Monitoring behavioral characteristics of the rockfish *Sebastescheni* inhabitinga seawall using LBL acoustic positioning system

YUKO SAKURAI[1] , KEIICHI UCHIDA[1], HIROMICHI MITAMURA[2], YOSHINORI MIYAMOTO[1],
TOSHIHARU KAKIHARA[1] and NOBUAKI ARAI[2]
[1]*Tokyo University of Marine Science and Technology, 108-8477 Tokyo, Japan*
Email: kuchida@kaiyodai.ac.jp
[2]*Graduate School of Informatics, Kyoto University, 606-8501 Kyoto, Japan*

ABSTRACT
Many members of the genus *Sebastes* exhibit homing behavior. Specifically, these species will return to the site where they have been captured after being released. In addition, *Sebastes* spp. exhibit site fidelity and diel migration in their home territories and foraging areas. The aim of this study was to use a high-precision ultrasonic biotelemetry system to accurately clarify the horizontal distribution patterns and the diurnal vertical movements of *Sebastescheni* inhabiting a seawall. Field experiments were conducted in Uraga Bay, Japan. The small bay is enclosed by seawalls and the sea floor of the area is smooth and approximately 10m deep. In 2011, experimental fish was captured using a hook and line and a transmitter with built-in a depth sensor was implanted into the peritoneal cavity of each fish. To reduce anomalous readings, the locality data were filtered using swimming speed, HDOP and excluded landing. Movement patterns were then monitored using a radio-linked acoustic positioning system after release at a site 40 m distant from the capture site. Tagged fish were observed to return to the site where they were captured, remaining in a relatively small area for the duration of the monitoring period. Tagged fish utilized three core areas in their home range, one was used during the day and the others were used between sunset and sunrise. Tagged fish remained at approximately 5m below the surface during the daytime, exhibiting more extensive vertical movements at night.

KEYWORDS: rockfish, *Sebastescheni*, acoustic positioning system, vertical migration

INTRODUCTION

Numerous studies have examined the behavior of rock fishes using ultrasonic biotelemetry systems (Jorgensen et al. 2006, Parker et al. 2008, Mitamura et al. 2009, Kristen &Richard 2011). While most of these studies have been conducted in areas of natural coast, in Tokyo Bay, most coastal areas have been artificially altered by large-scale land reclamation projects and the construction of ports. Consequently, most of the coastal sites in the bay are composed of artificial vertical seawalls. Although these seawalls are generally considered to have had an adverse impact on the marine ecosystem, several marine species have successfully colonized these environments; the target fish of this study, black rockfish *Sebastes cheni*, is one such species. Rockfishes are commonly found on rocky seafloors where obstacles and seaweed are abundant. They are also commonly found near vertical seawalls without obstacles, which are popular sites for pier fishing.

In this study, we investigated the behaviors of black rockfish found in an area bordered by vertical seawalls using an acoustic positioning system. Specifically, we used a long baseline (LBL) acoustic positioning system to accurately clarify behavioral patterns. However, since the presence of vertical seawalls around the study area interfered with the ultrasonic signals of the LBL system. In addition, because the positioning accuracy of the LBL system is dependent upon the geometric arrangement of the receiver, as well as the physical relationship between the target and the baseline of the triangle. We therefore developed a method to filtering the obtained locality data obtained using the LBL system under the confined water by seawall.

MATERIALS AND METHODS

The study was conducted in Uraga Bay in Kanagawa Prefecture, Japan, in June 2011. The bay is approximately 10 m-deep and is enclosed by a vertical seawall (Fig. 1). For the long baseline ultrasonic biotelemetry system, a VEMCO radio acoustic positioning system (VEMCO Radio-linked Acoustic Positioning (VRAP) system, Amirix Systems Inc., Halifax, Canada) was used. The VRAP telemetry system consists of three receiver buoys aligned in triangular array and a base station. Under optimal acoustic conditions, the position of transmitters can be determined to an accuracy of 1 to 2 m inside the buoy triangle (VEMCO 2003). Black rockfish were collected by hook and line from a pier in a closed-off section of Uraga Bay (Fig.1). The characteristics of the tagged fish and the acoustic transmitter are shown in Table 1. The transmitter was surgically implanted into the peritoneal cavity of the fish under anesthesia with 0.1% 2-phenoxyethanol.The fish were assumed to have established territories along the seawall at the sites where they were caught.

