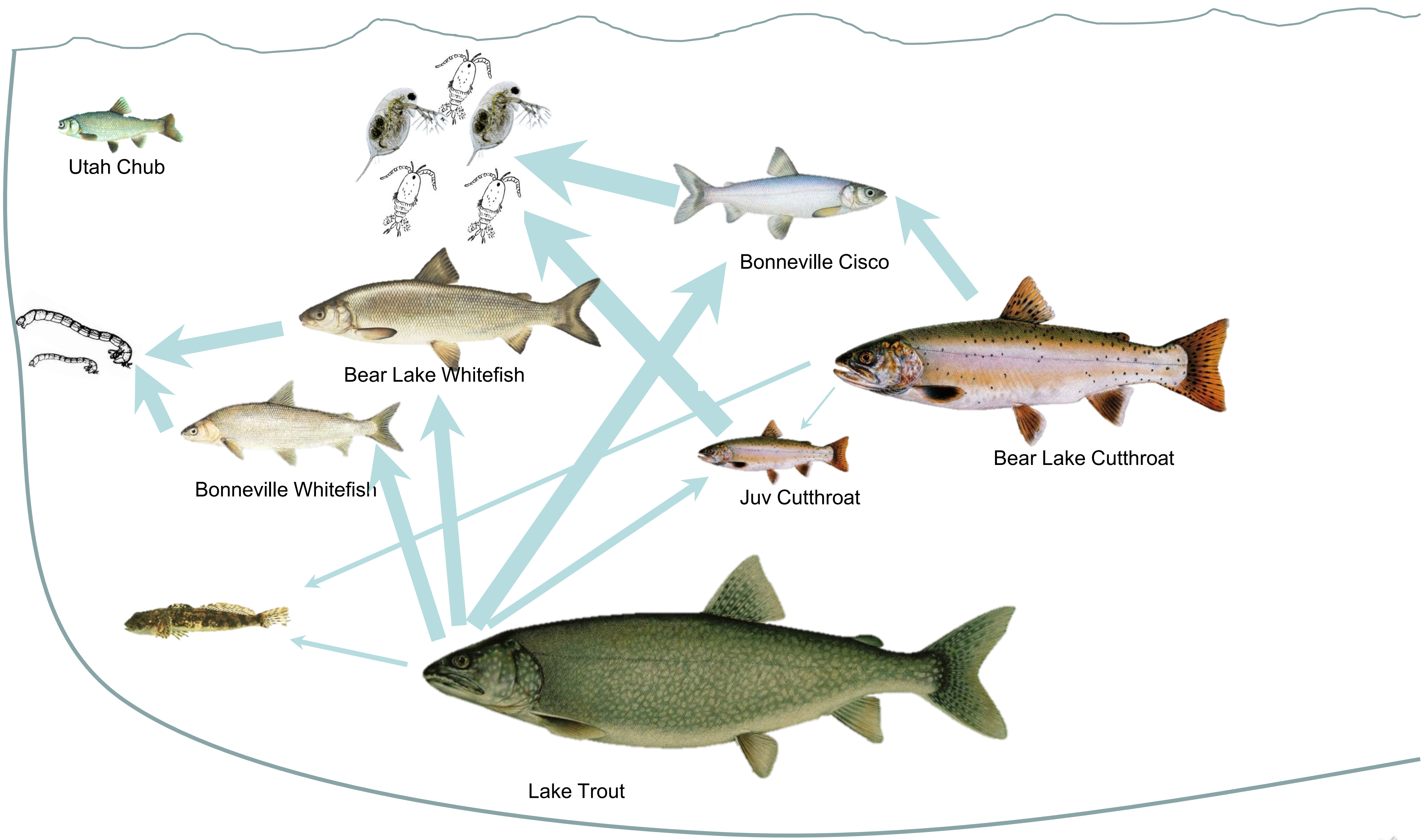
Fishery Assessments

Bear Lake Food Web



One way to estimate population consumption

- Production based approaches (Beauchamp 2007)
  - $P = GB$
  - $C_T = P/(G/C)$
  - G/C=gross food conversion efficiency

- $C_T = 2P + 3B$ (Ney 1990)

von Bertalanffy (1938)

$$\frac{dW_t}{dt} = HW_t^d - kW_t^n$$

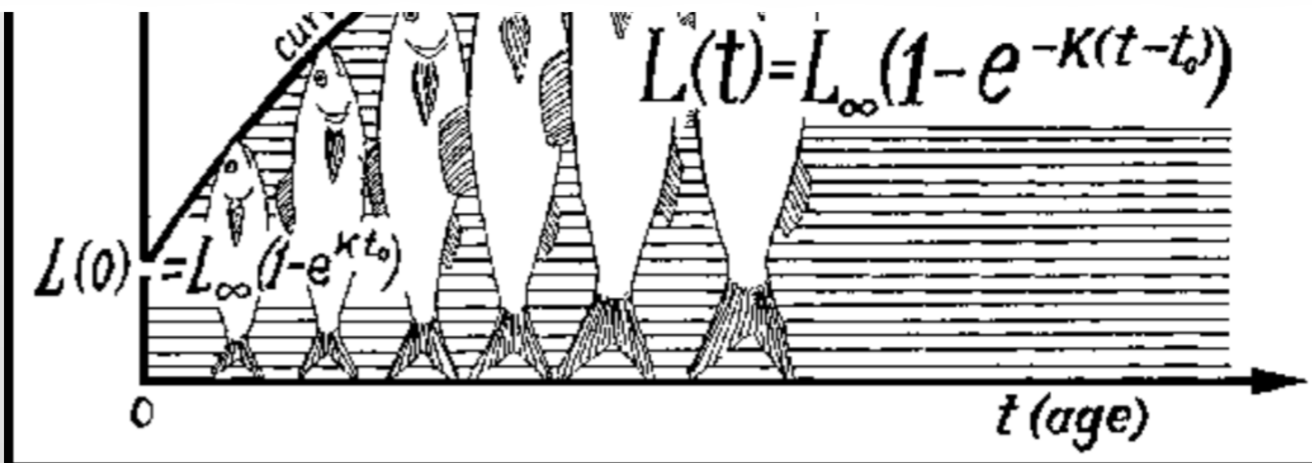
anabolism d=2/3

catabolism n=1

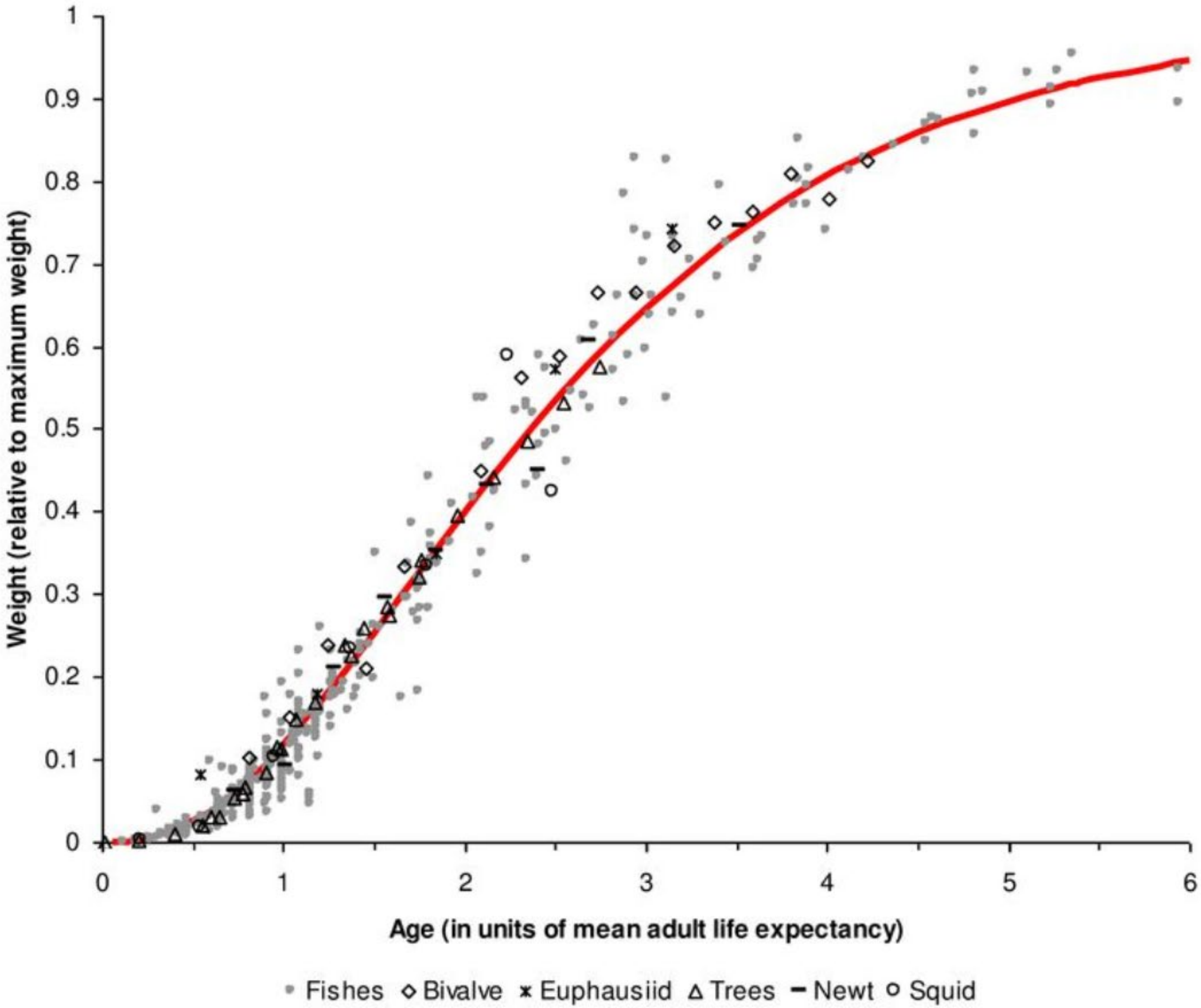
The von Bertalanffy growth function, bioenergetics, and the consumption rates of fish

