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Daily activity and movement of the land crab, *Cardisoma hirtipes* DANA, by radio-telemetry during non-breeding season

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Introduction

Migration of the crabs from sea to land is one of the most interesting subjects for estuarine ecologists, since pioneer study of Pearse (1927). Many studies have been conducted for this problem using mainly the comparative method of research between species (e.g. Bliss, 1968). The land crabs are the species most successfully adapted to the terrestrial life, and that makes these species beneficial in the study of comparative biology. There are, however, a few studies concerning the ecology of the land crabs in the natural condition so far (Silas and Sakarankutty, 1960; Gifford, 1962).

There are distributed four species of the land crabs, *Cardisoma hirtipes*, *C. rotundum*, *C. carnifex* and *Gecarcoidea lalandii*, in the Ryukyu Islands (Türkay and Sakai, 1976). *C. hirtipes*, the material of the present study, is the species commonly seen in the inland area of the islands. During non-breeding season, it inhabits in such areas as bush and grassland near seashore where the light condition on the ground is difficult to get a clear sight of animals, and sometimes lives in a few kilometer inland from the sea (Minei, 1966). Only ovigerous females migrate to the seashore to release zoeas within a few nights of highest high water during breeding season (Shokita, 1971; Okamoto, 1975). The activity pattern of this species during non-breeding season is primarily nocturnal. Therefore, it is difficult to observe its activity merely by optical method, and radio-telemetry was adopted to overcome the difficulty.

The aim of this study is composed of two; one, to make clear the problem whether the nocturnal pattern of daily activities of the land crab is independently defined by the tidal rhythm or not, and two, to measure the length of duration of occupation by one definite burrow, i.e. the degree of residentiality.

The study area and methods

The study was conducted in Kuroshima Islet in Yaeyama, Okinawa Prefecture from 12th to 20th July 1977. The islet is consisted of elevated coral reef being flat land covered with terrestrial trees (*Carica papaya*, *Calophyllum Inophyllum*, *Garcinia spicata*, etc.) and the grasslands. The study site was selected on the remains of a human habitation about 200m inland from the coast, and so broken hedges made of old-corals were piled up linearly in some places as shown in Fig.1.

A fixed route was followed to count the crabs which were out of the burrows (number of active crabs) every one hour for three days (Fig.1), and air- and soil-temperatures, relative humidity, relative light intensity and weather condition were recorded simultaneously.

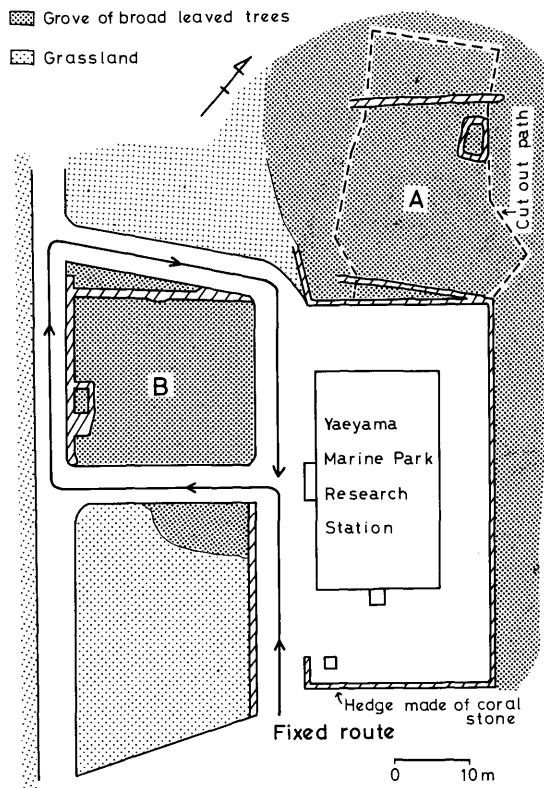


Fig. 1. Map showing the study area.

Activity of individual crab was revealed by use of radio-telemetrical technique. Three transmitters used for this study were controlled by crystals with a proper frequency of 53.2, 53.3 and 53.5 MHz, respectively. Each transmitter was packed together with mercury batteries (H-B type, 1.3V: National Mallory Electric Co.) burried in an epoxy resin on a plastic plate (about 30x20x5 mm). A transmitting antenna made of pliable steel wire (about 20 cm in length and 0.5 mm in diameter) was attatched to this pack. The pack was adhered directly on the carapace of the land crab. The transmitters with batteries were weighing 6.5 - 7.7 g being 6.1 - 6.7 % in body weight of the crab (body weight of the crab ranged from 106.5 to 114.6 g).

