Occurrence pattern of white-spotted conger larva, *Conger myriaster*, in the southern Tohoku area

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To reveal the occurrence pattern of white-spotted conger larvae (*Conger myriaster*) and its relationship to oceanographic conditions, we recorded daily changes in landings at a fish market and water temperature in southern Tohoku area from 1993 to 2002. Fishing season of larvae was from February to June, with its duration and peak fluctuating among years, corresponding to year-to-year variations in water temperature. Catch per unit effort (CPUE) of white-spotted conger larvae were approximately 0 at water temperatures $<$10 and $>$18°C in every year. Maximum and high values of CPUE occurred at 10–15°C. Leptocephalus larvae before metamorphosis occupied a greater proportion of the developmental stage compositions of samples collected before early April 2001 and 2002, whereas they scarcely appeared when the water temperatures were above 15°C after mid-April. It was concluded that the white-spotted conger larvae mainly immigrated into the southern Tohoku area at 10–15°C.

Key words: white-spotted conger, leptocephalus larva, immigration

Introduction

The white-spotted conger, *Conger myriaster* (Brevoort), is distributed from the East China Sea to the waters of Korea and Japan, and inhabits shallow coastal waters to the edge of the continental shelf (Yamada, 1986; Park 2001). In the Tohoku region of northern Japan, white-spotted conger is an important fisheries species, with its annual production in Miyagi, Fukushima and Ibaraki prefectures accounting for 750–1550 tons per year during 1990 and 2000. Age structure and growth pattern of white-spotted conger in the Tohoku region have been studied by Katayama *et al.* (2002), and its life history was intensively researched by Ishida *et al.* (2003) and Katayama *et al.* (2004). In these studies, no females at full maturation occurred throughout the year. In addition, newly hatched larvae have never been found in the Tohoku region to date. Therefore, spawning grounds are believed not to be within this region, but further south and in deeper waters (Takai 1959; Yamada 1986; Kurogi *et al.*, 2002), suggesting that recruitment of the white-spotted conger population in the Tohoku region depends on immigration of drifting larvae from southern sea areas. The Kuroshio current plays an important role in the recruitment process into the Tohoku region. However, the occurrence pattern of white-spotted conger larvae has never been reported, although their collection within the region has been recorded (Tsukamoto *et al.*, 2001; Kubota *et al.*, 2001; Kurogi, 2001).

This paper is intended to ascertain the recruitment process of white-spotted conger larvae in relation to water temperature. To determine the occurrence season of white-spotted conger larvae in the southern Tohoku area, daily changes in catch per unit effort (CPUE) of the larva were investigated based on the landings at a fish market over the last 10 years. Based on the relationship between CPUE and water temperature, the immigrating mechanism of conger eel larvae into the area is discussed.

Materials and Methods

CPUE of white-spotted conger larva

The seine fishery in Ibaraki Prefecture, southern Tohoku area of Japan, operates off the Pacific coast all year round to catch larvae of sardine, *Sardinops melanostictus*, anchovy, *Engraulis japonicus*, sand lance, *Ammodytes personatus*, glass fish, *Salangichthys ishikawae*, and krill, *Euphausia pacifica*. In spring, white-spotted conger larvae (*Conger myriaster*) are one of the target species of the fishery. Landings of the white-spotted conger larvae in Ibaraki Prefecture are the highest in Japan. The Oarai Fisheries Landing Market accounts for more than half the total landings of conger larvae in Ibaraki prefecture. (Fig. 1) A total of 20–30 boats land larvae at the market every day. Conger larvae even incidentally caught by seining are usually landed because of its high price. Thus, daily records of landings, number of fishing boat of white-spotted conger larvae, catch per unit effort (CPUE) and daily catch (kg) per boat were investigated to determine the year-to-year

