Evaluation of including the cost of reproduction in a growth model for bigeye tuna

in the eastern Pacific Ocean, and the effect on stock assessment results and management advice

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Carolina V. Minte-Vera, Mark N. Maunder, Alexandre M. Aires-da-Silva, Kurt M. Schaefer, Daniel W. Fuller

Growth issues for tropical tunas

- Stock assessments fit to length composition data are sensitive to growth parameters, particularly asymptotic length
- Growth is linear for young ages and then slows down rapidly
- The von Bertalanffy model does not well describe tropical tuna growth
- Aging from otoliths is difficult above age 4 or 5

Approach

- Fit to both age-length and tagging growth increment data
- Use a more flexible growth curve
  - The Richards growth curve
  - Include cost of reproduction
- Evaluate the impact on the stock assessment

Von Bertalanffy Log-Linf

$$L_a = L_\infty(1 - \exp(-K(a - t_0)))$$

$$L_\infty(a) = L_{\infty,1} + \varphi(a)\left(L_{\infty,2} - L_{\infty,1}\right)$$

$$\varphi(a) = \frac{1}{1+e^{\frac{-\ln(19)*(a-t_{50})}{(t_{95}-t_{50})}}}$$

Cost of Reproduction

$$L_a = L_{a-1} + G_a$$

$$G_a = \alpha - \beta L_{a-1} - \varphi(a)\gamma L_{a-1}^3$$

$$\varphi(a) = \frac{1}{1+e^{\frac{-\ln(19)*(a-t_{50})}{(t_{95}-t_{50})}}}$$

Likelihoods

The likelihoods take into consideration the fact the **data we need** is maturity at age and age at release of tagged fish, but the **data we have** is maturity at length and length at release (and we need to “transform” length into ages)

Age-length

$$\mathcal{L}_i[L|a,\theta] = N\big((L_i - \hat{L}_{a_i}), \sigma^2_{a_i}\big)$$

Tag

$$\mathcal{L}_{Ltag,Lrec,\delta} = \int p(a) * N\big((L_{tag} - \hat{L}_a), \sigma^2_a\big) * N\big((L_{rec} - \hat{L}_{a+\delta}), \sigma^2_{a+\delta}\big)da$$

Maturity

$$\mathcal{L}_{mat} = \int p(a) * P(mat|a) * N\big((L \;\; - \hat{L}_a), \sigma^2_a\big)da$$

Approximating the integrals

$$\mathcal{L}_{Ltag,Lrec,\delta} = \sum_{a=1}^{A} p(a) * N\big((L_{tag} - \hat{L}_a), \sigma_a^2\big) * N\big((L_{rec} - \hat{L}_{a+\delta}), \sigma_{a+\delta}^2\big)$$

$$\mathcal{L}_{mat} = \sum_{a=1}^{A} p(a) * P(mat|a) * N\big((L \quad - \hat{L}_a), \sigma_a^2\big)$$

