La mer 42 : 95–106, 2004
Société franco-japonaise d'océanographie, Tokyo

Seasonal abundance of three clupeoid larvae and juveniles occurring in the shirasu fishery ground in central Tosa Bay, Japan

DJUMANTO[1], Izumi KINOSHITA, Chiho BITO[2] and Jun-ichi NUNOBE

Abstract : The community of three clupeoid (*Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus*) larvae and juveniles were examined monthly in their fishery ground in central Tosa Bay, Japan between October 2001 and September 2002. A total of *ca.* 1.5 million clupeoid larvae and juveniles were collected at four depths (5, 10, 15 and 20 m) in areas off the Niyodo River mouth. *E. japonicus* occurred all year round, and was the most abundant (*ca.* 61% of total), followed by *E. teres* (*ca.* 25%) and *S. melanostictus* (*ca.* 7%). Dominant species changed seasonally, *i.e. E. japonicus* dominated from April to October with two peaks in April and August, *E. teres* dominated from November to February with a peak in February, and *S. melanostictus* dominated in March with a peak in February. Sizes were more widely distributed and larger for both *E. teres* (7–41 mm with two modes) and *S. melanostictus* (7–41 mm with one mode) than for *E. japonicus* (7–37 mm with one mode). Age determined by ring increments on otoliths (sagittae) showed multi-modal patterns in all species, *i.e.* modes were identified around 29–30 and 49–50 days for *E. japonicus*, 9–10, 29–30, 39–40 and 49–50 days for *E. teres*, and 17–18, 25–26, 31–32 and 51–52 days for *S. melanostictus*. According to relationships between monthly changes in the modes of size, age and hatching date, migrant and resident stocks were present, and all three species tended to be longer residents in the fishery ground during winter.

***Keywords** : Clupeoid Larvae and Juveniles, Tosa Bay, Shirasu Fishery Ground*

1. Introduction

"*Shirasu*" is a commercial Japanese term for the larvae and juveniles of fish, particularly eel and clupeoid fishes. In southern Japan, fisheries for catching clupeoid shirasu are common and commercially important, and the coastal waters facing Tosa Bay yield particularly high catches. The forming of fishery grounds for clupeoid shirasu must be no more than assemblages of their larvae and juveniles in coastal waters. Descriptions of larval and juvenile ichthyofauna have been reported in some areas (ISHIYAMA, 1950; HORI, 1971; HAYASHI *et al.*, 1988). *Engraulis japonicus* is the main species in catches and studied on their early life history (TSUJI and AOYAMA, 1984; MITANI, 1988a, b, c). These specimens were fragmentally shared by fishermen, and were sampled irregularly. Therefore, in order to obtain more detailed information on the community of larvae and juveniles, we employed fishermen and periodical collections were conducted. In the present paper, to better understand the mechanisms underlying the formation of shirasu fishery grounds, we examined seasonal recruitment of three clupeoid species in Tosa Bay.

2. Materials and methods

Larvae and juveniles of clupeoid species (shirasu) were sampled monthly at four stations (T1-T4) of increasing depth (5, 10, 15 and 20 m) from the mouth of the Niyodo River using trawlers between October 2001 and September 2002 (Fig. 1). Two boats towed a net along a depth-contour for *ca.* 1,000 m along each

Usa Institute of Marine Biology, Kochi University, Usa, Tosa, Kochi 781–1164, Japan
[1] Permanent address: Department of Fisheries, Faculty of Agriculture, Gadjah Mada University, Yogyakarta, 55283 Indonesia
[2] Present address: Nishinihon Institute of Technology, 9–30 Wakamatsu-cho, Kochi 780–0812, Japan

