



Change in fishing performance of tubular pot for conger eels according to the angle of inclination to seabed

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ABSTRACT

An experiment was conducted to investigate the fishing performance of tubular pots for conger eel in South Korea according to the inclination angle on the seabed. The experiment was conducted in a water tank by setting the angle of the tubular pot at 0°, 15°, 30°, 45° and 60° with respect to the bottom level. When the landing angle of the pot was relatively low, conger eels searched for the bait and focused on where the bait smell was being released. Subsequently, conger eels entered the pot. Thus, for catching conger eels, it is advantageous for the bait to be placed at the entrance side while installing the pot. The highest fishing performance in terms of catch per unit effort (CPUE) was at an inclination angle of 15°. There was a significant difference between the CPUEs and the landing angle (Kruskal-Wallis test, $p = 0.009$). The results of this study could be used to improve the efficiency of tubular pot operations for conger eels.

Keywords: Conger eel, Fish behaviour, Fishing performance, Landing angle, Tubular pot

Introduction

The conger eel (Order: Anguilliformes; Family: Congridae) is one of the major fisheries in the coastal waters of Korea and it is a target fish species for coastal pot fishing. It is widely distributed throughout the Korean peninsula, the southern coast of Hokkaido in Japan and the East China Sea (Park, 2001; Tokimura, 2001). Total production of conger eel in Korea has been 13,304 t in 2014; 12,641 t in 2015; 12,632 t in 2016 and 10,965 t in 2017 (KOSIS, 2018).

For catching conger eel, mostly tubular pots are used followed by net pots. Although tubular pots are historically made using bamboo, this is disadvantageous because its durability is low and inconvenient, and so recently, tubular pots produced using recycled polyethylene (PE) or polypropylene (PP) resin are more commonly in use (Kim *et al.*, 2014). Furthermore, the entrance of the pot has a funnel structure that prevents escape of conger eels from the pot (Kim and Ko, 1987). A large number of tubular pots are used in the pot fishery of conger eel. Coastal fishing boats (< 10 t), use about 1,500 pots per boat, and offshore fishing boats (>10 t) use 10,000-15,000 pots per boat.

During conger eel pot fishing, pots are frequently lost due to entanglement in reefs or by towed fishing gear, such as a trawl (Tschernij and Larsson, 2003; Ayaz *et al.*, 2006; Brown and Macfadyen, 2007). The lost

fishing gear could lead to environmental problems, such as ghost fishing (Sheldon, 1975; High, 1976; Matsuoka *et al.*, 2005). The resin used for tubular pots is typically a synthetic resin with a specific gravity lower than one. Thus, to stably land the pot onto the seabed and maintain its angle, an iron ring is attached to the entrance of the pot, which allows the pot to lean towards the seabed. Since recycled plastics are used, the shape of the pot that rests on the seabed depends on the mixed ratio of various plastic types that have different specific gravities (Kim and Ha, 1987). Furthermore, studies have reported that the number of fish caught depends on the landing angle at which the tubular pot lands on the seabed (Kim and Ha, 1987; Kim *et al.*, 2014).

In this study, we conducted a water tank experiment to investigate the fishing performance of tubular pots, which is the most frequently used pot type for catching conger eels in South Korea. The results of this study can be used to evaluate the suitability of pot shape for landing pots onto the seabed and to provide the basic data for the design and production of pots for catching eels.

Materials and methods

Experimental tubular pot

Commercial tubular pots were used, to study the effect of landing angle of tubular pots on the seabed on fishing

performance to catch conger eels on the southern coast of South Korea. The experimental pots were manufactured using recycled PE resin, and the shape of the pot is shown in Fig. 1. The tubular pot had a length of 550 mm, diameter of 120 mm, funnel length of 210 mm and a water-permeable hole with a diameter of 8 mm around the entire body of the pot. An iron ring, with a diameter of 5 mm, was inserted at the lower quarter end of the tubular pot to ensure that the tubular pot landed diagonally on the seabed.

