Early-life ontogenetic developments drive tuna ecology and evolution

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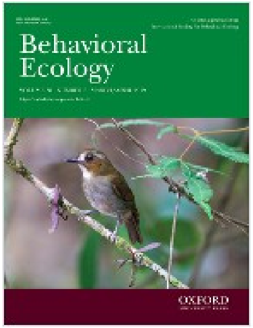
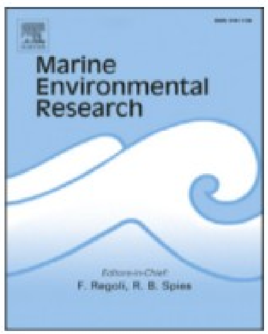


Thermodynamic constraints and the evolution of parental provisioning in vertebrates

Madeleine Beekman, Michael Thompson, Marko Jusup

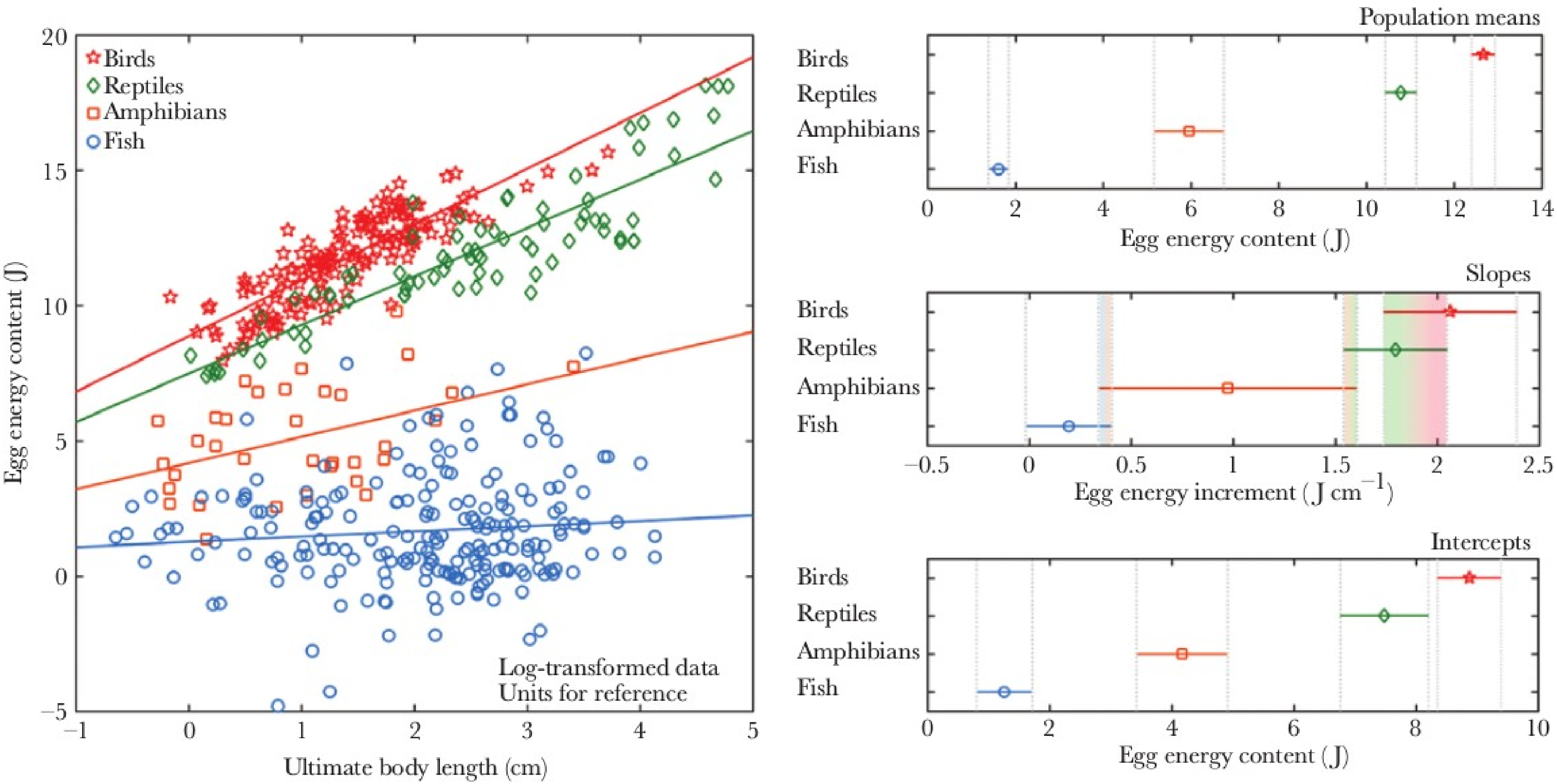


Effects of environmental change and early-life stochasticity on Pacific bluefin tuna population growth

Hirotaka Ijima, Marko Jusup, Takenori Takada, Tetsuya Akita, Hiroyuki Matsuda, Tin Klanjscek

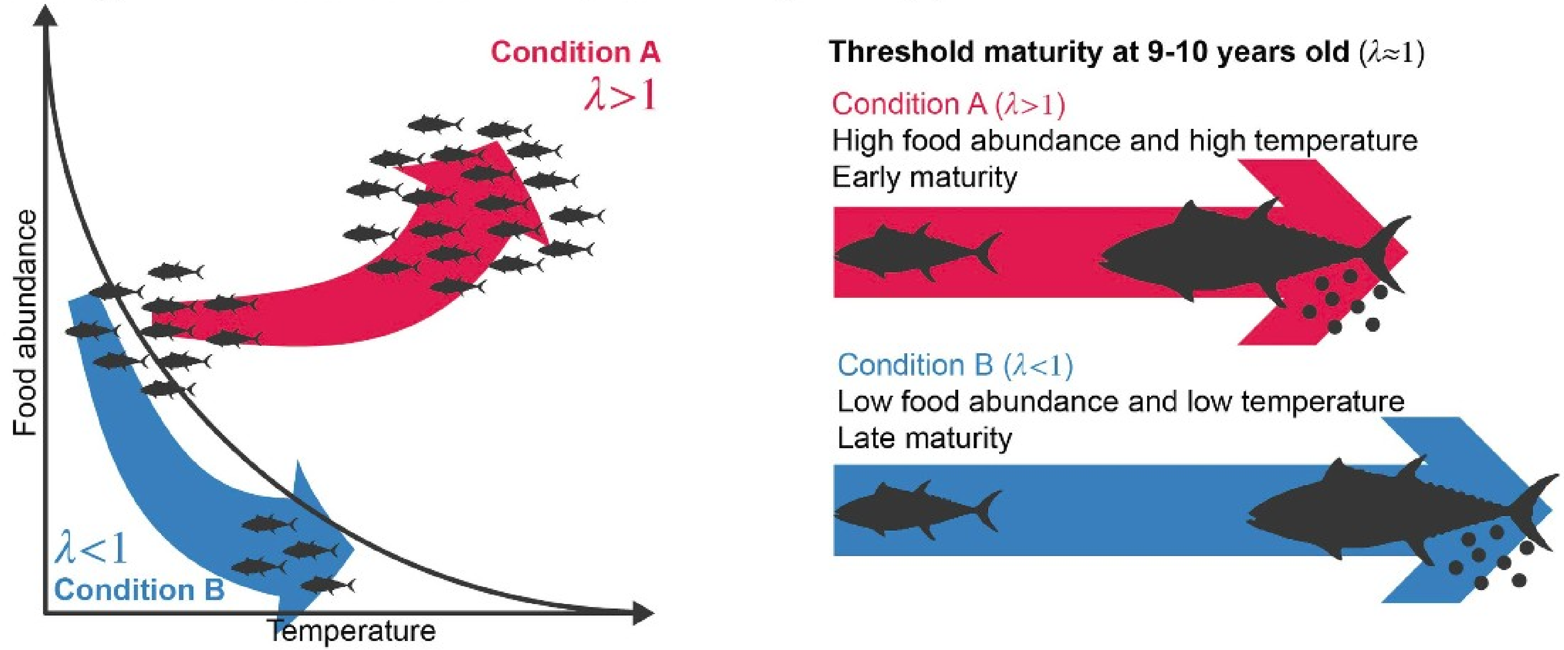
Early-life ontogenetic developments drive tuna ecology and evolution

