Study on the fishing performance of an alternative tubular-type pot for the common octopus, *Octopus minor*, in Korean coastal waters

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Abstract

We aimed to develop alternative fishing gear for catching the common octopus, to decrease the use of bait and operating costs in comparison to commercial net pots. A tubular-type pot was designed, and behavioral responses of the common octopus were experimentally monitored in tank and replicated 10 times to compare fishing performances between 300 experimental and 300 commercial net pots in the coastal sea of Gangjin, Korea. The behavioral responses under experimental conditions included emergence from the mud den, detection of the bait on the pot surface, and entry into the pot (toward the bait). The field experiment results indicate that numbers and weights of the catch during offshore fishing were 703 (56.0 kg) and 795 (86.3 kg) via tubular-type and net pots, respectively. The catch per unit effort (CPUE) for the number and weight of the tubular-type pot from 10 trials were 0.23 individuals/pot and 18.87 g/pot, respectively; and weight for the net pot were 0.27 individuals/pot and 28.77 g/pot, respectively. No significant difference was noted between the CPUE in catch number for tubular-type and net pots (Kruskal–Wallis test, $p=0.305 > 0.05$); however, the CPUE by weight was significantly higher using net pot than tubular-type pot (Kruskal–Wallis test, $p= 0.01<0.05$). The amount of bait used during the experimental period for the tubular-type pots were 1/3.4 less than that of the commercial net pot. Therefore, fishing operating cost for common octopus was reduced using tubular-type pot.

Keywords: Fishing performance, Common octopus, *Octopus minor*, Pot, Fishing gear design.

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Introduction

The common octopus (*O. minor*) is a major fishery resource in Korea, along with the common squid (*Todarodes pacificus*) and octopus (*O. vulgaris*).

The most common fishing method used in the coastal sea for the common octopus involves net pots and long-line fishing. Pot fishery, a passive type of fishery, is an economic fishery method because of its low fuel consumption and equipment costs when compared to large-scale fishery methods such as trawling or purse seining (Takeuchi, 1981). Moreover, the use of bait for fishing enhances fishing efficiency when compared to the use of other passive fishing gears such as gillnets.

To catch the common octopus, baited net pots are usually immersed for a period of 7 to 14 d in the sea. At major fishing grounds, where several nets are installed at a relatively high density, incidents of entangled fishing gear and loss of pots occurs because of adverse weather conditions during immersion; thus, the fishing gear is swept away to sea. Moreover, because the equipment is still fully functional, ghost fishing may occur (Tschernij and Larsson, 2003; Ayaz *et al*., 2006; Brown and Macfadyen, 2007).

Recent catches of the common octopus provide evidence of a declining trend, with a 17% decrease over a 3-year period, from 6954 t in 2010 to 5799 t in 2012. Of the reported values, 2922 t (50.4%) and1,589 t (27.4%) were caught using pots and long-line fishing, respectively (Korean Statistics, 2012). To attract the common octopus, the Japanese ghost crab (*Macrophthalmus japonicus*), which exudes a peculiar odor, is used as bait in common octopus net pots. Most Japanese ghost crabs are imported from China, and the price of this bait e is continually rising due to a rising exchange rate and declining resources of the Japanese ghost crab. Its rising price doubled daily bait costs over the course of only a few years (i.e., from 4000-5000 KRW/kg in 2009 to 8000 KRW/kg in 2011 and 7000 KRW/kg in 2012; Fig.1). Thus, it is increasingly difficult to operate pot fishing. Park *et al*. (2005) conducted a study on the development of artificial baits for a common octopus net pot; they suggested the use of artificial bait that was similar in shape to that of the Japanese ghost crab, which simulated movement *via* a spring device powered by the current. However, practical effects have not been reported.

Figure 1: The photo shows a common octopus (*O. minor*) caught in a net pot trying to escape through the mesh.

