Differentiated Spatial Distribution of Larvae and Juveniles of the Two Sparids, Red and Black Sea Bream, in Shijiki Bay*$^{1}$

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In Shijiki Bay of Hirado Island, diel discrete-depth horizontal tows with a larva net in May 1983 resulted in a total of 2,350 larval and juvenile red sea bream (2.1–10.7 mm SL), and 347 larval black sea bream (2.4–6.2 mm SL) being collected. During the daytime, black sea bream larvae were concentrated near the surface, but red sea bream larvae near the bottom, with these tendencies becoming more evident with their growth. During the nighttime, the larvae of both species were dispersed throughout the water column. In the surf zone of the sandy-beaches located in the innermost part of the bay, collections with a small seine net in June and July 1983 gave a total of 241 late-larval and early-juvenile black sea bream (6.2–20.1 mm SL), but no red sea bream. The separation of juvenile habitats between these related species seemed to be a consequence of the species-specific vertical distribution pattern differentiated during the pelagic larval period. A possible mechanism for inshore migration in the black sea bream was discussed in relation to their surface occurrence.

Among the sparid fishes distributed around the Japanese coast, the red sea bream Pagrus major (Temminck et Schlegel) and black sea bream Acanthopagrus schlegeli (Bleeker) are two of the most popular and highest-priced commercial species. These two species are known to spawn at nearly the same season, the larval distributions overlapping both temporally and spatially. However, recent ecological research on the early life history of coastal fishes has revealed the existence of species-specific nursery areas for juvenile fishes.

Since 1975, we have conducted comprehensive and continuous ecological studies on red sea bream in Shijiki Bay.$^{2-11}$ These studies demonstrated that the larvae hatched in offshore spawning grounds were gradually concentrated around the bay, before finally settling on the 10 to 15 m deep bottom at the innermost part of the bay. Although black sea bream larvae were collected together with red sea bream larvae by larva net tows, the juveniles were seldom collected by beam-trawl surveys until 1982.

Recent studies performed on surf zones of sandy-beaches revealed high aggregations of late-larvae and early-juveniles of black sea bream near shoreline.$^{12-14}$ In view of this information, we therefore sampled juvenile black sea bream in the sandy-beach surf zones of Shijiki Bay in 1983, and succeeded in the collection of late-larvae and early-juveniles.

The complete separation of juvenile habitats between the two sparids leads us to hypothesize that distributions, particularly vertical, might have already differentiated during their pelagic larval period. The main purpose of the present study is to clarify the species-specific difference in the vertical distribution of larvae of these two sparids and to discuss this phenomenon in relation to their discrete juvenile habitats in Shijiki Bay.

Materials and Methods

Figure 1 shows the sampling stations (L1–L11 and S1–S4) for larval and juvenile fishes. Day and night collections of the pelagic larvae were

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made by discrete-depth horizontal tows at 0, 10, 20, and 30 m depth with a larva net (1.3 m mouth-diameter, 6 m long, and 0.33 mm mesh-aperture: designed after Smith et al.15) at St. L2 located at the mouth of the bay on 9-10 May 1983. Towing was performed for 10 min at a speed of about 2 kt, depths of tow being monitored by depth recorder. The volume of filtered water was estimated from a flowmeter record equipped on the net. Salinities and temperatures were measured at 0, 5, 10, 20, and 35 m during the larva net sampling. All such sampling was conducted on RV “Yoko” (500 t) belonging to Seikai Regional Fisheries Research Laboratory. Additionally, two oblique tows with the same net were carried out by a fisherman’s boat at St. L2 on 24 May 1983.

At St. S1–S4 situated in the surf zone, larval and juvenile collections were made with a small seine on 13–14 June and 7–8 July 1983. The monthly collection consisted of four tows at each beach. The structure of the seine used and the collecting methods are described in Kinoshita.14)

The plankton samples including fish larvae were preserved in 10% sea-water formalin until sorting and measuring in the laboratory, and then transferred to 80% ethanol.

Collections obtained by oblique tows of the same larva net used here form St. L1 to L11 in late April and mid May 1977 were used for assessment of the horizontal distribution and size compositions of larval black sea bream in the bay.

