



## Laws of Thermodynamics

- 1<sup>st</sup> - Energy can be neither created or destroyed
  - Outputs = Inputs
  - Budget must balance
- 2<sup>nd</sup> – Entropy of the universe tends to increase
  - Being a fish is an uphill fight against chaos

## Bioenergetics Model

- Modeling Strategy - Focus on biomass dynamics
- Consumption = Metabolism (Respiration) + Waste (Excreted) + Growth (Production)
- $C = M + W + G$

## Bioenergetics Model

- Consumption = Respiration + Waste + Growth
- “TYPICAL”
- **Carnivores**     $100 = 44 + 27 + 29$
- **Herbivores**     $100 = 37 + 43 + 20$
- What can we see?
  - 1) Herbivores have lower growth rates and higher waste-loss rates – makes sense
  - 2) Both fishes have higher rates of growth efficiency than birds and mammals – but efficiency not a constant !! Growth highly variable – prey and environmental conditions.

## Bioenergetics Model

- Answer questions about factors that constrain growth:
  - diet quality or environmental stressors
  - use measured growth to estimate how much of an effect a predator has had on a population

## Bioenergetics Model

- **Further Breakdown – Core Processes in Bioenergetics: Energy Mass Balance Equation**
- Consumption = Metabolism (Respiration) + Wastes + Growth
- $C = R + W + G$
- $C = (\text{respiration} + \text{active metabolism} + \text{SDA specific dynamic action}) + (W = \text{egestion} + \text{excretion}) + (G = \text{somatic growth} + \text{gonad production} + \text{repairs})$
- $C = (R + A + S) + (F + U) + (B + G)$

## **Bioenergetics Model**

- Nuts and Bolts
- Consumption = proportion of the maximum daily ration for a fish at a particular mass and temperature (g prey per g body mass per day)
- Allometric function of mass from ad libitum feeding experiments at optimum temperatures

## **Bioenergetics Model**

- Nuts and Bolts
- Respiration = amount of energy used for routine metabolism; Dependent on fish size, water temperature and activity

## **Bioenergetics Model**

- Nuts and Bolts
- Waste Losses (Egestion= fecal waste and Excretion=nitrogenous waste) = constant proportion of consumption or as functions dependent on water temperature and consumption

## **Bioenergetics Model**

- Nuts and Bolts
- Growth – Reproduction – gonads produced during normal growth; loss occurs at spawning.

## **Bioenergetics Model**

- Nuts and Bolts
- Predator Energy Density = (joules per gram wet mass)
- Scaling from Individuals to Populations

## **Bioenergetics Model**

- Nuts and Bolts
- Cohort as a Population
- Cohort = group of similar sized (age) fish of same species experiencing identical environment conditions (temperature, diet, growth, and reproductive losses)

## **Bioenergetics Model**

- Nuts and Bolts
- Population Mortality – multiple causes and additive – fishing, natural etc.
- Can also do Extended Topics: Flow rates of other materials that are transferred through interactions of fishes and their prey.

## **Bioenergetics Model**

Analyses of Nutrient Regeneration – Items such as N and P are maintained at relatively constant conditions in fish tissue through homeostatic mechanisms – interested in transfer rates and rate of elimination (i.e. role fish play in lake nutrient cycles by regenerating these primary production limiting nutrients through excretion)

## Bioenergetics Model

- Contaminant Accumulation – Bioaccumulation – largely a function of its lipophilicity = efficiency with which it is eliminated from tissue; Heavy metals like mercury or polychlorinated biphenyls (PCBs). More concerned with predicting concentrations of material in fish tissue and how different environmental conditions (temperature, diet, growth, etc) alter concentrations.

## Bioenergetics Model

- Kitchell et al. 1997 – Ecological Applications
- Results (Current levels = large mesh, small mesh and beach seines):
- Absence of fishing, total predation on haplochromines increase 4X
- Large Gill Nets only, total predation on haplochromines increase 2X
- Beach Seines and small mesh gill nets = slightly greater
- Harvest of Nile Perch increase (about 3X) when only large gill nets allowed
- Conclusions:
- For cichlid conservation – let the fishery stay the same
- For Nile Perch and Fisheries economics – Ban small gill nets and beach seines – increase Nile Perch yields 2-3X
- Trade-Off :
- Goal A – Restore cichlids and old web web – do nothing, the fishery is doing it for us.
- Goal B - Maximize social/economic benefits of fishery yield – Large mesh gill nets only

## Applications Management

- Build bioenergetics model using a combination of laboratory and field methods.
- Evaluate age-specific diet and growth of fish on a seasonal basis
- Seasonal and age-specific caloric density of fish and evaluate seasonal energy density of major food types.
- Apply bioenergetics modeling to fish to examine which biological and physical factors are controlling growth.
- Apply management scenarios – see how populations and individuals respond

## Applications Conservation

- Energy costs of living in contaminated / stressed environments
- Energy allocation in contaminated / stressed environments
- Heavy Metals