Estimation of a temperature-dependent Gompertz-Laird growth equation of chub mackerel (*Scomber japonicus*) larvae

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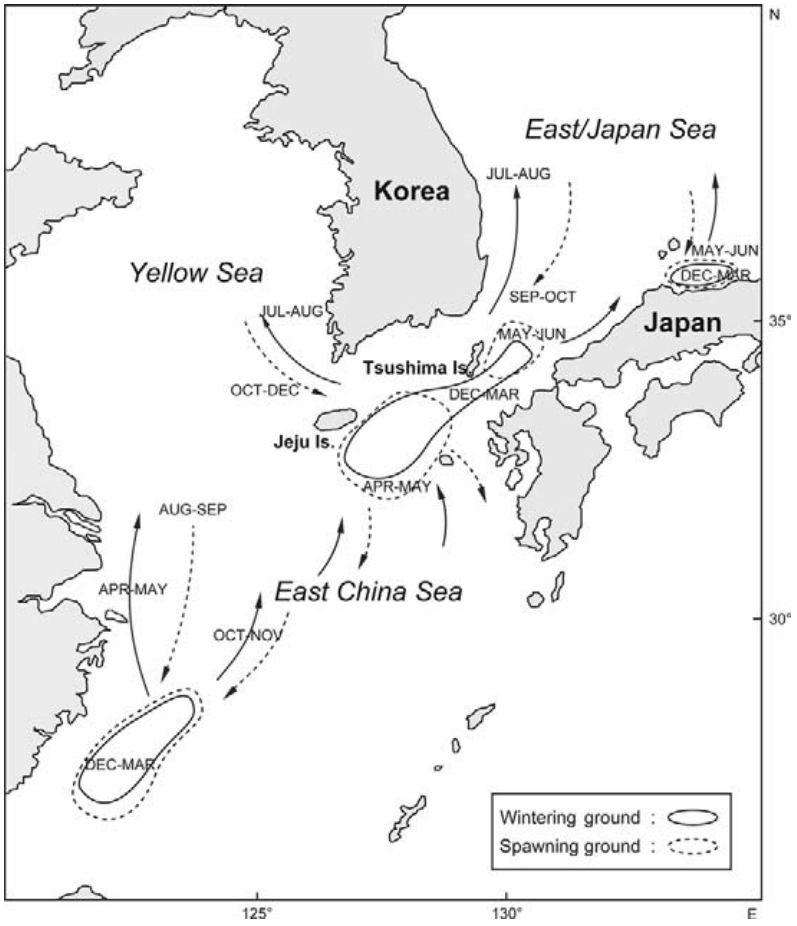
Introduction

- Chub mackerel (*Scomber japonicus*)
  - Distribution: subtropical and temperate coastal waters
  - Habitat depths: 0-200 m
  - Habitat temperatures: 7-25℃

Introduction

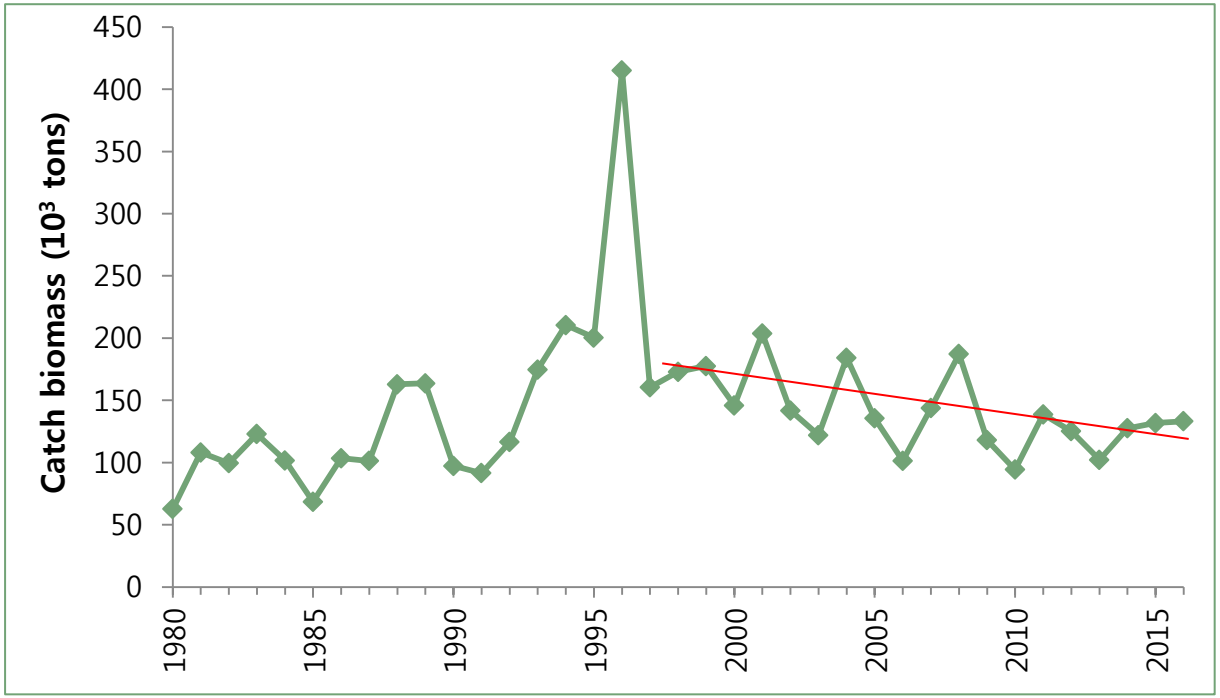
- Chub mackerel in the Korean waters spawn from March to May in the East China Sea and from May to June in the eastern waters off Jeju and the Korea strait.

