Thesis for the Degree of Master of Fisheries Science

Behavioral characteristics of thread-sail filefish (*Stephanolepis cirrhifer*) measured by acoustic telemetry

by

Lyes Mekhazni

KOICA-PKNU International Graduate Program of Fisheries Science

Graduate School of Global Fisheries

Pukyong National University

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음향 텔레메트리 기법을 이용한 쥐치의 행동특성

Advisor: Professor Hyeon-Ok Shin

by

Lyes Mekhazni

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Approved by :

(Chairman) Prof. Kyoungmi Kang

(Member) Prof. Bo-Kyu Hwang

(Member) Prof. Hyeon-Ok Shin

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Abstract

Understanding movement patterns and habitat of the target species is important in the application of an ecosystem approach to fisheries management. The swimming paths of two thread-sail filefish (*Stephanolepis cirrhifer*) were measured in Tongyeong to appreciate how to use the space inside the experimental cage and in the open sea. The fish were surgically tagged with the acoustic transmitters (including a depth sensor). Passive monitoring and active tracking methods were carried out for 4 days and 3 hours, respectively. Horizontal movements in the cage were affected by current direction. During high current speed (>15 cm/s), fish were more active and cumulated horizontal distances almost double of those at low

current. Vertical movements of fish were affected by high current speed that reduced the depth of the cage bottom. When the current exceed 15 cm/s, the depth of the cage bottom was reduced. Furthermore fish were closer to the cage bottom at those moments. After release the fish were tracked for 41 minutes and moved 150 m from the release point.

Introduction

Fish stocks protection is the first priority of fishery management, since most targeted stocks recorded worldwide have been overexploited. To recover the situation, new tools and high technologies in fisheries have been developed, giving precious information about spatiotemporal utilization by fish species.

Determination of fish behavior such as migration, feeding, spawning and avoiding hostile conditions is essential to gather basic information on species distribution. Measurement of the use of space through time by fishes is crucial to understand population and community processes as well as assisting management and conservation of fish stocks (Lucas and Baras, 2000).

Marine ranching systems in Korea are implemented to improve sustainable productivity of the coastal region and to revitalize eco-friendly coastal fisheries (Kang and Shin, 2006). Previous studies have shown that no-take areas perform well in achieving biomass recovery for species (Di Franco et al., 2009; La Mesa et al., 2011). In this context, effectiveness of Marine Protected Areas (MPAs) depends on the scale of fish movement in relation to the size of the MPAs (Kramer and Chapman, 1999; Sale et al., 2005).

To improve their performance, MPAs should be large enough to include appropriate habitats for containing the regular movements of the adult fish (i.e., the home range of the sedentary fish (Kramer and Chapman, 1999)).

The thread-sail filefish *Stephanolepis cirrhifer* has been declined in fish landings (Yoon et al. 2012). To protect this species from depletion and to perform its effective management, it is necessary to identify its ecological distribution area. The use of acoustic telemetry has refined the study of the spatial and temporal distribution of fish species over various scales of space and time (Parsons and Egli, 2005; Mitamura et al. 2005; Block et al. 2005; Ohta and Kakuma 2005; Dagorn et al. 2007; Bauer et al. 2004). It allows the remote sensing of the positions, movements of an animal (Baras and Lagardere, 1995). Therefore a useful method to investigate fish behavior and widely used to obtain biological information (Shin et al. 2004; Shin et al. 2005; Kang et al, 2008; Hwang and Shin, 2010; Guler and Ubeyli, 2002). Moreover understanding the behavior of fish in small living space can offer a wide range of possibilities to improve the protection and management in marine aquaculture. Captured fish may also be tagged with electronic tags, which usually radiate energy, enabling the fish to be tracked and or environmental data to be gathered (Lucas and Baras, 2000; Yasuhiko, 2004; Webber, 2009).

Monitoring fine-scale movement by acoustic telemetry will provide valuable information on behavior, ecological and biological characteristics of *S. cirrhifer* near the Tongyeong Marine Living Resources Research and Conservation Center (T-MRC), Korea. Active tracking and passive monitoring methods were used in this study to quantify the complex movements of filefish. Moreover environmental data are recorded to fit the swimming paths of *S. cirrhifer*. Some fishes usually have behavior of site fidelity (returning to their previously occupied areas), we hypothesized that after release the tagged fish should be back to near the experimental cage in which the fish has been experimentally reared for four days. Such information are capital to understand the ecological distribution area of fish, which is required in fish stock studies and fishery management to effective protection and well promoting fish resources.

Materials and Methods

Study site and environmental monitoring

The study was conducted in the experimental cage station of Tongyeong Marine Living Resources Research and Conservation Center (TMRC), located on latitude 34° 46' 12" N and longitude 128° 23' 00" E, belonging to the Korea Institute of Ocean Science and Technology (KIOST), South Korea (Fig. 1).

To find out the effects of physical environmental factors on fish behavior, physical environmental factors was measured with a RCM-9 (Aanderra DATA Instruments AS, Norway) submerged at 5 m depth and fitted the frame of the experimental cage. It recorded information on current speed and direction, temperature, conductivity, turbidity, DO and salinity at ten-minute intervals during the experimental period (from 9 to 12 April, 2014).

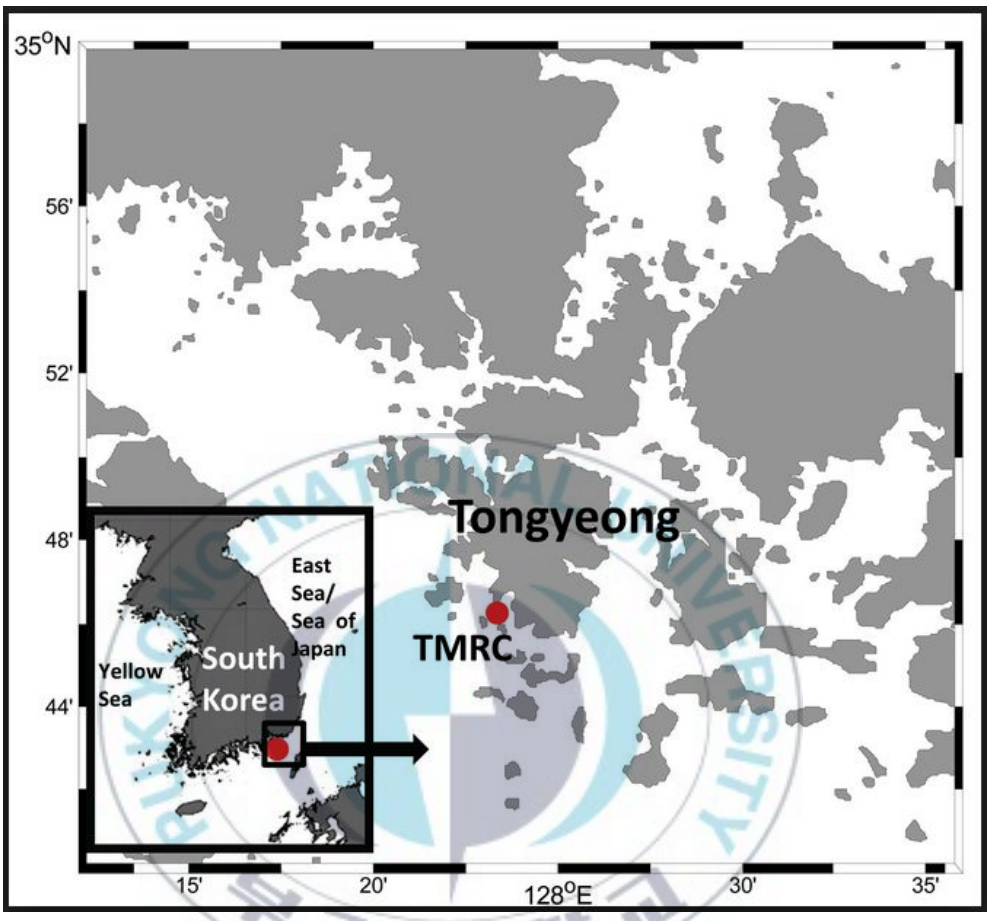


Fig. 1. Site study in Tongyeong Marine Living Resources Research and Conservation Center(TMRC).

Fish tagging

Two thread-sail filefish (*Stephanolepis cirrhifer,* T1 and T2) were captured near the marine ranching center of Tongyeong on April 9, 2014. The fish was anaesthetized with MS-222 (100 ppm) dissolved seawater to prevent straggling and prepare good environmental conditions with minimum stress when handling fish. Total length and weight were measured before surgical implantation. The fish was placed in the V-shaped table, and covered with a wet towel preventing dehydration. A small incision was made in the mid-ventral part, started after 2 cm from the anus towards the pelvic fin using a scalpel. Acoustic transmitter (Fusion Inc., Japan) was implanted into its abdomen through the incision. Incision closure was done using a monofilament surgical thread with a tapered needle, and then the betadine antibiotic was used on the wound to prevent infection and help in rapid healing. It took 5 minutes for surgical operation. Tagged fish was released into the experimental cage after it was shown normal behavior from anaesthetization in the recovery tank. Tagged fish and specification of acoustic tag were summarized in Table 1.