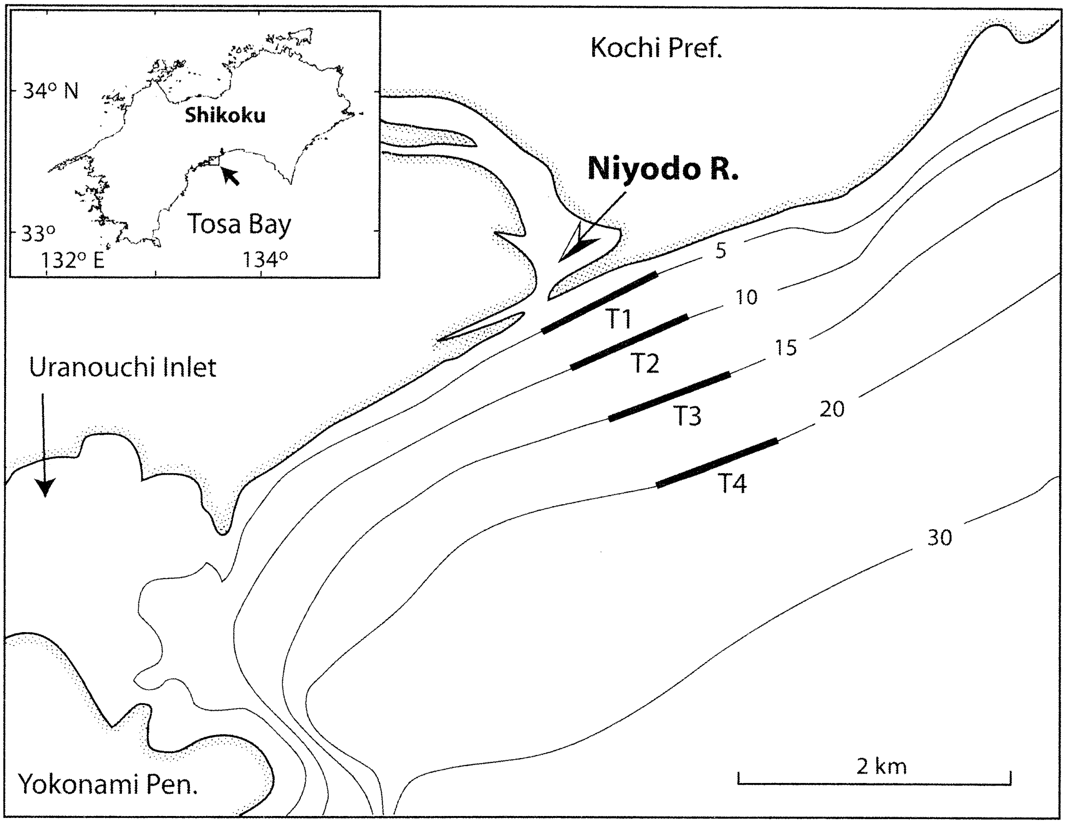

Fig. 1 A chart of Tosa Bay showing the stations (T1–T4) where larvae and juveniles were collected by shirasu trawls from October 2001 to September 2002. Stations were arranged by different depths (5, 10, 15 and 20 m).

station, the mesh aperture of bag-net was 2 mm. Water temperatures and salinities were measured using STD.

All samples fixed in 10% sea-water formalin were then transferred to 80% ethanol until clupeoid fishes were sorted based on developmental stages (KENDALL *et al.*, 1984) in the laboratory. In this study, unlabeled lengths indicate notochord length for preflexion and flexion larvae and standard length for postflexion larvae and juvenile.

A maximum of 100 specimens from collections 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 sagitta were counted with a light microscope at ×400–600, 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 dates. The daily periodicity of increment formation on sagitta in *E. japonicus*, *E. teres* and *S. melanostictus* was determined by TSUJI and AOYAMA (1984), HAYASHI and KAWAGUCHI (1994) and HAYASHI *et al.* (1989), respectively.

3. Results

Temperature and salinity

Seasonal changes in average water temperature and salinity among the depths (0.5 m interval) of all stations are shown in Fig. 2. The temperature was highest (27.7℃) in September, and lowest (15.9℃) in February. Highest and lowest salinities were recorded at 34.6 and 32.6 psu in February and October, respectively.

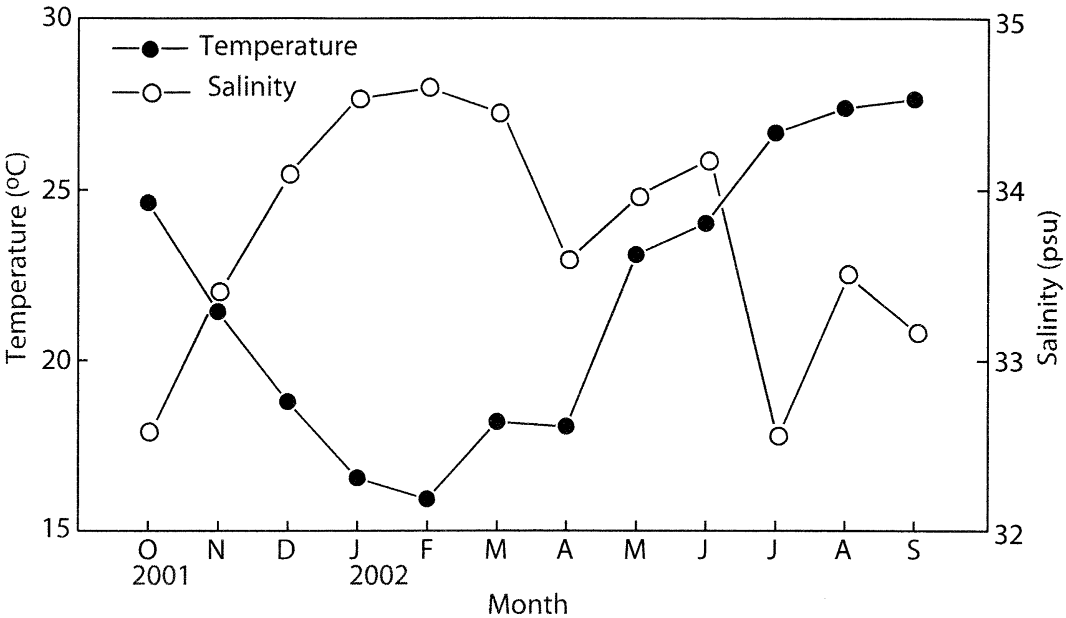

Fig. 2 Seasonal changes of mean temperatures and salinities off the mouth of Niyodo River in Tosa Bay from October 2001 to September 2002.

Table 1. List of clupeoid larvae and juveniles collected by a shirasu trawl in Tosa Bay from October 2001 to September 2002. Total number of fish larvae and juveniles = *ca.* 1.6 million. ne, not examined; +, less than 0.5%.

Species	%	Range of BL (mm)	Range of Age (day)
Engraulis japonicus	61	6.5–37.4	6–68
Etrumeus teres	25	6.6–40.5	4–80
Sardinops melanostictus	7	6.6–40.8	5–64
Sardinella zunasi	+	ne	ne
Spratelloides gracillis	+	ne	ne
Other species	7	ne	ne

The salinity was sporadically lower in July due to heavy rain. Consequently, seasonal patterns of the two physical parameters tended to be reciprocal.

Composition of clupeoid larvae and juveniles

Of *ca.* 1.6 million fish larvae and juveniles collected during the study period, *ca.* 1.5 million fish belonged to the clupeoid species. These comprised five species, with the dominant species being *Engraulis japonicus* (60.8% in numerical percentage), *Etrumeus teres* (24.7%) and *Sardinops melanostictus* (6.7%) (Table 1). Seasonal abundance of the three species is shown in Fig. 3. *E. japonicus* was present all year round, and was dominant in October and from April to September. *E. teres* was collected all year round except in August and September, and was dominant from November to February. On the other hand, *S. melanostictus* was present in limited numbers from November to April, and became dominant only in March. The dominant species thus changed on a seasonal basis.

