Life History Parameters

Jeff Kipp

ASMFC Mock Data Workshop

Week 2: March 22, 2023

Outline

- Week 2: Life History Parameters
  - Data
  - Overall purpose
  - Morphometric relationships
  - Growth
  - Maturity and reproductive capacity
  - Natural Mortality
  - Stock ID
  - Project: Life History

Data

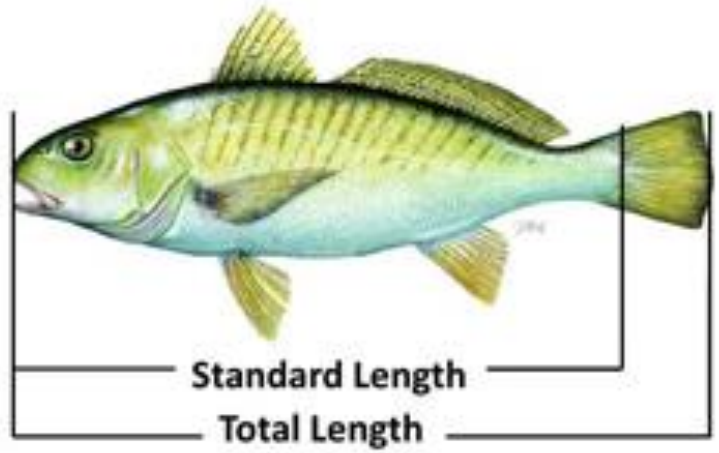
- Life history studies
- Tagging programs
- Survey biosampling
  - *Fishery removals*
  - *Population structure*
  - *Life history characteristics*

Data

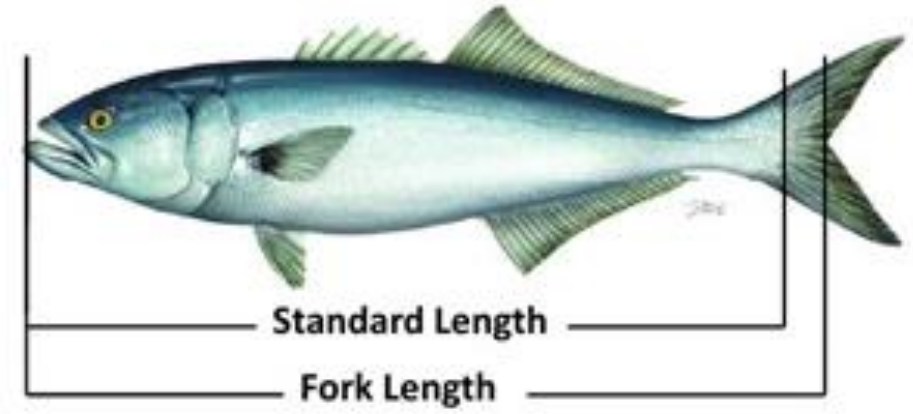
- Types of data
  - Length
  - Weight
  - Age
  - Maturity
  - Sex
  - * Fecundity
  - * Stomach contents
  - * Movement/migration
  - * Genetics
  - * Sex change
- Some data should be collected annually, some only need to be collected periodically

Length and Weight

- Type
  - Length: fork or centerline, standard, total, carapace
  - Weight: hole, gutted, head off

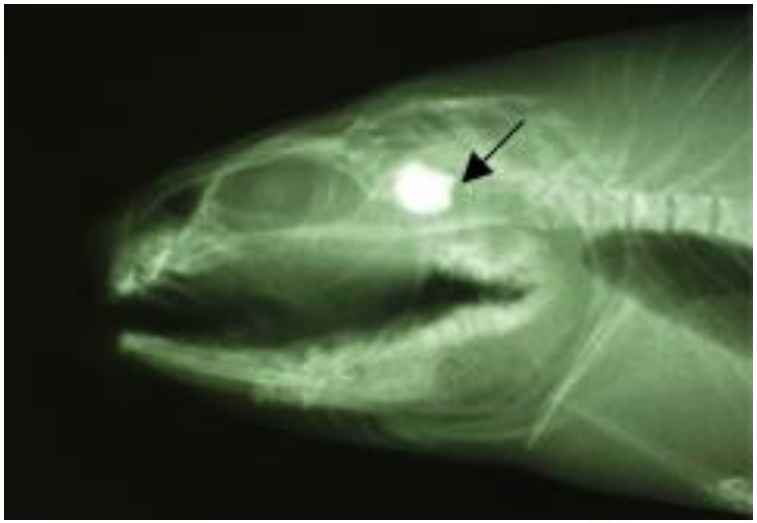


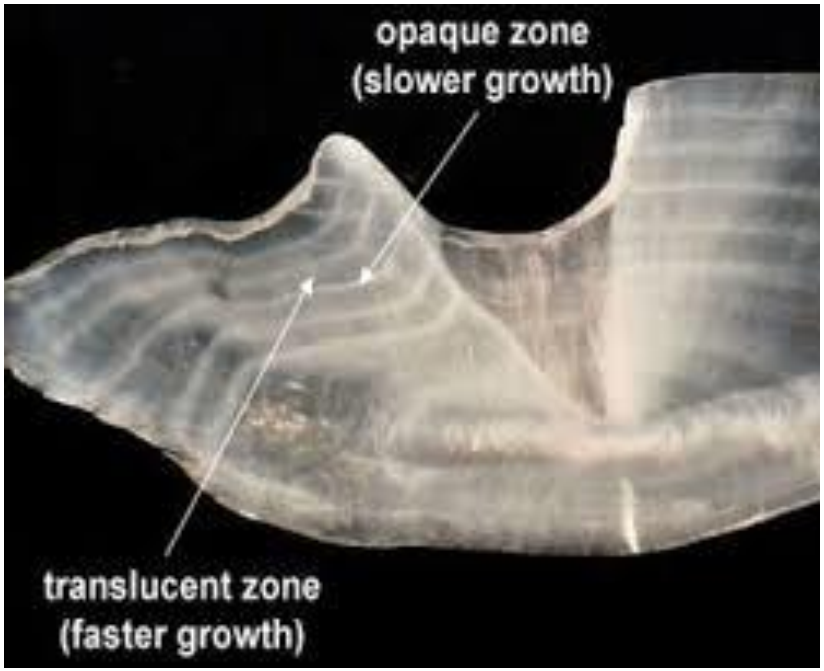
- Units and precision
  - Metric, non-metric

