Modelling temperature impacts on fish growth using a growth model with reproductive costs: can we reproduce the temperature-size rule?

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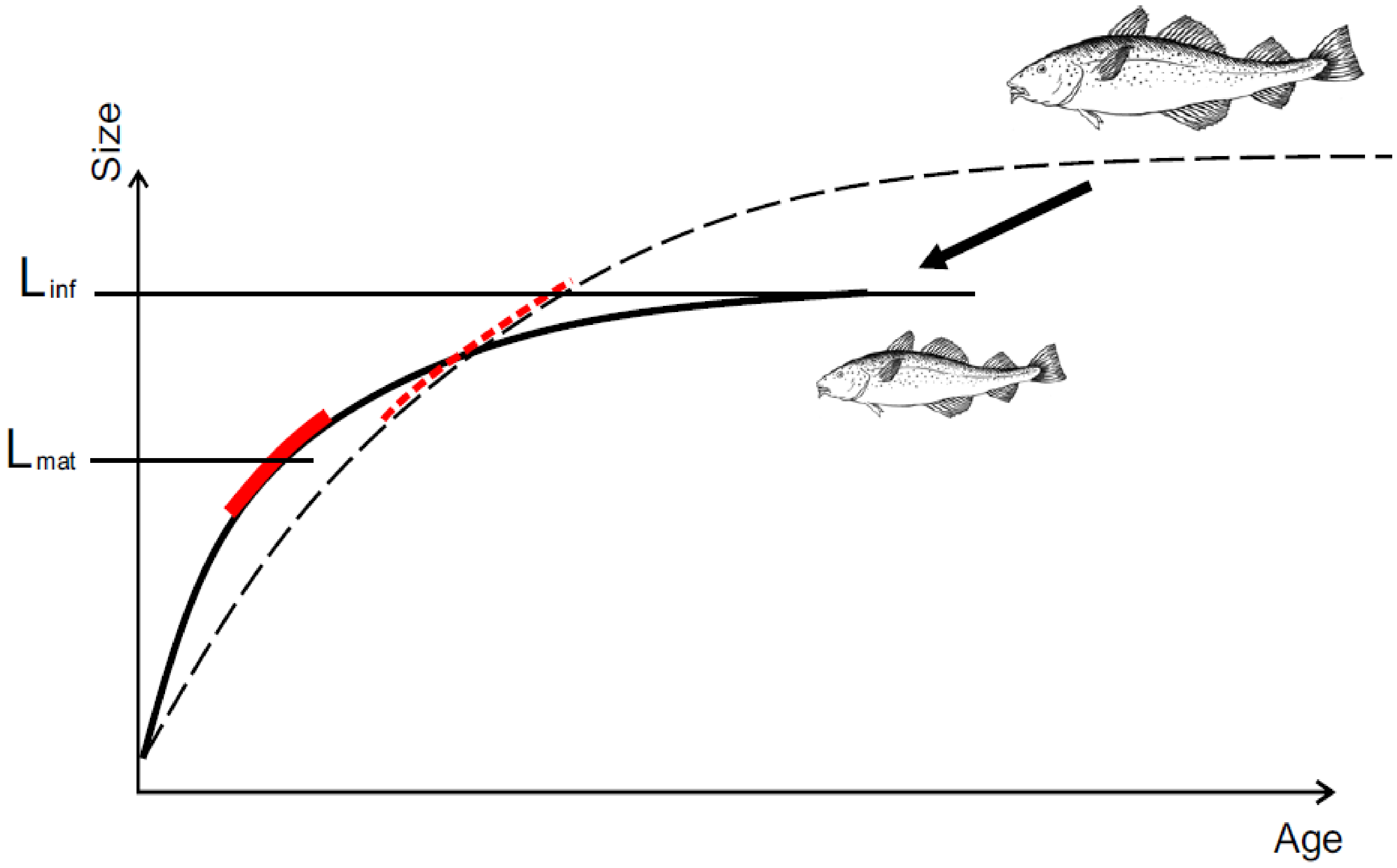
2014-2020 Operational Programme for the European Union Funds Investments in Lithuania

Can we explain temperature-size rule mechanistically?
Can we model it?



Model with EMERGENT maturation size and age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E-ARTICLE

The Energetic Cost of Reproduction and Its Effect on Optimal Life-History Strategies

