The mud crab (*Scylla serrata*) behavior in different inclination angles of funnel and escape vent for trap net

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Abstract. Mud crab (*Scylla serrata*) is one of the most valuable commodities among the Portunidae group that is caught by collapsible trap in Semarang, Indonesia. The trap entrance (funnel) is designed to allow adult crabs to pass in and prevent them from passing out, with the help of inclination angles. The other design uses escape vents that allow smaller crabs to escape. The trap used in this experiment was constructed of PE 210D/6 ¾ inch iron rode frame with 20°, 30°, 40°, 45° and 60° inclination angles, and 2, 3, 4 cm high escape vents. The objective of this experiment is to analyze mud crab behavior in different inclination angles of funnel and escape vent for trap net. The method used in this research is laboratory experiment of 2 life stages; sub-adult carapace width (CW < 10 cm) and adult carapace width (CW > 11 cm) crabs, by counting the crawling time and escape rate. Results show that the 40° inclination makes it easier for adult crabs to pass than the sub-adult crab and the 4 cm high escape vent enables 92.30% of sub-adult crabs to escape and keeps 69% of adult crab stuck in the trap. The conclusion found that the slope angle of 40° and a gap for passage of 4 cm providing opportunities mature crabs trapped in trap.
Key Words: mud crab, crawling, inclination, escape vent, life stage.

Introduction. Mud crab is a member of the Portunidae family (Order Decapoda; Class Crustacea). The growth of crustaceans is characterized by the process of molting. The members of order Decapoda are characterized by the presence of five pairs of legs, the first pair of legs is called claws that act as a catcher/food holder, the fifth pair of legs in a fan shaped (flat) serves as the swimming leg, and the rest are for crawling/walking legs. With the claws and legs, crab can run fast on land and they can swim quickly in water using the swimming legs that they are classified as swimming crab (Mohanty et al 2006). Mud crabs belong to the *Scylla* genus, which comprise fast growing species that attain larger sizes among portunids and are widely distributed throughout the coastal zones of the Indo-Pacific region (Viswanathan & Raffi 2015).

Mud crabs represent a valuable component of traditional, small scale coastal fisheries in several tropical and subtropical Southeast Asian countries which stands as a significant commodity that fetches a high price in the international seafood market (BOBP 1992). Prasad & Neelakantan (1988) explained that carapace width (CW) was used to know the stadia of crabs; < 7 cm for juvenile, 8.1-11 cm for sub-adult and > 11 cm for adult, respectively. Based on the Indonesian Ministry of Fisheries and Marine Regulation No. 1 year 2015 on crab's legal size, crabs that can be caught must have a carapace width (CW) of ≥ 15 cm or a weight of ≥ 250 gr. The legal size of crabs is determined by the maternity age which can be seen at CW > 11 cm. Therefore, we need to know the inclination on collapsible trap to catch adult crabs. Inclination angle is an important factor that determines how many adult crabs are caught and how many sub-adult crabs can escape.

According to Archdale et al (2006a), it is very important to study the crab's behavior when they entering a trap to understand their responses related to the surrounding conditions. In turn, the escaping habits of the crabs can be understood.

Another study by Jirapunpipat et al (2008) explained the effect of installing an escape vent on a trap and the size of *Scylla olivacea* (Herbst) mud crab in collapsible pots. The purpose of this study is to determine appropriate inclination angles based on crawling time to catch adult *Scylla serrata* crabs and the height of escape vents to release sub-adult crabs.

Material and Method

Materials. The experiment was conducted at the laboratory of Fishing Gears, Faculty of Fisheries and Marine Science, Diponegoro University. Fishing practice simulation using prototypes crab is used as materials research. We used in this research mud crabs, a collapsible trap, and dead *Leiognathus* sp. as bait (which were obtained from catch by another gear). The total mud crabs used in this experiment are 30 individuals consisting of 15 in sub-adult stage (CW 8-10 cm), and 15 in adult stage (CW > 12 cm). The experiment also involved the construction of a funnel (Figure 1) and an escape vent (Figure 2).

