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
Methods for Aging Fish

- Tagging
- Otoliths
- Jaw, other bones
- 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
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)
4. Multiple regression (Andrade et al. 2004)
5. K-means cluster analysis (Die and Drew 2008)
Dealing with Spines Featuring Central Vascularization

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4. Multiple regression (Andrade et al. 2004)
5. K-means cluster analysis (Die and Drew 2008)
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

\[ \text{age} = \text{rings}_{\text{inner}} + \text{rings}_{\text{outer}} \]

\[ \text{rings}_{\text{inner}} = \begin{cases} 0 & \text{no obliteration in young fish} \\ \text{Not Available} & \text{in old fish} \end{cases} \]
Bayesian-like Ring Imputation for Age Numbers (BRIAN)

Assume spine width follows von Bertalanffy* curve

\[ \text{rings}_{\text{inner}} \sim \text{Poisson}(\mu_v) \]
\[ \mu_v = \text{mean number of rings in vascularized region for fish of spine width } v \]

Calculate \( \mu_v \) 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

\[ X_i \sim \text{Poisson} \left( t_0 - \frac{\ln \left( 1 - \frac{D_{1i}}{D_\infty} \right)}{K} \right) \]

- \( t_0 \), \( K \), \( D_\infty \) \( \text{von Bertalanffy} \) 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)*

\[
\text{rings}_{\text{inner}} = \begin{cases} 
0 & \text{no obliteration in young fish} \\
\text{Not Available in old fish} & \text{Not Available in old fish}
\end{cases}
\]
## Preliminary Results Naïve method

<table>
<thead>
<tr>
<th>True Age</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>No. Fish True Age</th>
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</table>
### Preliminary Results BRIAN method

#### BRIAN Model Results

<table>
<thead>
<tr>
<th>True Age</th>
<th>Mode of Posterior Estimated Age</th>
<th>No. Fish True Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>93</td>
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<td>0.82 0.18</td>
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<tr>
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<td>0 1.00</td>
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<td>0 0 1.00</td>
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<td>6</td>
<td>0 0 0.01 0.89 0.10</td>
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<tr>
<td>9</td>
<td>0 0 0 0 0.10 0.87 0.03</td>
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</tr>
<tr>
<td>10</td>
<td>0 0 0 0 0 0.09 0.88 0.03</td>
<td>99</td>
</tr>
</tbody>
</table>
Preliminary Results comparison

Naïve model max age 9
BRIAN model max age 11

Naïve model $\rightarrow$ greater bias older fish, only does well young fish

BRIAN model is unbiased, gets it right $>74\%$
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

Dataset from AOTTP and Universidade Federal Rural do Semi-Árido – UFERSA (Brazil)
Yellowfin Tuna Data:
Is there evidence vascularization affects apparent growth?

![Graph showing the width of 1st observed ring (mm) vs. observed ring count with different sample sizes.](image)
### Yellowfin Tuna Example: von Bertalanffy Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BRIAN Model</th>
<th>Naïve Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_0 )</td>
<td>-0.65, 0.76, -0.57</td>
<td>-0.09, -0.33, 0.14</td>
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<tr>
<td>( K )</td>
<td>0.09, 0.06, 0.12</td>
<td>0.09, 0.06, 0.15</td>
</tr>
<tr>
<td>( D_\infty )</td>
<td>13.3, 10.5, 18.4</td>
<td>23.4, 16.0, 29.6</td>
</tr>
</tbody>
</table>
Yellowfin Tuna Data: von Bertalanffy growth curve – Naïve model

- Observed rings 1 to 7
- Straight line fit to data
  \[ D_\infty \text{ (and } L_\infty \text{) are high} \]
Yellowfin Tuna Data: von Bertalanffy growth curves

Remember, Max age is higher with BRIAN
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

Guelson da Silva
Atlantic Tropical Tuna Age & Growth Study

ICCAT Atlantic Ocean Tropical Tuna Tagging Programme

Grace Chiu
& ESTDatS
@ VIMS
Thank You