

The Influence of Salinity on a Tropical Estuarine
Shipworm *Nausitora hedleyi* SCHEPMAN
(Bivalvia - Teredinidae)

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ABSTRACT

Species belonging to the genus *Nausitora* (Bivalvia - Teredinidae) are generally confined to brackish waters. In the Cochin backwaters, a tidal estuary on the southwest coast of India, this genus is represented by the species *N. hedleyi* SCHEPMAN. Fresh settlement of the species in the area is noticed only during the period of low salinity, though the species is found to exist, throughout the year. Tests conducted to ascertain the effect of salinity changes on the activity of the borer showed that though it can endure a wide range, the optimum salinity range for early development was from 11.24—14.54‰.

INTRODUCTION

The importance of salinity as a limiting factor for the existence and distribution of shipworms has been known as early as 1733. SELLIUS (1733), BAUMHAUER (1860) and HARTING (1862) have noted a correlation between increased activity of shipworms and increase in salinity of the ambient water. NAIR & SARASWATHY (1971) have recently reviewed the more important references on teredines in relation to salinity endurances.

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Salinity affects the organisms by influencing the density of the medium and through variations in osmotic pressure. These are especially significant in the habitat of *Nausitora hedleyi*, namely the Cochin Harbour. This harbour is part of an elaborate net work of

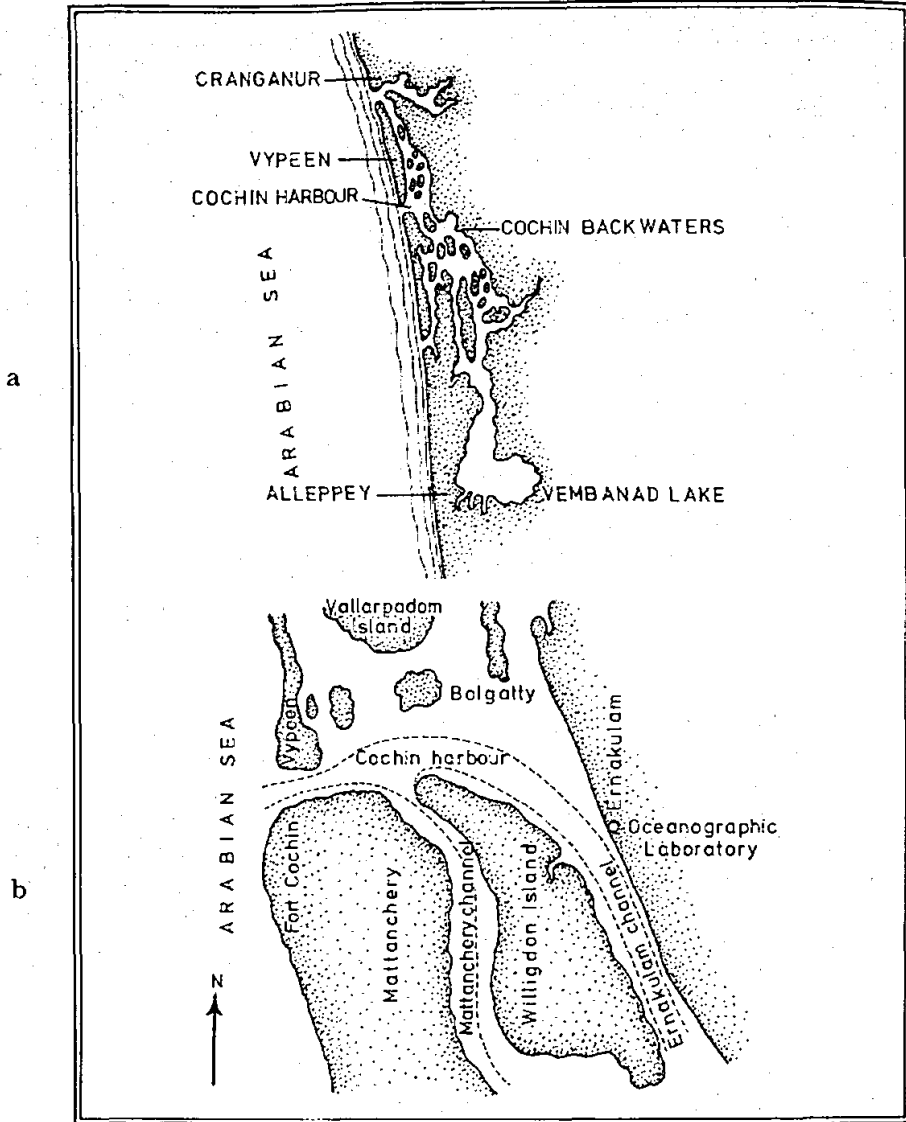


Fig. 1a. Map of the Vembanad Lake and the Cochin back waters. 1b. Enlarged view of the Cochin Harbour.

