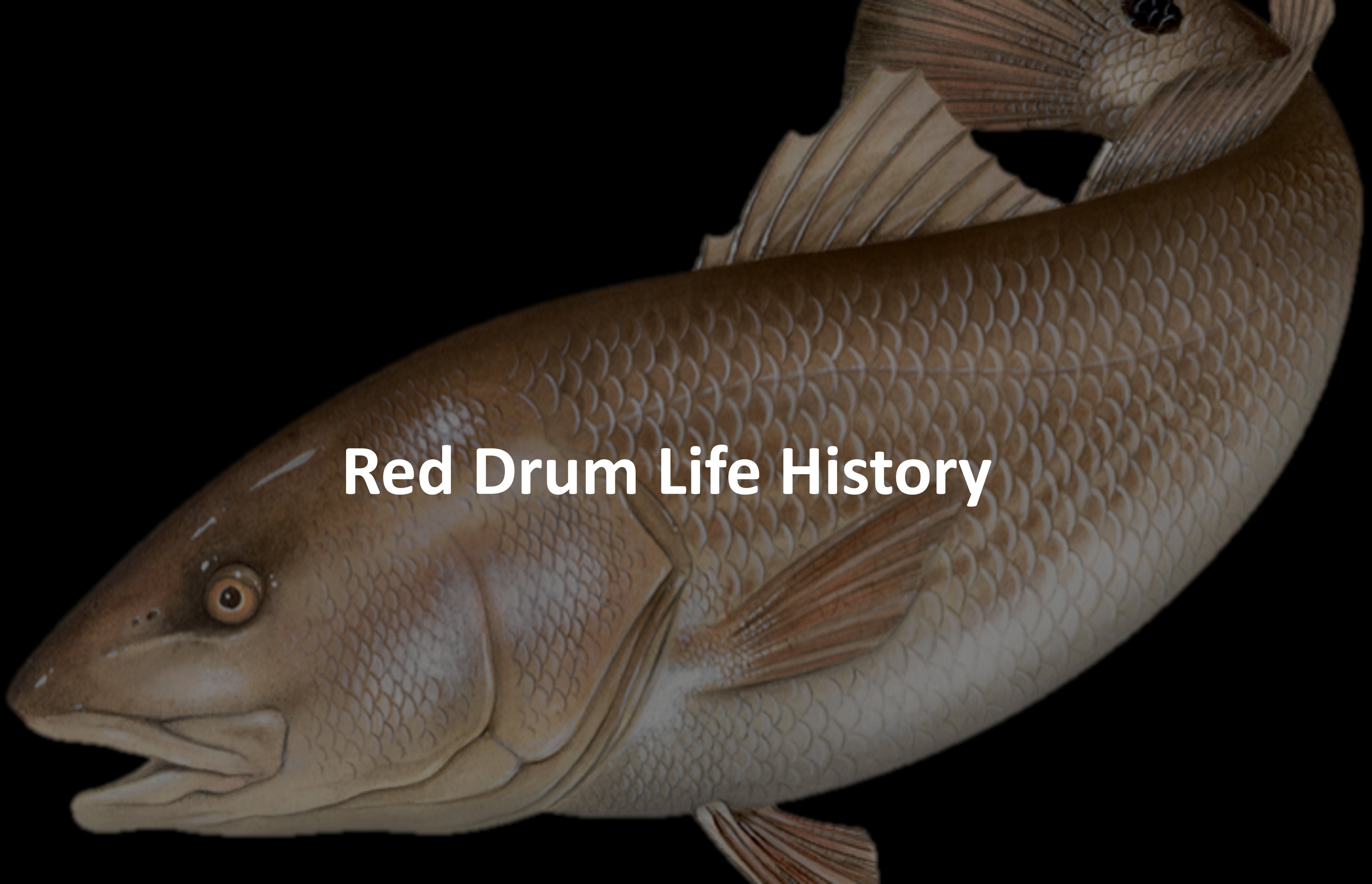
Red Drum Life History

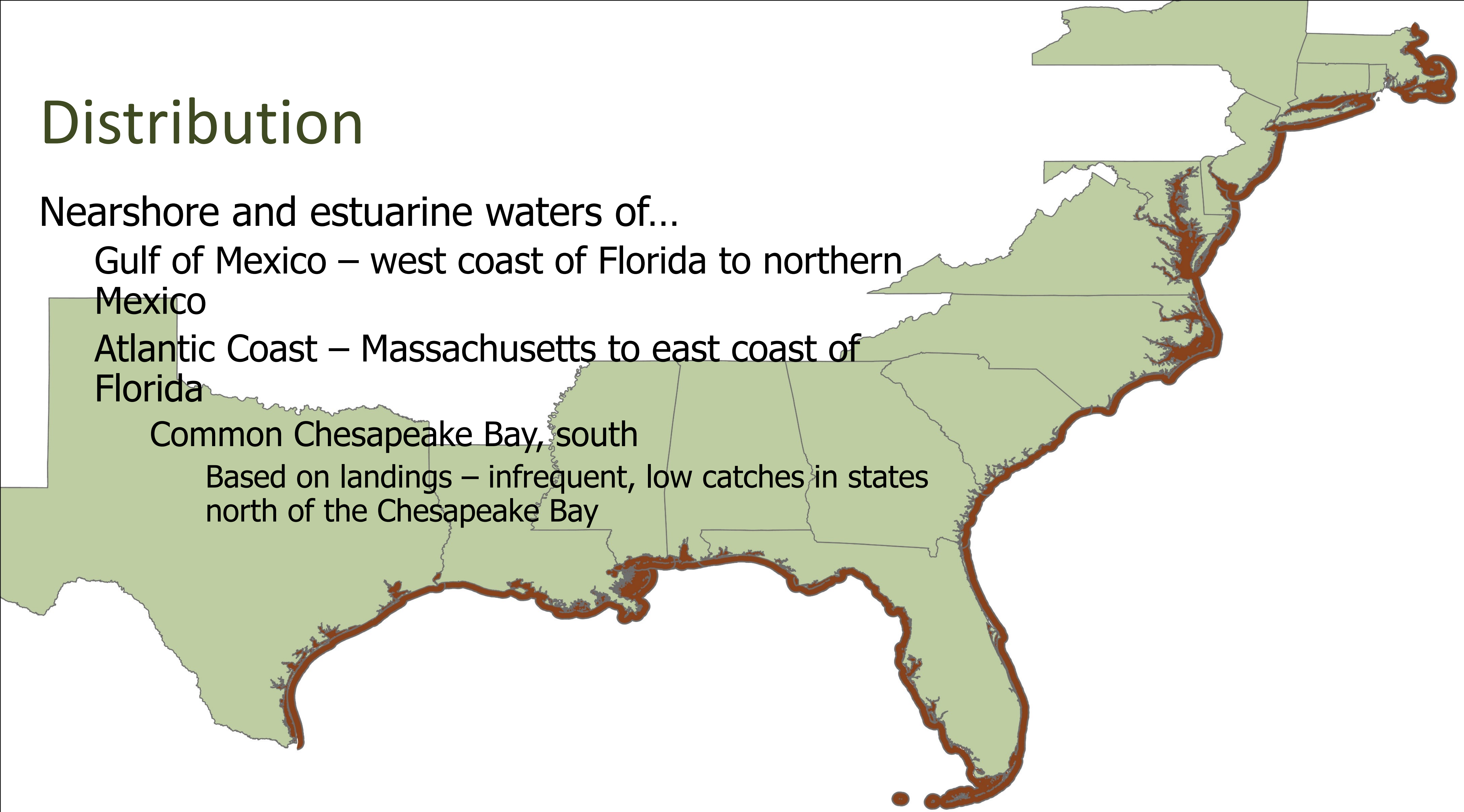


Distribution, Stock Definition & Red Drum Migration Patterns

Distribution

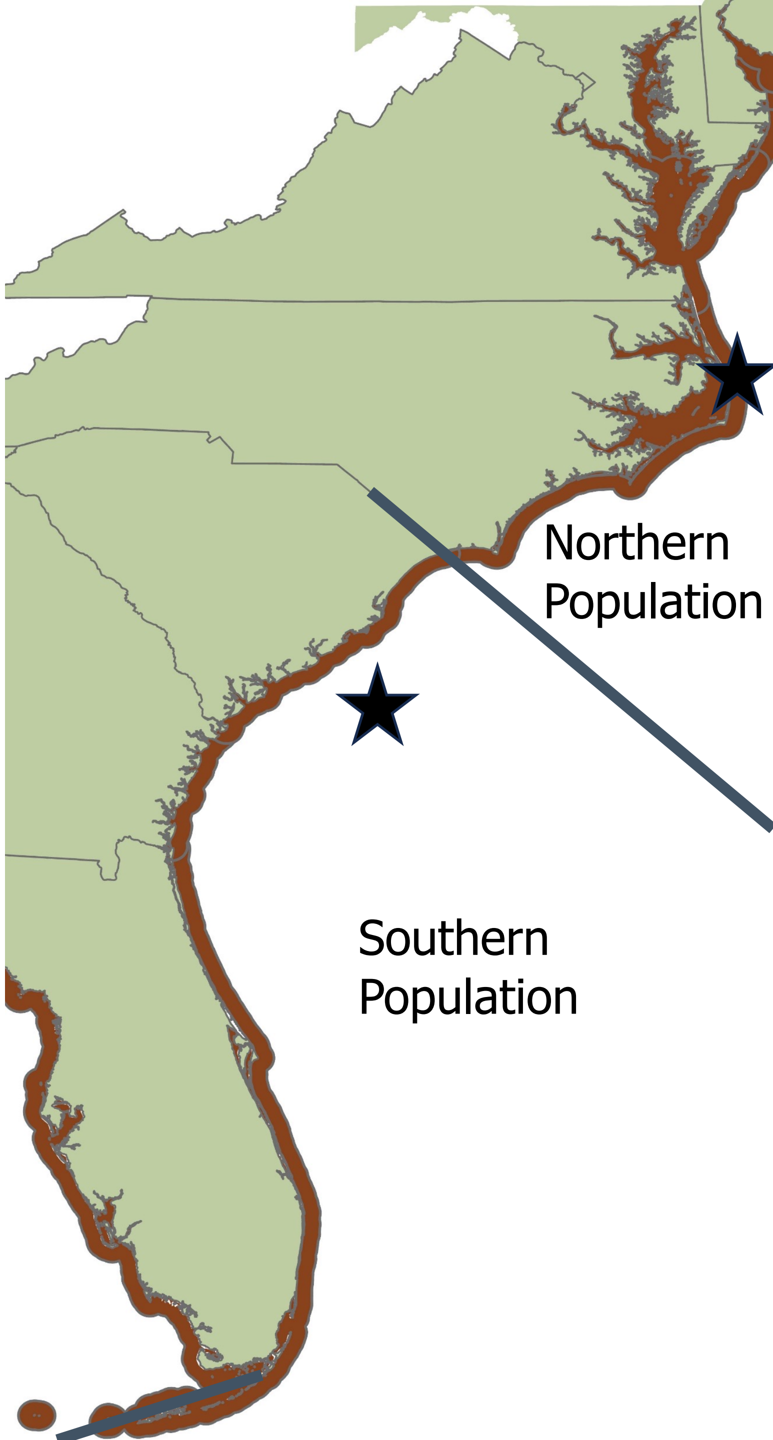
Nearshore and estuarine waters of…

- Gulf of Mexico – west coast of Florida to northern Mexico
- Atlantic Coast – Massachusetts to east coast of Florida
  - Common Chesapeake Bay, south
    - Based on landings – infrequent, low catches in states north of the Chesapeake Bay



