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Preliminary Study about Behaviour Characteristics of Red Seabream and Black Rockfish Around Artificial Reefs and Natural Habitats by Using Biotelemetry Techniques

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ABSTRACT

Movements and behaviour of red seabream *Pagrus major* (J1) and black rockfish *Sebastes schlegeli* (T1 and T2) inside or environs to artificial reefs determined by acoustic telemetry information were monitored. Both fish are associated with artificial reefs in two marine ranching areas (Jeju and Tongyeong) in South Korea but the knowledge of habitat use and fish movement around them is unclear. J1 was monitored in Jeju marine ranching area (October 24, 2012) and exhibited more activity at dusk hours, its stay in place around some artificial reefs was observed as well. In other hand, some tracking records of two wild adults T1 and T2 were tagged with acoustic transmitter tags and digital micro data logger, released then passive and manual tracking for hours in addition to compare both artificial reefs and natural habitats in Tongyeong marine ranching center during different periods (May 11 and June 6, 2013, respectively). T1 showed an association with artificial reefs while T2 released in one area without artificial reefs, it had wide displacements (>1 km in the last detected point), suggesting that the rockfish probably searched for the homeward direction.

Key words: Acoustic telemetry, fine-scale movements, marine ranching areas, *Pagrus major*, *Sebastes schlegeli*

INTRODUCTION

Artificial Reefs (AR) are considered as one of the most common alternatives into stock enhancement programs and defined as "natural and man-made objects deployed on the seafloor deliberately used for multiple processes related to living marine resources" (Pradal *et al*., 2005). The use of artificial habitats to increase fishing activity is a common practice in several countries. ARs are used for a long time over 200 years in small-scale fisheries. In South Korea, the AR Program was implemented in 1971 with the goal to increase fish stocks, known as "Fish stock enhancement" that artificially enhance fishery resources by installing these structures to create habitat and spawning grounds (approx. 202141 ha, 2007) established in Tongyeong, Yeosu, Jeju, Taean and Uljin areas (Lee, 2010a, b; Yoon *et al*., 2012). Concerning this program has been performed several studies related to obtain ecological information on behaviour, movement range and habitat of target fish through acoustic telemetry as well as hydro-acoustic survey to estimate a fish distribution at marine ranching area and aggregated fish schools at ARs (Shin *et al*., 1994, 1997, 2004, 2005; Shin and Lee, 1995; Kang and Shin, 2006; Kang, 2007; Kang and Shin, 2006, 2008a, b; Kim *et al*., 2011) in order to good management and monitoring of fisheries resources in coastal areas of South Korea.

Tracking fish by tagging has been very important to fisheries science as a part of a fishery management tool (for stock assessment, estimating survival and recruitment, evaluating movements, activity patterns and habitat integrations), so that, management requires proper knowledge of fish behaviour and habitat use, as can be achieved through telemetry techniques (Jadot *et al*., 2006; Schroepfer and Szedlmayer, 2006; Mitamura *et al*., 2002, 2009, 2011, 2012). The fish behaviour on ARs differs from one species to another. This fact determines the different aggregating ability (luring effect) of the artificial reef for various species (FAO., 2005). Undoubtedly, monitoring the marine ecology of AR is essential respect to changes in the complex marine environment, in local fishing productivity as well as the diversity of marine organism and species (Kang *et al*., 2011). Additionally, AR likes habitat restoration requires detailed knowledge of targeted fish species. In general, preservation of habitat is an essential component of the plan to restore damage and stressed fish habitats which have become a standard requirement of fishery management.

Both natural and habitat restoration require detailed knowledge of target fish species residence times, movements and habitat utilization. This study was conducted on the collecting information by using two kinds of biotelemetry techniques or bio-logging (ultrasonic telemetry and micro data logger) around artificial reefs in two marine ranching areas: Chawgido (Jeju) and Tongyeong (Daejangdudo) as well as natural habitats (without AR) with the purpose of determine the behaviour and spatial distribution of tagged wild fish for the clearly understanding under field conditions and appropriate management of coastal resources in Korea.

MATERIAL AND METHODS

Study site: This preliminary study took place at two different sites of near shore water, on the Korean peninsula. The first experiment was carried out in Chawgido (lat. 33°18'45"N, long. 126°08'53"E) marine park which occupies an area of approximately 2,872 ha, located off the west coast of Jeju Island (lat. 33°22'0.12"N, long. 126°31'59.88"E) and where is performed the marine ranching area by installing artificial reefs. These artificial reefs (more than 1900 among pieces and groups congregated) were deployed in 55 sites from 2007-2011 over open flat sand-mud sea bottom whose mean depth at the site was around 30 m (Fig. 1).

