Chapter 3 Brachyuran Crab Behaviour

1. Introduction

Animal usually compete for limited resources such as prey shelter and females (Huntingford and Turner, 1987) and the resulting conflicts are settled by size or resident asymmetries between contestants (Hammerstein and Parker, 1982; Maynard smith, 1982; Jaroensutasinee and Tantichodok, 2002). If contestants in territorial defence differ in both size and residency, it is difficult to determine which symmetries are actually used to settle the contests (Hammerstein and Parker, 1982; Leimar and Enquist, 1984). If a single asymmetry, such as size or residency, correlates strongly with fighting outcome, then individuals are expected to assess this asymmetry and adjust their behaviour accordingly (Maynard Smith and Parker, 1976). However, contestants can also assess their opponents in terms of mass (Reichert, 1984), display quality (Davies and Halliday, 1978; Clutton-Brock and Albon, 1979) and energy reserves (Marden and Waage, 1990; Marden and Rollins, 1994).Each individual of the fiddler crab, *Uca Annulipes*, maintains an area surrounding the entrance of its burrow as its territory. The species lives in protected, sandy-mud tidal flats and feeds within the territory after leaving its burrow. This crab is a diurnal animal and is active only during daytime. It scoops substratum with its minor cheliped and carries that to its mouthparts, subsequently separating food substances contained in the substratum (Miller, 1961; Yamaguchi, 2000). It is important for each individual to keep an area of adequate size in order to obtain a sufficient amount of food. Fiddler crab such as *U. pugilator*, *U. vocans* and *.U tangeri*has a habit of mass migration for feeding. They easily abandon their burrows and go to lower places on the beach to feed (Ens et al., 1993). However, *U. annulipes*rarely abandons its burrow, and, therefore, it is a suitable animal to examine the roles of the territory and the burrow in its behavioural pattern. Males of fiddler crabs have an enormously developed large cheliped. Males of *U. annulipes* wave their large chelipeds during the reproductive period to entice a female to their burrows and copulate inside the burrow (Yamaguchi, 1998, 2001). Therefore, the large cheliped is an important tool in courtship behaviour. However, the large cheliped is also a powerful weapon when males struggle with each other (Yamaguchi and Tabata, 2004). Females of fiddler crabs have no large cheliped and thus are missing a strong weapon comparable to that of the males.

The other crab found at study site is *Ilyoplax sayajiraoi*, do not possess large chelipeds like *U. annulipes,* however, they show similar kind of territorial behaviour and feed in their territories. *I. sayajiraoi* do not show migratory pattern except some wandering crab migrate in search of burrow or mate. Wada (1984) found in *Ilyoplax pusilla* a special behaviour to build an earthen structure, and named it a barricade. Larger crabs of that species build a mound-like, earthen structure at the entrance of the neighbouring crabs of lesser sizes. The crabs given a barricade are forced to extend their home ranges towards the areas devoid of the barricade; therefore, their home ranges do not show a circular but show an irregular form. No such structure has been recognized in *I. sayajiraoi*. Then our study was centred observe how each crab defends its territory and how it uses its territory to obtain food. Furthermore, overlapping zone accommodates both the species, *U. annulipes* and *I. sayajiraoi;* andintraspecific interactions between this two species have been studied and described in this chapter.

Crabs of family Dotillidae, commonly known as ‘soldier crabs’ or ‘Sand bubbler’ crabs often inhibit sandy and muddy shores (Takagi et al., 2010). *Dotilla* build their burrows in the area from mean low water level, just above meansea level. As a result, their habitat is periodically flooded, leading to a continuous renewal of organic content in the uppermost sediment layer (Allen, 2010). The organic components of the sediment (detritus, algae, bacteria) are the main food of *Dotilla*. They act as filter feeders, extracting their food from the substratum, which requires highly complex feeding apparatus and processes (Vogel 1984).Feeding activity in *Dotilla* is usually centred on the burrow, from which thecrabs move to and fro while scraping up and sorting the sand around their burrows (Ansell 1988). If disturbed whilst feeding, the crabs will retreat back into their burrows. Once the perceived danger has passed, the crabs re-emerge and continue to feed along the same trench as before they were disturbed.

Zimmer-Faust (1987) studied the foraging behaviour of *Scopimera inflata*, and observed that crabs rarely fed in the same place twice. The crabs only removed the top 3mm of sediment as they foraged, so the biomass concentrations between 0-3mm depth and 3-6mm depth were compared, and found to be significantly greater in surface sediments than those from the subsurface.Two different types of burrowing behaviour have been reported for two species of *Dotilla: D. fenestrata* (Hartnoll 1973) and *D. myctiroides* (Tweedie 1950). The first burrow type is a simple open vertical tube structure. Individual crabs dig these burrows in well-drained and firm sand, where the water table falls well below the bottom of the burrow at low tide. The second type of burrow involves the crab making a shallow depression in the sediment. Within this depression the crab turns onto its side, and rotates backward, pushing particles of sand upward and outwards. The semi-liquid pellets coalesce to form a circular wall, to which the crab adds further pellets, creating a dome-like structure, which has been termed the ‘igloo’ (Tweedie 1950). Igloos are only found in areas where the water drains inadequately, and do not occur in firm sand with a low water table.

The formation of dense aggregations of crabs, known as ‘droves’ (Crane 1975), is a behaviour that has been observed in several of the genera within the Ocypodidae, with *Dotilla* being no exception (Tweedie 1950; Zimmer-Faust 1987; Allen, 2010). For several Ocypodidae species drove formation has been attributed to serve a reproductive function by increasing the opportunity for crabs to encounter potential mates (*Ilyoplax pusillus* Wada 1978; *Scopimera globosa* Wada 1981; *Uca spp.*Crane 1975). Another suggested reason for drove formation is as a response to dry sediment conditions in burrow areas, forcing crabs to aggregate in an area where the sediment is moister in order to facilitate feeding (Wada 1981). High population densities have also been cited as a potential factor in causing droves to form (Wada 1981).

Droving behaviour constitutes an alternative foraging strategy to feeding around the burrows in *Dotilla fenestrate* (Allen, 2010). Crabs that wandered in a drove had stomach contents richer in both organic and microalgal mass than sedentary crabs (Gherardi et al. 2002). These results are similar to the studies done on several species of *Uca* (Crane 1975; Murai et al. 1982, 1983) and *Mictyris longidactylus* (Cameron 1966). Grouping in a drove offers passive defences against predation by the effects of dilution and confusion (Russo et al. 1998). Wandering in a drove increases the likelihood of encountering richer substrates, whilst at the same time reducing the amount of individual time (and energy) spent searching for food. However, such aggregations have the negative effect of forcing conspecifics to share resources and to compete with each other (Gherardi et al. 2002).

2 RESULTS

2.1 Intraspecific interaction in *U. annulipes* and *I. sayajiraoi*

Cheliped waving display was prominent behaviour in both the species of crabs, *U. annulipes* and *I. sayajiraoi.* This behaviour performs to repel the intruder or to attract the female crabs. When Intruder tried to enter to territory of resident crabs, they stare each other at specific distance by being motionless. In this study this behaviour called as staring; during this behaviour both the crab assess opponents. Asymmetries between individuals can lead to quick resolution of contests based on those asymmetries, but when competitors are evenly matched it results in escalated fighting (Maynard Smith 1982; Enquist and Leima, 1983). When resident crab assess that intruder is big sized and resident crab is near to burrow, it quickly hide in burrow. This event was called as hiding behaviour in study. A fight was defined as interaction inwhich the males touched claws, even briefly. Many fights are settledwith ‘pushing’: while facing each other, males align theirchelipeds and push. If this does not end an encounter, theyproceed to grapple by interlocking claws and twisting. Figure 1 and Figure 2 showing the different intraspecific interactions in *U. annulipes* and *I. sayajiraoi*.

Cheliped waving behaviour was encountered higher in big sized crab (119 ±17.41 events / 10 minutes) followed by medium sized crab (101 ±17.61events / 10 minutes) and very less reported in small sized crab (41 ±12.33 events / 10 minutes) in *U. annulipes* (Table 1). Staring was observed almost equally in all sized crab in *U. annulipes* (Figure 3). Fighting was observed higher in small sized crabs whereas Hiding was observed higher in medium sized and small sized crabs in *U. annulipes* (Figure 4).

Cheliped waving behaviour was encountered higher in big sized crabs (45 ±9.5 events / 10 minutes) followed by medium sized crabs (31 ±11.87 events / 10 minutes) and negligible in small sized crabs (1 ±0.94 events / 10 minutes) in *I. sayajiraoi* (Table 2). Staring was observed higher in big sized and medium sized crabs (4 ±1.79 events / 10 minutes and 4 ±1.56 events / 10 minutes respectively) compared to small sized crabs in *I. sayajiraoi* (Figure 5). Fighting and Hiding was recorded higher in small sized crabs followed by medium sized crabs in *U. annulipes* (Figure 6).

2.2 Interspecific interaction in *U. annulipes* and *I. sayajiraoi*

Interspecific interaction between *U. annulipes* and *I. sayajiraoi* recorded at overlapping zone (Figure 7). Cheliped waving was recorded almost equally in both big sized and medium sized *U. annulipes* (86 ±8.75 events / 10 minutes and 81 ±8.1events / 10 minutes respectively) (Table 3). Staring, Fighting and Hiding recorded higher in medium sized compare to big sized *U. annulipes* (Figure 8). Cheliped waving was recorded higher in big sized and almost negligible in medium sized *I. sayajiraoi* (24 ±5.72 events / 10 minutes and 2 ±1.58 events / 10 minutes respectively) (Table 3). Staring, Fighting and Hiding recorded higher in big sized compare to medium sized *I. sayajiraoi* (Figure 9).

