鹿児島大学理学部紀要（地学・生物学）
No.29, 151-161, 1996

Crawling of the whelk *Neptunea arthritica* on different substrata

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(Received September 10, 1996)

Abstract

Aquarium studies on the crawling behaviour of whelks on different substrata were carried out in a tank with continuous flow of fresh sea water.

It was observed that smaller sized whelks got bogged in between the larger mesh size netting materials. In case of other substrates like sand, concrete, gravel and acryl, whelks tend to move faster on gravel surfaces. Their movement on acryl surfaces was slower than sand, concrete and gravel surfaces.

Key words: Whelks, crawl, substrate, stimulant

Introduction

Whelks crawl using a single appendage, the foot, and the power of locomotion is typically provided by series of muscular waves on the foot's ventral surface[1,2)] These movements are coupled to the substratum by a layer of pedal mucus which allows the animal to adhere to the substratum. There are two consecutive disadvantages (i) the adhesiveness of the mucus must be overcome for the animal to move, and (ii) mucus must be produced to replace that expended during locomotion. Whelks can control the viscosity of the mucous according to the type of material and temperature. Locomotory waves have been described in detail by Jones[3].

It was observed from this experiment that the crawling speed of whelk on acryl surface was the lowest because more mucus was needed.

Materials and methods

Whelks of shell length ranging from 34.5mm to 93.4mm were used for this purpose and were fed with frozen mussels during this period. Prior to the experiment, whelks were

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starved for 2 days to minimize variability due to different levels of food consumption. During testing, whelks were kept separately in 100cm×60cm tank with continuous flow of sea water. All the experiments were carried out at water temperature of 15℃ to 20℃.

A fibre glass tank of 180cm×90cm×50cm was used for carrying out experiments on crawling of whelks on various materials. The experimental setup is shown in Fig. 1. For crawling experiments a 5cm×5cm grid was made on an acryl board measuring 89cm×43cm was used as a mark index to calculate the actual crawling distance of whelks on different substrate and netting materials of different mesh size.

Ten different materials were used to study the crawling speed of whelks. The details of the materials used is shown in Table 1. Also sand, gravel, and concrete surfaces were used. The sand particle diameter used was same as that of burrowing and resurfacing experiments[1]. The gravel size used was sieved in mesh "c" and later in mesh "e". The size retained was used for crawling experiment. Also a concrete slab measuring 88cm×42cm was used for crawling of whelks. This concrete slab was soaked in sea water for three weeks to eliminate the chemical effects and other odour from the slab.

Before the whelks were released into the racing track, the grid was kept above the substrate and recording was done for five minutes. The grid was read into the computer to facilitate recording of whelks' position. The position of all whelks in the test area were recorded immediately following the placement on the substrate and a recording was made of individual on a log sheet with the number shown on their shell.

Visual observations and video recording of whelk crawling were used to ascertain the crawling speed of whelks. Whelks were allowed to crawl on a sheet of acryl etched on with a 5cm×5cm grid. This also enabled observations to be made on the situation at the commencement of locomotion. The camera field covered the distance 5cm away from the release point of the track. When the whelks were actively crawling, the numbers for identification were taken note of to avoid confusion in recording of shell length. Frozen mussels were enclosed in polyvinyl netting container kept at the exit of the water jet. The whelks kept in

