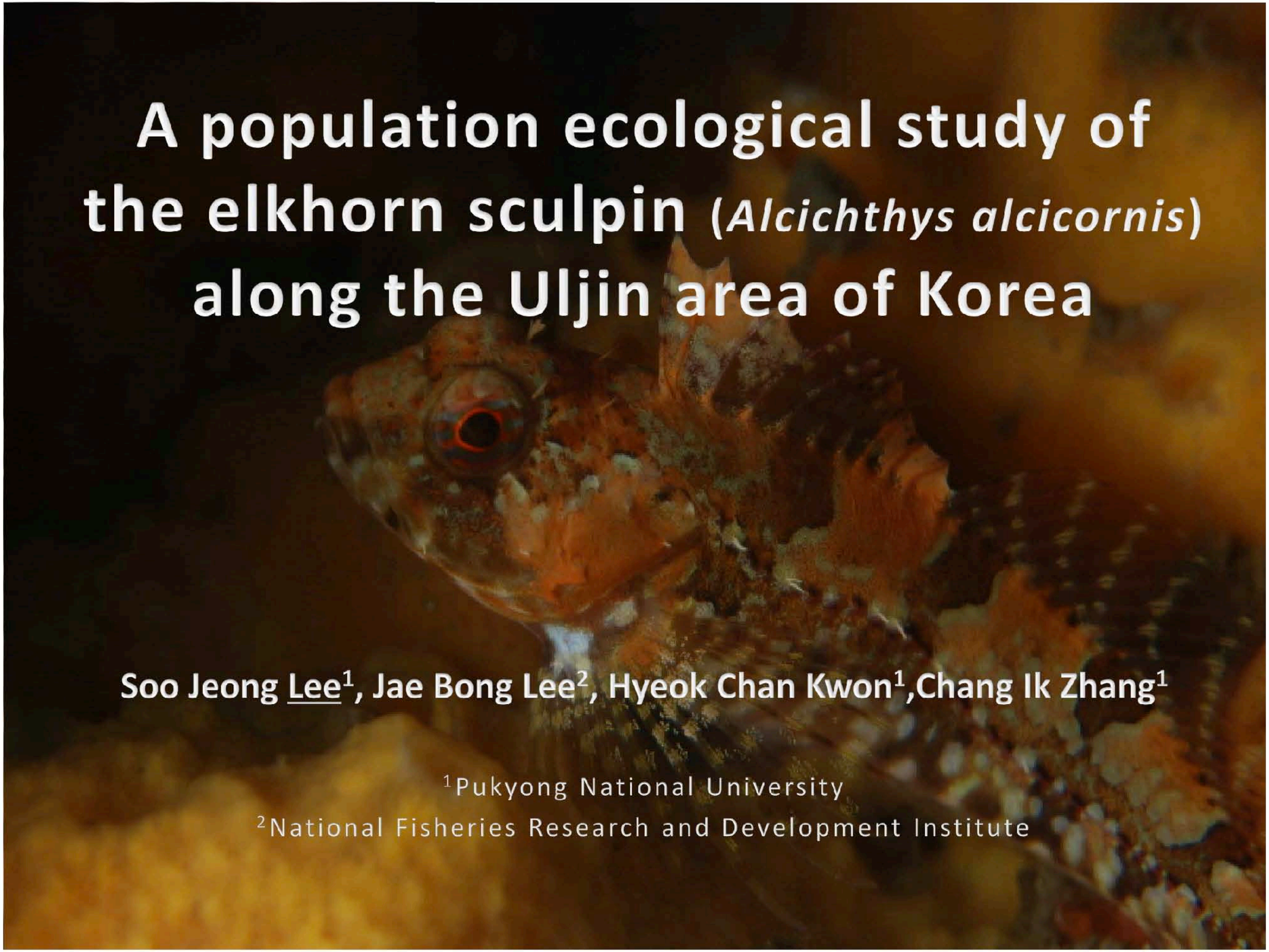

A population ecological study of the elkhorn sculpin (*Alcichthys alcicornis*) along the Uljin area of Korea

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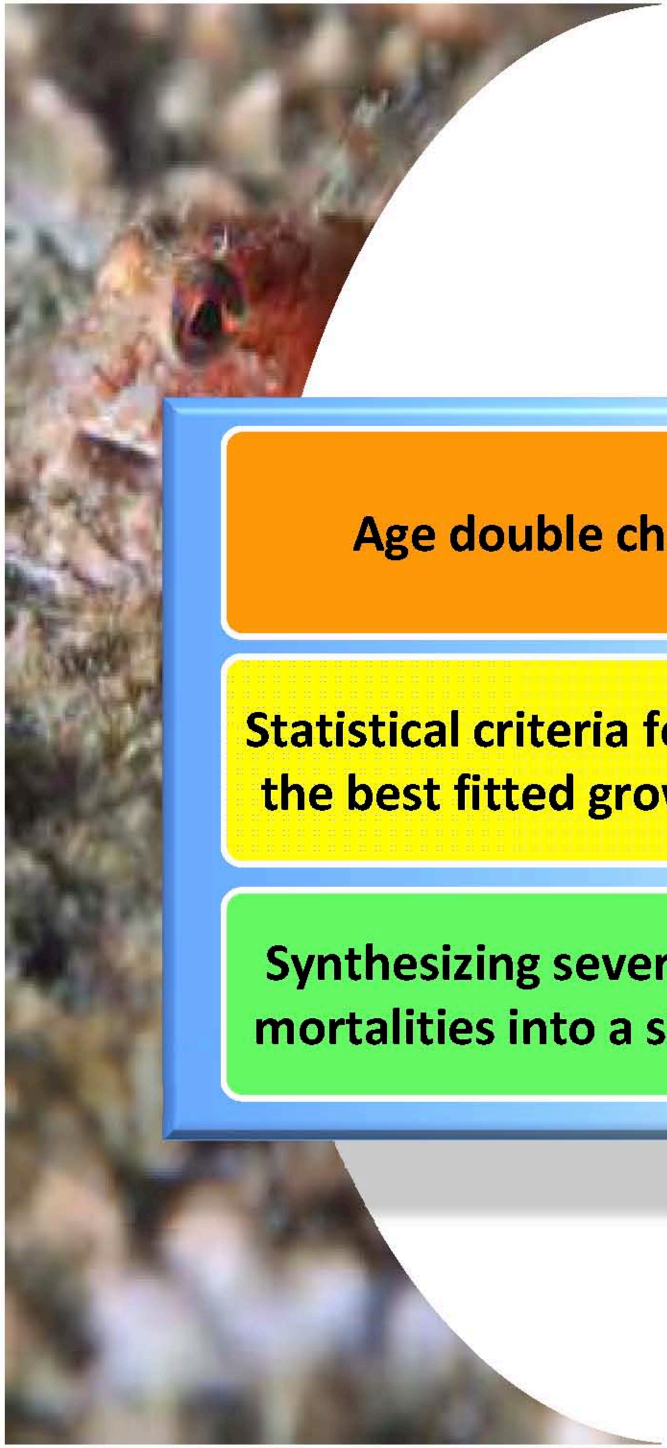
CONTENTS

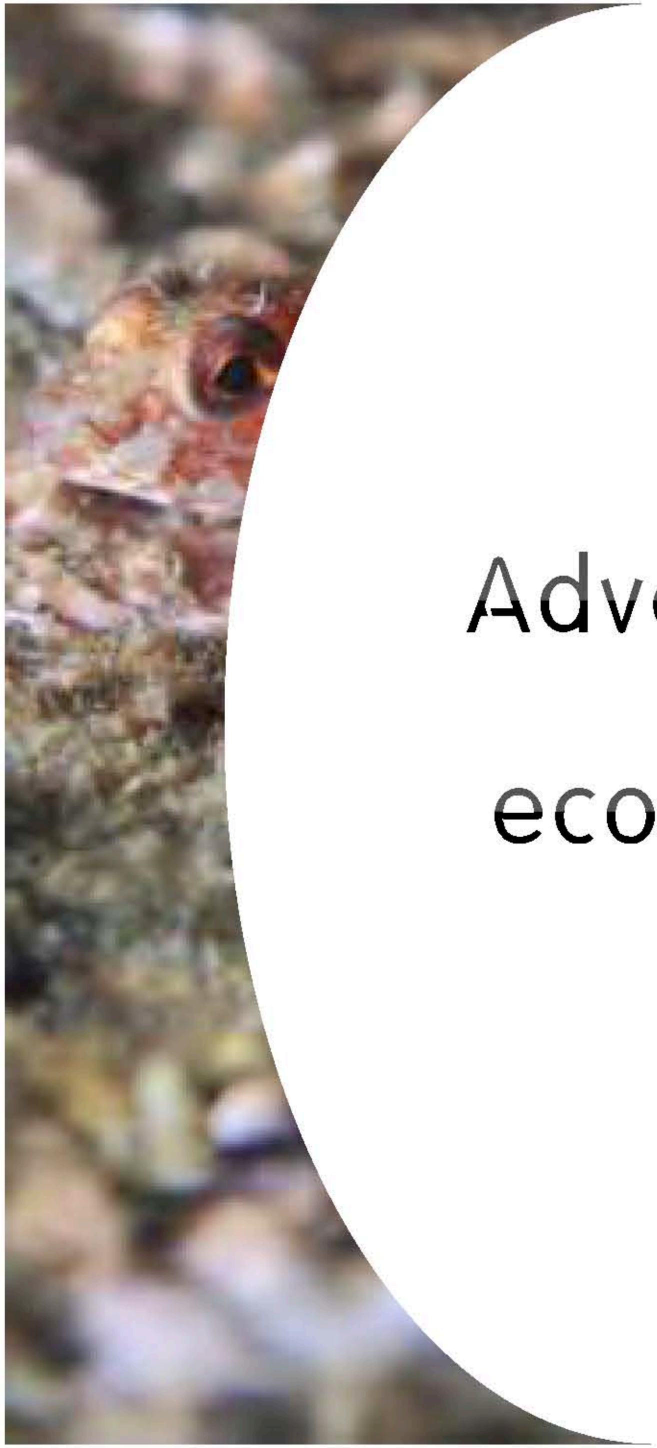
- Advances in estimating ecological parameters
- Materials and methods for other parameters
- Results
- Summary