2.3 Comparison of Intraspecific and Interspecific interaction in *U. annulipes* and *I. sayajiraoi*

Cheliped waving was recorded low during interspecific compared to intraspecific interactions in both, big sized and medium sized *U. annulipes* (Figure 10). Staring was recorded high during intraspecific interactions in large sized whereas during interspecific interactions in medium sized *U. annulipes* (Figure 10). Hiding was recorded almost equal during both the interactions while no event of fighting recorded during interspecific interactions in large sized *U. annulipes* (Figure 11). Hiding and Fighting was recorded high in medium sized crab during interspecific interactions compared intraspecific interactions in *U. annulipes* (Figure 11).

Chelipedwaving and Staring recorded high during intraspecific interactions compared to interspecific in both the sized crabs, big sized and medium sized in *I. sayajiraoi* (Figure 12). Hiding was recorded high during interspecies interactions compared to intraspecies interactions in big sized whereas revers pattern was observed in medium sized *I. sayajiraoi* (Figure 13). Fighting behaviour was recorded equally in big sized crabs during both interactions whereas no event of fighting recorded in medium sized crabs during interspecific interactions in *I. sayajiraoi.*

2.4 Impact of body size, tide and availability of food on the Cheliped waving frequency of *U. annulipes*

To observe the effect of different lunar cycle days on claw waving Observation was taken during two spring tides (14th, 15th, 16th, 29th, 30th and 1st days of lunar cycle) and two neap tides (6th, 7th, 8th, 21st, 22nd and 23rd days of lunar cycle) days. To check the effect of available food observation was taken during first two hours of low tide and after two hours of low tide. Chelipeds waving event was counted for 5 minutes on different time lapse and selected tide days.

Result suggests that body size had clear impact on Cheliped waving and under different variable big sized crabs encountered higher cheliped waving frequency compared to medium sized crabs. There was no significant difference recorded in cheliped waving frequency in different time lapse during neap tide in both the size crabs, medium sized and big sized crabs, whereas significant difference was recorded in cheliped waving frequency in different time lapse during spring tide in both the size crabs (Table 4).

2.5 Mating Behaviour of *U. annulipes* and *I. sayajiraoi*

Mating behaviour was observed throughout the year in *U. annulipes* and *I. sayajiraoi*. The burrows are used as breeding sites, for underground mating, and for incubation in both the species of crab. In *U. annulipes* burrow owner male crab approach and capture nearby burrow owner female crab and copulation occurred either at the entrance or within the female burrow or in male burrow. In *U. annulipes* wandering crab approach and capture burrow owner female crab and mating behaviour involved somewhat forceful component. Juveniles of *U. annulipes* settled towards upper intertidal area of Z2 and more or less separated from mature *U. annulipes* area whereas juvenile *I. sayajiraoi* settled towards lower region of Z3 within mature *I. sayajiraoi* area and uniform distribution with mature *I. sayajiraoi* found.

2.6 Juvenile distribution along the *U. annulipes* belt

For ease of study the 35 m belt of *U. annulipes* was divided into 7 sub belts (5 m each) and a specific distribution pattern of juvenile distribution was observed throughout the year.Juvenile *U. annulipes* is distributed in first 4 sub belts up to 20m belt in which first 2 sub belts contain more percentage of juveniles where as in last 15 m of *U. annulipes* belt exclusive adult distribution was found (Figure 14). Monthly distribution ratio of juvenile along transect belt shows that from November to March first 5 m sub belt remain exclusively juvenile zone but from April to October ratio of adult and juvenile is almost equal (Figure 14). Overall ratio of Juvenile along transect is decreased during post summer from May to July and found steady from August to February (Figure 15).

2.7 Chimney building activity and mass movement of *Dotilla sp.*

Dotilla sp. is homogenously distributed with relatively low density at Z5 from August to January and during this period they form first type of burrow simple open vertical tube by digging firm sand. During this period they feed around their burrow and showed territorial behaviour. As juvenile recruitment period initiated and density increased during the period of February to May. During this period they form second type of burrow structure, make a shallow depression within sediment and upwards make a chimney like structure. Tweedie (1950) described this type of structure and given name ‘Igloo’. In our study we referred this type of structured as chimney due to it’s appears more looks like chimney (Figure 16). During this period competitions for food and space was at its peak. During this period medium sized and small sized crabs move towards water logged area of upper inter tidal area of Z5 at the base of slope and aggregate there for feeding (Figure 17). This aggregation behaviour referred as ‘Drove’ and described by many scientist in Ocypodidae family.

During first few hours of low tide major part of Z5 remain covered with shallow water as a form of ‘tide pool’ and at the base of ripples and row formation was recorded the roof of ripples. After few hours water cover decreased and chimney building activity increased. During early hours of low tide greater movement of *Dotilla sp.* observed.

To understand the movement of crabs and time of chimney formation we recorded density of burrow of 36 quadrate covering 60 m^2 areas during one hours time lapse and also recorded Burrow with chimney and without chimney and % of water cover. The arrangement of quadrate is shown in Figure 18. Total 38.56 % of burrow without chimney and 61.44 % burrow with chimney recorded (Table 6). Linear regression showed negative relationship between water cover % and burrow count / m^2 (Figure 19). Results suggested that no significant difference found in burrow count / m^2 as we move from upper intertidal area to lower intertidal area (Table 4). Result suggests that burrow count burrow with chimney increased in later hours (Table 6, Figure 20). Suggesting that drove formation at upper intertidal area had major function of feeding during early hours and later hours they return to lower area and start chimney formation and close the chimney before initiation of high tide.

3. DISCUSSION

3.1 Intraspecific and interspecific interaction in *U. annulipes* and *I. sayajiraoi*

Most animal conflicts show asymmetries in fighting ability, resource value, and ownership status (Maynard Smith and Parker, 1976; Yamaguchi and Tabata, 2005). Contestants assess fighting ability in terms of size (Thornhill, 1984; Verrell, 1986; Jaroensutasinee and Tantichodok, 2002), residency status (Waage, 1974) or both (Hyatt and Salmon, 1978; Rosenberg and Enquist, 1991; Jennions and Backwell, 1996). This study shows that *U. annulipes* and *I. sayajiraoi* size asymmetry to settle intraspecific coflictics. Large sized and medium sized crabs showed more aggression and Hiding was performed less in big sized crabs in *U. annulipes and I. sayajiraoi*.

At overlapping zone big sized crabs and medium sized crabs showed equal results in cheliped waving but Staring, Hiding and Fighting behaviour increased in medium sized crabs in *U. annulipes*Cheliped waving, Staring, Hiding and Fighting recorded higher in big sized crabs compare to medium size crabs in *I. sayajiraoi*. Results suggest that there were conflicts between medium size *U. annulipes*and big sized *I. sayajiraoi* at overlapping zone.

3.2 Impact of body size, tide and availability of food on the Cheliped waving frequency of *U. annulipes*

Fiddler crab is the most studied group in terms of behavioral aspects. Male fiddler crabs wave a single greatly enlarged claw as both a weapon in agonistic contests with other males and an ornament to attract females for mating (Crane 1975; Christy 1987; Pope 2000). Large males with relatively large claws win more contests, wave with greater vigour and are attractive to females (Christy 1987; Jennions and Backwell 1998; Hayes et al. 2013). Wave rate is positively correlated with male carapace size and relative claw size

(Jennions and Backwell, 1998) hence larger male actively court females and rely more heavily on female cooperation to copulate successfully unless smaller males who obtain mating after forced copulation (Murai and Backwell, 2005). Present study showed that cheliped waving frequency was higher in big sized crabs compare to medium sized crabs. Sexual display is generally found to be extremely metabolically demanding (Matsumasa and Murai, 2005)and the expression of a male sexual signal was suggested to evolve to be condition-dependent (Kim 2003).*U. annulipes* inhibit upper intertidal area hence tides inundate during few days of spring tide so food availability higher during spring tide days compared to neap tide days. Jennions and Backwell (1998) described by operating a experiment on *U. annulipes* that wave rate of different sized males are more similar during neap tide as waving is affected by short term food availability. We can conclude that food availability was major concern in the difference frequency rate during neap tide and spring tide in present study. As food availability is high during spring tide, crabs make themselves more concentrate on food during early hours of low tide and in later hours they spent energy by increased frequency of cheliped waving for territory and mating contest.

3.3 Mating Behaviour and Juvenile settlement

Mating behaviour and juvenile settlement has been seen throughout year in *U. annulipes* and *I. sayajiraoi* and burrows are used as breeding sites, for underground mating, and for incubation. Juvenile settlement of *U. annulipes* was recorded towards upper intertidal area and *I. sayajiraoi* towards lower intertidal area. Juvenile recruitment of mudskipper and *Dotilla sp.* was seasonal which suggest that breeding season of mudskipper is monsoon while post winter in the case of Dotilla intermedia. There was a difference in the pattern of distribution between large and small sized crabs within the *Uca* zone. The uppermost intertidal area was dominated by smaller crabs, with larger crabs occurring mainly in the lower part of *Uca* zone. Size segregation may possibly act as a process to partition space and avoid intraspecific competition for food and space, with each population component having a differential capacity to select a desirable microhabitat (Defeo and McLachlan

2005). The Habitat Favourability Hypothesis (Caddy and Defeo 2003) suggests that under optimal conditions, the centre of a species' range may be occupied by larger and more dominant intraspecific competitors for food and space, whereas small individuals (recruits) may be displaced towards suboptimal conditions on one or both extremes of the species distribution range. *Uca annulipes* appears to follow the description of Favourability Hypothesis large crabs occupying favourable distribution, and the smaller crabs displaced towards one extreme.

