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THE SPAWNING AND SETTLEMENT SEASON OF *CHLOROPHTHALMUS ALBATROSSIS* ALONG THE PACIFIC COAST OF JAPAN

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ABSTRACT. – *Chlorophthalmus albatrossis* is a demersal fish, distributed along the continental shelf of the Pacific Ocean from Japan to Taiwan. This study aims to estimate the spawning and settlement season of *C. albatrossis* in Japan from otolith microstructure. Specimens were collected in offshore areas along the Southern, Central and Northern Pacific coast of Japan in 2002 and 2003 for this study. The right otolith of each individual was extracted, embedded in epoxy resin and polished along the sagittal axis. Otolith increments were then counted with a light microscope. The spawning season, based on the back-calculation from the number of daily increments, was estimated to be from January to May in the South, from May to July in the Central and from January to August in the Northern. Settlement seasons were estimated based on the number of otolith increments between the settlement check (formed when the individual shifts from a pelagic to a demersal life stage) and the otolith nucleus. The number of increments from nucleus to the settlement check in individuals gradually increased from the South to the North. Hence, settlement seasons were summer, autumn and winter in the Southern, Central and Northern areas, respectively. The estimated settlement season corresponded to the recruitment season in each area. This geographic difference of age at settlement in the sampling areas suggests that larval *C. albatrossis* is transported from the yet to be determined spawning ground, to Japan, by the Kuroshio Current.

KEY WORDS. – *Chlorophthalmus albatrossis*, Chlorophthalmidae, otolith, settlement, transportation.

INTRODUCTION

Chlorophthalmus albatrossis is a commercially important demersal fish and is distributed in offshore regions of the Pacific Ocean from Japan to Taiwan. The common name of this species is 'aome-eso' in Japanese and 'greeneyes' in English as it has very characteristic eyes that reflect light and appear bright green. *Chlorophthalmus albatrossis* used to be discarded as by-catch by offshore bottom trawl fisheries. However, its demand as a food fish has increased recently and this species has become an important commercial species for offshore bottom trawl fisheries along the Pacific coast of Japan.

Although catch amount of *C. albatrossis* is quite substantial (591 tons in Fukushima Prefecture, Japan in 2003), ecological knowledge of this species is very limited. There are no known records of mature adults (Hirakawa et al., 1990; Tominaga, 1997) and the spawning ground, spawning season, early life history, migration, maturation, etc., of this species are also virtually unknown.

Since Panella (1971) discovered daily increments deposit on the otolith of teleosts, the analysis of otolith microstructure has been applied to numerous species of fishes. The otolith microstructure reveals the chronological growth record, the water quality of the distribution area and key life history events (such as settlement from a pelagic to demersal life stage). These records are used for examining the birth date, growth, migration and other useful biological information.

This study aims to estimate the spawning and settlement season of *C. albatrossis* in Japan from otolith microstructure.

MATERIALS AND METHODS

Eighty one specimens used in this study were collected in Southern (Miyazaki Prefecture), Central (Shizuoka Prefecture) and Northern (Fukushima Prefecture) offshore areas along the Pacific coast of Japan in 2002 and 2003 (Fig. 1). Specimens were caught by commercial bottom trawl fishing boats and a research vessel "WAKATAKA-MARU". Standard length (SL, mm) and eye diameter (mm) were measured. The eye diameter was used to distinguish *Chlorophthalmus albatrossis* from *C. borealis*. As *C. albatrossis* is a hermaphrodite species (Yamauchi, 2003), the sex of each individual was not recorded. After measurements were taken, both sagittal otoliths were extracted and the right otolith was embedded in epoxy resin. Embedded otoliths were polished with emery papers #800 - #2000 and rapping film. The polished otoliths were etched in 1% hydrochloric acid solution for 10 seconds. The otolith daily increments were counted with a compound microscope at 400× – 600× magnification. The count of increments was repeated two times for each otolith and the average ring number was employed for analysis. The spawning date was calculated from the ring numbers and sampling date. The settlement date was estimated based on the number of ring increments from the nucleus to settlement check (SC) and sampling date. In order to validate daily deposition of increments, we sampled 15 individuals every month sequentially from the Northern area of the Pacific coast of Japan, from September 2002 to March 2003 to obtain the otolith increments from 103 individuals.

