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Movement Ranges and Routes of Black Rockfish *Sebastes schlegeli* in Summer and Autumn from Acoustic Telemetry

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The movement range and diurnal behavior of 17 wild black rockfish (*Sebastes schlegeli*) were monitored within the marine ranching area of Tongyeong from 27 July to 7 November, 2005 using acoustic telemetry. Coded transmitters were surgically implanted into the abdomen of fish. Two of ten fish released in summer moved about 2 km away from the capture point for 1 day. The others stayed within a 500-m radius of the release point for 1 week after release. The seven fish released in autumn stayed within 500 m of the release point. Most fish were more active and had a greater range of horizontal diurnal movement at night than during the day. Additionally, the range of horizontal diurnal variation was greater in summer than in autumn. While fish released in summer were more vertically active at night than during the day, those released in autumn preferred to move vertically during the day.

Key words: Acoustic telemetry, Diurnal behavior, Marine ranching area, *Sebastes schlegeli*

Introduction

The production of Korean fisheries has shown a significant decline, despite the modernization of fishing gear and methods. There is an urgent need to develop advanced technology to protect fish stocks and allow the fishing ground environment to recover. The goals of marine ranching systems in Korea are to improve the sustainable productivity of the coastal region and revitalize environmentally friendly coastal fisheries. A marine ranching program has been conducted in Tongyeong, Korea since 1998. The target fish are black rockfish (*Sebastes schlegeli*), rockfish (*Sebastes inermis*) and red seabream (*Chrysophrys major*), individuals have been released to promote fish stocks in Tongyeong.

Black rockfish is an ovoviviparous fish that inhabits rocky reef (Im and Hwang, 2002). The age and growth of black rockfish have been examined by various researchers (Utagawa and Taniuchi, 1999; Lee and Kim, 2000; Im and Hwang, 2002).

Whereas much is known regarding the biology of black rockfish, little is known of its ecological characteristics. However, it is necessary to obtain ecological data on the behavior, movement range, and habitat of target fish in the marine ranching system (Shin et al., 2004, 2005). Ecological data on target fish provide basic information for constructing artificial reefs or selecting marine ranching area. Thus far, ecological data have been obtained using SCUBA surveys and the release of marked fish. These methods are not optimal for obtaining ecological data because of limitations in diving time, viewing obstacle underwater, and the low recapture rates of marked fish (Mitamura et al., 2002). These problems could be overcome using acoustic telemetry, which allows continuous tracking of marked individuals.

Acoustic telemetry consists of ultrasonic (Matthews, 1990, 1992; Pearcy, 1992; Shin, 1992; Shin et al., 1994; O'Dor et al., 1998; Candy and Quinn, 1999; Shin and Lee, 1999; Mitamura et al., 2002) and digital telemetry (Colavecchia et al., 1998). It is mainly used to measure fish behavior in an ordinary swimming state. We measured the movement range and diurnal behavior of tagged black rockfish using acoustic telemetry. We then analyzed the use of space by tagged fish within the marine ranching area to obtain ecological information on black rockfish. We also showed that acoustic telemetry is an appropriate

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technique in the management of marine ranching systems.

Materials and Methods

Study site and equipment

The study was conducted within the marine ranching area in Tongyeong, Korea (Fig. 1). The marine ranching area is approximately 20 km^2, and is managed by the Korea Ocean Research & Development Institute (KORDI). Artificial reefs were installed at 29 sites in the Tongyeong marine ranching area. One of the artificial reefs, installed at 20-m depth below the cage of the Tongyeong marine ranching area was 10 m in length, 10 m in width, and 1 m in height.

Water depth at the site was measured using a hydrographic survey system composed of a real-time differential global positioning system (RTK DGPS), an echo sounder, and hydrographic survey software (Kim and Shin, 2001; Kang and Shin, 2004).

The movement range of individual tagged fish was tracked using a single channel automated ultrasonic receiver (VR2; Vemco, Canada), a general-purpose tracking system designed for manual tracking (VR60; Vemco, Canada), and a four channel tracking system (VR28; Vemco, Canada). The VR2 receiver is submersible and can identify coded transmitters. The receiver recorded fish telemetry data the appearance and stay time within a 500-m radius from its installation position in real time. The VR60 tracking system was used with an omni-directional hydrophone when tagged fish escaped from monitoring coverage (500 m) of VR2. The VR28 tracking system consisted of a four channel ultrasonic receiver, connected to a four-element hydrophone array. The quad hydrophone array provided 360° of monitoring coverage so that the bearing to a transmitter could be determined without having to rotate a directional hydrophone. The radio acoustic positioning system (VRAP; Vemco, Canada) measured real-time, detailed position information from underwater acoustic transmitters using a series of three buoys and a two-way radio link to a base station (Tae and Shin, 2004).

