Fish Bioenergetics Modelling

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What is bioenergetics?

- The study of the processing of energy by living systems, at any level of biological organization
- In fish bioenergetics, we are typically concerned with
  - The bioenergetics of individual organisms
  - Using this information to develop energy budgets for populations
  - Making predictions about fish production over a variety of changing environmental conditions
- Fish bioenergetics is a subset of a much broader field called **ecological energetics**

What is bioenergetics?

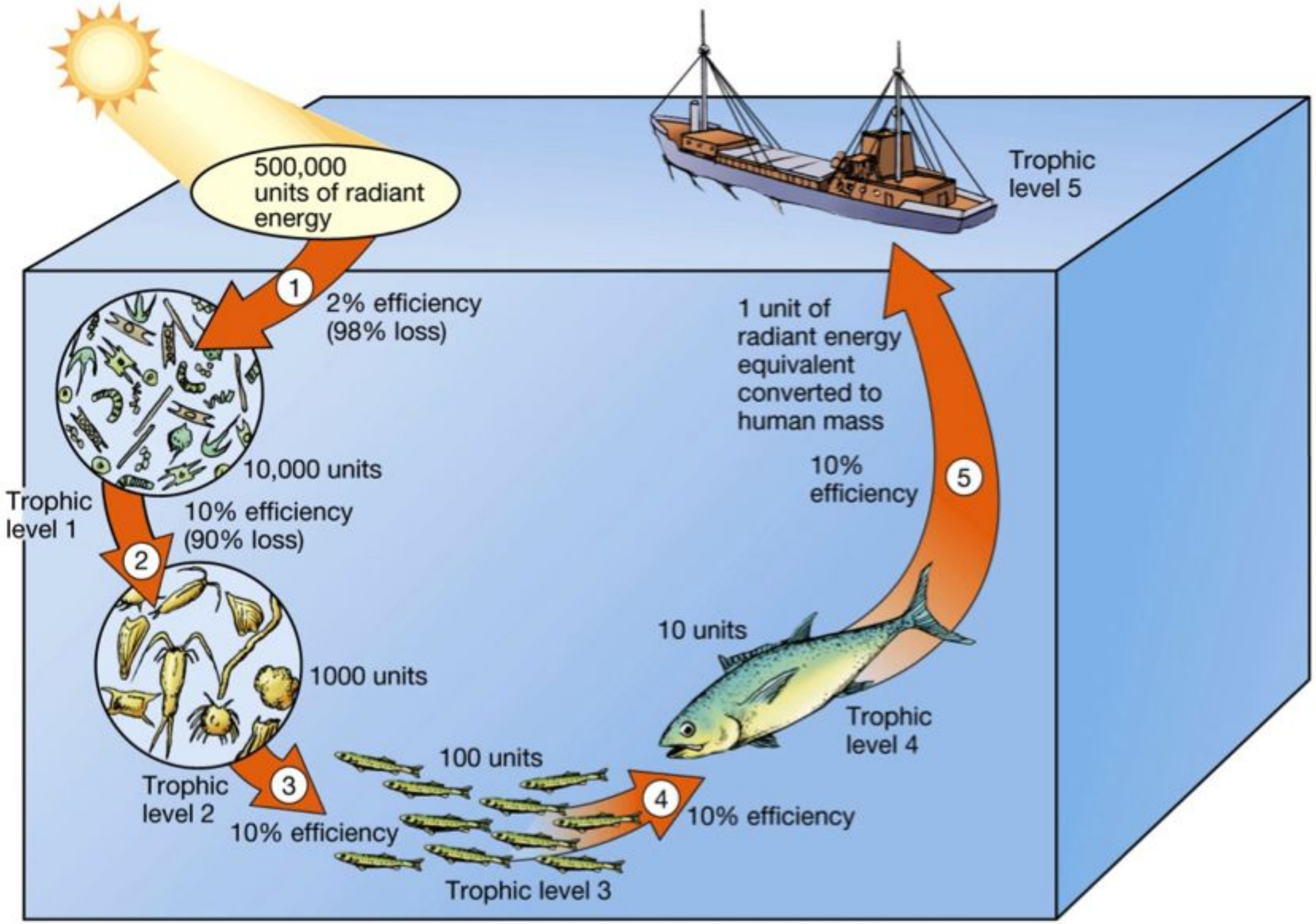
- **The study of the flow and transformation of energy in and between living organisms and between living organisms and their environment.**

