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An empirical model for estimating aquatic invertebrate respiration

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Summary

1. The role of metazoan respiration in aquatic system energetics has been neglected to some extent, particularly because limited resources hamper the simultaneous determination of individual respiration rates across many taxa. As global warming will affect poikilotherm metabolism on an ecosystem scale, we need versatile models to estimate respiration from 'easy-to-obtain' parameters.

2. Artificial neural networks were trained to estimate mass specific respiration of aquatic metazoans from 28 parameters: temperature, water depth, 19 taxon categories, body mass and 6 lifestyle parameters. The data base includes 22 920 data sets referring to 915 taxa (836 identified to species, 67 to genus, 12 to higher taxon) from 452 different sources.

3. Overall model fit is good ($R^2 = 0{\cdot}847$), but there is considerable residual variability of up to two orders of magnitude.

4. Variability of same species measurements between sources is almost as large as same-source variability between species, i.e. a substantial part of the residual variability in the data may represent methodical bias.

5. There are no universally valid scaling factors in the relationships of respiration to body mass and temperature, but a wide range of species-specific factors.

6. The model has been implemented in a Microsoft EXCEL spreadsheet that is available at http://www.thomas-brey/science/virtualhandbook.

Key-words: modelling < community ecology, modelling < population ecology

Introduction

Metabolic activity, i.e. the sum of all bodily processes that involve energy and matter transformation, is the foundation of life, as we know it. Therefore, the whole body metabolic rate is central to the understanding of physiological as well as of ecological function. Despite this significance, the role of metazoan respiration in system energetics has been neglected to some extent in aquatic ecology (Del Giorgio & Williams 2005). For instance, the leading aquatic ecosystem modelling tool Ecopath/Ecosim (Christensen, Walters, & Pauly 2005) does not use respiration as an input parameter, but estimates it *en passant* from other parameters of the energy budget. The significance of metabolic activity for the prediction of global warming effects on aquatic ecosystem functioning (e.g. O'Connor *et al.* 2009) further emphasizes the need for more intense studies.

Whole body metabolic rate can be approximated directly through the heat loss of an organism, i.e. the inevitable loss of energy tributed to the second law of thermodynamics, by means of calorimetry (see e.g. van Ginneken *et al.* 1994). The common approach, however, is the measurement of aerobic respiration, i.e. the amount of oxygen consumed per unit of time. Aerobic respiration is a reasonable approximation of metabolism in most animals under standard (= resting) conditions. Starting with Brody & Procter (1932), Kleiber (1932) and others, the standard respiration rate (i.e. of a resting, fasting, non-stressed animal) of literally thousands of species has been measured so far (see e.g. Clarke & Johnston 1999; Glazier 2006; Lovegrove 2000; Makarieva *et al.* 2008; White, Phillips, & Seymour 2006 for more recent data compilations). Today, the common ground is that mass specific (i.e. per unit of body mass) standard respiration rate MSR scales with body mass M by a power function, MSR $\approx M^{-b}$, and exponentially with temperature, MSR $\approx e^{-c/T}$. However, whether there are universally valid scaling factors b and c is a matter of active debate (see Brown *et al.* 2004; Glazier 2006; Kozlowski & Konarzewski 2004; White *et al.* 2006; Seibel 2007 for recent contributions). Apparently, even if such general scaling factors exist, there is substantial natural variability, e.g. owing to specific body designs or during specific phases of ontogenetic development (e.g. Glazier 2006; White *et al.* 2006).

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