WF4133-Fisheries Science

Lecture 5-Length-Weight Continued, Growth & Population Dynamics

Housekeeping

- MS Position-Peacock bass

Housekeeping

This class

Objective(s):

1. Continue size structure and condition

2. Understanding growth & population dynamics!

Fisheries icon: Bill Ricker

ENSHRINED 1993
DR. WILLIAM E. RICKER

Dr. Ricker developed many fish population systems and published, "Methods of Estimating Vital Statistics of Fish Populations," in 1948. In 1958, he published a more extensive text which is still used by field biologists and in the classroom today.

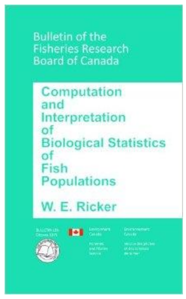
Dr. W.E. Ricker

- Started out as an entomologist-stoneflies
- Published over 400 items!
- 1950 Ricker became editor of the *Journal of the Fisheries Research Board*

Scientific contributions

- The Ricker Model
  - Relates stock size to recruitment

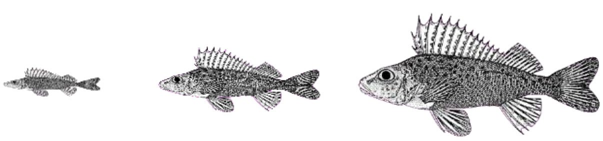
$$a_{t+1} = a_t \cdot e^{r \cdot (1 - \frac{a_t}{k})}$$



Allometric scaling

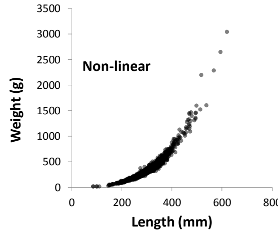
- if b>3 then fish gets more plump with time

$$W = a \cdot L^{b>3}$$

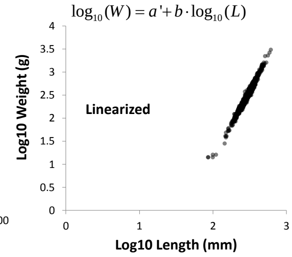


Estimating weight from length

$$W = a \cdot Length^b$$



$$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$$
$$\log_{10}(W) = a' + b \cdot \log_{10}(L)$$

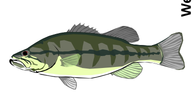


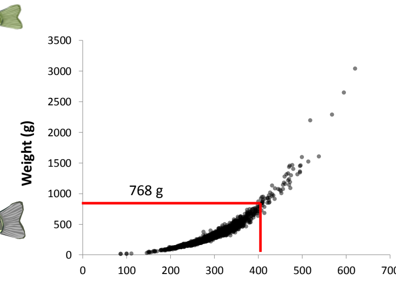
Straightening the curve

Law of logarithms

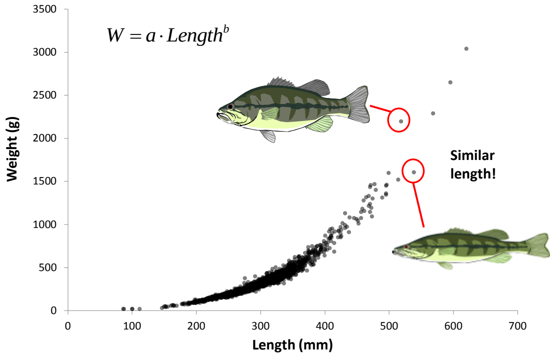
$$W = a \cdot L^b$$
$$\log_{10}(W) = \log_{10}(a \cdot L^b)$$
$$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$$
$$\log_{10}(W) = a' + b \cdot \log_{10}(L)$$
$$a' = \log_{10}(a)$$
$$10^{a'} = a$$

Length-weight data





Condition



Relative weight (W_r): a measure of condition

$$W_r = \frac{Weight}{Weight_{standard}} \cdot 100$$

Where,

Weight = actual weight

$Weight_{standard}$ = length-specific standard weight predicted by a length-weight regression constructed to represent the species (75th percentile)

$$Log_{10}(Weight_{standard}) = a' + b \cdot log_{10}(Length)$$

Where,

a' = intercept

b = slope

Standard Weight

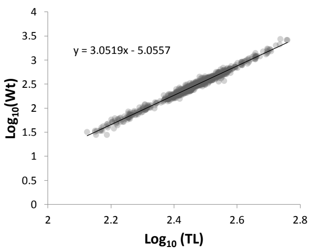
Standard weight equations are fit in several ways, but generally speaking, you use linear regression on weight-length data from the species range.