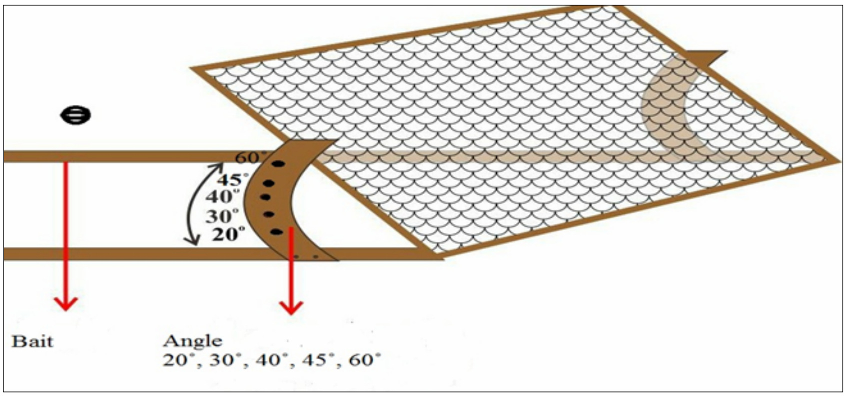

Figure 1. Funnel design.

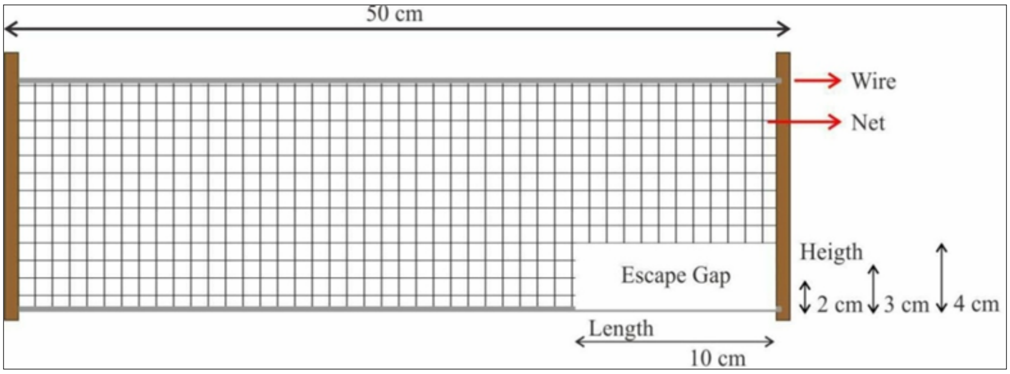

Figure 2. Escape vents size.

Collapsible traps target legally-sized mud crabs (CW > 12 cm), but if any under-sized crabs enter the pot, they can escape via the vents provided. The escape vent is rectangular in shape and is made of iron frame. The funnel size and escape vent height are used to know the percentage of crabs caught in the trap. Adult crab height from an earlier observation is known to be between CW: 8-12 cm, with the range of sub-adult crab at 2.34–3.7 cm. Hence, the experiment used 2, 3 and 4 cm heights for escape vents. The trap is constructed at 50 × 30 cm dimension using a ¾ inch PE 210D/6 iron frame, while the escape vents vary from 10 × 2 cm; 10 x 3 cm; and 10 x 4 cm. The iron frame allows the stacking of vents and prevents any folding by the crab's push.

Method. The experiment was conducted during 2 weeks (9-23 March 2016) with 15 times repetition per day in an experimental aquarium used, which is depicted in Figure 3. Bait was placed in the position between the funnel net with a certain slope angle (20^o, 30°, 40°, 45° or 60°) and the escape gap. It served as attractant for the crab to move through the funnel net to get the bait. In addition, the escape gap placement served as an escape media for the sub-adult crab stadia to get out, while the adult stadia remains in the bait area.

