M. paradoxus chronologies on sliced otoliths and growth from length-frequency analysis used as indirect age validation methods

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Conclusions

# 1. Age estimation methods used currently for *M. paradoxus* are valid and can be continued

# 2. Males and females of both *M. capensis* and *M. paradoxus* grow at the same rate
**Deep-water hake: *M. paradoxus***

- *M. paradoxus* feed on: cephalopods, krill, crustaceans, Myctophids, bearded goby, other demersal & pelagic fish spp.
- Otolith growth and zonation is fairly stable and more robust than for *M. capensis*
- Their deeper environment is more stable than that of *M. capensis*
Objectives

Use *M. paradoxus* otolith chronologies to:

1. Estimate mean annual growth 1988-2013
2. Validate the annual age determination method of *M. paradoxus*
3. Correlate growth rates from chronologies with other fish condition indices and growth rates estimated by other methods for further age validation
M. paradoxus (MP) otolith growth chronology
MP otolith growth chronology

N = 173
MP otolith growth chronology: De-trending – Mixed effects model

\[
\text{Log(Inc)} \sim \text{Log(Age)} + \text{Log(AAC)} + (\text{Log(Age)} | \text{FishID}) + (1 | \text{Year})
\]
MP otolith growth chronology: De-trending – ME model

• $\log(\text{Inc}) \sim \log(\text{Age}) + \log(\text{AAC})$
+ $(\log(\text{Age}) \mid \text{FishID}) + (1 \mid \text{Year})$
MP Final predicted annual growth (mm) ± 95% CI
MP age 3 to 4 growth calculation

Mean length (cm) at age – whole otolith method – total sample of survey otoliths each year:

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Age 0</th>
<th>Age 1</th>
<th>Age 2</th>
<th>Age 3</th>
<th>Age 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>2</td>
<td>9.7</td>
<td>22.1</td>
<td>31.0</td>
<td><strong>37.1</strong></td>
<td>43.0</td>
</tr>
<tr>
<td>2004</td>
<td>2</td>
<td>13.3</td>
<td>24.0</td>
<td>27.3</td>
<td><strong>34.6</strong></td>
<td><strong>43.5</strong></td>
</tr>
<tr>
<td>2005</td>
<td>2</td>
<td>10.1</td>
<td>19.7</td>
<td>24.0</td>
<td>33.2</td>
<td>42.6</td>
</tr>
<tr>
<td>2006</td>
<td>2</td>
<td>12.4</td>
<td>19.4</td>
<td>25.7</td>
<td>31.8</td>
<td>40.1</td>
</tr>
<tr>
<td>2007</td>
<td>2</td>
<td>12.0</td>
<td>22.2</td>
<td>27.7</td>
<td>35.3</td>
<td>40.4</td>
</tr>
<tr>
<td>2008</td>
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<td>23.7</td>
<td>30.9</td>
<td>35.7</td>
<td>42.4</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
<td>24.3</td>
<td>28.8</td>
<td>34.8</td>
<td>42.4</td>
<td></td>
</tr>
</tbody>
</table>
MP predicted annual growth (mm) & annual age 3–4 growth (cm)

MP growth 3–4 ~ MP chronology growth

PCC = 0.658, n = 15, \( p < 0.005 \)
MP predicted annual growth (mm) & annual age 3–4 growth (cm)

(1) This (indirectly) validates the annual age determination method of *M. paradoxus*

MP growth 3–4 ~ MP chronology growth

$PCC = 0.658, n = 15, p < 0.005$
MP Condition factor (CF) calculation

\[ y = 3.1826x - 2.4529 \]

\[ R^2 = 0.9922 \]
MP predicted annual growth (mm) & condition factor (CF)

MP condition ~ MP chronology growth

(PCC = 0.36, n = 20, \(p < 0.1\))
(2) This additionally verifies the annual age determination method of *M. paradoxus*.

MP condition ~ MP chronology growth

(PCC = 0.36, n = 20, \( p < 0.1 \))
MP Predicted growth correlates with local forcing

MP chronology growth ~ SST: PCC = -0.452, *p* < 0.025
MP Predicted growth correlates with local forcing

MP chronology growth ~ SST: PCC = -0.452, p < 0.025

(3) *M. paradoxus* growth responds to local forcing
(4) *M. paradoxus* grow 6–10 cm / year from otolith age & fish length data

*M. paradoxus* – survey length distributions
(4) *M. paradoxus* grow 6–10 cm / year from otolith age & fish length data

*M. paradoxus* – survey length distributions

Confirmed by survey length-frequency data: 8.8 (SA W coast) – 10.4 (Nam) cm / year)

Confirmed by Geopop model growth rate estimate (8.3 cm / year)
(4) *M. paradoxus* grow 6–10 cm / year from otolith age & fish length data

Confirmed by ICSEAF commercial LFD data (9.3 cm / year)
Conclusions

# 1. Annual age determination methods as used presently can be continued on *M. paradoxus*

# 1b. Growth from age-length data can be used for long-term correlations, as the time series goes back to 1977, further than the chronologies
MP otolith growth chronology: De-trending – ME model

• $\log(\text{Inc}) \sim \log(\text{Age}) + \log(\text{AAC})$
+ $(\log(\text{Age}) \mid \text{FishID}) + (1 \mid \text{Year})$
MC male and female mean length at age differences

Mean fish total length (cm)

Age (years)
MP male and female mean length at age differences
MP male and female length at age differences
# 2. Likelihood ratio tests for all VBGF growth parameters separate and all combinations of each:

No significant differences between full model (all parameters different) and alternative model (all parameters the same)

Chi-test ($\chi^2 = 0.0096$, df1=6, df2=5, p = 0.5)
Conclusions

# 1. No differences between ♀ and ♂ growth rates of *M. paradoxus* or *M. capensis*
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THANK YOU!