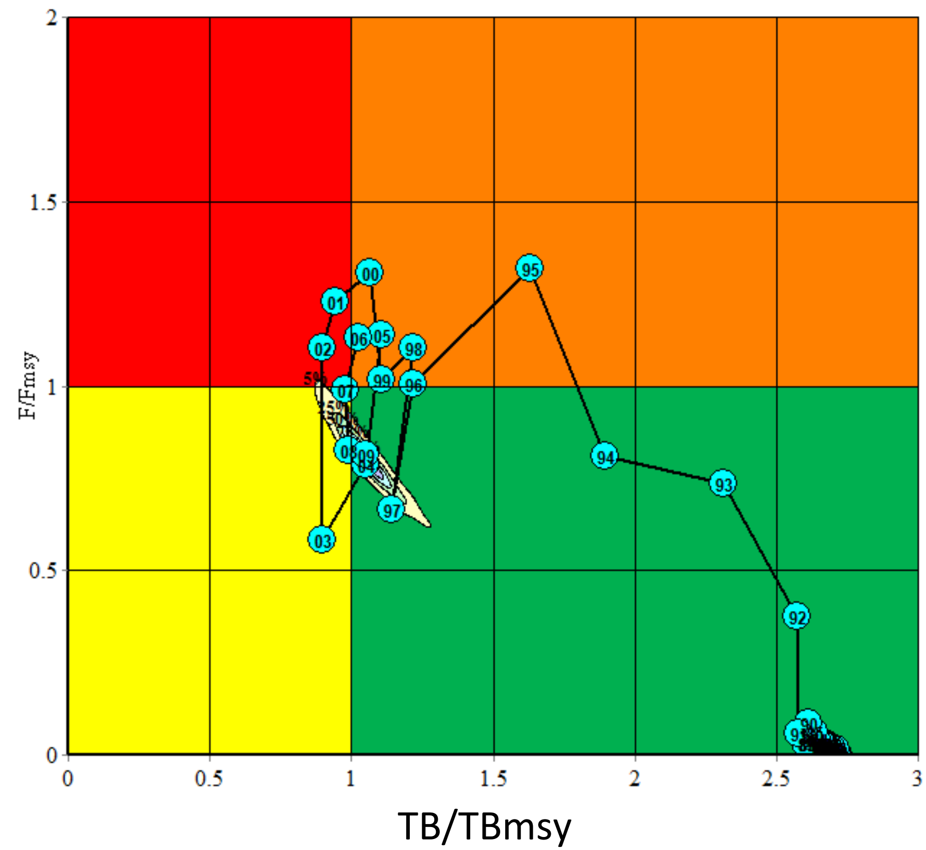


Results for SW (3) KOBE (by model)

