A population ecological study of the elkhorn sculpin (*Alcichthys alcicornis*) along the Uljin area of Korea

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Age double checking

Statistical criteria for choosing the best fitted growth model

Synthesizing several natural mortalities into a single value

to estimate ecological parameters by more statistical methods, which will be basic data to assess elkhorn sculpin
Advances in estimating ecological parameters
Age cross checking

Age cross checking with the otolith

reader 1

reader 2

2year VS. 3year

Do not use

Use only agreements

3year

3year

3year
Several growth functions

- von Bertalanffy growth function (VBGF)
- Generalized von Bertalanffy growth function (Richards)
- Robertson growth function

No criteria for choosing the VBGF
(Kim et al., 2010; Yang et al., 2008; Seo et al., 2007; Robillard et al., 2009)

It needs to know how accurately each model describes the data
### Growth functions

- **Standard von Bertalanffy growth function (VBGF)**
  \[
  L_t = L_\infty (1 - e^{-K(t-t_0)})
  \]
  - $L_\infty$: asymptotic maximum length
  - $K$: instantaneous growth coefficient
  - $t_0$: theoretical age

- **Generalized von Bertalanffy growth function (Richards)**
  \[
  L_t = L_\infty (1 + n e^{-K(t-t_0)})^{\frac{1}{n}}
  \]
  - $n$: fourth growth-equation parameter

- **Robertson growth function**
  \[
  L_t = \frac{L_\infty}{1 + e^{-Kt}} \cdot (c = \ln \left( \frac{L_\infty + L_0}{L_\infty} \right) + Kt_0)
  \]

- **Gompertz growth function**
  \[
  L_t = L_\infty e^{-a e^{-Kt}} \cdot (a = \ln \left( \frac{L_\infty}{L_t} \right) e^{Kt})
  \]
Comparison of functions

AIC (Akaike Information Criteria, 1974) and BIC (Bayesian Information Criterion, 1978) were used to assess model performance

\[
AIC = -2 \ln L + 2k \\
BIC = -2 \ln L + k \ln (n)
\]

\(L\) : the maximum likelihood \hspace{1cm} k : the number of parameters
\(n\) : the number of observations

Based on the smallest value of AIC and BIC, the best fitted model was selected.
Difficult to judge relative merits among methods

Rather than selecting one, synthesizing several M estimates

* Meta analysis
  Combining the results of several studies that address a set of related research
M estimation models

7 models for estimating M

1. Hoenig (1983) \[ \ln M = 1.46 - 1.01 (\ln t_{max}) \]

<Random effects model>

Both within-study sampling error (variance) and between-studies variation are included in the assessment of uncertainty

Integrated \( M = \frac{\sum (w_i^* x M_i)}{\sum (w_i^*)} \), \( w_i^* = 1/\text{var}(M_i) \)

6. Gunderson (2003) \( M = 1.79 \text{GSI} \)

7. Zhang and Megrey (2006) \[ M = \frac{\beta K}{e^{K(t_{m0} - t_0)} - 1} \]
Materials and methods for other parameters
Elkhorn sculpin (*Alcichthys alcicornis*)

- **Classification**: Actinopterygii > Scorpaeniformes > Cottidae
- **Distribution**: East coast of Korea, Japan and the Sea of Okhotsk
- **Environment**: Demersal, cold water fish, depth range around 50m, move to the deep sea bottom (below 200m) during the summer

- Getting more popular as the wild raw fish, but catch is reported in aggregate as “others”, therefore more rigid management is needed
Field sampling

- A total of 527 samples
- Area: Gyeongsangbuk-do, Uljin-gun
- Fishing gear: Trammel net
  (Mesh size 7.6~12.1cm)
- Duration: March 2010 ~ April 2011
  (No sample in August 2010)
Gonadosomatic Index (GSI)

- The ratio of fish gonad weight to body weight can determine the spawning season

\[
GSI = \frac{\text{Gonad weight}}{\text{Total weight}} \times 10^3
\]

Group maturity

- The length at which 50% of all specimens were sexually mature ($L_{50}$) was estimated from the logistic function described as

<Bootstrapping>
To reduce the uncertainty surrounding $L_{50}$, data was re-sampled with replacement 1,000 times
Survival rate ($S$) and instantaneous coefficient of total mortality ($Z$)