Yoshinori Aoki, Marko Jusup, Anne-Elise Nieblas, Sylvain Bonhommeau, Hidetada Kiyofuji, Takashi Kitagawa

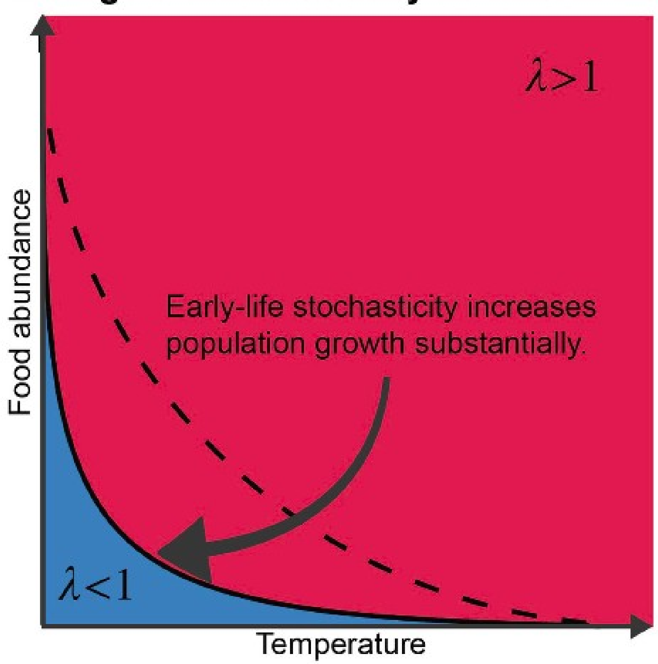


Offspring are cheap for ectotherms.

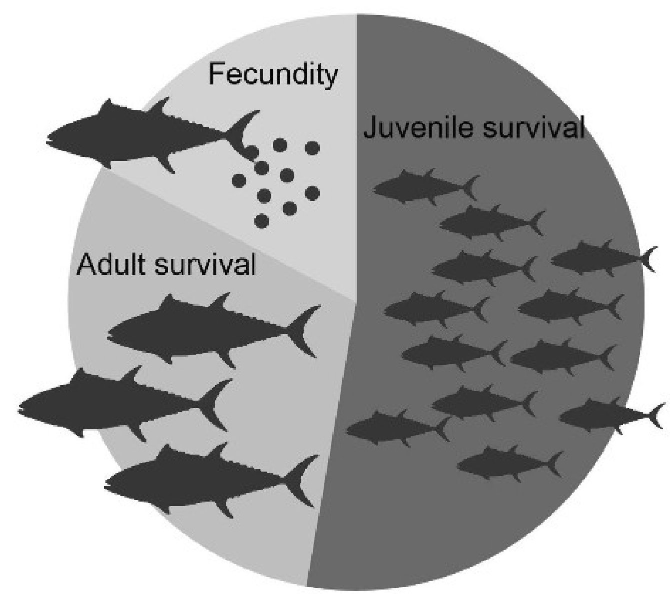
Finding 1: Enviromental effects on population growth (λ)



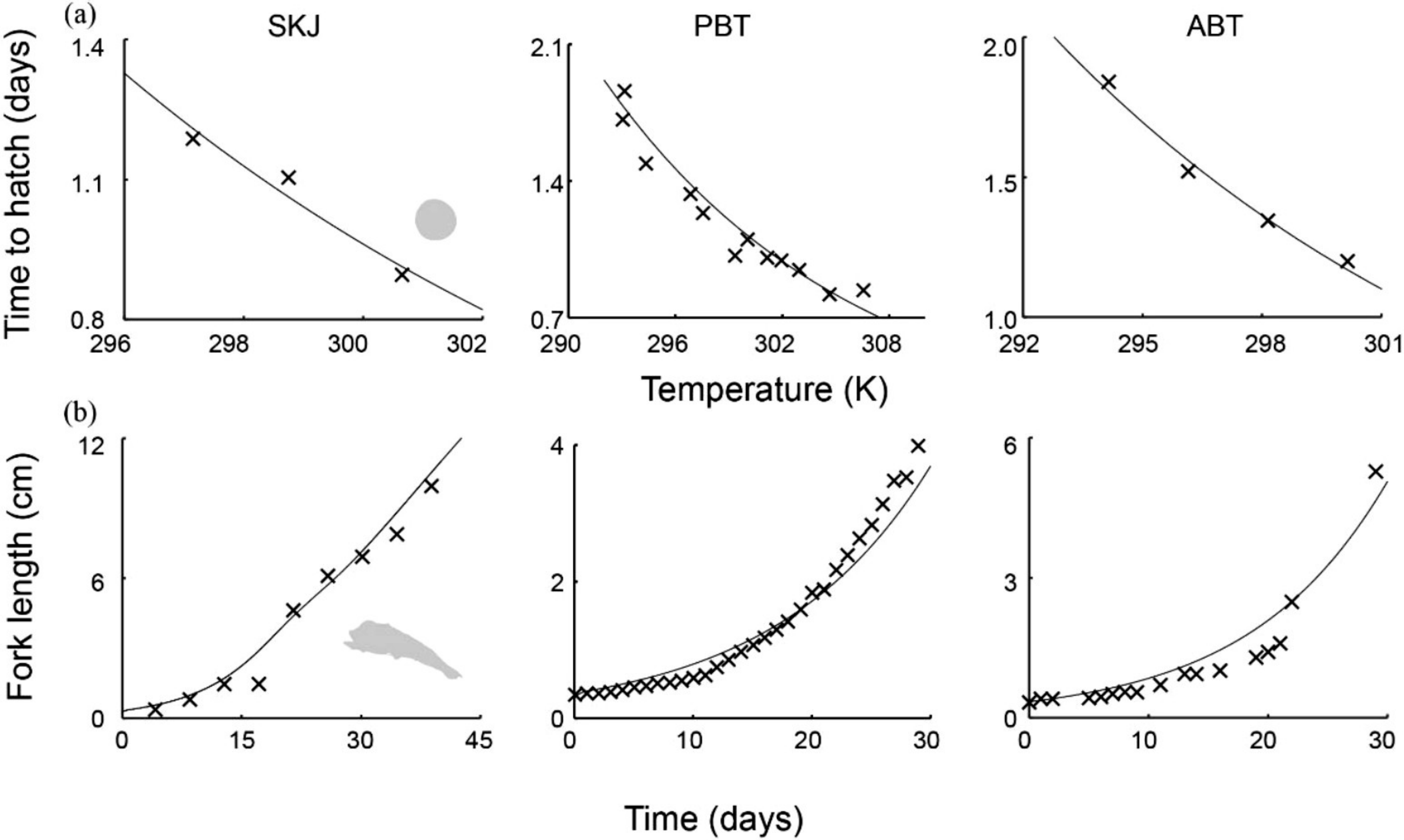
Finding 2: Effects of early-life stochasticity