Purpose

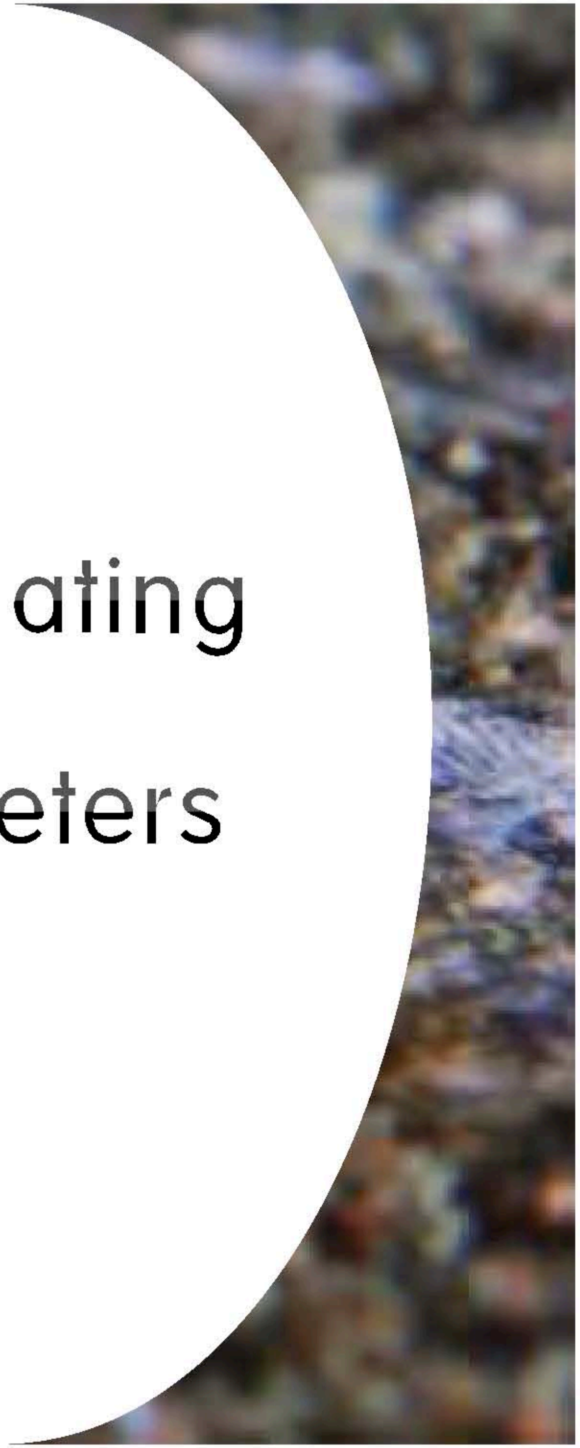


- Age double checking
- Statistical criteria for choosing the best fitted growth model
- Synthesizing several natural mortalities into a single value

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 determination

- Age cross checking with the otolith

reader 1

reader 2

2year

3year

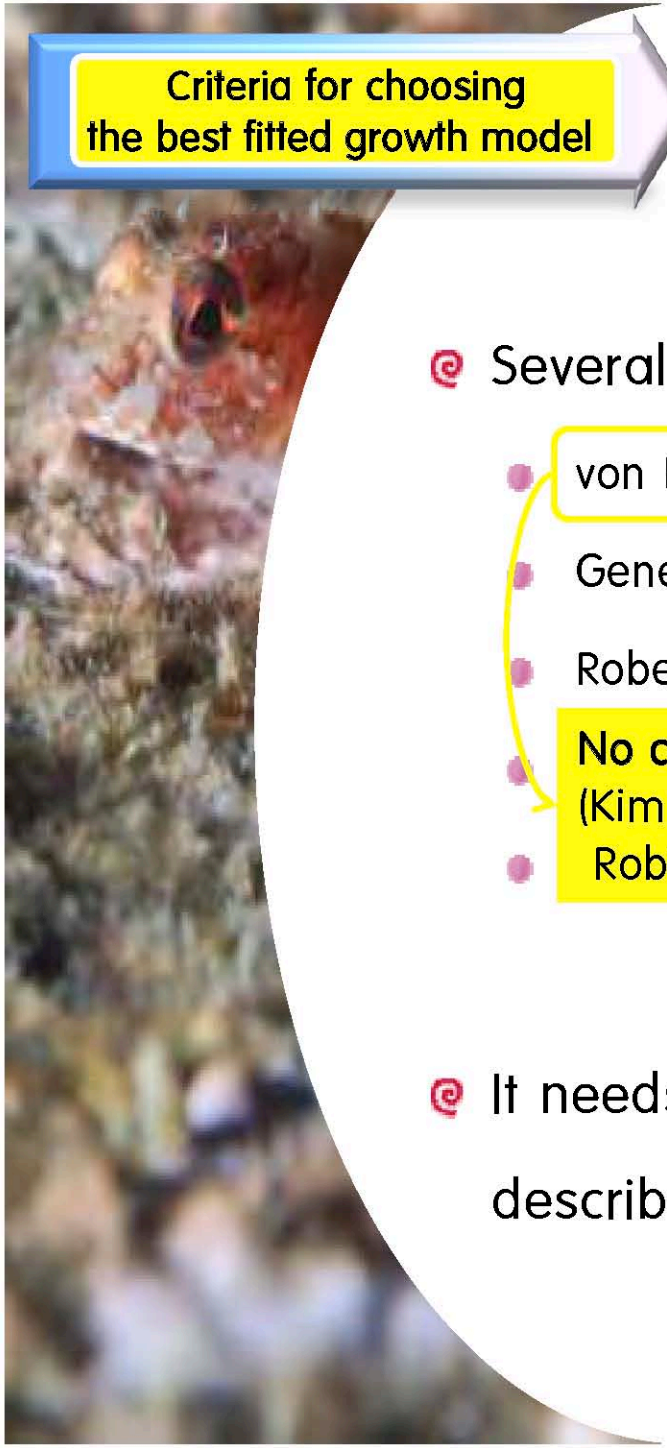
Do not use

vs.

3year

3year

Use only agreements

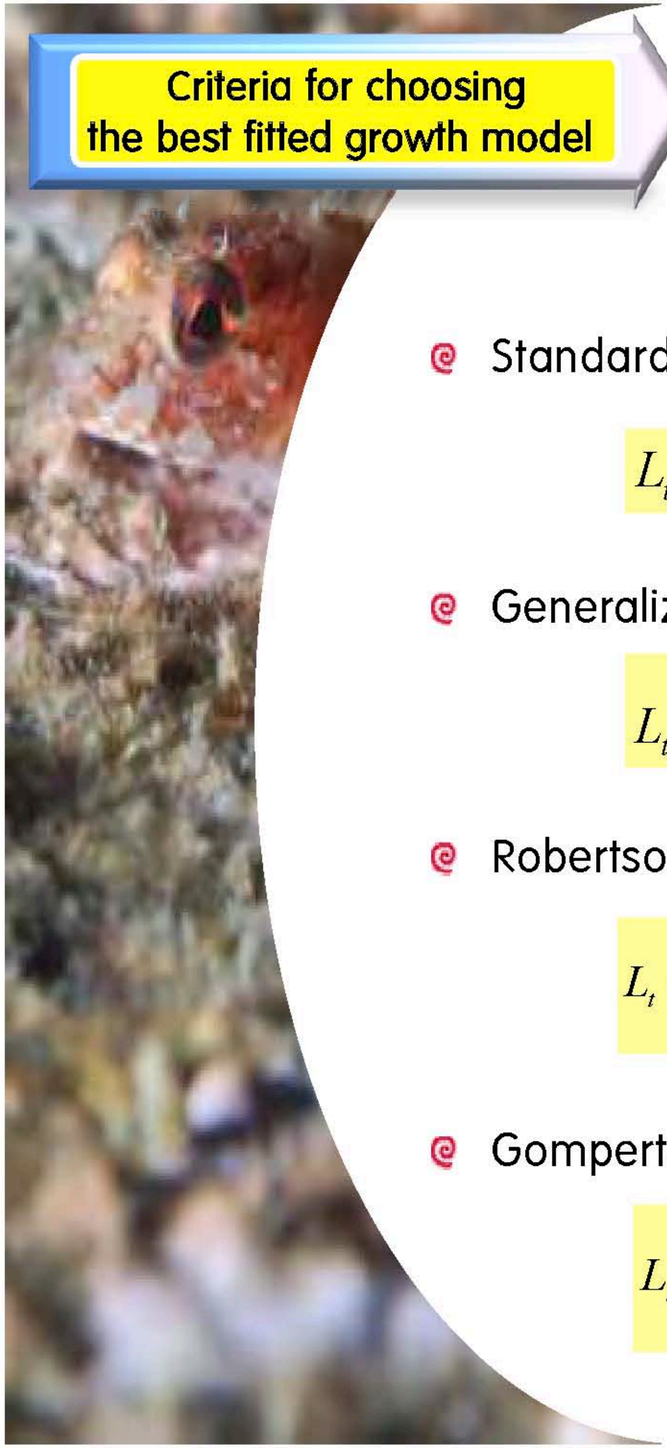


Criteria for choosing the best fitted growth model

Growth functions

- 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

Criteria for choosing the best fitted growth model



Growth functions

- Standard von Bertalanffy growth function (VBGF)

$$L_t = L_\infty (1 - e^{-K(t - t_0)})$$

L_∞ : asymptotic maximum length

K : instantaneous growth coefficient

t_0 : theoretical age

- Generalized von Bertalanffy growth function (Richards)