US Atlantic Coast

- Two stocks (genetics, tagging studies & life history)
  - Northern stock – SC/NC border north
    - NC, VA, MD, PRFC, DE, NJ
  - Southern stock – SC/NC border south
    - SC, GA, & east coast of FL
- SAS did some limited investigation of breakpoint between the two stocks
  - Cushman et al. 2014
    - Limited to no genetic samples between Cape Hatteras, NC and the NC/SC boarder
  - Investigated growth of southern NC red drum to see if matched northern or southern growth patterns
    - Not sufficient data to determine; warrants further future investigation where exactly the stock structure break occurs



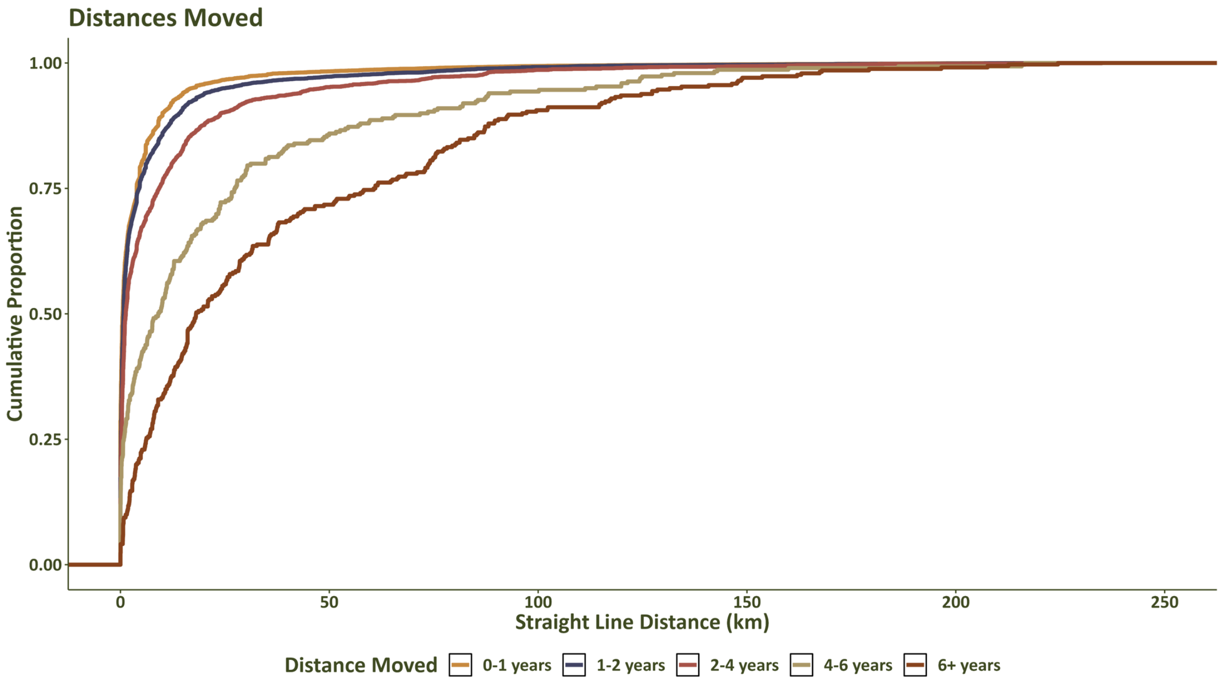
Migration Patterns

Genetics – some mixing during the non-spawning season of adult fish between South Carolina and North Carolina

- Population largely protected from exploitation during non-spawning season

Tagging Studies – limited movement of sub-adults and adults

- Northern population
  - Evidence of adult red drum movement between Virginia and North Carolina
    - Move into VA from NC in late-May, staying in the area through Sept, before overwintering off NC
    - Not all adults migratory; limited movement of sub-adults
- Southern population – limited movement
  - GA: >85% recaptured in GA
  - SC: >99% recaptured in SC
    - Held for both sub-adults and adults
    - Majority recaptured within 50 km of tagging location
      - Only 147 fish recaptured >150 km from tagging location (maximum 467 km)
      - Tendency of larger distances moved w/ age



Age and Growth

Age Data Sources

State Agencies

- Northern Stock – VMRC & NCDMF
- Southern Stock – SCDNR, GADNR & FLFWC

Aging Methodology

- Otoliths
- Scales

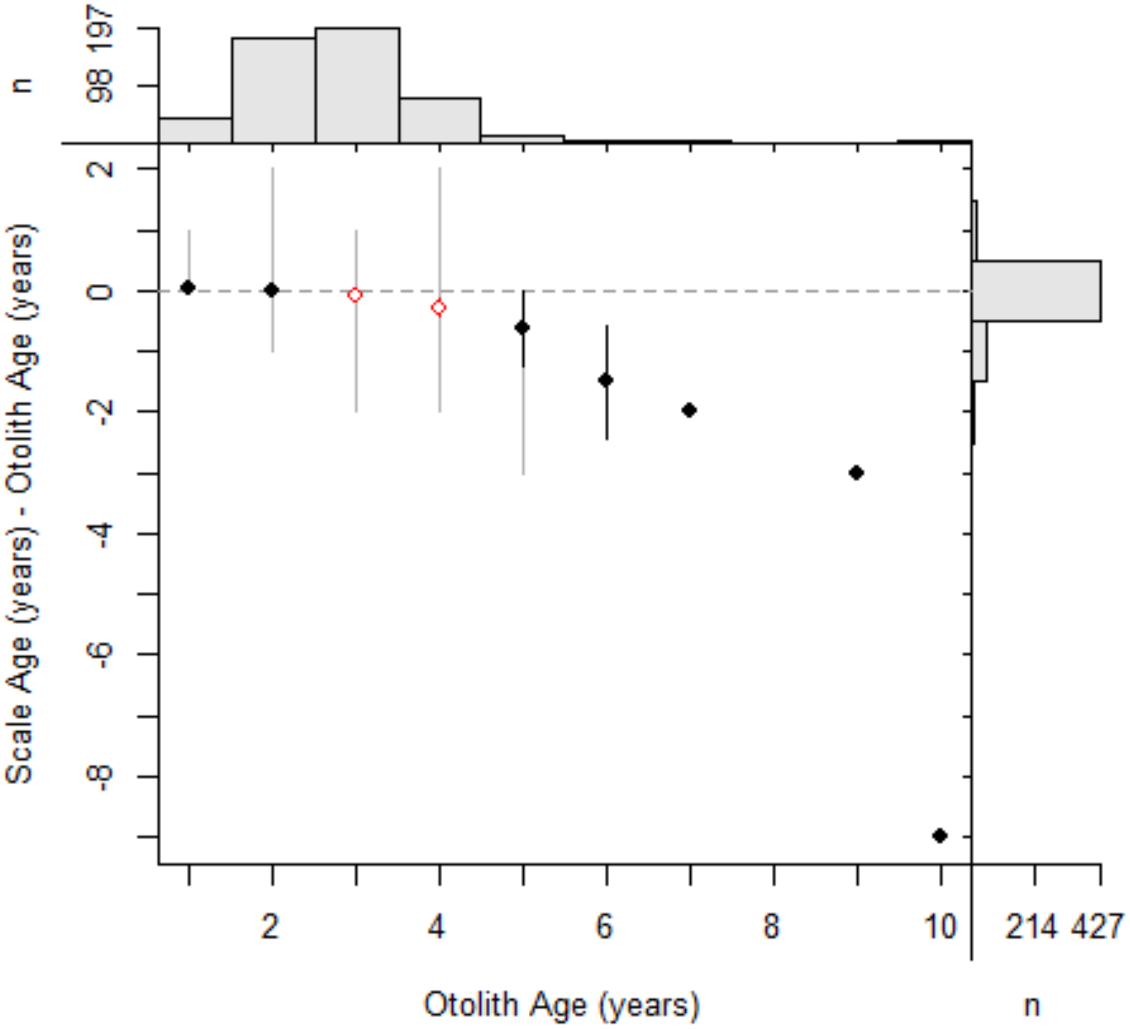
Age Data Sources

State Agencies

- Northern Stock – VMRC & NCDMF
- Southern Stock – SCDNR, GADNR & FLFWC

Aging Methodology

- Otoliths
- Scales
  - Bias (under-aging) in scale derived ages by age-3
  - Absolute agreement = 83%
  - **Discarded scale derived ages**



