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Partial stock transportation of three clupeoid, *Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus*, larvae into the shirasu fishery ground of Tosa Bay, Japan

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Abstract : In Tosa Bay, three species of clupeoid (*Engraulis japonicus, Etrumeus teres* and *Sardinops. melanostictus*) larvae were collected monthly by the commercial shirasu trawl between October 2001 and September 2002. *E. japonicus* occurred all year round, *E. teres* from October to July and *S. melanostictus* from November to April. Hatching dates, estimated by daily ring increment of otoliths were distributed all year round in *E. japonicus*, October to March and May to July in *E. teres* and October to March in *S. melanostictus*. Furthermore, from larva net collections made offshore in the bay from April 2002 to March 2003, eggs hardly or never occurred from July to February for *E. japonicus*, from April to October for *E. teres* and from April to December for *S. melanostictus*. Considering these facts with information by other institute, larvae of *E. japonicus*, *E. teres* and *S. melanostictus* which occur in November to January would not be born in Tosa Bay. Since their early larvae were collected with a larva net during the autumn, they must be transported after hatching from outside Tosa Bay. Hence, each larva assemblage of three clupeoid seems to originate from plural spawning stocks.

Keywords *: shirasu fishery, clupeoid larva, daily age, transportation, Tosa Bay*

1. Introduction

The shirasu (clupeoid larvae) fishery middle trawl is performed in Tosa Bay (OCHIAI, 1981), where a large fishery ground of three clupeoid, *Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus* shirasu are formed, and their major spawning stocks exist (HATTORI, 1982 ; KURODA, 1988 ; WATANABE *et al.*, 1997 ; ZENITANI and KIMURA, 1997 ; ZENITANI and YAMADA, 2000 ; UEHARA and MITANI, 2002). Therefore, Tosa Bay has played an important role as spawning and nursery grounds. However, little is known about the assemblage mechanisms of the shirasu, *i.e.* a formation of the fishery grounds after spawning. Our previous paper (DJUMANTO *et al.*, in press) clarified seasonal abundance and changes in sizes of the three clupeoid species. In the present paper, we report recruitment patterns into the fishery ground of the shirasu by examination of otolith daily rings, and compare the distribution pattern of their eggs and early larvae between the shoreline and offshore.

2. Materials and methods

Four stations (T1–T4) with increasing depth (5, 10, 15 and 20 m) from the mouth of the Niyodo River were sampled monthly for juveniles of three clupeoid species (*Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus*) using fishermen's middle trawlers (mesh size of bag-net : 2 mm) between October 2001 and September 2002 (Fig. 1). The trawl structure used and collection methods were described in DJUMANTO *et al.* (in press). Collections of eggs and early larvae were made by oblique tows (from near the bottom to the surface) with a larva net (1.3 m mouth diameter and 0.5 mm mesh aperture) at nine stations

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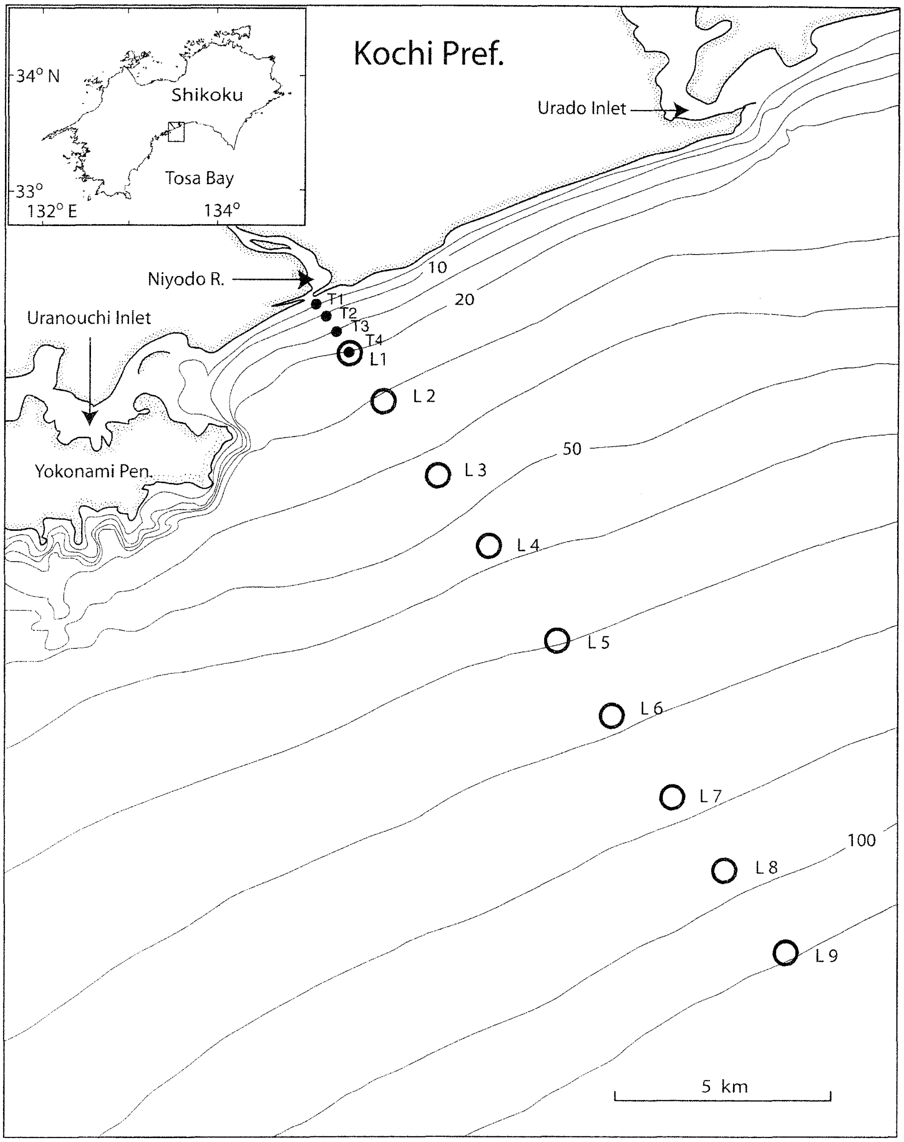