Receivers, which were portable MMB-type (Meisei Electric Co.), and handy antennas were used for locating and monitoring the activity of the crab. Radio locations were decided by two or three simultaneous determination of locations from stationary receiving points and then these were plotted on the maps of the study area. A locating search was made at about 1 hour interval, and intensity of signal and condition of radio contact were recorded continuously. Situation of the crab, whether being in or out of the burrow, was easily decided by the intensity of signal. When the crab was out of the burrow, intensity of signal was powerfull and easily caught by receiver, while weak or no signal means the crab being in the burrow. Activity of two crabs, which were marked by reflecting tape on the carapace, was also used for the observation of activity.

Results

1) Distribution pattern of the burrows of the land crab

Fig.2 shows the distribution of the burrows of the land crab in a part of the study area (A in Fig.1). There were 95 burrows in the area of about 651 m², the density of the burrows was 0.15 per m², and 98 burrows in the area B in Fig.1 (about 431 m²), 0.23 per m². In Fig.2, about half number of the burrows in the area A aggregated densely around the broken hedge of coral stone and the rest of them distributed at the base of tree stems. The burrows associated with the tree stems seem to show somewhat uniform distributional pattern. But this pattern is not the innate trend of the crabs, because the burrow is usually made associated with several supporting material of its wall such as tree stem or burried stone.

2) Activity of the natural population

Time sequences of the number of active crabs, which were counted in case of the routine counting on the fixed route, are shown in Fig:3 a,b together with the data of environmental factors.

No crab was seen during daytime except on rainy day. After sunset, the crab started activity and the number of active crabs increased towards the maximum at the time between 2:00 and 4:00. The activity decreased steeply towards the dawn

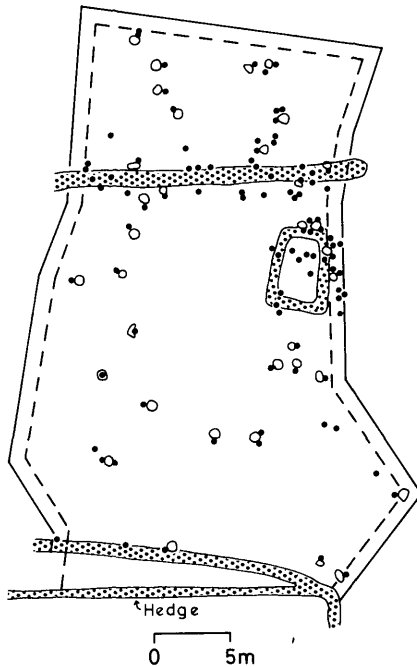


Fig. 2. Distribution of the burrows of the land crab in the area A in Fig.1.

- burrow of the land crab
- tree stem or stone
- - - cut out path

and it stopped at 6:00, just before sunrise. The land crab showed complete nocturnal activity pattern under fine weather condition as in 15/16th night and 17/18th night of July, and the maximum number of active individuals was only about five. While on rainy day of July 19th night, a certain number of crabs was observed active even during daytime and prominent activity started early in the evening: active crabs could be seen as early as 16:00, about 3 hours before sunset. Moreover, the number of active crabs was more abundant than on fine day.

3) Movement of individuals

Tracks and locations of the radio-tagged crab are shown in Fig.4. The crab A (male) was captured and released in the evening of July 14th (Fig.4). It moved about 2 m from releasing point and rest there during daytime. Next night it moved more than 2 m and rest there for three days without showing any activity, and afterward it moved suddenly to a point about 56 m north-east of its previous location in the rainy night of 19/20th.

The crab B (male) was captured and released in the evening of July 13th. It moved in the night about 8 m from the releasing point and stopped there. Next night (14/15), it moved long distance of about 94 m, and succeedingly about 128 m in the night of 15/16th.

