# THE SHIPWORMS OF SOUTH INDIA WITH A NOTE ON THE BREEDING SEASON OF *BANKIA INDICA* NAIR

BY

N. Balakrishnan Nair, Ph.D.

*Department of Zoology, Alagappa College, Karaikudi*

(*With a plate, three text figures, and a graph*)

## Introduction

The importance of the preservation of timber structures against the attack of marine borers has been recognised in India only very recently. While the teredines of Europe, Australia, the Pacific Islands, and the New World are well known, and we possess a vast body of information about the taxonomy of these molluscs through the papers of Jeffrey (1860), Wright (1865), Hedley (1901), Calman (1919), Bartsch (1921, 1922, 1923, 1927), Miller (1924), Lamy (1927), Sivickis (1928), Moll and Roch (1931, 1937), Iredale *et al.* (1932), Edmondson (1942, 1946), no serious attention has been paid to a systematic study of the shipworms of the Indian waters. Our present knowledge of the shipworms of India is due mainly to the contributions of Erlanson (1936), Roonwal (1954), Ganapati and Nagabhushanam (1955), and Palekar and Bal (1955), but none of these authors have made any exhaustive investigations into the taxonomy, anatomy, or physiology of these borers. In spite of the Indian coast-line of about 3,000 miles and a continental shelf of more than 100,000 square miles, and dependence on wooden country log-rafts and dug-out canoes for fishing operations, and timber for marine construction, it is strange that so little is known regarding these marine borers which cause immense economic loss to underwater wooden structures all along the sea-front. A taxonomic survey of the shipworms was, therefore, undertaken during 1953, especially as it would serve as a foundation for further work. The information presented in the following pages represents the results of an attempt to investigate the biology of these borers in the Indian waters as a preliminary to further investigations. It is most likely to help persons interested in the depredations by marine borers and to be of importance to industries and persons who have interest in local waterfront structures.

In order to procure specimens of as many of the existing species of borers as possible, and information as to their relative and actual importance and period of activity, different types of timbers such as drift logs, floating seeds, underwater wooden structures like piles, wharves, floating fenders, hulls of boats, and catamarans, were carefully examined. Further, a system of test planks were submerged in selected sites in the sea for the procurement of material for the study.

The teredines collected by the author from the South Indian waters are listed below on the basis of the classification used by Bartsch (1922).

LIST OF SHIPWORMS COLLECTED FROM SOUTH INDIA[1]

Genus **Bankia** Gray

1. *Bankia* (*Bankia*) *bengalensis* Nair
2. *Bankia* (*Bankia*) *bipalmulata* Lamarck

Sub-genus BANKIELLA Bartsch

3. *Bankia* (*Bankiella*) *indica* Nair
4. *Bankia* (*Bankiella*) *edmondsoni* Nair

Sub-genus NEOBANKIA Bartsch

5. *Bankia* (*Neobankia*) *lineata* Nair

Sub-genus NAUSITORA Bartsch

6. *Bankia* (*Nausitora*) *madrasensis* Nair
7. *Bankia* (*Nausitora*) *gabrieli* Nair

Genus **Teredo** Linnaeus

8. *Teredo* (*Teredo*) *madrasensis* Nair
9. *Teredo* (*Teredo*) *parksi* Bartsch
10. *Teredo* (*Teredo*) *furcillatus* Miller
11. *Teredo* (*Teredo*) *indica* Nair
12. *Teredo* (*Teredo*) *navalis* Linnaeus

Sub-genus TEREDORA Bartsch

13. *Teredo* (*Teredora*) *gregoryi* Dall *et al.*
14. *Teredo* (*Teredora*) *clava* Gmelin
15. *Teredo* (*Teredora*) *rehderi* Nair
16. *Teredo* (*Teredora*) *minoris* Nair

Sub-genus ZOPOTEREDO Bartsch

17. *Teredo* (*Zopoteredo*) *bengalensis* Nair

Sub-genus TEREDOTHYRA Bartsch

18. *Teredo* (*Teredothyra*) *linearis* Nair

The information regarding the distribution of the species along the Indian coast, the relative amount of damage of which the different species are capable, and the ecological conditions under which they live is very scanty. Such knowledge is necessary in order that possible attack may be predicted and prevented, or actual attack reduced in intensity or altogether stopped. There also seemed to be little information available regarding the food requirements of these borers, and still less about their breeding habits and development.