The second and third experiments took place on Tongyeong Marine Ranching Center (T-MRC) around Daejangdudo Island (lat. 34°46'12"N, long. 128°23'00"E) located in Tongyeong coastal city. One of them, second experiment was carried out in one artificial reef (10×10×1 m) located below the culture cage; while, the third experiment was at 0.5 km away from T-MRC without artificial reef (i.e., natural habitats) (Fig. 2). According to (Kang and Shin, 2006), Tongyeong marine ranching area covers approximately 20 km^2 and the sea-bottom consists primarily of mud with granules and gravels around the island. There, the artificial reefs were installed in 29 sites.

Fish tagging: Four adult fish: Red seabream (*Pagrus major*, J1), blackfish (*Girella punctata*, J2) and black rockfish (*Sebastes schlegeli*, T1 and T2) were captured with a single line hook around Jeju (Chawgido Island) and Tongyeong marine ranching area, respectively. In the first case, fish

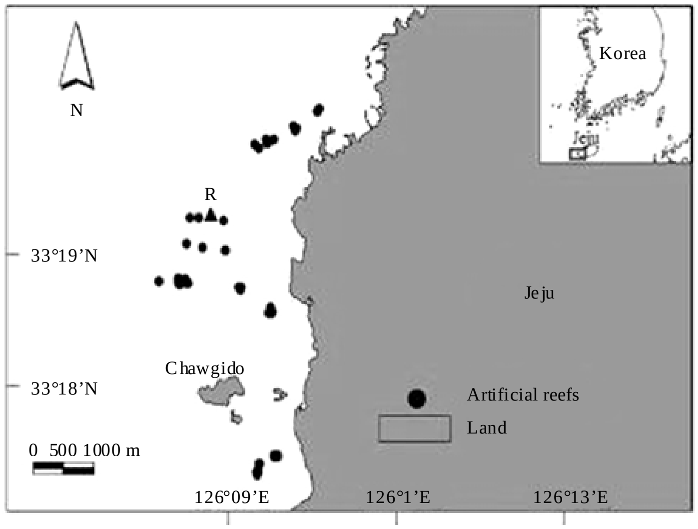

Fig. 1: Study site and map of: First experiment (October 24, 2012) in Chawgido marine park (Jeju Island) R: Release point, dark dots are the locations of artificial reefs in the area

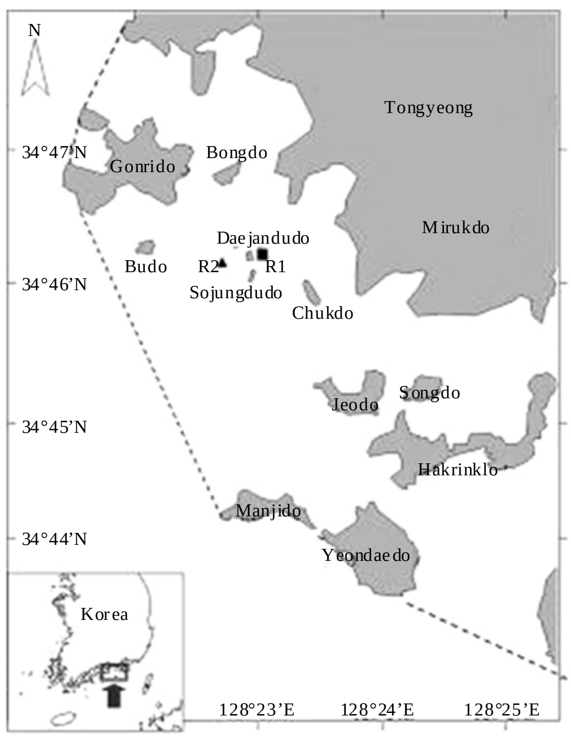

Fig. 2: Study site and map of second experiment (May 11, 2013) and third experiment (June 6, 2013) in Tongyeong marine ranching center, R1 and R2 are the release points

J1 and J2 were anesthetized on-board to prevent from struggling and to reduce stress during tagging. Then, they were tagged and released on October 24, 2012 and April 4, 2013 around the artificial reefs and more than 500 m away from the artificial reefs in Jeju marine ranching area (Table 1), respectively. While, fish T1 and T2 after catch, they were maintained in small cage

Table 1: Summary of the characteristics of wild fish tagged with continuous tag

Fish ID	Fish species	TL (cm)	BL (cm)	W (g)	Date released	Zone type	Study site
J1	Red seabream	46.5	40.0	1,500	2012-10-24	AR	J-MRA
J2	Blackfish	32.0	28.0	700	2013-04-12	AR	J-MRA
T1	Black rockfish	37.0	33.0	1,200	2013-05-11	AR	T-MRC
T2	Black rockfish	47.0	41.0	1,600	2013-06-06	WAR	T-MRC

J2 was lost right after release. TL: Total length, BL: Body length, W: Weight, AR: Artificial reef, WAR: Without artificial reef, J-MRA: Jeju marine ranching area, T-MRC: Tongyeong marine ranching center

fishing nets until tagging. In this case during the tagging procedure, the fish was not surgery and anesthetized because, external tag likes wire cord has been applied dorsally (anterior) before then to attach a "micro data logger" (digital data recording system). The fish T1 was released on May 11, 2013 in one of the artificial reef installed below to the fish cage and fish T2 was released in an area without artificial reefs on Jun 6, 2013 (Table 1).