Can. J. Fish. Aquat. Sci. **58**: 2129–2138 (2001)

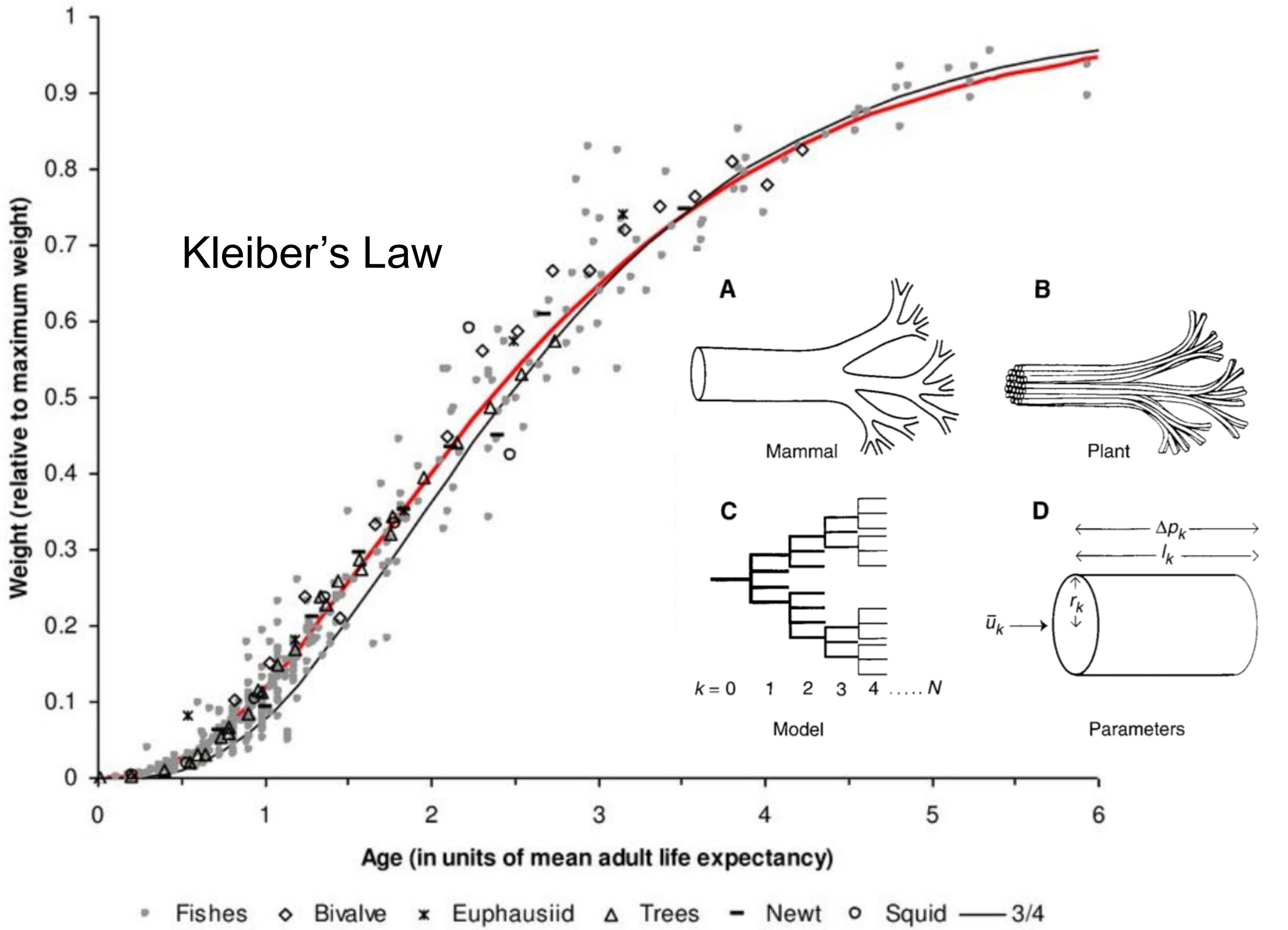
Timothy E. Essington, James F. Kitchell, and Carl J. Walters



Most Species (Exception: birds and mammals) Grow Throughout their Lifes



⅔ Versus ¾ Scaling

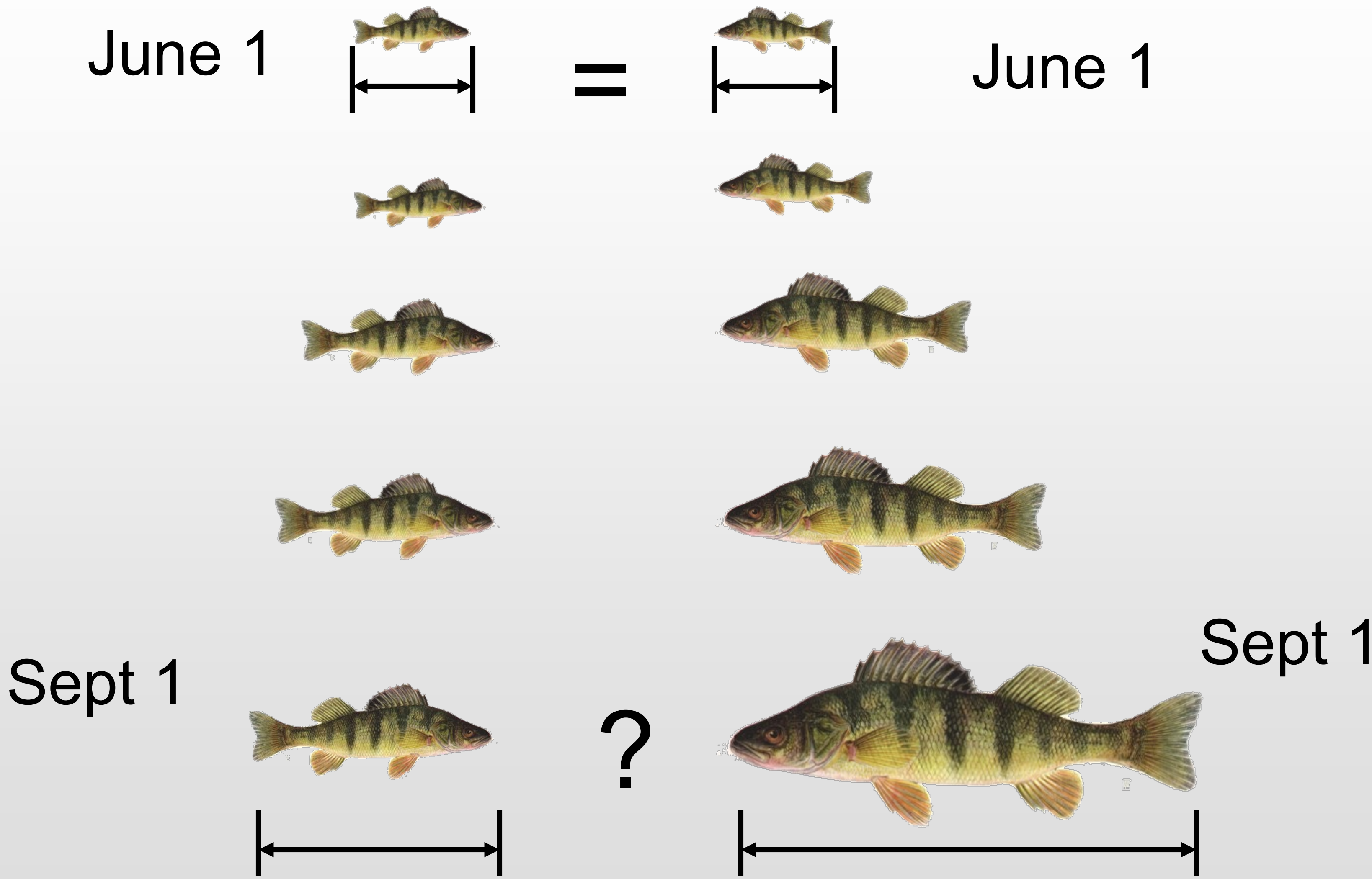


A General Model for the Origin of Allometric Scaling Laws in Biology

Geoffrey B. West, James H. Brown,* Brian J. Enquist

SCIENCE • VOL. 276 • 4 APRIL 1997

Lake Salad   Lake Cheese



Why could growth be different?

→ More food?

→ Better quality food?

→ Don't work as hard for food?

→ Lakes are different temperatures?

→ Stress, contaminants, food webs

→ Genetically different?

