Improving Age Composition Estimates: Evaluating a Bayesian-like Method for Estimating Ages from Spines with Vascularized Cores

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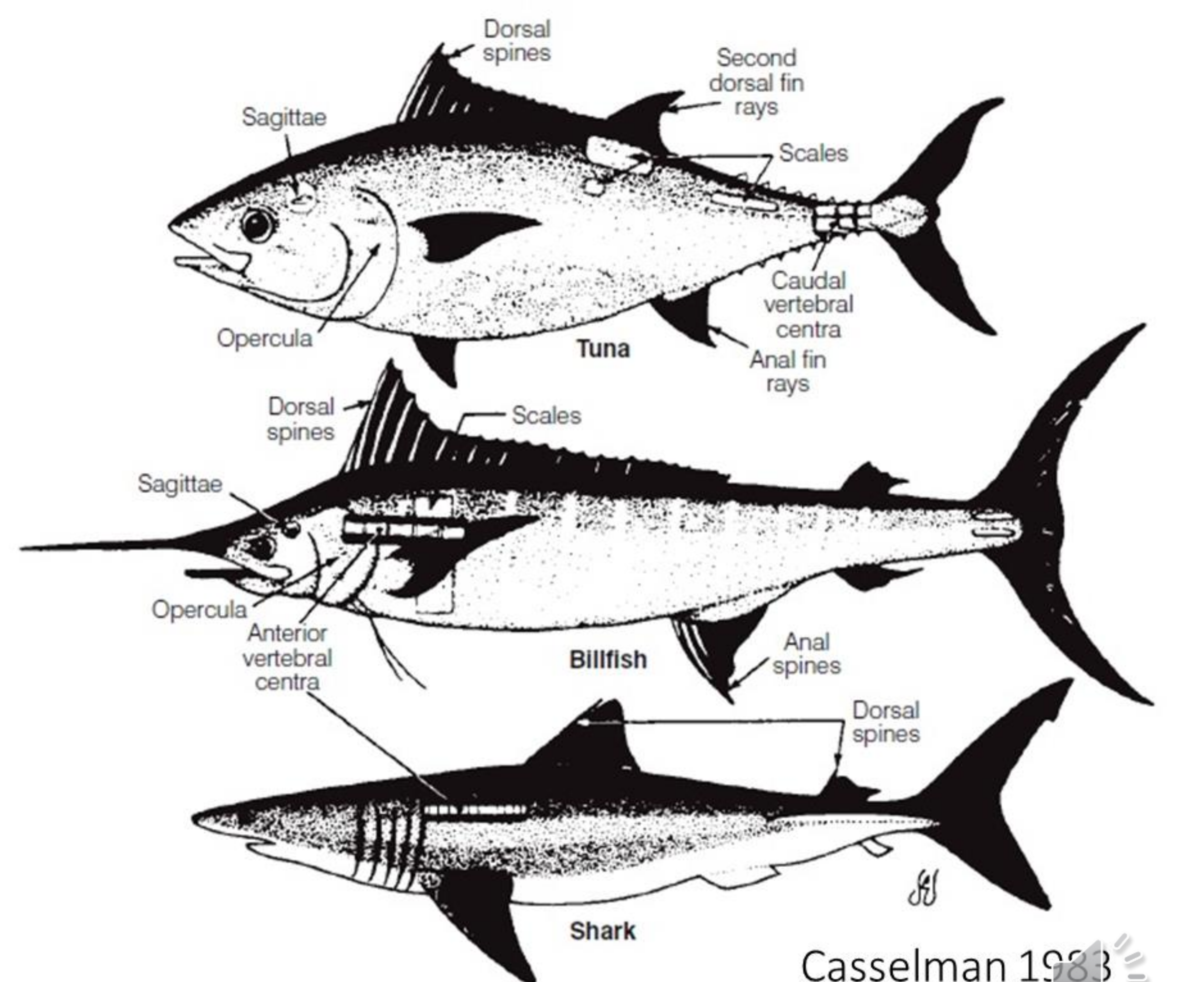
Methods for Aging Fish

- Tagging
- Otoliths
- Jaw, other bones
- Opercular series
- Scales
- Fin spines



Casselman 1983

Methods for Aging Fish

- Tagging
- Otoliths
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- Opercular series
- Scales
- Fin spines