At the fishing sites, the length of the branch line was set at approximately 30 cm, and it was connected to the main line to maintain a landing angle of approximately 30° to keep the pot underwater. The water tank experiment was conducted by setting the landing angle of the tubular pots at five stages of 0°, 15°, 30°, 45°, and 60° with respect to the bottom level (Fig. 2).

Tank experiments

A fishing performance test was performed in a rectangular concrete water tank according to the landing angle of the tubular pots. The experimental tank used was 2.7 m in length and 1.4 m in height. Considering the habitat environment of conger eel, 20 cm sand was placed at the bottom of the tank. During the experiment, the tank was filled with filtered natural seawater that was 80 cm high from the sand bottom (Fig. 3). The seawater supplied to the tank was obtained by directly pumping and

filtering natural seawater. A bait smell diffusion test was performed to measure how long it took for the bait smell to saturate the tank during the experiment. An ink diffusion experiment was performed by bundling eight sponge tubes (length x diameter, 6 x 0.3 cm), that contained blue water-based ink, and fixing the bundle at the position where the pot would land before the experimental apparatus is installed, which allowed the ink to diffuse naturally for observation. The results showed that the blue ink fully saturated the water tank after approximately 30 to 35 min. The experimental subjects used in this study were conger eels that were caught using pots in Tongyeong, South Gyeongsang Province. Considering the volume of the tank, 78 fish (total length 30 to 60 cm) were placed in the tank and allowed to acclimatise for approximately 15 days. The body length distribution of the conger eels used in the experiment is shown in Fig. 4.

A set of four pots for each condition were used for the experiment. The experiment was conducted by randomly selecting two types of test landing angles (e.g., 0° and 60°) from the five experimental angles. Experimental angles were paired at 2 stages to conduct twelve experiments for each angle. The landing angle of the pot was adjusted by controlling the height at which the pot was bound to the stainless-steel pile.

During the experimental study, conger eels were immersed in the tank for 1 h during day time, when conger eels are most active, which was from 18 00 to 20 00 hrs, and the state of the conger eel in the pot was identified. One infrared CCD camera (GIR-C8000, GCC Co., Korea) was installed on top of the tank as shown in Fig. 3 for observation, and images were recorded in real-time using a DVR (SDR-B5300N, Samsung, Korea). One frozen anchovy (fork length of approximately 12 cm) was inserted into the pot, and after each experiment, the eels went through an adjustment phase for at least 5 days, to prevent learning, before another experiment was performed. Furthermore, all the seawater was circulated and replaced to prevent the bait smell from remaining in the tank. The experiment was conducted under dark room conditions of 0.01 lux to exclude the effect of illumination.