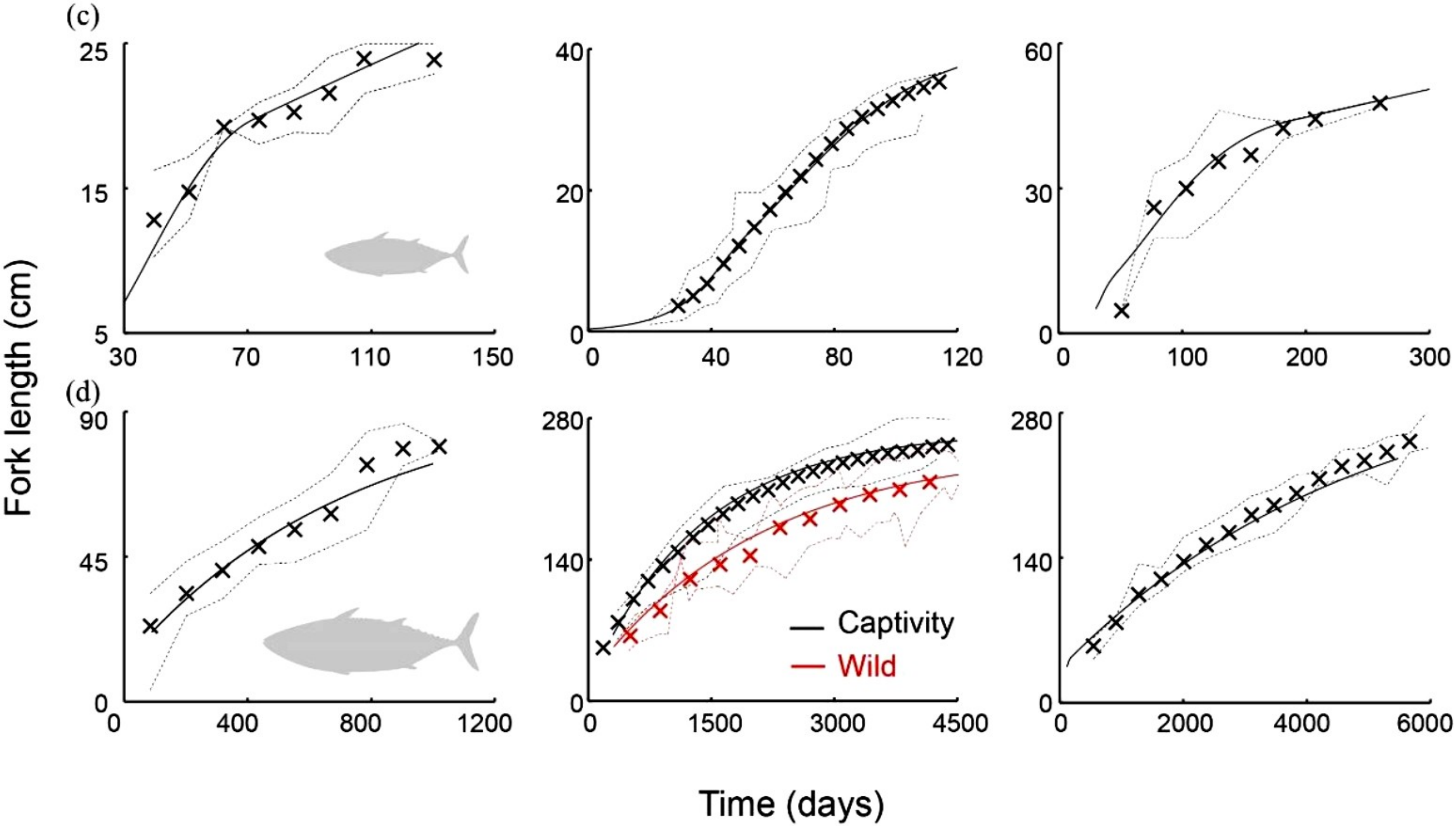
Finding 3: Impact of life history on population growth



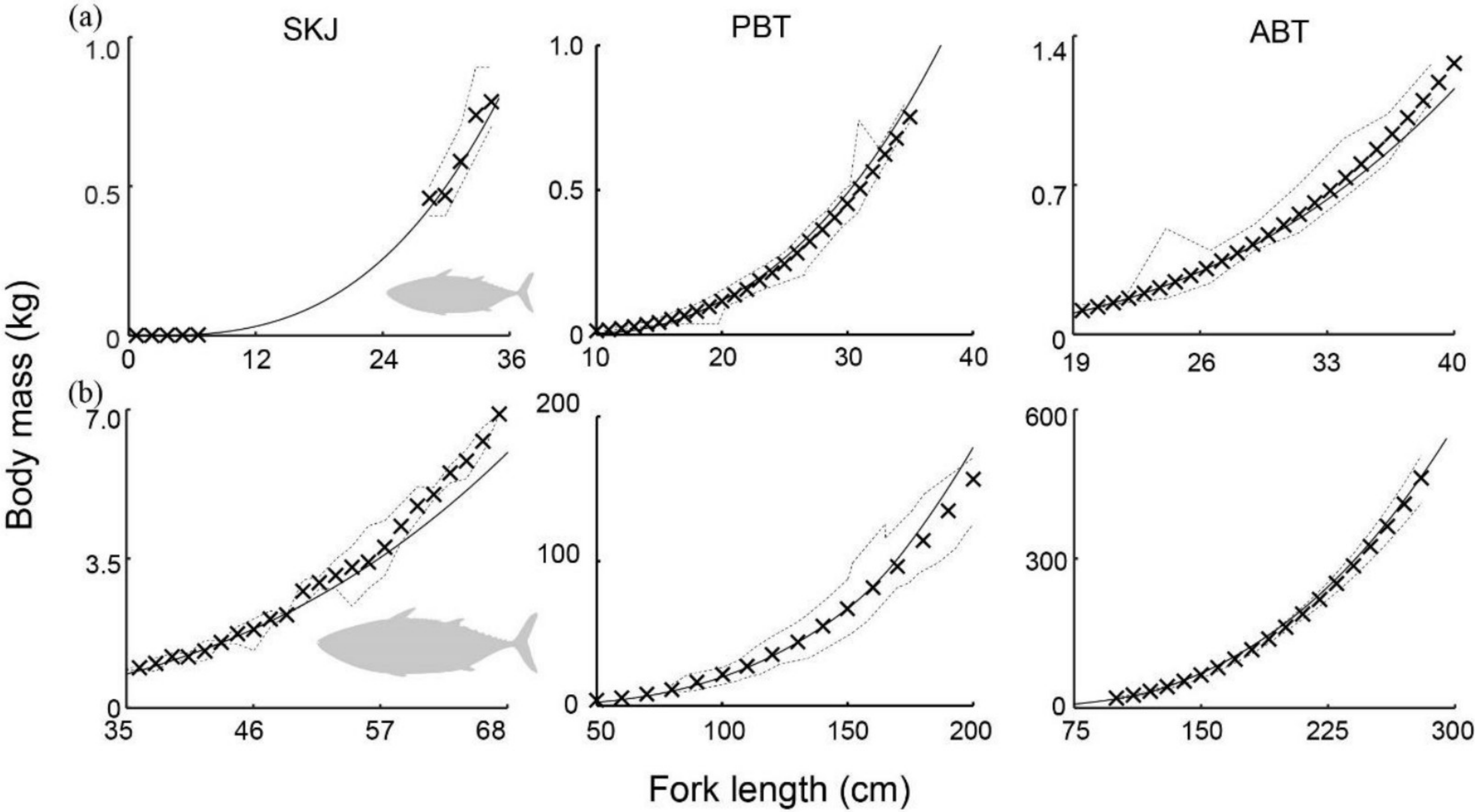
What did we do?
Fitted the model to the data, duh!