shallow (1—12 m. depth) brackish water lagoons known as the Cochin backwaters which are northward extensions of the Vembanad Lake situated on the south west coast of India (Fig. 1). These backwaters are separated from the Arabian Sea on the west by low stretches of sand and the main connection with the sea is through a

gut about 450 m wide which serves as the harbour entrance. Some of the major rivers of central Kerala originating in the Western Ghats empty into the lake or into the backwaters and the influx of fresh water from this source is considerable especially during the monsoons. The area of the Cochin Harbour is a typical tidal estuary, with inflow of fresh water at the upper end and penetration of sea water at the mouth during high tide. Diluted sea water flows out through the gut during ebb tide. The influence of the monsoons (south-west monsoon during May—August and north-east during October—December) on the hydrographical conditions of the backwaters is substantial (Fig. 11) causing both reduction and fluctuations in the salinity.

In this estuarine habitat *Nausitora hedleyi* is the only wood boring mollusc occurring throughout the year during the course of which the surface salinity may fluctuate between 33.63‰ and 0.65‰. Nevertheless, this species has the ability to settle, grow and reproduce only during the low salinity period. Those that survive the breeding period may continue to live without further reproductive activity during the highly saline conditions of the pre-monsoon period. This apparently intimate influence of salinity on the life and activity of *N. hedleyi* prompted an enquiry into the conditions of salinity under which these borers live in this habitat and the influence of this factor on the early development of this species.

A series of tests were conducted with a view to finding out the lowest salinity at which *N. hedleyi* can feed, grow and propagate normally, the approximate periods during which they can survive in salinities lower than the minimum and higher than the maximum needed for normal existence, the reactions of the animal when the salinity of the ambient water fluctuates gradually or suddenly and the effect of low or high salinities on the early developmental stages. The results of these tests help to some extent towards understanding of the condition under which this species lives, grows and reproduces in its habitat.

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MATERIAL AND METHODS

Specimens for the tests were obtained by exposing wooden panels of *Mangifera indica* 15 x 5 x 1.5 cm at the quay of the Oceanographic Laboratory at Cochin. On removal from the water the foulders were carefully scraped off without in any way damaging the pallets of shipworms. A count of the number of entrance holes was made before

