

## Structure and Histochemistry of the Skin of a Flat-headed Goby, *Luciogobius guttatus* (Gobiidae, Pisces) from Korea

Jong-Young Park\*, Yong-Joo Lee<sup>1</sup> and Ik-Soo Kim

Faculty of Biological Sciences and Institute for Biodiversity Research,  
Chonbuk National University

<sup>1</sup>Jeonju National University of Education, Korea

To investigate the skin of the flat-headed goby, *Luciogobius guttatus*, it was used 8 body regions such as the head, the upper and lower jaw, the chin, the back, lateral region, abdomen, and the operculum. The epidermis consisted of three layers: the outermost layer, middle layer and stratum germinativum (basal layer). The outermost layer consisted of rather flattened cells arranged in 1 to 4 layers and mucous cells. The middle layer consisted of large epidermal cells occupying the height of the epidermis with 1 to 10 layers, causing a web-shaped structure. Due to the large epidermal cells of the middle layer, *L. guttatus* had a thick epidermis. The large epidermal cell contains tonofilaments, lucent contents, and desmosome. The basal layer was comprised of a single layer having cuboidal cells. A large number of fine blood capillaries were found just under the basal layer. The dermis consisted mostly of stratum compactum with numerous blood capillaries but had no scale.

**Key words :** epidermis, mucous cell, swollen cell, intertidal fish, *Luciogobius guttatus*

### Introduction

Intertidal fishes live at the area of land and sea where they are alternately submerged in water and exposed to the air as tide recedes. Rocky shores include boulder flats, rock pools, or combinations of all of these, along with gravel, sand, and shell substrate. By the tide causing the presence or absence of water, the intertidal fishes come out water during a low tide. According to these emergence behaviors, Martin (1995) classified the intertidal fishes into three groups: the skippers, the tidepool emergers and the remainers. In the rocky shores, the remainder fish may become out of water passively, simply by remaining in a site that is usually covered with water, but during a low tide is exposed to air

(Horn and Riegler, 1981; Martin, 1995; Horn *et al.*, 1999). These sites may be protected from desiccation by cover, such as a boulder or seaweed, and there may be an extremely shallow layer of water on the substrate. Finally, these fishes may be found under boulders or in crevices during low tides, resulting in aquatic hypoxia in tide pools (Horn and Riegler, 1981; Horn *et al.*, 1999).

Therefore, intertidal fishes have an additional air-breathing mechanism to overcome their hypoxia (Bridges, 1988; Graham, 1997; Horn *et al.*, 1999). However, most marine intertidal fishes, unlike freshwater air-breathing fishes, have no specialized or enclosed air-breathing organ (Graham, 1997). According to Horn *et al.* (1999), respiratory gas exchanges in the marine fishes must take place across the same surfaces in air as it does in water: the gills, the skin, and perhaps the linings of the opercular and buccal cavities. A

\*Corresponding author: park7877@chonbuk.ac.kr

flat-headed goby, *Luciogobius guttatus*, are small and demersal, and they distribute in Northwest Pacific of China, Korean Peninsula, and Japan (Nelson, 1994). Like other intertidal fishes, *L. guttatus* inhabits tidepools and river mouths, and stays under stones on the dried bottom for the duration of the low tide. Although about 60 species in 12 families among the intertidal fishes were reported on air emergences and aerial respirometry (Graham, 1997; Horn *et al.*, 1999), *L. guttatus* had not been studied. Through the histology of the skin, therefore, we are going to get information related cutaneous air respiration in *L. guttatus*.

## Materials and Methods

Two males and three females, ranging from 59.8 mm to 71.6 mm in standard length, were collected in June, 2004 by a hand and a small net from Gigo-ri, Changseon-myeon, Hanam-gun, Jeollanam-do, in the southern coast Korea, 34° 20'30"N and 126° 30'10"E. The specimens were anaesthetized with MS222. For histological examination, the skin fragments, 5 × 5 mm<sup>2</sup>, were fixed in 10% neutral buffered formaldehyde and 8 regions of the skin were taken from the following regions of the body: the top of the head, the cheek near the operculum, the upper jaw and lower jaw, the outer operculum close to the pectoral fin, the dorsal region near the dorsal fin, the lateral region just beneath the dorsal fin, and the ventral region near the anal fin.

We dehydrated these sections through a standard ethanol series to 100%, cleared in xylene and then embedded in wax (Paraplast, Oxford). We deparaffinized 5 μm sections and stained them with Harris hematoxylin, Ehrlich hematoxylin, and counter-stained with eosin, and Masson trichrome stain (Gurr, 1956) for general histology. Mucins of gland were demonstrated by alcian blue solution (AB) at pH 1.0 and 2.5 (Steedman, 1950; Lev and Spicer, 1964), and the periodic acid-schiff (PAS) method. In addition, the PAS technique was employed in combination with AB and vice-versa for neutral and acid mucins. Acid mucin was shown by metachromatic reactions with toluidine blue (Tock and Pearse, 1965). Also, high iron diamine (HID) and with AB (Spicer, 1965) were used for nature of the acid mucins.

