Growth and maturation of Japanese anchovy in the Sea of Japan and the East China Sea; implementation for estimating catch at age

Yuko HIRAOKA, Haruhiko HINO, Shota KUNIMATSU, Soyoka MUKO, Hiroyuki KUROTA

Summary

This document describes biological information, such as growth and maturation, to implement for estimating catch at age for Japanese Anchovy (*Engraulis japonicus*) in the Sea of Japan and the East China Sea. The monthly GSI values showed two peaks in Spring and Autumn. Therefore, von Bertallanfy's growth functions were estimated "Spring cohort" and "Autumn cohort", respectively. Based on two seasonal growth curves, catch-at-age for this subpopulation was constructed.

Introduction

Japanese anchovy distributes widely around Japan including the Sea of Japan and the East China Sea (Iseki and Kiyomoto, 1997; Iversen et al. 1993; Ohshimo, 1996). This species is one of the important species for Japanese fisheries in the coastal area and mainly by caught middle-small-sized purse seine fishery. The fishery targets small size anchovy due to its high values for boiled and dried processing producers.

In Japan, the Tsushima Warm Current (TWC) stock of Japanese anchovy is assessed by VPA (virtual population analysis) method. The VPA requires accurate catch-at-age (CAA) based on biological characteristics. Therefore, this document introduces the biological characteristics and process for estimating the CAA of the Japanese anchovy TWC subpopulation.

Materials and Methods

Maturation

Body length (scaled length), weight (BW), and gonad weight (GW) were measured, and some of the gonads were preserved in 10% formaldehyde. The gonad somatic index (GSI) was calculated as follows,

GSI=GW X 100 / BW.

The preserved gonads were dehydrated and embedded in Paraffin. The embedded gonads were sectioned (about 8μm), and the sections were stained by Hematoxylin-eosin solutions. The stained sections were observed under the optical microscope.

The testes were categorized into six stages, 1) spermatogonial: SP, 2) early maturation: EM, 3) mid maturation: MM, 4) late maturation: LM, 5) functional maturation: FM and 6) post-spawn: PS. The ovaries were categorized into seven stages, 1) perinucleolus: PN, 2) yolk vesicle: YV, 3) primary yolk: PY, 4) secondary yolk: SY, 5) tertiary yolk: TY, 6) migratory nucleus: MN, and 7) maturation stage: MT.

Growth estimation

Because it was too difficult to read annual rings on the scale and otolith, monthly length distributions were used for the estimation of growth curve. Length data of Japanese anchovy in the Sea of Japan and the Ease China Sea were archived in the database (FRESCO system) in Japan. A total of 349,812 individuals were used for calculating the growth function and the length-weight relationship. In the present study, length distributions were applied to the multivariate normal distribution to divide the age. The von Bertallanfy growth function was as follows.

$$\mathrm{BL}_t = \mathrm{BL}_\infty \{1 - exp[K(t - t_0)]\}$$

, where BLt is the body length (mm) at age t, BL_∞ is the asymptotic BL, K is the growth coefficient, and t_0 is the hypothetical age at an BL of zero. Least squares are used for estimating the model parameters.

Results

Maturation

Based on the results of the monthly GSI value, the mean GSI for females and males peaked in April, and the values were 5.1 and 6.0, respectively. The mean GSI value decreased and the mean values for females and males in August were 1.6 and 1.2, respectively. In November, the mean values increased again (Fig. 1).

In this document, the spawning capable stage was assumed to be LM and FM for males and MN and MT for females. The minimum body length at the spawning capable stage was about 100 mm and 90mm for males and females, respectively. The spawning-capable individuals were observed from March to December for both sexes.

Growth

Based on the results from maturation, two cohorts can be divided as “spring cohort” and “autumn cohort”. The mean monthly body length can be distinguished between two seasonal cohorts less than ca. 120 mm.BL; however, it becomes to be difficult over 120mm BL. Therefore, the length distribution of larger than 140 mm BL was pooled in two cohorts.

