

The Biology of *Nausitora Hedleyi* (Schepman) in the Cochin Backwaters

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The tropical estuarine shipworm *Nausitora hedleyi* Schepman is a highly destructive species in the Cochin back waters. In this area this species occurs throughout the year, during the course of which the salinity of the medium may fluctuate between 33.63 ‰ and 0.65 ‰. The reactions and nature of activity of *N. hedleyi* in different salinities are described, the lethal salinity determined and the effects of gradual acclimatisation ascertained. The most suitable salinity range for the early development has also been determined for the species. The sequence of sexual phase in *N. hedleyi* has been elucidated, the reproductive cycle is described based on a study of the gonad index, and the nature of settlement has been studied using test panels. The results of the above mentioned tests indicate that the breeding of *N. hedleyi* is strictly seasonal in the estuarine conditions prevailing in the Cochin backwaters being restricted to the period of medium salinities. Growth rates of *N. hedleyi* were followed based on a scrutiny of the burrow length, increase in weight of the body, increase in length of the pallet and increase in the size of the shell. The effect of over crowding on growth rates is explained. A brief account is also presented on the fluctuations of the various biochemical constituents of the body of the shipworm in relation to the breeding cycles. The effects of hydrographical conditions on the activities of this species are discussed.

Introduction

Nausitora hedleyi Schepman is a very destructive shipworm in the Cochin backwaters. Even though this species is found throughout the year in the estuarine conditions prevailing in this habitat, the breeding is apparently restricted to the low saline period. In this tropical estuary the wet season with low salinity is in the summer and the resultant changes in the salinity and temperature are both considerable. Though lower salinities may be tolerated at summer temperatures in general (Moore : 1958), the drop in this locality is not slow and steady but sudden and continues to be at a very low level for a long period and in this process several less adapted stenohaline representatives of the sea are ruthlessly removed. The south-west monsoon is active over the west coast during the period May-August and there is also some influence of the north-east monsoon during November-December causing both reduction and fluctuations of salinity in the backwaters. In this estuary there is inflow of fresh water at the upper end and there is influx of saline water from the sea through the narrow bar mouth

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during high tide, and diluted sea water flows out during ebb tide. Though tropical estuaries support a much wider range of species, in the Cochin backwater, *N. hedleyi* is the only shipworm which occurs throughout the year, during the course of which the surface salinity of the medium may fluctuate between 33.63 *p.p.t.* and 0.65 *p.p.t.* The continued existence of *N. hedleyi* under this wide range of salinity during the annual cycle is a remarkable physiological adaptation. A series of tests were conducted to find 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 salinity on the early developmental stages.

Besides this, other aspects of the biology of this estuarine shipworm such as the sequence of sexual phases, the reproductive cycle, nature of settlement, growth rates and fluctuations in the biochemical constituents in relation to the breeding cycle have also been studied.

Material and methods

Cleaned wooden panels infested with *N. hedleyi* were used for the tests on salinity tolerance. The panels after a period of acclimatisation were transferred to different grades of salt water and examined at definite intervals of time and the length and activity of the siphons recorded. Material used for the salinity tolerance of developing eggs was obtained from healthy mature specimens using artificial fertilisation. Nature of settlement was studied by exposing wooden test panels at the Ernakulam channel. Biochemical tests were done using standard procedures (see, Saraswathy and Nair 1969).

Results and discussion

In Table 1 is presented the nature of activity of the siphons and the percentage of mortality of the shipworms in the various grades of salinity. Results of this test indicated that the lethal salinity can be expected between 25 and 29 *p.p.t.* To fix the exact salinity detrimental to the species, another experiment was conducted. The results of this are presented in Table 2, which shows the percentage of specimens alive at the end of 1, 2, 3, 4, 5 and 6 days in the respective salinities. These results also indicate a general interruption of function in salinities above 25.28 *p.p.t.* As a matter of fact in the Cochin backwaters some could live even in as high a salinity as 34 *p.p.t.* during the pre-monsoon period extending from about February to May. This observation prompted to test whether gradual acclimatisation to higher salinities may enable the animal to tolerate wider ranges of salinities. It was possible to observe a shift in the tolerance to a much higher grade than was noticed in the first test where specimens were transferred suddenly to the different

grades. Observations showed that the hardy forms found in the backwaters surviving the highly saline periods of the pre-monsoon represented physio-