Table 1. Summary of tagged *Stephanolepis cirrhifer* and specification of acoustic transmitter used in the study

Fish	Total length (cm)	Weight (g)	Acoustic t						
			Frequency (kHz)	Source level (dB re 1μPa at 1m)	Signal interval (s)	Battery life (days)	Size (mm)	Weight in water (g)	Effective range of depth sensor (m)
T1	22.0	152	60	155	5	15	Φ9 x 37	2.0	50
T2	21.5	118	60	155	5	15	Φ9 x 37	2.0	50

Acoustic positioning system

In this study, two acoustic positioning systems were used to measure movement of the experimental cage and behavior of free-swimming fish in the cage from 9 to 12, April 2014. To monitor fish behavior in the cage, it was used an acoustic positioning system (FRX 4002, Fusion Inc., Japan) consisting of three sea stations and a base station (Table 2). Each sea station had acoustic receivers with an omni-directional hydrophone to receive the emitted signals from the tagged fish. The receivers were arrayed within 152 m^2 (17 m between each sea station) covering the cage, and each receiver connected the base station to record the signals and to calibrate underwater position of the tagged fish (Fig. 2).

Table 2. Specification of acoustic positioning system (FRX 4002, Fusion Inc., Japan)

Equipment	Specification	
FRX 4002	Tracking mode	Long baseline
	Frequency	Receiving: 25~70 kHz, Transmitting: 31.2 and 62.5 kHz
	Hydrophone channel	4 channel
	Multi-target tracking	Up to 32 coded type transmitters
	Size	Receiver: 27 × 24 × 13 cm Hydrophone: Φ45 x 40 Cable: 25 m
	Power	AC100 ~ 220W

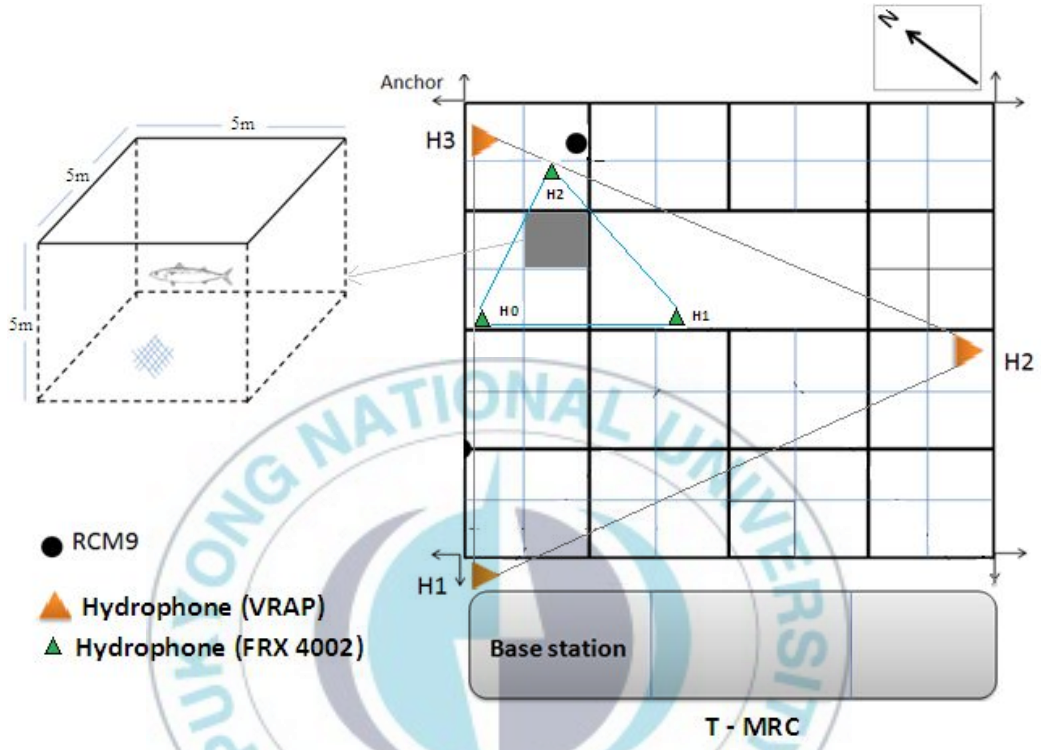


Fig. 2. Deployment of acoustic positioning systems in the experimental cage.

It was simultaneously measured the movement of the experimental cage with a radio-linked acoustic positioning system (VRAP, AMIRIX System Inc., Canada) to analyze the effect of cage movement on fish behavior. It also consisted of three sea stations and a base station. Each sea station (RAP buoy) had an omni-directional hydrophone to detect acoustic signals from ten acoustic transmitters (P1 – P10, AMIRIX System Inc., Canada) attached on the cage, and communicated to the base station with a VHF modem and an antenna concurrently (Table 3). The base station calibrated underwater positions of each acoustic transmitter with the transferred signals through RAP buoys, and displayed their positions on a monitor in real-time before saving on a hard disk. The specification and deployment of the acoustic transmitters were shown in Table 4 and Fig. 3, respectively.

Table 3. Specification of radio-linked acoustic positioning system (VRAP, AMIRIX System Inc., Canada) to measure movement of the experimental cage

Equipment		Specification
RAP buoy	Tracking mode	Long baseline
	Positioning accuracy	0.5 m to 2 m
	Frequency	Receiving: 50~85 kHz, Transmitting: 51 kHz
	Detectable range	Typically 500 m
	Operating hours per charge	7 days
	Dimensions of buoy	60 cm diameter × 100 cm height
	Buoy weight	43 kg (reserve buoyance: 60 kg)
RF MODEM	Frequency	456.2 MHz
	Communication mode	Two ways
	Modulation	FM 9600 baud
	Output power	2 W
Software	Multi-target tracking	Up to 12 continuous type transmitters
	Chart overlays	Yes
	Version	VRAP 5.0

Table 4. Specification of ten acoustic transmitters (AMIRIX System Inc., Canada) to measure movement of the experimental cage

Frequency (kHz)	Source level (dB re 1μPa at 1m)	Signal interval (s)	Size (mm)	Weight in air (g)	Effective range of depth sensor (m)
69	158	40-120	Φ18 x 117	36	68

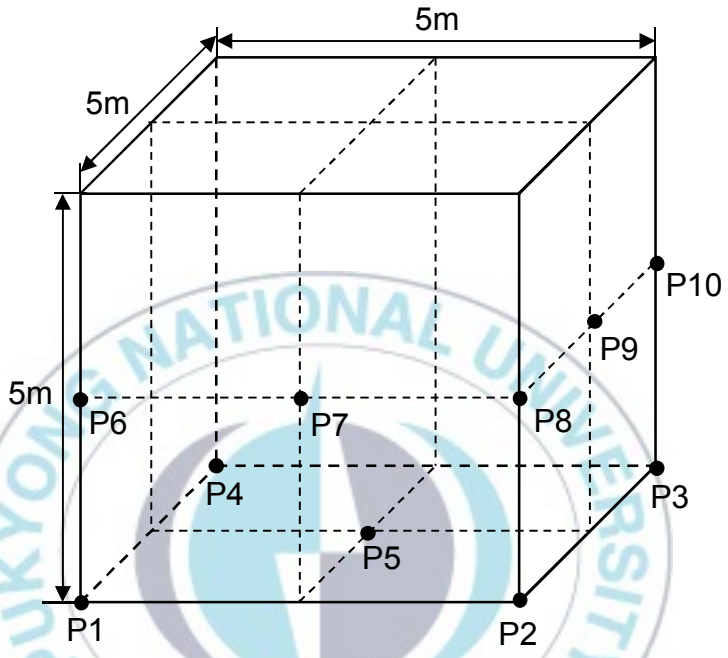


Fig. 3. Deployment of the acoustic transmitters attached on the experimental cage.

Calibration of underwater position data

The underwater position coordinates of the acoustic transmitter was calculated with the hyperbolic positioning algorithms. The velocity of underwater sound is hypothesized 1,500 m/s in constant and time difference between each hydrophone is shown as a distance difference from the acoustic transmitter to each hydrophones. The coordinate of the acoustic transmitter (P) and three hydrophones (H_0, H_1, and H_2) are P (x, y, z), $H_0(x_0, y_0, z_0)$, H_1 (x_1, y_1, z_1) and H_2 (x_2, y_2, z_2), the distance from the acoustic transmitter to each hydrophones is ρ_0, ρ_1 and ρ_2, respectively (Fig. 4).

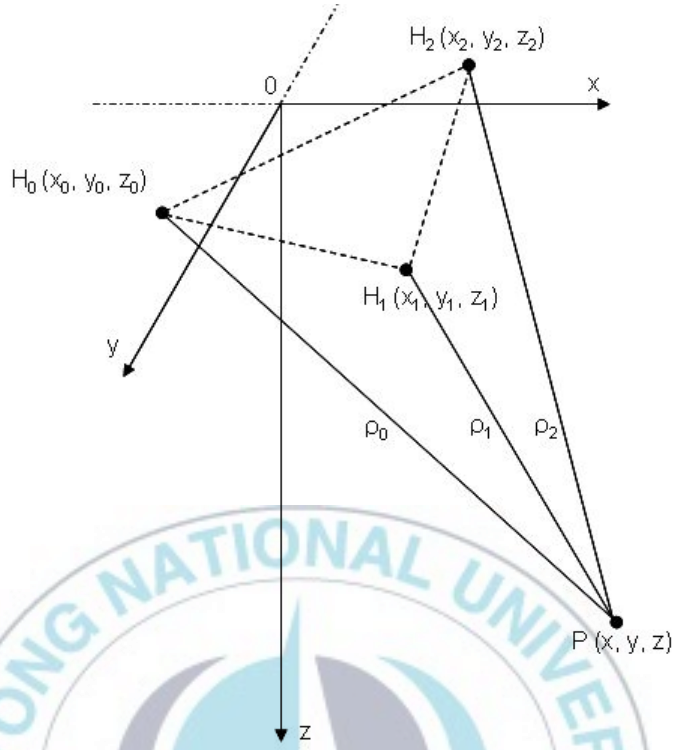


Fig. 4. 3-D coordinates of the acoustic transmitter and the hydrophone. ρ_0, ρ_1 and ρ_2 are distances between the acoustic transmitter (P) and each hydrophone (H_0, H_1, and H_2).

