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Age and Growth of Marbled Sole (*Pleuronectes yokohamae*) in the Coastal Waters of Western Aomori Prefecture, Japan

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Abstract

The age and growth of marbled sole (*Pleuronectes yokohamae*) in the coastal waters of western Aomori Prefecture were examined and compared with those of the nearest population in Kikonai Bay, which is situated at southwestern Hokkaido. Although the mean back-calculated total lengths at age of these two populations were similar in both sexes, the relative abundances of females older than 4 years and males older than 3 years in western Aomori were very low, suggesting that this population is exposed to high fishing pressure.

Key words: Age, Growth, marbled sole, Aomori Prefecture

Introduction

Marbled sole (*Pleuronectes yokohamae*) is one of the dominant flatfishes in the coastal waters of western Aomori Prefecture and supports a commercial fishery. During 1975-80, this fishery yielded up to 236 metric tons annually, but by 1989, total catches declined to 67 metric tons (Anon., 1991a).

The change of life history traits is observed in fish populations when environmental conditions change or in populations exposed to fishing pressure. Therefore, knowledge of the age and growth of marbled sole may provide the crucial information needed for proper management. Although there is much literature on the age and growth of this species (Suzuki, 1967; Masaki et al., 1986; Solomon et al., 1987; Tanda et al., 1992; Shafieipour et al., 1999), no information is available for populations in the coastal waters of western Aomori Prefecture. To contribute to the fish resource management, this paper estimates the age and growth of marbled sole in this area for samples taken by the commercial fishery during 1989-91. In addition, results are compared with data collected from the nearest population in Kikonai Bay, which is situated at southwestern Hokkaido, to evaluate resource level from the information of growth patterns.

Materials and Methods

A commercial fishery for marbled sole occurs in the shelf region (less than 100

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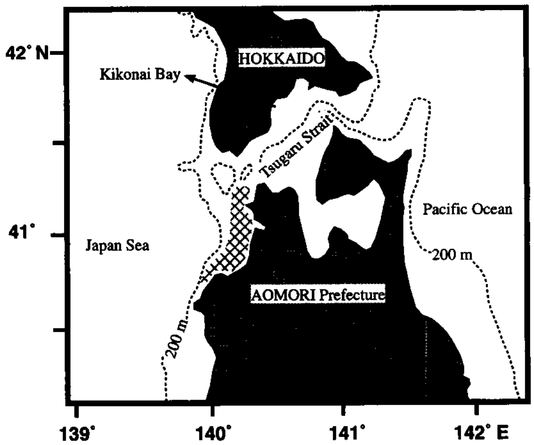

Fig. 1. Sampling area (meshed portion) in the coastal waters of western Aomori Prefecture. Broken line indicates 200 m isobath.

m depth) of western Aomori Prefecture (from 40°40′ to 41°20′N in latitude and from 139°50′ to 140°20′E in longitude; Fig. 1). A total of 769 specimens were collected with commercial fishing gear (bottom trawl net or set net) between November 1989 and April 1991. For each sample, the total length was measured to the nearest mm, and the sex was determined by visual examination of the gonads. Sagittal otoliths were removed, cleaned and stored dry.

The ocular side of the otolith pair was removed, polished to reveal the otolith's focus and rings, and viewed using a binocular microscope with reflected light and a dark field. The annulus was defined as the translucent zone. The distance from the focus to the outer edge of the translucent zone of each growth ring and the otolith radius were measured along the longest axis through the focus. The regression method of back-calculation was used. Takahashi et al. (1995) described the method of age estimation in detail. The percentage of individuals with a translucent zone at the otolith edge was calculated for each month (all study years pooled) to determine if otolith annuli form annually. The von Bertalanffy growth curve was fit to the observed age-length data using a nonlinear regression procedure (Microsoft Exel solver routine). The equation is:

$$L_t = L_{\mathrm{inf}} \, [1 - \exp\{-K(t - t_0)\}]$$

where L_t is the length at age t (in years), L_{inf} is the asymptotic length, K is the coefficient of growth, and t_0 is the theoretical age at zero length.

Results

The percentage of individuals with a translucent zone at the otolith edge changed periodically (Fig. 2). The maximum occurred during July-November, and the minimum occurred in May. When the percentages of individuals with a translucent zone were plotted separately for ring groups, a similar pattern was seen (Fig. 3). This analysis confirmed that one annulus formed per year.

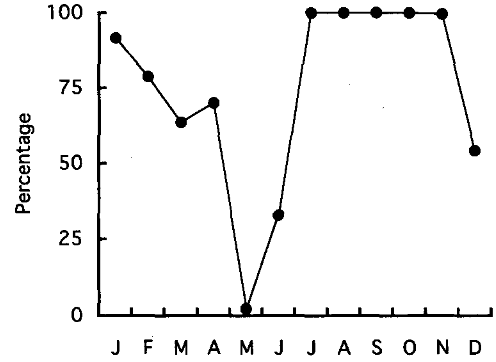

Fig. 2. Percentage occurrences of otolith with translucent edge for marbled sole collected with bottom trawl net or set net between November 1989 and April 1991. All age class data were combined.