TABLE 1—SHOWING NATURE OF ACTIVITY OF *N. HEDLEYI* IN DIFFERENT SALINITIES

Salinity <i>p.p.t.</i>	Time taken for display of siphone	Nature of response of siphons after 24 hours	Length of siphons		Percentage of specimens alive after 24 hours
			1-6 hrs	24 hrs.	
1	2	3	4	5	6
0.43	1 hour	moderate	...	3 mm	100
1.42	"	"	1 mm	5 mm	100
2.83	"	"	1.5 mm	5 mm	100
3.1	"	rapid	1.5 mm	5.5 mm	100
3.6	"	"	1.5 mm	5 mm	100
4.7	"	"	2 mm	5 mm	100
6.4	"	"	1.5 mm	6 mm	100
8.1	"	"	2.6 mm	6 mm	100
10.3	"	"	3 mm	7.5 mm	100
11.1	Immediate	"	4.5 mm	7 mm	100
13.8	"	"	4.5 mm	7 mm	100
14.9	30 minutes	"	4.0 mm	7 mm	100
17.4	2½ hours	"	4 mm	6 mm	100
21.4	within 24 hrs.	"	1.5 mm	6 mm	100
24.7	"	moderate	1 mm	6 mm	100
26.6	"	"	0 mm	5 mm	78
29.6	No display	Nil	nil	nil	nil
31.7	"	"	nil	nil	nil
33.8	"	"	nil	nil	nil

TABLE 2—SHOWING THE PERCENTAGE OF SPECIMENS ALIVE AT THE END OF 1,2,3,4,5 & 6 DAYS IN THE RESPECTIVE SALINITIES
S.P.P.T.=SALINITY PARTS PER THOUSAND

Days	S. <i>p.p.t.</i> 28.89	S. <i>p.p.t.</i> 27.99	S. <i>p.p.t.</i> 26.73	S. <i>p.p.t.</i> 25.28	S. <i>p.p.t.</i> 24.4	S. <i>p.p.t.</i> 23.26	S. <i>p.p.t.</i> 22.41	S. <i>p.p.t.</i> 21.33	Control 13.04-18.0 <i>p.p.t.</i>
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

gically different forms having the ability to effectively acclimatise to the changing salinity of the ambient water from as low a grade as 0.5 *p.p.t.* to 38.3 *p.p.t.* Nevertheless, these are incapable of reproduction until June-July when the salinity becomes favourable for breeding activity.

The effects of different grades of salinity (Table 3) on the developing eggs
 TABLE 3—SHOWING THE EFFECTS OF DIFFERENT GRADES OF SALINITY
 ON THE DEVELOPING EGGS OF *N. HEDLEYI*

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

of *N. hedleyi* indicated the following facts. (1) Very low and very high salinities are not favourable. (2) The optimum salinity for the early develop-

ment is apparently the range between salinities 8.73 and 16.80 *p.p.t.* in which extrusion of polar bodies was normal followed by regular segmentation leading to free moving stage of the embryo within a period of 4 hours. Even within this range which is here designated as optimum, the range between 11.24 and 14.54 may be considered as most suited. These studies indicated that adults apparently seem to have powers to tolerate a greater range of salinities than the larvae as observed by Kinne (1963).

The breeding period of *N. hedleyi* was determined by scrutinising the gonad index of adult specimens, and the settlement of larvae on test panels. In Table 4 is presented the average gonad indices for the males, females, speci-

TABLE 4—SHOWING AVERAGE GONAD INDICES (G. I.) OF THE MALES, FEMALES AND SPECIMENS WITH INDETERMINATE GONADS

Month	No. examined	Average G. I. for the month	Male		Female		Indeterminate	
			No.	G.I.	No.	G.I.	No.	G.I.
November	14	15.81	4	18.35	11	14.79	—	—
December	13	15.42	4	10.93	9	17.42	—	—
January	12	6.11	4	7.18	6	7.25	2	0.52
February	14	7.29	7	8.04	6	7.63	1	gonad very small
March	14	12.8	—	—	2	20.65	12	11.49
April	12	15.56	4	17.31	—	—	8	10.68
May	7	13.46	3	13.48	2	15.02	2	11.87
June	12	4.99	2	5.73	2	5.63	8	4.65
July	12	16.36	9	13.99	3	23.45	—	—
August	12	23.62	8	21.39	4	28.09	—	—
September	15	32.28	7	30.48	7	33.12	1	39.09
October	16	32.45	8	28.54	6	35.12	2	39.82