The estimated von Bertallanfy’s growth functions for two seasonal cohorts were as follows,

Spring cohort: $BL_t = 143.96\{1 - exp[-0.15(t + 0.44)]\}$

Autumn cohort: $BL_t = 158.59\{1 - exp[-0.09(t + 0.74)]\}$.

Growth coefficient (K) in spring cohort was larger than that in autumn cohort (Fig. 2).

Discussion

Growth and maturation

This document describes the basic biological characteristics of Japanese anchovy in the Sea of Japan and the East China Sea. The spawning periods of this species was reported from March to June in the southwestern Sea of Japan (Shimura et al. 2008). In the present study, the long spawning seasons from March to December and two peaks of GSI, indicating spawning in the winter of Japanese anchovy could be stopped and two main spawning periods (spring and autumn).

The results indicated the two seasonal growth functions for Japanese anchovy were required. Hayashi and Kondo (1957) reported the growth functions for spring and autumn cohorts of this species in Pacific area as follows.

Spring cohort: $BL_t = 148.2\{1 - 0.915exp[-0.142t]\}$

Autumn cohort: $BL_t = 152.3\{1 - 0.944exp[-0.0842t]\}$.

, where t is monthly age. The results between the previous (Hayashi and Kondo, 1957) and ours were almost the same. These facts indicate that the CAA should be constructed based on seasonal growth functions.

Age length key and catch at age estimation.

Based on the results of growth functions for seasonal cohorts, we established the age-length key for estimating the CAA. The monthly age-length key for Japanese anchovy is shown in Tables 1-3.

To estimate the CAA, the length measurement data was aggregated by three areas: East China Sea, Western Sea of Japan, and Eastern Sea of Japan. Each length distribution was converted to age composition according to the catch data as follows.

Because most of the catch data were reported in weight, to estimate age composition in weight, we established the length-weight conversion formula. The relationship between body length (BL; cm) and body weight (BW; g) (Fig. 3) was as follows.

$BW=0.0086BL^{3.08}$.

The calculated body weight for each 5mm body length bin was applied above the formula. The monthly CAA of Japanese anchovy was calculated as follows.

$$C_{t,i} = \left[\frac{n_i \times BW_i}{\sum_0^{150} n_i \times BW_i} \times CW \times ALK_{t,i}\right] / BW_i$$

where $C_{t,i}$, n_i, BW_i and $ALK_{t,i}$ mean catch number, number of individuals fish measured, body weight and age-length key at body length i mm at age t, respectively. The CW represents the monthly catch weight estimated by the monthly reports from prefectural official reports of catch.

References

Hayashi, S. and Kondo, K. (1957) Growth of the Japanese anchovy – IV. Age determination with the use of scales. Bull. Tokai Reg. Fish. Res. Lab., 17, 31-65.

Iseki, K. and Kiyomoto, Y. (1997) Distribution and settling of Japanese anchovy (*Engraulis japonicus*) eggs at the spawning ground off Changjiang River in the East China Sea. Fish. Oceanogr., 6, 205-210.

Iversen, S.A., Zhu, D., Johannessen, A. and Toresen, R. (1993) Stock size, distribution and biology of anchovy in the Yellow Sea and East China Sea. Fish. Res., 16, 147-163.

Ohshimo S. (1996) Acoustic estimation fo biomass and school character of the Japanese anchovy *Engraulis japonicus* in the East China Sea and the Yellow Sea. Fish. Sci., 62, 344-349.

Shimura, T., Yamamoto, J., Morimoto, H., Ohshimo, S., Shimoyama, S., Sakurai, Y. (2008) Maturation and spawning of the Japanese anchovy in the Sea of Japan off the Tottori coast during spring. Bull. Jpn. Soc. Fish. Oceanogr., 72, 101-106.