Manual and passive tracking, equipment: During the first experiment on October 24, 2012, a portable receiver (FRX-4002, 25-70 kHz, FUSION Inc., Japan) with four omnidirectional hydrophones (Fusion Inc., Japan), Global Position System (GPS) device and two laptops were used to monitor individual red seabream (*Pagrus major*, T1) movements, actively tracked via surface on-board small fishing vessel using to determine their fine-scale movement around artificial reefs by short periods during the day, so that red seabream was tracked continuously for about 6 h. The hydrophone, placed in the water (launching), detects the signal emitted by the transmitter tag when it is located within range. The receivers continuously monitor the transmission of signals emitted by the tags and then record the date, time and identity of tagged fish within the detection range of the unit. The signal from the tag detected within a radius of approximately 300 m (engine off) and 150 m (engine on) during stop the vessel; the movement range of fish was tracked by using a general-purpose tracking system which had four hydrophones that can detect fish direction. Signals from the continuous type transmitter were received through the four-channel receiver. The omnidirectional hydrophone provides 360° of monitoring coverage that enable manual tracking of fish was conducted with speed less than 3.7 km h^{-1} (2 knots, approximately).

During the second experiment on May 11, 2013, the monitoring of black rockfish behaviour (*Sebastes schlegeli*, T1) was passively tracking by using LBL (Long Base Line) method per 6 h after fish released. The system consisted of four sea stations and a base station in the experimental sea cage off Tongyeong marine ranching center. Each station was fitted with omnidirectional hydrophone an array of transponders with a baseline (several meters long) within an area around 200 m^2 (13.65×14.48 m) outside the fish cage (Fig. 3). The hydrophones were connected to four channels of portable receiver (counter clockwise arrangement) and the position was recorded by using the GPS.

The last experiment on June 6, 2013, was conducted in natural habitats. Fish T2 was monitored actively on board the fishing boat. The manual tracking system consisted of four channels ultrasonic receiver with four omnidirectional hydrophones as short base line tracking and the detected signal position was measured by using the GPS system. The four omnidirectional hydrophones were installed on the rectangular stainless steel frame (100×100×19 cm), it was launched each 3 min approximately. This depended on the signal detection by ultrasonic transmitter. All the fine-scale tracking took around 8 h which, 1 h approx. of tracking (outboard) was carried out in the culture cage of the T-MRC. Additionally, marine-environmental data was recorded by RCM 9 that was installed inside the fishing cage (Fig. 4).

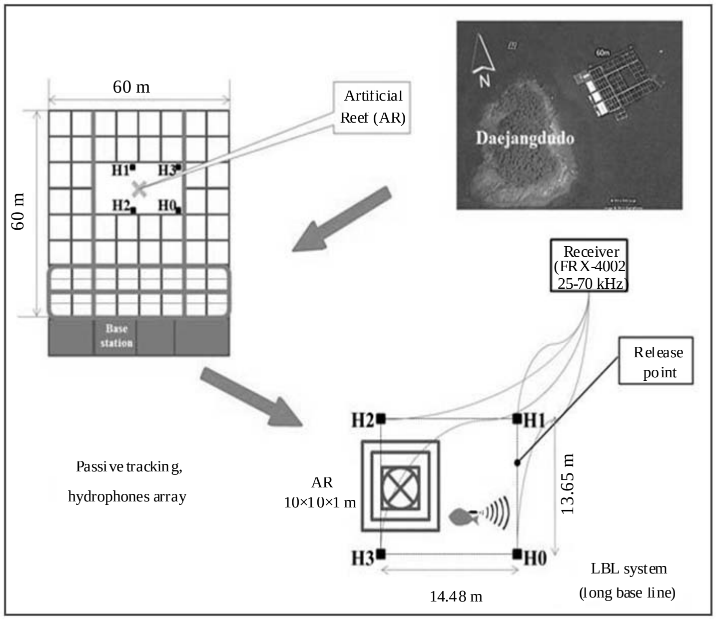

Fig. 3: Fixed omnidirectional hydrophone array by using LBL method, this system has been used to monitor the behaviour of black rockfish, T1 in the experimental culture cage off T-MRC (Second experiment)

