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A comparative study of the regional epidermis of an amphibious mudskipper fish, *Boleophthalmus pectinirostris* (Gobiidae, Pisces)

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A b s t r a c t . The epidermis of the amphibious mudskipper fish, *Boleophthalmus pectinirostris*, consists of three layers: the outermost layer, middle layer and stratum germinativum. The outermost layer consists of polygonal cells or rather flattened cells arranged in one to eight layers. In between these cells, round small cells and mucous cells are present. The round small cells are ovoid to round with an inclusion of fine granules, which are weakly positive to acid chemical reaction. The mucous cells are predominantly acid mucopolysaccharide in nature. The middle layer consists of 1 to 50 layers of small or voluminous cells swollen by epidermal cells. Owing to various sizes and layers of the swollen cell, the middle layer shows a web-like structure. The stratum germinativum consists of a single layer of cuboidal cells, or more or less columnar cells. A dermal bulge is located at each apical area of the epidermis of the body regions, but does not exist in all the fins or in the sucking disc. In the epidermis of the body regions, the dermal bulges are sparsely occupied by dermal tissue and have dermal capillaries just beneath the stratum germinativum. The value of the diffusion distance is the lowest in the top of the head (mean 5.5 μm) and the highest in the ventral region (mean 44.3 μm).

Key words: epidermis, swollen cell, blood capillary, dermal bulge, mudskipper fish

Introduction

Mudskippers, gobiid teleosts such as *Boleophthalmus, Periophthalmus, Periophthalmodon* and *Scartelaos* are amphibious, and mostly inhabit mangrove and mudflat areas of intertidal zone. They spend the greater part of their lives on land and are exposed to the atmosphere during low tide. For their terrestrial locomotion, they have been known as air-breathing fishes, which use air directly through the skin, called cutaneous respiration. In *Boleophthalmus* and *Periophthalmus,* many physiological studies on aerial respiration have been carried out (J o h a n s e n 1970, T a m u r a et al. 1976, N i v a et al. 1981, G r a h a m 1997, I s h i m a t s u et al. 1998). The general skin structure of the mudskippers has been reported in *Periophthalmus* (W h i t e a r 1986, S u z u k i 1992, Y o k o y a & T a m u r a 1992, Z h a n g et al. 2000, P a r k et al. 2000, P a r k 2002), *Boleophthalmus* (A l - K a d h o m i t y & H u g h e s 1988, L o w et al. 1990, Y o k o y a & T a m u r a 1992, Z h a n g et al. 2000) and *Scartelaos* (Z h a n g et al. 2000).

Among mudskippers, the genus *Boleophthalmus* of the subfamily Oxudercinae consisted of five species (M u r d y 1989). Of them, the epidermal structure of three species, *B. dussumieri, B. boddarti* and *B. pectinirostris*, was reported in relation to cutaneous respiration (Y o k o y a & T a m u r a 1992, Z h a n g et al. 2000). However, studies of

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B. pectinirostris (Z h a n g et al. 2000) were limited to five different regions of body skin, and the histochemistry and the structure on their epidermal cells was not described. Moreover, there are no reports on the epidermis of the fins and sucking disc.

In *B. pectinirostris*, we observed the structure and histochemistry on the epidermis, and compared the thickness and the diffusion distance from 15 different regions. And this study was made to describe which regional epidermis is more effective for oxygen uptake during terrestrial life.

Material and Methods

Two males and four females were collected from Nampo-ri, Gangjin-eup, Gangjin-gun, Jeollanam-do in the southern coast of Korea (126°45'E and 34°30'N) during the non-spawning season and ranged from 133.0 to 149.3 mm in standard length. The specimens were fixed in 10 % neutral buffered formaldehyde. Skin fragments were taken from 15 different regions: 9 regions of body (the middle part of the interorbit, the top of the head, the chin, the upper jaw and lower jaw, the operculum close to the pectoral fin, the dorsum near the first dorsal fin, the lateral region just beneath the first dorsal fin, and the ventral region near the anal fin), 5 regions of fins (the pectoral, the first dorsal, the second dorsal, the anal and the caudal fin), and the sucking disc. These fragments were dehydrated through a standard ethanol series to 100 %, cleared in xylene and then embedded in wax (Paraplast, Oxford). Five μm-cut sections were deparaffinized and stained with Ehrlich hematoxylin and counter-stained with eosin, and Masson trichrome stain (G u r r 1956) for general histology. For blood cells the giemsa method was used. Mucins of gland were demonstrated by alcian blue solution (AB) at pH 1.0 and 2.5 (S t e e d m a n 1950, L e v & S p i c e r 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 (T o c k & P e a r s e 1965). Also, high iron diamine (HID) and with AB (S p i c e r 1965) were used for nature of the acid mucins.