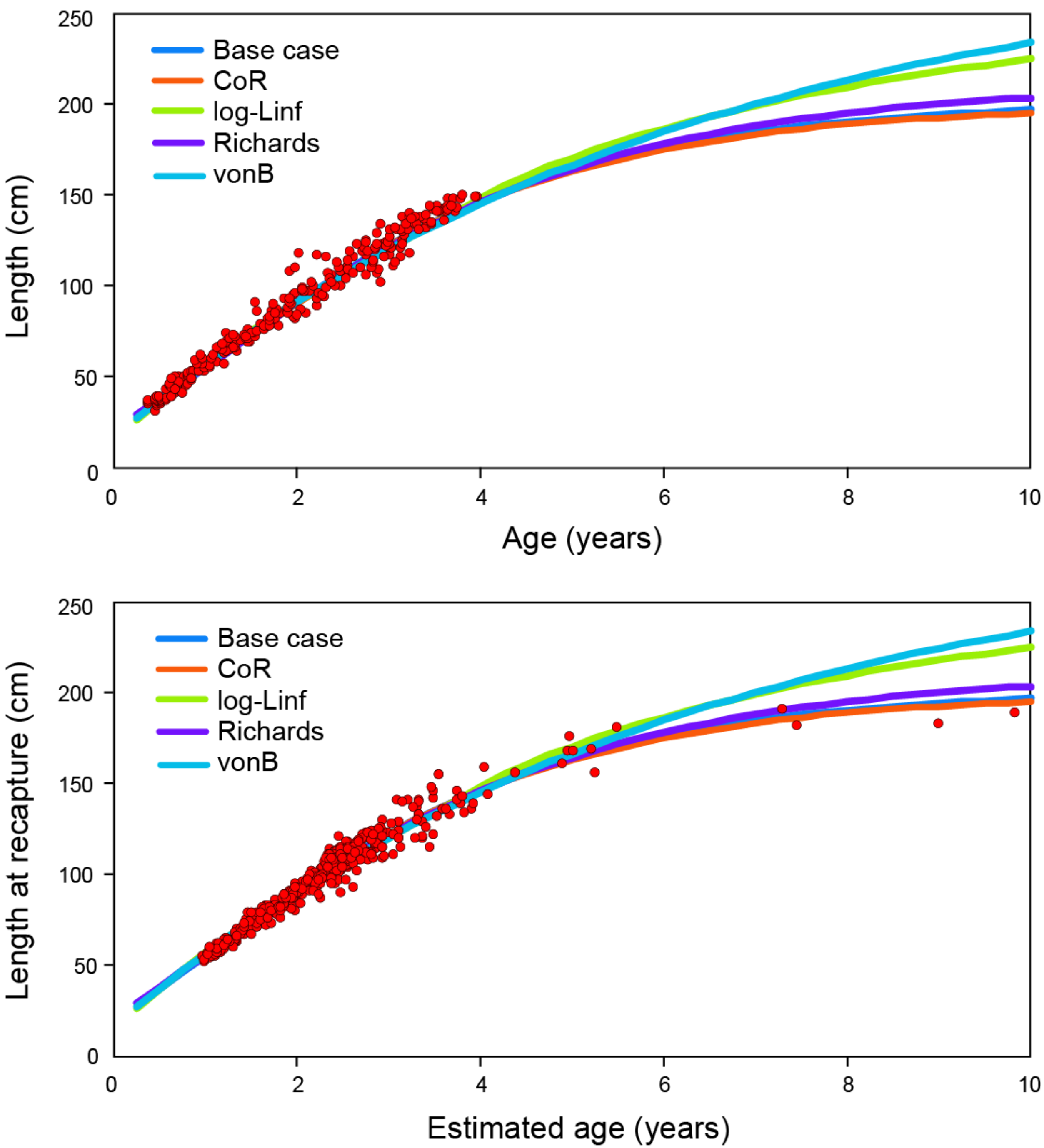
Estimation method

- Estimate the growth parameters (including for the variation of length-at-age) conditioned on fixed values of the maturity parameters and using only the age-length and tag growth-increment likelihood components.
- Estimate the maturity parameters conditioned on fixed values of the growth parameters and using only the maturity likelihood component.