- Spawning temperatures: 15-22℃



Commercial exploitations

- Chub mackerel is an economically important fish species in Korea.
- The annual catch biomass of chub mackerel has steadily decreased since the late 1990s in Korea.



The catch biomass of chub mackerel in Korea

Effect of water temperature on larvae

- During the early life stages, fish are vulnerable to change in the physical environment because their limited swimming ability for moving to a favorable habitat for survival.

- Temperature variability during spawning season influence the growth, survival and recruitment of eggs and larvae.

Problems

- There were studies on the growth equation of the chub mackerel larvae, but they did not consider varying water temperature which is critical in their early growth.

- The experimental data of the daily growth of chub mackerel at different water temperature conditions were provided by Hunter and Kimbrell (1980), but the temperature-dependent growth equation has not yet been derived.

Objective

- Derive the temperature-dependent growth equation of chub mackerel larvae from the data of Hunter and Kimbrell (1980).

Experimental data (Hunter and Kimbrell, 1980)

- Growth experiment for seven groups of different water temperature conditions of chub mackerel larvae (unit: mm)

Age (days)	22.1° C[1]			20.4° C			19.6° C			19.5° C			19.2° C			18.9° C			16.8° C		
	n	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	$\bar{x}$	SD
1										10	3.1	0.24							31	3.5	0.12
2	14	3.3	0.21	16	3.8	0.06	16	3.7	0.10	15	3.9	0.09	15	3.8	0.06						
3	14	3.5	0.30																		
4	10	3.6	0.22	18	3.8	0.26	33	4.2	0.23	10	4.0	0.17	15	4.0	0.20	10	3.7	0.20			
5																					
6	10	3.9	0.21	15	4.2	0.41	15	4.8	0.44	13	4.2	0.14	15	4.4	0.37	10	4.1	0.39	15	4.3	0.42
7										27	4.5	0.40									
8	12	4.5	0.55	15	5.7	0.77	15	6.0	0.39	25	4.7	0.56	15	5.0	0.40				15	5.1	0.43
9													5	5.9	0.13						
10	12	6.0	1.13	15	6.3	0.91	15	6.6	0.70	15	4.8	0.43	19	5.6	0.77	11	5.2	0.45			
11																			15	6.5	0.70
12	22	8.4	1.88	16	8.2	1.31	15	6.5	0.75	11	5.9	1.08	25	6.4	0.68	12	6.1	0.60	15	7.0	0.50
13																					
14	10	8.9	1.46	10	11.5	1.54	15	8.4	1.12	30	6.4	1.09	15	6.6	0.80				17	7.7	1.40
15																			11	8.1	1.08
16	10	14.9	1.45	15	14.1	2.01	15	8.9	1.76	16	8.5	2.21	15	7.1	0.81	13	7.6	1.50			
17										10	10.0	2.71				12	9.0	1.33	15	10.3	2.11
18				15	17.8	1.70	15	10.3	2.48				15	10.3	3.21	13	9.4	1.61	17	10.8	2.84
19	15	24.1	5.81																		
20							15	12.5	3.18	17	17.7	4.21	15	11.7	2.88				9	11.5	2.81
22							15	17.5	4.51				15	14.6	4.62						
23																15	13.7	1.26			
24							24	20.4	5.10				16	18.5	5.38	10	19.8	2.36			
25																			17	17.1	5.07