For evaluations of the epidermis, we took two

skin fragments by each region per specimen by Video Test-Master (VT image analysis program, USA) on hematoxylin and eosin preparations. More than 10 sections were used for measurement per two skin fragments.

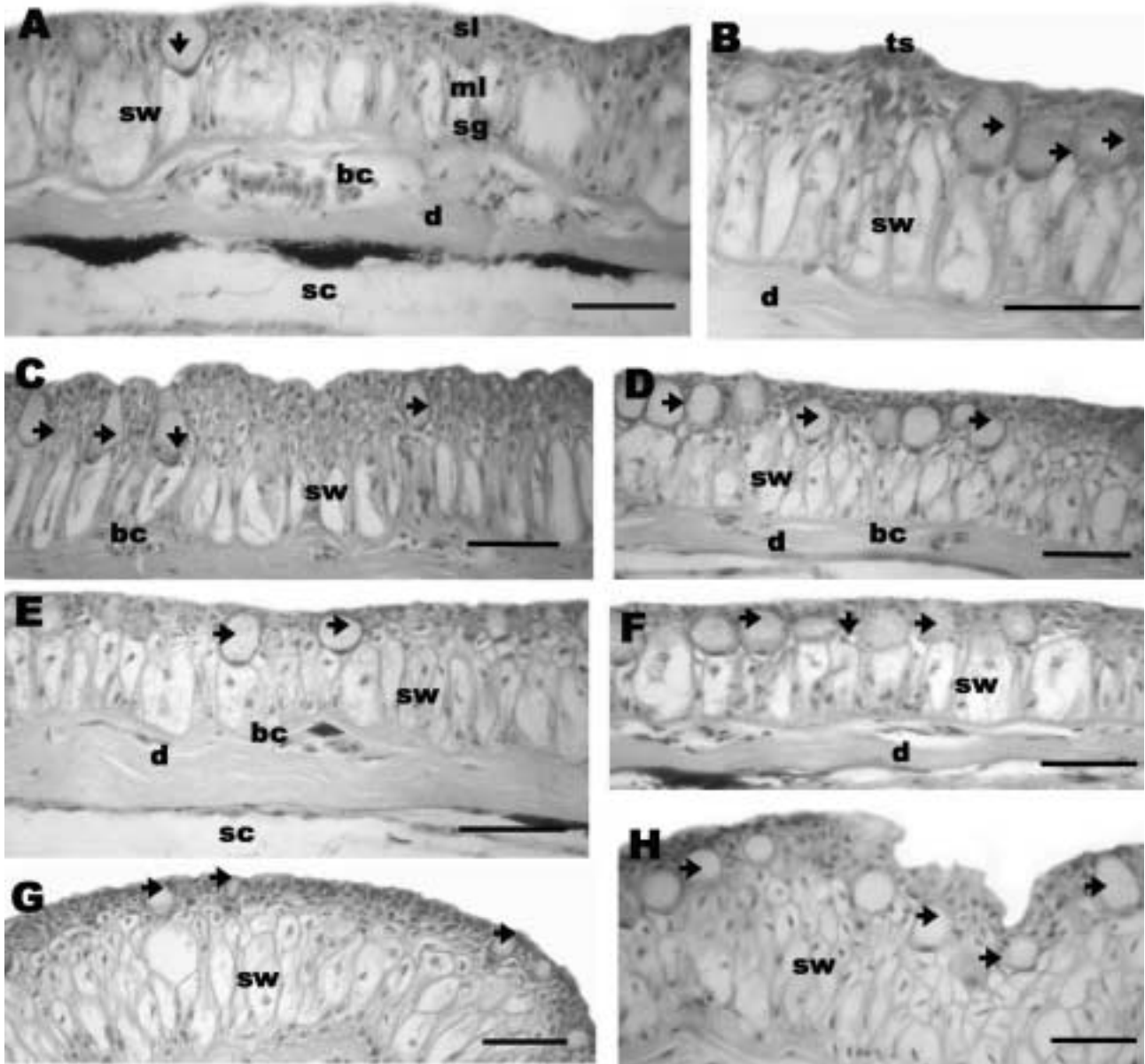
## Results

### 1. Epidermis

In 8 different body regions, the structures of the epidermis exhibited always a stratified epithelium which consisted fundamentally of the superficial layer, the middle layer and the stratum germinativum (Fig. 1, A to F). This principle structure is seen in all 8 regions although there are differences in their thickness or stratum especially in the middle cell layer.