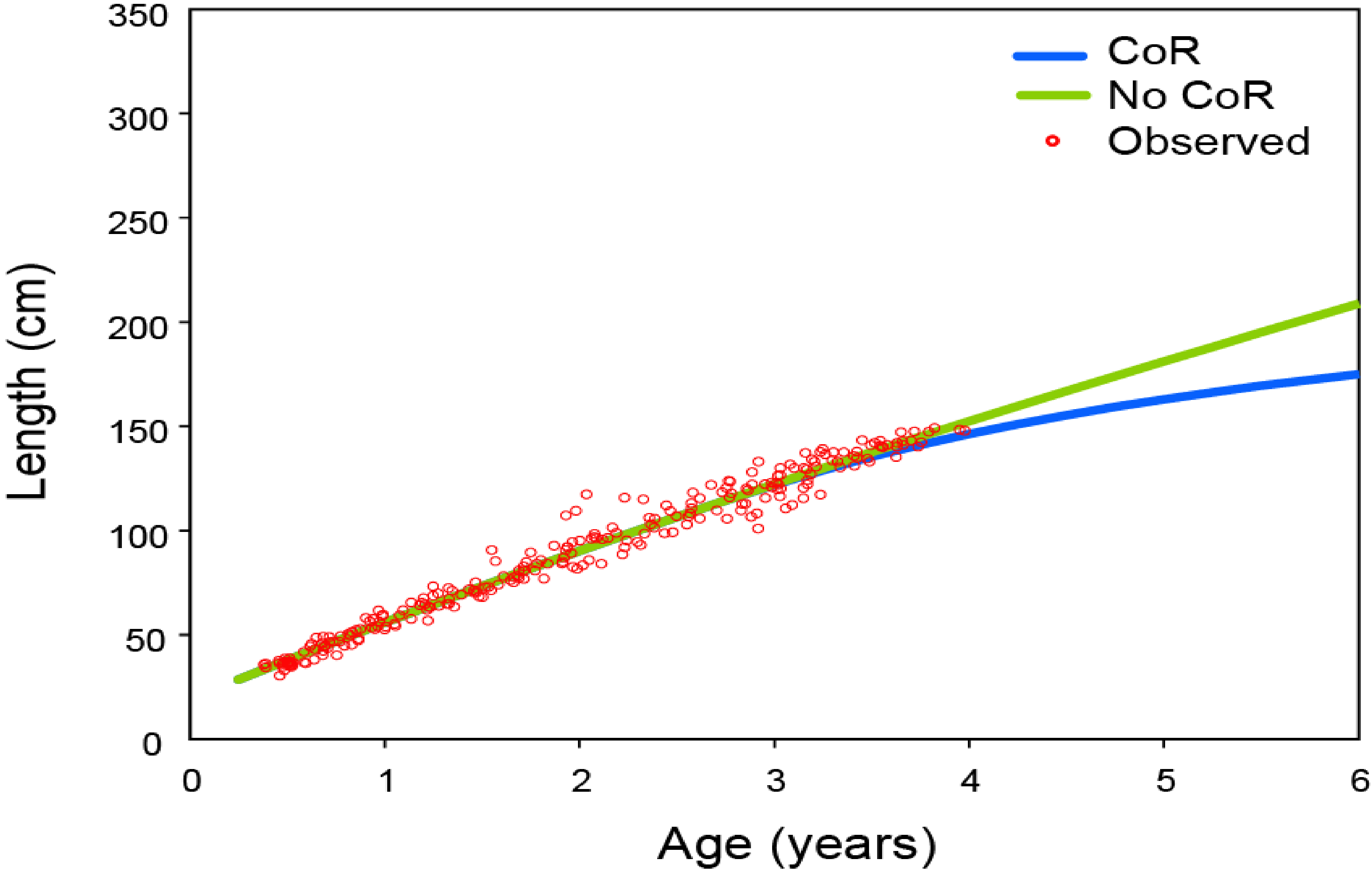
Results

	Data: maturity at length, length at tagging and recapture (tag), otolith (age)		Data: length at tagging and recapture, otolith	
	CoR	log-L_{inf}	VB	Richards
f	-13820.40	-13782.96	-6902.87	-6918.29
Relative Likelihoods age	4.33	0.58	0.00	3.60
tag	0.00	25.81	30.36	11.34
mat	0.00	15.38		
age+tag	0.00	22.06	26.03	10.61
Number of parameters	7	7	4	5
AIC	0.00	74.89	28.84	0.00
AIC age+tag	0.00	44.12	46.06	17.23

