Behavior of the Commercial Sand Crab *Portunus pelagicus* (L.) at Trap Entrances

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Abstract

Time lapse video recordings were used to study the trap entrance behavior of the sand crab (*Portunus pelagicus* L.) in the laboratory. The trap used was cylindrical with two opposite entrance funnels, as commonly used in the Australian commercial fishery. Crabs usually made several entrance attempts ($\bar{x} = 2$), and 66% and 72% of males and females, respectively, searched less than one-quarter of the trap circumference before entry. It was not uncommon for sand crabs to miss the entrances; for crabs that made an entrance attempt, males missed funnels an average of 2.2 times as compared to females 1.7 times. Entry success rates were 30% and 25% for males and females, respectively, although there was no significant difference in the number of entries between the sexes. Entry order into the baited trap by sex or size was not significant. Antagonistic interactions rarely prevented a crab from entering the trap, but occasionally (<5% of entries) trapped crabs inside the trap prevented newcomers from entering the trap. Crabs also occasionally backed out of a funnel for no apparent reason. The trap was not considered efficient at catching crabs. A more efficient trap would require more entrance space presented to an approaching crab.

Introduction

The sand crab *Portunus pelagicus* (L.) is an important commercial species found throughout the Indo-Pacific region, where it is taken by a variety of methods including traps, trawling and netting. In Australia all three methods are used, though traps are the most important in Queensland, where the commercial sand crab fishery is the State's third most valuable fishery (Matilda and Hill 1981). It is concentrated in Moreton Bay (153°15'E, 27°15'S), where sand crabs are taken commercially in baited wire traps or as an incidental catch to otter trawling for shrimp. Minor variations in trap design exist,

depending on the fisherman's preference, but all are cylindrical in shape (approximately 1.0 m diameter and 0.3 m high), and made of galvanized wire mesh over a mild steel frame (Fig. 1). There are usually two diametrically opposing entrance funnels, each with a gradual upward incline into the trap. The preferred bait is whole mullet (*Mugil* spp.) wired to the center of the bottom of the trap and sometimes protected by a bait protection bag (Smith and Sumpton 1987). Regulations restrict the maximum number of traps per commercial fisherman to fifty and prohibit the retention of any female sand crabs or any males <150 mm carapace width.
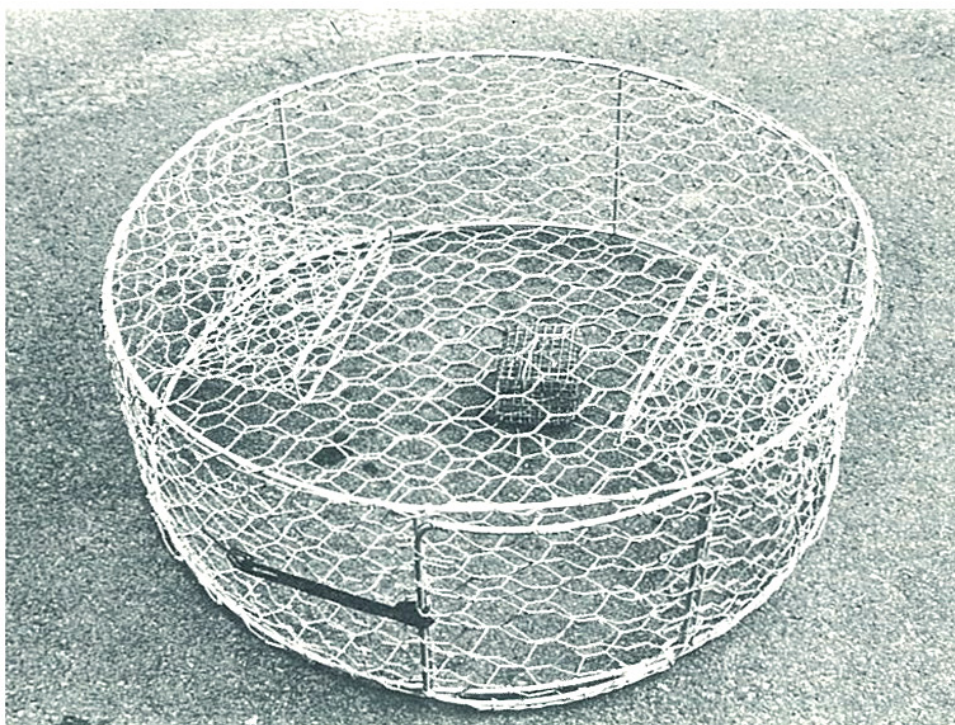

Fig. 1. Commercial sand crab trap of the type used for each trial.