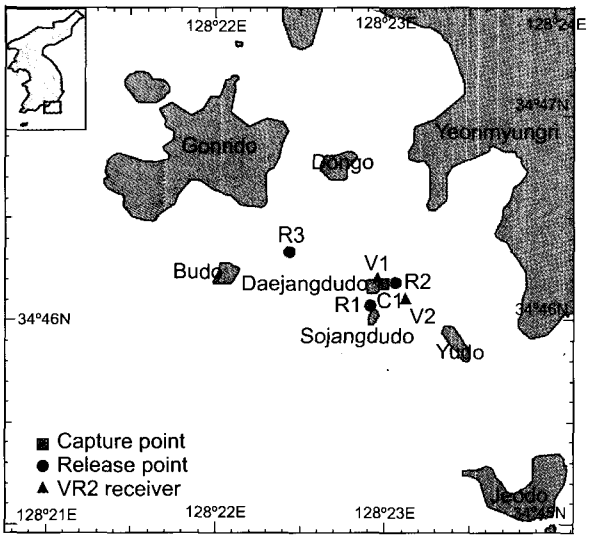

Fig. 1. Location of the study site and arrangement of the experimental equipment.

Measurements were conducted from 27 July to 7 November 2005. The measured VRAP data were divided into day and night to determine diurnal fish behavior. The VR60 or VR28 was used to track the movement ranges of tagged fish that out of the monitoring coverage of VR2 and the detected signal position was measured using the GPS system.

Tagging fish with the coded ultrasonic transmitter

Seventeen black rock fish were captured in a trap near the cage of the Tongyeong marine ranching area (C1, Fig. 1). We used two types of coded transmitters. One (V8SC-2L and V9-1L; Vemco, Canada) sent acoustic pulse trains that contained a sync period and an identification (ID) number. This transmitter was 9 mm in diameter, 24 mm in length, and weighed 2.6 g in water. The other transmitter (V9P-1L; Vemco, Canada) contained a depth sensor to measure depth and included these data in the acoustic transmission. This transmitter was 9 mm in diameter, 40 mm in length, and weighed 2.6 g in water. The full range of the coded transmitter the depth sensor, was 50 m in depth. The transmitters were surgically implanted into the abdomen of the fish (Mitamura et al., 2002). Of the ten fish captured on 27 July 2005 (summer), six were released at R2, about 30 m from C1, and four were released at R3, about 850 m from C1 (Fig. 1). Of the seven fish captured on 6 November 2004 and 1 November 2005 (autumn), two were released at R1 on 6 November 2004, about 250 m from C1, and five were released at R2 on 1 November 2005. All tagged fish were tracked using acoustic telemetry and measured continuously 24 h/day for 7 days after release using the VRAP system (Table 1).

Results and Discussion

Movement range

The movement ranges of 10 fish released in summer was measured for 1 week after their release at R2 and R3 (Fig. 2). Tag No. 64 released at R2 moved approximately 2 km from R2 for 1 day and

Table 1. Summary of the characteristics of wild black rockfish (*Sebastes schlegeli*) equipped with coded transmitters and released in the Tongyeong marine ranching area

Tag No.	Transmitter model	Body length (cm)	Total length (cm)	Weight (g)	Release		Distance from home site (m)
					Date	Point	
34	V8SC-2L	28.5	33.0	680	6/Nov/04	R1	250
38	V8SC-2L	27.5	31.5	480			
63	V9P-1L	33.0	38.0	689	27/Jul/05	R2	30
64	V9P-1L	35.0	40.0	1,062			
70	V9-1L	32.5	36.5	792			
71	V9-1L	31.5	35.5	760			
72	V9-1L	32.0	36.0	360			
73	V9-1L	34.0	39.0	920			
74	V9-1L	32.0	36.0	720	27/Jul/05	R3	850
75	V9-1L	30.5	34.5	620			
76	V9-1L	31.0	35.0	730			
77	V9-1L	37.5	42.5	1,180			
85	V9-1L	31.5	35.5	638	1/Nov/05	R2	30
87	V9-1L	27.5	31.5	440			
88	V9-1L	29.0	33.0	560			
89	V9-1L	30.0	33.7	506			
102	V9P-1L	38.0	43.0	1,046			