In light microscopy, the superficial layer, outermost layer, of epidermis is composed of rather flattened cells arranged in one to five layers. Between these cells, small spherical or flask-shaped unicellular mucous cells are present (Fig. 1, A to H). The mucous cells with a large or small spherical body open to the exterior by a short narrow neck that opens on the surface by a wide pore. They have a basal, spherical or oval nucleus with a thin rim of slightly basophilic cytoplasm. The mucous cells with highly vacuolated and basophilic secretory matter are varied ranging from 14.0 to 22.6 μm in height in the 8 regions (Table 1). Of them, the mucous cells in the abdomen were the largest, mean 22.6 ± 5.8 μm (10.0 to 37.1 μm) and in the upper jaw the smallest, 14.0 ± 3.9 μm (6.9 to 25.5 μm). Whereas, the number of the mucous cell was much, 1 to 10, in the upper jaw, but the rest was mostly similar. Some mucous cells extend to the upper middle layer. The mucous cells gave a deep red color reaction with PAS technique, which is diastase resistant, γ-metachromasia with toluidine blue, blue with the AB at pH 1.0 and 2.5 (Fig. 2, A to E, Table 3). The mucous cells, giving a red color with aldehyde fuchsin and black color with high iron diamine, were likely to be sulfomucins. In mild methylation/AB and acetylation/PAS techniques they were negative, and in methylation/saponification-AB they were stained blue. Their nuclei were purple or red color with AB-PAS reaction and Masson trichrome stain (Fig. 2, D to E)

The middle layer of epidermis is simpler in structure (Fig. 1, A to H). This layer consists of smaller and voluminous cells. Due to the volumi-



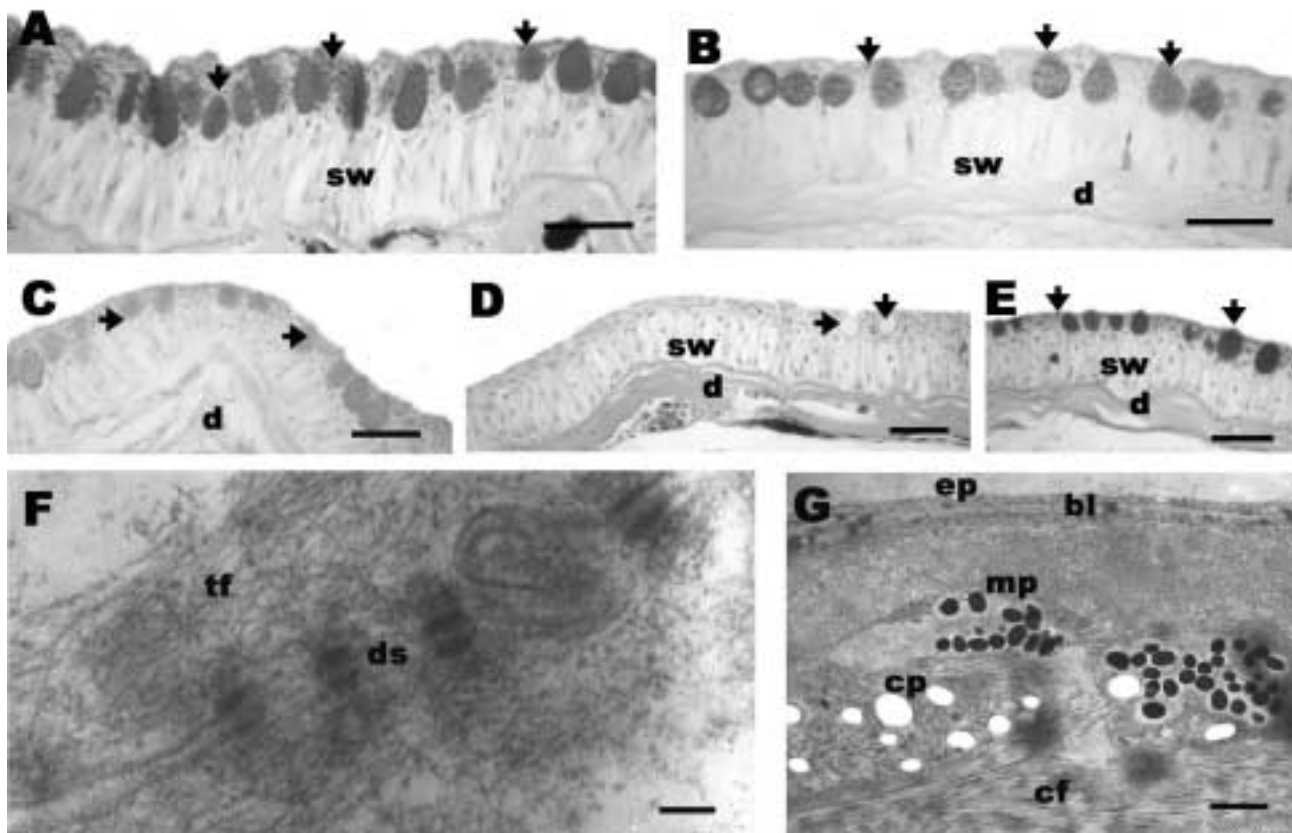
**Fig. 1.** Transverse sections of the epidermis of *Luciogobius guttatus* with Ehrlich haematoxylin and eosin (bars indicate 50  $\mu$ m). A, The skin of the back consisted of epidermis, dermis (d) and subcutis (sc). The epidermis consisted of superficial layer (sl), middle layer (ml) and stratum germinativum (sg). bc, blood capillary; d, dermis; sw, swollen cell; arrow, mucous cell. B, The base of the operculum. d, dermis; ts, taste bud; sw, swollen cell; arrow, mucous cell. C, The base of the abdomen. bc, blood capillary; sw, swollen cell; arrow, mucous cell. D, The head. bc, blood capillary; d, dermis; sw, swollen cell; arrow, mucous cell. E, The base of the cheek. bc, blood capillary; d, dermis; sc, subcutis; sw, swollen cell; arrow, mucous cell. F, The lateral region. d, dermis; sw, swollen cell; arrow, mucous cell. G, The upper jaw. See the stratified swollen cell (sw) in the middle layer. a, mucous cell. H, The lower jaw. The stratified swollen cell (sw) occupies the entire height of the epidermis. arrow, mucous cell.

