Jocylin D. Pierro
2017 DEB Course

Modeling Toxicological Threats to Endangered Species via *in vitro* data and Dynamic Energy Budget

In my laboratory we work with the endangered loggerhead sea turtle (*Caretta Caretta*). Due to its endangered status, by law toxicity testing cannot be conducted on individual sea turtles. Our laboratory is permitted to obtain biopsies, from which we cultivate cells. The question becomes, what can you understand about the toxicological chemicals' effects on individuals and populations of loggerhead sea turtles with just cells? I propose that the answer to that question is the combination of cytotoxicity *in vitro* data with the use of the Dynamic Energy Budget (DEB) is the answer to that question.

In this course we have explored the details of DEB. In 1979, theoretical biologist Bas Kooijman began the process of developing a method of interpreting toxic effects for various levels of a biological organization. Kooijman determined that the evolutionary quality that ties all organisms together is metabolic organization (Jager 2013). All living organisms (i.e. plants, microorganisms, and animals) will take in and use substrates for their maintenance, growth, maturation, and propagation. In the last forty years Kooijman's theory that metabolic mechanisms are the common biological trait of all organisms has provided the formation of a modeling method that attempts to interpret toxicity testing findings for relevant levels within a biological system (Kooijman 2010). DEB for toxicological (DEBtox) purposes is founded on the evolutionary biology theory that Kooijman and his successors have developed – all organisms have a means and mechanistic reason for how they budget their energy (Jager 2005; van der Meer 2006; Nisbet 2000). This common concept of budgeting energy serves as the starting point for a model designed to provide a general method for accurately interpreting toxicity testing results throughout biological organizations (Nisbet 1997). The effects of toxicants can be measured by estimating the toxic effect scaling parameters using DEB modeling methods (Muller 2010).

DEB is both theoretical and applicable. What this means is that the assumptions that are part of this modeling technique are based upon biological theory, and not necessarily quantitative data. A "standard" DEB animal would feed on one type of food and remain isomorphic for its lifespan (Jager and Zimmer 2011). This simple form would take up food, and part of that energy from the good would be expended for organismal maintenance. The other portion of energy would go into a reserve so the organism could flex its energy if an environment became more dynamic and demanding. Lastly, a share of energy must necessarily be used for maturing physically and reproductively.

When modeling toxicological effects, one takes into consideration developmental, especially reproductive effects of toxic substance. When considering the developmental effects, energy inputs and outputs are notably affected by these changes. Consequentially, energy acts as an indicator for both the toxicokinetic and toxicodynamic components of organismal functionality, making energy-based modeling ideal for simulating toxicological effects. It is this combination of energy-based modeling appropriately mimicking toxicological effects, the use of energy tying different levels of biological organization together, and the ability to utilize molecular data as a starting point make DEB a fitting modeling technique for endangered animals. While there has been little to no DEB work done on extrapolating from the cellular level to the individual or population organizations, according to the theory, it should be possible. The life history of loggerhead sea turtles is known to some degree, it is largely the toxicological response to chemicals is not known. If we take the life history data that is available, and find a way to extrapolate in vitro cytotoxicity findings, DEB may accomplish something new, and extremely important. If DEB utilizes cellular data effectively to makes multi-organizational level predictions and interpretations, endangered species everywhere have the potential to be toxicologically analyzed with minimally invasive techniques. This course provides the groundwork for entering into the DEB modeling world, and begins the process of answering our original question – how do we start with cellular data and arrive at sound individual and population level predictions?

References:

Jager, T. (2013). "Making Sense of Chemical Stress: Applications of Dynamic Energy Budget Theory in Ecotoxicology and Stress Ecology." Retrieved October 8, 2014.

Jager, T. K., S.A.L.M. (2005). "Modeling Receptor Kinetics in the Analysis of Survival Data for Organophosphorus Pesticides." Environmental Science and Technology **39**(21): 8

Kooijman, S. A. L. M. (2010). Summary of Concepts of Dynamic Energy Budget Theory for Metabolic Organisation. Vrije Universiteit, Amsterdam, Cambridge University Press.

Nisbet, R. M., E. B. Muller, A. J. Brooks and P. Hosseini (1997). "Models Relating Individual and Population Response to Contaminants." Environmental Modeling and Assesment **2**: 5.

Nisbet, R. M., E. B. Muller, K. Lika and S. A. L. M. Kooijman (2000). "From Molecules to Ecosystems Through Dynamic Energy Budget Models." Journal of Animal Ecology(69): 13.

Muller, E. B., C. W. Osenberg, R. J. Schmitt, S. J. Holbrook and R. M. Nisbet (2010). "Sublethal toxicant effects with dynamic energy budget theory: application to mussel outplants." Ecotoxicology **19**(1): 9.

van der Meer, J. (2006). "An introduction to Dynamic Energy Budget (DEB) models with special emphasis on parameter estimation." Journal of Sea Research **56**(2): 17.