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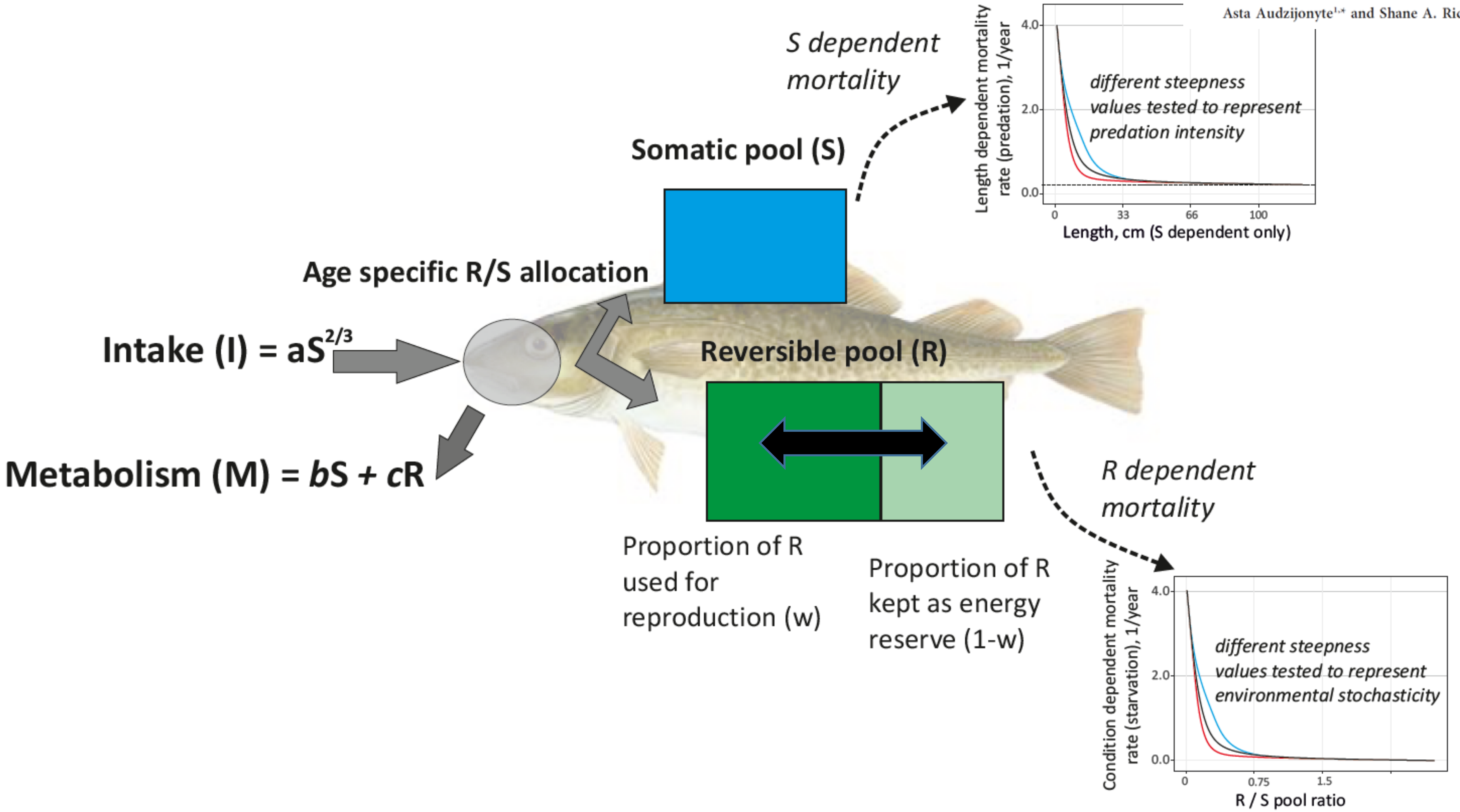
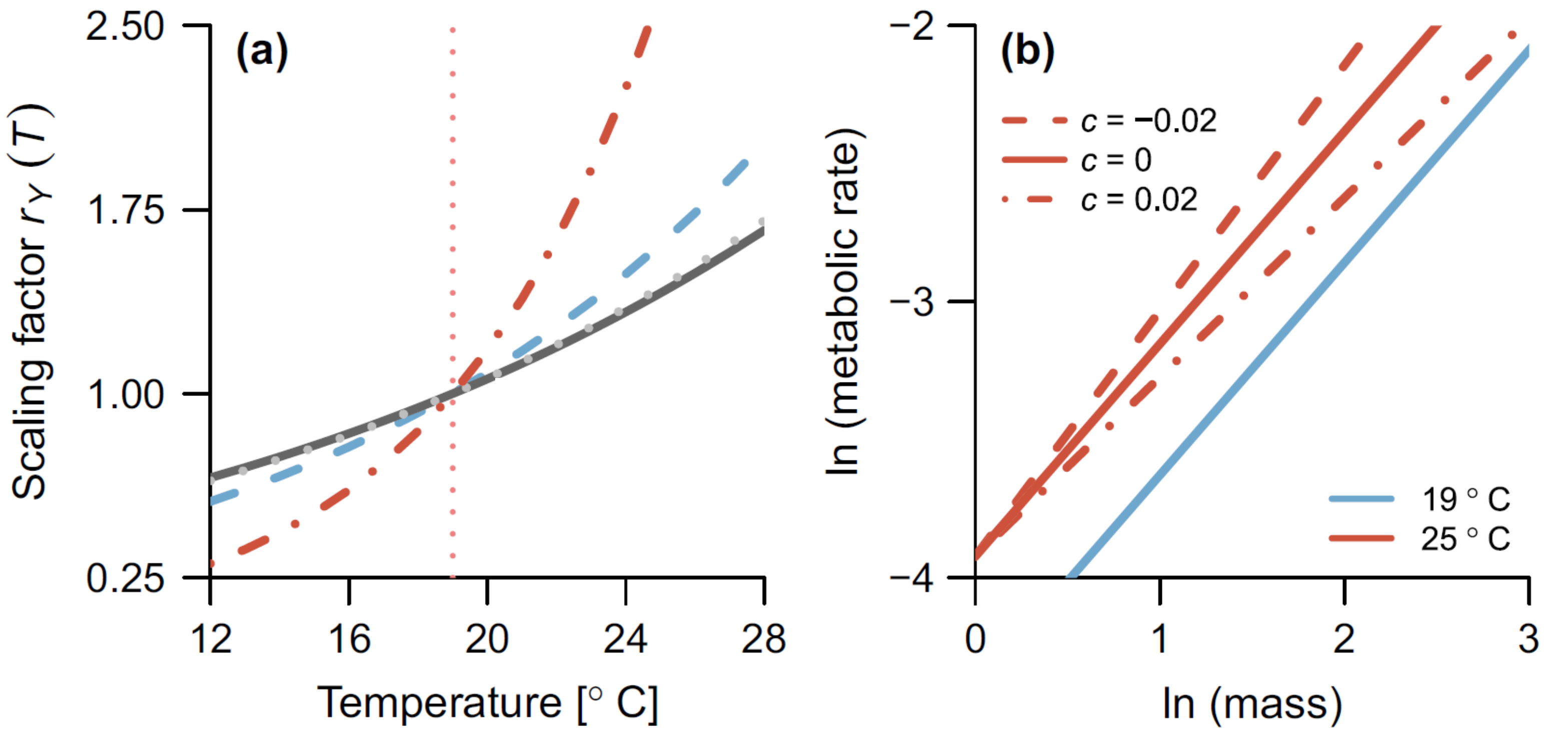