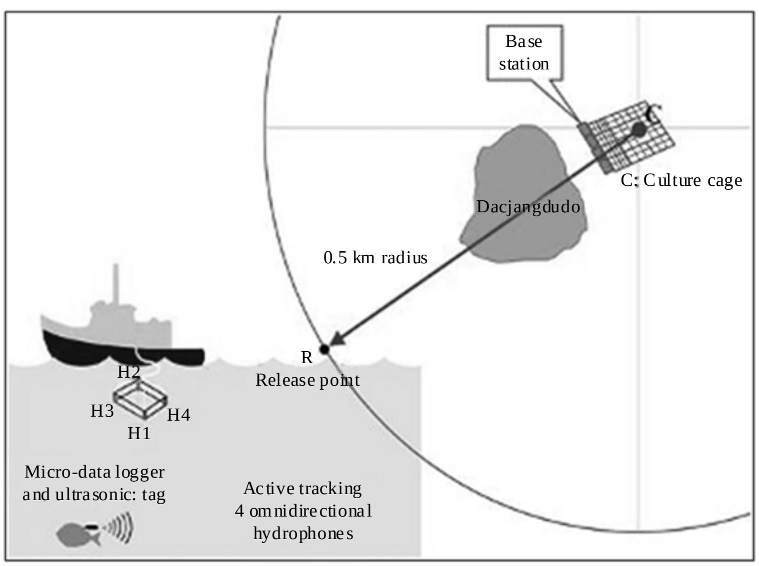

Fig. 4: Active tracking fish in the open sea carried out with small fishing boat by using 4 omnidirectional hydrophones installed on the rectangular stainless steel frame. Black rockfish, T2 released away from the experimental sea cage off T-MRC (Third experiment)

Data analysis: The directionality of fish tagged was determined by the test of directionality or Rayleigh's z-test (Zar, 1996). The test requires formulating H_0: The direction of movement was uniformly distributed around the circle (or H_0: $\rho = 0$) versus H_A: The direction of movement was not uniformly distributed around the circle (or H_A: $\rho \neq 0$). All differences were considered statistically significant at $p<0.01$ or $p<0.05$ levels. A quantity referred to as "Rayleigh's R" is obtained as R = nr. Where "n" and "r" indicate number of angles and mean vector length, respectively and it was defined by equations. The rectangular coordinates of the mean angle are:

$$r = \sqrt{x^2 + y^2}$$

$$x = \sum_{i=1}^{n} \cos a_i / n$$

$$y = \sum_{i=1}^{n} \sin a_i / n$$

where, "x" and "y" are the rectangular coordinates of the mean angle.

The "Rayleigh's z" may be utilized for testing the null hypothesis of no population mean direction:

$$z = R^2/n \quad \text{or} \quad z = nr^2$$

The approximation of the probability of Rayleigh's R is:

$$p = e^{[\sqrt{1+4n+4(n^2+R^2)}-(1+2n)]}$$

RESULTS AND DISCUSSION

Movement range and vertical distribution: During the first experiment on October 24 2012, the red seabream (J1) released during the morning (around 10:30 h) was manual tracked continuously for almost 8 h within 520 m radius approx. After release, it moved in the opposite direction and the average movement speed was 2.0 TL sec^{-1} (total length per second). This fish changed movement direction and the signal was lost for around 1 h after this, from 13:00-16:00 h tagged fish stayed in one position and the fishing boat anchored during this time for tracking. Around 16:07 h, the signal lost again. Then from 17:00-18:45 h, the boat changed the position for finding a strong signal but it was not possible, the fish moved more active, therefore the signal was lost completely (Fig. 5).

In relation to fish heading, fish J1 was never randomly oriented during the tracking time. The hourly movement direction from release point was conducted to a common direction (southwest) and in all but one case p-value was less than 0.01. After 2 h of tracking, it emitted strong signals then after 6 h, there was poor signal and probably fish became more active and made long displacements (Fig. 6).

In the second experiment on May 11, 2013, the wild fish, black rockfish *Sebastes schlegeli* (T1) tagged with micro data logger was released on the artificial reef during dark hours (04:28 h) and tracked passively for signal detection almost 6 h. After this time the device will detach to fish automatically and retrieve after all. However, the signal detection emitted by ultrasonic