stayed between small islands. Tag No. 76 released at R3 also moved approximately 2 km from R3 to near the coast for 1 day. The other fish stayed within 500 m of R1 and R3 for 1 week after release. The water temperature near R1 was 22.1°C at a depth of 5 m on 27 July 2005. The movement ranges of seven fish released in autumn were monitored similarly to those of the fish released in summer (Fig. 3). Tag No. 34 and 38 released at R1 on 6 November 2004, moved to the capture point (C1) for 45 min and 38 h respectively, after release, and have stayed on 7 November 2005. All tagged fish released on 1 November 2005 stayed within 500 m of R2 for 1 week. The

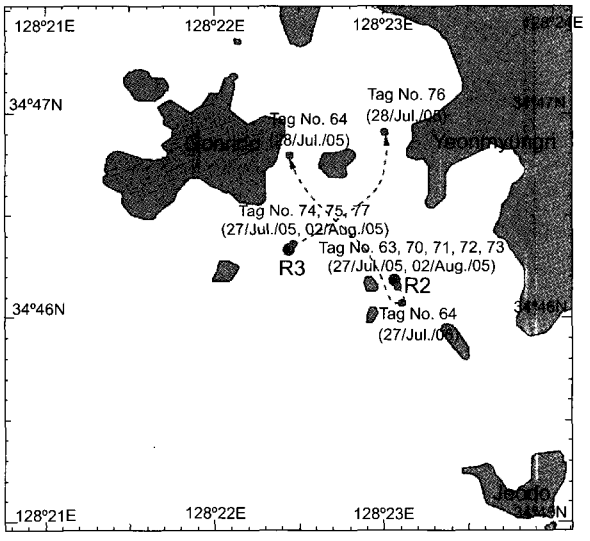

Fig. 2. Movements of tagged fish for 1 week after their release in summer (released on 27 July 2005).

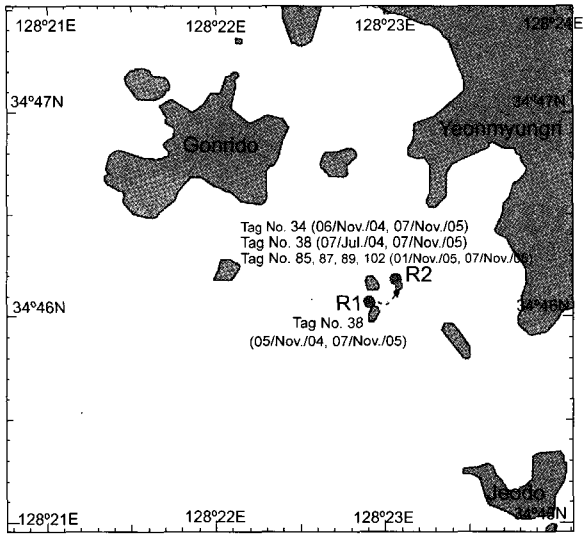

Fig. 3. Movements of tagged fish for 1 week after their release in autumn (released on 6 November 2004 and 1 November 2005).

water temperature was 17.9°C at 5 m in depth on 1 November 2005.

Diurnal behavior

Regular diurnal movement occurred in all fish within 2 days of release. Most fish were more active at night and the range of horizontal diurnal movement was greater at night than during the day (Figs. 4 and 5). Furthermore, the range of horizontal diurnal movement was greater in summer than in autumn (Figs. 4, 5). Tag Nos. 34 and 38 were released between Daejangdudo and Sojangdudo, about 240 m from C1 on 6 December 2004 (Fig. 1). As more time