Lethal, high extractive cost

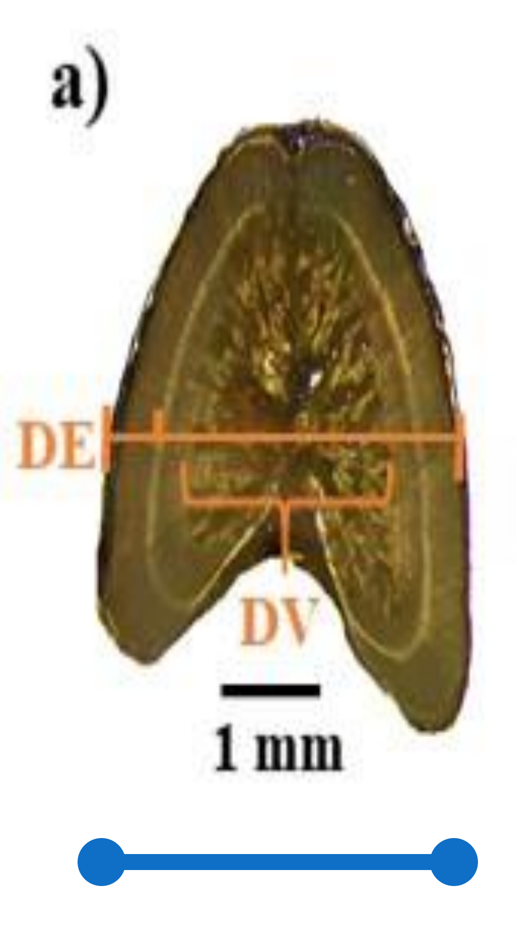
Non-lethal, quick sample, doesn't affect market value

Problem with Using Fin Spines/Rays:

Many fish have vascularization in the core

Marlin	Skipjack
Yellowfin	Catfish
Brown trout	White suckers

Zone of vascularization expands with growth, obliterating earliest growth rings



Guelson da Silva

Guelson da Silva

Dealing with Spines Featuring Central Vascularization

1. Naïve model (assume observed rings = true age)
2. Impute with representative samples from each size (Holden and Meadows 1962 & Seed 1968)
3. Simple ratio method (Andrade et al. 2004)
4. Multiple regression (Andrade et al. 2004)
5. K-means cluster analysis (Die and Drew 2008)

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6. Bayesian-like imputation

Methods we compare today

Bayesian-like Ring Imputation for Age Numbers (BRIAN)

Goal: estimate number missing rings to get total age

$$age = rings_{inner} + rings_{outer}$$

$$rings_{inner} = \begin{cases} 0 \text{ no obliteration in young fish} \\ \text{Not Available in old fish} \end{cases}$$

Bayesian-like Ring Imputation for Age Numbers (BRIAN)

Assume spine width follows von Bertalanffy* curve

$rings_{inner} \sim \text{Poisson}(\mu_v)$

μ_v = mean number of rings in vascularized region for fish of spine width v

Calculate μ_v by solving von Bertalanffy eqn for age given vascularized width v

Data required for Bayesian method (BRIAN Model)

1. Count of observed rings (C_i)
2. NA when some rings may be missing (X_i)
   0 if no missing rings
3. Spine width (D_i)
4. Vascularized region width (D_{1i})

BRIAN Model

Vascularized Width

$$X_i \sim Poisson\left(\underbrace{t_0 - \frac{ln\left(1 - {D_{1i}}/{D_\infty}\right)}{K}}_{\text{Age from vascularized region}}\right)$$

Missing rings

$t_0, \mathrm{K}, D_\infty$ von Bertalanffy parameters for spine growth

Bayesian-like Ring Imputation for Age Numbers (BRIAN)

Why Bayesian-like instead of Bayesian?

- Priors not purely hierarchical

- Methods used in data science where interest is in prediction

Model Evaluation & Comparison

1. Naïve model
2. Bayesian Ring Imputation for Age Numbers (BRIAN)

Using:

- Simulated datasets
- Yellowfin tuna data

Simulated Data – 1000 fish

- Ages 1 to 10
  - *Uniform age distribution*
- Spine width based on age (von Bertalanffy model)
  - *Add random error (sd=0.1)*
- Vascularized region proportional to spine radius
  - *Random error added in logit space on proportion of spine vascularized (sd=sqrt(0.003))*
- Calculate location of each ring
  - *Scale by ratio spine width to expected width*
  - *Notion small fish are always small, big fish are always big*