- **Survival rate ($S$)**: Chapman and Robson method

\[
S = \frac{\bar{X}}{1 + \bar{X} - \frac{1}{\sum N_i}} \quad \bar{X} = \frac{\sum (i \cdot N_i)}{\sum N_i}
\]

- $\bar{X}$: mean of age
- $\sum N_i$: age
- $N_i$: specimen number at age $i$

- **Instantaneous coefficient of total mortality ($Z$)**

\[
Z = -\ln S
\]

Age at first capture ($t_c$)

- **Length-converted catch curve**

\[
\ln(1/S - 1) = T_1 - T_2 (L_1 + L_2)
\]

\[
t_c = \frac{T_1}{T_2}
\]
Results
Size structure and length-weight relationship

- Sample size: \(N=527\)
- Average length: \(\bar{L} = 16.6\text{ cm}\)

Length-frequency distribution

Length-weight relationship

\[
W = 0.0051L^{3.2979}
\]

\(R^2 = 0.978\)

Data points: \(N=527\)
Age determination

(Surface ground otolith of 3-year-old elkhorn sculpin)

(Monthly changes in otolith marginal index)
Within-reader agreements for age readings were
reader 1 = 83.8% and reader 2 = 91.2%

Based on these ages, the agreement between readers was checked
Age cross checking

- A total of 385 agreements between readers (agreements 82.3%)
- Only 385 agreements were used for the growth function
Comparison of growth functions

- After completing 4 growth functions, one function was chosen by AIC and BIC

<table>
<thead>
<tr>
<th>Function</th>
<th>AIC</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBGF</td>
<td>-8.957</td>
<td>-8.719</td>
</tr>
<tr>
<td>Richards</td>
<td>-7.137</td>
<td>-6.820</td>
</tr>
<tr>
<td>Robertson</td>
<td>-7.462</td>
<td>-7.224</td>
</tr>
<tr>
<td>Gompertz</td>
<td>-8.941</td>
<td>-8.703</td>
</tr>
</tbody>
</table>

\[ L_t = 29.41(1-e^{-0.247(t+0.609)}) \]
7 different M's were synthesized by meta-analysis

<table>
<thead>
<tr>
<th>Method</th>
<th>Parameters used</th>
<th>M estimates</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoenig</td>
<td>maximum age</td>
<td>0.377</td>
<td>0.0073</td>
</tr>
<tr>
<td>Jensen</td>
<td>K</td>
<td>0.600</td>
<td>0.0563</td>
</tr>
<tr>
<td>Jensen</td>
<td>Age at maturity</td>
<td>0.596</td>
<td>0.0441</td>
</tr>
<tr>
<td>Roff</td>
<td>K, Age at maturity</td>
<td>0.613</td>
<td>0.1031</td>
</tr>
<tr>
<td>Pauly</td>
<td>K, $L_{\infty}$, temperature</td>
<td>0.571</td>
<td>0.0394</td>
</tr>
<tr>
<td>Gunderson</td>
<td>GSI</td>
<td>0.815</td>
<td>0.3097</td>
</tr>
<tr>
<td>Zhang &amp; Megrey</td>
<td>$t_{0}$, $\beta$, K, maximum age</td>
<td>0.677</td>
<td>0.1174</td>
</tr>
</tbody>
</table>

*inverse variance weighted mean*

0.467/year
(95%CI 0.336~0.597/yr)
### Survival rate (S) and instantaneous coefficient of total mortality (Z)

<table>
<thead>
<tr>
<th>Method</th>
<th>S</th>
<th>Var(S)</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapman and Robson</td>
<td>0.334/year</td>
<td>0.0005</td>
<td>1.096/year</td>
</tr>
</tbody>
</table>

### Age at first capture ($t_c$)

\[
\ln(C/dt) = -0.6613t + 6.8444 \\
R^2 = 0.9335
\]

$te = 2.41$
Summary

1. The first ecological study of elkhorn sculpin
2. Improving accuracy by age double checking
3. Using statistical criteria for the best fitted growth model
4. Synthesizing several Ms into the one by meta analysis

Providing the **basic data to assess** elkhorn sculpin (*Alcichthys alcicornis*) **by more statistical methods**