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Comparative physiological energetics of three commercial tuna species

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Interspecies comparisons of physiological energetics are possible only through the prism of a formal metabolic approach such as the Dynamic Energy Budget (DEB) theory which uniformly describes how individuals of different species acquire and utilise energy. We used the DEB theory to infer the energy budgets of three commercial tuna species (skipjack, Pacific bluefin, and Atlantic bluefin) throughout all stages of ontogenetic development—from an egg to an adult individual and its eggs. Energy budgets were inferred from scarce and disjointed data sets fed into a DEB-based mathematical model tailored for tuna fish until reaching a high goodness of fit and thus the reliable estimates of the model parameters.

The results show that life histories of all three species are strongly influenced by morphological and physiological adaptations which accelerate ontogeny during the larval stage, although the effect is more pronounced in bluefin than skipjack tuna. We identify that in energetic terms the accelerated ontogeny is a simultaneous improvement of energy acquisition (higher intake) and utilisation (higher expenditure) without changing the capacity of fish to build energy reserve as intake and expenditure increase in unison. High energy expenditure, an even higher intake by necessity, and a limited capacity to build energy reserve, make all three tuna species vulnerable to starvation, thereby theoretically underpinning the description of tuna fish as "energy speculators". We furthermore find that energy allocation to reproduction maximises fecundity of all three tuna species, thus suggesting that the evolution of tuna favoured higher fecundity at the expense of growth.

Thinking beyond just physiological energetics (e.g., wild stock projections), we discuss why DEB-based models are a natural foundation for physiologically structured population dynamics wherein the environment influences the population growth rate via metabolism. We suggest several concrete modelling techniques which allow progress in this direction.

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