Fig. 1. A chart of Tosa Bay showing the stations where ichthyoplankton were collected. Shirasu trawls were performed at solid circles (T1–T4) arranged by different depths (5, 10, 15 and 20 m) from October 2001 to September 2002. Oblique tows by a larva net (1.3 m mouth-diameter, 0.5 mm mesh aperture) were made at open circle stations (L1–L9) from April 2002 to March 2003.

(L1–L9) performing a transect south-east from the mouth of the Niyodo River between April 2002 and March 2003 (Fig.1). All samples were preserved in 10% sea-water formalin then transferred to 80% ethanol, subsequently fish specimens were sorted and measured their sizes by developmental stages (KENDALL *et al.*, 1984) in the laboratory. Unlabeled lengths are body lengths (notochord length in yolk-sac, preflexion and flexion larvae, and standard length in postflexion larva and juveniles). Water temperatures and salinities were measured using STD at each station.

A maximum of 100 and 50 specimens from

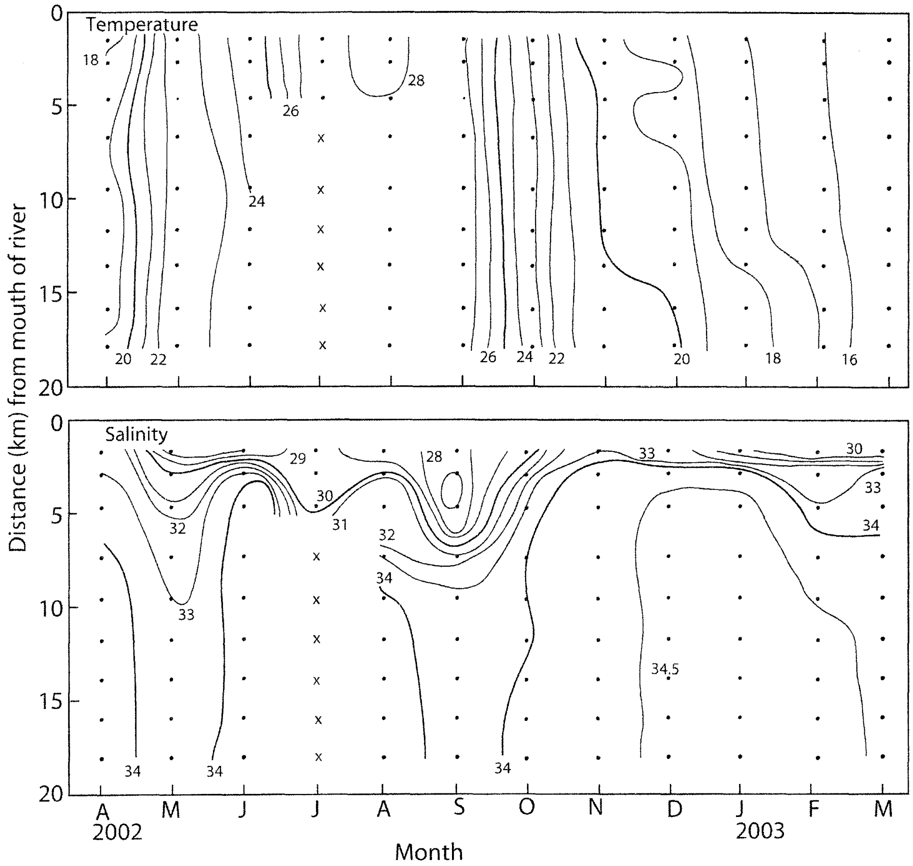

Fig. 2. Seasonal changes of horizontal distributions of water temperatures (°C, 5 m depth layer) and salinities (psu, surface) in Tosa Bay from April 2002 to March 2003. Dots indicate sampling stations and crosses indicate no survey.

the shirasu trawl and larva net collections, respectively, for each species on each sampling date was selected randomly for age determination from otolith (sagitta). The right side sagittae were removed from specimens, and fixed on a microscope slide face up with epoxy resin. Rings outside the nucleus of the sagittae were counted with a light microscope at 400–600 times magnification, and the mean of five replicate counts was used as the estimated ring number. Hatching dates were estimated from the increment of daily rings and the collection date. The daily periodicity of increment formation on sagitta in *E. japonicus*, *E. teres* and *S. melanostictus* was ascertained by TSUJI and AOYAMA (1984), HAYASHI and KAWAGUCHI (1994) and HAYASHI *et al.* (1989), respectively.