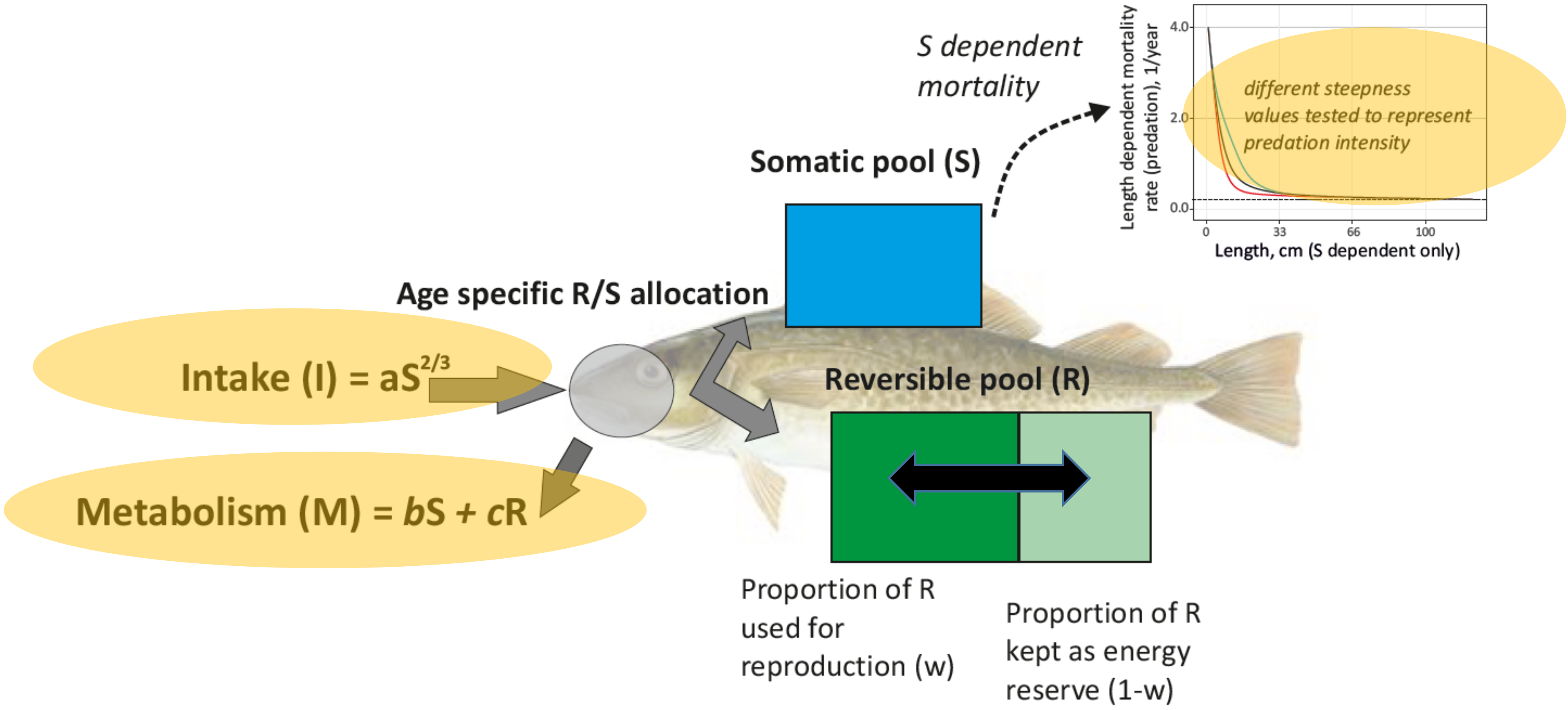
Adding temperature. Temperature speeds up life processes