3.4 Mass movement and Chimney building activity in *Dotilla sp.*

As to mass wandering of sand bubbler crab*,* the following has been reported: (1) the period of its appearance was from the end of July to the beginning of August at Urayasu of Chiba Prefecture (Sugiyama, 1961) and from May to August at Amakusa, Kyushu (Yamaguchi and Tanaka, 1974), (2) the members were mainly larger crabs (Sugiyama, 1961; Yamaguchi and Tanaka, 1974), (3) it invariably occurred at the water-logged place near the water edge (Sugiyama, 1961; Ono, 1965; Yamaguchi and Tanaka, 1974) and (4) it was attributed to more intensive interactions between individuals due to overcrowding, because it was observed in the high density area on warm and fine days when crabs were active (Sugiyama, 1961; Ono, 1965; Yamaguchi and Tanaka, 1974, Koga, 1995).

According to theresults, numerous medium sized and small sized crabs wandered observed during February to May in study area. In addition, mass wandering was encountered also in relatively high density areas, observed also on the windy and intermittently raining days when crabs were supposed to be less active than on fine days. Mass wandering has been well-known also in other ocypodid, such as *Dotilla myctiroides*(Tweedie, 1950),*U. vocans vocans* (Nakasone, 1977), *Scopimera Globosa* (Koga, 1995), *D. fenestrata* (Gheraldi et al., 2002) and *D. intermedia* (Allen, 2010). Mass wandering of all these species was reported to occuron the water-logged place. In these ocypodidsmass wandering has been generally interpreted in such a way that the deficiency of the water indispensable for feeding (Miller, 1961) due to the dryness of the substratum caused the crabs to wander toward the lower water-logged place (Miller, 1961; Nakasone, 1977, Wada, 1981; Flores et al. 2003). But, Mass movement towards water logged area found from February to May in *Dotilla sp.* at study area during the time of high density and not found during June and July when density was low and comparatively drier period. Thus, thishypothesis does not explain the movements of this species.

Among the various Hypotheses suggested by various scientists for the formation of droves in the water saturated area, 'Social interaction hypothesis' (Sugiyama, 1961; Ono, 1965; Yamaguchi and Tanaka 1974; Koga, 1995) fitted best for the *Dotilla sp.* at present study site. When population density in the area is high, crabs losing in combats move to water saturated area. Because competitive ability depends partly on body size, small sized crabs excluded from the burrow area with large ones remain there. In contrast, small sized crabs as well as large ones, remain in the burrow area when population density of the burrow area is low because competition pressure is relaxed (Koga, 1995). This is the reasons for that the medium and small sized crabs found during mass movement in present study site.

First few hours they feed at water logged area and than returned to burrow area and start chimney forming activity and hence in later hours burrow density with chimney formation increased. Similar kind of timing in chimney building formation described by Gheraldi (2002) in *D. fenestrata*. Burrows of *Dotilla sp.* found on the slopes of ripples and if water logged at base of ripples, Burrow formation area was decreased. Hence regression analysis suggests negative relation between water cover % and burrow count.

Figure 1. Intraspecific behaviour of *U. annulipes,* a) Cheliped waving b) Staring c) Fighting d) Hiding

Figure 2. Showing intra specific behaviour of *I. sayajiraoi,* a) Cheliped waving b) staring c) Fighting d) Hiding

Table 1. Showing different behaviour (mean events / 10 minutes) in *U. annulipes* during intraspecific interactions

Behaviour	BIG SIZE	MEDIUM SIZE	SMALL SIZE
Cheliped waving	119 ±17.41	101 ±17.61	41 ±12.33
Staring	2 ±1.63	2 ±1.99	2 ±1.83
Fighting	1 ±0.91	1 ±0.94	2 ±1.58
Hiding	2 ±1.58	3 ±2.12	3 ±1.033

Table 2. Showing different behaviour (mean events / 10 minutes) in *I. sayajiraoi* during intraspecific interactions.

Behaviour	BIG SIZE	MEDIUM SIZE	SMALL SIZE
Cheliped waving	45 ±9.5	31 ±11.87	1 ±0.94
Staring	4 ±1.79	4 ±1.56	3 ±1.05
Fighting	1 ±0.92	1 ±0.94	2 ±1.58
Hiding	2 ±1.68	3 ±2.71	4 ±2.2

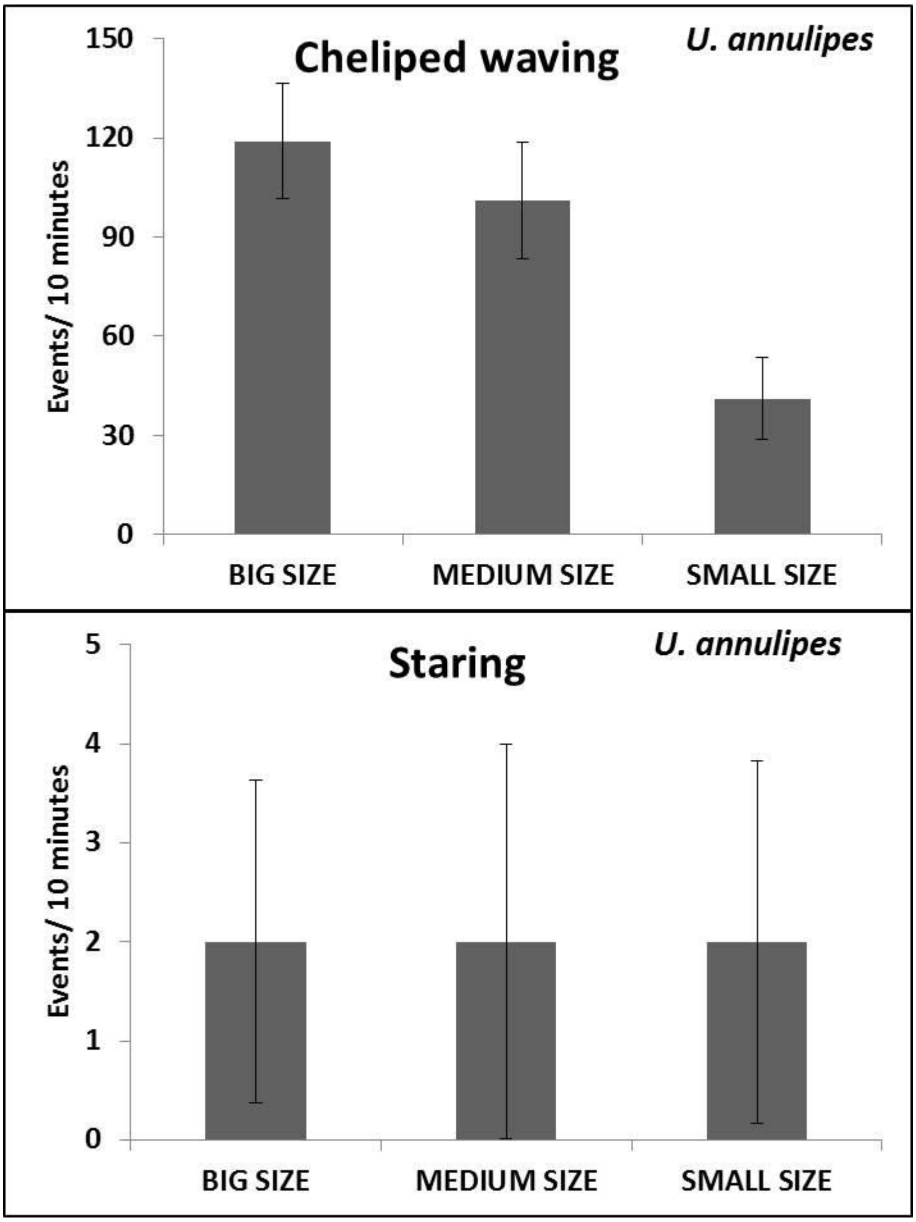

Figure 3. Cheliped waving and staring behaviour in *U .annulipes during* intraspecific interactions

