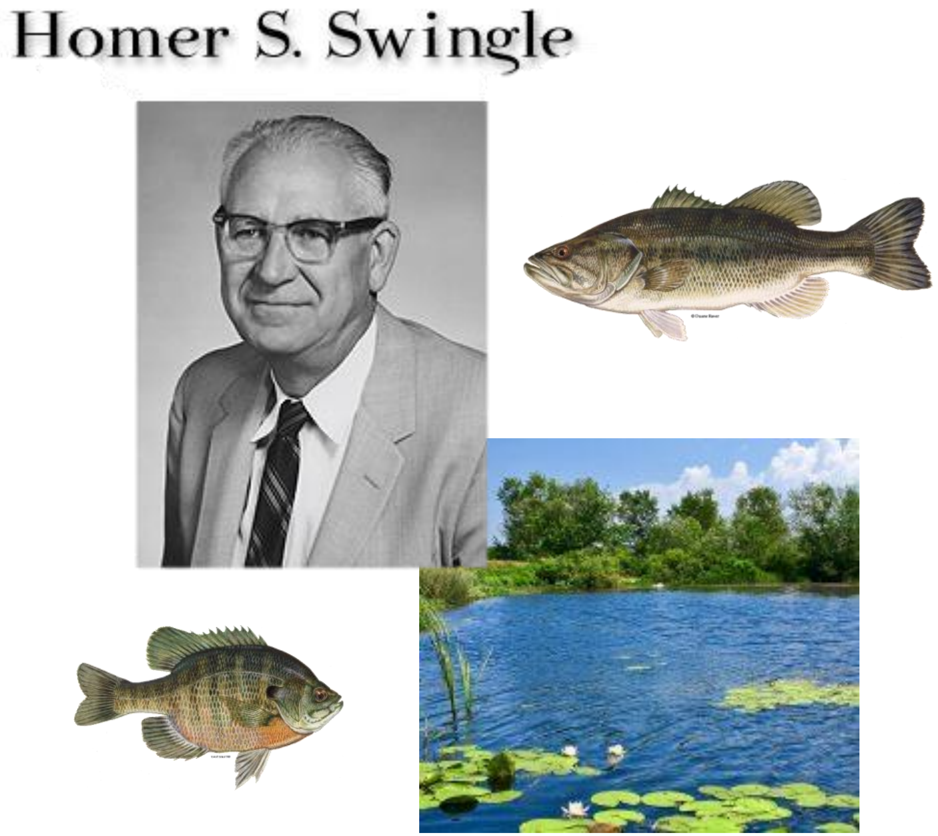
# Homer S. Swingle

*"Father of Modern Aquaculture"*

Entomologist – Auburn University

Pioneered field of pond management

Ponds beyond water storage

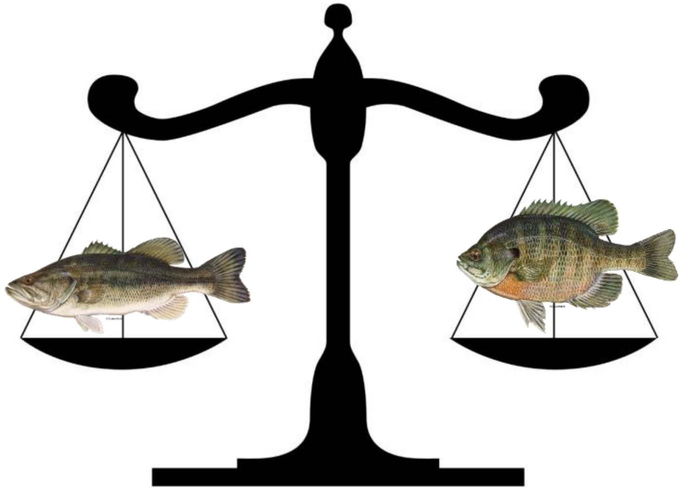


# Swingle and Smith 1940

Stocked fish into ponds

Determined ratio of fish needed for “balanced” population

Balance between predator vs. prey spp.



# Swingle and Smith 1940

Objective: to produce a self-sustaining system that produces fish year after year

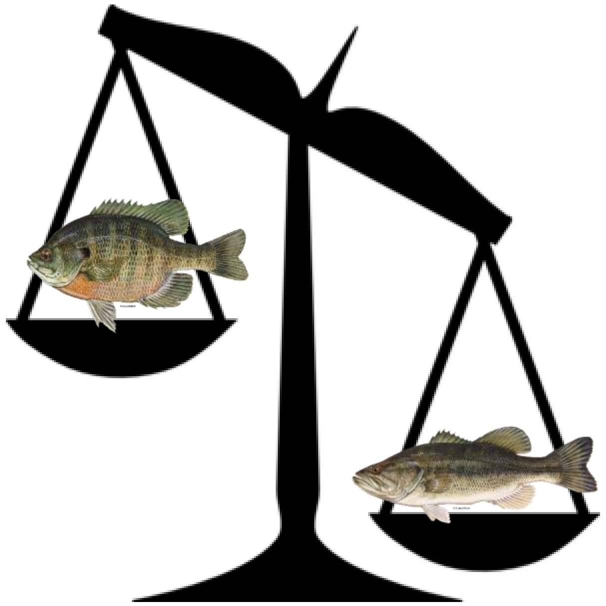
Advanced the field of aquaculture

Insight into population-dynamics

Demonstrated that balanced ponds can provide good fishing > 1year

Based on biomass

Lead to development of established predator/prey ratios in small simple systems



# Biomass Indices

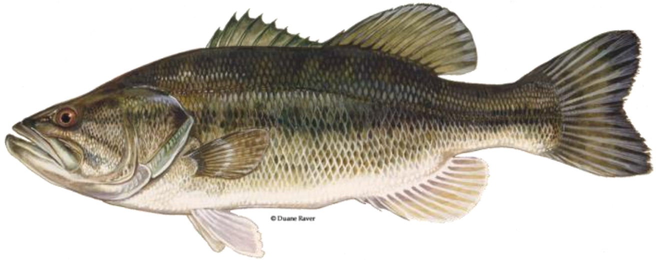
Swingle 1950 – Development of *F/C* ratio

