Accounting for age uncertainty in growth modeling, the case study of yellowfin tuna (Thunnus albacares) of the Indian Ocean

Emmanuelle Dortel, F. Massiot-Granier, Etienne Rivot, J. Million, Jean-Pierre Hallier, Eric Morize, Jean-Marie Munaron, N. Bousquet, Emmanuel Chassot

APPENDIX A. Presentation of data used in the coupling of ageing error and growth models

TABLE A1. Summarize of data used in ageing error model; *It*: section between nucleus and OTC mark , *Im*: section between the OTC mark and edge, *Ir*: section between the nucleus and edge

	Fish from RTTP-IO program knowledge of time-at-liberty: with			without	Fish from WSTTP program
Otolith section	*It*	*Ir*	*Im*	*It*	*It*
Number of fishes	80	14	27	30	38
Fork length at tagging (cm)	43 to 85	50 to 72			
Fork length at recapture (cm)	49.7 to 135.4	59.5 to 114.1	49.7 to 131	47.9 to 146.5	19 to 46.6
Time-at-liberty (days)	43 to 969	33 to 414	43 to 969		

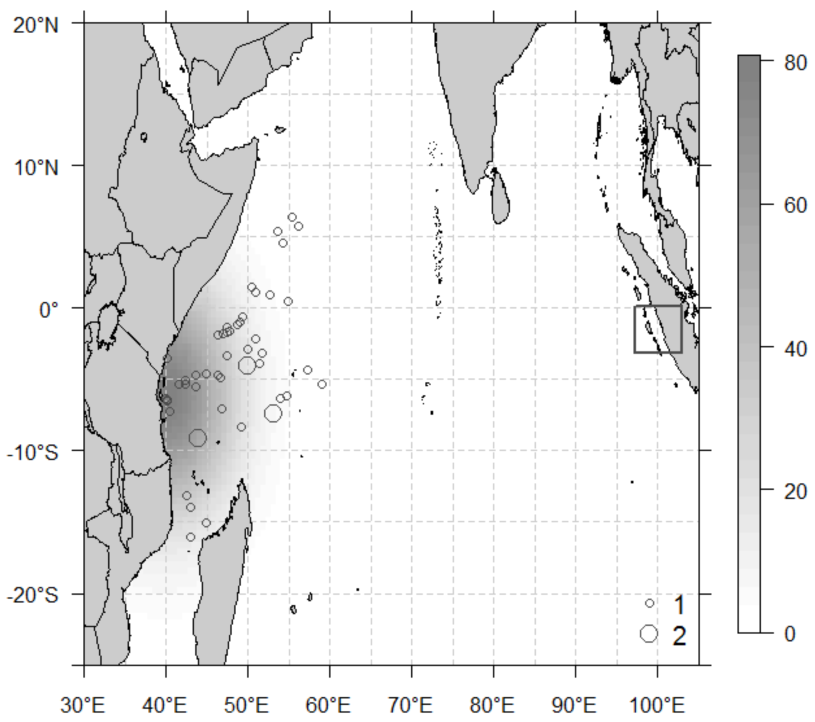

FIG. A1. Tagging area (gray-colored) and points of tag recovery (circles) of RTTP-IO program and sampling area (square) of WSTTP program

APPENDIX B. Evaluation by simulation of ageing error model: general approach and results