The interaction formula of the distance, ρ_i is followed as:

$$\rho_i^2 = (x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2 \qquad (i = 0, 1, 2) \qquad (1)$$

where, ρ_0 is unknown value, and f_i and z are the measured distance difference and depth of the acoustic transmitter. f_i is calculated as:

$$f_i = \rho_i - \rho_0 \qquad (i = 0, 1, 2) \qquad (2)$$

where, z is the measured depth of the acoustic transmitter, and its position P (x, y) is calculated with two paired distance. If the initial position of the acoustic transmitter is P_s (x_s, y_s), the distance difference from the initial position of the acoustic transmitter (f_{is}) is determined as:

$$\rho_{is}^2 = (x_s - x_i)^2 + (y_s - y_i)^2 + (z_s - z_i)^2 \qquad (i = 0, 1, 2) \qquad (3)$$

$$f_{is} = \rho_{is} - \rho_{0s} \qquad (i = 0, 1, 2) \qquad (4)$$

The partial differentiation of f_{is} is followed as:

$$\frac{\partial f_{is}}{\partial x} = \frac{(x_s - x_i)}{\rho_{is}} + \frac{(x_s - x_i)}{\rho_{0s}} \qquad (i = 1, 2) \qquad (5)$$

$$\frac{\partial f_{is}}{\partial y} = \frac{(y_s - y_i)}{\rho_{is}} + \frac{(y_s - y_i)}{\rho_{0s}} \qquad (i = 1, 2) \qquad (6)$$

If Δf_{is} is the difference between the measured and the calculated value of distance, Δx and Δy are calculated as:

$$\Delta f_{is} = f_i - f_{is} \qquad (i = 1, 2) \qquad (7)$$

$$\begin{bmatrix} \Delta x \\ \Delta y \end{bmatrix} = \begin{bmatrix} \frac{\partial f_{1s}}{\partial x} & \frac{\partial f_{1s}}{\partial y} \\ \frac{\partial f_{2s}}{\partial x} & \frac{\partial f_{2s}}{\partial y} \end{bmatrix}^{-1} \cdot \begin{bmatrix} \Delta f_{1s} \\ \Delta f_{2s} \end{bmatrix} \qquad (8)$$

The final position of the acoustic transmitter is determined as:

$$x = x_s + \Delta x$$
$$y = y_s + \Delta y \tag{9}$$

where, Δx and Δy are the calibrated value, and calculated repeatedly when the values are smallness than the initial reference.

Tracking fish behavior

Two tagged fish (T1 and T2) were tracked fish behavior in the experimental cage with the acoustic positioning system from 9 to 12 April, 2014. The fish were released out of the cage at 11:50 on 12 April, 2014, and then tracked with an active tracking system and a global positioning system (GPS) installed on a research vessel. The hydrophone detected the signal of the tagged fish, and the receiver recorded identification number, detected date and time and swimming depth from the detected signal. All information was displayed on the monitor. The vessel tracked continuously the tagged fish with a speed around 2 knots

Results

Environmental factors in the study site

During the experimental period, water temperature was averaged 12.9 ℃ (±0.3), and the average of turbidity and dissolved oxygen was 1.0 NTU (±0.3) and 10.5 mg/l (±0.2), respectively. During the period, maximum and minimum of the current speed was 31.3 cm/s (at 7:32 on 12 April) and 0.5 cm/s (at 19:22 and 12:42 on 9 April, 18:42 and 23:12 on 10 April, 4:12 on 11 April and 10:02 on 12 April). When the current speed was over 20 cm/s from 10 to 12 April, the dominant current was flowing toward east-south. On 9 April, 2014, the maximum current speed was 7.3 cm/s (18:52), and the dominant current direction was east-southward (Fig. 5).

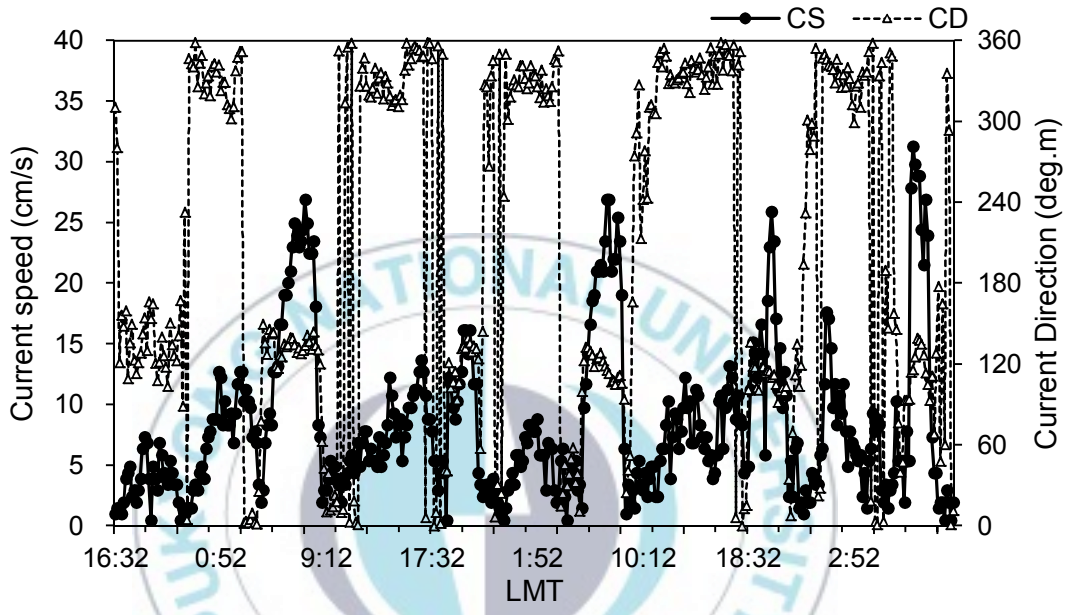
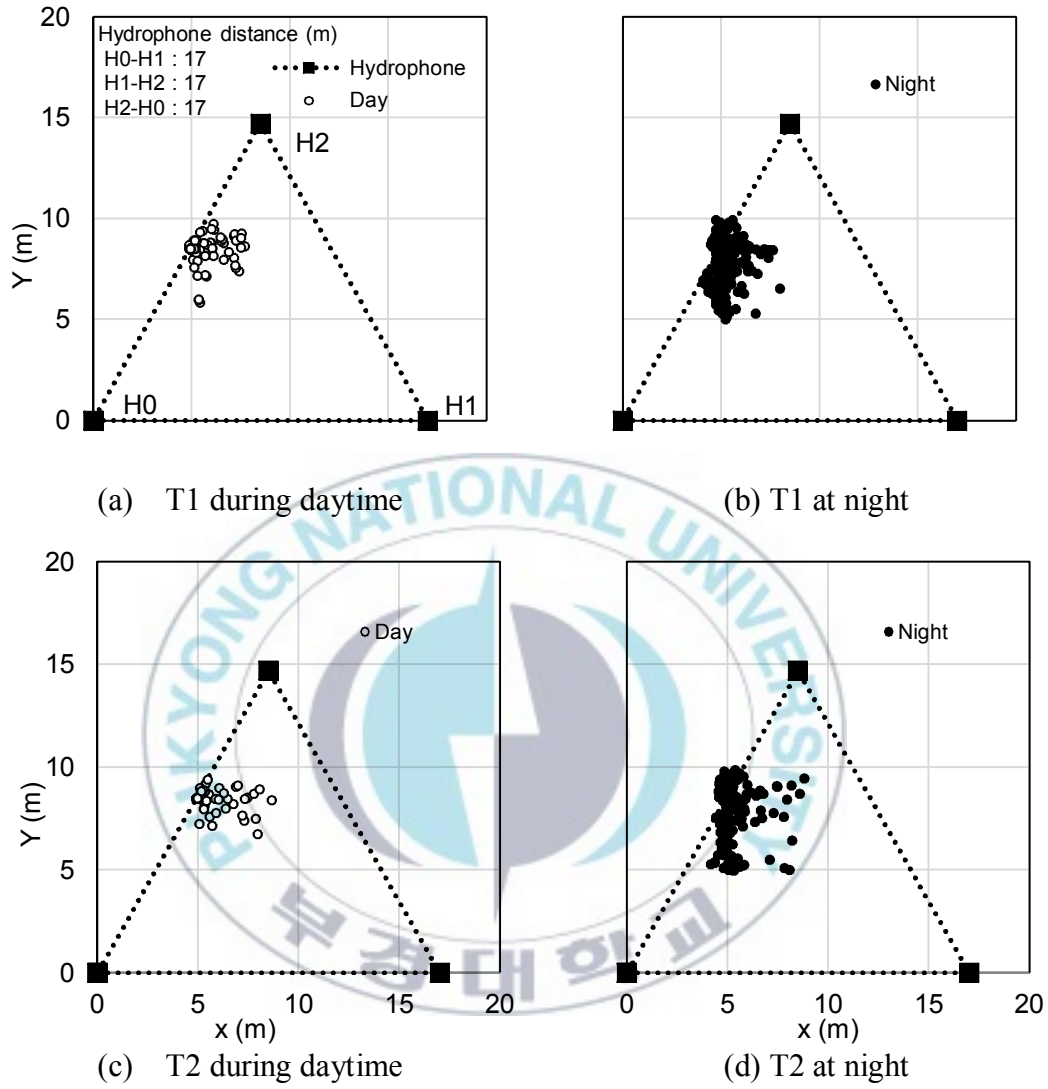


Fig. 5. Variation of current speed (CS) and direction (CD) in the study site from 9 to 12 April, 2014.