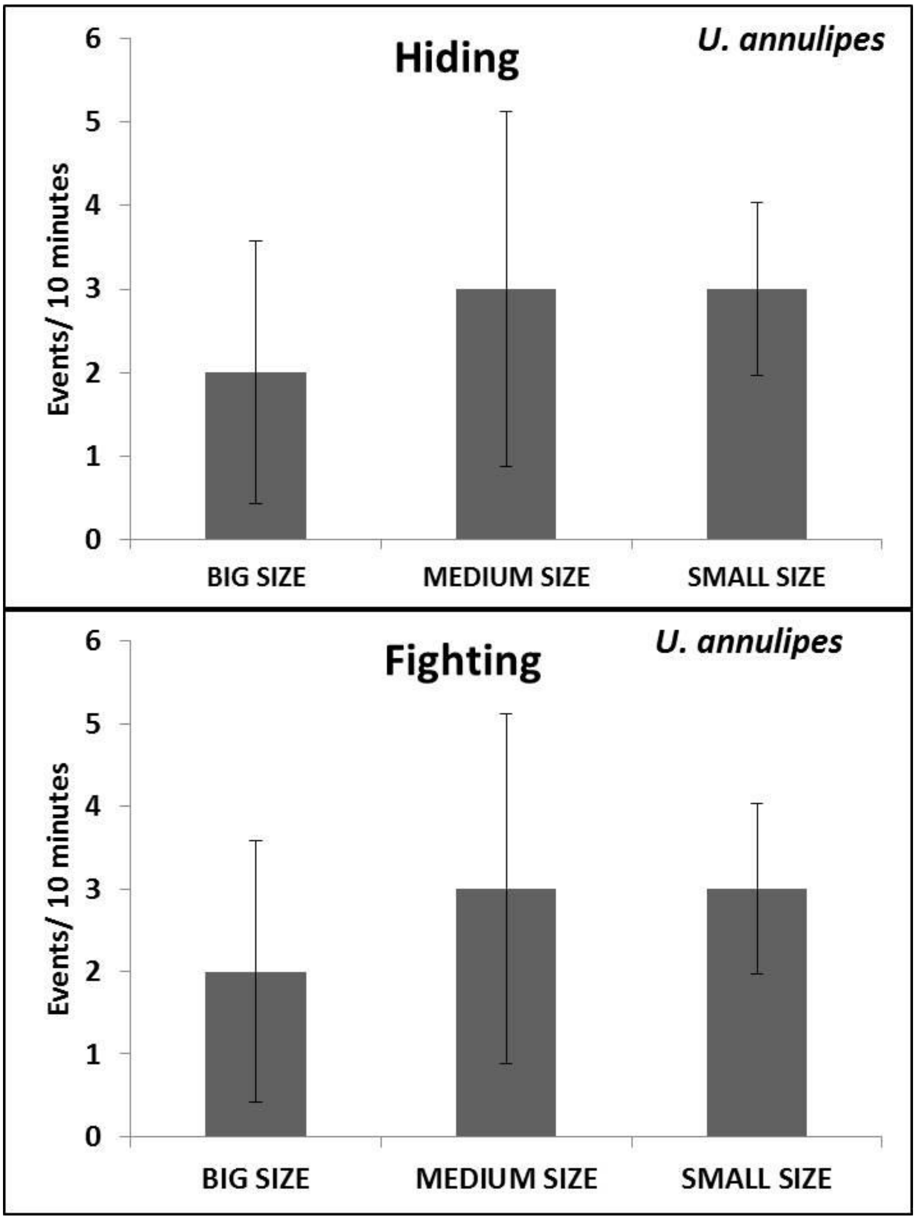

Figure 4. Hiding and fighting behaviour in *U .annulipes during* intraspecific interactions

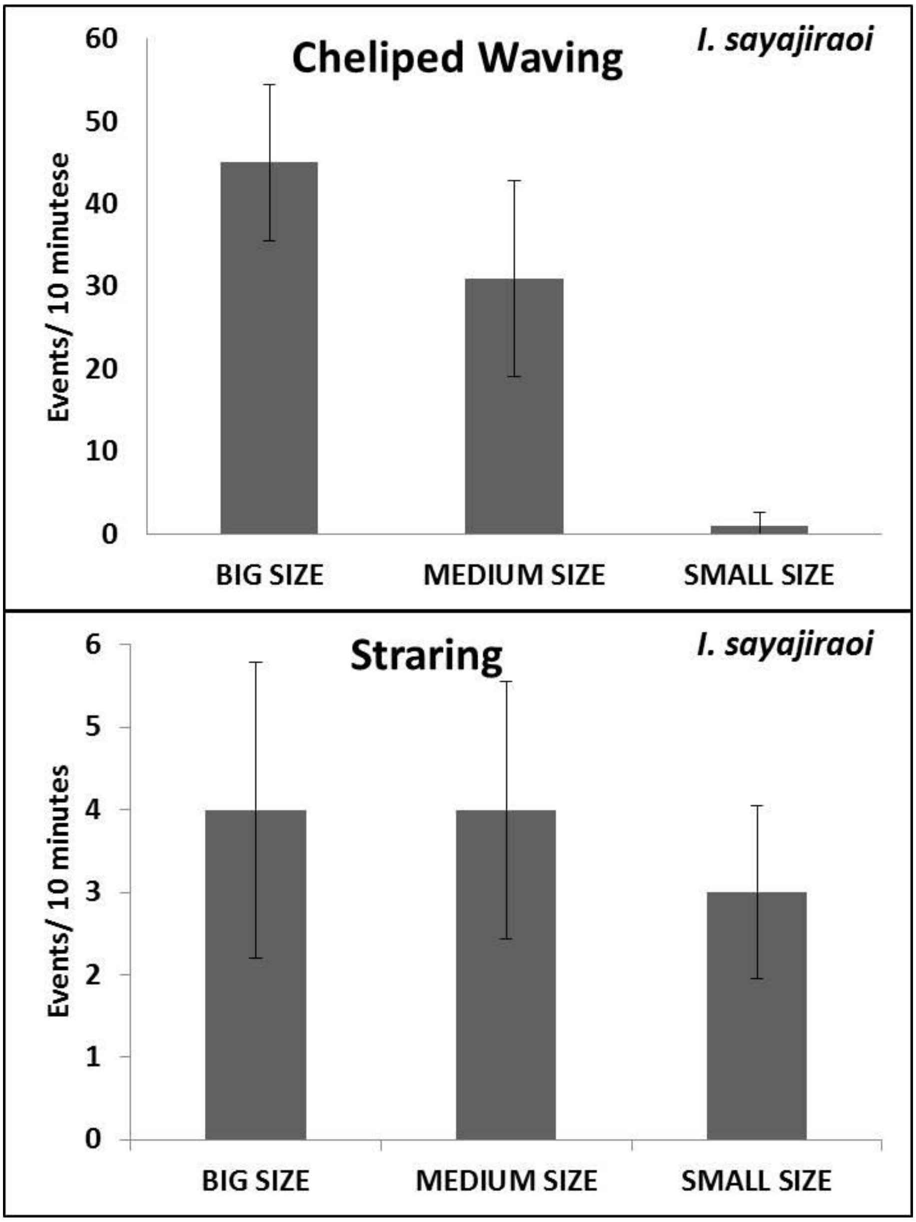

Figure 5. Cheliped waving and Staring behaviour in *i. sayajiraoi during* intraspecific interactions

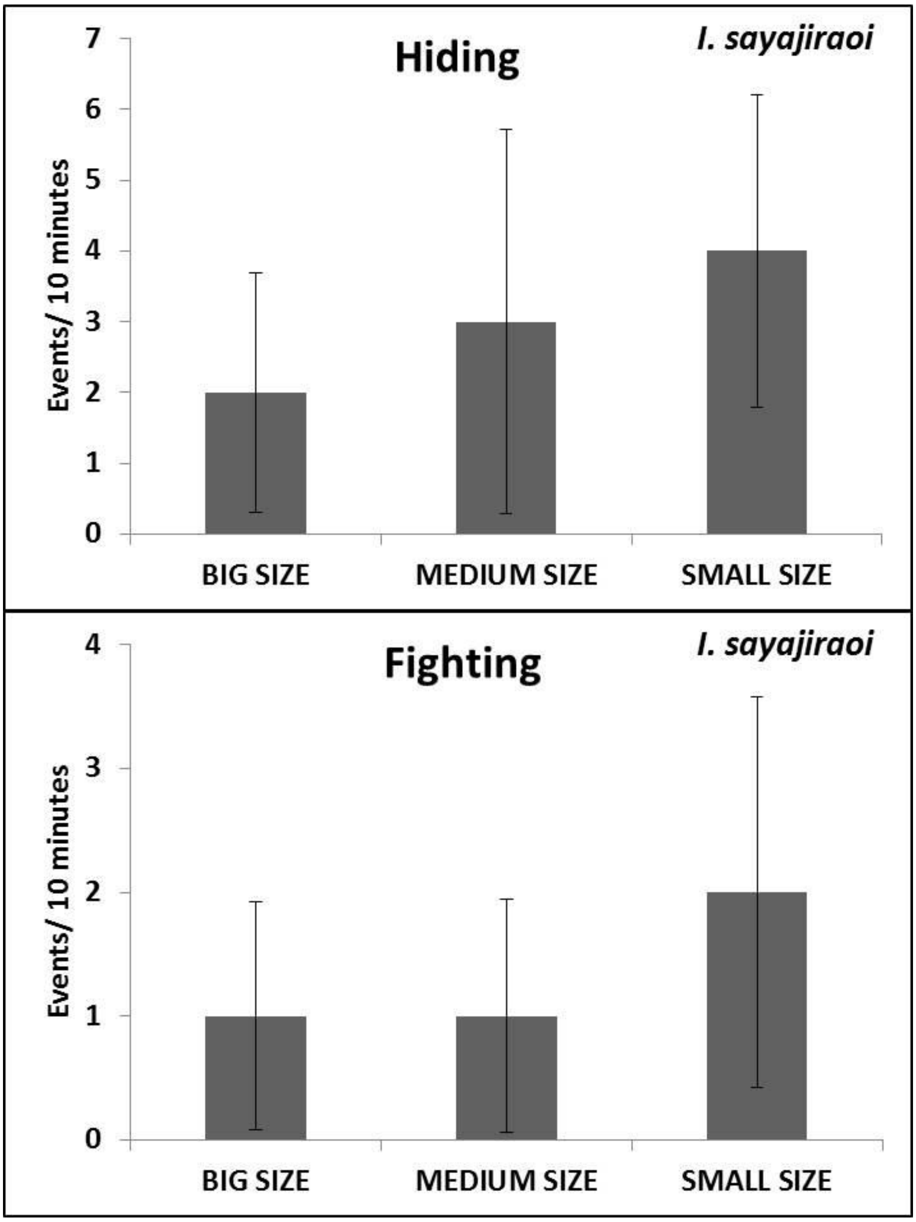

Figure 6. Hiding and fighting behaviour in *I. sayajiraoi during* intraspecific interactions