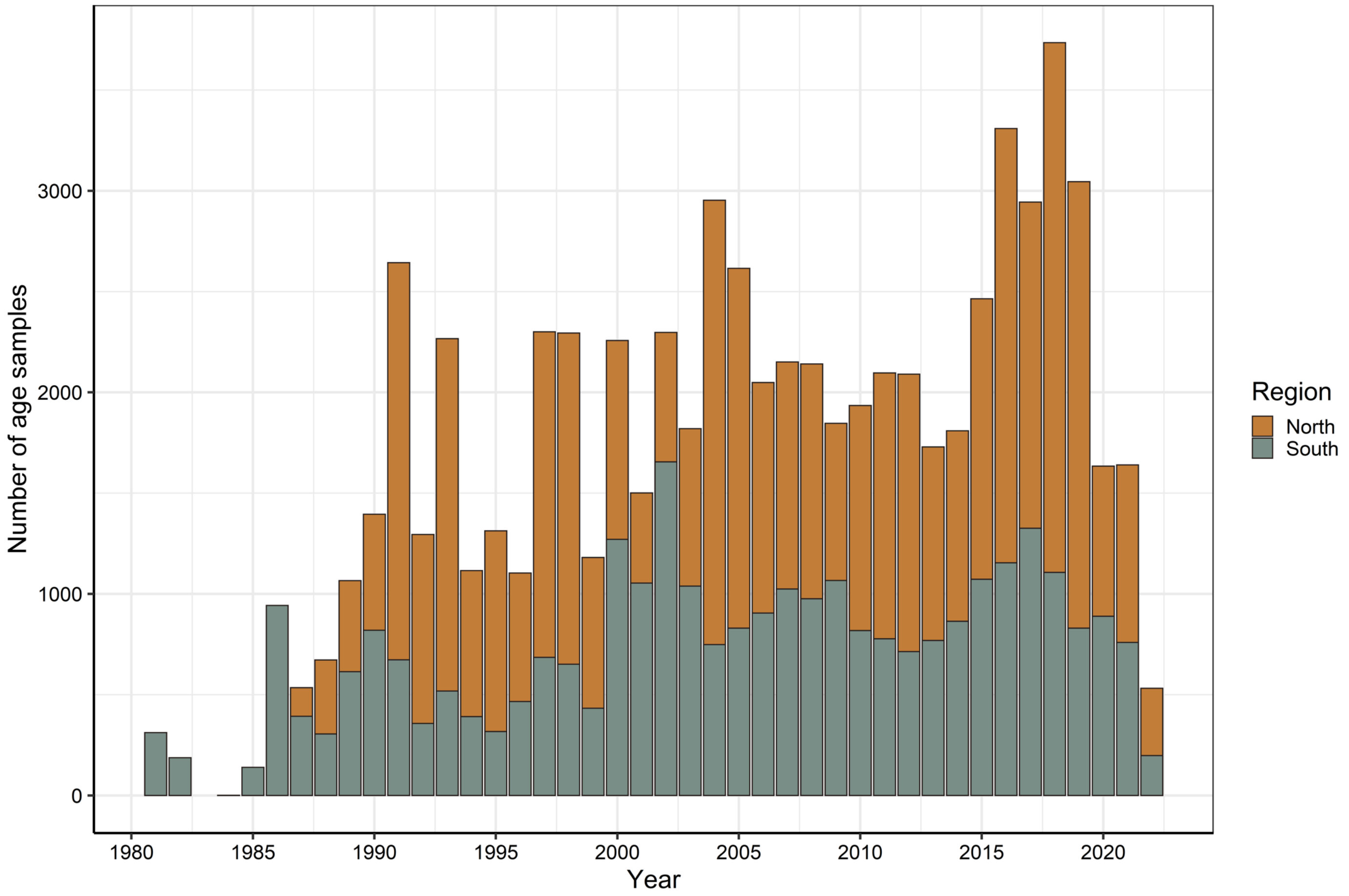
Otolith Derived Age Data

N = 71,355 aged fish

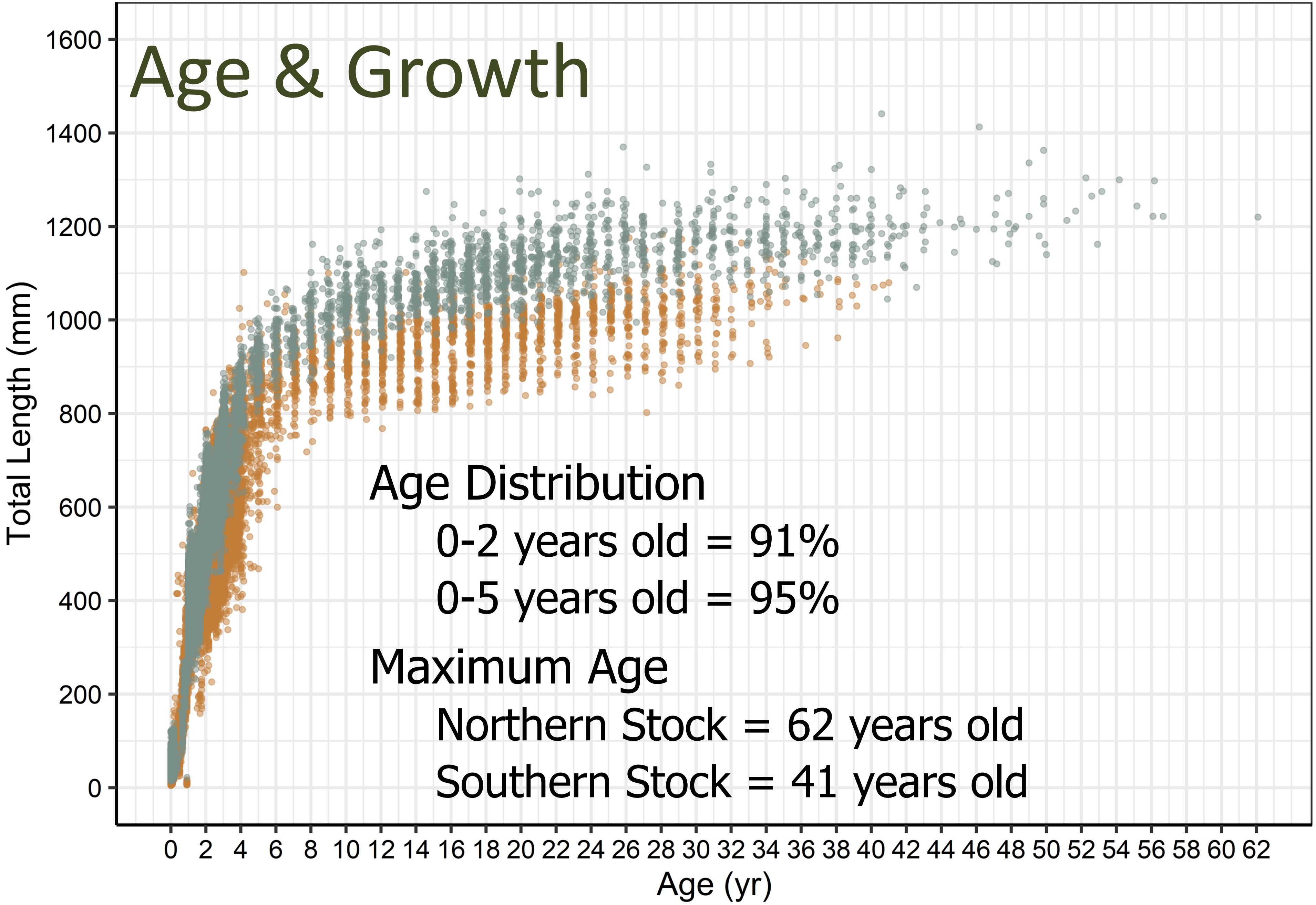
- Northern Stock: 57.9% (n = 41,301)
- Southern Stock: 42.1% (n = 30,054)

# of Annual Samples

- > 500 annual samples every year since 1986



Age & Growth



Age Distribution

0-2 years old = 91%

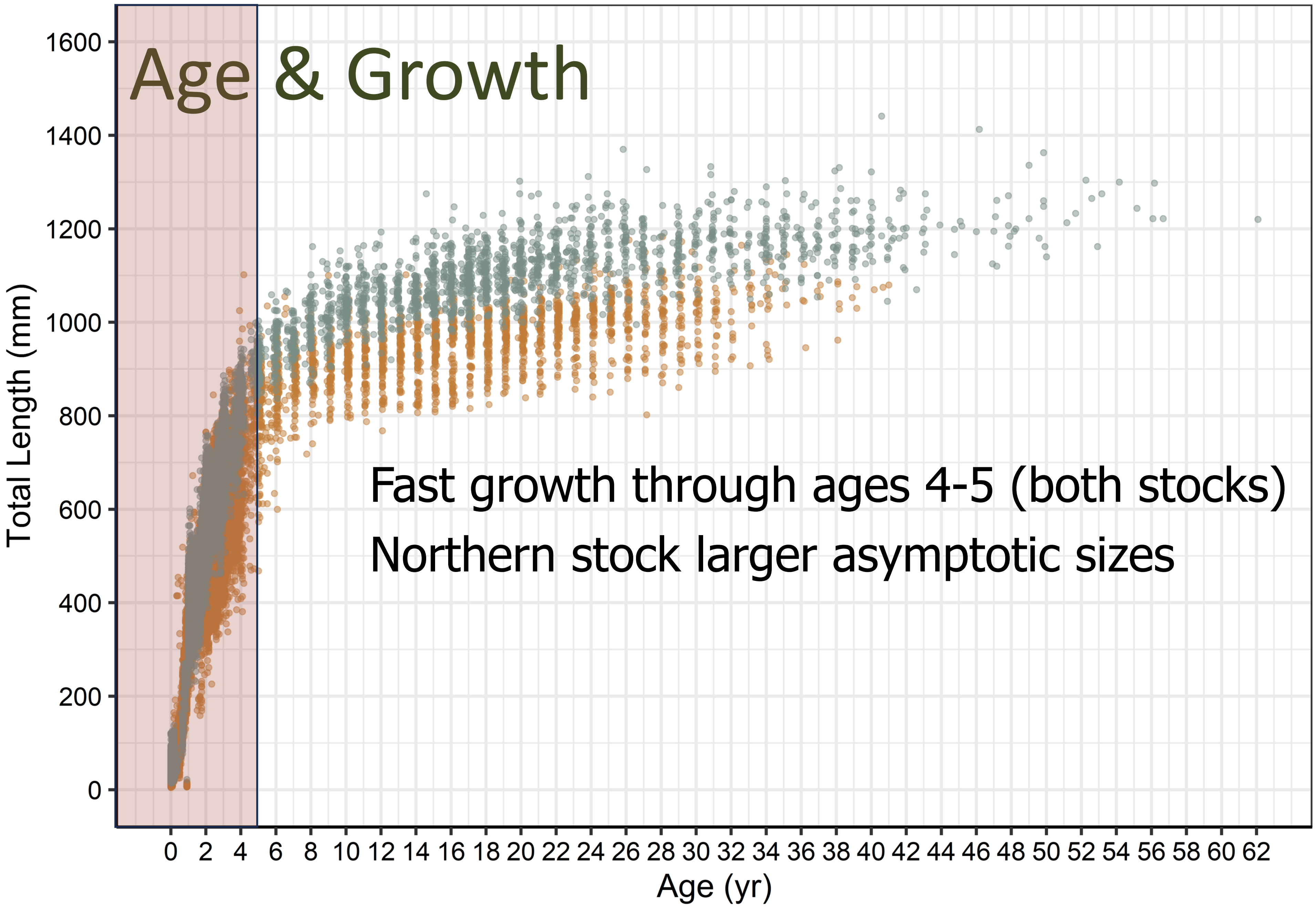
0-5 years old = 95%

Maximum Age

Northern Stock = 62 years old

Southern Stock = 41 years old

Age & Growth



Fast growth through ages 4-5 (both stocks)

Northern stock larger asymptotic sizes

Age & Growth

Red drum growth does not conform to traditional growth functions (e.g., Von Bertalanffy; see Porch et al. 2002 & Cadigan 2009)

- Strong seasonal influences on growth
- Evidence of changing growth rates over the age range of the stocks

Custom growth models not compatible with SS

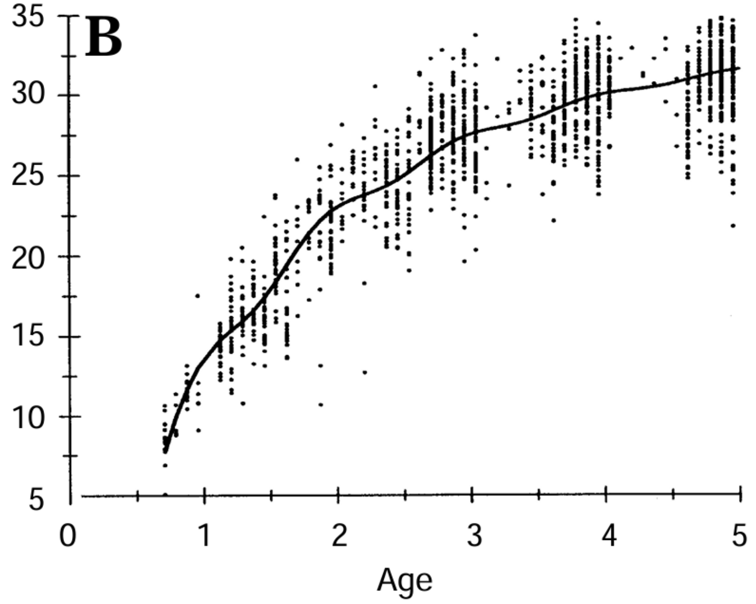


Figure 1B from Porch et al. 2002: Seasonal growth model fit for younger ages

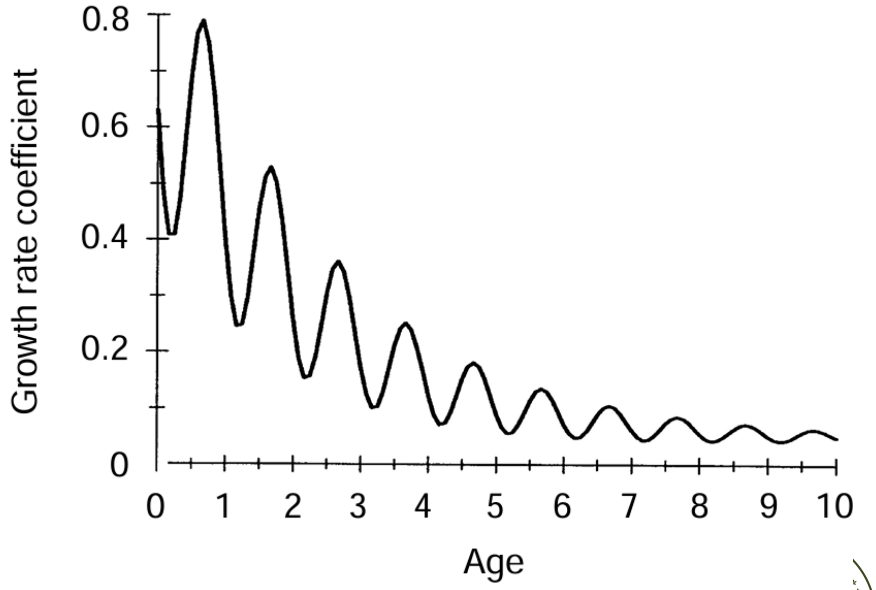


Figure 2 from Porch et al. 2002: Growth rate coefficient from seasonal model as a function of