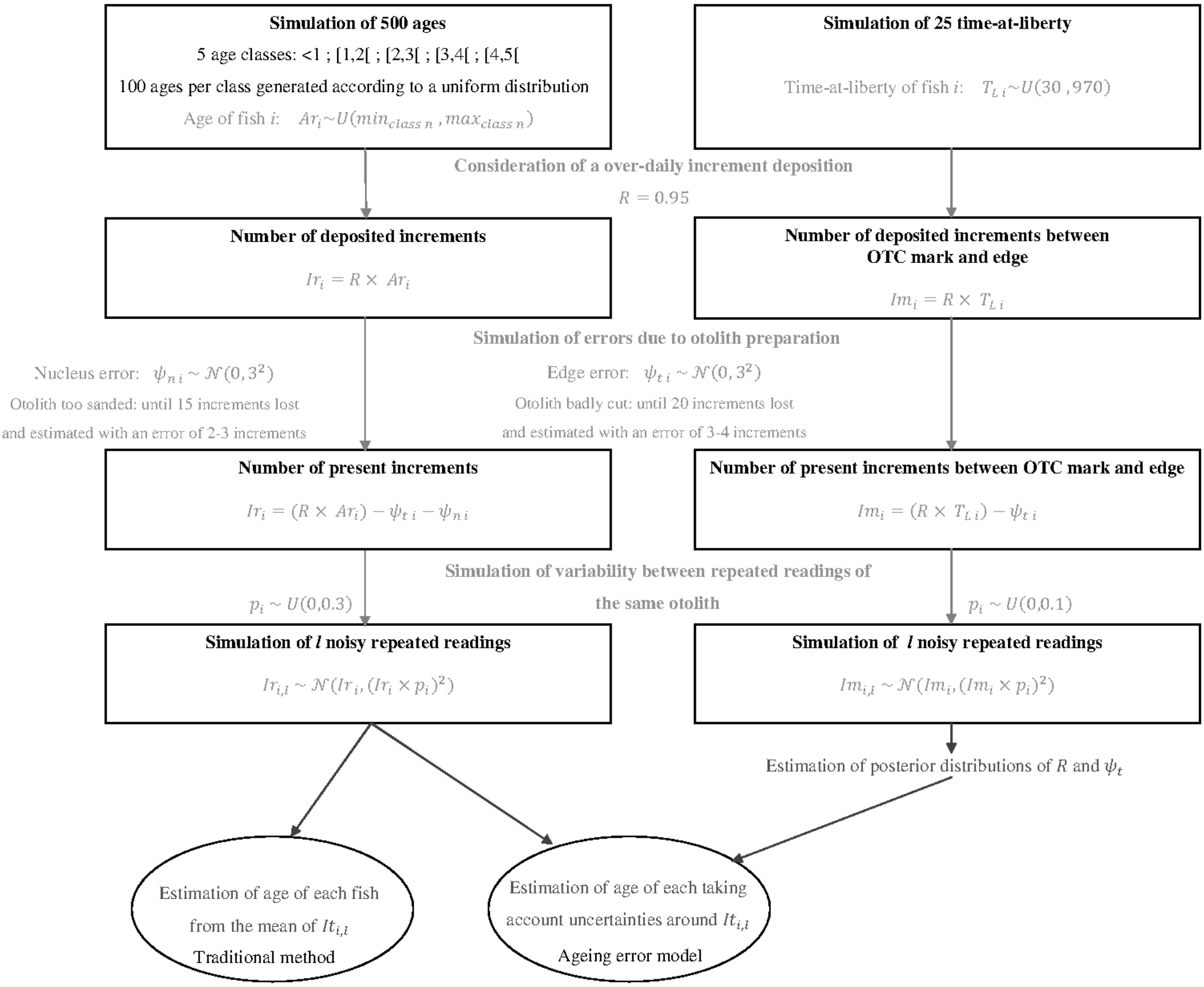

FIG. B1. Simulation framework for testing the ageing error model; different sources of uncertainty are added to simulated ages to randomly generate noisy increments that were then used as inputs in the model