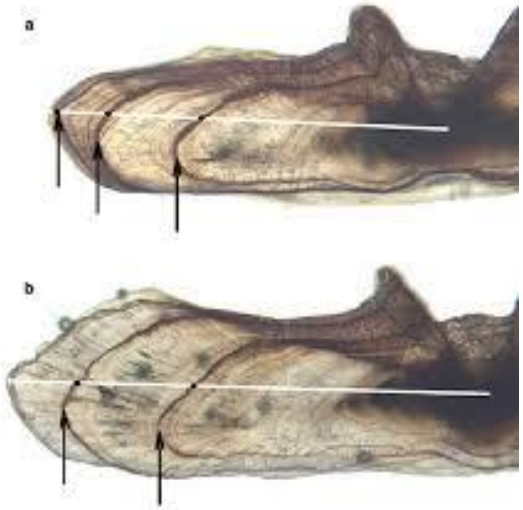


Age

- Typically estimated from a hard part (otolith, scale, operculum)
  - Annuli
  - Hard part margins

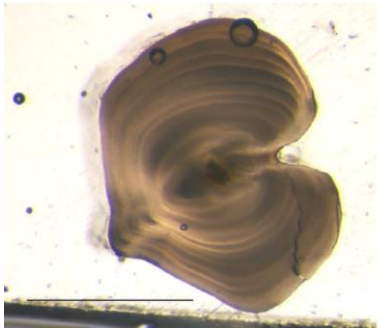


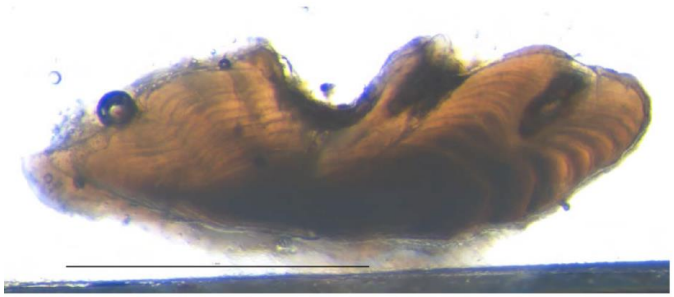


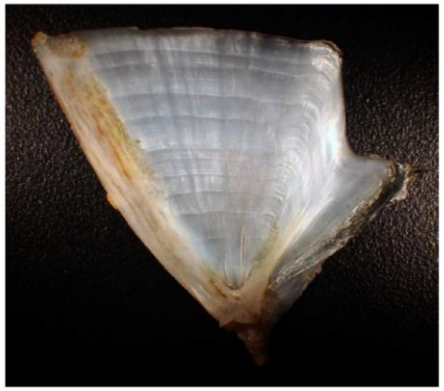


Ageing error

- Studies conducted to estimate ageing error
  - Validate age structure
  - Quantify error within ager, among agers
- This information can be incorporated into models
- Campana 2001



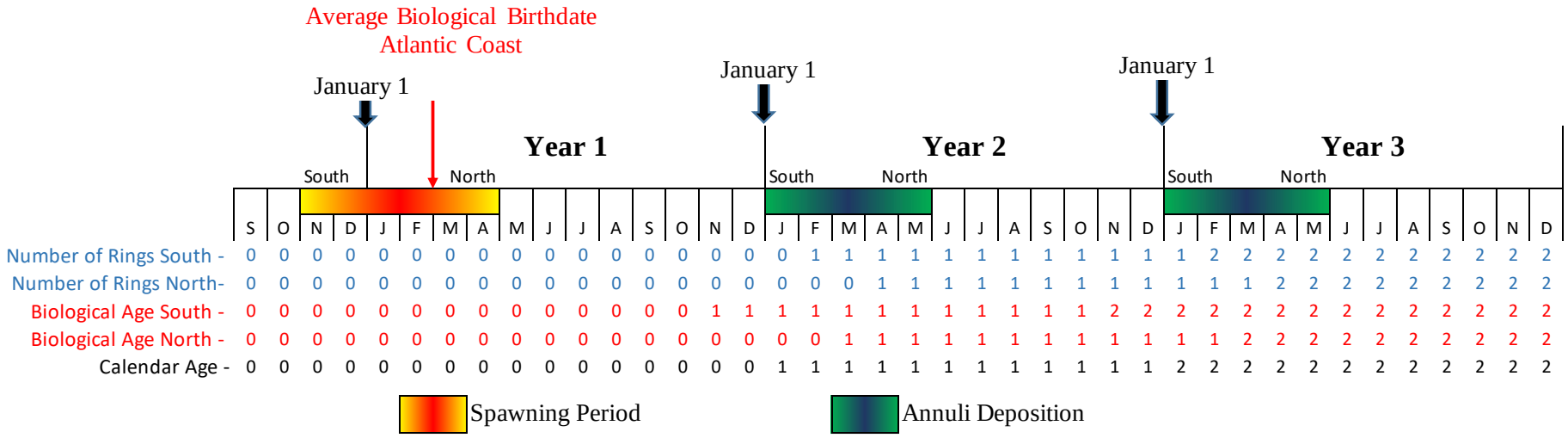




- http://www.asmfc.org/fisheries-science/research#Ageing

Age

- Do ageing error studies indicate age data are useful?
- Is everyone using the same methods?
- Have methods changed over time?
  - E.g., scales to otoliths
- What do the age data represent?



Maturity

- How was the determination made?
  - Macroscopic or histological
- Classification?
  - Brown-Peterson et al. 2011

Uses for Life History Data

- Stock ID
- Growth
- Natural mortality
- Maturity ogive
- Morphometric conversions
- Catch age compositions
- Differences in life history between sexes
- Sex transitions
- Fecundity ogive
- Predator-prey relationships
- Migration