Gompertz-Laird growth equation

- Temperature-dependent growth equation for larvae (Nancy, 1983)

$$L_t = L_\infty \left[\frac{L_0}{L_\infty}\right]^{e^{-\alpha t}} \qquad \text{where} \qquad \alpha = ae^{bT}$$

  - L_t is the live length (mm) at age t days
  - L_∞ is mean asymtotic length (mm)
  - L_0 is length of hatched egg of chub mackerel (mm)
  - T is water temperature (℃)

- α is originally the coefficient of growth but we took α as a variable of the temperature-dependency.

Analysis

- We used a nonlinear least-squares method to estimate the parameters of the temperature-dependent Gompertz-Laird growth equation.

Results

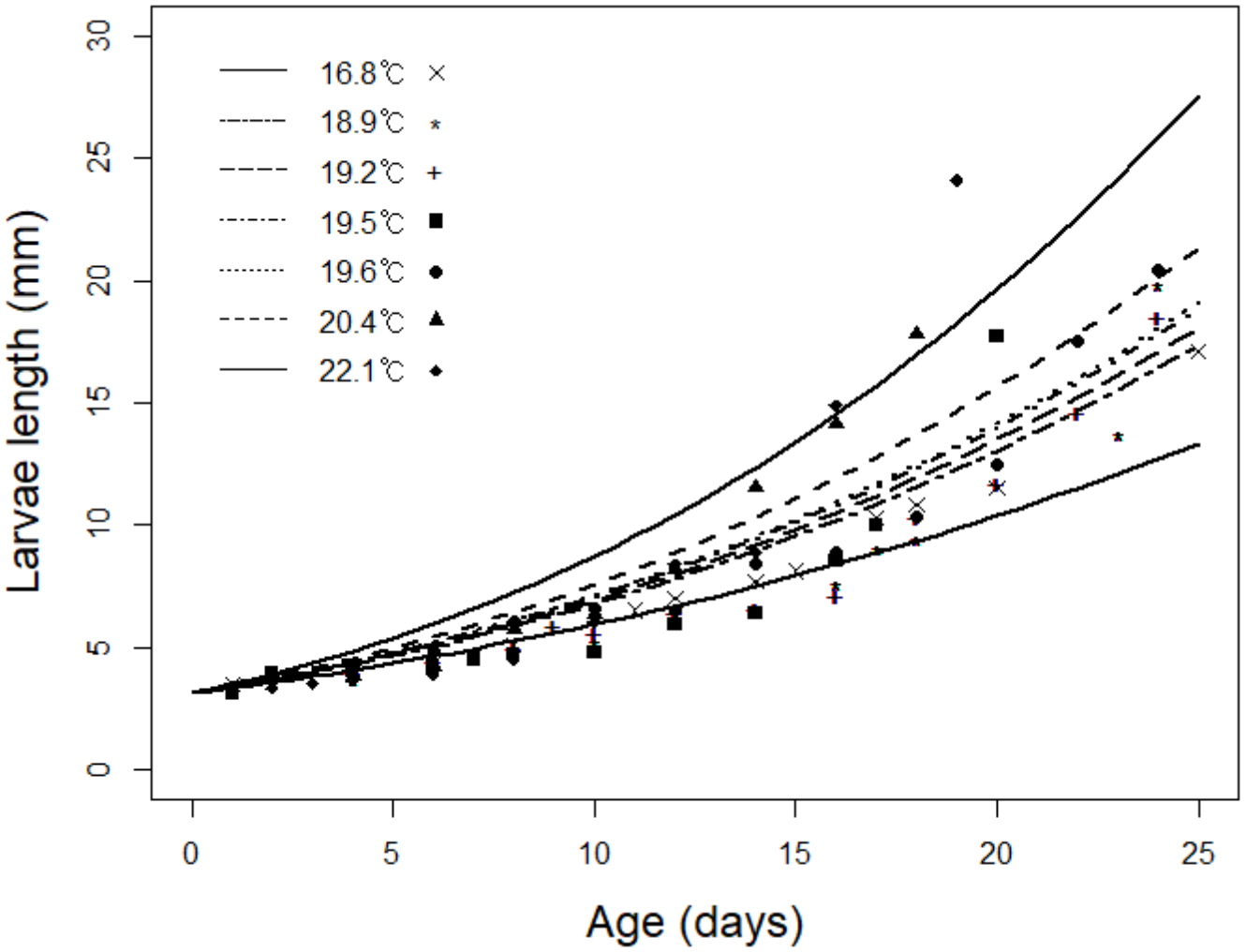
Growth equation for chub mackerel

- The temperature-dependent growth equation for chub mackerel larvae derived from the experimental data is