Recently, fishermen trapping the common octopus have requested a change in the regulation size of the mesh (i.e., 22 mm) used in net pots because the size of the Japanese ghost crab is variable, resulting in their escape through gaps in the mesh (Kim *et al*., 2013). Moreover, the common octopuses caught in the net pots usually try to escape through the mesh, thereby resulting in deaths or skin abrasions that reduce their commercial value (Fig. 2).

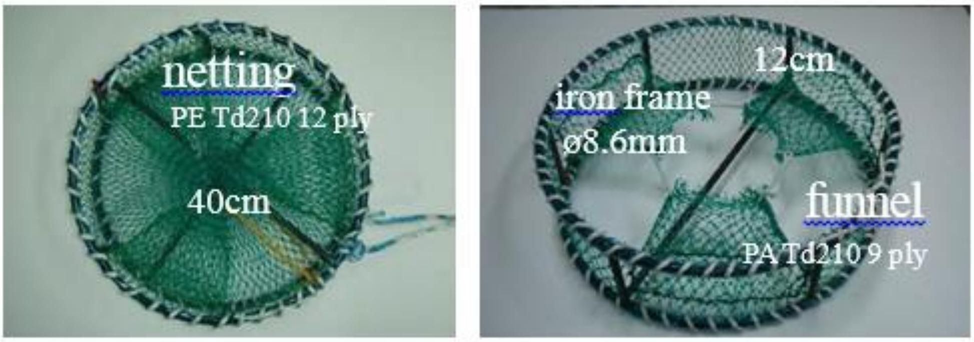


Figure 2: The net pot used for catching the common octopus in the coastal sea of Korea.

Few studies have investigated the efficiency of the fishing gear for the common octopus in other countries because it is not a global commodity. In a domestic study, Kim *et al*. (2007) reported the fishing power of the common octopus *via* pot fishing. Ahn *et al*. (2007) assessed the fishing power index, and Park *et al*. (2006) reported on the entry behaviors of the common octopus and fishing performance. Only limited number of studies is present on the common octopus net pot, and no studies have shown the development and improvement of the net pot. In this study, we describe the development of an alternative fishing gear for the common octopus that decreases bait use and operating costs when compared to those of the commercial net pot. We designed a tubular-type pot, observed the entry behaviors of the common octopus in an experimental tank fabricated to simulate the natural marine environment, and conducted fishing performance test at sea.

Materials and Methods

Experimental fishing gear

The diameter and height of the commercial net pot for the common octopus were 40 and 12 cm, respectively. The pot was shaped with an iron frame (8.6 mm in diameter) and covered with netting (i.e., PE Td 210 12 ply; Fig. 3). There were 3 entrances (i.e., 18 cm wide and 10 cm deep). The entrance was made from polyamide (PA) Td 210 9 ply, and the ends of each entrance were connected to maintain its shape.

The alternative net pot had a tubular shape for designing the smallest possible pot, taking into consideration the load capacity of the fishing boat deck because the majority of fishing boats used for common octopus pot fishery are <1–2 t. By using PVC pipes, we manufactured tubular-type pots measuring 9 cm in diameter, 25 cm in length, and 5 mm in thickness.

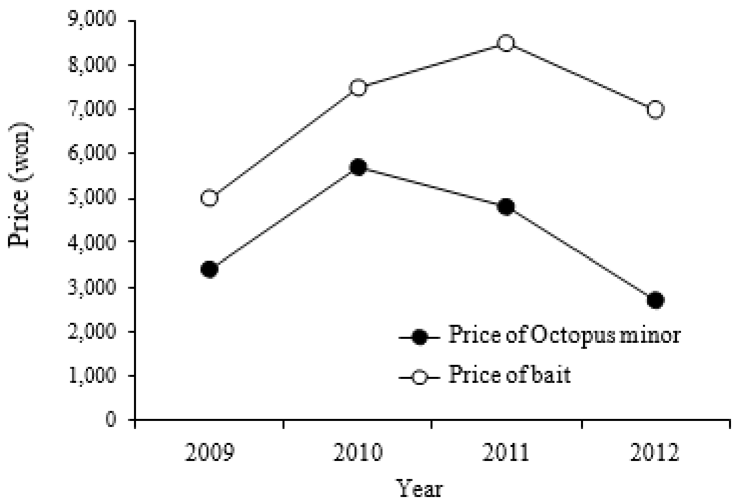


Figure 3: Prices of common octopus (per individual) and bait (per kg) for a net pot.