Total compositions of size and developmental stage of three species were shown in Fig. 3 of DJUMANTO *et al.* (2004). Juveniles larger than 30 mm were appreciably common for *E. teres* and *S. melanostictus*, but rare for *E. japonicus*. All species were chiefly composed of the

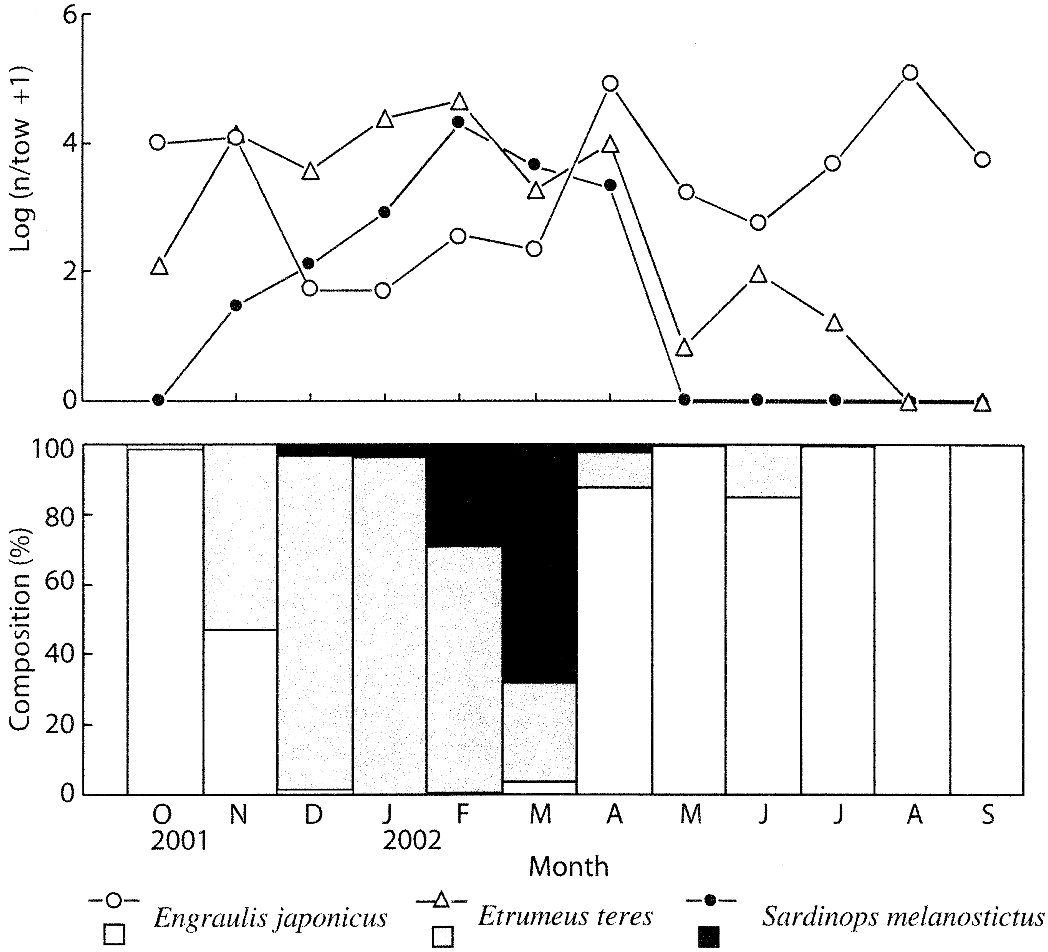

Fig. 3 Monthly fluctuations of CPUE (upper) and monthly compositions (bottom) in larvae and juveniles of three clupeoid species collected by a shirasu trawl off the mouth of Niyodo River in Tosa Bay from October 2001 to September 2002.

postflexion larva stage. 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*.

Ages were distributed from 6 to 68 days for *E. japonicus*, from 4 to 80 days for *E. teres*, and from 5 to 64 days for *S. melanostictus* (Fig. 4). Thus, age ranges for the three species were almost equal. Age frequencies also showed a multi-modal pattern, and modes were found roughly at 29–30 and 49–50 days for *E. japonicus*, 9–10, 29–30, 39–40 and 49–50 days in *E. teres*, and 17–18, 25–26, 31–32 and 51–52 days in *S. melanostictus*. Therefore, younger specimens tended to occur in *E. teres* followed by *S. melanostictus* and *E. japonicus*.

Seasonal changes in size and age

In order to examine the duration of residency in the three clupeoid larvae and juveniles, their size, age and hatching date distributions were compared for each month (Figs. 5–7).

E. japonicus : Modal size increased from October to November, December to February, and June to July, and did not vary substantially during the other months. Size ranges widened from January to March, and were relatively narrow in other months. Modal age was 21–30