This speeding up might be size dependent

Lindmark et al. 2017, Ecology Letters

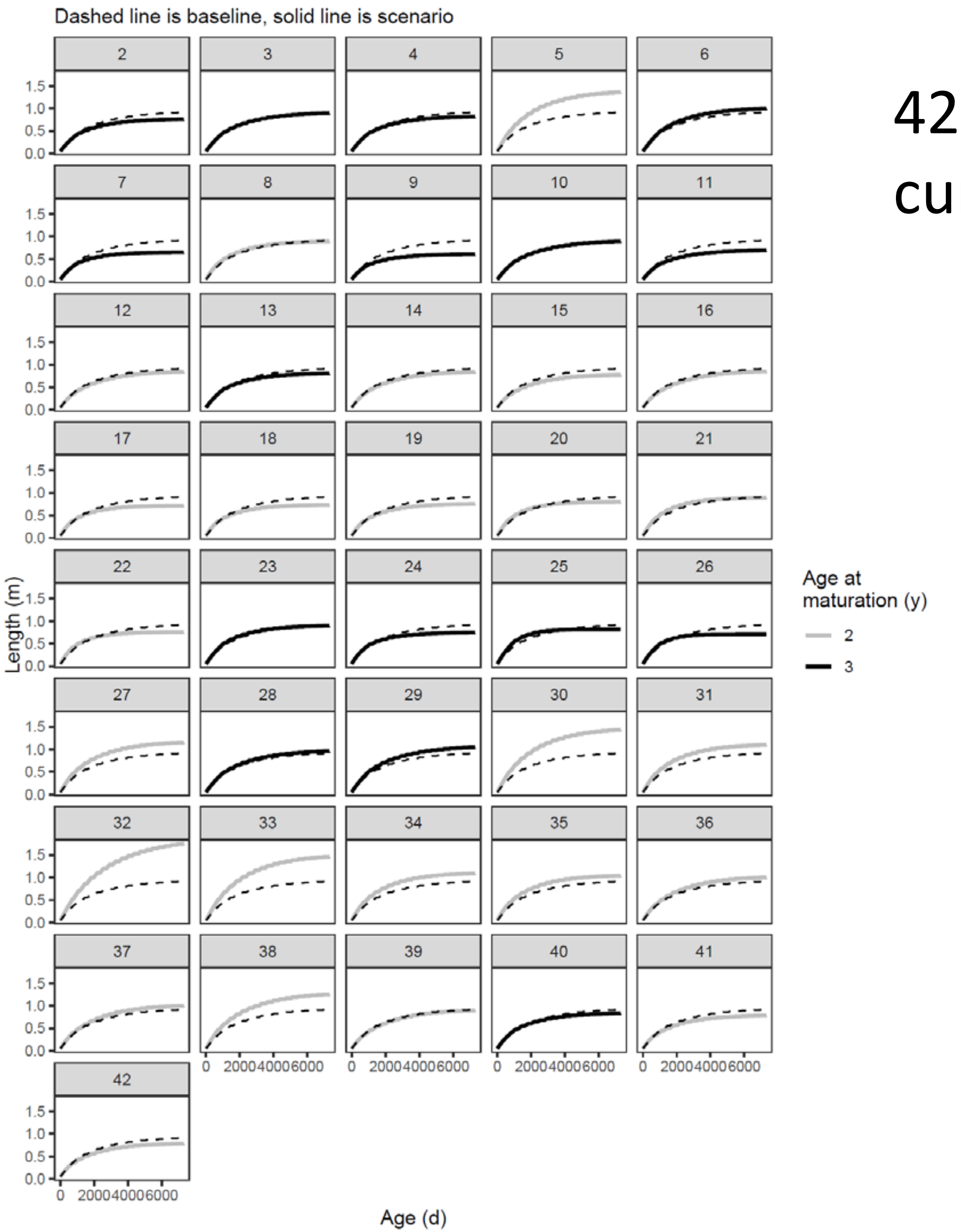
Temperature can affect intake, metabolism and mortality