Despite the fishery's almost total reliance on these traps, little is known of their selectivity and catching efficiency or the behavior of crabs in and around a trap. Sand crabs are known to be antagonistic in their social relationships (Eales 1972) and this study was partly prompted by fishermen's anecdotal reports of large trapped crabs inhibiting the subsequent entry of other crabs into a trap. Specifically this paper examines, under laboratory conditions, the behavior and interactive antagonism of male and female *P. pelagicus* attracted to a commercial trap (Fig. 1) and assesses the efficiency of such traps which are in widespread use in Australia. These data would be useful in improving gear efficiency and also for future stock assessment surveys using these traps.

Materials and Methods

Male and female sand crabs (118-170 mm carapace width) were collected from Moreton Bay, Queensland, in baited traps set in 2 to 10 m of water depth and held until required (no longer than two weeks) in an outdoor 2-m diameter by 1-m depth seawater tank at the Southern Fisheries Research Centre (Deception Bay). Crabs were fed daily on chopped fish *(Sillago maculata)* but were starved for 48 hours prior to experimental observation.

The indoor observation tank was circular (3 m x 0.4 m deep) and supplied with flow-through ambient temperature seawater (7 l.min⁻¹ exchange) and 10-15 cm of clean sand substrate. Water circulated in a very slow anti-clockwise gyre. Temperature ranged from 21.5 to 28°C and salinity from 17 to 35 ppt over the experimental period, October 1987 to May 1988. This period corresponds to the commercial fishing season.

A low-light video camera (RCA TC2000 with Newvicon tube) was suspended 1.5 m above water level over the tank's center and connected to a time lapse video recorder fitted with an inbuilt time generator that gave time accurate to one second. The field of view of the camera was about 2 x 1.5 m. Light was artificially controlled by two white 150W and four red 250W incandescent floodlights fitted with dimmer controls. All lights were controlled by a time switch to give white light between 0600 and 1800 hours and red light from 1800 to 0600 hours, to simulate day and night, respectively. Red light was used to enhance video image quality at night since crustaceans are known to have low sensitivity to red wavelengths (Kennedy and Bruno 1961).

The probable dispersion pattern of bait odor in the tank was monitored with no crabs in the observation tank. A dye was inserted in a porous bag inside the trap's bait container and the trap placed in the same tank position as for each trial. The resulting dye dispersion was monitored over several hours with the time lapse video recorder.

Prior to each observation period two male and two female sand crabs of unequal size (size difference was not kept constant) were selected from the outdoor holding tank, and individually marked with quick drying typewriter correction fluid on the carapace to enable their identification during tape playback.

All crabs used experimentally had no more than two missing appendages and were intermoult as indicated by a hard shell relatively free of epizoic organisms. Premoult crabs were unsuitable

as these are known to cease feeding (Williams 1982) and thus be unlikely to enter a baited trap. Nonovigerous females were commonly used but on occasions ovigerous females were substituted when nonovigerous females were unavailable.

The four selected and marked crabs were placed in the observation tank at 1100 hours and allowed 3 hours to acclimatize. At 1400 hours recording commenced and a baited standard commercial trap (1 m diameter x 0.3 m high with 45 mm wall mesh and 75 mm roof mesh and floor; funnel exits 30 x 5 cm) was placed immediately below the camera. The same trap was used for each observation period (trial) with the funnels always orientated in the same direction. Bait used was whole fish *(Sillago maculata)* protected by a wire mesh container to prevent the first crab entering from consuming the bait. At 0900 hours the following morning crabs were removed from the tank and the video tape replayed. Crabs that had made no attempt to enter the trap during the trial were sacrificed to ascertain accurately their moult stage. Thirty-seven trials were conducted, using different crabs on each occasion.