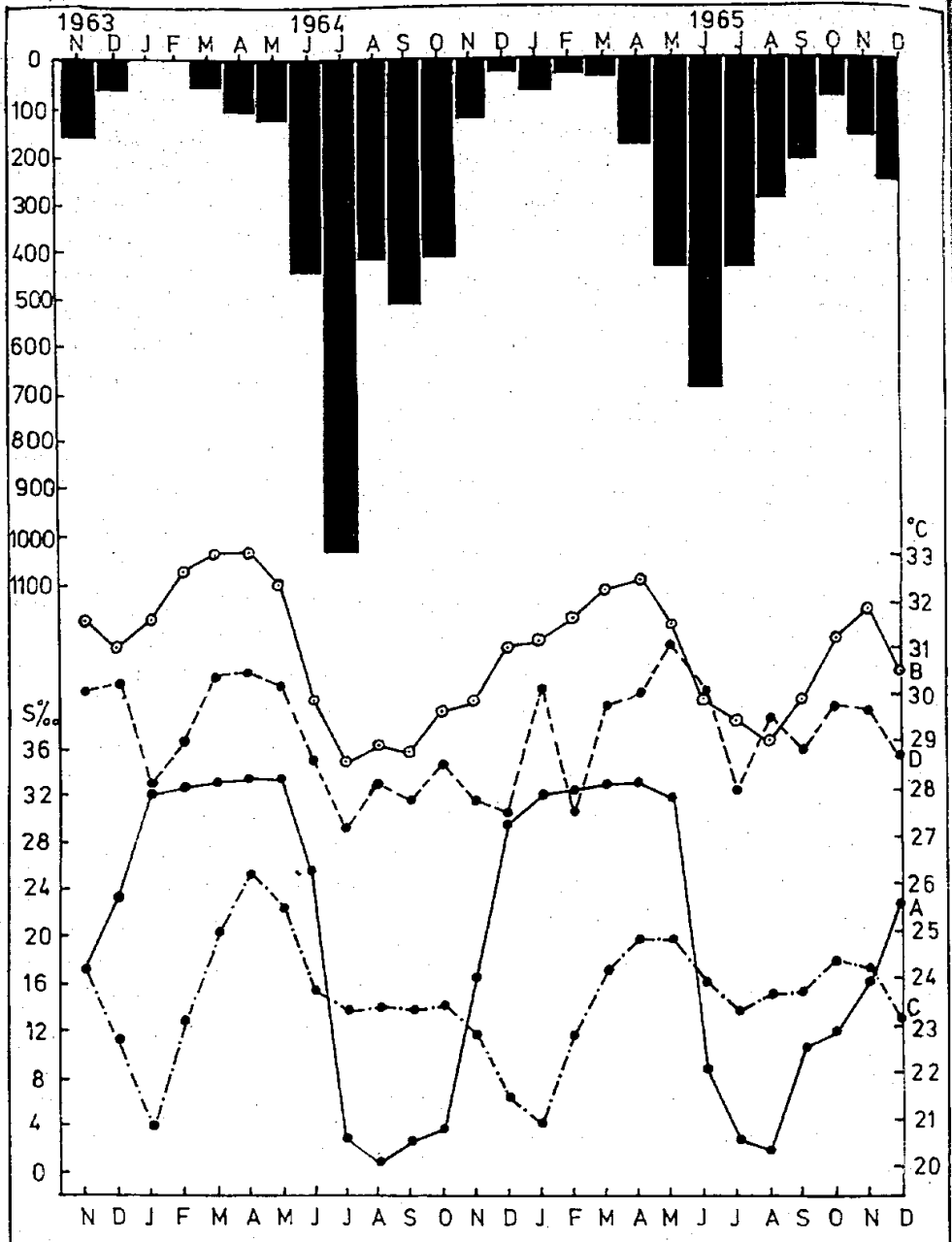


Fig. 2. The hydrographical and Meteorological data for the Cochin Harbour A. Average salinity (surface) ‰. B. Average maximum atmospheric temperature °C. C. Average minimum atmospheric temperature °C. D. Average water temperature (surface). Black bars indicate rainfall measured ... in millimeters.

transferring the panels to a large jar containing water of optimum salinity i.e., the salinity in which the animal was found to exhibit normal activity. Within a short time the pallets were withdrawn and the siphons could be seen displayed through the entrance hole.

The resumption of normal activity was indicated by the ejection of faecal matter. A count of the siphons was carried out and this tallied with the number of the entrance holes noted. Except a few *Sphaeroma*, no other borer was present at the time and this facilitated an easy count of the siphons and holes. The specimens were permitted to acclimatise for at least a period of 2 hours by which time all the siphons could be seen displayed normally. Then the blocks were transferred to the different grades of salt water which was aerated at intervals. Activity was tested by teasing the siphons, with a needle. A quick response could be noticed if conditions were normal. In less favourable salinities the reaction was less rapid and in very low salinities paralysed, non-sensitive siphons could be seen extended through the entrance hole. In such cases the palletal mechanism was also found to be non-functional. The duration for the first experiment was fixed in all cases at 24 hours and this was considered sufficient since the specimens reacted well to unfavourable salinities within this period and 100 per cent death could be noticed in those grades which were apparently not suitable for the animal. Specimens from such blocks failed to recover even when exposed to favourable salinities. It was borne in mind that within a period of 24 hours in this estuarine habitat the composition of the medium is likely to undergo rapid change at least twice owing to the strong influence of the tides. Therefore, it was felt that prolonged exposure in the different grades was unnecessary for an understanding of the effects of salinity on these organisms. To find out the effect of gradual acclimatisation to higher salinities, the specimens were kept in each grade for 24 hours. In the third experiment the purpose of which was to locate the lethal salinity of the species, the duration of the test was prolonged until all specimens were killed in each grade. In every test, controls with the most suitable salinity were always maintained and the medium aerated at intervals and changed every day. Care was taken to see that the specimens used were healthy and actively boring forms as may be inferred from the display of siphons and from the steady ejection of faecal filaments. The condition of the shipworms in each experimental jar was checked at intervals, the display of the siphons, their sensitivity, the formation of true and pseudo faeces and their quality etc. were noted. During the period of the tests, except for change of water of the respective grades which were made with lake water containing some planktonic food, no additional plankton feeding was resorted to. All the salinities recorded in the tables represent the average of the readings taken at the beginning and at the end of each test for each jar and the difference between the two readings was usually not more than 1.5‰.