Simulated Data – part 2

- Calculate # of missing rings

- Determine if rings are missing
  - *If you believe you have 1 year olds in data, use smallest 1st ring diameter*
  - *Otherwise assume all fish are censored (have missing rings)*

$$rings_{inner} = \begin{cases} \text{0 no obliteration in young fish} \\ \text{Not Available in old fish} \end{cases}$$

Preliminary Results Naïve method

Naïve Model Results											
	Naïve Age (Observed Rings)										No. Fish True Age
True Age		1	2	3	4	5	6	7	8	9	10	
	1	1.00	0	0	0	0	0	0	0	0	0	93
	2	0	1.00	0	0	0	0	0	0	0	0	91
	3	0	1.00	0	0	0	0	0	0	0	0	86
	4	0	0	1.00	0	0	0	0	0	0	0	111
	5	0	0	0	1.00	0	0	0	0	0	0	88
	6	0	0	0	0.08	0.92	0	0	0	0	0	98
	7	0	0	0	0	0.43	0.58	0	0	0	0	120
	8	0	0	0	0	0	0.75	0.25	0	0	0	114
	9	0	0	0	0	0	0	0.92	0.08	0	0	100
	10	0	0	0	0	0	0	0	0.93	0.07	0	99

Preliminary Results BRIAN method

BRIAN Model Results

		Mode of Posterior Estimated Age											No. Fish True Age
		1	2	3	4	5	6	7	8	9	10	11	
True Age	1	1.00	0	0	0	0	0	0	0	0	0	0	93
	2	0	0.82	0.18	0	0	0	0	0	0	0	0	91
	3	0	0	1.00	0	0	0	0	0	0	0	0	86
	4	0	0	0	1.00	0	0	0	0	0	0	0	111
	5	0	0	0	0	1.00	0	0	0	0	0	0	88
	6	0	0	0	0	0.01	0.89	0.10	0	0	0	0	98
	7	0	0	0	0	0	0.12	0.68	0.20	0	0	0	120
	8	0	0	0	0	0	0	0.11	0.79	0.10	0	0	114
	9	0	0	0	0	0	0	0	0.10	0.87	0.03	0.00	100
	10	0	0	0	0	0	0	0	0	0.09	0.88	0.03	99