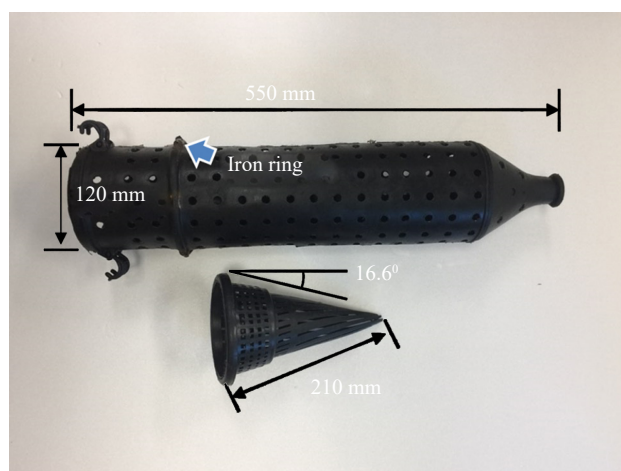


Fig. 1. Tubular pot trap for conger eels used in the study

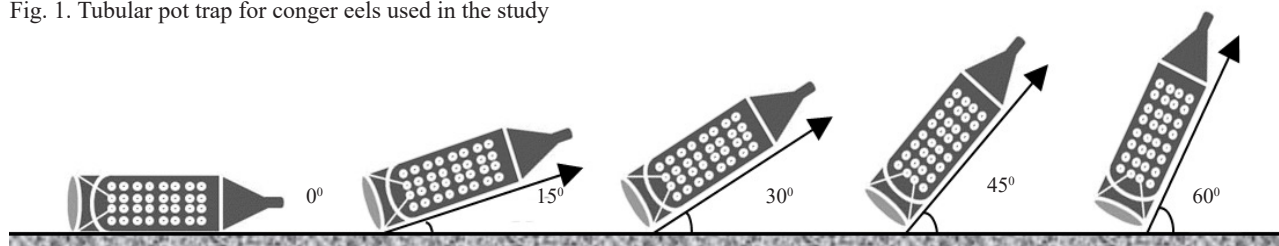


Fig. 2. Tubular pots showing angle of inclination used in the tank experiments

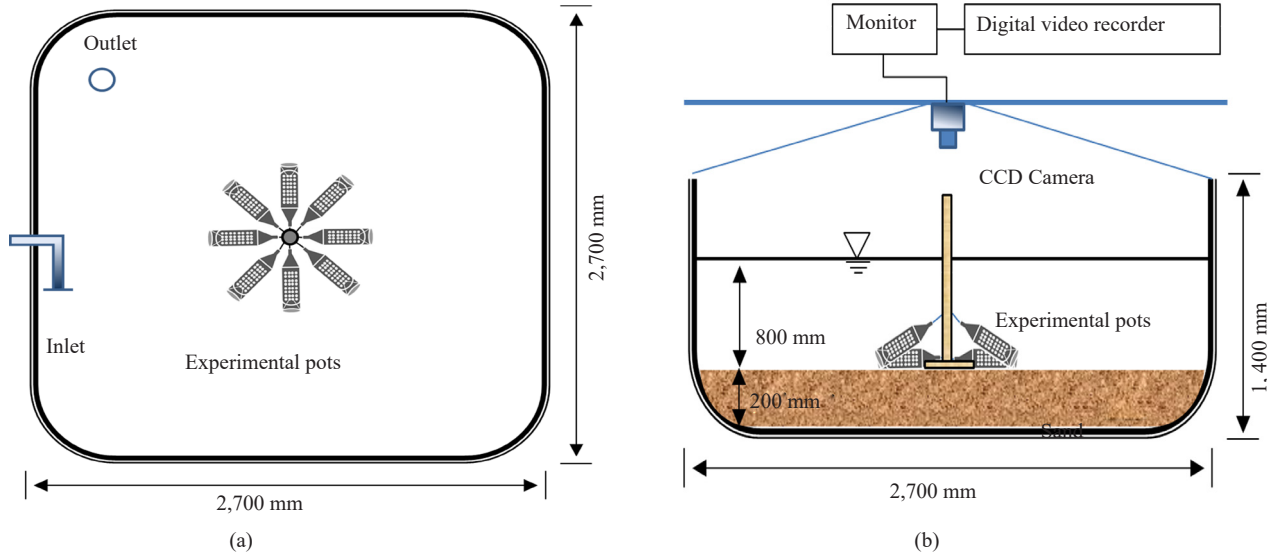


Fig. 3. Top (a) and side (b) views of the experimental tank and apparatus

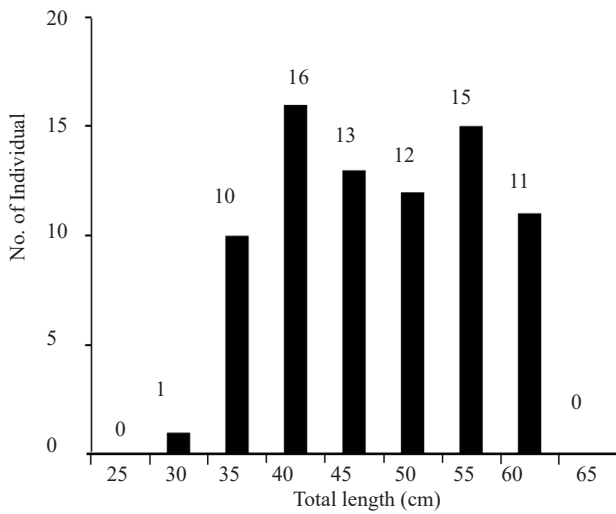


Fig. 4. Length distribution of conger eels used in the tank experiments

Data analysis

The images obtained from the CCD camera were reproduced to analyse the behaviour of the conger eels in the pots. Behaviour patterns were classified into 5, and the frequency of behaviour was counted for each factor. The frequency of a behaviour was represented using the frequency of each factor as a percentage after analysing the entire experiment. Each behaviour pattern was described by an element as shown in Table 1. After the end of the experiment, the conger eel was harvested from the experimental pot, and the length and weight were measured. Furthermore, the fishing performance was determined by comparing the catch per unit effort (CPUE), which was based on the number of eels caught per experiment.

Results

Behaviour patterns of experimental fish

The tank experiment was conducted 12 times for each condition from April to September 2014. According to the observation results for conger eel behaviour

Table 1. Classification of conger eel behavior patterns in the experiment pot

Pattern	Symbol	Explanation
Body touch	BT	Touched and stayed at the body of the tubular pot
Entrance touch	ET	Touched and stayed at the entrance of the tubular pot
Entering pot	EP	Entered the tubular pot through the entrance funnel
Leave pot	LV	Moved away from the tubular pot after touch
Route 1	R1	Moved to the entrance of the pot after touching the body of the pot
Route 2	R2	Moved to enter the pot after touching the body and the entrance of the pot
Route 3	R3	Moved to enter the pot after touching the entrance
Route 4	R4	Moved away from the pot after touching the entrance of the pot
Route 5	R5	Moved away from the pot after touching the body of the pot

in the water tank, conger eel primarily hid in the sand and started to move after being attracted to the smell of the bait. Approximately 5 min after the installation of the experimental pot in water tank, the conger eel appeared and entered the pot and showed active behaviour. The activity of the conger eel remarkably reduced after 30 min when the bait smell had saturated the tank. The entrance of the conger eel into the pot was completed at approximately 35 min after installation of the pot. The entrance frequency of the conger eel for each experimental pot is shown according to the time period in Fig.5 .