$$W = a \cdot Length^b$$

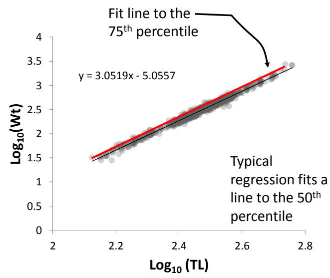
However, we regress through the 75th percentile to get an equation that represents the healthiest fish. The equation above can be linearized:

$$Log_{10}(Weight_{standard}) = a' + b \cdot log_{10}(Length)$$

Fitting Standard Weight



Fitting Standard Weight



Standard Weights

- Predicted as the 75th percentile of mean weights from many populations given observed length
- Largemouth Bass W_s equation

$$W_s = 10^{-5.528} \cdot L^{3.273}$$

Relative Weights (Wr)

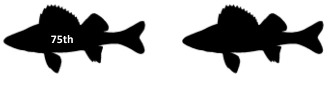
- Generally accepted method of computing body condition
  - More accepted in N.A. than in Europe
- Computed as

$$W_r = \frac{W}{W_s} \cdot 100$$

Where W is the length and W_s is the standard weight

Wr Interpretation

- Thus, Wr=100 if fish is at 75th percentile of mean weights for many stocks



Wr=100

- If Wr < 100 then a fish is less “plump” than an average fish of the same length from 75% of stocks.

Wr<100

Intercept (*a′*) and slope (*b*) parameters

Species	Intercept (*a′*)	Slope (*b*)	Minimum TL	Source
Largemouth bass	-5.528	3.273	150	Henson (1991)
Bluegill	-5.374	3.316	80	Hillman (1982)
Redear sunfish	-4.968	3.119	70	Pope et al. (1995)
Channel catfish	-5.800	3.294	70	Brown et al. (1995)
White bass x striped bass	-5.201	3.139	115	Brown and Murphy (1991)
Black crappie	-5.618	3.345	100	Neumann and Murphy (1991)
White crappie	-5.642	3.332	100	Neumann and Murphy (1991)

Example:

A largemouth bass is caught by electrofishing the is 356 mm and 632 g.

- Henson (1990) determined a’ = -5.528 and b = 3.273 for largemouth bass.

$$W_r = \frac{W}{W_s} \cdot 100$$

$$W_r = \frac{632}{10^{-5.528} \cdot 356^{3.273}} \cdot 100$$

$$W_r = \frac{632}{665} \cdot 100$$

$$W_r = 95$$

Interpretation

- If the mean W_r < 100 then fish in stock are less plump, on average,
- Relative to an fish from the 75th percentile
  - less plump than an "above average" standard.
  - should not be surprised to see values < 100

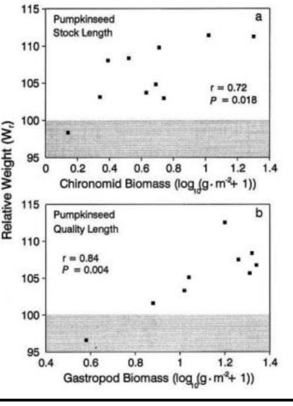
Some uses

- W_r values are well below 100 for an individual or a size-group, problems may exist in food or feeding conditions
- W_r values are well above 100, fish may not be making the best use of a surplus of prey.

Trends and patterns?

- Can be evaluated by plotting individual W_r values by fish length or mean W_r values for length-groups
- Calculation of mean W_r for an entire sample can mask important length-related trends in fish condition
- The length-groups defined by the five-cell PSD model provide a convenient basis for determination of W_r values.
- Low W_r for a length-group could be evidence of competition influencing growth.

Wr Interpretation -- Example



Low W_r values are assumed to reflect prey scarcity, whereas high values are assumed to reflect an abundance of prey. Our results provide some support for this relationship. Benthic invertebrates are known to be very important in the diets of pumpkinseeds (Scott and Crossman 1973; Sadzikowski and Wallace 1976; Keast 1978), and W_r of both stock and quality length pumpkinseeds was positively correlated with benthos biomass in our study lakes. Our results also corresponded well with the known dietary shift by pumpkinseeds; W_r of stock length fish was positively correlated with chironomid biomass, and W_r of quality length fish was positively correlated with gastropod biomass.

