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Anti-predatory performance in hatchery-reared red tilefish (*Branchiostegus japonicus*) and behavioral characteristics of two predators: Acoustic telemetry, video observation and predation trials

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ABSTRACT

The anti-predatory performance of hatchery-reared red tilefish (*Branchiostegus japonicus*) using tube-shaped burrows was studied together with the behavioral characteristics of potential predators, the white spotted conger (*Conger myriaster*) and the marbled rockfish (*Sebastiscus marmoratus*). White spotted conger were released in Maizuru Bay (Kyoto, Japan) and tracked using acoustic telemetry; they were also observed in a tank using video recording. White spotted conger tended to remain inside shelters, but occasionally swam outside briefly at night. Attacking behavior of predators and predation avoidance behavior of red tilefish were also recorded in a tank. Red tilefish construct tube-shaped burrows into which they retreat to avoid attack. White spotted conger wandered around the tank, often invading the burrows to prey on red tilefish. Predation by white spotted conger occurred at night. Inside the burrows, red tilefish were not easily caught and were able to escape through the other entrance of the tube-shaped burrow. Marbled rockfish, on the other hand, pounced on red tilefish immediately after prey recognition, ambushing their prey near the burrow entrance. Predation by marbled rockfish was frequently observed around dusk and dawn, but some red tilefish that remained inside burrows survived. White spotted conger is nocturnal and probably an olfactory predator, whilst marbled rockfish is crepuscular and an ambush predator. For stock enhancement of red tilefish, the construction of tube-shaped burrows and their diurnal behavior around the burrows are desirable characteristics in reducing predation by both white spotted conger and marbled rockfish.

1. Introduction

In stock enhancement programs, predation is the primary cause of mortality in released juveniles (Bell et al., 2008; Howell, 1994; Masuda and Tsukamoto, 1998; Oliver et al., 2008; Støttrup et al., 2008). Some of this mortality is attributable to the inferior behavior of hatchery-reared fish compared with their wild counterpart (Álvarez and Nicieza, 2003; Brown and Day, 2002; Olla et al., 1994). It is, therefore, important to evaluate and improve fish quality in terms of behavioral characteristics in each target species for stock enhancement (Tsukamoto et al., 1997, 1999).

In Japan, red tilefish (*Branchiostegus japonicus*) is a target species for stock enhancement due to its high commercial value and relatively sedentary behavior (Kiyono et al., 1977). In the 1990s, yearly production of 100 000 juveniles was achieved at Miyazu Station (Kyoto, Japan), National Center for Stock Enhancement of the Fisheries Research Agency (FRA) (Hondoh et al., 2001; Okumura, 2001). Since 1998, hatchery-reared red tilefish juveniles of ~100 mm total length (TL) have been released in the Sea of Japan. However, of ~20 000 fish marked with spaghetti tags and released in Wakasa Bay (a coastal area of the Sea of Japan) up to 2003, only 18 individuals have been recovered. The rate of recovery was extremely low (Machida et al., 2007), and released juveniles were found in the stomach contents of white spotted conger (*Conger myriaster*) and rockfish (Scorpaenidae) caught 1 day post-release (Kyoto Prefecture, 2003, 2004).

Post-release mortality of hatchery-reared juveniles can be reduced by improvement of the behavioral characteristics that enable red tilefish to avoid predation. Wild red tilefish are diurnal, construct tube-shaped burrows, remain in the burrows at night to avoid predators and emerge during the day (Mitamura et al., 2005; Yokota et al., 2004, 2006, 2007a). Hondoh et al. (2002) reported that hatchery-reared red tilefish also have the ability to construct burrows.

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Table 1
Conger myriaster. Data summary for white spotted conger released in Maizuru Bay in the acoustic telemetry (Sections 2.2. and 3.1.). Body weight (BW), percentage of transmitter weight to BW, tracking period, VR2 station recording the greatest number of signals after the fish was detected at the same position using the VR60, and major peak in VR2 record frequency shown by fast Fourier transformation.

Fish	BW (g)	Percentage of transmitter weight/BW (transmitter type[a])	Tracking period[b] (days)	Station of VR2 recording the greatest number of signals[c]	Major peak in VR2 record frequency[d] (hours)
C1	324	1.45 (V9-2L)	11 Sep 2006–14 Sep 2006 (3)	–	–
C2	722	0.72 (V9P-1L)	11 Sep 2006–9 Nov 2006 (59)	5	Unclear
C3	248	1.90 (V9-2L)	15 Sep 2006–15 Sep 2006 (0)	–	–
C4	387	1.21 (V9-2L)	15 Sep 2006–18 Apr 2007 (215)	1	23.87
C5	391	1.20 (V9-2L)	15 Sep 2006–26 Jan 2007 (133)	8	23.82
C6	263	1.79 (V9-2L)	15 Sep 2006–21 May 2007 (248)	2	23.85
C7	431	1.21 (V9P-1L)	15 Sep 2006–17 Apr 2007 (214)	5	23.64
C8	507	1.03 (V9P-1L)	15 Sep 2006–20 Sep 2006 (5)	–	–
C9	395	1.32 (V9P-1L)	15 Sep 2006–10 Mar 2007 (176)	7	Unclear
C10	952	0.54 (V9P-1L)	15 Sep 2006–19 Feb 2007 (157)	9	Unclear
C11	507	1.03 (V9P-1L)	20 Sep 2006–3 Feb 2007 (136)	5	23.52

[a] VEMCO Ltd., Canada.
[b] The period from the release to the last record.
[c] Positions of the station are shown in Fig. 1.
[d] The peak indicates the long-term cyclical behavioral pattern of the white spotted conger.