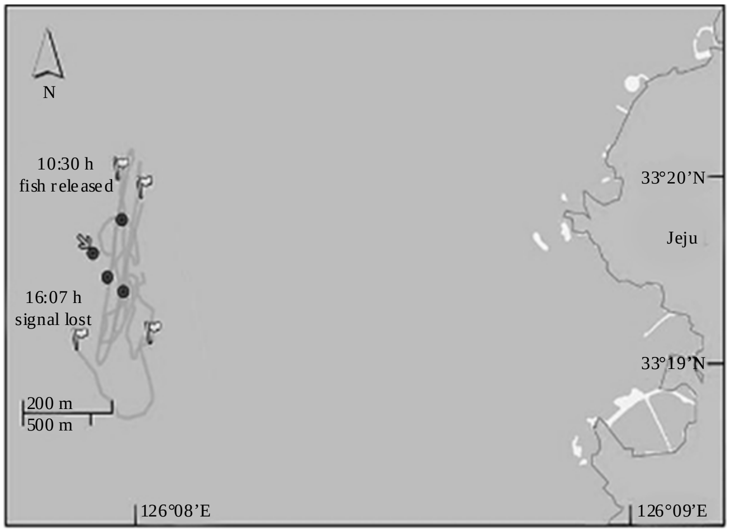

Fig. 5: Movements trace of red seabream *Pagrus major* (J1), fish released in the marine ranching area (Chawgido Marine Park) on October 24, 2012

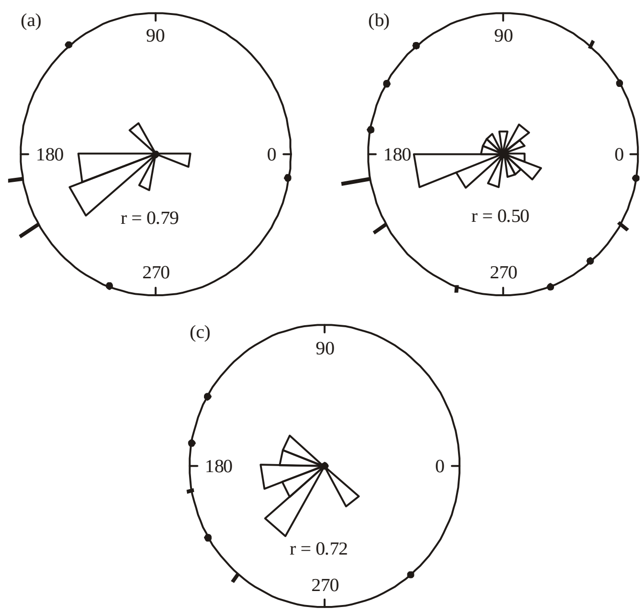

Fig. 6(a-c): Orientation of red seabream *Pagrus major*, J1 during the active tracking periods, (a) After 1, (b) 2 and (c) 6 h of signal detection by rose diagram. None of the three cases, fish was randomly oriented (p<0.01) and r-values (Raleigh test) for the fish headings are also shown

transmitter attached to the device was weak or in the majority of the cases no signal, during this elapsed time. By assuming in these first hours, the fish was moving inside the artificial reef where the signal was impossible to detect and then, it moved away.

During the third experiment on June 6, 2013, tagged fish T2 with micro data logger+ultrasonic transmitter was released during the morning (around 10:50 h) then, it was manual tracked

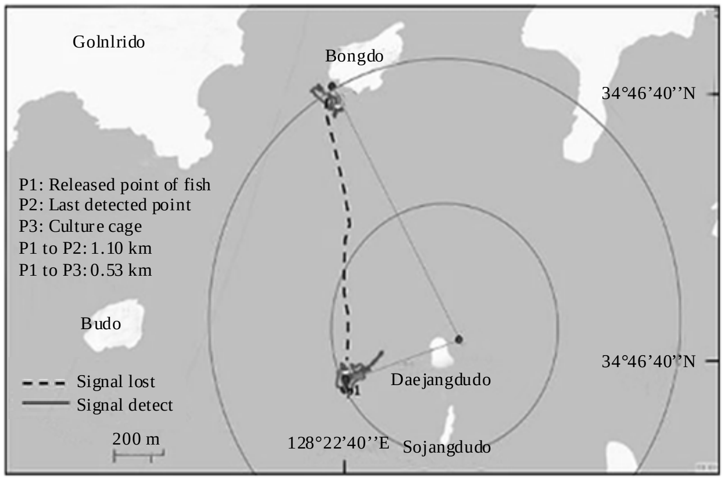

Fig. 7: Movements trace of black rockfish *Sebastes schlegeli*, T2 released in the marine ranching center (Tongyeong) on June 6, 2013

continuously for almost 8 h between 500 and 1000 m radius approx. After released, this fish was in the same place for 1 h (with an average speed of 2.14 TL/sec). Then, it moved away that involved several hours of monitoring without signal detection and after 4 h (around 14:50 h), strong signals were detected at 1.1 km away to release point. However, it was lost in less than 1 h (Fig. 7).