For evaluations of the skin, we took two skin fragments by each region from one specimen of 133 mm standard length and the measurement was made by a micrometer eyepiece on the PAS whole mount preparations, haematoxylin and eosin preparations under a light microscope. More than 10 sections were used for measurement pert two skin fragments. The distance between the capillary endothelial cell and the epidermis was measured by a micrometer eyepiece and was assumed to represent the diffusion distance

Results

G e n e r a l m o r p h o l o g y

The epidermis of *Boleophthalmus pectinirostris* could be divided into three layers: outermost layer, middle layer and stratum germinativum (Fig. 1A).

Outermost layer

The superficial or outermost layer was composed of polygonal cells and rather flattened cells arranged in one to eight layers. In between these cells, two types of cells were present (Figs 1A to 1D). Small cells, reaching from 5 to 7 μm in height and from 5 to 8 μm in width, were

situated mainly along the outermost layer (Fig. 1D). They were regular, and compactly arranged in one to two rows. These small cells were mostly round or ovoid and had inclusion of fine granules, which are weakly positive to AB (pH 2.5) and AB (pH 2.5)-PAS. The small cells did not show any reaction in AB at pH 1.0 and PAS technique, but a few small cells showed very weak reaction in AB (pH 1.0) staining. The small cells were seen mainly in the epidermis of the jaws and all the fins.

Under or between the small cells, more or less large spherical or flask-shaped mucous cells were discernible (Figs 1A, 1C and 1D). The mucous cells were always unicellular. They were randomly distributed and reached from 10 to 18 μm in height and from 8 to 15(m in width. The mucous cells had a basal, spherical or oval nucleus with a thin rim of slightly basophilic cytoplasm, pushed at the periphery of the cell due to the heavy accumulation of its basophilic secretions. The mucous cells were vacuolated and had a short narrow neck that opens on the surface by a wide pore. The mucous cells were spread over such epidermis as the interorbit, the head, the chin, the jaws, the dorsum, the operculum, the lateral and ventral region except for all the fins and the sucking disc. However, the mucous cells were not so much in number, reaching from zero to five by 100 μm. Their secretory matter gave a deep red color reaction with the PAS technique, γ-metachromasia with toluidine blue, blue with the AB at pH 1.0 and 2.5 (Fig. 1C, Table 1). The mucous cells showed a black color with high iron diamine. Their nuclei were a purple or red color with AB (pH 2.5)-PAS reaction and Masson trichrome stain. The mucous cells and the capillaries situated at the apex of the dermal bulges were separately distributed (Figs 1E and 1F).

Middle layer

The middle layer of the epidermis consisted of simple structure (Fig. 1A). This layer was made up of several strata of small and large voluminous cells, which were characterized by having a large vacuole in the cytoplasm. These voluminous cells, the so-called swollen cells, had an oval nucleus and a homogeneous cytoplasm, and its boundary was clear (Figs 1A, 1B, 1D and 1E). Occasionally, they appeared as vesicles or vacant acellular structures due to a loss of nucleus. The cytoplasm was not stained with HE, toluidine blue, AB and PAS. In the 15 regional epidermises, the size and the shape of the swollen cell as well as the number of

Table 1. A summary of the histochemical tests performed to show the nature of the mucous cell of the epidermis in *Boleophthalmus pectinirostris*.

Techniques employed	Mucus	Remarks
Weigerts iron haematoxylin	±	B
Masson trichrome	+	G
PAS	++	R
Alcian blue(1.0)	±	B
Alcian blue(2.5)	+ or ++	B
Alcian blue/PAS	++	B, BR, R
PAS/Alcian blue	++	B, BR, R
Toluidine blue	±	γ-meta
High iron diamine	±	N
High iron diamine /alcian blue	++	BN

B, blue; BN, bluish black; BR, bluish red; G, green; N, black; PN, pink; R, red; RB, redish blue; +, increasing intensity of reaction; ±, fairly present.

strata of the swollen cell was more variable. Such features were closely related to the thickness of the middle layer as well as the epidermis (Table 2). Generally, the swollen cells were about 7.5 to 40 μm in height and 7.5 to 42.5 μm in width, and the middle layer consisted of 1 to 15 strata by regions. The number of the strata was between 1 to 12 in all the fins, the sucking disc, the jaws, the operculum and chin. The others had 6 to 15 strata, particularly 15 strata in the dorsum. Due to the swollen cells and its strata, the middle layer looked like a web in appearance. Dermal bulges, however, pushed up the middle layer and then the thickness of the middle layer became greatly thin. The middle layer with these dermal bulges was composed of 1 to 3 strata, including small swollen cells (Table 2).

Stratum germinativum

The stratum germinativum consisted of a single layer of cuboidal cells, or more or less columnar cells (Fig. 1A). The basal cells had prominent, lightly stained, centrally placed spherical or oval nuclei and the cytoplasm was homogeneous. At the apex of the dermal bulges, the basal cells were located close to the outermost layer, the superficial epithelial cells.