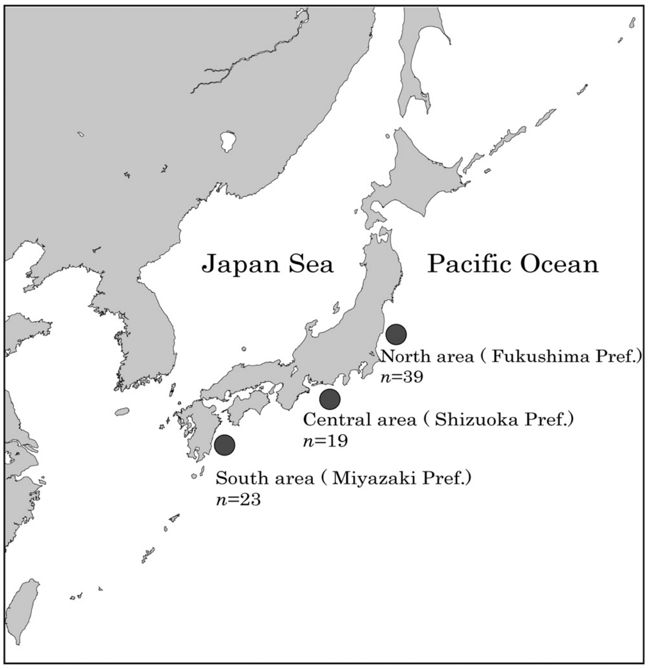

Fig. 1. Sampling area of *Chlorophthalmus albatrossis* along the Pacific Ocean coast of Japan.

RESULTS

***Validation of otolith daily increments.* –** Figure 2 indicates the relationship between the number of otolith increments and days after 27 September 2002. The average number (± SD) of increment was 446.7 (± 19.0) in September 2002, 473.0 (± 22.1) in October 2002 and 612.2 (± 22.1) in March 2003. The increment increased linearly with date. The relationship between increment number (I) and day (t) was calculated by the following linear equation:

$$I = 0.91t + 440.8;\ r^2 = 0.88$$

The slope of regression line did not significantly differ from 1.0 (t-test, $P > 0.05$). Thus, this fact indicates that otolith increments are formed once a day.

***Spawning season.* –** The spawning season was estimated through back-calculation from the number of daily increments. The spawning season was estimated to be from January to May in the South, from May to July in the Central and from January to August in the North (Fig. 3). Hence, the spawning season of *Chlorophthalmus albatrossis* sampled was from January to August.

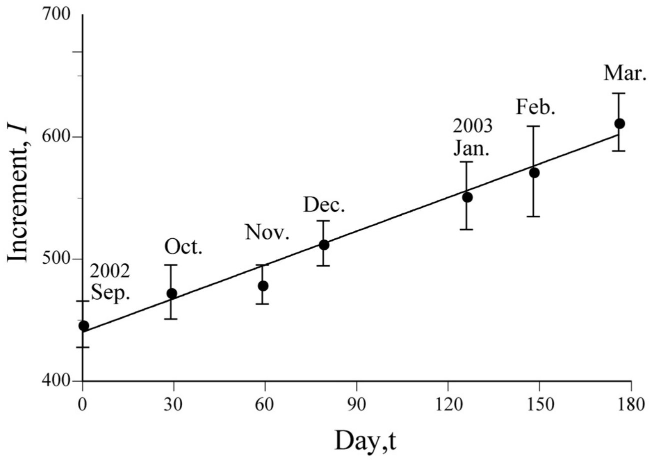

Fig. 2. Relationship between the number of otolith increments (I) and days (t) after 27 September 2002. Circle and vertical line show the average and standard deviation of otolith increments respectively.

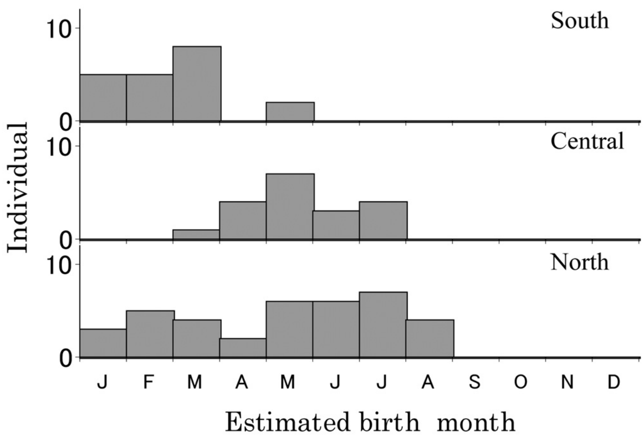

Fig. 3. Frequency distribution of spawning season estimated from otolith daily increments. Upper, middle and lower figure indicate Southern, Central and Northern offshore areas in Pacific Ocean of Japan, respectively.