Age-varying *k* Growth

Allows the von Bertalanffy growth coefficient parameter (*k*) to change across ages

- Compatible with SS

k changes at **<u>user specified</u>** older ages

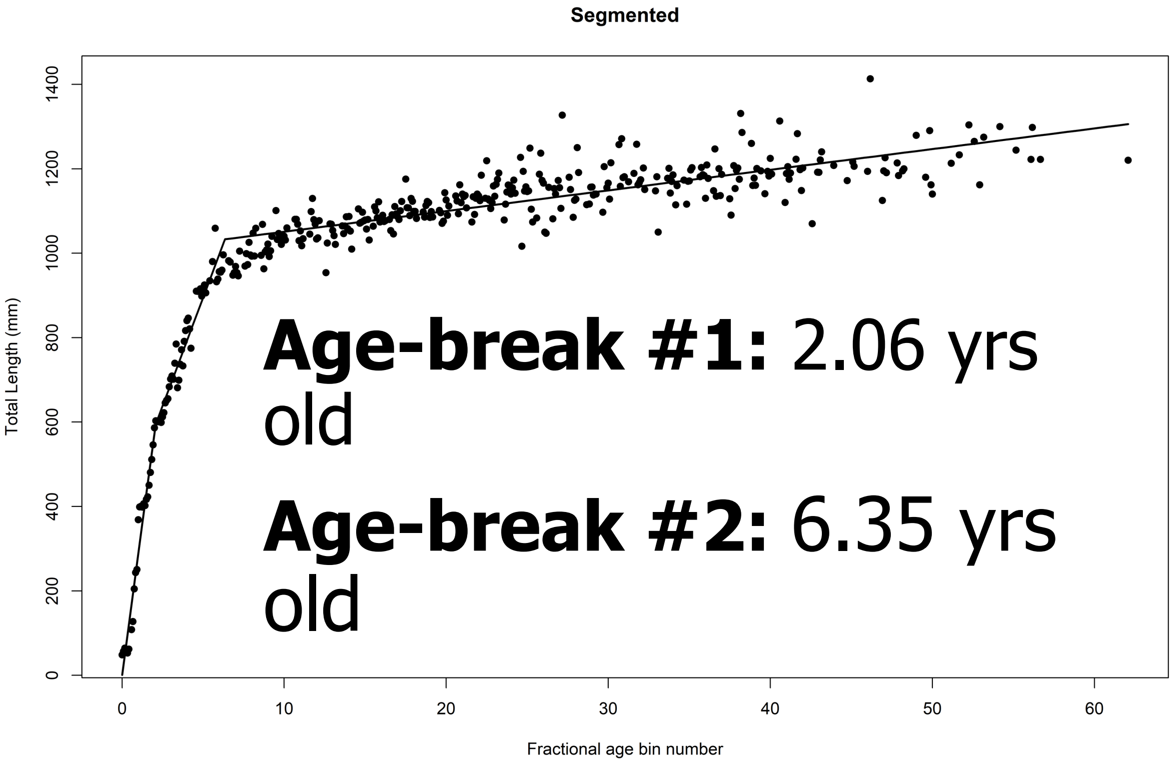
- Flexibility to the growth curve

Externally, initially used segmented regression to identify age break points

- Investigated 1 vs 2 “breaks” for each population – 2 breaks preferred

Segmented Regression Fits

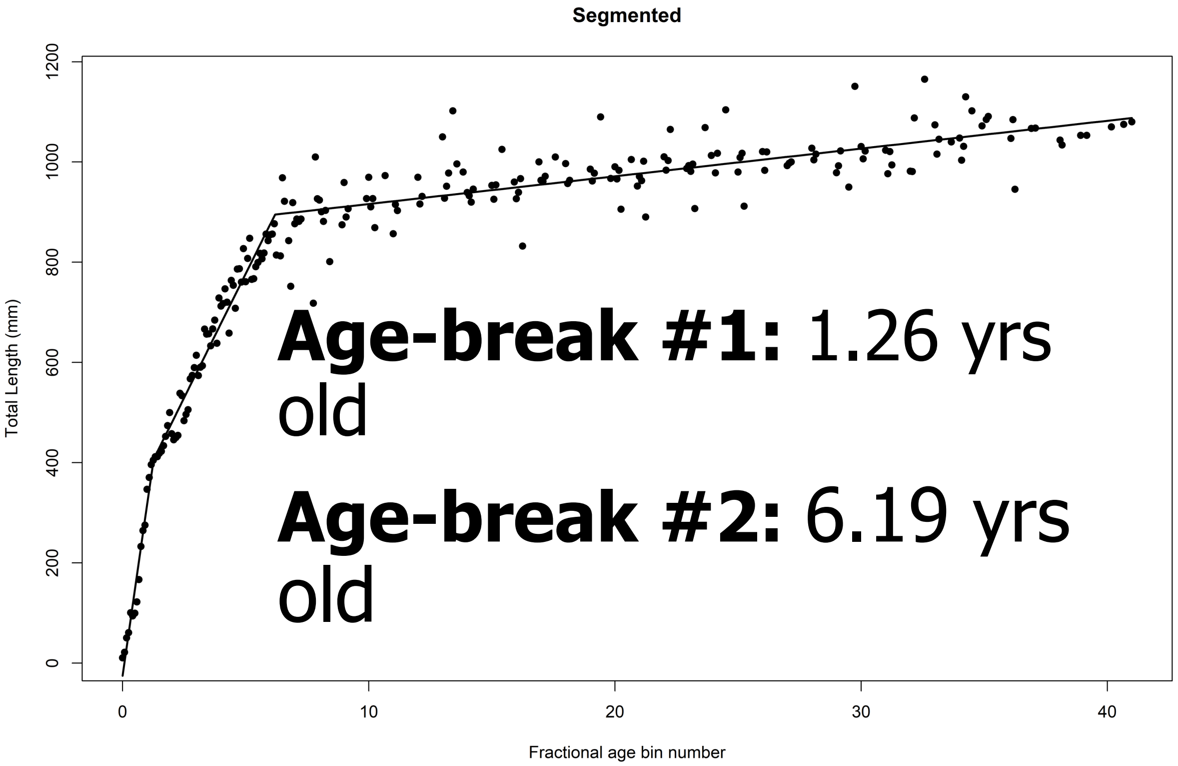
Northern Population



Age-break #1: 2.06 yrs old

Age-break #2: 6.35 yrs old

Southern Population



Age-break #1: 1.26 yrs old

Age-break #2: 6.19 yrs old

Age-varying *k* Growth

Fit to observed **population specific…**

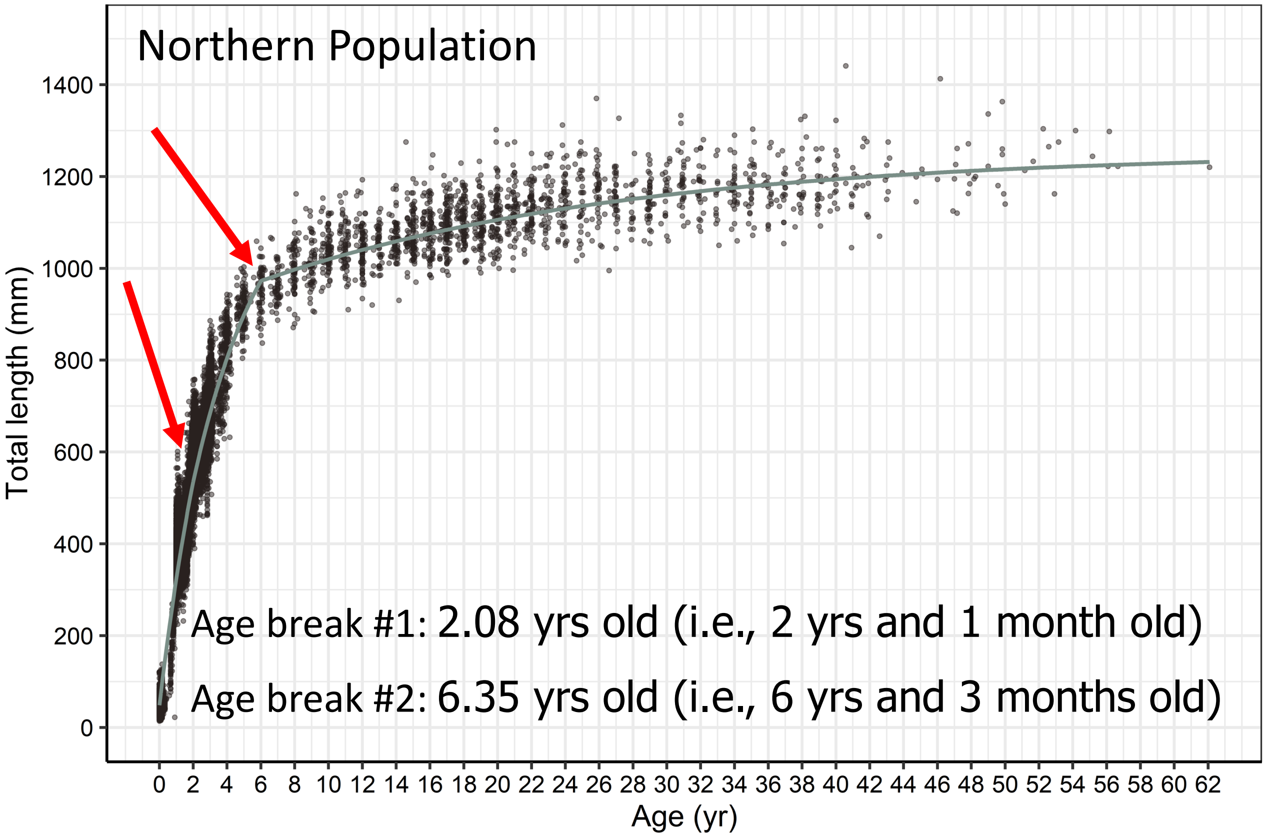
- Biological age and associated mean total length-@-biological age data