A shipworm was considered dead only after the following tests. No display of siphons, pallets limp and loose in the entrance holes, without any reaction when pushed with a needle. (In live specimens gentle pushing with a needle will quickly be followed by a further forceful outward thrust of these structures, thereby closing the entrance hole more tightly). When these symptoms were noticed, the block containing the specimens was transferred to a jar containing water of optimum salinity. If this treatment also failed to bring about a display of the siphons, the specimens were considered dead. In very low salinities and in fresh water, the paralysed, collapsed and flabby siphons may sometimes be seen hanging out through the entrance hole.

Material used for salinity tolerance of developing eggs was obtained from healthy, sexually mature specimens. In all cases artificial fertilization was resorted to which was successful in the majority of cases. Of the 17 times artificial fertilization was conducted, in 14 cases during September, early development could easily be followed and tests on salinity tolerance were undertaken during this period. The gonads of ripe females were slit open with a clean, sterilised scalpel and the contents pipetted out into a clean petri-dish containing a small quantity of filtered lake water. This was mixed with similarly extracted sperm. The determination of the most favourable salinity range for the early development was carried out by transferring this mixture of eggs and sperm into different grades of saline water in separate petri-dishes. Controls with estuarine water were always kept during each experiment. During the period of the present test (September, 1965), the salinity of the lake water ranged from 9.7 to 14.0‰ and therefore, higher grades had to be prepared by the addition of crude common salt obtained by evaporation of sea water. The temperature fluctuated about $27^{\circ} \pm 3^{\circ}\text{C}$ during the course of the experiments.

The cleavage stages were closely followed until the embryos showed signs of movement within the fertilization membrane. In these experiments the early developmental stages were followed only upto this stage since the purpose of this experiment was to get information regarding the most suitable salinity range for the early stages of development. Since a quantitative determination of normal moving larvae was contemplated, equal quantities of the mixture of the gametes were transferred into the various dishes containing water of different grades of salinity. The presence of immature eggs in the suspension interfered to some extent with the counting and therefore, the actual number of developing eggs in each grade could be noted only approximately. The ripe eggs could be recognised from the immature ones by their size and circular outline, but owing

to variations, these criteria were not always very helpful towards an accurate assessment. Aliquot samples were taken for observation from each dish into a cavity slide and the number of normally developing eggs counted. If all the mature eggs have undergone normal cleavage and attained the moving stage, it was concluded that 100 per cent have developed.

RESULTS

In Table I is presented the nature of activity of the siphons and the percentage of mortality of the shipworms in the various grades of salinity tested during the first experiment. When a test block was transferred from the control to aerated distilled water, *Nausitora* did not close up their burrows for a long time, for, their siphons were found protruding a little beyond the entrance hole. The siphons, however, were not very sensitive even though they were displayed to a length of 3 mm beyond the entrance hole. That there was activity despite being in such a medium was evident from the fair amount of wood borings that accumulated in the jar. At the end

