

Ex situ and in situ measurements of juvenile yellowfin tuna *Thunnus albacares* target strength

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Abstract To provide target strength (TS) information for estimating the body length of yellowfin tuna *Thunnus albacares* and its abundance around fish aggregating devices, TS was measured ex situ and in situ. In the ex situ TS measurements, two cameras synchronized with a 200 kHz echosounder were used to obtain the precise orientation of the yellowfin tuna under free swimming conditions. The ex situ TS (dB re 1 m²)–fork length (FL, cm) regression was: $TS = 27.06 \log(FL) - 85.04$. Ex situ TS was found to reach its maximum in the tilt angle range of -15° to -20° after excluding TS samples with insignificant correlation to the tilt angle. The angle between the vertebra and the swim bladder was approximately 25° according to X-ray images, supporting the above tilt range. The relationship between the swim bladder volume (V_{SB} , ml) and the fork length was: $V_{SB} = 0.000213 FL^3$. The results from the in situ TS measurements indicated that the tilt angle was highly concentrated between -10° and 15° . The results from a

calculation using the ex situ TS–FL equation with the fork length from biological sampling agreed strongly with the average in situ TS.

Keywords Target strength · Fork length · Yellowfin tuna · FAD · Swim bladder

Introduction

Yellowfin tuna *Thunnus albacares* (YFT) was once one of the most abundant resources for tuna fisheries around the world; however, stocks of YFT have been depleted by many commercial fisheries in the three main oceans since the 1950s. According to the 2007 FAO Yearbook, the global catch of YFT began to decline in 2003 because fishing efforts have increased and advanced fishing technologies have been commonly applied to the tuna fishing industry [1]. One important reason for the downturn in YFT stocks could be the mortality of juvenile YFT caught as by-catch. Documentation from the Western and Central Pacific Fisheries Commission pointed out that 80% of the YFT caught by purse seine using a fish aggregating device (FAD) were immature in the Western Central Pacific Ocean (WCPO) [2]. This was true not only in the WCPO but also in other oceans. For example, 42 anchored FADs in the coastal waters of Taiwan were set up by the Taiwan Fisheries Research Institute (TFRI). Most of the YFT around the FADs in Taiwan were found to be immature. The annual catch of migratory fish per FAD was estimated to be about 200–300 tons in Taiwan, so the areas where the FADs are effective have become extremely important fishing grounds for coastal fishermen [3]. However, FAD-aided fishing has become a controversial issue in domestic and sustainable fisheries management. Therefore, some

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