A funnel was embedded at the entrance of the experimental gear to facilitate entry and prevent escape of the common octopus, whereas the opposite end was designed to open and close to ease removal of the catch and placement of the bait.

To enhance the pot's attraction, a slit-type draining hall cut (3 mm in width) was made around the pot for protrusion of the legs of the Japanese ghost crab, taking into account the average ghost crab carapace height of 5 mm.

Additionally, because the common octopus habitat is seabed mud , to prevent the entry of mud into the tubular-type pot, a float was installed at the juncture connecting the pot to the branch line to form a contact angle of ~30° to the bottom. The prototype experimental gear is shown in Fig. 4.

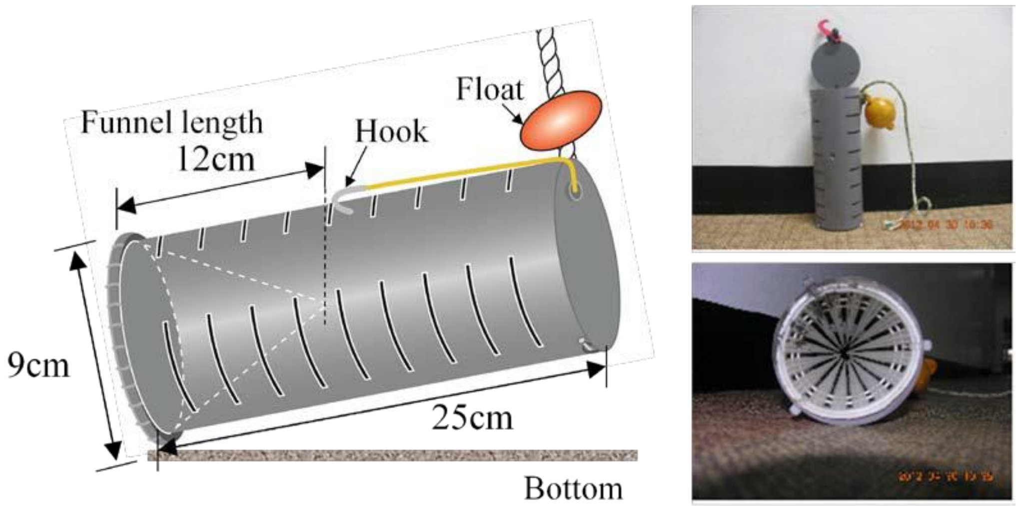


Figure 4: Specification of an experimental tubular-type pot to catch the common octopus.

Tank experiments

Tank experiments were conducted to observe entry behaviors of the common octopus into the experimental fishing gear. To avoid over-evaluation of experimental results and enhance the reliability of the behavioral experiments, the experimental tank was designed to simulate the natural habitat of the common octopus. This was achieved by using a cylindrical aqua tank measuring 2 m in diameter and 1.2 m in height (Fig. 5). Mud harvested from the actual habitat was spread across the bottom of the tank. To ensure continuous circulation of seawater and prevent the mud from erosion during the experiment, a seawater supply pipe was installed under the tank, and the pipe was covered with sand to 20 cm. Additionally, ~50 g of lugworms were placed in the tank to minimize the occurrence of elements that might disturb the validity of the experiment (e.g., mud decay). The seawater for the tank was pumped directly from the sea and filtered prior to u use.