Fish Behavior in the experimental cage

Horizontal movements

On 9 April, T1 and T2 were detected from 16:35 to 23:59 (Fig. 6). T1 was detected 134 times during daytime and 299 times at night, respectively. The average point during daytime and at night was (5.4, 8.5) and (5.2, 7.8), respectively. T2 was detected 98 times during daytime and 231 times at night, respectively, and its average point during daytime and at night was (5.4, 8.5) and (5.3, 7.7), respectively. The movement range of T1 and T2 was greater at night than during a daytime.

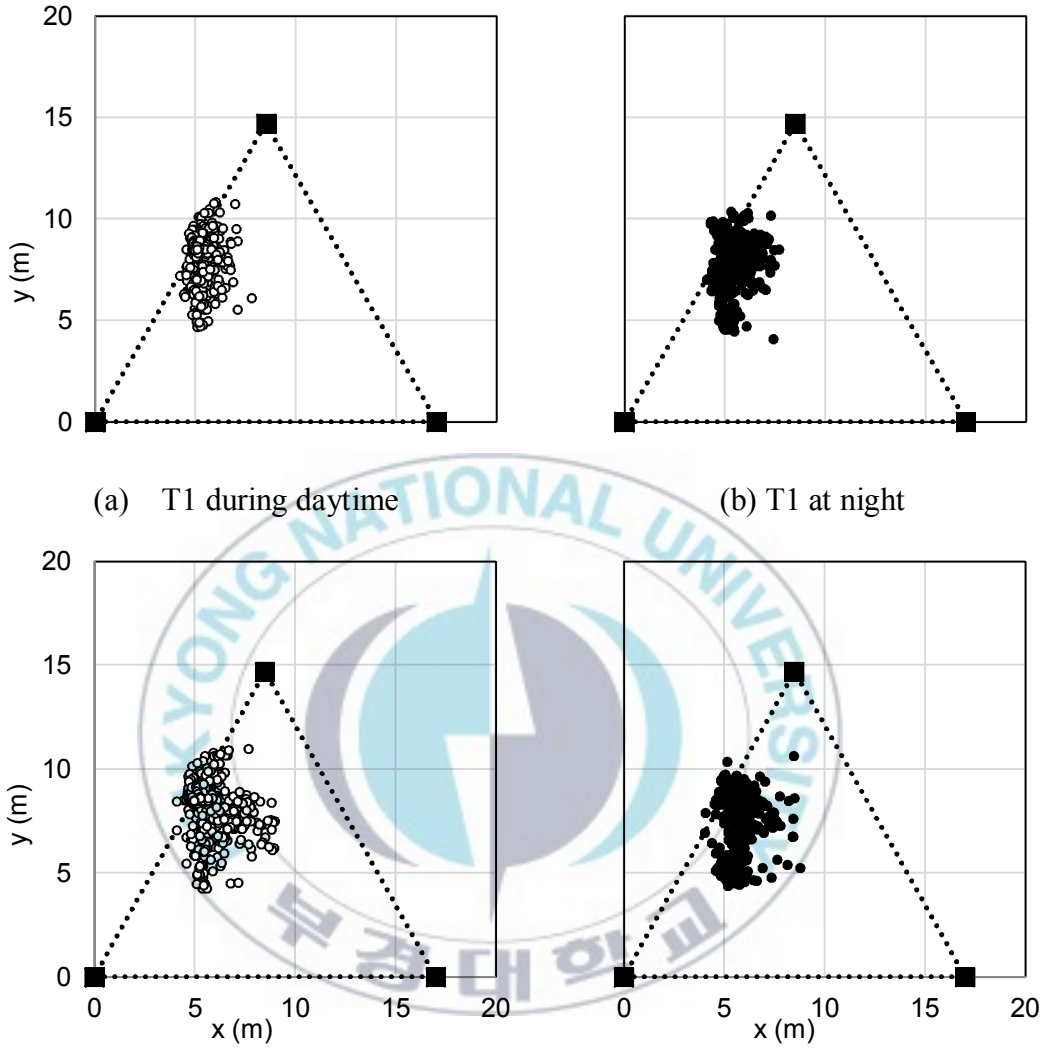


(a) T1 during daytime (b) T1 at night

(c) T2 during daytime (d) T2 at night

Fig. 6. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) in the experimental cage on 9 April, 2014.

On 10 April, T1 and T2 were detected from 00:00 to 23:58 (Fig. 7). T1 was detected 767 times during daytime and 652 times at night, respectively. The average point during daytime and at night was (5.3, 8.3) and (5.3, 7.8), respectively. T2 was detected 735 times during daytime and 494 times at night, respectively, and its average point during daytime and at night was (5.6, 8.2) and (6.6, 7.5), respectively. Both of the tagged fish were detected more frequently during a daytime than at night. Especially, the number of detected signals of T2 was less than T1 during the period. The movement range of T1 and T2 was similar during daytime and at night. However, the movement range of T2 was greater than T1 during daytime and at night.



(a) T1 during daytime (b) T1 at night

(c) T2 during daytime (d) T2 at night

Fig. 7. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) in the experimental cage on 10 April, 2014.

On 11 April, T1 and T2 were detected from 00:00 to 23:59 (Fig. 8). T1 was detected 774 times during daytime and 623 times at night, respectively. The average point during daytime and at night was (5.2, 6.5) and (5.2, 7.5), respectively. T2 was detected 668 times during daytime and 577 times at night, respectively, and its average point during daytime and at night was (5.2, 6.5) and (5.3, 6.9), respectively. Both of the tagged fish were detected more frequently during a daytime than at night. While the movement range of T1 was similar during daytime and at night, T2 was greater at night than during a daytime and greater than T1.

To compare the number of detected signals from 10 to 11 April, both tagged fish were detected more frequently during a daytime than at night. Total detected number of T1 was higher than T2. There was a different tendency in the detected number between T1 and T2. While total detected number of T1 was reduced on 11 April, the number of T2 was increased. Additionally, the difference of the detected number of T2 between daytime and night was decreased on 11 April. Whereas, the difference of T1 was increased.

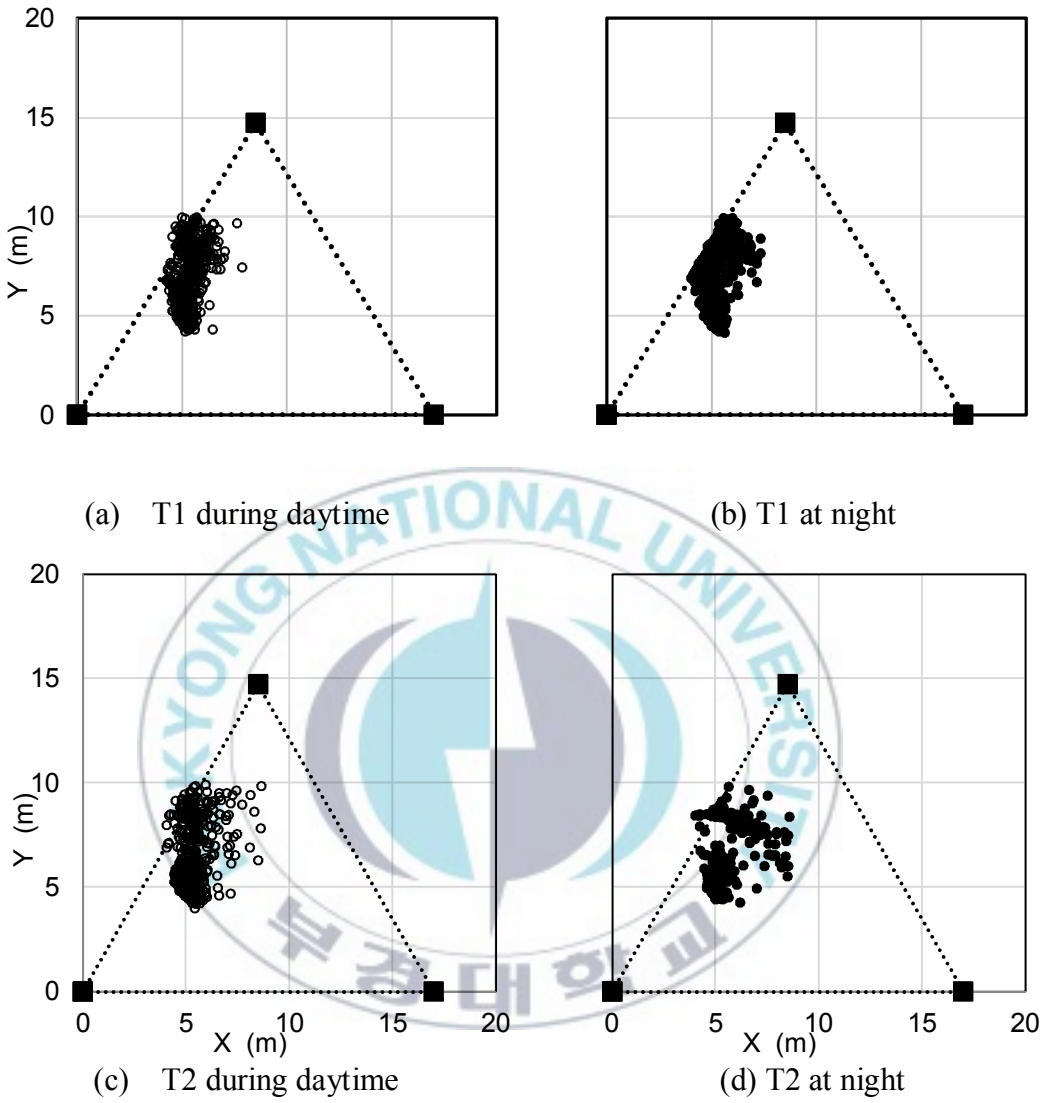


Fig. 8. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) in the experimental cage on 11 April, 2014.