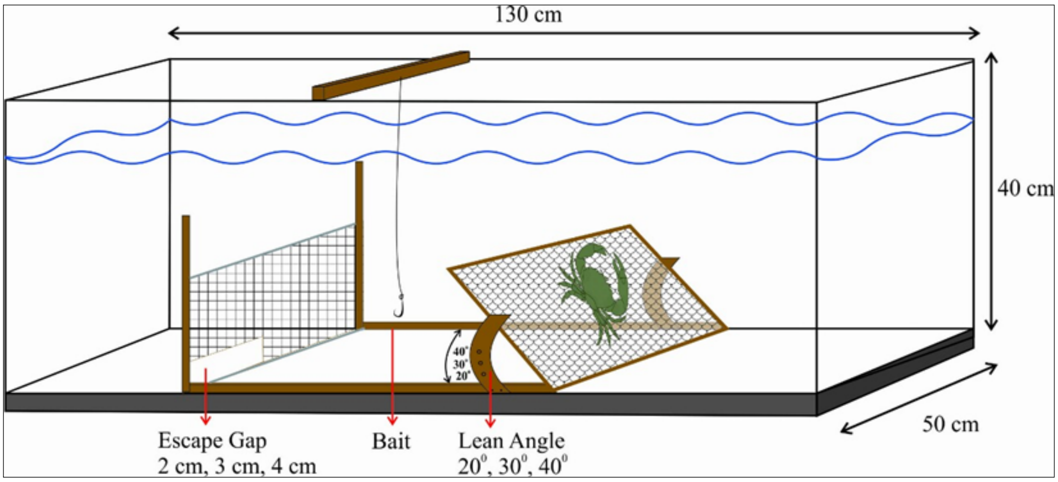

Figure 3. Experiment aquarium.

There were 3 stages in this aquarium experiment: acclimatization, pretreatment, and treatment. Acclimatization is a stage prior to treatment. Mud crabs were adapted in the tank with 20-22% salinity and 1 x per day feeding in the afternoon with 100 g *Leiognathus* sp. for 2 weeks. Pretreatment, is the other stage prior treatment, where every single mud crab was placed in the tank for 24 hours prior treatment and being starved. Every single tank only took one treatment and one crab. The treatment tank was prepared in an aquarium of 130 × 40 × 50 cm dimension covered in black colored plastic as to give a dark condition effect. Pre-treatment was used to prepare a space before treatment was carried out. Figure 4 shows the separation of crawling and escaping crab treatment area.

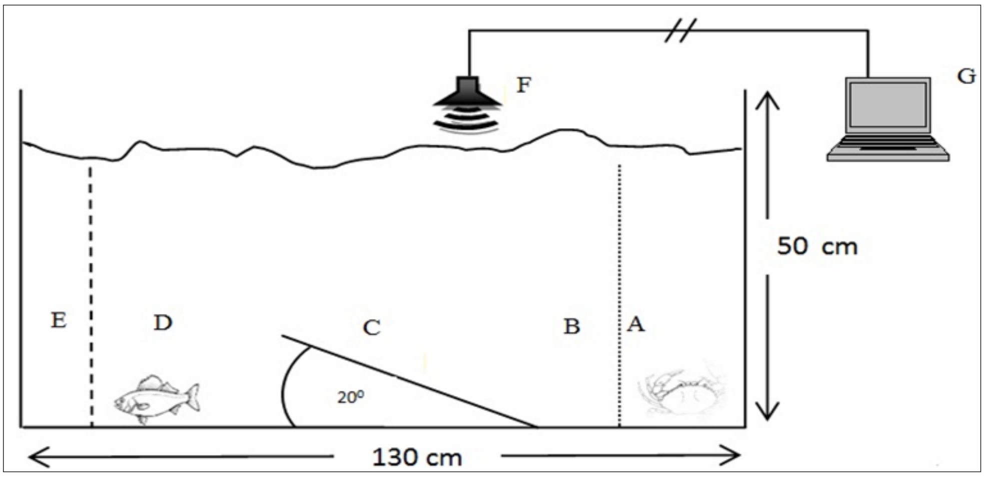

Figure 4. Separated treatment area.