During the course of the systematic study, the author found that there are different species of borers infesting the same type of timber,

---

[1] A detailed account of this is in the course of publication in *Records of the Indian Museum.*

as well as a single species infesting different types of timber (Nair, 1956). *Bankia indica*, the commonest form found in the clear off-shore waters of Madras, was found to attack mainly red cedar (*Cedrela*) and *Melia composita*. *Teredo gregoryi* and *Teredo madrasensis* rank second and third in abundance and degree of destruction, and attack a wider range of timber *Cedrela toona*, *Terminalia* sp., *Aegle marmelos*. On the west coast it was found that piers and jetties made of teak (*Tectona grandis*), coco-nut stems (*Cocos nucifera*), and mango wood (*Mangifera indica*) are affected by *Bankia* (*Nausitora*) *gabrieli* and *Teredo navalis*. *Teredo navalis* was obtained in large numbers from parts of discarded country canoes of *Thespesia* in the Pulicat Lake and from the turtle cages of *Borassus flabellifer* in Tondi. The more important forms collected from Madras harbour were *Teredo madrasensis*, *Teredo furcillatus*, *Teredo indica*, and *Teredo parksi*, chiefly from underwater timber structures, and with the help of test panels of *Myristica* sp. *Teredo clava* was collected from the floating corky seeds of the mangrove *Carapa* sp. *Teredo rehderi* was found infesting *Mangifera indica*, *Bursera* sp., and also from drifting bamboo poles. *Bankia lineata* was obtained in large numbers from floating logs washed ashore on Madras beach during the monsoon times. (Plate, photo 1.)

## The Resistance of Untreated Timbers to Marine Borer Attack

From an examination of 16 species of timbers belonging to eleven families, Nair (1956*a*) observed that green sections without exception offered more resistance to marine borers than did dry ones. It was also noticed that barks of timbers offer considerable protection against these pests. Of the 16 species studied, only very few showed any notable resistance and the majority showed no promise of any resistance at all. Coco-nut and palmyra stems showed considerable powers of resistance for the first 12 months and teak for 6 months of the experiment. Hence, untreated coco-nut and palmyra stems, as well as teak wood, assure their usefulness for sea-water exposures for some months at least, and even for longer duration if properly treated.

The exact factor which serves as the security against marine borers is not properly understood. It has been shown that presence in appreciable amounts of silica, alkaloids, oils, acids, and resins can inhibit the activity of the borers (Edmondson, 1955).

## The Marine Growths and their Effects on Borer Attack

During the course of the study, the effect of marine growths on the attachment of borer larvae was studied. It was observed that undisturbed marine growth retarded larval infestation with a consequent effect on the development of borer destruction. It is probable that the barnacles, polyzoans, tunicates, and the mussels found in large numbers on the test panels, when alive would consume great quantities of the larvae as part of their planktonic diet. The barnacles provide calcareous bases, which adhere to the timber so closely that they prevent outside penetration into the areas they cover,

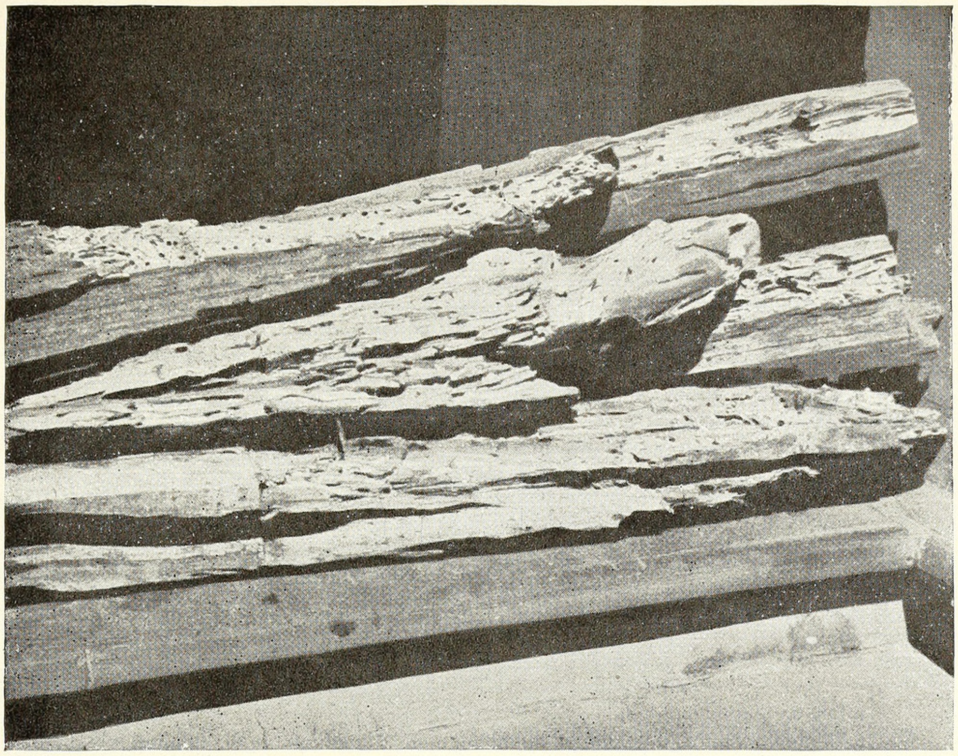


PHOTO 1. Experimental test planks of *Cedrela* sp. showing the destruction caused by Shipworms.