Fish – Habitat Relationships

Fish Habitat

Physical Habitat

Valley Setting

Channel Morphology

Hydraulics

Substrate Composition

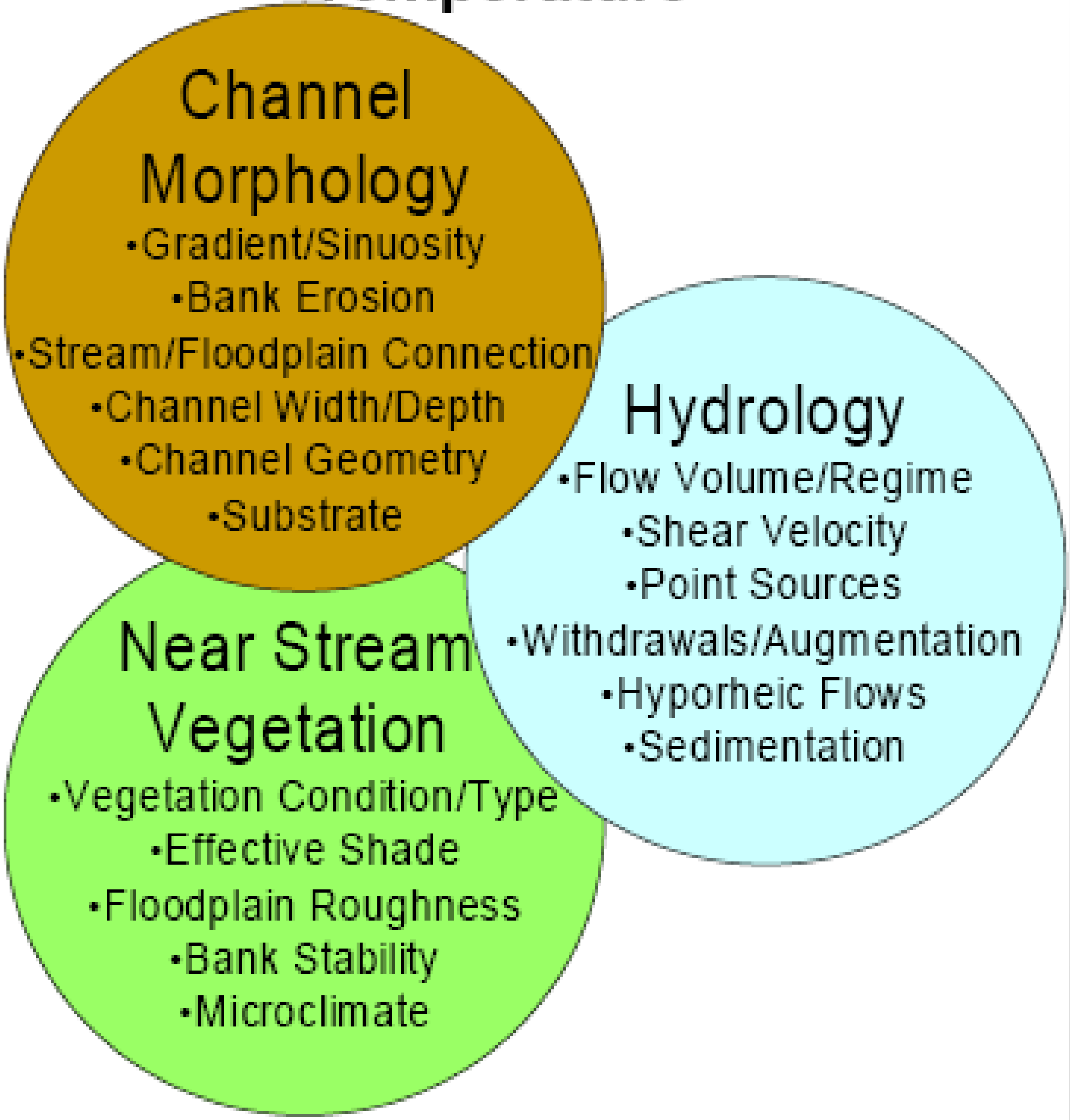
Cover

Stream Temperature

Stream Productivity

Fish Food Availability and Transfer of Energy

Factors that Affect Stream Temperature



(Many of these parameters are interrelated)

Temperature

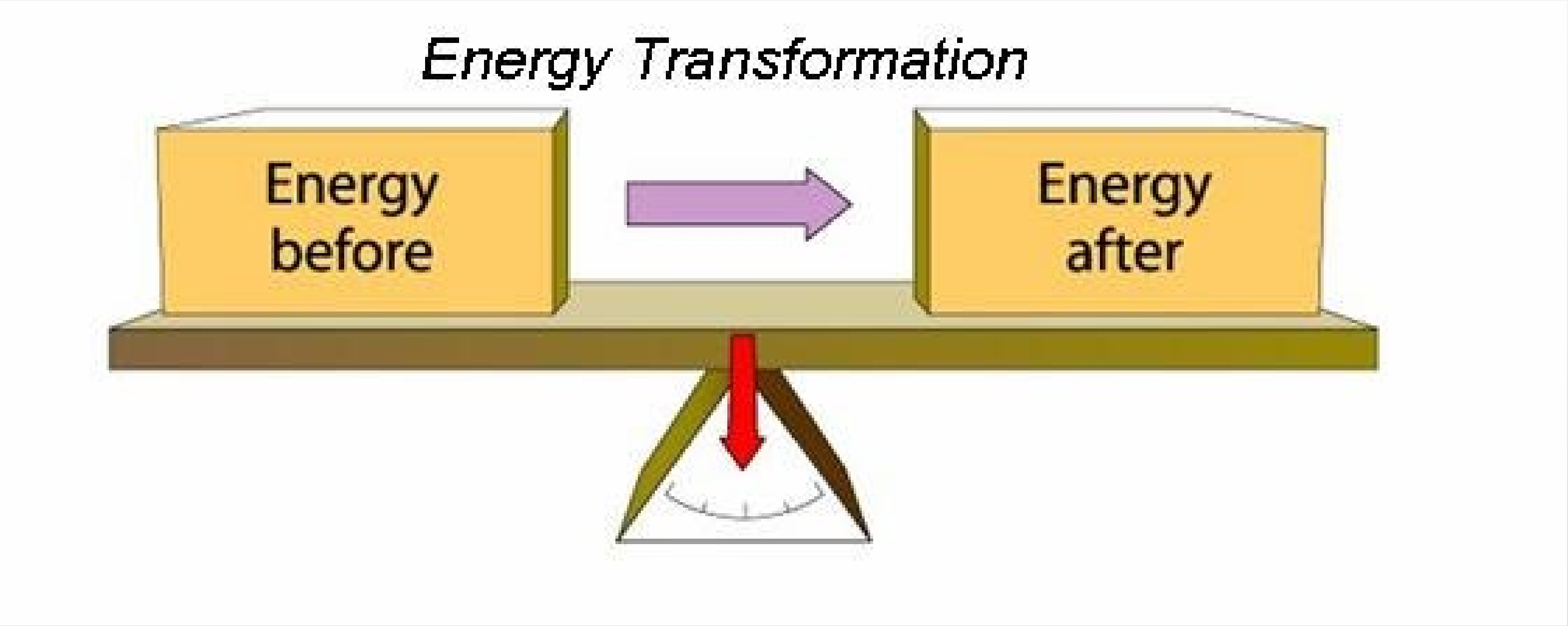
- Most physiological processes of all life are temperature dependent

- Ultimately affects growth and survival of fish across all life stages

What is Bioenergetics?

"…..the study of the flow and transformation of energy in and between living organisms and their environment"

First Law of Thermodynamics



Bioenergetics

IN
Consumption

OUT

Metabolism

Waste

Growth

Consumption = Metabolism + Waste + Growth

The Wisconsin Bioenergetics Model

What do bioenergetics have to do with the University of Wisconsin?

Applications of a Bioenergetics Model to Yellow Perch (*Perca flavescens*) and Walleye (*Stizostedion vitreum vitreum*)[1,2]

JAMES F. KITCHELL AND DONALD J. STEWART

Laboratory of Limnology, University of Wisconsin, Madison, Wisc. 53706, USA

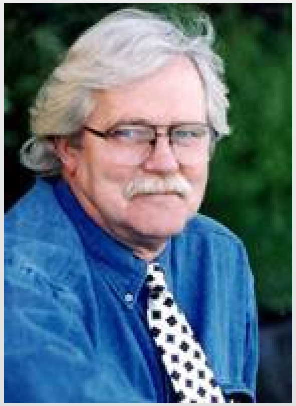
AND DAVID WEININGER

Water Chemistry Laboratory, University of Wisconsin, Madison, Wisc. 53706, USA

KITCHELL, J. F., D. J. STEWART, AND D. WEININGER. 1977. Applications of a bioenergetics model to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). J. Fish. Res. Board Can. 34: 1922–1935.

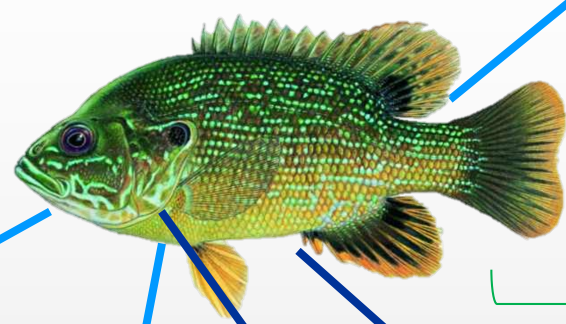
A simple energy budget equation is developed to yield a bioenergetics model designed to simulate fish growth. Parameters for the model are estimated from the literature for application to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). Simulations are presented that demonstrate model output as functions of body size, activity level, ration level, food quality, and environmental temperature. Sensitivity analyses identify the importance of food consumption, activity, and excretion as biological processes represented in the parameters. On the basis of temperature conditions in selected lakes and specified feeding levels, simulations are presented to quantify the importance of year-to-year variation of temperature in determining growth. In heterothermal systems, temperature selection by percids can have a significant effect on growth. For walleye on fixed rations, annual growth can vary from zero to twofold increments due entirely to differences in summer temperatures. Variations in food quality have lesser effects.