Crab activities relative to the trap and the area covered in the camera's field of view were classified as follows:

Attempt: a forward approach to the trap and contact with one or both of the crab's chelipeds against the trap's wire mesh wall. Often accompanied by the insertion of one or both chelipeds through the mesh towards the bait. If the crab moved away from the trap and out of the camera's field of view after contact, then the attempt was deemed complete. If a crab during an attempt moved away from the trap but remained in the camera's field of view and then made further trap contact, it was scored as the same attempt. Reversing against the trap or a casual lateral contact whilst passing was not scored as an attempt.

Arc searched: the estimated arc covered by a crab around the trap's circumference during an attempt.

Point of contact: that 90° quadrant of the trap's circumference that a crab first contacted during an attempt (Fig. 2).

Entry: a crab enters the body of the trap through one of the entrance funnels, releases its hold of the funnel exit and is deemed caught.

Entry order: the sequence in which crabs entered the trap.

Entry type: which trapped crab, if any, was either at the bait or alongside the funnel as a subsequent crab entered the trap.

Trap top attempt: an attempt by a crab to reach the bait through the trap's top horizontal wire area as opposed to an attempt where the crab comes in contact with the trap's vertical wall.

Funnel miss: moving past a funnel entrance without entering the trap during an attempt. This included the crab walking up the funnel slope, without entering the body of the trap through the funnel exit.

Funnel antagonism: the raising of chelipeds and fending off, with or without physical contact, a crab in the funnel by a crab inside the trap.

Escape: a caught crab leaving the trap through one of the funnels.

Results

Dye dispersion into the water around the trap was rapid and the dye plume which formed within 30 minutes was most concentrated in quadrant 4 (Fig. 2), indicating bait odor dispersal had not been random and probably was strongest in that quadrant. Dye remained most concentrated in the trap's immediate vicinity but could be seen in lower concentration throughout the tank.

The frequency of initial contact for each attempt (Fig. 2) was significantly higher for quadrant 4 ($x^2 = 10.69$, df = 3, P < 0.05).

The 74 males and 74 females made a total of 167 attempts; seven males and nine females made no attempt at entry. Dissection revealed that the majority of crabs not attempting entry were intermoult. The majority of crabs which attempted entry were successful within three attempts (Fig. 3). No crab was observed swimming on approach to the trap, but rather all approached and entered by walking on their dactyls. Crabs frequently swam inside the trap, particularly when one crab retreated from an antagonistic interaction with another.
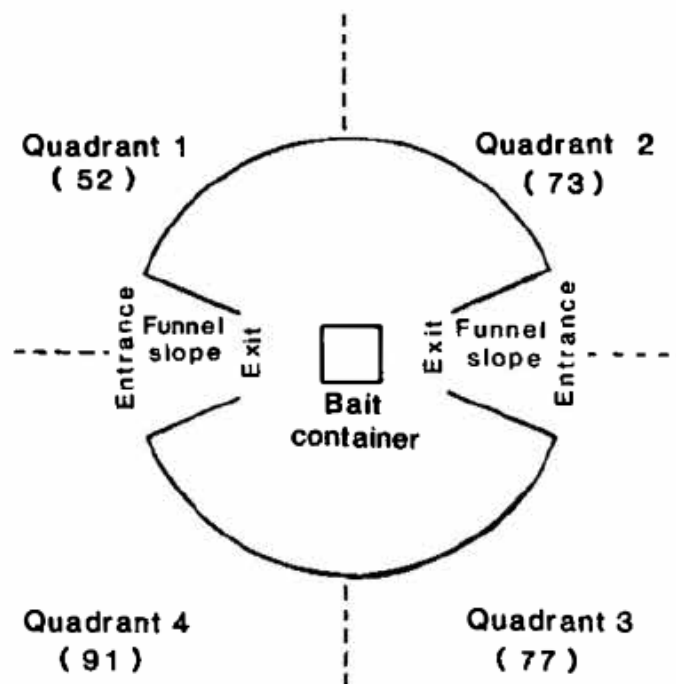