mens of indeterminate sex as well as the average for the total number collected during the respective months. The months showing high values in general are indicative of greater gonadal activity and, may, therefore, be considered as the breeding period and the months showing comparatively low values suggest either a spawned out condition or a resting period. The data clearly show that *N. hedleyi* is not a continuous breeder in this locality. The high values noted for females during the months following June till October suggest very high activity of the ovary during this period. High gonadal activity of *N. hedleyi* is restricted in this habitat to a period of nearly six months from July to December. It was considered worthwhile to check the results obtained from a study of the gonad index by following the incidence of post settled stages on test panels.

In Tables 5 and 6 are presented the results obtained from an examination

TABLE 5—SHOWING THE SEASONAL SETTLEMENT OF SHIPWORMS ON SHORT-TERM PANELS (A SERIES)

Period of immersion	<i>Nausitora hedleyi</i>				<i>Teredo furcifera</i>		
	Panel No.	Inter-tidal	Sub-tidal	Bottom	Inter-tidal	Sub-tidal	Bottom
Pre-Monsoon							
1st Feb. — 1st Mar.	A1	—	—	3	11	159	507
1st Mar. — 1st Apr.	A2	—	—	—	35	217	305
1st Apr. — 1st May	A3	—	—	—	30	145	340
1st May — 1st June	A4	—	—	—	81	113	258
Monsoon							
1st June — 1st July	A1	—	—	—	2	5	43
1st July — 1st Aug.	A2	—	—	7	—	—	5
1st Aug. — 1st Sept.	A3	9	3	21	—	—	—
1st Sept. — 1st Oct.	A4	—	6	9	—	—	—
Post-Monsoon							
1st Oct. — 1st Nov.	A1	2	15	9	—	—	—
1st Nov. — 1st Dec.	A2	—	43	31	—	2	—
1st Dec. — 1st Jan.	A3	—	11	9	7	14	25
1st Jan. — 1st Feb.	A4	—	3	1	13	12	49
Total for the year		11	81	90	179	667	1532

TABLE 6—SHOWING THE SEASONAL SETTLEMENT OF SHIPWORMS ON THE LONG-TERM PANELS (B SERIES)

Period of immersion.	Panel No.	<i>Nausitora hedleyi</i>			<i>Teredo furcifera</i>		
		Inter-tidal	Sub-tidal	Bottom	Inter-tidal	Sub-tidal	Bottom
Pre-Monsoon							
1st Feb. — 1st Mar.	B1	—	—	3	11	159	507
1st Feb. — 1st Apr.	B2	—	—	—	23	76	221
1st Feb. — 1st May	B3	—	—	—	13	111	434
1st Feb. — 1st June	B4	—	—	—	21	94	487
Monsoon							
1st June — 1st July	B1	—	—	—	2	5	43
1st June — 1st Aug.	B2	—	9	17	7	3	26
1st June — 1st Sept.	B3	14	43	49	—	14	93
1st June — 1st Oct.	B4	29	57	62	1	No data	
Post-Monsoon							
1st Oct. — 1st Nov.	B1	2	15	9	—	—	—
1st Oct. — 1st Dec.	B2	127	193	138	—	—	9
1st Oct. — 1st Jan.	B3	39	223	207	11	31	54
1st Oct. — 1st Feb.	B4	28	213	220	9	46	117
Total for the year		239	753	705	98	539	1991

of the short-term and long-term test panels to note the larval strike during the pre-monsoon, monsoon and post-monsoon periods. To the question whether the settlement takes place in a restricted season or evenly throughout the year this system provides a direct answer. It is clear from the data that the settlement of *N. hedleyi* at Cochin harbour is not continuous but strictly seasonal. The data show that during the present study, November represents the period of intense settlement by the species. Another period when fair settlement was noticed was during August. The long-term series give an idea of the progress of settlement during the pre-monsoon, monsoon and post-monsoon periods. The general trend of settlement is the same in both the series, there being practically little settlement during the pre-monsoon period.

