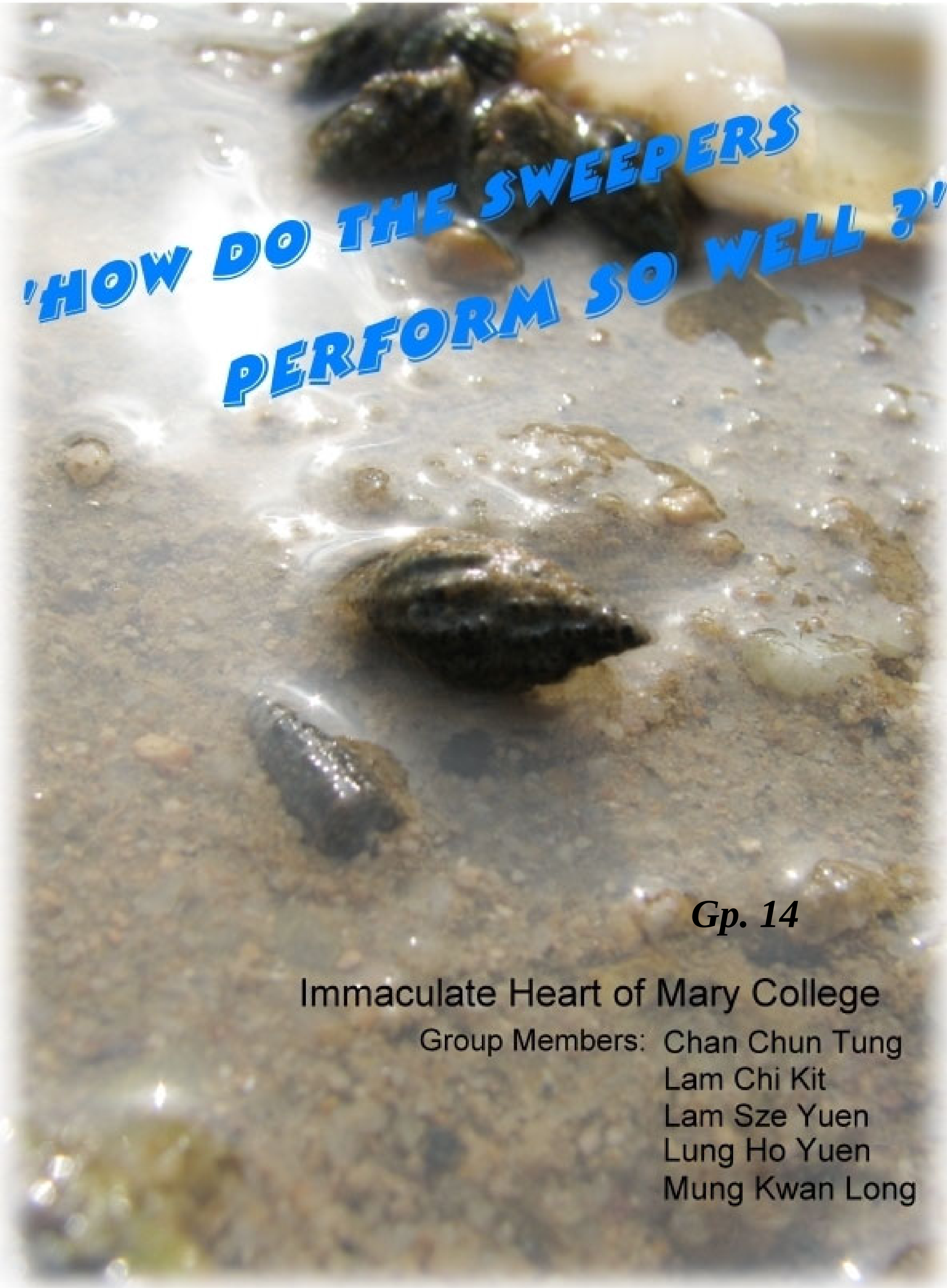

'HOW DO THE SWEEPERS PERFORM SO WELL ?'

Gp. 14

Immaculate Heart of Mary College

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<u>Adaptations of *Nassarius festivus* to Sandy shore based on its feeding behaviour</u>

Abstract

Field studies found out Nassarius festivus' adaptations based on their feeding habit on sandy shore, conducted at the intertidal zone at Starfish bay in Hong Kong. Trials had been done to investigate their sensitivity to carrions in two different approaches. Ranging from 0.05 g/ml to 0.0015625 g/ml of concentration of carrion in agar blocks at fixed distance, mean time taken to arrive at the blocks decreases with concentration. The shortest mean arrival time is 130 s recorded at 0.05 g/ml carrion concentration. A estimation of 5.14m was also found to be the maximum distance they could sense the presence of food. These help them overcome the difficulties of insufficient food on the shore. Apart from chemical sensation, their distribution on the shore was found to locate at lower zone of the shore. They also expectedly exhibited behaviour of burrowing to an extent of coverage of their shells by sand, enabling swift response to natural carrion's presence whenever sensed. Regarding their tolerance of starvation, results show their vulnerability to adverse situation with no sign of living after a day in the artificial habitat. It can be said that Nassarius festivus are well adapted in terms of feeding, both morphologically and behaviourally.

Introduction

On a typical sandy shore, which some only regards as a recreation venue, lives a large variety of organisms which show special features and adaptations to their habitat. Mobile and fine substrate particles, small slope and the resulting subdued wave actions are the unique properties of a sheltered sandy shore, being absent on other shores or environment, neither terrestrial nor marine, and they flourish the organisms living there and its biodiversity. Its intertidal zone is paid particular attention to due to its high accessibility and rich biodiversity. This study, through investigations on a particular organism on the shore, enables us to probe into the interesting facts around us and appreciate the beauty of nature.

