PEEIR

Pacific Estuarine Ecosystem Indicator Research Consortium

Value Added to Indicators through Mechanistic Modeling

Issue

The effects of stressors are typically characterized by effects on individual organisms. PEEIR has been studying many indicators that refine our ability to identify stressors and characterize their physiological effects. This was achieved through a carefully designed mix of observations, experiments, and mathematical models focusing on resident organisms. These resident species are common organisms in many west coast marshes, but are not necessarily species of concern to managers. Related observations on the resident species to other species in different environments requires understanding the biological and ecological mechanisms responsible for changes in indicator values.

Approach and Rationale

PEEIR used dynamic energy budget (DEB) models for this purpose. DEB models describe the acquisition by organisms of energy from food and its utilization for growth, maintenance, and reproduction, as shown in Figure 1.

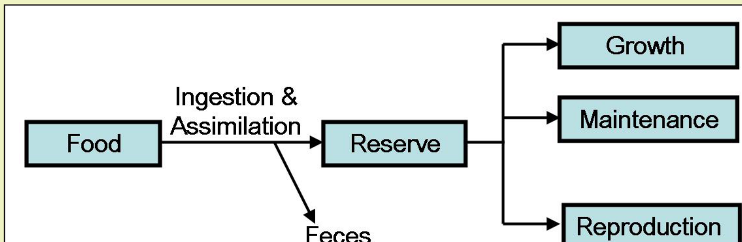

Figure 1

- Modifications of the models can be used to describe the flow of elemental matter and bioaccumulation of contaminants. With additional information on mortality, DEB models are a key component of a population model (Link to Modeling Populations).

- DEB models are process-based, and offer an attractive compromise between the competing requirements of generality (a model should be applicable to many combinations of species and stressors) and testability (predictions should be based on verified mechanisms, not speculation). By determining how model parameters varied among species and environments, and how the changes co-varied with biomarkers (Link to Fish Integrated Indicators), we sought to relate biomarkers more rigorously to physiological processes, thereby adding value to these biomarker measurements.

- Deterministic DEB models incorporating contaminant effects have been used by previous workers, notably S.A.L.M. Kooijman in the Netherlands, to interpret standardized toxicity tests, however the PEEIR studies required new theory to describe growth and reproduction in fluctuating (stochastic) environments (Gurney et al. 2003, Gurney and Nisbet 2004, Fujiwara et al. 2004), and new methods for estimating model parameters (Nisbet et al. 2004, Fujiwara et al. 2005).

Findings and Impact

- We investigated different representations of sub-lethal toxic effects in our DEB model against published laboratory data on feeding, respiration, growth and reproduction from a range of marine organisms. In all cases model fits were good, but there were serious data limitations. PEEIR laboratory experiments on the response of larval topsmelt to cadmium exposure (Rose et al.) provided a more rigorous test.

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Figure 2

Findings and Impact, cont.

- We developed a method to estimate DEB model parameters from fish growth information, such as was obtained by PEEIR investigators from otoliths. The model has one unobservable state variable (energy reserve – see figure 1), so we used a numerical nonlinear state–space approach. We assessed the estimability of parameters using size trajectory data from delta smelt (*Hypomesus transpacificus*). We are currently fitting our model to growth data from otoliths of one of our indicator species, the mudsucker *Gillichthys mirabilis* (Figure 2), from the PEEIR study sites (Link to Fish Integrated Indicators). We continue to investigate the correlation of estimated DEB model parameters with biomarkers.

- PEEIR has gathered data on the proportions of stable isotopes of nitrogen in indicator species for all our marshes (Link to Plants Salt Exudates). These have immediate value as indicators, but they also relate directly to ecological processes, notably trophic interactions. These processes are dynamic, so interpretation commonly requires unique assumptions. We are currently using DEB models to develop more powerful methodology for interpreting these stable isotope data.

Applications

DEB models have been shown to characterize quantitatively the responses of individual organisms to environmental stress. They can also be used as a component of population models (Link to Modeling Populations). The work reported here establishes that indicators based on individual physiology can help in parameterizing models used to anticipate long-term population changes.

Publications

Fujiwara, M., Kendall, B.E. and Nisbet, R.M. 2004. Growth autocorrelation and animal size variation. *Ecology Letters* 7:106-113.
Fujiwara, M., Kendall, B.E., Nisbet, R.M., and Bennett, W.A. 2005. Analysis of size trajectory data using an energetic-based growth model. *Ecology* 86:1441-51
Gurney, W.S.C., Jones, W., Veitch, A.R. and Nisbet, R.M. 2003. Resource allocation, hyperphagia and compensatory growth in juveniles. *Ecology* 84:2777-2787.
Gurney, W.S.C. and Nisbet, R.M. 2004. Resource allocation, hyperphagia and compensatory growth. *Bulletin of Mathematical Biology* 66:1731-1753.
Muller, E.B., Nisbet, R.M. and Berkley, H. *submitted*. Sublethal effects of toxic compounds on dynamic energy budgets: tests of theory and an application.
Nisbet, R.M., McCauley, E., Gurney, W.S.C., Murdoch, W.W. and Wood, S.N. 2004. Formulating and testing a partially specified dynamic energy budget model. *Ecology* 85:3132-3139.
Rose, W.L., Nisbet, R.M., Green, P.G. Norris, S., Fan, T., Smith, E.H., Cherr, G.N. and Anderson, S.L. *submitted*. Using an integrated approach to link biomarker responses and physiological stress to growth impairment of cadmium-exposed larval topsmelt.

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