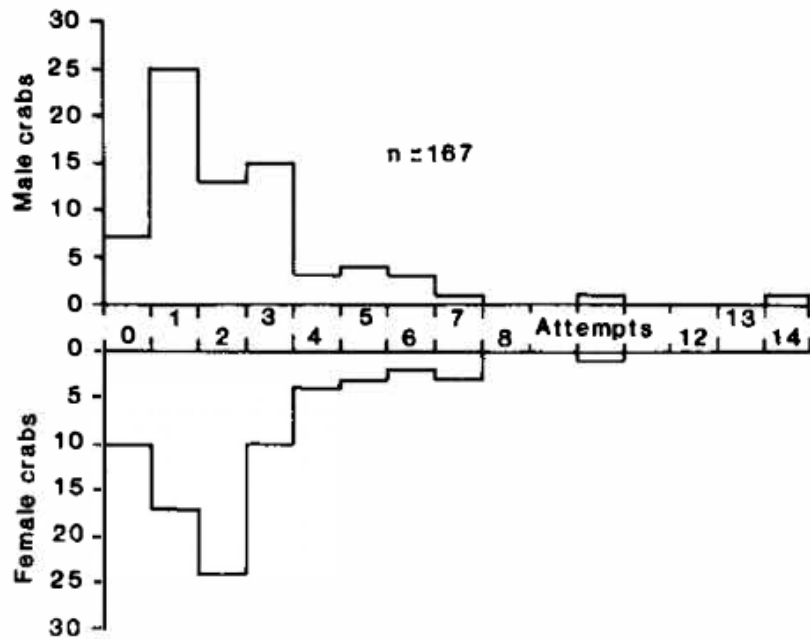Fig. 2. Total number of trap contacts by crabs in each quadrant.

Fig. 3. Frequency of attempts by male and female *P. pelagicus* to enter the trap in 36 trials.

The arc around the trap's circumference searched during an attempt was ≤90° for 66% and 72% of attempts by males and females, respectively (Fig. 4). Only 12% of males and 5% of females searched >180°. Searching usually consisted of moving short lateral distances around the trap for several minutes, using the chelipeds to periodically reach through the mesh towards the bait.

There was no statistically significant trend for large males to enter the trap before other crabs (x^2 = 4.42, df = 3, P > 0.5). There was also no significant difference between the sexes with respect to order of entry to the trap (x^2 = 0.999, df = 3, P > 0.5). Males entered on 50 occasions and females on 42 occasions; this gave a success rate (for total attempts) of 30% and 25%, respectively (Table 1). Data from one trial were not used here as a male moulted during the trial.

Males were more likely than females to miss the funnel entrance during an attempt (x^2 = 27.7, df = 3, P < 0.001) with nine males and two females missing the funnel ≥5 times (Fig. 5). For crabs that made an entrance attempt, male crabs averaged 2.2 funnel misses compared with 1.7 funnel misses for females.

Fifty-two per cent of males which entered the trap did so within the first hour of the trap being placed in the tank whilst 40.5% of females entered during the same period. All crabs that entered did so within 18 hours of the 19-hour experimental period (Fig. 6). Thirty-eight per cent of males and 36% of females entered the trap in ≤5 min
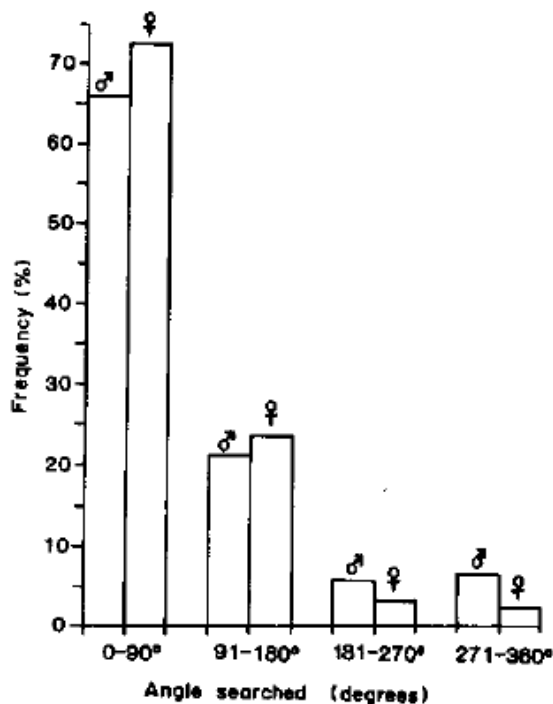
Fig. 4. Arc searched around the trap's circumference during a crab's attempt.

