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A practical survey with vertical-longline for characterizing vertical fish species distributions on Hachirigase Sea Hill, Sea of Japan: A case study assuming a complement for echosounder-based fish stock assessment

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Abstract: Accurate estimation of fish stocks is crucial for the sustainable use of fishery resources in offshore sea hills. However, bottom trawling is not practical for estimating fish stocks in areas with bumpy or rocky seabed topography. Although quantitative stock surveys using echosounders are effective, the identification of fish species from echograms remains a challenge. This study investigated the efficacy of vertical longlining in identifying fish species distributions near the seabed during an echosounder survey around Hachirigase Sea Hill in the Sea of Japan in June 2006. Seven species were caught at 7 of the 8 stations, resulting in a CPUE (inds./10-minute longlining) of 1.15. Threeline grunts and red lizardfish were the most abundant species, accounting for 43.7% and 37.0% of the CPUE, respectively. Threeline grunts were caught between the seafloor and 9 m above the seafloor, while red lizardfish were caught only in a narrow layer between the seafloor and 3 m above the seafloor. A significant difference in height above the seafloor was revealed between the two species. The study found that vertical longlining could complement echosounder-based surveys and may be an effective approach to determining the abundance of fish on a sea hill where trawl surveys are difficult.

Keywords : *acoustic survey, sampling gear, sampling method, sea hill*

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1. Introduction

Located on the continental shelf of the Sea of Japan, Hachirigase Sea Hill off Mishima Island, Japan, is an important spawning and nursery ground supporting coastal fisheries (Fig. 1). However, fishers are concerned that unplanned and illegal fishing is devastating fish resources in this area (e.g. HAMANO and UCHIDA, 2000). The accurate estimation of fishery resources is essential for their sustainable use and conservation (HAMANO and NOMURA, 2002).

The undulating rocky seabed at Hachirigase Sea Hill prevents the surveying of fish stocks using trawls. The area is accessible by an unusual trawl, with strong synthetic net fibers, large rubber bobbins, metal discs along the footrope, and precise electronic positioning systems; however, it destroys the habitat (KOSLOW *et al.*, 2001). We previously applied an acoustic monitoring method to assess the distribution and abundance of fish in this area (TANOUE *et al.*, 2008; HAMANO *et al.*, 2015). This method still requires the identification of fish species detected in echograms (e.g. VILLAR *et al.*, 2021), such as through *in situ* surveys, for the accurate estimation of fish abundance (SIMMONDS and MACLENNAN, 2005).

In waters with bumpy terrain such as rocky reefs, sampling can be accomplished through fishing with longlines or rods (MCCLATCHIE *et al.*, 2000); for example, *Tamanawa* (Japanese name), a type of longlining, is a fishing method wherein one main line connected to floats (buoys) at regular intervals is spread out over the sea surface with many branch lines suspended vertically in the water, allowing for the assessment of the relative density and vertical distribution of fish near the seabed (MAEDA *et al.*, 1982; ARIMOTO *et al.*, 1983).

In addition, the simple fishing method known as vertical longlining employs one main line with multiple branch lines attached at intervals that is vertically suspended in the sea so that one end reaches the seafloor. This method enables prompt casting and recovery of the fishing gear for real-time sampling of fish detected by an echosounder. In surveys using quantitative echosounders to estimate the biomass of alfonsino, *Beryx splendens,* around a seamount, this vertical-longline method has been used to identify fish species (KOMATSU *et al.*, 2002). This study examines the characteristics of fish species distributions using vertical-longline on Hachirigase Sea Hill.

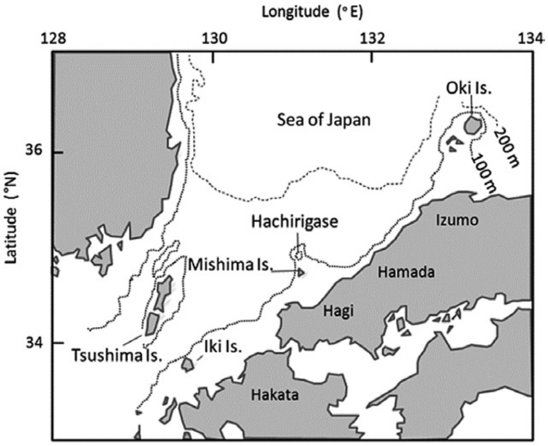

Fig. 1 Hachirigase Sea Hill, one of the most important offshore natural reef fishing grounds on the continental shelf southwest of the Sea of Japan.

2. Materials and methods

On 21 and 22 June 2006, we conducted vertical-longline sampling of fish on Hachirigase Sea Hill aboard a fishing boat (6.08 tons). The survey period was limited to daytime on two consecutive days in consideration of possible changes in fish behavior between daytime and nighttime and to ensure concurrency of the observations (SIMMONDS et al., 1992; TANOUE *et al.*, 2007).

