Vol. 4: 365–367, 1981 | MARINE ECOLOGY – PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published March 31

SHORT NOTE

Ciliary Movements in Guts of Early Clupeoid and Salangid Larvae

T. Iwai[1] and H. Rosenthal[2]

[1] Department of Fisheries, Kyoto University, Kyoto, 606 Japan
[2] Biologische Anstalt Helgoland, Zentrale, Palmaille 9, D-2000 Hamburg 50, Federal Republic of Germany

ABSTRACT: Ciliated epithelial gut cells were studied in newly-hatched larvae of the clupeoids *Clupea harengus, Clupanodon punctatus, Engraulis japonicus* and the salangid *Salangichthys microdon*. Ciliary movements occur mainly in the posterior part of the gut; they start shortly after hatching and disappear within a few days. Ciliated cells in the gut epithelium of early larval stages are interpreted as retained features of a more primitive type of gastric epithelium.

Ciliated epithelial cells in the digestive tract are, in general, uncommon in teleost fishes – apart from some primitive members of the Actinopterygii (Barrington, 1957). In larvae of two teleost species, *Plecoglossus altivelis* and *Hypomesus olidus*, Iwai (1967 a, b) discovered ciliated cells in the gut epithelium and suggested that these provide a means for transporting food particles in the gut for a limited period during early larval life. Both his observation and conclusion were in need of confirmation and extension. This note presents further information on ciliary activities in the guts of larvae of the clupeoids – herring *Clupea harengus*, gizzard shad *Clupanodon punctatus*, anchovy *Engraulis japonica* – and of the salangid *Salangichthys microdon*.

Herring larvae were obtained from artificially fertilized, laboratory-incubated eggs of Baltic spring spawners. Water temperatures during incubation and growth were ca 10 °C. Gizzard shad larvae and anchovy larvae were raised from fertilized eggs collected in coastal waters of the Japan Sea. Two series of rearing experiments were conducted in full strength salinity and at different water temperatures (ca 20 °C and 25°–27 °C). *Salangichthys microdon* larvae were reared in the laboratory from artificially fertilized eggs obtained from Yoshii River, Okayama Prefecture, Japan. Incubation and rearing temperatures ranged from 11.8° to 13.7 °C.

Ciliary movements in the gut epithelium were observed in larvae anaesthetized with MS 222 (0.01 %) and placed in a watch glass under an ordinary light microscope. With transmittant light, the gut epithelium was visible through the transparent body wall. For additional histological studies, larvae at various stages were fixed in 10 % formalin. Serial paraffin sections (7 μm) were stained with Mayer's haemalaun and eosin.

Larvae of the 3 clupeoid fishes do not hatch at the same developmental stage. Newly-hatched larvae of gizzard shad and anchovy appear to be in a much less advanced stage than herring larvae; mouth and gut lumen are not yet open, eyes unpigmented. Newly hatched herring are far more developed; their mouth and gut are functional and their eyes pigmented. However, the digestive organs are very similar in all 3 species at the stage of initial feeding. The gut is a long, straight tube reaching almost to the caudal base; it consists of foregut, midgut and hindgut. The lining of the foregut is composed of cuboidal epithelial cells; these cells are stratified near the pharyngeal portion. The lining of the relatively long midgut and of the short hindgut consists of a simple columnar epithelium. The columnar epithelial cells are distally covered by the striated border consisting of microvilli. The nucleus is located in the basal half of the cells. This columnar epithelium (Fig. 1a) harbours ciliated epithelial cells.

In herring larvae (ca 7 mm total length = TL), ciliary movements became visible in the posterior half of the gut 1d after hatching. Ciliary movements were especially vigorous in the posterior portion towards the anus; cilia beats were directed backwards. Ciliated

* Prepared under the auspices of Japanese-German scientific and technical cooperation agreement (Publication No. 3)

0171-8630/81/0004/0365/$ 02.00

fields seem to occur in patches scattered over the inner surface of the gut. This suggests that ciliated cells are located among normal columnar cells provided with microvilli, as in the larvae of *Plecoglossus altivelis*. Ciliary movements disappeared in herring larvae about 2 d after hatching, except in the gut end near the anus.