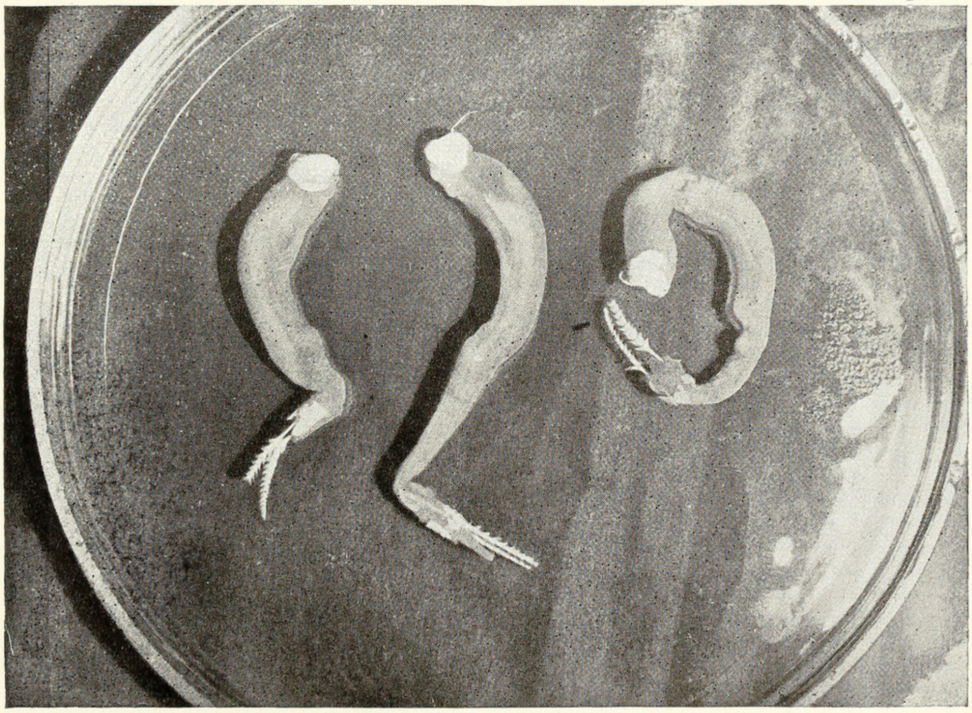


PHOTO 2. Three entire Shipworms (*Bankia indica*).

even after the death of the animal. The dense fleshy compound tunicates also probably can temporarily slow down the attack of borers.

## **Bankia indica** Nair

### GENERAL ORGANISATION OF THE BODY

The common shipworm *Bankia indica* occurring in large numbers on the fishing floats used in San Thome, Madras was studied in detail regarding the anatomy, sex changes, breeding season, development, and physiology of digestion.

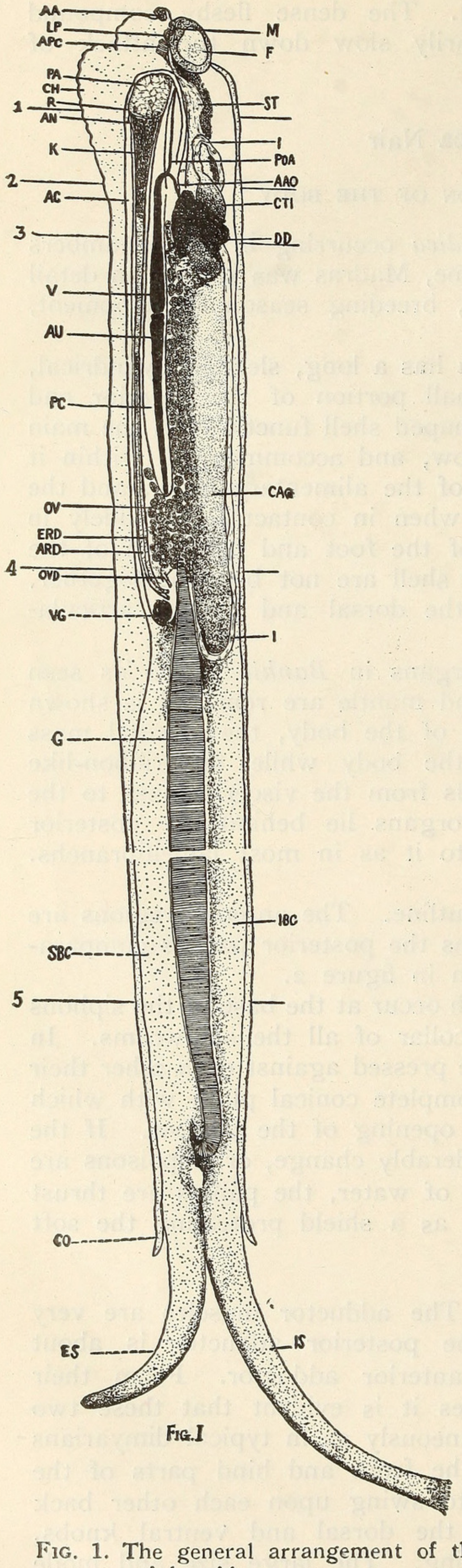
Like other teredines, *Bankia indica* has a long, slender, cylindrical, and soft body. Covering only a small portion of the anterior end of the visceral mass, the irregularly-shaped shell functions as the main organ for the excavation of the burrow, and accommodates within it only the discoidal foot, anterior part of the alimentary canal, and the adductor muscles. The shell valves when in contact gape widely in front and behind for the projection of the foot and extension of the body respectively. The edges of the shell are not brought together, because of the modified contact on the dorsal and ventral articulations. (Fig. 2.)