TABLE I
Showing nature of activity of *N. hedleyi* in different salinities

| Salinity ‰ | Time taken for display of Siphons | Nature of response of Siphons after 24 hours | Length of Siphons | | Percentage of speci- mens alive after 24 hours |
|---------------|---|--|-------------------|--------|--|
| | | | 1-6 hrs | 24 hrs | |
| 0.43 | 1 hour | moderate | ... | 3 mm | 100 |
| 1.42 | 1 hour | moderate | 1 mm | 5 mm | 100 |
| 2.83 | 1 hour | moderate | 1.5 mm | 5 mm | 100 |
| 3.1 | 1 hour | rapid | 1.5 mm | 5.5 mm | 100 |
| 3.6 | 1 hour | rapid | 1.5 mm | 5 mm | 100 |
| 4.7 | 1 hour | rapid | 2 mm | 5 mm | 100 |
| 6.4 | 1 hour | rapid | 1.5 mm | 6 mm | 100 |
| 8.1 | 1 hour | rapid | 2.6 mm | 6 mm | 100 |
| 10.3 | 1 hour | rapid | 3 mm | 7.5 mm | 100 |
| 11.1 | Immediate | rapid | 4.5 mm | 7 mm | 100 |
| 13.8 | Immediate | rapid | 4.5 mm | 7 mm | 100 |
| 14.9 | 30 minutes | rapid | 4 mm | 7 mm | 100 |
| 17.4 | 2½ hours | rapid | 4 mm | 6 mm | 100 |
| 21.4 | within 24 hrs | rapid | 1.5 mm | 6 mm | 100 |
| 24.7 | within 24 hrs | moderate | 1 mm | 6 mm | 100 |
| 26.6 | within 24 hrs | rapid | 0 mm | 5 mm | 78 |
| 29.6 | No display | nil | nil | nil | nil |
| 31.7 | No display | nil | nil | nil | nil |
| 33.8 | No display | nil | nil | nil | nil |

of 24 hours the medium was found to have a salinity of 0.86‰ through diffusion from the panel. With a view to finding out how long these animals can remain alive in fresh water, this block was again replaced in fresh aerated distilled water. Activity was evident within three hours when the tips of the siphons were displayed through the entrance holes. There was no sign of any mortality even at the end of 24 hours. Activity was only moderate and in addition to the small quantity of wood borings, a white mucous-like substance was seen, occasionally passing out, a condition noticed by LOOSANOFF (1952) in oysters subjected to low salinities. At the end of 24 hours all the siphons were projecting out and were apparently sensitive to the needle prick though withdrawing very slowly. At the end of 43 hours, only 40 per cent of the siphons were exposed and these appeared moribund. Examination of the specimens by splitting the block, revealed that the animals were dead, with tissues disintegrating and emitting a foul odour.

In the grades 0.43 to 2.83, the siphons responded moderately with 100 per cent survival at the end of 24 hours. From 3.1 upwards to 21.4, the response of the siphons was rapid thereby showing that this range is apparently suitable for the species. On the basis of the length of siphons extended at the end of 6 hours and 24 hours respectively, it was observed that the range between 10.3 and 17.4 was the optimum even within this suitable range. In and above 21.4‰ signs of stress could be noticed. The length of siphons extended showed a noticeable reduction. Above 24.7‰ the response of the siphons was moderate and in 26.6‰ only 78 per cent of the animals were alive. The rate of mortality shot up to reach 100 per cent in 29.6‰ where there was neither any display of siphons nor other visible signs of activity at the end of 24 hours. In none of the grades above this level there was any live animal at the end of the experiment. These results show that adults of this species are capable of tolerating a fairly wide range of salinities from almost fresh water to 26.6‰ for a period of 24 hours.

Results from experiment I suggested that the lethal salinity can be expected between 25 and 29‰ . To fix the exact salinity detrimental to the species, another experiment was conducted. The results of this are presented in Table II which shows the percentage of specimens alive at the end of 1, 2, 3, 4, 5 & 6 days in the respective salinities. These results also indicate a general interruption of function in salinities above 25.28‰ . In all the grades below 25.28‰ there was 100 per cent survival even at the end of 6 days. In 25.28‰ survival was 58 percent on the fourth day, 33 per cent on fifth day and none survived on the sixth day. In 26.73‰ 40 per cent survived on the third day and there was 100 per cent mortality on

th. fourth day. In 27.99 only 23 per cent survived on the second day while in 28.89‰ there was only 16 per cent survival even at the end of the first day.