nous cell, the so-called swollen cell, the middle layer exhibits a web-like structure in appearance (Figs. 1 and 2). The swollen cells have an oval nucleus and a homogeneous cytoplasm, and their

boundary is clear (Fig. 1). Occasionally, they appeared to vesicles or vacant acellular structures due to a loss of nucleus. The swollen cell does not any reactions against histochemical

**Table 1.** The thickness of epidermis, height of the swollen cell and mucous cell in the 8 body regions of the epidermis of *Luciogobius guttatus*

Regions	Thickness of the epidermis ( $\mu\text{m}$ )		Height of the swollen cell ( $\mu\text{m}$ )		Stratum of swollen cell	Height of the mucous cell ( $\mu\text{m}$ )		No. of mucous cell per a length of 100 ( $\mu\text{m}$ )
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range		Mean $\pm$ SD	Range	
Top of Head	59.8 $\pm$ 13.5	32.9~80.9	20.3 $\pm$ 12.5	5.1~57.6	1~6	18.5 $\pm$ 2.9	12.5~23.8	0~6
Cheek	68.0 $\pm$ 26.6	27.1~149.3	22.4 $\pm$ 11.4	4.8~52.6	1~11	16.5 $\pm$ 3.4	8.8~22.9	1~6
Operculum	85.2 $\pm$ 46.6	45.4~208.3	27.6 $\pm$ 13.1	8.9~56.9	1~20	18.8 $\pm$ 5.2	7.1~28.1	1~5
Upper jaw	54.5 $\pm$ 36.5	13.9~195.7	15.7 $\pm$ 5.9	6.6~36.5	1~12	14.0 $\pm$ 3.9	6.9~25.5	1~10
Lower jaw	60.4 $\pm$ 24.9	10.5~124.4	18.8 $\pm$ 9.2	6.6~46.5	1~7	17.4 $\pm$ 4.5	8.8~28.1	0~6
Back	56.4 $\pm$ 9.4	40.6~83.7	22.4 $\pm$ 11.1	6.2~52.8	1~3	17.4 $\pm$ 3.6	7.5~24.7	1~4
Lateral region	72.2 $\pm$ 10.8	53.5~90.2	22.9 $\pm$ 13.8	5.8~57.4	1~5	20.7 $\pm$ 4.9	10.7~34.6	1~5
Abdomen	71.5 $\pm$ 12.4	42.2~102.4	27.0 $\pm$ 14.0	5.6~59.3	1~3	22.6 $\pm$ 5.8	10.0~37.1	1~8

**Fig. 2.** Special staining reactions on the mucous cell of the epidermis (A-E) (bars indicate 50  $\mu\text{m}$ ) and transmission electron micrographs (F and G) of the skin of *Luciogobius guttatus*. A, The operculum. PAS rection. sw, swollen cell; arrow, mucous cell. B, The abdomen. HID/AB stain. sw, swollen cell; arrow, mucous cell. C, The operculum. AB (1.0). d; dermis; arrow, dermis. D, The cheek. Masson trichrome stain. d, dermis; sw, swollen cell; arrow, mucous cell. E, The cheek. AB/PAS stain. D, dermis; sw, swollen cell; arrow, mucous cell. F, The swollen cell of the epidermis in the dorsum. dorsum, ds, desmosome; tf, tonofilaments. Bar indicates 0.5  $\mu\text{m}$ . G, The dermis of the dorsum. bl, basal layer; cf, collagen fibers; cp, chromatophores; ep, epidermis; mp, melanophores. Bar indicates 4  $\mu\text{m}$ .

tests.