Figure 5: Experimental tank for behavioral experiments.

To prevent satiation with bait odor during the experiment, a bait odor diffusion experiment was conducted. This experiment consisted of fixing 6 sponge tubes (i.e., 6 cm in length by 3 mm in diameter) containing water-soluble blue ink and then observing diffusion in the seawater flowing counter clockwise (Fig. 6). After confirming saturation of the blue ink in the tank within 25–30 min, the amount of seawater moving through the inlet and outlet was controlled to a constant rate of 30 L/min. Experiments were performed using continuous attracting effects of the bait odor without saturating the tank environment. The common octopus specimens used in the experiments were caught from the coastal sea of Gangjin, Korea. Thirty specimens, deemed appropriate for the tank size, were released into the tank and subjected to experimentation after acclimatization. Three experimental gears were used in the experiments, with the pots installed at a contact angle of 30° to the bottom to prevent mud infiltration from the seabed. Five Japanese ghost crabs were placed in each pot, and the flow of the seawater was directed from the end side to the pot entrance, thus allowing the bait odor to diffuse to the entrance.

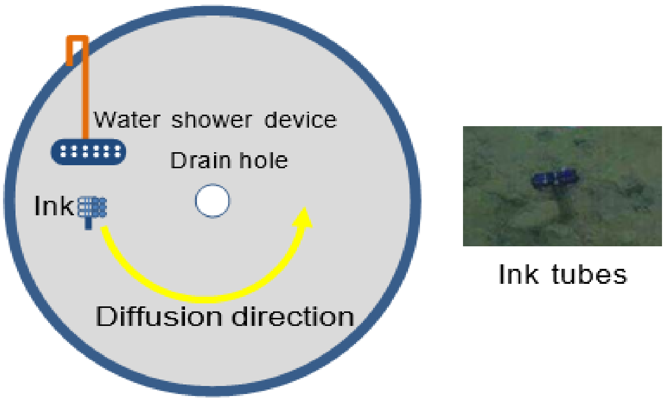


Figure 6: Bait odor diffusion experiment device by using ink tubes.

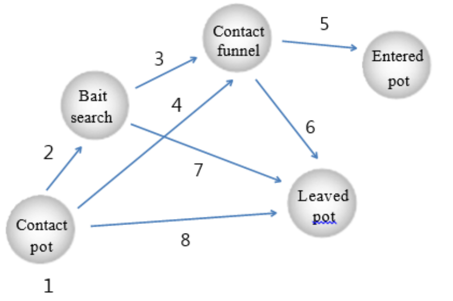
To exclude the effect of lighting, experiments were conducted in a 0.01-lx darkroom condition. The experiment was performed as follows: pots were installed at ~08:00, the catch was checked after immersing the pots for 36 h (per experiment) using 2 infrared CCD cameras (GIR-C8000, GCC Co., Korea) installed over the tank (Fig. 5), and a time-lapse recorder (VCR; HV-GR2, Aiwa, Japan) was used for real-time recording. The subsequent experiment was conducted after sufficient post-experimental adaptation to prevent learning effects. A total of 5 experiments were conducted.

Catch mechanism analysis

Behavioral responses were observed by playback of the time-lapse video captured using the CCD camera. The behavior patterns were classified according to 5 behavioral responses (Table 1), and we counted the number of each behavioral pattern (Fig. 7).

Table 1: Classification of the common octopus behavioral responses toward an experimental pot.