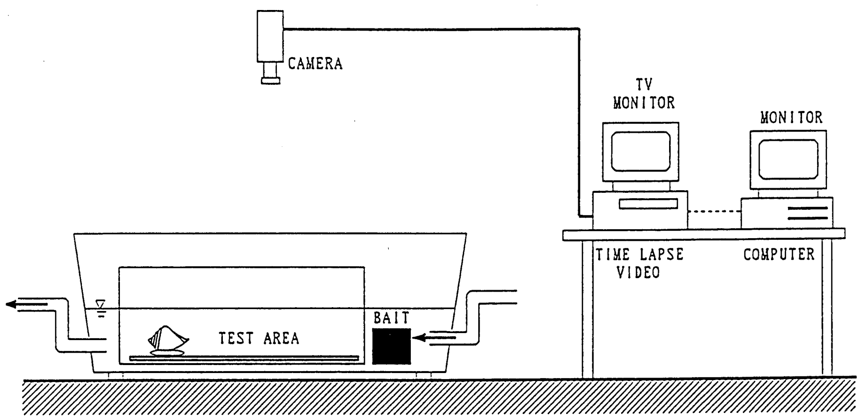

Fig. 1 Schematic diagram of experimental setup for recording the crawling of whelks

Table 1. Netting materials used for crawling of whelks in the laboratory with continuous flow of sea water.

Material Identity	Mesh size 2 ℓ (mm)	Mesh diameter (mm)	Remarks
a	44.5	1.68	Polyester knotless netting (straight type)
b	33.5	1.68	Polyester knotless netting (straight type)
c	34.0	1.34	Polyester knotless netting (rachel type)
d	20.0	0.35	2 ply polyamide netting (weaver's knot)
e	18.5	1.68	Polyester knotless netting (straight type)
f	10.0	0.55	2 ply polyamide netting (weaver's knot)
g	22.0mm×22.0mm		Polyethylene material had 8mm mesh thickness.
h	1.0mm×3.0mm (trap B)	—	Polyethylene material had 3mm high humps in between
i	2.1mm×2.1mm	—	Polyamide minnow net (regular size 44-240. 210 denier)
j	5.0mm×5.0mm	—	Polyethylene material (black)
k	—	—	Acryl (smooth white surface)

the isolated storage tank were then transferred to the experimental tank and kept on the race track.

For each set of experiment six whelks were kept on the down current of the race track and continuous recording was done until the whelks crawled to the bait end. The whelks which came close to each other were eliminated from this data. Each experiment was run for a maximum of 2 hours or was stopped when the whelks reached the bait end of the track separating from the race track. The equipment used for recording the crawling of whelks was same as that of burrowing and resurfacing experiments. The video camera, however, was kept vertically above the race track at a distance of 240cm.

The crawling distance was read at every 30 seconds interval in the computer. Initially three positions on the whelk ie the apex, siphon and the highest summit of shell, were marked by a dot in white or black indelible paint. These positions were marked by keeping the whelk with its opercular side facing a flat surface.

Results

A reading taken for three different sized whelks is shown in Fig. 2. The moving position was same and there was a zig zag movement of the shell, so only the summit position for rest of the whelks was read in the computer for recording their crawling distance and for calculation of their crawling speed.

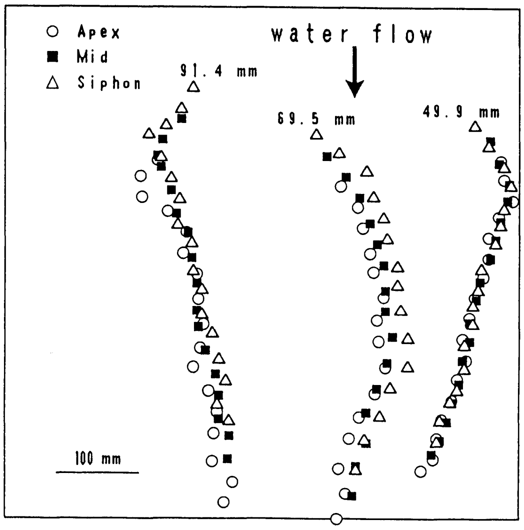

Fig. 2 An illustration showing the zig-zag movement of whelks on acryl surface

The crawling speed was calculated as described in Fig. 3. P_0 is the initial point taken when the whelks crawled towards the order plume on the race track. At every 30 seconds the position of whelk was taken as $p_1(x_0, y_0)$, $P_2(x_1, y_1)$, $P_3(x_2, y_2)$, $P_4(x_3, y_3)$ and the last position was taken as $P_n(x_n, y_n)$.