- **Economics, with a healthy dose of thermodynamics.**

Laws of thermodynamics

1. Energy and matter cannot be created or destroyed, but they can be changed from one form to the other.
2. Any transformation of energy or matter results in some loss of "useful" energy- in other words, no energetic process is 100% efficient.

Energy flow through a food web



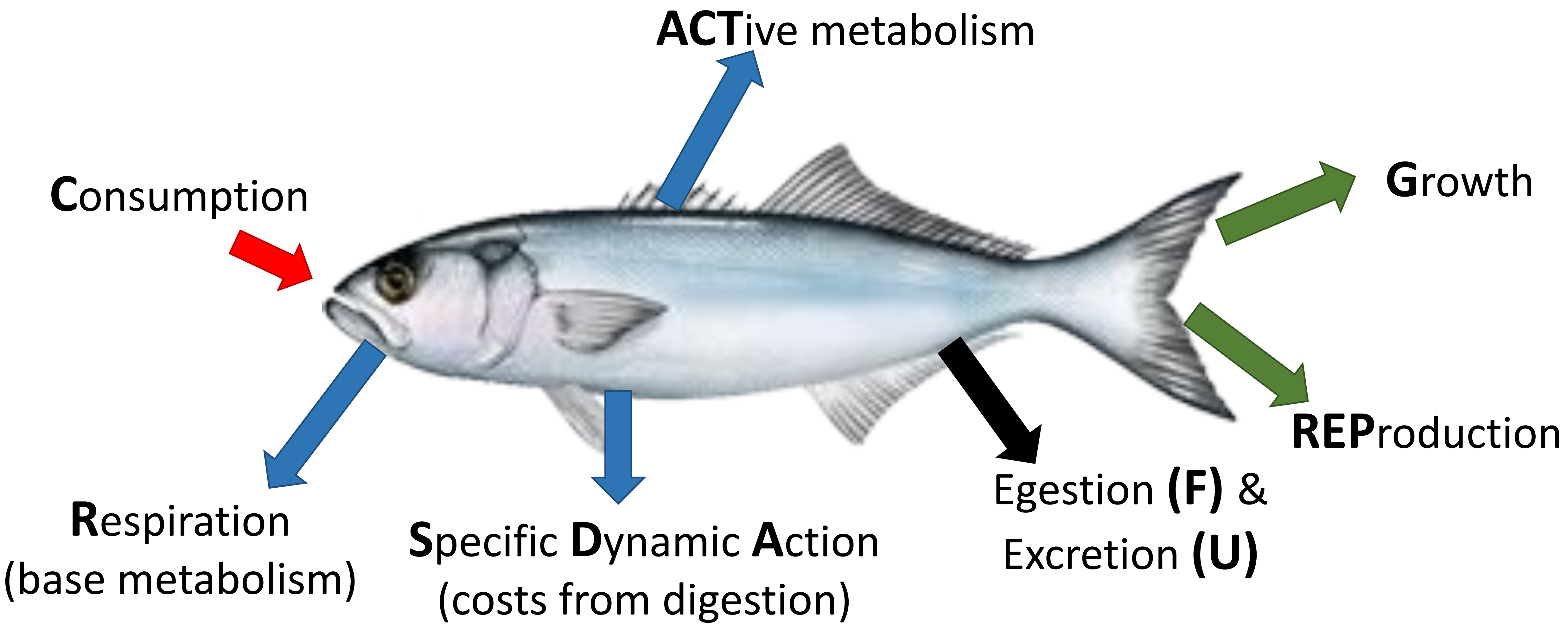
Energy budgets

- Are like bank accounts: inputs (like deposits), outputs (like withdrawals), storage (like a bank balance), and growth (like interest)
- It all has to balance