3. Results

Temperature and salinity

Seasonal changes in the horizontal distribution of water temperatures and salinities offshore from the mouth of the Niyodo River in Tosa Bay are shown in Fig. 2. Temperatures were approximately equal when examined horizontally through the waters, but changed seasonally. For salinities, horizontal discontinuity layers were formed around 5 km offshore in spring and summer, and salinity tended to be higher in nearer stations from the shore during autumn and winter.

Comparison of size between larva net and shirasu trawl collections

From larva net collections, all three species

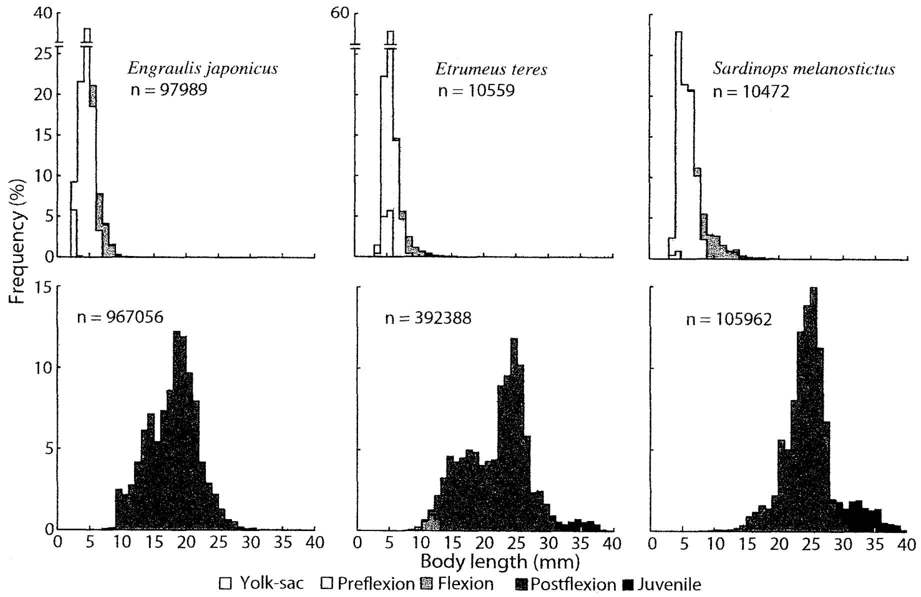

Fig. 3. Body length frequencies of three clupeoid fishes collected by a larva net (upper) and a shirasu trawl (bottom) in Tosa Bay during study period.

were mainly composed of preflexion stage larvae, with a mode at *ca.* 5 mm (Fig. 3). Larvae over 10 mm were rather abundant for *Sardinops melanostictus*, as opposed to never for *Engraulis japonicus*.

In the shirasu trawl samples, juveniles over 30 mm occurred appreciably for *Etrumeus teres* and *S. melanostictus* but never for *E. japonicus*. All three species were composed of chiefly the postflexion larvae. Modes were considered to be 18.1–19.0 mm for *E. japonicus*, 17.1–18.0 and 24.1–25.0 mm for *E. teres* and 25.1–26.0 mm for *S. melanostictus*.

Seasonal changes of eggs and early larvae

E. japonicus eggs occurred from February to April, with a further isolated production of eggs in June and September, and were chiefly distributed 5–10 km and 10–15 km offshore in April and June, respectively (Fig. 4). In winter, eggs were dispersed, and tended to be abundant over 20 km offshore. Early larvae were collected all year round, with peak in April, when they were aggregated around 5 and 15 km offshore. In other months, larvae tended to be dispersed along the transect.

E. teres eggs and early larvae occurred chiefly from October to March, and were more abundant in the period between January and March (Fig. 5). Dense distributions were found over 15 km offshore for eggs, but distinctive distributions for larvae were difficult to ascertain.

For *S. melanostictus*, the eggs were collected from January to March, and were concentrated around 10 km offshore in January (Fig. 6). The larvae, however, started to be found over 10 km offshore in November, and the distribution changed monthly, *i.e.* near the shore in January, around 10 km offshore in February and over 15 km offshore in March.

Age (days) of larvae and juveniles

For the larva net collected larvae, the ages of all three species were concentrated at 6–10 days old (Fig. 7). On the other hand, for the shirasu trawl samples, the ages were distributed from 6 to 68 for *E. japonicus*, 4 to 80 for *E. teres* and

