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Juvenile swimming performance of three fish species on an exposed sandy beach in Japan

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Abstract

Surf zones of sandy beaches, physically dynamic environments due to high wave exposure, provide an important nursery habitat for the juveniles of many marine fish species. This study was specifically aimed at clarifying the juvenile swimming and positioning abilities of three surf zone species (*Mugil cephalus cephalus*, *Terapon jarbua* and *Trachinotus baillonii*), using an experimental tank. Average critical swimming speed was greater for *M. cephalus cephalus* (47.03 cm s^{-1}) than in the other two species (*T. jarbua* = 22.79 cm s^{-1}, *T. baillonii* = 26.16 cm s^{-1}) and critical swimming speed standardized by total length tended to be greater for *M. cephalus cephalus* than in the other two species. The greater swimming ability of *M. cephalus cephalus* was primarily due to greater propulsive ratio, muscle ratio and body fineness ratio. The positioning ability, defined as the amplitude of fish oscillations relative to water flow, did not differ significantly among the three species. The fish amplitude was about 0.15–0.36 times that of water amplitude. The lack of significant differences in positioning ability, despite the greater swimming ability of *M. cephalus cephalus*, was due to greater fineness ratios and shorter nose to pectoral fin base distances, resulting in greater drag when the body was turned. The results of present study suggested that juvenile surf zone fishes do not necessarily have significantly greater swimming ability in order to resist the effects of high wave exposure.

Keywords: Juvenile fish; Morphological traits; Oscillatory flow; Positioning ability; Surf zone; Swimming ability

1. Introduction

Although sandy beach surf zones are physically dynamic environments due to high wave exposure that provides little habitat complexity, numerous studies have shown that they support numerous species and abundant numbers of fishes (e.g., Lasiak 1981, 1984; Gibson et al., 1993; Clark et al., 1996). In fact, such fish faunas are dominated by postlarvae and/or juveniles (e.g., Gibson et al., 1993, 1996; Suda et al., 2002), indicating a strong likelihood of surf zones functioning as a nursery habitat for many marine fish species (Brown and McLachlan, 1990).

Several studies have demonstrated that the degree of wave exposure affects species-specific fish occurrence in surf zones. For example, Beyst et al. (2001) found a negative correlation between the total density of fish species and wave height, and Romer (1990) also reported that the number of both individuals and species decreased in accordance with high wave exposure. On the other hand, Clark (1997) reported that highest species richness and highest diversity in fishes were recorded at intermediate levels of wave exposure. Other studies have shown that turbidity caused by wave

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breaking had a positive influence on species richness and/or abundance of fish assemblages in a surf zone (e.g., Lasiak, 1986; Beyst et al., 2002). Lasiak (1986) suggested that high wave exposure might have a positive effect on the abundance of juvenile fishes due to protection from predators. Thus, it is reasonable to conclude that wave exposure influences the species richness and/or abundance of fishes in surf zones.

The spatial distribution of fishes in terms of degree of wave exposure has been reported as being closely related to their swimming ability (Fulton et al., 2001; Fulton and Bellwood, 2004). However, although previous studies have emphasized the effects of wave exposure on fish assemblage structures in surf zones (e.g., Romer, 1990; Beyst et al., 2001, 2002; Watt-Pringle and Strydom, 2003), the swimming ability of juvenile fishes in surf zones has received rather less attention. One of the specific aims of the present study was to clarify the swimming ability of three species of juvenile fishes occurring in surf zones in Japan. Since the surf zone of a sandy beach is characterized as a location in which continuous oscillatory flow is caused, the reactions of juvenile fishes to such flow should be investigated. In this study, the reactions of juvenile fishes against oscillatory flow were measured as positioning ability (for definition, see Materials and methods), such being measured for the three species.

2. Materials and methods

2.1. Test animals

Juvenile fishes were collected on the Kashimanada coast, located on the easternmost part of Honshu Island, Japan (35°46.6′ N, 140°48.3′ E). Sea bottom inclination was about 7/1000, wave height between 0.5 to 2.5 m and median particle diameter of a bottom sediment about 0.2 mm (Higano, 2003). The collection site was categorized as an ’exposed beach’ in accordance with McLachlan (1980).

A small seine net and push net were used to collect fishes in September 2003 and December 2005. The seine was fitted with a weighted footrope and operation conducted parallel to the shoreline by two to six people (water depth = approximately 0.3–1.0 m). Sampling by push net was conducted by one person. Fishes were immediately transferred to a seawater tank after collection and transported to the laboratory.

Three species, *Mugil cephalus cephalus* (L.), *Terapon jarbua* (Forsskål) and *Trachinotus baillonii* (Lacepéde), were used for the experiment, since the former two being dominant in the study area (Gomyoh et al., 1994) and exhibiting few stress symptoms after collection (Nanami, personal observation). Although not a dominant species at the sampling site (Gomyoh et al., 1994), *T. baillonii* was also included in the analysis since few stress symptoms were apparent after collection. Although three other species (*Salangichthys ishikawae* Wakiya and Takahashi, *Plecoglossus altivelis altivelis* Temminck and Schlegel and *Engraulis japonicus* (Houttuyn)) were also dominant in the study area (Gomyoh et al., 1994; Nanami, unpublished data), they were not subjected to experiment due to having been significantly damaged during collection. Since the aim of the study was to measure the swimming ability and positioning ability of juvenile fishes occurring in the surf zone, adults were not collected.

2.2. Tank for experiment

Experiments were conducted in an experimental tank at the National Research Institute of Fisheries Engineering, Ibaraki, Japan. The tank consisted of an O-shaped pipe with a rectangular 70-cm long × 16-cm wide × 15-cm high working section (Fig. 1). A motor attached and rotating impeller controlled the water movement in the working section. By alternating the spin direction regularly, an oscillatory flow was caused. The amplitude and cycle period of the impeller (T) was adjusted so as to produce a nearly sinusoidal water movement. Fishes were retained in the working section by two sheets of a 0.7-mm wire netting. The relationship between impeller revolutions and water velocity at the center of the working section is shown in Table 1.

The swimming performance of fish in the working section may be affected by hydrodynamic interactions with the walls, the energy cost of swimming in low speed water being reduced if undertaken near the wall (Webb, 1993). Indeed, fishes that were measured in the present study mainly swam near the wall and/or bottom of the working section. Thus, the relationship between impeller revolutions and water velocity <1.0 cm from the bottom was clarified using an Acoustic Doppler Velocimeter (Nortek). In this procedure, water velocity was measured 1000-times with 0.1-second intervals, and averaged. Subsequently, the relationship among impeller revolutions, setting velocity (water velocity at the center of the working section) and water velocity near the bottom was obtained (Table 1). The area of the working section was large enough to accommodate swimming for juvenile fishes and few constraints of fish locomotor movements caused by the wall were observed during the experiment.