At the Data Workshop

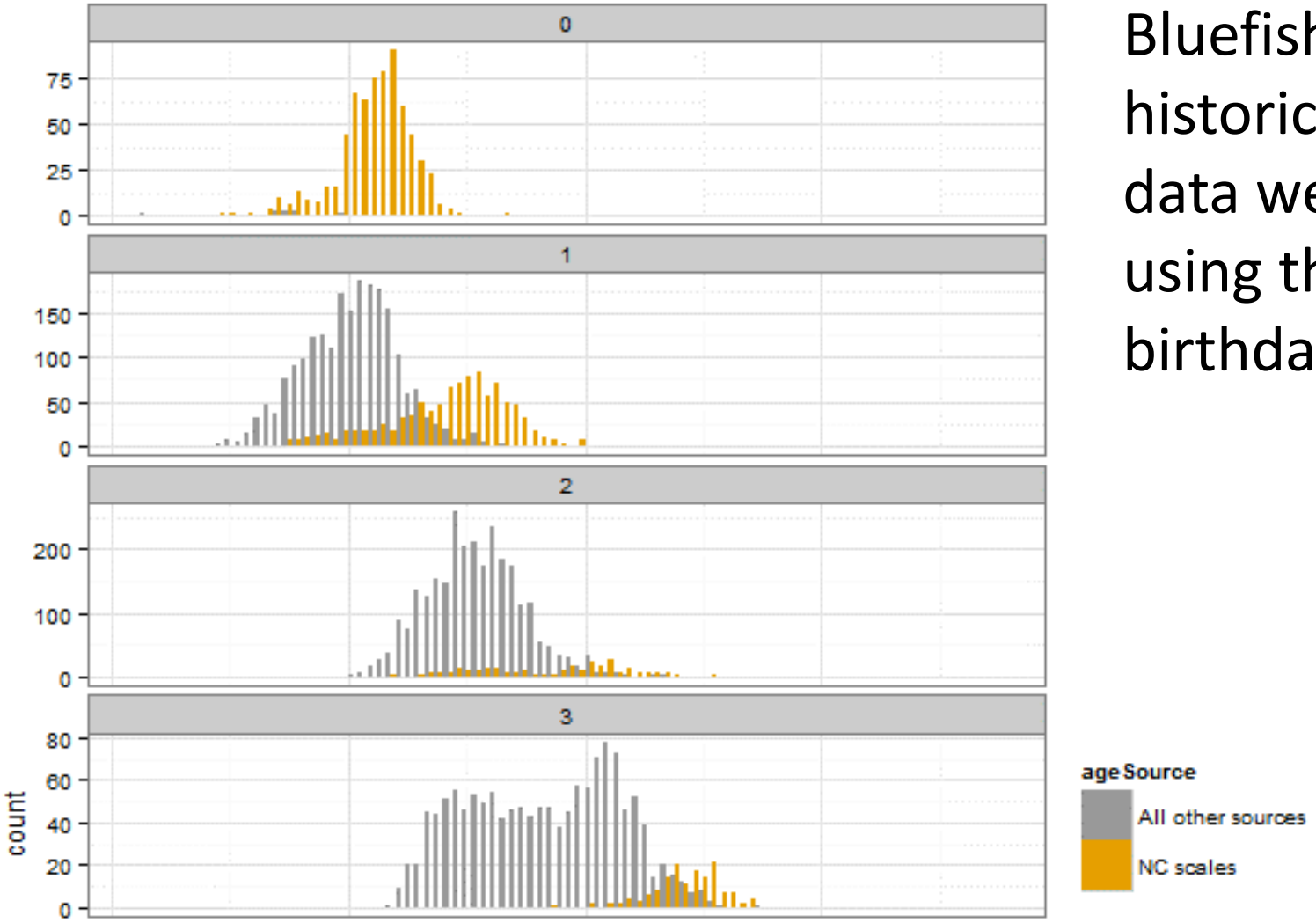
- You will be working with data from multiple different programs and agencies
- Data collection may not be standardized across sources
- Pay attention to metadata:
  - Units (cm, mm, in, kg, lbs)
  - Measurement types (fork length vs. total length, dressed weight vs. live weight)

Simple Evaluations

- Plot your data!!
  - Magnitudes, Units ...do they 'look right'
  - "In the ball park"
  - Outliers, data gaps
  - Temporal or spatial patterns
  - Discrepancies between data sources
- Time to catch major omissions, extraction issues

Starting to understand the data before being used in life history analyses

Simple Evaluations



Bluefish: historical NC data were not using the Jan. 1 birthdate

Life History Parameters

- What are the biological characteristics of a stock and how do these characteristics change over the lifetime of an individual?
- How productive is the stock?
- How is the stock likely to respond to fishing pressure?

$$YPR = \sum_{a=1}^{\infty}\left[\left(\frac{F_a}{F_a + M_a}\right)\cdot\left(1-e^{-(M_a+F_a)}\right)\cdot N_a \cdot w_a\right]$$

$$SPR_y = \frac{\sum_a Mat_a W_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a W_a \prod_1^a e^{-M_a}}$$

Life History Parameters

- Stock ID dictates structure of data inputs
- May be used elsewhere in data development (L-W relationship for CAA as we'll see later)
- These are often used in stock assessment models as fixed inputs
- Develop estimates during the Data Workshop to support assessment models earlier in the process

Input Data
- **Life history parameters**
- Fishery removals
- Biological sampling
- Fishery independent surveys

Stock status
- Overfished or overfishing?

Morphometric Relationships

- Length-length relationships to convert from one length type to another

- Simple linear regression models with slope-intercept form:

$$y = mx + b$$

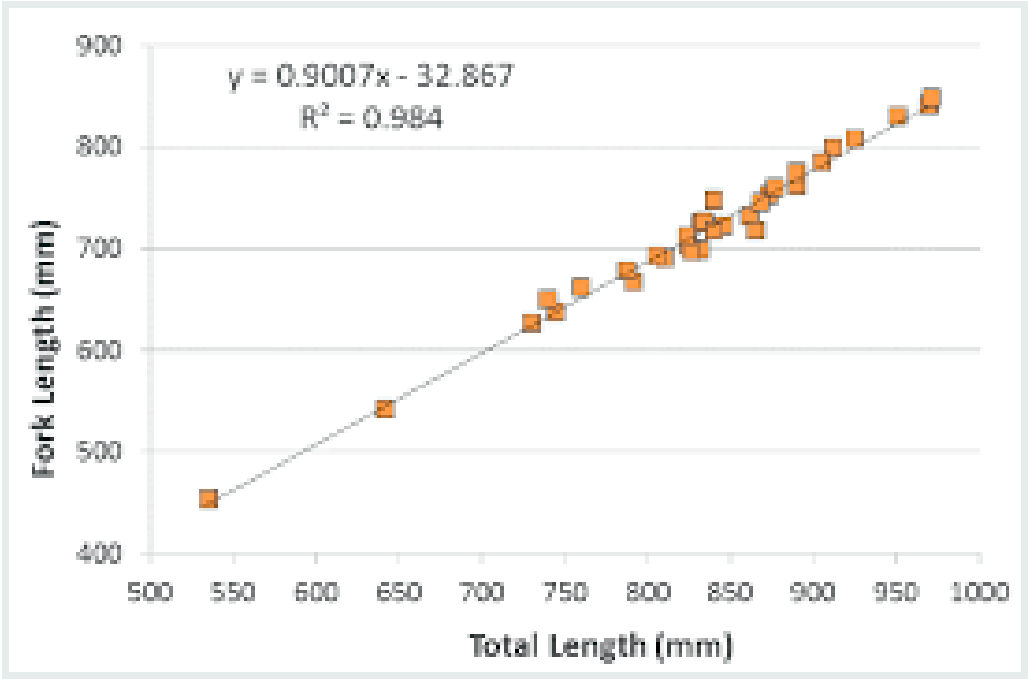
  - Where:

    y=dependent length you are interested in predicting

    m=slope of the relationship

    x=independent length you want to convert

    b=y-intercept



- Typically strong relationships with high R^2

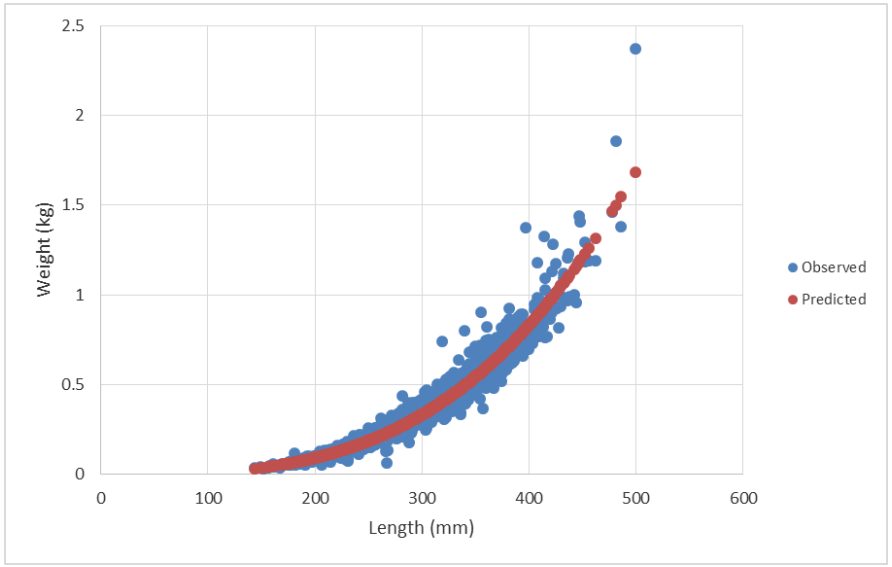
Morphometric Relationships

- Length-weight relationship to convert length to weight

$$W = aL^b$$

- Can log transform to model with a linear model:

$$log(W) = log(a) + b * log(L)$$



– Where:

log(W)=log transformed weight

b=slope of the relationship

log(L)=log transformed length

log(a)=y-intercept

$$SPR_y = \frac{\sum_a Mat_a W_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a W_a \prod_1^a e^{-M_a}}$$

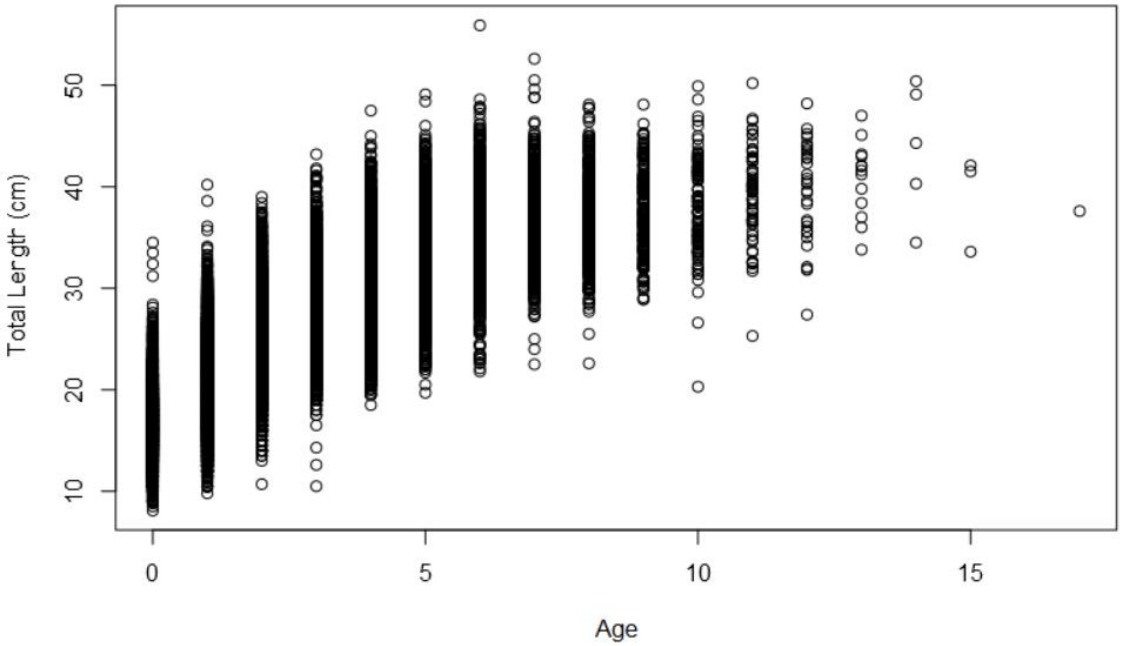
Length-Weight Example

- For example using Excel see the end of the intro recording for week 3 “Components of a Stock Assessment – Life History” using MLE_exercises.xls at: *https://www.youtube.com/playlist?list=PL21PzNp1mlVUMu5A_Ikep5MW1tozrs2_J*

- For R example, open length-weight example.R

Growth

- Length-at-age, weight-at-age
- How does size and weight change across an individual's life?
- Fit model to observed paired length and age data to predict the mean size at any given age



$$SPR_y = \frac{\sum_a Mat_a W_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a W_a \prod_1^a e^{-M_a}}$$

Growth

- Models
  - von Bertalanffy model the most common

$$L_t = L_\infty * \left(1 - e^{-K*(t-t_0)}\right)$$

  - Where:

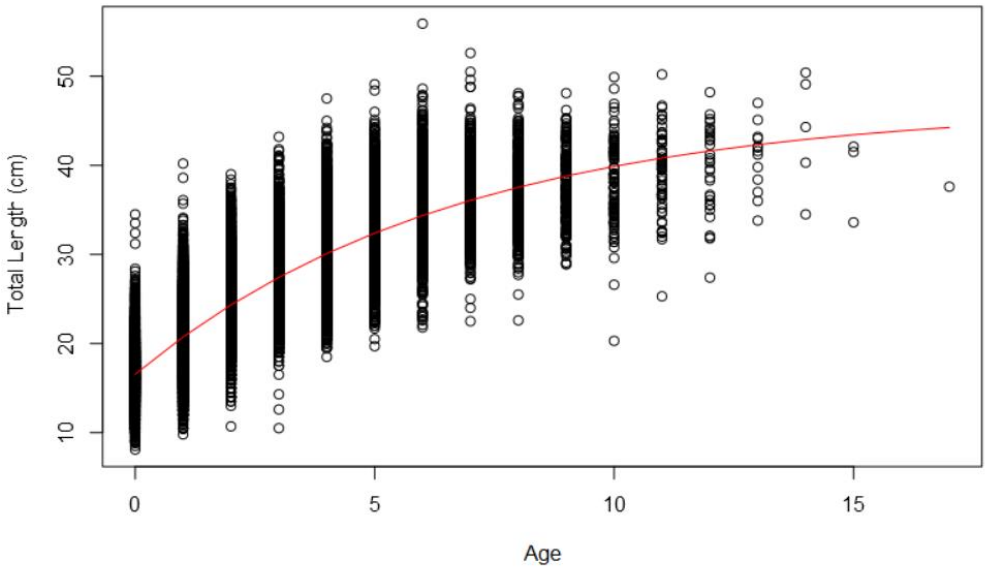
Lt = length at age ***t***

L_∞ = asymptotic length

K = growth rate coefficient

t = age

t0 = age when L=0

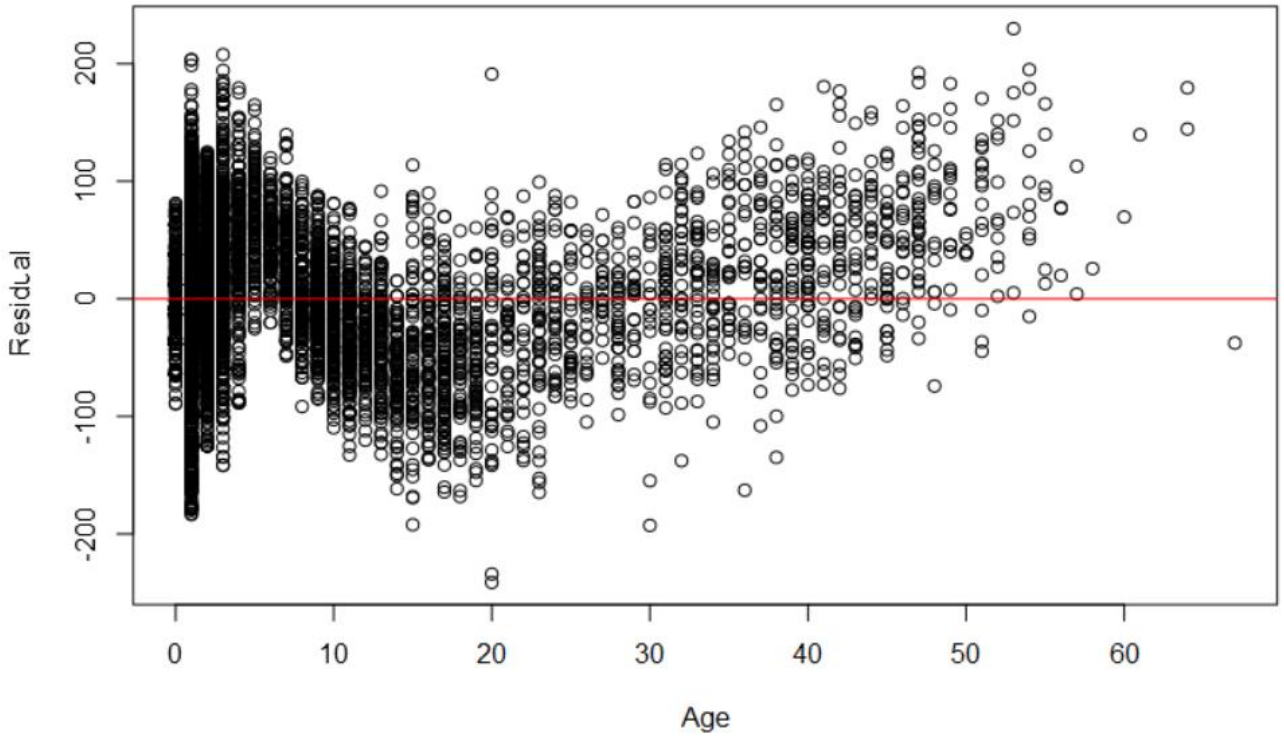


  - Growth parameters can be informative of natural mortality

  - Growth can also be informative of an appropriate plus group

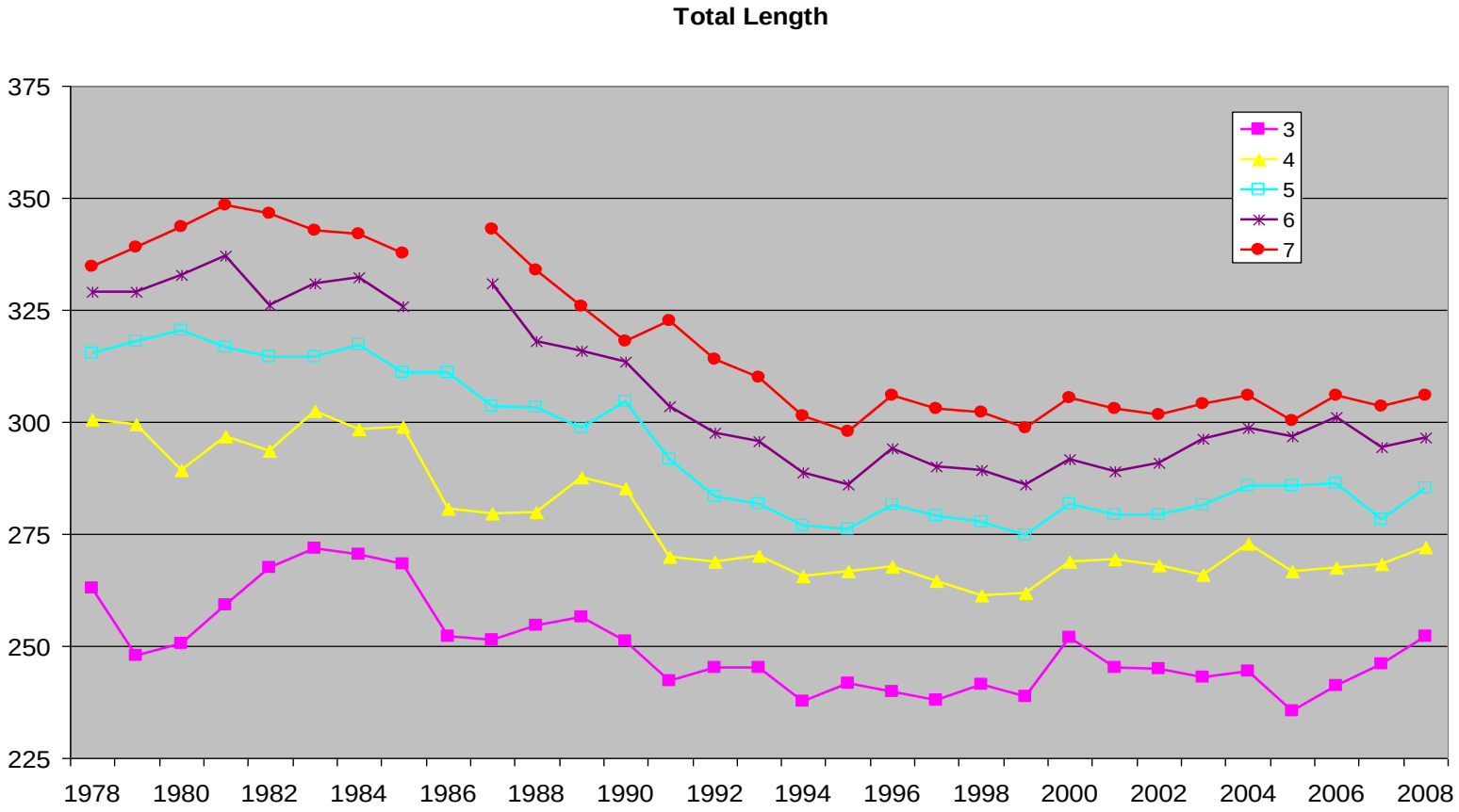
Growth

- Does the growth model provide a good fit to the data? Or is there a better way to predict growth?