Figure 7. Interspecific behaviour of *I. sayajiraoi and U. annulipes* a) Cheliped waving b) staring c) Fighting d) Hiding at overlapping zone

Table 3. Different behaviour (mean events / 10 minutes) in *U. annulipes* and *I. sayajiraoi* during intraspecific interactions

Behaviour	***U. annulipes***		***I. sayajiraoi***	
	BIG SIZE	**MEDIUM SIZE**	**BIG SIZE**	**MEDIUM SIZE**
Cheliped waving	**86 ±8.75**	**81 ±8.1**	**24 ±5.72**	**2 ±1.58**
Staring	**1 ±0.91**	**3 ±1.8**	**4 ±1.475**	**2 ±1.03**
Fighting	**0 ±0**	**3 ±1.8**	**1 ±0.94**	**0 ±0**
Hiding	**2 ±0.81**	**4 ±1.5**	**3 ±1.35**	**2 ±1.42**

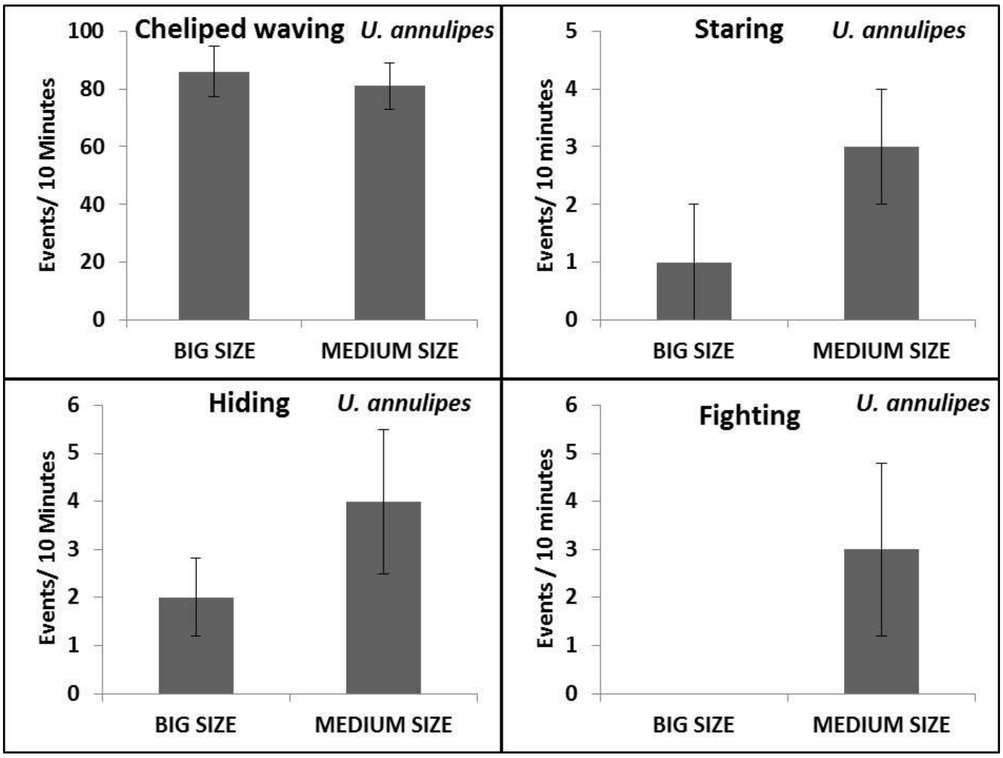

Figure 8. Cheliped waving, Staring, Fighting and Hiding behaviour of *U. annulipes* during interspecific interactions

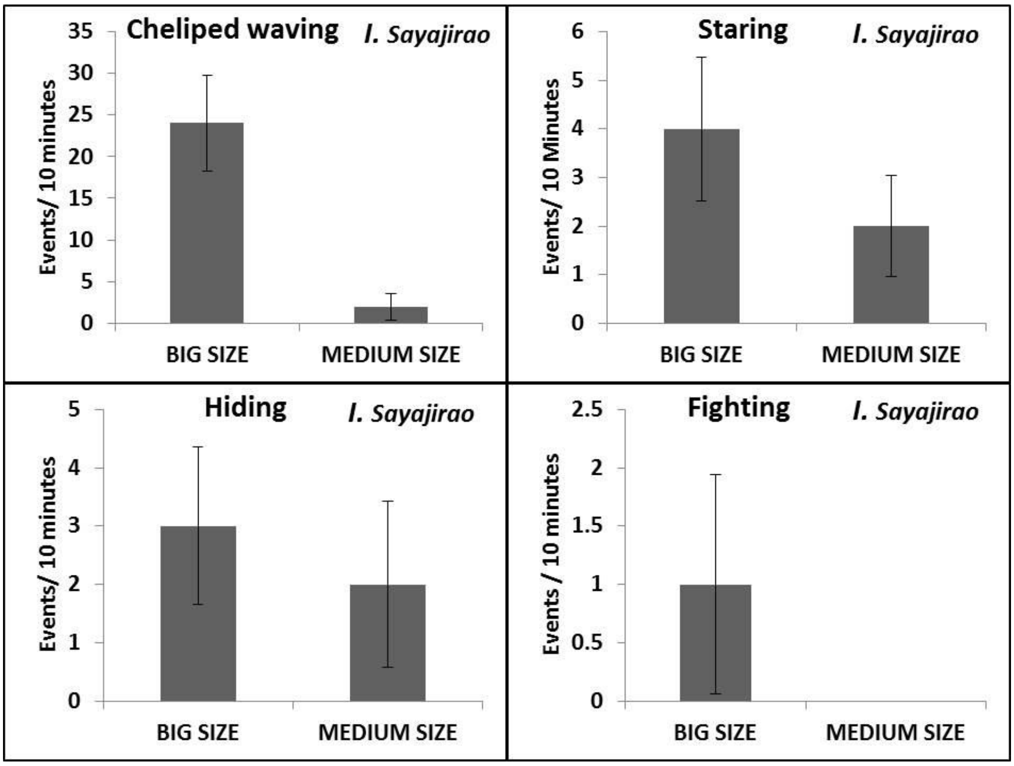

Figure 9. Cheliped waving, Staring, Fighting and Hiding behaviour of *I. sayajiraoi* during interspecific interactions

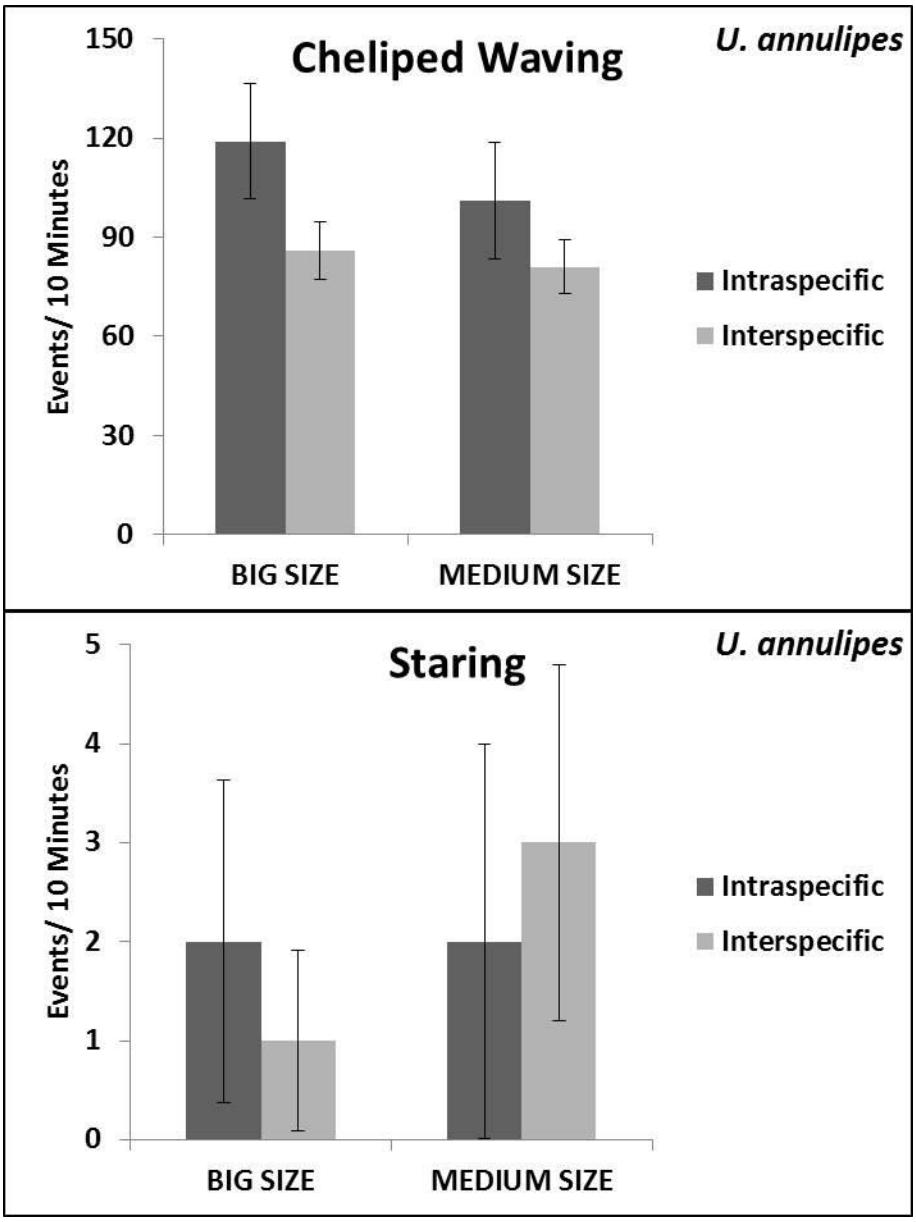

Figure 10. Comparison of Cheliped waving and staring behavior between intraspecific and interspecific interactions in *U. annulipes*