Key words: *Perca*, *Stizostedion*, bioenergetics model, growth, sensitivity, simulations



Jim Kitchell
Father of modern bioenergetics

Model Components:



Active Metabolism
→ Costs from activity

Consumption →

Gonads
→Reproduction

Respiration
→ Basal Metabolism

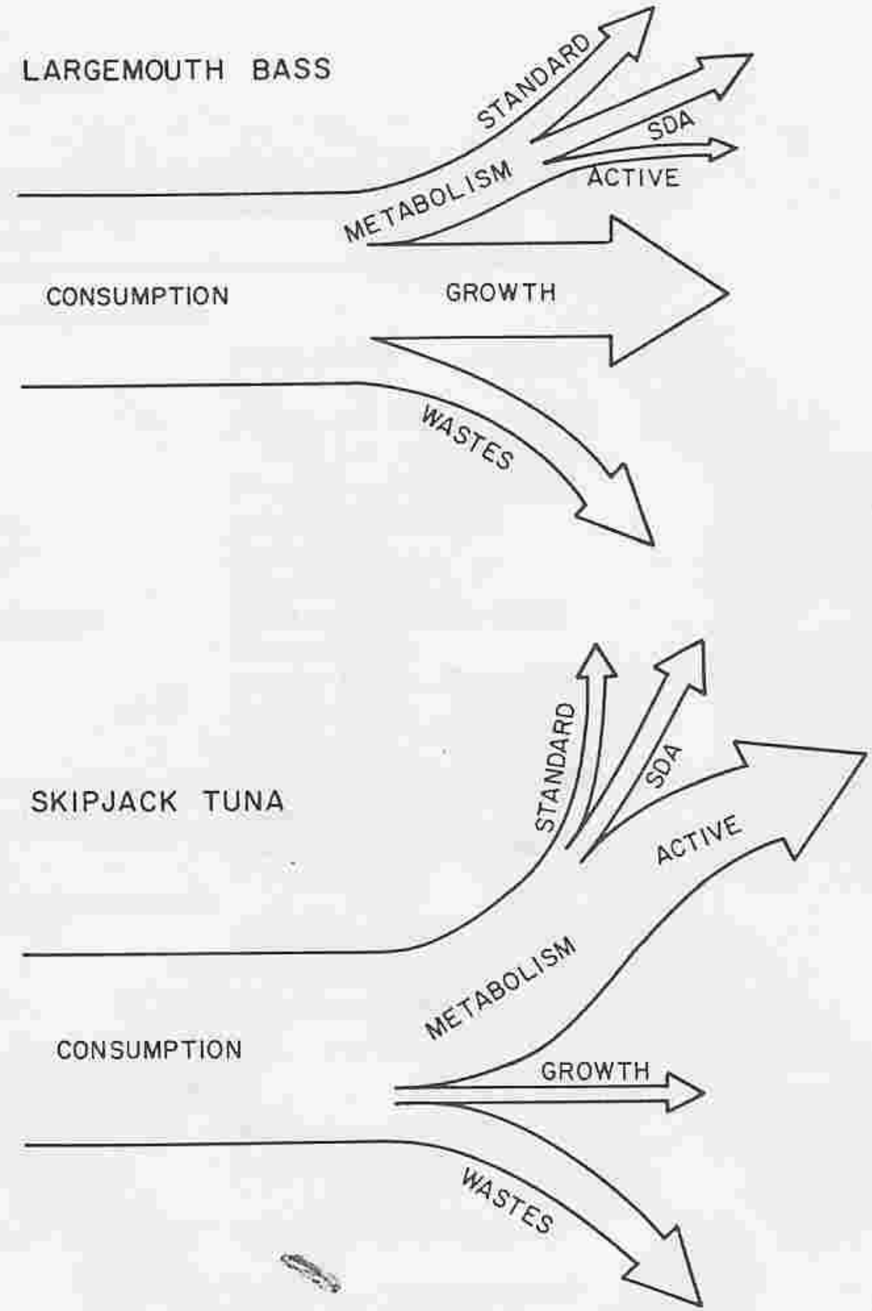
ΔBiomass

Specific Dynamic Action
→ Costs from digestion

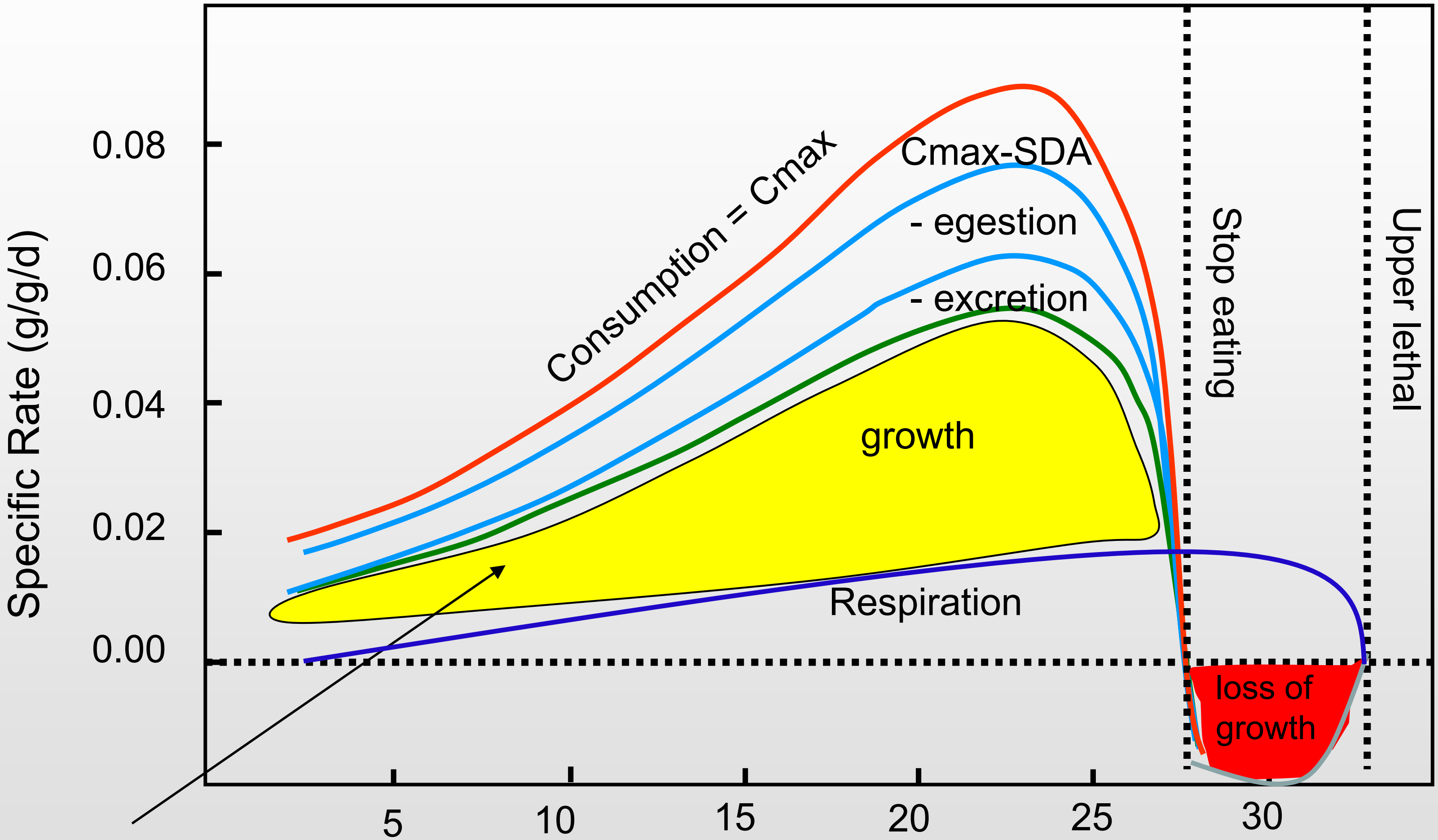
U- Excretion & F-Egestion

$$C = (R + A + S) + (U+F) + (G+\Delta B)$$

Consumption = Metabolism + Waste + Growth


LARGEMOUTH BASS
STANDARD
SDA
ACTIVE
METABOLISM
CONSUMPTION
GROWTH
WASTES
SKIPJACK TUNA
STANDARD
SDA
ACTIVE
METABOLISM
CONSUMPTION
GROWTH
WASTES