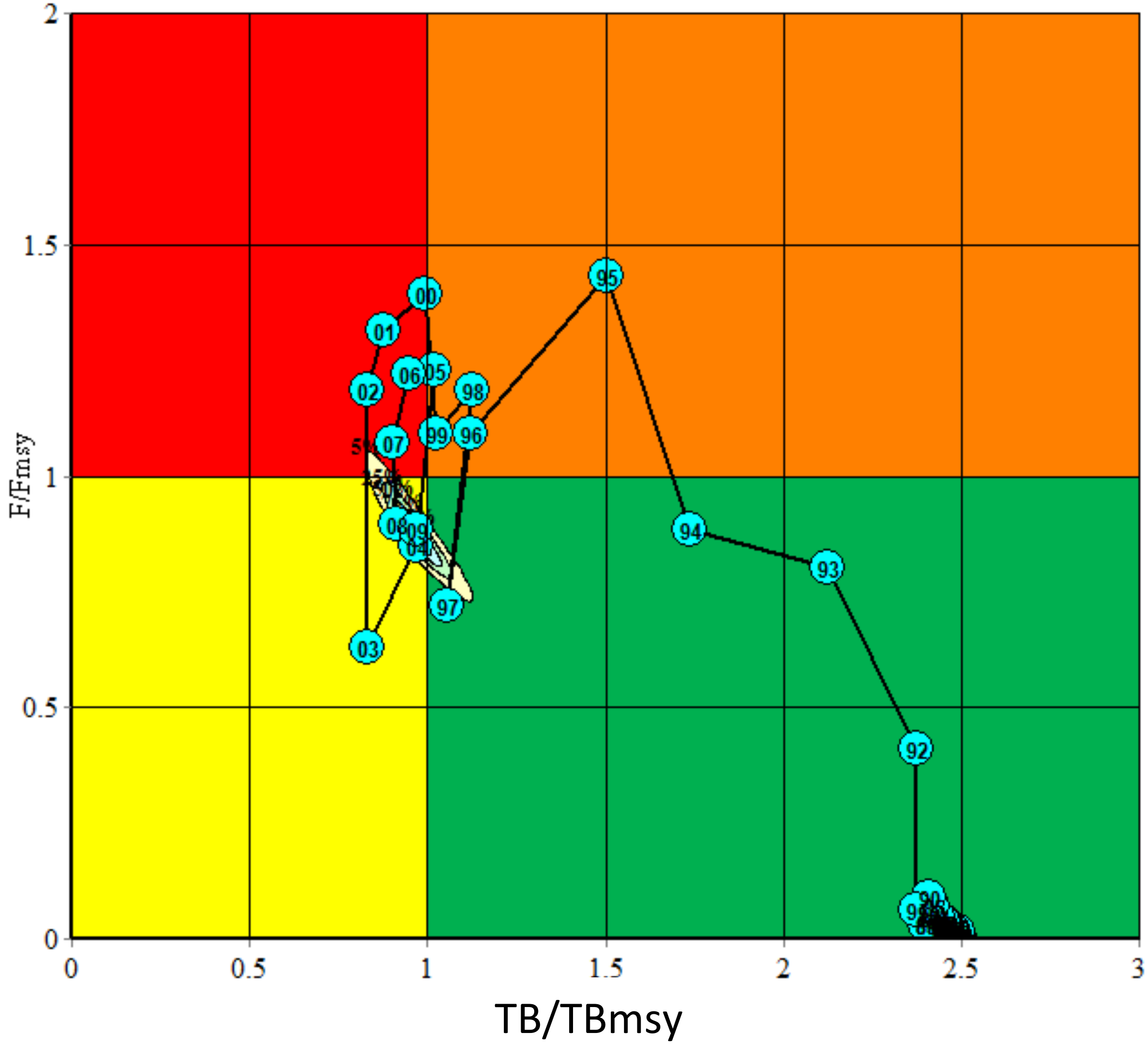
(a)Schaefer model



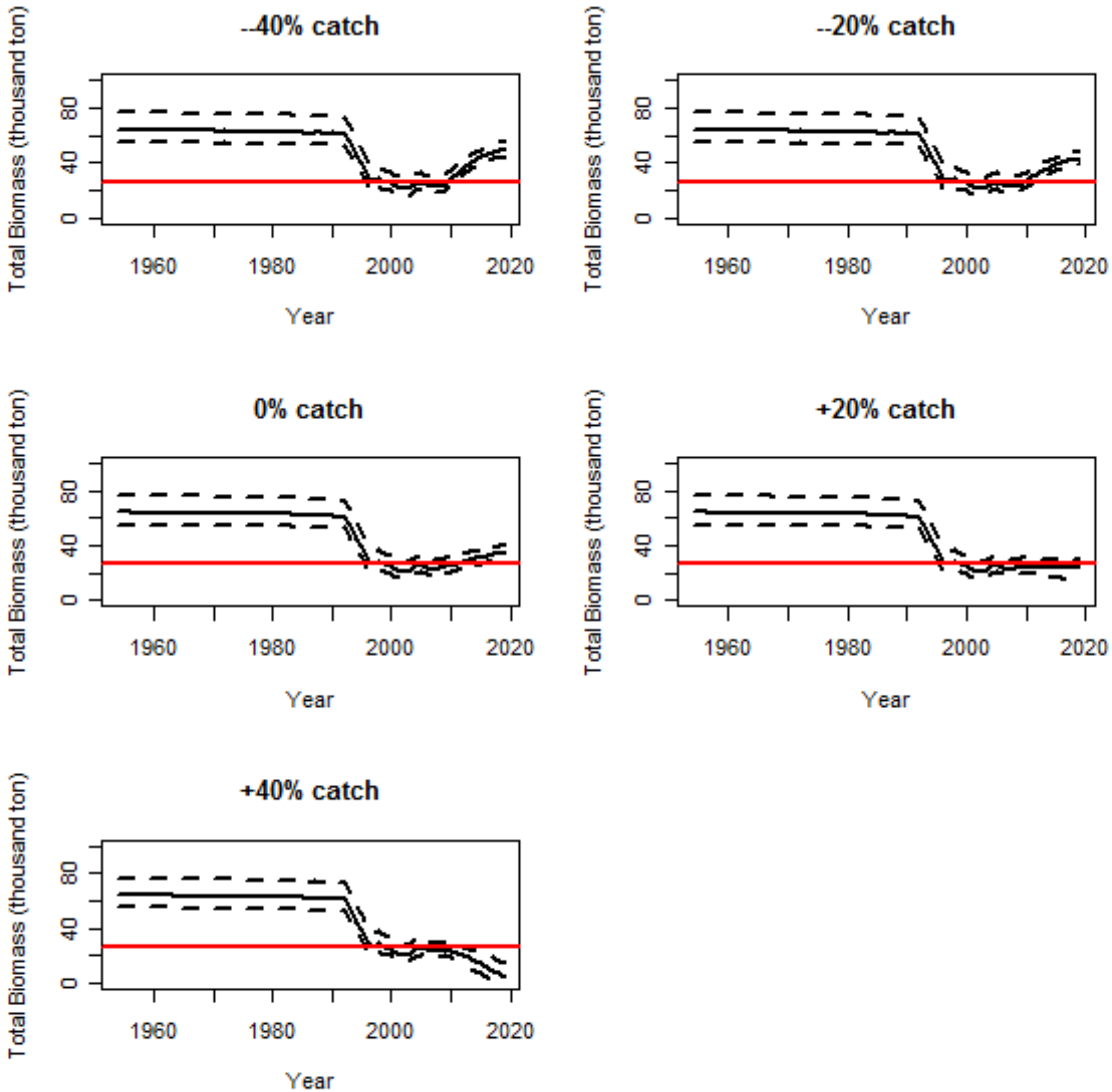
(b) Fox model



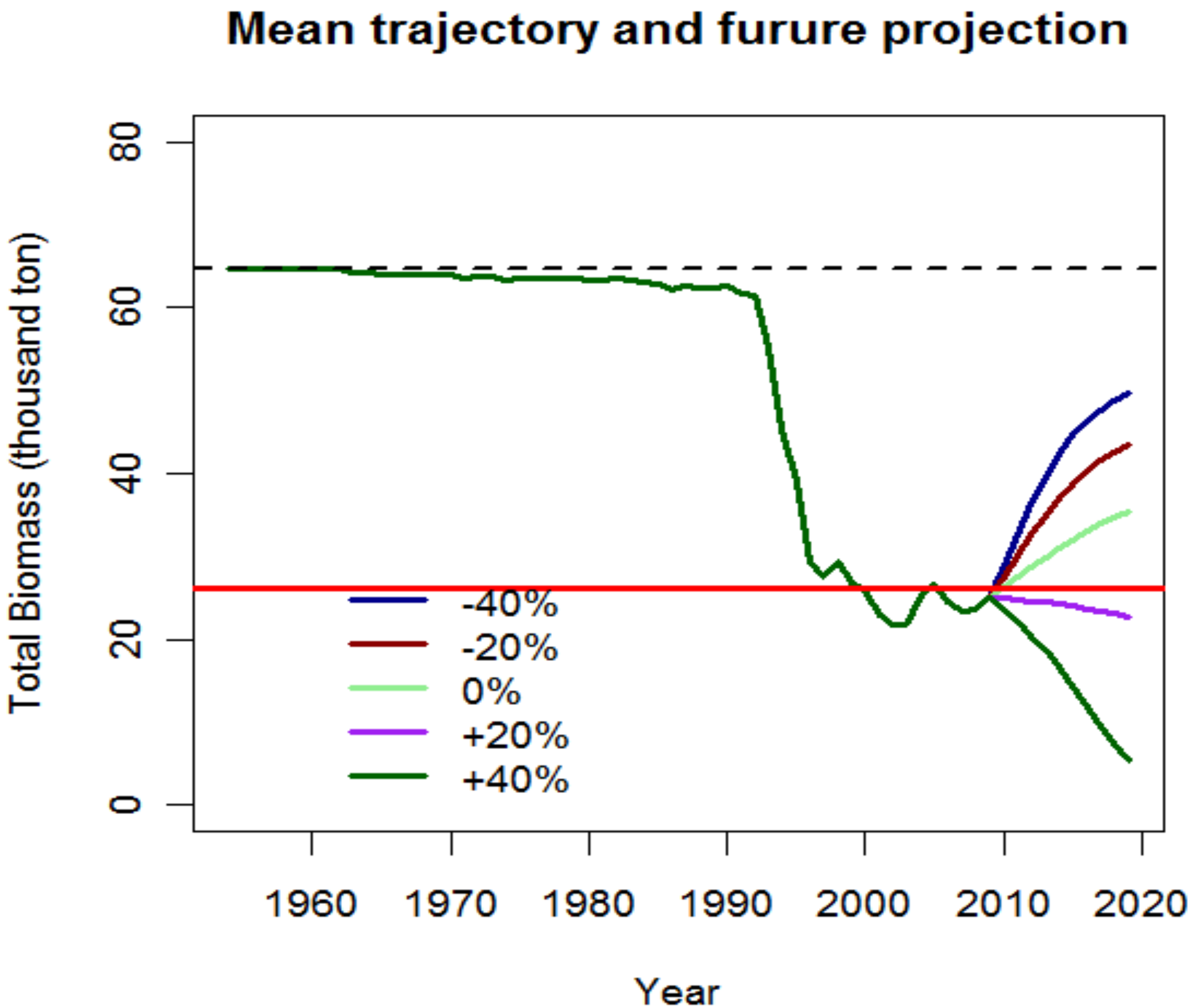
Results for SW (4) KOBE (averaged)