The general arrangement of the organs in *Bankia indica* as seen from the right side when the shell and mantle are removed is shown in figure 1. Due to the lengthening of the body, the visceral mass occupies approximately a third of the body while the ribbon-like posterior part of the ctenidium extends from the visceral mass to the base of the siphons. Most of the organs lie behind the posterior adductor muscle instead of anterior to it as in most lamellibranchs. (Fig. 1.)

The shell valves are irregular in outline. The anterior regions are sculptured with sharp denticles whereas the posterior part is comparatively smooth. The details are shown in figure 2.

Pallets are peculiar structures which occur at the base of the siphons on either side beneath the muscular collar of all the shipworms. In *Bankia indica*, when the two pallets are pressed against each other their semi-circular outer surfaces form a complete conical plug, with which they can effectively close the circular opening of the burrow. If the salinity of the sea water should considerably change, or if poisons are introduced or the timber is taken out of water, the pallets are thrust into the opening, closing the burrow as a shield protecting the soft animal inside.

The Adductor Muscles: The adductor muscles are very highly modified. In cross-section the posterior adductor is about 11 times larger in area than the anterior adductor. From their position and attachment on the valves it is evident that these two muscles instead of contracting simultaneously as in typical dimyarians do so alternately, drawing together the front and hind parts of the shell valves causing the two valves to swing upon each other back and forth on the pivot formed by the dorsal and ventral knobs. This type of movement helps in boring. The large size and mode




*Key to the Lettering of Figure.*

| | |
|---|---|
| AA | Anterior adductor. |
| AAO | Anterior aorta. |
| AC | Anal canal. |
| AN | Anus. |
| APC | Anterior part of the ctenidium. |
| ARD | Afferent renal duct. |
| AU | Auricle of the heart. |
| CAG | Caecum of the stomach. |
| CH | Cephalic hood. |
| CO | Collar of the mantle. |
| CTI | Coiled typhlosole of the intestine. |
| DD | Digestive diverticula. |
| ERD | Efferent renal duct. |
| ES | Exhalant siphon. |
| F | Foot. |
| G | Gill. |
| I | Intestine. |
| IS | Inhalant siphon. |
| K | Kidney. |
| LP | Labial palp. |
| M | Mouth. |
| OV | Ovary. |
| OVD | Oviduct. |
| PA | Posterior adductor. |
| PC | Pericardium. |
| POA | Posterior aorta. |
| R | Rectum. |
| SBC | Suprabranchial cavity. |
| ST | Stomach. |
| V | Ventricle. |
| VG | Visceral ganglion. |

FIG. 1. The general arrangement of the organs in *Bankia indica* as seen from the right side.

of attachment of the posterior adductor suggest that the valves can be brought together at the anterior end, and that its vigorous adduction is responsible for the powerful outward thrust of the anterior part of the shell valves. The divarication of the denticulated front ends is of significance in the boring operations, the relatively feeble adduction through the contraction of the anterior adductor being sufficient to bring back the shell to normal position.

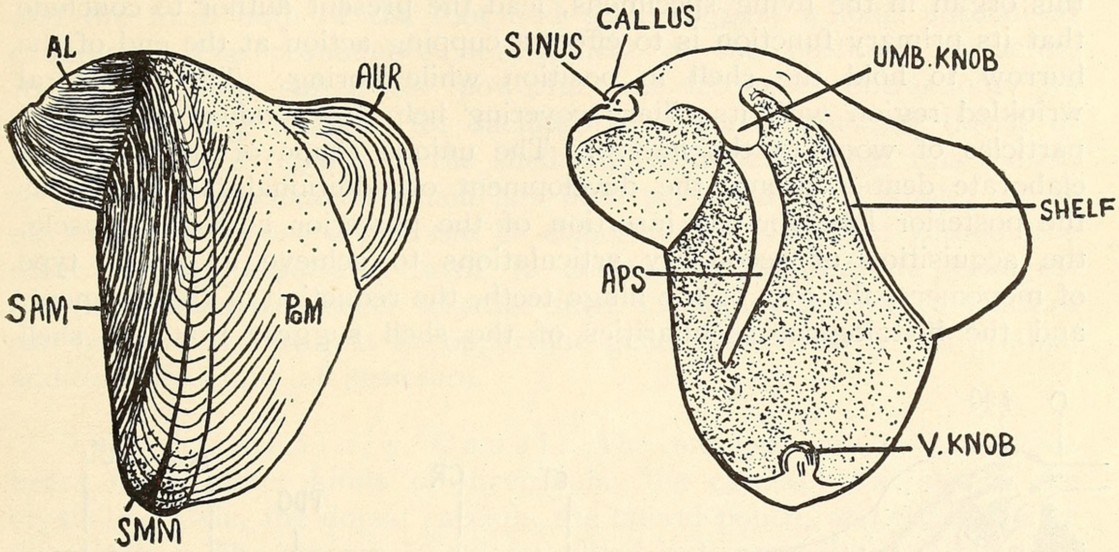



FIG. 2. Outer and inner views of the shell of *Bankia indica.*

*Key to the Lettering of Figures.*

| | |
|---|---|
| AL | Anterior lobe. |
| AUR | Auricle of shell. |
| APS | Blade. |
| POM | Posterior median lobe. |
| SAM | Anterior median lobe. |
| SMM | Middle median lobe. |