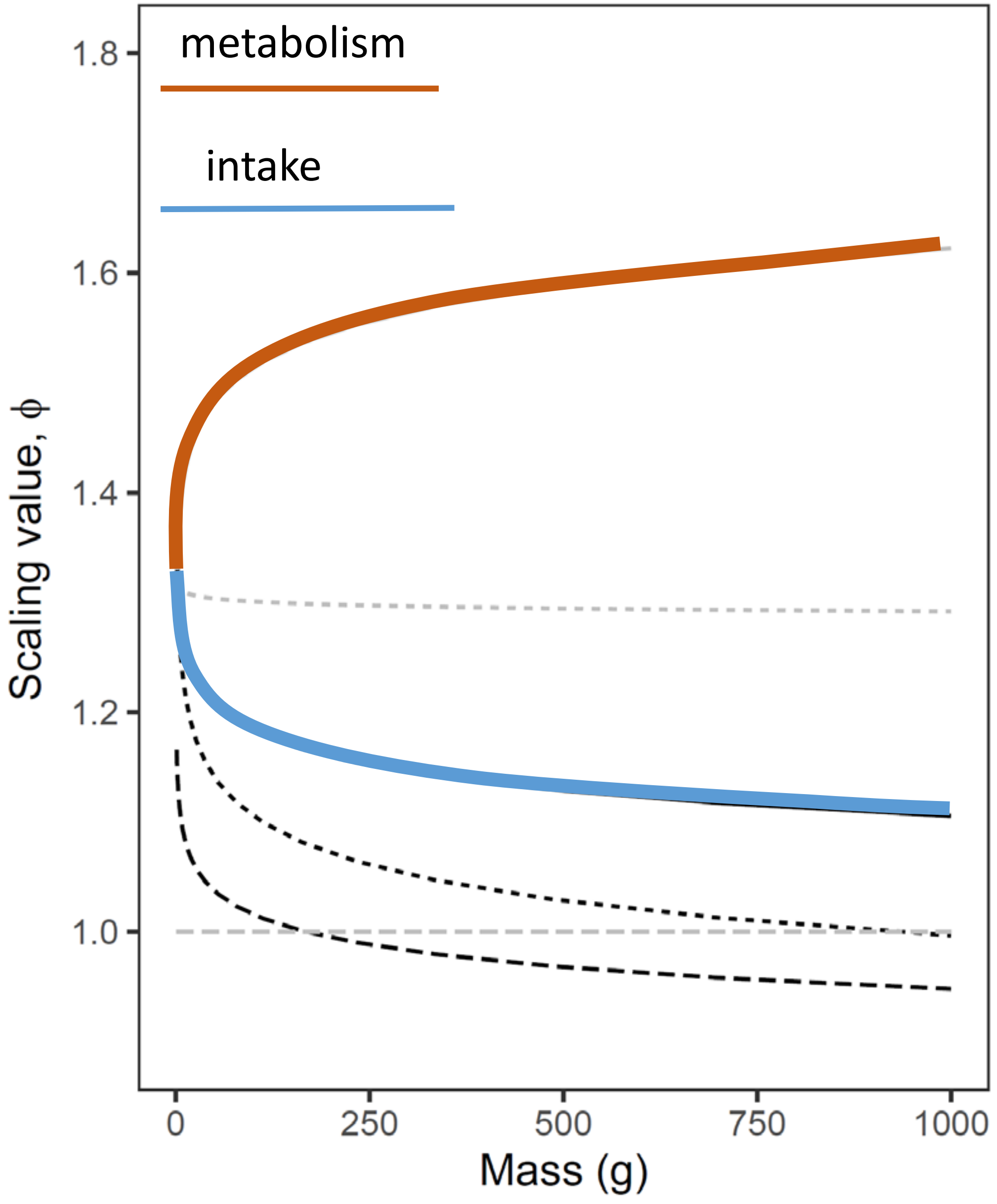


42 scenarios of different parameter combinations

Name	Mat age	Mat wgt	Wgt 1y	Wgt 5y	Wgt 10y	Wgt 15y	Spawn 3y	Fitness	E_M	E_I	A_M	A_I	z_P	$M_{P,min}$
Life-history responses in baseline scenario														
Base (1)	3	632	99	3026	6860	9063	150	314	0	0	0	0	8	0.2
Scenario group I: Original TSR explanation – metabolism activation energy is higher: $E_M > E_I$														
I-1 (2)	3	*0.83*	0.94	*0.77*	*0.66*	*0.61*	0.91	0.58	0.7	0	0	0	8	0.2
I-2 (3)	3	1.02	*1.04*	1.01	*0.98*	*0.97*	*1.09*	1.03	0.15	0.05	0	0	8	0.2
I-3 (4)	3	*0.96*	*1.05*	*0.91*	*0.80*	*0.75*	*1.13*	0.84	0.6	0.1	0	0	8	0.2
Group Ia: Metabolism activation energy is higher, combined with different temperature-size interactions														
I-4 (5)	*2*	1.12	*2.34*	2.93	3.22	3.30	*4.28*	7.41	0.7	0.63	0	0.01	8	0.2
I-5 (6)	3	1.28	*1.14*	1.33	1.34	1.32	*1.56*	1.66	0.7	0.01	0	0.01	8	0.2
I-6 (7)	3	*0.73*	0.93	*0.62*	*0.46*	*0.39*	0.95	0.38	0.7	0.01	0.01	0	8	0.2
I-7 (8)	*2*	*0.64*	*1.67*	1.22	1.07	*0.99*	*1.88*	1.74	0.7	0.63	0	-0.005	8	0.2
I-8 (9)	3	*0.58*	0.81	*0.48*	*0.36*	*0.32*	0.64	0.22	0.7	0.01	0	-0.01	8	0.2
I-9 (10)	3	*0.95*	0.97	*0.94*	*0.94*	*0.95*	0.90	0.89	0.7	0.01	-0.01	0	8	0.2
I-10 (11)	3	*0.65*	0.82	*0.58*	*0.50*	*0.46*	0.58	0.32	0.7	0.01	-0.01	-0.01	8	0.2
Group Ib: Metabolism activation energy is higher, combined with increased mortality														
I-11 (12)	***2***	***0.41***	***1.06***	***0.85***	***0.83***	***0.81***	***1.53***	0.23	0.15	0.05	0	0	8	0.4
I-12 (13)	3	*0.97*	*1.05*	*0.90*	*0.78*	*0.72*	*1.24*	0.21	0.6	0.1	0	0	8	0.4
Scenario group II: Life-history explanation - increased mortality only														
II-1 (14)	***2***	***0.42***	***1.02***	***0.86***	***0.82***	***0.80***	***1.49***	0.02	0	0	0	0	4	0.2