Results for SW (5) Population trajectories

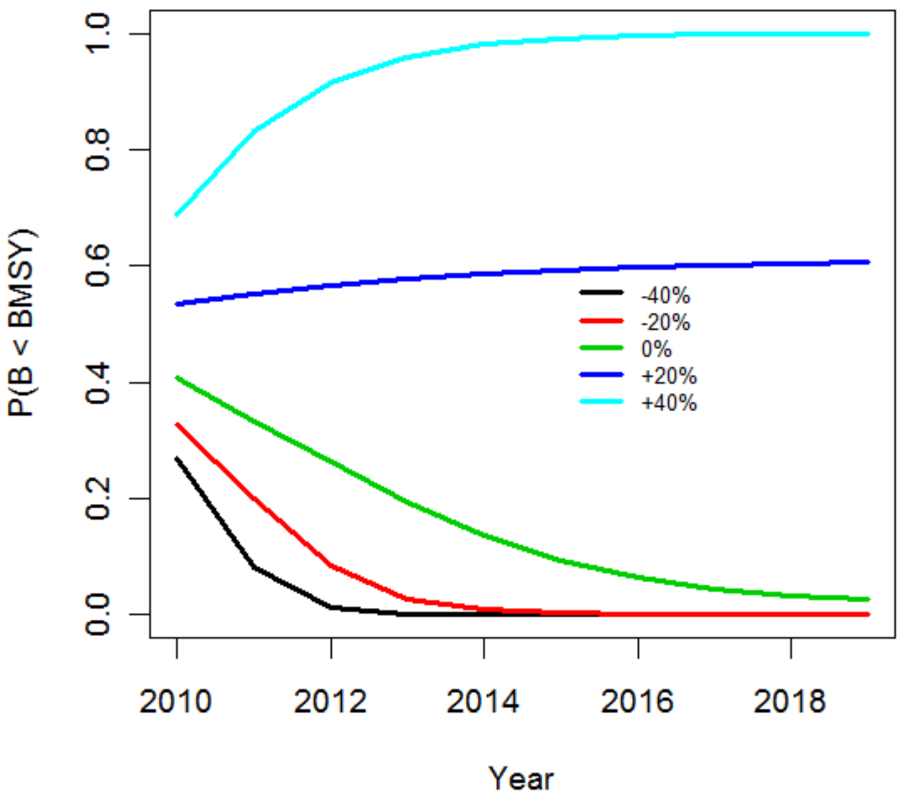


Results for SW (6) Future catch

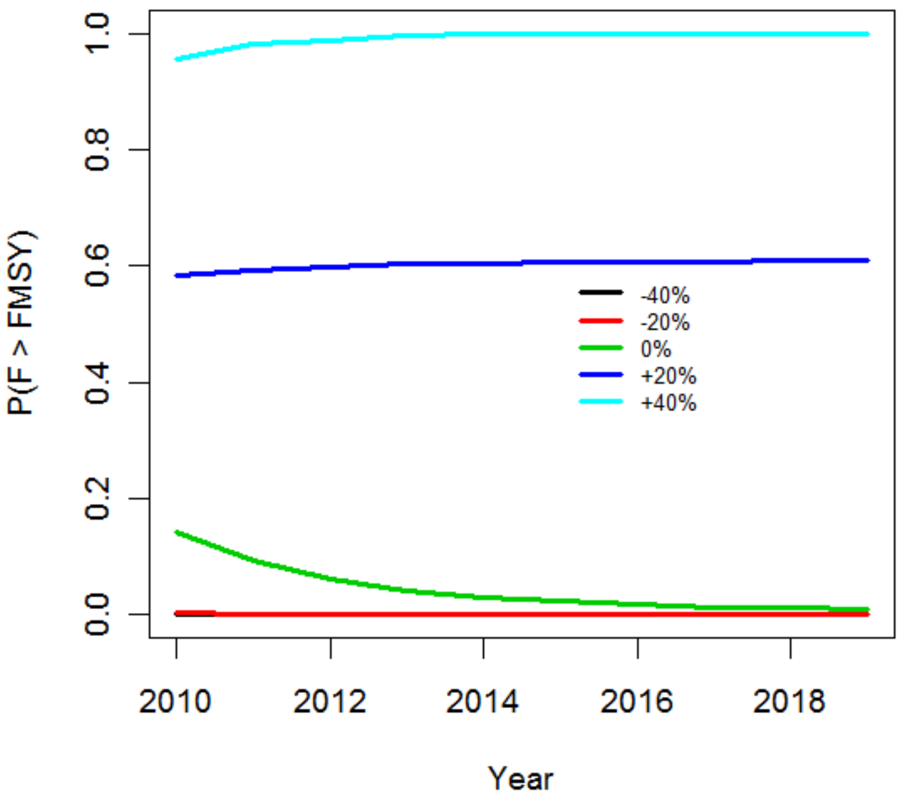


Results for SW (7) Risk Assessment

P(B<BMSY)



