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Feeding and extracellular digestive rhythms in some intertidal bivalve molluscs

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Abstract. The tidal rhythms for changes in morphology, length, dry weight and protein content of the crystalline style are studied in two venerid clams, *Meretrix meretrix* and *Katelysia opima* and in a donacid clam, *Donax cuneatus*. In the two venerid clams the style is housed in a sac conjoined with midgut and there is a tidal rhythm of feeding and extracellular digestion involving a partial dissolution of the style in the ebb tide and reformation in flood tide. But in the donacid clam where the style sac is completely separated from midgut, no detectable changes in the style parameters are recorded during a tidal cycle. However, the rhythmicity in feeding activity is indicated, by the presence of 'mudcap' and food particles in the style during flood tide and their subsequent absence during ebb tide. Hence the tidal rhythm of feeding and digestion in *Donax cuneatus* may be without corresponding changes in the crystalline style. Also this study throws light on the mode of style dissolution.

Keywords. Crystalline style; extracellular digestive rhythm; tidal rhythm; *Meretrix*; *Katelysia*; *Donax*.

1. Introduction

Feeding and digestive processes in bivalve molluscs are generally considered to be continuous and simultaneous provided that the environmental conditions are favourable (Owen 1966; Purchon 1968). But recent studies by Morton (1973, 1983) have suggested that many bivalves from mid-tidal to sub-littoral zone have clearly defined cycles of feeding and extracellular digestion in stomach and intracellular digestion in digestive diverticula. Morton (1956) has shown in *Lasae rubra* and Hameed (1984) in *Cranostrea madrasensis* and *Anadara rhombea* that there is a tidal rhythm of feeding and digestion and the style is completely dissolved when the tide ebbs and reformed during flood tide. Tidal rhythm in feeding and extracellular digestion involving partial dissolutions and reformation of the crystalline style was also recorded in *Cardium edule* (Morton 1970), *Pecten maximum* (Mathers 1976) and *Mytilus edulis* (Langton 1977). The purpose of the present investigation was to find out the presence of rhythms of feeding and extracellular digestion in 3 intertidal bivalve species.

2. Materials and methods

Meretrix meretrix (Linnaeus), shell length 60–61 mm and *Katelysia opima* (Gmelin), shell length 40–42 mm were collected from the mud flats of the Vellar estuary at

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Porto Novo (lat. 11°29′ N and 19°49′ E long.) and transferred to a series of wooden quadrants that were exposed at the low tide for 3 h during each tidal cycle. The bivalves were acclimated to these conditions for a week before the commencement of the experiments. The donacid clam *Donax cuneatus* (Linnaeus), shell length 39–41 mm were sampled directly from the intertidal zone of Porto Novo sea shore. Each species was sampled at 90 min intervals for a continuous period of 15 h. The sampling periods were based on the Indian Tide Table part I, 1982.

2.1 *Length of crystalline style*

The crystalline style was extracted from each species by dissection, washed in distilled water and blotted dry. The length of the style was measured to the nearest 0·1 mm. After measuring the length, the styles were preserved in 10% formaldehyde solution.

2.2 *Dry weight*

The crystalline styles of 5 individuals from each sample were dried in a hot air oven (60°C) to constant weight. The dry weight of each style was determined on a micro-balance to the nearest 0·1 mg.

2.3 *Total protein*

The protein content of the style was determined by the modified biuret method of Raymont *et al* (1964). The percentage of protein was estimated individually for 5 styles from each sample.

2.4 *Relative size of entire style and its central core*

Formaldehyde preserved styles were used for this purpose. Cross sections (2–3 mm) were made with sharp razor at the region of maximum width. The diameter of the central granular core and that of the entire style were measured micrometrically. The ratio of the granular core diameter to the total style diameter was calculated. This study was limited to *K. opima* and *D. cuneatus*.

3. Results

The rhythmic changes in the crystalline style length, dry weight and protein content and physical consistency in relation to tidal cycle in *M. meretrix* and *K. opima* are presented in figure 1. The maximum values for these style parameters recorded during high tide regime gradually decreased during low tide. Thus in *M. meretrix* (shell length 60–61 mm) the style length fluctuated between 30·9 ± 0·8 mm and 33·0 ± 1·1 mm, style dry weight between 7·2 ± 0·7 mg and 9·4 ± 0·5 mg and style protein between 9·9 ± 0·8% and 11·9 ± 0·8% (figure 1).