The Foot: The foot of *Bankia indica* is short and cylindrical, and is situated at the extreme anterior end of the visceral mass ventral to the mouth. This organ serves to grip at the burrowing end, while the shell is rotated round this point of attachment during the drilling process. The front surface of the foot which is thus applied to the wood is cordate in outline with a smooth central disc-like area or 'sole' bounded by elevated, wrinkled, peripheral, glandular margins, which are ciliated and thrown into folds. This shape and structure are quite in keeping with its habit of using this organ for attachment.

The Boring Mechanism: The foot of this pelecypod illustrates how plastic the organic body proves when an animal adopts an entirely new habit. It is so specialised that it is just a subcircular disc with pedal muscles of other lamellibranchs modified for assisting in boring into wood. There has been much discussion as to whether these animals do this boring by mechanical or chemical means or a combination of both. Notwithstanding the correct suggestion of Home that the foot adheres to the wood acting as a centre-bit while the animal is boring with the shell, there have been repeated claims that the foot is directly concerned with the boring activities (Jeffreys, 1865; Hedley 1901; Kuhlman, 1914). These authors considered that the shell effects a grip on the sides of the burrow supporting the foot against the wood. A study of the histological structure of the organ in *Bankia indica,* as well as observation of this organ in the living specimens, lead the present author to conclude that its primary function is to effect a cupping action at the end of the burrow to hold the shell in position while boring. The peripheral wrinkled region with its ciliary covering helps to conduct the grated particles of wood to the mouth. The unique shape of the shell, its elaborate denticulations, the development of additional faces such as the posterior lobe for the insertion of the posterior adductor muscle, the acquisition of secondary articulations to achieve a special type of movement, the loss of the hinge teeth, the reduction of the ligament, and the histological peculiarities of the shell suggest that the shell

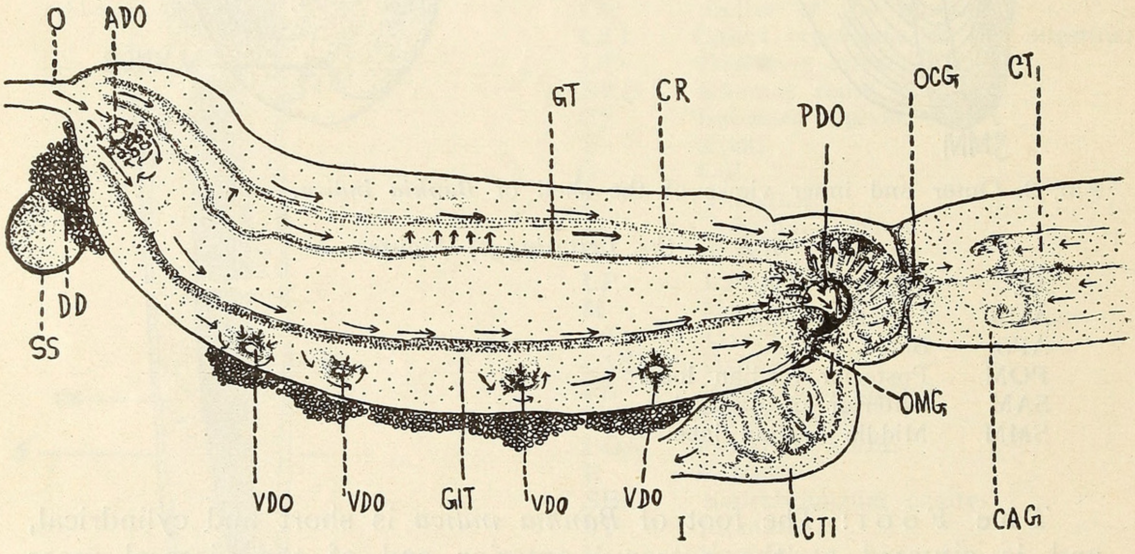



FIG. 3. Diagrammatic sketch of the stomach and caecum showing the ciliary currents.