P(F>FMSY)



Results for SW (8) KOBE II matrix

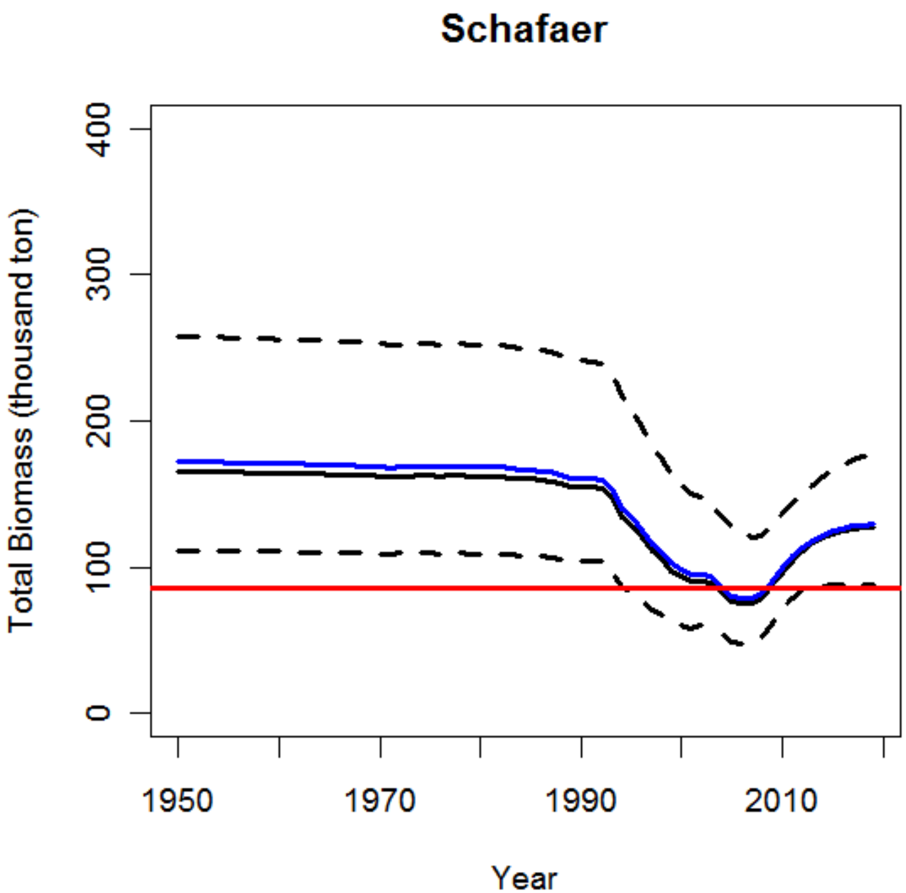
	Constant Catch Level (relative to 2009)				
Probability	**60%**	**80%**	**100%**	**120%**	**140%**
B(2012) <B(MSY)	0.011	0.083	0.264	0.567	0.915
F(2012) >F(MSY)	0.000	0.000	0.060	0.597	0.989
B(2019) <B(MSY)	0.000	0.000	0.025	0.606	1.000
F(2019) >F(MSY)	0.000	0.000	0.010	0.609	1.000

