La mer 34, 11-17, 1996
Société franco-japonaise d'océanographie, Tokyo

Automatic recording system of the position of a lobster in experimental tank

Takashi KOIKE*, Miyuki MAEGAWA*, Masako HIRAYAMA* and Yutaka NAGATA*

Abstract: In order to trace the movement of the spiny lobster, an automatic recording system of the position of the lobster was designed and applied in our experimental tank. The upper part of the lobster cage is supported with a triangle frame. A pointed supporting bar is set at each corner of the frame, and is placed on an electronic balance. The measured weights of the cage at three corners are fed to a personal computer, and the position of the lobster is automatically calculated and recorded for every 2.7 sec. The accuracy of the position determination is less than 0.9 cm. Several results of the preliminary experiments are also introduced. The recording system is very useful to trace the lobster, especially in the nighttime when we cannot see its movements by eyes.

1. Introduction

Spiny lobsters have nocturnal habit. KOIKE *et al.* (1993, 1995 and 1996) observed moving activities of Japanese spiny lobster, *Panulirus japonicus*, in an experimental tank, and found that it scarcely moves when underwater brightness is higher than 5.2×10^{-3} *lx* and that it moves actively when brightness is lower than 2.3×10^{-5} *lx*. In these experiments, the lobster was kept in the relatively small rectangular cage which is hung by three wires. We measured variation of the tension of one of three wires, and obtained a measure of lobster activity by counting occurrence frequency of significant tension changes. The lobster movement in the traverse direction, however, would not be detected in this simple system, and the exact moving distance or the moving speed of the lobster cannot be observed. In order to measure the position of the lobster on two dimensional plane, we improved the recording system by measuring tensions of all three supporting points of the lobster cage. The new system works successfully enough to detect two dimensional movements of the lobster. The recording system is introduced with several preliminary experimental results in this paper.

* Faculty of Bioresources, Mie University, Kamihama-cho 1515, Tsu, Mie 514, Japan

2. Constitution of the recording system

A cylindrical plastic tank of 100 cm diameter and of 80 cm depth is used, and the lobster is kept in a cylindrical cage of 80 cm diameter and of 40 cm depth. The cage is made by plastic net of 0.3 cm mesh size which is put on an aluminum frame work. The upper part of the cage is supported by a triangle frame made of aluminum angles as shown in Fig. 1. A pointed supporting bar is set downward from each corner of the triangle frame, and is placed on electronic balance. Each electronic balance (A&D Co., EWA/B) is set on a small tabel, the surface of which is carefully adjusted to be horizontal and to have the same level as the other tables. The electronic balances has zero adustments, and their outputs are set to be zero at the beginning of each experimental run.

The experimental tank is set in a large dark box in a dark room of the main building of the Faculty of Bioresources of the Mie University. The sea water used is collected in the sea off Kumano-nada by R/V *Seisui-maru* or off the Fisheries Research Laboratory of the Mie University located on Zaga Island in Ago Bay of

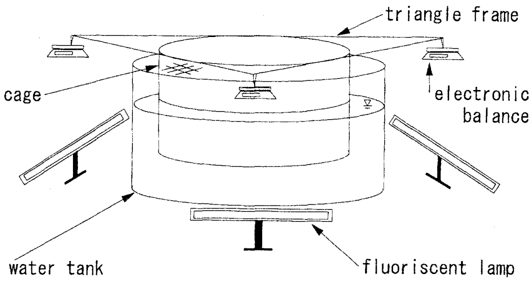

Fig. 1. Schematic view of the experimental apparatus.

the Mie Prefecture. To keep the water fresh, the water is supplied to the tank through two filter tanks filled with ceramic filtering grain and coral sands. The water is supplied through a sub-tank where the water is overflowing so as that the pressure head and so the supply rate of the water is kept to be constant (about 9 l/min.). Multiple intakes and drains are applied in order to minimize flows in fixed direction in the experimental tank. Three intakes is set near the bottom, and two drains near the water surface and two drains near the bottom. The water in the tank is lost by evaporation at the rate of about 2 l per day, and the tap water which has been kept in the room for several days is supplied every two days.