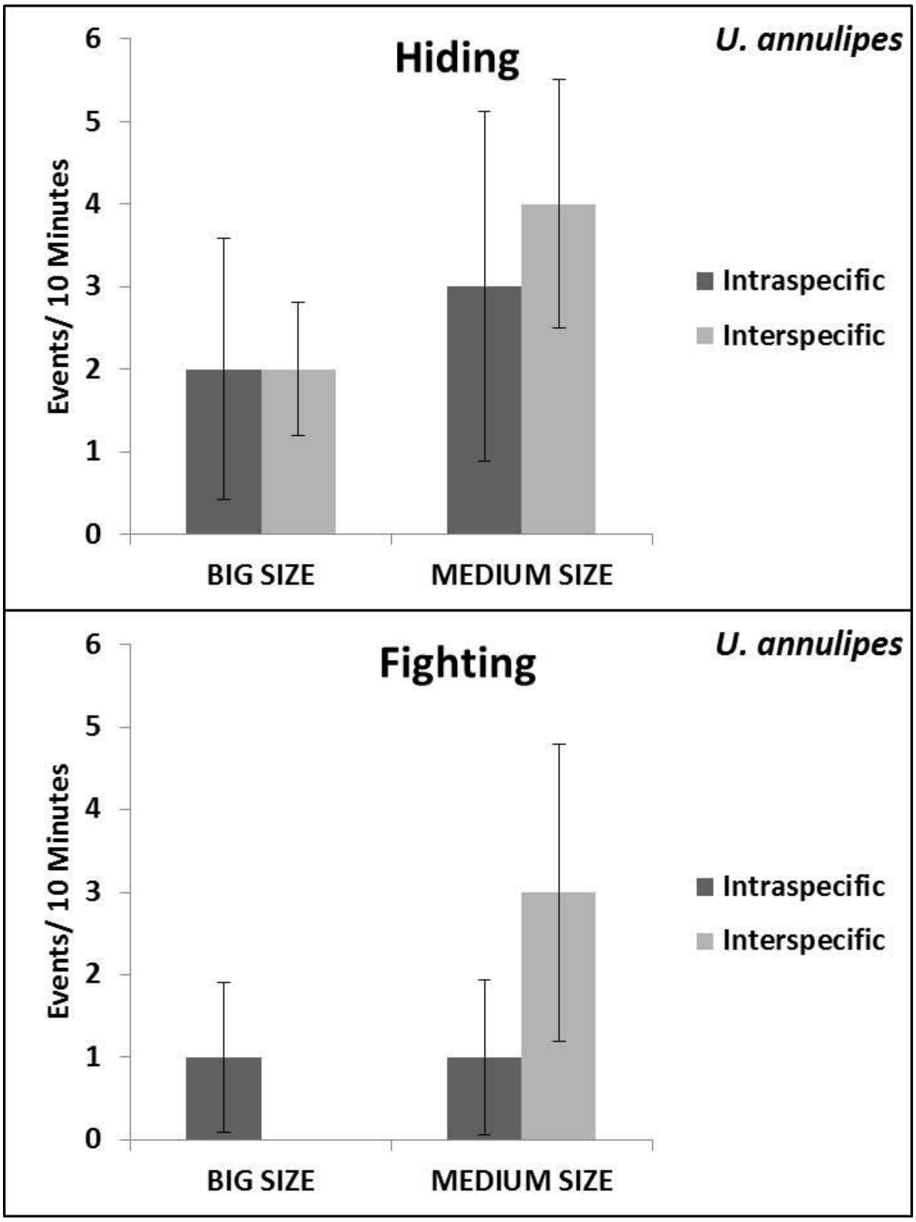

Figure 11. Comparison of Hiding and Fighting behavior between intraspecific and interspecific interactions in *U. annulipes*

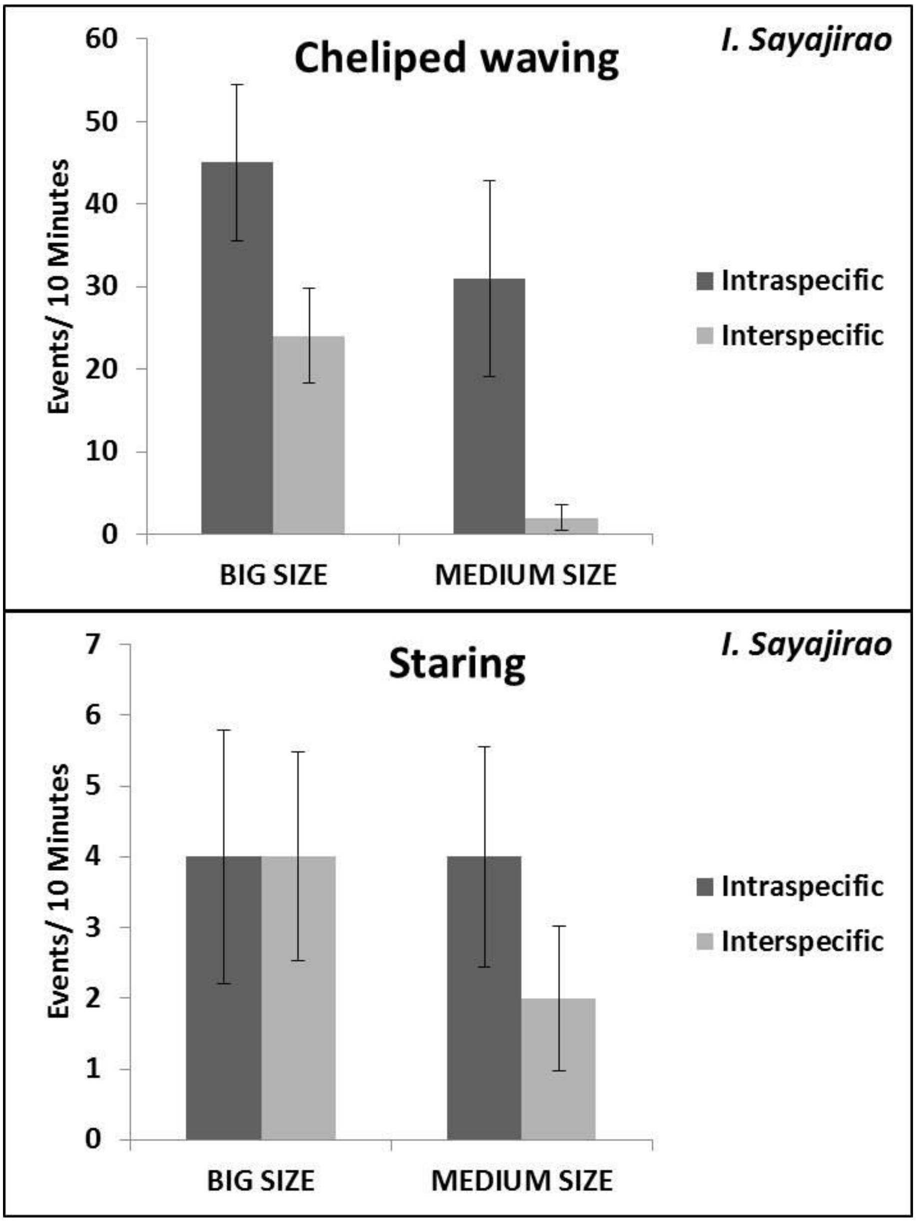

Figure 12. Comparison of Cheliped waving and staring behavior between intraspecific and interspecific interactions in *I.sayajiraoi*