TABLE II

Showing the percentage of specimens alive at the end of 1, 2, 3, 4, 5 & 6 days in the respective salinities. S = Salinity.

| Days | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | S ⁰ / _∞ | Control |
|------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|------------|
| | 28.89 | 27.99 | 26.73 | 25.28 | 24.4 | 23.26 | 22.41 | 21.33 | 13.04—18.0 |
| | | | | | | | | | ‰ |
| 1 | 16 | 50 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2 | 0 | 23 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3 | 0 | 0 | 40 | 100 | 100 | 100 | 100 | 100 | 100 |
| 4 | 0 | 0 | 0 | 58 | 100 | 100 | 100 | 100 | 100 |
| 5 | 0 | 0 | 0 | 33 | 100 | 100 | 100 | 100 | 100 |
| 6 | 0 | 0 | 0 | 0 | 100 | 100 | 100 | 100 | 100 |

The results of Experiment II indicate that *N. hedleyi* collected during the low salinity period of September is incapable of existing in salinities higher than about 29‰, but actual observations in the Cochin backwaters showed that some could live even in as high a salinity as 34 ‰ during the pre-monsoon period extending from about February to May, though in a less active condition. This observation prompted to test whether gradual acclimatisation to higher salinities may help the animal to tolerate higher grades of salinities.

Table III presents the results of such an experiment. The duration of the experiment was 8 days and blocks transferred to the

TABLE III

Showing the effects of acclimatisation on the salinity tolerance of *N. hedleyi*

| S ⁰ / _∞ | Percentage of active Siphon at the end of 24 hrs. | Length of Siphon at the end of 24 hrs. | Remarks |
|-------------------------------|---|--|---|
| 13.87 | 100 | 7 mm | |
| 16.87 | 100 | 7 mm | This seems to be the most suitable salinity - woodborings maximum |
| 22.03 | 100 | 6 mm | |
| 24.2 | 100 | 6.5 mm | |
| 26.6 | 100 | 5 mm | Only tip of Siphons projecting beyond entrance holes after 3 h. |
| 27.6 | 100 | 2—3.5 mm | Even at the end of 24 h. Siphons not well expanded. |
| 29.5 | 50 | 1—4 mm | Exhalent Siphon longer. May be an abnormal behaviour owing to stress. |
| 16.4 | 100 | 4 mm | All specimens recovered when changed into brackish water. |

respective higher grades at the end of every 24 hours. Percentage of active siphons and the length to which they were extended at the end of every 24 hours were noted. No stress of any kind was noticed until the grade 24.2. At 29.5 only 50 per cent of the siphons were active, but when replaced in optimum salinities for 24 hours, all the siphons were extended. It was not possible to continue the experiment for a longer period. To get convincing results, these molluscs will have to be observed for much longer periods, reproducing as much as possible the very gradual acclimatisation that takes place in its natural environment through a period of 3 to 4 months. However, it was possible to observe a slight shift in the tolerance, to a much higher grade than was noticed in the first experiment, where specimens were transferred suddenly to the different grades.

The data suggested the probability that the hardy forms found in the backwaters surviving the highly saline periods of the pre-monsoon, may represent a different kind produced from the larvae liberated during the final phases of spawning during November—December. The gonad of this species does not show either any indication of activity or signs of maturity during the highly saline periods. It is probable that they have special powers of endurance to this stress of the medium. To check whether this assumption is true, a test conducted in January when the salinity of the medium rose to 30 ‰ gave interesting results. The specimens used in this study were from a fresh set of specimens which settled during the early part of November. Contrary to the results of the previous experiment with specimens from the August set it was most interesting to note in these specimens normal activity and 100 per cent survival for 24 hours in all the panels from as low a grade as 0.5 ‰ (distilled water at the end of the test) to 38.3 ‰ in the twenty two different grades tested in this series. This suggests that these specimens are physiologically different, having the ability to effectively acclimatise to the changing salinity of the ambient water and some are capable of just surviving even in the high salinity of full sea water of the pre-monsoon period though incapable of reproduction. These become sexually mature and propagate the species on the onset of favourable salinity conditions during June—July when salinity drops owing to rainfall and drainage.

A fact of observation during the several tests conducted was that, except in the case of the tests on early developmental stages, (*vide infra*) two similar tests did not give exactly identical results. This may be seen from the observations recorded in Table I & II. In the first test, with 26.6 ‰ (Table I) at the end of 24 hours, the percentage of active individuals was 78, while in the experiment II reported in Table II, there was 100 per cent survival in 26.73 ‰ at

the end of 24 hours. Perhaps this was due to the fact that the number of specimens in the test block for the first test was comparatively less than that in the final test and may also be due to difference in the nature of specimens in the panels.

The experimental data on the effects of different grades of salinity on the developing eggs of *N. hedleyi* are presented in Table IV.