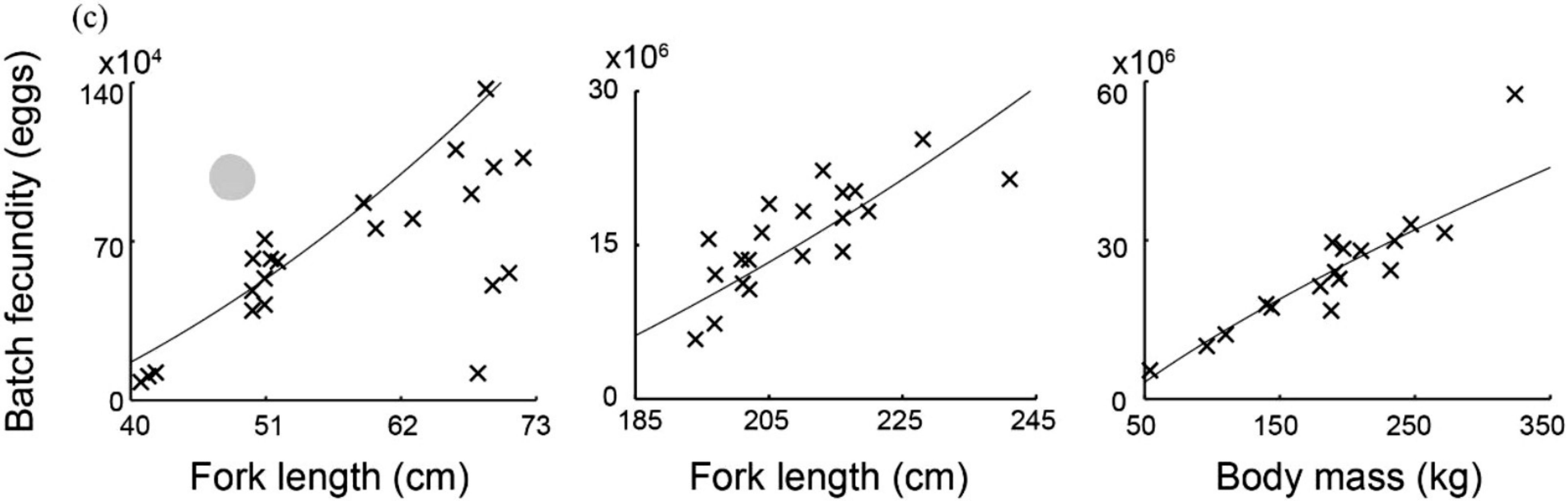
Goodness of fit, part 1.



Goodness of fit, part 2.

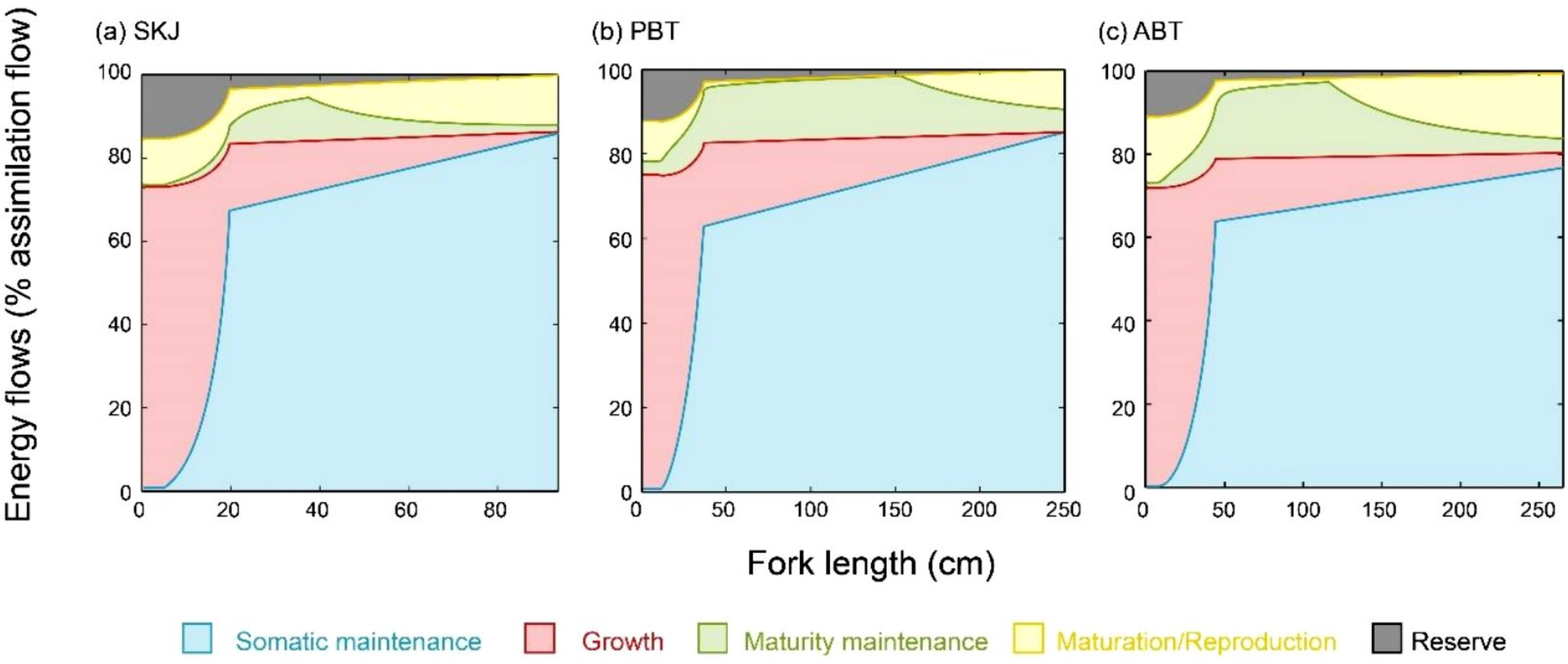


Goodness of fit, part 3.