The distance between P_0 to P_1 was taken as r_1, P_1 to P_2 as r_2 and P_n as $(r_n\text{-}1)$

The total distance travelled by a whelk was:

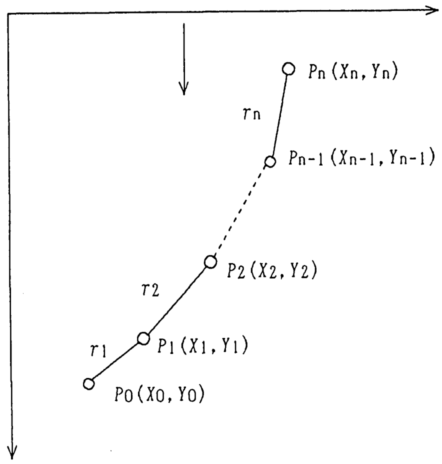

Fig. 3 Illustration of calculation method for the crawling speed of whelk

$$Total\ distance = r_1 + r_2 + r_3 + \cdots\cdots r_n \quad \cdots\cdots (1-1)$$

Distance travelled was:

$$r_k = \sqrt{(X_k - X_{k-1})^2 + (Y_k - Y_{k-1})^2} \quad \cdots\cdots (1-2)$$

Moving distance covered "L" was:

$$L = \sum_{k-1}^{n} r_k \quad \cdots\cdots (1-3)$$

and the crawling speed was calculated as follows:

$$Crawling\ speed = \frac{L}{n\,\Delta t} \quad \cdots\cdots (1-4)$$

It was seen that whelks' crawl at constant speed on smooth surfaces and the zig zag, pauses, rotates and detours as they continue to move forward. This is shown in Fig. 2.

On occasions whelks were seen colliding with one another, but continued moving in the direction of the odour plume. These whelks were not accounted for in measuring their crawling speed.

The crawling speed in relation to shell length on various materials is shown in Fig. 4 to 8. The crawling speed changed with respect to sediment qualities, mesh size and different types of materials used. There was a linear relationship between shell length and crawling speed of whelks. The regression lines for the crawling speed on different materials is given in Table 2 which indicates that as the shell length increases in size the crawling speed

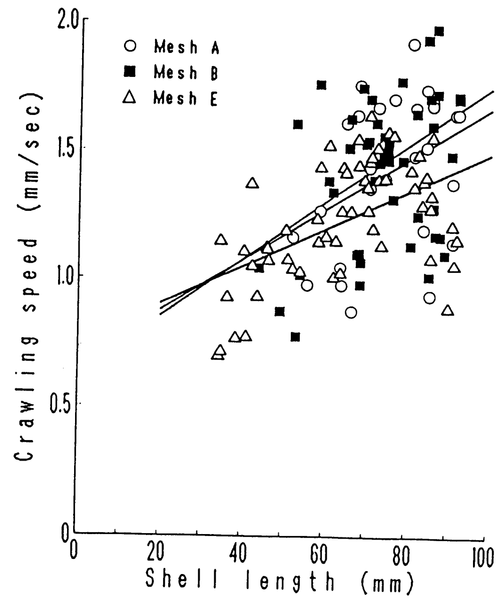

Fig. 4 Relationship between shell length and crawling speed of whelks on polyester knotless netting (straight type) having same twine diameter of 1.68mm

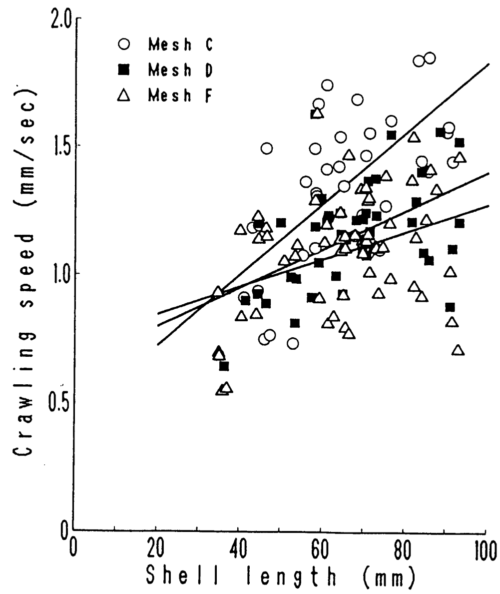

Fig. 5 Relationship between shell length and crawling speed of whelks on netting material of different mesh size