$$L_t = L_\infty (1 + n\, e^{-K(t - t_0)})^{-\frac{1}{n}}$$

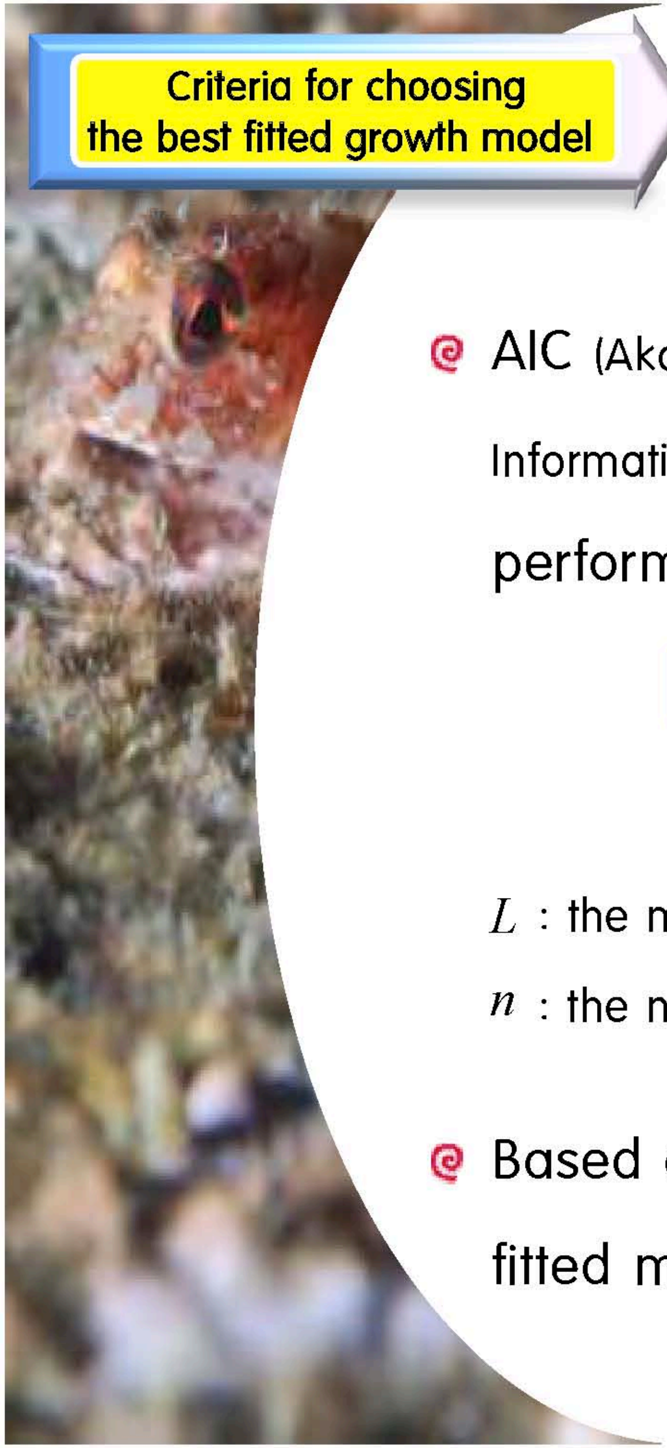
n : fourth growth-equation parameter

- Robertson growth function

$$L_t = \frac{L_\infty}{1 + e^{c - Kt}}, \quad \left(c = \ln\left(\frac{L_\infty + L_0}{L_\infty}\right) + Kt_0\right)$$

- Gompertz growth function

$$L_t = L_\infty\, e^{-a \cdot e^{-Kt}}, \quad \left(a = \ln\left(\frac{L_\infty}{L_t}\right) e^{Kt}\right)$$



Criteria for choosing the best fitted growth model

Comparison of functions

- AIC (Akaike Information Criteria, 1974) and BIC (Bayessian 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 k : the number of parameters

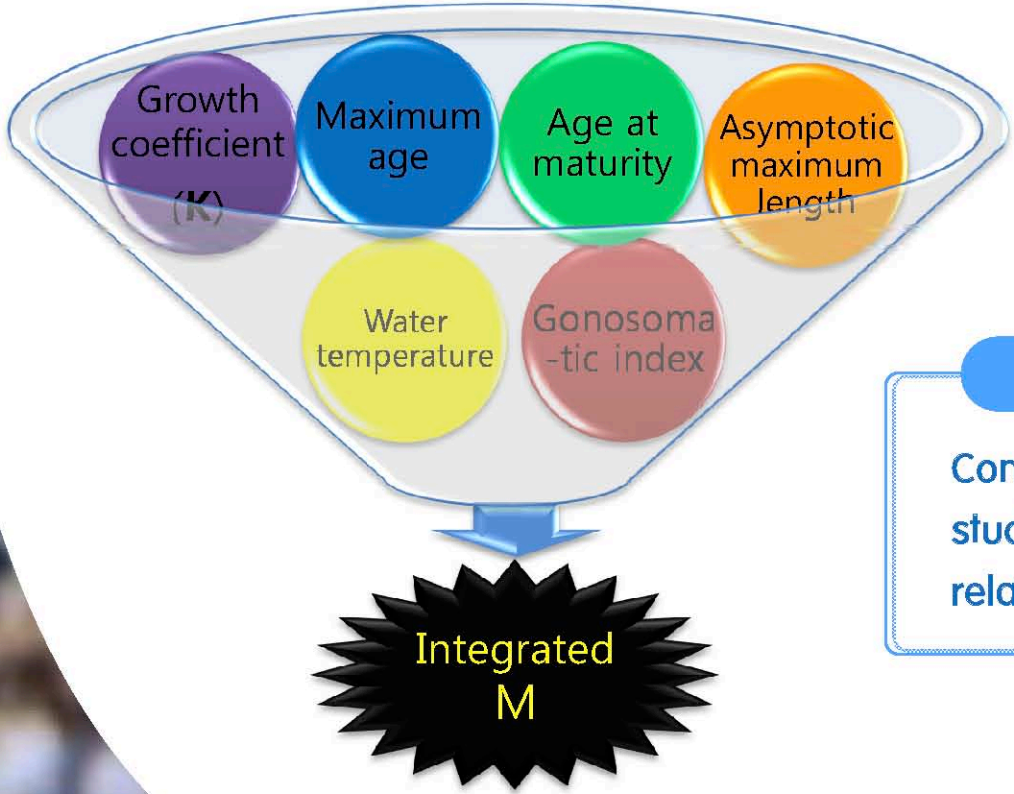
n : the number of observations

- Based on the smallest value of AIC and BIC, the best fitted model was selected

Synthesizing several Ms into a single M estimate

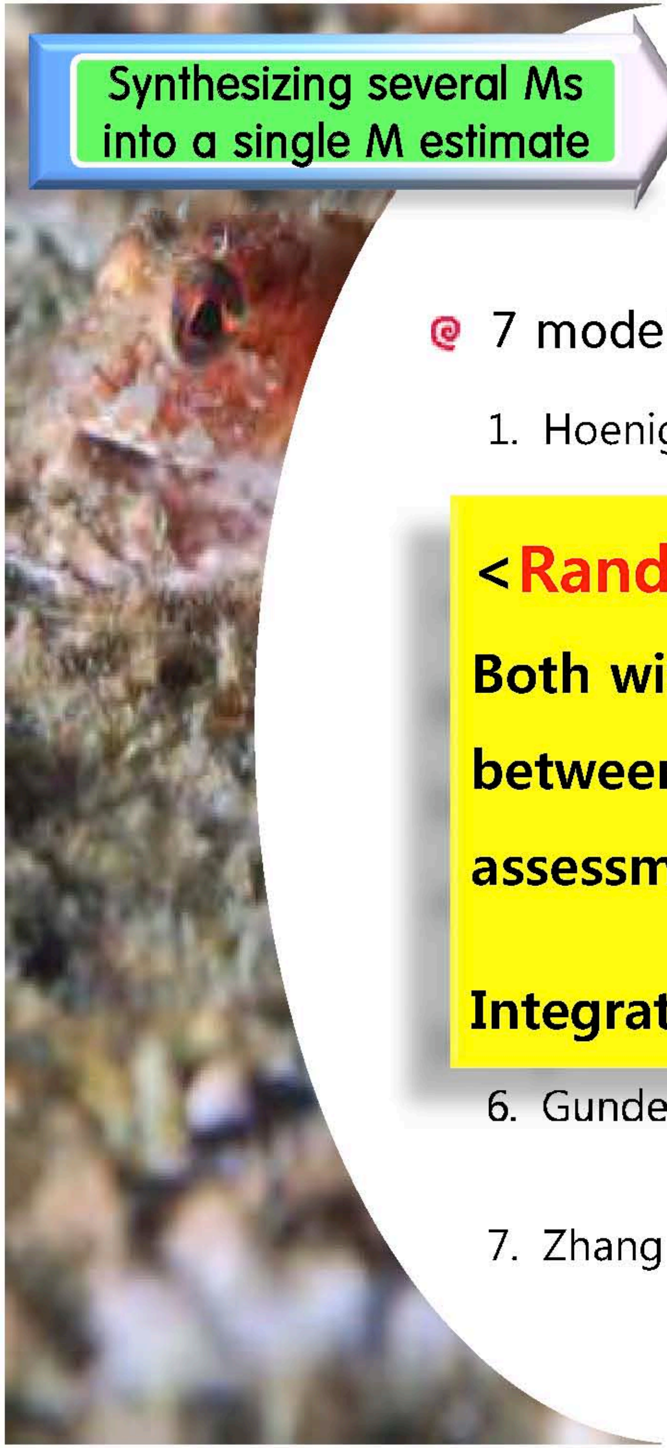
Instantaneous coefficient of natural mortality (M)

- 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



Synthesizing several Ms into a single M estimate

M estimation models

- 7 models for estimating *M*

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

$4(\log T)$

<Random effects model>

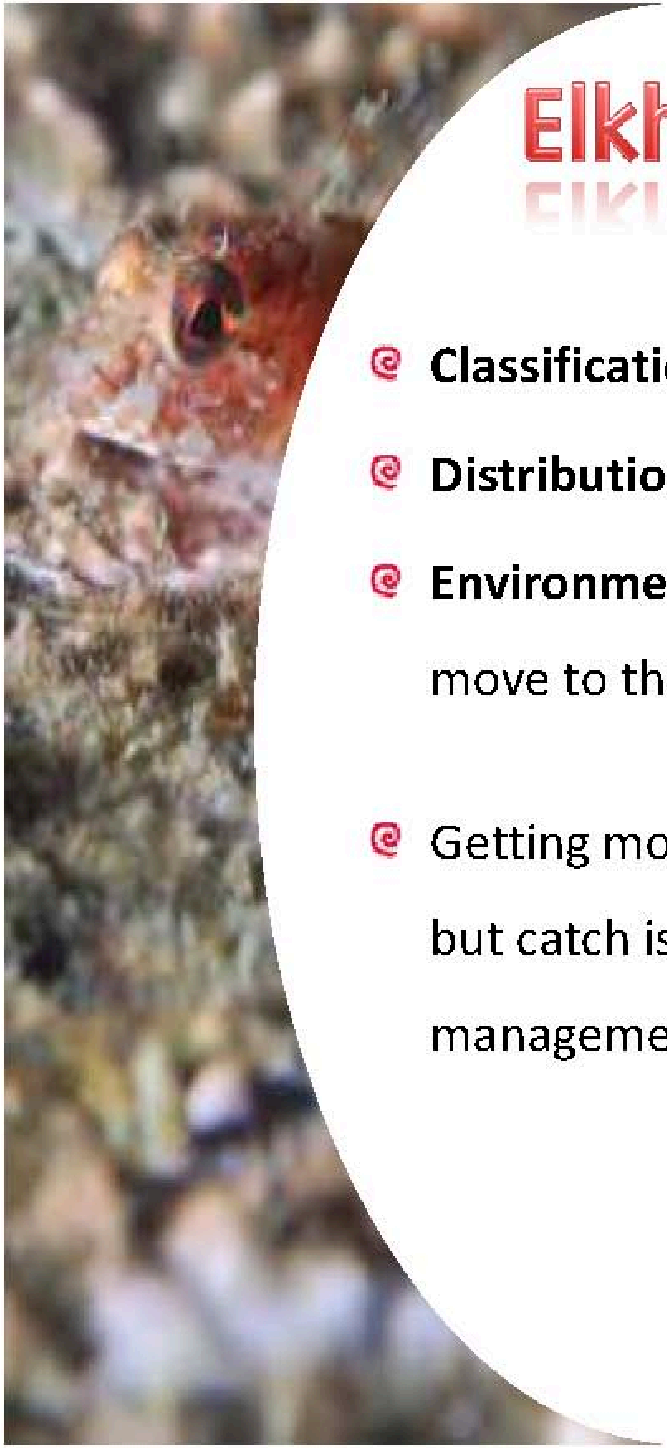
Both within-study sampling error (variance) and between-studies variation are included in the assessment of uncertainty