Behavioral response	Explanation
Contact pot	Coming in c angle he camera view
Bait searching	Searching fo erimental pot
Contact funnel	Staying arou erimental pot
Entered pot	Entering the
Exited pot	Exiting from the experimental pot after coming in contact with the body or funnel of the pot



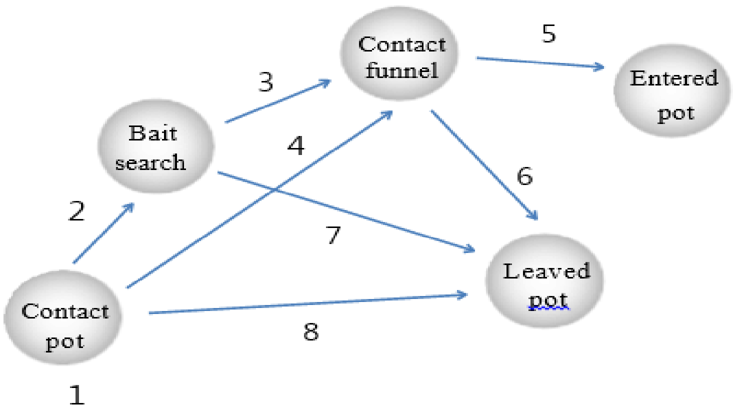


Figure 7: Schematic diagram of different behavioral responses of the common octopus to the tubular pot.

*1Number indicates the frequency of behavioral responses of the common octopus.

*2Behavioral responses described in Table 1.

Sea trials

Sea trials were conducted in the coastal sea of Gangjin, Jeonnam Province, Korea from April to June 2012. Approximately 300 experimental gears were installed at 5-m intervals, arranged in 3 lines of 100 pots, and shot in a line in the same major fishing ground at a depth of 10–15 m. Japanese ghost crabs were used as bait, with 4–5 specimens per pot. Moreover, 300 commercial net pots arranged in 3 lines of 100 net pots were shot in the same fishing ground to compare fishing performance. Alternatively, tubular-type and net pots for the common octopus were shot in a line at 100-m intervals in the same fishing ground. In general, net pots were installed in a main line 9–10 m apart from each other. For the tubular-type pot, sea trials were conducted using 5-m intervals because of the limited bait use, with the intent to enhance attraction. Fig. 8 illustrates composition of the experimental gear, and Fig. 9 indicates location of the site for the sea trials.

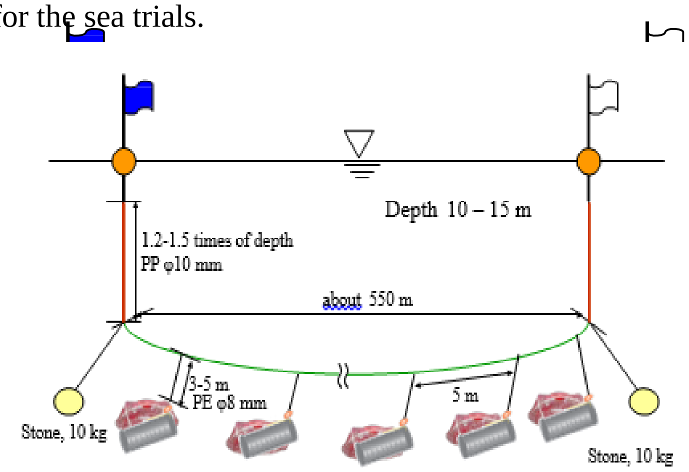


Figure 8: Composition and arrangement of the experimental pots for catching the common octopus in the coastal sea of Gangjin, Korea.

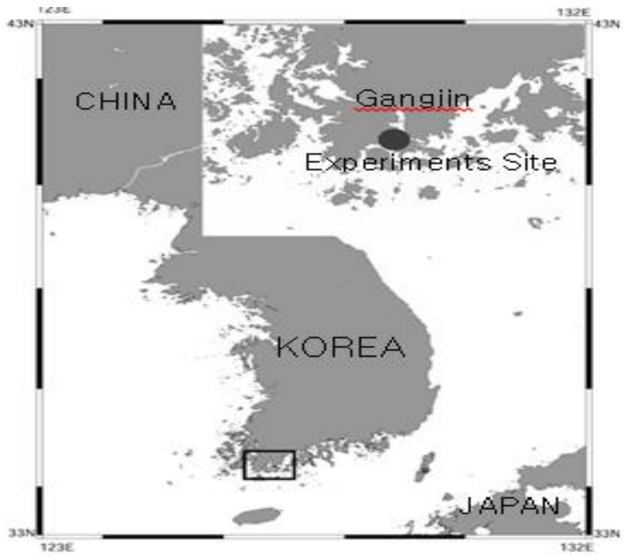


Figure 9: Fishing ground for the experiments for catching the common octopus by using tubular pots inGangjin, Korea.