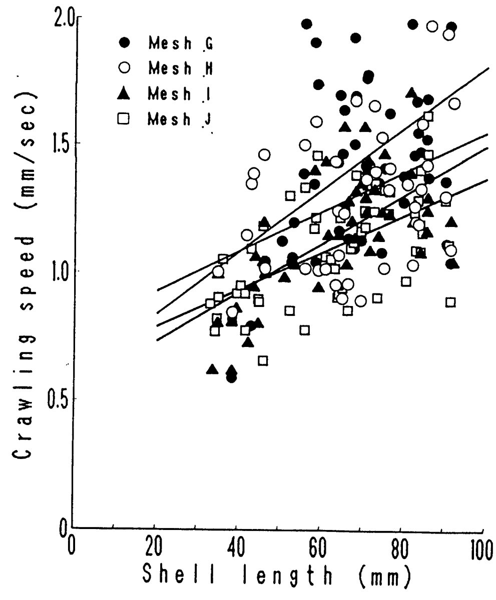

Fig. 6 Relationship between shell length and crawling speed of whelks on netting material of different mesh size.

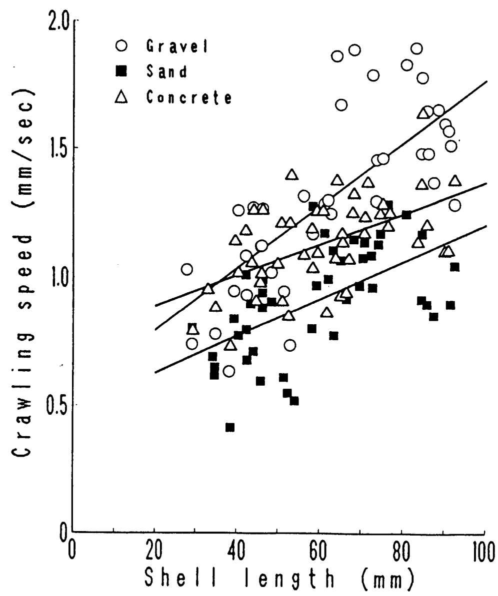

Fig. 7 Relationship between shell length and crawling speed of whelks on gravel, sand and concrete surface.

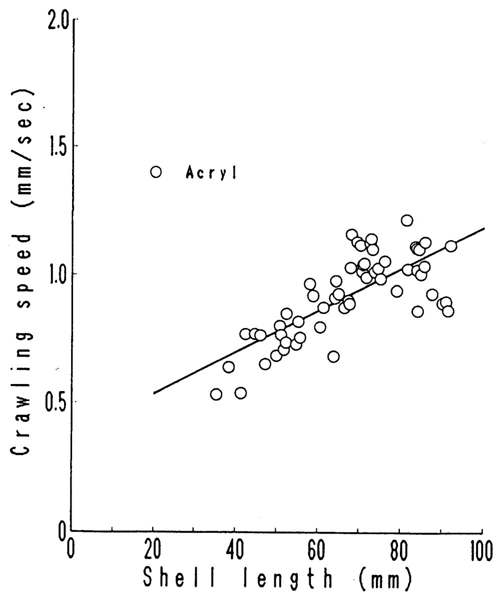

Fig. 8 Relationship between shell length and crawling speed of whelks on acryl surface

Table 2 Slope fitness line on crawling speed of whelks on various materials.