Table 1 Age-length-key for Age 0 Tsushima current stock of Japanese anchovy

BL (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 - 14	1	1	1	1	1	1	1	1	1	1	1	1
15 - 19	1	1	1	1	1	1	1	1	1	1	1	1
20 - 24	1	1	1	1	1	1	1	1	1	1	1	1
25 - 29	1	1	1	1	1	1	1	1	1	1	1	1
30 - 34	1	1	1	1	1	1	1	1	1	1	1	1
35 - 39	1	1	1	1	1	1	1	1	1	1	1	1
40 - 44	1	1	1	1	1	1	1	1	1	1	1	1
45 - 49	0.8	1	1	1	1	1	1	1	1	1	1	1
50 - 54	0.5	1	1	1	1	1	1	1	1	1	1	1
55 - 59	0.2	0.8	1	1	1	1	1	1	1	1	1	1
60 - 64	0	0.5	0.8	1	1	1	1	1	1	1	1	1
65 - 69	0	0.2	0.5	0.8	1	1	1	1	1	1	1	1
70 - 74	0	0	0.2	0.5	1	1	1	1	1	1	1	1
75 - 79	0	0	0	0.2	0.8	1	1	1	1	1	1	1
80 - 84	0	0	0	0	0.5	0.8	1	1	1	1	1	1
85 - 89	0	0	0	0	0.2	0.5	0.8	1	1	1	1	1
90 - 94	0	0	0	0	0	0.2	0.5	0.8	1	1	1	1
95 - 99	0	0	0	0	0	0	0.2	0.5	0.8	1	1	1
100 - 104	0	0	0	0	0	0	0	0.2	0.5	0.8	0.8	1
105 - 109	0	0	0	0	0	0	0	0	0.2	0.5	0.5	0.8
110 - 114	0	0	0	0	0	0	0	0	0	0.2	0.2	0.5
115 - 119	0	0	0	0	0	0	0	0	0	0	0	0.2
120 - 124	0	0	0	0	0	0	0	0	0	0	0	0
125 - 129	0	0	0	0	0	0	0	0	0	0	0	0
130 - 134	0	0	0	0	0	0	0	0	0	0	0	0
135 - 139	0	0	0	0	0	0	0	0	0	0	0	0
140 - 144	0	0	0	0	0	0	0	0	0	0	0	0
145 - 149	0	0	0	0	0	0	0	0	0	0	0	0
150 - 154	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 Age-length-key for Age 1 Tsushima current stock of Japanese anchovy

BL (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 - 14	0	0	0	0	0	0	0	0	0	0	0	0
15 - 19	0	0	0	0	0	0	0	0	0	0	0	0
20 - 24	0	0	0	0	0	0	0	0	0	0	0	0
25 - 29	0	0	0	0	0	0	0	0	0	0	0	0
30 - 34	0	0	0	0	0	0	0	0	0	0	0	0
35 - 39	0	0	0	0	0	0	0	0	0	0	0	0
40 - 44	0	0	0	0	0	0	0	0	0	0	0	0
45 - 49	0.2	0	0	0	0	0	0	0	0	0	0	0
50 - 54	0.5	0	0	0	0	0	0	0	0	0	0	0
55 - 59	0.8	0.2	0	0	0	0	0	0	0	0	0	0
60 - 64	1	0.5	0.2	0	0	0	0	0	0	0	0	0
65 - 69	1	0.8	0.5	0.2	0	0	0	0	0	0	0	0
70 - 74	1	1	0.8	0.5	0	0	0	0	0	0	0	0
75 - 79	1	1	1	0.8	0.2	0	0	0	0	0	0	0
80 - 84	1	1	1	1	0.5	0.2	0	0	0	0	0	0
85 - 89	1	1	1	1	0.8	0.5	0.2	0	0	0	0	0
90 - 94	1	1	1	1	1	0.8	0.5	0.2	0	0	0	0
95 - 99	1	1	1	1	1	1	0.8	0.5	0.2	0	0	0
100 - 104	1	1	1	1	1	1	1	0.8	0.5	0.2	0.2	0
105 - 109	1	1	1	1	1	1	1	1	0.8	0.5	0.5	0.2
110 - 114	1	1	1	1	1	1	1	1	1	0.8	0.8	0.5
115 - 119	1	1	1	1	1	1	1	1	1	1	1	0.8
120 - 124	0.8	1	1	1	1	1	1	1	1	1	1	1
125 - 129	0.5	0.8	1	1	1	1	1	1	1	1	1	1
130 - 134	0.2	0.5	0.8	1	1	1	1	1	1	1	1	1
135 - 139	0	0.2	0.5	0.8	0.8	0.8	1	1	1	1	1	1
140 - 144	0	0	0.2	0.5	0.5	0.5	1	1	1	1	1	1
145 - 149	0	0	0	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	1
150 - 154	0	0	0	0	0	0	0	0	0	0	0	0

