WF4133-Fisheries Science

Lecture 4: Size Structure, Length, Weight, & Conditions

This class

Objective(s): Understanding population characteristics

- ***Length based Population characteristics***
- ***Interpreting PSDs***
- ***Length-weight relationship***
- ***Estimating weight***
- ***Condition***

Housekeeping

- Lab this afternoon!
- Lab 1 responses due by 5 pm today!

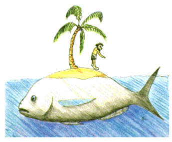
Fisheries icon: Dr. Carl Walters

Carl Walters

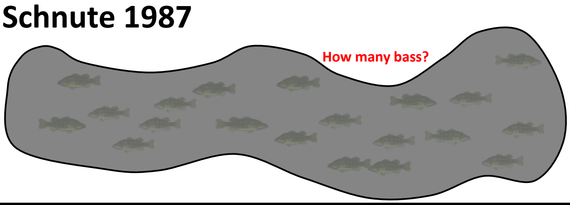
- Retired from University of British Columbia
- Ground floor of the IBP program
- Colorado State University
- Humboldt State University BSc

Scientific contributions

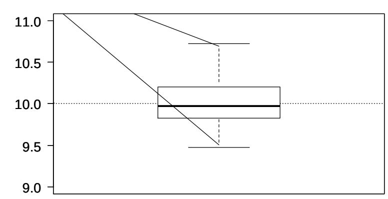
- Foraging arena theory
- Ecopath with Ecosim
- Adaptive management!
- Just to name a few!



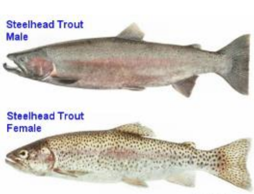
"The trouble with fish is that you never get to see the whole population. They're not like trees, whose numbers can be estimated by flying over a forest. Mostly you see fish only when they're caught…" Schnute 1987



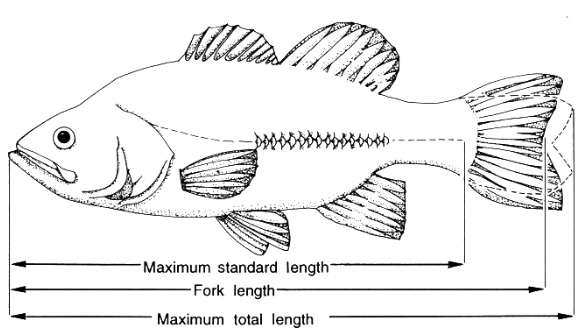
Yes, they are centered around 10, the mean using a random sample is unbiased



Sometimes there are reasons to stratify the sampling units.



Measuring length

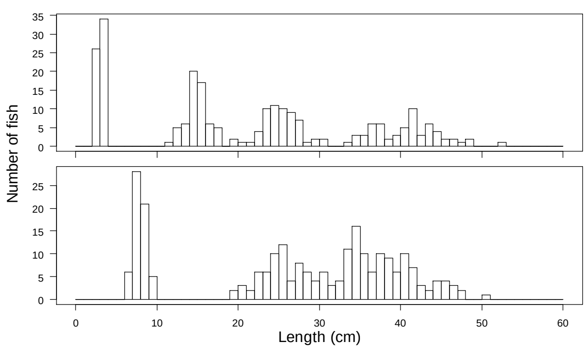


Rules of thumb for binning

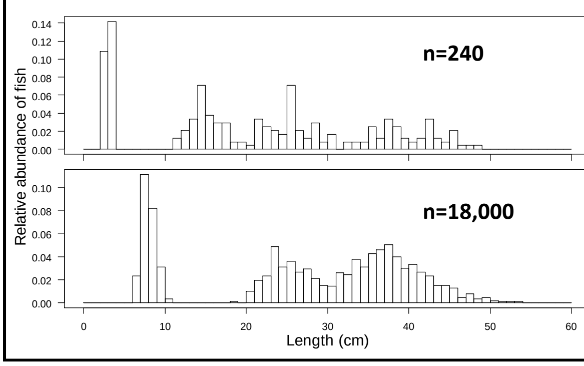
Anderson and Neumann (1996) suggested:

- 1-cm intervals for fish species that reach 30 cm
- 2-cm intervals for fish species that reach 60 cm
- 5-cm intervals for species that reach 150 cm