Table 1 Summary of tagged fish and acoustic transmitter

Fish	
fork length	21.6 cm
weight	182 g
Acoustic transmitter with depth sensor (MP-9-SHORT)	
size	9 mm × 35 mm
weight in water	2.2 g
manufacturer	THELMA, Trondheim, Norway
emission interval	1/sec (life: 45 days)

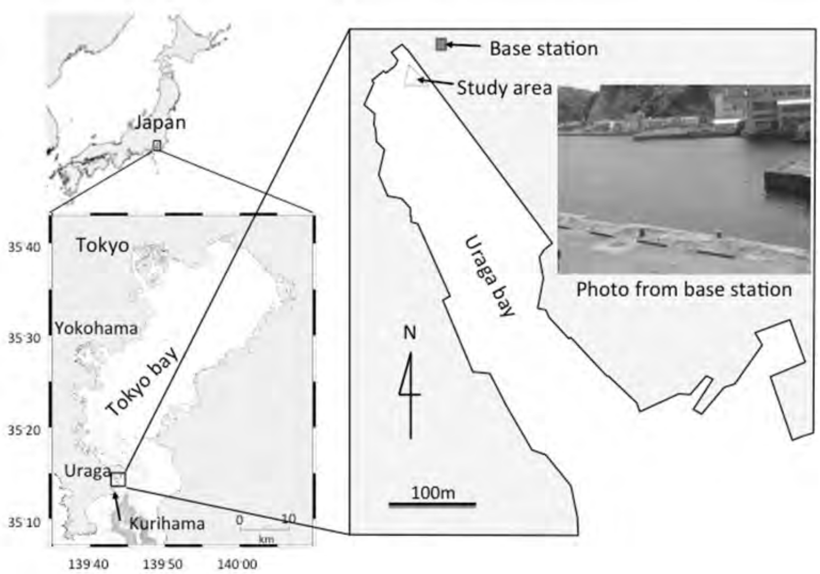

Fig. 1Map of the study site in Uraga Bay, Kanagawa Prefecture, Japan.

VRAP buoys were positioned in an equilateral triangle array around the sites where the fish were caught. However, the base line of the triangle could not surround it, because it was close to the seawall. So baseline A-B was positioned such that it was parallel to the pier and the buoys were arranged such that the site of capture was located between buoys. Since previous studies have demonstrated that the home ranges of black rockfish are several tens-of-meters in size (Mitamura et al. 2009), the distance between each buoy was kept to about 40 m (Figs. 1, 2).

To reduce anomalous readings, the locality data were filtered using the following procedure. First, the data were filtered based on swimming speed. We used a maximum speed of 63 cm/s, according to Mitamura et al. (2009). If the swimming speed between consecutive data points exceeded the limitation of an outlier, then the latter was excluded. Second, to optimize the performance of the VRAP system, the transmitter tag (target fish) was kept within the triangle formed by the buoys. If transmitters moved outside of the triangle, positioning errors increased along with their position. In addition, the positioning accuracy was in determinacy in the area of extension of baseline. A previous study showed that the territory of black rockfish was

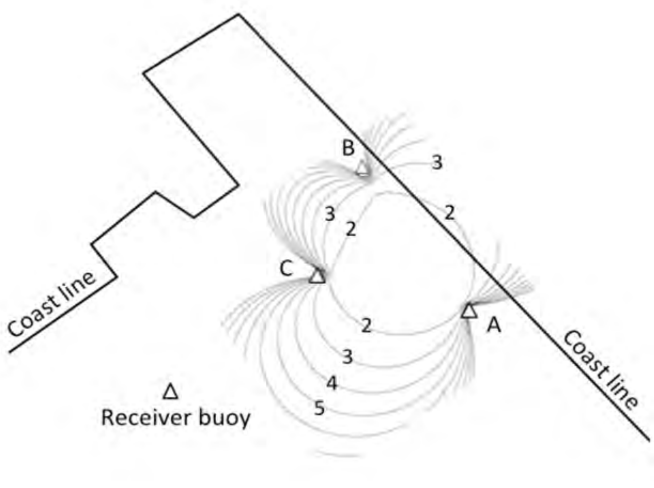

Fig. 2 Arrangement and location of VRAP receiver buoys (△) and distribution HDOP. Distance between A and B was 45 m, B and C was 30 m, A and C was 39 m.

approximately 45 m in diameter (Mitamura et al. 2009), which meant that readings obtained where the horizontal dilution of precision HDOP>5 were excluded, i.e. positioning accuracy was inadequate (5 or 10 m to infinity; Fig. 2), and the area of precision HDOP<5 could cover the territory of a fish.