*Key to the Lettering of Figure.*

| | |
|---|---|
| ADO | Anterior openings of the digestive diverticula. |
| CAG | Caecum of the stomach. |
| CR | Ciliated ridge. |
| CT | Coiled typhlosole. |
| CTI | Coiled typhlosole of the intestine. |
| DD | Digestive diverticula. |
| GIT | Gastro-intestinal typhlosole. |
| GT | Gastric typhlosole. |
| O | Oesophagus. |
| OCG | Opening of the stomach into the caecum. |
| OMG | Opening of the stomach into the intestine. |
| PDO | Posterior opening. |
| SS | Style sac. |
| VDO | Ventral openings of the diverticula. |

in *Bankia* has a specific function to perform. When one considers that the shell in these forms is not only a boring organ but a feeding organ as well, Hedley's suggestion (1901) that the shell in Teredinidae is degenerate and the next step would be its complete disappearance sounds strange. It is true that the shell has lost its protective character, but in this specialised bivalve in which protection is afforded by the nacre-lined burrow the shell is assigned the role of scraping such fine particles of wood as will be easy to feed upon, and the form both of the foot and shell suggest a long specialised evolution. The pronounced development of the posterior adductor, its fibres being suited for powerful and frequent contractions, its insertions being adapted for facilitating powerful outward thrust of the denticulated regions of the shell valves, indicates that this muscle is part of a mechanism which has been perfected as a whole. It is obvious that no one organ can be elaborated or simplified without the other organs associated with it undergoing appropriate changes. One is inclined to wonder whether such a complex mechanical pattern can be produced by just an opportune gene pattern or by the gradual addition of details of structure.

The Alimentary Canal: The stomach of *Bankia indica* bears five distinct kinds of diverticula, the caecum, the sac of the crystalline style, the dorsal caecum, the lateral pouch, and the digestive diverticula. The caecum is a long cylindrical, non-ciliated, blind tube extending from the stomach, and forms the largest part of the alimentary canal. This organ is usually filled with wood particles and its ventral wall is infolded to form a two coiled typhlosole extending through the entire length. The free edge of the typhlosole is further rolled up, considerably increasing the internal surface area of the caecum. The wood particles held between the folds of this typhlosole are found in a state of dissolution, suggesting that a certain amount of digestion of wood takes place in the caecum. The crystalline style sac is pyriform and opens into the stomach at its left side on the anterior end. It contains the crystalline style, which is a gelatinous flexible body of a glassy transparency, shaped like a club. The style of this form is smaller than those of *Martesia* and *Mya*. Since the style matter is continuously added on, the style was found intact, retaining its bulk in all specimens, assisting both in digestion by the liberation of the enzymes as well as in the mechanical process of pushing the particles of wood into the stomach. The gastric shield, which in other bivalves functions as a protective shield against the abrasive action of the tip of the rotating style, covers only a very small area of the stomach wall. The dorsal caecum is an outpocketing of the anterior, dorsal wall of the left side of the stomach. Since this sac also is filled with particles of wood, it is probable that it serves as a receptacle for large particles of wood, too many of which would block the proximal region of the stomach and impede normal functioning. The lateral pouch is a distinct outpocketing of the stomach wall in between the dorsal caecum and the sac of the crystalline style. Since the wall of this pouch shows several muscle fibres it is probable that this sac by its pulsations aids in the movement of food in the stomach. The digestive diverticula are composed of numerous blind tubules and occupy the ventral region and posterior side of stomach and also extend into the foot and communicate with the stomach by ducts. Those of the posterior side are by far the largest and are distinguishable into a large more dorsal right half and a small left half. The right part is brownish green and lies on the right side of the posterior part of the stomach, while the left part is fawn-coloured, composed of few tubules and containing particles of wood. The ducts being lined by ciliated epithelium help the movement of particles. These facts and the presence of wood particles in the fawn-coloured region lead to the inference that this region of the digestive diverticula serves as a place where wood can be received and acted upon by enzymes.

Even though the essential food-collecting mechanism of the gills is represented and functions as in typical lamellibranchs, the enormous development of the caecum and the attenuation of the branchial groove into a passage of such a length and narrow diameter that the food particles that can travel along this to the mouth become limited in size and quantity. This involves such a rigorous elimination, that the major part of the plankton and suspended particles conveyed by the water currents have to be rejected as pseudofaeces. Thus the function the gill discharges as a region of reception of food in other lamellibranchs is minimised owing to the high specialisation towards the exploitation of the wood which they bore into as food. This accounts for the absence of plankton and diatoms in the alimentary canal. As a direct consequence of the specialisation towards a wood boring habit and a diet of wood particles, this mollusc has become so incapable of making full use of the water-borne planktonic food that, when the wood supply is exhausted, it becomes helpless even-though it is equipped with enzymes which can digest carbohydrates, fats, and proteins, available from the plankton (Nair, 1955).