An interesting sequence of sexual phases has also been noticed in this species. This is of special interest since this species is one of the few tropical molluscs with a restricted breeding period owing to the influence of salinity. Details regarding the sexual condition in specimens examined are presented in Table 7. There is a preponderance of ambisexual males among smaller

TABLE 7—NAUSITORA HEDLEYI CONDITION OF THE SEX OF SPECIMENS

Length group in mm	True males		Ambisexual males		Hermaphro- dites		Females		Immature		Total No. of specimens
	No.	%	No.	%	No.	%	No.	%	No.	%	
1-50	4	1.7	128	55.9	—	—	45	19.7	52	22.7	229
50-100	5	4.5	53	48.2	6	5.5	33	30	13	11.8	110
100-150	1	1.4	23	31.4	14	19.2	27	37	8	11	73
150-200	—	—	3	14.3	5	23.8	13	61.9	—	—	21
200-250	—	—	7	43.8	—	—	9	56.2	—	—	16
250-300	—	—	2	20.0	1	10	7	70	—	—	10
Above 300	—	—	2	18.2	—	—	9	81.8	—	—	11

individuals (1-50 mm) and as growth continues there is tendency towards increase in the percentage of females with hermaphrodites appearing in the intermediate size group (50-200 mm). This suggests protandry and a probable change of sex from the initial bisexual male phase to the female phase. Of the 26 hermaphrodites examined only a few had gametes of both sexual types in the same follicle, 25 changing from the male to the female phase and one in the 250 to 300 mm size group was apparently changing from female to male, giving evidence of a probable change from female to male during the breeding season.

The growth rates of *N. hedleyi* in the indigenous timber *Mangifera indica* were examined taking into consideration the length of the burrow, wet and dry weights of the animal, weight of the shells and of the pallets, the number of denticulated ridges over the shell, length and height of the shell, proportion of the pallet blade and stalk and the number of cones that form the blade were all considered over a period of nearly six months. The salient features of growth rates of this species assessed on the basis of the above mentioned characters were as follows. Growth was rapid during the period between 45 and 135 days after settlement with the maximum growth between 105 and 120 days of age. Thereafter growth slackened and the trend indicated that growth was negligible at the end of 150 days. This might be owing to retardation in growth as a result of the effects of over-crowding and the depletion of substrate preventing further boring and to effects of an unfavourable salinity.

Studies on the biochemical constituents in relation to breeding cycles revealed the following interesting facts. The water content varied from 57.04–83.60% with an average from specimens of varying sizes collected throughout the year of 71.49% for this species. The relatively low values obtained are probably due to the stress of high salinity on the life and activity of this shipworm. An inverse relationship between the water content of the body and the salinity of the ambient water was evident. Glycogen values were notably high during the non-breeding months especially during February to May when they fluctuated between 33.35 and 52.22% of the dry weight of the animal. From June to January the values were comparatively low. On the onset of breeding season there was a perceivable fall in the glycogen content probably owing to the initial mass spawning during June. After January the values were comparatively high and reached the highest value for the year in March. The protein content was generally high from June to January. The total nitrogen content was, apparently, steady both during the breeding and non-breeding periods. Non-protein nitrogen content was generally poor during a major part of the breeding season. The lipid content expressed in terms of percentage of dry weight varied from 3.46 in June to 8.34 in November and was low during April and May. A distinct correlation between lipid content and breeding period was not evident. The percentage of salts (chloride as sodium chloride) expressed as percentage of dry tissues showed a distinct fall on the onset of breeding season, which in this case, coincided with a fall in salinity. During the highly saline period of February, March and April the salt content of the body was low. Similarly the ash content also showed a noticeable fall soon after the onset of breeding. The values for calcium and phosphorus were comparatively high during July, August and September and were low during October and November. The data regarding the mineral constituents give the impression that coinciding with the period of spawning and the consequent loss of weight owing to a

fall in organic constituents there is an apparent increase as in oysters (Durve and Bal : 1961).

Thus two periods of variations are noticeable, one from June to December coinciding with breeding activity and the other from January to May representing a period of rest. During the breeding period values for water content, protein, total nitrogen and in general for calcium and phosphorus are high while during the non-breeding period glycogen and non-protein nitrogen show an increase with an apparent fall in the percentage of the constituents which showed higher values during the first period.

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