Preliminary Results comparison

Naïve model max age 9
BRIAN model max age 11

Naïve model → greater bias older fish, only does well young fish

BRIAN model is unbiased, gets it right >74%

Parameter Estimates from von Bertalanffy Naive vs. BRIAN method

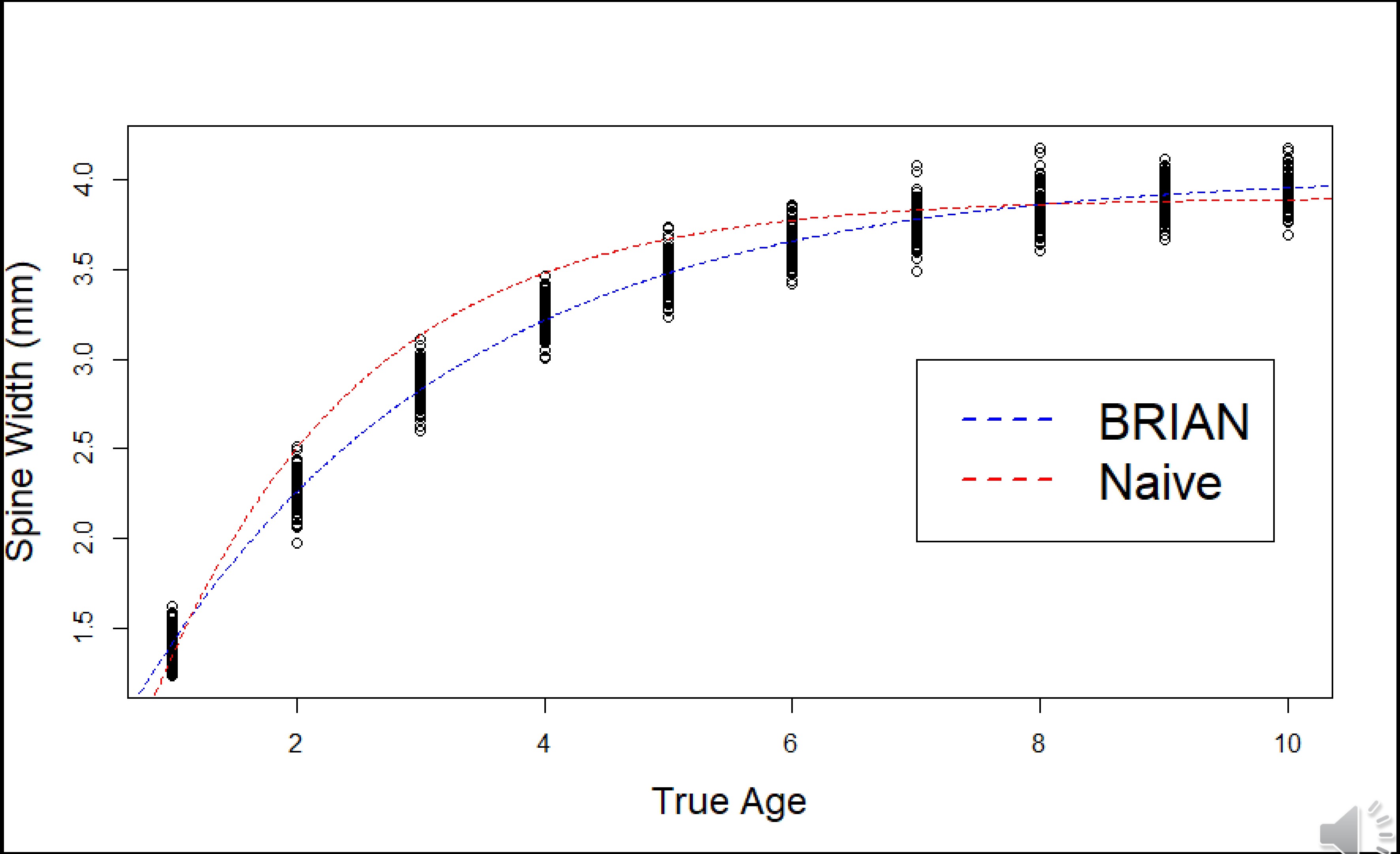
Parameter	True Value	BRIAN Model		Naïve Model	
		Median	95% CI	Median	95% CI
t_0	-0.1	-0.12	-0.17, -0.08	0.29	0.22, 0.30
K	0.4	0.39	0.38, 0.40	0.60	0.58, 0.62
D_∞	4	4.0	4.0, 4.1	3.9	3.9, 4.0

Naïve estimate of K is 50% higher

→ Total mortality estimate will be 50% higher using Beverton-Holt mean length estimator