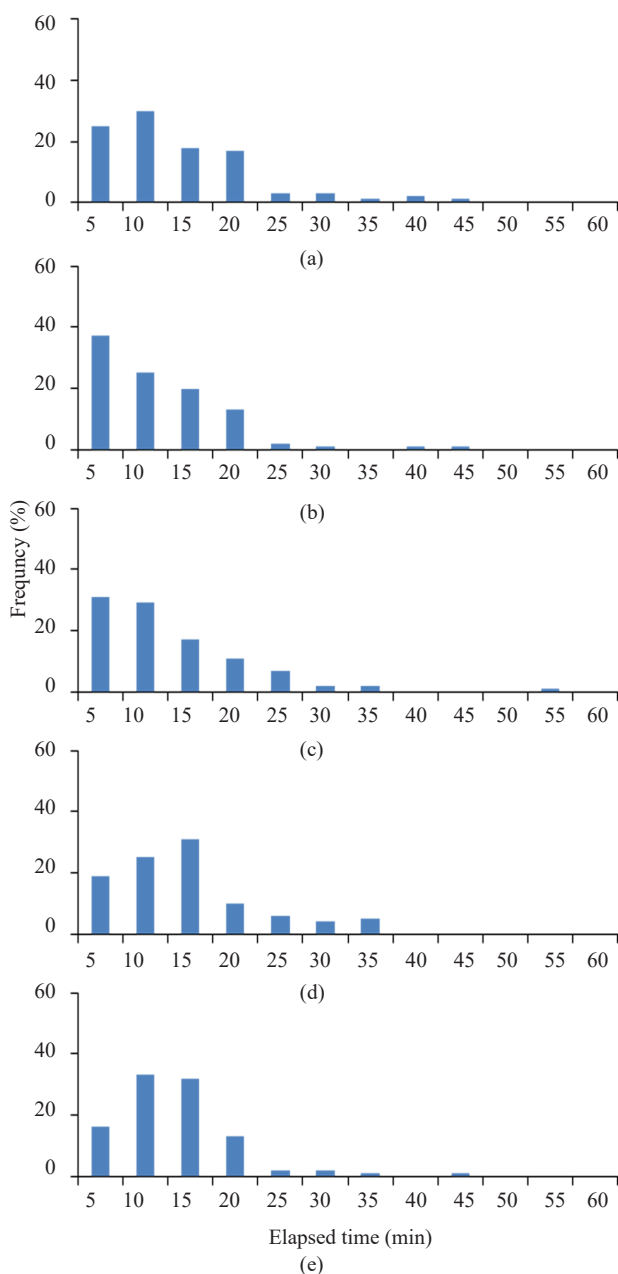


Fig. 5. Frequency of conger eels entering each pot over time at angle of inclination (a) 0°; (b) 15°; (c) 30°; (d) 45°; (e) 60°

The behaviour patterns of the conger eels were classified into 5 categories, and the frequency (%) for each pot was measured and is shown in Table 2. The observed behaviour patterns of the conger eel with respect to the pot were as follows: when the landing angle of the pot was relatively low, conger eel searched for the bait through the water-permeable holes after approaching the body of the pot; the conger eel then moved and entered the pot. The following behaviour pattern accounted for 22% of all of the patterns: when the landing angle of the pot was 0°, the conger eel first contacted the body of the pot attracted by the bait smell, moved towards the entrance area, and then entered the pot. Meanwhile, the following pattern occurred 34% more often than the other patterns: some conger eels failed to enter the pot and left after contacting the body of the pot. The following pattern occurred only 4% of the time: some conger eels entered the pot immediately after contacting the entrance of the pot.

When the landing angle of the pot was relatively high, conger eels searched for the bait by approaching the entrance where the bait gathered. Subsequently, conger eels entered the pot through the funnel. When the landing angles of the pots were 45° and 60°, most conger eels contacted the entrance where the bait gathered and then entered the pot, which corresponds to the pattern frequency occurrence of 26 and 23%, respectively. Some conger eels failed to enter the pot and left the pot after contacting the entrance (71 and 76%, respectively). In this case, numerous subjects contacted the entrance of the pot, and left the pot without entering. Furthermore, there was no case where conger eels first contacted the body of the pot.

Fishing performance of experimental pots

Table 3 shows the results of the tank experiment on the fishing performance according to the landing angles. The number of conger eels that entered the pots were as follows: 32 at 0°; 51 at 15°; 34 at 30°; 26 at 45° and 29 at 60°, which was the highest landing angle of the pots. The highest catch number was found for pots at 15°, which was approximately 1.96 times more than the minimum catch number at 45°. The body length distribution of conger eels for each pot is shown in Fig. 6. The non-parametric statistical test showed no significant difference (Kruskal-Wallis test, $p=0.175 < 0.05$) between the body length distribution of conger eels and the landing angles.

The fishing performance results from the comparison of CPUEs for the catch number per pot are shown in Table 3.

The highest CPUE value was 4.64 (individuals/experiment time) at 15° and was followed by 3.00 and 2.70 at 45° and 30°, respectively. The difference between the values was not significant in the range of 2.13 to 3.00 (individuals/experiment time), except for the value at 45°. Thus, the fishing performance CPUE value was highest for the landing angle of 15° when compared to that of the other types of experimental pots, and the non-parametric statistical test showed a significant difference (Kruskal-Wallis test, $p = 0.009 < 0.05$) between the CPUE and the landing angle.