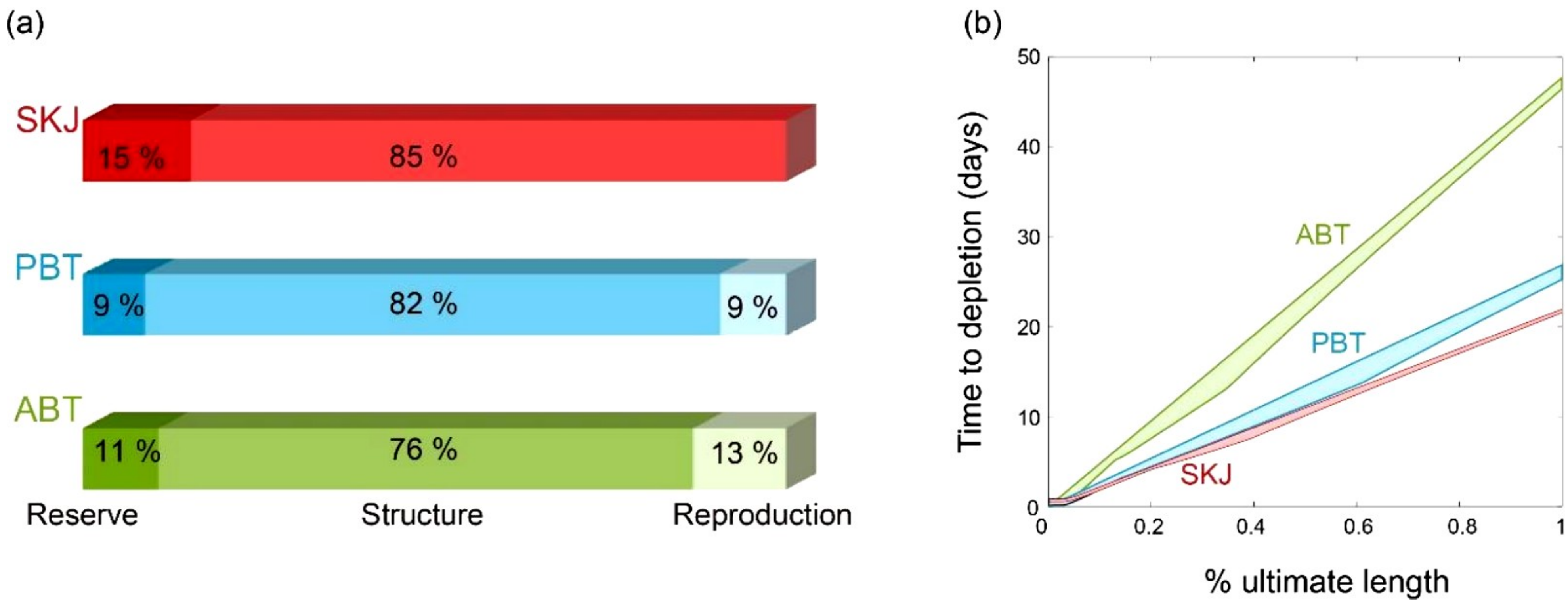


Goodness of fit, part 4.

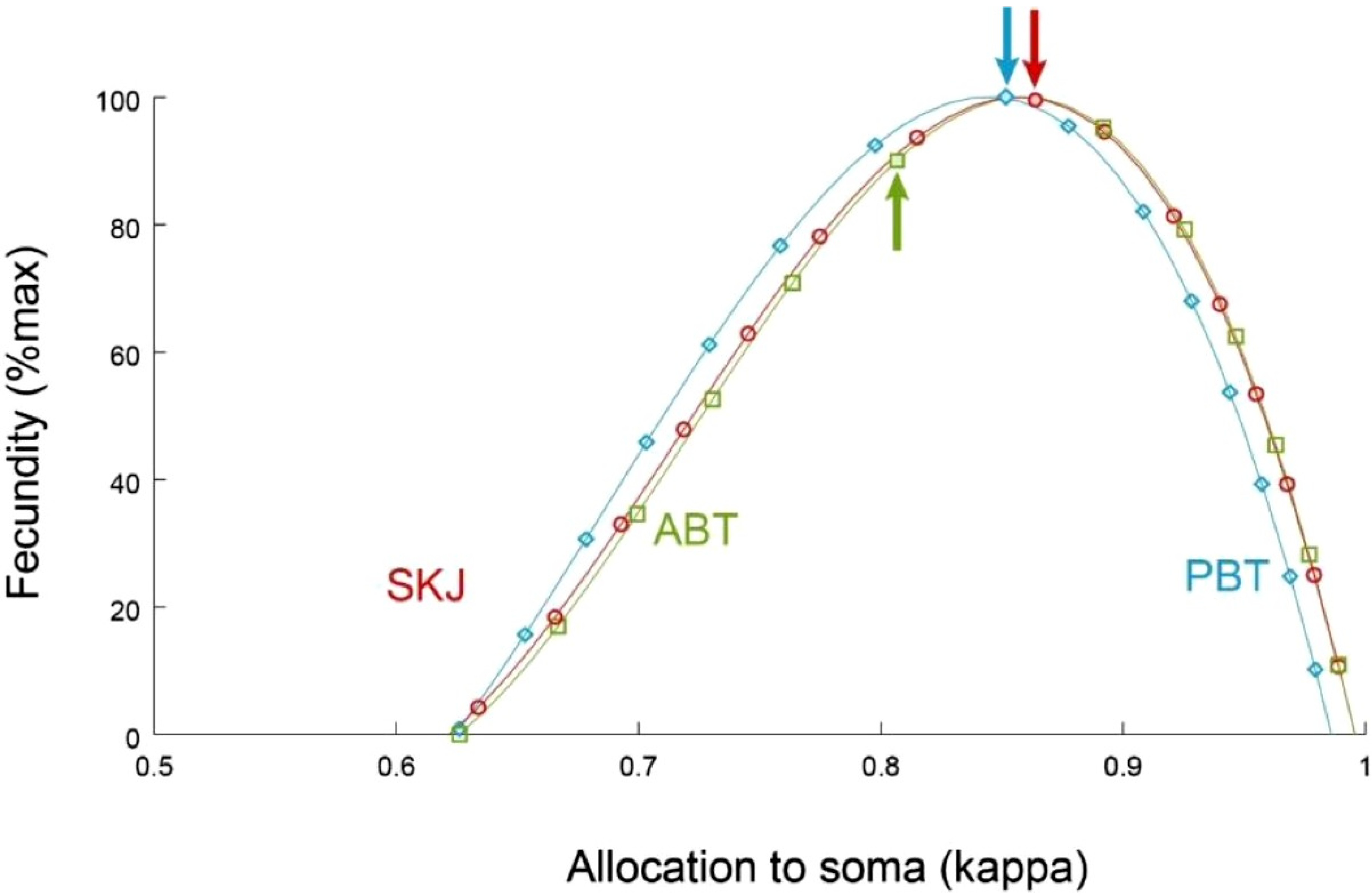
So... what did we learn?
A lot, actually.