We used a 50-kHz echosounder (FCV-291,

Furuno Electric Co., Ltd.) equipped on the boat to measure fish echoes and their depths (Tanoue *et al.*, 2007; Tanoue *et al.*, 2013a). Vertical-longline fishing methods can be classified into two techniques: longlines operated through handling of the main line and longlines deployed with attached floats called *tarunagashi* (drifting barrels) in Japanese. In this survey, the former method was used to catch fish displayed on the echosounder, which reduced the risk of lost gear. Lost gear causes various problems, including ghost fishing (e.g. Ruitton *et al.*, 2019).

In vertical-longline fishing, fish are caught on a line deployed by hand, without the use of floats or fishing rods. To investigate fish species distributions by depth, we attached 10 branch lines (length: 0.375 m; diameter: 0.285 mm; load capacity: 5 kg) to the main line (diameter: 0.375 mm) at intervals of 1.5 m. A 187.5-g weight was attached to the end of the main line. The species and size selection (e. g. Hovgård and Lassen, 2000; Yamashita *et al.*, 2010), and fish catch (e.g. Porsmoguer *et al.*, 2015) vary depending on the hook. In this study, it was important that fish distributed on the hill were caught without selection, so we decided to use the following hook based on the results of a preliminary survey (e.g. Hamano *et al.*, 2001; Hamano and Nomura, 2002).

Circle hooks (called *nemuri-bari* or *mutsu-bari* in Japanese) with a curved shape (gap: 7 mm; height: 16 mm) were used as fishing hooks (e.g. Prpmjinda *et al.*, 2008) and attached to the branch lines. In addition to the fishing lures that fishermen normally use in the field, boiled mysids were also used as bait to catch species that are less dependent on sight in order to reduce the selectivity of fish species as much as possible (e. g. Kawamura *et al.*, 1970; Wolf and Chislette, 1974; Kawamura and Tamura, 1990).

We set eight sampling stations across the hill

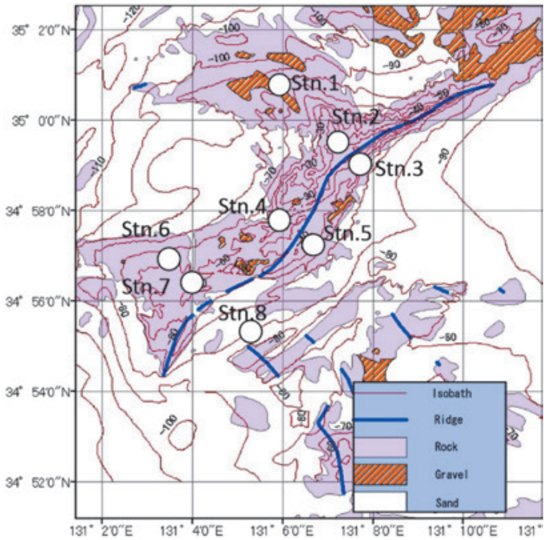

Fig. 2 Sampling stations (open circles) on Hachirigase Sea Hill in June 2006.

and allocated 10 minutes for catching fish with a vertical longline at each station (Fig. 2). If more than one fish was caught in a 10-minute fishing session with a vertical longline, the sampling time at that station was extended by 10 minutes. This extension was repeated until no more fish were caught. The catch per unit effort (CPUE: individuals/10-minute longlining) of vertical-longline fishing was defined as the number of fish caught divided by the number of 10-minute fishing sessions.

3. Results and discussion

We caught 7 species at 7 of a total of 8 sampling stations and during 18 of a total of 27 sampling times, resulting in a CPUE of 1.15. The proportional contribution to the CPUE for each fish species was 43.7% for threeline grunt (*Parapristipoma trilineatum*), 37.0% for red lizardfish (*Synodus ulae*), and less than 5% each for the other species, including cherry bass (*Sacura margaritacea*), bottom perch (*Apogon semilineatus*), filefish (*Thamnaconus modestus*), John dory (*Zeus faber*), and rockfish (*Sebastes inermis*). In this study, as only one type of hook was used and the size was constant, we did not correct CPUE due to differences in these variables. Although it is very difficult to eliminate species selectivity completely by hook, we caught fish species that are expected to be distributed in the Hachirigase, which has been confirmed by market research and underwater camera surveys (e.g. HAMANO *et al.*, 2001; HAMANO and NOMURA, 2002; FUJIWARA *et al.*, 2018). Thereafter, we discuss the distribution of the main catches of threeline grunt and red lizardfish.

Threeline grunt is a commercially harvested species that swims in schools (SUZUKI *et al.*, 2003; KOMATSU *et al.*, 2011; TANOUE *et al.*, 2013b), is benthopelagic (FROESE and PAULY, 2021), and inhabits rocky coastal seafloor areas, which are important fishing grounds for this species. The mean fork length of the threeline grunts (n = 13) caught at six sampling stations (Stns. 2–7) in a rocky area with bottom depths < 60 m was 28.3 ± 4.7 (mean ± standard deviation) (range: 19.4–34.0) cm, and mean body weight was 440.8 ± 191.9 (range: 119.3–646.8) g. The red lizardfish is demersal and lives on coastal reef flats with sandy or rocky bottoms (FROESE and PAULY, 2021). The mean fork length of red lizardfish (n = 12) collected at five stations in rocky and sandy areas (Stn. 4–8) was 17.0 ± 2.5 (range: 13.0–23.0) cm and the mean body weight was 47.5 ± 31.0 g with a range of 24.9 to 144.2 g.