Integrated M=∑(w_i*x M_i) / ∑(w_i*), w_i*=1/var(M_i)

6. Gunderson (2003) $M = 1.79 GSI$

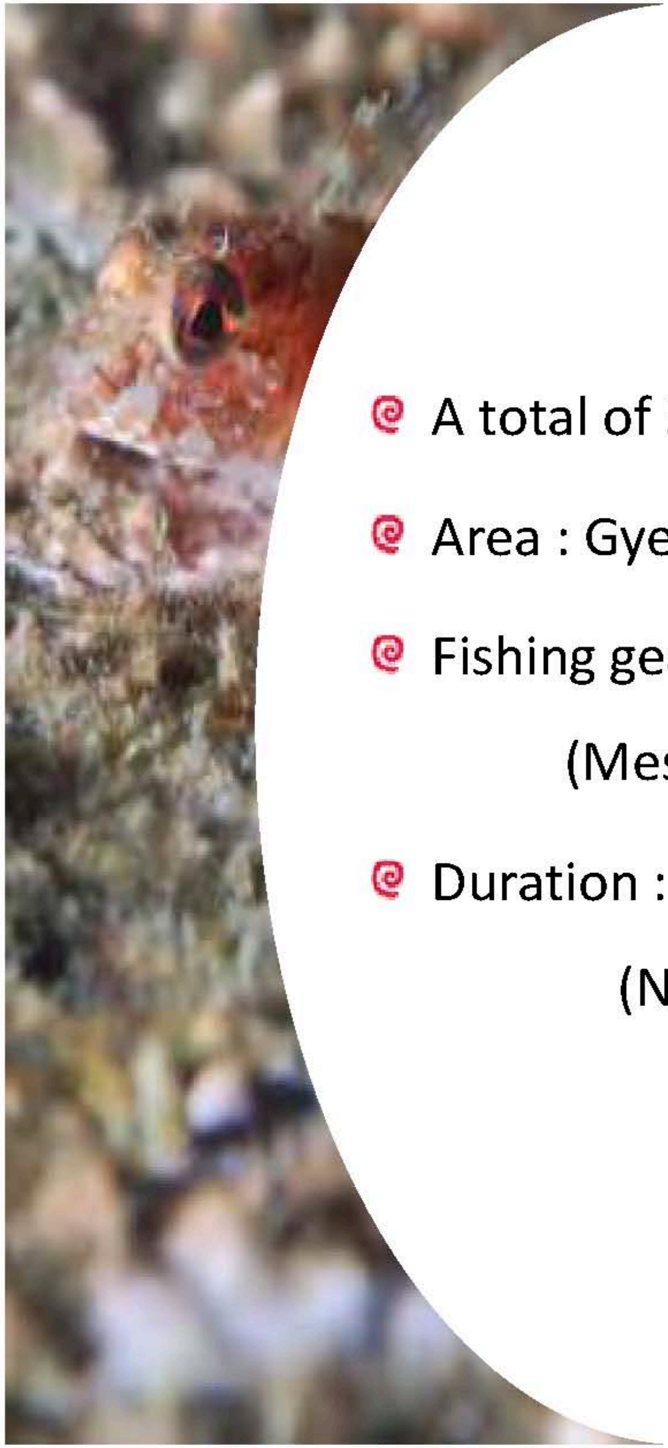
7. Zhang and Megrey (2006) $M = \frac{\beta K}{e^{K(t_{mb} - t_0)} - 1}$

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

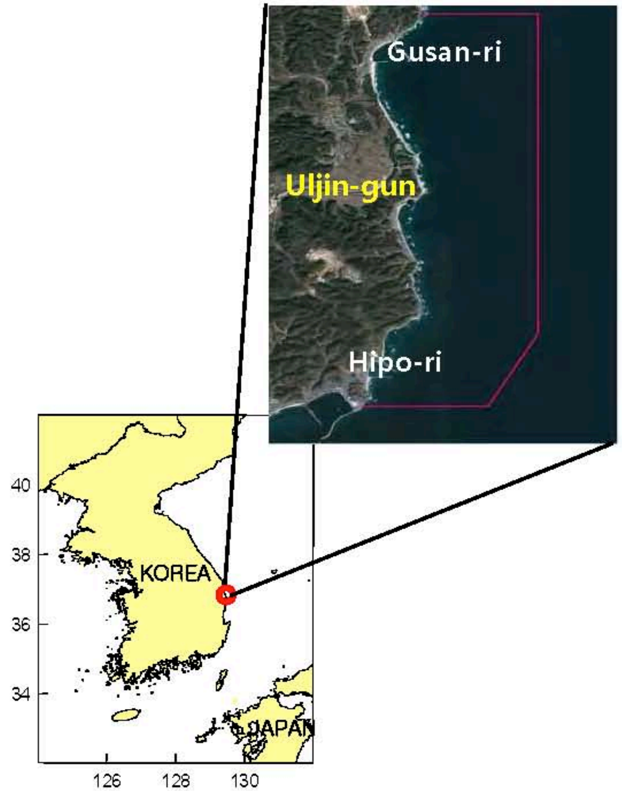


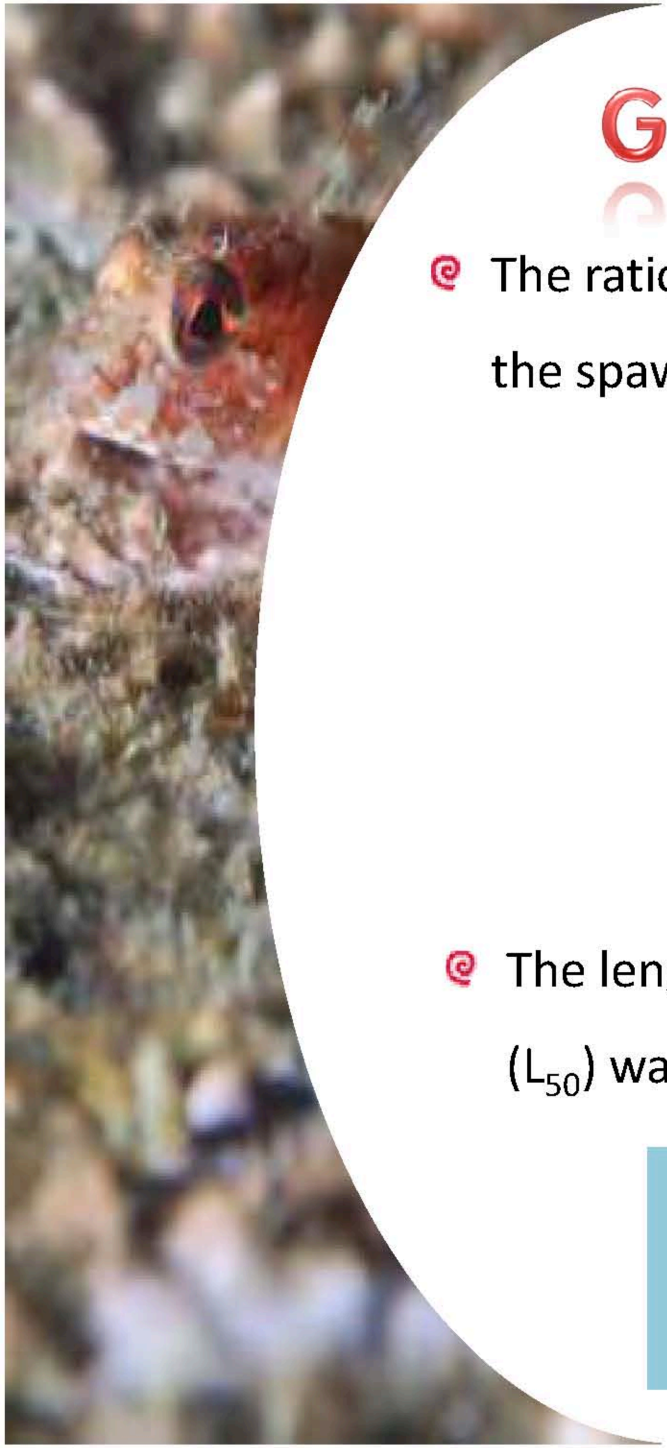
Field sampling

- 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)

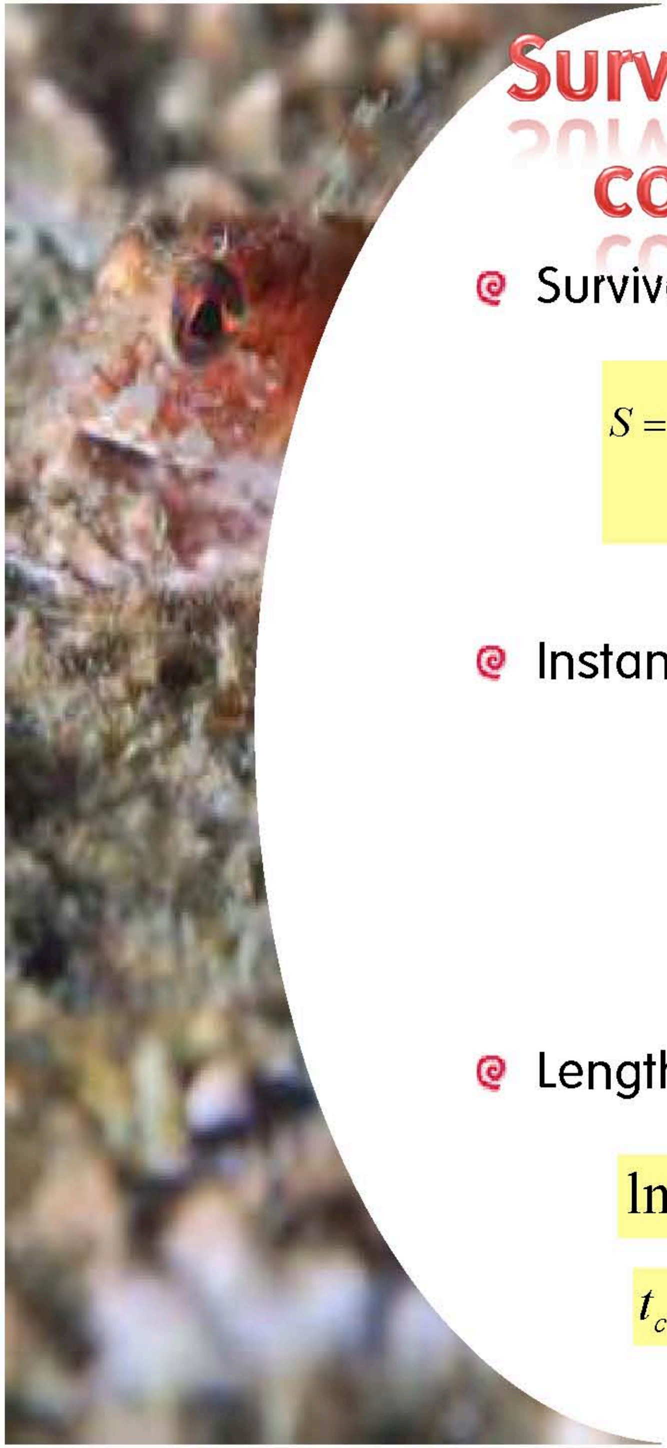
- The ratio of fish gonad weight to body weight can determine the spawning season

$$GSI = \frac{Gonad\ weight}{Total\ weight} \times 10^3$$

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

$$S = \frac{\overline{X}}{1 + \overline{X} - \frac{1}{\sum N_i}}, \quad \overline{X} = \frac{\sum (i \cdot N_i)}{\sum N_i}$$