All processes are temp. and size dependent



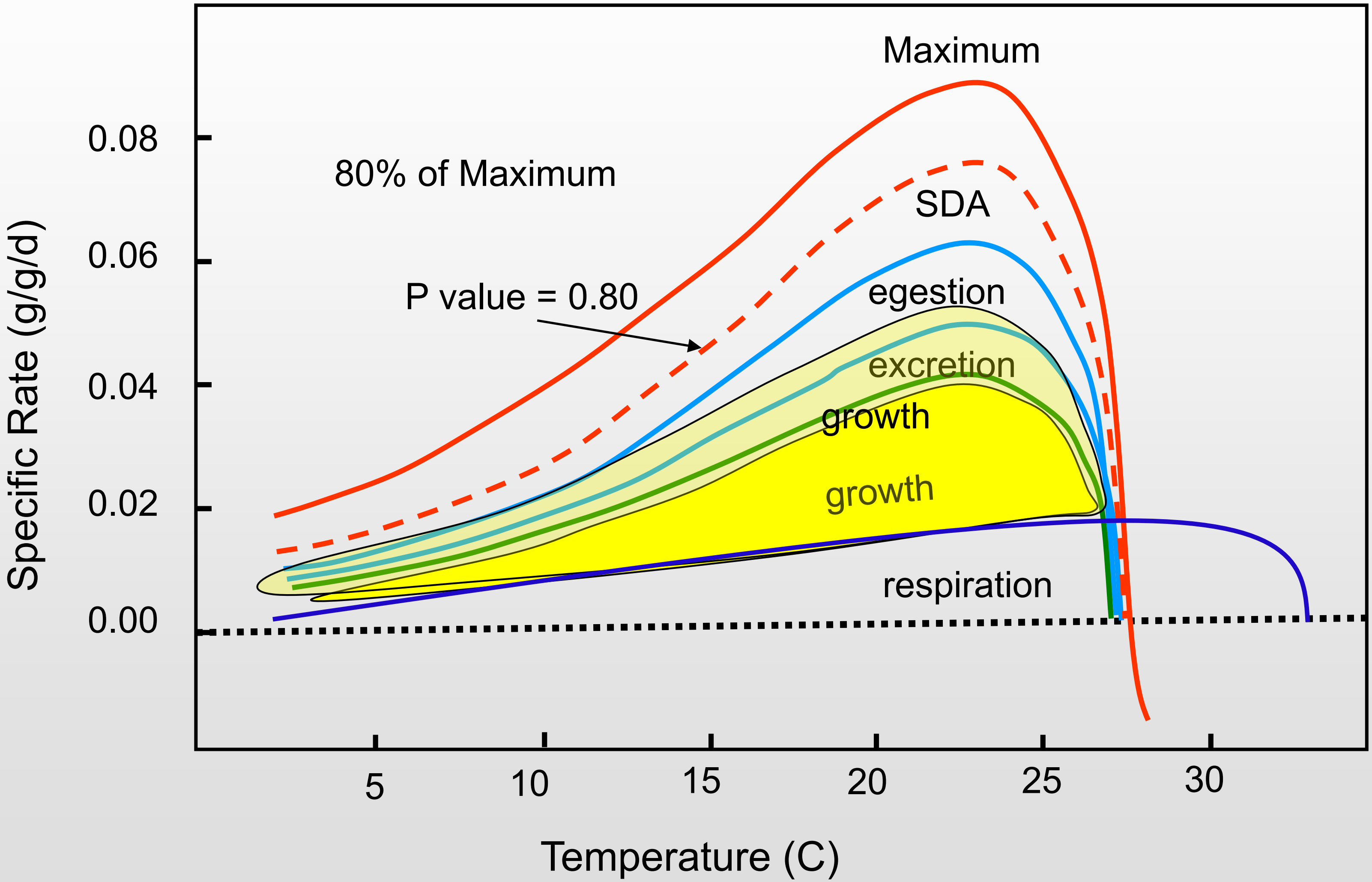
Scope for growth

“Golden Banana”

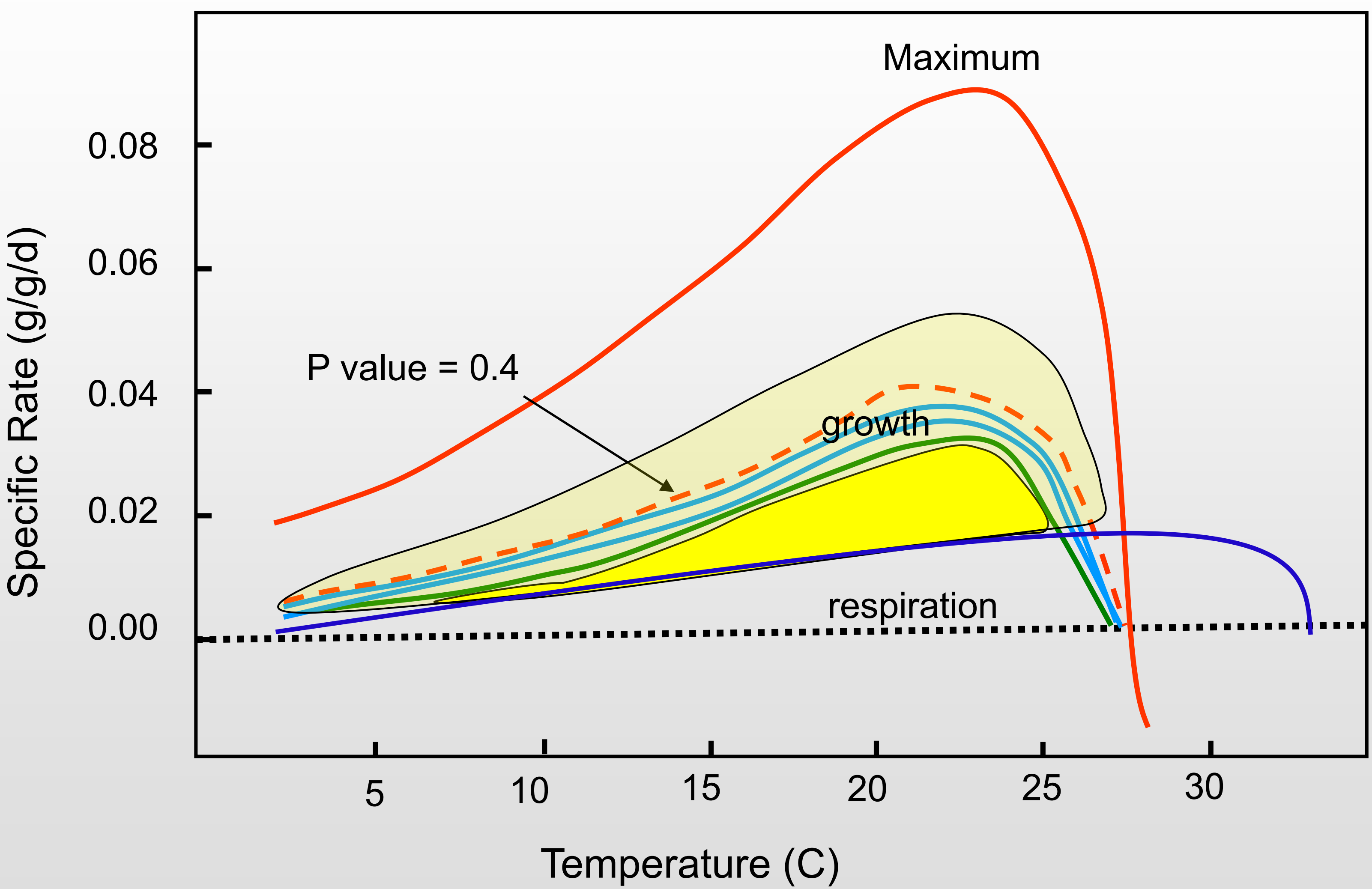
P value

- Proportion of maximum consumption
- Ranges ~ 0-1,
  - P value = 1 = consuming at 100% maximum capacity based on W and T
  - P value = 0.5 = 50%
- Index of realized consumption
- Can be related to differences in food availability, behavior, food*temperature interactions

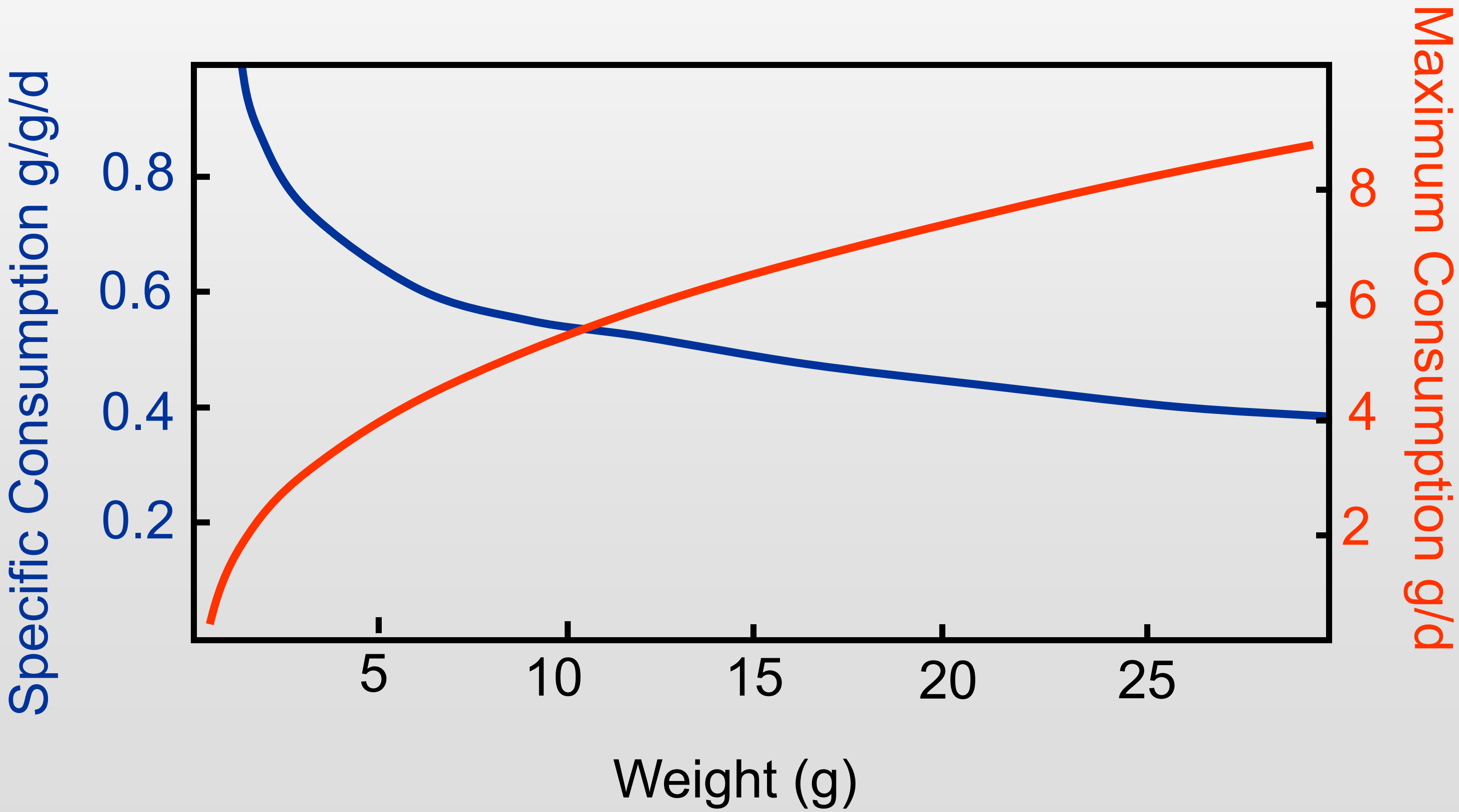
Maximum consumption isn't realistic
p-value = proportion of maximum consumption