The experimental gear was immersed for 7 days; it was then extracted at 06:00. The catches were harvested, and the mantle length and body weight of common octopuses were measured. Furthermore, the CPUEs (catch per unit efforts) by number of catch and weight were calculated and compared to quantitatively evaluate fishing performance of the tubular-type and net pots based on the sea trials.

Results

Tank experiments

Tank experiments were conducted 5 times in April and May, and each experiment was conducted over a 3-days period; adaptation after each experiment lasted for 4 days.

Here, we describe the entry behavior of the common octopus into the experimental gear in the tank. The sample common octopus started to appear ~1 h after pot installation. Common octopuses came out of the mud, approached the pot surface, and searched the bait by putting their tentacles into the draining hall, thereby exhibiting the patterns of staying on the pot surface or moving towards and entering the pot after detecting the bait.

Common octopus entry was completed within an average of 1.5 d after pot installation. Only one common octopus entered each pot. After each experiment, we let at least 3–4 days of interval before resuming the experiment to prevent learning effects.

The total number of pot contacts for searching bait made by the 30 specimens for the experimental pots in the 5 trials (No. 2) was 198, and the total number of contacts with the funnel of the pot after reaching the pot surface for searching bait (sum Nos. 3 and 4) was 62 (i.e., 31.3%). Of these, the total number of common octopuses that entered the pots (No. 5) was 12. The entry rate after making contact with the funnel was 19.4%, whereas the rate of moving on without entering the pot (No. 8) was 80.6% (Table 2).

Table 2: Frequency of different behavioral responses of the common octopus to tubular pot for tank experiments.

Behavioral response	Contact pot	Contact pot →Bait searching	Bait searching →Contact funnel	Contact pot →Contact funnel	Contact funnel →Entered pot	Contact funnel →Leaved Pot	Bait searching →Leaved Pot	Contact pot →Leaved Pot
Behavioral	1	2	3	4	5	6	7	8
Trial 1	70	37	4	2	1	10	33	31
Trial 2	117	35	5	4	3	12	30	78
Trial 3	20	13	4	2	1	10	9	5
Trial 4	80	35	5	3	2	12	23	52
Trial 5	176	78	18	15	5	56	64	84
Total	471	198	36	26	12	100	159	250

The common octopus entry process involved the following pattern: exploring the bait by stretching of the long tentacle across the draining hall, moving toward the entrance area, and putting the tentacle into the funnel and trying to catch the bait, thereby gradually entering into the pot. The common octopus that entered the pot in the tank experiments could only stretch its tentacle through the draining halls, and no cases of common octopus injury were observed.

Sea trials

We conducted experiments to compare an experimental gear as an alternative to the conventional fishing gear for trapping the common octopus with 10 replications between April and June 2012.

Ten trials resulted in a catch of 703 common octopuses (56.6 kg), with an average weight of 80.5 g. Of the catch collected using the experimental gear, 99.7% were common octopuses, whereas 0.3% was blennies. This observation suggests that the tubular-type pot had a very low rate of catching species other than the common octopus. Further, the common caught octopuses that weighed 60–90 g accounted for 60.1% of the total common octopus catch.