$\overline{X}$: mean of age

i : age

N_i : specimen number at age i

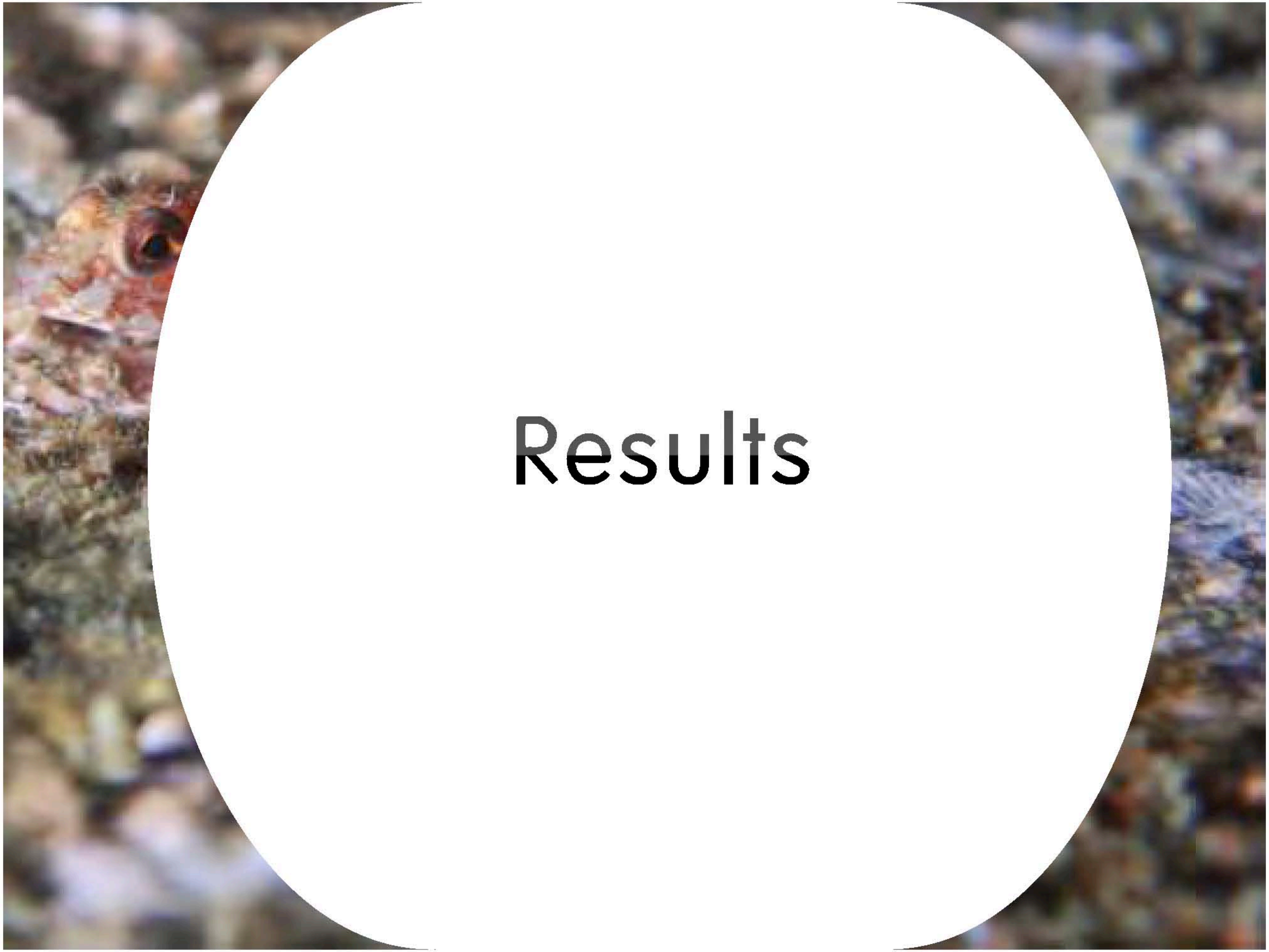
- Instantaneous coefficient of total mortality (Z) $Z = -\ln S$

Age at first capture (t_c)