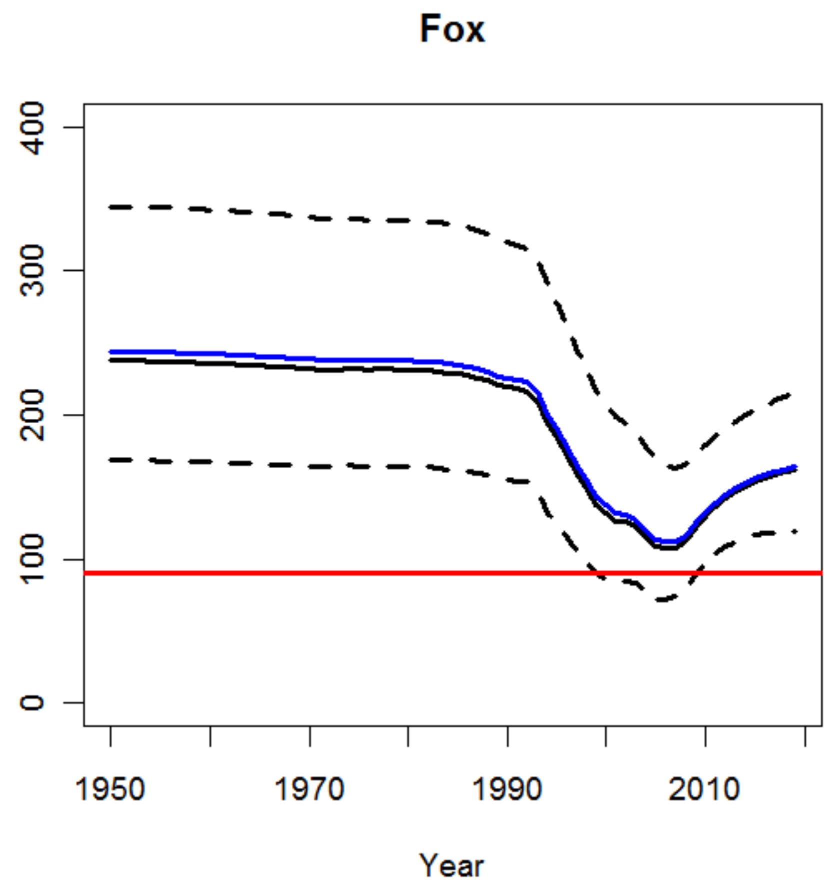
Results for SW (9) Reference points

Management Quantity	Aggregate Indian Ocean	SW Region Only
Most recent catch estimate		
Mean catch over last 5 years		
MSY (1000 t)		7.91 (SE=0.199)
Current Data Period		Catch:1954-2009 CPUE:1980-2009
F(Current)/F(MSY)		0.884 (SE=0.071)
B(Current)/B(MSY)		0.942 (SE=0.071)
SB(Current)/SB(MSY)	NA	NA
B(Current)/B(0)		0.375 (SE=0.028)
SB(Current)/SB(0)	NA	NA
B(Current)/B(Current, F=0)	what?	what?
SB(Current)/SB(Current, F=0)	NA	NA