FIGURE 5.—Relationships of relative weight (W_r) of **(a)** stock length (80 mm) pumpkinseeds with chironomid biomass and **(b)** quality length (150 mm) pumpkinseeds with gastropod biomass in southern Quebec lakes. Data points represent lake averages; prey data are from Pierce et al. (1994). Spring 1988 W_r data were not included in calculation of lake averages. Shaded areas indicate W_r less than 100.

From Liao et al. 1995. *Transactions of the American Fisheries Society 124:387-400.*

Body Condition

Wr Interpretation -- Example

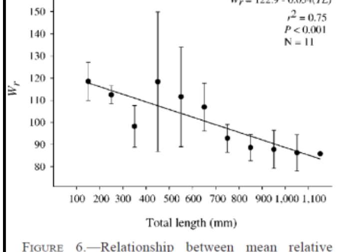


FIGURE 6.—Relationship between mean relative weight (W_r) and total length (TL) for flathead catfish collected from the lower St. Joseph River, Michigan, during 2002 and 2003. Individuals were pooled into 100-mm length groups. Error bars represent 95% confidence intervals. Confidence intervals were not calculated for the 1,100-mm size-class because only one fish was collected.

the decline in W_r with increasing length may indicate a lack of adequate prey sizes for larger fish. Adult flathead catfish are known to be highly piscivorous (Minckley and Deacon 1959; Turner and Summerfelt 1971; Jackson 1999); forage fish make up as much as 95% of the diet of fish greater than 600 mm TL (Weller and Robbins 1999). Studies by Brown and Dendy (1961) and Haas et al. (2001) found a positive relationship between prey size and the TL of flathead catfish, suggesting that larger fish selected larger forage. The high relative abundance of large flathead catfish in the lower St. Joseph River, which results from low exploitation and high survival, may limit the availability of prey items selected by these fish.

From Daugherty and Sutton. 2005. *North American Journal of Fisheries Management 25:1191–1201.*

Body Condition

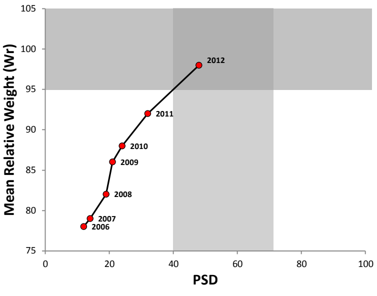
Factors affecting condition data

- Not a good idea to combine condition data from different seasons.
- Mature and immature fish are best analyzed separately.
- May need to analyze male and female fish separately.

Factors affecting condition data

- Target W_r may need to be adjusted for region.
- Genetic differences may play a role.
- W_r provides a means for comparison and standardization across habitats.

Integration of size structure and W_r



Rules of thumb

- Five fish per length interval (e.g., 1 cm)
- Measure more fish if males and females have different weight–length relationships
- Do not include small fish in weight–length analyses if weights are inaccurate or precision is low.

GROWTH

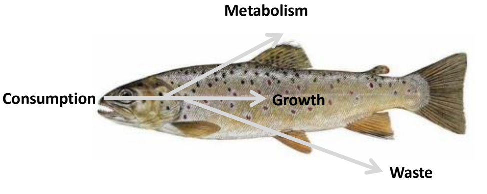
What is growth?

- Addition of mass in the form of new tissue
- Assimilation of prey items
- Measured as a rate with units:

$$\frac{Weight}{Time} \quad \text{Or} \quad Weight^{-Time}$$

The energy budget:

Writing the simplest form of the energy budget:
Consumption = Metabolism + Waste + Growth



Measuring individual growth

Instantaneous growth

$$G = \frac{log_e weight_{t+dt} - log_e weight_t}{dt}$$

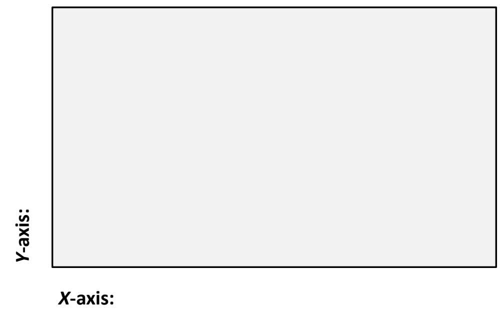
Where

G is growth in weight time^{-1}

Weight is weight

dt is change in time

Why all the logs?