Substrate identity	slope	r^2
sand	$C_{sp} = 0.007 S_\ell + 0.48$	0.34
Gravel	$C_{sp} = 0.012 S_\ell + 0.55$	0.52
Concrete	$C_{sp} = 0.006 S_\ell + 0.76$	0.29
Acryl	$C_{sp} = 0.008 S_\ell + 0.37$	0.55
a	$C_{sp} = 0.010 S_\ell + 0.67$	0.15
b	$C_{sp} = 0.010 S_\ell + 0.63$	0.17
c	$C_{sp} = 0.014 S_\ell + 0.44$	0.39
d	$C_{sp} = 0.007 S_\ell + 0.64$	0.28
e	$C_{sp} = 0.007 S_\ell + 0.75$	0.29
f	$C_{sp} = 0.005 S_\ell + 0.74$	0.13
g	$C_{sp} = 0.012 S_\ell + 0.59$	0.22
h	$C_{sp} = 0.007 S_\ell + 0.77$	0.16
i	$C_{sp} = 0.009 S_\ell + 0.54$	0.43
j	$C_{sp} = 0.007 S_\ell + 0.64$	0.33

also increases.

Crawling behaviour on concrete, sand and gravel showed that whelks of shell length greater than 40mm crawled faster on gravel than on the other two substrates, whilst those with shell length less than 30mm found it difficult to proceed as far because of the particle size used in gravel. Compared to other materials used for crawling of whelks their speed was the slowest on acryl surface. On acryl surface more mucus was used and had greater friction when trying to move forward. As for other materials with variation in twine diameter and mesh size, no significant difference was seen. In larger mesh net of 4.45cm, whelks of less than 44mm shell length got bogged and could not move further. This result suggests that as the mesh size increases whelks find it difficult to control their balance and hence the locomotry speed is reduced. There wasn't much difference in the crawling speed of whelks on mesh a, b and c which had the same twine diameter.

DISCUSSION

From the crawling experiment on various substrate it was found that whelks bigger than 46mm got bogged in between the net mesh of 4.45cm with a 70% hanging ratio as shown in Fig. 9. Even those whelks with shell length of 58.1mm were seen losing their balance and had irregular movements. The area of the foot plays an important role in crawling and to verify this the foot area of different size of whelk were measured by taking photographs from the base of a glass aquarium with etched grids. The relationship between shell length and foot area is shown in Fig. 10 and the regression curve is expressed in the following