Maximum consumption isn't realistic
p-value = proportion of maximum consumption



Consumption and Respiration → Size Dependent



Bioenergetics

IN

Consumption

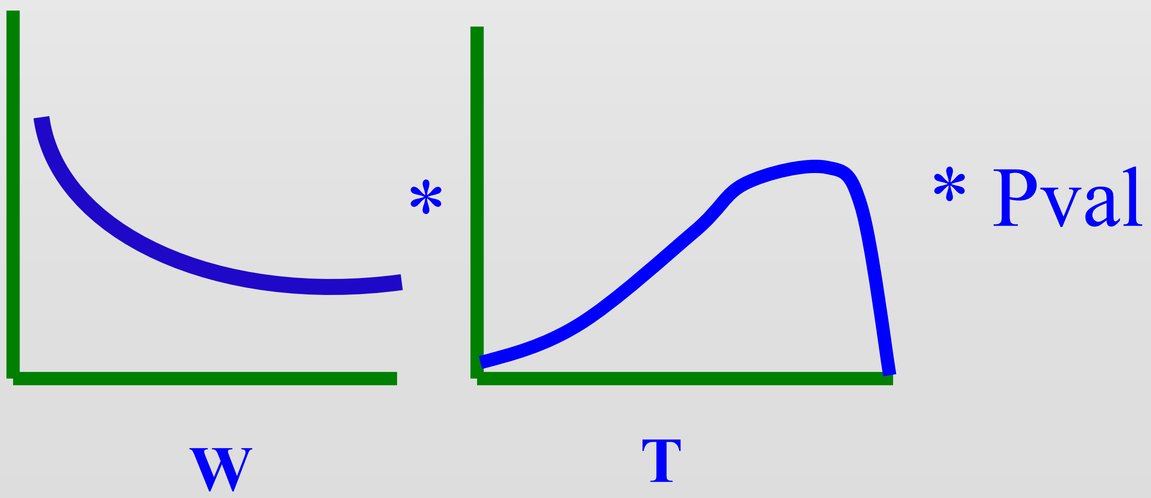
$C = M + W + G$

All energy acquired through consumption of food

$$C = G + R + W$$

Based on allometry and temperature

$$C = C\mathit{max} * f(T) * \mathit{P\text{-}value}$$



Consumption function

determined *ad libitum* feeding experiments

Size

Temp

0

2

4

6

…

28

Bioenergetics

OUT

Metabolism

C = M + W + G

(R+A+SDA)

Bioenergetics

OUT

Metabolism

$C = M + W + G$

$(\mathbf{R}+A+SDA)$

Respiration = metabolism at rest (basal metabolism)

Bioenergetics

OUT

Metabolism

C = M + W + G

↓

(R+**A**+SDA)

→ Active metabolism = cost of activity

Respiration function

determined *respirometer* experiments

Size

Temp

0

2

4

6

…

28

To estimate activity cost, you would do this across a range of velocities

Measuring Metabolism

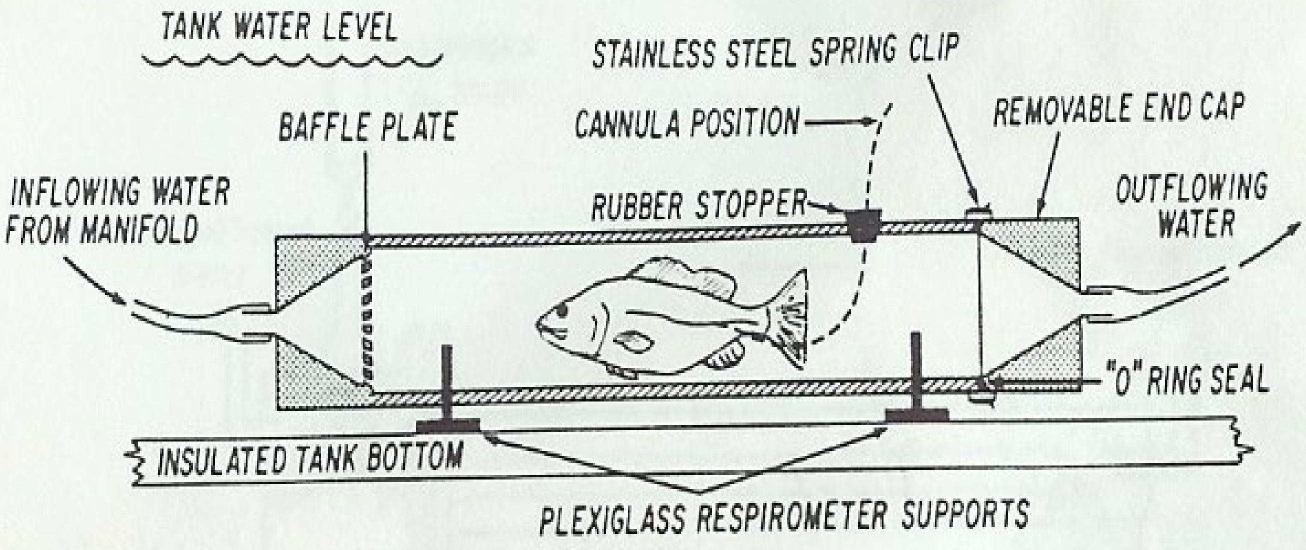
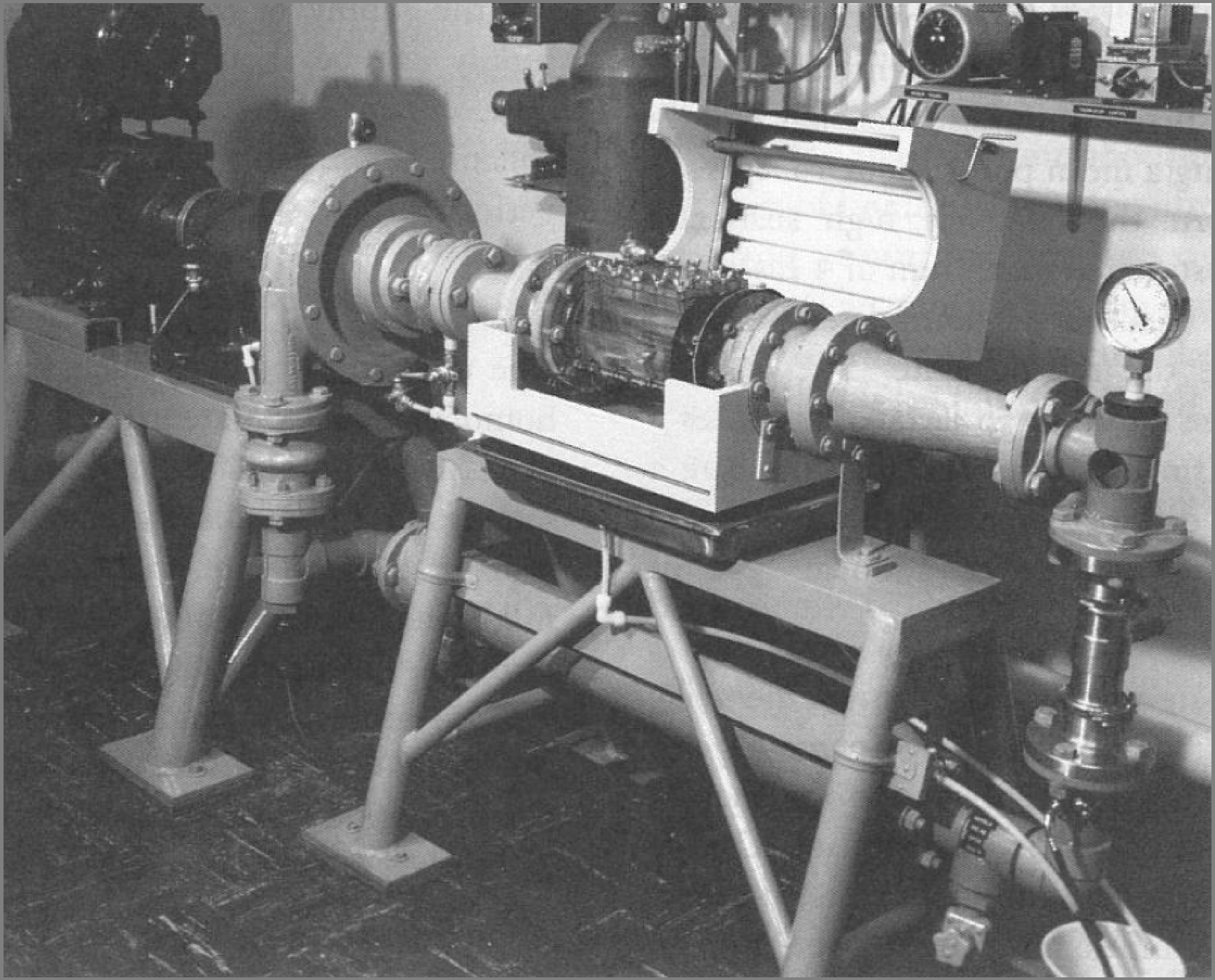