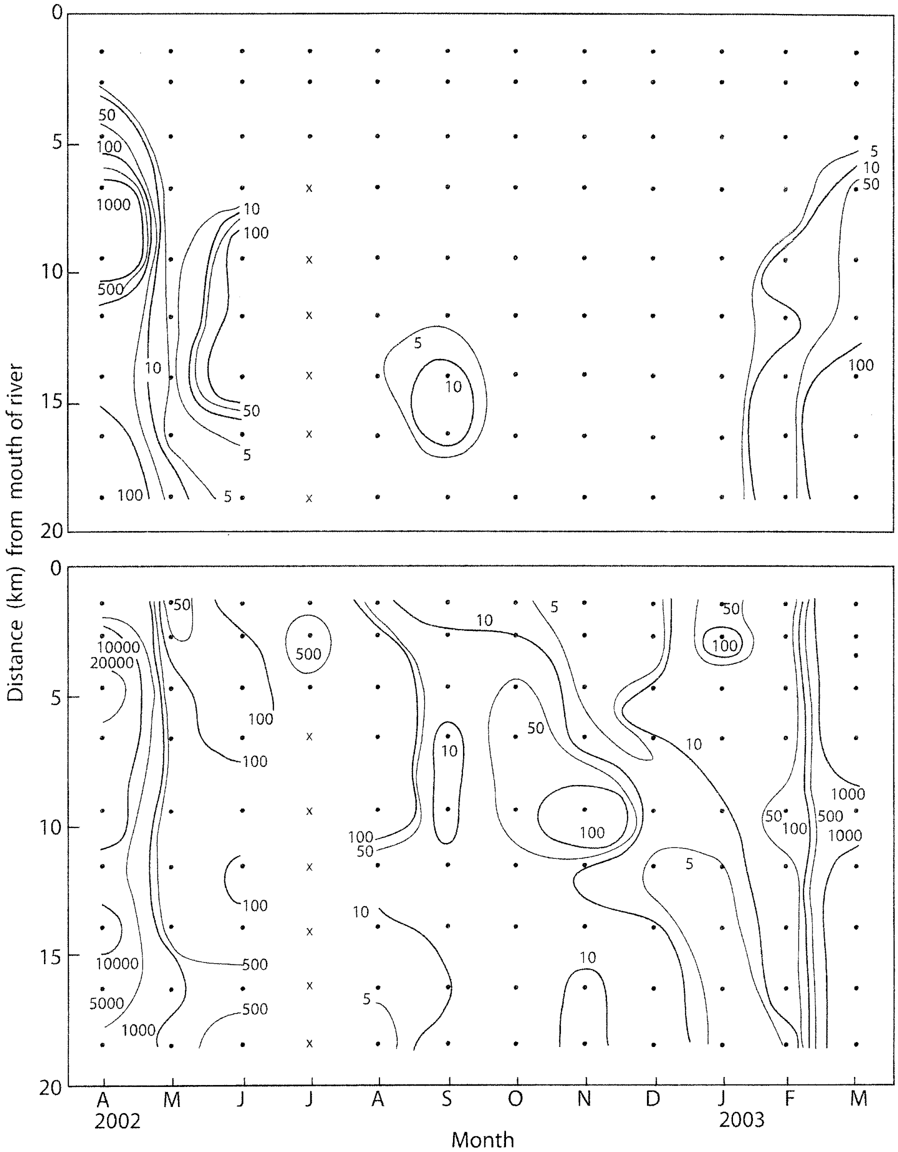

Fig. 4. Monthly changes of horizontal density (n/1000 m^3) of egg (upper) and larva (bottom) in *Engraulis japonicus*. Dots indicate sampling stations and crosses indicate no survey.

from 5 to 64 days for *S. melanostictus*. Furthermore, there was little differentiation of age ranges among the three species. Their modes were found at 26–30 days old for *E. japonicus*, 11–15 days old for *E. teres*, and 16–20 days old for *S. melanostictus*.

Relationship between egg monthly distribution and hatching dates of larvae

E. japonicus eggs were most abundant in April, with few or no eggs from July to January (Fig. 8). Hatching dates of the larvae by both collection methods were distributed almost over the year, with a peak in July for the larva net and in October for the shirasu trawl collections.