Growth

- Does growth vary spatially or temporally?
- Does growth vary by sex?



Questions?

Break Time

Return at:

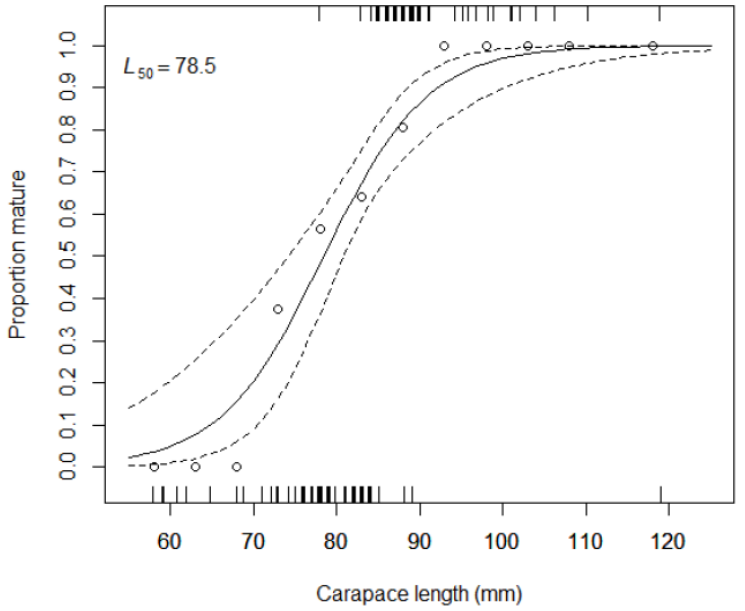
Growth Example

- For example using Excel see the intro recording for week 2 “Intro to Modeling” using MLE_exercises.xls at: *https://www.youtube.com/playlist?list=PL21PzNp1mlVUMu5A_Ikep5MW1tozrs2_J*

- For R example, open growth example.R

Maturity and Reproductive Capacity

- Maturity ogive
  - What proportion of individuals are mature in each size or age class?
  - L_{50} parameter informative for size regulations



- Spawning stock biomass
  - Maturity ogive * weight-at-age/size
  - Proxy for reproductive capacity
  - If using a spawner-per-recruit relationship in model, SSB helps you predict R

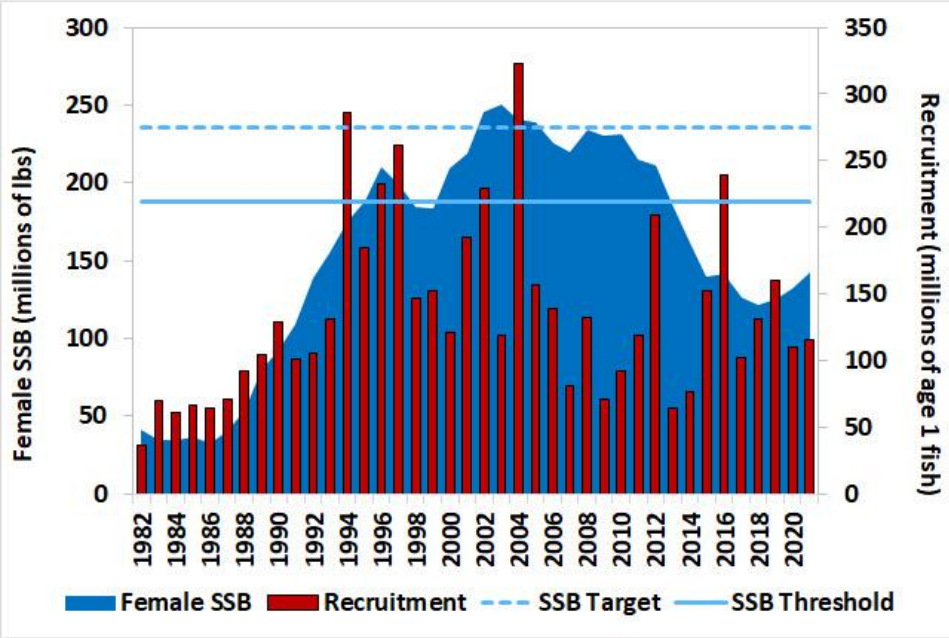
- Fecundity (egg production)

$$SPR_y = \frac{\sum_a Mat_a W_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a W_a \prod_1^a e^{-M_a}}$$

Maturity and Reproductive Capacity

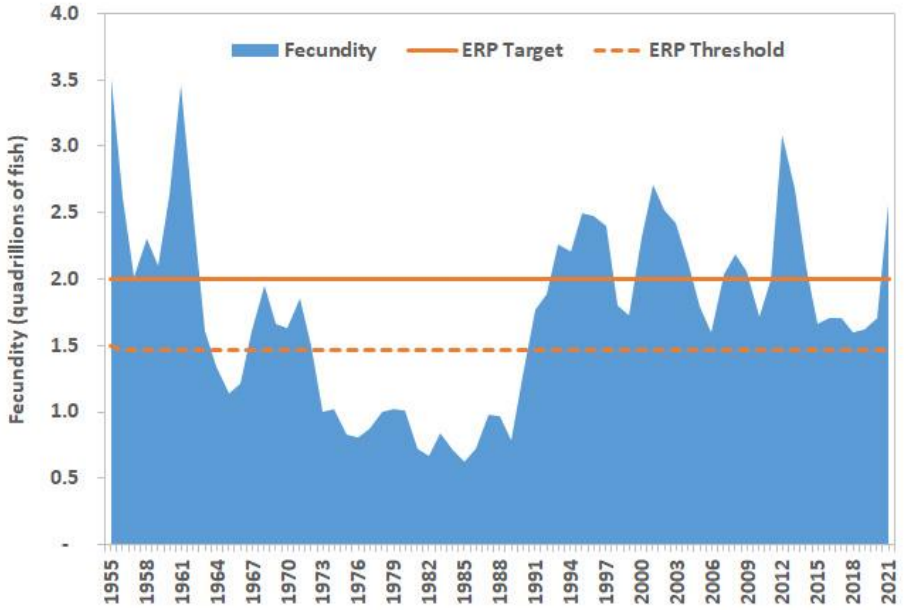
Atlantic Striped Bass Female Spawning Stock Biomass and Recruitment

Source: Atlantic Striped Bass Stock Assessment Update, 2022



Atlantic Menhaden Fecundity

Source: ASMFC Atlantic Menhaden Stock Assessment Overview, 2022



Maturity and Reproductive Capacity

- Things to consider:
  - Maturity at length vs. age
  - Does maturity trigger differences in behavior, growth, survival?
  - Has maturity changed over time?
  - Are there spatial differences in maturity schedules?
  - How does maturity relate to fishery regulations?
  - Are there sex differences in maturity schedules?
  - Is weight an adequate proxy for reproductive capacity?
  - If not, are fecundity data available?