Table 3 Age-length-key for Age 2 Tsushima current stock of Japanese anchovy

BL (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 - 14	0	0	0	0	0	0	0	0	0	0	0	0
15 - 19	0	0	0	0	0	0	0	0	0	0	0	0
20 - 24	0	0	0	0	0	0	0	0	0	0	0	0
25 - 29	0	0	0	0	0	0	0	0	0	0	0	0
30 - 34	0	0	0	0	0	0	0	0	0	0	0	0
35 - 39	0	0	0	0	0	0	0	0	0	0	0	0
40 - 44	0	0	0	0	0	0	0	0	0	0	0	0
45 - 49	0	0	0	0	0	0	0	0	0	0	0	0
50 - 54	0	0	0	0	0	0	0	0	0	0	0	0
55 - 59	0	0	0	0	0	0	0	0	0	0	0	0
60 - 64	0	0	0	0	0	0	0	0	0	0	0	0
65 - 69	0	0	0	0	0	0	0	0	0	0	0	0
70 - 74	0	0	0	0	0	0	0	0	0	0	0	0
75 - 79	0	0	0	0	0	0	0	0	0	0	0	0
80 - 84	0	0	0	0	0	0	0	0	0	0	0	0
85 - 89	0	0	0	0	0	0	0	0	0	0	0	0
90 - 94	0	0	0	0	0	0	0	0	0	0	0	0
95 - 99	0	0	0	0	0	0	0	0	0	0	0	0
100 - 104	0	0	0	0	0	0	0	0	0	0	0	0
105 - 109	0	0	0	0	0	0	0	0	0	0	0	0
110 - 114	0	0	0	0	0	0	0	0	0	0	0	0
115 - 119	0	0	0	0	0	0	0	0	0	0	0	0
120 - 124	0.2	0	0	0	0	0	0	0	0	0	0	0
125 - 129	0.5	0.2	0	0	0	0	0	0	0	0	0	0
130 - 134	0.8	0.5	0.2	0	0	0	0	0	0	0	0	0
135 - 139	1	0.8	0.5	0.2	0.2	0.2	0	0	0	0	0	0
140 - 144	1	1	0.8	0.5	0.5	0.5	0	0	0	0	0	0
145 - 149	1	1	1	0.8	0.8	0.8	0.5	0.5	0.5	0.5	0.5	0
150 - 154	1	1	1	1	1	1	1	1	1	1	1	1