- Length-converted catch curve

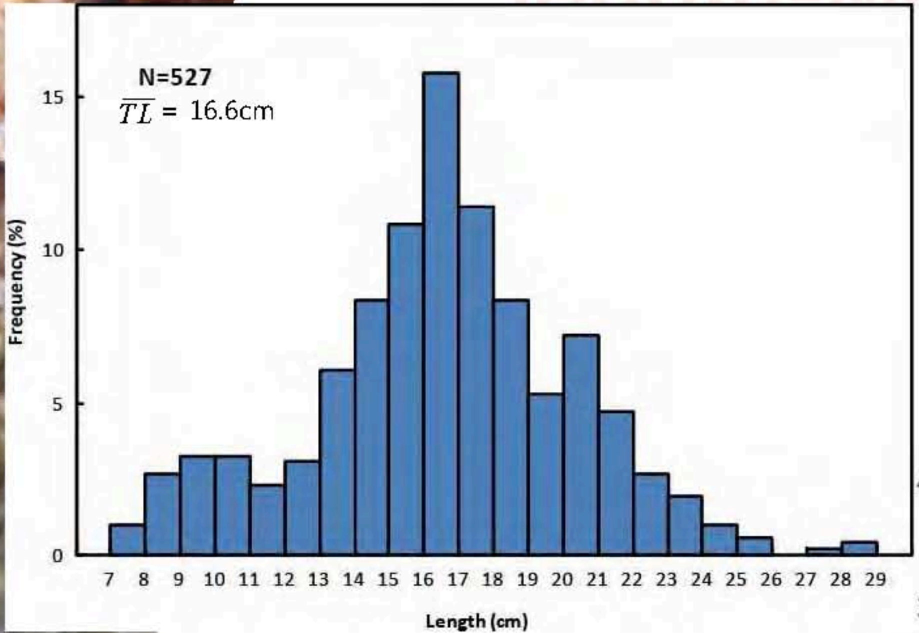
$$\ln(1/S - 1) = T_1 - T_2(L_1 + L_2)$$

$$t_c = T_1 / T_2$$



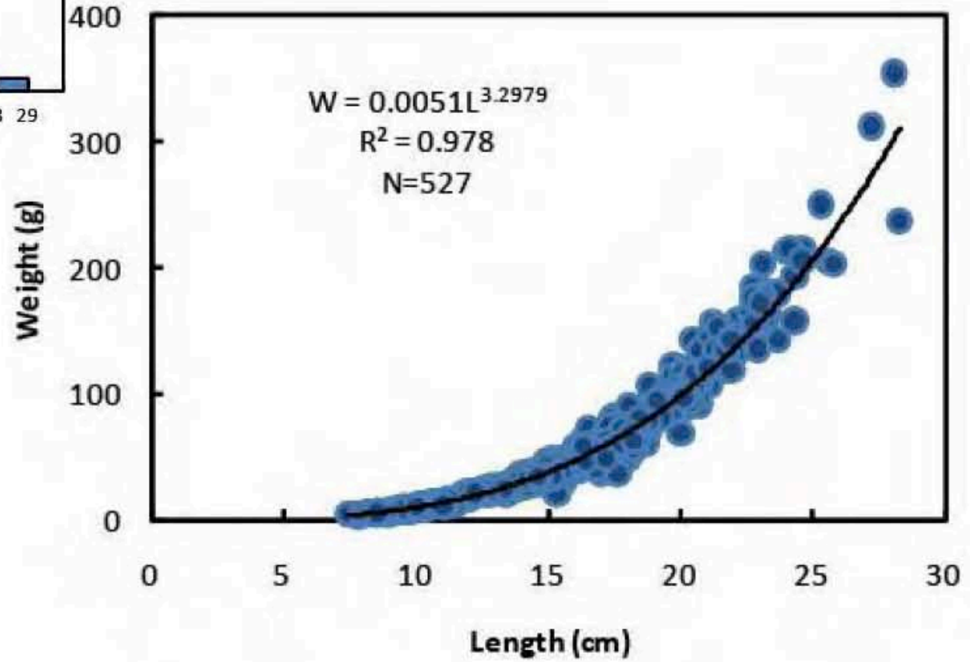
Results

Size structure and length-weight relationship

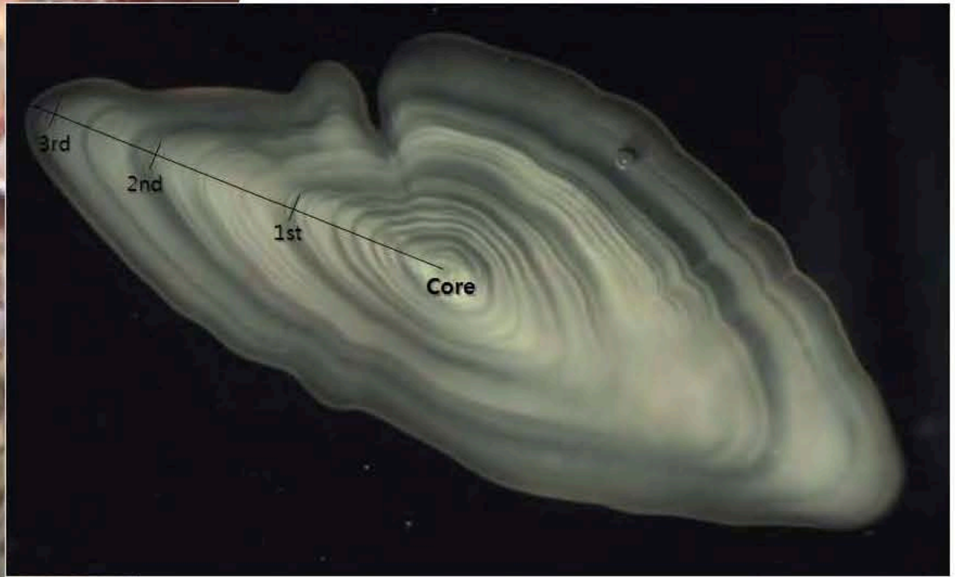


<Length–frequency>

<Length-weight relationship>

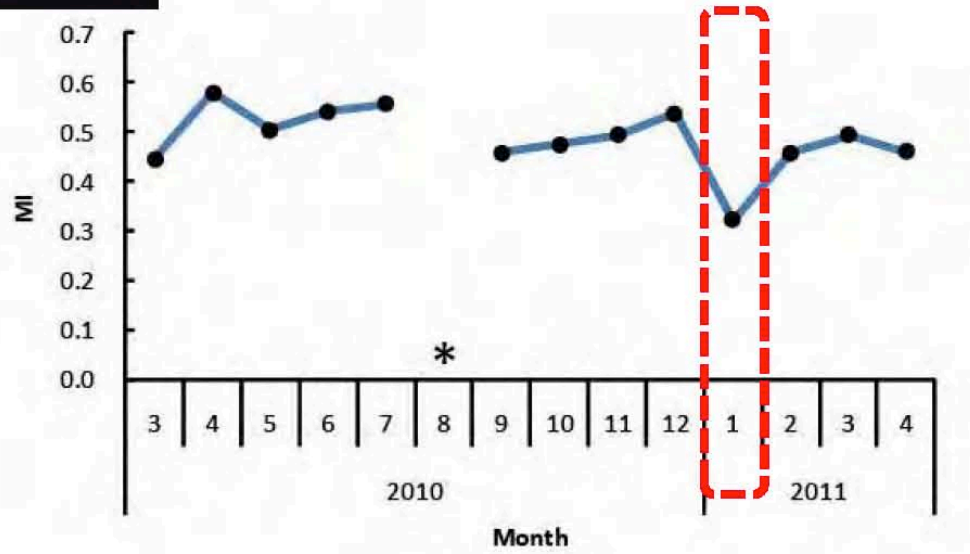


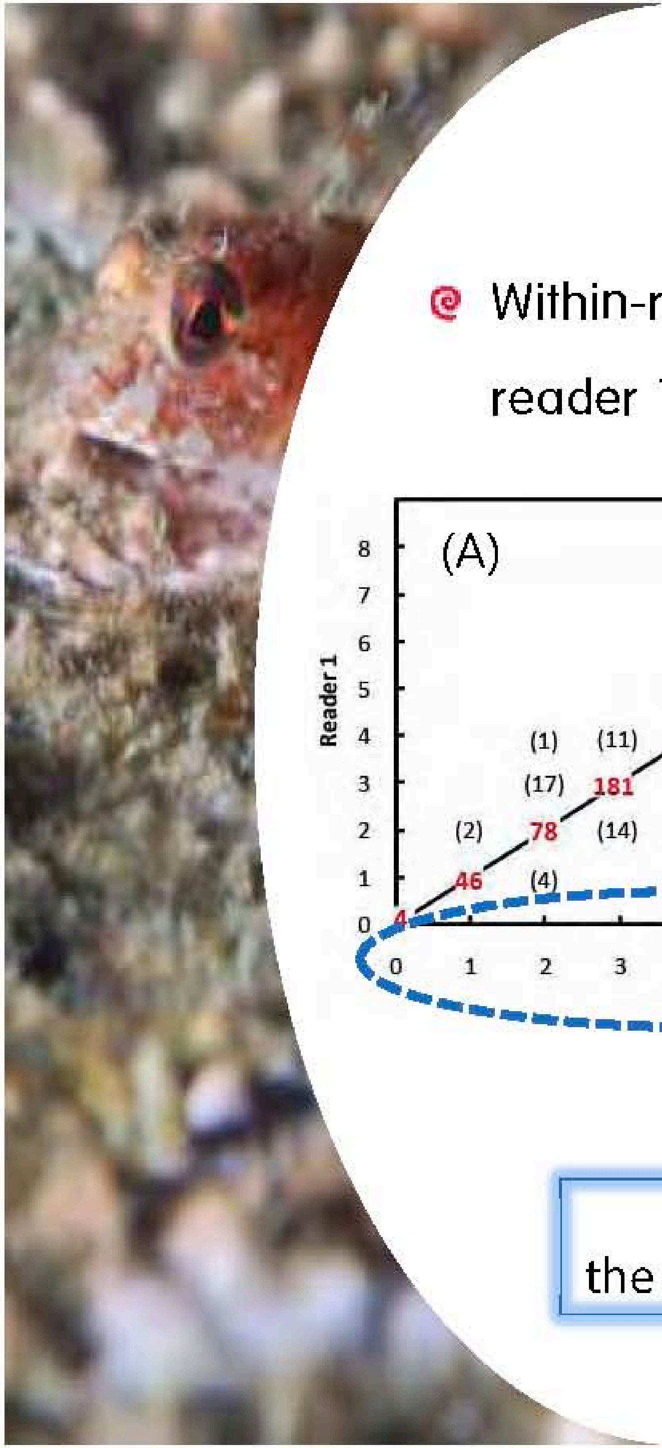
Age determination



〈Surface ground otolith of
3-year-old elkhorn sculpin〉

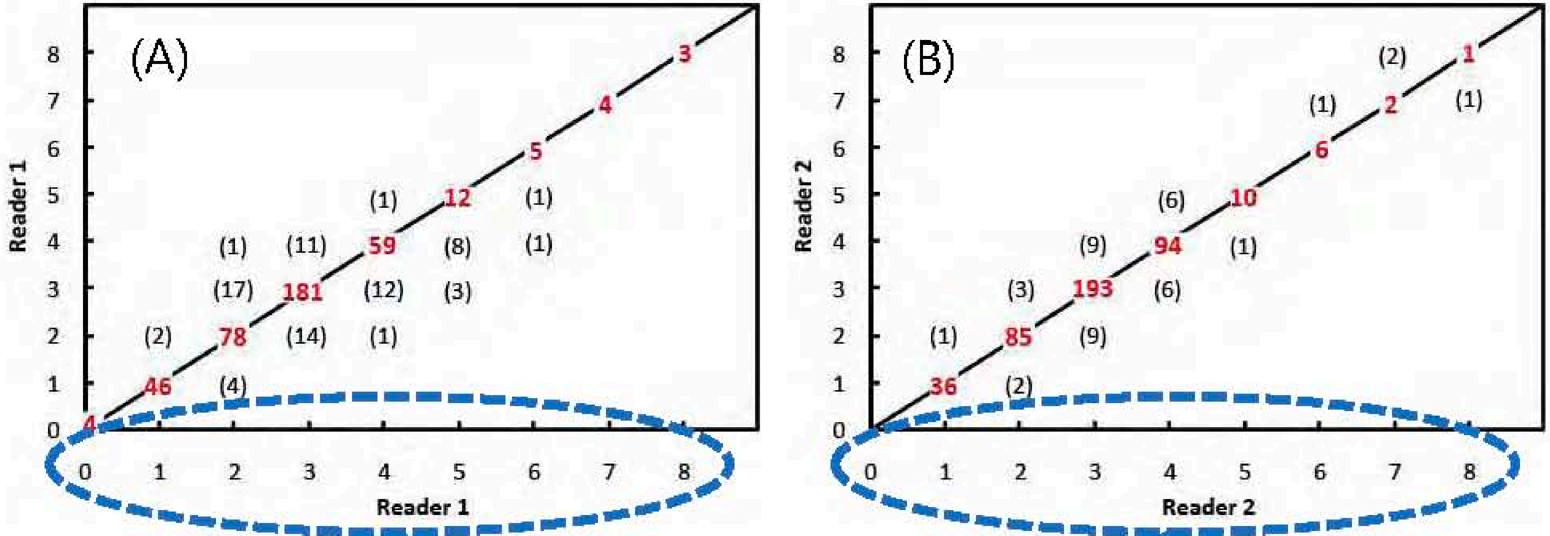
〈Monthly changes in otolith marginal index〉



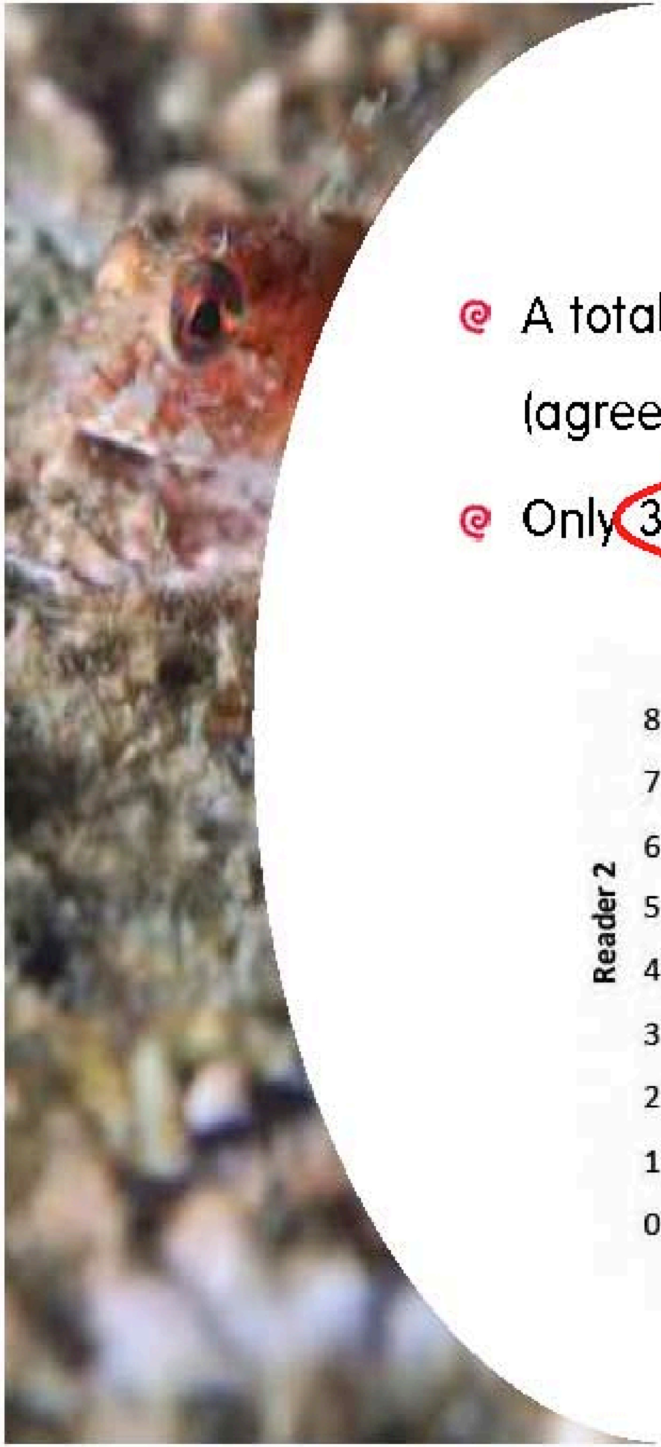


Age double checking

- Within-reader agreements for age readings were reader 1 = 83.8% and reader 2 = 91.2%