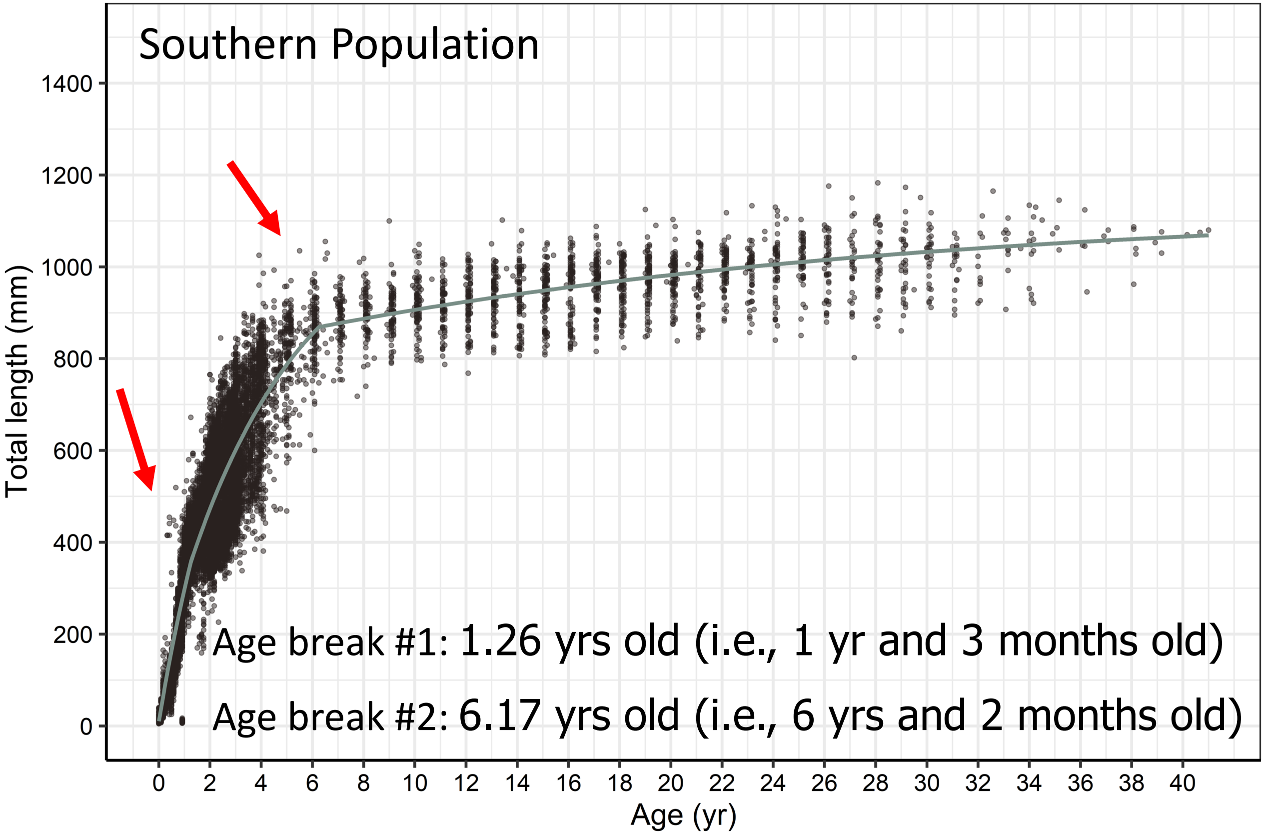
Estimated parameters: L_∞, k_{base}, k_1, *and* k_2

- *k* allowed to change at previously identified breakpoints (rounded to nearest integer month)
  - Northern population: Ages 2.08 and 6.25
  - Southern population: Ages 1.5 and 6.17

External estimates used as starting values in SS models

Age-varying *k* Growth





Reproduction

Spawning Seasonality, **Sexual Maturity**, Sex Ratio, Spawning Frequency, Spawning Location, Batch Fecundity, and Recruitment Drivers

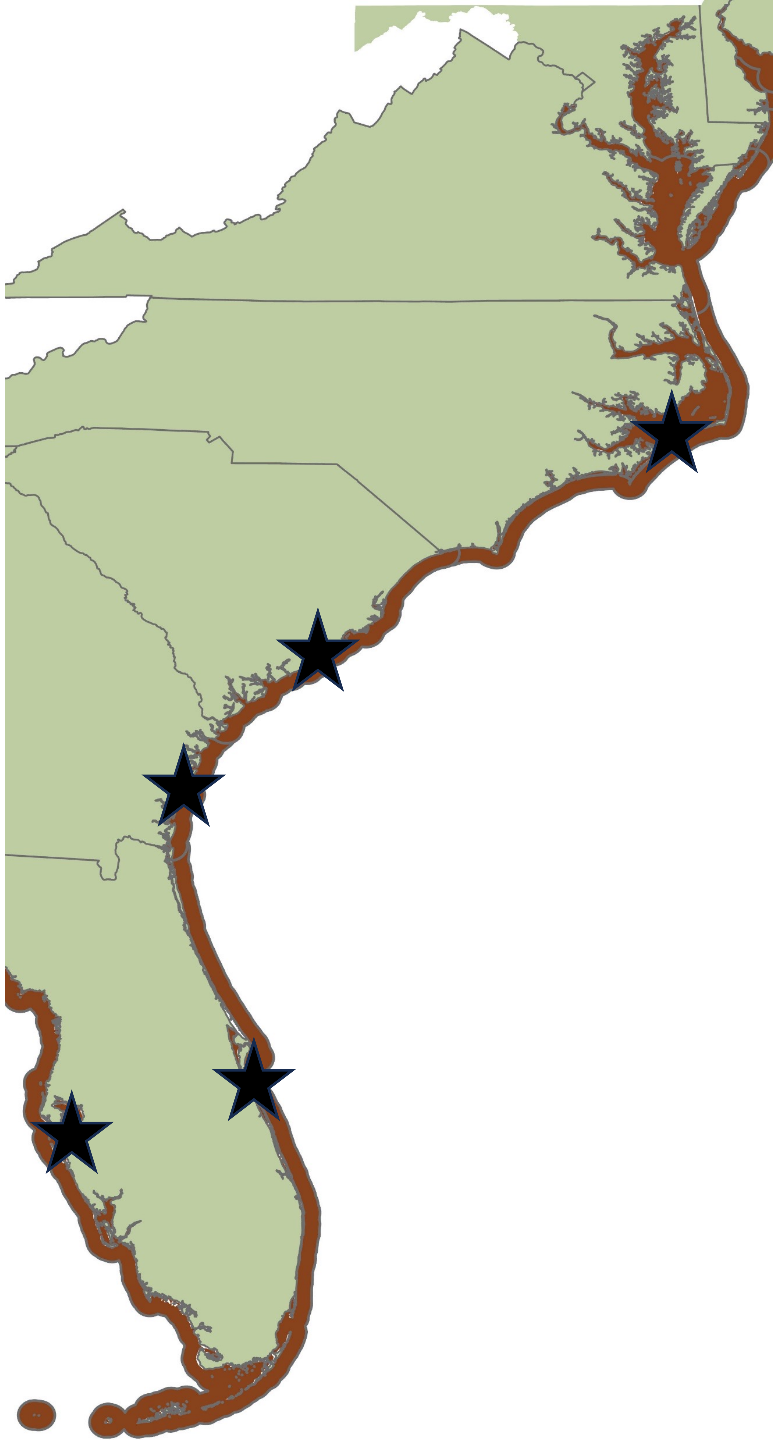
Spawning Seasonality

Consistent, if with a slight latitudinal cline (later further South)

- Southern Florida: Sept-Oct peak
- Georgia: Aug to mid-Oct
- South Carolina: mid-Aug to Sept peak
- North Carolina: Aug-Sept

45-60 day spawning season, w/ timing varying based on location

- Models assume a **<u>Sept. 1</u>** birthdate



Sexual Maturity

- Sexually dimorphic sizes- and ages-at-maturity reported in the literature
  - Females maturing at larger sizes and older ages than males
- Re-analyzed available histologically derived reproductive maturity status data from the Atlantic coast for the current assessment
  - Change in assessment year definition

Assessment Year Definition

Historically

- Calendar year (i.e., January 1 through December 31)
  - Exception – SC state specific assessment
- Adjusted age data assuming a January 1 birthdate

Current Benchmark Assessment

- Fishing year (i.e., September 1 through August 31)
- Better aligns datasets to red drum population dynamics (e.g., fall spawning)

Year Definition	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Calendar Year (1/1 – 12/31)	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Fishing Year (9/1 – 8/31)	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1

Sexual Maturity

- Sexually dimorphic sizes and ages of maturity reported in the literature
  - Females maturing at larger sizes and older ages than males
- Re-analyzed available histologically derived reproductive maturity status data from the Atlantic coast for the current assessment
  - Change in assessment year definition
  - Inclusion of some macroscopically derived reproductive data