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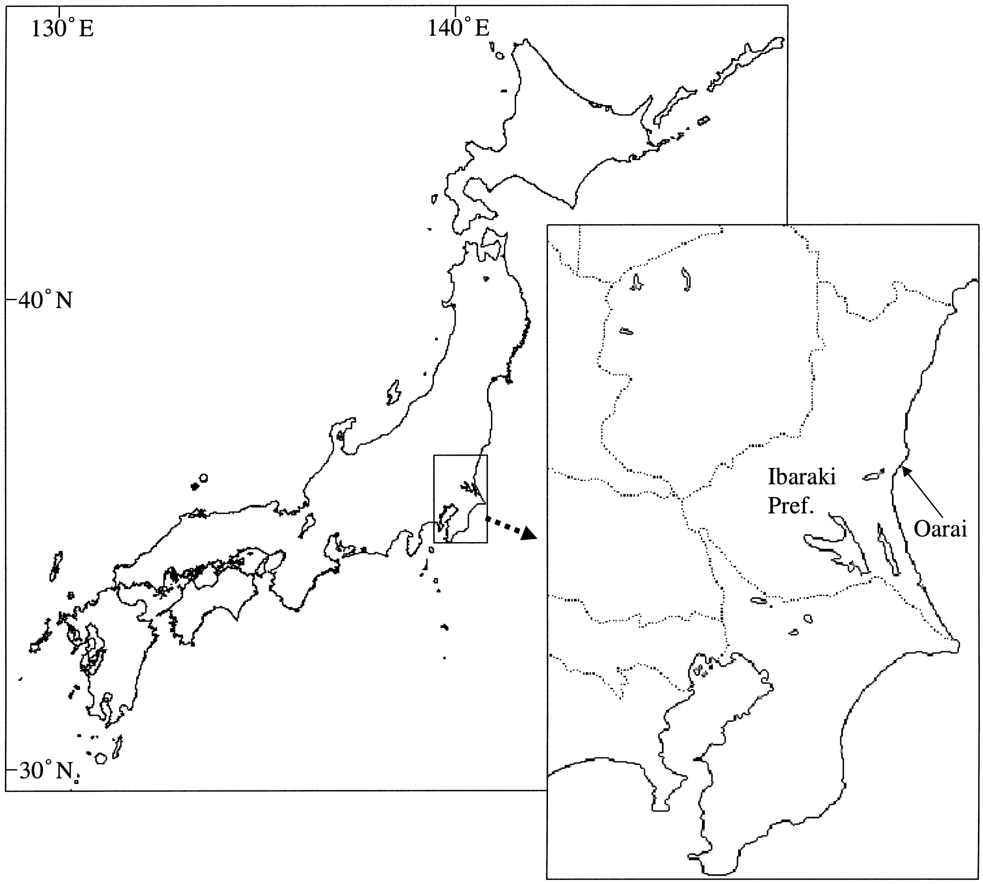

Figure 1. Map showing locations of Oarai, Ibaraki Prefecture, southern Tohoku.

variation in the occurrence season of white-spotted conger larva from 1993 to 2002. CPUE data were absent when no boat caught white-spotted conger larvae. For stock management purposes, landing per boat of the white-spotted conger larvae has been restricted to 30 kg since 2001.

Water temperature

Seine fishing is carried out in the coastal sea area, at depths of 5–15 m, off Oarai. Inshore water temperature time-series for the fishing ground had been collected by the Ibaraki Prefectural Fisheries Experimental Station. Daily water temperature was recorded for water drawn offshore, at about 3 m depth, approximately 5 km to the north of Oarai Fisheries Landing Market.

Biological characteristics

More than 100 individuals of white-spotted conger larvae were randomly sampled from the catches of the seine fisheries about twice a week at Oarai Fisheries Landing Market in 2001 and 2002. Sample fish were preserved frozen. Total length (TL) was measured. No newly hatched larvae were found throughout our sampling period. Anal position of the larval body moves anteriorly as metamorphogenesis progresses, so the developmental stage of white-spotted conger can be determined based on PAM/TM (pre-anal myomere/total myomere). A PAM/TM >0.80 is leptocephalus stage, while a PAM/TM <0.80 is metamorphic stage (Kubota, 1961; Tanaka *et al.*, 1987; Lee, 1996).