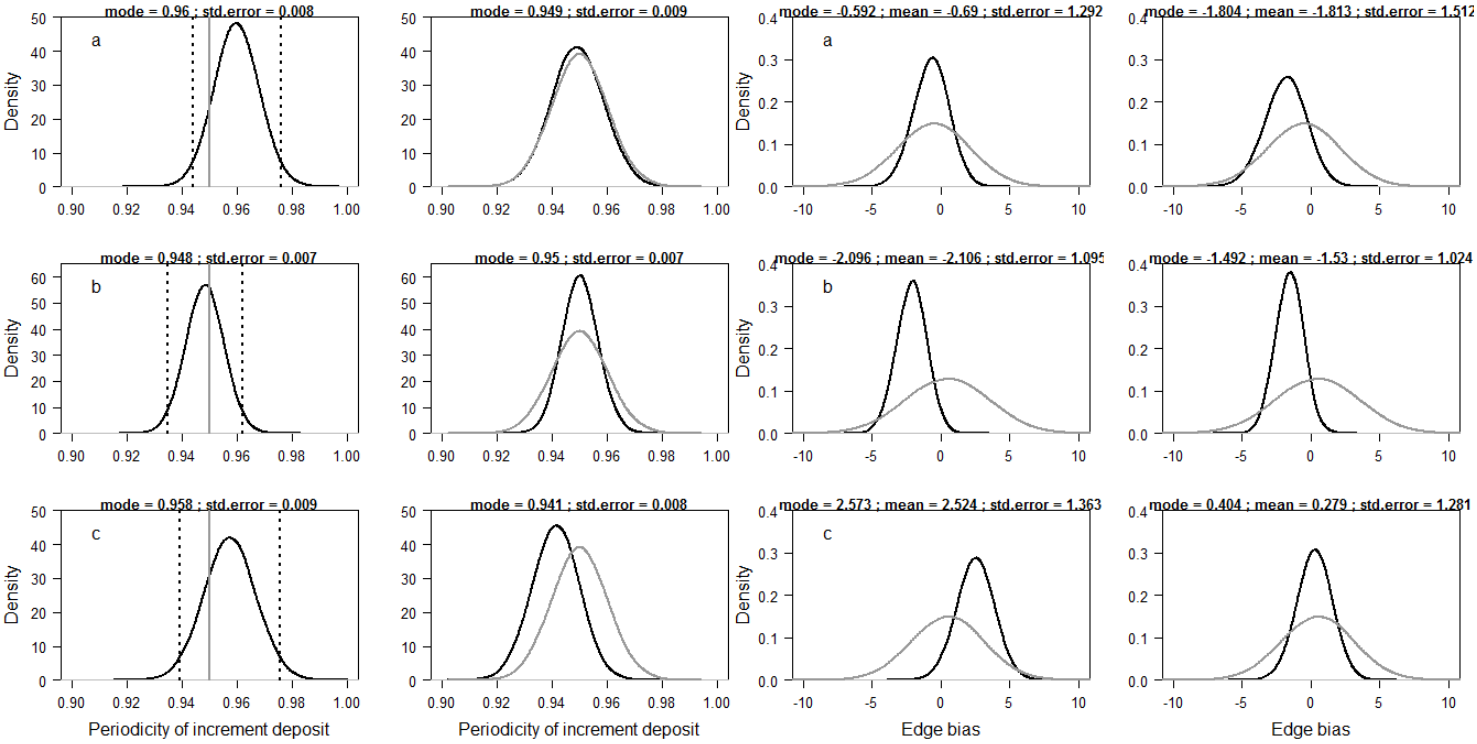

FIG. B2. Marginal posterior distributions of the ageing error model parameters (black) compared with the simulated distributions (grey) with individual variability (right) and without (left); a, b and c represents the first, second and third simulated data set respectively