The pattern of rhythmicity observed in the style of *K. opima* was essentially similar to that of *M. meretrix*. During the tidal cycle, *K. opima* (shell length 40–42 mm)

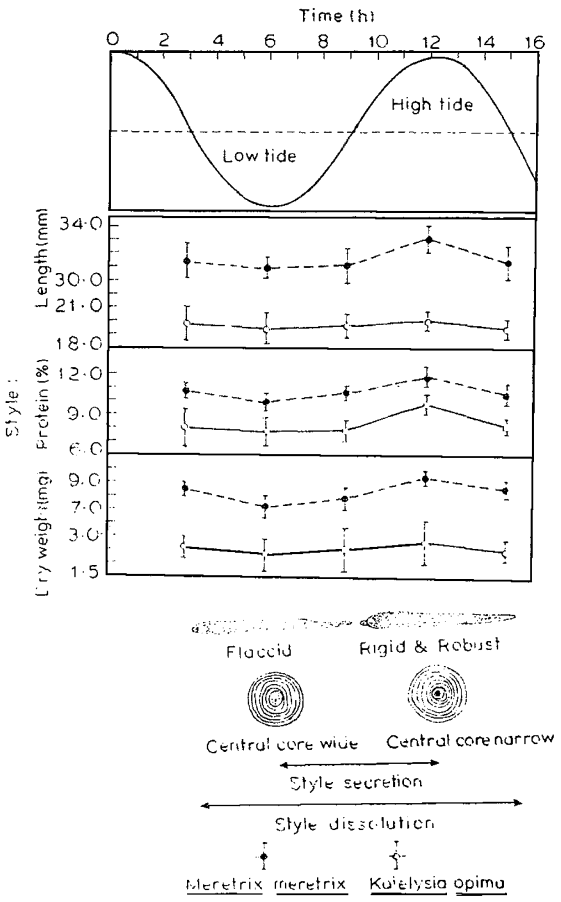

Figure 1. Rhythmic changes involving partial dissolution of the crystalline style in *M. meretrix* and *K. opima* during a tidal cycle (values are mean ± SD of 5 styles).

showed variation in the style length (19·4 ± 1·2 mm at low tide and 20·0 ± 0·7 mm at high tide), style dry weight (2·3 ± 0·6 mg in low tide and 2·8 ± 0·8 mg in high tide) and style protein content (7·7 ± 1·2% at low tide and 8·6 ± 0·8% at high tide).

The changes in the physical consistency of the crystalline style observed in *M. meretrix* and *K. opima* were also similar. During high tide the style was a firm conical transparent rod-like structure. The style head was covered with a firm 'mud cap', a mixture of organic particles and sand grains and extruded style matrix, and the body of the style embedded with food particles. The food laden mucous cord from the oesophagus was also found connected to the head of the style. During the low tide period, the style became flaccid. The 'mud cap' and adherent food particles were absent. The semi fluid central granular matrix was found oozing out from the head indicating the active process of dissolution.

Examination of cross section of *K. opima* style revealed that the style consisted of a central semi fluid granular core surrounded by a concentric rings of crystalline layers. The ration of the central core diameter to the entire style diameter during peak high tide was minimum (0·22) and maximum during low tide (0·55).

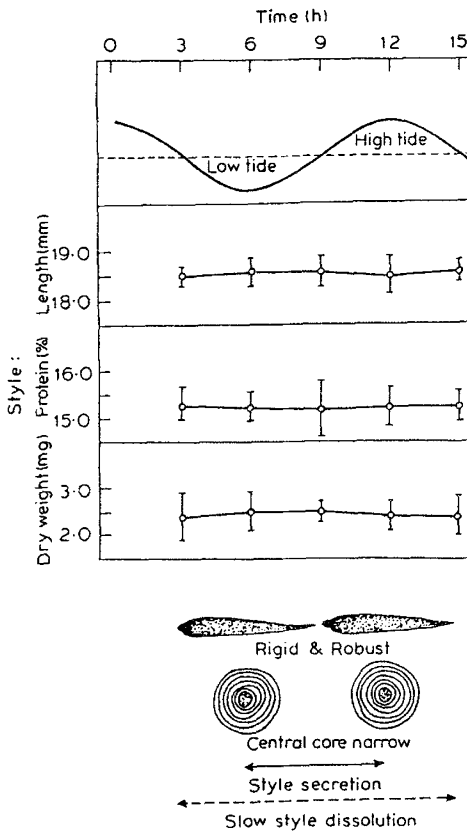

Figure 2. Changes in crystalline style of *D. cuneatus* during a tidal cycle (values are mean ± SD of 5 styles).

No detectable changes in style parameters was recorded in *D. cuneatus* during a tidal cycle (figure 2). The style was rigid and robust throughout the tidal cycle. However, the rhythmicity in feeding activity was indicated by the presence of a 'mud cap' and food particles in the style during high and their absence in low tide. The diameter of central core did not vary with the tidal cycle and the ratio of central core diameter to the style diameter remained constant (0·1) throughout the tidal cycle.