Nassarius festivus, with its classification stated in table 1, dwelling in the intertidal zone of some of the sandy shores in Hong Kong, feeds on carrion brought onshore by tidal actions as scavengers. They can be observed in great amount at the

Table 1 Classification of *Nassarius festivus*

Kingdom Animalia
Phylum Mollusca
Subphylum Conchifera
Superclass Visceroconcha
Class Gastropoda
Subclass Orthogastropoda
Superorder Caenogastropoda
Order Sorbeoconcha
Suborder Hypsogastropoda
Infraorder Neogastropoda
Superfamily Buccinoidea
Family Nassariidae
Genus Nassarius
Species Festivus (Powys, 1835)

presence of carrion. Being regarded as epifauna, they emerge from sediments on the shore upon appearance of carrion while on the other hand, burrow in sand for most of the time, unlike the foraging behaviour observed at particular time of the tidal cycle for other nassariids like *Nassarius dorsatus*. Its sensation of carrion is obviously achieved by chemical receptors present on its siphon, which sways left and right for detection.

Chemical sensation depends greatly on the concentration of chemical or fragments of the carrion, which is very low in the tremendous amount of water in the sea. Strong and sensitive chemical receptors are hence required under this condition so that swift response and directional search for food are possible. It is particularly important in the habitats where the presence of wave actions may carry the chemical away within a short period of time. Moreover, the essence of water as a medium for the transfer of chemical and its sensation confines *Nassarius festivus* in the lower part of the intertidal zone, covered by water for most of the time.

Within the zone, regions covered by a thin layer of water provide favourable conditions for them to search for carrion. They include the small volume of water allowing a high concentration of chemical, subdued wave actions enabling easier locomotion on the dynamic sand with the ventral muscular feet as well as the evasion from predators present in deeper regions. It is hypothesized that they may follow the tide, migrating towards the shallow region during both onshore and offshore tides so as to maximize the chance of getting food and avoid desiccation during exposure to sunlight. In addition, though they burrow in sand on the conditions bereft of carrion, they cannot burrow deeply but should remain superficial in the sand so that they can sense rapidly the approach of food and breathe as they do not have long siphons.

In this study, the feeding behaviour of *Nassarius festivus* was investigated in the aspects of the strength of their chemical receptors in sensation and the factors affecting it, their distribution on the shore, depth of burrow and their tolerance of starvation, to show its adaptations to the environment.

Materials and Methods

This study was carried out on Starfish bay in Wu Kai Sha, Ma On Shan which is a sheltered sandy shore. Its location being far from residential area and factories enables little interruption by human activities. With its gentle slope being typical of a sheltered sandy shore, a large intertidal zone is available for field study. Much wave actions are obstructed by the surrounding land area.

Map of our site of study, Starfish Bay. The red crosses indicate the location.

Field study

	Date	Duration
Observations	3rd November, 2007	8:30 a.m. – 10: 00 a.m.
Trials	17th November, 2007	7:15 a.m. – 11:00 a.m.
Data Collection	30th December, 2007	7:15 a.m. – 12:00 a.m.
	31st December, 2007	7:30 a.m. – 11:00 a.m.
	24th March, 2008	1:00 p.m. – 6:00 p.m.
	4th April, 2008	9:30 a.m. – 1:30 p.m.

<u>Chemical sensation</u>

To investigate their strength on chemical sensation, two approaches were employed.

a. Concentration

The first approach is concerned about *N. festivus'* performance on different concentrations of carrion. Agar blocks holding different concentrations of clam solutions were used to carry out experiments.

10.00800 g of clam flesh weighed with an electronic balance was blended with 50 ml tap water. 10 ml of the resultant solution, with a concentration of 0.2 gml^{-1}, was transferred to a test tube with 10 ml tap water. 10 ml of this solution was then transferred to another tube with 10 ml tap water. By repeating it five times, six concentrations were obtained: 0.1 gml^{-1}, 0.05 gml^{-1}, 0.025 gml^{-1}, 0.0125 gml^{-1}, 0.00625 gml^{-1}, 0.003125 gml^{-1}. 5.0010 g agar in 500 ml water was then boiled to prepare agar solution.

1 ml of 0.05 gml^{-1}agar solution was transferred to each of 6 groups of aluminium foil containers, each group comprising 10. The containers in the same group were filled with 1 ml clam solution of the same concentration. Being placed in a freezer, 60 agar blocks (6 groups with 6 different concentrations: 0.05 gml^{-1}, 0.025 gml^{-1}, 0.0125 gml^{-1}, 0.00625 gml^{-1}, 0.003125 gml^{-1}, 0.0015625 gml^{-1}, 10 blocks in each group) were prepared.

Regarding the experiments carried out, plastic basins of radii 10 cm were filled with sand and sea water in order to create an environment similar to the shore except the absence of wave actions, which is a factor affecting their sensation. 8 individuals of *N. festivus* were placed evenly on the basin's circumference and an agar block of a particular concentration put at the centre. The time for the first individual to reach the block was recorded for each agar block, with cases over 10 minutes neglected. Each measurement was carried out with the water depth controlled to be small and experiments of low concentrations were conducted before the high ones. Also, 8 new individuals collected from the shore were used and allowed to adapt to the environment for several minutes before the inception of another measurement.

b. Distance

The second approach is concerned about the maximum distance their chemical sensation covers. Carrion bait was fixed at different regions on the shore and the corresponding numbers of *N. festivus* and water depth were recorded for every 5-minute interval until the numbers level off. Fixation of the bait was to avoid its movement due to the water current which would lead to error in measurement. Natural carrion was searched for and removed in the surrounding area before setting the bait to avoid errors caused due to its presence diverting a portion of the *N. festivus* from the bait. The longest distance of their chemical sensation of carrion was hence able to be estimated with their latest arrival time and their velocity of locomotion measured by counting the average time they spent moving a certain distance, assuming they wasted no time during their trip towards the bait and neglecting the time required for the diffusion of chemical.