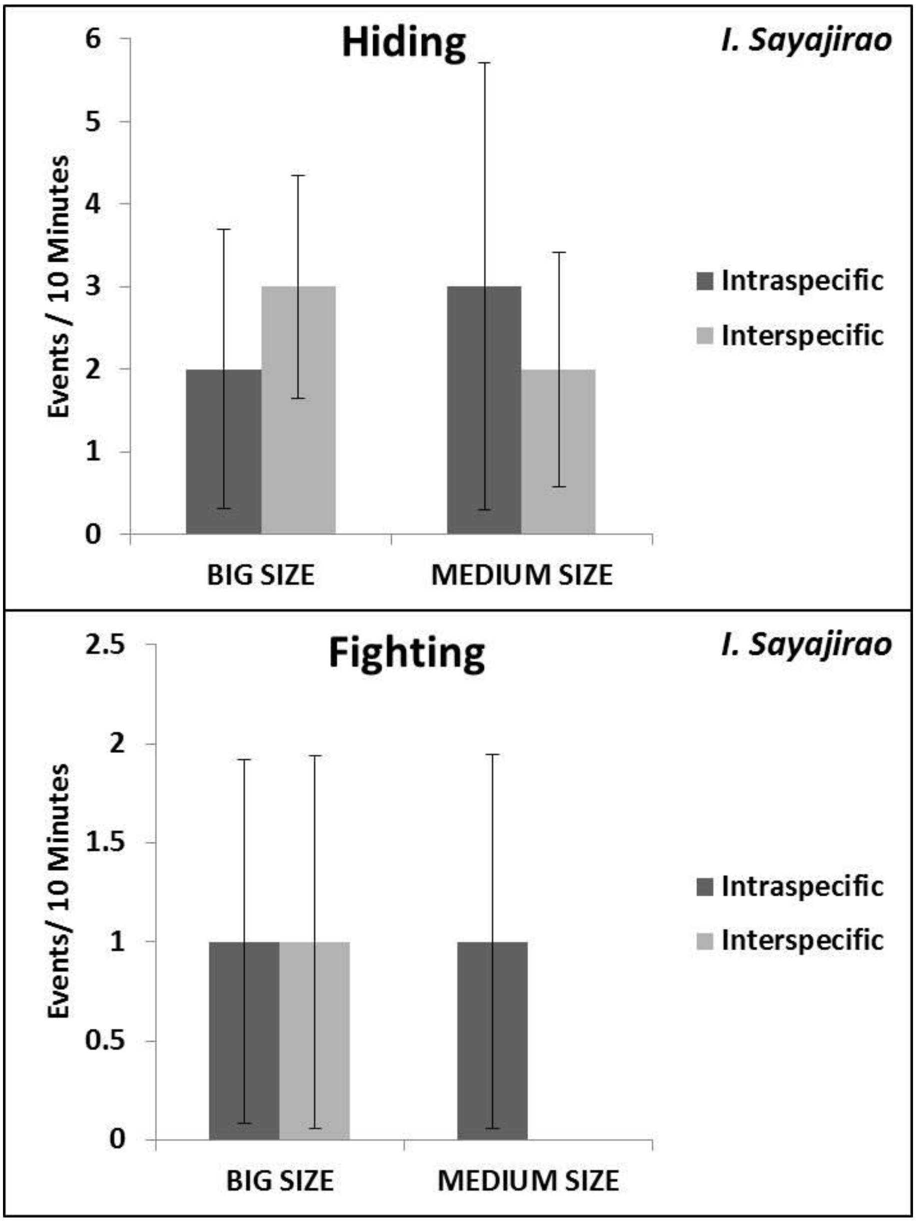

Figure 13. Comparison of Hiding and Fighting behavior between intraspecific and interspecific interactions in *I.sayajiraoi*

Table 4. Mean cheliped waving under different variable in Medium sized and Big sized *U. annulipes*

Tide	Hour	Cheliped waving (Events / 5 minutes) MEDIUM SIZE	Cheliped waving (Events / 5 minutes) BIG SIZE
Neap	**First Two**	22.33 ±5.2	30.66 ±6.49
	After Two	22.73 ±5.1	31.00 ±5.95
Spring	**First Two**	28.13 ±7.17	37.60 ±7.94
	After Two	38.4 ±8.6	49.86 ±16.99

Table 5. Mean density of crab / m^2 at one hr time lapse along the 36 quadrate

Quad. No.	1st Hour		2nd Hour		3rd Hour		4th Hour	
	Burrow count / m^2 (Mean)	Stdv	Burrow count / m^2 (Mean)	Stdv	Burrow count / m^2 (Mean)	Stdv	Burrow count / m^2 (Mean)	Stdv
Q- 1 to 6	28.33	16.30	58.00	31.73	94.67	28.73	120.67	29.04
Q- 7 to 12	46.33	42.50	79.00	58.24	106.83	71.05	172.00	142
Q- 13 to18	64.67	17.81	119.50	50.76	133.67	68.13	130.86	75.95
Q- 19 to 24	21.33	10.37	57.17	17.06	89.50	19.3	109.83	32
Q- 25 to 30	28.33	7.89	46.67	13.41	72.33	14.55	96.83	18.13
Q- 31 to 36	25.83	22.88	43.83	42.54	56.17	38.37	84.50	37.67

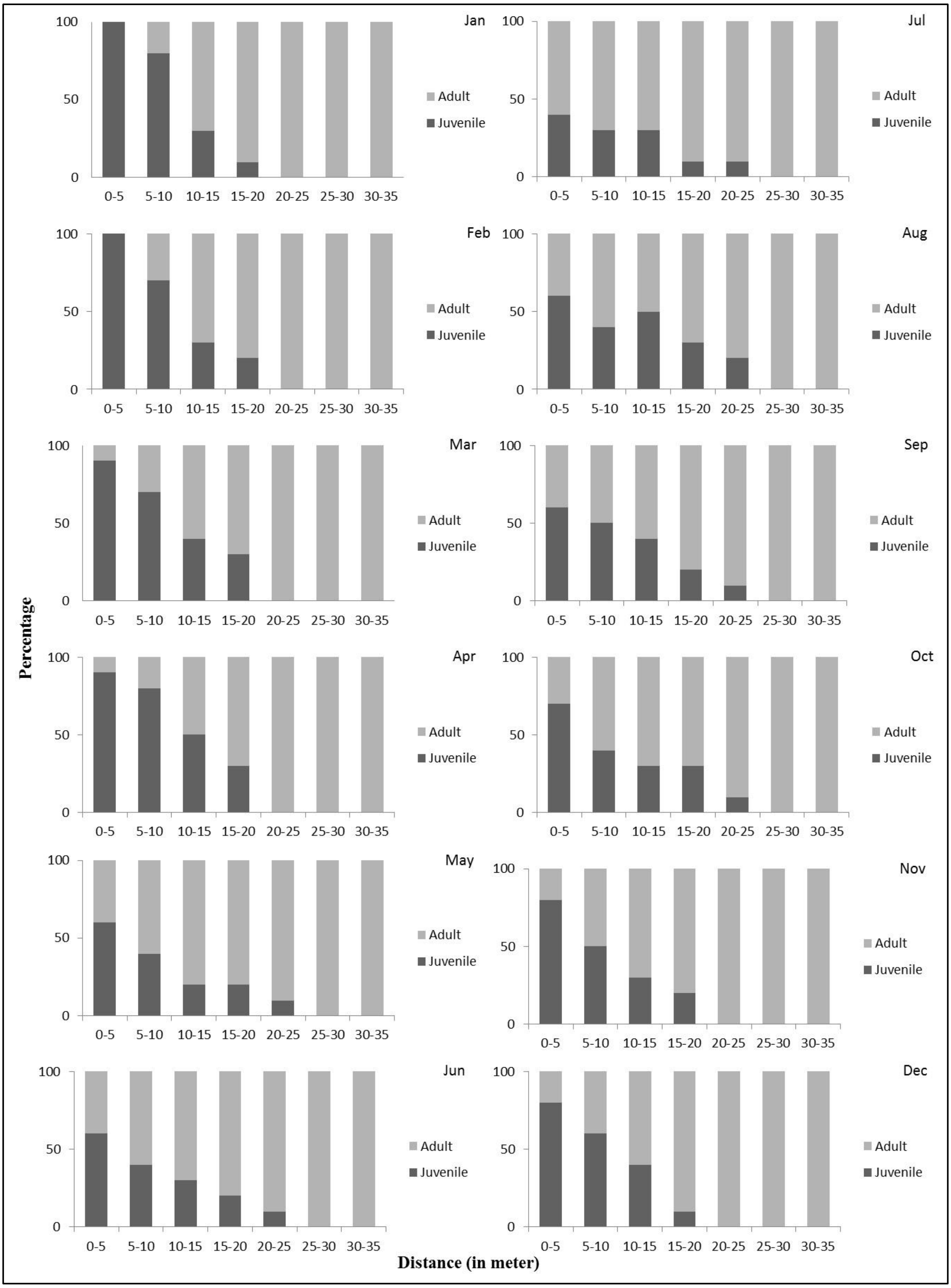

Figure14. Monthly ratio of adult and juvenile population along the of *U. annulipes* belt

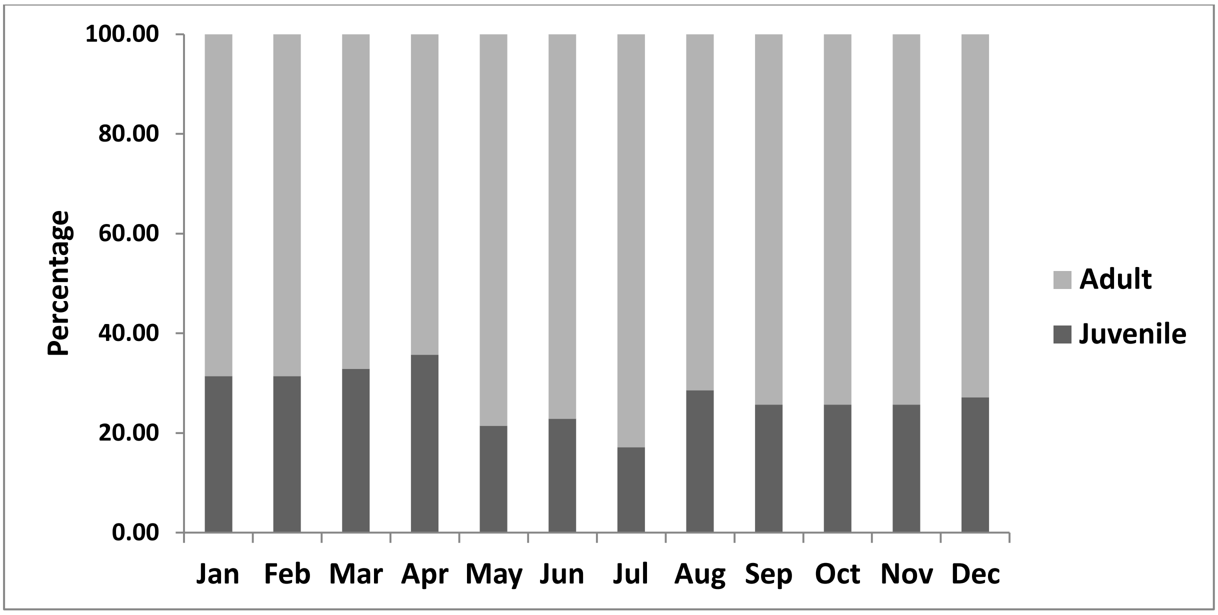

Figure 15. Monthly ratio of adult & juvenile population in *U. annulipes* belt

Table 6. Mean density of burrow with chimney and without chimney per meter square at one hr time lapse