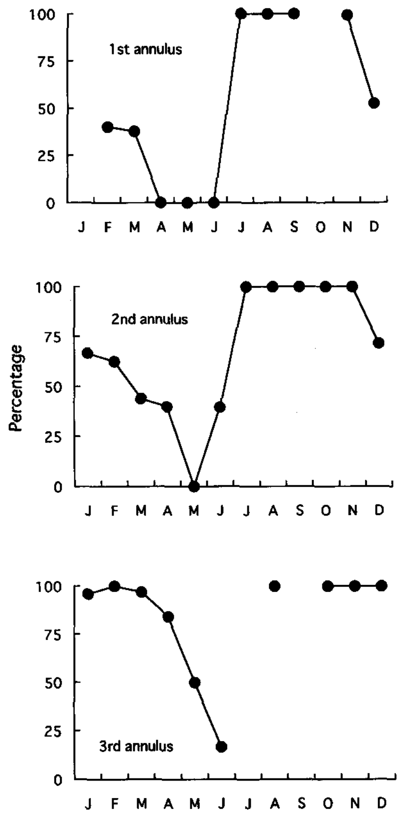

Fig. 3. Percentage occurrences of otolith with translucent edge for marbled sole at the first, second, and third annulus. Samples were collected with bottom trawl net or set net between November 1989 and April 1991.

Table 1. Mean back-calculated total lengths (mm) for male and female marbled sole at the time of each annulus formation. Length data in Kikonai Bay are from Shafieipour et al. (1999).

Estimated age	western Aomori		Kikonai Bay	
	Female	Male	Female	Male
1	108.7	112.3	105.6	107.4
2	205.6	198.1	197.4	189.6
3	262.9	251.9	263.8	245.2
4	306.6	289.5	311.9	282.9

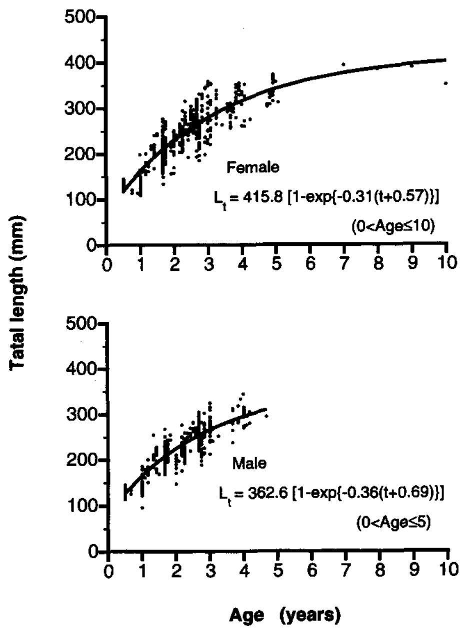

Fig. 4. von Bertalanffy growth curves for female and male marbled sole collected with bottom trawl net or set net between November 1989 and April 1991. Each dot shows observed total length at age.

The mean back-calculated total lengths at age of the populations in western Aomori area and Kikonai Bay were similar in both sexes (Table 1). All observed lengths at age were used when fitting the von Bertalanffy growth curves (Fig. 4). The oldest marbled sole examined were a 350-mm female estimated to be 10 years old and a 294-mm male estimated to be 4 years old. Relative abundances of females older than 4 years and males older than 3 years were very low. Although the growth coefficients did not differ between the sexes, females attained a greater asymptotic length than males.

Discussion

Age estimation techniques must be validated for all age classes in a population (Chilton and Beamish, 1982; Francis, 1995). Annual ring formation in marbled sole has been confirmed for age classes 1 and 2 (Masaki et al., 1986), but not for older classes. The present study validated annulus formation in age class 3.

The mean back-calculated total lengths at age of the populations in western Aomori area and Kikonai Bay were similar for each age class up to age 4 (Table 1). Although the growth rates of these two populations are relatively high compared with those of populations in the Inland Sea of Japan, the relative abundance of older fish was lower in western Aomori than in Kikonai Bay, as reported by Shafieipour et al. (1999). Possible causes of this difference include immigration and emigration from other populations, the influence of temperature or food availability, and high commercial exploitation in the coastal waters of western Aomori Prefecture.

Allozyme analysis and discrepancies in the spawning period have shown that the population in the coastal waters of western Aomori Prefecture is different from the adjacent three populations (Ishino and Sano, 1996). Therefore, immigration and emigration could not affect the growth pattern of this population.

In general, fish growth is mostly affected by ambient water temperature and food availability, and both factors are highly correlated (Wooton, 1990). If food is not limited, the growth rate increases up to the optimal temperature and decreases at higher temperatures. The maximum daily ration that marbled sole will consume (C_{max}) rapidly decreases below 5°C and above 25°C, and all fish die at 30°C (Takahashi et al., 1987). In brown trout (*Salmo trutta*), both C_{max} and growth decline abruptly at temperatures above 18°C (Elliott, 1976). The growth of marbled sole probably decreases at temperatures below 5°C and above 25°C. Bottom water temperatures in Kikonai Bay range about 6–20°C (Shafieipour et al., 1999), indicating water temperature does not limit the growth rate, because relatively high C_{max} values were reported for this temperature range. Temperature probably does not affect the growth rate either, in the population in the coastal waters of western Aomori Prefecture because this area, like Kikonai Bay, is influenced by the Tsushima Warm Water Current. Furthermore, younger (age 1 and 2) fish dominate the commercial landings in this area (Anon., 1991b), suggesting that fishing pressure is high. It is possible that this pressure improved the feeding environment of marbled sole.

In conclusion, the high growth rate of age 1-4 marbled sole and low relative abundance of older fish in the coastal waters of western Aomori Prefecture are due to high fishing pressure. In recent years, commercial landings of marbled sole have been in low (Ito et al., 1999). It seems likely that heavy exploitation and low resource levels of marbled sole will continue, if fishing effort, fish assemblage structure, or environmental condition does not change in this area. Growth parameters estimated in this study should be incorporated in the stock assessment model for proper management of marbled sole.

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