Results

Vertical Distribution in the Mouth of the Bay

A total of 2,350 larval red sea bream (including a few early-juveniles) and 347 larval black sea bream were collected at St. L2 on 9–10 May 1983. General vertical profiles and their diel changes of the two species are shown in Fig. 2, and those of salinities during the larva net sampling in Fig. 3.

Red sea bream larvae were dispersed throughout the layer from 10 to 30 m at the first nighttime (0350–0432 h), but mainly near the bottom at daytime (1157–1238 h). They moved upward at twilight (1901–1938 h), and were generally dispersed throughout all layers (except for 20 m layer) at the second nighttime (0002–0044 h). In contrast, black sea bream larvae were distributed mainly in the layers shallower than 20 m at both nighttime, and in the surface at daytime and twilight, being particularly highly concentrated at the surface at twilight.

Length-related differentiation in the vertical distribution patterns of the two species is shown in Fig. 4. Larvae of both species were inclined to be dispersed throughout all layers, irrespective of size class, at nighttime. At daytime, red sea bream larvae under 3 mm SL were distributed in
the middle layers, while those over 3 mm SL were concentrated near the bottom. The 6–9 mm size larvae occurred exclusively at the 30 m layer. At twilight and nighttime, size-related vertical distribution showed a considerable difference from that of the daytime; mid-layer occurrence was more apparent with increase in size, particularly at nighttime. In black sea bream, larvae over 6 mm SL were only rarely encountered at any sampling time unlike those of red sea bream which were abundant in all samples. Black sea bream larvae over 4 mm SL were found predominantly in the surface layer during the day and at twilight. Except for 6 mm size larvae (only two fishes), surface occurrence combined with size-increase was also observed even at nighttime.

Size Compositions in the Mouth of the Bay
A total of 781 larval and juvenile red sea bream and 89 larval black sea bream were collected during two oblique tows on 24 May 1983. Size compositions of this sample of the two species were compared with those obtained on 9–10 May (Fig. 5).

The size compositions of red sea bream showed a marked difference between the two collection dates: 2.1 to 10.7 mm SL, with a mode of 3.1–4.0 mm SL on 9–10 May, and 2.3 to 10.6 mm SL, with a mode of 5.1–6.0 mm SL on 24 May. In the black sea bream, larval sizes ranged from 2.4 to 6.2 mm SL on 9–10 May, and from 2.6 to 7.1 mm SL on 24 May. The mode of 3.1–4.0 mm SL on 9–10 May slightly increased to 4.1–5.0 mm SL on 24 May. The percentage of larvae over 6 mm SL was 11.9% in the red sea bream, but only 0.8% in the black sea bream.

Occurrence in the Surf Zone
A total of 241 late-larvae and early-juveniles of black sea bream was collected in the surf zone on 13–14 June and 7–8 July 1983, but no red sea bream was found.

Black sea bream ranged in size from 6.2–20.1 mm
SL in June, and 6.6–10.5 mm SL in July (Fig. 6). No larvae of less than 6 mm SL were found in the surf zone, this size composition clearly differing from that at the mouth of the bay. The largest number was obtained at St. S2 (Fig. 1) in June. The size distribution indicates the presence of two groups, a smaller one with a mode of 8.1–9.0 mm SL and a larger one of 13.1–14.0 mm SL. This larger size group was not seen at any stations in July (Fig. 6).

Discussion

Previous studies on the diel vertical migration of red sea bream larvae made in Shijiki Bay clearly demonstrated the larvae to inhabit mainly near the bottom during daytime, to move up to the mid layer at twilight, and to disperse finally throughout the water column, with a slight peak near the surface during nighttime. Although the nighttime migration to the surface layer is not as evident in the present study, the overall diel changes in vertical distribution in these studies are regarded as being fundamentally similar. However, little is known of the diel vertical distribution of black sea bream larvae, but recent surveys made in western Wakasa Bay showed larvae to be distributed mainly near the surface during daytime, but somewhat dispersed down to the mid layer during nighttime. This pattern is almost identical to that found in the present study. Together, these findings demonstrate that the main vertical habitat of black sea bream larvae is near the surface and shallower than that of red sea bream larvae.