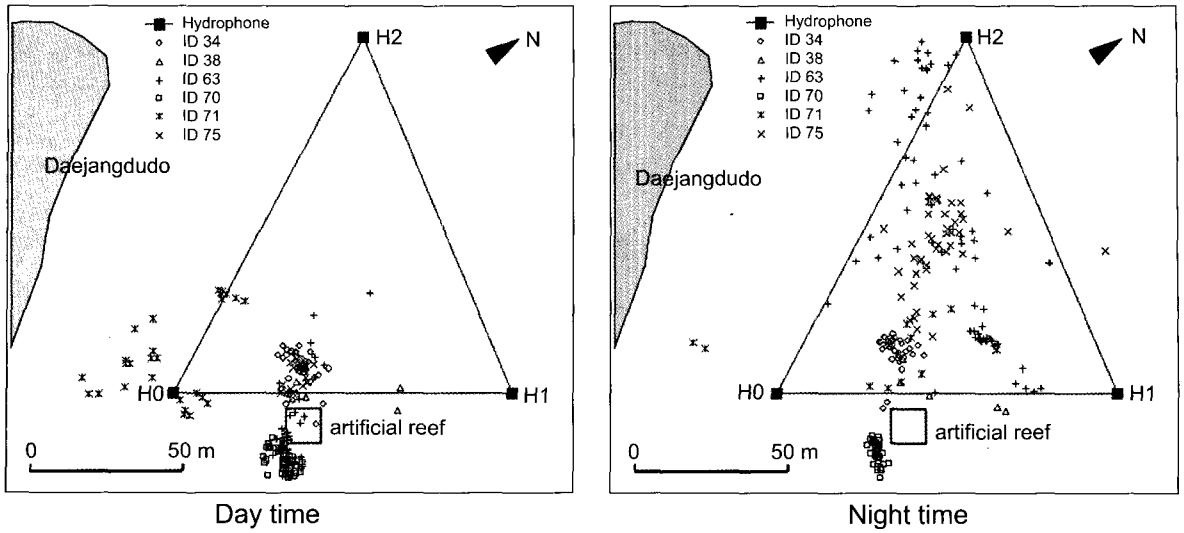

Fig. 4. Horizontal diurnal movement of the black rockfish in summer.

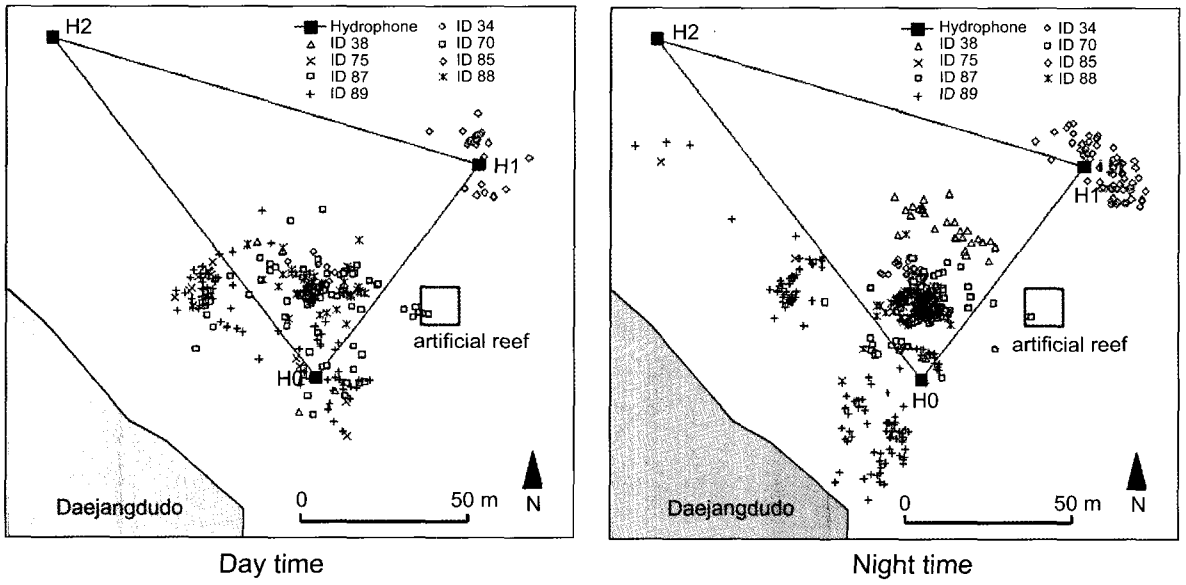

Fig. 5. Horizontal diurnal movement of the black rockfish in autumn.

passed, they more strongly preferred the artificial reefs after returning to home site. Furthermore, the difference in the movement range between night and day for these two fish was probably smaller than that of the other fish.

Regarding vertical diurnal movement, fish released in summer tended to stay in shallower zones at night than during the day (Fig. 6). Tag No. 63 moved to deep water after sunrise and remained at a fixed swimming depth for 5 h. Tag No. 102, containing a depth sensor, was released at R2 on 1 November 2005 to monitor vertical diurnal movement. Unfortunately, this individual disappeared within the study site during the experimental period, so it was not possible to measure the vertical diurnal movement in autumn.