The separation areas in the treatment tank include:

- arousals (A), where the crab starts and accepts stimuli sources or detect food Archdale et al (2003), the odor diffused from the bait and the water current would affect an area exposed to the active area;
- searching (B), where the crabs are, after walking from arousal to the net. Searching means the crab walks, moves and searches the funnel as it is attracted by the

bait. Archdale et al (2003) stated that crabs crawl out from the arousal area and follow the odor direction and approach to the net;

- crawling (C), where the funnel net is placed to count crawling time and walking speed in the net of different angles. Crawling net inclinations are 20^o, 30^o, 40^o, 45^o and 60^o. Archdale et al (2006b) mentioned that an entry attempt was defined as crawling in to the pot entrance resulting in contact with the slit or an open entrance;
- finding (D), where the crabs find the food. Finding areas are similar with catchable areas in which every fish placed in a catchable area is trapped inside pot. Finding area is a place after funnel equipped with the bait (*Leiognathus* sp.);
- escaping (E), where crabs are excluded as they walk out the escape vent. Crabs placed on this area are free crabs coming out from the trap. These crabs are then counted to determine the escape percentage of the net.

Pre-treatment is the stage when the crabs were starved for 1 day to lead them to the funnel by attracted them with a bait (Figure 3 and Figure 4). This treatment is only for one crab at one treatment. The crab was placed at the start area – covered by a screen – that is separated from the searching area. After 5 minutes, the lights were turned off and the camera (Sony Handy Camera A430) was turned on as to enable it to take a shot as the screen was opened. This footage was then stored in a computer. Similar to a previous study by Archdale et al (2006a), after setting the pot on the tank bottom, it took several minutes for the crab to detect the bait and left the start area. Only the crawling time was counted when the crab tried to crawl or touch the funnel and walk until, at times, fall in the searching area. The next stage was observing the escape vent passed by the crab, and counted where the crabs exited or stayed in the finding area. Fifteen repetitions were used for new individuals, baits, and water replacements as to minimize influence from previous treatments. The treatment limit time is 1 hour. This relates to the time of amino acid release in proteins. Amino acids immersed in sea water decrease after 1 hour.

Data analysis. Data were taken from treatment recordings in 2 different life stages at 5 different funnel angles to get crawling speed, and 2 different life stages at 3 different escape vents to get release rate. Crawling speed is taken when a crab passes the funnel and stops after it gets into the finding area. Statistical analysis was carried out with ANOVA to test the differences in crab life stages and crawling speeds at different funnel inclinations when the fundamental requirements for parametric test were satisfied.

Results and Discussion. The crawling speeds in different funnels in all 15 repetitions (2 groups and 5 variables) were normal, as shown from the Kolmogorove-Smirnov test and ANOVA with Completely Randomized design, which yields < 0.05. Hence, there is a difference of crawling speed between 2 groups and inclination angles.

Crawling time. Crawling times were calculated for each inclination angle and for each group. Crawling time is assumed as the speed by which a crab walks in the net. Crawling times for adult and sub-adult are shown in Figure 5.

Based on Figure 5, the difference in speeds between adult and sub-adult leads to a trend in which adults move faster, but at 45^o and 60^o, sub-adults recorded faster speed. Li et al (2006) and Susanto et al (2014) explained in their research that the steep inclination angle complicates a crab's movement across the net. The longest time was shown for 40^o for sub-adults with an average time of 57.33 s, whereas the longest time for adults was for 45^o and 60^o inclinations, at 43 s. The fastest crawling speed for both adults and sub-adults was 20^o inclination. Therefore, a tilt of 20^o is the best one that allows both adults and sub-adults to move fast (Susanto et al 2014). This also means that increasing inclination angle leads to slower crab movement. This finding is certainly applicable in fisheries by designing traps and funnel inclination angles that facilitate the catching of legally-sized mud crabs.