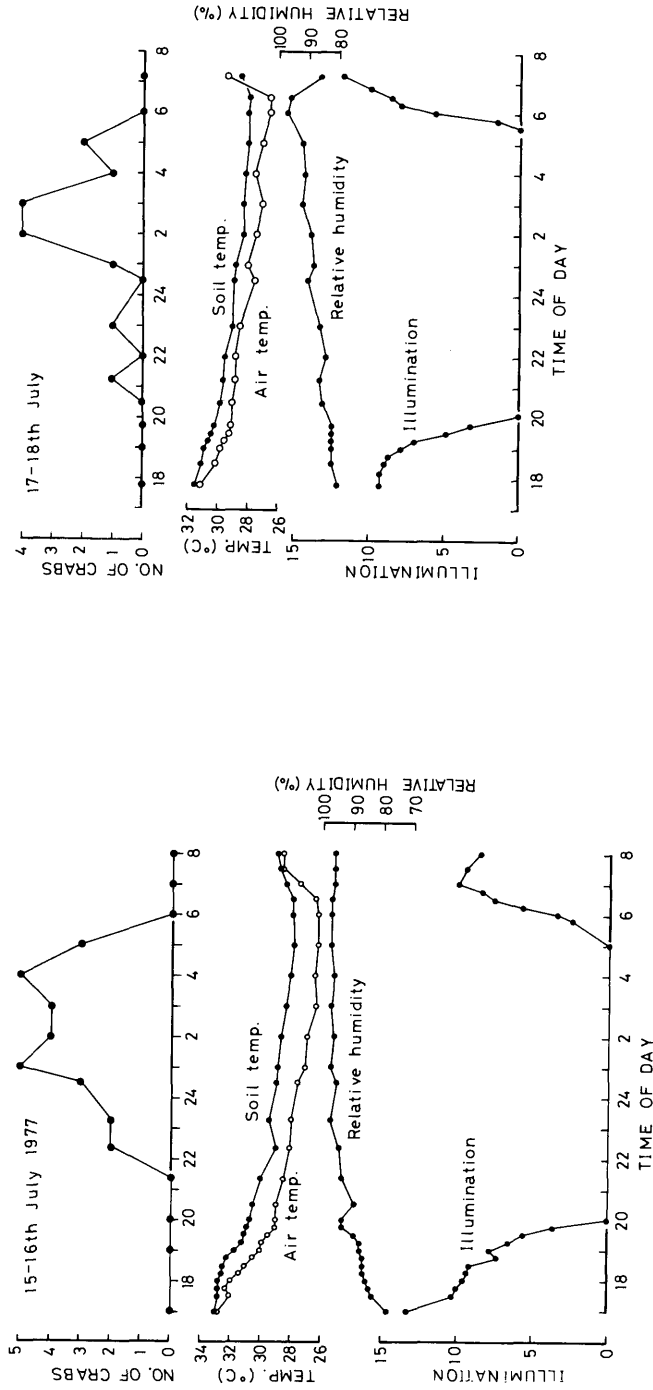


Fig. 3a. Time sequences of number of active crabs counted at an hour interval following the fixed route with the data of environmental factors in 15/16th night (left) and in 17/18th night (right). Illumination is represented by the measure of exposure meter for camera.

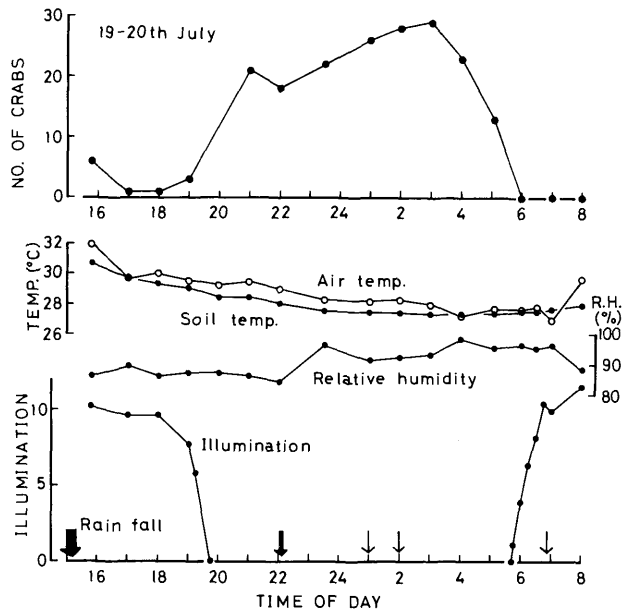


Fig. 3b. Time sequence of number of active crabs counted at an hour interval following the fixed route with the data of environmental factors in 19/20th night July. Illumination is represented by the measure of exposure meter for camera.