It may be seen that very low and very high salinities are not favourable for early development. In the highest grades the eggs become deformed while in the lowest grades they became oedematous. On the basis of the nature of development in the different

TABLE IV

Showing the effects of different grades of salinity on the developing eggs of *N. hedleyi*

| Range | Grade No. | Salinity ‰ | Extrusion of polar body | Nature of Segmentation | Beginning of movement | Percentage of moving embryos |
|-----------------------|-----------|------------|-------------------------|------------------------|-----------------------|------------------------------|
| Range I too low | 1 | 1.1 | nil | nil | nil | nil |
| | 2 | 1.91 | nil | nil | nil | nil |
| | 3 | 2.21 | few | nil | nil | nil |
| Range II low | 4 | 3.95 | 30 minutes | nil | nil | nil |
| | 5 | 4.36 | 30 minutes | abnormal | nil | nil |
| | 6 | 6.55 | 30 minutes | normal | 4 h | 40 |
| | 7 | 7.81 | 30 minutes | some abnormal | 4 h | 40 |
| Range III. Optimum | 8 | 8.73 | 30 minutes | mostly normal | 4 h | 50 |
| | 9 | 9.22 | 30 minutes | mostly normal | 4 h | 60 |
| | 10 | 9.70 | 30 minutes | mostly normal | 4 h | 65 |
| | 11 | 10.21 | 30 minutes | mostly normal | 4 h | 65 |
| | 12 | 10.44 | 30 minutes | mostly normal | 4 h | 75 |
| | 13 | 11.24 | 30 minutes | mostly normal | 4 h | 80 |
| | 14 | 11.91 | 30 minutes | mostly normal | 4 h | 80 |
| | 15 | 13.60 | 30 minutes | mostly normal | 4 h | 85 |
| | 16 | 14.54 | 30 minutes | mostly normal | 4 h | 82 |
| | 17 | 15.32 | 30 minutes | mostly normal | 4 h | 65 |
| Range IV High | 18 | 15.73 | 30 minutes | mostly normal | 4 h | 65 |
| | 19 | 16.80 | 30 minutes | mostly normal | 4 h | 50 |
| | 20 | 17.18 | 30 minutes | a few normal | few at 4 h | 35 |
| | 21 | 19.52 | 30 minutes | a few normal | few at 4 h | 30 |
| | 22 | 20.30 | 30 minutes | a few normal | few at 4 h | 20 |
| | 23 | 21.44 | 30 minutes | a few normal | few at 4 h | 15 |
| | 24 | 22.41 | 30 minutes | mostly abnormal | very few | 15 |
| | 25 | 23.42 | 30 minutes | mostly abnormal | nil | nil |
| | 26 | 25.26 | 30 minutes | mostly abnormal | nil | nil |
| Range V too high | 27 | 27.14 | nil | nil | nil | nil |
| | 28 | 28.15 | nil | nil | nil | nil |
| | 29 | 30.52 | nil | nil | nil | nil |
| | 30 | 33.84 | nil | nil | nil | nil |

grades of salinities, they may be grouped into five distinct ranges as shown in the table. When the fertilised ova were transferred to distilled water, the eggs swelled up and there was no further development. There was an increase in egg diameter from 53μ to about 80μ . In range I representing too low grades from 1 to 2.21‰ , though a few eggs extruded polar bodies, in the majority there was no perceivable development. Range II represents low salinities ranging from 3.95 to 7.81. There was uniformity in respect to the extrusion of polar bodies which was completed within a period of 30 minutes. However, the nature of segmentation was abnormal and the development defective, abnormal or incomplete till the grade 4.36‰ . While in the grade 4 (3.95) there was neither segmentation nor any development, in grade 5 (4.36) segmentation was abnormal and development abortive and in the grades 6 & 7 the embryos began to show signs of movement at the end of 4 hours which is the normal period for this species. Despite these apparent signs of normal development, only 40 per cent of the eggs succeeded in reaching this particular stage. The apparently optimum salinity for the early development of this species thus seems to be represented in range III between salinities 8.73 and 16.80‰ . The optimum range has been tentatively fixed in these experiments when 50 per cent of the eggs reached the stage of moving embryos. In these grades it may be seen that extrusion of the polar bodies was normal, followed by regular segmentation leading to the free moving stage of the embryo within a period of 4 hours. However, in no case the 100 per cent limit was noticed with reference to the moving embryos. Even within this range which is here designated as optimum, the range between 11.24 and 14.54 may be considered as most suited, with 80 per cent or more eggs reaching the stage of the moving embryos. In range IV the salinity may be considered high, since from 17.18 upwards, the cleavage became more and more abnormal and there was delay in the subsequent development with only a small percentage completing the target of moving embryos. After 22.41 segmentation was mostly abnormal and after 23.42 none reached the moving stage. Range V i.e., salinities above 27.14 seemed to be distinctly too high for this species, with no sign of development in any of the grades, since the majority of the eggs remained unchanged. These observations indicate that for the early development of *N. hedleyi* the most suitable salinity range seems to be 11.24 to 14.54‰ , with range 8.73 to 16.80‰ being suitable. In the grades above and below this range, segmentation was abnormal and the percentage of normally developing embryos fell considerably. In salinities lower than 4.36 and above 27.14‰ , there was no evidence of any development.