Despite the time that involves the manual tracking, this study tried to obtain enough information related to movement trace of fish tagged and its preference to submerged objects (artificial reefs) but not in spanned 24 h of tracking which is usually applied. Nevertheless, the restricted information has been considered and it has permitted to assume as well as verify the behaviour of tagged fish. In the case of porgies as red seabream *Pagrus major* by references, this fish prefers complex reef structures with large volume (Kim *et al*., 2011). In the present study, fish J1 (*Pagrus major*) had preference for small areas close to artificial reefs (polygon artificial reefs) deployed in the study site during daylight hours (after released). Nevertheless, this movement at short distances changed at dusk hours when fish became more active and difficult to detect by manual tracking (Fig. 8 and 9).

For example, the fine-scale movements around artificial reef of red snapper *Lutjanus campechanus* were relatively small and close, associated especially with complex structures (as army tanks) but in this case, red snapper was tracked during 24 h; however, this tracking period has permitted to know the preference of this kind of fish associated at these reef structures (Topping and Szedlmayer, 2011). Or in another case, individual movement patterns on unicorn fish (*Nurcia unicornis* and *Nurcia lituratus*) around natural reefs (coral reefs) were strong influenced by habitat preference (shallow and sheltered reef flat) in Piti Bomb Holes Marine Preserve, that is sedentary and extensive movements were observed according to their behaviour (Marshell *et al*., 2011) as well as movement patterns in reef fish as parrotfish *Sparisoma cretense* are related to spawning season with daily migrations to the 'territorial' areas in that case, the patterns of relocation among adult individuals are because of social dynamics, daily foraging migrations and mating opportunities (Afonso *et al*., 2009). After release the black rockfishes *Sebastes schlegeli* (fish T1 and T2), the time programmed for 6 h (timer) was done. In the case of fish T1, micro data logger was discovered detached from it around six days after released. The

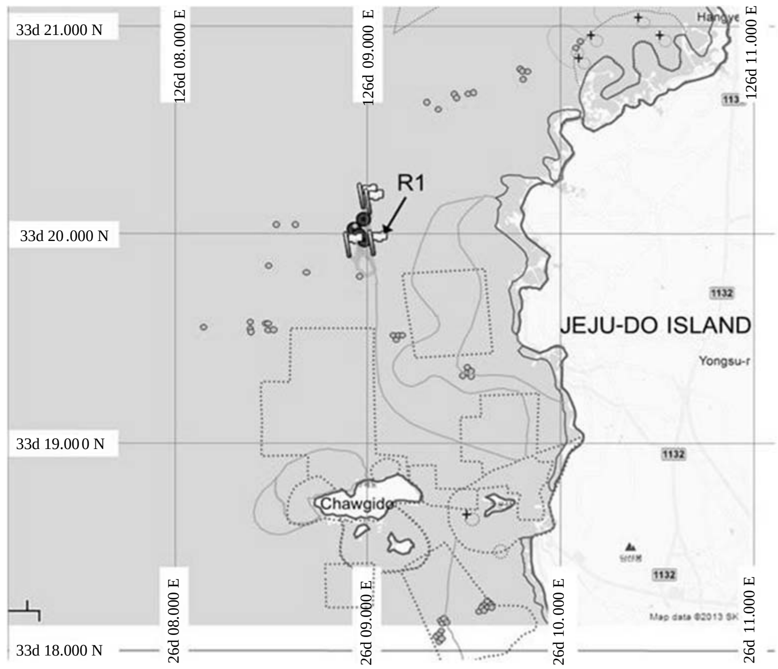

Fig. 8: Movements trace of tagged fish (remarked by flags, J1) and artificial reefs deployment (small circles) during the first experiment on October 24, 2012