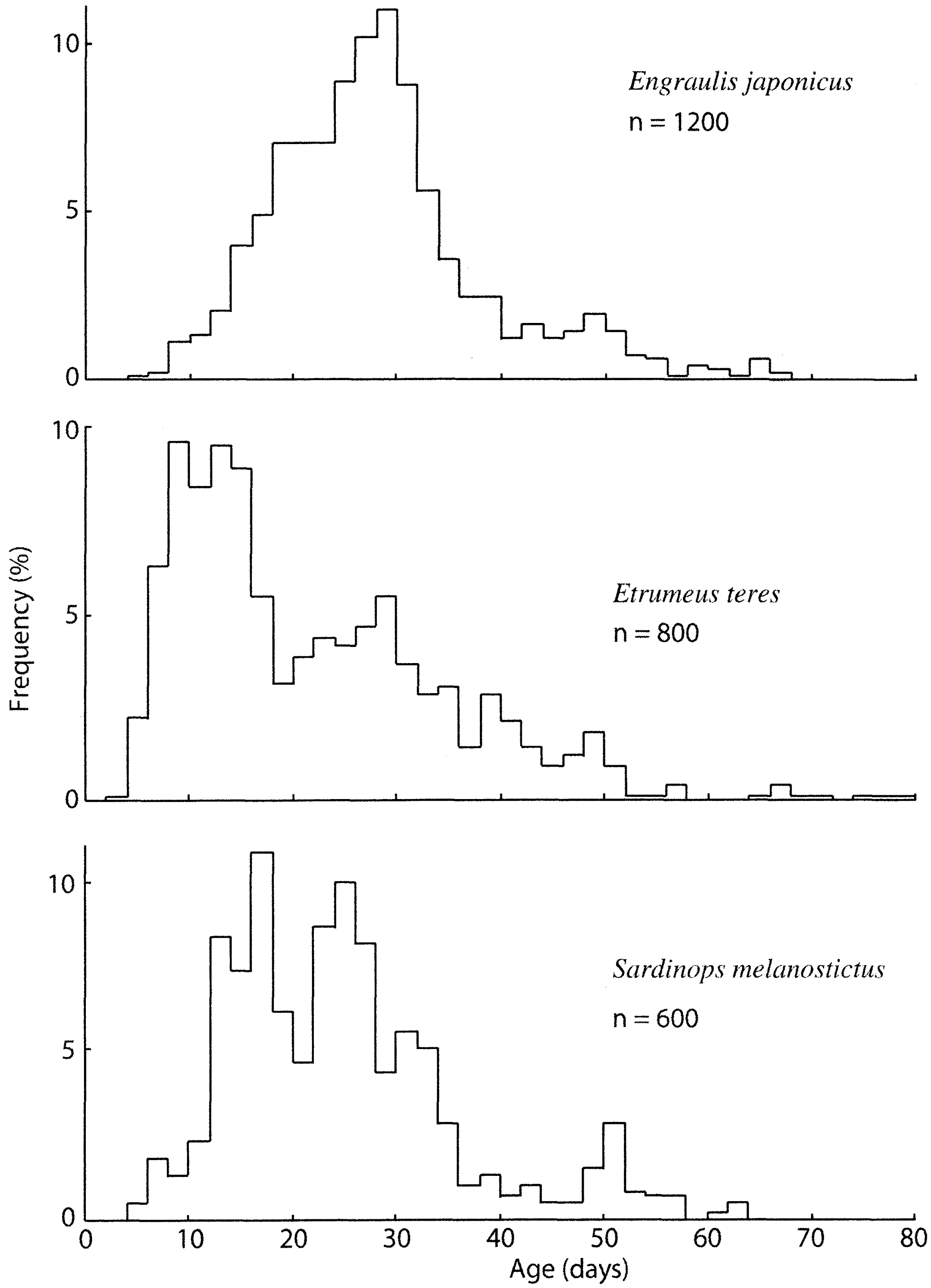

Fig. 4 Age frequencies of three clupeoid fishes collected by a shirasu trawl off the mouth of Niyodo River in Tosa Bay from October 2001 to September 2002.