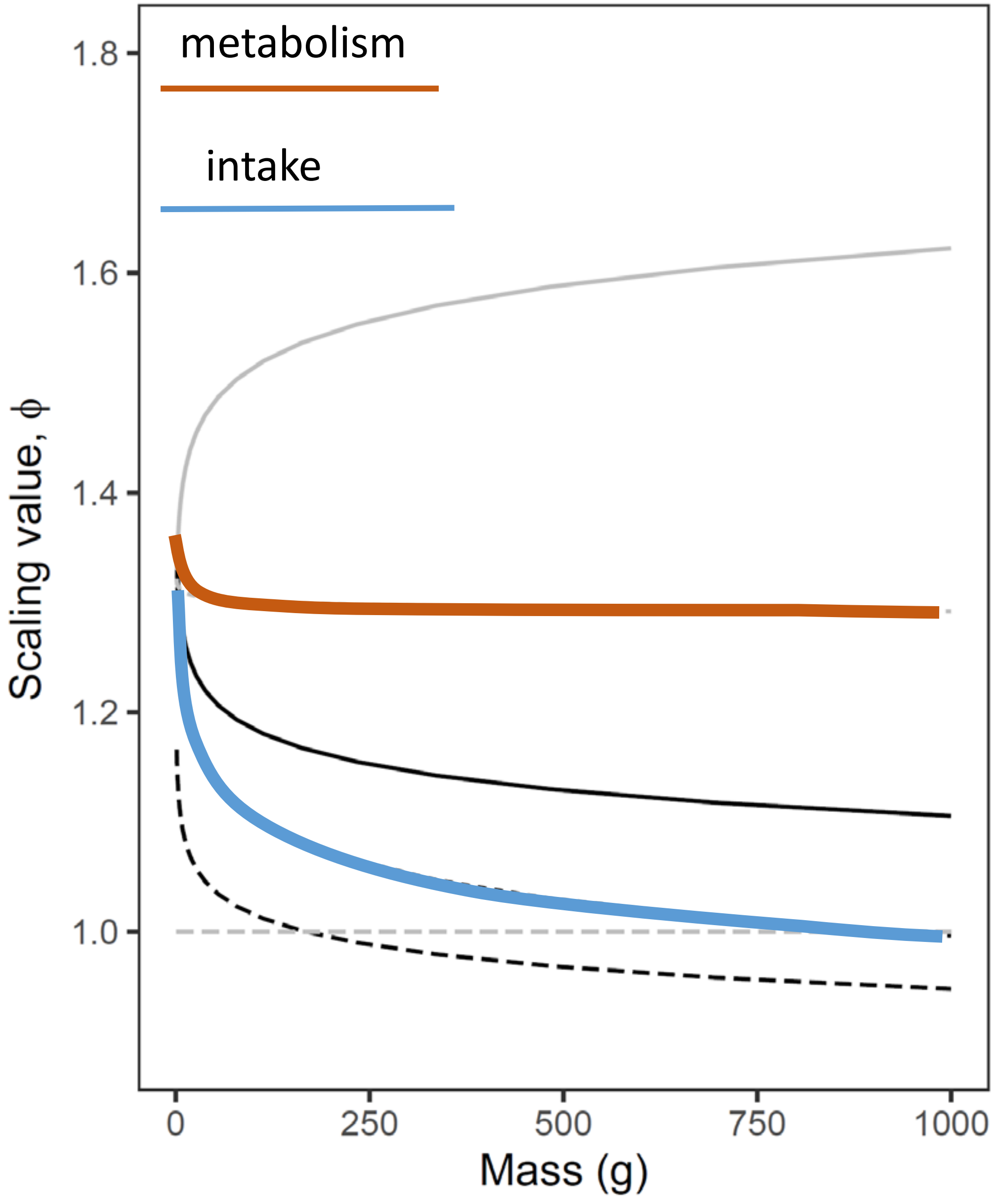
42 emergent growth and maturation curves





