Changes in growth with fluctuation of chub mackerel abundance in the Pacific waters off central Japan from 1970 to 1997

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Introduction

Changes in growth as stock size fluctuates have been found in many fish populations. Size-at-age of Japanese sardine (*Sardinops melanostictus*) has varied remarkably with the stock fluctuations from the late 1970s to the early 1990s (Wada 1989, Hiyama 1989, Wada *et al.* 1995); these have been considered to be density-dependent change in fish size.

Chub mackerel (*Scomber japonicus*) are one of the most important fish populations in Japanese waters. Two stocks are recognized, the Tsushima Current stock and the Pacific stock. The Tsushima Current stock is distributed in the East China Sea and the Sea of Japan, and the Pacific stock occurs along the Pacific coast of Japan. The biomass of the Pacific stock is larger and more variable than that of the Tsushima Current stock. Most of the catch of the Pacific stock is from the purse seine fishery in the waters off central and northern Japan. The Pacific stock spawns from March to June around the Izu islands off central Japan. Juveniles of about 6 months of age recruit to purse seine and set net fisheries from August or September in the coastal area off northeastern Japan.

The landings of the Pacific stock increased from the 1960s, to a maximum of 1.5 million tons in 1978, and then declined to 23 thousand tons in 1990 (Fig. 42). Recently, good year-classes occurred in 1992 and 1996 (Fig. 42), but most of these cohorts were exploited before first maturation, and therefore spawning stock did not recover and total biomass stayed low. With the drastic stock level fluctuations, size-at-age and maturity-at-age of the Pacific stock changed (Iizuka 1974, Chiba 1995). This study describes long-term changes in stock size and size-at-age of the Pacific chub mackerel stock and investigates the relationship between stock size and year-class abundance.

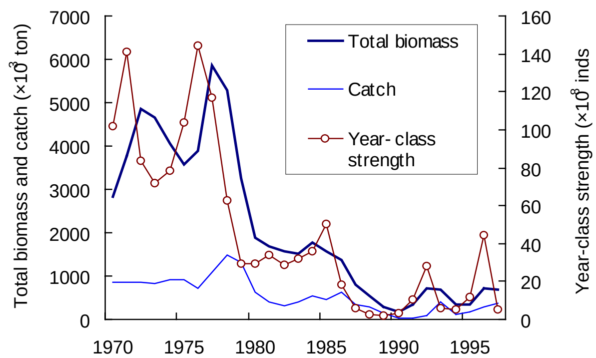

Fig. 42 Total biomass, catch and year-class strength of the Pacific stock of chub mackerel (*Scomber japonicus*). Total biomass and year-class strength were estimated by VPA.

Materials and methods

Data. Length composition and age-length keys for 1970-1997 were used to calculate mean length-at-age for each year. The length composition data of purse seine catches from September to December were used because total catches in these months were usually largest during the year. Scales were used for age determination. Length compositions of fish samples were applied to length compositions of total catches. Length compositions of total catches were divided into age groups from 0 (6 months old) to 5 years based on age-length keys. Mean fork length was calculated from length compositions of total catches for each age. Total biomass was represented by sum of VPA (virtual populations analysis) estimated biomass of chub mackerel from age 0 to age 6+. Year-class strength was represented by abundance in number at age 0.

Statistical analysis. ANOVA was used to determine if the mean length-at-ages 0 to 5 were significantly different among years. Regression analysis was applied to examine the relationships between mean length-at-age and total biomass and year-class strength.

Result and discussion

Mean length-at-age fluctuated greatly, especially at age 0 and 1, ranging from 164-259 mm at age 0 and 242-316 mm at age 1. While the biomass of chub mackerel decreased from the 1970s to the 1990s, mean lengths-at-age increased. Figure 43 shows the relationship between the total biomass and the mean length at age 0 among years. Regression analyses indicated significant negative relationships between the total biomass and the mean fork length-at-age of a year (Table 8, p<0.05). The biomass variations explained 19-36% of the inter-annual fluctuation of length-at-age.

Figure 44 demonstrates the relationship between the year-class strength and the mean length-at-age 0. Mean length-at-age of each year-class was negatively correlated with the year-class strength (Table 9, p<0.01). The variability in year-class strength explained 25-63% of the fluctuation of length-at-age.

The deviations of the mean fork length of a year-class from the mean of the 28-year time series (1970 to 1997) were calculated for several ages. Figure 45 shows the relationships between deviation at age 0 versus deviation at age 1 and the deviation at age 0 versus deviation at age 4. Regression analysis suggested significantly positive relationships between deviations at age 0 and ages 1 to 5, and between the deviations at age 1 and ages 2 to 5 (Table 10), indicating that the trend of length-at-age 0 is consistent through the life time (until 5 years old).