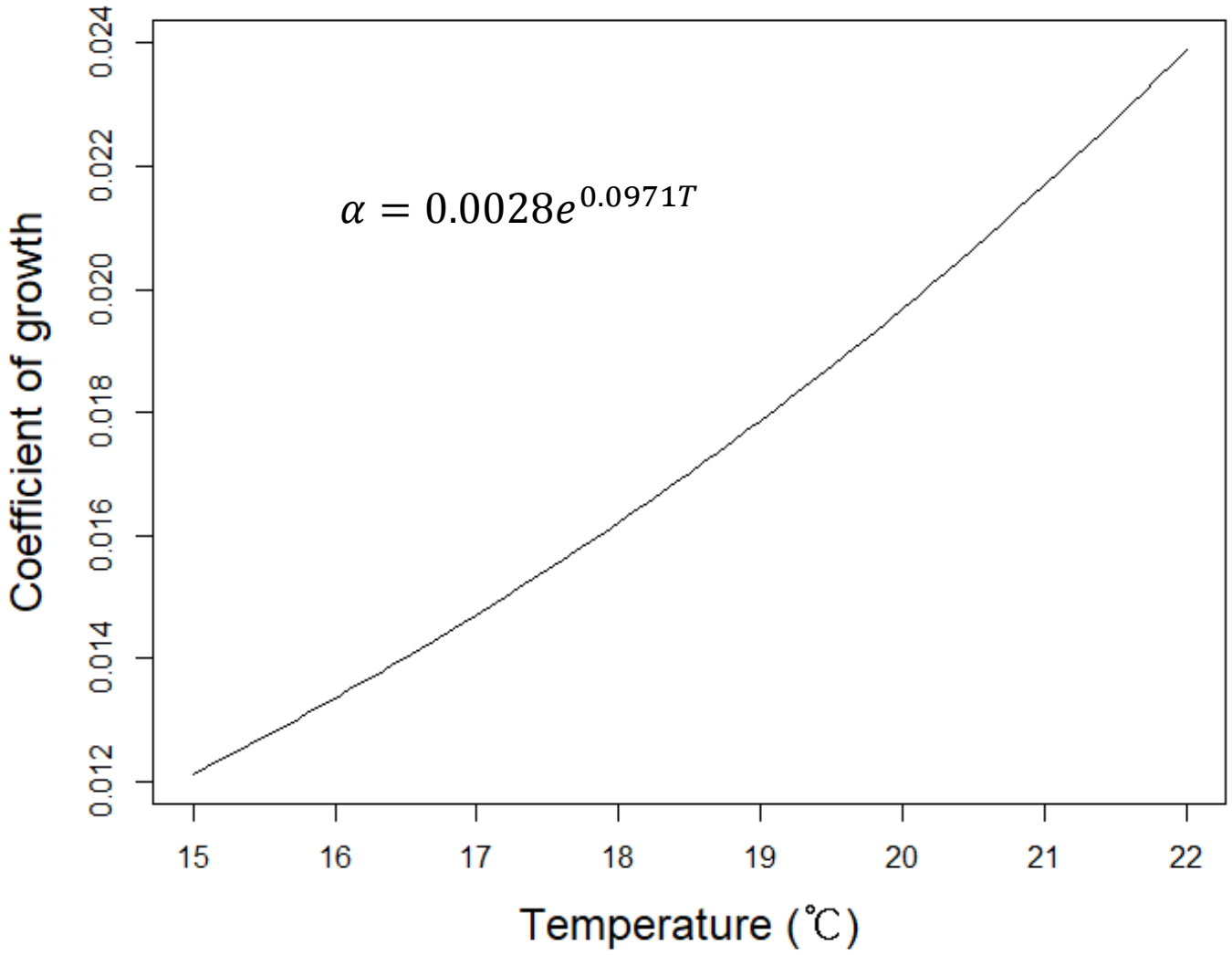
$$L_t = 385.126\left[\frac{3.1}{385.126}\right]^{e^{-\alpha t}} \quad \text{where} \quad \alpha = 0.0028e^{0.0971T}$$