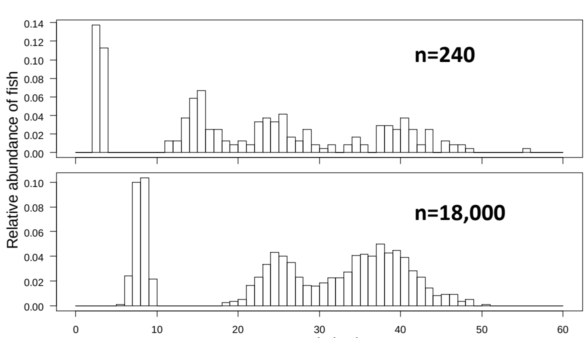
Compare populations



Compare populations



Other comparisons



STOCK DENSITY INDICES

Stock density indices

PSD (which specifically indicates Q/S) is a basic measure of size structure, and thus, balance within fish populations. “Balance” suggests a stable predator prey dynamic with adequate recruitment and growth of both predator and prey.

Proportional stock density (PSD)

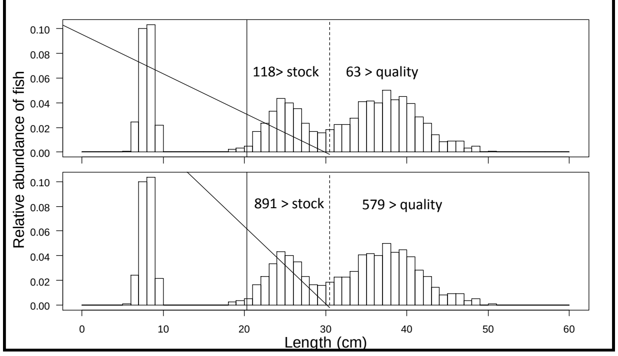
$$PSD = \frac{\text{Number of fish} \geq \text{ quality length}}{\text{Number of fish } \geq \text{ stock length}} \cdot 100$$

Where

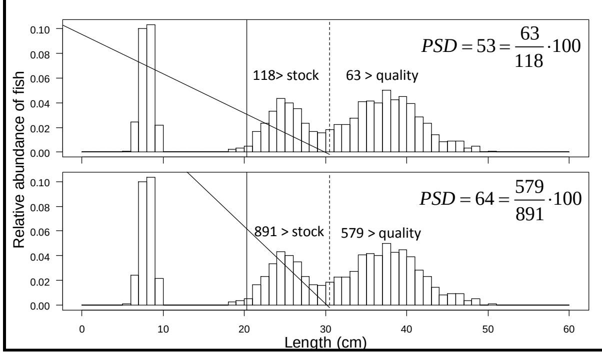
- Stock length fish = 8 inches
- Quality length fish = 12 inches

For largemouth bass

Stock and quality largemouth bass



Largemouth bass PSD



Interpreting PSD

$$PSD = 53 = \frac{63}{118} \cdot 100$$

- 53% of stock size fish are quality size

$$PSD = 64 = \frac{579}{891} \cdot 100$$

- 63% of stock size fish are quality size

Adjusting stock and quality lengths

Anderson and Weithman (1978)

- Defined stock and quality lengths as percentages of all-tackle world record lengths
- Suggested stock and quality lengths for 26 species

New stock and quality lengths

Stock: 20-26% of world record

Quality: 36-41% of world record

Relative stock density

$$RSD = \frac{\text{Number of fish} \geq \text{ specified length}}{\text{Number of fish } \geq \text{ stock length}} \cdot 100$$

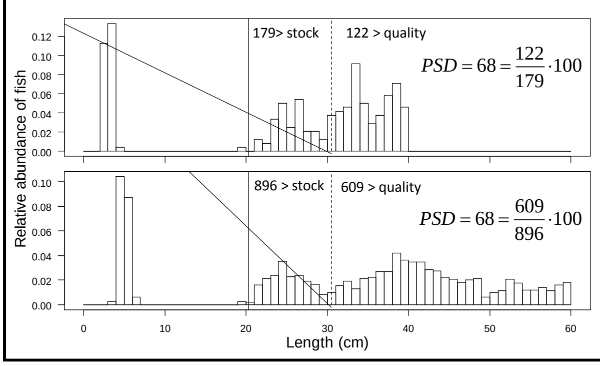
Where a:

- Stock length fish 20-26%
- Quality length fish 36-41%
- **Or any other specified length (e.g., 15 inches)**

$$RSD - 15 = 30 = \frac{30}{100} \cdot 100 = \frac{\text{Number of fish} \geq 15 \text{inches}}{\text{Number of stock fish}} \cdot 100$$

- 30 fish greater than 15 inches
- 100 fish that were stock size or greater

Issues?