Inputs = Outputs + Growth

- Should always use the same units (like currency)
- Examples of typical units: calories or joules (energy), carbon, or biomass (grams)

Model Components



Typical Energy Budgets Differ for Carnivores & Herbivores:

Normalized Percentages	Consumption	Respiration		Waste		Growth
Carnivore	100 =	44	+	27	+	29
Herbivores	100 =	37	+	43	+	20


Green Sunfish


Muskellunge


Largescale Stoneroller

Bioenergetics Model

- $G = [C \ - (R + SDA + F + U + REP)]$

Growth = Consumption – Metabolism, Waste, and Reproduction

Bioenergetics in Fisheries Management

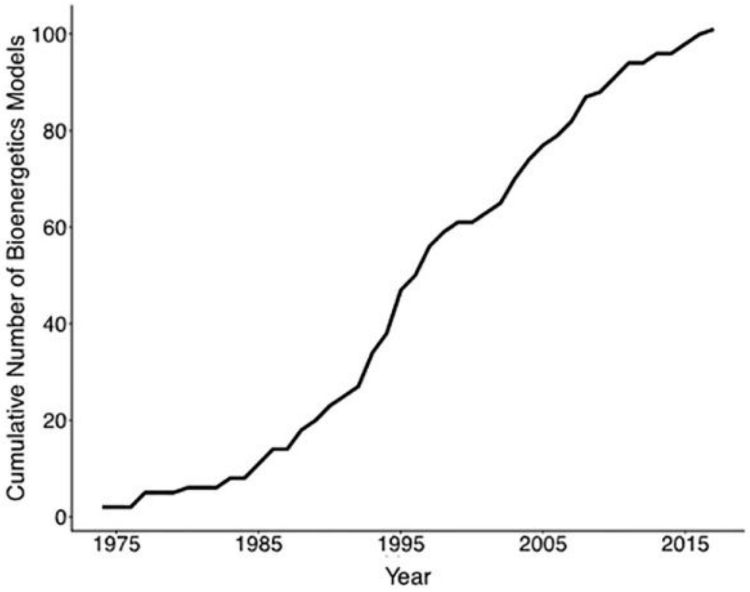
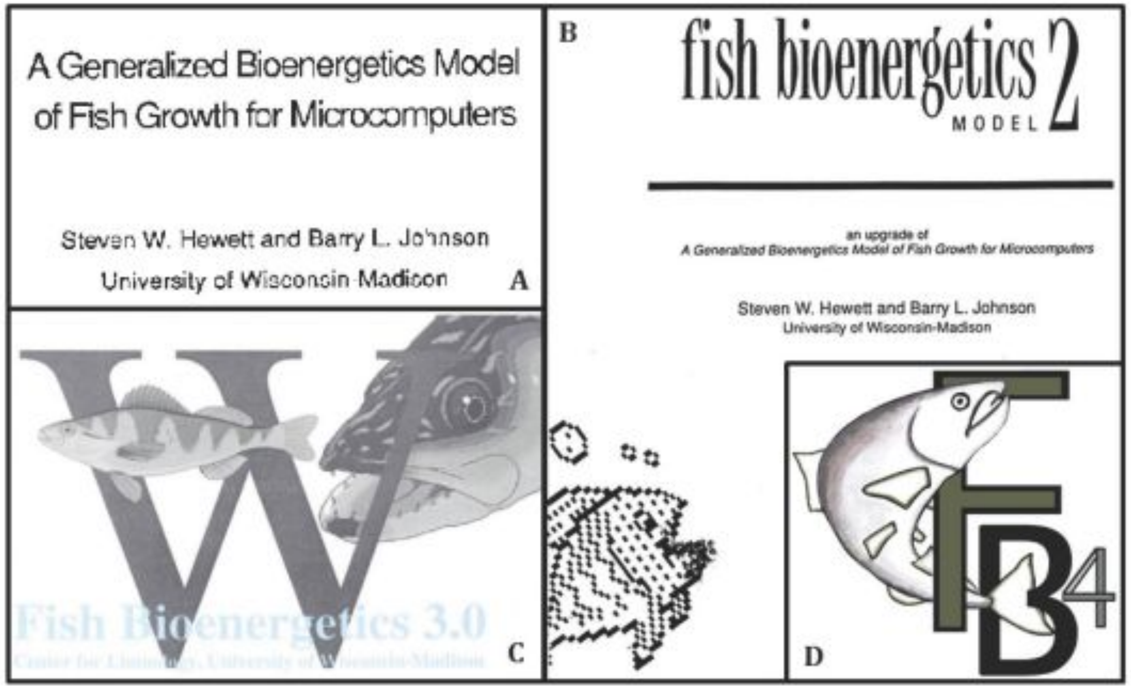