Table 1. Number of crabs which entered the trap (36 trials).

Order of entry	Small male	Large male	Small female	Large female
First	8	14	7	7
Second	11	8	6	8
Third	5	3	8	4
Fourth	1	0	1	1
Never	11	11	14	16

after initial trap contact (irrespective of how long the trap had been in the tank) on the first attempt, whereas 26% of males and 33% of females required > 60 min with more than one attempt (Table 2). Three males and one female entered within one minute by approaching the trap at a funnel entrance and immediately entering on their first attempt.

On 15% of all attempts to enter the trap, the crabs also climbed on top of the trap. Of these, 36% were by large males, 24% by large females, 12% by small males and 28% by small females (n = 25). There was no significant difference between the sexes ($x^2 = 3.0$, df = 3, $P > 0.05$).

Fig. 5. Frequency of male and female *P. pelagicus* entrance funnel misses during an attempt.
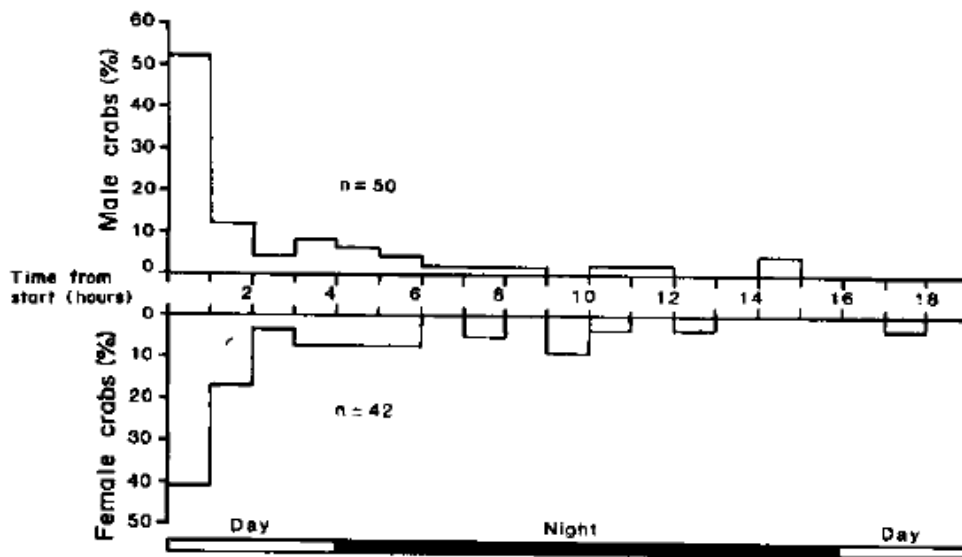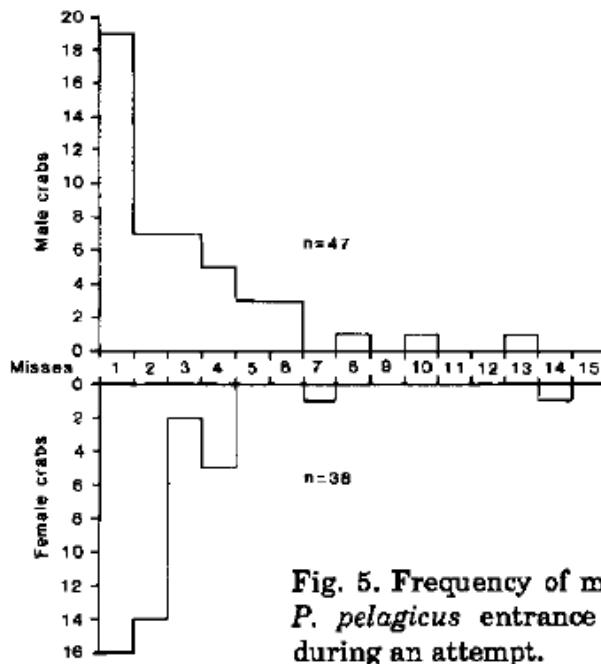

Fig. 6. Trap entry time for male and female *P. pelagicus* from when trap was placed in the observation tank. Data from 36 trials.