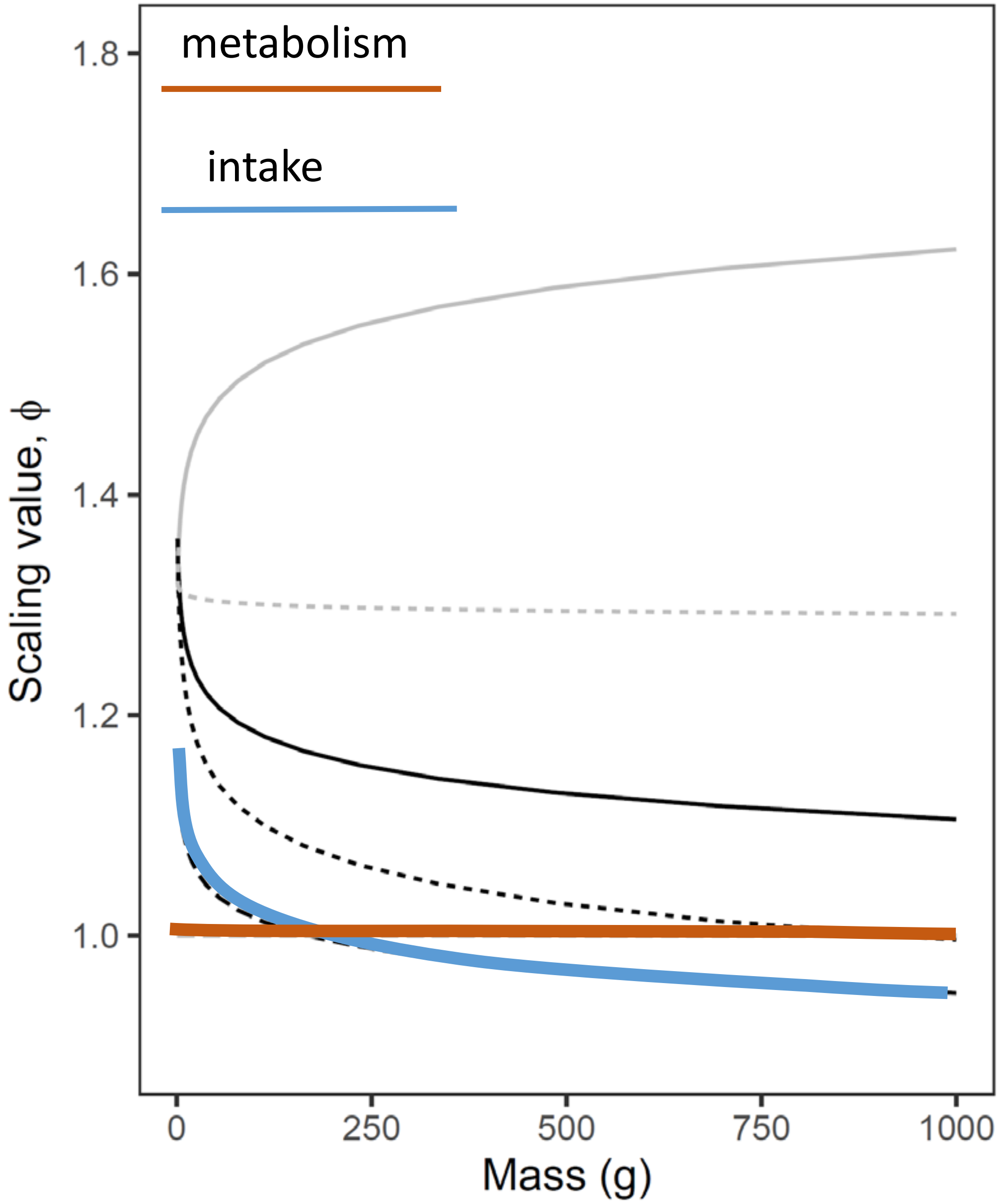
Two main ways how TSR can emerge

1. Metabolism increases more with size than intake



Two main ways how TSR can emerge

1. Or at least metabolism decreases with size slower than intake

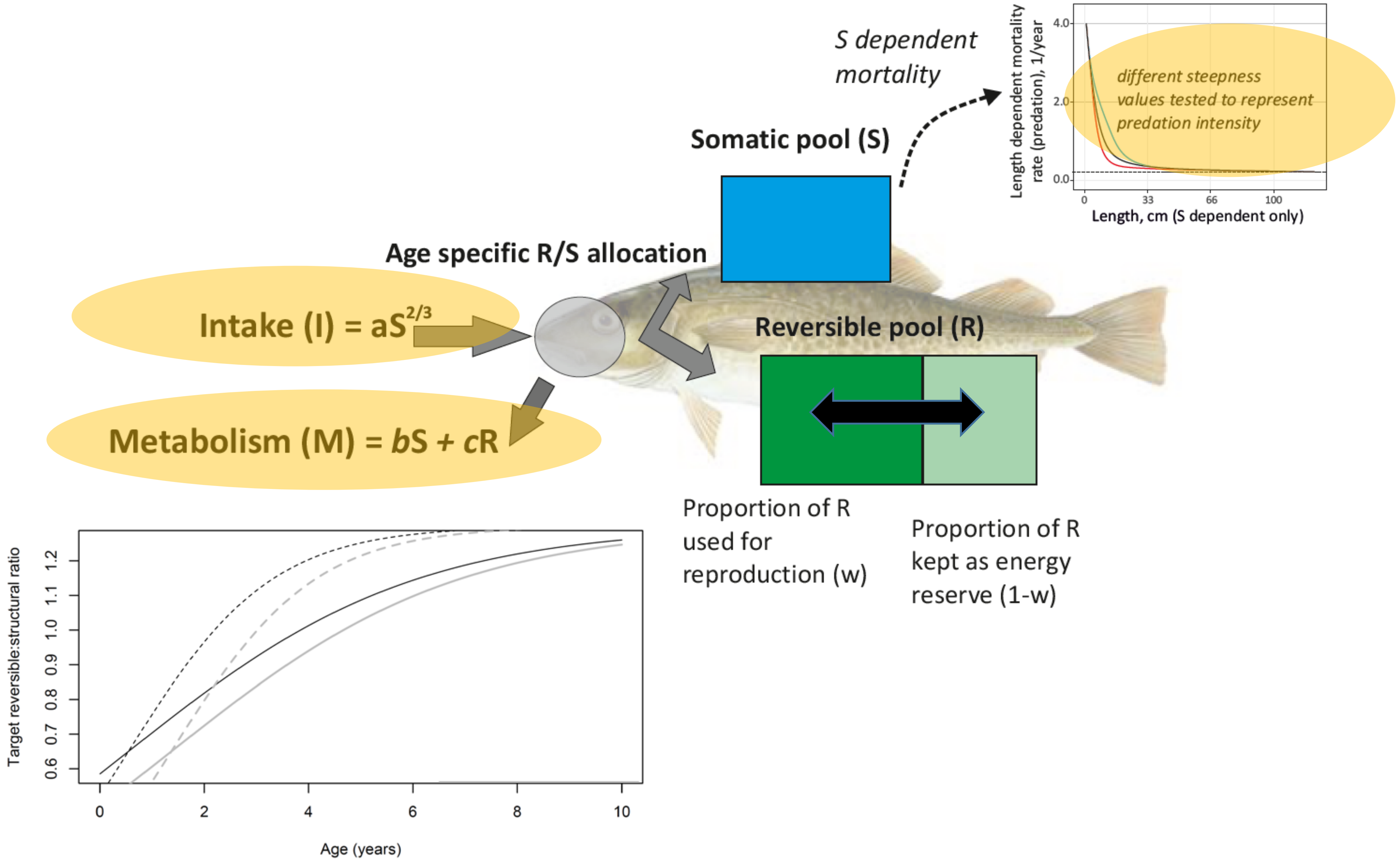


Two main ways how TSR can emerge

2. Metabolism does not increase, but relative intake rate decreases in large fish + mortality increases

Wootton et al. 2022, Ecol. Letters – TSR observed without increased baseline metabolic rate

In each case life-history optimisation is important



Take home & significance