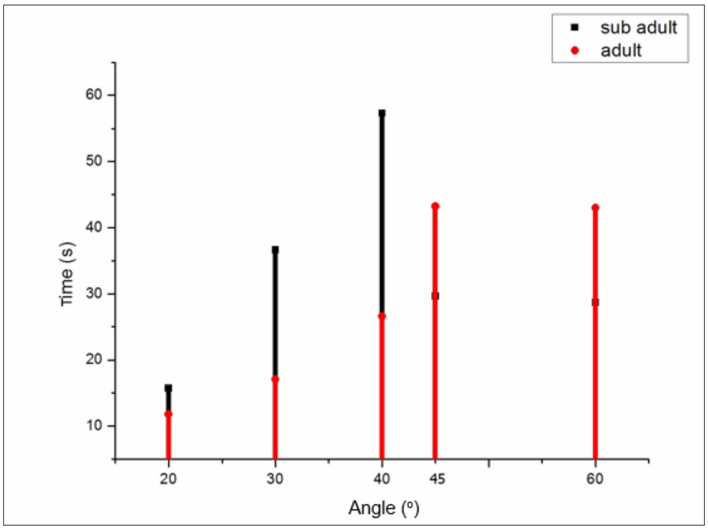

Figure 5. Crab crawling times for different angles.

Figure 6 show that crawling time increases with greater tilt angle. It is easy to see as steeper tilts make it difficult for crabs to cross the funnel. On the other hand, a gentle slope allows crabs to easily enter the net. Li et al (2006) proposed that the dimension of funnel traps with 30^{o} inclination is aimed at making it easy for crabs to enter the net, and at the same time, making it difficult for them to escape the net. This best inclination angle is supposed to be used in the design of fishing gears. In order to catch only the legally-sized crabs, a consideration must be taken concerning the crawling time of sub-adult crab as shown in the Figure 6. The bars show different inclination angles that affect crab speed. Sub-adult mud crabs walks most speedily at 20^{o} angle. Therefore, this inclination is not recommended as they are not mature enough to be harvested. Fishing gears should be technically designed to use funnel inclination that influences the catchment of adult crabs (CW > 12 cm). The best inclinations for both sub-adult and adult crabs are 20^{o} and 30^{o}, while the worst inclination angles for adult crabs are 45^{o} and 60^{o}, as adult crabs move slower that sub-adults crabs. These angles are not recommended for fishing operations.

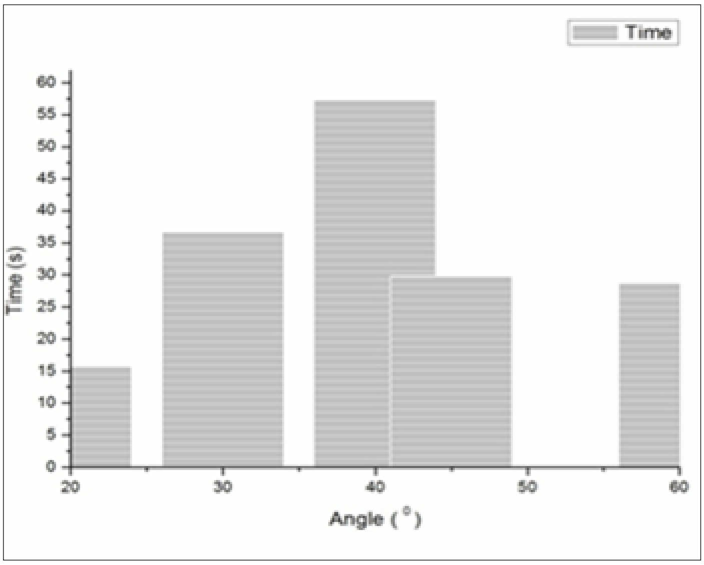

Figure 6. Crawling time for adult mud crabs.

The recommended application for mud crab is not to use the fastest speed sub-adult crab pass the funnel, but to use the most difficult inclination for sub-adult crabs to move at. This most difficult inclination for them is 40^{o}. This is where sub-adult crabs move slower than their adult counterparts. Archdale et al (2007) said that the design of a funnel trap net is the determining factor in catching fish, because this is the first selector that allows the reduction of under-sized mud crab catching.