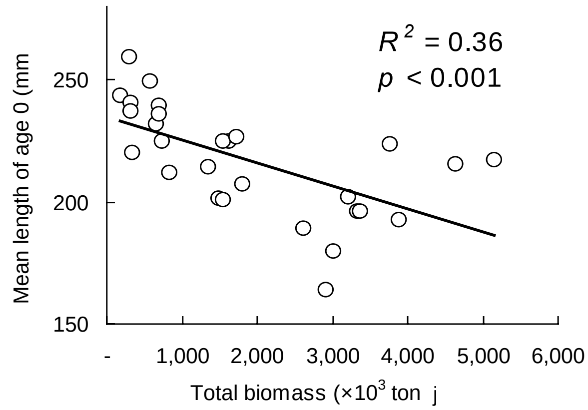

Fig. 43 Relationship between the total biomass and the length at age 0 of *Scomber japonicus*.

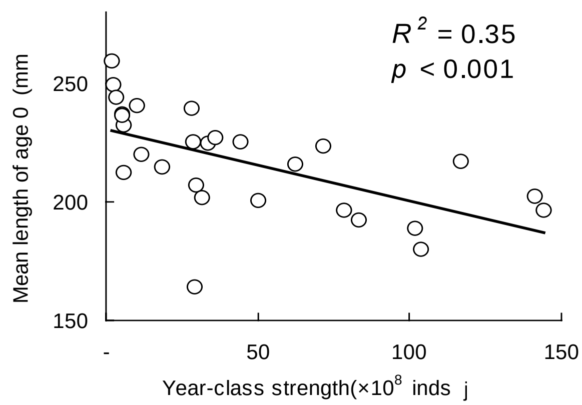

Fig. 44 Relationship between the year-class strength and the length-at-age 0 of *Scomber japonicus*.

Table 8 Statistics from regression of mean length-at-age of chub mackerel *vs*. biomass.

age	df	R	R^2	p
0	27	-0.60	0.36	0.001
1	27	-0.48	0.23	0.010
2	27	-0.53	0.28	0.004
3	27	-0.44	0.19	0.019
4	26	-0.47	0.22	0.013
5	26	-0.45	0.20	0.018

Table 9 Statistics from regression of mean length-at-age of each year-class *vs*. recruitment.

age	df	R	R^2	p
0	27	-0.59	0.35	0.001
1	27	-0.47	0.25	0.007
2	26	-0.60	0.34	0.001
3	25	-0.67	0.46	0.000
4	24	-0.80	0.63	0.000
5	23	-0.67	0.48	0.000

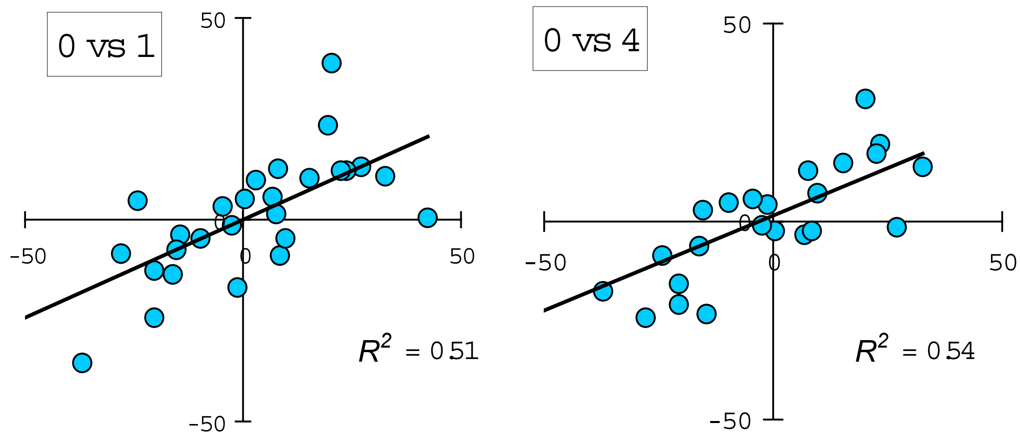

Fig. 45 Relationships between the annual mean length deviation at age 0 and age 1 (left), and between the annual mean length deviation at age 0 and age 4 (right).

Table 10 Statistics from regressions of annual mean length deviations at age 0 versus age 1 to 5 and deviations at age 1 versus age 2 to 5.

age		R	R^2	p
0	1	0.71	0.52	0.001
	2	0.54	030	0.003
	3	0.54	0.29	0.005
	4	0.73	0.54	0.000
	5	0.53	0.28	0.009
1	2	0.67	0.44	0.000
	3	0.54	0.29	0.005
	4	0.71	0.50	0.000
	5	0.54	0.29	0.007

Our data confirmed that the trend in length of a year-class was determined during the first summer of life and maintained throughout the life span. These results are in agreement with Iizuka (1974), who reported on the growth of 1963-1973 year-classes of the Pacific stock of chub mackerel and found that the trend of growth at age 0 was maintained at least until age 2.

In this study, we investigated the effect of mackerel biomass and/or year-class strength on the mean length-at-age. Year-class strength significantly affected size-at-age of chub mackerel, but it only explained 25-63% of the fluctuations in the mean length-at-age. Other factors such as abiotic and/or biotic environment, sardine and spotted mackerel stocks may also influence the growth of chub mackerel.

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