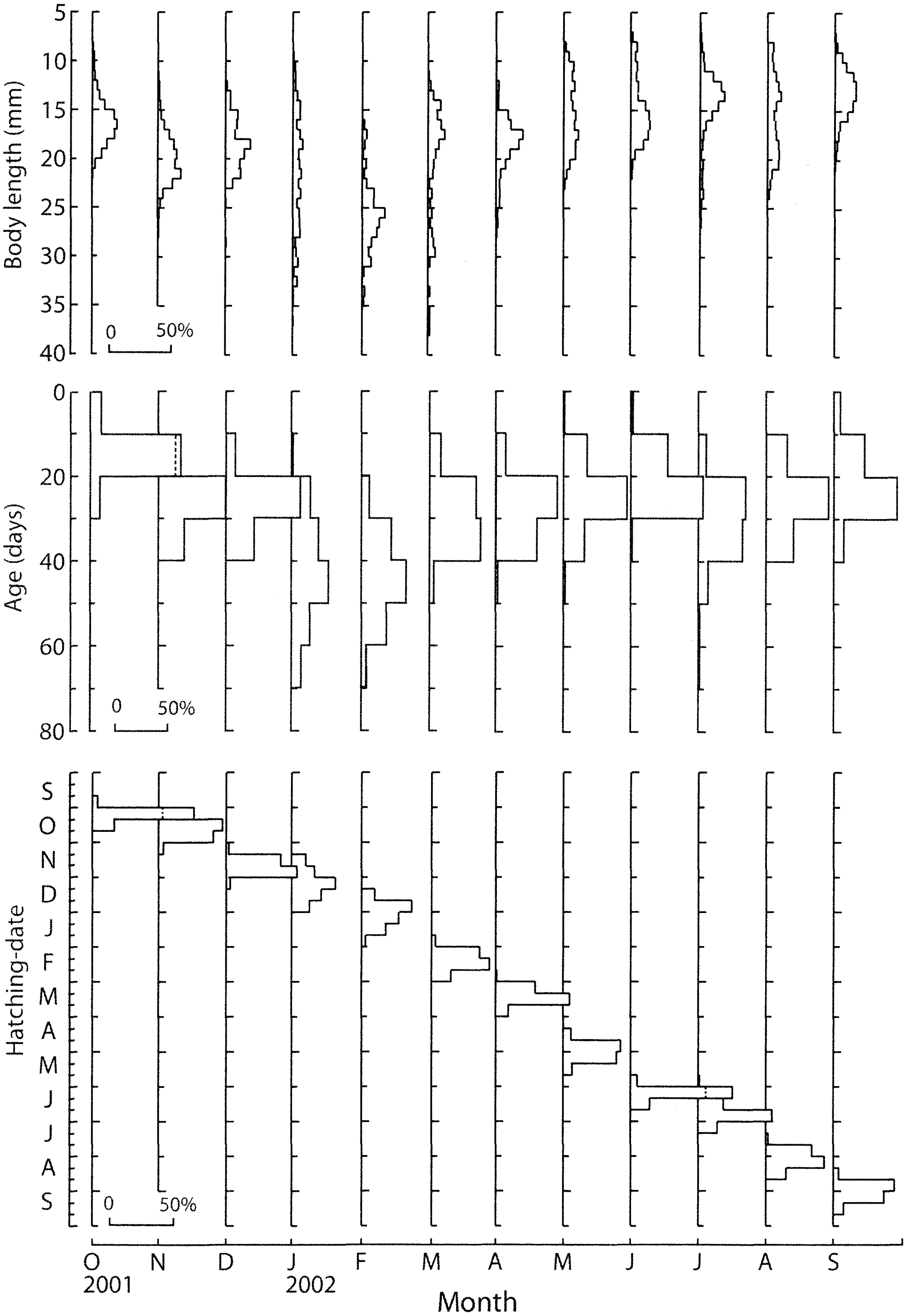

Fig. 5 Seasonal changes in the body length, age and hatching-date distributions of *Engraulis japonicus* collected by a shirasu trawl from October 2001 to September 2002.

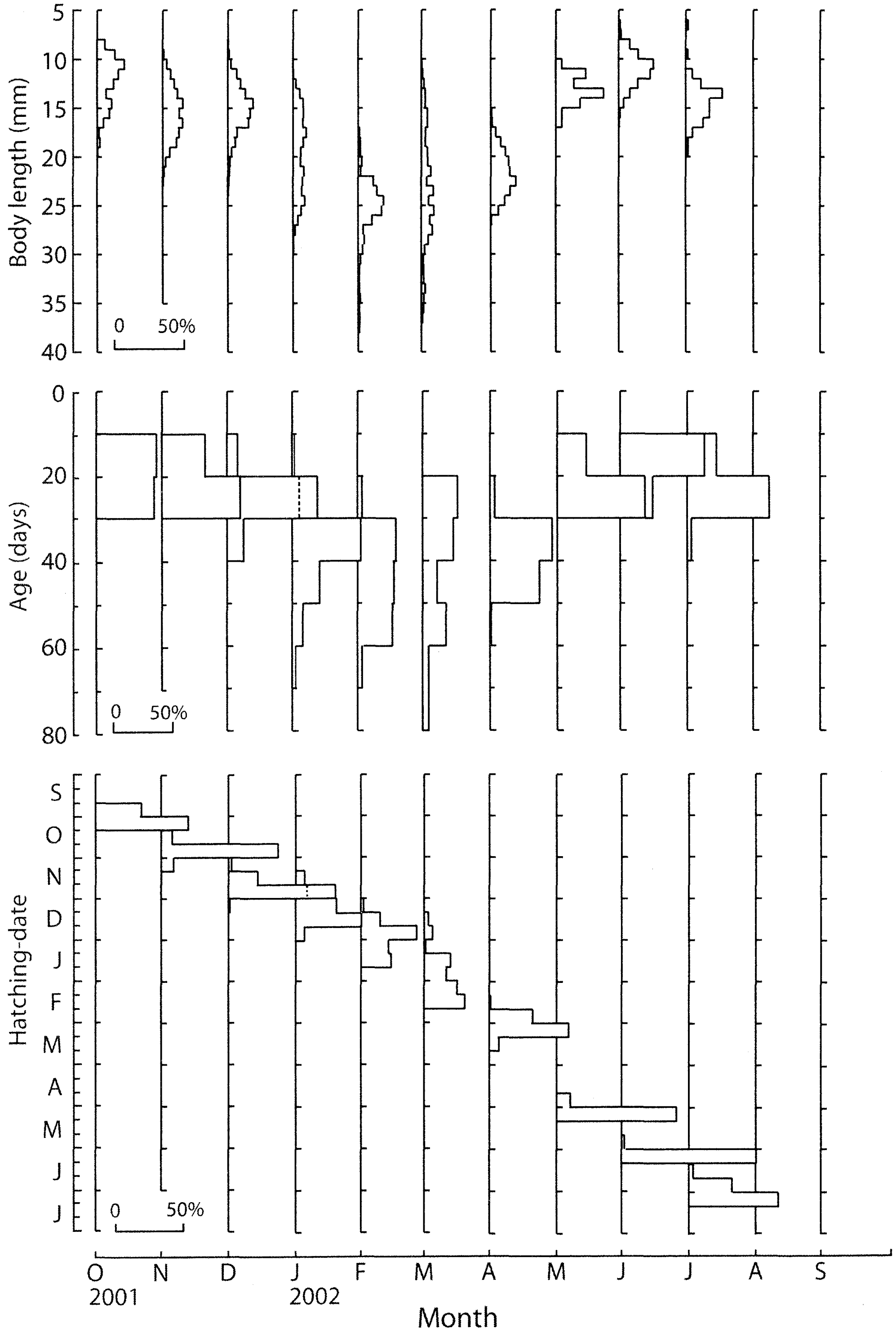

Fig. 6 *Etrumeus teres*. Otherwise same as in Fig. 5.