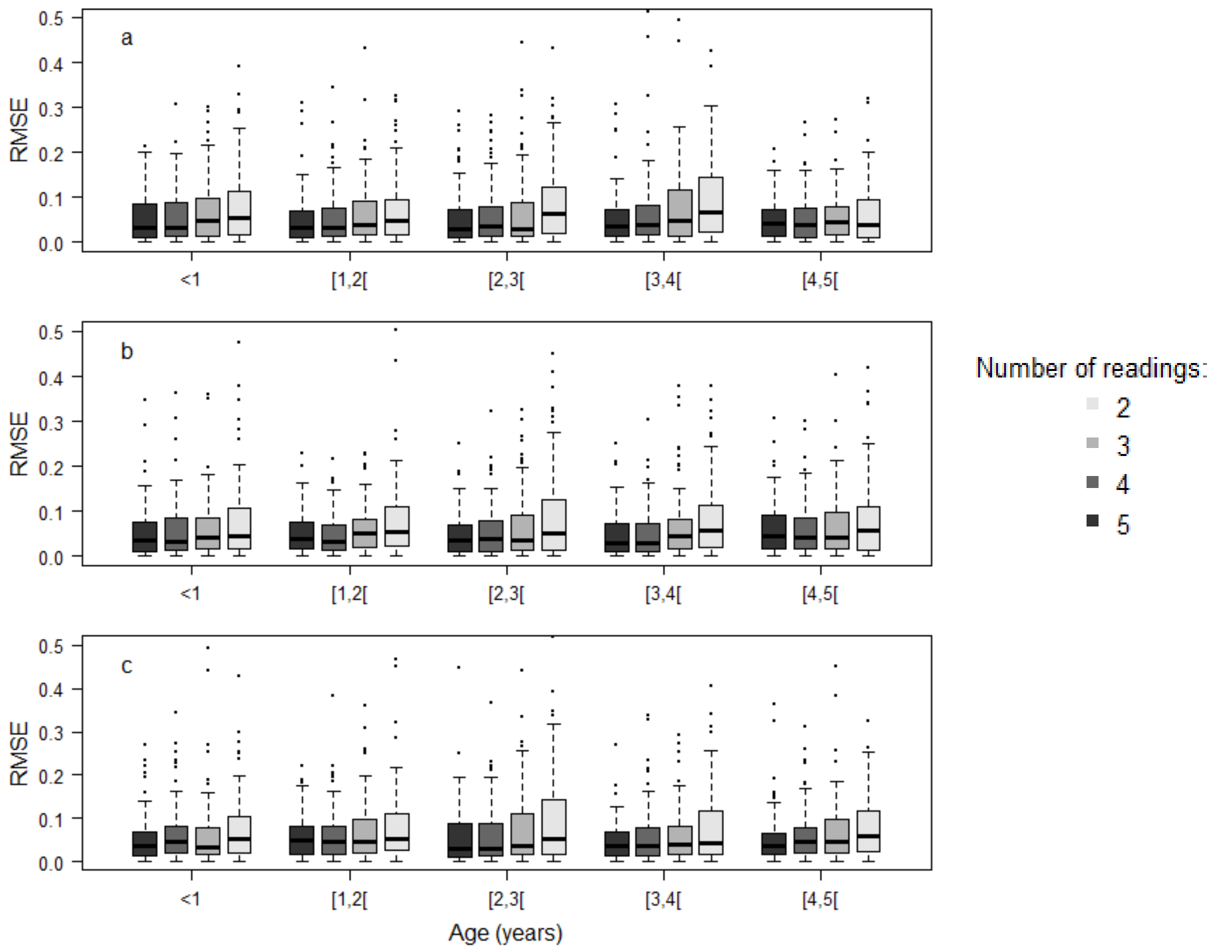

FIG. B3. Boxplot of the relative mean square error (RMSE) of estimated age by ageing error model for 2,3,4 or 5 readings of the same otolith; a, b and c represents the first, second and third simulated data set respectively

TABLE B1. Comparison of the RMSE values of estimated age by ageing error model using a Wilcoxon test; 2L, 3L, 4L and 5L correspond to the number of readings of the same otolith; a, b and c represents the first, second and third simulated data set respectively

		4L	3L	2L
a	5L	V = 54527 p-value = 0.01224		
	4L		V = 48750 p-value = 1.767e-05	
	3L			V = 45892 p-value = 2.260e-07
b	5L	V = 54789 p-value = 0.01535		
	4L		V = 69539 p-value = 0.0324	
	3L			V = 45324 p-value = 8.683e-08
c	5L	V = 46959 p-value = 1.257e-06		
	4L		V = 69539 p-value = 0.0324	
	3L			V = 45324 p-value = 8.683e-08