Balance between predator (LMBS) and prey (BLGL)

Swingle and Shell 1971 – Index of relative plumpness

Based on Alabama statewide averages

Expanded development of condition indices (e.g., $W_r$)



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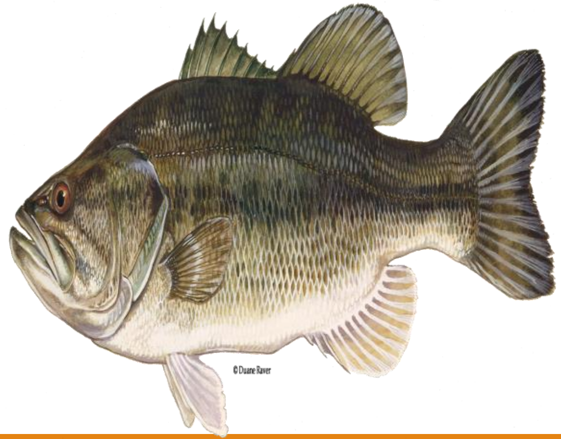


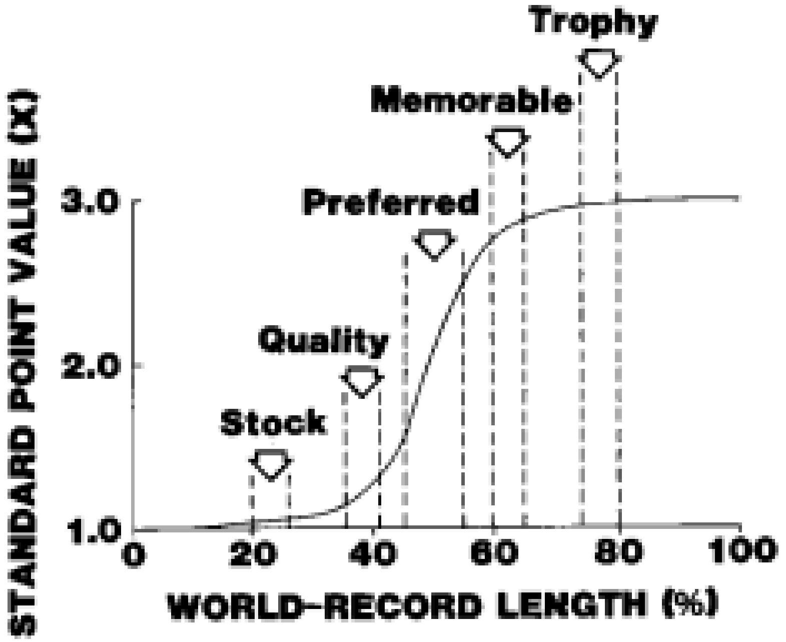
# Richard Anderson

Biomass data – difficult and expensive to obtain

Development of length based indices

Anderson 1976 – Development of Length Based Indices for LMBS and BLGL (proportional stock density; PSD)

Wege and Anderson 1978 – further expanded Swingle and Shell 1971 and developed relative weight indices



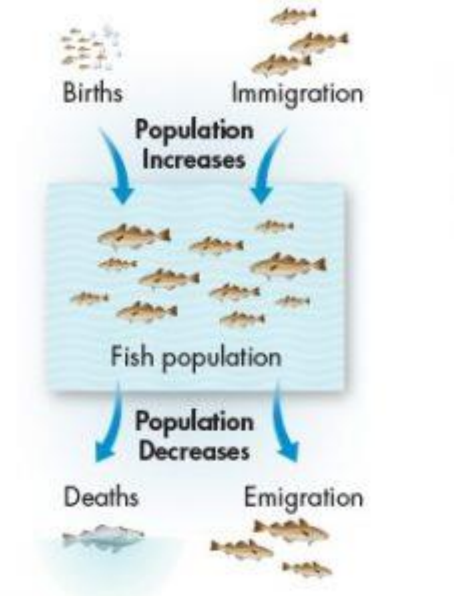
# Foundations of Fisheries Management

Swingle, Anderson, and others – pivotal in developing basis for indices used by managers today

Concepts of PSD and Wr started in small impoundments – later developed and expanded for larger systems and more fishes

Allows biologists a simple tool for assessing population dynamics (i.e., recruitment, growth, mortality)

More recently expanded for non-game fishes (e.g., Blacktail Redhorse), fishes of special concern (e.g., Pallid Sturgeon), and non-native fishes (e.g., Asian Carp)




# Application of a Traditional Fisheries Management Technique on a Newly Established Fish Species in North America

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# Northern Snakehead

Native to eastern Asia

First Discovered in 2002 Crofton, MD (Potomac River drainage)