Questions?

Natural Mortality

- Natural mortality (*M*) = rate of death from natural causes

  →Predation, disease, starvation, senescence, poor environmental conditions, etc.

- Trends in catch-at-age and FI surveys reflect effect of both natural and fishing mortality
  - Need to be able to tease apart effects of fishing to manage fisheries effectively

$$SPR_y = \frac{\sum_a Mat_a W_a \prod_1^a e^{-M_a - F_{y,a}}}{\sum_a Mat_a W_a \prod_1^a e^{-M_a}}$$

Natural Mortality

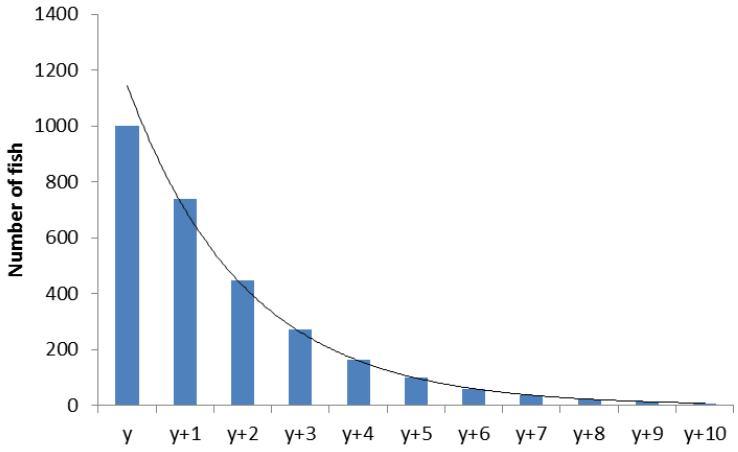
- Typically:
  - Difficult to estimate empirically
  - Estimated with meta-analyses using other life history information (e.g. maximum age)
  - Varies by age/length/stage
  - Varies over time (especially for prey species)

Natural Mortality

- Empirical estimates of *M*

  → Track the decline of age classes in unexploited/lightly exploited populations (catch curve analysis)

  → Tagging studies (dependent on good estimates of reporting rate)



Natural Mortality

- Meta-analysis-based approaches

→ Open up Natural Mortality Estimators.xlsx

Natural Mortality

- Things to consider
  - Can you estimate it?
  - Does it change with age/size and/or over time?
  - How are your model results affected by assumptions regarding *M*?
  - Also, think about literature, similar species, what you know…

Questions?

Stock ID

- Stock = a group of individuals of the same species that behave (migrate, spawn) as a unit and are genetically identical, affected by the fishery as a unit

- Is there a single coastwide stock or are there biologically distinct units within the range?

- Nail this down early: it affects the rest of your data decisions and input development
  - Can you split the catch/index/biosample data into separate stock units?
  - Internationally boundaries and data availability

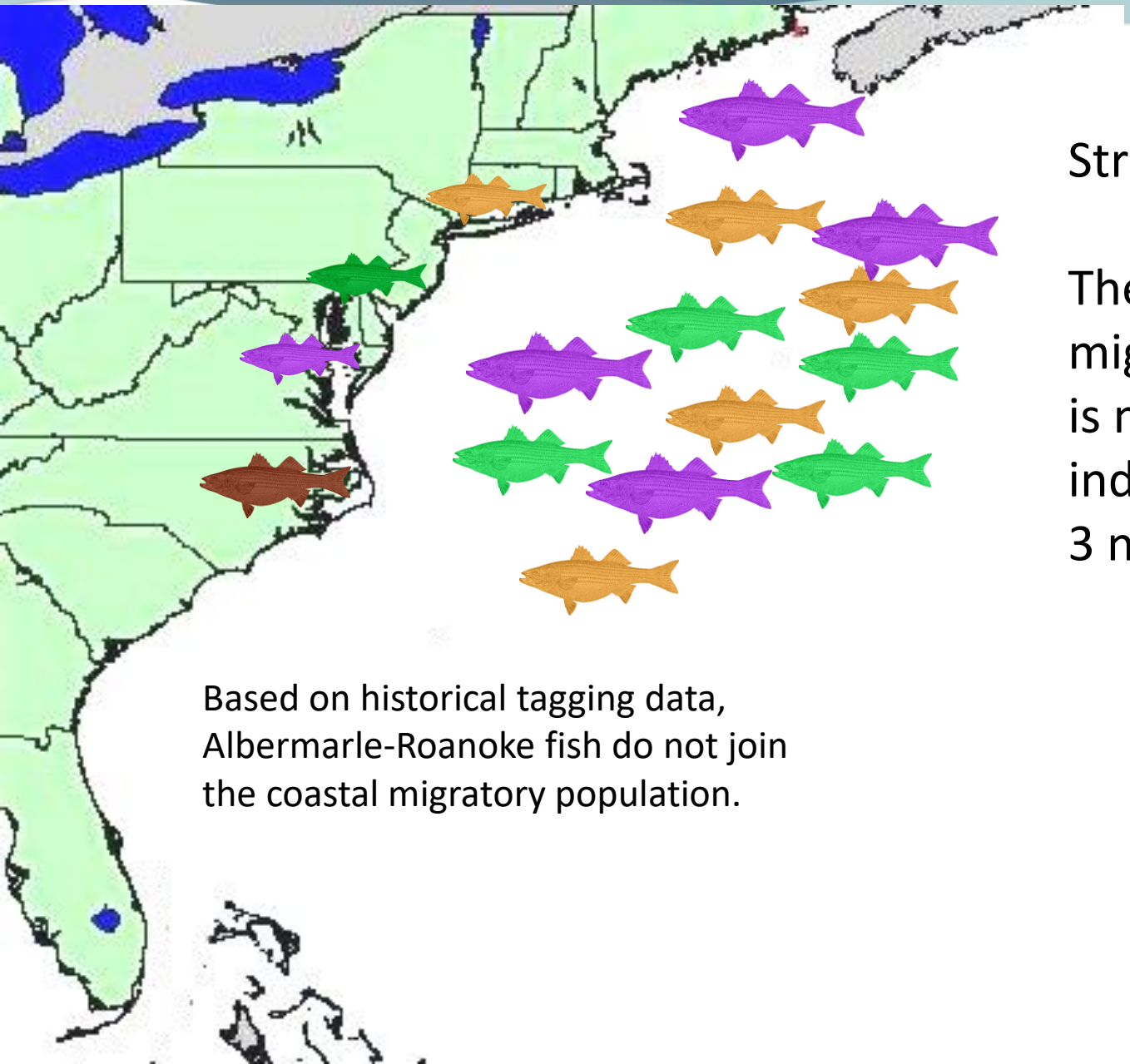
How Do You Define a Stock?