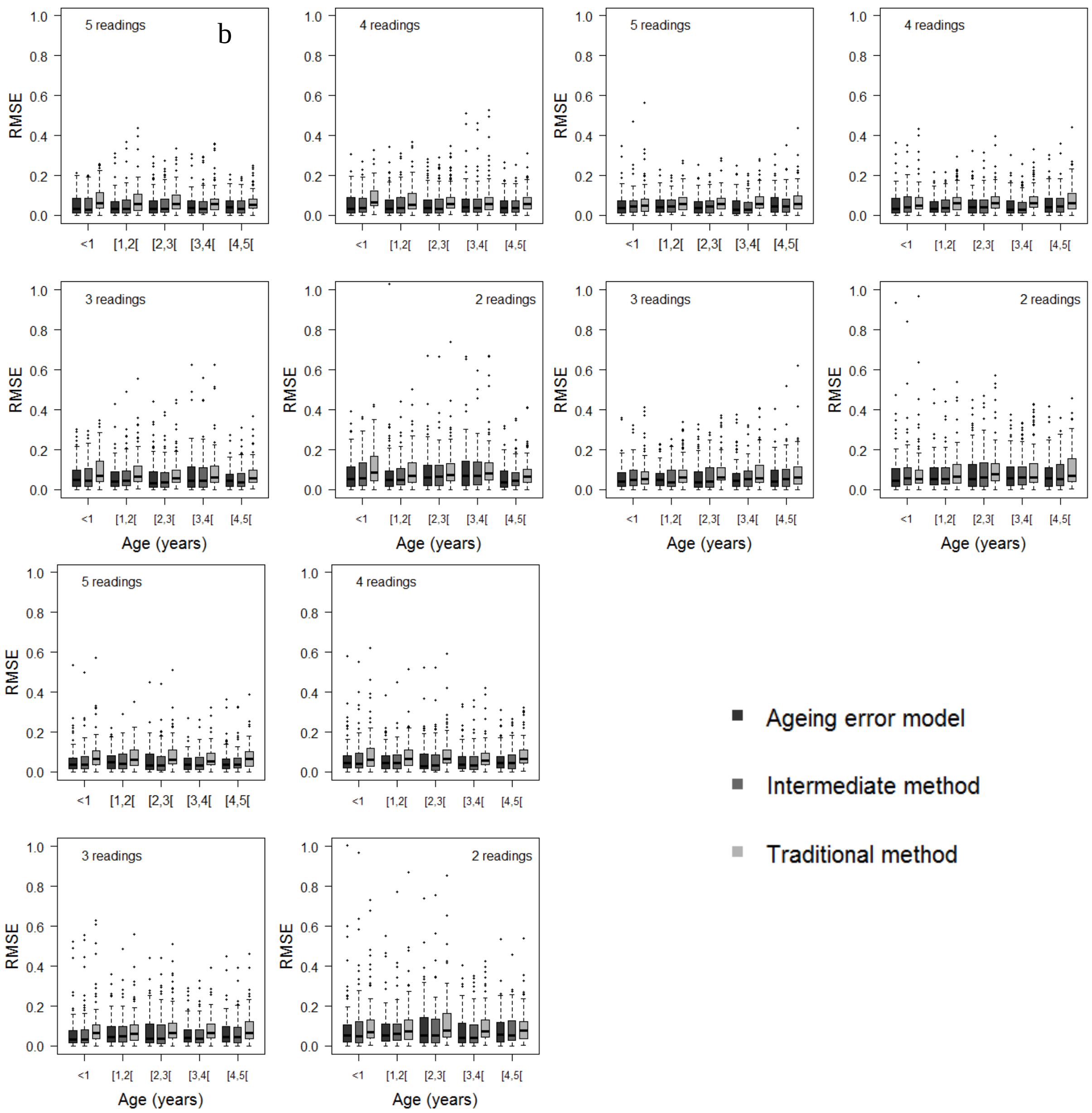

FIG. B4. Boxplot of the relative mean square error (RMSE) of estimated age by the ageing error model, the conventional method and the intermediate method for 2, 3, 4 or 5 readings of the same otolith; a, b and c represents the first, second and third simulated data set respectively

TABLE B2. Comparison of the RMSE values of estimated age by ageing error model, the traditional method and the intermediate method using a Wilcoxon test; 2L, 3L, 4L and 5L correspond to the number of readings of the same otolith; a, b and c represents the first, second and third simulated data set respectively

			Traditional method	Intermediate method
a	Ageing error model	2L	V = 28741, p-value < 2.2e-16	V = 55196, p-value = 0.02155
		3L	V = 28165, p-value < 2.2e-16	V = 57314, p-value = 0.1004
		4L	V = 28080, p-value < 2.2e-16	V = 59300, p-value = 0.3037
		5L	V = 28796, p-value < 2.2e-16	V = 59429, p-value = 0.3229
	Intermediate method	2L	V = 17140, p-value < 2.2e-16	
		3L	V = 16009, p-value < 2.2e-16	
		4L	V = 16139, p-value < 2.2e-16	
		5L	V = 18954, p-value < 2.2e-16	
b	Ageing error model	2L	V = 37313, p-value = 4.85e-15	V = 52640, p-value = 0.002009
		3L	V = 35248, p-value < 2.2e-16	V = 49274, p-value = 3.623e-05
		4L	V = 32274, p-value < 2.2e-16	V = 53918, p-value = 0.007069
		5L	V = 35057, p-value < 2.2e-16	V = 55195, p-value = 0.02153
	Intermediate method	2L	V = 36636, p-value = 8.97e-16	
		3L	V = 35714, p-value < 2.2e-16	
		4L	V = 29036, p-value < 2.2e-16	
		5L	V = 32230, p-value < 2.2e-16	
c	Ageing error model	2L	V = 26437, p-value < 2.2e-16	V = 60299, p-value = 0.4719
		3L	V = 26608, p-value < 2.2e-16	V = 62971, p-value = 0.9149
		4L	V = 22487, p-value < 2.2e-16	V = 67331, p-value = 0.1455
		5L	V = 23658, p-value < 2.2e-16	V = 68155, p-value = 0.08714
	Intermediate method	2L	V = 24027, p-value < 2.2e-16	
		3L	V = 19659, p-value < 2.2e-16	
		4L	V = 14297, p-value < 2.2e-16	
		5L	V = 15527, p-value < 2.2e-16	