Three fluorescent lamps are used as light sources as shown in Fig 1. The lamps are set at the level significantly lower than the tank surface, and only the reflected lights are allowed to penetrate into the tank. All of the instruments are painted with frost black paint. The measured brightness distribution on the level of the water surface is shown in Fig. 2. The shadow of the side wall of the tank appears to exist, and the brightness near the edge is a little lower than that at the center. The lamps are put on at 7:00 and off at 19:00 every day, and the bright daytime of 12 hours and the dark nighttime of 12 hours produced.

The output of the three electronic balances are lead to a personal computer (PC 9801 F) through RC232C cable, and the lobster position is calculated for every 2.7 sec and recorded in floppy disks. The movement of the lobster is also displayed and monitored on a Braun tube.

The lobsters used in our experiment were caught in the sea off Wagu of the Shima

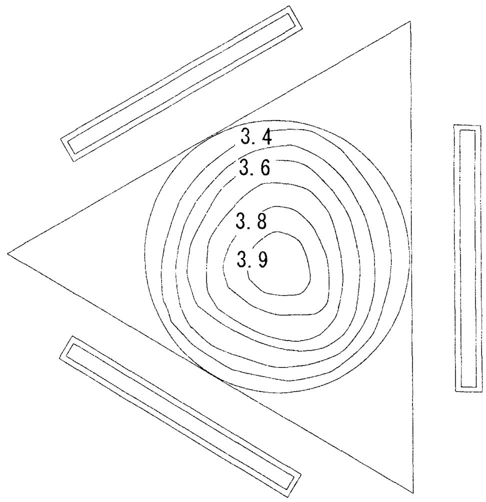

Fig. 2. An example of the measured distribution of the brightness in *lx* on the level of water surfacet.

Peninsula, Mie Prefecture. The lobsters were put in the experimental cage a few days after their catch, but they can be used usually longer than one year. Only male lobsters of medium size (carapace length from 7.0 to 8.5cm and weight from 250 to 350 *gw*) are used as large lobsters are often not so active. The activity of female lobsters appears to be changed in their spawning season. The lobsters in the tank are fed with one living mussel *Mytilus edulis* having the weight from 3.0 to 5.0 *gw* once a day in daytime. The shell of the mussel is partly broken so as the lobster can easily eat it.

3. The determination of the lobster position and its accuracy

We take the positions of the edges of the triangle support or the measuring positions of the weight to be A(0,0), B(e,f), and C($e, -f$), and the position of the center of gravity of the lobster G(m, n) as shown in Fig. 3. We denote the measured weights at A with a, at B with b and C with c, respectively. If we adjust the outputs of the three electronic balances to be zero before the lobster is put into the cage. We have the relations:

$$m = (b+c)\,e/(a+c),$$
$$n = (b-c)\,f/(a+c).$$

e and f can be represented by the side length of the triangle L (=138.5cm) or by the semi-

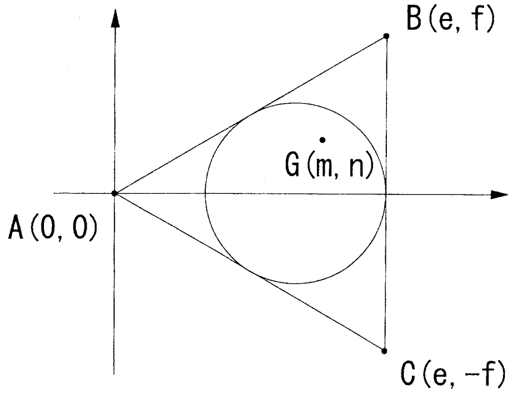

Fig. 3. Coordinate system used in the calculation of the lobster position G (m, n). A, B and C denote three positions where the weight of the cage is measured. See details for the text.

diameter of the cage r (=40cm):

$e=(3^{1/2}/2)\ L=3r,$

$f=(1/2)\ L=3^{1/2}r.$

If we take the origin of the coodinate at the center of the cage(or the center of the gravity of the triangle), and if we denote $a+b+c$ with the weight M of the lobster in the water, the position (x, y) of the lobster in the new coordinate system is