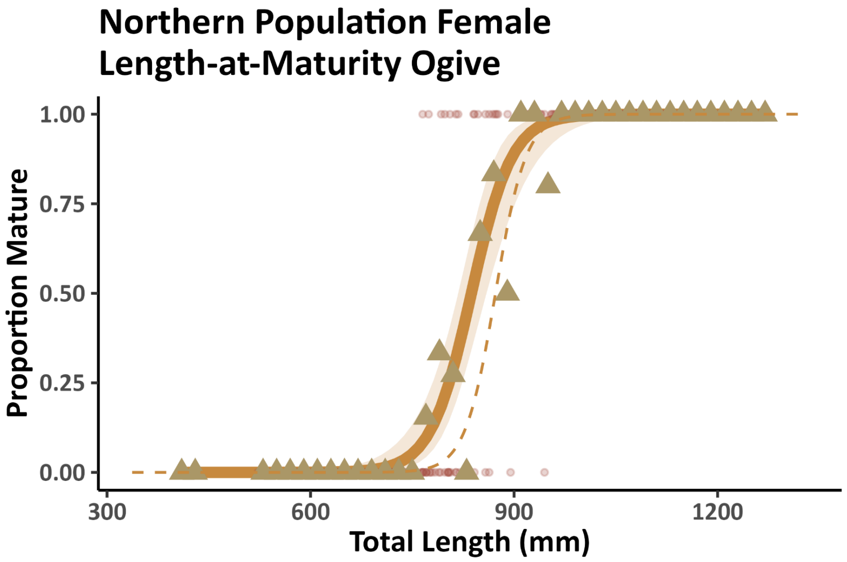
Total Length-@-Maturity

Females

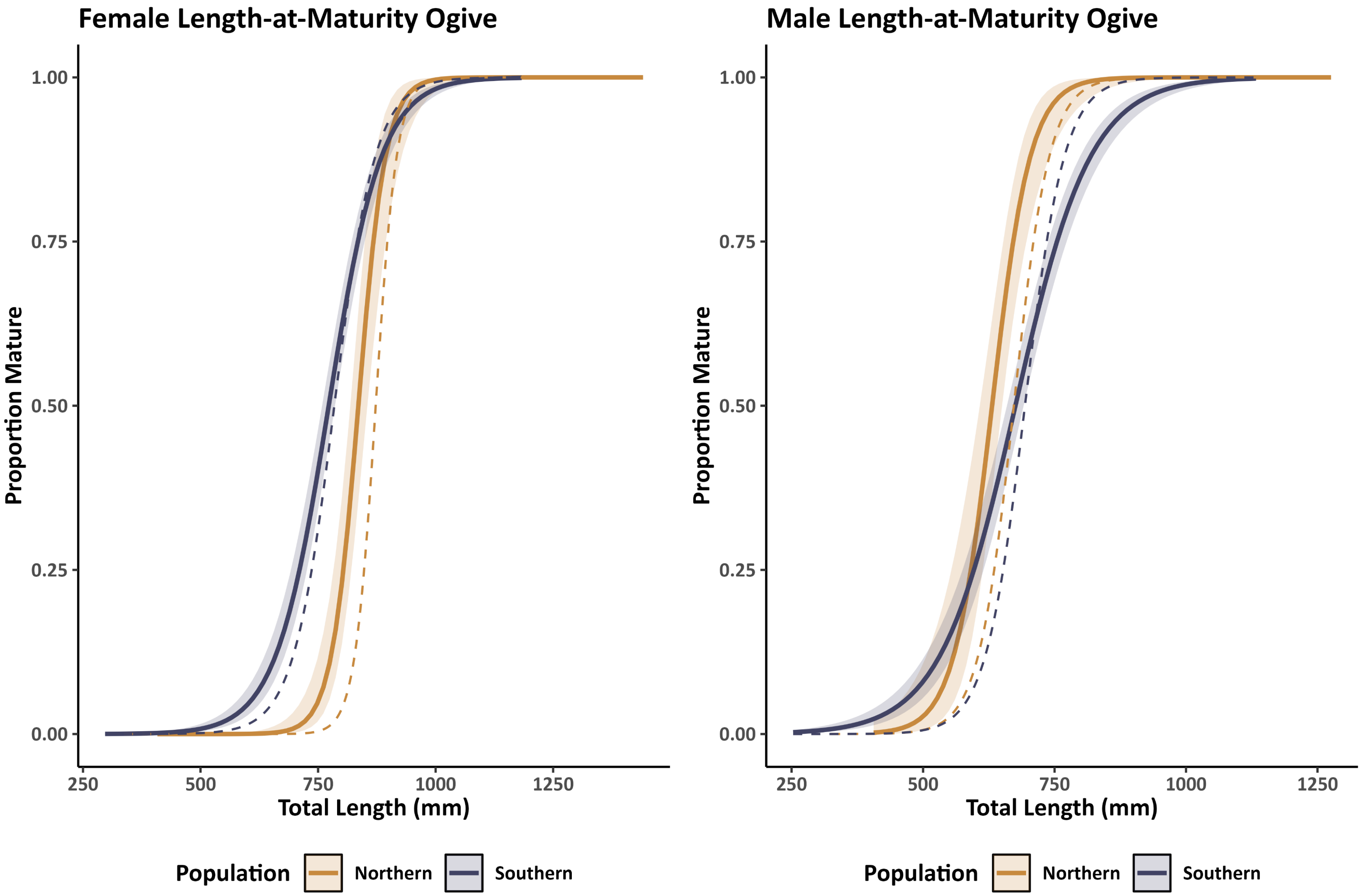
- Northern: 836 mm
  - 95% CI: 818-853 mm
- Southern: 766 mm
  - 95% CI: 753-778 mm

Males

- Northern: 631 mm
  - 95% CI: 611-651 mm
- Southern: 673 mm
  - 95% CI: 658-688 mm