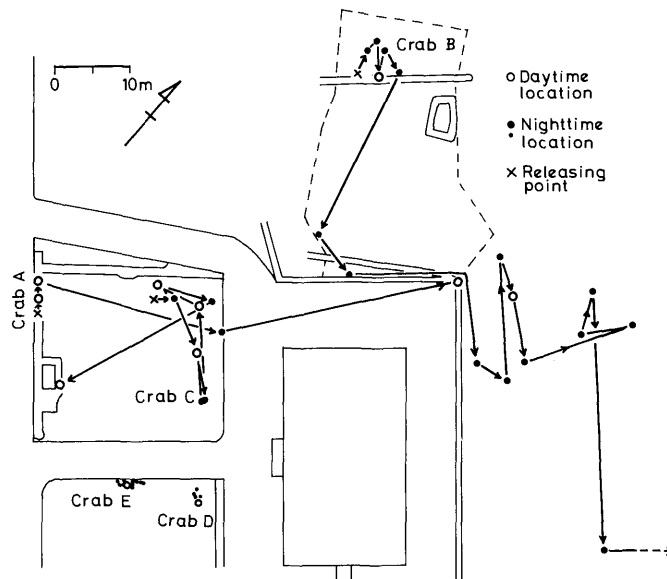


Fig. 4. Tracks of the radio-tagged crabs and locations of the marked crabs observed at an hour interval.

The crab C (female) was captured and released in the night of July 15th and was tracked for 5 days from 15 to 20th. This crab moved in the relatively confined area of 16×8 m for 4 days, and moved to a point about 20 m from the previous area in the rainy night of 19/20th as the crab A and B did.

The crabs D and E (both were male) were marked by plastic tape and released on 15/16th night. The locations of these crabs were observed and mapped also at an hour interval for 5 days (Fig.4). They moved only within confined area around their burrows, about 2×1 m for the crab D and about 3×1 m for the crab E.

Two quite different patterns of movement were recognized for the radio-crabs and marked crabs; one is short distance movement seen in the case of the crabs C, D and E, and the other is long distance or migratory movement seen for the crabs A, B and C. The crab C moved around relatively wider area than the crabs D and E. The burrow of the former individual changed three times within five days, while the latter two did not.

4) Active time duration of a crab in a day

The length of active time in a day was measured for three radio-crabs and is shown in Table 1. Activity pattern for the three individuals is also shown in Fig.5, in which two different patterns of movement are indicated. Average daily value for three individuals was least (0.29 hr) in 17/18th night and longest (3.77 hr) in 19/20th night, a rainy day, being similar trend with the case of

Table 1. Active time duration of the radio-tagged crabs and the frequency of appearance of marked ones observed at one hour interval. Figures in parentheses are the estimated active time duration for each day.

Crab	Sex	Date			Mean	
		15/16th	17/18th	July, 1977 19/20th		
Radio- tagged	A	male	0.17 hr	0.00 hr	5.58 hr	1.92 hr
	B	male	5.00	missed	missed	5.00
	C	female	3.00	0.58	1.95	1.84
	Mean		2.72	0.29	3.77	2.33 hr
Marked	D	male	1(0.77hr)	0(0.00hr)	3(2.31hr)	1.3(1.00hr)
	E	male	3(2.31)	2(1.54)	7(5.39)	4.0(3.08)
	Mean		2.0(1.54)	1.0(0.77)	5.0(3.85)	2.7(2.08hr)
	Mean		2.25 hr	0.53 hr	3.81 hr	2.20 hr