Our previous papers clearly showed the distribution pattern of the demersal juveniles of red sea bream in Shijiki Bay. The juveniles aggregate near the bottom of 10 to 15 m deep areas at the innermost part of the bay, and are sparsely distributed in near-shore areas shallower than 5 m. Furthermore, previous beam-trawl surveys clearly showed the absence of black sea bream juveniles from the main habitat for juvenile red sea bream. The present sampling performed in the surf zones obtained a considerable number of late-larvae and early-juveniles of black sea bream. Thus, the present data combined with the previous information reveals a clear horizontal separation of the main habitats for early-juveniles of these two sparid fishes.

The horizontal habitat separation of the juveniles seems to be intimately related to the vertical habitat differentiation of the larvae. Black sea bream juveniles are well known to be distributed in near-shore eelgrass beds and exhibit a high tolerance towards low-salinities. The development of low-salinity tolerance with larval growth was preliminarily reported. This ability has been reexamined by Kimura and Tanaka who showed involvement of hypophyseal prolactin in low-salinity adaptation. These facts suggest that black sea bream larvae begin to show a preference for lower salinities in their early larval phase, resulting in their occurrence near the surface, where salinities are commonly lower than the deeper strata.

The surface occurrence may be of significance as regards immigration into the near-shore areas such as surf zones. In general, there is a horizontal salinity gradient near the surface, and this is from higher in offshore to lower in inshore areas. The combined effects of this salinity gradient and lower-salinity preference of the larvae seem to accelerate the inshore migration. Tidal currents play an important role in transporting larvae into near-shore nurseries in pleuronectiform larvae, and in larvae of the Australian yellowfin sea bream, a lunar-phased immigration into estuaries, apparently caused by tidal currents, has also been shown. Since this effect acts strongly

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in surface waters, black sea bream larvae may easily be carried to near the shoreline.

The size frequency difference which exists between black sea bream at the mouth of the bay and the surf zone, clearly shows the boundary size of 6–7 mm SL (Fig. 7). This seems to be a critical phase in inshore migration from coastal to near-shore areas. Figure 8 shows the size compositions of black sea bream at the mouth, central, and innermost parts of the bay surveyed in 1977. Although little difference is evident in the size composition among the three parts as a whole, larvae over 6 mm SL are more abundant in the innermost part of the bay, strongly suggesting that larvae migrate toward the bottom of the bay when they grow beyond 6 mm SL.

The swimming ability improves dramatically following the completion of the notochord flexion,24) which in the black sea bream, starts at approximately 4 mm SL and is completed at 6 mm SL.24,25) Recent analysis of tissue thyroxine concentration in laboratory-reared black sea bream larvae revealed the existence of a surge at 6–7 mm SL.26) This evidence suggests that black sea bream larvae begin to migrate inshore owing to their development of locomotion system and endogenous physiological function just after about 6–7 mm SL.

Near-surface concentrations of larvae during daytime are found in the silverside Hypoatherina bleekeri, mullet Liza affinis, whiting Sillago japonicus, opaleye Girella punctata, and tigerfish Rhyncopelates oxyrhynchus,27)*1 all of which utilize surf zones as their juvenile nurseries.12) The correlation between larval surface appearance and juvenile surf zone nurseries might be a general rule in coastal marine fishes.

The main food animals of early-juvenile red sea bream are two species of copepod, Acartia omorii and A. steueri, and gammarids.7) The juveniles tend to aggregate toward the innermost part of the bay according to the density gradient of the near-bottom aggregations of copepods.9) This means that the route of inshore migration in red sea bream is along the bottom. Conversely, black sea bream occurring in the surf zone mainly feed on three genera of copepod, Paracalanus, Oncaea, and Oithona, but not on Acartia.*2 The former three copepod genera are rarely found near the bottom in the mouth and central parts of the bay.13) The differentiation in feeding habits might have occurred from the rather early larval phase. Further consideration from the viewpoint of feed.

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ing ecology is also necessary to understand the mechanism of inshore migration.

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