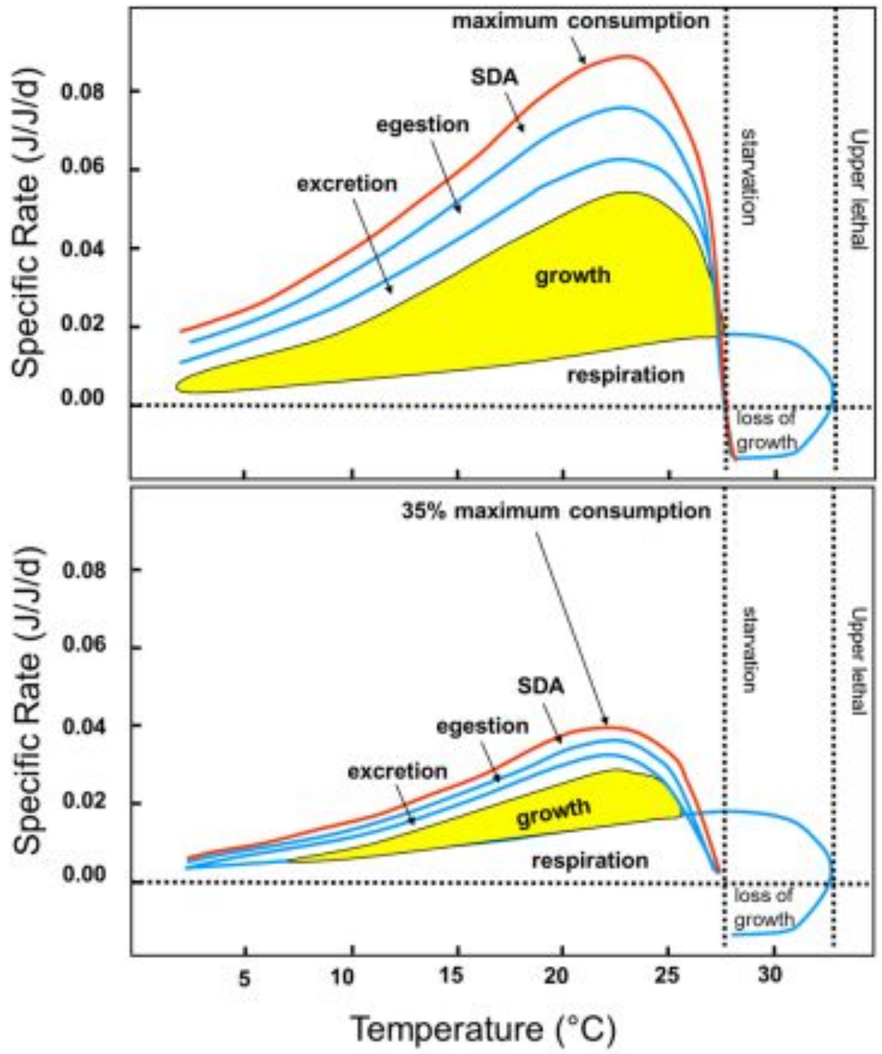
Figure 2. Cumulative number of published bioenergetics models, 1974–2017, representing 70 fish species (some at multiple life stages) and three invertebrate species.