APPENDIX C. Bayesian fit of the growth model coupled with the ageing error model

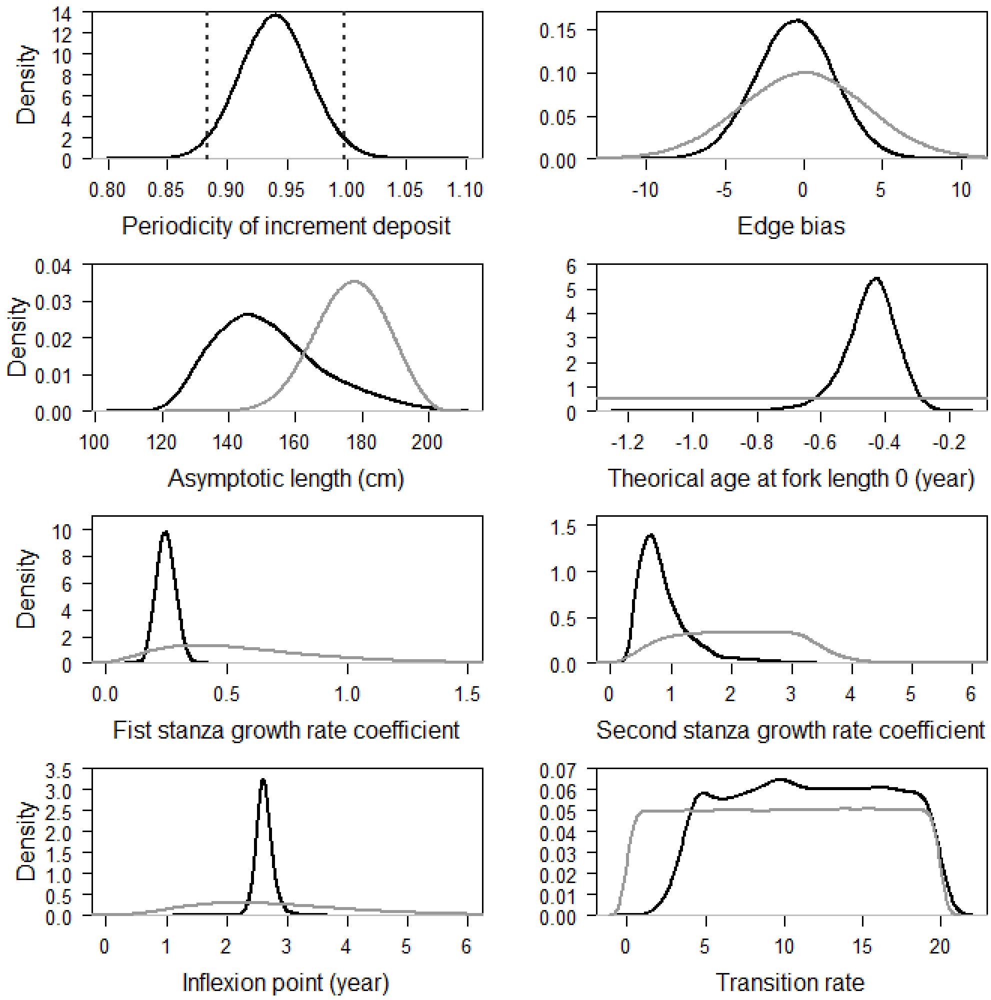

FIG. C1. Marginal posterior distributions of the parameters of the growth model coupled with the ageing error model (black) compared with the prior distributions (grey)

TABLE C1. Correlation-covariance matrix of growth parameters; numerals in bold represent the covariances

	L_∞	k_1	k_2	α	β	t_0
L_∞	**254.808**	-0.93	-0.8	-0.29	-0.027	-0.43
k_1	**-0.593**	**0.002**	0.8	0.21	0.093	0.67
k_2	**-5.527**	**0.014**	**0.189**	0.48	-0.12	0.34
α	**-7.568**	**0.001**	**0.034**	**0.026**	-0.3	-0.074
β	**-2.044**	**0.018**	**-0.259**	**-0.236**	**23.11**	0.17
t_0	**-0.601**	**0.002**	**0.013**	**-0.001**	**0.074**	**0.007**