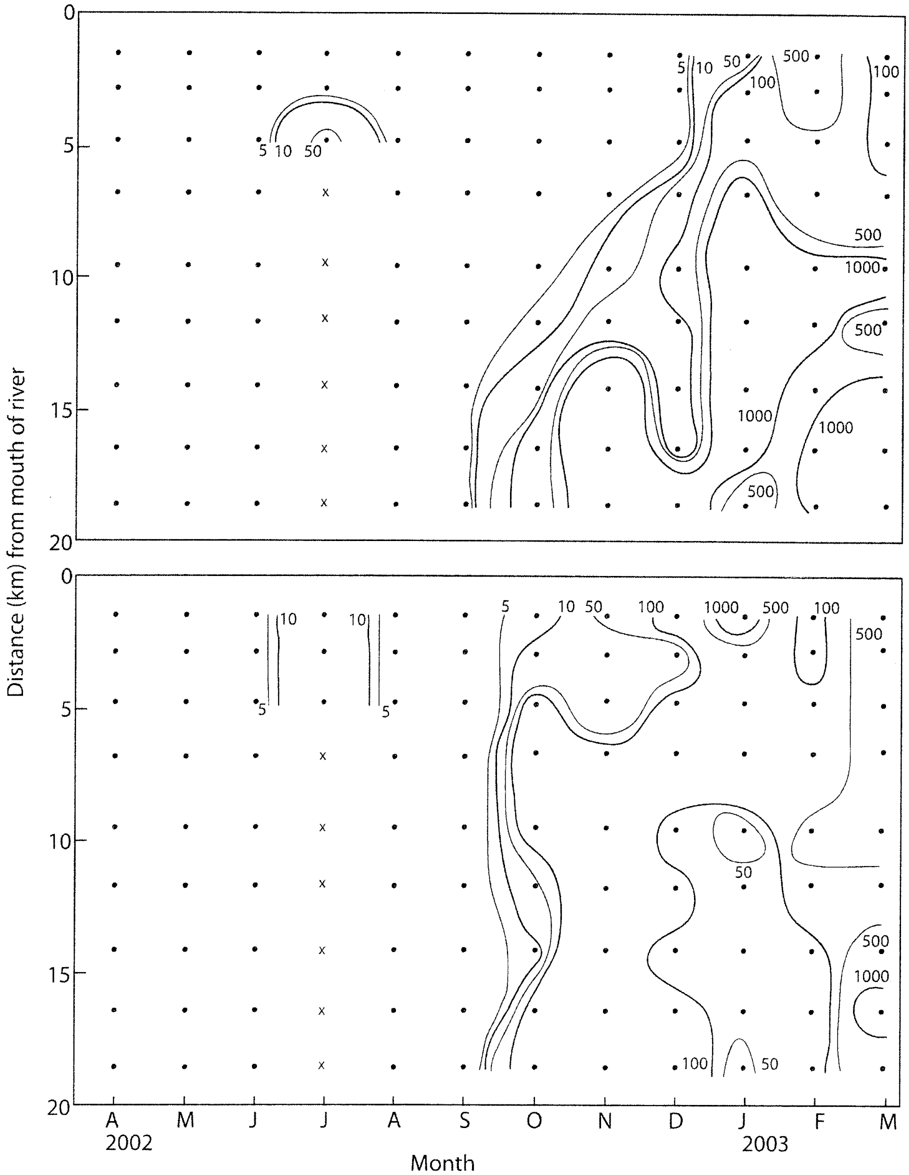

Fig. 5. *Etrumeus teres*. Otherwise same as in Fig. 4.

Eggs of *E. teres* were collected in July and from October to March, with a peak in February (Fig. 9). They were, however, utterly absent from April to June. Hatching dates of the larvae collected with the larva net were distributed from October to March, peaking in November and larvae collected by the shirasu trawl were distributed from May to July with a peak in June and from October to March with a peak in December.

S. melanostictus eggs occurred from January to March with a peak in January (Fig. 10). Hatching dates of the larvae by the larva net were distributed from November to March, being most abundant in January from the larva net collection method, and from October to March, with the greatest abundance in January from the shirasu trawl.

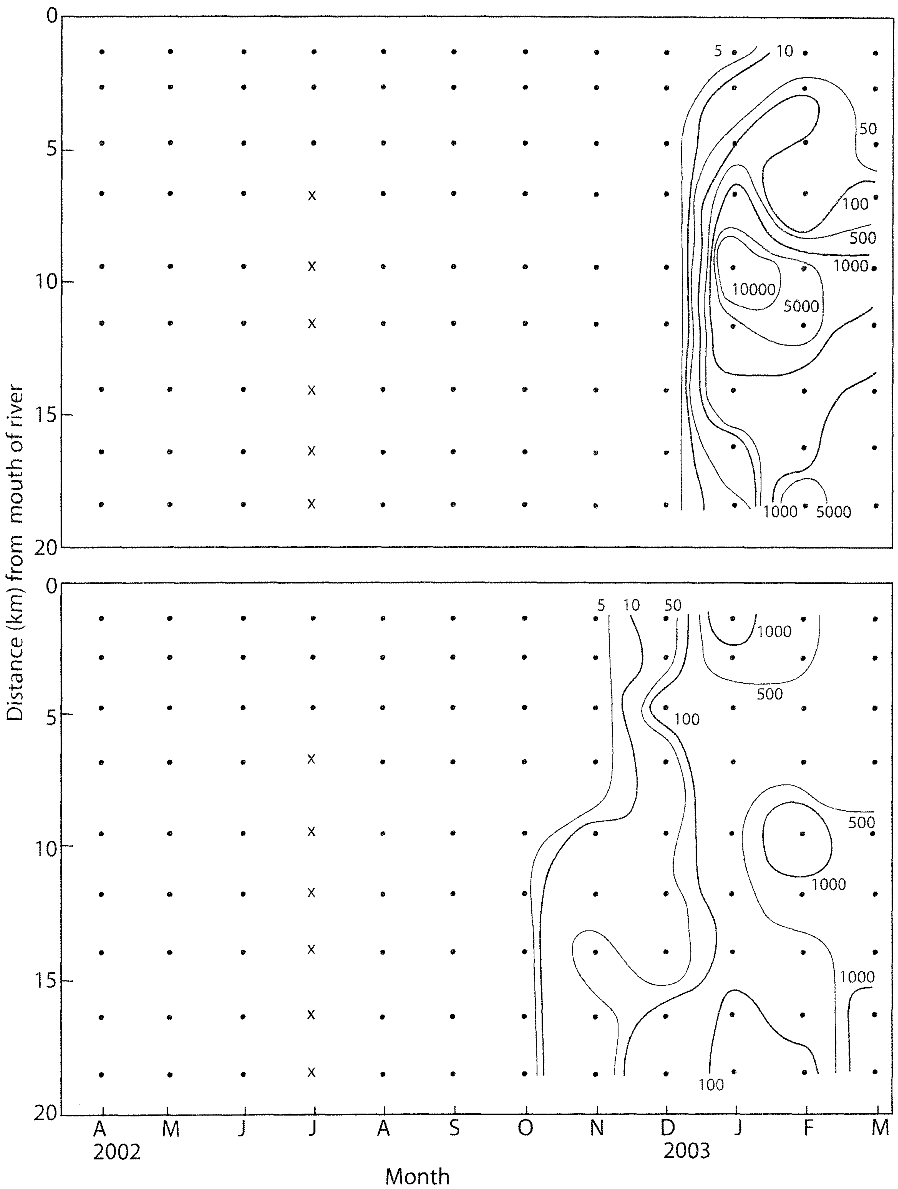

Fig. 6. *Sardinops melanostictus*. Otherwise same as in Fig. 4.