<u>Distribution on the shore</u>

In order to investigate the regions on the shore that they were active in searching for food on the presence of carrion, a 20 m transect was drawn from the upper zone to the lower zone, through the intertidal zone, and 25 × 25 cm^2 quadrats were set at points of 0 m, 5 m, 10 m and 20 m from the end located at the upper zone. A piece of carrion bait was fixed at the centre of each quadrat and the numbers of *N. festivus* found inside as well as the water depth within 60 minutes were recorded. The five-meter distance was obtained from the estimation of the longest distance this species can sense the presence of carrion in the previous measurement and it was assumed to be long enough to avoid interruption of adjacent bait on each other so that there was no overlapping.

Later, another approach was employed to obtain more accurate results. A 50 m transect was set perpendicular to the coastline from the lower zone to the upper one. Two 50 cm × 50 cm quadrats were laid on both right and left hand sides of the transect at intervals of 5 m. When the water depth at the interval dropped to below 0.5 cm, concentrated clam solution was spread within each quadrat to activate all the *N. festivus* in the region. After that, the number of individuals of *N. festivus* inside each quadrat was counted and the mean number between the two taken. Water depth below 0.5 cm was chosen to reduce the dilution effect caused by the large volume of water and wave action so as to activate them effectively.

Depth of burrowing

For its estimation, cotton threads with diameter less than 1 mm were attached to their shells and having them returned the shore, they were allowed to burrow. Time allowed for burrowing was recorded and the distances they burrowed were estimated by measuring how long the thread was pulled down. Same measurement was repeated by lengthening the time allowed until the smallest deviation was obtained. The cotton thread was chosen for its lightness so that it minimized the hindrance posed on their locomotion.

Tolerance of starvation

Groups of *N. festivus* were fed with food quantified in mass and kept in an artificial habitat with sand and sea water obtained on the shore. Days of survival were counted to show their tolerance to starvation.

Results

The first two days of data collection, 30th and 31st December, were cold and the studying site was having a receding tide to around 0.7 m on 30th and 0.8 m on 31st for around the first hour we started our work, followed by a rising tide. (Data obtained from the website of Hong Kong Observatory) On these days, lots of corpses of *Leiognathus brevirostris* were found on the shore, both exposed and covered with a thin layer of water, and a large amount of algae found on the upper zone. On 17th December, bivalves were prepared for trials. On 30th and 31st December, *Leiognathus brevirostris* was used as the carrion bait since it was observed to be natural carrion *Nassarius festivus* fed on.

On 23rd March and 4th April, it was warm and the tide receded to around 0.6 m and 0.9 m respectively. No corpses of fish were found and the amount of algae observed on sight was significantly reduced. Only a little carrion was found being fed on by *N. festivus*.

Chemical sensation

a. Concentration

	Arrival time (s) on different concentrations of clam solutions				
Trial no.	0.05 gml^{-1}	0.0125 gml^{-1}	0.00625 gml^{-1}	0.003125 gml^{-1}	0.0015625 gml^{-1}
1	169.63	107.52	268.68	>10	289.06
2	147.33	155.42	411.5	>10	309.73
3	85.62	162.53	(110.2)	>10	(>10)
4	157.82	124.74	140.96		(>10)
5	62.06	171.29	(>10)		(>10)
6	72.58	124.48	283.23		(>10)
7	128.54	143.8	(>10)		162.36
8	182.29	175.28	204.79		(>10)
9	(489)	159.54	(>10)		(>10)
Mean	125.73	147.18	267.83	-	253.72

Table 2 Arrival time at the agar blocks 10 cm away of the first individual of *N. festivus* on different concentrations of clam solutions measured in seconds. Bracketed data are neglected due to large deviation from others.

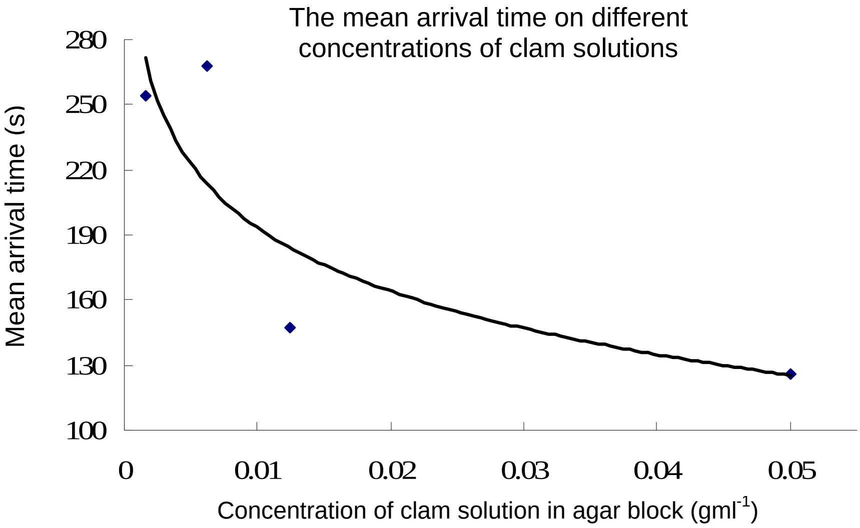


Fig. 1 The graph of the mean arrival time on different concentrations of clam solutions showing their relationship

The results show that the mean time travelled by *N. festivus* decreases with concentration of clam solution in agar block, but levels off afterward.

Great variation on their sensitivity to the clam solution was also found.

b. Distance

Regarding another measurement with fixed bait set on the shore, a cumulative frequency curve (fig.2.) was plotted with numbers of *N. festivus* arrived at and remained on the carrion bait recorded after each 5-minute interval against the time, with the variation of water depth over time included (except trial 3 in which the doer forgot to record the water depth).

All graphs resembled a sigmoidal curve, having an accelerating phase at the beginning and a decelerating phase at the end and a whole trend of increasing.