However, the diel activities of some hatchery-reared fish differ from those of wild fish (Yokota et al., 2006, 2007a, 2007b). This difference might result in more frequent encounters between hatchery-reared fish and predators, high predation mortality and low recovery rates of released juveniles.

Two factors are critically important for the survival of red tilefish juveniles: the diurnal behavior in avoiding predation and the ecological characteristics of predators in encountering prey. White spotted conger is distributed in the coastal waters of Japan and it is a predator of red tilefish. Japanese commercial fishermen catch white spotted conger using baited tubular pots (Uchida et al., 2005), implying that this species has a habit of entering holes and crevices. The behavioral characteristics of white spotted conger larger than 400 mm TL (piscivorous size) (Nabeshima, 2001), have not been studied; thus, foraging periods and when they encounter red tilefish juveniles are unknown. Another potential predator of red tilefish is marbled rockfish (*Sebastiscus marmoratus*). They are sedentary, demersal, and commonly distributed in both in-shore and off-shore waters at depths shallower than 200 m; they are well known as a crepuscular feeder (Fujita and Kohda, 1996; Imaizumi, 1974; Ishida, 1997; Kusakabe et al., 2005; Yatomi et al., 2005).

It is important to determine the time periods during which white spotted conger are active foragers. In addition, predator–prey interactions should not be overlooked (Fairchild et al., 2008). It is important to know the search and attack behavior of predators but, as regards stock enhancement, it is also important to describe the anti-predator performance of red tilefish. While spotted conger were hypothesized not to be active during the day, because wild red tilefish would avoid encounter with predators. Diurnal activity was expected to ensure low predation mortality of hatchery-reared red tilefish. Fish having constructed tube-shaped burrows were hypothesized to be less vulnerable to predators than those having no shelter. The objectives of this research were to (1) study the behavioral characteristics and diel activity of white spotted conger and marbled rockfish and (2) investigate whether the diurnal pattern of burrow use by red tilefish juveniles is advantageous for reducing predation mortality.

2. Materials and methods

2.1. Fish collection and husbandry

Sixty-five red tilefish juveniles (74–132 mm TL) were hatched and raised for 9 months in 25-L tanks in the Miyazu Station (FRA) at temperatures of 10.0–27.0 °C and a natural photoperiod. Thirty-eight white spotted conger (494–848 mm TL) and 12 marbled rockfish (174–233 mm TL) were caught with set nets around the mouth of Maizuru Bay (Kyoto, Japan), which forms part of Wakasa Bay. Eighteen white spotted conger were kept in Maizuru Fisheries Research Station (MFRS) of Kyoto University, while the remaining conger and marbled rockfish were transferred to Miyazu Station of FRA. White spotted conger and rockfish were kept for less than 1 month in 500-L tanks at temperatures of 15.0–27.0 °C with a natural photoperiod.

2.2. Acoustic telemetry of white spotted conger in the wild

Acoustic telemetry on 11 white spotted conger (C1–11; 540–848 mm TL; Table 1) was conducted between September 2006 and May 2007 in Maizuru Bay (Fig. 1) to study the horizontal/vertical movement and diel activity in the wild. Transmitters V9-2L (9.0 mm

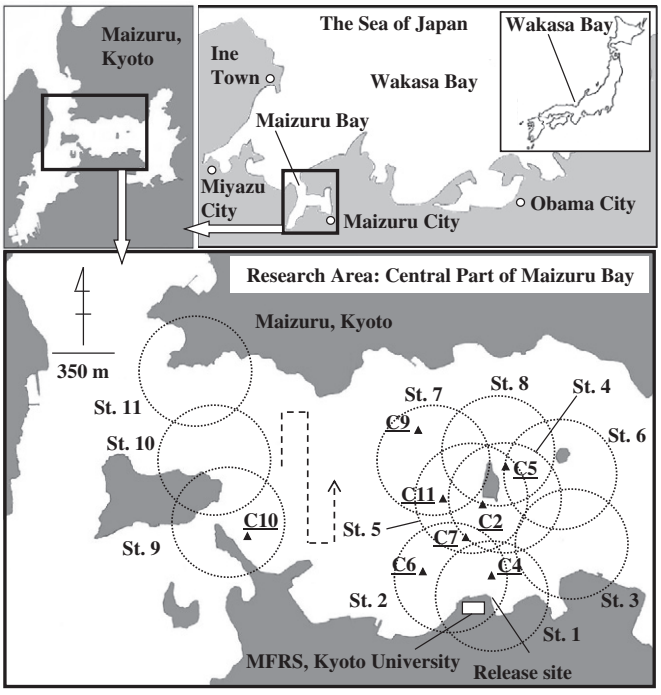

Fig. 1. *Conger myriaster*. Location of Maizuru Bay (Kyoto, Japan) and map of research area in the acoustic telemetry on white spotted conger (Sections 2.2 and 3.1, Table 1). Dashed circles and solid triangles represent the receiving ranges of VR2s and the settled positions of fish, respectively. The fish were released from the center of the receiving range at St. 1. Dashed line with arrowhead shows an example of a sample route in searching for fish using the VR60. Maizuru Fisheries Research Station: MFRS.