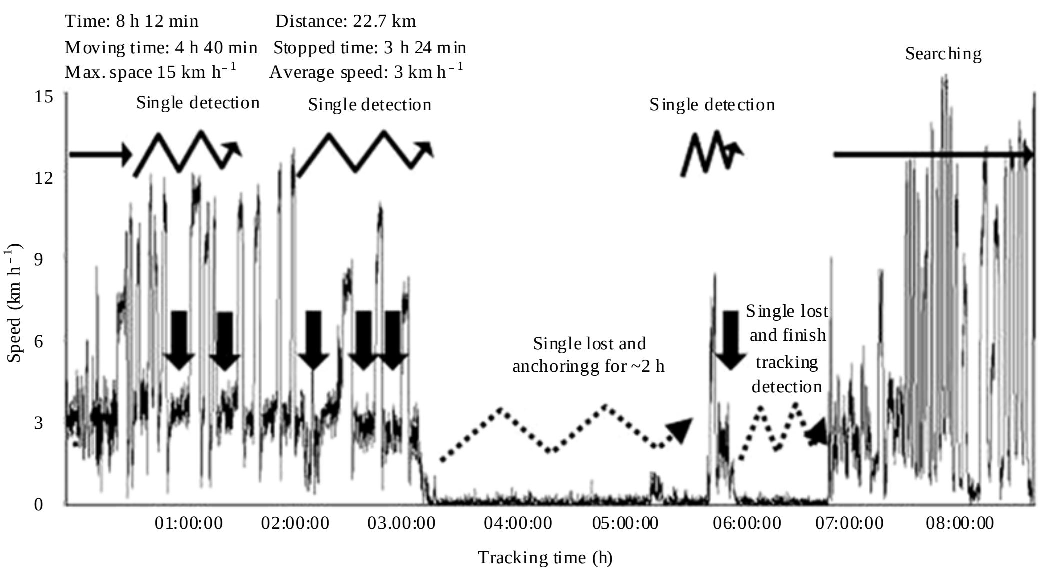

Fig. 9: Elapsed time and speed related to tracking fish during the first experiment on October 24, 2012

distance between release and recapture point was 120 and 80 m after the last signal detection (Fig. 10). But in the case of fish T2, released in some area without AR was complicated to find after one week due to the device could be trapped in some hole, crevice or kelps where the transmitter signal was very weak. Therefore, information recorded from ultrasonic transmitter was only considered in the third experiment.

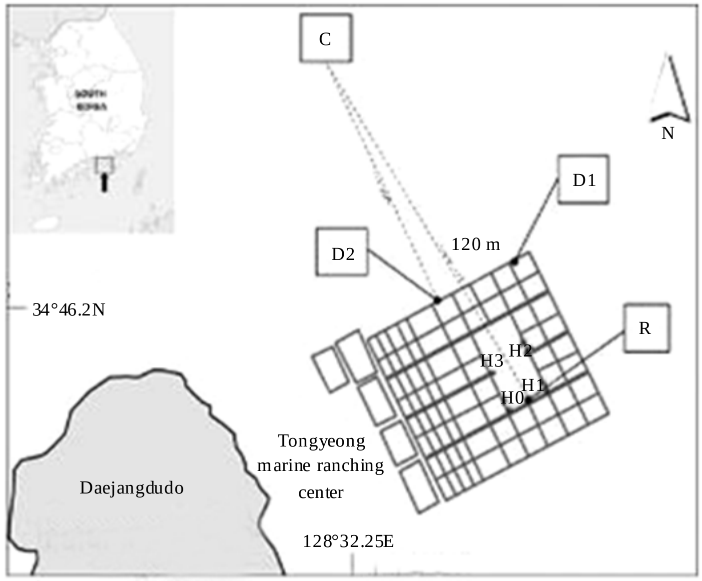

Fig. 10: Black rockfish *Sebastes schlegeli*, T1 was released in the sea (R). D1 and D2 indicate the first and last detection on the culture cage after 6 h estimated drop off the micro data logger from the fish body. The micro data logger was recovered (C) inside the big artificial reef

In the present study, the short time has been a crucial factor owing to the period of tracking that involved some hours but it can show some aspects related to movements. Studies of porgies in Korea suggested that tagged fishes showed at behaviour pattern going to deep water and returning to shallow water and had a tendency to move wider range in night-time than day-time but some of them rarely showed a significant response to artificial reefs (Shin *et al*., 2004). Without artificial reef, fish T2 was tracked for 8 h continuously; nevertheless, the long displacement from release point to another area (1.1 km) occasioned loss of signal for several hours. It could be due to natural behaviour of rockfishes during the diurnal movement as: strong affinity at crevices, holes or vegetated habitats as mentioned in Mitamura *et al*. (2012).

Vertical movement of wild fish tagged: The distribution of black rockfish (*Sebastes schlegeli*, T1) according to the temporal profile of swimming depth for short time was shallower (above 5 m) then; it dived up to 20 m depth. This process occurred at 30 min approx. after release time (4:28 h); however, it should be considered the process of adaptation among fish and external device during the first hours of freely-swimming stage. Progressively, the depth of dives reached for the fish tended to be stabilizing around 18 m despite the instability of the external tag attached on the fish (it could have caused some errors in the recording); nevertheless, it has permitted to have a picture of the temporal free swimming distribution of the specie.

Furthermore, respect to the temperature profile in the first 30 min was high (>20°C) because during this process, the environment temperature was recorded due to the move and attach the fish with micro data logger on land before to release. After this time, black rockfish dived to greater depth where the temperature was around 14°C and fish remained for long time during 6 h of tracking process (Fig. 11-13).