Since expanded – now established in 5 states

Need for management action – assessing population

# Population Dynamics

Fish populations managed through vital rates–recruitment, growth, mortality

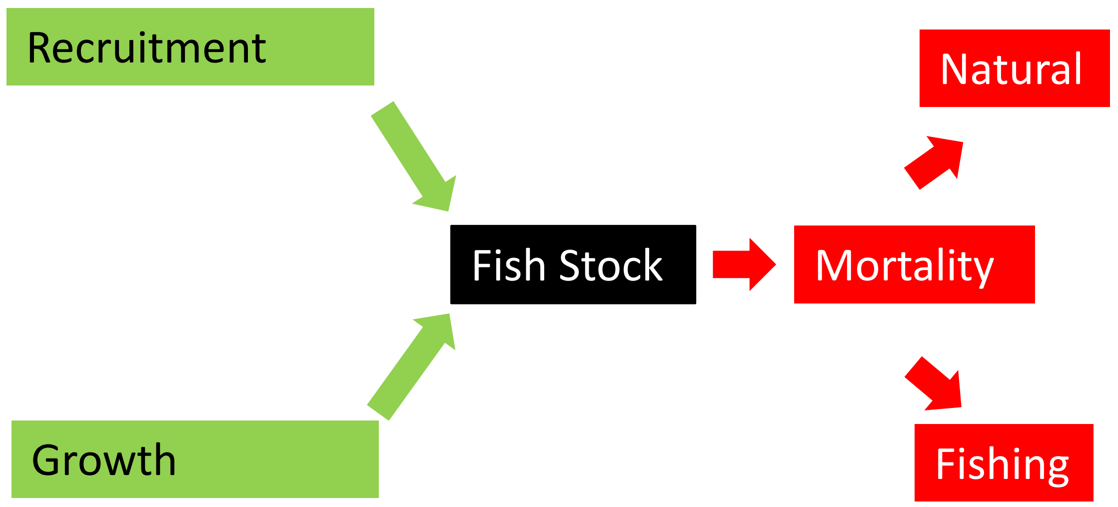
Recruitment - # indiv. entering pop.

Growth – addition somatic/gonadal tissue

Mortality – rate of indiv. leaving pop.

Basis of characterizing population

Leads to better informed decision making



# Proportional Size Distribution

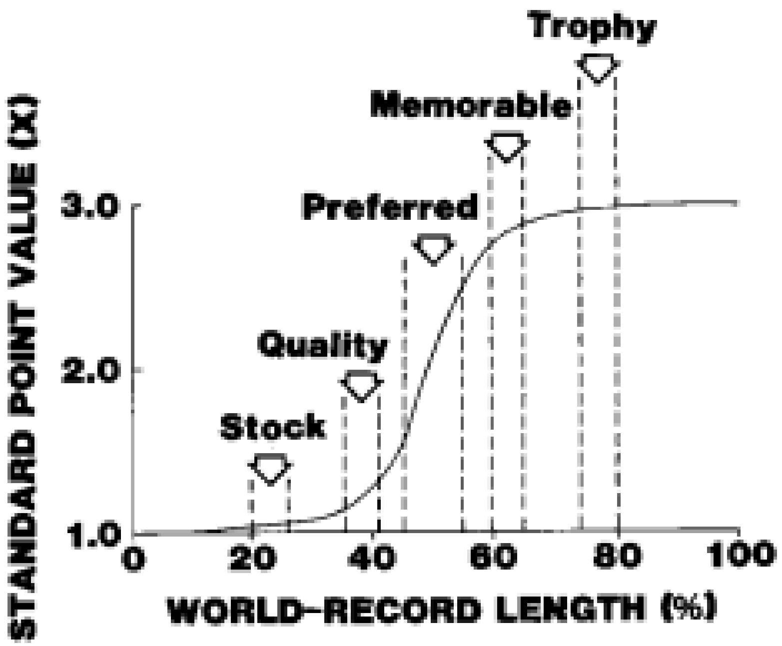
Quantifies length-frequency histograms

Percentage based on world-record length (Gablehouse 1984)

Provides insight into vital rates (recruitment, growth, mortality)

Inexpensive and easily collected

However, these standard categories have not been developed for Northern Snakehead



# Relative Weight

Relative Weight (Wr) – calculated from Standard Weight (Ws) equation

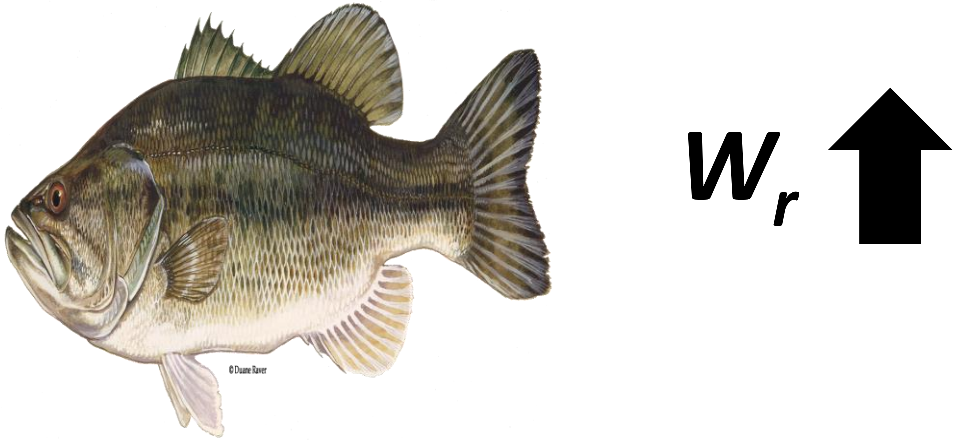
Measure – relative plumpness, surrogate for fish condition