Version 4.0 almost doubles available models (from 56 to 105)

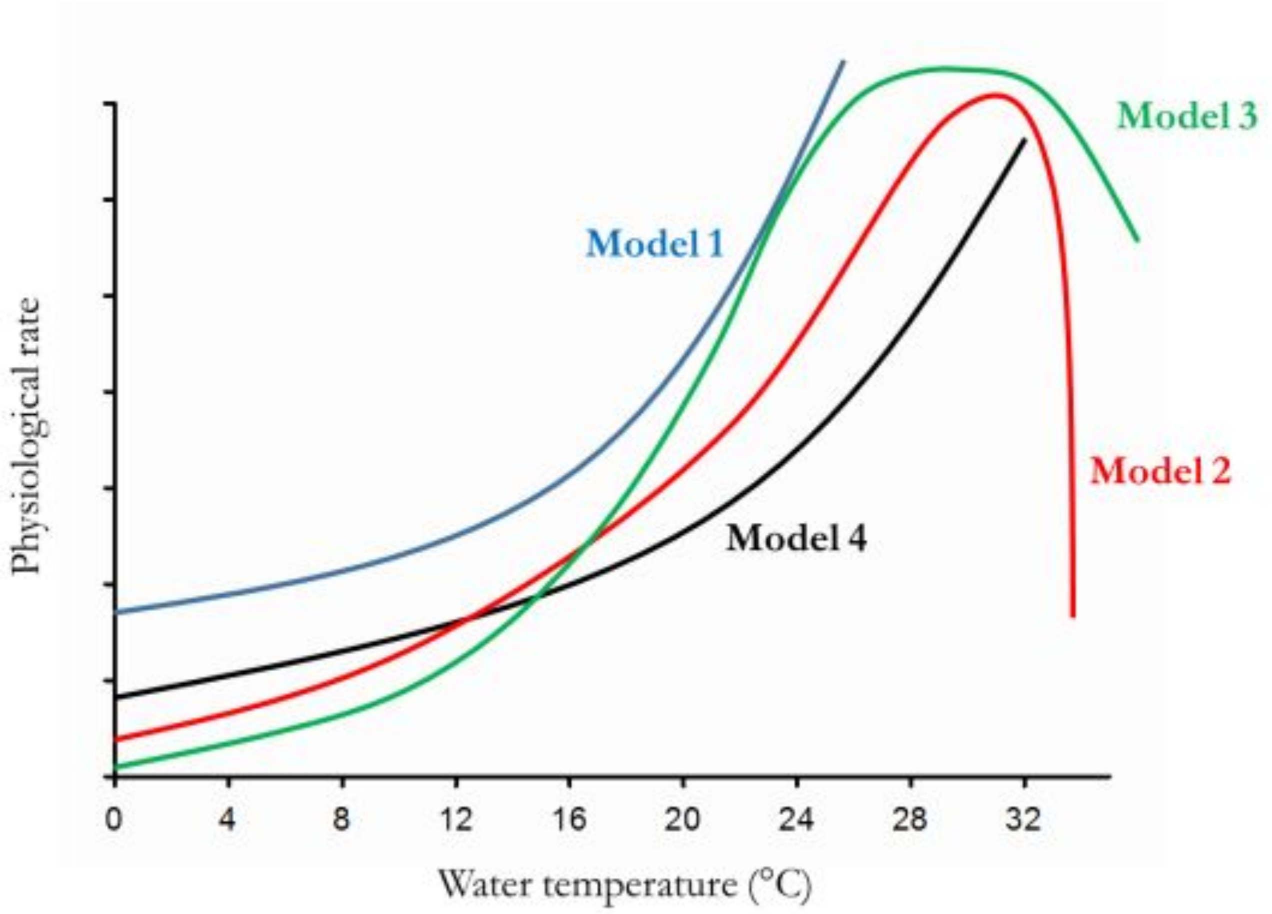
Generalized Energy Budget

- Nonlinear function of temperature
- Depends on fish feeding rate, generally expressed as proportion of maximum consumption (P).



Consumption

- Many different models possible
- FB4 adopts 4
- Depends on species
  - Warm water versus cold water



What do we need to run the model?

- Temperatures where fish live
- Fish diet
- Prey and predator energy densities

What do we need to run the model?

