LIMNOLOGY
and
OCEANOGRAPHY: METHODS

Limnol. Oceanogr.: Methods 10, 2012, 581–589

A multi-parameter artificial neural network model to estimate macrobenthic invertebrate productivity and production

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Abstract

I developed a new model for estimating annual production-to-biomass ratio P/B and production P of macrobenthic populations in marine and freshwater habitats. Self-learning artificial neural networks (ANN) were used to model the relationships between P/B and twenty easy-to-measure abiotic and biotic parameters in 1252 data sets of population production. Based on log-transformed data, the final predictive model estimates log(P/B) with reasonable accuracy and precision (r^2 = 0.801; residual mean square RMS = 0.083). Body mass and water temperature contributed most to the explanatory power of the model. However, as with all least squares models using nonlinearly transformed data, back-transformation to natural scale introduces a bias in the model predictions, i.e., an underestimation of P/B (and P). When estimating production of assemblages of populations by adding up population estimates, accuracy decreases but precision increases with the number of populations in the assemblage.

Secondary production is the quantitative base of energy flow and of trophic interactions between heterotrophs and thus constitutes a key parameter of ecosystem functioning. The amount of secondary production and its distribution between populations are measures of trophic position and of linkage in aquatic food webs (Benke 2011) and may be indicative of ecosystem and population health (Buffagni and Comin 2000; Dolbeth et al. 2005). For a number of reasons, secondary production of the benthic compartment is of particular interest in aquatic ecology: (i) the sediment-water interface is, especially in shallow waters, a place of intense energy and matter turnover, relevant for both nutrient recycling and channeling of matter to higher trophic levels such as (commercially exploited) demersal fish; (ii) compared with pelagic organisms, benthic animals are less subject to random and/or short-term variability in space and time, because they are less mobile and, on average, live longer. Therefore, effects of external drivers such as increasing water temperature may be seen earlier and clearer in benthic populations and communities than in pelagic ones.

Demand for benthic secondary production studies is rising exponentially with the growing use of spatially explicit approaches (based on Geographical Information Systems, GIS) in aquatic ecosystem research (e.g., Ardron 2002; Dunton et al. 2005; Friedlander et al. 2007), which may require production estimates for many geographic reference points instead of the "average" population only. However, assessment of secondary production in aquatic systems is expensive and time-consuming. Multiple linear regression models (MLM), based on empirical data that predict population production P or production-to-biomass ratio P/B, are the favorite approach to shortcut this task (see Brey 2001, Cusson and Bourget 2005, and Dolbeth et al. 2005 for reviews and comparisons of published models).

Most of these predictive models, however, have their weak spot. Many models are restricted to taxonomic, functional, or habitat-defined subsets of macrobenthic populations (e.g., Plante and Downing 1989; Morin and Bourassa 1992; Tumbiolo and Downing 1994) or require independent variables such as life span, which are laborious to determine (e.g., Cusson and Bourget 2005). Furthermore, these published models lack a proper evaluation of their statistical properties, such as error distribution, accuracy, and precision. The model type used is a further concern. It is not yet clear whether or not there are universally valid scaling factors (e.g., Brown et al. 2004) between body mass or temperature and metabolic activity as well as its derivates such as production (Kozlowski and Konarzewski 2004; Glazier 2006; Seibel 2007; Brey 2010), i.e., MLM may not describe the existing relationships appropri-

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Acknowledgments

I am indebted to literally hundreds of colleagues who built the base of this empirical study by their laborious field and laboratory work on the population dynamics of benthic invertebrates. Hopefully my empirical model will make their contribution to science even more valuable.

DOI 10.4319/lom.2012.10.581