Based on the assumption that no more *N. festivus* would arrive after several unchanging numbers recorded at the end of each trial, the longest time taken for their arrival was 60 minutes (recorded at trial 3, the15th 5-minute interval in which 2 individuals of *N. festivus* arrived at the bait.

Three individuals were selected by random sampling to measure their time required to travel 1 cm during their trip moving towards the bait. A mean of 7 s which is equivalent to 5.14 mhr^{-1} was obtained, by which the maximum distance that they could sense the presence of carrion was therefore estimated to be 5.14 m.

At each trial, the greatest increase in number occurred when water depth was around 5 cm Also, the eventual size in trials 1 and 4 (11 and 12) deviate greatly from those in trials 2 and 3 (both 83).

Moreover, in trial 1, before the bait was flooded with water at the fifth minute, neither *N. festivus* was recorded arriving at the bait nor was there found any around it, in contrast with an early record of their arrival in the first 5-minute interval in other trials.

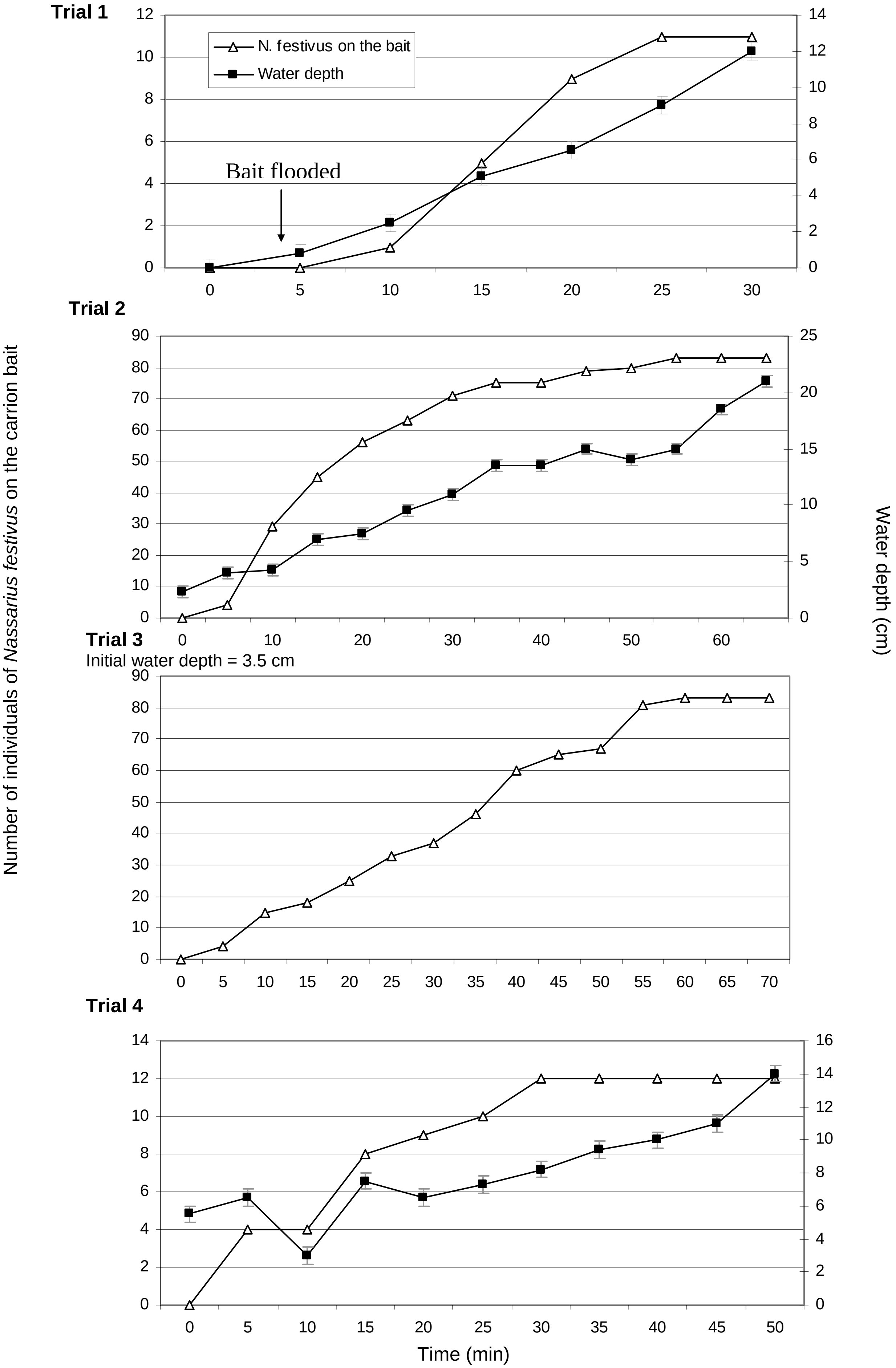


Fig. 2 Number of individuals of *Nassarius festivus* arrived at and remained on the carrion bait (*Leiognathus brevirostris*) and the variation of water depth ($\pm$ 0.5 cm) over time due to tidal actions.

Distribution on the shore

Referring to fig. 3, the numbers of individuals of *N. festivus* found in the quadrats located at different points on a 20 m transect were plotted against time for two trials, so was the water depth.

In trial 1, the numbers recorded at all points increased in the first 30 minutes whereas all but that in the 0 m quadrat decreased in the next. The range of water depth at the 0 m quadrat was small (6 cm ± 1 cm) in contradistinction to the large range (21.5 cm ± 1 cm) at other points. At the 60th minute, the fixed carrion bait at the 20 m quadrat was removed by the large wave actions.

In Trial 2, only in the first 15 minutes were the numbers in 5 m and 20 m quadrats found increasing, followed by a decline. At the 30th minute, the quadrats at points at 5 m, 10 m, and 20 m were removed by wave. Throughout the experiment, the 0 m quadrat was exposed and no individual of *N. festivus* recorded.