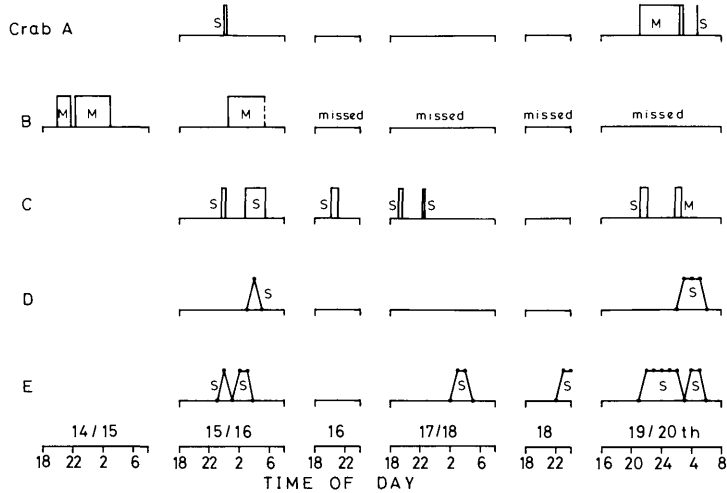


Fig. 5. Daily activity pattern of the radio-tagged (crab A, B and C) and marked crabs (D and E). S, short distance movement; M, migratory movement. Time not indicated by S or M shows resting in the burrow.

number of active crabs shown in Fig.3 a, b. All average was 2.33 hours per crab in a day.

Frequency of appearance of two marked crabs (crab D and E) observed every an hour is also shown in Table 1 and Fig.5. But active time duration of these crabs were not known, then the relationship between the active time duration and the frequency of appearance counted at an hour interval for each radio-crab was obtained at first and the result is shown in Table 2 ; 0.77 hour per appearance for short distance movement and 0.99 hour for migratory movement. Pattern of move-

Table 2. Estimates of actual length of active time per appearance for the marked crabs from the data of the radio-tagged crabs.

Short distance movement		Migratory movement	
No. of appearance	Active time duration (hr)	No. of appearance	Active time duration (hr)
1	0.17	5	5.23
3	2.70	2	1.90
1	1.25	5	4.75
1	0.25	5	5.00
1	1.03	1	0.92
0.77hr/app.		0.99hr/app.	

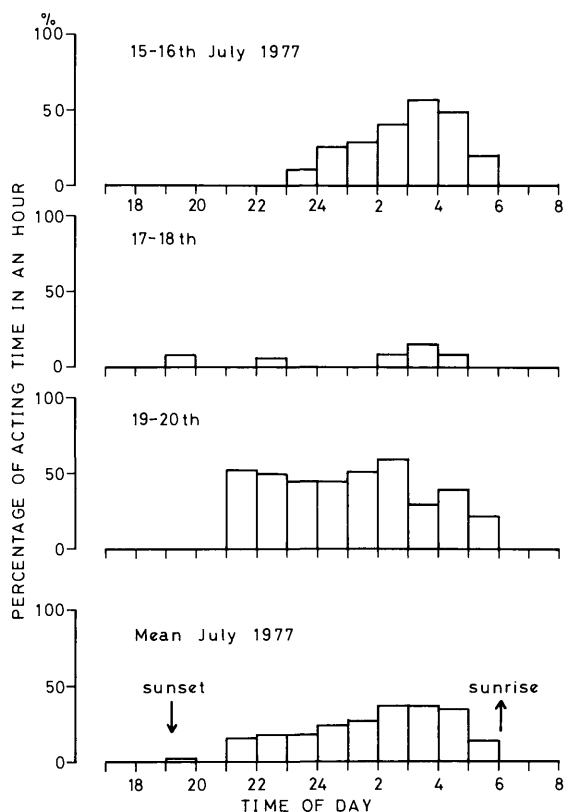


Fig. 6. Percentage of acting time in each hour calculated for the radio-tagged and marked crabs.

ment for the two marked crabs was all short distance movement. Using a figure for short movement, active time duration of each marked crab was estimated from the frequency of appearance and the result is shown in parentheses in Table 1 which has a same trend of that of radio-tagged crabs, least (0.77 hr) in 17/18th night and longest (3.86 hr) in 19/20th night.

Although there are difference of movement pattern among individuals, it is apparent that the length of active duration in a day is more variable among days than among individuals (Table 1). Percentage of acting time in each hour of the radio-tagged and marked crabs was calculated for each day and the result is shown in Fig.6. The trend is similar with the case of number of active crabs. Mean percentage of acting time in each hour of all individuals for three days is also shown in Fig.6, and the length of active duration of a crab was calculated to be only 2.2 hours in a day (Table 1).

Discussion

It is difficult to study the activity of the animals which are nocturnal and inhabit in bush or forest where a clear line of sight is not available between observers and subjects, like the land crab in this study. Wolcott (1977) showed the circuit for the study of nocturnal animals, which produced a timed flashing light to overcome some of the limitation of radio-telemetry. However, radio-telemetry is seemed to be one of the most usefull methods to observe the activity of the land crab inhabiting in the forest as such the present case.