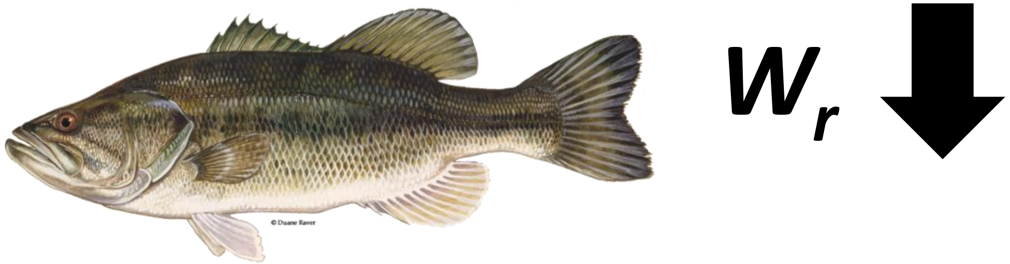
Provides baseline pop. Condition

Based on baseline of lengths & weights from across range and across seasons

Deviations provide insight to environmental changes

Again, no such index exist for Northern Snakehead



# Quantifying Vital Rates

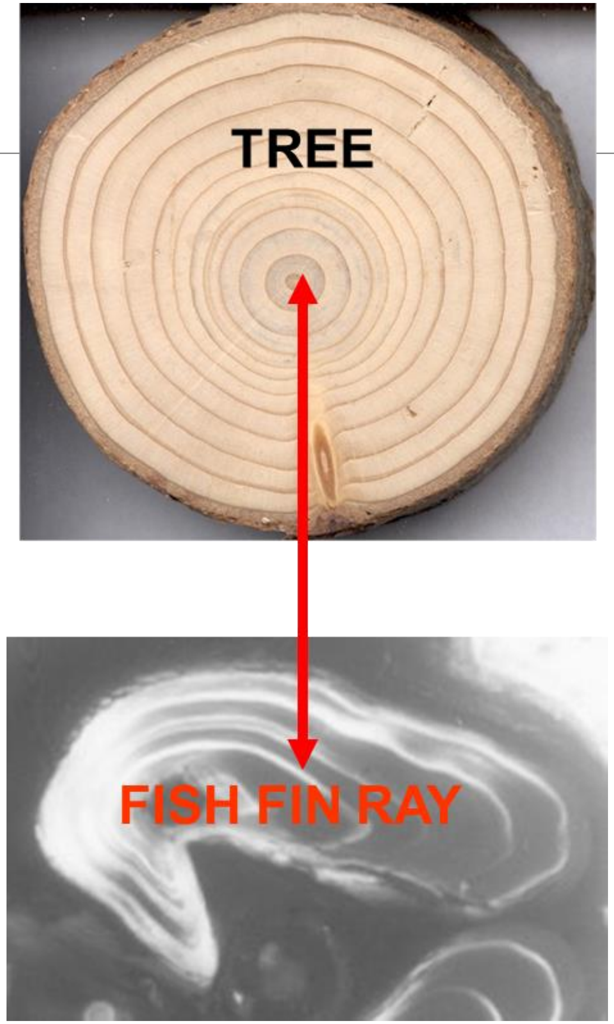
Various approaches (e.g., mark-recap)

Best approach – age data

Regressions (Linear models, VB Growth Curves) most commonly used by fishery managers and requires age estimates

Importance of ageing structure choice

Need for reliable/accurate age estimates



# Structure Choice

Various structures (e.g., Scales, opercles, fin rays, spines, vertebrae, and otoliths)

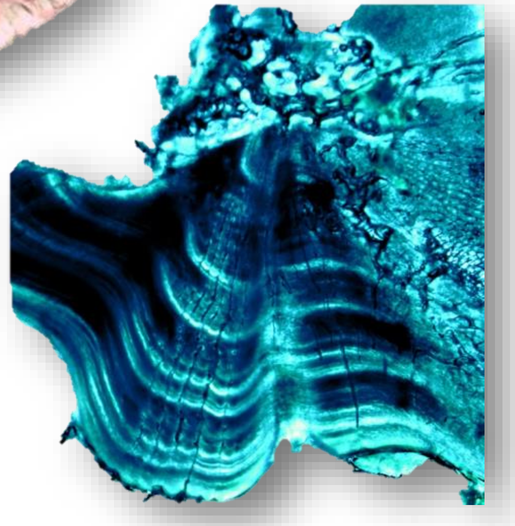
Balance between quality of age estimates (i.e., accuracy)

Readability of the structure

**Validity of marks on the structure as true annuli**

Otoliths generally considered best structure

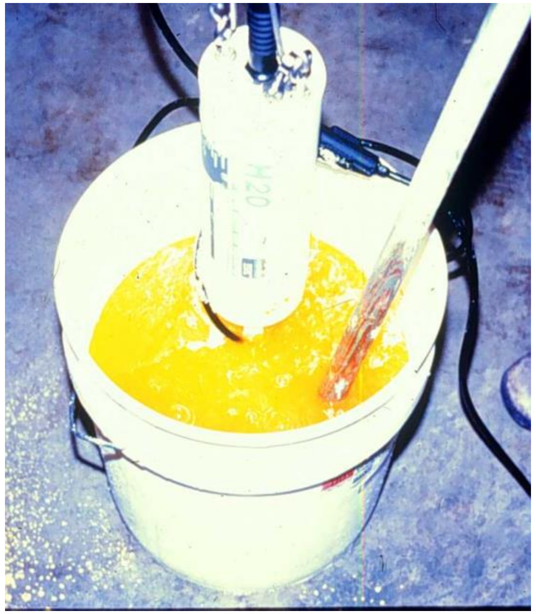
Greater accuracy – esp. older individuals

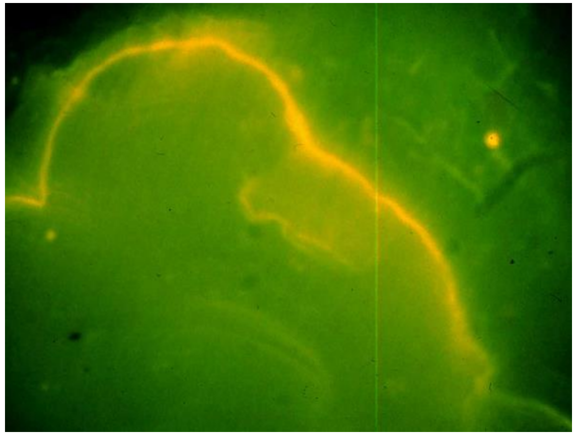


# Validation

Common approaches – mark-recapture (direct validation) or increment analysis (in-direct validation)

Mark-recaptured individuals determine periodicity of annuli formation (e.g., oxytetracycline)