Adding length categories

Gabelhouse (1984): need to move beyond a two-cell model of length categorization and further refine PSD by using:

- stock (S)
- quality (Q)
- preferred (P)
- memorable (M)
- trophy (T)

Calculation of length categories

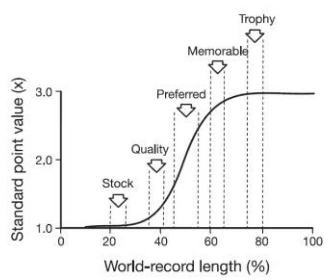


Figure 14.3 Gabelhouse's adoption of Weithman's (1978) fish quality index to identify length ranges from which (or near to which) minimum stock, quality, preferred, memorable, and trophy lengths were selected (from Gabelhouse 1984a).

Length categories

Category	Largemouth bass (mm)	Bluegill (mm)
Stock	200	80
Quality	300	150
Preferred	380	200
Memorable	510	250
Trophy	630	300

Traditional PSD

$$PSD - X = \frac{\text{Number of fish} \geq \text{ specified length}}{\text{Number of fish } \geq \text{ stock length}} \cdot 100$$

Category	N	Value
PSD-S	400	100
PSD-Q	100	40
PSD-P	75	25
PSD-M	80	14
PSD-T	10	2

Incremental PSD

$$PSD - X = \frac{\text{Number of fish in bin}}{\text{Number of fish } \geq \text{ stock length}} \cdot 100$$

Category	N	Value
PSD-S-Q	400	60
PSD-Q-P	100	15
PSD-P-M	75	11
PSD-M-T	80	12
PSD-T	10	2

Should sum to 100

Linguistic uncertainty?

- PSD
- RSD
- Incremental PSD
- Traditional PSD

Terminology

Table 14.1 Terminology for former proportional stock density (PSD) and relative stock density (RSD) indices and corresponding revised terminology for proportional size distribution (PSD) index. Note that under the former terminology PSD and RSD-Q were equivalent. Suffixes are stock (S), quality (Q), preferred (P), memorable (M), and trophy (T) lengths.

Former terminology	Current terminology
PSD	PSD
RSD-P	PSD-P
RSD-M	PSD-M
RSD-T	PSD-T
RSD S-Q	PSD S-Q
RSD Q-P	PSD Q-P
RSD P-M	PSD P-M
RSD M-T	PSD M-T

Guy, C. S., R. M. Neumann, and D. W. Willis. 2006. New terminology for proportional stock density (PSD) and relative stock density (RSD): Proportional size structure (PSS). Fisheries **31**:86-87.

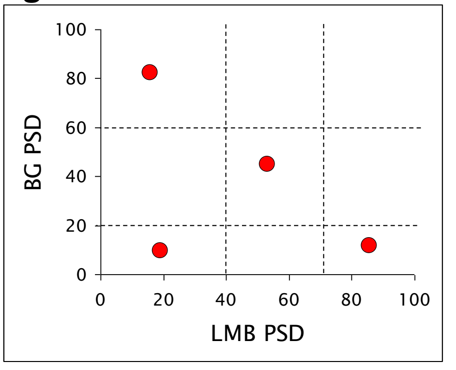
Formalities…

- All expressions of PSD should be rounded to the nearest whole number and reported without the percent symbol; decimals represent significant digits beyond the original data (Box 14.1).
- Willis et al. (1993) encouraged fisheries biologists to use values as established in either English or metric units rather than converting from English to metric units.

Table 14.3 Generally accepted PSD index values for balanced fish populations (from Willi
al. 1993). Indices for crappies are based on fish from midwestern U.S. ponds.

Species	PSD	PSD-P	PSD-M	Source
Bluegill	20–60	5–20	0–10	Anderson (1985)
Crappies	30–60	>10		Gabelhouse (1984b)
Largemouth bass	40–70	10–40	0–10	Gabelhouse (1984a)
Northern pike	30–60			Anderson and Weithman (19
Walleye	30–60			Anderson and Weithman (19
Yellow perch	30–50			Anderson and Weithman (19

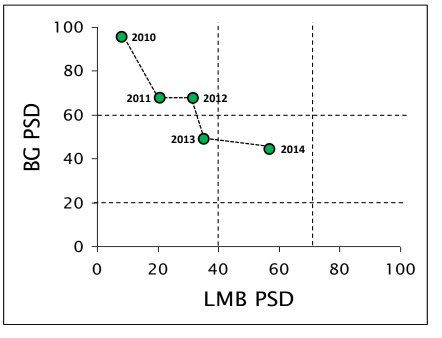
Using PSD as an assessment tool:



An assessment tool

- This index *supposedly* gives insight or predictive ability of population dynamics.
- Both high and low values and wide variation in PSD over time are indicative of populations with functional problems such as unstable recruitment, growth, or mortality.

