Energy Investment in Growth Rate and Reproduction

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Abstract

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Code and Data Availability

Code is available at: `https://github.com/Don-Burns/Masters_Project`

Contents

1 Introduction

Understanding how organisms grow and what factors play a role in determining growth Larger fish produce more offspring and may even lead to more offspring than if the same mass were spread over two fish (Barneche et al. 2018). Larger fish also use energy more efficiently than multiple smaller ones per unit mass (because they have a lower mass specific metabolic rate (Peters 1983)) so it may actually reduce stress upon the ecosystem from an energetic perspective which could be useful when trying to manage fish stocks It is already known that metabolic rates and the size of fish is dependant on temperature and with global warming understanding in greater detail how increased metabolic rates may affect growth is useful.

Growth is in essence a balancing act between how much energy an organism can acquire and the amount of energy required for maintenance, that is movement, digestion et cetera.

Key to understanding rates and their relationship with mass is the concept of power laws. Many biological traits can be described as scaling to the power of some other biological trait. That is some rate, Y, can be expressed for any mass by $Y = Y_0 m^{\beta}$. Power laws can be broadly categorised based on the value of their exponent, β. Where the exponent does not equal one, the relationship is said to be allometric. That is the trait does not increase at the same rate as the trait being compared against. Where the exponent equals one the relationship is described as isometric, that is the two traits increase at the same rate. For the purposes of describing growth these relationships are indispensable.

Traditionally ontogenetic growth models have relied on knowing how large an organism is expected to grow. The von Bertalanffy growth equation relies on knowing the longest a fish can be and the length of the fish at the beginning of measurements (Bertalanffy 1938; Pütter 1920). From here for a known growth rate, the length of the fish after a set amount of time has passed can be predicted. One of the best known examples of an OGM is the model developed by West, Brown, and Enquist 2001. This model is parametrised around the average energy content of tissue asymptotic mass. Asymptotic mass being the mass at which growth has essentially stopped due to metabolic cost and energy intake equalling each other.

In classic OGMs this is most notable in determining how much energy an organism acquires at a given mass where gain = constant × mass$^{0.75}$. This scaling is based on the work of West, Brown, and Enquist 1997

In the face two of the key assumptions of Charnov, Turner, and Winemiller 2001; West, Brown, and Enquist 2001 OGM not being true, that reproduction and metabolism scale isometrically, there is a need to take a novel approach to modelling fish growth, in particular choosing to focus on developing how intake is described to better reflect the real world. To do this an obvious starting point is to model intake as a functional response (Holling 1959) so as to reflect real world intake rates.

2 Methods

3 Results

3.1 tables and figures

4 Discussion

5 Conclusion

Table 1: Table describing parameters used in the model, along with values units and sources where applicable.

Parameter	Description	Value	Units	Range	Source
m	Mass	?	kg day^{-1}	-	
B_m	Metabolic Cost	-	kg day^{-1}	-	Peters 1983
α	Age of maturity	-	day	-	-
c	Reproduction scaling constant	-	kg day^{-1}	0-1	-
ρ	Reproduction scaling exponent	-	-	0-1.5	-
Z	Rate of instantaneous mortality	$2/\alpha$			Charnov, Turner, and Winemill
k	Reproductive senescence	0.01			
ϵ	Resource Conversion Efficiency	0.70	-	-	Peters 1983
X_r	Resource Density	-	kg	?	-
γ	Search rate scaling exponent	0.68 in 2D	-	-	Pawar, Dell, and Savage 2012
		1.05 in 3D			
a_0	Search rate scaling constant	$10^{-3.08}$ in 2D	m^2 s^{-1} kg$^{-0.68}$		Pawar, Dell, and Savage 2012
		$10^{-1.77}$ in 3D	m^2 s^{-1} kg$^{-1.05}$		
β	Handling time scaling exponent	0.75	-	-	Pawar, Dell, and Savage 2012
$t_{h,0}$	Handling time scaling constant	$10^{3.95}$ in 2D	kg$^{1-\beta}$ s	-	Pawar, Dell, and Savage 2012
		$10^{3.04}$ in 3D	kg$^{1-\beta}$ s		

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Supplementary Information

5.1 notes

need section on value conversions and derivations