Results for Aggregated Indian Ocean

Results for IO (1) Model specific

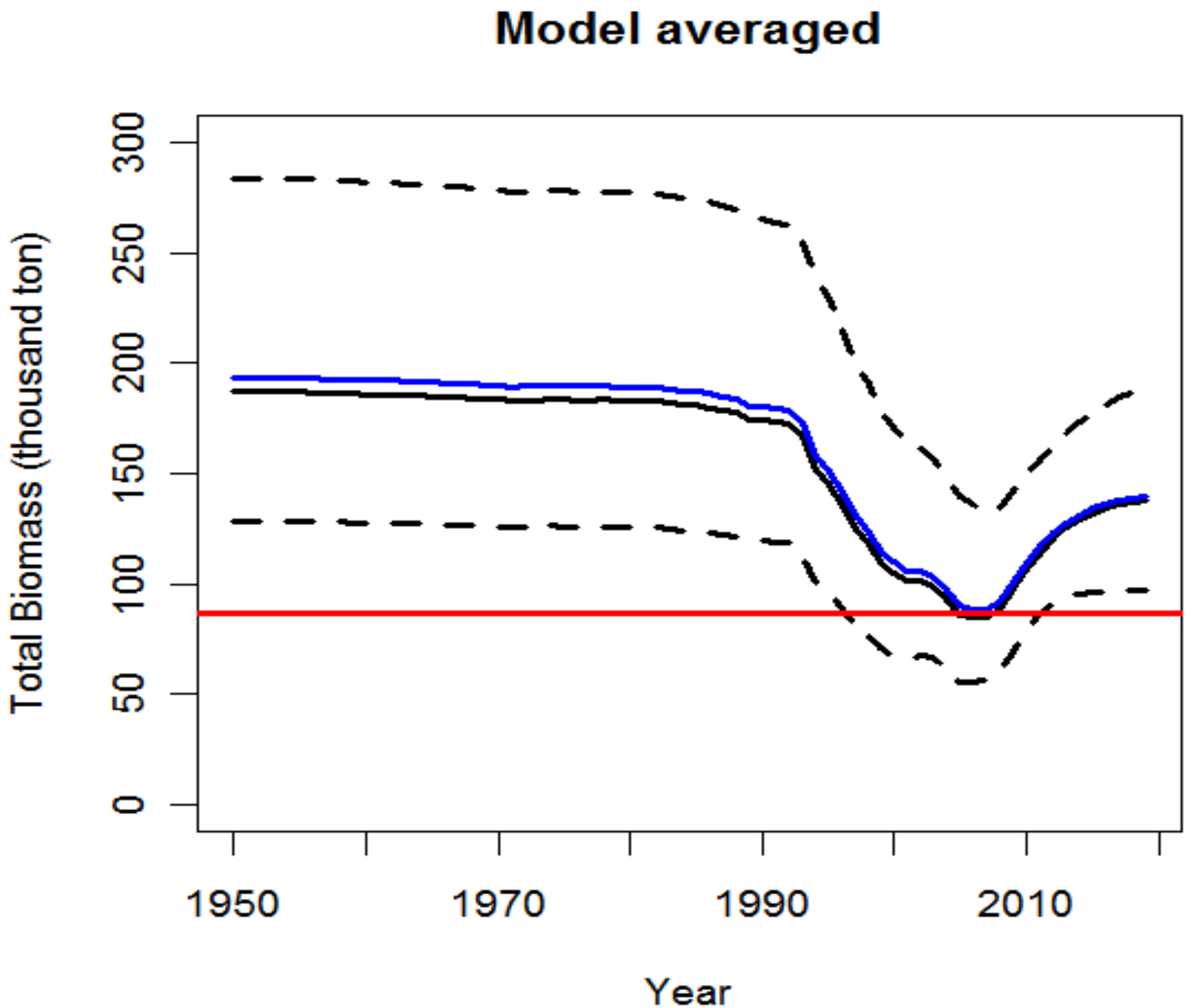




$$\omega_{Schaefer} = P(Model_{SC} \mid Data) = 0.699$$

$$\omega_{Fox} = P(Model_{FX} \mid Data) = 0.301$$

Results for IO (2) Model averaging

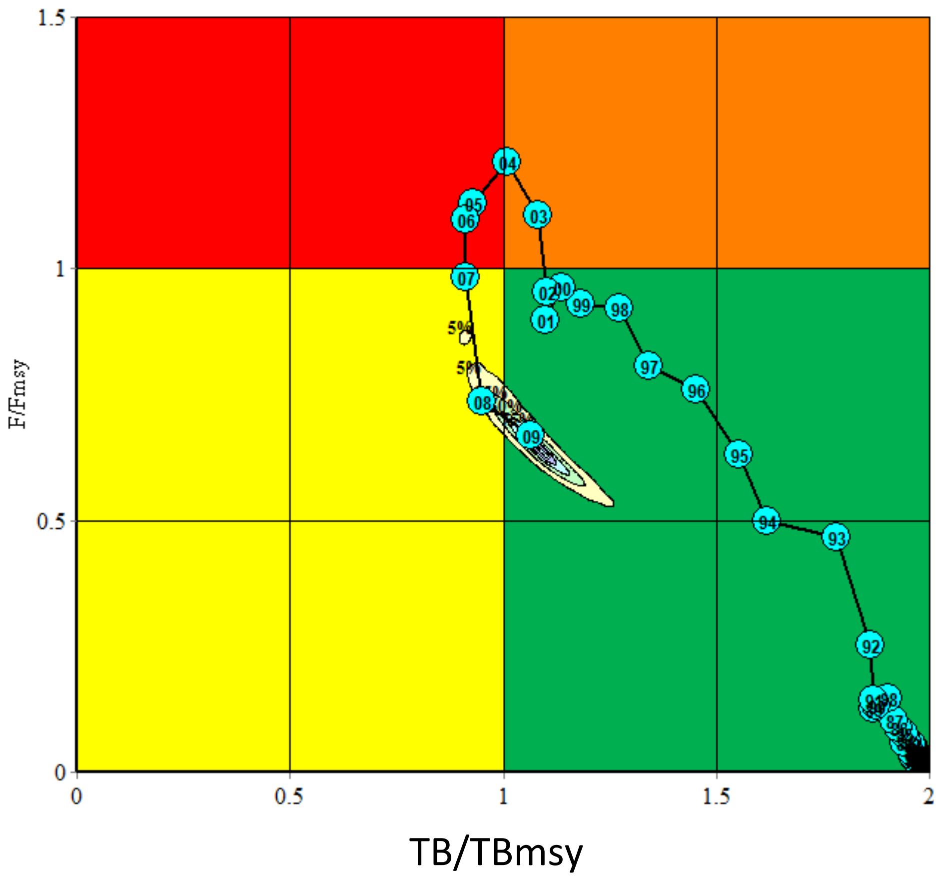


Results for IO (3) Reference points

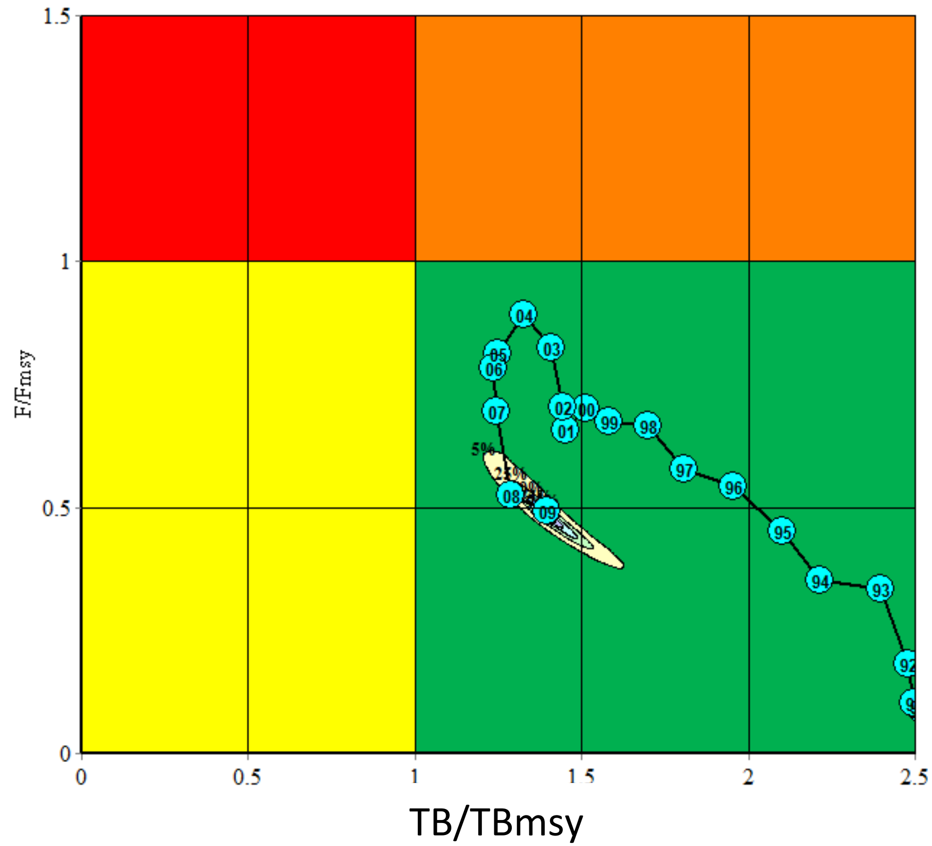
Management Quantity	Aggregate Indian Ocean	SW Region Only
Most recent catch estimate		
Mean catch over last 5 years		
MSY (1000 t)	30.77 (SE=0.880)	7.91 (SE=0.199)
Current Data Period	Catch:1950-2009 CPUE:1980-2009	Catch:1954-2009 CPUE:1980-2009
F(Current)/F(MSY)	0.615 (SE=0.053)	0.884 (SE=0.071)
B(Current)/B(MSY)	1.073 (SE=0.090)	0.942 (SE=0.071)
SB(Current)/SB(MSY)	NA	NA
B(Current)/B(0)	0.481 (SE=0.043)	0.375 (SE=0.028)
SB(Current)/SB(0)	NA	NA
B(Current)/B(Current, F=0)		
SB(Current)/SB(Current, F=0)	NA	NA

Results for IO (4) KOBE (by model)