- Genetic data
- Tagging data
- Spawning and larval transport
- Other life history differences

Stock ID

- Red Drum
- Managed & assessed as 2 separate stocks
- Life history information
  - Max age and size differences
- Tagging information
- Genetics information

Stock ID

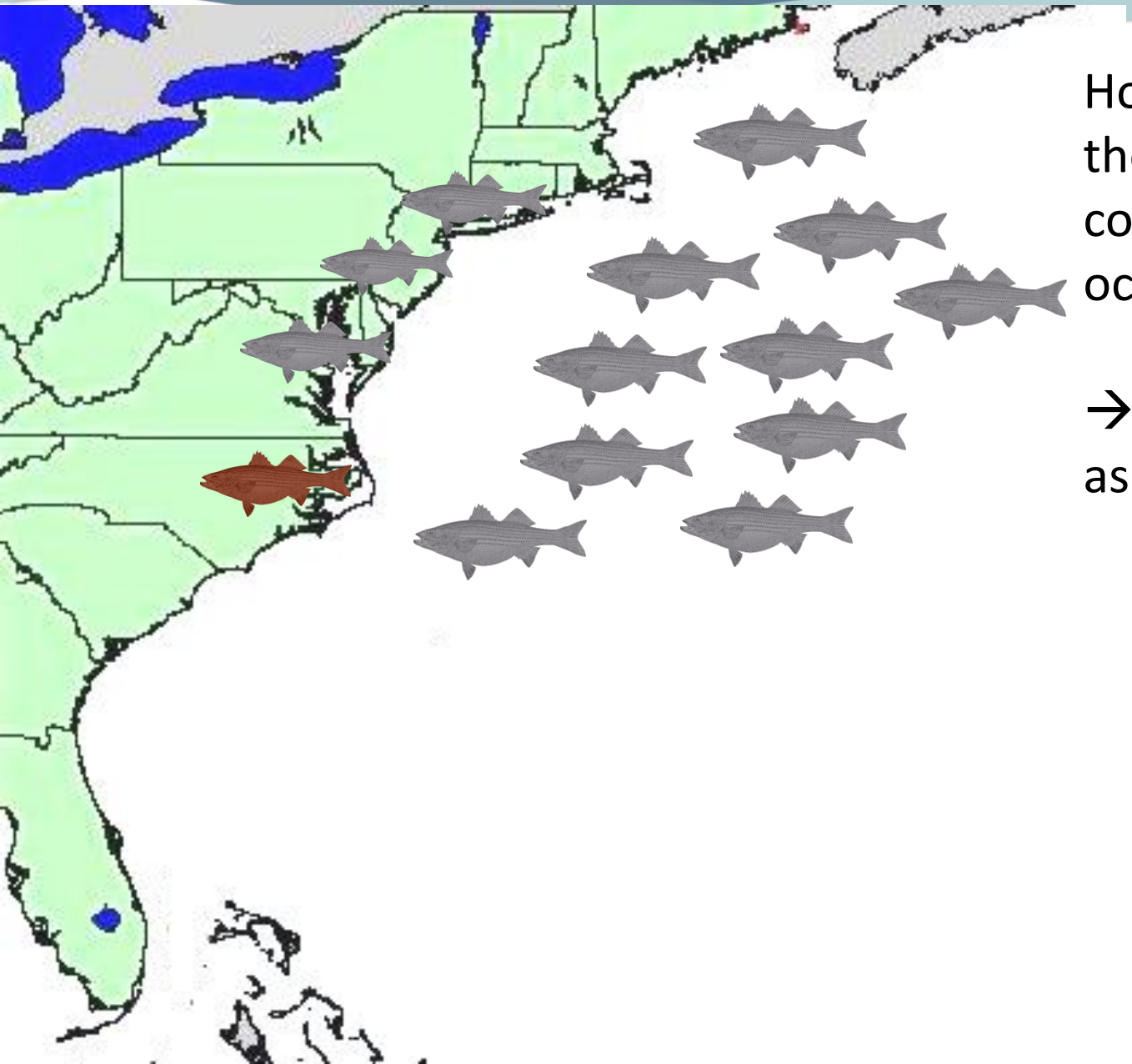


Based on historical tagging data, Albermarle-Roanoke fish do not join the coastal migratory population.

Striped Bass

The coastal migratory population is made up of individuals from the 3 northern stocks.

Stock ID



However, we can't ID the individual stock components of the ocean catch

→ Manage & assess as a single stock

Stock ID

- Is there tagging/genetic/spawning evidence to support a unit stock?
- Do you have the data to assess the entire stock? If not, reconsider or caveat your conclusions!
- How serious are substock dynamics relative to model assumptions?
- Unless your model includes migration, it assumes your stock is homogeneous

Questions?

Life History: Project

- Project and working session next week….

1. **Calculate length-weight relationship and size-at-age for 2015. Evaluate spatial or seasonal differences in growth.**

2. **Develop estimates of M using more than one method. Compare the results and recommend a preferred method.**

- Give these a try using the examples provided or your own code and bring questions next week

Group Assignments

Life History: L-W, Size-at-Age
(Life History Q1)
Margaret Conroy
Brendan Harrison
CJ Schlick
Holly White
Caitlin Craig

Life History: M
(Life History Q2)
Daniel Sasson
Shelby White
Tara Dolan
Michaela Pawluk
Tori Kentner

Age-Length Keys
(Catch Q1)
Jes Waller
Heather Christiansen
Brooke Lowman
Rich Pendleton
Conor O'Donnell

2015 CAA
(Catch Q2 & Q3)
Eddie Leonard
Judd Curtis
Matthew Jargowsky
Ryan Harrell
Tyler Grabowski

FD Index
(Indices Q1 & Q2)
Alexa Galvan
Kelli Mosca
Lulu Bates
Corey Pelletier
Somers Smott

FI Index
(Indices Q1 & Q2)
Chad Power
Julia Livermore
Jimmy Kilfoil
Ana Vaz
Corinne Truesdale
Halie O'Farrell

Questions?