According to KAWANO (1997), the fork lengths of 2, 3, 4, 5, 6 and 7-year-old threeline grunts on the Sea of Japan side of Yamaguchi Prefecture were estimated to be 18.4, 22.8, 26.2, 28.9, 31.1 and 32.0 cm, respectively. In addition, the mean and deviation fork length of the threeline grunts caught in this study were almost the same as the threeline grunts inhabiting the coast of Hagi City, including Hachirigase reported by KAWANO (1997). Additionally, the fork length of the captured red lizardfish was as wide as the threeline grunts. Some reports (e.g. ERZINI *et al.*, 1996; KATAYAMA and FUJIMORI, 2018) have shown that the hook width selectivity curves of longlines are much wider than typical curves, such as those of gillnets. In addition, as red lizardfish have a large mouth and swallow bait, the tendency to select the size of the catch (ERZINI *et al.*, 1997) was moderate.

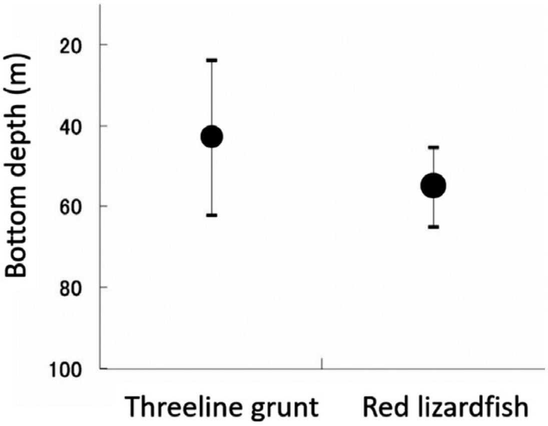

Fig. 3 Mean bottom depths (closed circles) at which threeline grunts and red lizardfishes were caught with a vertical-longline on Hachirigase Sea Hill in June 2006. Bars indicate standard deviations.

Threeline grunts and red lizardfishes were sampled at sites with bottom depths of 43.3 ± 19.3 and 55.5 ± 10.0 m, respectively (Fig. 3). No significant difference in the bottom depth of the sampling sites where these fishes were caught was found between the two species (Mann-Whitney U test, $p > 0.05$). Threeline grunts, a benthopelagic species, were caught between the seafloor and 9 m above the seafloor, whereas red lizardfishes, a demersal species, were caught only in a narrow band between the seafloor and 3 m above the seafloor (Fig. 4). The mean heights from the seafloor where threeline grunts

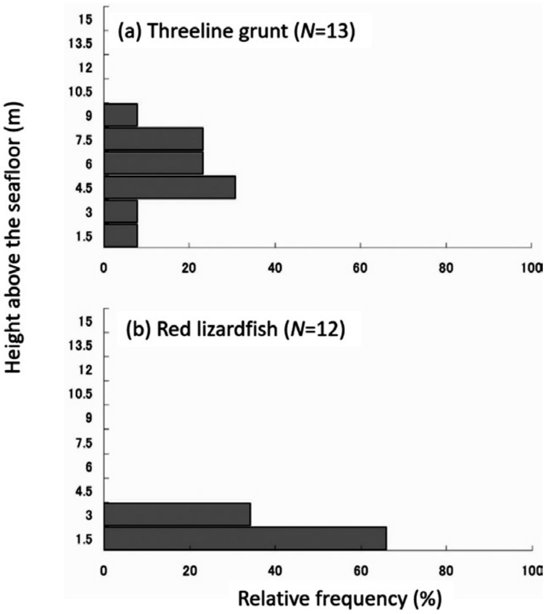

Fig. 4 Sampling frequencies of threeline grunts (a) and red lizardfishes (b) by height above the seafloor on Hachirigase Sea Hill in June 2006.

(n = 13) and red lizardfishes (n = 12) were caught were 5.5 ± 2.0 and 2.0 ± 0.7 m, respectively. A significant difference was found between the two fish species in height from the seafloor (Mann-Whitney U test, $p < 0.01$).

Our surveys revealed that the dominant species below a height of 9 m from the seabed in rocky areas shallower than 60 m in the fish echoes observed from Hachirigase Sea Hill was an important commercial fish in that area, threeline grunt. When investigating threeline grunts in June using an echosounder, surveying was most efficient around noon, when the fish do not move (TANOUE *et al.*, 2013b). We predicted catch, based on information from a preliminary survey, but cross-checking by underwater visual censes (e. g. RUITTON *et al.*, 2000) and environmental DNA (e.g. SATO *et al.*, 2021) are also important for verification.

This study shows that the vertical-longline sampling is effective for characterizing vertical fish species distributions on a sea hill where trawl surveys are difficult. If fish species can be assigned to fish echoes using criteria based on height-specific contribution to total CPUE, the accuracy of fish stock estimation is expected to improve.

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