Results

Daily changes in average CPUE of white-spotted conger larva during January–June from 1993 to 2002 (Fig. 2) show that landings commenced in February every year (except for 2000). However, the major fishing season varied among years. Temporal fluctuation of CPUE showed several patterns. These fluctuations corresponded to water temperature (Fig. 3). In 1993 and 1998, CPUE widely fluctuated, with two peaks in late April and mid-May when water temperature ranged from 10 to 15°C, whereas CPUE diminished temporally in early and mid-March when water temperature reached the minimum below 10°C. In 1995 and 2001, water temperature seldom fell below 10°C and was 10–15°C in April. A small peak of CPUE was found in February, but the major fishing season continued from late March to late May. In 1997, 1999 and 2002, CPUE maintained a low level from February to April and diminished after May. Water temperature never fell below 10°C and rose above 15°C by late April, which was earlier than in other years. In

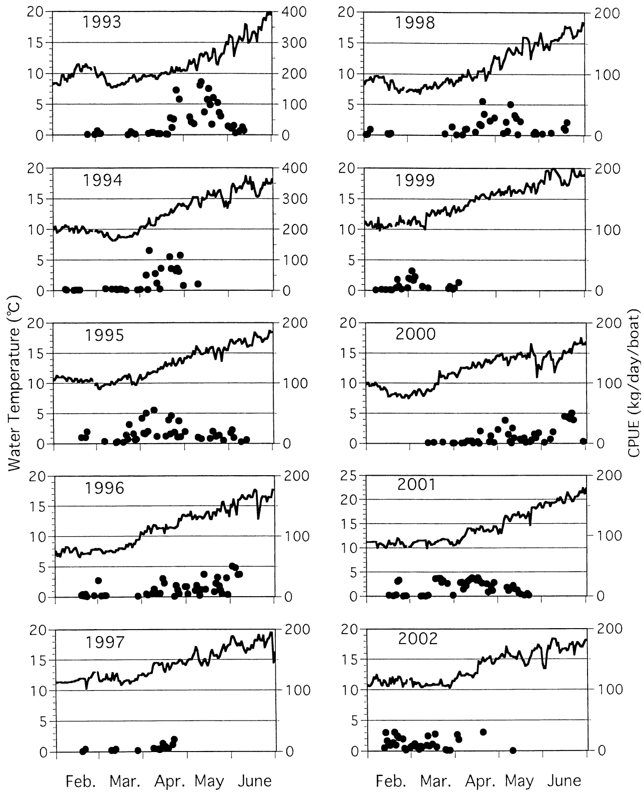

Figure 2. Temporal fluctuations in CPUE (closed circles, kg/day/boat) of white-spotted conger larva at Oarai Fisheries Landing Market and water temperature (lines). 1993–2002.