The following formula was used to calculate HDOP:

$$\mathrm{HDOP} = \frac{1}{\sqrt{2}\sin\gamma}\left(\mathrm{cosec}^2\frac{\alpha}{2} + \mathrm{cosec}^2\frac{\beta}{2} + \mathrm{cosec}\frac{\alpha}{2}\mathrm{cosec}\frac{\beta}{2}\cos\gamma\right)^2 \quad \text{(Swasson 1978).}$$

Each VRAP buoy was referred to as buoy A, buoy B and buoy C, and these buoys formed two lines; A to B and B to C (Fig. 2). If the angle between A to B is α while that subtended by B to C is β, then the crossing angle of AB and BC must be $\gamma = \alpha/2 + \beta/2$. In addition, if the recorded position is on land, regardless of movement speed and HDOP, the point was excluded.

Finally, the recorded depth was corrected on the basis of nearly lowest low water. The height of the tide was estimated at hourly intervals based on measurements for Kurihama (http://www1.kaiho.mlit.go.jp/KANKYO/TIDE/tide_pred/index.htm), which is near Uraga Bay. Depths greater than the maximum depth of the study area and above the water of corrected depth were excluded from the analysis. Since the positions of the tags were displayed on a computer screen in real time, we were able to search for the tagged fish using an underwater camera.

RESULTS

A total of 9848 data points were recorded over a one-month period in this study (Fig. 3).The figure shows that many of the points were either over land or exhibited a hyperbolic pattern around buoys.

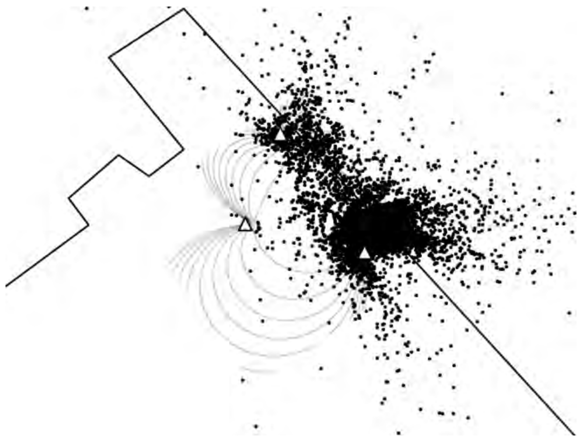

Fig. 3 Black dots show recorded position before filtering.

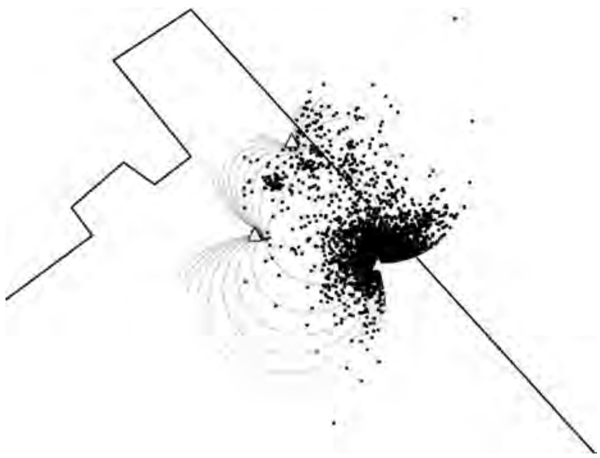

Fig. 4 Distribution of recorded position after filtering by swimming speed and HDOP.

After filtering position data based on swimming speed, the number of valid data points did not change markedly, i.e. 8137 points. Similarly, after filtering the data using HDOP, the number of valid data points decreased only slightly to 8114 points (Fig. 4). After the excluding those locality points over land, the number of valid data points decreased to 2578 points (Fig. 5).

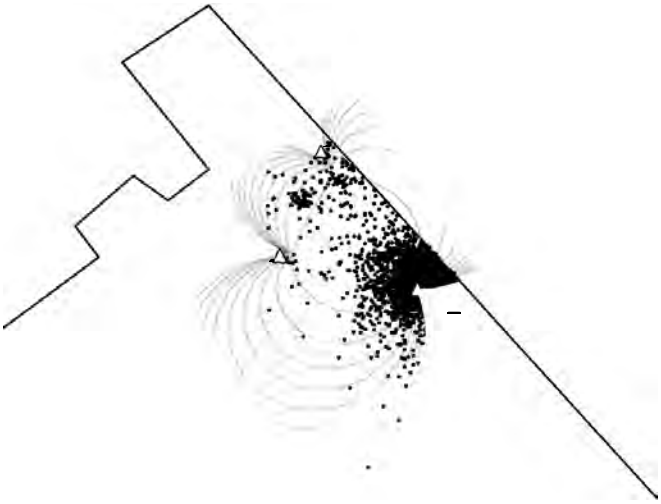

Fig. 5 Distribution of recorded position after excluding landing position.