4. Discussion

The crystalline style is a prominent structure in the digestive system of most bivalve and a few gastropods. It is primarily concerned with feeding and extracellular digestion. The style is assumed to rotate and drag the food laden mucous cord into stomach and triturate it against the gastric shield (Morton 1952). The style also dissolves slowly liberating into stomach, a number of carbohydrases and lipases (Owen 1974; Morton 1983). Feeding and digestive processes in the intertidal bivalve molluscs are influenced greatly by the tidal cycle (Morton 1983). The present study indicates that the feeding and extracellular digestion are rhythmic and correlated to the phases of tide in all the 3 species tested. In *M. meretrix* and *K. opima* where the

style is housed in a style sac conjoined with midgut. The rhythmic changes in the style parameters observed in a tidal cycle suggest that style secretion is restricted to high tide regime and cessation of secretory activity may promote the style dissolution during the low tide regime. Morton (1970) established through histological study that the style of *C. edule* is secreted only during high tide. Langton and Gabott (1974) have shown in *Ostrea edulis* a correlation between the tidal cycle and changes in pH, total protein and length of crystalline style. Langton (1977) reported variation in style pH, style length and style amylase of *M. edulis* in relation to tidal cycle.

From the observation made in the present study, it is considered that the style secretion is periodic and takes place during high tide only and its dissolution is continuous throughout the tidal cycle contrary to the view of Morton (1973). Hameed (1985) reported that the optimum pH (8·0) for *in vitro* style dissolution of *M. meretrix* and *K. opima* approximately corresponds to the pH of the high tide water of the Vellar estuary and hence the style is likely to dissolve faster during high tide and releases digestive enzymes into the stomach and promote the extracellular digestion. Style dissolution during high tide has also been suggested by Mathers (1974, 1976) in *Ostrea* and *Pecten*. The visual observation of style dissolution during high tide is probably concealed since dissolution of the style is profitably compensated by the secretion of new style matrix. The increase in the central core diameter of the style of *K. opima* in low tide implies that the concentric crystalline layers become liquefied into more liquid granular central core which moves anteriorly into stomach. *In vitro* observation of the style under low power of the microscope reveals that the dissolution of style is effected by expelling the style material from the central core. This observation formed the basis for the concept of continuous style dissolution. A similar mode of dissolution was also reported by Kristensen (1972). It is therefore, suggested that the dissolution of style housed in conjoined style sac, is a continuous physical process, taking place throughout the tidal cycle while style secretion is a physiological and rhythmic one, occurring only during the high tide.

The stability of the crystalline style of *D. cuneatus* over a tidal cycle can be attributed to the fact that the style in this species is housed in a style sac completely separated from the midgut. Therefore the style in *D. cuneatus* is isolated from the influence of the gut content as suggested by Yonge (1923). However, the rhythmicity in feeding activity is indicated by the presence and absence of adherent 'mud cap' and food particles on the style. In the case of *D. cuneatus* the rhythm of feeding and digestion may be without corresponding changes in the crystalline style.

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References

Hameed P S 1984 *Studies on the crystalline style of some bivalve molluscs of Porto Novo coastal waters*, Ph.D. thesis, Annamalai University, Annamalainagar

Kristensen J H 1972 Structure and function of crystalline styles of bivalves; *Ophelia* **19** 91–108

Langton R W 1977 Digestive rhythms in the mussel *Mytilus edulis*; *Mar. Biol.* **41** 53–58

Langton R W and Gobbott P A 1974 The tidal rhythm of extracellular digestion and response to feeding in *Ostrea edulis*; *Mar. Biol.* **24** 181–187

Mathers N F 1974 Digestion and pH variation in two species of oysters; *Proc. Malacol. Soc. London* **41** 37–46

Mathers N F 1976 The effects of tidal currents on the rhythm of feeding and digestion in *Pecten maximus* L; *J. Exp. Mar. Biol. Ecol.* **24** 271–283

Morton B S 1970 The tidal rhythm and rhythm of feeding and digestion in *Cardium edule*; *J. Mar. Biol. Assoc. UK* **50** 499–512

Morton B S 1973 A new theory of feeding and digestion in the filter feeding Lamellibranchia; *Malacologia* **14** 63–79

Morton B S 1983 Feeding and digestion in the Bivalvia; *Mollusca* **5** 65–147

Morton J E 1952 The role of crystalline style; *Proc. Malacol. Soc. London* **29** 85–92

Morton J E 1956 The tidal rhythm and action of digestive system of the lamellibranch *Lasaea rubra*; *J. Mar. Biol. Assoc. UK* **35** 563–586

Owen G 1966 Digestion; *Physiol. Mollusca* **2** 53–56

Owen G 1974 Feeding and Digestion in Bivalvia; *Adv. Comp. Physiol. Biochem.* **5** 1–35

Purchon R D 1968 *The biology of mollusca* (Oxford: Pergamon Press)

Raymont J E G, Austin J and Linford E 1964 Biochemical studies on the marine zooplankton I. The biochemical composition of *Neomysis integer*; *J. Cons. Perm. Int. Explor. Mer.* **28** 354–363

Yonge C M 1923 Studies on the comparative physiology of digestion. The mechanism of feeding, digestion and assimilation in the lamellibranch: *Mya. Brit. J. Exp. Biol.* **1** 15–63