Tracking Predator-Prey Dynamics



Does PSD correlate fish density?

Largemouth bass in small impoundments

TABLE 3
Correlation Coefficients (r) between Proportional Stock Density and Density, Relative Abundance, Condition, or Rate Functions for Single Species as Reported by Various Authors

Species	Density	CPUE[a]	Wr[b]	Recruitment	Growth	Mortality	Ref.
Largemouth bass	Inverse[c]					-0.64	Reynolds and Babb (1978)
		-0.85					Gabelhouse (1984b)
		-0.70					Guy and Willis (1990)
		-0.98					Saffel et al. (1990)
					0.69[d]	-0.52[d]	Miranda (1983)
			-0.75[e]				Wege and Anderson (1978)
		-0.79					Boxrucker (1987)
Bluegill				-0.85	0.87		Novinger and Legler (1978)
Crappies			0.90				Gabelhouse (1984b)
Northern pike			0.59[f]		0.96[g]		Willis and Scalet (1989)
Walleye			0.36				Murphy et al. (1990)
Sauger			0.38				Guy et al. (1990)
Yellow perch			0.27[h]		0.85[i]		Willis et al. (1991)
Brook trout	-0.76		0.81				Johnson et al. (1992)

Willis et al 1993

Pond Management

Using PSD for management

Table 14.4 Proportional size distribution values for largemouth bass and bluegill under three different management strategies described in section 14.3.3 (from Willis et al. 1993).

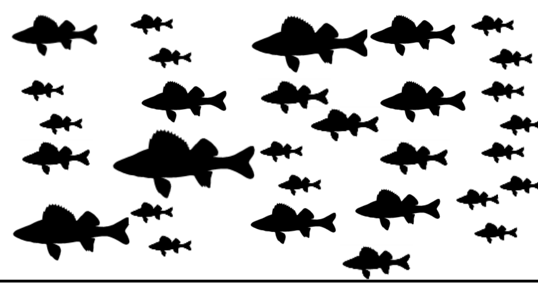
Management strategy	Largemouth bass PSD	Largemouth bass PSD-P	Largemouth bass PSD-M	Bluegill PSD	Bluegill PSD-P
Panfish	20–40	0–10	0	50–80	10–30
Balanced	40–70	10–40	0–10	20–60	5–20
Big bass	50–80	30–60	10–25	10–50	0–10

Cautions

- Predicting or drawing conclusions about population dynamics based on the structural indices is not as straightforward in larger waters or in systems with more complex fish communities.
- These systems require stock assessments
- Management decisions should be grounded in other procedures (e.g., relative abundance, recruitment , growth, mortality)

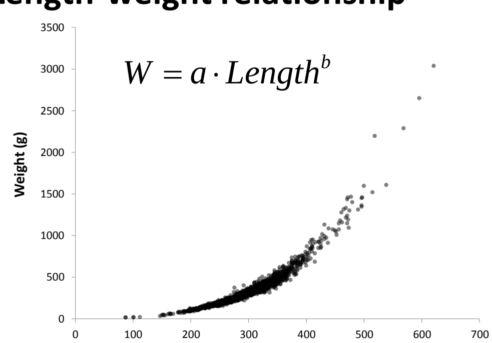
Population characteristics

Quantities and indices of a population



A real datasheet

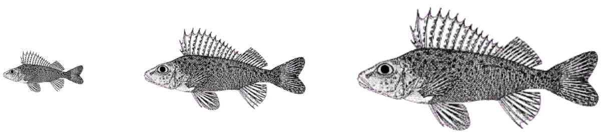
Length-weight relationship



Isometric scaling

If b=3 then fish growth is isometric

- all dimensions change similarly over time
- shape of fish does not change over time