- Basic physiological parameters/relationships
  - Consumption (size & temp dependent) = C
  - Egestion (size & temp dependent) = F
  - Excretion (size & temp dependent) = U
  - Specific Dynamic Action = SDA
  - Basal Metabolism (size & temp dependent) = R
  - Active Metabolism = ACT

Fish Bioenergetics 4.0

- Follows a cohort through time, estimating consumption rates and growth
  - Changes with diet, temperature, etc.
- Cohort can be an individual fish, or a population
  - Group of similar sized fish of the same species, experiencing the exact same environmental conditions
- User input data are imported through .csv files
- You can add new bioenergetics models by editing a .csv file
- Everything else can be adjusted in menus, no need to know how to code in R!

Types of scenarios

- Final weight
  - User specifies the mass in g of wet weight the fish will reach at the end of the simulation
  - FB4 uses this information to iteratively calculate a P-value (proportion of C max) that will allow for the simulated final weight to equal the input final weight

Types of scenarios

- Consumption
  - User specifies the total amount of food (in g of wet weight of prey) that will be consumed by an individual fish during the simulation.
  - FB4 uses this information to iteratively calculate a P-value (proportion of C max) that will allow for the simulated final cumulative consumption to equal the input final cumulative consumption.

Types of scenarios

- Ration (wet weight)
  - User specifies a constant mass (g) of prey eaten by an individual fish on each day of the simulation.
  - With this option the model uses user-specified consumption rather than the consumption estimation function in the model.

Types of scenarios

- Ration (% of predator weight)
  - User specifies a constant percentage of predator body weight eaten by an individual fish on each day of the simulation.
  - With this option the model also uses user-specified consumption rather than the consumption estimation function in the model.

Types of scenarios

- P-value
  - User specifies a P-value (the proportion of C-max)
  - The P-value is applied to C-max (size and temperature dependent) for each day of your simulation.

Getting Started

- Install R
  - http://cran.r-project.org
- Install R Studio
  - http://www.rstudio.com/products/rstudio/download
- Download the FB4 folder
  - fishbioenergetics.org

FB4 Exercises

Simple Growth Simulation

- We have a 65 g Yellow Perch, and after a year (365 days) we want this fish to weigh 122 g.
- How much cumulative prey (in grams) did the fish eat?
- What does P equal for a fish to grow this much over the specified period of time?
- Produce a line graph showing fish weight over time (Day), as well as temperature.

Modeling Climate Effects

- Let’s model the effects of global warming on food consumption and growth of age 5 Largemouth Bass in North Carolina.
- Estimate the P-value and annual food consumption for an age-5 Largemouth Bass with an initial weight of 540 g on day 1 and a final weight of 660 g on day 365, and record your results as “Baseline”.
- Let’s assume that average, daily water temperature in High Rock Lake increases by 2 °C. For the next simulation, adjust water temperature values in the .csv file by increasing each value +2.
- Re-run your analysis assuming that feeding rate does not change. To do this, check the Fit to: P-value option, and enter the P-value from your Baseline run.
- Record total consumption and final weight as “Warming”. Calculate net change from Baseline conditions as [(Warming-Baseline)/Baseline x 100].

Population Mortality

- Run the Population (Mortality) and Reproduction submodels for a cohort of 10000 Bay anchovy
- 365 days, initial weight 15 g, fit to P-value of 0.3
- Graph Weight, Population Number, and Population Biomass
- Why doesn’t Population Number increase, even though the anchovy are reproducing?

R GRP Exercises

Modify the code: Additional days/depths

- Modify the code to run additional days or depths.

Red Snapper P Value

- In the current model, Red Snapper are assumed to feed at C max
- Add a P value to reflect a lower feeding rate
- Calculate the mean GRP before and after reducing the feeding rate.
- Is the decrease in GRP proportional to the decrease in feeding rate?

Energy density

- For one of the models, reduce prey energy density by half.
- Calculate the mean GRP before and after reducing the prey energy density.
- Is the decrease in GRP proportional to the decrease in prey energy density?