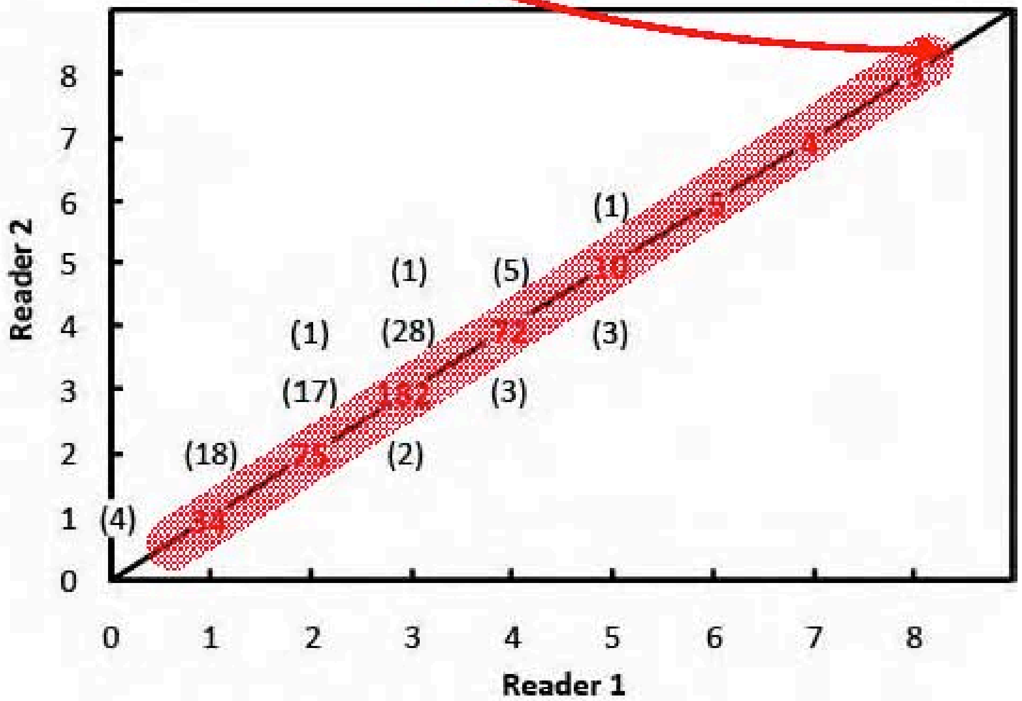


Based on these ages,
the agreement between readers was checked



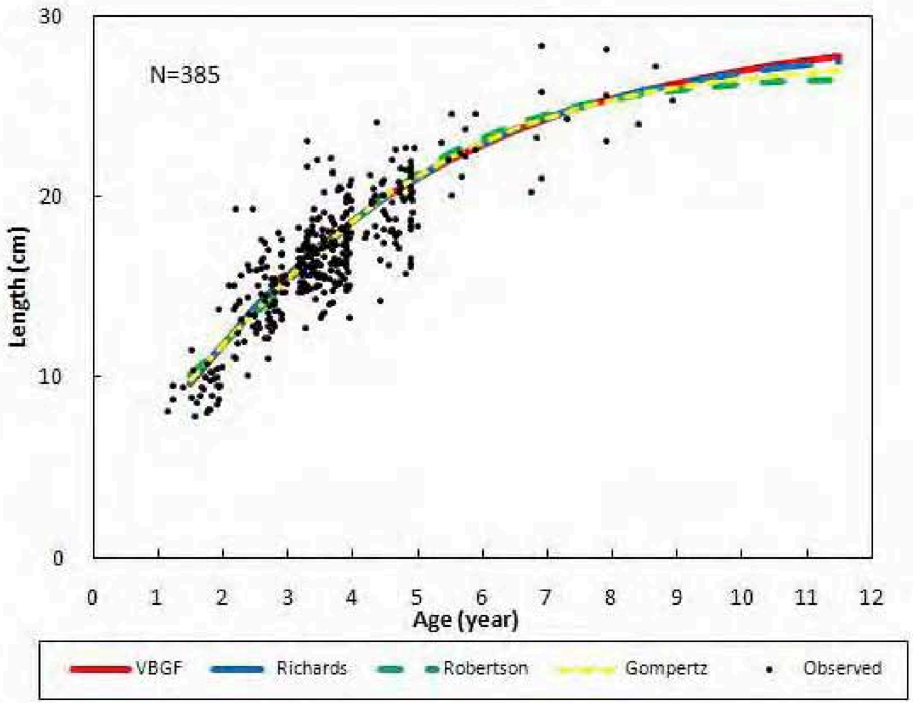
Age cross checking

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



Comparison of growth functions

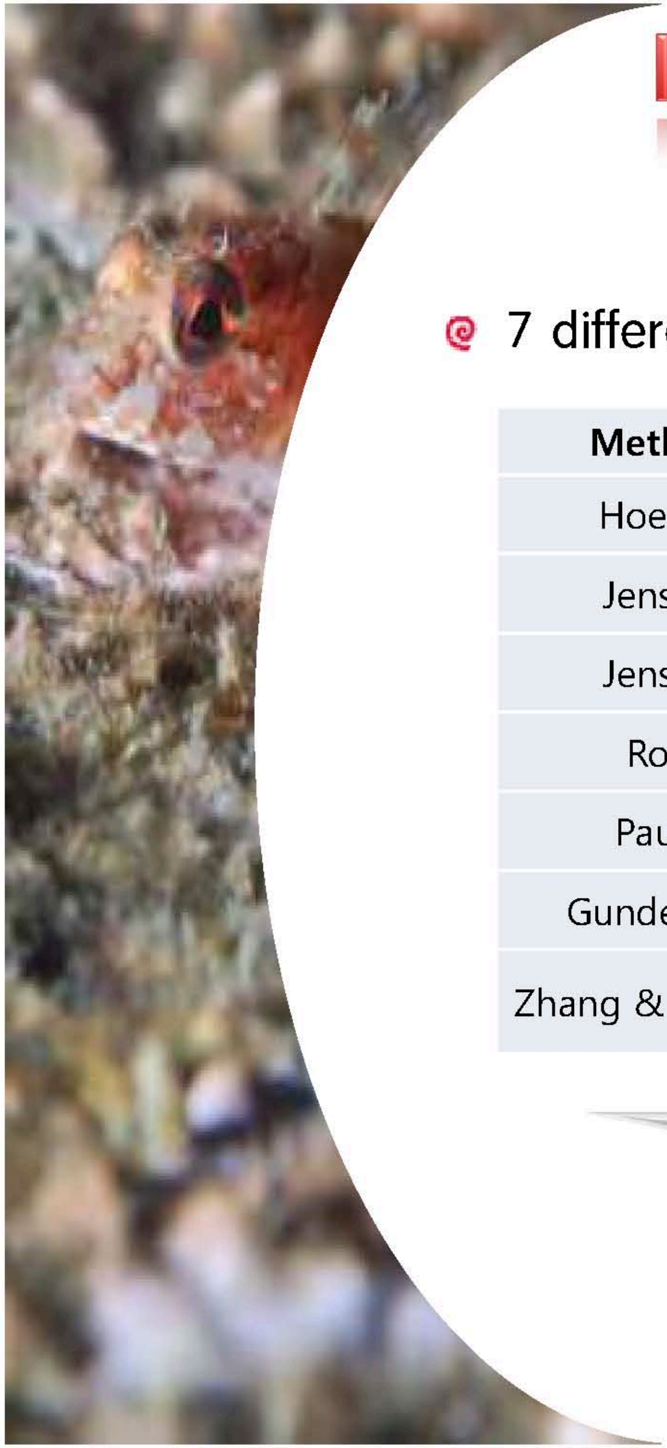
- After completing 4 growth functions, one function was chosen by AIC and BIC



〈Fitted growth curves from four growth functions〉

Function	AIC	BIC
VBGF	-8.957	-8.719
Richards	-7.137	-6.820
Robertson	-7.462	-7.224
Gompertz	-8.941	-8.703

$$L_t = 29.41(1 - e^{-0.247(t+0.609)})$$



Instantaneous coefficient of natural mortality (M)

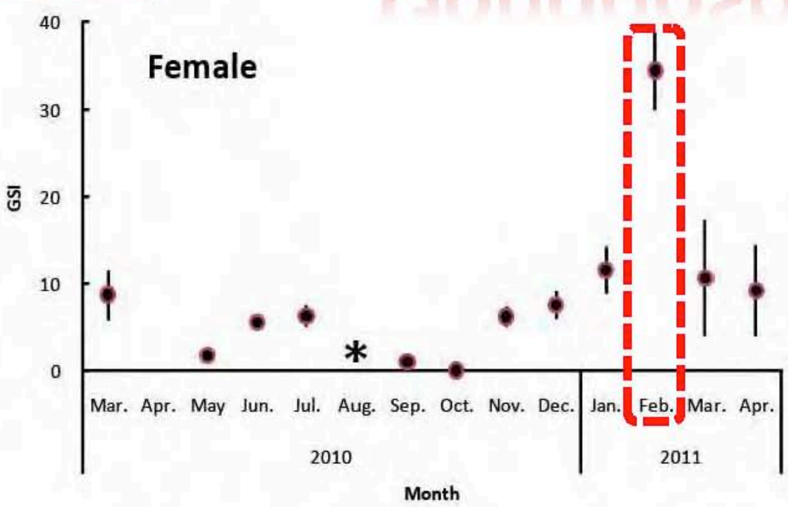
- 7 different Ms were synthesized by meta-analysis