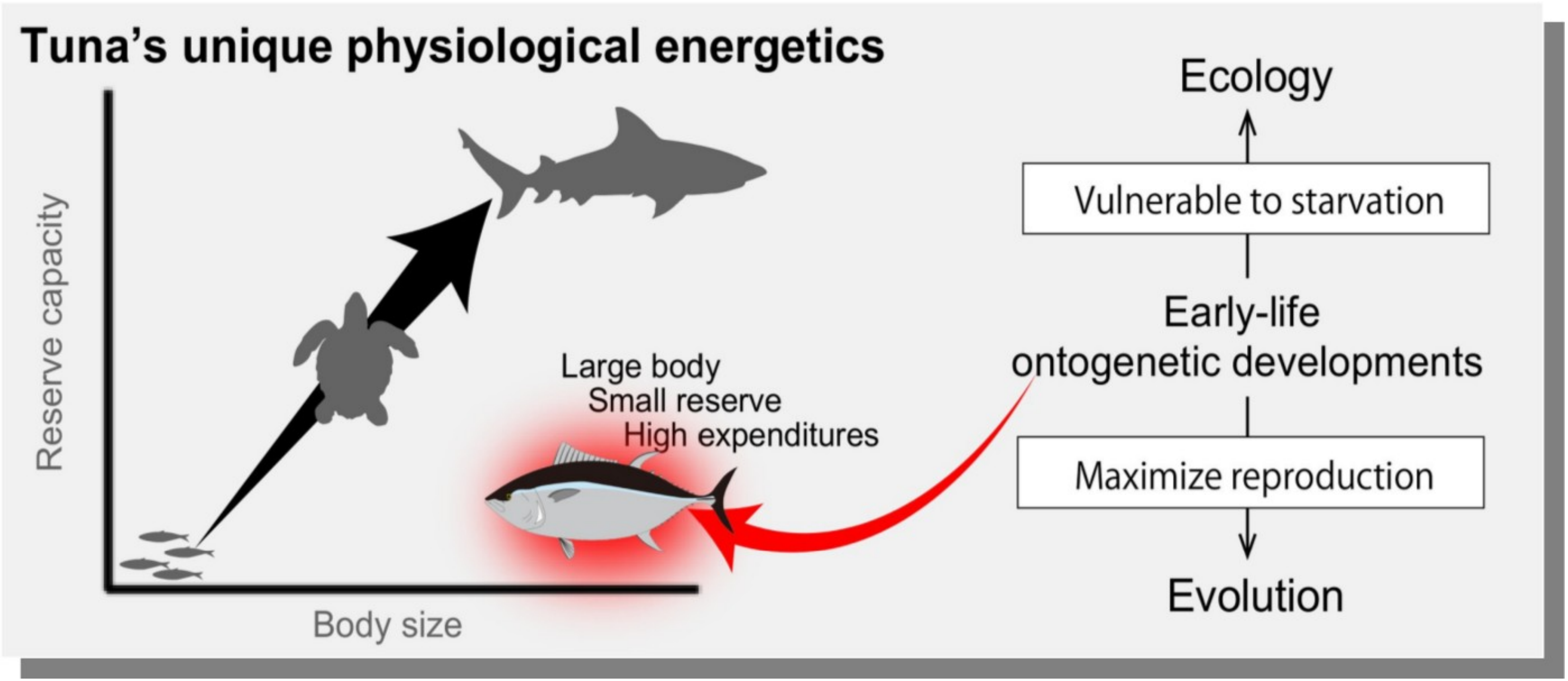
Energy budgets of three commercial tuna species.



Reserve size and the ability to handle starvation.



Reproductive potential and the actual reproductive output of three commercial tuna species.



Large body, small reserve, and high expenditures are tuna's recipe for uniqueness.

Wait! What was the model again?
Umm, a not-entirely-standard DEB.

$$\frac{dE}{da} = \dot{p}_A - \dot{p}_C \tag{1}$$

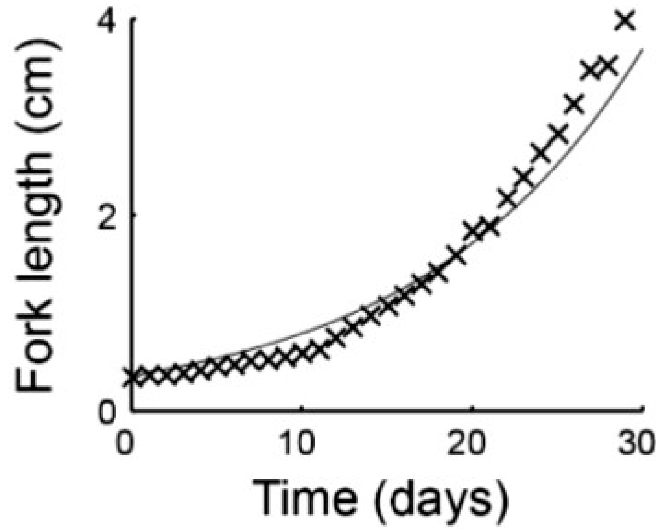
$$\frac{dL}{da} = \frac{\dot{p}_G}{3L^2\left[E_G\right]} \tag{2}$$

$$\frac{dE_H}{da} = \begin{cases} \dot{p}_R, & 0 < E_H < E_H^p \\ 0, & E_H = E_H^p \end{cases} \tag{3}$$

$$F\left(a\right) = \frac{\kappa_R}{E_0}\left[\left(1-\kappa\right)\int_{\max\{a_p, a-\Delta a\}}^{a} \dot{p}_C da - \dot{k}_J E_H^p \Delta a\right] \tag{4}$$

$$\dot{p}_*(T) = \dot{p}_*(T_0)\exp\left(\frac{T_A}{T_0} - \frac{T_A}{T}\right) \tag{5}$$

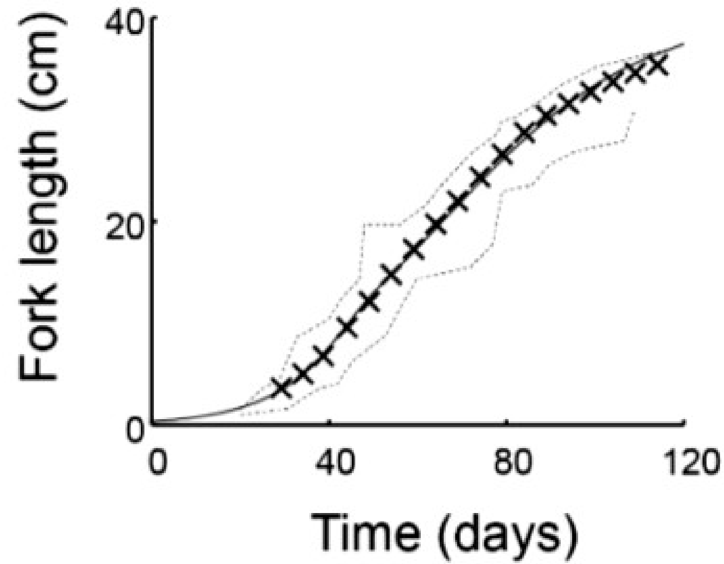
The standard stuff.



$\{\dot{p}_{Am}\} \mapsto M_1\{\dot{p}_{Am}\}$, where

$$M_1(L, E_H) = \begin{cases} 1 & E_H < E_H^b \\ \frac{L}{L_b} & E_H^b \le E_H < E_H^j \\ \frac{L_j}{L_b} & E_H^j \le E_H \end{cases} \quad (6)$$

Larval-stage growth acceleration.



$\{\dot{p}_T\} \mapsto M_2\{\dot{p}_T\}$, where

$$M_2(E_H) = \begin{cases} 0 & E_H < E_H^j \\ \frac{E_H - E_H^j}{E_H^y - E_H^j} & E_H^j \le E_H < E_H^y \\ 1 & E_H^y \le E_H \end{cases} \qquad (7)$$

Early juvenile growth deceleration.