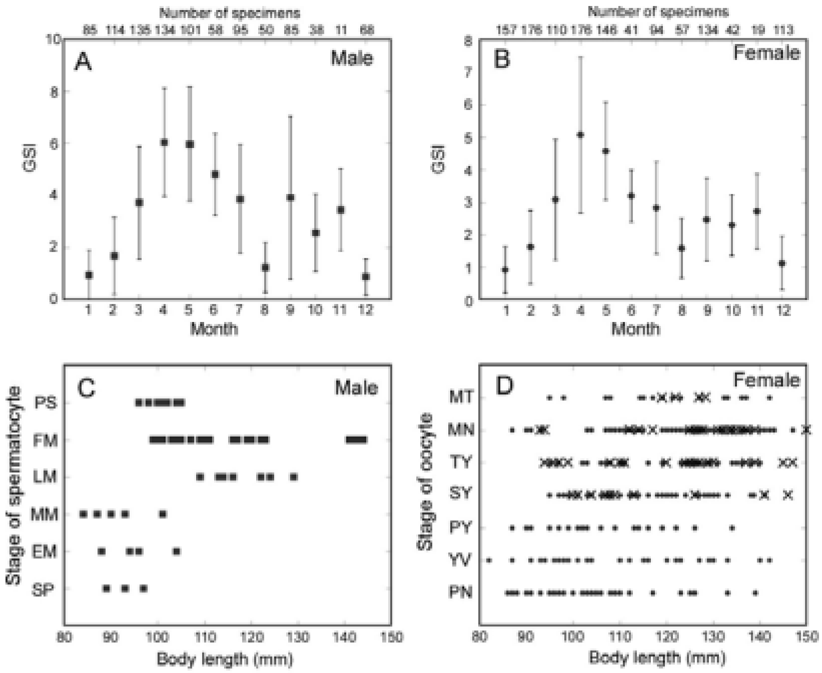

Fig. 1. Monthly changes in the gonad somatic index (GSI) of male (A) and female (B), and the relationship between body length and ovarian developmental stages of male (C) and female (D) Japanese anchovy in the coastal area off northern and western Kyushu.

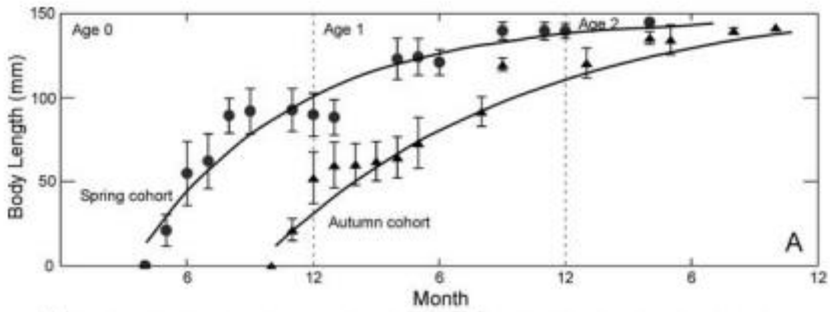

Fig. 2 Growth pattern of Japanese anchovy for spring cohort (circles) and autumn cohort (triangles).

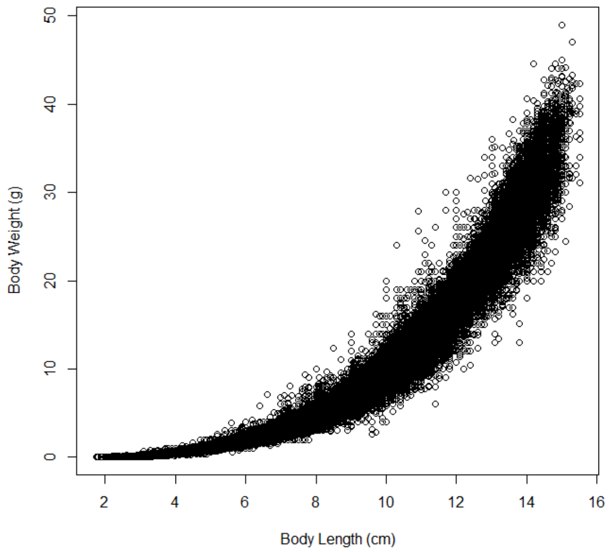

Fig. 3 Length-weight relationship for Japanese anchovy.