It has been reported by some authors that many land crabs are nocturnal (Bliss and Sprague,1958; Gifford,1962; Bliss,1968; Shokita,1971), but there has been no quantitative study to make clear the activity pattern of the land crab. It is evident from the present study that the land crab is primarily active at night; it is active for only 2.2 hours per crab in a day on an average. Although this value is not compared with other species of the land crabs, the data of the activity of a semi-terrestrial sesarmid crab, *Sesarma (Holometopus) dehaani*, is available for comparison. Active time of the land crab is much less than that of *S. (H.) dehaani*. This species was out of the burrow for about 12.3 hours in a day in summer at the river-bank where no tidal influence is observed (Goshima et al.,1978).

The influence of some environmental factors to the daily activity pattern of the land crab is examined. As the habitat is completely terrestrial one, no direct influence of tidal rhythm is expected. There is no relationship between the daily activity pattern and tidal rhythm. Light is one of the major factors which determined the time of activity of the land crab, being primarily nocturnal. Intensive solar illumination may rise the rate of evaporation from the crab's body. Many burrows of the land crab distributing around the roots of trees also suggests their avoidance of exposing to the direct rays of the sun. Similar distributional pattern of the burrows of *Cardisoma carnifex* has shown by Hogue and Bright (1971). Moisture in the air also affects the activity of the land crab. Although the maximum numbers of the active crabs were almost same for both 15/16th and 17/18th nights, but the total number of them in 15/16th night (28) was more abundant than that in 17/18th night (14). Mean active time duration of individual was also much longer on 15/16th than that of 17/18th night. This phenomenon may be attributed to the effect of relative humidity. Mean relative humidity of night time of 15/16th was about 95 % and that of 17/18th night was about 88 %. Relative humidity may be related with the rate of water loss of crabs.

The influence of rain was most striking. That is revealed by increasing the activity of the land crab during rainy day of 19/20th even daylight hours in spite of being lower humidity than that of 15/16th night. Same phenomenon has been reported for the other land crab, *C. guanhumi*, by Bliss (1968). Thus the inten-

sive light of the sun and lower moisture in the air and soil are major factors decreasing the activity of the land crab in summer. In other words, their activities are restricted to those times of relatively low rates of evaporation, during night and/or times of rainfall.

Considering these results together with their reproductive habits in which they must go down to the seashore for spawning (Gifford, 1962; Shokita, 1971), the land crabs are seemed to be less successful on land than the terrestrial isopods and amphipods those can live and breed entirely on land.

Details of the activity, e.g. walking, resting and feeding time, were not revealed for the land crab in the present. There has been remained a doubt whether food consumption of the land crab is sufficient in short active time. However, it was frequently observed that the land crab took a dead leaf of trees to its burrow. As it was one of its food items, there is a possibility that the land crab feeds in the burrow. Hogue and Bright (1971) observed that the burrows of the other land crab which is the same genus, *C. carmifex*, were filled at the bottom with an accumulation of silt and organic matter undergoing active decomposition. This decomposing material may be rest of food brought into the burrow by the land crab. If the land crab feeds in the burrow, limited active time duration of them may be covered by collecting of supplementary food materials.

Two different patterns of movement were recognized for the land crab. The degree of residentiality of the land crab is considered as follows. The land crab inhabits in the relatively confined area for a few days, in which it does not always use a definite burrow as the shelter, sometimes use a few burrows. The pattern of short distance movement is seen in that period. After a few days, it moves long distance to search a suitable burrow and/or habitat and again inhabits in the relatively confined area. Migratory movement is the case of this long distance movement and it is accelerated in those times of relatively low rates of evaporation; times of rainfall.

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Summary

1. Daily activity and movement of the land crab, *Cardisoma hirtipes*, was revealed by the radio-telemetry at Kuroshima Islet, Okinawa, Japan during non-breeding season.

2. It is ascertained that the land crab is primarily active at night, and its activity was increased to those times of relatively low rates of evaporation, during night and/or times of rainfall.

3. Active time duration of a crab was estimated to be only 2.2 hours in a day. This value was much less than that of a semi-terrestrial sesamid crab.

4. Two quite different patterns of movement were recognized; short distance movement and migratory movement. The degree of the residentiality of the land crab was discussed in relation to the pattern of movement.

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