An individual-based model for an energetic cost-benefit analysis of diel vertical migration

Matthew S. Woodstock[1] & Gregory L. Britten[1]

[1]Woods Hole Oceanographic Institution

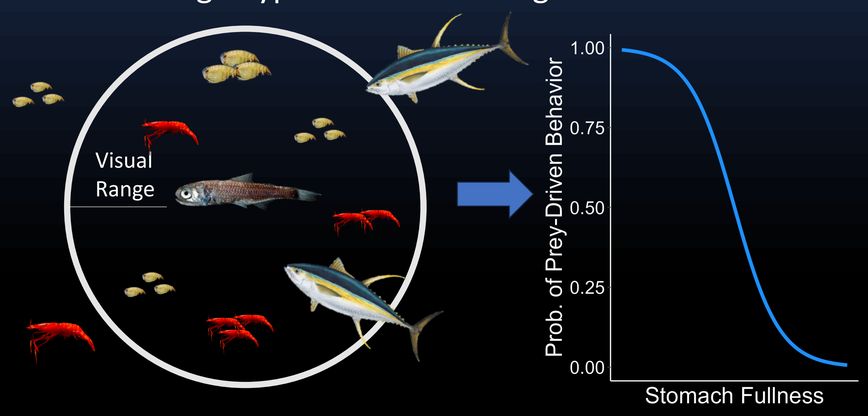
Rationale

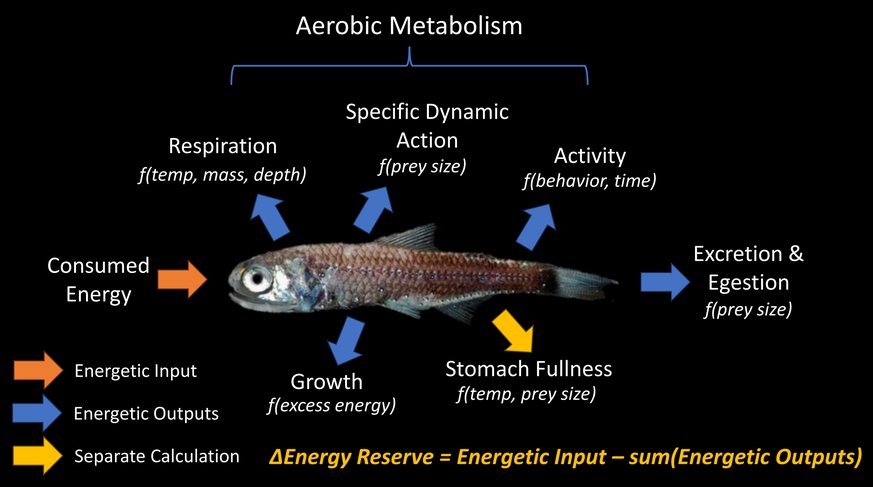
- Oceanic ecosystems are anticipated to become **warmer and more stratified** because of climate change
- Diel vertically migrating deep-pelagic animals are inextricably **linked to near-surface conditions** and are likely to be impacted by climate change
- Temperature-dependent bioenergetic rates and a reliance on near-surface production suggest **energy budgets are affected by biophysical factors**

Do climate change impacts influence the energetic cost of diel vertical migration (DVM)?

Model Structure

- Developed with the Julia Programming Language
- Species-specific traits and behaviors (DVM, diving)
- Size-structured populations
- Each individual has its own energy budget
- Visual range hypothesis and energetics drive behavior