Growth process

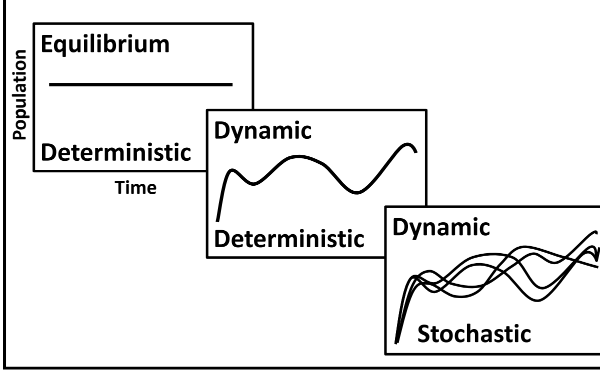
Population dynamics are important to understand the effect of fishing on fish populations.

POPULATION DYNAMICS

Population dynamics

- What are population dynamics?
- Suppose in 2005 we have a pond with 10 Largemouth bass in it.

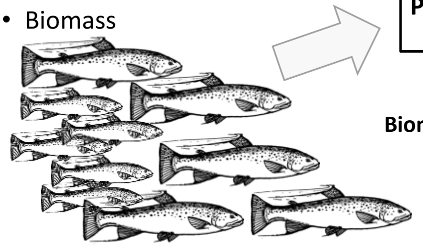
Population model types



Thinking *inside* the box

Population

- Abundance
- Biomass



Population

N=10
Or
Biomass = 10.2 kg

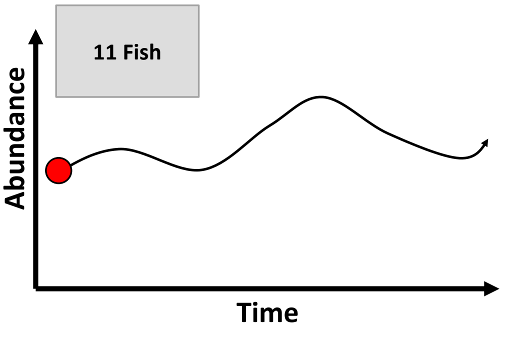
46

Thinking *outside* the box

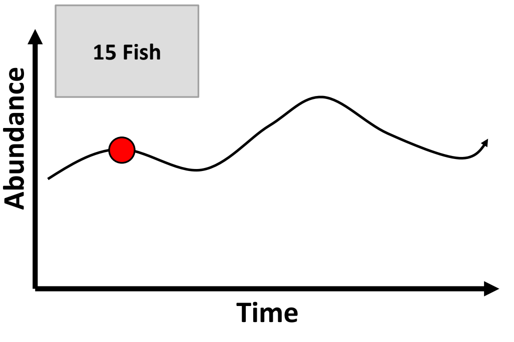
Population dynamics in a nutshell:

[Population change] = [Inputs] – [Outputs]