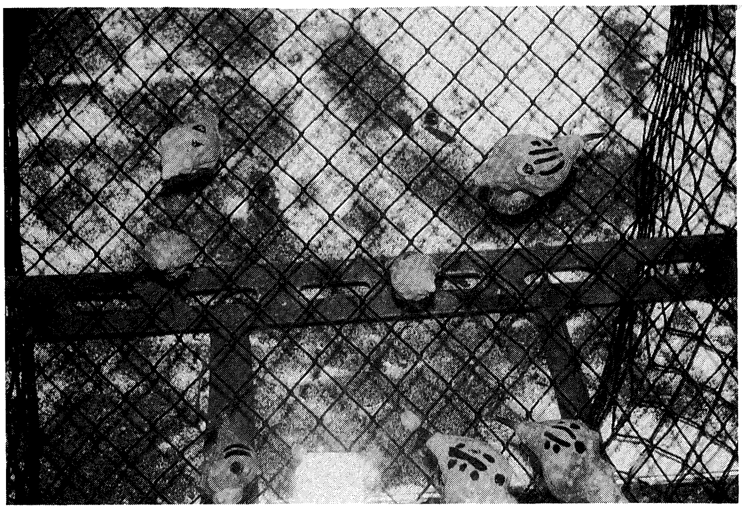

Fig. 9 A 40.0mm whelk as seen bogged in between the 44.5mm mesh net

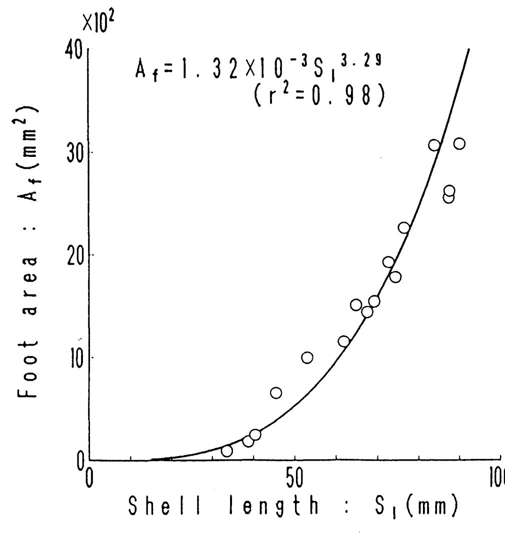

Fig. 10 Relationship between shell length and foot area of whelks

equation.

$$A_f = 1.36 + 10^{-3} S_1 \, 3.29 \quad \cdots\cdots\cdots\cdots (1-5)$$

Where A_f is the foot area in mm² and shell length in mm. Knowing the foot area of the whelk it would be possible to choose a mesh size that would be most appropriate. Broader foot may give more stability in crawling, and in burrowing, forming a more secure anchor in the sand to enable the shell to be drawn[4]

Previous workers, notably Lissmann[5,6], have shown that when crawling, pedal locomotory waves is being used. Each wave has a region of longitudinal compression that is lifted from the substrate and during the commencement of locomotion, a wave of longitudinal compression appears towards the front of the foot.

It was also seen that while crawling the younger ones had their shell well above the substrate and the whelks having shell length greater than 50mm tended to crawl close to the substrate. The area of mesh diameter plays an important role in crawling of whelks. One of the reasons for this phenomenon is that the shell part gets heavier and as the whelks grow larger in size they tend to crawl close to the base of the substrate. So while crawling on netting material they have to keep their shell well above the substrate to avoid the tangling of the siphonal notch. It was seen from this experiment that the crawling speed of whelk on acryl surface was the lowest because more mucus was needed. The crawling speed on different materials in relation to twine area of one mesh/foot area and crawling speed/shell length is shown in Fig. 11. Foot area is calculated by Eq. (1-5)

In this figure it is seen that there is a slight variation in crawling speed of whelks on different mesh sizes, however, a convex curve could be drawn. The maximum value of non-dimensional crawling speed was 0.10 of non-dimensional twine area of one mesh. From the results obtained from the crawling speed on various materials, it is possible to choose a mesh size most appropriate for covering the walls of the trap. The results show that using small mesh size reduces the crawling speed of whelks and it would be wise to avoid using small mesh size materials for catching whelks.

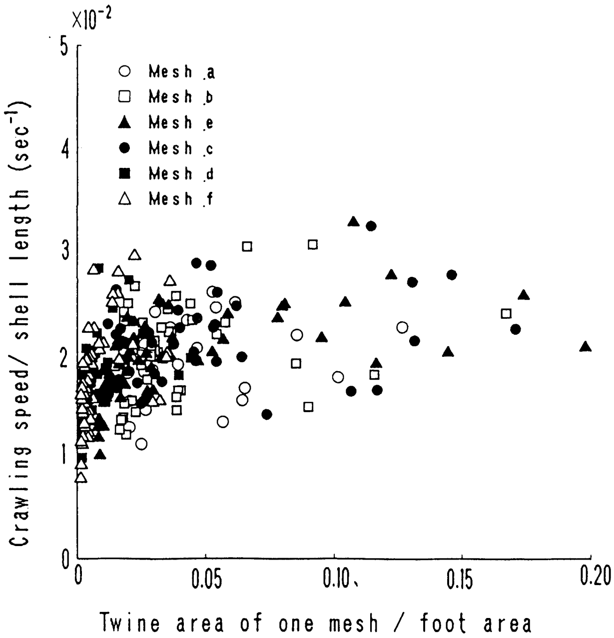

Fig. 11 Relationship between shell length and twine area of one mesh/foot area of whelk

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