DISCUSSION

The reaction of shipworms to different salinities shows considerable variations. Some species can tolerate only high salinities, others can tolerate fairly wide range of salinities while a few are capable of enduring very low salinities and even fresh water.

The results of the tests with *N. hedleyi* give clues regarding the influence of salinity on the activity and development of this species. Though a majority of the adults are typically euryhaline, capable of enduring the whole range of salinities present in the environment, the breeding of the species is undoubtedly restricted to the low saline period in the Cochin backwaters. A review of the occurrence of this genus is given by NAIR & SARASWATHY (1971).

Records of the occurrence of *Nausitora* clearly show that this genus is sensitive to higher salinities of the medium and is therefore, restricted in its distribution to areas where estuarine conditions prevail. However, the results of the present study show that forms like *N. hedleyi* can withstand wider changes of salinity of the medium than allied species like *N. dunlopei* and are capable of tolerating much lower salinities than typical marine forms. In common with other typical estuarine organisms this species demonstrates characteristics of individual and species vigour. Thus great damage can be expected from species of this genus in the low saline localities of river mouths etc., where species sensitive to the stress of low salinities cannot survive. Thus *Nausitora* occupies this ecological niche very effectively thereby spreading the zone of operation of shipworms to river mouths and even farther upstream. The construction of dams both for hydro-electric power generation and irrigation across the major rivers of India and the consequent check on the river flow may lead to a greater spread of tidal water upstream and this can result in the extension of shipworm activity farther up the rivers.

References to salinity tolerance of shipworm larvae are very few. SCHELTEMA & TRUITT (1954) give a review of all previous observations which brings forth the fact that the larval forms cannot tolerate the lower limits of salinities which can be endured by the adults of the species. M'GONIGLE (1926) finds 10‰ detrimental to *T. navalis* larvae. EDMONDSON (1942) noticed that '60 hours is about an average period of resistance of various species of Hawaiian shipworms to freshwater', and that the larvae could survive only for much shorter time. LOOSANOFF & DAVIS (1963) have observed in the case of oysters that the older the larvae the better they withstood salinity variations. BROEKHUYSEN & FISCHER-PIETTE have found eggs of *Carcinus* and *Purpura lapillus* less tolerant than adults to low salinities

(See MOORE, 1958). KINNE (1963) observes that the narrowest range of tolerance is often confined to the period of embryonic development. Thus the adults apparently seem to have powers to tolerate a greater range of salinities than their larvae, a feature noticed in the present series of tests also for the estuarine species *N. hedleyi*.

SUMMARY

Nausitora hedleyi SCHEPMAN is the only species of shipworm present throughout the year in the Cochin backwaters, a tropical tidal estuary. During the course of the year the surface salinity fluctuates roughly between 0.5‰ to 34.00‰, depending on the monsoons and river discharges. Absence of any fresh settlement of the species on test blocks during the high salinity period was noticed.

To determine how the species reacts to changes in the salinity of the ambient water, a series of tests were conducted.

For early development of the species, the most suitable salinity range was found to be 11.24‰ to 14.59‰. Salinity of 29‰ and above was detrimental to the population during the low salinity period, but the hardy forms present in the backwater surviving the highly saline period were found capable of enduring a wider range from 0.5‰ to 38.3‰.

The reactions and the nature of activity of the two distinct populations of *N. hedleyi* in different salinity grades are described.

Results are discussed in relation to the activity and distribution of shipworms.

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