  - L_t is the length (mm) at age t days
  - T is water temperature (℃)

Derived growth equation of chub mackerel larvae

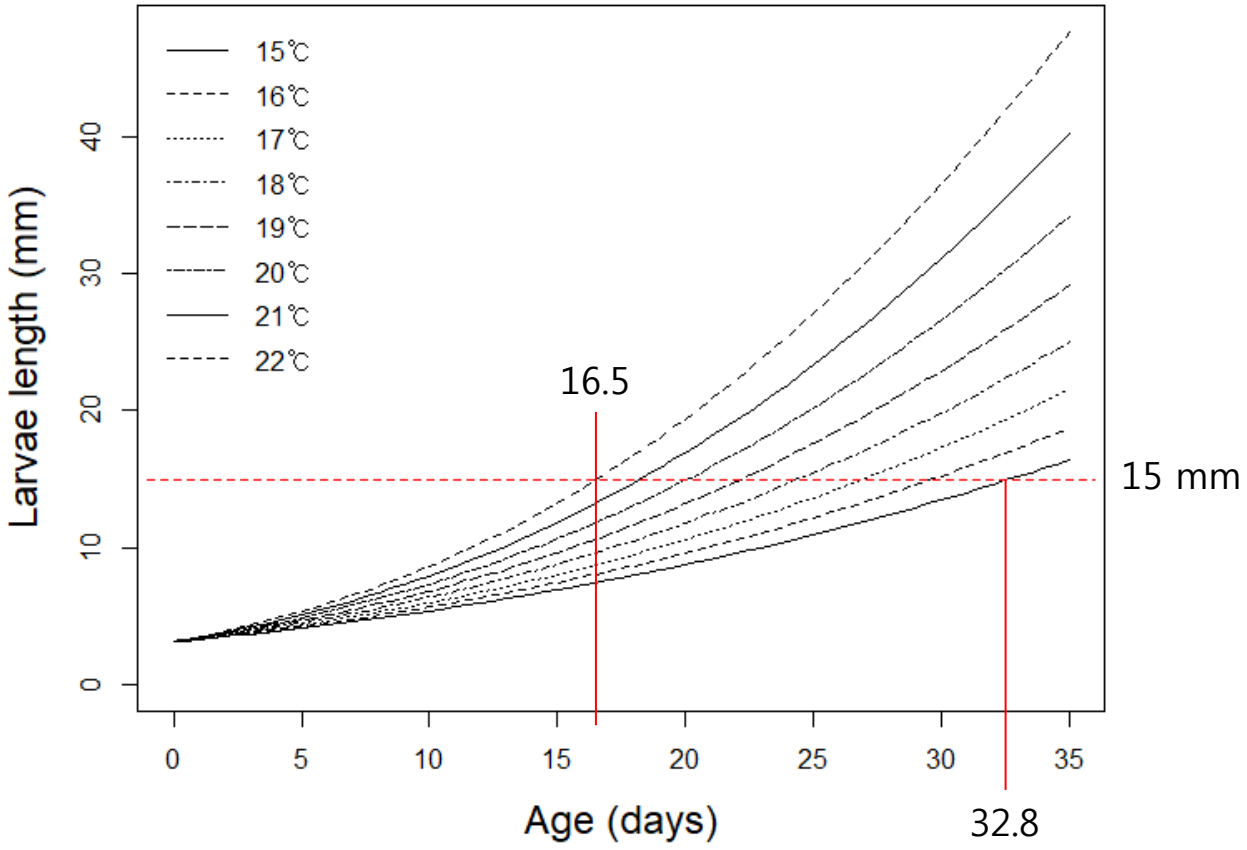


Variable of temperature dependency (α)



Metamorphosis time

- Chub mackerel larvae grew rapidly, completing metamorphosis at 15 mm (Hunter and Kimbrell, 1980).



Limitations and problem of the present study

- We assumed that the growth rate increases with temperature but there is an optimal temperature beyond which the growth rate does decrease. Thus, we need more experimental data for temperatures higher than 22℃.

- The data were from the eastern North Pacific not from the western North Pacific including the Korean waters.

Further studies

- Validation of the larval growth equation derived from the indoor experiments by comparison with field data.

- Derive temperature-dependent growth equation of chub mackerel collected in the Korean waters (western North Pacific), including temperature ranges higher than 22℃.

- Global comparisons of growth of chub mackerel populations. (e.g., the Korean waters, the Mediterranean, the Japanese waters, and etc)

Acknowledgements