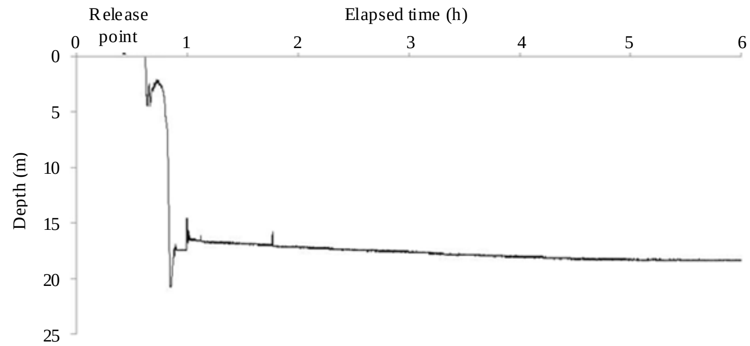

Fig. 11: Vertical track of 37 cm black rockfish, T1 fitted with a micro data logger and released at 04:28 h on May 11, 2013

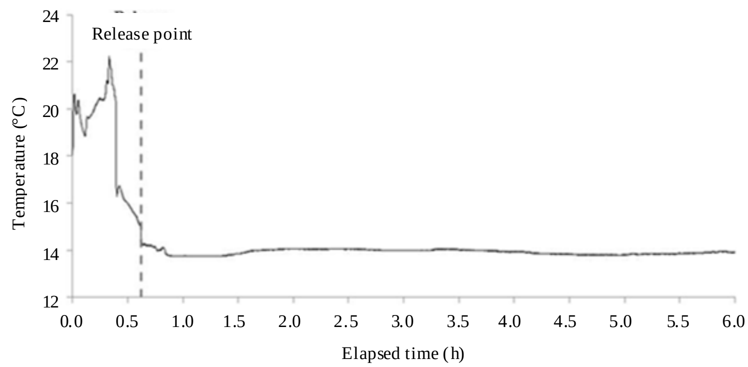

Fig. 12: Profile of environment temperature of black rockfish, T1 fitted with micro data logger on May 11, 2013

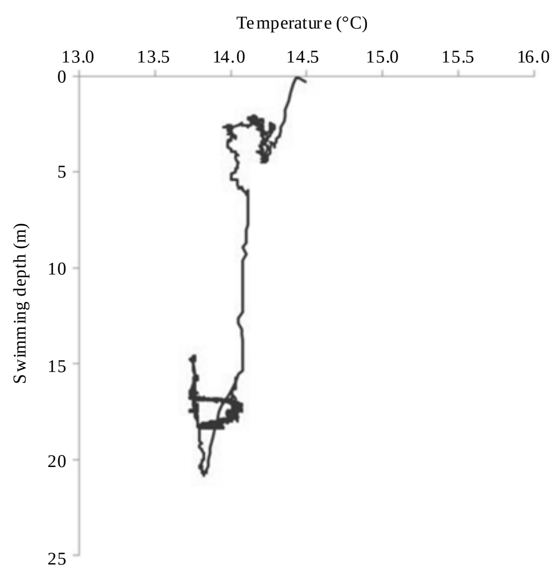

Fig. 13: Vertical distribution of water temperature and swimming depth of black rockfish, T1 fitted with micro data logger on May 11, 2013

Swimming behaviour: Analysis of vertical movement by using micro data logger through passive tracking technique, it has permitted to record the dive behaviour of black rockfish (fish T1). Black rockfish was more active in dawn hours (specifically at first hour to release) than daylight hours where the range of space was small (Fig. 11). Historically, genus *Sebastes* has been described as sedentary and territorial that tends to home back after displacement (Green and Starr, 2011; Mitamura *et al*., 2012) by using predominantly the olfactory sense in its homing behaviour (Mitamura *et al*., 2002; Mitamura *et al*., 2005). Additionally, Seaman *et al*. (2011) reported that rockfish is characterized to gather in dark and small spaces and for this reason; the affinity in a specific artificial reef is related to shapes like crevice spaces. Means of seasonal and direct movements among artificial reefs, Topping and Szedlmayer (2011) reported the behaviour of red snapper that is where fish moved to different structures for long periods and then go back to original release site.

Moreover, black rockfish (fish T1) has preferred to stay in shallower water after release and recovered. Similarly, Green and Starr (2011) and Kang and Shin (2006) reported the tendency of adult rock fish for shallower waters in long time also its preference to stay in artificial or natural reef especially in dark hours than during the day.

CONCLUSION

Fine-scale studies may be used as references to defining determined areas for no-take marine reserves and provide guidelines that could optimize artificial reefs placement as well as promote in areas even not carried out. In addition, the application of biotelemetry in this preliminary study, has offered a powerful means for the remote monitoring free-swimming of wild fish. Although biotelemetry techniques provide part of the answers for fisheries management, it can be used or included with traditional fisheries management approaches. But, this kind of study on artificial reefs and natural habitats requires covering a wide time range of tracking by using more individuals tagged.

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