Population Comparison- Length-@-Maturity



Age-@-Maturity

Females

Northern: 3.5 yrs

95% CI: 3.4-3.7 yrs

Southern: 4.2 yrs

95% CI: 4.0-4.4 yrs

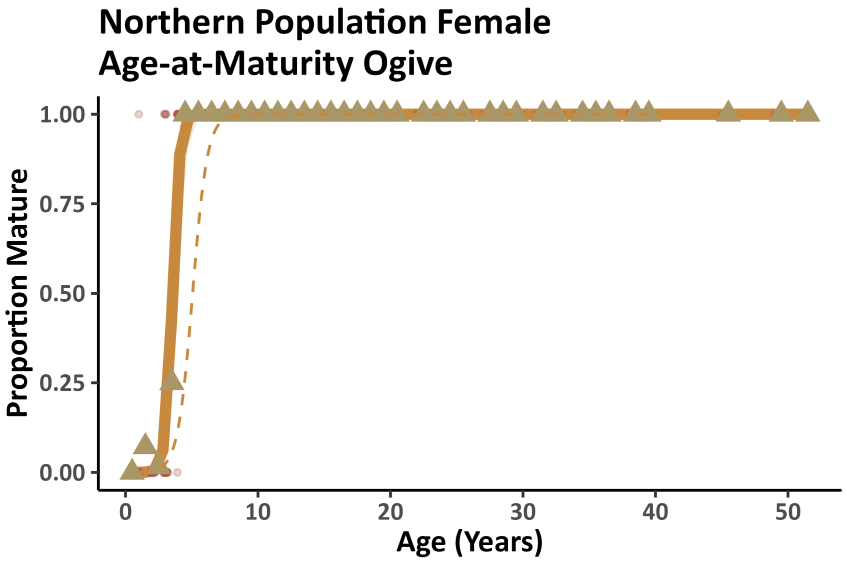
Males

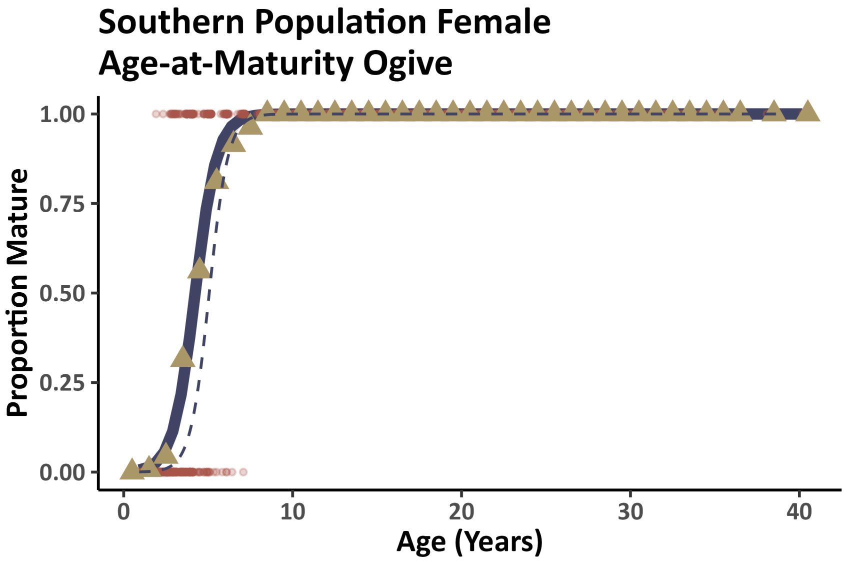
Northern: 2.2 yrs

95% CI: 2.1-2.4 yrs

Southern: 3.4 yrs

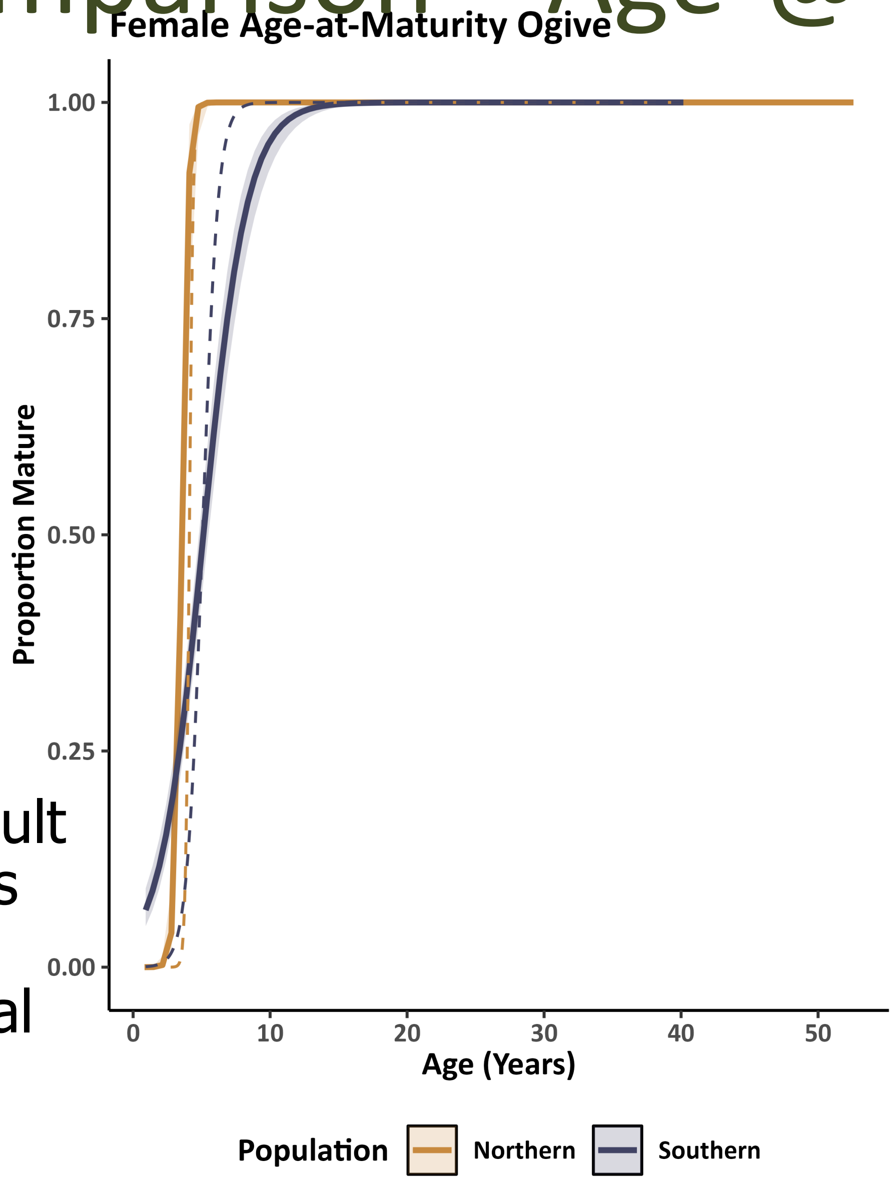
95% CI: 3.2-3.6 yrs

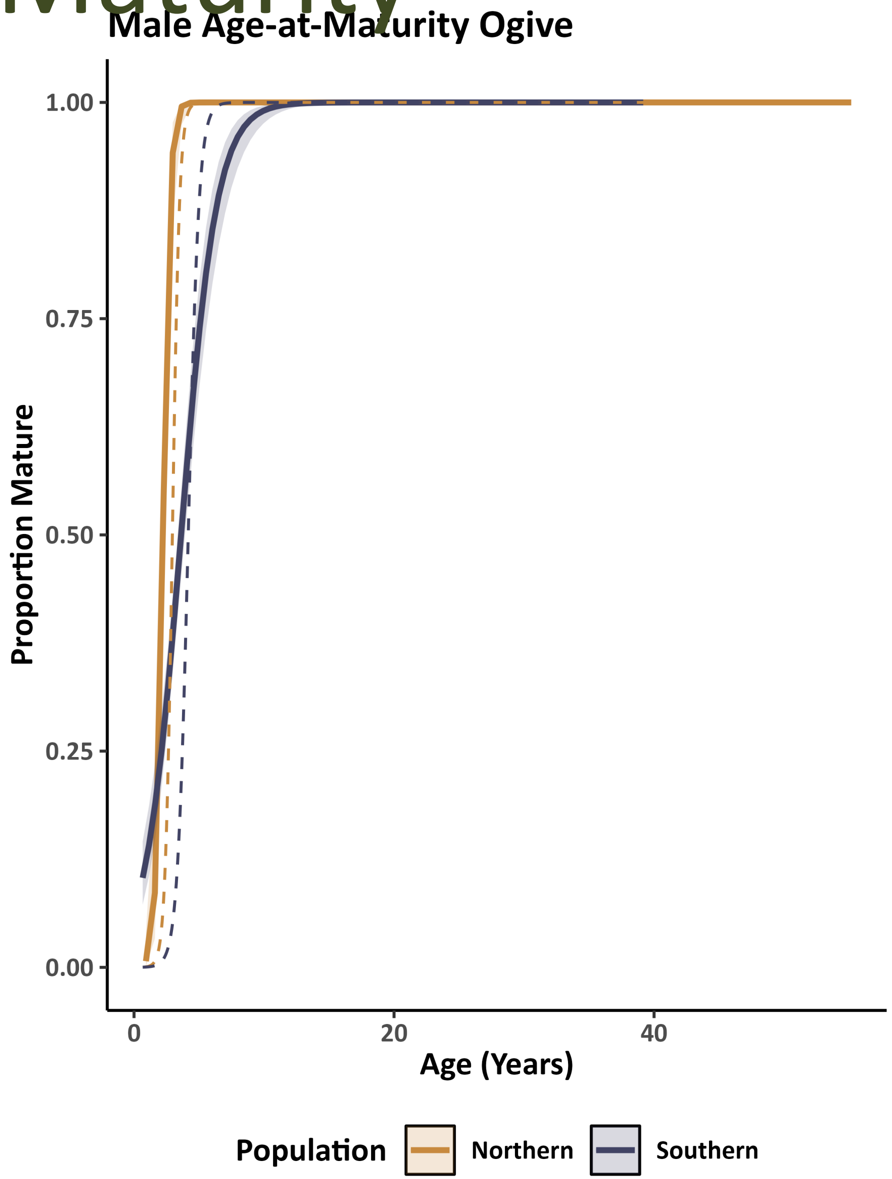




Population Comparison – Age-@-Maturity

- Northern population
  - Shift to younger age-@-maturity
    - Driven by shift in year definition
- Southern Population
  - Change in maturity "slope"
    - Broadening the result of combined effects of year definition change and removal of macroscopically staged individuals





Sex Ratio & Spawning Frequency

Sex Ratio – assumed 1:1

- Supported by most literature (Ross et al. 1995; Wilson & Nieland 1994)

Spawning Frequency – used only SCDNR reproductive stage data

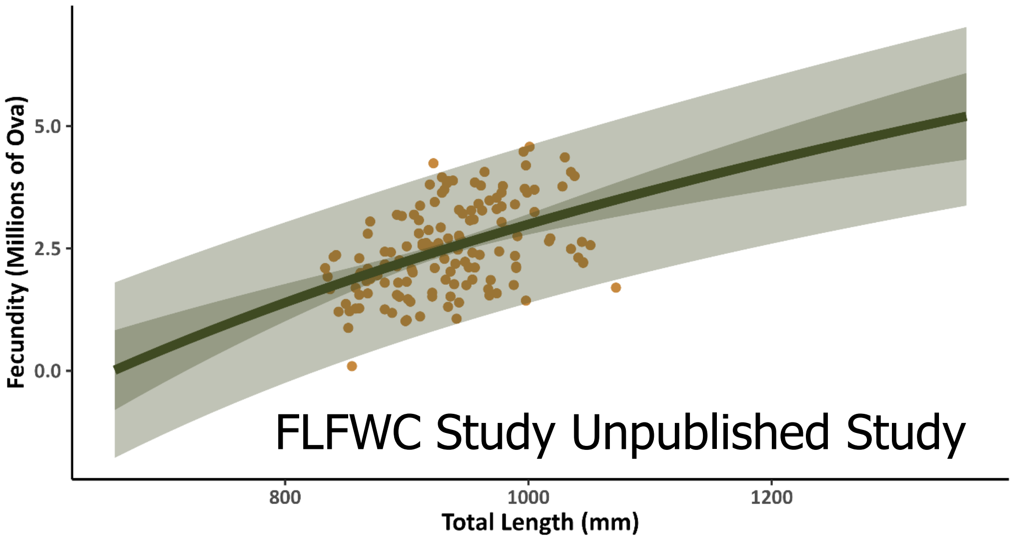
- 29.8% probability of spawning on a given day from mid-August through September (# actively spawning females/# mature females)
  - Spawning frequency = **3.4 days** (1/0.298)
    - Gulf of Mexico: every 2-4 days (Wilson & Nieland 1994)
  - Spawns per spawning season = **13.4 spawns**
    - Assumes a 45-day spawning season (45/(1/0.298))

Batch Fecundity

No estimate available from the Atlantic; only information available from GOM

- Wilson & Nieland (1994): 1.5 million ova per batch
    - Age = 3-33, FL = 697-1005 mm, batch fecundity = 0.16-3.27 (ova $x10^6$)
- FLFWC unpublished study in Tampa Bay (n = 143):
    - Drawbacks
        - Geographic location
        - Lack of smaller (and larger) mature females (smallest female 833 mm TL; larger than Atlantic length-@-50% maturity)

SAS recommended continued use of spawning stock biomass as a proxy for reproductive potential



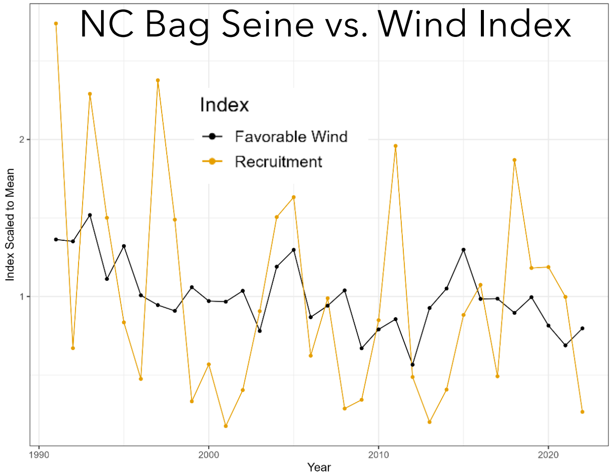
Recruitment Drivers

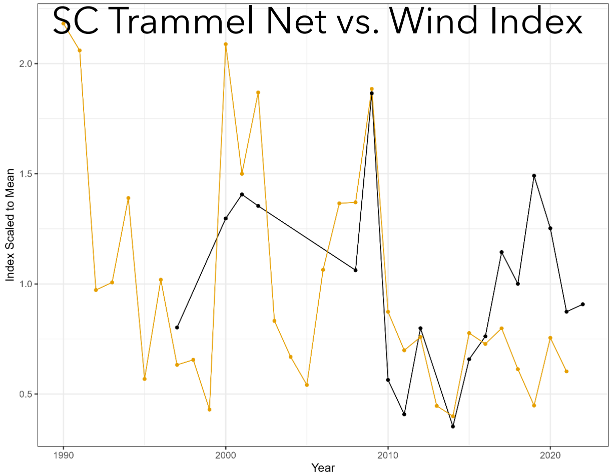
Goldberg et al. 2020 evaluated the relationship between year class strength and environmental variables in NC

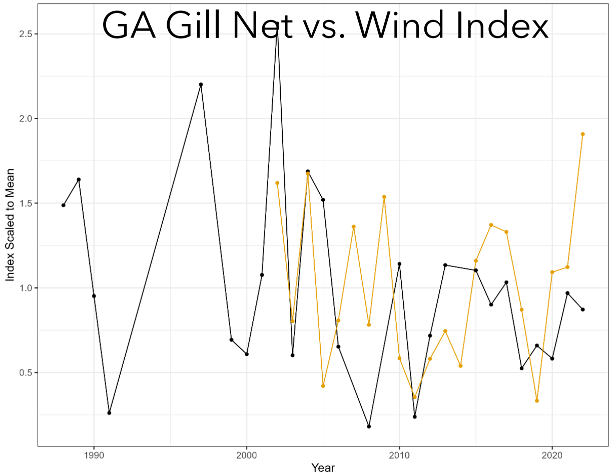
- Best predictor
  - Earlier shifts (late-August) to favorable coastal wind conditions
- Other significant predictors
  - Favorable winds in early-October & across the recruitment season (late-July through earl-October)
  - Elevated late-July sea surface temperature
  - Positive association with chlorophyll concentrations

Recruitment Drivers

- Goldberg et al. 2020 evaluated the relationship between year class strength and environmental variables in NC
- Re-evaluated relationships as an exploration of a potential recruitment covariate data stream for assessment models
  - Used updated data (northern population) and expanded to wider areas (southern population)
  - Although significant, positive correlations were detected between recruitment indices and wind indices, these correlations were…
    - Weak (r < 0.5)
    - Need some approach to spatial aggregation (southern stock)
      - Lack of broader spatial correlation
  - Limited utility of wind indices as an environmental variable to predict recruitment in the assessment models on their own
    - Complexity of abiotic and biotic factors affecting red drum recruitment







Natural Mortality (M)

M Methodology

Explored size- and age-dependent estimates of M using the ‘generalized length-inverse mortality (GLIM)’ paradigm presented by Lorenzen (2022)

- Incorporated approaches and recommendations presented in Maunder et al. (2023)

M models assumed the age-varying *k* von Bertalanffy growth parameterization discussed previously

Used the Hamel & Cope (2022) population specific constant M estimate ($M = \frac{5.4}{t_{max}}$) to scale the cumulative mortality rate from age-2+ in the age-varying M to the cumulative survival estimated by the age-constant approach