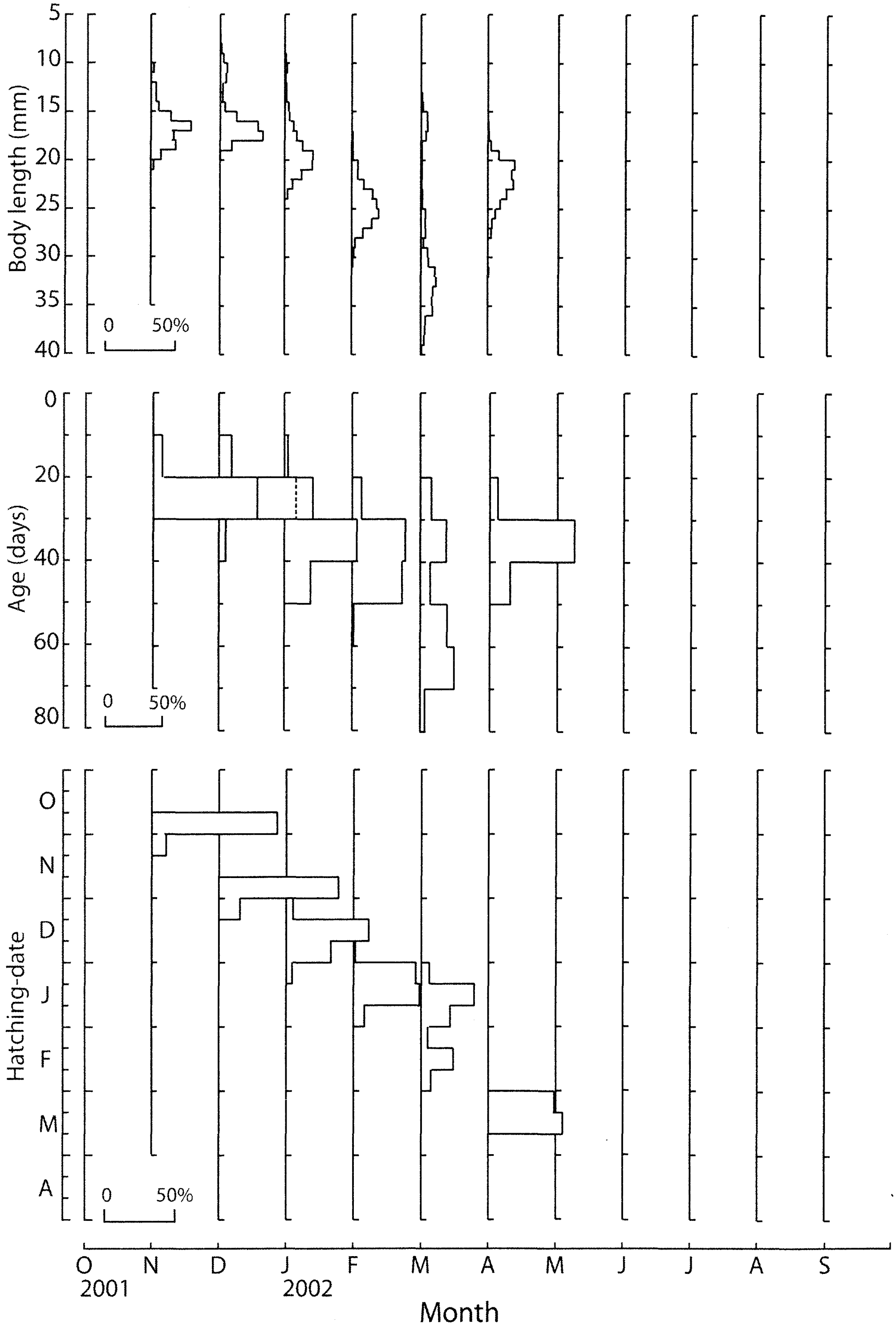

Fig. 7 *Sardinops melanostictus*. Otherwise same as in Fig. 5.

days in most months, but increased to 41–50 days in January and February, when age ranges were also wider than in other months. Hatching dates were distributed over the year, and overlapped between October and November, December and January, January and February, and June and July. The frequency distributions of other months exhibited no distinct patterns.

E. teres: Modal size increased from December to March and June to July, and remained roughly the same in other months. Size ranges widened in January-March, and were relatively narrow in other months. Modal age of 21–30 days was most frequent, and younger and older modes were present in October and June, and from January-April, respectively. Hatching dates were distributed over the year except August and September, and overlapped between January and February, and February and March, and in other months were largely isolated.

S. melanostictus : Modal size increased from January to March, but little differentiation was seen between November and December. Size ranges were wider from January to March, but were narrower in November, December and April. Modal age was at 21–30 days from November to December, 31–40 days in January, February and April, and exhibited two peaks at 31–40 and 61–70 days in March. Hatching dates were distributed from November to April, and distribution overlaps were seen from January to March.

Seasonal changes in horizontal distribution

In autumn (October-December), both *E. japonicus* and *E. teres* were dispersed, and tended to be extend their distributions beyond 2 km offshore (Fig. 8). In winter (January-March), all species were clearly aggregated 0.5 1 km offshore, while they expanded somewhat beyond 1 km offshore in spring (April-June). In summer (July-September), the most dense aggregation of *E. japonicus* was formed near the coast.

4. Discussion

Etrumeus teres larvae and juveniles were dominant from November to February, and were the major shirasu component in Tosa Bay (Fig. 3). Other coasts facing the Pacific seldom or never yield this species of shirasu (ISHIYAMA, 1950; HORI, 1970). This differentiation makes the shirasu community of Tosa Bay unique.