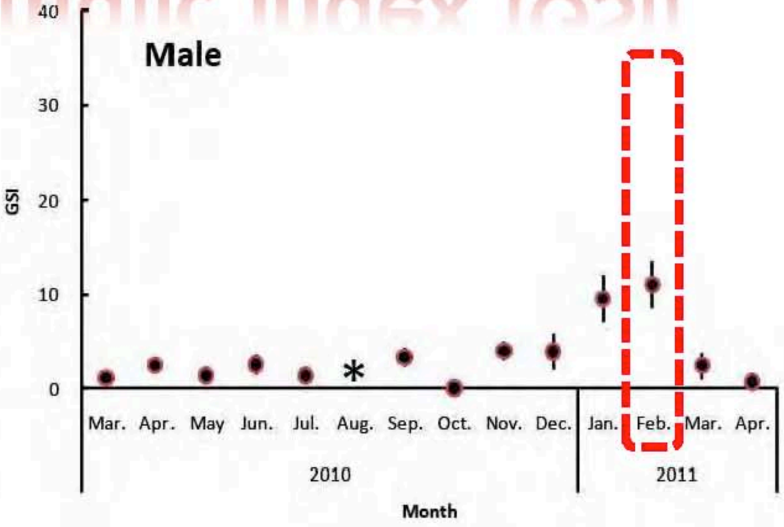
Method	Parameters used	M estimates	Variance
Hoenig	maximum age	0.377	0.0073
Jensen	K	0.600	0.0563
Jensen	Age at maturity	0.596	0.0441
Roff	K, Age at maturity	0.613	0.1031
Pauly	K, L_∞, temperature	0.571	0.0394
Gunderson	GSI	0.815	0.3097
Zhang & Megrey	t_0, β, K, maximum age	0.677	0.1174

inverse variance weighted mean

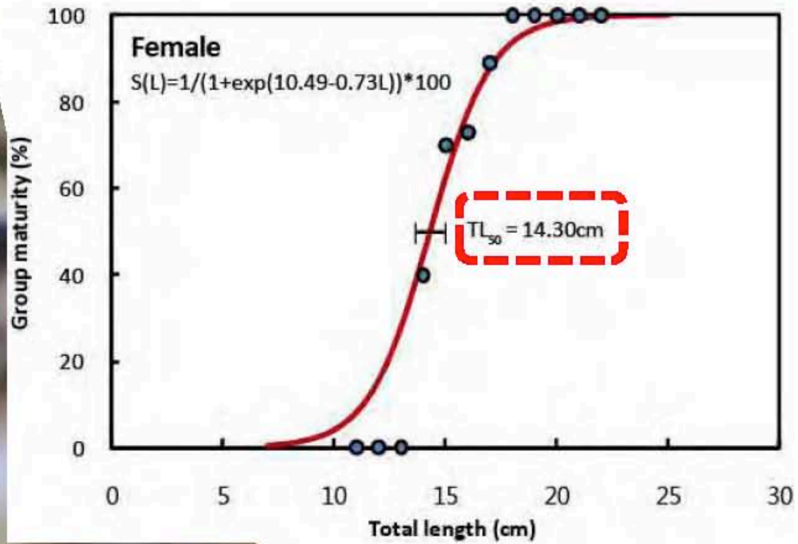
0.467/year
(95%CI 0.336~0.597/yr)

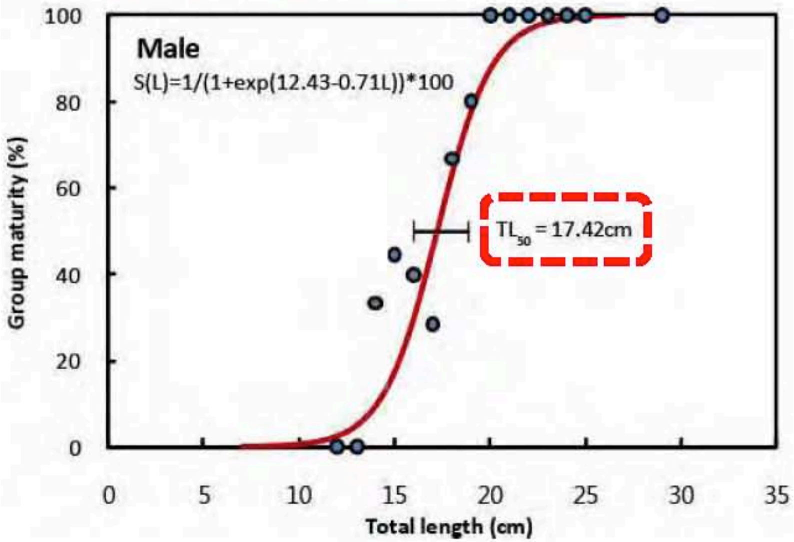
Gonadosomatic Index (GSI)

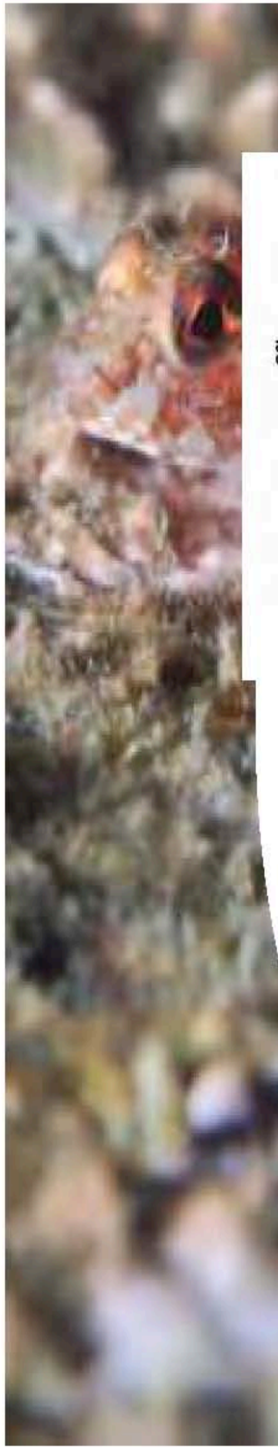




Group maturity



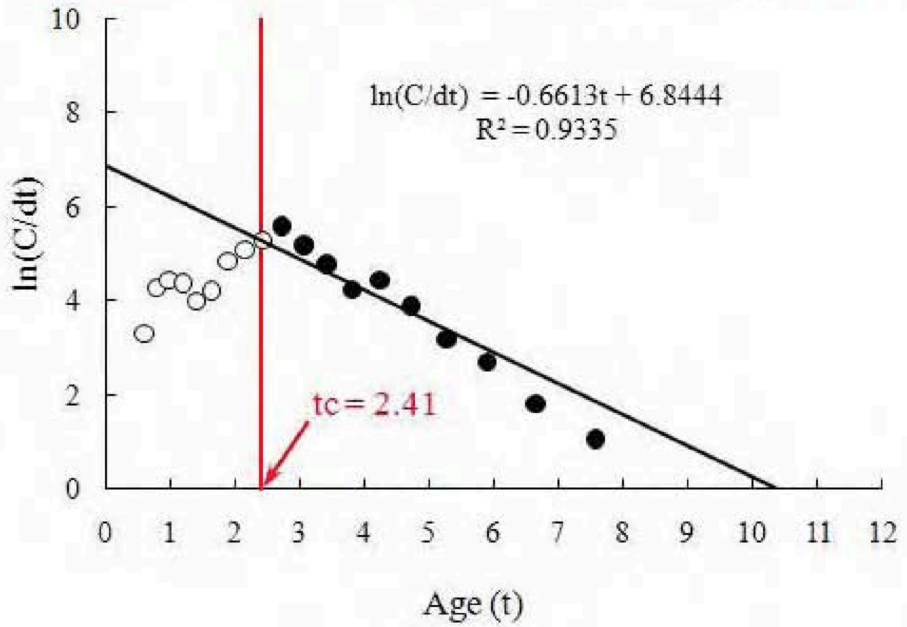


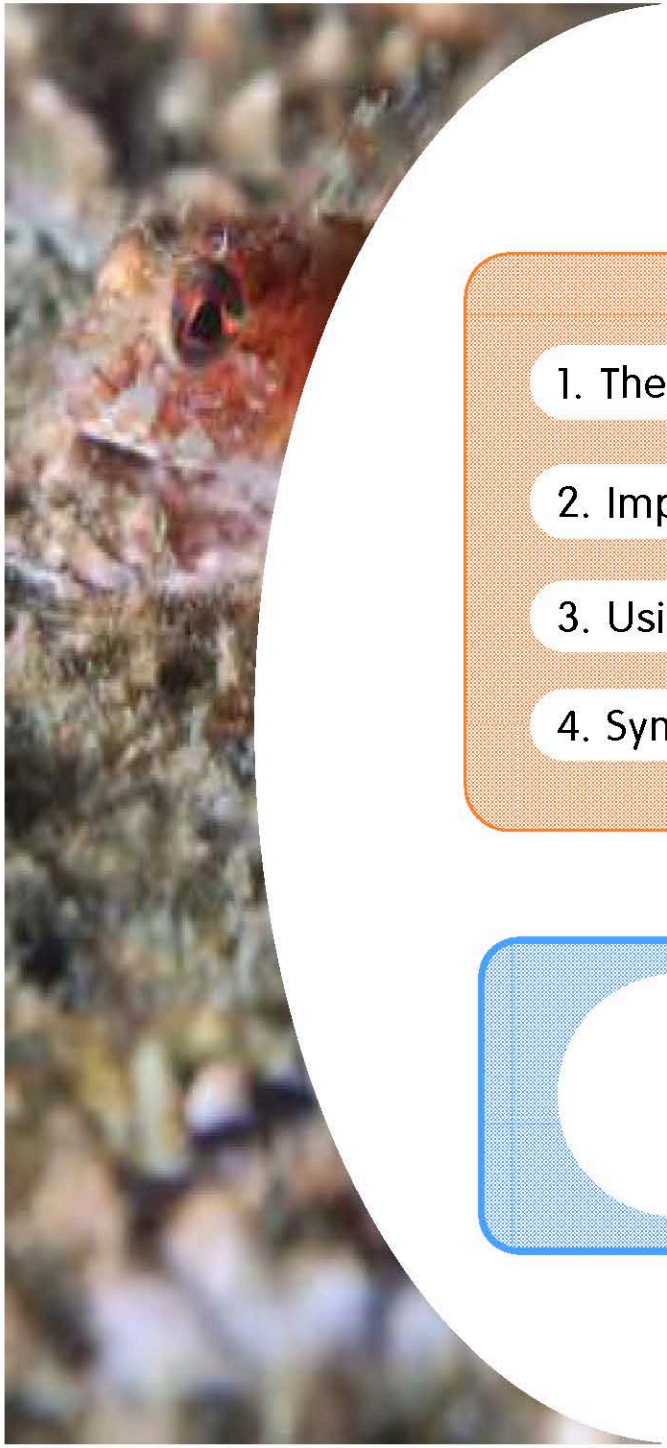


Survival rate (S) and instantaneous coefficient of total mortality (Z)

Method	S	Var(S)	Z
Chapman and Robson	0.334/year	0.0005	1.096/year

Age at first capture (t_c)





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