On 12 April, T1 and T2 were detected from 00:00 to 11:50 (Fig. 9). T1 was detected 342 times during daytime and 346 times at night, respectively. The average point during daytime and at night was (5.3, 7.2) and (5.0, 6.7), respectively. T2 was detected 281 times during daytime and 350 times at night, respectively, and its average point during daytime and at night was (5.3, 7.7) and (5.8, 8.1), respectively. Both tagged fish were detected more frequently during a daytime than at night. While the movement range of T1 was similar during daytime and at night, T2 was greater during a daytime than at night and greater than T1.

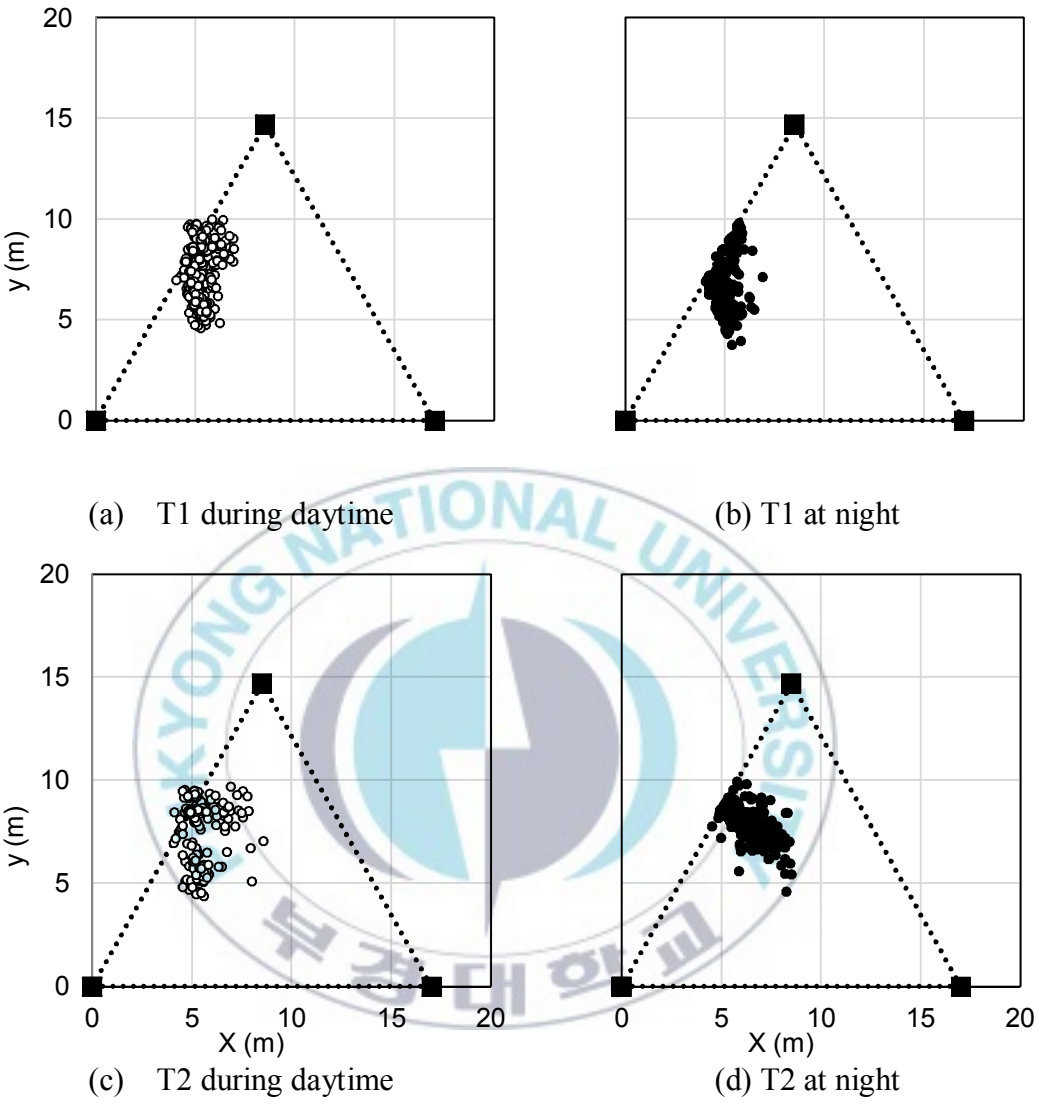
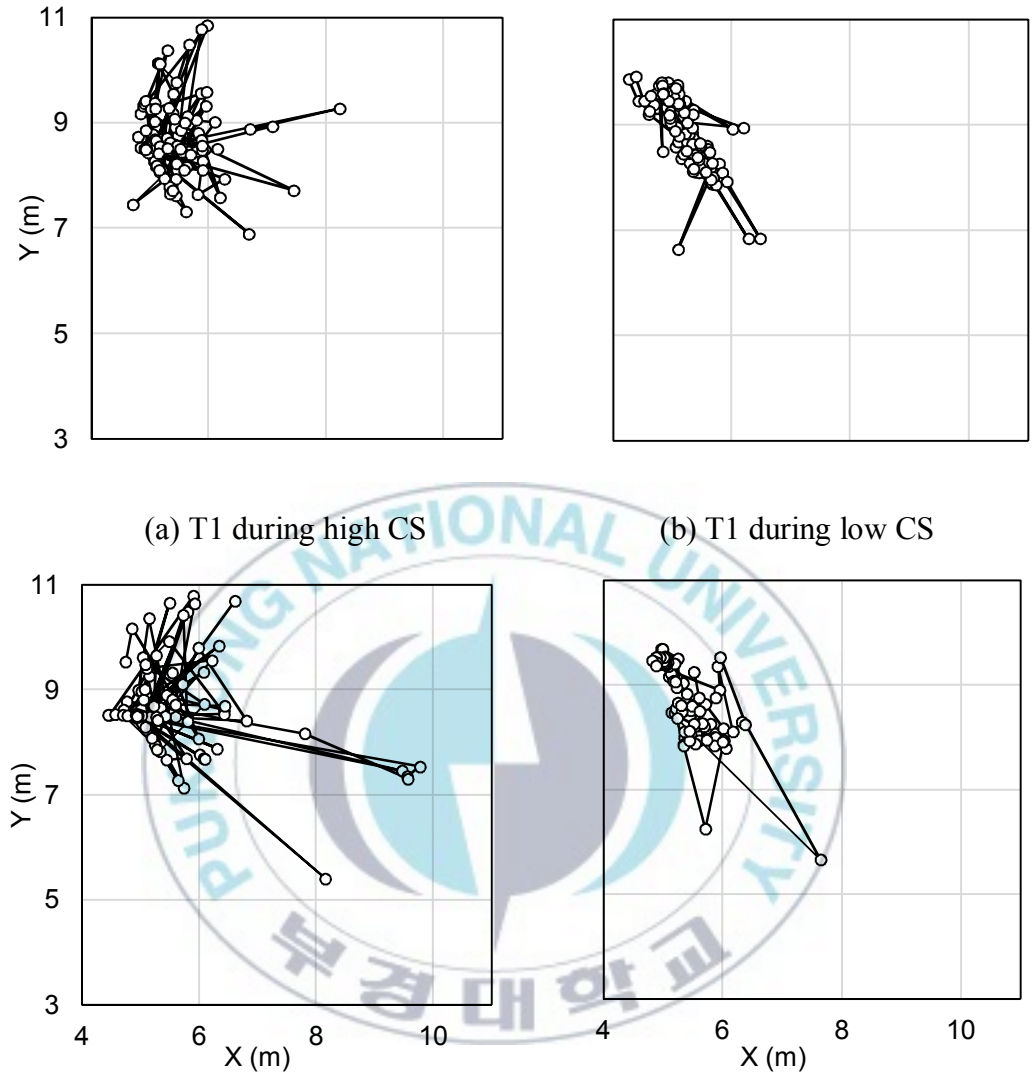


Fig. 9. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) in the experimental cage on 12 April, 2014.

It was carried out to analyze horizontal movement of the tagged fish when the current speed was intraday high and low from 10 to 12 April, 2014 (Fig. 10, 11 and 12). Movement distance was calculated for 2 hours when the current speed was high and low each day. During the experimental period, the tagged fish did not swim circularly in the experimental cage. Both fish seemed to focus on a small area and made straight displacements from one point to another or back to the same point. On 10 April, the average point of T1 during high and low current speed was (5.4, 8.6) and (5.2, 8.9), respectively. There was no significant difference in the average point by current speed. However, there was a significant difference of the movement distance of T1 by current speed. The movement distance of T1 during high and low speed was 102.5 m and 48.2 m, respectively. T1 preferred to move greater during high speed than during low speed (Fig. 10a and 10b).