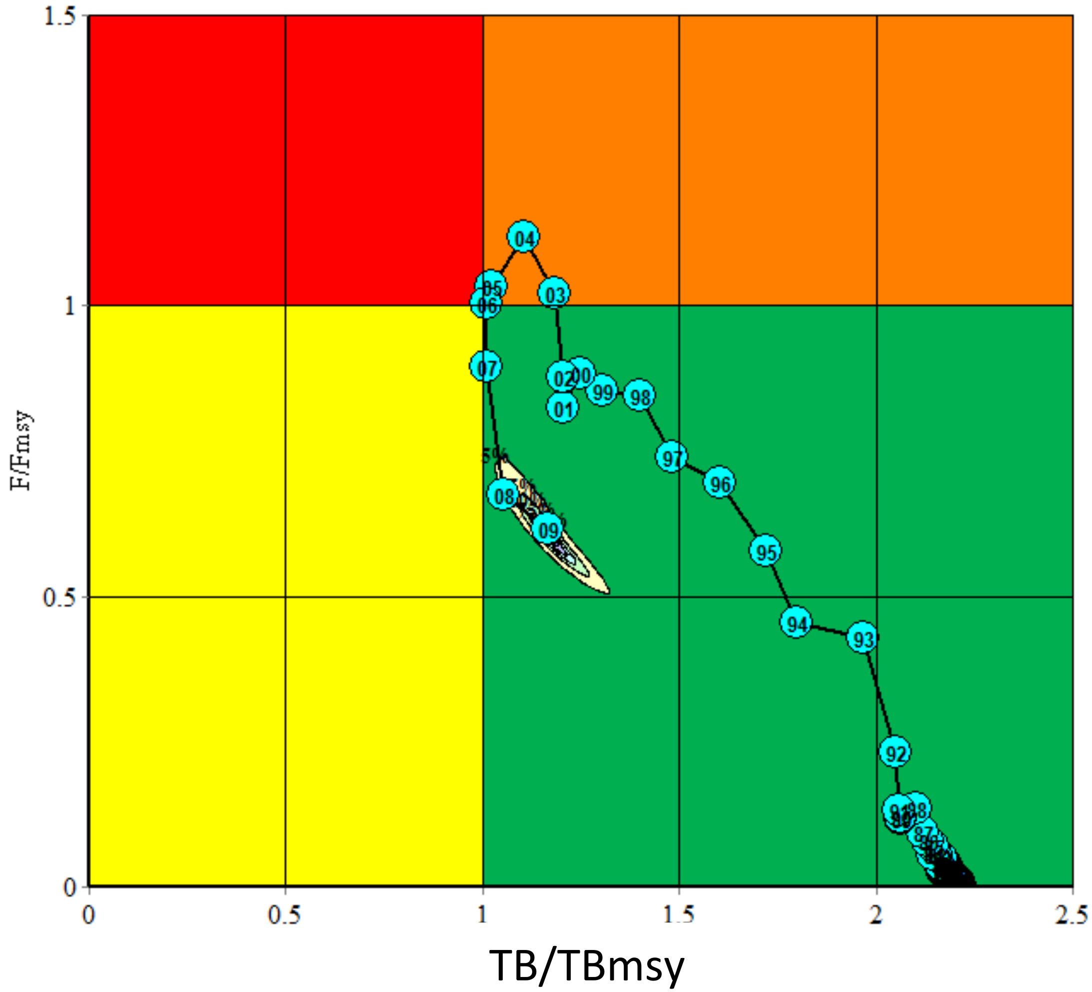
(a)Schaefer model



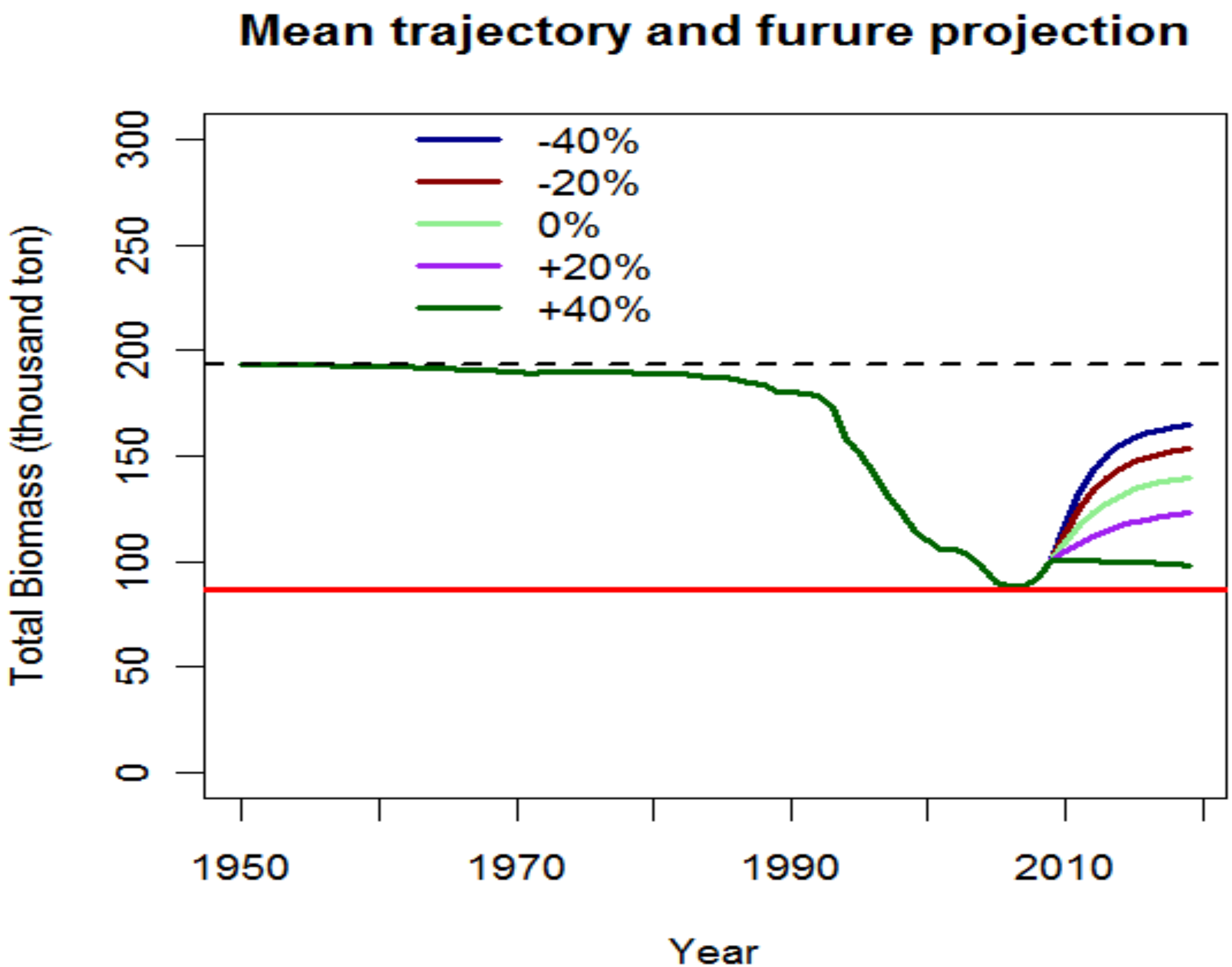
(b) Fox model



Results for IO (5) KOBE (averaged)