Settlement season. **–** A distinct check mark was observed at a distance of 1.2 - 1.5 mm from the otolith nucleus (Fig. 4) in the opaque zone. The check was also observed in newly-settled *C. albatrossis* which ranged between 40 - 50 mm SL. The check was found at the outermost edge of the otolith in these individuals, of which the otolith radius was from 1.2 to 1.4 mm. Consequently, we concluded that this check was a settlement check (SC), formed when individuals shifted from a pelagic to demersal life stage. The average number of increments from the nucleus to SC was 89.2 (± 14.4) in the Southern area, 119.2 (± 13.7) in the Central area and 147.2 (± 1.37) in the Northern area (Fig. 5). The number of increments from nucleus to SC differed significantly among areas (ANOVA, $P < 0.01$, F-statistic 110.53) and increased gradually in individuals from the Southern to the Northern areas. The settlement seasons were summer, autumn and winter in the Southern, Central and Northern areas, respectively (Fig. 6). We considered that the settlement season corresponds to the fishery recruitment season in each area.

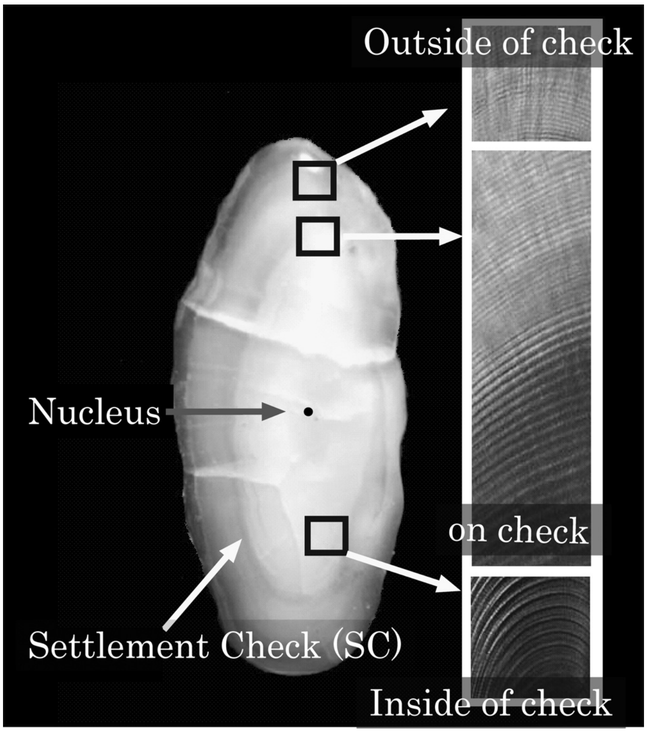

Fig. 4. The otolith of *Chlorophthalmus albatrossis*.

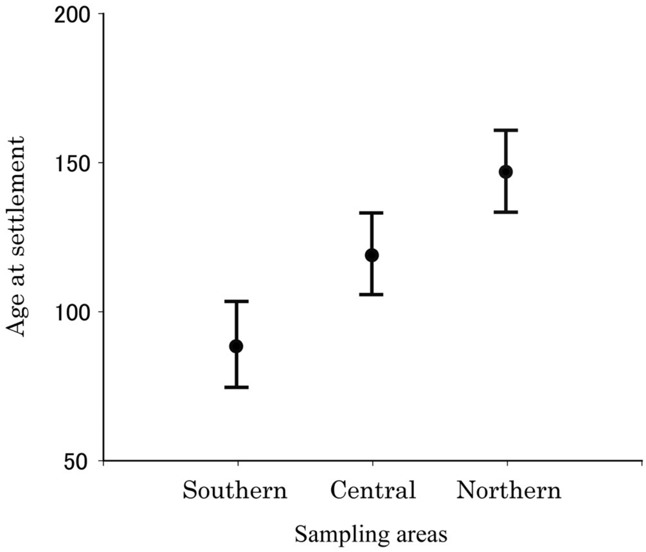

Fig. 5. Age at settlement of *Chlorophthalmus albatrossis* in Southern, Central and Northern offshore areas in Pacific Ocean of Japan. Circle and vertical line show the average and standard deviation of settlement age respectively.