Quad. No.	1st Hour		2nd Hour		3rd Hour		4th Hour	
	WC	C	WC	C	WC	C	WC	C
Q- 1 to 6	12.17	16.17	15.50	42.50	30.33	64.33	33.00	87.67
Q- 7 to 12	15.50	30.83	26.50	52.50	42.50	64.33	113.33	58.67
Q- 13 to18	25.00	39.67	40.50	79.00	51.00	82.67	49.50	103.17
Q- 19 to 24	8.00	13.33	24.00	33.17	40.00	49.50	42.83	67.00
Q- 25 to 30	9.67	18.67	20.33	26.33	28.67	43.67	40.00	56.83
Q- 31 to 36	6.83	19.00	16.17	27.67	13.17	43.00	31.83	52.67

Figure 16. a) chimney building activity b) Chimney of *Dotilla sp.*

Figure 17. ‘Drove formation’ in *Dotilla sp.*

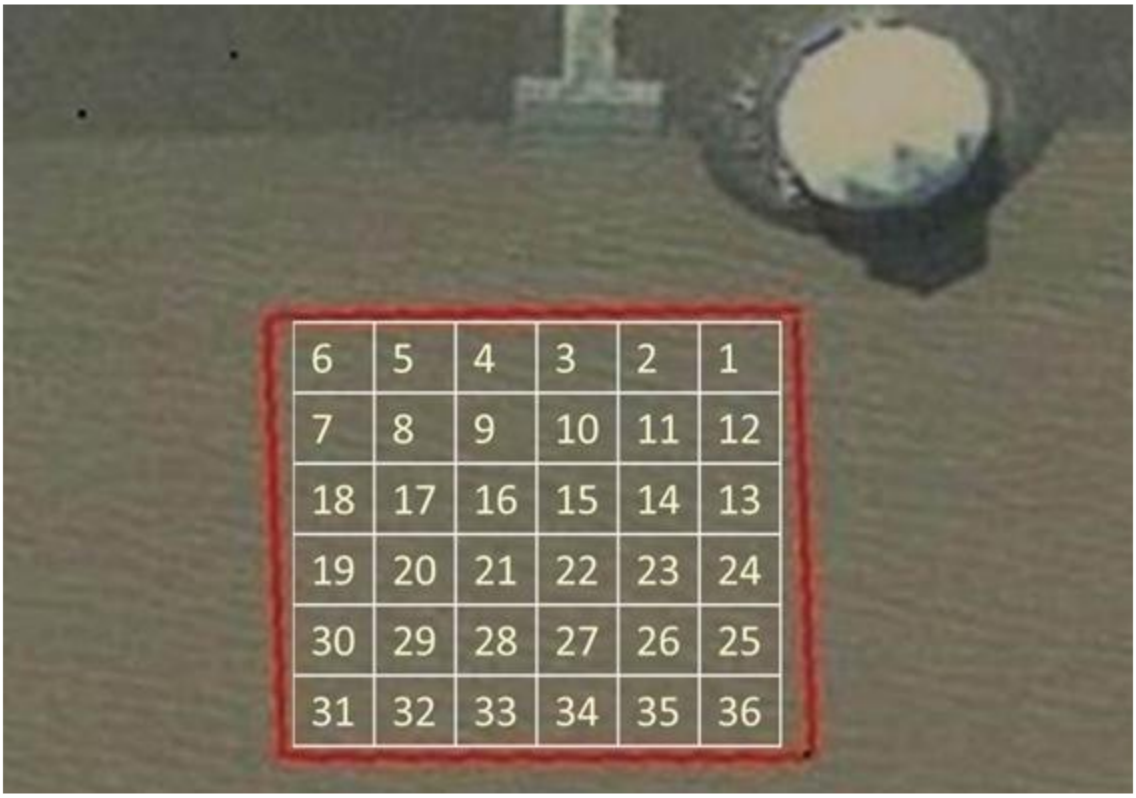

Figure 18. Quadrate arrangement along the Z5 for *Dotilla Sp.* experiment

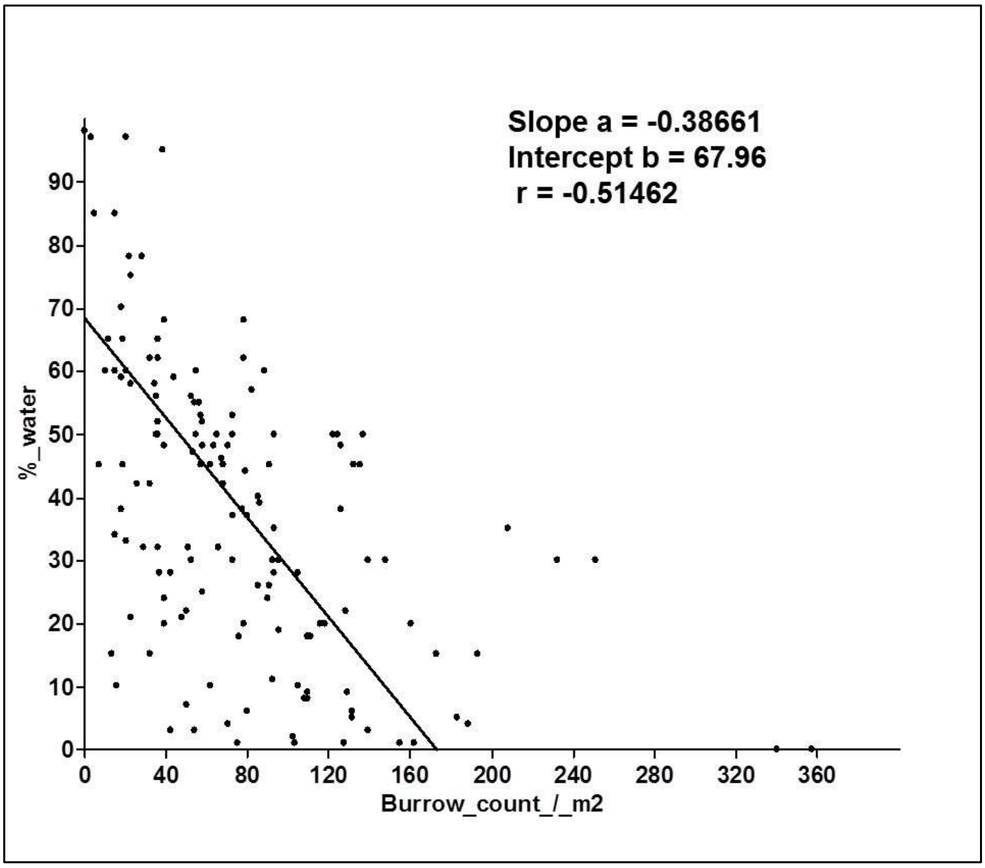

Figure 19. Linear regression between burrow count and water % at Z5

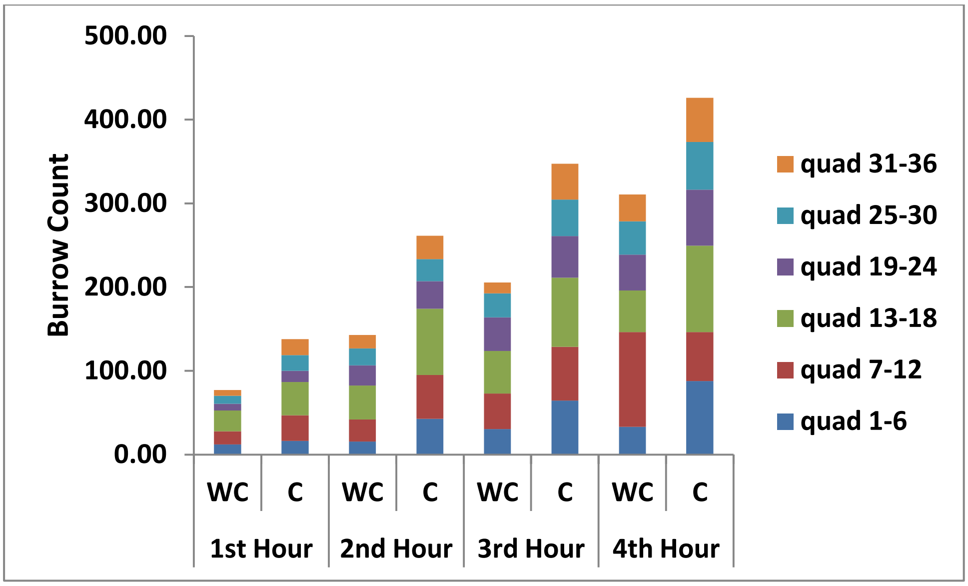

Figure 20. Mean density of burrow with chimney and without chimney at one hr time lapse