Studies on the early life history of the genus *Seriola* in the East China Sea

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The population of marine fishes is mainly determined by survival during the early life stages. Thus, clarifying the spawning ground, the larval transport processes and the survival strategy of larval and juvenile fishes are necessary to understand the recruitment mechanism of fishes. *Seriola* spp. is one of the most important fish for aquaculture in Japan. Yellowtail *Seriola quinqueradiata* and greater amberjack *S. dumerili* comprise approximately 60% of the marine finfish aquaculture in Japan. Their annual production is about 150,000 tons, and valued 100 billion yen. It has been reported that the spawning of *S. quinqueradiata* mainly occurs from January to June around the edge of the continental shelf in the East China Sea (ECS). In addition, *S. quinqueradiata* juveniles (1.0 cm standard length; SL–18.0 cm total length; TL) associate with drifting seaweeds, and are transported to Japanese coast by the Kuroshio Current or Tsushima Warm Current. Juveniles of *S. dumerili* (1.7–29.7 cm SL) also associate with drifting seaweeds, and relatively large juveniles (over 15 cm TL) occur with drifting seaweeds in early summer around Japan. However, little information is available on the early life history of *Seriola* spp. in the ECS, especially the spawning ground and transport route of *S. dumerili*. In Japan, *Seriola* spp. juveniles associating with drifting seaweeds in the ECS are used for aquaculture seedlings. However, the strategy of associative behavior with drifting seaweeds in *Seriola* spp. juveniles is still unclear. It is necessary to determine *Seriola* spp. spawning ground, the larval transport route and survival strategy of juvenile in the ECS in order to achieve sustainable farming. In this study, I estimated the spawning ground and transport route of larval and juvenile *Seriola* spp., and investigated their associative behavior strategies with drifting seaweeds in order to understand the early life history of *Seriola* spp. in the ECS.

In order to investigate spawning ground and transport route of *S. dumerili*, research cruises were conducted in the northern and western part of Taiwan in 2015. Larval and juvenile fishes were collected by surface towing of large plankton net (Φ1.3 or 1.6 m, 330 μm mesh), while fish juveniles associated with drifting seaweeds were collected by a hand net (Φ45 cm, 3 mm mesh). Hydrographic condition data and zooplankton in the sampling sites were also collected. Results showed that larvae and early-juveniles of *S. dumerili* (7.4–42.5 mm TL) were collected in the thermal fronts by surface towing, but not from drifting seaweeds in May and July 2015 around the Penghu Islands, Taiwan. Based on the otolith analysis, ages of *S. dumerili* samples were between 18 to 56 days after hatching, indicating they hatched between April to June. Consistent northward current was observed around the Penghu Islands, which is presumed to be one of the spawning grounds of *S. dumerili* was the southern part of the Penghu Islands in the South China Sea (SCS). It is possible that *S. dumerili* spawned from April to June in the SCS occur in western Kyushu coast in early summer from the

estimated transportation period by current (Chapter II).

To determine the strategy of associative behavior with drifting seaweeds in *Seriola* spp. juveniles, research cruises were conducted in the Goto Sea, Japan which is in the northeastern part of the ECS. First, I hypothesized that *Seriola* spp. juveniles associate with drifting seaweeds for effective feeding. To test this hypothesis, the “concentration of food supply” hypothesis (fish juveniles attracted by phytal animals on the drifting seaweeds) and the “indicator-log” hypothesis (fish juveniles use drifting seaweeds as an indicator of productive areas such as frontal area for food) were tested. Zooplankton abundance of frontal areas was not significantly different from other areas, and drifting seaweeds were aggregated around the frontal areas of surface currents. A total of 14 drifting seaweed masses were collected and gut content analysis of fishes associated with the seaweed were examined. I found that 49.7–99.7% of the individual fishes fed on planktonic food, and the feeding incidence on phytal animals was less than 50% (22 species, *n*=408). Among *Seriola* spp. juveniles, 98.7% of *S. quinqueradiata* and 100% of *S. dumerili* fed on planktonic food, whereas feeding incidence on phytal animals was lower than other species, 3.8% in *S. quinqueradiata* and 0% in *S. dumerili*. Based from the results, it was revealed that *Seriola* spp. juveniles do not associate with drifting seaweeds for feeding (Chapter III).

Second, I hypothesized that *Seriola* spp. juveniles associate with drifting seaweeds to form a school or to reduce predation risk. Fourteen rafts equipped with a GPS buoy, still and video cameras, and seaweed clump were deployed in the Goto Sea from April to June in 2013 and 2014, in order to test the “meeting point” hypothesis (fish juveniles use drifting seaweeds as an indicator to increase the encounter rate with conspecific) and/or the “shelter from predator” hypothesis (fish juveniles use floating structures as a refuge from predators). The number of fish and school size of *Seriola* spp. juveniles significantly increased over time, up to 9 days after releasing. Furthermore, *Seriola* spp. juveniles swam around the seaweeds during the daytime and attached to the seaweeds or conspecifics at night, indicating that *Seriola* spp. juveniles maintained the school at night by associating with drifting seaweeds. Some of the solitary fish and a small school hide into the seaweeds when potential predators appeared. Based from these results, it was revealed that the “meeting-point” and the “shelter from predator” match the strategies of associative behavior with drifting seaweeds in *Seriola* spp. juveniles (Chapter IV).

In conclusion, it was suggested that the larval and juvenile *S. quinqueradiata* were transported from various part of the spawning ground in the ECS to the Goto Sea, whereas larval and juvenile *S. dumerili* hatched in the SCS were transported to Japanese coast. *Seriola* spp. juveniles utilized drifting seaweeds as a refuge from predators when their school size was small and increased their school size using drifting seaweeds as an indicator. Forming school is advantage such as anti-predation and effective feeding, thus *Seriola* spp. juveniles may increase survival and growth rates by associating with drifting seaweeds.