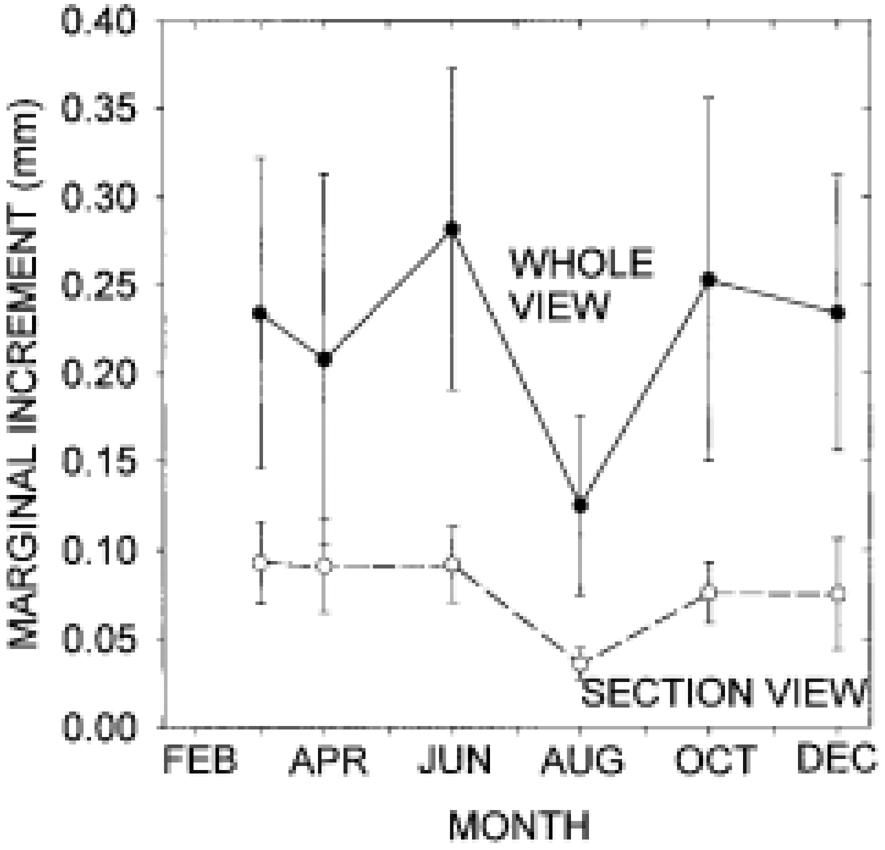




# Marginal Increment Analysis

Widely used technique for validating annulus formation

Measures annuli completion from fish collected across multiple months



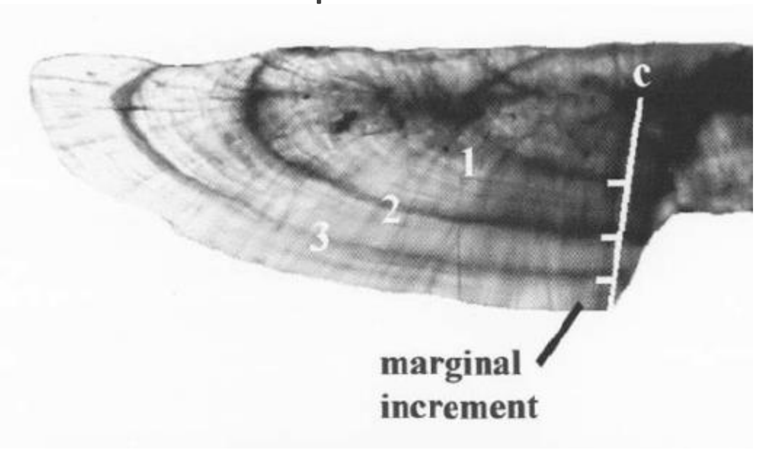
# Relevance of Study

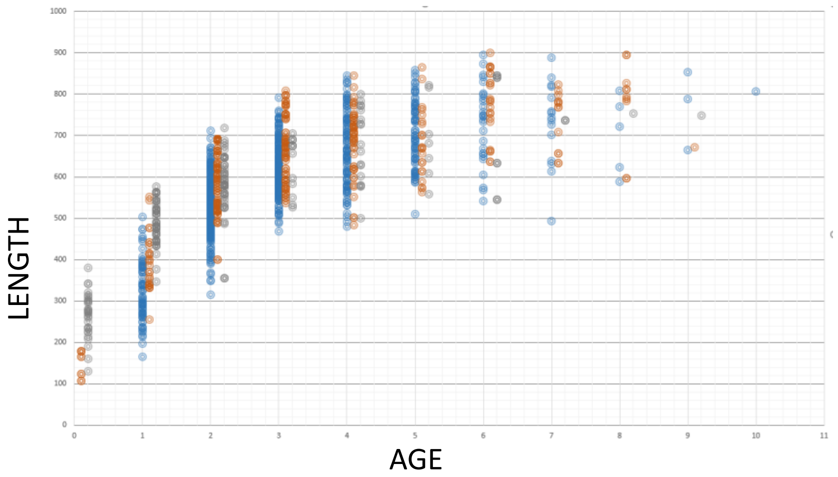
Objective 1: Develop standard length categories for North American Northern Snakehead

Objective 2: Develop standard weight equations for assessing relative weight of North American Northern Snakehead

Objective 3: Validate otolith ageing techniques for Northern Snakehead

Provides managers a tool for quick assessment of population dynamics, further validate ageing methods for quantification of theses vital rates



# Methods - PSD

Step 1: Determine longest *confirmed* Northern Snakehead

Solicited data from states with established Northern Snakehead pop.

Communication with biologists, literature review.