Trial 1

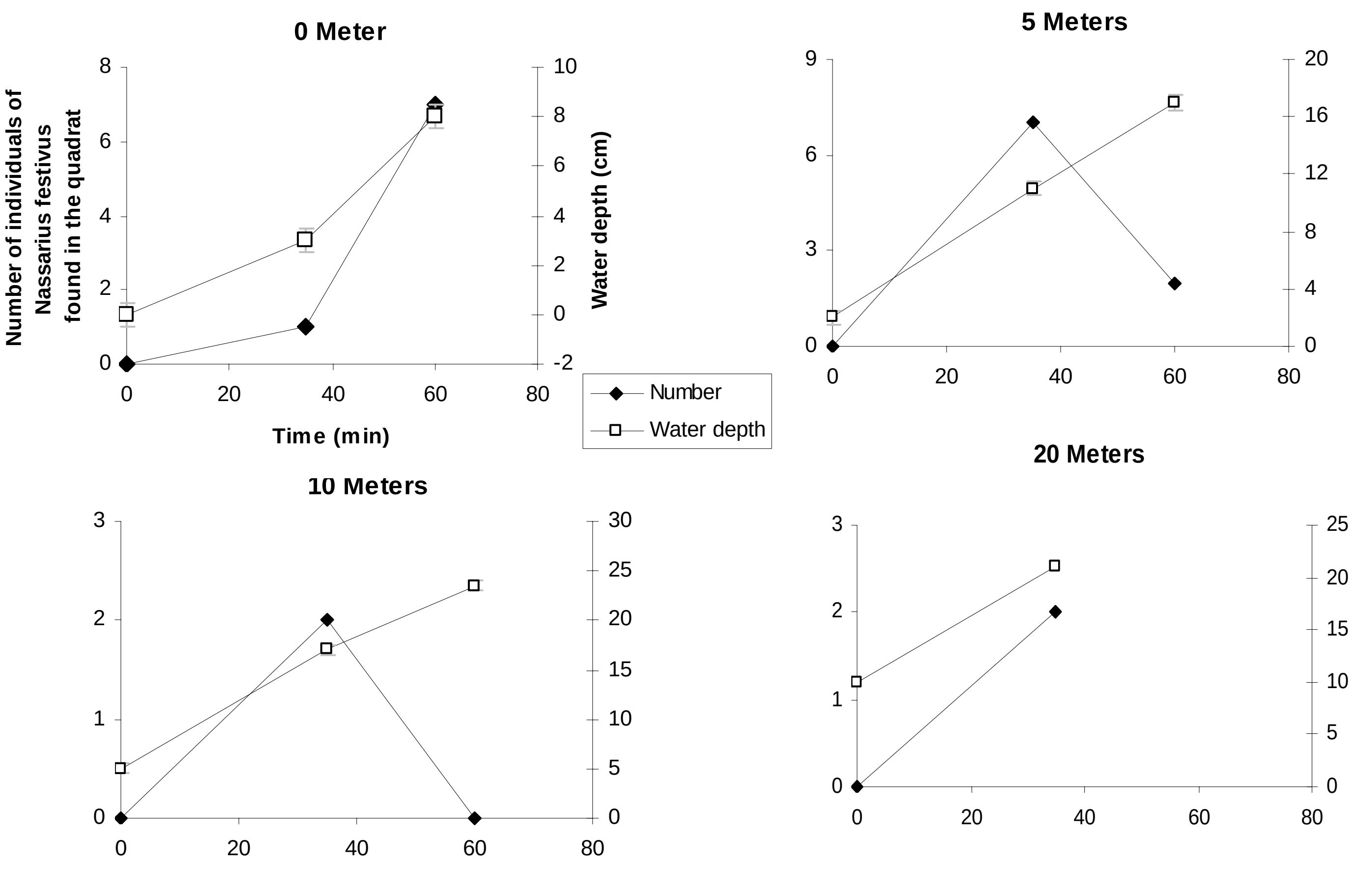
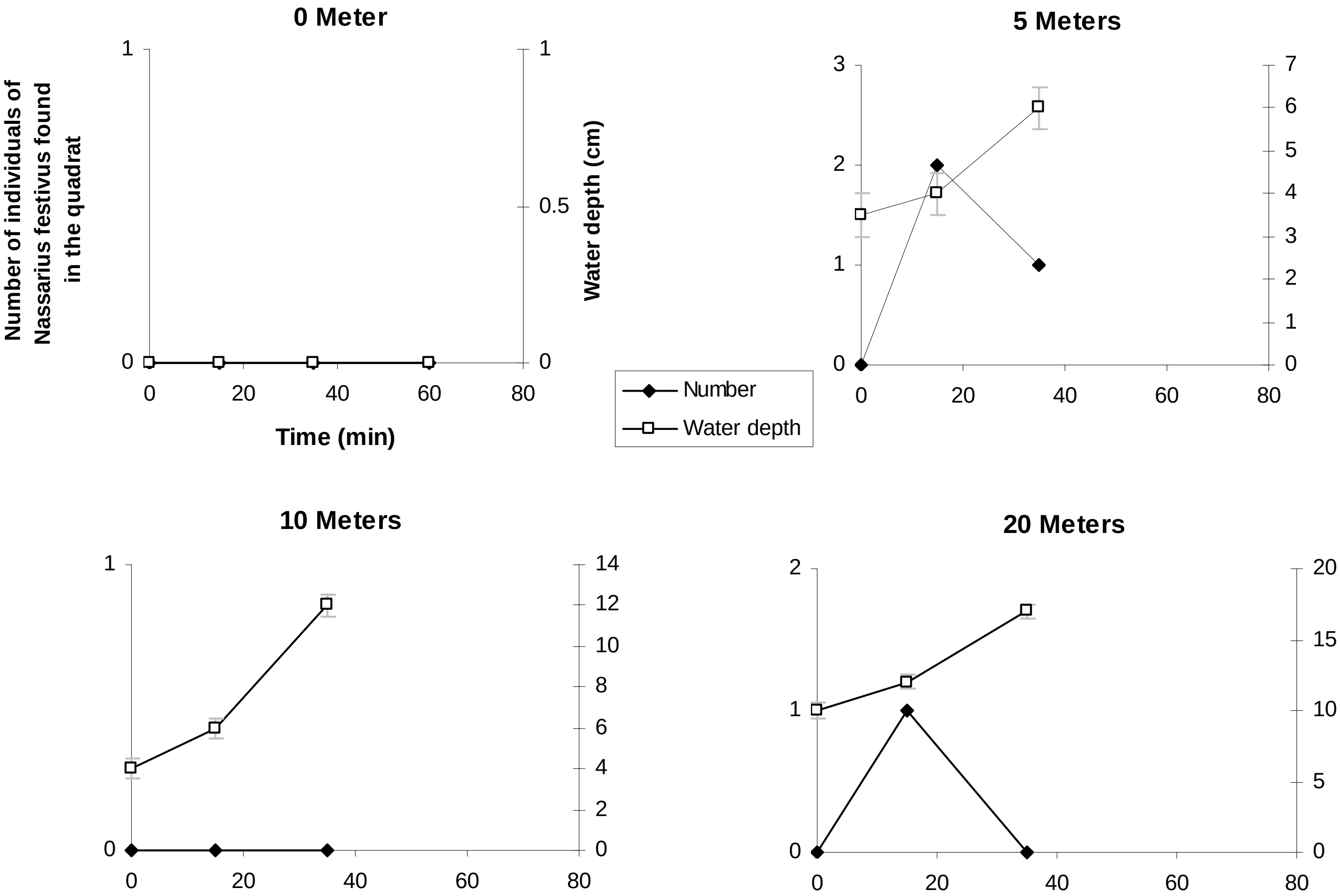