Figure 10.2 A basic flow-through respirometer. Fresh water continuously enters a cylindrical fish chamber through a baffle plate. Baffle holes are incrementally angled from horizontal in the center of the plate to the angle of the expansion cone at the margins. Dye studies show that this design minimizes eddies and dead spaces in the respirometer. Blood can be sampled through an optional vascular cannula that is led out of the respirometer via a hypodermic needle shaft inserted through a rubber stopper. (From Cech et al. 1979.)

5 degrees
10 degrees
15 degrees

5 grams
50 grams
500 grams



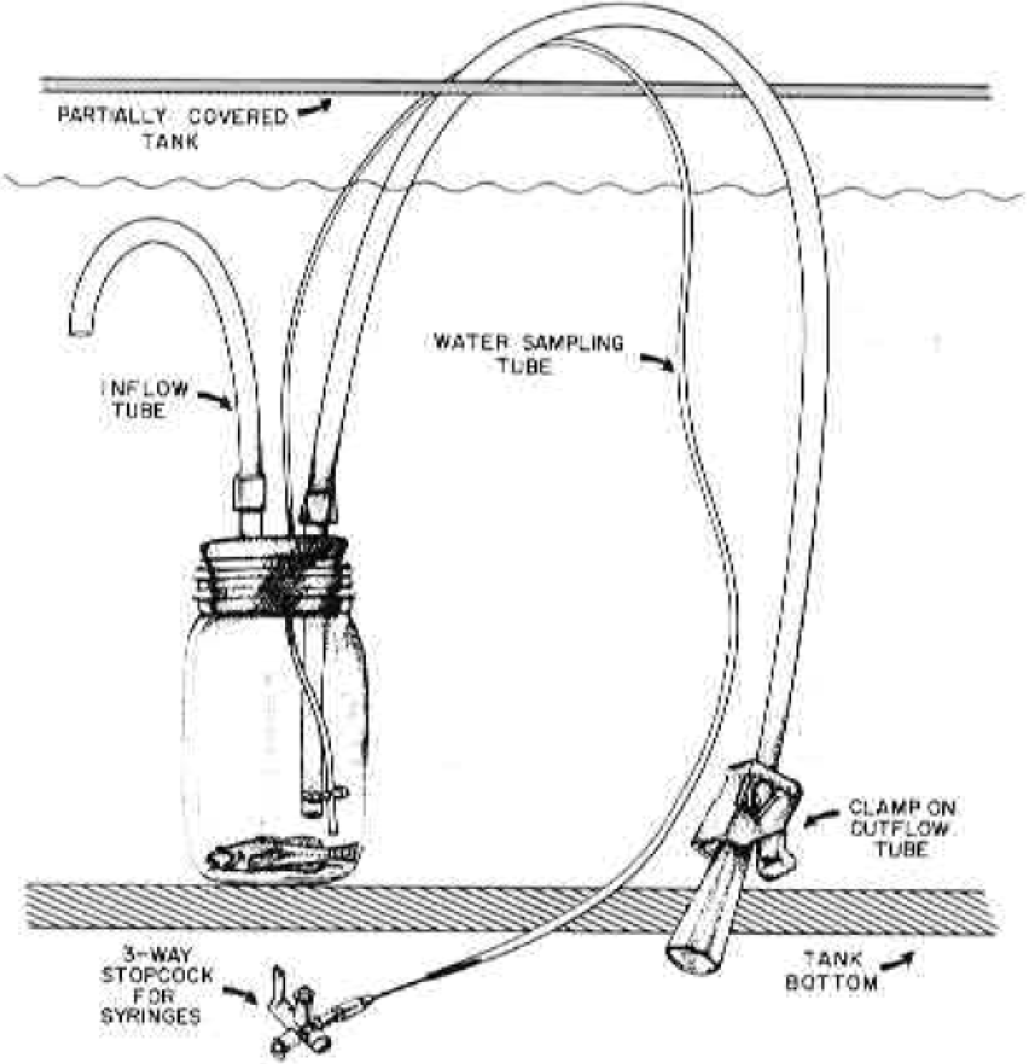


Figure 10.1 A basic static respirometer. Large-diameter tubes are used to flush the respirometer between experiments. The small-diameter tube is used to obtain water samples for O_2 analyses.

Cech 1990

Bioenergetics

OUT

Metabolism

C = M + W + G

(R+A+**SDA**)

Specific Dynamic Action

Energetic costs of processing food

Deamination of proteins etc.

Modeled as a constant proportion of food consumed (~ 15-17%)

Bioenergetics

OUT

Waste

$C = M + W + G$

$(F + U)$

Waste = Egestion (Feces) + Excretion (Urine)

- Depends on how efficiently animal digests food
  - Mixed diet = 80%
  - Carnivores = 90%
  - Herbivores = 80%

Modeled:

- constant proportion of diet
- dependent on T and ration size
- relatively insensitive

Bioenergetics

OUT

Growth

C = M + W + G

(ΔB+G)

Growth = synthesis of fish tissue/ time

i.e., change in biomass

Somatic

Gonad

$$C = (R + A + S) + (F + U) + (\Delta B + G)$$

Solve for consumption (estimate P value iteratively based on growth)

Can also organize equation in terms of growth..

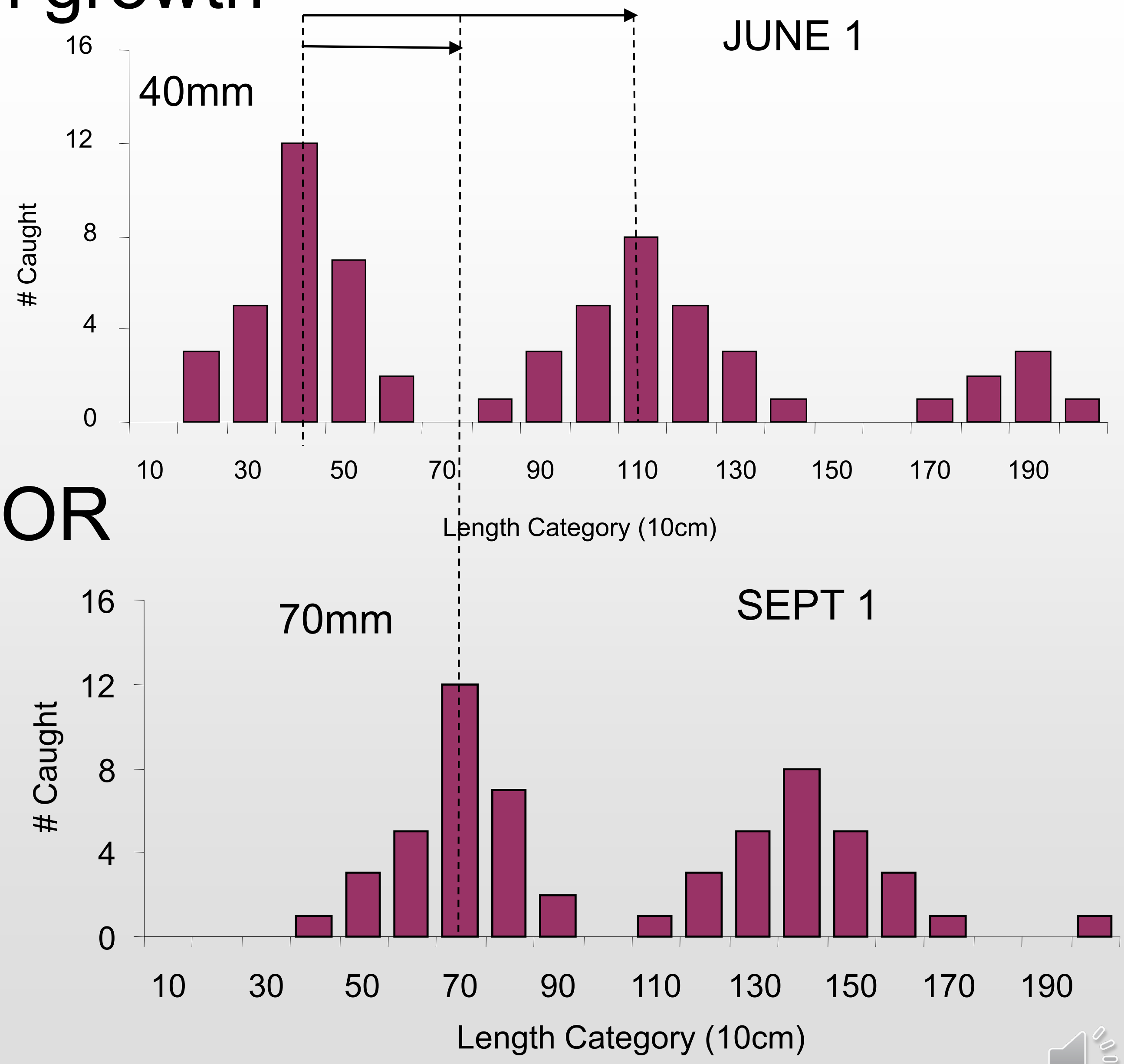
$$\Delta B = C - (R + A + S) - (F + U) - G$$