DISCUSSION

The spawning season of many demersal fish is long in duration as there is little change in the water temperature and photo period (Ohtomi & Sakata, 2006). Oda (2002) suggested

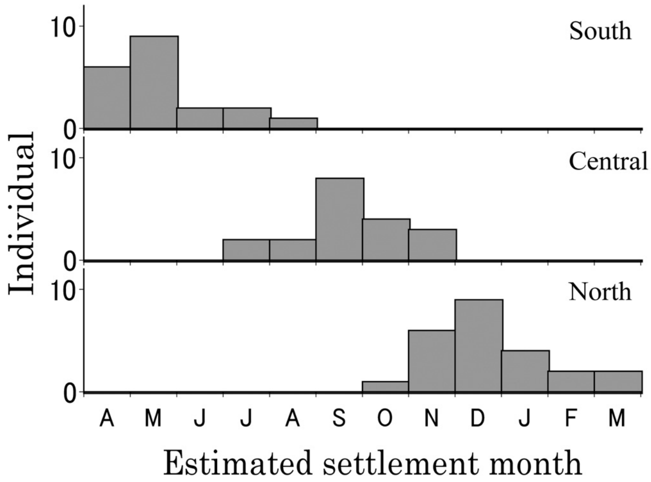

Fig. 6. Frequency distribution of settlement months of each sampling area estimated from the number of daily increments formed between the nucleus and the settlement check. Upper, middle and lower figure indicate Southern, Central and Northern offshore areas in Pacific Ocean of Japan, respectively.

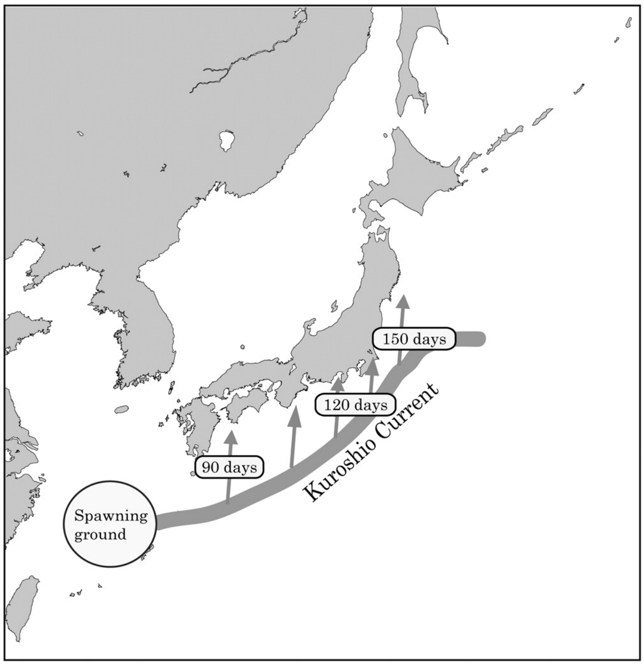

Fig. 7. Transportation hypothesis of larvae and juveniles of *Chlorophthalmus albatrossis* along the Pacific coast of Japan by the Kuroshio Current.

that the spawning season of *Chlorophthalmus albatrossis* caught at the Central area (Suruga Bay) is from January to August based on the otolith microstructure. Takagi (1965), based on the growth curve, estimated that the spawning season of *C. albatrossis* caught at Kumano-nada, which is located around the Central area to be in winter. The present study shows a similar result in that the spawning season of *C. albatrossis* was estimated to be from January to May, May to July and January to August in the Southern, Central and Northern areas, respectively. This indicates that the spawning season of *C. albatrossis* lasts from January to August.

The check mark of the otolith is formed by psychological stress which is induced by maturity, starvation and migration (Campana, 1983; Wilson & McCormick, 1997). Saruwatari et al. (2005) suggest that *C. albatrossis* lives in the pelagic waters in the larval and juvenile stages and changes from pelagic to demersal as it matures into an adult. These facts indicate that the SC is formed when individuals shift their habitat from pelagic to demersal .Therefore, in this study, we considered that a distinct check mark at a distance of 1.2 - 1.5 mm from the otolith nucleus was the settlement check.

The spawning season was from January to August but the settlement season was significantly different among the three areas. This study indicates that the estimated settlement season corresponds to the fishery recruitment season in each area. Saruwatari et al. (2005) indicated that most of larval and juvenile *C. albatrossis* are distributed around the Kuroshio Current. The geographic difference of age at settlement among these three sampling areas suggests that larval *C. albatrossis* are transported from a yet to be discovered spawning ground to Japan by Kuroshio Current (Fig. 7).

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