Modelling the bioenergetics of zebrafish, *Danio rerio*, over its entire lifecycle using Dynamic Energy Budget (DEB) theory

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INTRODUCTION

This study takes place in the context of pollution to the environment by uranium in freshwater ecosystems. While uranium is a naturally occurring element its concentration can increase due to anthropogenic activities (e.g. inefficient storage of uranium mine tailings, gold and phosphate mining, airplane accidents…) .

Danio rerio is the chosen biological model . In addition to having an entirely sequenced genome it reproduces easily and rapidly in the laboratory and is widely used for ecotoxicity tests.

The response of zebrafish at different levels of biological organization (molecular, cellular, individual) to waterborne uranium are currently being studied at the Laboratory of Radioecology and Ecotoxicology.

This project seeks to focus on effects of uranium toxicity on the zebrafish metabolism in order to link the observed responses which are occurring at different time and space scales using DEB theory.

DEB theory has not yet been applied to zebrafish and offers the conceptual framework for interpreting previous experimental results. In addition it provides powerful tools for the mechanistic formulation of physiological processes governing the zebrafish's metabolism.

It is very important to characterize the metabolism of the control organism (zebrafish in non polluted constant environment) when determining metabolic consequences of uranium exposure.

Therefore we present here a bioenergetic model of *Danio rerio* which takes into account each stage of the its life cycle : embryo to larvae to juvenile to adult. This model will be later used as a predictive tool to determine effects of uranium on individual *D. rerio*. With this in mind an emphasis is put into characterizing biological processes known (e.g. reproduction) or hypothesized (e.g. growth, aging) to be affected by waterborne uranium.

THE MODEL

State Variables :

L Volumetric length

[E] Reserve density

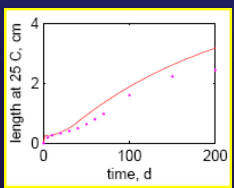
E_H Cumulative energy invested in maturation

13 DEB primary parameters whose values capture energetics and aging of *D. rerio*

The model describes the evolution in time of the three state variables over the entire life cycle of *Danio rerio*

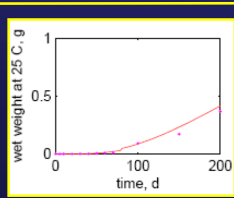
	Descriptive stages	Embryo / prolarvae	larvae	Juvenile	adult
	DEB stages	embryo	Juvenile I	Juvenile II	adult
Surface area-volume relationships	Growth	ISOMORPHIC	V-1 MORPHIC	ISOMORPHIC	ISOMORPHIC
	Stage Transition	birth	metamorphosis	puberty	
PARA-METERS	Maturity threshold	E_H^b	E_H^j	E_H^p	
Quantities (dependant on food level)	Length	L_b	L_j	L_p	
	Age	a_b	a_j	a_p	

OUTPUT



Lengths and wet weight as a function of days post fecundation at 25°C. The red curves are model output. The data points correspond to values taken from [1].

11 such one-dimensional data sets were used to estimate primary parameter values. Another 9 scalar data points were used as well (e.g. L_b).



METHODS

Estimation of primary parameters by fitting model to different datasets in the literature. To initiate estimation procedure primary parameter values corresponding to a 'generalized animal' were used. All operations were done with DEBtool software.

An extensive literature on zebrafish is available. Data pertaining to lengths, weights, reproductive output, and egg size were used to estimate the parameters ([1][2][3][4]). A temperature correction factor was applied to the data to set all metabolic rates in the model at a reference temperature of 20°C.

At the end of the estimation procedure values for primary parameters, growth, lengths at age, lengths at stage transition, age at stage transition were obtained.

Model output was compared to datasets. Estimation procedure was complete when the maximum amount of information was extracted from datasets.

CONCLUSIONS

The model captures the growth of *Danio rerio* over its whole lifecycle..

The reproduction buffer handling rules still need to be specified. Not enough reproductive data was gathered so far.

The cost of maturity maintenance still remains poorly fixed by the collection of data used.

Experiments will therefore be designed to complete the data collected from the literature.

Thought experiments will be designed to study how the metabolism of zebrafish behaves in different scenarios (starvation, different levels of food density, different osmotic pressure of water).

The biology of zebrafish (extensive literature available) will be used to interpret all results.

References:

[1] Barrionuevo, W.R., Burggren, W.W. O2 consumption and heart rate in developing zebrafish (Danio rerio): Influence of temperature and ambient 02. 1999. *Am. J. Physiol. Regulatory Integrative Comp Physiol* 276:505-513

[2] Bagatto, B., Pelster, B., Burggren, W.W. Growth and metabolism of larval zebrafish: Effects of swim training. 2001. *J. Exp. Biol.* 204(24):4335-4343.

[3] Spence, R., Gerlach, G., Lawrence, C., Smith, C. The behaviour and ecology of the zebrafish, *Danio rerio*. 2008. *Biol. Reviews.* 83(1):13-34

[4] Eaton, R. C., Farley R. D. Spawning cycle and egg production of zebrafish, Brachydanio rerio in the laboratory. 1974. *Copeia*. 1:195-204.

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