Can solve for any of the different parameters of the equations....hence the power of bioenergetics

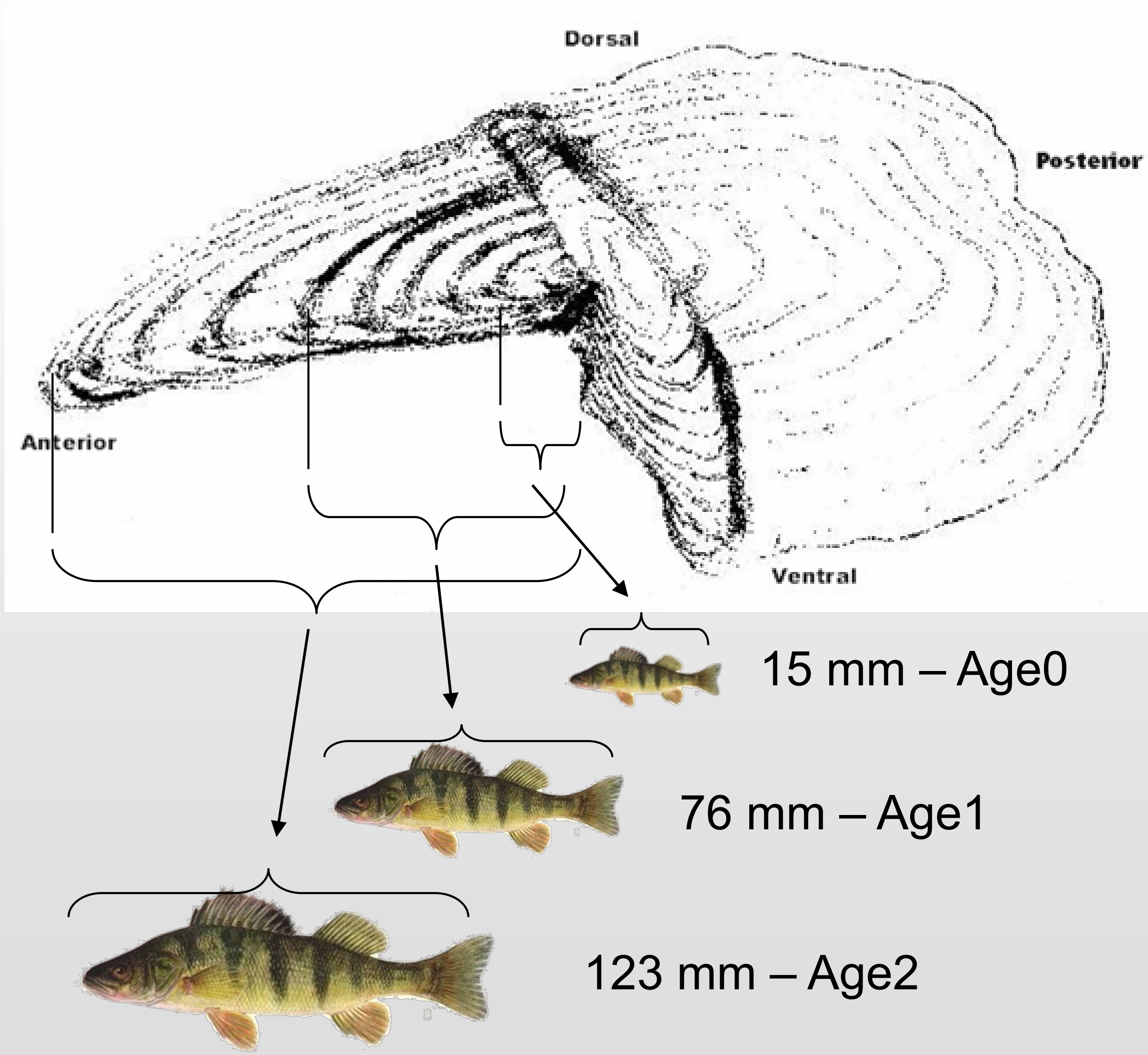
What do we need to run the model?

Measuring fish growth

OR



Measuring Fish Growth



15 mm – Age0

76 mm – Age1

123 mm – Age2

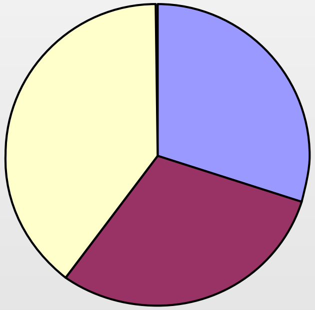
What do we need to run the model?

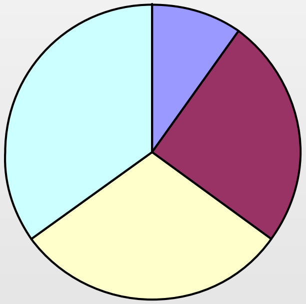
Temperatures where fish live…

- alewife - 20° C
- bluegill - 29° C
- coho salmon - 15° C
- largemouth bass – 27.5° C
- muskellunge - 26° C
- northern pike - 24° C
- rainbow smelt - 13° C
- rainbow trout - 20° C
- striped bass – 21.6° C
- walleye - 22° C
- yellow perch - 26° C
- smallmouth bass – 29 ° C
- sea lamprey - 18° C
- chinook salmon - 15° C

What do we need to run the model?

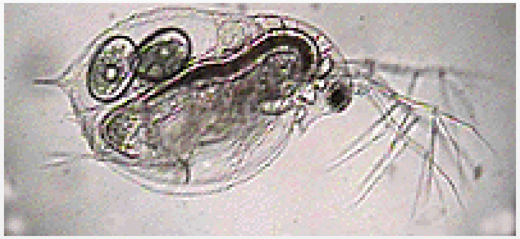
What a fish eats …





What do we need to run the model?

Prey and Predator Energy Densities …



Zooplankton – 2513 j/g wet mass

Inverts ~ 2500 j/g wet mass

Snails – 18000 j/g dry mass

Crayfish – 3766 j/g wet mass

Yellow Perch – 5000 j/g wet mass

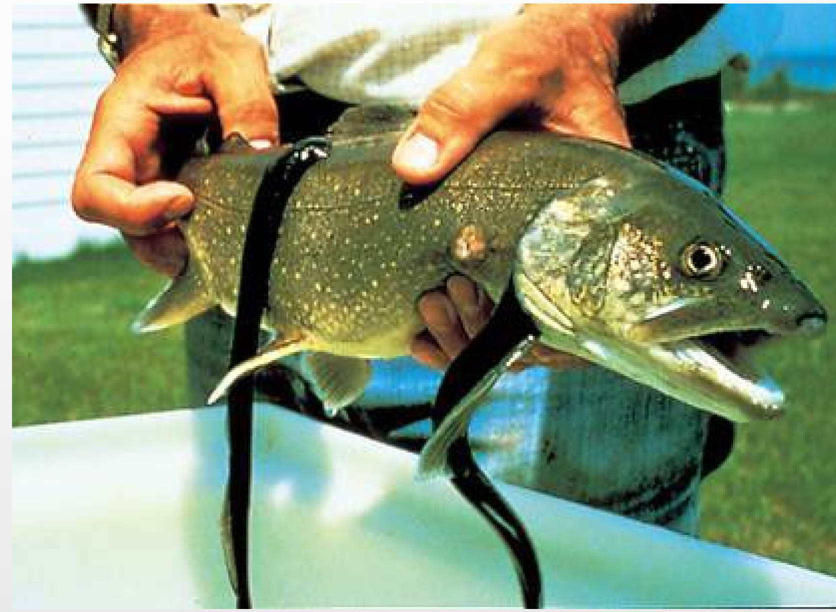
Leech – 24000 j/g dry mass

Alewife – 7225 j/g wet mass

How have bioenergetic models been used in fisheries?

Sea Lamprey Control and Lake Trout

Control of sea lamprey will result in a 5% increase in lake trout survival



How much will rainbow smelt mortality increase?

Calculate increase in trout biomass, then use bioenergetics to calculate increase in consumption of rainbow smelt

Rainbow smelt mortality will increase by 3 percent

(La Bar 1993)

Alewives and P Cycling in Lake Michigan

Alewives may promote phytoplankton growth by recycling P through egestion and excretion

Question: How much do alewives in Lake Michigan contribute to phosphorus regeneration?

Bioenergetics nutrient analysis was used to find that 12,000 metric tons of P were regenerated per year

Strong year classes may result in algal blooms

(Kraft 1993)

Climate change and sockeye salmon production

Climate change may result in increased temperatures and less upwelling

How will this affect production of sockeye salmon?

If temperatures increase 2-4 degrees C, the combination of lower food availability and higher temperatures would result in a 10-30% decrease in adult mass may also lead to lower juvenile survival

(Hinch et al 1995)