The average point of T2 was similar to T1. It was (5.5, 8.6) during high speed and (5.4, 8.8) during low speed. It also had a similar tendency for movement distance by current speed. The movement distance of T2 during high and low speed was 129.8 m and 36.4 m, respectively (Fig. 10c and 10d). T2 preferred to move more active during high speed. In these results, the current speed clearly affected on horizontal movement of the tagged fish that swam more active during high current speed.

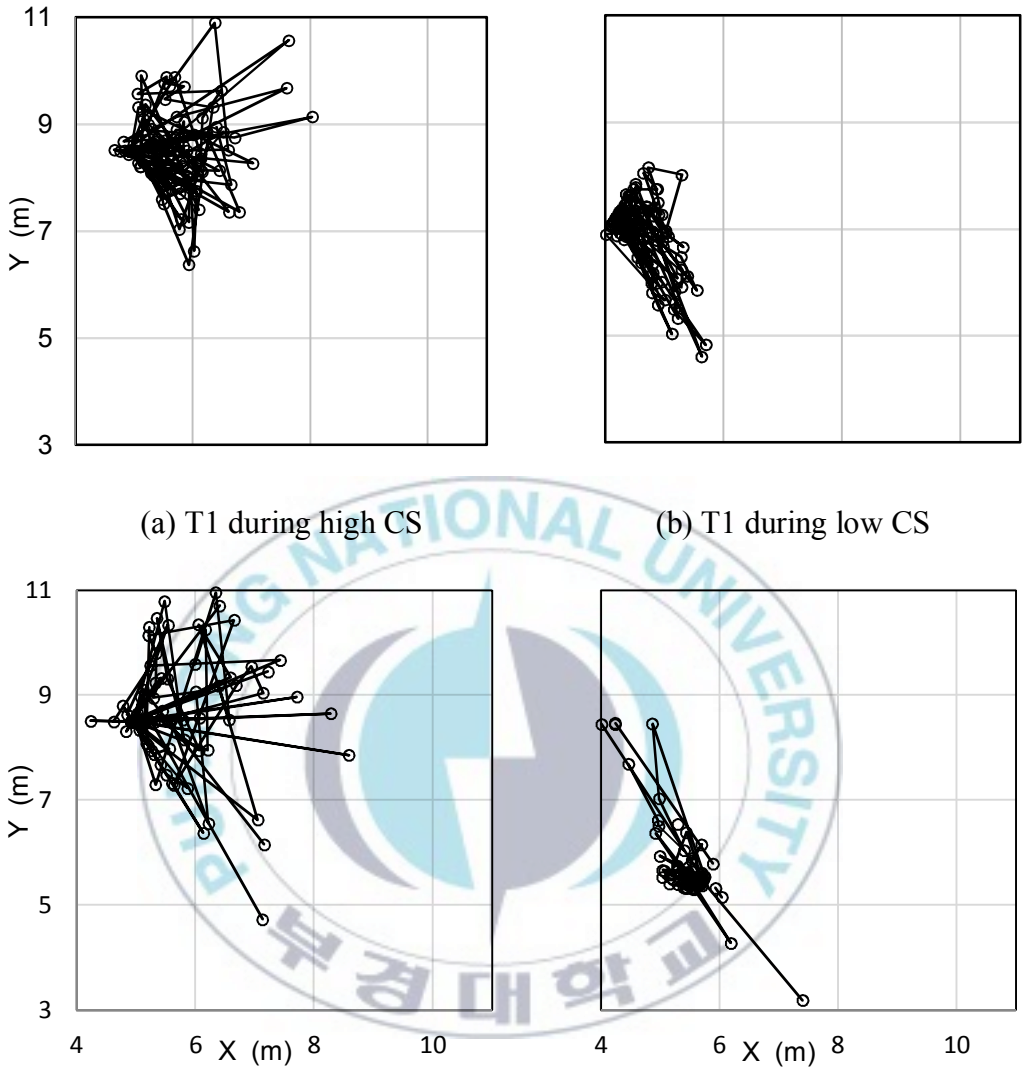


(a) T1 during high CS (b) T1 during low CS

(c) T2 during high CS (d) T2 during low CS

Fig. 10. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) during high and low current speed (CS) on 10 April, 2014.

On 11 April, the average point of T1 during high and low current speed was (5.6, 8.5) and (4.6, 6.9), respectively. There was a significant difference in the average point and the movement distance by current speed. The movement distance of T1 during high and low speed was 113.6 m and 63.3 m, respectively. It moved more active during high speed than during low speed (Fig. 11a and 11b). In the same time, the average position and the movement distance of T2 was (5.5, 8.6) and 136.6 m during high speed and (5.5, 5.7) and 61.7 m during low speed, respectively. It also moved more active during high speed than during low speed (Fig. 11c and 11d). Total movement distance of T1 during high and low current speed was less than T2.



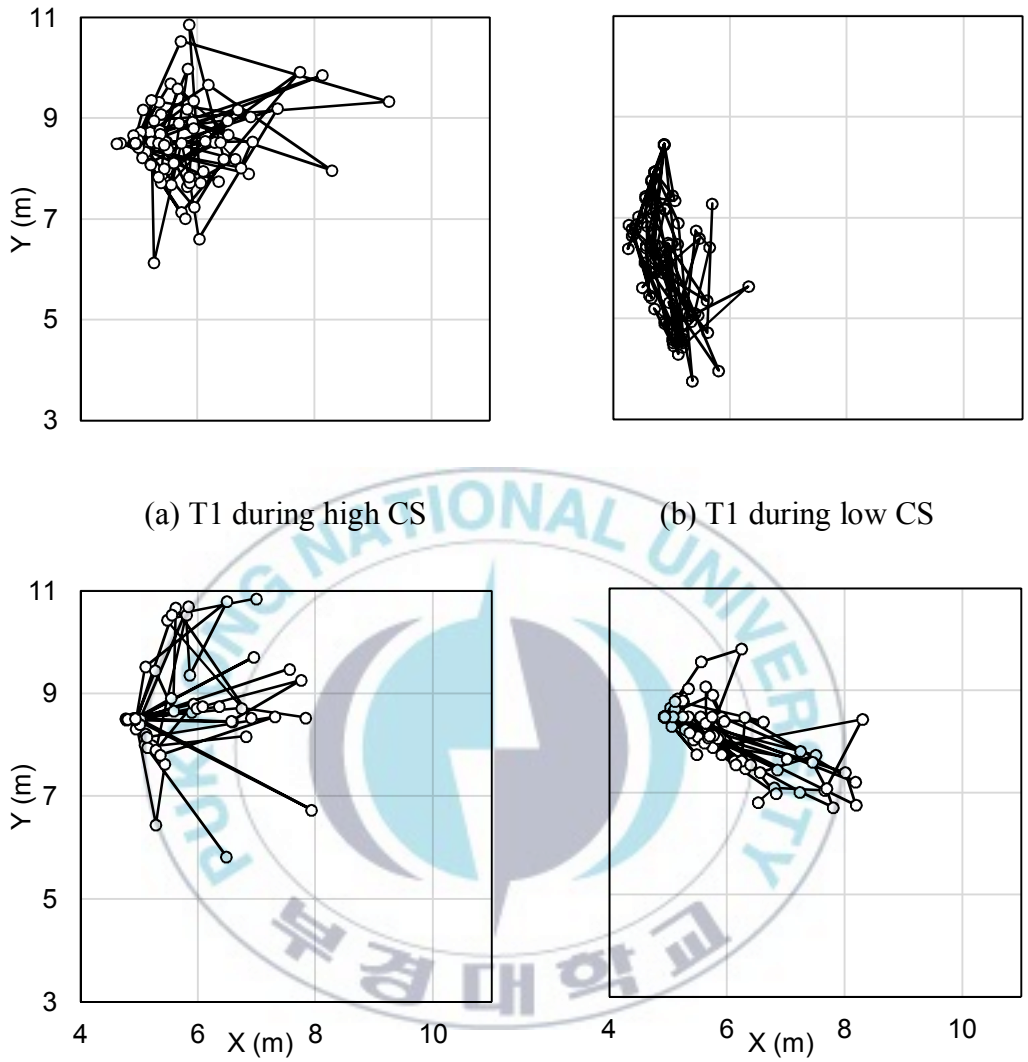
(a) T1 during high CS (b) T1 during low CS

(c) T2 during high CS (d) T2 during low CS

Fig. 11. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) during high and low current speed (CS) on 11 April, 2014.

On 12 April, the average point of T1 during high and low current speed was (5.8, 8.5) and (4.9, 6.2), respectively. There was a significant difference in the average point and the movement distance by current speed. The movement distance of T1 during high and low speed was 107.6 m and 92.5 m, respectively. It moved more active during high speed than during low speed (Fig. 12a and 12b). In the same time, the average position and the movement distance of T2 was (5.6, 8.7) and 88.6 m during high speed and (5.9, 8.1) and 77.2 m during low speed, respectively. It also moved more active during high speed than during low speed (Fig. 12c and 12d). Contractively, total movement distance of T1 during high and low current speed was longer than T2.

Consequently, T1 and T2 were more active during high current speed than during low current speed. Both tagged fish was affected by current speed.



(a) T1 during high CS (b) T1 during low CS

(c) T2 during high CS (d) T2 during low CS

Fig. 12. Horizontal movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) during high and low current speed (CS) on 12 April, 2014.