Standard Length Categories

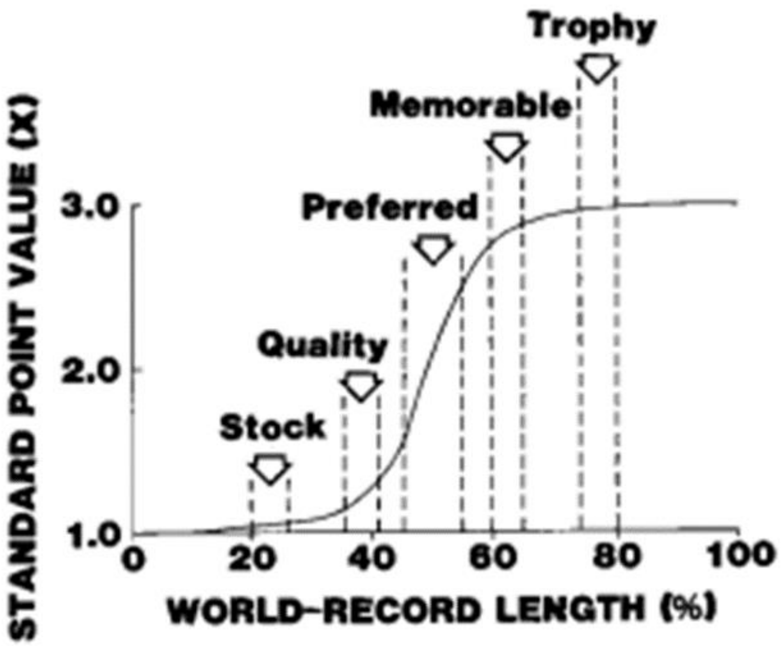
- stock (20%)

- quality (36%)

- preferred (45%)

- memorable (59%)

- trophy (74%)



# Methods - Wr

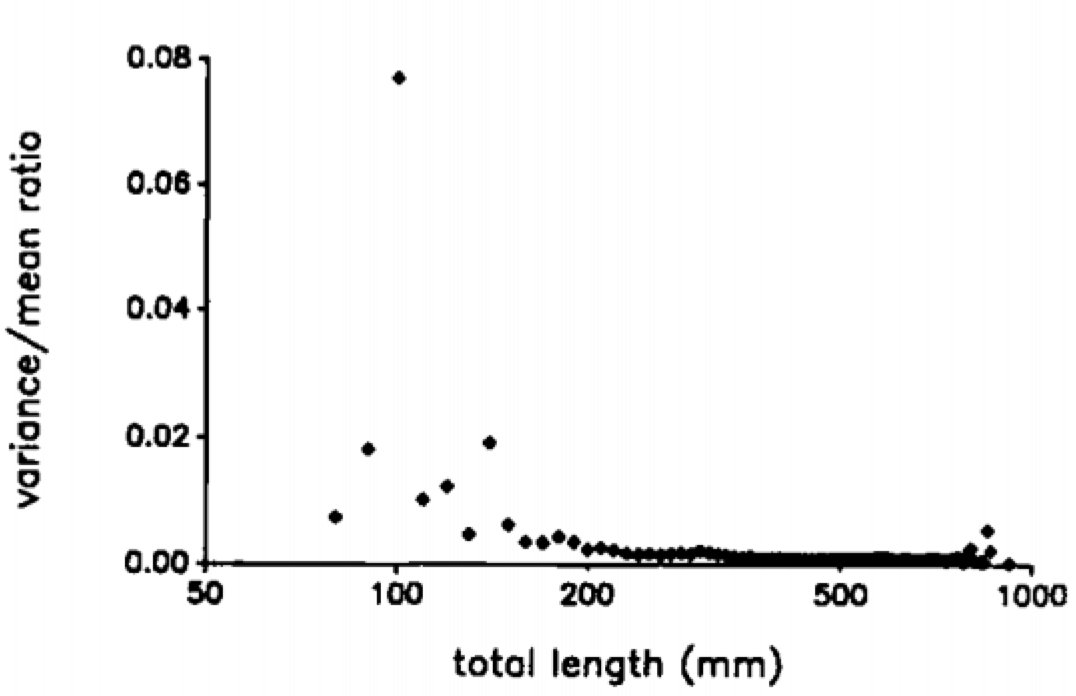
Solicited length-weight data from established pops.

Data separated by drainages & all outliers removed

Regression Line Percentile (RLP) – 75th percentile as benchmark, based off multiple length-weight regressions (Murphy et al. 1980)

Minimum size – determined from variance-to-mean ratio, due to inaccuracies of small fishes

All analysis conducted in SAS



# Methods – Marginal Increment Analysis

Northern Snakehead – collected through standardized electrofishing by VDGIF biologists

During each sampling event (March to October) 25 Northern Snakehead were randomly selected (from all sampled), otoliths removed, and measured for MIA

200 NSH were used for analyses (ages ranged from 2 through 10)

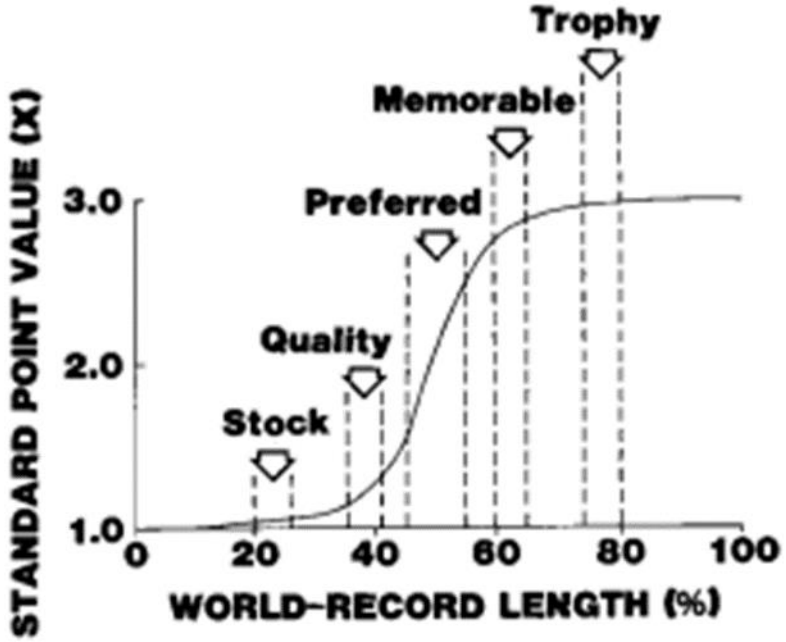
Index of completion (C) $C = W_n/W_{n-1}$, where $W_n$ is the width of the marginal increment on the distal edge of the otolith and $W_{n-1}$ is the width of the most recent complete increment