$x=3r\ (b+c)/M-2r=(b+c-2a)\ r/M$

$y=3^{1/2}r\ (b-c)/M.$

The measurable range of the electronic balances used is 300 *gw* in full scale and their precision is 0.1 *gw*. If one of the measured weight has an error of E, the resulted error of the lobster position would be rE/M in the x-direction and $3^{1/2}\ rE/M$ in the y-direction. If we take $E=0.1$ *gw*, M=25 *gw* and $r=40$ cm, the errors in the x-and y-directions are 0.16 cm and 0.28 cm, respectively. The total error resulted from three weight measurements would be 3 times of these estimation in maximum. We may evaluate the error, however, to be about 2 times as one of the measurements is not independent from other two, as the weight of the lobster M is constant for each experiment. We checked the errors in the position determination by placing a lead weight of 25 *gw* at various points on the bottom of the cage. The obtained error is smaller than 0.9 cm, and the measurement is accurate enough judging from the size of the lobster (carapace length from 7.0 to 8.5 cm).

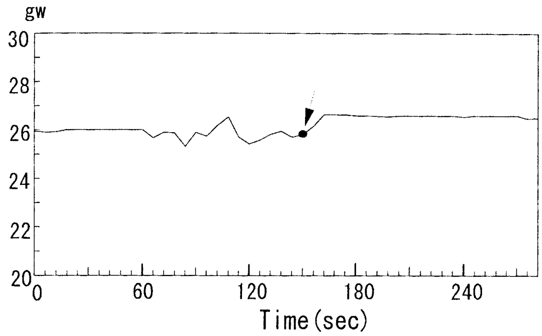

Fig. 4. An example of the change of the total weight (in *gw*) during the feeding operation. Black circle indicate the time when we put a mussel into the tank. The time is taken in abscissa.

Error of the measurement may be caused by feeding processs. In Fig. 4, the variation of the total weight M when we put a mussel of 4.8 *gw* (in air) in the vicinity of the center of the cage. Some irregular variation was observed during the feeding operation as we inevitably touched the cage, though no movement was recognized in that time. The weight was increased by 0.34 *gw* due to the added mussel weight. However, the error of the lobster position caused is only 0.58 cm. So, we did not make any correction during each experimental run.

4. Several preliminary results

4-1. Moving speed of the lobster

A male lobster of 8.1cm carapace length and of 285 *gw* weight (27.0 *gw* in water) is used in the preliminary experiment to test our automatic recording system of lobster position. We set 12 hours bright period of 3.4-3.9 *lx* brightness (daytime) and 12 hours dark period of 0 *lx* brightness (nighttime) on each day, respectively. The experiment was made for 6 weeks from January 5 to February 15, 1995.

An example of the moving trajectory of the lobster is shown in Fig. 5. Though the lobster usually stays near the cage wall and moves around the circular cage, this example shows a movement to reach the mussel place at the center of the cage. The lobster left its usual moving path rounding the cage, and approached to the mussel. The lobster stayed for a while at the center of the cage, and then the lobster carried the mussel near to the wall. Therefafter,

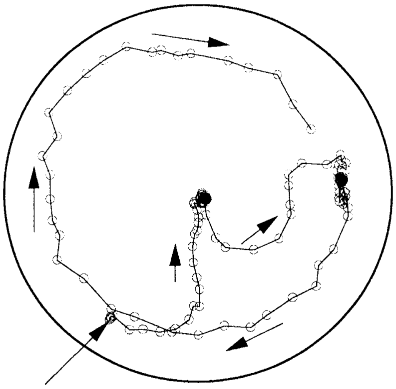

Fig. 5. An example of the moving path of the lobster. The trajectory is shown for the period from 22:41 to 22:50 on February 15, 1995. Though the lobster moves usually clockwise along the cage wall, the lobster appears to find the mussel placed at the center of the cage, and approached to carry it to the vicinity of the cage wall. The positions determined for every 2.7 sec are shown with white circles. The moving direction is shown with arrows.

the lobster started again to move clockwise along the cage wall. The lobster never approaches to the mussel in daytime, and the movement shown here is firstly recorded by the new recording system. This example also shows that the adopted interval of the position determination (2.7 sec) is frequent enough to trace the lobster position even in nighttime when the lobster moves actively.