$$\hat{Z} = \frac{K(L_\infty - \bar{L})}{(\bar{L} - L_c)}$$

Parameter Estimates from von Bertalanffy Naive vs. BRIAN method



Yellowfin Tuna Example

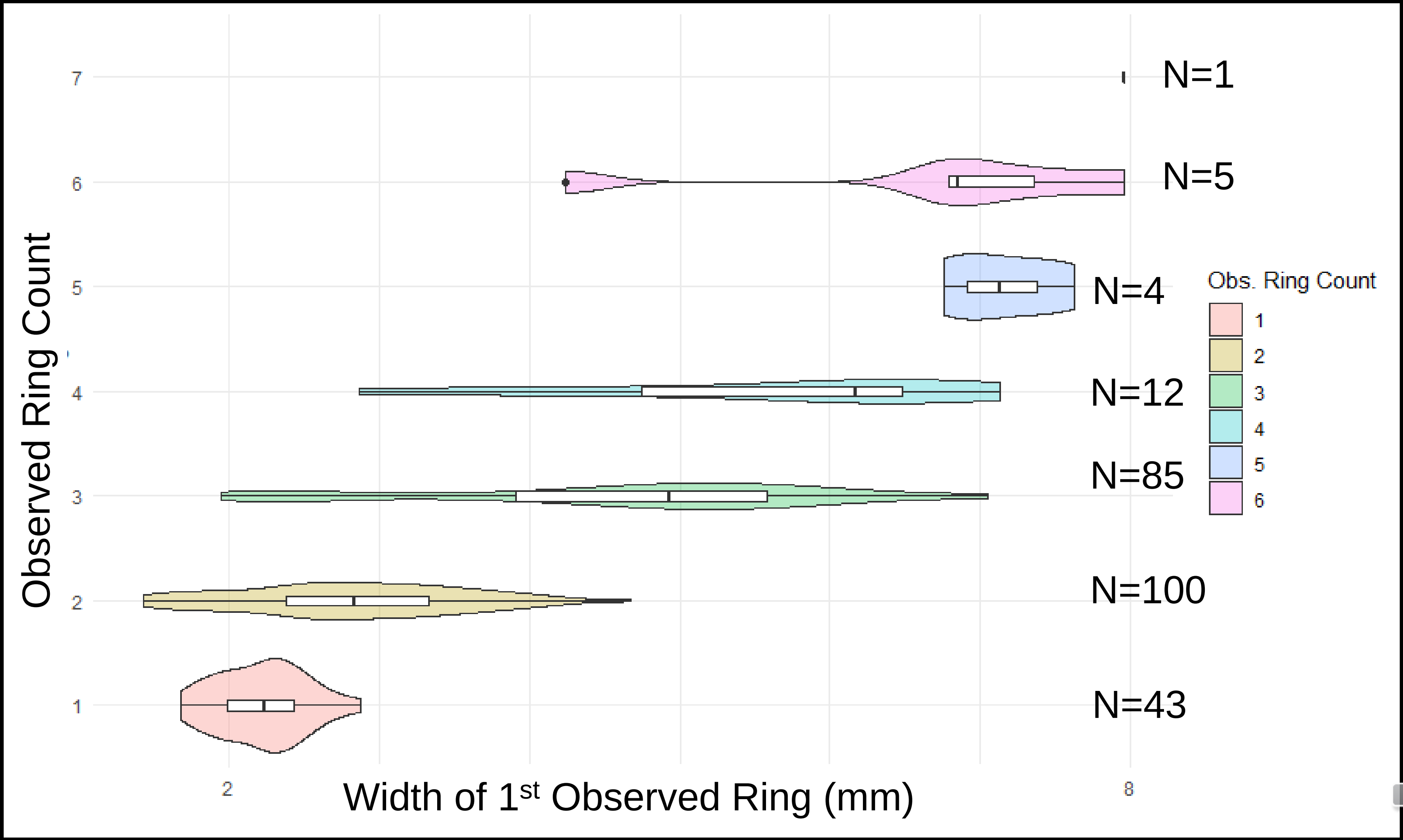
Thunnus albacares

Atlantic ocean

NOAA

Dataset from AOTTP and Universidade Federal Rural do Semi-Árido – UFERSA (Brazil)

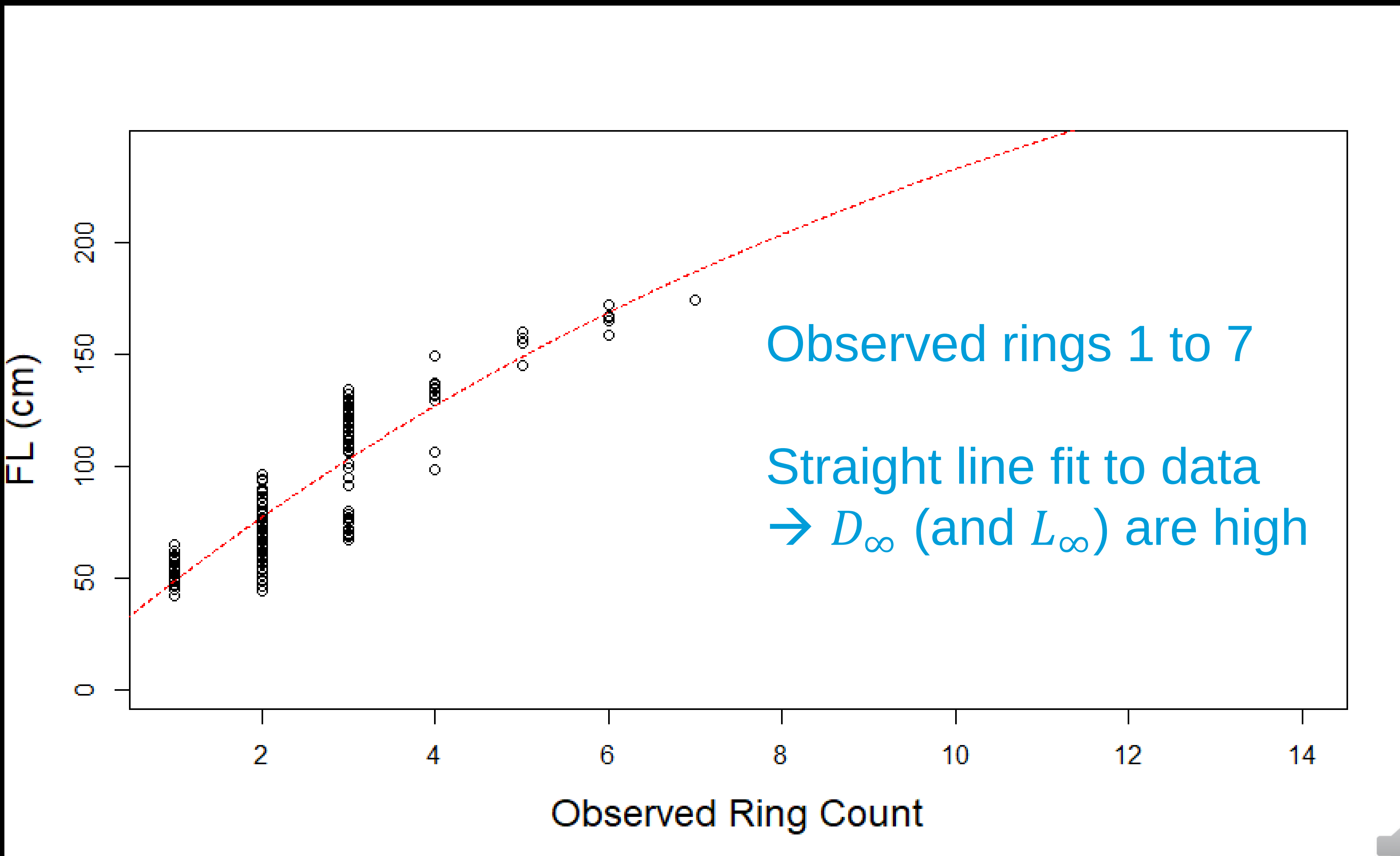
Yellowfin Tuna Data: Is there evidence vascularization affects apparent growth?