4. Discussion

Owing to the fact that mesh sizes were 0.5 and 2 mm in the larva net and shirasu trawl bag-net, respectively, it is possible that larger larvae avoided the larva net, and conversely, smaller larvae may pass through the mesh of the bag-net during the trawl. However, Fig. 3 shows that *Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus* larvae are likely to assemble in fishery grounds near the coast over 10, 10 and 15 mm in size, respectively, just after attaining postflexion stage. This fact shows that the formation of the fishery ground of clupeoid larvae is attributable to higher swimming ability as a result of the development of the caudal fin (KENDALL *et al.*, 1984).

Since the larva net collection method had not

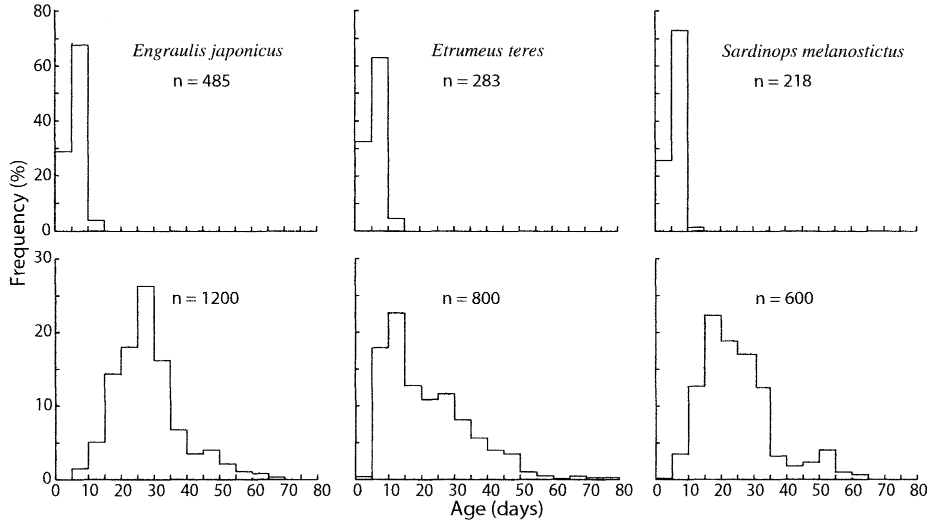

Fig. 7. Age frequency of three clupeoid larvae collected by a larva net (upper) and a shirasu trawl (bottom) in Tosa Bay during the study period.

been carried out before April 2002, we studied the origins of the shirasu trawl specimens by examining information (ISHIDA *et al.*, 1999, 2000, 2001, 2002, 2003) from the National Research Institute in more detail.

No or few eggs corresponding to the shirasu trawl larvae which hatched between July and August, May to July, and October to December for *E. japonicus*, *E. teres*, and *S. melanostictus*, respectively, were found in our study waters. Although data were from different years, *E. japonicus* also showed the same situation from October to January.

Hatching dates of early larvae were distributed in July and November, when the shirasu larvae of *E. japonicus* and *S. melanostictus*, respectively, had hatched. In *E. teres*, no early larvae had hatched between May and July, when hatching dates of the shirasu larvae were distributed.

First, *E. japonicus* had spawned in July to September not only outside the western and eastern parts of Tosa Bay, but also inside this bay in 2002 (ISHIDA *et al.*, 2003). Hence, it is likely that we could not collect eggs, because eggs were distributed offshore over our present waters in the summer of 2002 (ISHIDA *et al.*, 2003). However, eggs which could not be collected by us in the present waters, had been distributed outside the western part of this bay in the autumn every year (ISHIDA *et al.*, 1999, 2000, 2001, 2002, 2003). Therefore, it is certainly that the autumn born stocks of the shirasu trawl were transported from outside the western side of Tosa Bay.

Second, in *E. teres*, eggs being the origin of specimens born in May–July of the shirasu trawl were hardly collected in our present waters, but usually occurred inside Tosa Bay and outside the eastern part of the bay (ISHIDA *et al.*, 1999, 2000, 2001, 2002, 2003). For the specimens born in Autumn 2002, however, their original eggs had only occurred marginally outside the eastern part of Tosa Bay (ISHIDA *et al.*, 2003). Thus, the autumn born stock of this species was likely to be transported from outside the eastern part of the bay, at least in 2002.

Finally, *S. melanostictus* eggs had been a little found only outside the eastern part of the bay in the autumn of 2001 (ISHIDA *et al.*, 2002), when a number of shirasu larvae had been born. It is likely that they had also been transported from outside the eastern part of the bay.