M Inputs

Northern Population

t_{max} = 62

Growth

- L_{∞} = 1,253 mm TL
- k_{base} = 0.259
- k_{age2} = 0.235
- k_{age6} = 0.046

Weight-Length Regression

- *a* = 0.0000165
- *b* = 2.931

Constant *M* = 0.087

Southern Population

t_{max} = 41

Growth

- L_{∞} = 1,132 mm TL
- k_{base} = 0.296
- k_{age1} = 0.216
- k_{age6} = 0.041

Weight-Length Regression

- *a* = 0.0000113
- *b* = 2.983

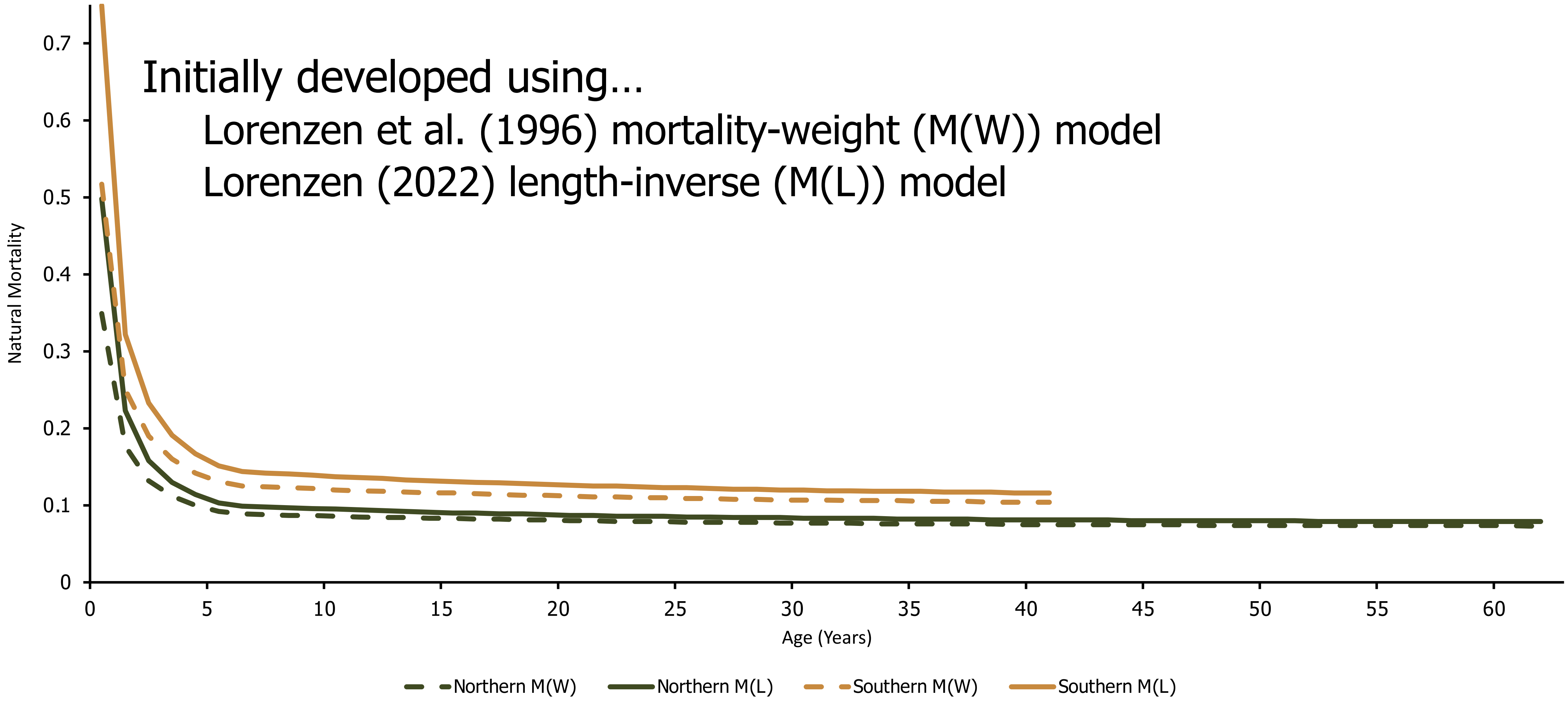
Constant *M* = 0.132

Age-varying M Estimates

Initially developed using…

Lorenzen et al. (1996) mortality-weight (M(W)) model

Lorenzen (2022) length-inverse (M(L)) model

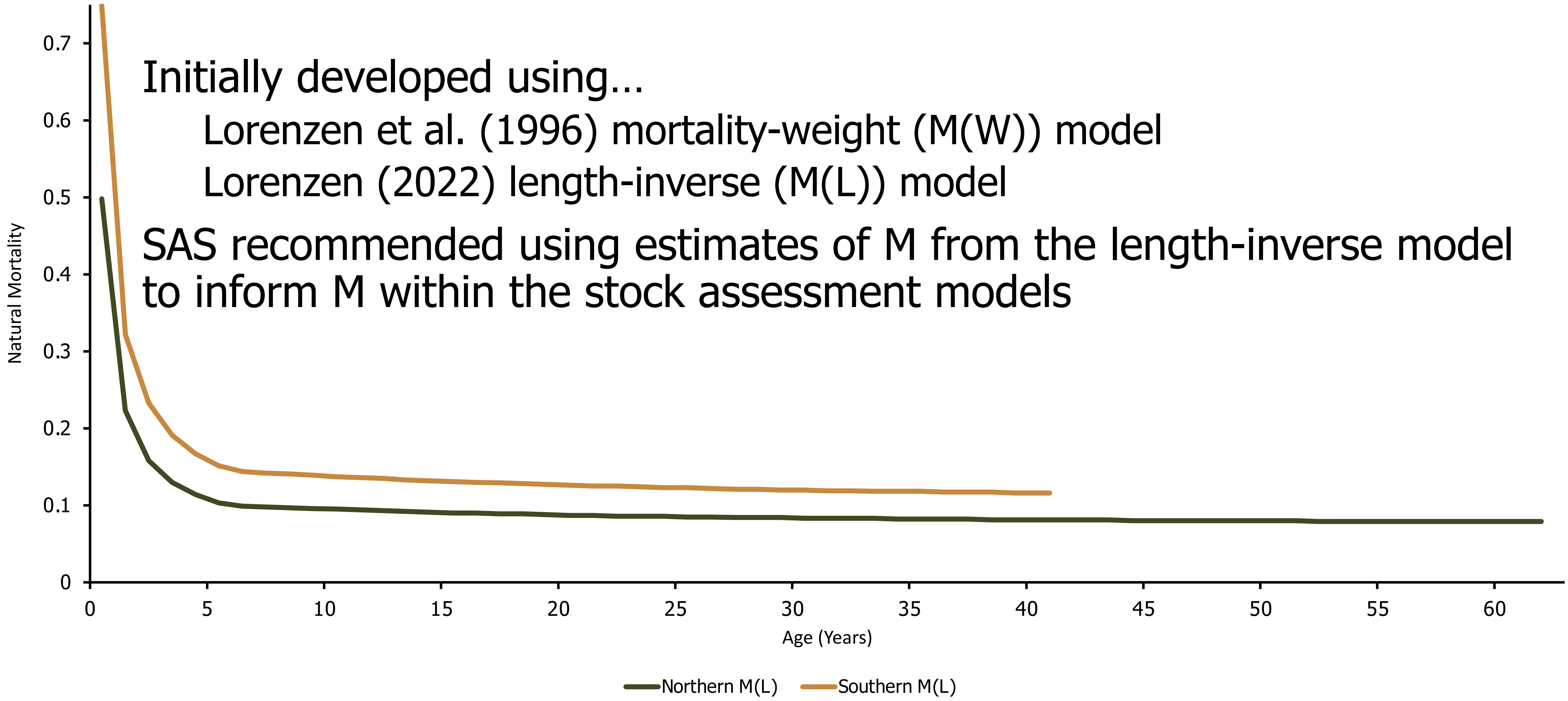


Age-varying M Estimates

Initially developed using…

- Lorenzen et al. (1996) mortality-weight (M(W)) model
- Lorenzen (2022) length-inverse (M(L)) model

SAS recommended using estimates of M from the length-inverse model to inform M within the stock assessment models



Age-varying M Estimates

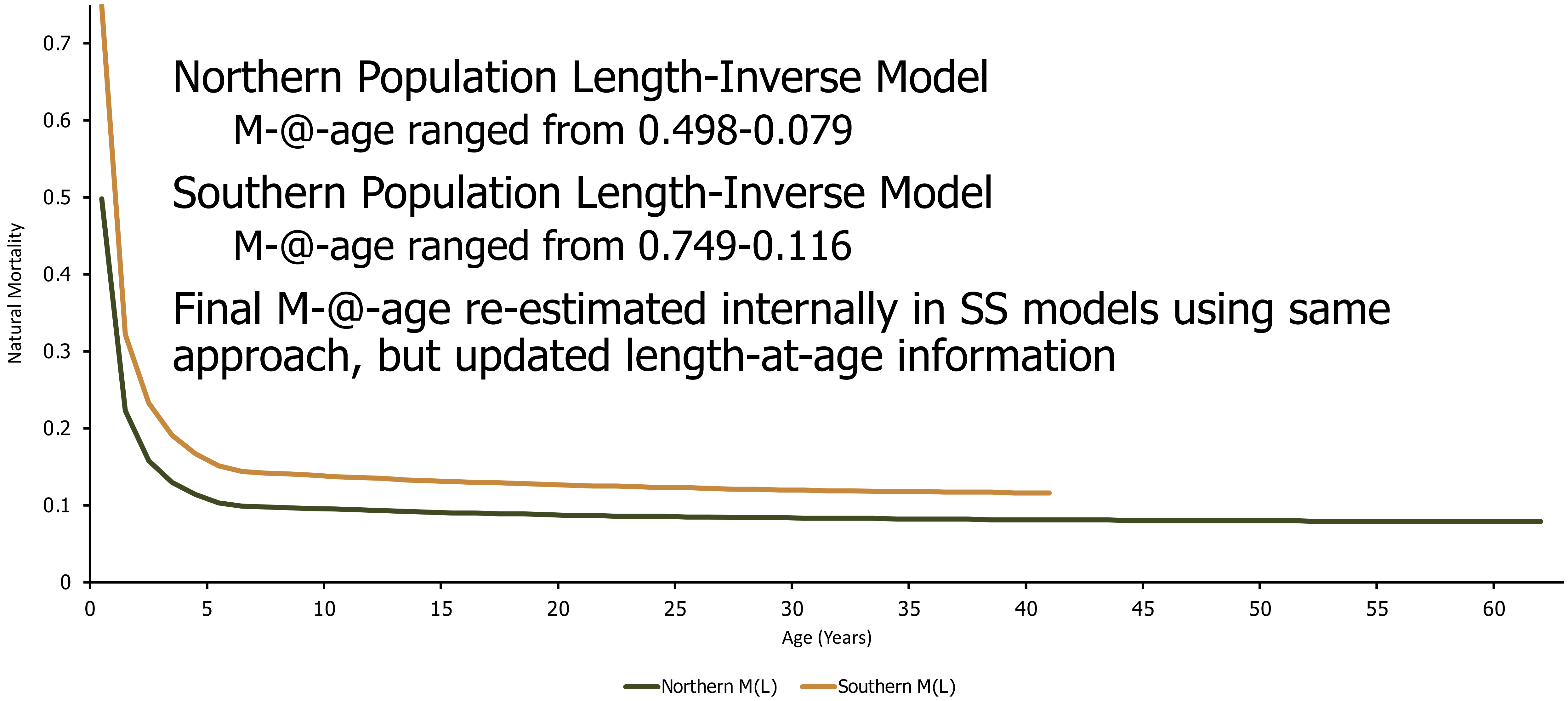
Northern Population Length-Inverse Model

M-@-age ranged from 0.498-0.079

Southern Population Length-Inverse Model

M-@-age ranged from 0.749-0.116

Final M-@-age re-estimated internally in SS models using same approach, but updated length-at-age information



Habitat

Adult, Spawning, Egg and Larvae, Juvenile, and Sub-Adult Habitats

Red Drum Life Cycle

Life's Better

Adults

- Deeper coastal waters
- Form aggregations @ mouths of estuaries

Red Drum Life Cycle

<u>Juveniles</u>

- Small creeks
- Upper estuaries

<u>Adults</u>

- Deeper coastal waters
- Form aggregations @ mouths of estuaries

Red Drum Life Cycle

Juveniles
- Small creeks
- Upper estuaries

Sub-adults
- Shallow salt marsh edge and oyster reef habitats
- Lower estuaries

Adults
- Deeper coastal waters
- Form aggregations @ mouths of estuaries