Larvae and juveniles of *Engraulis japonicus* and *E. teres* continued to occur in the fishery ground over most of the year (Fig. 3). This phenomenon is attributable to recruitment from stocks outside as well as inside Tosa Bay (DJUMANTO *et al.*, 2004). *Sardinops melanostictus* larvae and juveniles occurred chiefly in winter for shorter periods than the two species above. This shows that outside stocks have the spawning period as Tosa Bay stock.

Overlapping degree of the hatching date distribution between months for three species indicate that a continual influx and departure of individuals from the fishery ground occurs. This tendency was also found in *E. japonicus* shirasu from Sagami Bay, central Japan (MITANI, 1988a). However, there were overlaps in hatching date distributions in each species. Based on these results of monthly changes of size, age and hatching date, *E. japonicus* were apparently resident during October-November, December-January-February, and June-July, and showed growth during these periods. *E. teres* and *S. melanostictus* hatched from December to February tended to remain for one month and grew in the fishery ground. Although it is unusual that species would be resident for longer periods when the water is coldest, this phenomenon may be attributable to 1) food, 2) density of the fish larva community, or 3) specificity of the cohort.

1) Food: It has been clarified that copepods are a major food source for the shirasu period of the three species (YAMASHITA, 1955, 1957a, b; YOKOTA, 1961; KUWAHARA and SUZUKI, 1984; MITANI, 1988b, c). The longer residence periods in winter may be supported by sufficient biomass of copepods as a food source. Little is known about the seasonal distribution of copepods in coastal waters, such as the fishery grounds of shirasu in Tosa Bay, but HIROTA (1998) reported seasonal abundance of copepods in surf zones of Tosa Bay where their densities were rather lower in winter. Hence, it is

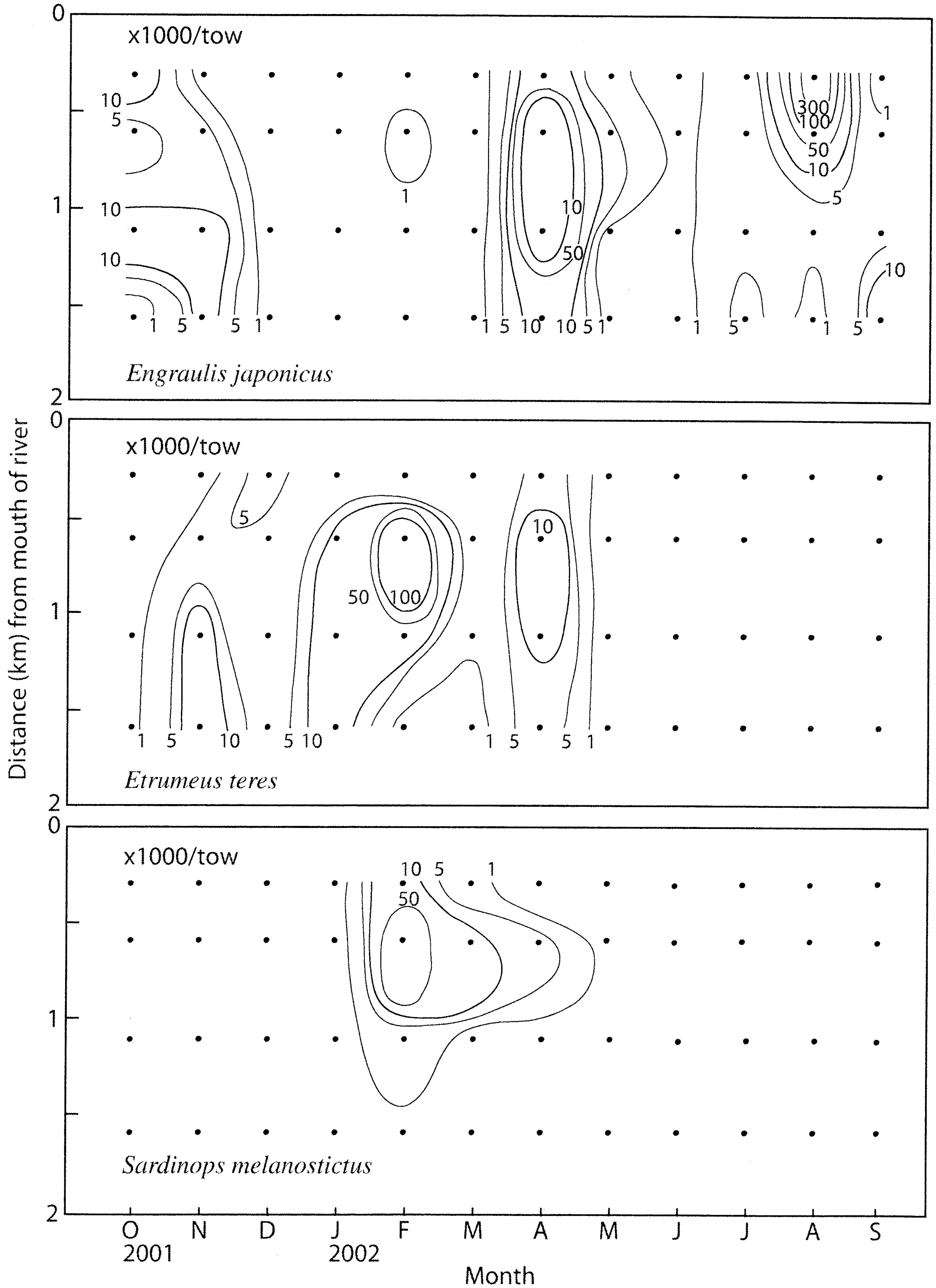

Fig. 8 Seasonal changes of horizontal distributions of three clupeoid shirasu in coastal Tosa Bay from October 2001 to September 2002.

unlikely that residency in winter is attributable to food abundance.