In gizzard shad larvae (ca 4.2 mm TL), weak ciliary movements were observed in the posterior half of the gut 2 d after hatching. When the larvae were 6 mm

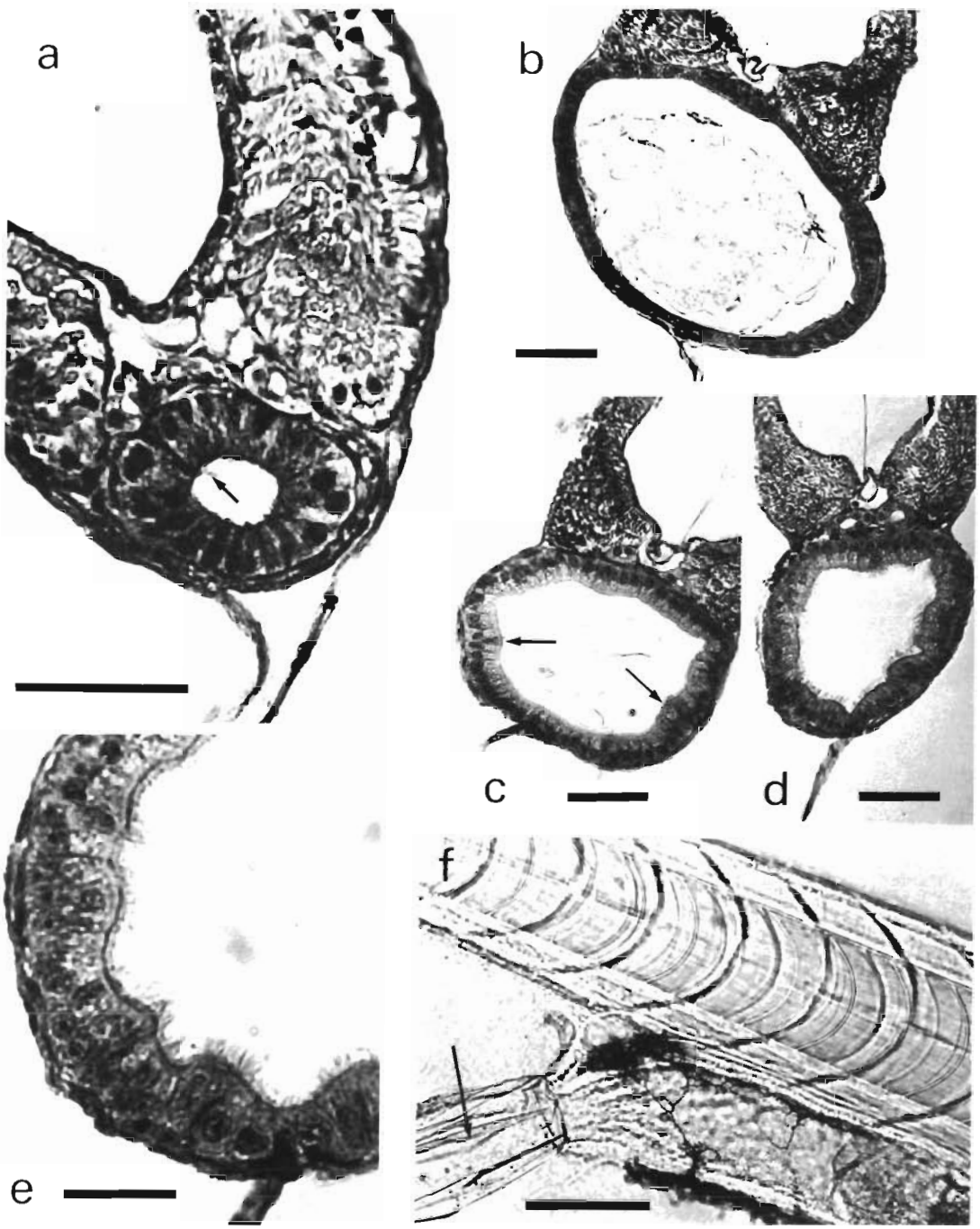

Fig. 1. (a) Cross section of newly hatched herring larva (7 mm TL) showing ciliated gut epithelium (arrow). (b–e) Cross sections of larvae of *Salangichthys microdon* (7.6 mm TL); (b) Mid gut containing food (rotifer); note the epithelium which is composed entirely of usual columnar cells with striated border (c) Anterior region of ciliated epithelium with interspersed ciliated cells; arrows show ciliated cells. (d) and (e) Ciliated epithelium of hind gut. (f) Larva of *S. microdon* showing fecal lorica of rotifer (arrow) protruding from anus. Calibration bars: 50 μm for a–d; 20 μm for e; 0.2 mm for f

long, 3 d after hatching, they displayed conspicuous ciliary movements in the same region of gut as just described. Thereafter, ciliary movements became indiscernible, except in the posterior gut end. Ciliary currents were still recognized just in front of the anus even in larvae measuring 10 mm.

In anchovy larvae (3.5–4.8 mm TL), ciliary movements were seen in parts of the posterior portion of gut, ca 2 d after hatching. Ciliary currents were especially conspicuous near the anus. Occasionally peristalsis was observed in the muscular coat of the gut. All anchovy larvae examined died at this stage.