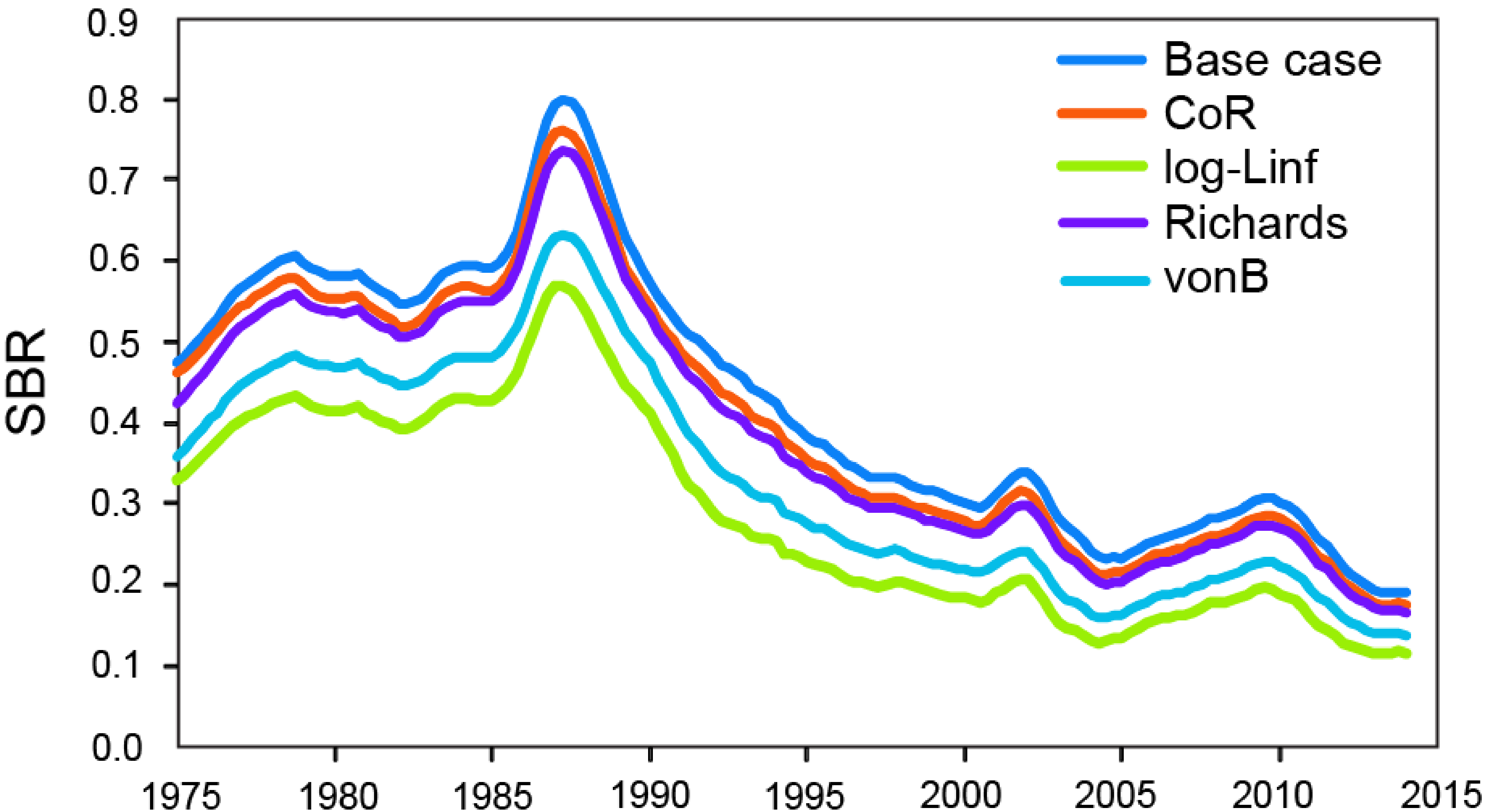
NLL – negative log-likelihood , AIC – Akaike information criterion


Base case
CoR
log-Linf
Richards
vonB
Length (cm)
Age (years)
0
50
100
150
200
250
0
2
4
6
8
10
Base case
CoR
log-Linf
Richards
vonB
Length at recapture (cm)
Estimated age (years)
0
50
100
150
200
250
0
2
4
6
8
10

Cost of Reproduction



Spawning biomass ratio (SBR)



Conclusions

- The growth curve can influence management quantities
- The Cost of Reproduction model provides the best statistical fit
- The Richards curve is less complicated and gives similar results
- More data on old fish is needed
- Sex specific data and consequent growth curves should be a priority
- A proxy used the cost of reproduction included only the maturity schedule. Other information should also be combined to compose a proxy for the cost of reproductions such as batch fecundity, frequency of spawning.