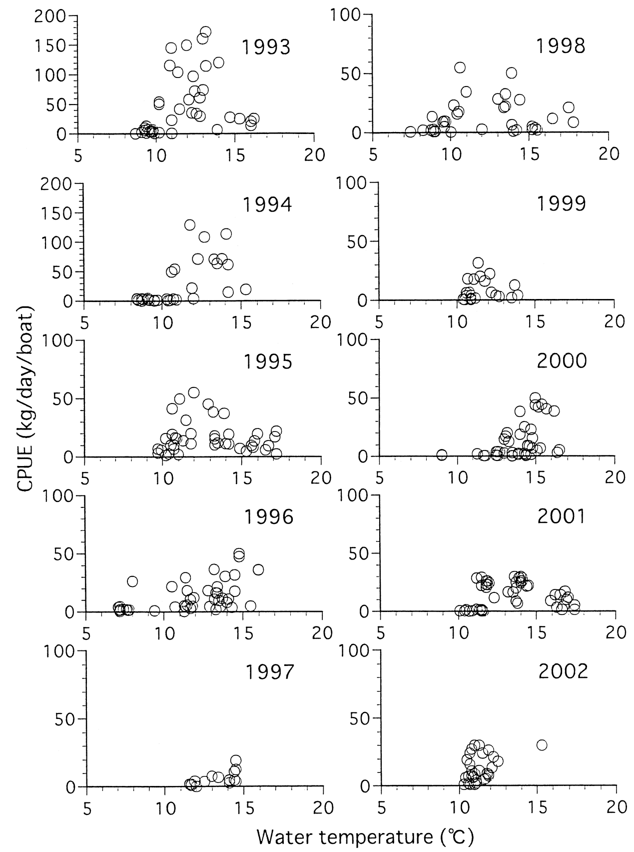

Figure 3. Relationships between water temperature and CPUE (kg/day/boat) of white-spotted conger larva, 1993–2002.

1994, 1996 and 2000, temperatures below 10°C occurred from February to March, and 10–15°C from April to May. The pattern of CPUE in 1994 and 1996 was similar to that in 1995 and 2001, but CPUE decreased completely during mid- and late March in the former year. In 2000, catches occurred in mid-March and continued until late June: a delay compared to other years. The association of water temperature and CPUE of white-spotted conger larvae suggests that the major fishing season occurs at the time water temperatures are between 10 and 15°C every year. CPUEs were approximately 0 at water temperatures below 10°C every year during 1993 and 2002. The maximum and high values of CPUE occurred from 10 to 15°C. CPUE gradually decreased above 15°C and disappeared above 18°C.

Almost all larvae caught in the coastal area off Oarai in 2000 and 2001 were at the leptocephalus stage (PAM/TM >0.80) in February (Fig. 4). In March, when water temperature was stable at 10–12°C, small-scale decreases in the proportion of leptocephalus larvae were found once in 2001 and twice in 2002. In early April, leptocephalus larvae were still in high proportions, whereas larvae at the metamorphic stage occupied a great proportion after mid-April in both years. These changes from leptocephalus to metamorphic stages synchronously followed steep rises in

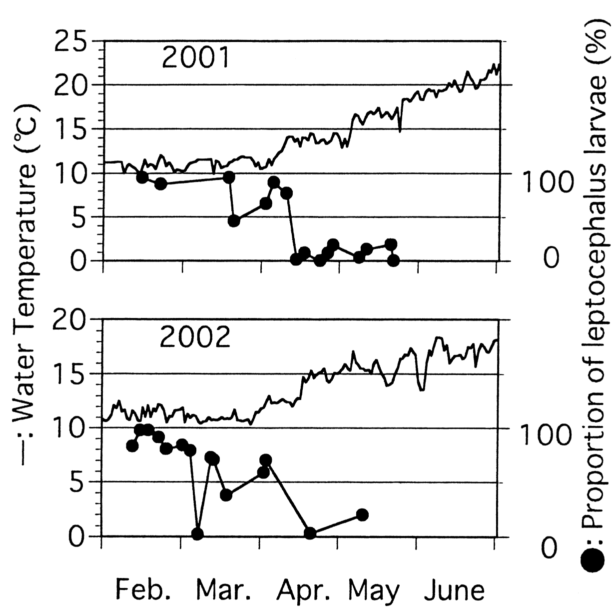

Figure 4. Temporal changes in the proportion of leptocephalus larvae in each samples caught in the coastal area off Oarai (closed circles) with daily changes in water temperature (lines) in 2001 and 2002.