The total number of common octopus caught using the net pots was 795 (86.3 kg), which is 1.13-fold higher in number and 1.52-fold higher by weight when compared to the catch number and weight obtained using the tubular-type pots. At 108.5 g, the average weight of the total catch was 28 g higher than that using the tubular-type pots. Moreover, the weight contribution of the common octopus caught by net pots showed a wider range when compared to that using the tubular-type pots; the weight class most frequently caught was 150–160 g. The total harvest using the net pots included the common octopus (98%), conger eel (0.8%), webfoot octopus (0.7%), and blenny (0.2%).

Size composition of common octopus catches using tubular-type and net pots is presented in Fig. 10; the CPUEs in terms of the number of catch and weight of each trial are presented in Table 3. The CPUE in terms of the number and weight for the tubular-type pot from the 10 trials were 0.23 individuals/pot and 18.87 g/pot, respectively, whereas those of the net pot were 0.27 individuals/pot and 28.77 g/pot, respectively. Although the CPUE for the number of catch was higher for the net pot when compared to that of the tubular-type pot, a nonparametric statistical test did not reveal a significant difference (Kruskal–Wallis test, $p=0.305>0.05$). However, the CPUE by weight was higher using the net pot, and a statistical significant difference was confirmed (Kruskal–Wallis test, $p=0.01<0.05$).

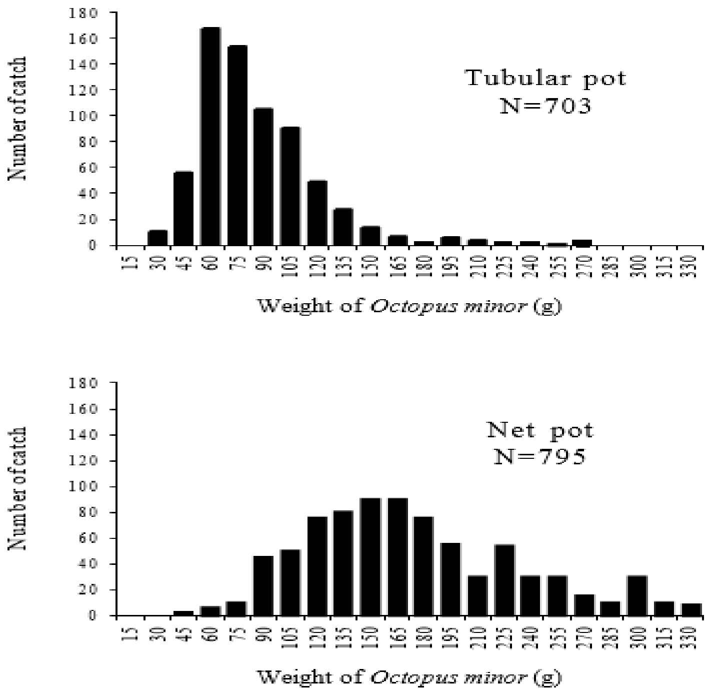


Figure 10: Distribution of weights of the common octopi caught by using tubular and net pots in Gangjin, Korea. The graph shows the result of 10 experimental replications by using 300 pots for each pot type.

Table 3: The number of catch and the weight of the common octopus caught by tubular-type and net pots across 10 replicated field experiments for each pot type.

Trials	Tubular pot pot (CPUE)		Net pot		Tubular pot (CPUE[1])		Net	
	Number of	Weight (g)	Number of	Weight (g)	Number of	Weight (g)	Number of	Weight (g)
1	59	4,750	60	6,410	0.20	15.83	0.20	21.37
2	63	5,070	87	9,650	0.21	16.90	0.29	32.17
3	84	6,760	95	10,110	0.28	22.53	0.32	33.70
4	67	5,390	77	8,360	0.22	17.97	0.26	27.87
5	32	2,580	66	7,170	0.11	8.60	0.22	23.90
6	71	5,720	89	9,230	0.24	19.07	0.30	30.77
7	78	6,280	85	9,660	0.26	20.93	0.28	32.20
8	89	7,170	59	6,510	0.30	23.90	0.20	21.70
9	69	5,560	76	8,250	0.23	18.53	0.25	27.50
10	91	7,320	101	10,950	0.30	24.40	0.34	36.50
Total	703	56,600	795	86,300	0.23 [2]	18.87 [3]	0.27 [2]	28.77 [3]

[1]Catch per unit efforts (CPUEs) were calculated to divide the number of catch and weight with 300 pots, respectively.