The moving speed of the lobster averaged over this experiment is 0.64 cm/s. The lobster moves much actively in nighttime with averaged speed of 1.15 cm/s, while the averaged speed in daytime is only 0.12 cm/s. The moving distance for each day ranges from 172m to 1484 m, and its average value is 549m (52m in daytime and 497m in nighttime). In our previous exeriment (KOIKE *et al.*, 1995), they traced a lobster with a small red luminous diode on its back in the shaded outdoor pool for 24 hours. The averaged moving speed of the lobster was 200.5m/h (66.8 cm/s) in nighttime (0 *lx*) and was 12.3 m/h (4.1 cm/s) in daytime (4.6×10^2 *lx*). The moving deistance of a tagged Japanese spiny lobster was estimated as about 1,800 m/day by TAKAGI (1972) in the sea south of the Boso Peninsula, and that of New Zealand spiny lobster, *Jasus edwardsii*, as 5,000–7,000 m/day by HERRNKIND (1980). The influence of the environmental conditions on the moving speed has not clarified yet, but our results appear to coincide with these previous works.

4-2. Diurnal variation pattern of spiny lobster

The variation of the moving distance for each hour is shown in Fig. 6. The diurnal variation of the lobster movements, active in nighttime and almost rest in daytime, is clearly seen in this figure. This figure shows that the lobster does not move continuously all night through, and the variation pattern of the nighttime movement is very changeable day by day. The nighttime activity patterns found in the previous papers, however, appears to keep nearly constant high level in nighttime, and do not exhibit such day-by-day variations as shown in the figure. The moving distance is adopted here as an indicator of the lobster activity, while the frequency of the lobster movement in the longitudinal direction larger than a prescribed value is used in the previous paper. The new system may describe much more detailed nature of the lobster movements, which was not resolved in the simple old system. Also, the differences in the cage size and cage shape, and in the lightening system which may influence the experimental results. The further investigations are needed to clarify the difference of the variation pattern discussed above.

However, the basic nature of the diurnal variation pattern measured in the new system is just same as that measured in the old system. The averaged diurnal variation pattern of the moving distance (Fig. 7) is very similar to that of the activity frequency discussed in the previous papers (KOIKE *et al.*, 1995 and 1996): the lobster starts to move actively at 19.00 just after the lights are put off. The sharp change from the inactive phase to the active phase is always observed exactly in phase with the brightness variation, while the shift from the active phase to the inactive phase does not occur exactly in phase with the brightness change. The pahse relation of the shift from active phase to inactive phase to the time when the lights are on appears to be changed lobster