Vertical movements

On 9 April, T1 swam in almost the entire vertical column in the experimental cage (Fig. 13a). Maximum and minimum of swimming depth was 7.0 m (23:52) and 2.9 m (20:42), respectively. Average of swimming depth was 5.5 m (±0.9). T2 also used the entire vertical column of the cage (Fig. 13a). Maximum and minimum of swimming depth was 7.8 m (22:22) and 1.6 m (5:02), respectively. Average of swimming depth was 4.3 m (±1.4). It was slightly shallower than T1. When current speed was low (1.5 ~ 5.0 cm/s), it did not effect on the swimming depth of both T1 and T2, and the cage bottom was mainly stable around the depth of 8.5 m.

On April 10, the layer of swimming depth of T1 was from 1.5 m to 7.9 m. Average of swimming depth was 6.3 m (±1.6). The swimming depth of fish was significantly different by high current speed (Mann-Whitney test, $n=484$, $p<0.001$) and when it exceeded 15 cm/s, the depth of fish was decreased and swimming depth was around 4.2 m and did not exceed 6.6 m (Fig. 13b). When the cage bottom floated 6 m in depth, the swimming depth of T1 was around 5 m. In contrary, when the cage bottom sank more than 8 m in depth, T1 preferred to stay deeper than 7 m in depth.

The layer of swimming depth of T2 was from 3.9 m to 7.9 m. Average of swimming depth was 6.0 m (±1.2) (Fig. 13b). In general, the swimming depth of tagged fish was affected by current speed and the movement of the cage bottom (Mann-Whitney test, n=110, p=0.013). When current speed became higher (more than 15 cm/s), T2 floated from 7.3 m to 4.3 m and the depth of the cage bottom also floated from 8.5 m to 6.1 m.

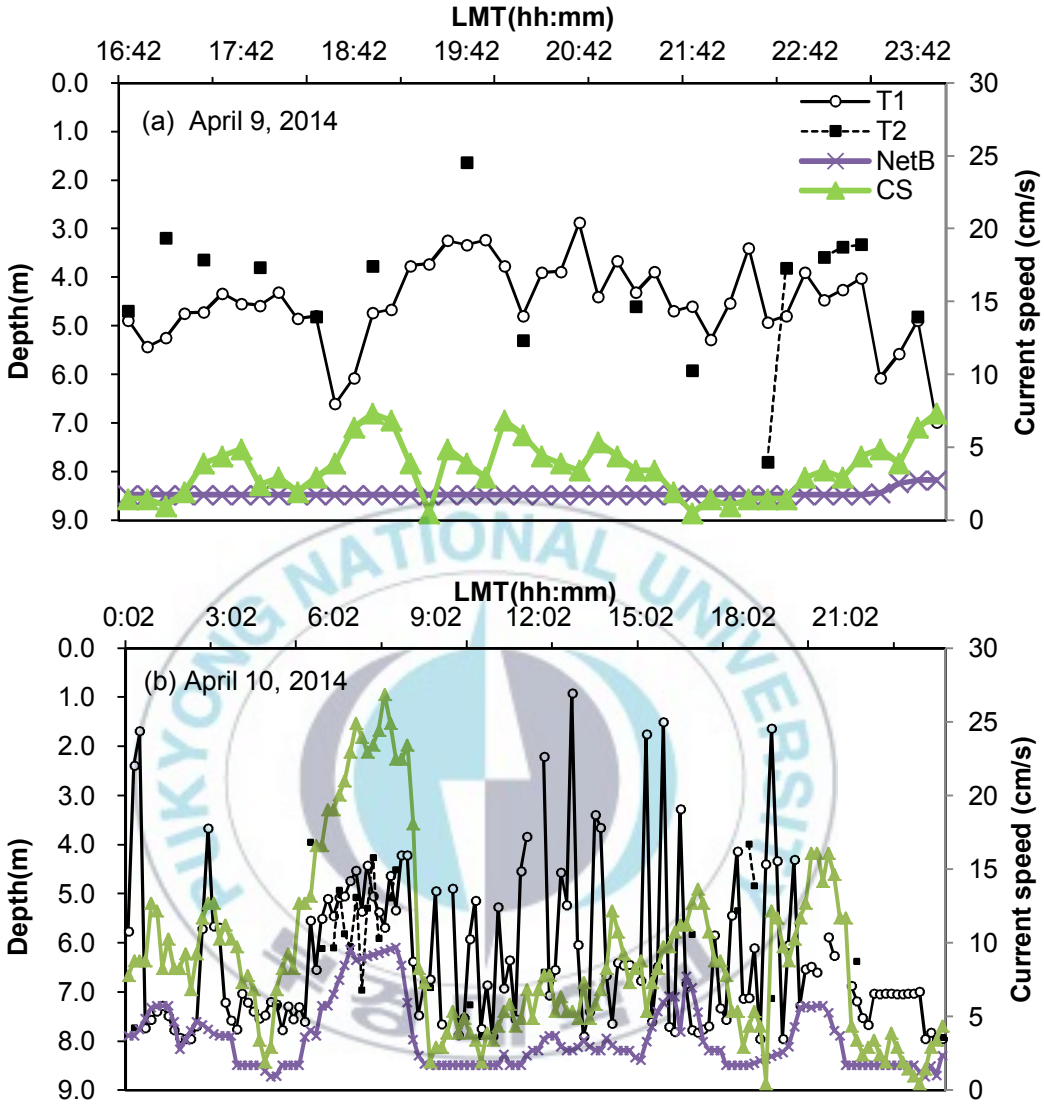


Fig. 13. Vertical movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) with current speed (CS) and the movement of the experimental cage bottom (NetB) from 9 to 10 April, 2014.

On April 11, swimming depth of T1 varied from 2.0 m to 7.9 m. Average of swimming depth was 6.6 m (±1.5) (Fig. 14a). The swimming depth of T1 was affected by current speed and the movement of the cage bottom (Mann-Whitney test, n=349, $p<0.001$). When current speed was 23.5 cm/s, depth of the cage bottom and swimming depth of T1 was 6.7 m and 6.3 m in depth, respectively. The tagged fish preferred to stay near the cage bottom during high current speed. When the cage bottom sank 8.8 m in depth during low current speed (5.4 cm/s, 21:52), the fish floated and preferred to swim in the middle of the cage (around 5.0 m). T2 swam between 1.1 m to 7.8 m in the cage. Average of swimming depth was 6.0 m (±1.7) (Fig. 14a). The swimming depth of T2 was not affected by current speed (Mann-Whitney test, n=79, $p=0.475$). The fish showed different variations in swimming depth. When current speed was at the first peak, the fish seemed to decrease its swimming depth.

On April 12, swimming depth of T1 was between 1.6 m to 7.9 m, and its average was 6.0 m (±2.1) (Fig. 14b). It was shown a similar tendency in swimming depth by current speed and the movement of the cage bottom. The swimming depth of T1 was affected by current speed during the period (Mann-Whitney, n=278, $p<0.001$). When the cage bottom floated 4.9 m in depth (7:52), the swimming depth of T1 was 4.6 m. The fish also preferred to stay near the cage bottom during high current

speed. T2 swam between 3.2 m to 7.4 m, and average of swimming depth was 5.5 m (±1.6) (Fig. 14b). The fish was not affected by current speed (Mann-Whitney test, n=74, p=0.364). Both tagged fish had almost the same response to the environmental stimuli.