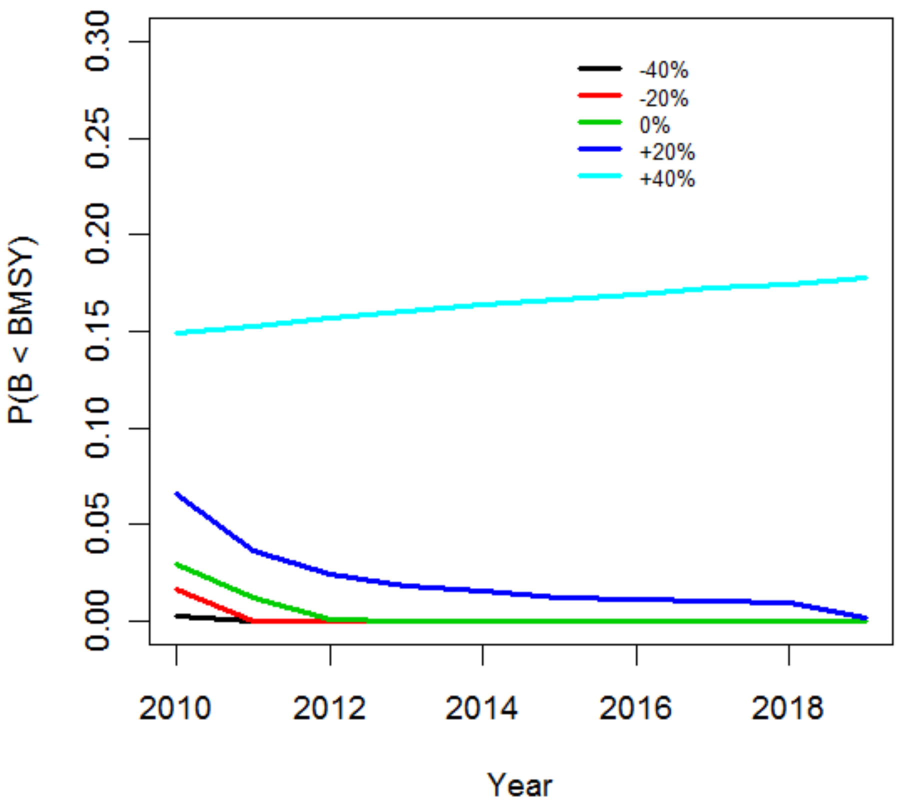


Results for IO (6) Future catch

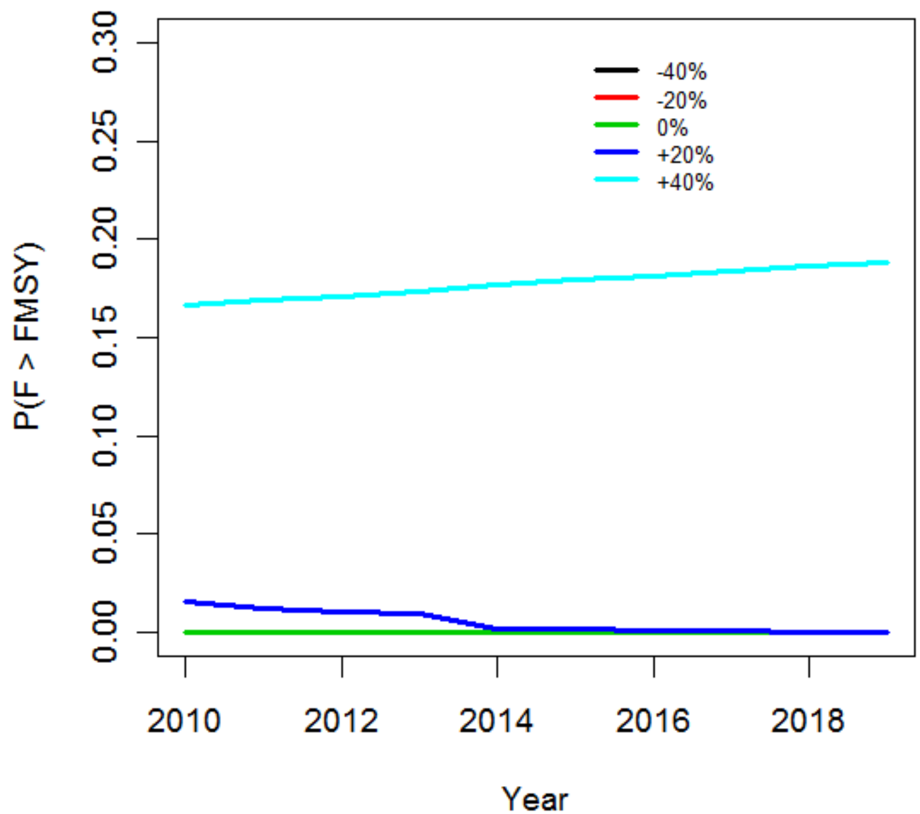


Results for IO (7) Risk Assessment

P(B<BMSY)



P(F>FMSY)



Results for IO (8) KOBE II matrix

	Constant Catch Level (relative to 2009)				
Probability	**60%**	**80%**	**100%**	**120%**	**140%**
B(2012) <B(MSY)	0.000	0.000	0.001	0.024	0.157
F(2012) >F(MSY)	0.000	0.000	0.000	0.011	0.171
B(2019) <B(MSY)	0.000	0.000	0.000	0.002	0.178
F(2019) >F(MSY)	0.000	0.000	0.000	0.011	0.188

Remarks

1) We consider averaging of only “two models”
   - possible to extend SC/FX/PT, K=P1950/1980, etc

2) Impact of choice of priors are not discussed

3) Another Bayesian computation: a reversible jump

4) A frequentist method, "bootstrapped weight", is
   an alternative possible approach (in the future)

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Thank you very much
for your kind attention!