ANOVA and Tukey's HSD – compare differences

# Results – PSD

Determined longest individual – 940mm (~37”)

| Length category | % Record length | Proposed standard (mm) | Proposed standard (in) |
|---|---|---|---|
| Stock | 20 | 190 | 7.5 |
| Quality | 36 | 340 | 13 |
| Preferred | 45 | 420 | 16.5 |
| Memorable | 59 | 550 | 22 |
| Trophy | 74 | 700 | 27.5 |

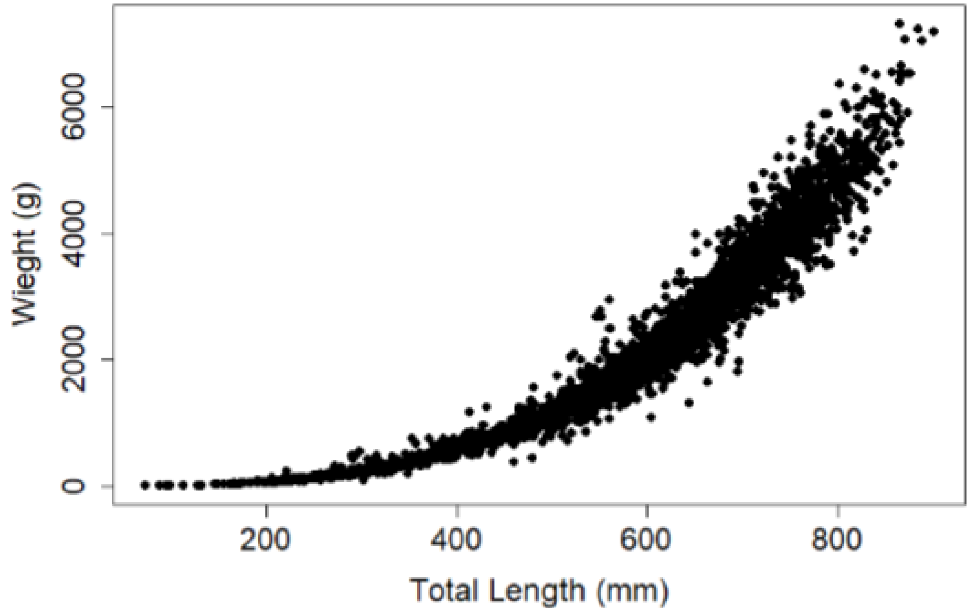


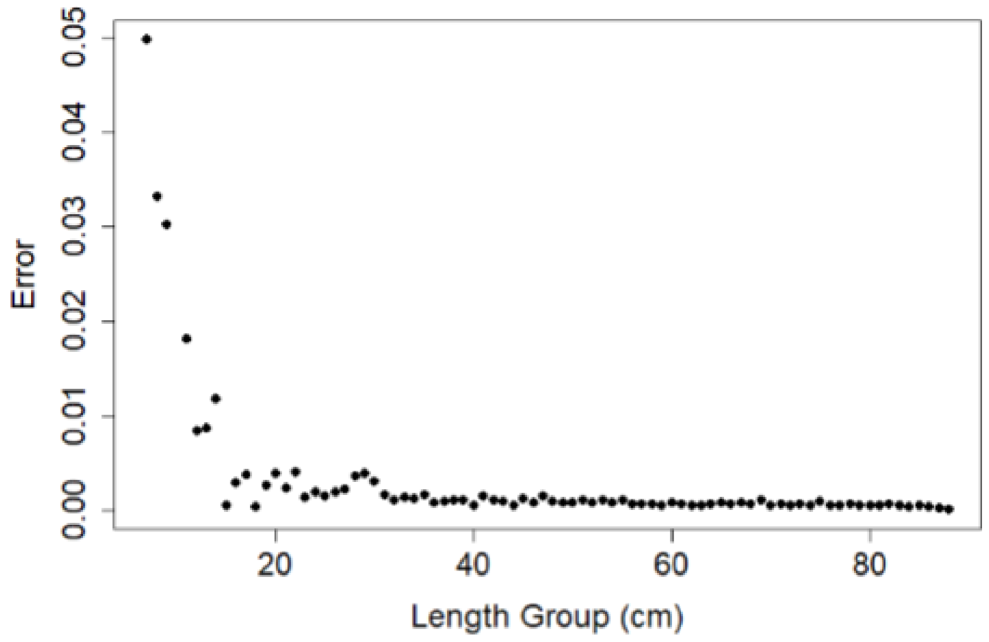
# Results – Wr

Data analyzed from 5 states, 6 agencies, 4 major watershed (*N* = 4445)

Minimum size – 200mm

$$\log_{10} Ws = -5.142 * 3.0418 \log_{10} TL$$



# Results – Marginal Increment Analysis

Highest in March and April

Lowest in July to August

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| March | 25 | 18.02 | 0.7208 | 0.019366 |
| April | 25 | 17.53 | 0.7012 | 0.008569 |
| May | 25 | 18.37 | 0.7348 | 0.011026 |
| June | 25 | 14.43 | 0.5772 | 0.097471 |
| July | 25 | 9.31 | 0.3724 | 0.073786 |
| August | 25 | 7.94 | 0.3176 | 0.023836 |
| September | 25 | 13.36 | 0.5344 | 0.025076 |
| October | 25 | 15.57 | 0.6228 | 0.012663 |