Towards the outermost layer of the epidermis these swollen cells become stratified. They occu-

ried the entire height of the epidermis (Fig. 1). The swollen cells are various in height, reaching 15.7  $\mu\text{m}$  to 27.0  $\mu\text{m}$  and arranged in several layers

**Table 2.** The thickness of the epidermis, the dermis, and the subcutis in 8 the body regions of the skin of *Luciogobius guttatus*

Regions	Thickness of the epidermis ( $\mu\text{m}$ )		Thickness of the dermise ( $\mu\text{m}$ )		Thickness of the subcutis ( $\mu\text{m}$ )	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
Top of Head	59.8 $\pm$ 13.5	32.9 ~ 80.9	26.7 $\pm$ 7.1	12.6 ~ 43.3	26.2 $\pm$ 8.4	14.5 ~ 43.9
Cheek	68.0 $\pm$ 26.6	27.1 ~ 149.3	27.1 $\pm$ 8.5	10.7 ~ 42.5	26.4 $\pm$ 10.1	12.9 ~ 52.0
Operculum	85.2 $\pm$ 46.6	45.4 ~ 208.3	22.8 $\pm$ 7.2	14.8 ~ 43.8	14.9 $\pm$ 10.1	10.0 ~ 19.0
Upper jaw	54.5 $\pm$ 36.5	13.9 ~ 195.7	10.9 $\pm$ 4.0	4.8 ~ 24.1	8.8 $\pm$ 1.9	2.5 ~ 11.5
Lower jaw	60.4 $\pm$ 24.9	10.5 ~ 124.4	12.8 $\pm$ 3.8	7.1 ~ 21.7	8.9 $\pm$ 1.3	2.7 ~ 10.9
Back	56.4 $\pm$ 9.4	40.6 ~ 83.7	27.6 $\pm$ 9.4	13.9 ~ 57.5	25.5 $\pm$ 7.5	18.4 ~ 34.2
Lateral region	72.2 $\pm$ 10.8	53.5 ~ 90.2	30.8 $\pm$ 10.8	15.2 ~ 56.6	24.3 $\pm$ 6.9	8.1 ~ 39.1
Abdomen	71.5 $\pm$ 12.4	42.2 ~ 102.4	25.7 $\pm$ 8.2	9.8 ~ 42.5	20.5 $\pm$ 5.5	10.4 ~ 30.4

(Table 1). Among the 8 regions, the swollen cells are the largest in the abdomen, mean  $27.0 \pm 14.0 \mu\text{m}$  (5.6 to  $59.3 \mu\text{m}$ ), and the smallest in the upper jaw, mean  $15.7 \pm 5.9 \mu\text{m}$  (6.6 to  $36.5 \mu\text{m}$ ), as in the number of mucous cell. The stratum of swollen cell arranged in the middle layer was much in the operculum (1 to 20 layers), the upper jaw (1 to 12 layers) and the chin (1 to 11 layers), and less in the back (1 to 3 layers), the abdomen (1 to 3 layers) and the lateral region (1 to 5 layers) (Table 1). In transmission electron microscopy, the swollen cells contain few organelles, and they have tonofilament, lucent contents, and desmosome. Pigment cells are present in this layer.

The basal layer, the stratum germinativum was composed of a single layer of either cuboidal cells, or more or less columnar cells (Fig. 1). Blood vessels located adjacent to the sense organs of the epidermis are found in the intraepithelial layer. A number of blood capillaries are present just under the basal membrane.

The epidermis has taste buds, which is typically composed of sensory cells and is a bottle-shaped expansion (Fig. 1, B).

## 2. Dermis

The dermis lacks scales and there was no clear differentiation between the stratum laxum and the stratum compactum. However, the upper region just under basal membrane was supplied with fine blood capillaries and nerve fiber (Fig. 1, A and E). The stratum compactum consists of bundles of coarse collagenous fibres arranged compactly in several layers (Fig. 1, A and E). This layer is weakly PAS positive and become a deep green color in Masson trichrome-stained preparations for collagen. This layer contains a few pigment cells, nerve cells and blood capillaries.

**Table 3.** A summary of the histochemical tests performed to show the nature of the mucous cell of epidermis in *Luciogobius guttatus*

Techniques employed	Mucous cell	Remarks
Weigerts iron Haemaoylin	$\pm$	B
Masson trichrome	+	G
PAS	++ or +++	R
PAS after digestion in malt diastase/PAS	++	R
AB (1.0)	+ or +	B
AB (2.5)	++	B
AB/PAS	++	B, BR, R
PAS/AB	++	B, BR, R
Toluidine blue	+	$\gamma$ -meta
Acetylation/PAS	-	
Acetylation/Saponification /PAS	+	
Methylation/AB	-	
Methylation/Saponification/AB	+	B
Aldehyde fucshin	$\pm$	R
Aldehyde fucshin/AB (2.5)	++	BR
HID	$\pm$	N
HID/AB	++	BN

B, blue; BN, bluish black; BR, bluish red; G, green; N, black; R, red; Intensity: -, no reaction;  $\pm$ , weak reaction; + clear reaction; ++ strongly reaction.