shape factor

embryonic δ_M^1 asymptotic adult δ_M^2

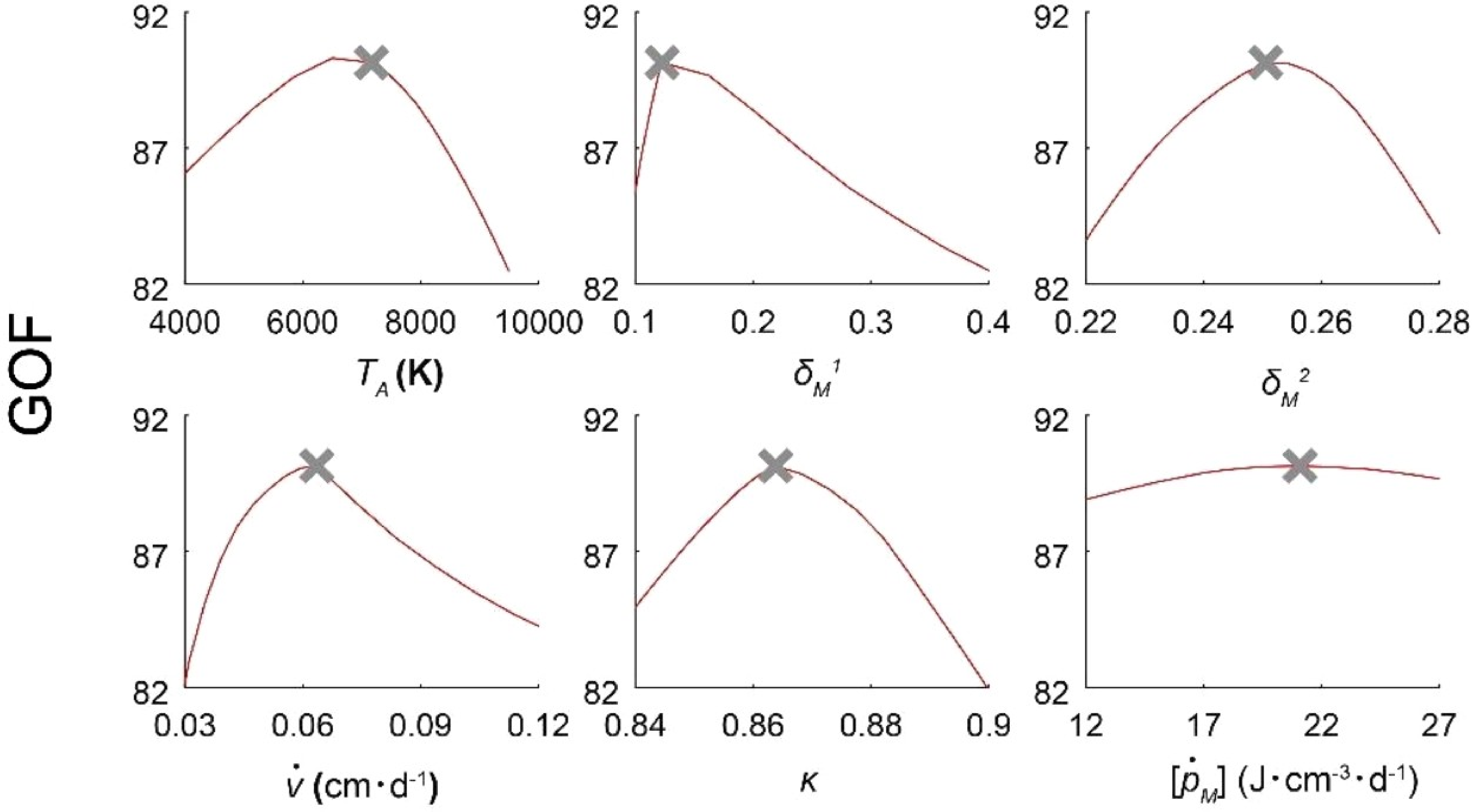
$$\delta_M\left(E_H\right) = \begin{cases} \delta_M^1 & E_H < E_H^b \\ \frac{\delta_M^1\left(E_H^2 - E_H^b\right) + \delta_M^2\left(E_H - E_H^b\right)}{E_H + E_H^2 - 2E_H^b} & E_H^b \leq E_H \leq E_H^p \end{cases} \quad (8)$$

where

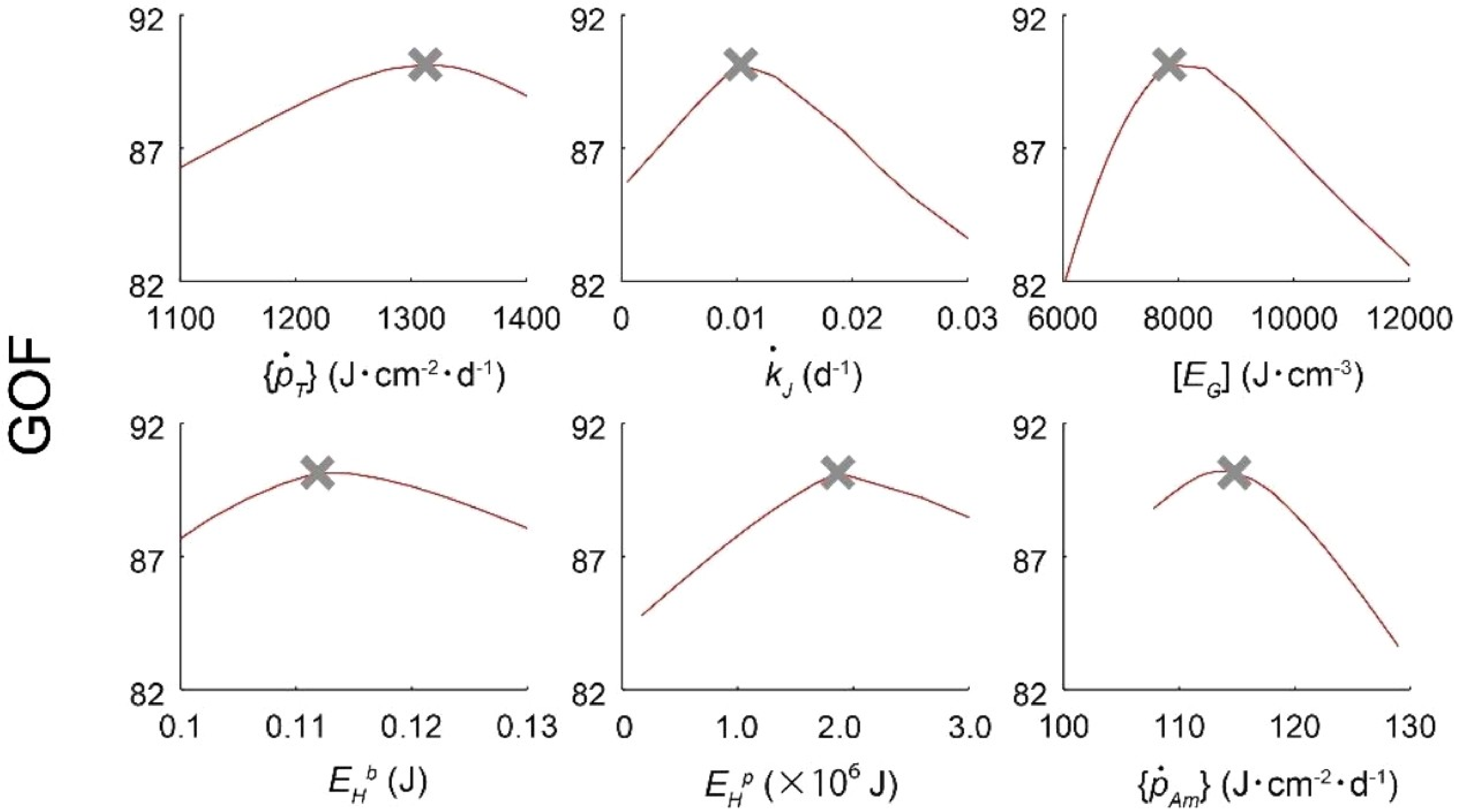
$$\delta_M\left(E_H^2\right) = \left(\delta_M^1 + \delta_M^2\right)/2$$

Changes in body shape.