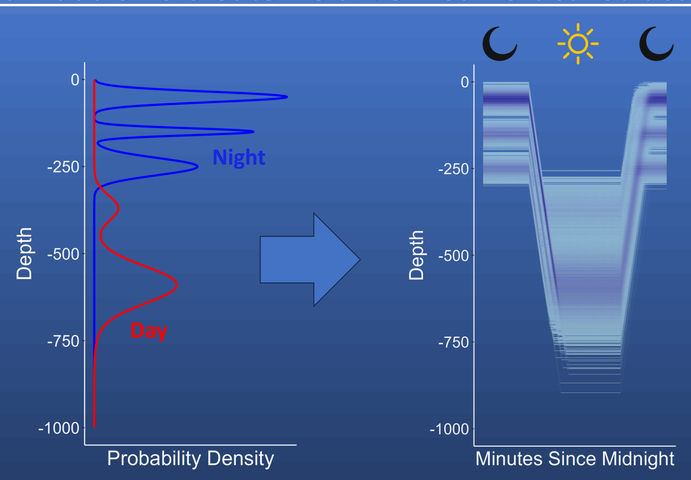
ΔEnergy Reserve = Energetic Input – sum(Energetic Outputs)

Study Objectives

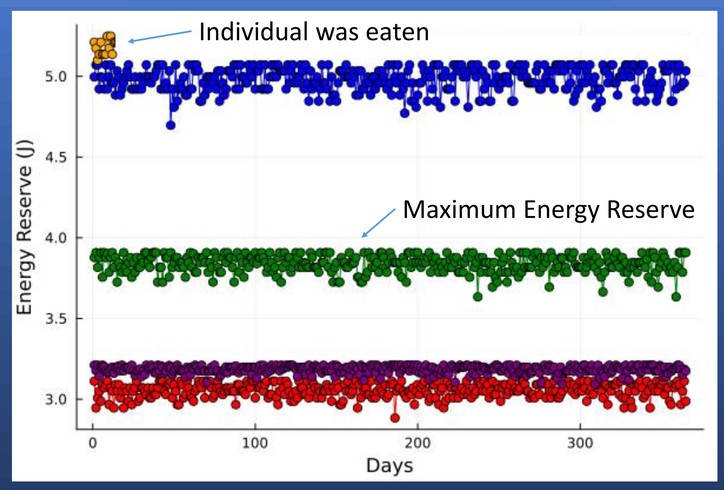
- Test model functionality with representative input data
- Estimate the energetic cost of diel vertical migration in a changing climate through 15 representative scenarios of water temperature and surface productivity
- Compare behavior and energy budgets among scenarios after 1 year

Model Diagnostics

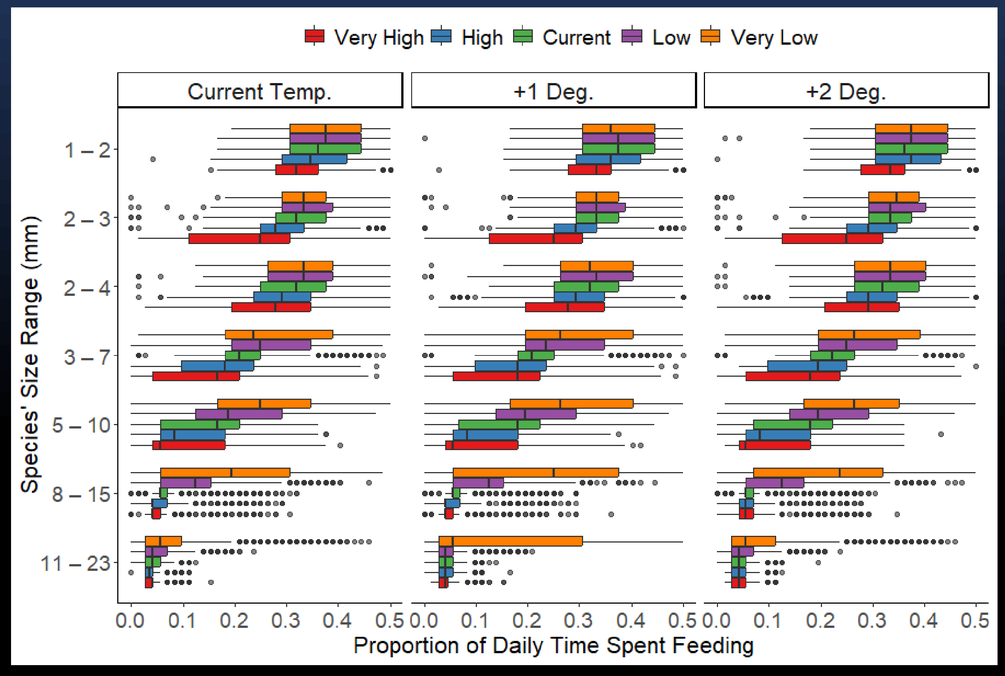
Individuals Re-create Field-Derived Vertical Structure