All of the estimated fish locations were along the pier. If the adverse effects associated with the seawall were excluded, then the HDOP for the fish territory was approximately 2, which means that the positioning accuracy was about 2 to 4 m. The study area was then divided into a 2 m mesh. The frequency of fish location recorded in each square of the mesh was represented as a 3D plot (Fig. 6). The data points were then separated into those recorded during the day and during the night, because rockfish distribution varies according to a diurnal pattern (Mitamura et al. 2009). The results showed that rockfish inhabited areas close to the baseline AB and near buoy A during the day. Conversely, at night time, fish moved from their daytime territories to buoys A and B. Generally, however, the movement of rockfish appeared to occur along the pier.

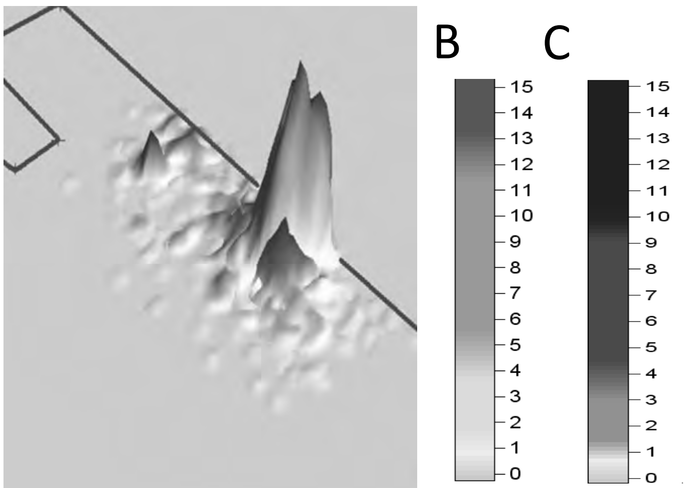

Fig. 6 Three-dimensional contour showing frequency distribution for recorded position during the day and night.

Figure 7 shows depths recorded for fish. The three disruptions in data collection indicate the three occasions on which the batteries inside the buoys had to be recharged during the experiment. Although the depth of the habitat changed according to the tides during the day, after correcting for tides, the average water depth was taken as 5 m. From sunset to sunrise, the fish moved to surface and sometimes to the bottom. We surveyed the habitat of the tagged fish during the day with an underwater camera. Although we were unable to determine whether any of the rockfish that were observed next to seawall were tagged or not, several rockfish were observed in the area (Fig. 8).