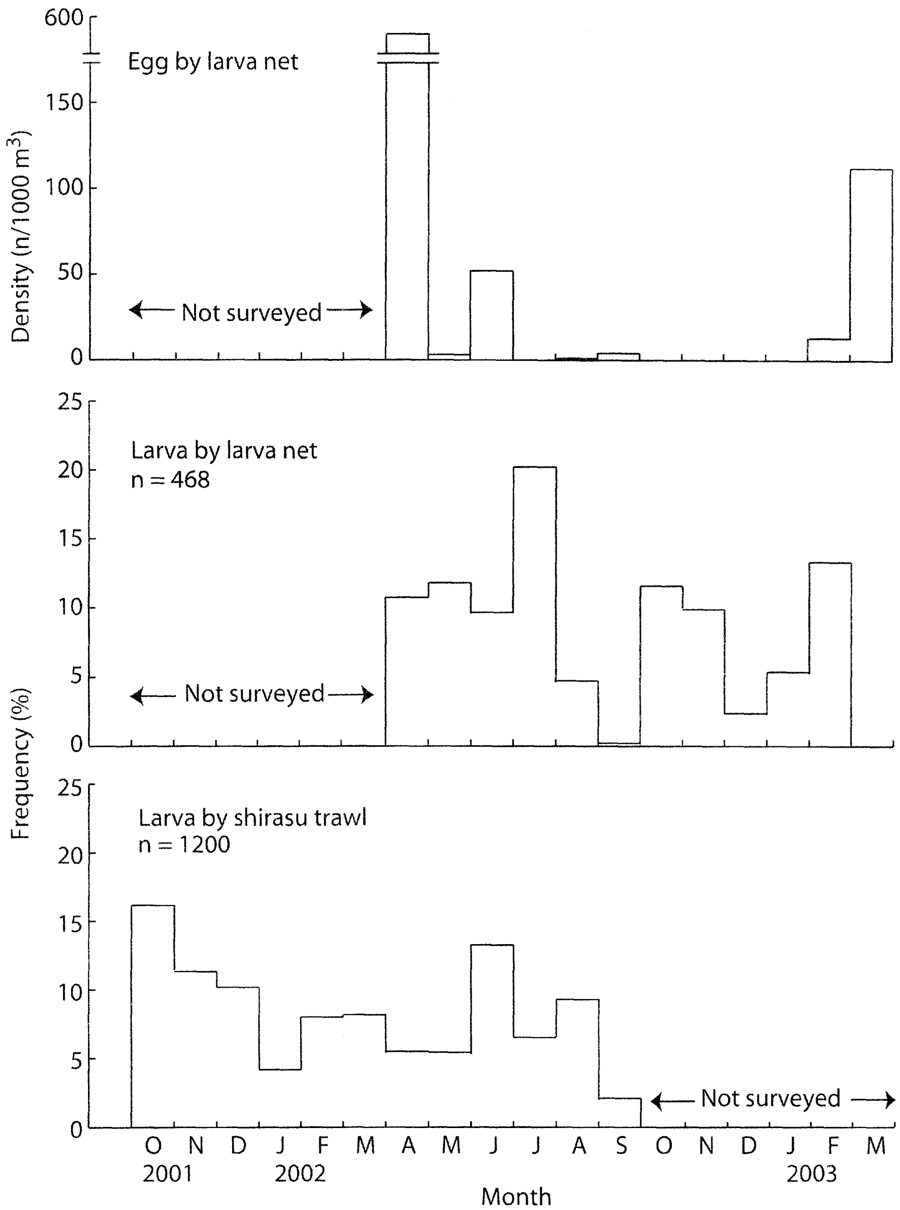

Fig. 8. Comparison of seasonal changes between egg abundance and hatching period of the larvae in *Engraulis japonicus*.

Consequently, in all three species, it is suggested that the larvae and juveniles caught by the shirasu trawl in Tosa Bay are composed of different stocks, a part of which being recruited from outside the western part of the bay in *E. japonicus*, and from outside the eastern part of the bay in *E. teres* and *S. melanostictus*. Since in all species, early larvae born in autumn were present in our study waters, recruitment from outside the bay seems to occur at the early larval stage.

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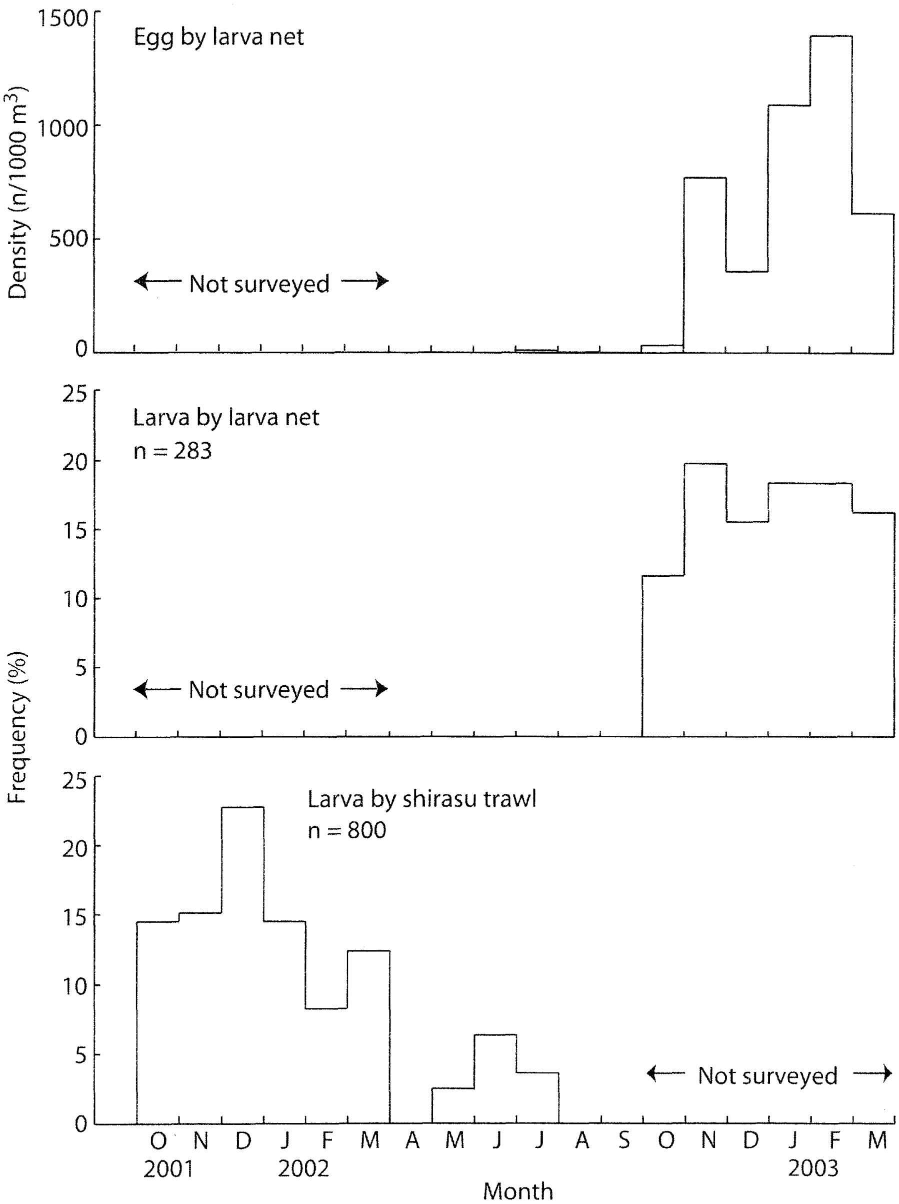