Yellowfin Tuna Example: von Bertalanffy Estimates

Parameter	BRIAN Model		Naïve Model	
	Median	95% CI	Median	95% CI
t_0	-0.65	-0.76, -0.57	-0.09	-0.33, 0.14
K	0.09	0.06, 0.12	0.09	0.06, 0.15
D_∞	13.3	10.5, 18.4	23.4	16.0, 29.6

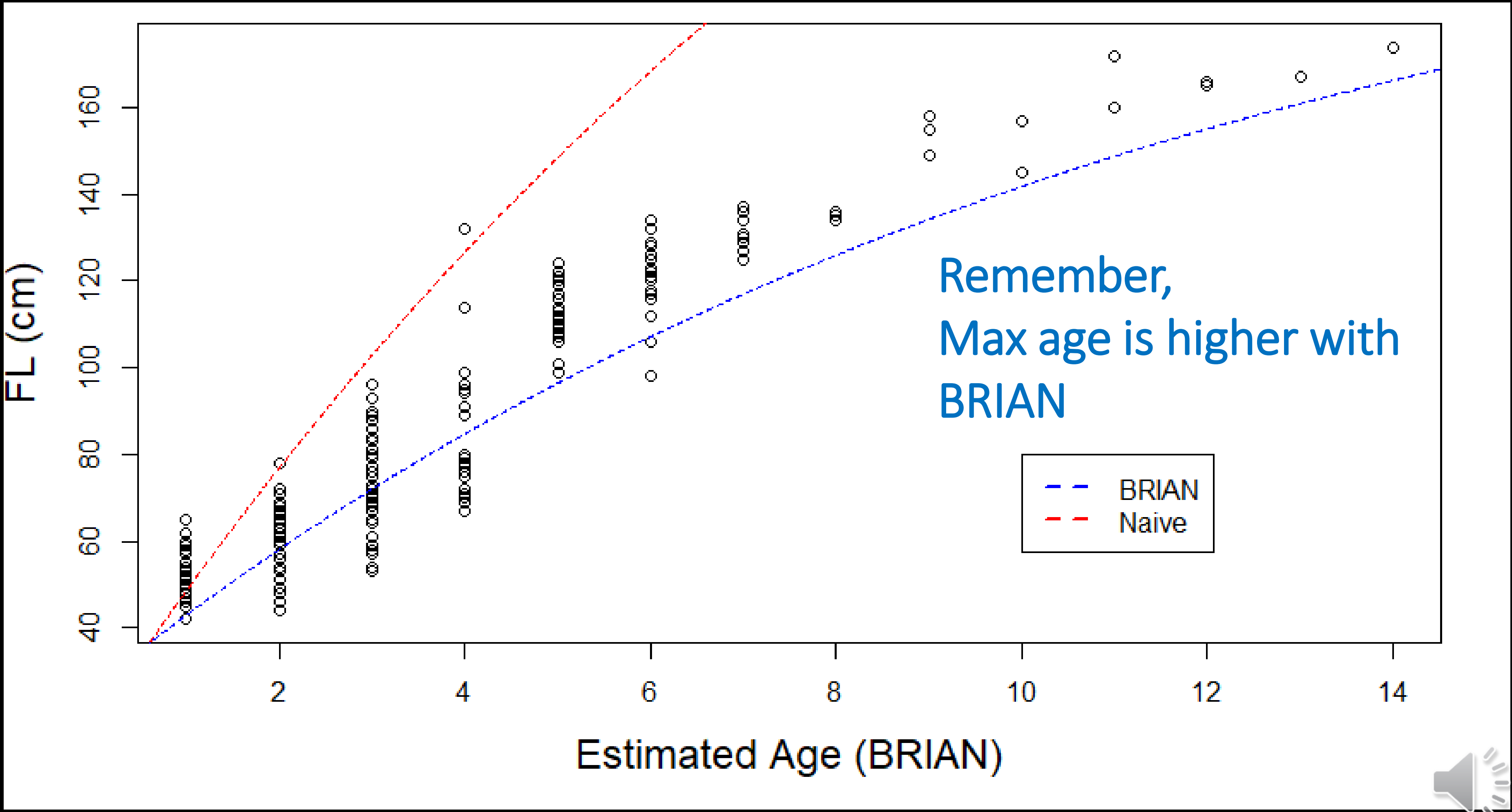
Yellowfin Tuna Data: von Bertalanffy growth curve – Naïve model