The thickness of the dermis is varied from 10.9 to  $30.8 \mu\text{m}$  in the 8 regions (Table 2). In the 8 region, the lateral region is the thickest,  $30.8 \pm 10.8 \mu\text{m}$  (15.2 to  $56.6 \mu\text{m}$ ), whereas the upper jaw and the lower jaw are thin,  $10.9 \pm 4.0 \mu\text{m}$  (4.8 to  $24.1 \mu\text{m}$ ) and  $12.8 \pm 3.8 \mu\text{m}$  (7.1 to  $21.7 \mu\text{m}$ ), respectively.

The dermis has two kinds of chromatophores, melanophore and colorless pigmented cells (Fig. 2, F and G). Melanosomes of melanophores are electron-opaque ellipsoidal structures, whereas colorless pigments, reflecting platelets, appear a stack of empty space. Reflecting platelets are cuboidal, polygonal, or squamous, and have highly

variable dimensions.

### 3. Subcutis

This layer is situated under dermis (Fig. 1, A and E). The average thickness is approximately 56.9  $\mu\text{m}$ , ranging from 29.7 to 79.2  $\mu\text{m}$ . Fine collagen fiber bundles from the stratum compactum traverse this layer. The main branches of the nerves and blood vessels are found in this layer. In hematoxylin and eosin preparations, this layer has numerous empty spaces composed of fat cells (Fig. 1, A and E). The thickness of the subcutis ranges from mean 8.8  $\mu\text{m}$  to 26.4  $\mu\text{m}$  in the 8 regions (Table 2), and the values are somewhat less than those of the dermis. Their thickness show similar values except for the upper jaw, the lower jaw and the operculum, mean 8.8  $\mu\text{m}$ , 8.9  $\mu\text{m}$ , and 14.9  $\mu\text{m}$ , respectively. The subcutis of the upper jaw, the lower jaw and the operculum is not clear differentiation.

## Discussion

The skin of cutaneously respiratory fishes, have been documented as the following structures: a thicker epidermis due to several types of glands, intraepithelial blood capillaries, abundant blood capillaries in the superficial dermis, a well-developed vascularization, reduction or absence of scales, and a definite area with acid mucopolysaccharides in the dermis (Jakubowski, 1958; Liem, 1967; Johansen, 1970; Mittal and Munshi, 1971; Mittal and Banerjee, 1974; Mittal *et al.*, 1980; Whitear, 1986; Suzuki, 1992; Yokoya and Tamura, 1992; Park and Kim, 1999, 2000; Park, 2002a, b; Zhang *et al.*, 2003; Park *et al.*, 2003a, b, 2006).

Of characters in well-known cutaneously respiratory fishes, a thicker epidermis was dependent on several kinds of glands and a specific large epidermal cell. Firstly, epidermis having two kinds of gland cells, both a small mucous cell and a large club cell, or a small mucous cell and a large sacciform cell, were known in *Mastacembelus*, *Amphipnous*, *Misgurnus*, *Iksookimia*, and *Liobargus* (Mittal and Munshi, 1971; Mittal and Banerjee, 1974; Mittal *et al.*, 1980; Park and Kim, 1999; Park, 2002a; Park *et al.*, 2003b). Because two gland cells occupy the most height of the middle layer in their epidermis, their epidermis was thicker. Secondly, the synbranchoid fish, *Monopterus albus*, has only mucous gland cells. Nevertheless, the epidermis has thicker due to a

large mucous cell occupying the entire height of the epidermis (Liem, 1967). Thirdly, although the mucous cell in the epidermis is small or absent, there was specific large and voluminous epidermal cells swollen by epidermal cell, swollen cell. Multi-stratified swollen cells occupy the entire height of the epidermis, which it shows web-structure in appearance. The swollen cell in the middle layer of the epidermis was characteristic of amphibious mudskippers, *Periophthalmus*, *Scartelaos* and *Boleophthalmus*, which undergo cutaneous respiration using air (Whitear, 1986; Al-Kadhomy and Hughes, 1988; Yokoya and Tamura, 1992; Zhang *et al.*, 2000; Park, 2002b; Park *et al.*, 2000, 2006).

The swollen cell found in the epidermis of *L. guttatus* was only reported in mudskipper fish, *Scartelaos*, *Boleophthalmus*, and *Periophthalmus*. The epidermis of *L. guttatus* have found mucous cell and swollen, as reported in *Scartelaos* and *Boleophthalmus*. Otherwise, *Periophthalmus* has only swollen cell without mucous cell. In particular, the swollen cell was known as a modification of epidermal cell which undergo cutaneous respiration using air, in *Periophthalmus*, *Scartelaos* and *Boleophthalmus* (Whitear, 1986; Al-Kadhomy and Hughes, 1988; Yokoya and Tamura, 1992; Park *et al.*, 2000; Zhang *et al.*, 2000; Park, 2002; Park *et al.*, 2006). Also, it was known that the swollen cell has desmosome in some *Periophthalmus* (Whitear, 1986; Suzuki, 1992; Park, 2002). Also, the swollen cell of *L. guttatus* contains tonofilaments, lucent contents, and desmosome, as in the above three genera mudskipper fishes.