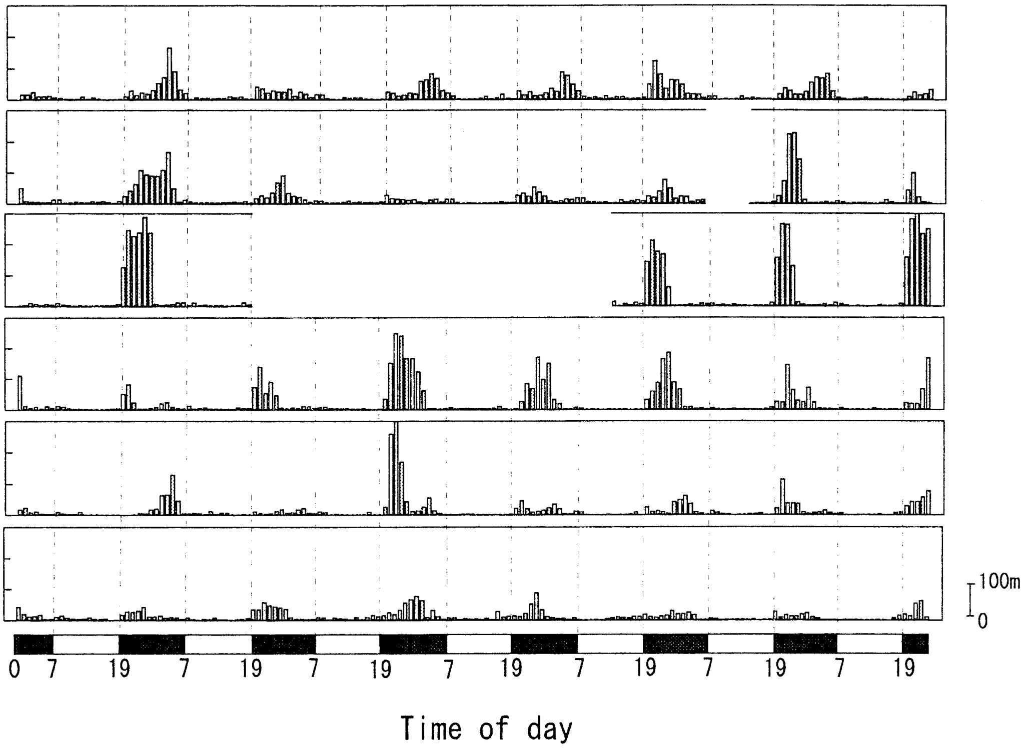

Fig. 6. Temporal variation of the moving distance per hour of the lobster during the experimental period of 6 weeks from January 5 to February 15, 1995. The variation is shown separately for each week, and the segments are aligned from top to bottom. The measurements were interrupted for about 8 hours on January 17 due to shock of the Hanshin Large Earthquake and from January 20 to is shown in the bottom of the figure, and the black bar and white bar indicate the nighttime and daytime, respectively. The scale of the moving distance is shown at the right-down corner of the figure.

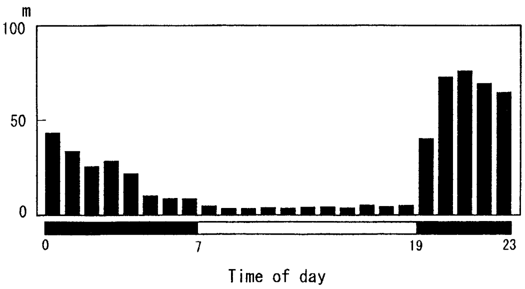

Fig. 7. The diurnal variation of the moving distance per hour averaged over the experimental period. The moving distance in m is taken in ordinate. The time of day is taken in abscissa, and the night time and daytime are shown with black bar and white bar, respectively.

by lobster. The figure indicates that the activity in the first half of the nighttime tends to be higher than in the second half of the nighttime. Similar tendency is also seen in some of the variation patterns in the previous experiments (KOIKE *et al.*, 1995 and 1996). These similarities suggest that the simple measuring system is effective enough if we discuss only the diurnal variation pattern of the lobster activity.

4-3. Preferable position of the lobster in the cage

An example of the nighttime moving trajectory for one hour is shown in Fig. 8. The lobster usually moves around along the wall, but occasionally leaves the side wall and crosses the interior of the cage. The moving speed of the lobster is faster in crossing the central part than in rounding along the wall, except when it found the mussel there.

In order to clarify the preferable position of the lobster in the cage, we set 24 sub-domains having the same area as shown in Fig. 9. The

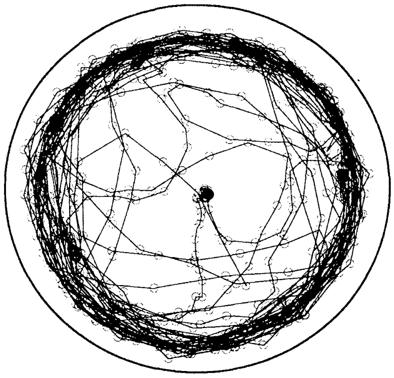

Fig. 8. Same as in Fig. 5 except for the period from 22 : 00 to 23 : 00 on February 15.

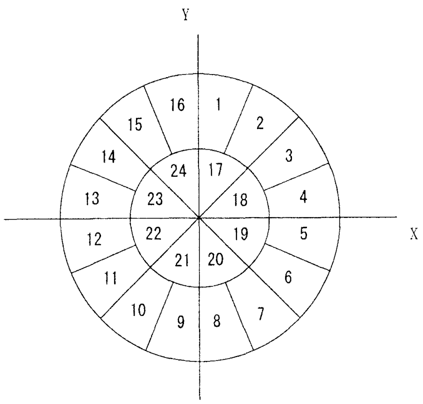

Fig. 9. Sub-domains where the residence frequencies of the lobster are obtained.