Observed rings 1 to 7

Straight line fit to data
→ D_∞ (and L_∞) are high

Yellowfin Tuna Data: von Bertalanffy growth curves



BRIAN Model Flexibility

Other growth models can be used instead of von Bertalanffy

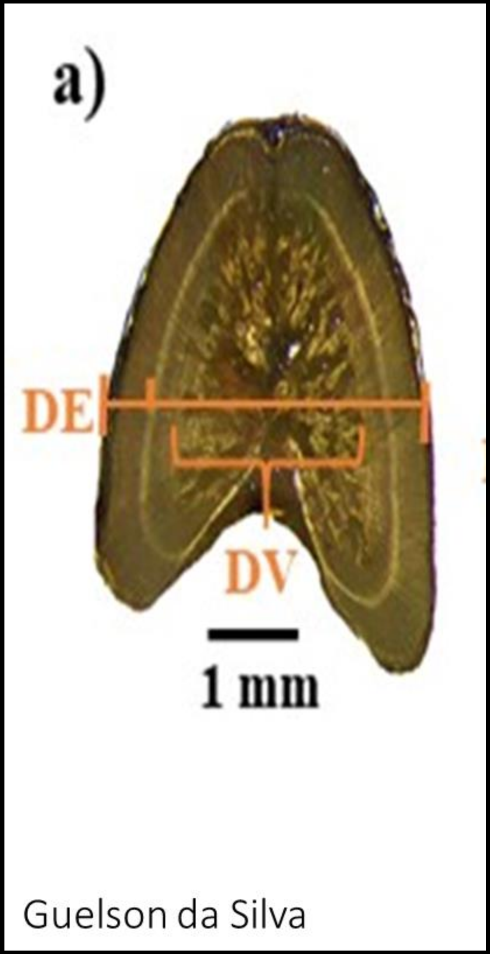
With simulated data, model still runs if 100% of your data has missing rings from vascularization

Broader Application

Utilize data in more efficient manner

→Increase sample size by collecting from catch & release anglers and commercial fishermen

→Avoid naïve mistake of underestimating age, overestimating K and Z



Atlantic Tropical Tuna Age & Growth Study

ICCAT Atlantic Ocean Tropical Tuna Tagging Programme

ICCAT CICTA CICAA

UNIVERSIDADE FEDERAL
UFERSA
RURAL DO SEMI-ÁRIDO

Grace Chiu
& ESTDatS
@ VIMS

VIMS | William & Mary
Virginia Institute of Marine Science

Shedd Aquarium

Thank You