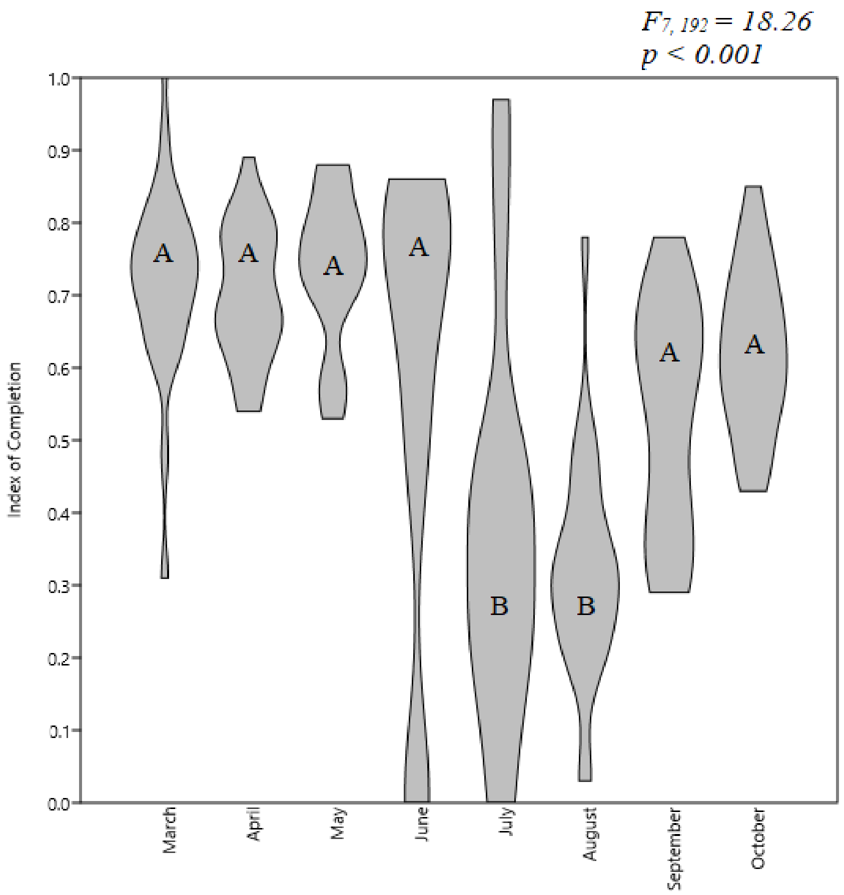
# Results – Marginal Increment Analysis

Differences among completion index scores

High incidence of zeros in July

Suggests annuli deposition

Increases in marginal increment in months following



# Importance – PSD & Wr

Invasive species – increasing across North America

Need for management and insight into population dynamics (Simberloff 2007)

Ease and utility of common indices

Provide managers with rapid assessment tool – characterize population, insight into population dynamics

Further, allows managers to track trends over time – application to existing data

# Importance – Marginal Increment Analysis

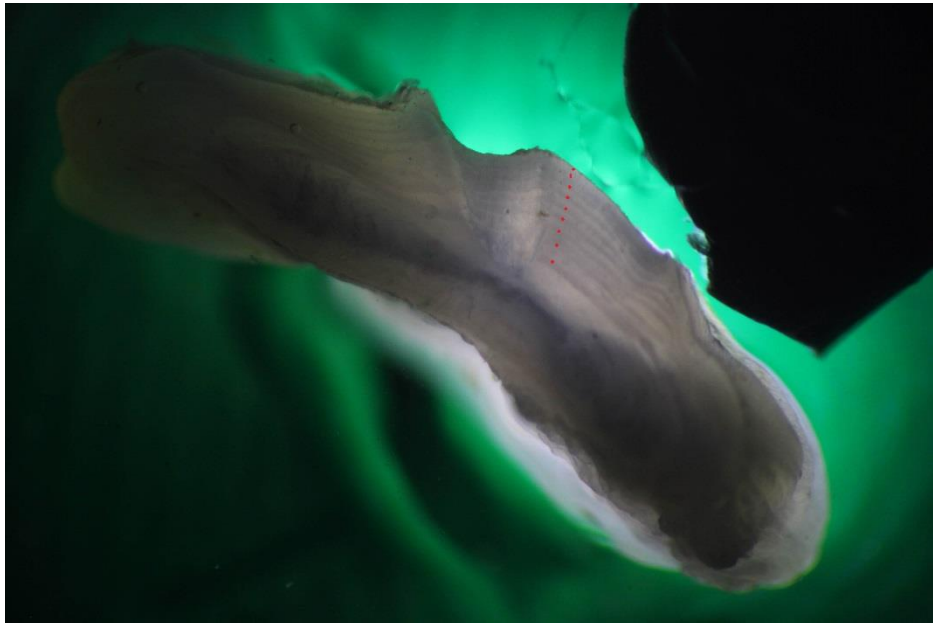
Sagittal otoliths are a valid aging structure

Annulus formation occurred only once per annual cycle

Similar to many other freshwater fishes (e.g., Largemouth Bass)

Additionally, MIA has focused on single age groups

However, we expanded out analysis to include a range of ages



**9 YEAR OLD NORTHERN SNAKEHEAD**

# Conclusion

PSD and Wr still useful tools – frequently utilized by biologists today

Application is broadened

Northern Snakehead sagittal otoliths are a valid structure for estimating age

Further, we recommend the use of sagittal otoliths for accurately determining age and subsequently determining vital rate functions for proper management

# Acknowledgements


Virginia Department of Game and Inland Fisheries, Maryland Department of Natural Resources, D. C. Fisheries, Arkansas Fish and Game Commission, New York Department of Environmental Conservation, United States Fish and Wildlife Service

Mississippi River Basin Panel, Mid-Atlantic Panel on Aquatic Invasive Species, Virginia Chapter of the American Fisheries Society, and Dominion Energy – funding travel to present this research

# Conclusion

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# RLP vs EMP

Inherent length related bias (Ranney et al. 2011)

EMP does not resolve issue any better than RLP

Standardization – across Ws equations

Index – better analysis available

Management Tool