Escape rate. Another factor to reduce the adult crab escape from technical analysis is the introduction of escape vents. They function to reduce the number of escaping adult crab and help sub-adult crabs to escape. The inclination angle for funnel is the first selector of fishing operation, and then the escape vent is used as the second selector to give an opportunity for under-sized crabs to escape. The escape vents will raise selectivity when sub-adult or juvenile crabs enter the trap and still have the opportunity to continue their life cycle. Escape vents are designed as to allow small crabs to exit and ensure that only adult crabs are caught. The making of escape vents based on previous observations in the field is carried out by measuring the carapace length and height, both for sub-adult and adult samples.

Commonly, traditional fishermen do not use escape vents and automatically catch under-sized crabs. This study helps introduce escape vents by measuring the height and length of both sub-adult and adult carapace. The escape size is 10 cm in length and either 2 cm, 3 cm or 4 cm in height, as stated in Table 1. The rectangular shape was chosen in the previous study by Putsa et al (2016) because it is more effective in allowing small crabs to escape than its circular counterpart. The vent is equipped with iron frame to make it stable, as crabs stretch nets when they try to escape.

Table 1

Measures of mud crab carapace

Life stage	*Carapace width (cm)*	$\bar{x}$ *carapace length (cm)*	$\bar{x}$ *carapace height (cm)*
Adult	11-12	5.2	4.2
Sub-adult	8-10	8.4	3.1

Fifteen (15) repetitions for each vent height and life stage show that the 2 cm height to kept both sub-adult and adult crabs stay inside the net, even though they try to push themselves out. The 3 cm height was able to exclude 57% sub-adult crab and keep adult crabs (CW > 12 cm) to stay, while the 4 cm height was able to let 92.30% sub-adult crabs to escape and keep 69% adult crabs inside (Figure 7). This later escape rate is in line with Ministry of Fisheries and Marine Regulation No. 1 year 2015.

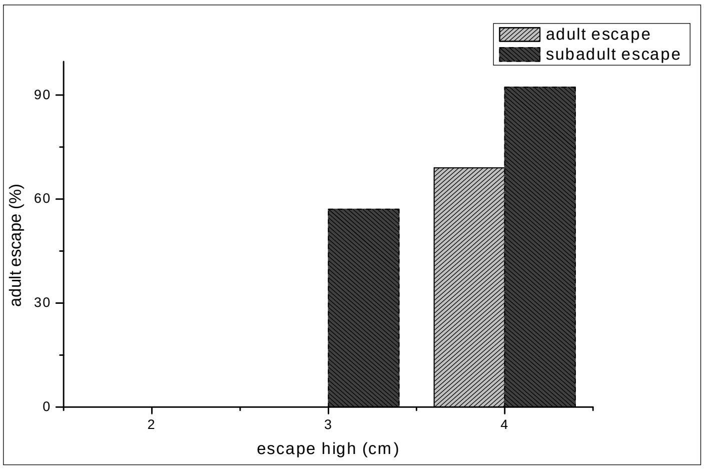

Figure 7. Escape rate of mud crab for different vent height.

Mud crab behavior. Crabs creep out of the funnel using the limbs of their body side first, then push the body and crawl up (Archdale et al 2006b; Wale et al 2013). Crabs walk by using their side limbs to cross the funnel directly when there was no maneuver direction (Figure 8). Crabs easily go inside the net by crawling sideways towards the bait without any change in behavior. Sometimes a crawling crab is detained as their tapered limbs sink and it will try again by hanging up its limbs. At other times, a crab may stop crawling and squeeze itself back in (Figure 9). After stopping a crab may try to maneuver with another position and continues to creep. An earlier research by Susanto et al (2014) and Wale et al (2013) showed that crabs walk more easily in a square mesh than in a diamond mesh, and then easily creep up the lower inclination as the is easier to reach. Crabs crawling through the funnel tend to use their walking legs than their swimming legs. The swimming legs are not used when crawling. It is only the walking legs that are actively in action and push the body one step at a time. As the crabs reach the end of the funnel, they descend to the finding area using their huge claws as a pedestal and land their bodies.