The size and abundance of mucous cells play an important role in supporting and maintaining the normal relationships of the cutaneous epithelium (Liem, 1967). Also, the appearance of the mucous cell in the epidermis is specifically adapted to a common ecology in which protection from desiccation and lubrication during burrowing (Liem, 1967; Mittal and Munshi, 1971).

No the epidermis of *L. guttatus* have intraepithelial blood capillaries, unlike *Periophthalmus* and *Liobargus*. Nevertheless, breathing is possible through the blood vessels in the dermis because diffusion of oxygen take place readily across the mucous coat of the epithelium (Jakubowski, 1958; Liem, 1967; Mittal and Munshi, 1971; Whitear, 1986; Graham, 1997; Horn *et al.*, 1999). Liem (1967) had been experimentally demonstrated in the epidermis of *Monopterus albus* with only large mucous cells devoid of intra-

epithelial blood capillaries. However, *L. guttaus* has plenty of blood capillaries just beneath the basal layer of the epidermis. It means that oxygen obtained through the mucous cell is sufficient to be able to diffuse to the deeper dermis.

*L. guttaus* has no well-defined lymphatic spaces in the epidermis and definite areas with acid mucopolysaccharides in the dermis, as described in other cutaneously respiratory fishes as *Heteropneustes*, *Mastacembelus*, *Amphipnous*, *Iksookimia*, *Misgurnus*, *Periophthalmus*, and *Boleophthalmus* (Mittal and Munshi, 1971; Park and Kim, 2000; Park, 2002b; Park *et al.*, 2003a).

*L. guttatus* has no scale. Absence and reduction of the scales was mainly found in cutaneously respiratory fishes such as *Misgurnus*, *Periophthalmus*, *Heteropneustes*, *Mastacembelus*, *Iksookimia*, *Amphipnous*, *Monopterus*, and *Liobagrus* considered as an adaptation for movement or burrowing (Liem, 1967; Mittal and Munshi, 1971; Whitear, 1986; Park, 2002; Park *et al.*, 2003a, b).

On the basis of the ecological aspect and structural characteristics of the skin, *L. guttatus* seems to be related to a cutaneous respiratory system for adaptation to its environments.

## Acknowledgements

This work was supported by Jeonju National University of Education Research Grant (2005).