Temperature – size rule growth is likely to be caused by a combination of **physiological processes related to food or oxygen intake and use**

AND

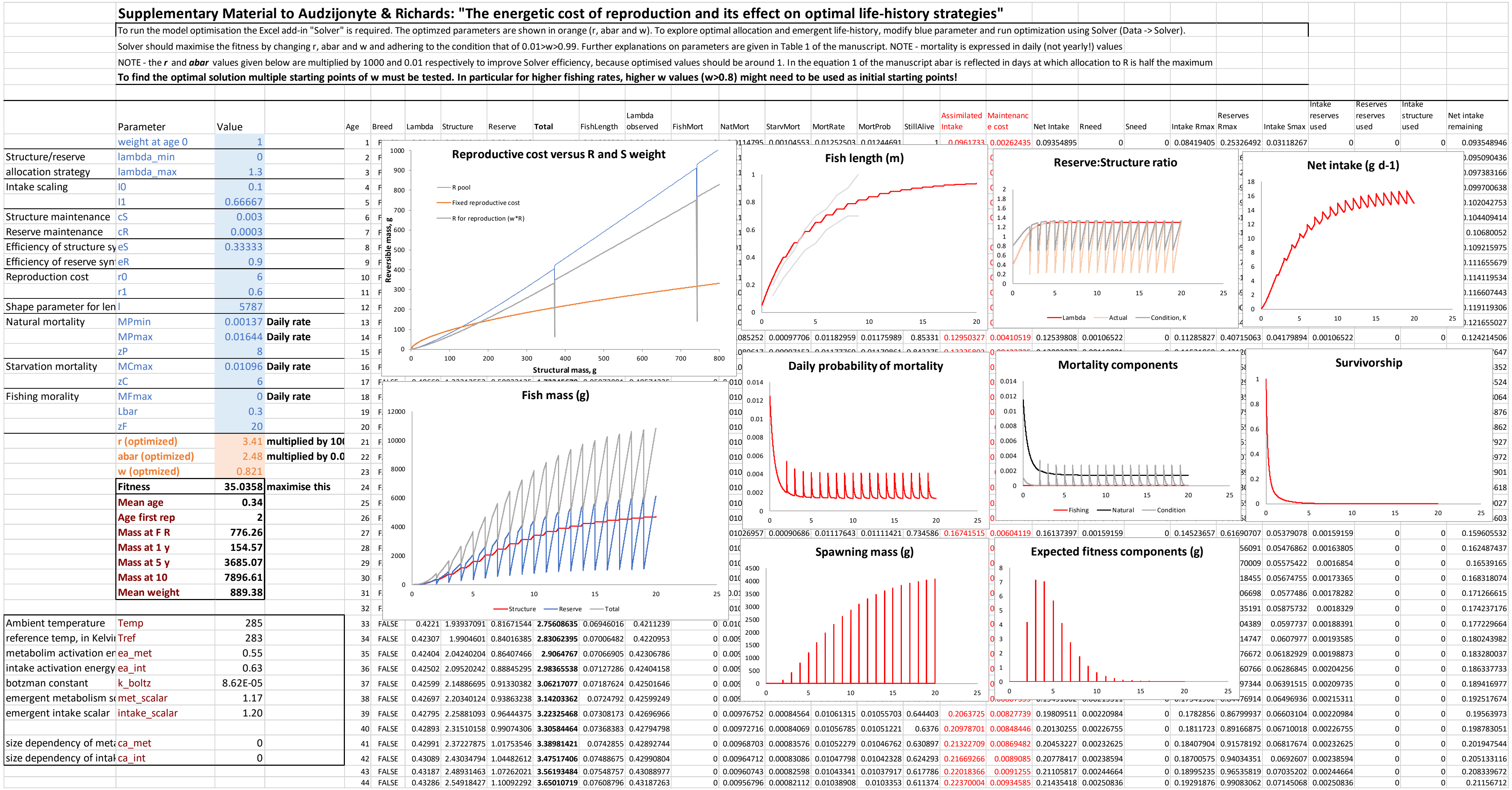
life-history optimisation of energy allocation between growth, reproduction and other processes

To understand how it works we need cross-disciplinary research and dialogue

Publication accepted in The Biological Bulletin special issue "An oxygen perspective on climate change"

Play with the model yourself!

github.com/astaaudzi/TSRmodel



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