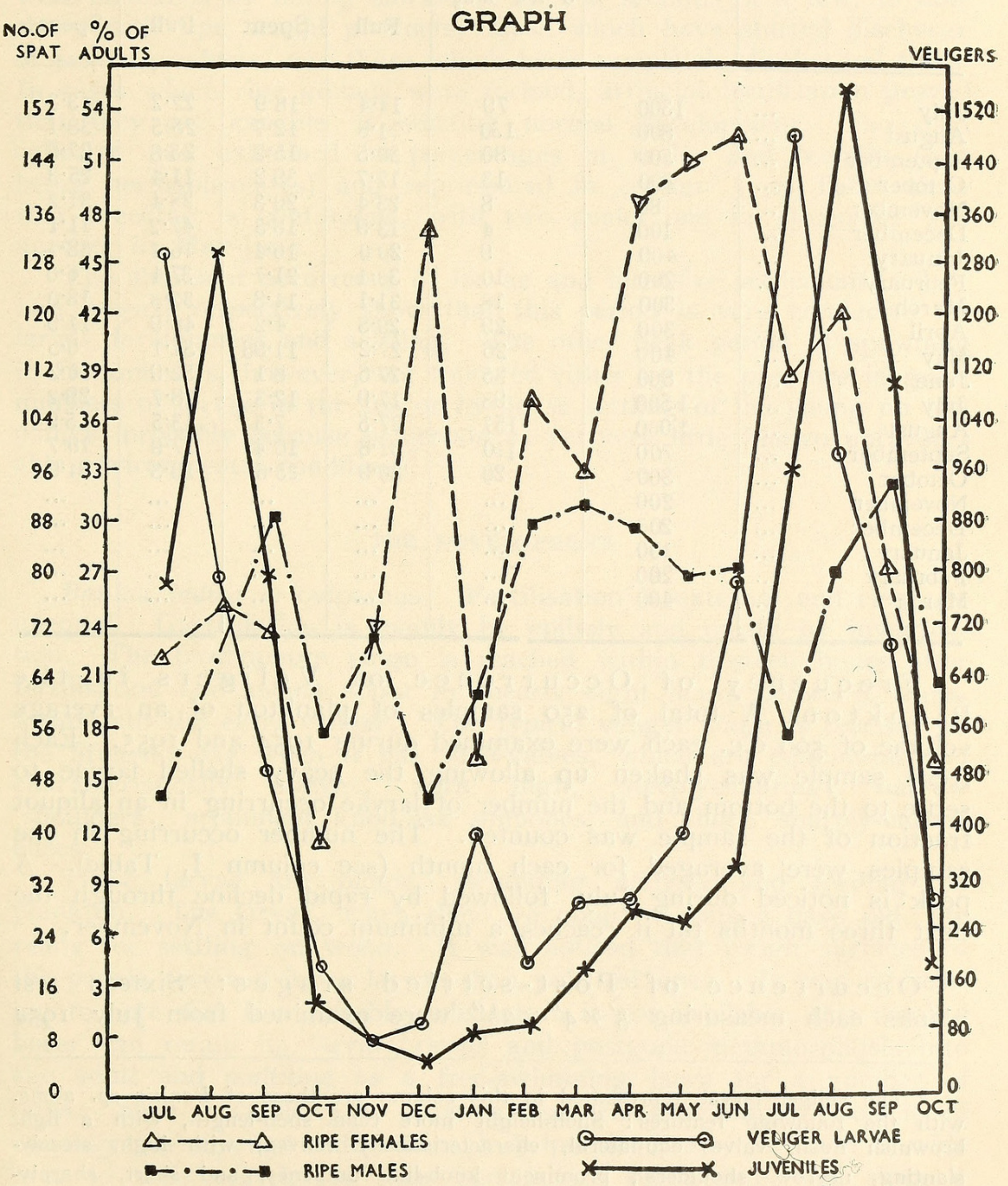
## THE SEX CHANGES

*Bankia indica* is unique in the possession of a seminal receptacle closely connected with the reproductive organs. In these timber borers which live in floating wood and therefore form isolated communities, storage of sperms and their conservation will be of survival value.

*Bankia indica* is essentially protandric, nearly all females passing through a preliminary functional male phase before reaching the female phase. In view of the presence of a few spermatocytes in the cortical regions of the follicles, it is not improbable that the females after a functional spawning phase may revert to the male phase and produce spermatozoa.

## THE BREEDING SEASON

During the course of the study, it was felt that an exact knowledge regarding the breeding season of *Bankia indica* will be of value to formulate means for the conservation of timber against their attack. In this boring pelecypod, as in many invertebrates of tropical seas, breeding appears to be continuous, marked by seasonal intensity. The frequency of the occurrence of larvae in plankton tow-netted in the in-shore area, the appearance of post-settled stages on test planks, as well as the condition of the gonads of adults studied during the different months support this conclusion.




GRAPH. Curves illustrating the occurrence of larval veligers in plankton, settlement of spat on test planks, and the condition of the adults in respective months.