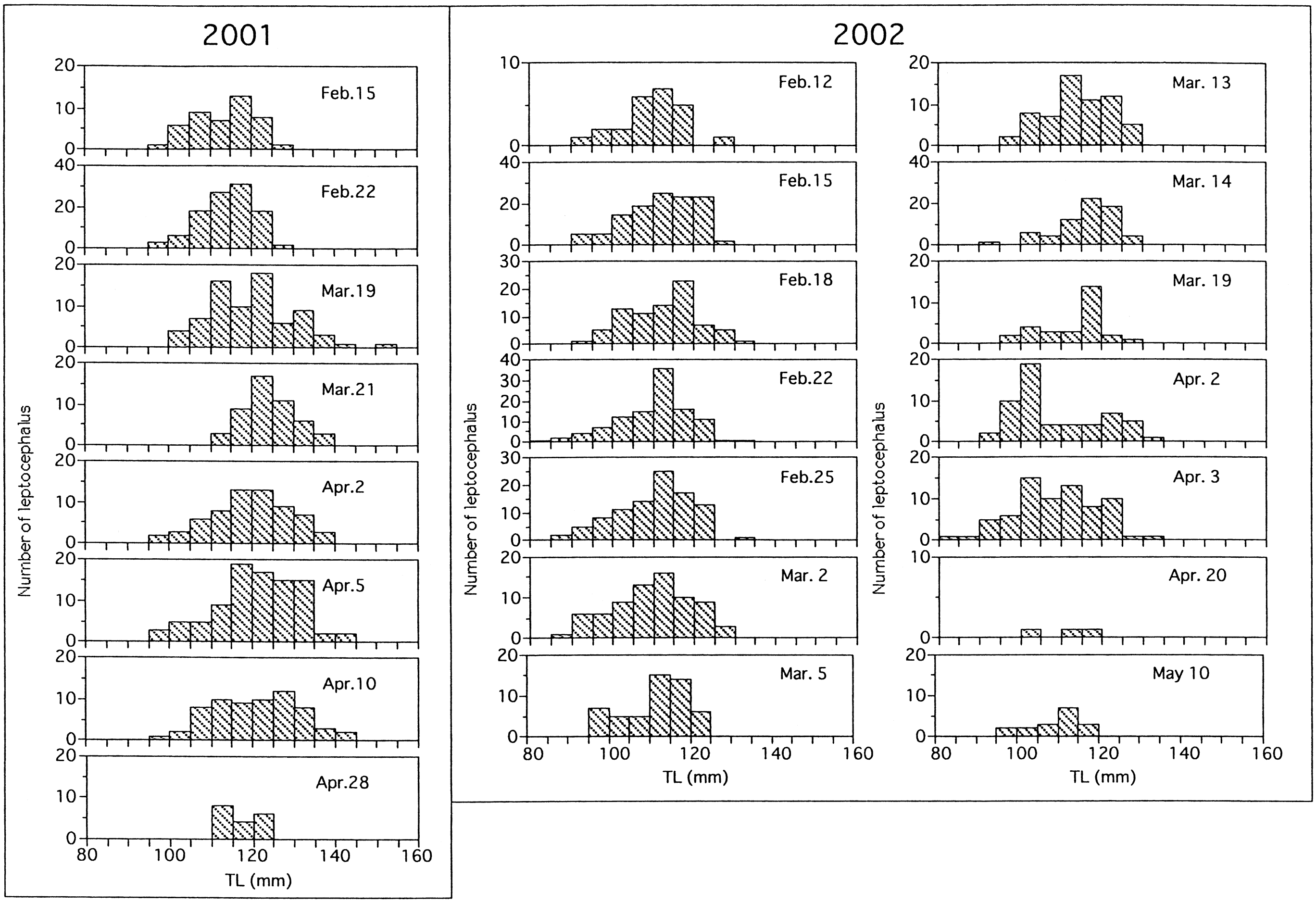

Figure 5. Temporal changes in total length distributions of leptocephalus larvae in 2001 (a) and 2002 (b).

water temperature toward 14–15°C in early April 2001 and mid-April 2002.

Fig. 5 shows total body length distribution of white-spotted conger larvae at the leptocephalus stage. The total length ranged widely from 80 to 155 mm. The modes of distribution were 105–135 mm, and the modes did not shift toward larger total length as time progressed.