2) Density of the fish larva community: For the *Plecoglossus altivelis altivelis* larvae occurring along surf zones, AZUMA *et al.* (2003) speculated that transition from short- to long-term residence may be caused by an expansion of the distribution range of larvae during the mass-recruitment period, and this expansion contributed to a moderate increase in larval density in the surf zone during the mass-recruitment period. The present study also showed that cohorts became resident in October (*E. japonicus*), December, January (three species) and June (*E. japonicus*), whenever CPUE of all fish decreased (Fig. 3). This indicates that clupeoid larvae are dispersed offshore in a similar manner as *P. a. altivelis* larvae.

3) Specificity of the cohort: It should be noted that long-term resident cohorts of the three species seem to originate from stocks of outside Tosa Bay, other than *E. japonicus* born in June (DJUMANTO *et al.*, 2004). Because earlier larvae should be more easily transported, immigrants seem to grow in new waters, and are less likely to be transported further. Thus, Tosa Bay may be a terminal and supply a nursery ground for transported larvae. Furthermore, they must be recruited into the adult stocks in Tosa Bay. It is suggested this phenomenon is also found in other waters facing the Pacific, and thus these waters seem to supply fish stocks to one another.

Long-term residency of clupeoid larvae is probably attributable to the increased density of larvae and/or origination (immigrants or natives) of cohort.

Acknowledgements

We express our gratitude for assistance from laboratory staffs during fieldwork. This study was partly supported by a Joint Project of Kochi Prefecture and Kochi University. This article English was corrected by T. Jones.

References

AZUMA, K., I. TAKAHASHI, S. FUJITA and I. KINOSHITA (2003): Recruitment and movement of larval ayu occurring in the surf zone of a sandy beach facing Tosa Bay. Fish. Sci., **69**, 355–360.

DJUMANTO, I. KINOSHITA, C. BITO and J. NUNOBE (2004): Partial stock transportation of three clupeoid, *Engraulis japonicus, Etrumeus teres* and *Sardinops melanostictus*, larvae into the shirasu fishery ground of Tosa Bay, Japan. La mer, **42** (in press).

HAYASHI, M., N. TANIGUCHI and K. YAMAOKA (1988): Quantitative analysis on fish larvae and juveniles caught by sardine drag net in Tosa Bay. Usa. Mar. Biol. Inst. Kochi Univ., **10**, 83–92.

HAYASHI, A., Y. YAMASHITA, K. KAWAGUCHI and T. ISHII (1989): Rearing method and daily ring of Japanese sardine larvae. Nippon Suisan Gakkaishi, **55**, 997–1000.

HAYASHI, A. and K. KAWAGUCHI (1994): Growth and daily otolith increment of reared round herring *Etrumeus teres* larvae. Fish. Sci., **60**, 619.

HIROTA, Y. (1998): Ecology of copepods and mysids as prey. *In* Biology of larval and juvenile fishes in sandy beaches. Senta, T. and I. Kinoshita (eds.), Koseisha-koseikaku, Tokyo, p. 78–88 (in Japanese).

HORI, Y. (1971): On the "shirasu" fishery of Ibaraki Prefecture-I. On objective species, sizes, catches and fishery grounds. Rep. Ibaraki Pref. Fish. Sta., **45d**, 10–25 (in Japanese).

ISHIYAMA, R. (1950): Study of the larvae and youngs of the several clupeoid fishes. J. Fish. Sci., **40**, 1–21.

KENDALL, A.W., E.H. AHLSTROM and H.G. MOSER (1984): Early life history stages of fishes and their characters. *In* Ontogeny and systematics of fishes. Moser, H.G., W.J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall, Jr. and S.L. Richardson (eds.), Ame. Soc. Ichthyol. Herpetol., Spec. Publ., **1**, p. 11–22.

KUWAHARA, A. and S. SUZUKI (1984): Diurnal changes in vertical distributions of anchovy eggs and larvae in the western Wakasa Bay. Bull. Japan. Soc. Sci. Fish., **50**, 1285–1292.

MITANI, I. (1988a): Characteristics of daily age composition of larvae of Japanese anchovy *Engraulis japonica* in the fishing ground in Sagami Bay. Nippon Suisan Gakkaishi, **54**, 209–214.

MITANI, I. (1988b): Distribution pattern cyclopoid copepods *Oithona* spp. in the shirasu (anchovy larvae) fishing ground in Sagami Bay. Nippon Suisan Gakkaishi, **54**, 215–219.

MITANI, I. (1988c): Food habits of Japanese anchovy in the shirasu fishing ground within Sagami Bay. Nippon Suisan Gakkaishi, **54**, 1859–1865.

TSUJI, S. and T. AOYAMA (1984): Daily growth increments in otoliths of Japanese anchovy larvae *Engraulis japonica*. Bull. Japan. Soc. Sci. Fish., **50**, 1105–1108.

YAMASHITA, H. (1955): The feeding habit of sardine, *Sardinia melanosticta*, in the waters adjacent to Kyushu, with reference to its growth. Bull. Japan. Soc. Sci. Fish., 21, 471–475.

YAMASHITA, H. (1957a): Relations of the foods of sardine, jack mackerel, mackerel and so on, in the waters adjacent to west Kyushu. Rep. Seikai Reg. Fish. Res. Lab., **76**, 45–53.

YAMASHITA, H. (1957b): On the relation between the food and the shape of the intestines of sardine, jack mackerel, mackerel and their kindered species found in the west coast Kyushu. Rep. Seikai Reg. Fish. Res. Lab., **77**, 55–68.

YOKOTA, T. (1961): On the feeding habit of juvenile fishes. Rep. Nansei Reg. Fish. Res. Lab., **14**, 41–152, 230–232.

Received December 13, 2004
Accepted January 27, 2005