Table 2. Frequency of conger eel behaviour for tank experiments

Behaviour pattern	Gradient angle of tubular pot				
	0°	15°	30°	45°	60°
BT→R1→ET→R2→EP	22	19	11	0	0
BT→R1→ET→R4→LV	24	9	6	0	0
BT→R5→LV	33	13	8	3	1
ET→R3→EP	4	28	22	26	23
ET→R4→LV	17	31	53	71	76
Total frequency (%)	100	100	100	100	100

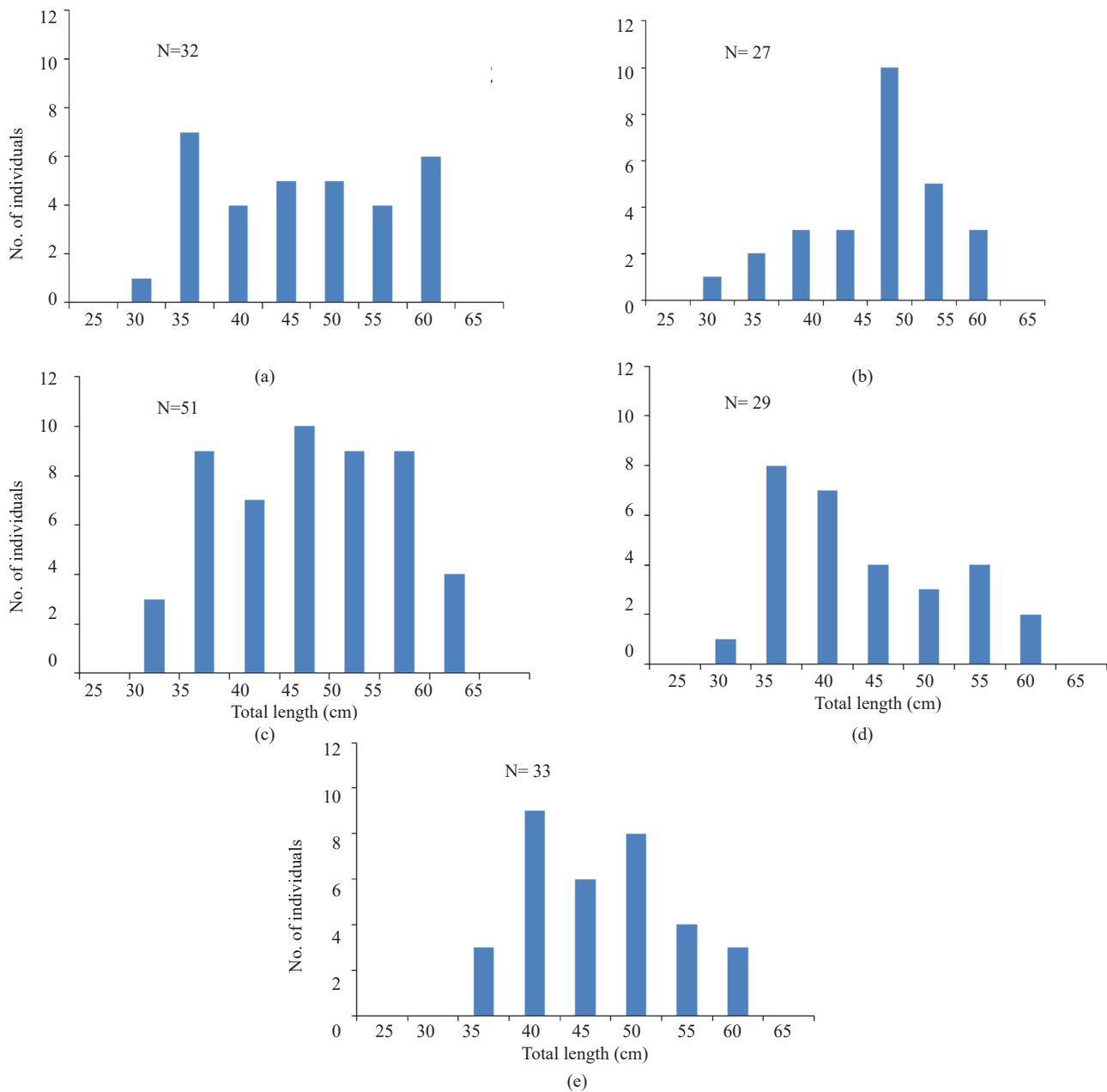


Fig. 6. Distribution of total length (TL) of conger eels caught by each tubular pot at angle of inclination (a) 0°; (b) 15°; (c) 30°; (d) 45°; (e) 60°