Discussion

White-spotted conger larvae caught and landed at Oarai Fisheries Landing market were at leptocephalus and metamorphic stages. The metamorphic larva is about to settle on the bottom and is not transported long distance afterwards. Therefore, we can assume that the immigrating season of white-spotted conger larvae into the Oarai coastal area coincides with the occurrence of the leptocephalus larval stage.

White-spotted conger leptocephalus larvae were caught from February to July. The question arises as to whether catching other target species depresses the conger larval catch and CPUE after June–July. The results of developmental stage composition of leptocephalus provides a key to answer this question. White-spotted conger larvae were at a metamorphic stage after mid-April, while the majority of them were at the leptocephalus stage from mid-February to early April in 2001 and 2002. This means that white-spotted conger larvae immigrated mainly from February to mid-April in these years. However, the immigrating season fluctuates among years, indicated by the major fishing season in some other years occurring after mid-April. This fluctuation in the fishing season was associated with year-to-year changes in water temperature. The relationship between CPUE of white-spotted conger larvae, which includes larvae at leptocephalus and metamorphic stages, and water temperature, showed that CPUEs were approximately 0 at temperatures <10 and >18°C throughout the 10 years studied. In 2001 and 2002, small numbers of larvae were estimated to immigrate late in the fishing season after mid-April when water temperatures were around 15°C, due to the majority of larvae being at metamorphic stage. It can be concluded that leptocephalus larvae mainly immigrated and appeared in the southern Tohoku area at sea temperatures of 10–15°C. Since the sea surface temperature is usually higher than 15°C along the Kuroshio Extension axis (Kawai, 1965) and leptocephalus larvae are rarely caught at temperatures above 15°C, the larvae may not be directly transported to the Tohoku coast by the Kuroshio Extension. To discover the migration mechanism of leptocephalus larvae to the coastal area, oceanographic conditions between the coast and the Kuroshio Extension need to be investigated.

In 2001 and 2002, body length distribution of leptocephalus larvae were multi-modal. This suggests the immigration of white-spotted conger larvae is not continuous, but intermittent. However, immigrating groups could not be separated and the growth trajectory could not be determined by the body length distribution data. Thus, the relationship of immigrating groups with hatching groups and/or discontinuous onshore migration could not be revealed. Although body length distribution of white-spotted conger larvae have been reported (Lee and Byun, 1996; Huh and Kwak, 1998), the relationship between immigrating and hatching groups are unknown. To uncover this association, hatching date composition should be estimated through daily otolith increment analysis. The use of tidal currents for arrival into near-shore nursery grounds has been described for a number of fish species (Gibson, 1973; McCleave and Kleckner, 1982; Yamashita *et al.*, 1996; Boss, 1999; Plaza *et al.*, 2002). In addition, oceanographic conditions between the coast and the Kuroshio Extension, and onshore migration of the white-spotted conger larvae needs to be analyzed with reference to tidal conditions.

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東北南部海域におけるマアナゴ葉形仔魚の出現パターン

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東北南部海域におけるマアナゴ葉形仔魚の来遊時期およびその海洋条件を明らかにするために，1993–2002年の茨城県大洗における船曳網CPUEの経日変化を調べた．葉形仔魚が漁獲される時期は2月から6月にかけての期間であったが，漁獲期間および盛漁期は年によって大きく異なっていた．葉形仔魚のCPUEは，水温が10度未満の時には，いずれの年もほぼ0であった．最も高いCPUEの値が見られたのは10度から15度にかけての範囲にあり，15度以上では水温が高くなるにつれて減少し18度以上になると0になった．2001–2002年に漁獲された葉形仔魚の発育段階を調べたところ，4月中旬までは変態前の個体が大半を占めたが，水温が15度近くに上昇する4月中旬以降は，変態期の個体が大半を占めた．以上のことから，東北南部海域においてマアナゴ葉形仔魚は、主に表面水温が10–15度であるような海洋条件の時期に来遊することが示された．

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