Fig. 9. *Etrumeus teres*. Otherwise same as in Fig. 8.

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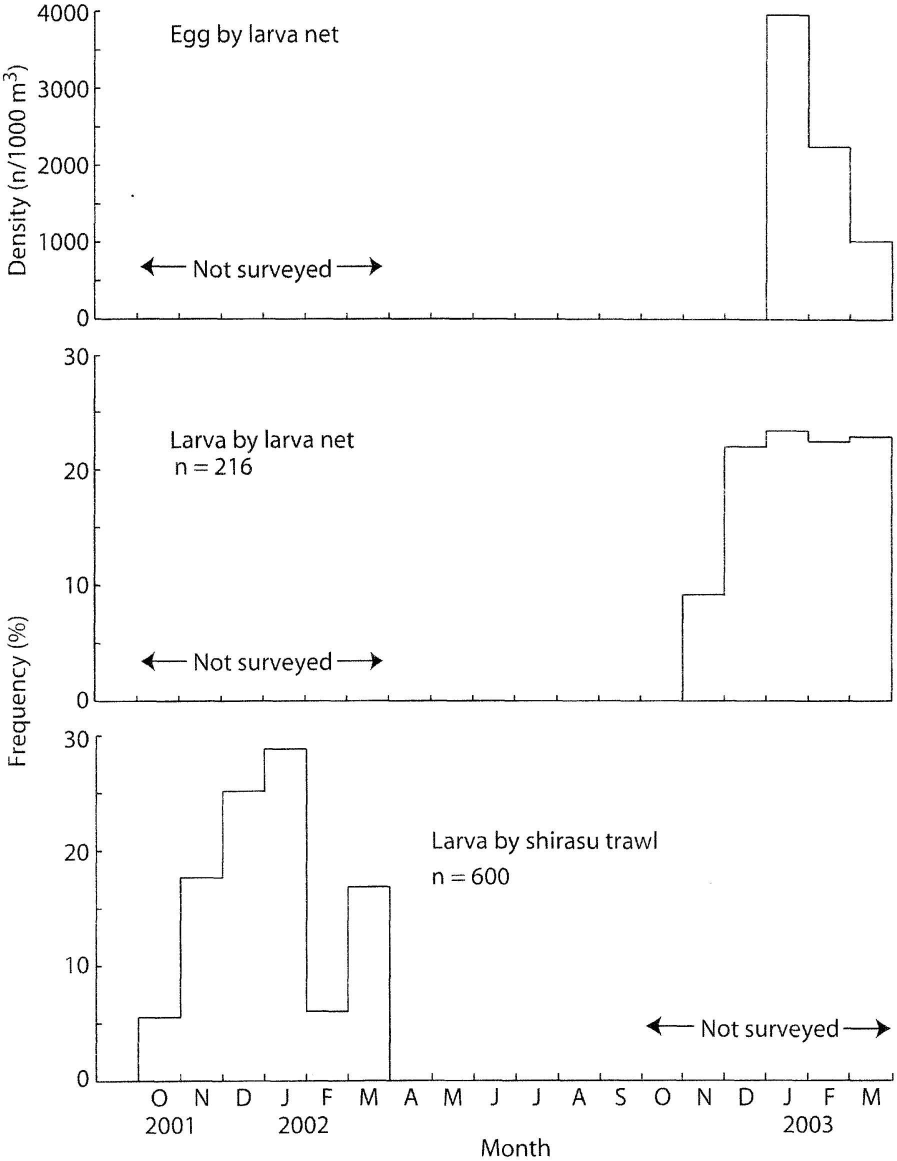

Fig. 10. *Sardinops melanostictus*. Otherwise same as in Fig. 8.

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