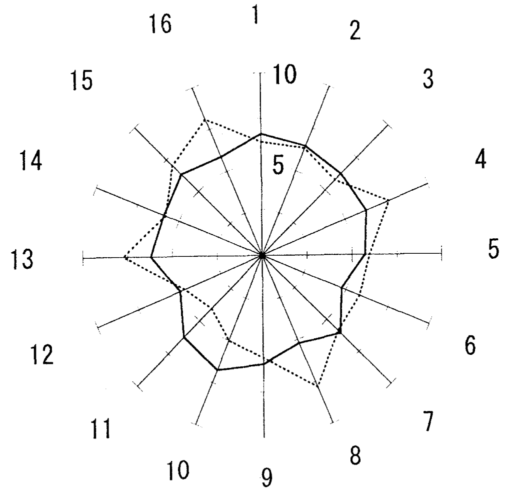

Fig. 10. Residence frequency in % each outer sub-domain from domain 1 to domain 16. The domain numbers are shown outer rim of the figure (see Fig. 9 for positions of the sub-domains). Frequencies are calculated for nighttime (the full line) and for daytime (dotted line), separately. Note that the total frequencies shown in this figure is not 100 % : they would become 100% if we add the frequencies shown in Fig. 11, respectively.

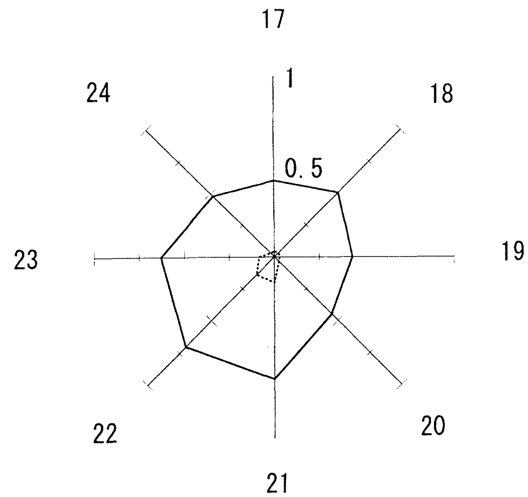

Fig. 11. Same as in Fig. 10 expect in each inner sub-domain from domain 17 to domain 24. Note that the furequency scale is much expanded in comparison with Fig. 10.

frequency in % that the lobster stays in each subdomain is calculated and are shown in Fig. 10 and 11. It is clear that the lobster selects rather to stay in the vicinity of the cage wall. The frequency distributions both in the outer sub-domains and in the inner sub-domains are almost symmetrical, indicating that our apparatus including the lightening system is arranged symmetrical enough.

5. Concluding remarks

By supporting the lobster cage with a triangle frame and by measuring the weights at its three corners, the automatic recording system of the lobster movement is designed and adopted in our experimental tank. The preliminary experiments showed that the system is accurate enough to observe the detailed lobster movements, and showed that it is very useful to trace the lobster especially under a pitch dark condition when the lobster movement is not visual.

This automatic recording system would be applicable also to observe the other benthic animals, such as clawed lobster, shrimps and various kinds of crabs in the experimental tanks.

Acknowledgements

The authors wish to thank the staffs of the Fisheries Research Laboratory of the Mie University for their kind supports. This research was supported in part by a Grant-in-aid for Scientific Research from the Ministry of Education, Sceience and Culture of Japan, and by Kakushin Foundation of Research and Education.

References

HERRNKIND, W.F. (1980) : Spiny lobsters : Patterns of movement, in The Biology and Management of Lobsters I (ed. by J. Stanley Cobb and Bruce F. Phillips), Academic Press, New York, 349–407.

KOIKE, T., Y. MORIKAWA, M. MAEGAWA, and T. MORINAGA (1993) : Effects of underwater brightness on Japanese spiny lobster behavior during nighttime scotophase. Nippon Suisan Gakkaishi, 59, 1689–1694. (in Japanese)

KOIKE, T., Y. MORIKAWA, M. MAEGAWA (1995) : Underwater brightness in nighttime and behaviors of Japanese spiny lobsters. La mer, 33, 107–117.

KOIKE, T., K. HAYASHI, and Y. NAGATA (1996) : Minimum daytime brightness recognized by Japanese spiny lobsters. La mer, (in press).

TAKAGI, K. (1972) : Migration of the tagged spiny lobster, *Panulirus japonicus*, on the southern Boso Peninsula, Chiba Prefecture: A continuous experiment, 1951-1968. La mer, 10, 95–110.

Received May 19, 1995
Accepted December 14, 1995