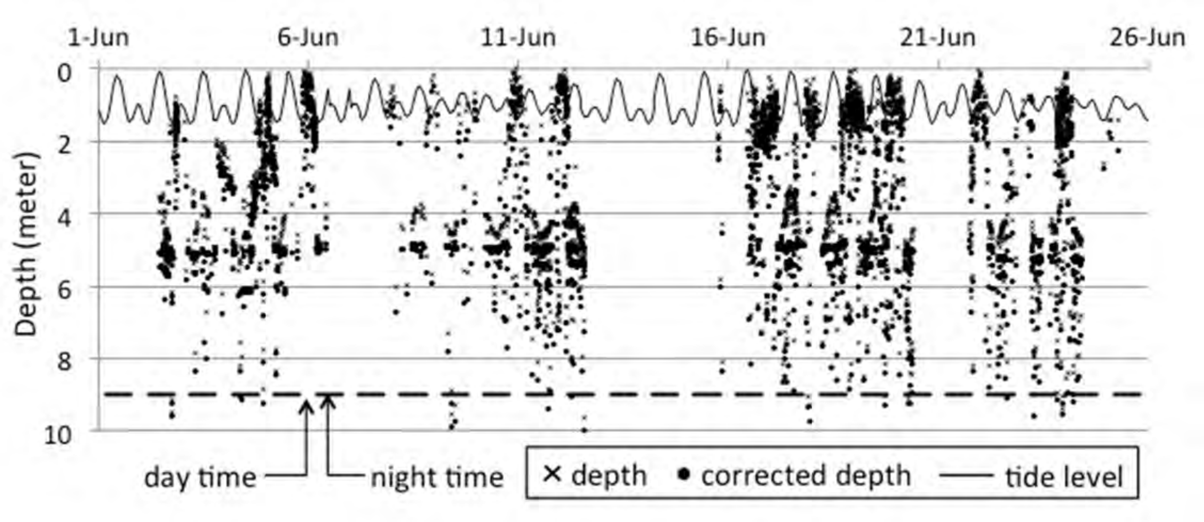

Fig. 7 Swimming depth of tagged fish. Crosses show depth data, solid circles show corrected depth after collecting tide level data, solid line shows tide level.

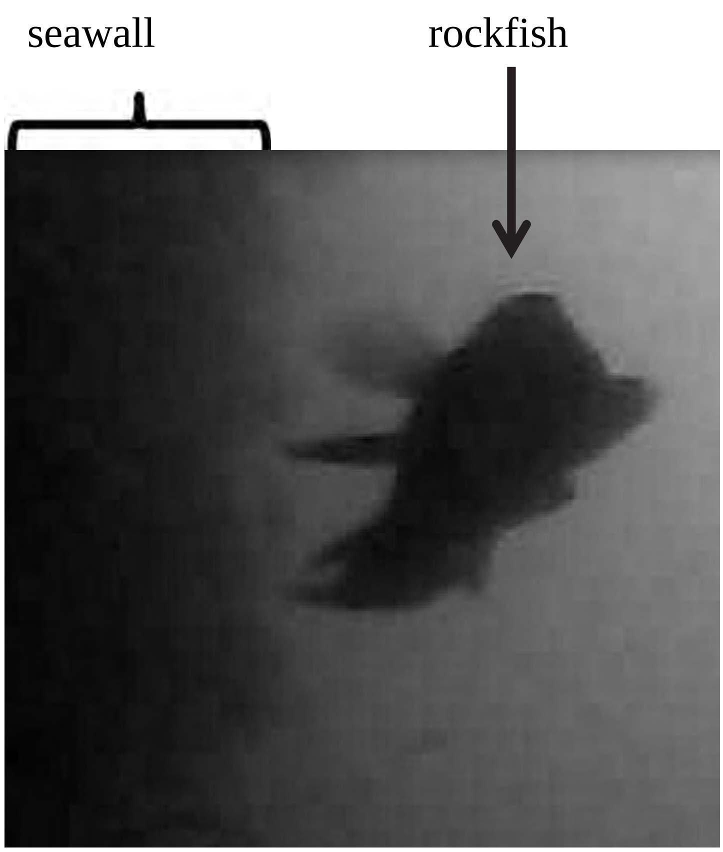

Fig. 8 Photos of the black rockfish *Sebasteschenі* adjacent to a seawall at the study site.

DISCUSSION

Using the LBL ultrasonic telemetry system, the position of the transmitter can be located to within 1 to 2 m inside the buoy triangle. As the transmitter moves outside the buoy triangle the accuracy decreases. This decrease is particularly apparent in the area beyond the baseline which becomes shadow zone where hyperbolic geometry diverges (VEMCO 2003). In this study, we did not allocate buoy keeping catch point in the buoy triangle. In addition, the monitoring area was enclosed by a vertical seawall and the territories of the fish were near seawall. Together, this physical environment is not very well suited to obtaining accurate acoustic data. It is considered that more than 70% of the recorded positions were recorded on the pier.

Using the buoy alignment employed in the study, HDOP could be kept to approximately 2 (positioning accuracy < approx. 4 m) at the estimated core area of the fish surveyed area. Depth, telemetry and camera data showed that the tagged fish appeared to remain in almost the same recorded position next to the seawall from sunrise to sunset. After sunset, the fish moved from the day-time core area to the surface around buoys A and B before sunrise. Similar vertical diurnal movements were reported by Parker et al. 2008 and Mitamura et al. 2009. Mitamura et al. 2009 reported that some of this behavior is feeding behavior and our results appear to corroborate their findings.

This study was conducted in an environment that was not well suited for acoustic telemetry analysis. Many of the recorded positions were excluded from the analysis because the core territories of the fish were near the seawall. However, by filtering the data, we were able monitor the diel behavioral patterns of rockfish. Future studies will examine the behavior of rockfish inhabiting the seawall in greater detail.

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