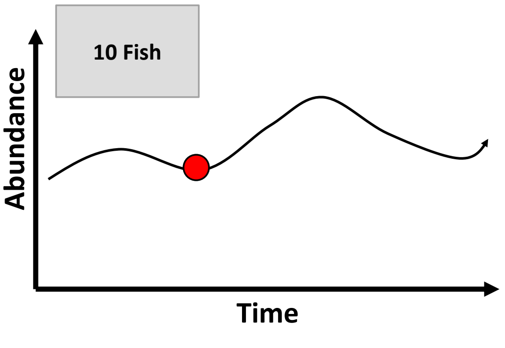
2014



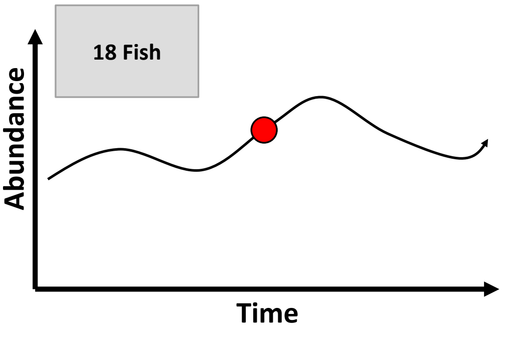
2015



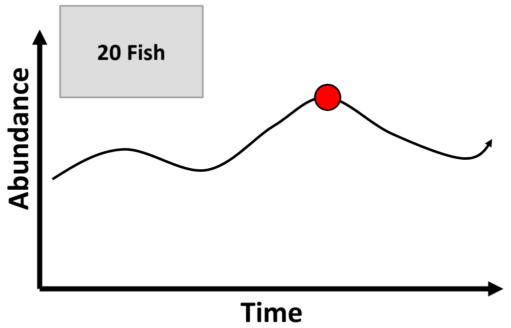
2016



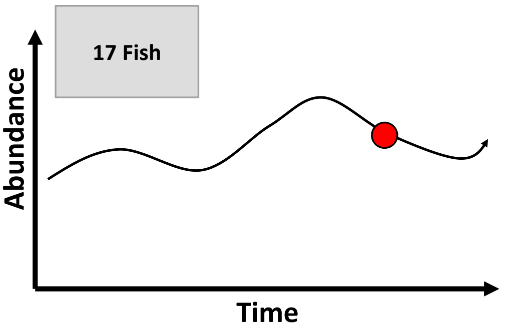
2017



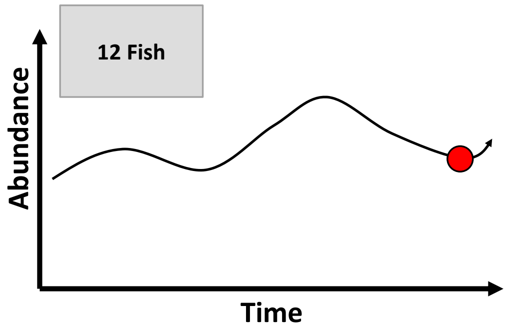
2018



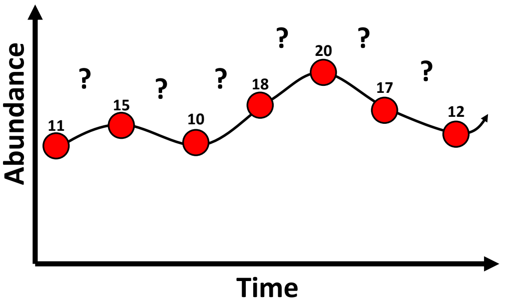
2019



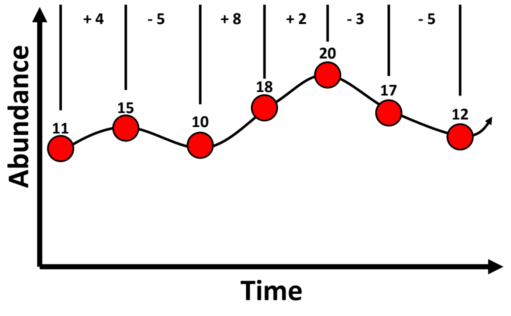
2020



2014 … 2020



Change in population abundance over time



Year	Abundance	$\text{Abundance}_{\text{year}}$-$\text{Abundance}_{\text{year-1}}$
2014	11	? = 11 – ?
2015	15	4 = 15 – 11
2016	10	-5 = 10 – 15
2017	18	8 = 18 – 10
2018	20	2 = 20 – 18
2019	17	-3 = 17 – 20
2020	12	-5 = 12 – 17

Population dynamics is…

The change in the population state (abundance, biomass) over time!

$$\frac{dAbundance}{dt} = Abundance_{year+1} - Abundance_{year}$$

Year	Abundance	$Abundance_{year}$-$Abundance_{year-1}$
2014	11	? = 11 – ?
2015	15	4 = 15 – 11
2017	18	8 = 18 – 10
2018	20	2 = 20 – 18
2019	17	-3 = 17 – 20
2020	12	-5 = 12 – 17

$$\frac{dAbundance}{dt} = Abundance_{year+1} - Abundance_{year}$$

Population changes (gains & losses)

Year	Abundance	$Abundance_{year}$-$Abundance_{year-1}$
2014	11	? = 11 – ?
2015	15	**4** = 15 – 11
2016	10	**-5** = 10 – 15
2017	18	**8** = 18 – 10
2018	20	**2** = 20 – 18
2019	17	**-3** = 17 – 20
2020	12	**-5** = 12 – 17

Thinking *inside* & *outside* the box