Fig. 3 Numbers of individuals of *Nassarius festivus* found on the quadrats set on a transect at points of 0 m, 5 m, 10 m and 20 m from the end at the upper zone, and the corresponding variation of water depth (± 0.5 cm).

Fig. 3 (cont.)

Trial 2



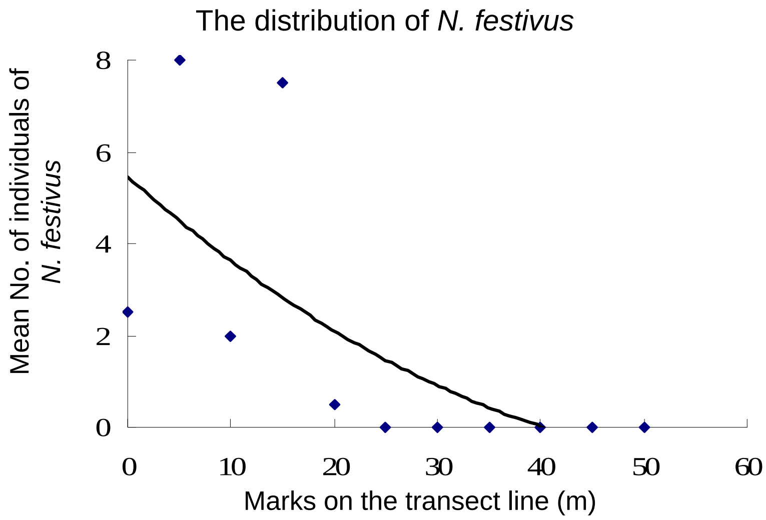


Fig. 4 The distribution of *N. festivus* shown by its population density (mean no. of individuals in 25╳25 cm^2 area) on a transect line drawn from lower to upper zone

For another approach, referring to fig. 4, the mean number of individuals of *N. festivus* decreases with the marks on the transect line, showing that *N. festivus* are located at lower zone of the shore and can hardly be found on the upper zone. The large deviation in numbers of individuals was also found.

Depth of burrowing

All the cotton threads’ records were zero. It was observed that they did shake their ventral muscular feet left and right to burrow into the mobile sand, however, only to an extent of coverage of the apertures of their shells. Afterwards, they remained stationary among the sand and the covering of their left exposed shells were often aided by wave actions which carried sand particles onshore.

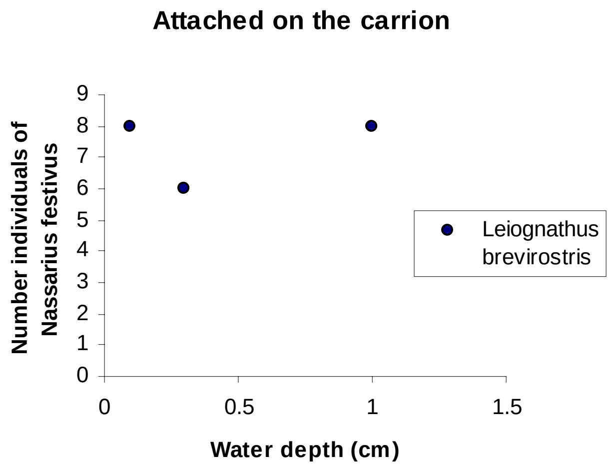
After the completion of covering, when they were totally covered by sand, they were reactivated within seconds upon addition of a piece of carrion bait, emerging from sand and moving towards the bait. These all only occurred at regions where water was present. At dried regions or those without water covering, they were inert and did not burrow.