Tracks Individual Energy Reserves



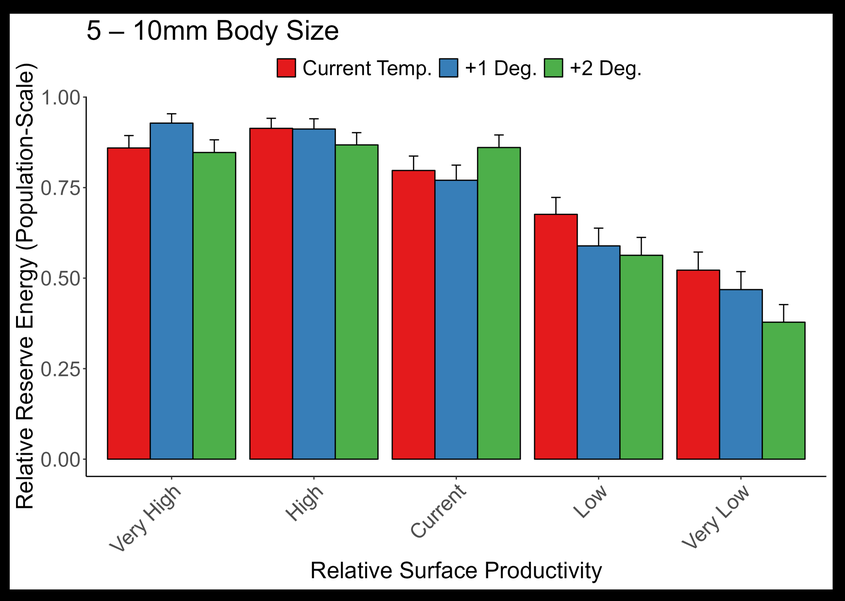
Small Migrants in Nutrient-Poor Environments Spend More Time Foraging



- Negative relationship between surface productivity and foraging time
- No noticeable effect of temperature at this scale
- Considerable individual variability from individual prey fields and energy budgets
- Time spent feeding is time actively moving and not avoiding predators

Surface Productivity and Temperature Affects Energy Reserves

- Surface productivity influences the energy intake of individual migrants, which affects population-scale energy budgets
- Average Q10 of ~1.9 for modeled species
- Increased temperature = increased cost of migration and gut evacuation rate
- Compounding effect of temperature and surface productivity
- Reduced energy reserves were directly proportional to reduced survivability



Additional Model Capabilities

- Quantify **spatially explicit food-web structure** at modular spatiotemporal scales (e.g, day vs. night, seasonally)
- Predict heterogeneous **species distributions** (i.e., patches) and associated food-web impacts
- Emerge **functional response curves** as a result of predator-prey dynamics, behavior, and physical factors

Try the Model Yourself

- Github: fishesofthedeep/SwimmingIndividuals
- Package under development (started 11/2023)
- Intend to make hybrid (GPU/CPU) compatible

Next Steps

- Apply real species traits and size structure from the **Northwest Atlantic Ocean**
- Link current environmental characteristics with **climate projections** to refine of biophysical factors
- Compile model functions into a Julia package for **community usage**

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OCEAN TWILIGHT ZONE

Contact

www.matthewwoodstock.com
matthew.woodstock@whoi.edu
@fishesarefrandz