TABLE

Table showing the gonadic condition of adult *Bankia indica*, the frequency of the occurrence of the larvae in plankton, and the number of post-settled stages on test planks in respective months.

| Month | | 1<br>Veliger* larvae in plankton 500 cc.. | 2<br>Post-settled stage 2 cm. long from test panel 5′ × 4″ × 3½″ | 3<br>Percentage of adults from test panels of 5′ × 4″ × 3½″ | | | |
|---|---|---|---|---|---|---|---|
| | | | | Males | | Females | |
| | | | | Full | Spent | Full | Spent |
| July | ... | 1300 | 79 | 14·4 | 18·9 | 22·2 | 43·3 |
| August | ... | 800 | 130 | 21·8 | 12·7 | 25·5 | 38·1 |
| September | ... | 500 | 80 | 30·5 | 15·2 | 23·8 | 27·6 |
| October | ... | 200 | 13 | 17·7 | 39·2 | 11·4 | 25·3 |
| November | ... | 80 | 8 | 23·4 | 20·3 | 23·4 | 31·2 |
| December | ... | 100 | 4 | 13·9 | 19·3 | 47·2 | 11·1 |
| January | ... | 400 | 9 | 20·0 | 16·4 | 16·4 | 38·1 |
| February | ... | 200 | 10 | 30·1 | 21·7 | 37·4 | 6·0 |
| March | ... | 300 | 18 | 31·1 | 14·8 | 32·8 | 18·0 |
| April | ... | 300 | 29 | 29·8 | 4·2 | 48·9 | 14·9 |
| May | ... | 400 | 26 | 27·2 | 11·96 | 51·1 | 6·5 |
| June | ... | 800 | 35 | 27·6 | 8·1 | 52·9 | 10·2 |
| July | ... | 1500 | 98 | 17·9 | 12·3 | 38·7 | 29·2 |
| August | ... | 1000 | 157 | 27·5 | 7·3 | 43·5 | 15·9 |
| September | ... | 700 | 110 | 32·8 | 16·4 | 27·9 | 19·7 |
| October | ... | 300 | 20 | 20·9 | 25·6 | 16·3 | 34·9 |
| November | ... | 200 | ... | ... | ... | ... | ... |
| December | ... | 200 | ... | ... | ... | ... | ... |
| January | ... | 100 | ... | ... | ... | ... | ... |
| February | ... | 200 | ... | ... | ... | ... | ... |
| March | ... | 400 | ... | ... | ... | ... | ... |

Frequency of Occurrence of Veligers in the Plankton: A total of 250 samples of plankton of an average volume of 500 c.c. each were examined during 1954 and 1955. Each fresh sample was shaken up allowing the heavy shelled larvae to settle to the bottom and the number of larvae occurring in an aliquot fraction of the sample was counted. The number occurring in the samples were averaged for each month (see column I, Table). A peak is noticed during July, followed by rapid decline through the next three months till it reaches a minimum count in November.

Occurrence of Post-settled stages: Sixteen test planks each measuring 5′ × 4″ × 3½″ were examined from July 1954

* The veliger larvae represented in this column are those of *Bankia* sp. alone, with the following features: Shell-height more than shell-length, with a light brownish flush, valves equilateral, characteristically convex, with high, steeply-slanting, narrow 'shoulders', prominent knob-like umbones, and short, sharply-curved bases; well-spaced lines of growth present, especially towards the ventral margin where radial rays are also distinguishable; at the posterior end of the foot a transparent byssus thread is present.

to October 1955 for post-settled stages (about 2 cm., long which it reaches within a month). These blocks which were anchored in the sea off San Thome at a distance of about three miles from the shore were removed each month and brought to the laboratory. The shipworms were carefully chiselled out and the number of juveniles noted. The post-settled stages were observed during all the months, but they were clearly more during the month of August than at other times as will be seen from column 2, Table.

Condition of the Adults: The gonads of 1287 adult shipworms collected from test planks in the course of sixteen months were examined by taking smears of all and sections of a few, to note those with ripe sexual products, those which have started discharge of sexual products, and those which have completely discharged them. In cases where ripe gonads were formed, artificial fertilisation proved that they are capable of starting normal development. The data collected and examined in percentages of males and females (rest being hermaphrodites) and represented in column 3 of Table show that breeding is continuous, with two peaks one in December and another in May-June.

The abundant occurrence of larvae and intensive settlement in July and August respectively show that this period is very conducive for larval development and settling. The other peak period of spawning in December is, however, not followed either by the presence in great numbers of larvae in the sea or by dense settling of the young on test planks, probably because of certain as yet very little known unfavourable environmental conditions.

## THE DEVELOPMENT

*Bankia indica* is oviparous. Fertilisation is external and cleavage unequal. Gastrulation is mainly by epiboly and partly by invagination. The trochophore stage is reached within thirteen hours after fertilisation and swims about for nearly eight hours before it transforms into the early veliger. The typical veliger stage is reached on the fifteenth day when it has shell-valves, which are equilateral and characteristically convex, with high, steeply-slanting, narrow 'shoulders', prominent knob-like umbones, and short, sharply-curved bases.

These larvae are plagic, swimming actively and feeding on plankton. The larvae, when they are about seventeen days old, are ready for settling on wood. It was noticed that rough surfaces of the panels received more larvae than polished ones. It was interesting to note that if a suitable substratum is not available, this tropical borer can retain its larval organs and postpone metamorphosis into the adult and continue as a free-swimming larva for a number of days. Such a capacity to prolong the free-swimming period is of considerable survival value since it helps the larvae to cover a wide area in their search for their appropriate substratum, and since it increases the chances of their encountering a piece of wood on which they can settle and perpetuate the species (Nair, 1956*b*).