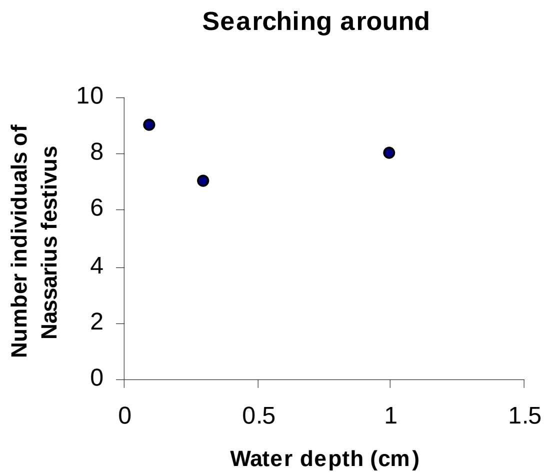
Natural carrion

As lots of corpses of marine organisms were found on the shore on the first two days, either covered by water or exposed to sunlight, corpses sampled haphazardly

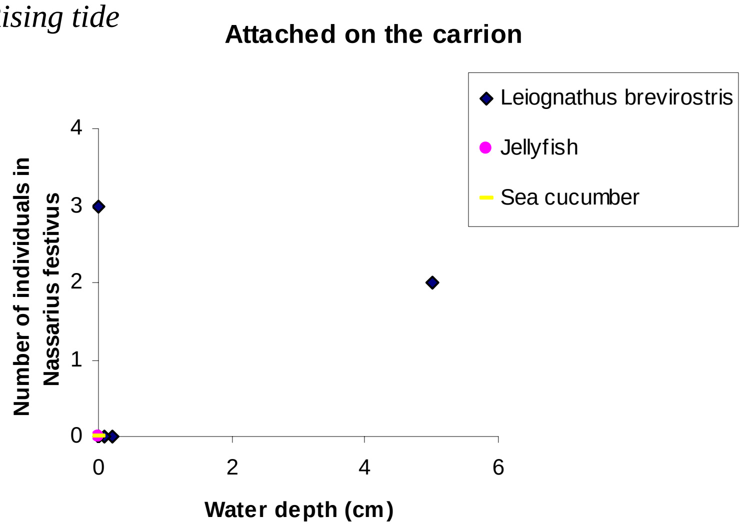
Fig. 5 Numbers of individuals of *Nassarius festivus* found on natural carrion selected haphazardly on the shore at different water depth during the rising and receding tides.

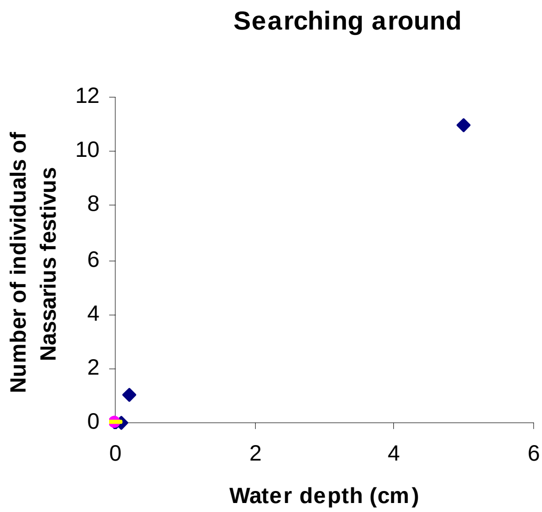
Receding tide





Rising tide





were recorded with the water depth at the point they were located and the numbers of *N. festivus* feeding on them, shown in Fig. 5.

During receding tide, most of the carrion found were being fed on and surrounded by a number of individuals of *N. festivus* at shallow regions, while during the rising tide, nearly all of them were left dried and without any feeders.

During the onshore tide, for most carrion found exposed to air as well as those floating on the water surface, none was found, yet with two exceptions observed - around the algae, where a *Leiognathus brevirostris* was found still wet, 3 individuals were spotted feeding on it; another found in a pond formed by little humps and vales of sand where wave temporarily was out of reach, being fed on 2 individuals but surrounded by many of *N. festivus*.

For other organisms like jellyfish and sea cucumber, none individual of *N. festivus* were found on them.

<u>Tolerance of starvation</u>

They showed no sign of living after keeping one day in the artificial habitat.

Discussion

Nassarius festivus exhibited a very strong chemical sensation for the search of food, namely carrion carried onshore by tidal actions. Obviously from the setting of agar blocks can their strength be observed. Their reaction time, i.e. the time from being inert to activated by the agar blocks, decreases with concentration of the carrion. Yet, successful arrivals were recorded for extremely low concentration (1.56×10^{-3} gml^{-1}) in the experiments, approving their strong chemical sensation capable of detecting low concentration of chemical caused by the large dilution effect in the real situation. In fig1, the tendency for the curve to level off as concentration increases is due to the major limiting factor confining their arrival time – their slow moving speed as a typical characteristic of mollusca due to the use of a single muscular foot for locomotion. Time taken for diffusion of chemical also limits its speed.

From another measurement of the numbers of their individuals arrived at the carrion bait over time showed in another aspect their receptors' strength. A maximum distance of 5.14 m (which is equivalent to 257 times their body length!) that they can sense and arrived at the carrion portrayed the well development of their chemical receptors on their siphons. However, the estimated value had some errors as the routes they took were not horizontal or linear, individual variations on the velocity of locomotion may be high and their responses to chemical may not be instant.

It is one of their adaptations to their habitat to have strong and well-developed chemical receptors, allowing them to survive on the sandy shore. As the tidal cycle repeats only twice a day in Hong Kong and the shore is large, chances for rising tide to convey carrion onshore to a particular are low. The resulting low density of carrion on the shore thus lowers the opportunity for a single *N. festivus* to locate beside carrion without moving. Also, as they do not forage on the shores but remain inert until a detection of food. Therefore, long distance sensation and the ability to detect low concentration are helpful in searching food, especially in regions with a high water depth.

The accelerating and decelerating phases in the sigmoidal curves in fig. 2 were explained by respectively the buffering periods for the diffusion of chemical and their reaction, and the progressively decreasing concentration of chemical around the carrion with radius due to the increasing volume of solvent, water. Both indicated the importance of the strong chemical receptors mentioned before. The rapid response observed from the graphs at the first 5-minute intervals in trials 2, 3 and 4, shown by the increment in the numbers of individuals, and the greatest increase in numbers of individuals arrived at the bait within 20 minutes are also a sign of their adaptations to the environment. This swift reaction as an adaptation allows them to approach the carrion as soon as possible in order to maximize the chance of having food and allow time for ingestion.