Newly-hatched larvae of *Salangichthys microdon* (5.3 mm TL) possess a very elongated yolk sac reaching almost to the anus. Their mouth is still undeveloped, but a straight gut tube runs from the pharyngeal region to the anus, situated far back as in clupeoid larvae. Within 24 h after hatching, the larvae reached an average length of 5.7 mm and their jaws became functional. The epithelium of the gut exhibited, in general, the same features as in clupeoid larvae. In well-fed larvae the gut lumen was expanded and the columnar epithelium was rather low in the mid part of the gut (Fig. 1b). In the anterior region of the ciliated epithelium, ciliated cells occurred sparsely among the usual columnar cells with microvilli on their distal border (Fig. 1c). In the posterior region, especially in the hind gut, a number of ciliated cells lie on the epithelium (Fig. 1d, e).

In 1-d old larvae (ca 5.7–5.9 mm TL), ciliary movements were visible along the epithelium of the posterior region of the gut. In 3-d old larvae (6.8 mm TL), vigorous ciliary movements were observed in the posterior region of the gut, 2.1 mm anterior to the anus. In 4-d old larvae (6.9–7.0 mm TL), the transition from the mid gut to hind gut was marked by a prominent constriction. Ciliary movements were vigorous in the posterior half of the gut, especially near the anus. The rotifers used as larval food and fecal lorica conveyed by ciliary currents were often seen at the anus opening (Fig. 1f). In 7-d old larvae (8.8 mm TL), ciliary movements were still observed in the posterior region of the gut including the anus.

Recently, Wang et al. (1980), reported the occurrence of ciliated gut epithelium in larval eels. The function of this ciliated epithelium remains to be explained. A considerable body of literature deals with ciliated cells in the anterior portion of the digestive tract (e.g. esophageal or gastric mucosa; see for example, M'Intosh and Prince, 1890; Hopkins, 1895; Purser, 1928). Based on the fact that fishes with a ciliated gastric mucosa are primitive members of the Actinopterygii, Barrington (1957) offered the fairly plausible explanation that ciliated cells represent a retained feature of a more primitive type of gastric epithelium. This view is supported by the fact that ciliated epithelial cells are usually found in the intestine of both larval and adult lampreys (Battle and Hayashida, 1965; Yamamoto, 1965). Phylogenetically, ciliated cells in the gut epithelium of clupeoid larvae may be an example of retained primitive features.

The appearance of ciliary movements in the gut of clupeoid larvae seems to coincide with a certain part of the initial feeding period. Therefore, it cannot be excluded that ciliated epithelial cells of the gut are partly responsible for transporting food material. Engulfed particles are moved towards the end of the gut by a combination of ciliary action and peristaltic waves of the gut wall. Furthermore, ciliary currents near the anus participate in faeces elimination. Hence, ciliated cells seem to serve for transporting food and faecal material over a limited period during larval development. According to Wier and Churchill (1945), the lining of the small intestine in adult gizzard shad consists exclusively of ciliated columnar epithelial cells.

Acknowledgements. We wish to thank J. Klinkmann, G. Fürstenberg, T. Minami, M. Matsuoka and S. Yamamoto for excellent technical assistance.

LITERATURE CITED

Barrington, E. J. W. (1957). The alimentary canal and digestion. In: Brown, M. E. (ed.) The physiology of fishes. Academic Press, New York, pp. 109–161

Battle, H. I., Hayashida, K. (1965). Comparative study of the intraperitoneal alimentary tract of parasitic and non-parasitic lampreys from the Great Lakes Region. J. Fish. Res. Bd Can. 22: 289–306

Hopkins, G. S. (1895). On the enteron of American ganoids. J. Morph. 11: 411–442

Iwai, T. (1967 a). The comparative study of the digestive tract of teleost larvae – I. Fine structure of the gut epithelium in larvae of Ayu. Bull. Jap. Soc. Sci. Fish. 33: 489–496

Iwai, T (1967 b). The comparative study of the digestive tract of teleost larvae – II. Ciliated cells of the gut epithelium in pond smelt larvae. Bull. Jap. Soc. Sci. Fish. 33: 1116–1119

M'Intosh, W. C., Prince, E. E. (1890). On the development and life-histories of the teleostean food and other fishes. Trans. R. Soc. Edinb. 35: 665–946

Purser, G. L. (1928). Calamoichthys calabaricus J. A. Smith. Part I. The alimentary and respiratory systems – concluded. Trans. R. Soc. Edinb. 56: 89–101

Wier, H. C., Churchill, E. P. (1945). The anatomy and histology of the digestive system of the gizzard shad. Proc. S. Dak. Acad. Sci. 25: 34–43

Yamamoto, T. (1965). Some observations on the fine structure of the epithelium in the intestine of lamprey *(Lampetra japonica)*. Okajimas Fol. anat. jap. 40: 691–713

Wang, Y., Zhao, C., Shi, Z., Tan, Y., Zhang, K., Li, Y., Yang, Y., Hong, Y. (1980). Studies on the artifical inducement of reproduction in common eels. J. Fish. China 4: 147–156

Accepted for printing on January 8, 1981