[2]Total number of catch per total number of pots.

[3]Total weight per total number of pots.

Discussion

This study addressed the problems of increasing bait use and a recent rise in bait price that has plagued the common octopus fishery in coastal Korea, which generally involves cylindrical-type net pots, by developing an alternative fishing gear that can be used to harvest the common octopus with the minimal use of bait. Fishermen have conducted numerous attempts to catch the common octopus by replacing live Japanese ghost crab baits with other fish species, pork fat, and small crustaceans. However, these attempts have resulted in low catch rates and an increase in by-catches, including starfish and small conger eel. Research efforts have also focused on developing artificial bait by using the odor of the Japanese ghost crab. However, they did not generate positive outcomes because of lower catch rates compared to that obtained using live Japanese ghost crab bait (Park *et al*., 2005).

In this study, we utilized a tubular-type pot that narrows the activity range of the bait, with a volume (1589.6 cm^3) reduced to approximately 1/9.5 that of the commercial net pot volume (15,072 cm^3). In general, the volume of a pot is related to the number of fishing targets that have entered it (Kim and Ko, 1987a). In the case of the net pot, usually one (2 on rare occasions) common octopus enters a pot. In the case of the tubular-type pot, only one common octopus entered each pot throughout the experiment. Pots for crustaceans such as the blue crab and lobster should be built with additional space based on their spatial behaviors (Kim and Ko, 1987b; Millar, 1990; Vazquez *et al*., 2003;). In terms of the weight of the common octopus harvested using a tubular-type pot, the individual sizes were smaller than those obtained using a net pot. By using the weight classes of large, medium, and small, the price for a large common octopus is 1.2–1.5 times higher than that for smaller individuals. Several factors may be responsible for the size of the individuals entering the pots. Some studies report on the effects of the entrance size and shape of the pot (Fuwa *et al*., 1994; Sugimoto *et al*., 1996; Li *et al*., 2006); in particular, Fuwa *et al*. (1994) reported that the length of the funnel highly influences the probability of escape after entry. In terms of the tubular-type pot, because the pot length was 25 cm, a funnel length of 12 cm is short enough for a large individual to detect the bait by extending its arm but too long for a small individual to detect the bait without entering the pot. Based on this theory, it is possible that smaller individuals are more likely to enter a pot than larger individuals. Additionally, in the case of the tubular-type pots for the conger eel, a good fishing efficiency can be expected only when using an adequate pot length, based on the actual length of the conger eel. If the pot is not long enough, the conger eel can easily eat the bait by advancing only a part of its body and pulling out the bait, thus escaping entrapment (Kim and Ko, 1987b).

In terms of the amount of bait used during the experimental period for the 300 tubular-type pots with 138 kg (966,000 KRW; 878 US$) across 10 trials, the average amount of bait per trial was 13.8 kg (considering that a part of the bait remained in each trial and that a different amount of bait was used for each trial). On the other hand, 467 kg (3,269,000 KRW; 2972 US$) of bait was used for the 300 commercial net pots across 10 trials, yielding an average of 46.7 kg per trial. The amount of bait used for tubular-type pots was 1/3.4 of the amount used for the net pots, and the bait cost saved ~2094 US$. Moreover, in the offshore experiments using the net pots, some of the bait disappeared from the pots with no catch in them. This may be explained by the partial escape of bait through the mesh (mesh size: 22 mm), thus leading to a corresponding increase in bait use (Kim *et al*., 2013).

The tubular-type pot proposed in this study warrants further studies on various types of fishing gears based on shape and efficiency.

Acknowledgments

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