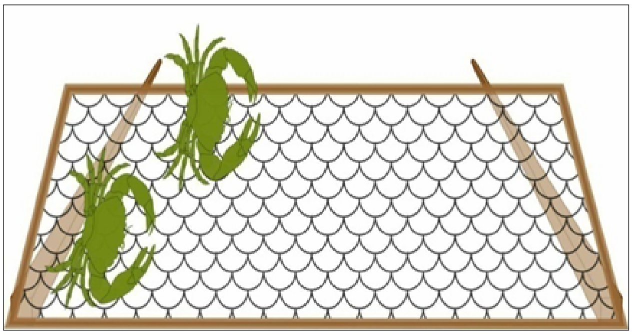

Figure 8. Crabs crawling sideways.

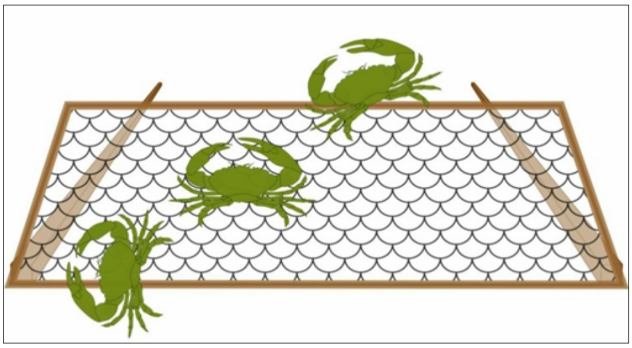

Figure 9. Crabs' maneuvering positions.

After landing at the finding area, they search for the stimuli source and walk around the bait with the guidance of their vibrating antennules and mouth. Crabs reach the bait and eat it directly by using their claws. Jachowski (1974) mentioned that most chelipeds serve as organs of expression as well as weapons, and also function to halt the approach of others. Once meal is done, crabs try to sense their way out by looking around, walk sideways, and once an open hole is found, they ease themselves out. At times, they have to fit their body to the hole and push themselves out (Figure 10).

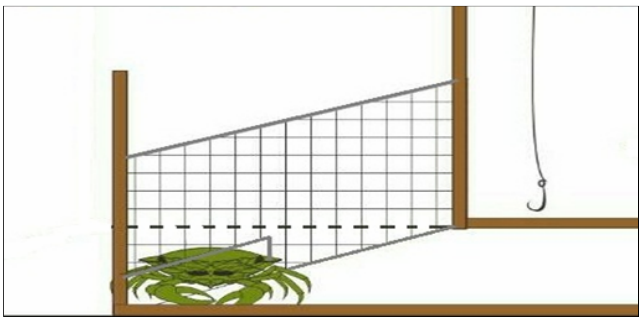

Figure 10. A crab passing an escape vent.

Escape vent is the other factor affecting capture effectiveness of a pot and the recommended vent height for commercial purpose is 4 cm. This height is suitable to capture adult crabs (CW > 12) and allow sub-adult crabs (CW < 10 cm) to escape and remove juvenile crabs. Escaping crabs approach escape vents differently, for the 4 cm vent, they approach it directly, while for the 2 cm vent, they approach it laterally.

Conclusions. Different crawling times towards the inclination angle between 2 groups are observed, in which 40^o is easier to pass in by adult crabs (CW > 12 cm) and difficult to pass by sub-adult crabs (CW < 10 cm). The height of escape vent which is appropriate to exclude sub-adult crabs is 4 cm. This height allows 92.30% sub-adult crabs to escape and keeps 69% adult crabs in. Mud crab behavior, when crawling the funnel, would push the body up and balance the position by step of the leg on one side of the body. The crabs continued to walk through the funnel towards the attractant (the bait) without making the maneuver direction. When going down from the funnel, the crab used the big claws to hold the bottom funnel to put the body in the bottom of waters and move toward to the bait. The behavior of crabs when going to escape were observing the surrounding area and walking sideways slowly along the wall. Once the crab found the escape vent, the crab would try to come out by placing and pushing the body continuously in order to get out of the slice. This finding supports the implementation of the regulation from the Ministry of Fisheries and Marine, concerning under-sized crabs that must not be caught by collapsible traps. Two selectors that facilitate that goal are inclination angle and escape vent.

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