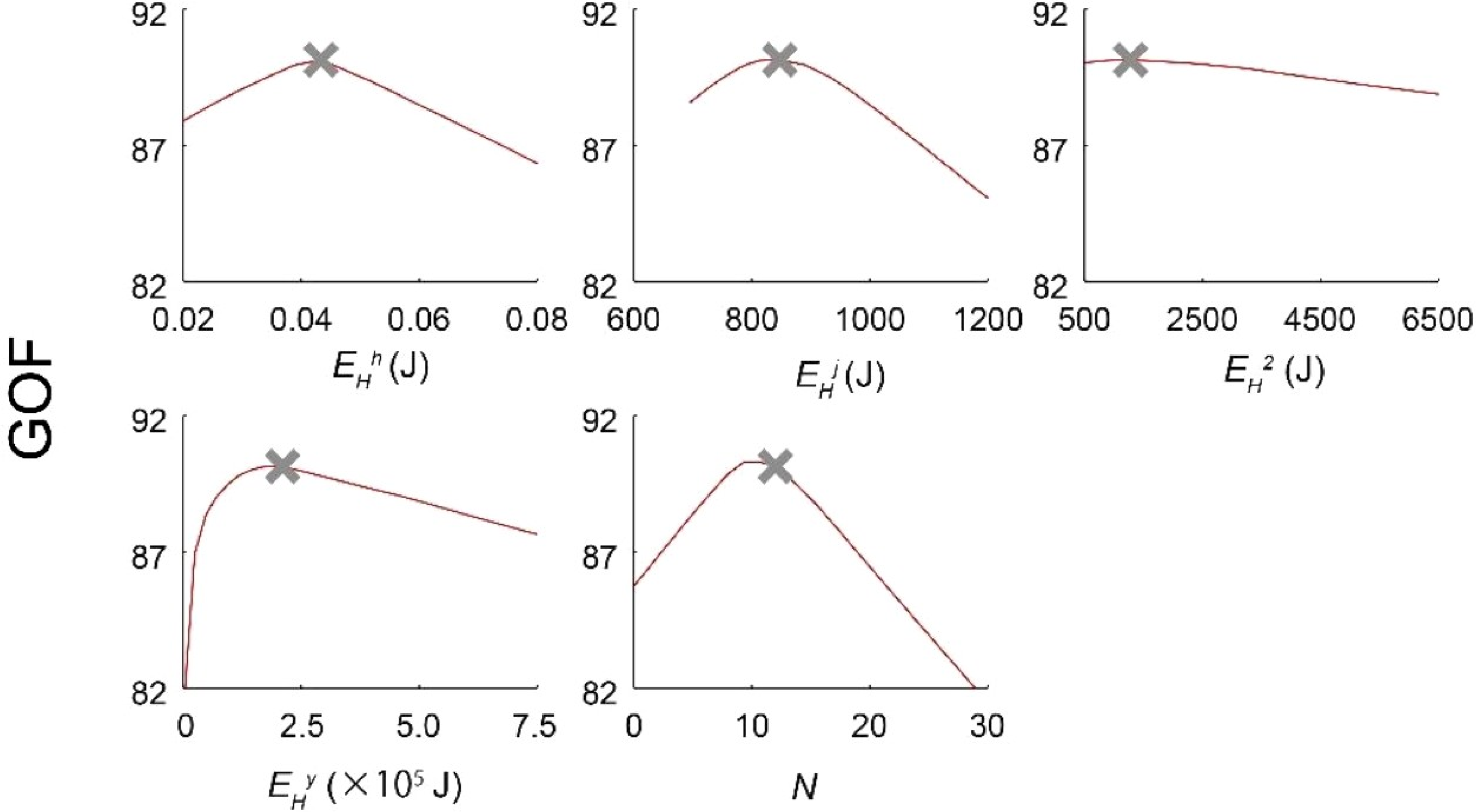
But are those parameters really any good?
Oh, yeah!



Estimated parameter values for Skipjack tuna maximise the goodness of fit, part 1.



Estimated parameter values for Skipjack tuna maximise the goodness of fit, part 2.



Estimated parameter values for Skipjack tuna maximise the goodness of fit, part 3.

Elasticities and the resulting interval estimates of primary DEB parameters for skipjack (SKJ), Pacific bluefin (PBT), and Atlantic bluefin (ABT) tunas.

Parameter	SKJ		PBT		ABT	
	LHS[1]	RHS[2]	LHS	RHS	ELL	ELR
$\{\dot{p}_{Am}\}$	-0.025	0.005	-0.009	0.002	-0.006	0.001
	[100.2, 117.9]		[77.4, 86.8]		[123.6, 128.4]	
$[E_G]$	-0.008	0.059	-0.017	0.017	-0.009	0.009
	[7551, 10163]		[5574, 7858]		[8206, 8979]	
$\dot{v}$	-0.070	0.010	-0.013	0.026	-0.041	0.014
	[0.04, 0.07]		[0.07, 0.10]		[0.07, 0.10]	
$[\dot{p}_M]$	-0.122	0.112	-0.011	0.017	-0.010	0.015
	[8.3, 32.9]		[10.1, 13.3]		[6.3, 7.1]	
$\{\dot{p}_T\}$	-0.014	0.018	-0.003	0.015	-0.002	0.001
	[1219, 1430]		[1644, 1936]		[1736, 1762]	
$\dot{k}_J$	-0.029	0.067	-0.038	0.040	-0.020	0.014
	[0.009, 0.014]		[0.038, 0.085]		[0.015, 0.018]	
κ	-0.001	0.002	-0.003	0.001	-0.004	0.002
	[0.86, 0.87]		[0.82, 0.86]		[0.79, 0.82]	
E_H^b	-0.006	0.037	-0.007	0.008	-0.002	0.009
	[0.11, 0.13]		[0.17, 0.19]		[0.23, 0.25]	
E_H^p	-0.025	0.041	-0.019	0.049	-0.013	0.013
	$[1.633, 2.256]\cdot10^6$		$[0.897, 1.639]\cdot10^7$		$[2.457, 2.795]\cdot10^7$	

Elasticities and the resulting interval estimates of auxiliary parameters specific to the tuna DEB model.

Parameter	SKJ		PBT		ABT	
	LHS[1]	RHS[2]	LHS	RHS	LHS	RHS
E_H^h	-0.053	0.024	-0.038	0.064	-0.067	0.014
	[0.03, 0.05]		[0.05, 0.13]		[0.13, 0.20]	
E_H^j	-0.055	0.027	-0.024	0.005	-0.017	0.004
	[616, 962]		[5476, 7531]		[2652, 2961]	
E_H^2	-0.533	0.608	-0.112	0.597	-0.872	0.329
	[0, 5172]		[0, $1.389\cdot10^4$]		[0, $7.931\cdot10^4$]	
E_H^y	-0.293	0.103	-0.241	0.132	-0.473	0.070
	[0, $3.196\cdot10^5$]		[0, $1.212\cdot10^6$]		[0, $3.535\cdot10^6$]	
T_A	-0.012	0.010	-0.029	0.042	-0.072	0.074
	[6739, 7537]		[4121, 8322]		[4099, 8760]	
δ_M^1	-0.005	0.072	-0.047	0.007	-0.018	0.018
	[0.12, 0.17]		[0.07, 0.15]		[0.12, 0.15]	
δ_M^2	-0.004	0.021	-0.002	0.002	-0.006	0.004
	[0.25, 0.28]		[0.26, 0.27]		[0.25, 0.26]	
N	-0.081	0.022	-0.156	0.028	-0.041	0.019
	[7, 13]		[0, 15]		[7, 10]	

Thank you for your attention!

ご清聴ありがとうございました。