Vertical distribution of water temperature

The distribution of water temperature around the capture point (C1) was monitored from 30 July to 1 November 2005 (Fig. 7). In summer, the water temperature from the surface to the bottom layer changed 22.9°C. Furthermore, a thermocline occurred between 5 m and 15 m in depth, with a water-temperature difference of 3.2°C. In autumn, the water temperature from the surface to the bottom layer changed 17.9°C;

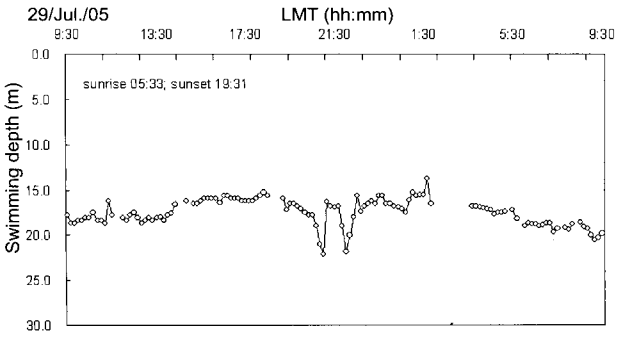

Fig. 6 Vertical diurnal movement of black rockfish (Tag No. 63) in summer.

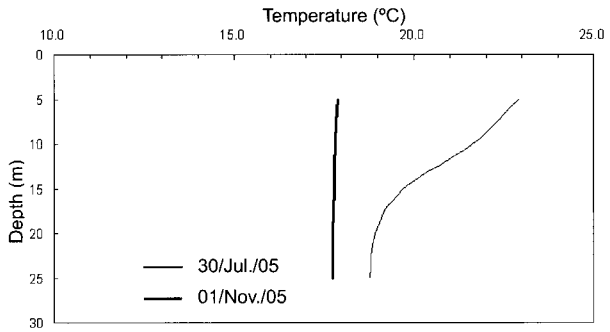

Fig. 7 Vertical distribution of water temperature around the capture point (C1) of black rockfish.

thus, the variation in the water temperature was much smaller in autumn than in summer.

Response of fish to reefs determined by their duration of stay

The response of fish to reefs was determined by their duration of stay, monitored at different location and times for tagged fish released on 6 November 2004, and on 27 July and 1 November 2005, after returning to the home site. The number of detections was measured at a fixed position using the VR2 receiver for 48 h from 4 to 6 November 2005 (Fig. 8). Sunrise and sunset on 5 November 2005 occurred at 06:50 and 17:28, respectively. The pulse interval of transmitters was 60 to 180 s. Tag No. 34 returned to the home site within 1 h after release and has stayed there for 1 year. Tag Nos. 70 and 88 have stayed for 3

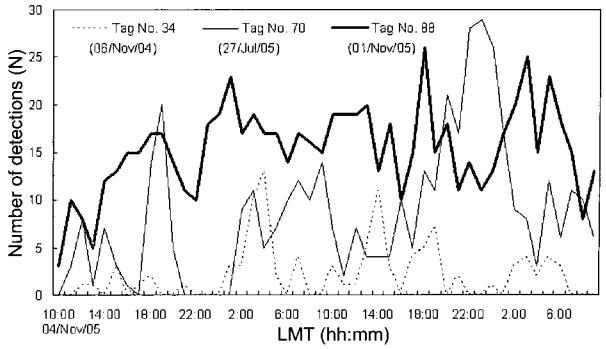

Fig. 8 Variation in the number of detections for three tagged fish (Tag Nos. 34, 70 and 88) monitored from 4 to 6 November 2005.

months and 5 days, respectively. The number of detections made by the VR2 increased, in the main, during sunset, and decreased during sunrise, and theses tendencies deceased over time (Table 2). The tagged fish (Tag Nos. 34, 70 and 88) preferred to stay in artificial or natural reefs in the water at night rather than during the day. Furthermore, they were likely to stay in reefse by time after returning home site.

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Table 2. Comparison of the average number of detections for tagged black rockfish (Tag Nos. 34, 70, and 88) during the day and at night

Tag No.	Average number of detections		Release		Duration of stay after returning to the capture point (day)
	Day (N/h)	Night (N/h)	Date	Distance from capture point (km)	
34	1.7±2.6	2.5±3.3	6/Nov/04	0.24	365
70	5.9±4.1	10.8±8.7	27/Jul/05	0.90	94
88	13.6±4.7	16.9±4.2	1/Nov/05	0.03	5

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