Table 2. Number (and %) of crabs which entered the trap within four different periods from the time of the crab's initial contact with the pot wall. Data from 32 trials.

| | \u2264 | Minutes | | |
	\u22645	6-30	31-60	>60
Male	16 (38%)	11 (26%)	4 (10%)	11 (26%)
Female	14 (36%)	9 (23%)	3 (8%)	13 (33%)

Entries and near entries for trials 13-37 inclusive are summarized in Table 3. Entry behavior data for trials 1-12 were not recorded in sufficient detail and are not shown. Of 63 crabs that entered the trap, 20 entered unmolested by other crabs inside the trap as the second, third or fourth into the trap. Eighteen crabs still entered though threatened by one or more crabs inside the trap while the remainder were first into the trap. Seven crabs (four males, three females) were chased back out of the funnel by a crab inside the trap and either entered the trap successfully later on or not at all, while five crabs (two males, three females) backed out of the funnel during an attempt for no apparent reason.

Table 3. Number of crabs which entered or attempted to enter the trap. Trials 13-37 inclusive.

| | | Entry type | | Near entry | |
Crab	First in and unmolested	Enters unmolested by crab in trap	Enters though threatened by crab inside trap	Chased out of funnel	Backed out of funnel of own accord
Small male	6	6	5	2	1
Large male	11	5	4	2	1
Small female	2	6	6	1	0
Large female	6	3	3	2	3

Of 91 trap entrances, only one crab (female) escaped. This resulted from a sudden lateral movement back out of a funnel. Another female of 118 cm carapace width was able to freely move in and out through the trap's wire mesh wall and was thus not counted as an escape.

Discussion

The higher frequency of crabs making initial contact with the trap quadrant where the dye plume concentrated was not unexpected. Other authors (Miller 1979, 1980; Wassenberg and Hill 1987) have shown that crabs approach a bait from downstream as they follow the bait odor trail. Therefore, it is more likely that they would make initial trap contact where bait odor was strongest. Many sand crab trap fishermen consider that orientating a trap with the axis of the funnels parallel to the current, will increase the crab catch. In practice this is difficult to do except in shallow, slow running water.

As the large males being targetted are found more often in deeper waters such as channels and gutters, fishermen are not able to control funnel orientation with any accuracy.

Males and females were equally attracted to the baited trap since both made the same total number of attempts. Other workers who have investigated feeding in crabs and behavior towards bait or a baited trap (Miller 1979; Haddon and Wear 1987; Wassenberg and Hill 1987) have also found no sexual difference in reaction to bait.

The frequency of attempts show *P. pelagicus* is usually willing to make several attempts, but with a marked decline after three unsuccessful attempts. Only three crabs made more than ten attempts to enter the trap. Extrapolation to the commercial trap fishery suggests that a crab may make more than one attempt to enter a baited trap, but if unsuccessful after a few attempts, will probably move off and seek an alternative food source.

The fact that some crabs made no attempt to enter the trap may be due to several factors and suggests that it may also occur in the commercial fishery where there is natural crab moulting and feeding variability. Haddon and Wear (1987) showed that the commonly used procedure of starving crabs for 24 or 48 hours before experimentation (as used here) was ineffective for standardizing appetite in the portunid *Ovalipes catharus*. They concluded that it was invalid to accept the assumption that short periods of starvation can standardize appetite. Other factors that influence feeding include moult phase, reproductive cycle, temperature (Dare et al. 1983) and light (Hill 1976), although these factors were standardized during the present study. Additional factors such as capture trauma and unnoticed mechanical damage may also have caused individual crabs to show no interest in the baited trap.

The percentage of successful entries to total attempts was surprisingly low, but males were marginally more successful than females. Miller (1979) found for *Cancer productus* and a side-entry baited trap perpendicular to the current that there was a low approach and entry success rate of 7%. When the side-entry trap was set with entrances parallel to the current, 65% of approaches resulted in entry. Miller also found, as with this study, that *C. productus* had difficulty locating the entrance, even when it was as close as 30 cm to the crab. *P. pelagicus* also had difficulty locating an entrance with about two-thirds of crabs searching ≤90° around the trap, often moving short lateral distances for several minutes before abandoning the attempt and moving away. Wassenberg and Hill (1987) found

that *P. pelagicus* moved towards a bait in a zigzag path, resulting in the crab crossing and recrossing the probable scent trail coming from the bait. Similar behavior here is likely as the crabs came in contact with the trap wall, attempted to follow the bait odor by short lateral movements, but usually did not attempt wider movements that may have found a pathway through to the bait. Only a minority of crabs searched > 180°.