Table 3. CPUE of conger eels (No. per pot) for each inclination angle (No. of pots operated: 4)

Trials	CPUE at different gradient angle of tubular pot				
	0°	15°	30°	45°	60°
1	0.75	0.75	0.50	0.50	0.00
2	0.50	1.50	0.75	0.50	0.25
3	0.50	0.75	0.50	0.75	0.75
4	1.00	1.00	1.00	0.75	0.75
5	0.50	1.50	0.75	0.50	1.00
6	1.00	0.50	1.00	0.50	1.00
7	0.75	1.00	0.25	0.75	0.50
8	0.25	0.50	1.00	0.50	0.25
9	1.00	1.25	0.50	0.50	0.50
10	0.50	1.50	1.00	0.25	0.50
12	0.75	1.00	0.75	0.75	1.00
12	0.50	1.50	0.50	0.25	0.75
Average	0.67	1.06	0.71	0.54	0.60

Discussion

There are various types of pots for fishing conger eels. In South Korea, drum-shaped net pots and tubular pots are typically used. In the neighbouring country of Japan, the pots have similar shapes as South Korea. However, their tubular pots have entrances on both ends, and the pot lands horizontally with respect to the seabed. The fishing grounds for catching conger eel in South Korea mainly comprise seabed types that include mud or sandy mud. Particularly, if the fishing grounds are composed of mud or sandy mud, the entry of conger eel to the pot is prevented because the entrance of the pot can be buried or blocked by the mud depending on the landing angles of the pot onto the seabed (Kim and Ha, 1987). For this reason, fishermen commonly insert buoyancy material into one end of the pot and they adjust the length of the branch line to allow the pot to be inclined at a certain angle. In addition, if the entrance of the pot does not land on the seabed and floats in the water, it is difficult for conger eels to enter the pot, and thus, because the pot will shake which will scare the eels. In this regard, the shape of the pot that rests on the seabed is considered to have a close relationship with catching performance. Furthermore, bait gathers towards the entrance when a pot is inclined, which attracts conger eels. This effect has been reported to increase the probability of contact and the entrance rate (Kim and Ha, 1987; Kim *et al.*, 2014). Results of the present experiment suggests that conger eels do not resort to visual cues at the time of entrance, because after a conger eel is attracted to the bait smell and contacted the pot, it moves towards the entrance while continuously hitting the pot in the direction of the bait smell. Thus, when a pot lands, it is more advantageous for fishing conger eels if the bait gathers around the entrance rather than in the middle of the pot when the pot is inclined.

Kim *et al.* (2014) reported that the angle of the pot, which was measured by sensors in the ocean, showed a change in the range of 0° to 33°, depending on the flow rate. If a pot lands horizontally on the seabed due to flow, the bait would be spread across the pot, and may lower the probability that the conger eel would find the entrance and enter the pot due to clogging of the entrance by mud or other debris.

This study revealed that the best catching performance was obtained when the pot had a seabed landing angle of 15°. Considering an inclination angle (16.6°) actually formed between the funnel in the pot and the body wall of the pot, conger eels enter the pot along the inclined surface at approximately 31.6° at the time of entry. In this regard, experimental pots with higher landing angles of 45° and 60° are unsuitable for conger eels to enter the pot when considering the inclination of the inner funnel. Since the inlet direction is towards the bottom, rather than the front, at these landing angles, it would be hard for conger eels to find and enter the inlet when compared to pots at different angles. As a result, the inclination angle of the funnel in the pot has been reported as a factor that affects the catching performance of other target fish (Sugimoto *et al.*, 1996; Li *et al.*, 2006). Recently, tubular pots are commonly produced using recycled plastic materials, such as polyethylene (PE) or polypropylene (PP), and using mixture of multiple resins in various ratios. Furthermore, the proportion of pots made of different materials have been shifting in fisheries, and PE materials, which were once less used, have been applied for the main line or branch line. For this reason, flow has affected the landing shape of pots. For the stable landing of pots, depending on the seabed type, steel rings could be added to the pot or appropriate buoyancy material could be applied to one end of the pot.

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