## References

- Al-Kadhomy, N.K. and G.M. Hughes. 1988. Histological study of different regions of the skin and gills in the mudskipper, *Boleophthalmus boddarti* with respect to their respiratory function. *J. Mar. Biol. Ass. U.K.*, 68 : 413~422.
- Bridges, C.R. 1988. Respiratory adaptations in intertidal fish. *Amer. Zool.*, 28 : 79~96.
- Graham, J.B. 1997. Air breathing fishes: Evolution, diversity, and adaptation. Academic Press, San Diego, 299pp.
- Gurr, G.T. 1956. A practical manual of medical and biological staining techniques. Interscience, New York.
- Horn, M.H., K.L.M. Martin and M.A. Chotkowski. 1999. Intertidal fishes. Academic Press, San Diego, 399pp.
- Horn, M.H. and K.C. Riegler. 1981. Evaporative water loss and intertidal vertical distribution in relation to body size and morphology of stichaeoid fishes California. *J. Exp. Mar. Biol. Ecol.*, 50 : 273~288.
- Jakubowski, M. 1958. The structure and vascularization of the skin of the pond-loach (*Misgurnus fossilis* L.). *Acta Biol. Cracoviensia*, 1 : 113~127.
- Johansen, K. 1970. Air breathing in fishes. In: Hoar W.S. and D.J. Randall (eds), *Fish Physiology IV*. Academic Press, New York, pp. 361~411.
- Lev, R. and S.S. Spicer. 1964. Specific staining of sulphated groups with alcian blue at low pH. *J. Histochem. Cytochem.*, 12 : 309.
- Liem, K.F. 1967. Functional morphology of the integumentary, respiratory, and digestive systems of the synbranchoid fish, *Monopterus albus*. *Copeia*, (1967) : 375~388.
- Martin, K.L.M. 1995. Time and tide wait for no fish: Intertidal fishes out of water. *Environ. Biol. Fish.*, 44 : 165~181.
- Mittal, A.K. and J.S.D. Munshi. 1971. A comparative study of the structure of the skin of certain air-breathing fresh-water teleosts. *J. Zool. Lond.*, 163 : 515~532.
- Mittal, A.K. and T.K. Banerjee. 1974. Structure and keratinization of the skin of a fresh-water teleost *Notopterus notopterus* (Notopteridae, Pisces). *J. Zool. Lond.*, 174 : 314~355.
- Mittal, A.K., M.A. Whitear and S.K. Agarwal. 1980. Fine structure and histochemistry of the epidermis of the fish, *Monopterusuchia*. *J. Zool. Lond.*, 191 : 107~125.
- Nelson, J.S. 1994. *Fishes of the World*. 3rd ed. John Wiley and Sons, New York, 600pp.
- Park, J.Y. 2002a. Morphology and histochemistry of the skin of the spined cobitid fish, *Iksookimia korensis*, in relation to respiration. *Folia Zool.*, 51 : 241~247.
- Park, J.Y. 2002b. Structure of the skin of an air-breathing mudskipper fish, *Periophthalmus magnuspinnatus*. *J. Fish Biol.*, 60 : 1543~1550.
- Park, J.Y. and I.S. Kim. 1999. Structure and histochemistry of skin of mud loach, *Misgurnus anguillicaudatus* (Pisces, Cobitidae), from Korea. *Korean J. Ichthyol.*, 11 : 109~116.
- Park, J.Y. and I.S. Kim. 2000. Structure and cytochemistry of skin in spined loach, *Iksookimia longicarpus* (Pisces, Cobitidae). *Korean J. Ichthyol.*, 12 : 25~32.
- Park, J.Y., I.S. Kim and S.Y. Kim. 2000. Histological study on skin of the amphibious fish, *Periophthalmus modestus*. *Korean J. Biol. Sci.*, 4 : 315~318.
- Park, J.Y., Y.I. Lee, I.S. Kim and S.Y. Kim. 2003a. A comparative study of the regional epidermis of an amphibious mudskipper fish, *Boleophthalmus pectinirostris* (Gobiidae, Pisces). *Folia Zool.*, 52 : 431~440.
- Park, J.Y., I.S. Kim and S.Y. Kim. 2003b. Structure and histochemistry of the skin of a torrent catfish, *Liobagrus mediadiposalis*. *Environ. Biol. Fish.*, 66 : 3~8.
- Park, J.Y., I.S. Kim and Y.J. Lee. 2006. A Study on the vascularization and structure of the epidermis of the air-breathing mudskipper, *Periophthalmus magnuspinnatus* (Gobiidae, Teleostei), along different parts of the body. *J. Applied Ichthyol.*, 22 : 62~67.
- Spicer, S.S. 1965. *Histochemistry manual*. The university of Kansas Medical Center, Kansas City, 54pp.
- Steedman, H.F. 1950. Alcian blue 8G: a new stain for mucin. *Quart. J. Micr. Sci.*, 1 : 477~479.
- Suzuki, N. 1992. Fine structure of the epidermis of the mudskipper, *Periophthalmus modestus* (Gobiidae). *Japan. J. Ichthyol.*, 8 : 379~396.

- Tock, E.P.C. and A.G.E. Pearse. 1965. Preservation of tissue mucins by freeze-drying and vapour fixation. *J. R. microsc. Soc.*, 84 : 519~537.
- Whitear, M. 1986. The skin of fishes including cyclostomes: epidermis. In: Bereiter-Hahn, J., A.G. Matoltsy and K.S. Richards (eds), *Biology of the integument Vol. 2 Vertebrates*. Springer Verlag, New York, pp. 9~64.
- Yokoya, S. and O.S. Tamura. 1992. Fine structure of the skin of the amphibious fishes, *Boleophthalmus pectinirostris* and *Periophthalmus cantonensis*, with special reference to the location of blood vessels. *J. Morphol.*, 214 : 287~297.
- Zhang, J., T. Taniguchi., T. Takita and A.B. Ali. 2000. On the epidermal structure of *Boleophthalmus* and *Scartelao* mudskippers with reference to their adaptation to terrestrial life. *Ichthyol. Res.*, 47 : 359~366.

Received : May 14, 2007

Accepted : June 4, 2007

## 한국산 미끈망둑 *Luciogobius guttatus* (망둑어과) 피부의 구조 및 조직화학적 특성

박종영\* · 이용주<sup>1</sup> · 김익수

전북대학교 생물과학부 · 생물다양성연구소,

<sup>1</sup>전주교육대학교 과학교육학과

한국산 미끈망둑 (*Luciogobius guttatus*)의 피부구조가 머리, 위턱, 아래턱, 뺨, 등, 체측, 배, 아가미뚜껑 등 모두 8개 부분에서 비교 조사되었다. 이들 모두 표피는 맨바깥층, 중간층, 기저층으로 구성되었다. 맨바깥층은 1~4층의 편평세포와 점액세포로 구성되었으며, 중간층은 1~10층의 대형 표피세포를 가지며 이러한 표피세포는 마치 거미줄 같은 형태를 보여주고 있다. 이러한 대형 표피세포의 존재는 두꺼운 표피를 갖도록 하며, tonofilament와 desmosome을 가진다. 한편 기저층은 한 층의 입방상피로 구성되어 있으며, 많은 모세혈관들이 기저층 바로 아래부분에 존재한다. 진피에는 비늘이 존재하지 않으며 거의 대부분 모세혈관을 가지는 치밀층으로 구성되어 있다.