In trial 1 of the same measurement, the zero number of *N. festivus* arriving at or found around the carrion bait in the first 5 minutes was accompanied by the initial zero water depth, in contrast with records of arrival within that time in other trials. Water is henceforth attested to be essential for their chemical sensation. This statement was reinforced by results in trial 2 of fig.3 that both the number and water depth of the quadrat at 0 m remained zero for an hour.

The large deviation of the eventual size in trials 1 and 4 of fig. 2 (11 and 12) from those in trials 2 and 3 (both 83) is explained by the results obtained from investigations on their distribution on the shore. In trial 1 of fig. 3, only the quadrat at 0 m had an expected increase in the number of individuals of *N. festivus* from 35th minute to 60th minute while the others had a decrease. At those points, the water depth increased to a high value (but not larger than half the wavelength of the water waves as the water below that length shows small water motion and is not disturbed by waves) at the 60th minute and hence the wave actions they confronted were greater in strength. It was deduced from observations that it was the wave actions accounting for this phenomenon. Water current and wave actions create forces that can crush against and remove them from the carrion they are feeding on. Therefore, the wave actions should be responsible for the removal of *N. festivus* from the carrion bait and it was more obviously observed in trial 2 that even the quadrats were removed at the 60th minute. As a result, wave actions was probably the major factor contributing to the difference in size previously mentioned as they can hinder their locomotion as well as lowering the concentration of chemical. Zonation is another possible reason that as trials 2 and 3 were done in the beginning of the two days, followed by trials 1 and 4 at later time. Since the shallow regions were selected as the location for measurement, and the tide was rising, locations of trials 2 and 3 were at the lower part of the intertidal zone whereas those of trials 1 and 4 were at zones higher. Based on their background information, they should be at the lower part of the intertidal zone and that helps explain for the smaller size in trials 1 and 4.

At the second approach of measuring the zonation pattern in fig.4, *N. festivus* was found to be dwell at lower zones and appear in clusters shown by the larger amount of individuals at lower zones and large deviation in numbers found. The latter may be due to their nutrition method as they may gather and burrow at the same area after eating a piece of carrion previously.

Their behaviour in burrowing observed suits much our expectation as they only burrow till the sand covered the apertures. This allows them to remain close to the surface so that response and the subsequent emerging from the sand can be swift when chemical of carrion is detected while their delicate part can be hid from exposure to the outer environment that prevents being damaged. The reactivation on addition of carrion bait within seconds strengthened the point that they had swift response. Their burrowing behaviour was also how they adapt to the shore fraught with wave actions which can threaten their life.

In spite of the largest amounts of *N. festivus* (83 individuals) found on fixed carrion in trials 2 and 3 in fig.3, only about 7 individuals were found on natural carrion found on the shore with about 8 individuals searching around it during the receding tide. The large difference between set experiments and observations on the shore may be due to the fact that the exposure of the carrion to water had just started when the record was made. The mobility of the carrion is also a factor affecting their number present attaching on it since mobile carrion which could be carried by water current was difficult for them to arrive at. Rising tide showed entirely different results that rare corpse was found being fed by *N. festivus*. It is because during the rising tide, the water current brought the carrion to higher zone of the shore while *Nassarius festivus* were mostly active in the lower zone of the shore, resulting in this decrease in number of individuals found. Also, the carrion was often floating on the water surface due to the rising tide, making them unreachable by the *N. festivus*. One exception was observed that on the shore where there was no water covering, *N. festivus* were still found feeding on a *Leiognathus brevirostris* which was surrounded by algae. The algae are believed to be able to trap water and those *N. festivus* could make use of this to take the chance to feed.

In conclusion, *Nassarius festivus* confront several obstacles on the shore for feeding, namely wave actions and water current, a large amount of water in high water depth and low density of carrion available. There was a slight competition observed during the setting of carrion bait that a small number of individuals of hermit crabs were found feeding on it. They show several adaptations to these problems they encounter Firstly, they possess very strong and sensitive chemical receptors in terms of both the concentration and the maximum distance so that they can sense the presence of and arrive at the carrion successfully within a large region where they locate as water is always in a large volume on the shore, low frequency of input of carrion by tide and the density of carrion on the shore are low. As well as these, as opportunists, they only wait under sand until there is the presence of carrion so that carrion brought by the tidal actions can seldom reach any *N. festivus*. These well-developed chemical receptors were therefore important adaptations for them to survive in the environment. Secondly, their responses were fast after the detection of chemical from carrion so as to raise the chance of arriving at the carrion and allow more time for digestion as procrastination may lead to unexpected results such as strong wave actions which may remove them. Thirdly, water is essential to them as it prevents them from desiccation and more importantly, provides a medium for the transfer of chemical which enables chemical sensation. Therefore, their choice to dwell in the lower part of the intertidal zone is also an adaptation as the coverage of water there has the longest time among zones in the intertidal zone and competition perhaps is fierce in other zones. In addition, burrowing into a depth that covers the apertures and remaining superficial are their method of burrowing so that rapid responses and chemical sensation were possible.

However, because of the unsuitable rising tide, the testing of the hypothesis for migration was missed. It would be conducted were there a further study done. It was previously planned that groups of marked *N. festivus* were placed in a quadrat at shallow region of water. After some time when the water previously covering the quadrat receded, marked *N. festivus* were searched in adjacent quadrats with certain amount of water.

For the investigations on the tolerance of starvation done, results showed that there were no sign of living after keeping them on day in the artificial habitat. The results were not as expected as they were vulnerable to adverse environment and it was difficult to set a similar habitat as the real sandy shore. Accumulation of toxic waste, lack of tidal actions that exchange the water logged in the substrate, etc were left to be dealt.

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