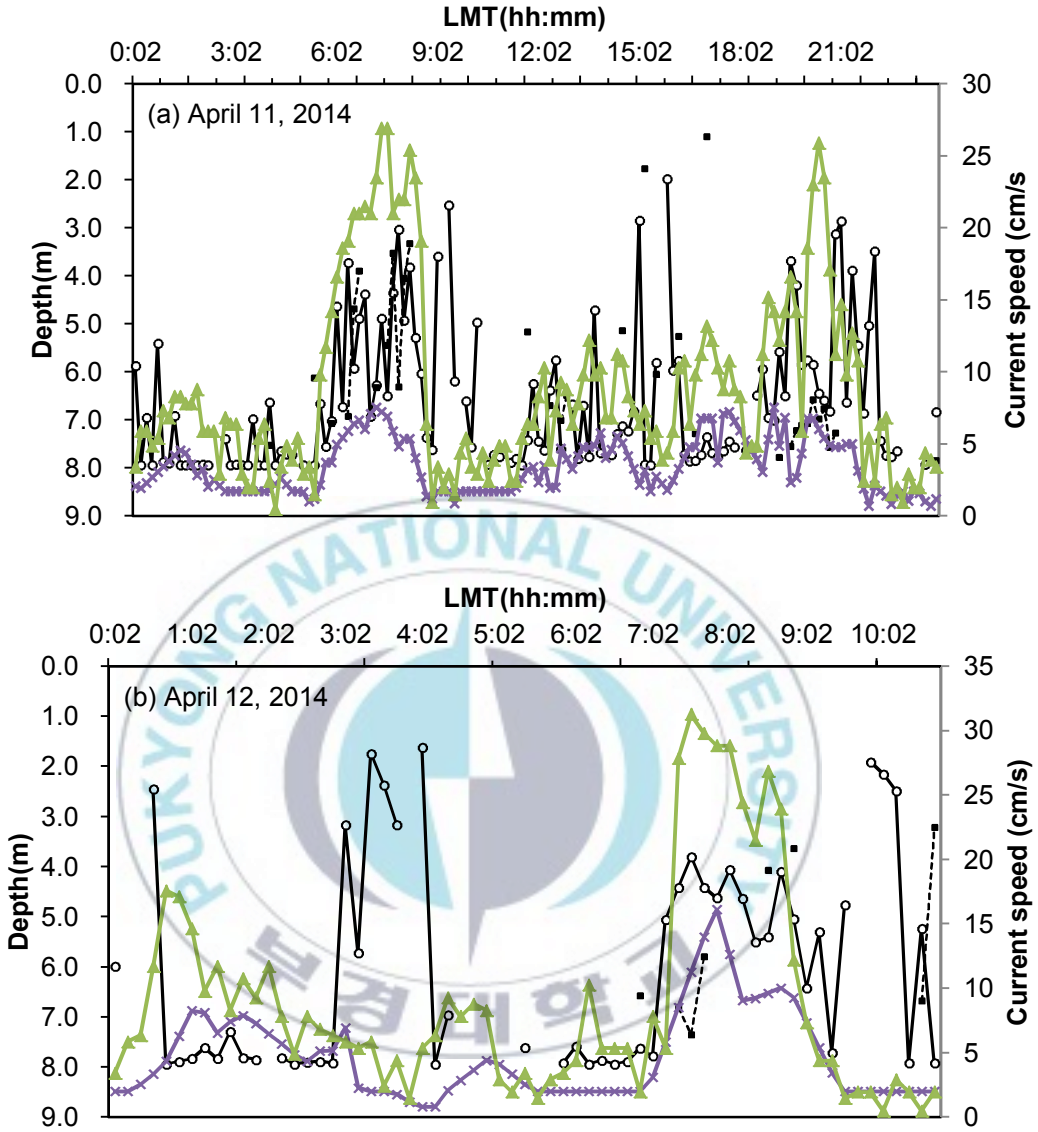


Fig. 14. Vertical movement of the tagged *Stephanolepis cirrhifer* (T1 and T2) with current speed (CS) and the movement of the experimental cage bottom (NetB) from 11 to 12 April, 2014.

T1 and T2 were released out of the experimental cage at 11:50 on 12 April, 2014. Both fish were traced with active tracking system installed on the research vessel. After release, T1 and T2 stayed near the experimental cage for 25 min and 41 min. T1 was found near the small island, Daejangdudo (150 m far from the release point) 2 hours later. It was not detected again during the experimental period.

In the study site, T1 preferred to swim between 7 m and 12 m, and average of swimming depth was 9.1 m (±2.8). The swimming depth of T2 was 11 ~ 17 m, and its average was 13.3 m (±3.0). The deepest of swimming depth was 28 m near the seabed. T2 preferred to swim deeper than T1.

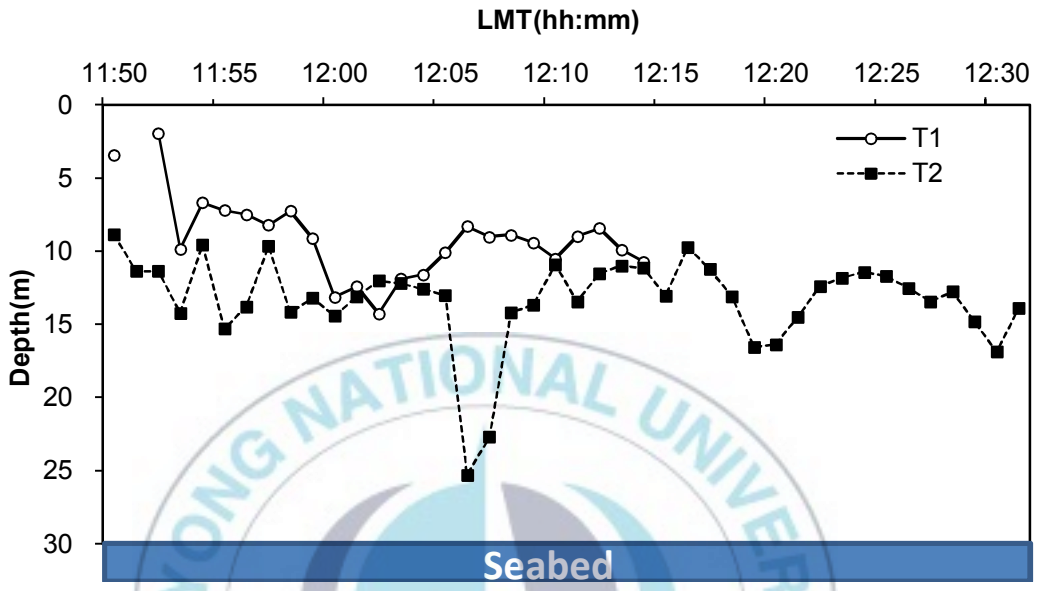


Fig. 15. Vertical movements of the tagged *Stephanolepis cirrhifer* (T1 and T2) after release out of the experimental cage on April 12, 2014.

Discussion

The thread-sail filefish (*Stephanolepis cirrhifer*) is a demersal species belonging to the family Monacanthidae. It is an economically important species for the Korean fishery and aquaculture industries. *S. cirrhifer* aquaculture has received particular attention because of the fish's high per weight market price and rapid growth rates (market size is reached in only one year) (Miyajima et al., 2011; Yoon et al., 2012). In Korean coastal water, seedlings of *S. cirrhifer* and *T. modestus* have been released to control jelly fish population since filefish are known the predator of jelly fish (Kim et al., 2013; Masuda *et al.*, 2008; Miyajima *et al.*, 2011). Concerning the ecological reproduction, Kawase and Nakazono (1996) found that this species spawned on the sandy bottom in pairs, and showed maternal egg care lasting only for a few minutes. However, there is a need of protecting this species from intensive fishery, which caused huge declining on its population stocks (Yoon et al., 2012), and little is known about its real distribution to consider the protection and management of *S. cirrhifer*.

Biotelemetry is likely play an important role in many research fields including aquatic ecology and fishery and aquaculture sciences (Komeyama et al., 2011).

Potentially, biotelemetry allows the remote sensing of the positions, movements, and aspects of physiological or behavioral variables of an animal or of environmental conditions around it by radio (30-150 MHz) or acoustic signals (20-300 kHz) (Baras and Lagarde, 1995).

The horizontal distribution of *S. cirrhifer* in the experimental cage of Tongyeong was characterized by the use of all the space formed by the net. In this study, the movement range of *S. cirrhifer* was revealed that the light was not the principal factor affecting in horizontal distribution. However, it had a high possibility that the volume of the experimental cage affected on fish behavior. Reduced cage volume led to be grouped and to increase stress of fish (Lader et al., 2007). In this study, the horizontal swimming path of tagged fish presented great differences of fish positions according to the intensity of currents. There was a significant affection of high current speed on horizontal fish motions. It can be negative in energy expenditure in aquaculture cage.

The movements of fish are related to external and internal factors. Environments within sea-cages are typically highly variable in both space and time, with the greatest variation occurring with depth (Oppedal et al., 2010). The results of this study highlighted that in general both tagged *S. cirrhifer* used all the accessible vertical space of the experimental cage. However the two fishes preferred to swim

in the layer 4.3 m - 6.6 m, the lower part of the cage, which fitted with the natural swimming characteristics of this species. *S. cirrhifer* was commonly found on rocky reefs and sandy bottoms to depths of 100 m (Matsuura, 1984).

The influence of the current velocity on the behavior of filefish was clarified in this results. The swimming depth of fish was limited by the depth of the cage bottom and affected by high current speed. Where increasing in its force (> 15 cm/s), it changed the shape of the cage and reduced the depth of the cage bottom. The results of swimming depth in this study was similar to the results of Suzuki et al. (2009). As the current velocity increased, the deepest point of the cage changed position and moved toward the downstream direction.

However, fish seemed to be closer to the cage bottom because the vertical fluctuations were reduced at those moments, which could be explained by the natural behavior of demersal fish. The results was supported by the findings of Fowler et al. (1998). The researchers had reported that at times of high current speeds (>0·3 m $s^{-}1$), schools of pouting were observed to move close to reef units. The fish remained low in the water column and maintained the position within the lee of the unit where was generally characterized by reduced currents. Consequently, it was able to reduce energy lost or metabolic costs.

In this study, it was not detected a significant difference in vertical distribution of fish in the water column between during a daytime and at night. The swimming pattern of both tagged fish in the experimental was not linked to specific period of night or day (Fig. 13 and 14). Such results were found in the reef fish by Devakarne (2004). The researcher reported that individuals seemed to have a uniform occupation of the water column whatever time monitoring. However, they had a demersal behavior since they occurred mainly between 3 and 8 m from the bottom.

Once fish were in released out of the experimental cage, it reached directly great depths comparing to the experimental cage. Horinouchi et al (2013) found that filefish showed a strong preference for the structure provided by seagrass, staying significantly longer in the seagrass area. When active tracking was conducting, the detection range after releasing fish out of the cage was reduced probably by environmental noises. Thus, the acoustic receiver needs an integrated gain device in the system to perform well detection range in the future study.

The application of ecosystem approach to fisheries management demands knowledge of the patterns of habitat use of target species (Afonso et al., 2012). The most important environmental factor affecting the behavior of fish in the experimental cage was the currents despite the light which is an important factor in fish distribution; our results determined no regular diel pattern on the use of space

by fish. Fish activities are set into motion by various stimuli and oriented by gradients of light, currents and temperature (Holland et al, 1990). Horizontal movements of *S. cirrhifer* are affected by current direction and high current speed and the vertical movements also altered by current speed. The volume stability of the cage in aquaculture is capital to reduce stress and alteration of fish behavior, which could be fatal for reared fish or threatened species in protecting programs. Future studies must obtain sufficient data to understand more the underlying behavior of tread sail filefish according to home range and site fidelity for worthy application in marine protected area and fishery management.

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