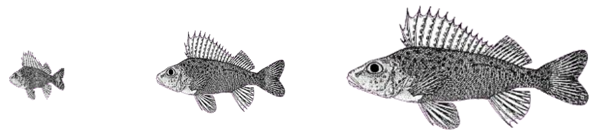


$$W = a \cdot L^{b=3}$$

Allometric scaling

- if b<3 then fish gets more fusiform with time

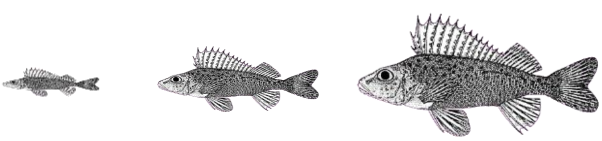
$$W = a \cdot L^{b<3}$$



Allometric scaling

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

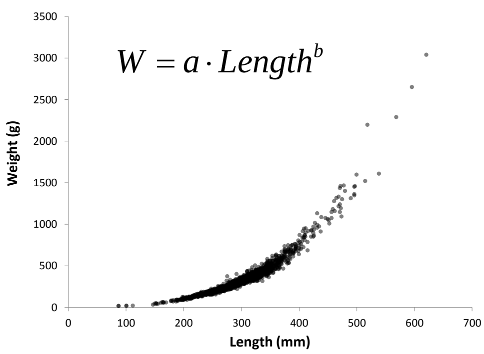
$$W = a \cdot L^{b>3}$$



Using length-weight relationships

- Estimate weight from length
- Measure variation from the **expected** weight for length of individual fish or relevant group of individuals as indications of fatness, general ‘well-being,’ gonad development, etc.
  - Does a fish weigh more than another even though they are the same length?

Estimating weight from length



Straightening the curve

Law of logarithms

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

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

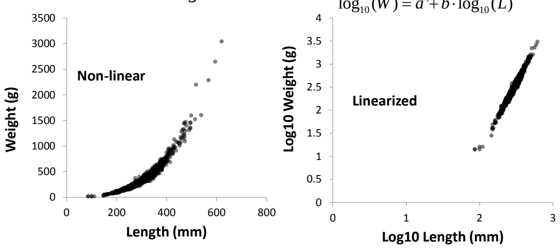
$$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$$

Estimating weight from length

$W = a \cdot Length^b$

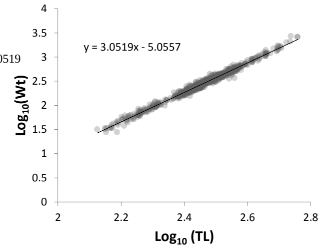
$\log_{10}(W) = \log_{10}(a) + b \cdot \log_{10}(L)$

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

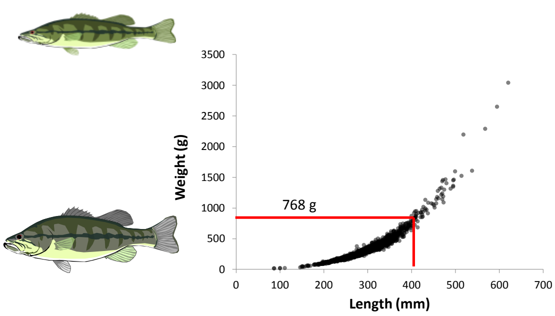


Can estimate weight from length!

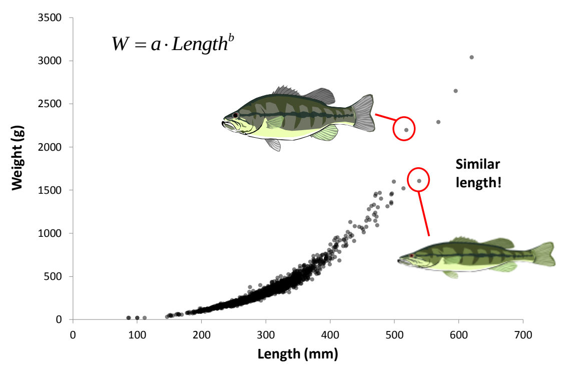
$$Weight = 10^{-5.0557} \cdot Length^{3.0519}$$
$$Weight = 10^{-5.0557} \cdot 400^{3.0519}$$
$$Weight = 768\,g$$



Length-weight data



Condition

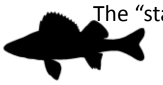


Condition Metrics

- Differ in how **standard** weight is computed
  - Cubic of observed length (L^3)
    - *Fulton's condition factor (K)*
  - Predicted weight from observed length using length-weight relationship for studied stock
    - *LeCren's relative condition factor (Kn)*
  - Predicted 75th percentile of mean weights from many populations given observed length
    - *Relative weight (Wr)*

Standard weights

How much does the fish weigh relative to some **standard weight** based on its length?



The "standard" fish

Both the same length

How do weights compare?

Fulton's condition factor (K)

- When metric

$$K = \frac{Weight}{Length^3} \cdot 100000$$

- When english

$$C = \frac{Weight}{Length^3} \cdot 10000$$

Assumes isometric growth!

Relative Condition Factor (Kn)

- Relative condition factor (K_n) allows for allometric growth; that is, when shape changes as fish grow (Le Cren 1951).

$$K_n = \frac{Weight}{a \cdot Length^b}$$

Can be difficult to interpret and compare, largely unused today. But good precursor!

Relative weight

- Relative weight (W_r) represents refinement of the K_n concept (Wege and Anderson 1978)
- Standardization among populations
- Facilitate comparison and interpretation

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