Entry order into the trap was not dependent upon sex or size of the crab, suggesting it was linked to which crab reacted first to the bait odor, approached the trap, and made a successful attempt. Similar conditions in the commercial fishery are likely with crabs approaching and entering a trap, depending on factors such as hunger, strength of bait odor and current, proximity to the trap, their moult cycle, light and temperature.

Decapod crustaceans, including *P. pelagicus* (Wassenberg and Hill 1987) tend to be most active in terms of foraging and feeding around sunset (Hill 1980; Skinner and Hill 1986). They are also opportunistic scavengers (Wassenberg and Hill 1987) and the strong bait odor within the confines of the laboratory tank may account for the elevated frequency of trap entrances during the first hour. In this study the white light intensity was certainly not a deterrent; crabs often emerged from the substrate and sought the bait within five minutes of the trap being placed in the observation tank. Approximately one-third of all crabs entered on the first attempt within five minutes. The majority of crabs took longer than five minutes with several attempts before they successfully entered the trap.

When a crab did come to a funnel during an attempt it was common for it to miss the funnel and continue searching around the other side. Large males, the crabs being targetted in the fishery, were more likely to do this than small males or females.

The behavior of sand crabs with the trap top surface was not unexpected. Queensland commercial trap fishermen are aware that top entrance traps are not efficient in catching sand crabs and they are not used in the fishery.

Entry of sand crabs into the trap demonstrated there was often interactive antagonistic behavior from crab(s) already inside the trap towards the one attempting an entry. The first crab into the trap often defended the bait and funnel mouth against newcomers. On occasions the trapped crab threatened another outside the trap with raised chelipeds and attempted to move towards it. Occasionally such

tactics succeeded and the newcomer was driven away but more commonly it managed a successful entry despite the threat display, and occasional physical contact. Threat displays against the newcomer sometimes succeeded when the newcomer was in the trap funnel and subsequently forced to retreat. Miller (1979, 1980) reported that similar antagonistic encounters occurred frequently between crabs inside and outside traps for *Cancer productus, C. irroratus* and a spider crab *Hyas araneus*. He found that crabs often accumulated on the downward side of the trap, where antagonistic encounters led to many being chased away by the more aggressive crabs.

The combination of observations including funnel misses and small ($\leq 90°$) area searched, shows that the present design of commercial sand crab traps is not particularly effective at trapping *P. pelagicus* of either sex. Sand crabs generally responded well to the bait odor but were hindered on approach to the trap by the trap wall and their lateral search pattern that often did not lead them to an entrance. A solution that presents more entrances to the trap, increasing the probability that a crab will locate an entrance and enter the trap, should increase trap efficiency. Miller (1979) suggested that a crab trap should be designed so that the bait odor leads the crabs to the trap entrance, not just to the trap. The ideal trap would present no barriers to a crab. The addition of one or two extra funnels to the present design should improve crab catch. This may lead to increased escapement, but in our experiments, except for the small (118 mm) female that was able to move through the mesh, only one crab (1.1%) escaped through a funnel entrance. Sand crabs < 120 mm carapace width are rarely captured in Queensland commercial traps suggesting that smaller crabs are capable of moving freely in and out of commercial traps or that small crabs seldom enter the traps. These results suggest that a continuous funnel around the trap's circumference or three to four funnels would result in a small increase in the low risk of escapement. Evaluation of increased catch versus increased escapement in modified traps, perhaps with one-way entrance triggers, would be useful for *P. pelagicus*. An increase in trap efficiency may have to be offset by a decrease in the maximum number of traps permitted to each commercial sand crab fisherman in order to keep total fishing effort constant. This could be advantageous by decreasing labor for trap hauls and equipment for the same catch.

Acknowledgements

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