Dermal bulge

In general, the dermal bulges were generally located at each apical area of the scales (Figs 1A, 1H and 2C). However, although the epidermis such as the interorbit, the head and the chin had no scale, there was the dermal bulge (Figs 2A and 2B). In contrast to the above epidermis, the epidermis of all the fins and the sucking disc did not have the scale and dermal bulges (Figs 2D and 2E). The dermal bulges were sparsely occupied by dermal tissue with some dermal capillaries (Figs 1E to 1G). The inner of the dermal bulge had amorphous and acelluar dermal tissues, which were positive with PAS and AB, AB (pH 2.5)-PAS reaction. In addition, the blood vessels, the loose dermal tissues and pigments were scattered in the dermal bulge. The dermal bulges pushed up the epidermis, becoming flattened ventrally or posteriorly. As the dermal bulges are deeply penetrated into the epidermis, the thickness of the epidermis was greatly reduced.

The dermal bulge size varied, ranging mean 82 to 391 μm in height and mean 172 to 485 μm in width: the chin was mean 391 μm in height and 251 μm in width, the top of the head 235 μm and 458 μm, the dorsum 203 μm and 416 μm, the interorbit 250 μm and 267 μm, and ventral region 295 μm and 485 μm (Table 2). The lower jaw was smaller, mean 119 μm in height and 172 μm in width. The lateral region showed the lower value of mean 82 μm in height but the higher value of mean 485 μm in width (Table 2). The number of dorsal bulges distributed over the epidermis per 1mm was variable, ranging from 0 to 6: the interorbits had the most, 5 to 6, the lateral and ventral region 3 to 5, the top of the head 2 to 3, the dorsum 0 to 5, and the lower jaw 0 to 2 (Table 2).

The blood vessels and capillaries near the surface of the epidermis

Blood vessels were situated at the dermis and entered the dermal bulges. The dermal capillaries were found just beneath the stratum germinativum, which is the apex of the dermal bulges (Figs 1E to 1G). Eventually, as the dermal bulge pushed up the epidermis, dermal capillaries were always situated at the outermost surface of the epidermis. The capillaries formed circles including some erythrocytes. The blood vessels and the capillaries were not located in the epidermis between the dermal bulges. All the fins and the sucking disc without

Table 2. General features of the regional epidermis in *Boleophthalmus pectinirostris*, 133 mm SL.

Regions		Thickness of the epidermis in the area between the dermal bulge (μm)	Swollen cells of the epidermis			Dermal bulges		
			Height (μm)	Width (μm)	No. of strata	Height (μm)	Width (μm)	No./ 1mm
		Mean (Min-Max)	Mean(Min-Max)	Mean (Min-Max)		Mean (Min-Max)	Mean (Min-Max)	
	Interorbit	270 (239-317)	18.8 (7.5-20)	27.5 (7.5-42.5)	15-18	250 (219-288)	267 (109-406)	5-6
	Top of the head	206 (119-297)	16.4 (10-30)	25.4 (10-40)	9-20	235 (208-277)	458 (297-644)	2-3
B	Upper jaw	251 (208-327)	15.4 (10-25)	18.9 (7.5-30)	5-50	267 (218-347)	314 (258-366)	3-5
o	Lower jaw	92 (59-119)	21.7 (10-35)	15.8 (7.5-25)	2-10	119 (109-128)	172 (99-208)	0-2
d	Chin	236 (78-297)	23.9 (10-40)	23.9 (10-42.5)	7-11	391 (228-307)	251 (287-317)	2-5
y	Operculum	112 (99-178)	23.8 (7.5-30)	17.9 (7.5-27.5)	3-6	137 (119-158)	263 (198-327)	1-4
	Dorsum	140 (59-267)	17.5 (10-27.5)	17.5 (15-22.5)	2-10	203 (168-238)	416 (396-436)	0-5
	Lateral region	154 (119-198)	11.0 (7.5-12.5)	19.5 (10-32.5)	10-21	82 (59-109)	463 (347-693)	3-4
	Ventral region	193 (119-267)	24.2 (10-40)	18.3 (7.5-27.5)	12-17	295 (198-347)	485 (228-693)	3-5
	Pectoral fin	69 (40-109)	9.2 (7.5-12.5)	15.8 (10-22.5)	6-10		absent	
F	First dorsal fin	59 (50-69)	9.2 (7.5-10)	14.2 (10-17.5)	1-3		absent	
i	Second dorsal fin	73 (40-109)	13.2 (7.5-17.5)	14.4 (7.5-25)	4-12		absent	
n	Anal fin	66 (50-79)	10.0 (7.5-20)	16.8 (12.5-20)	4-8		absent	
	Caudal fin	86 (50-158)	16.9 (10-27.5)	30.7 (17.5-32.5)	2-6		absent	
Sucking disc		91 (40-149)	13.8 (10-20)	22.5 (12.5-27.5)	5-10		absent	

Min, minimum; Max, maximum

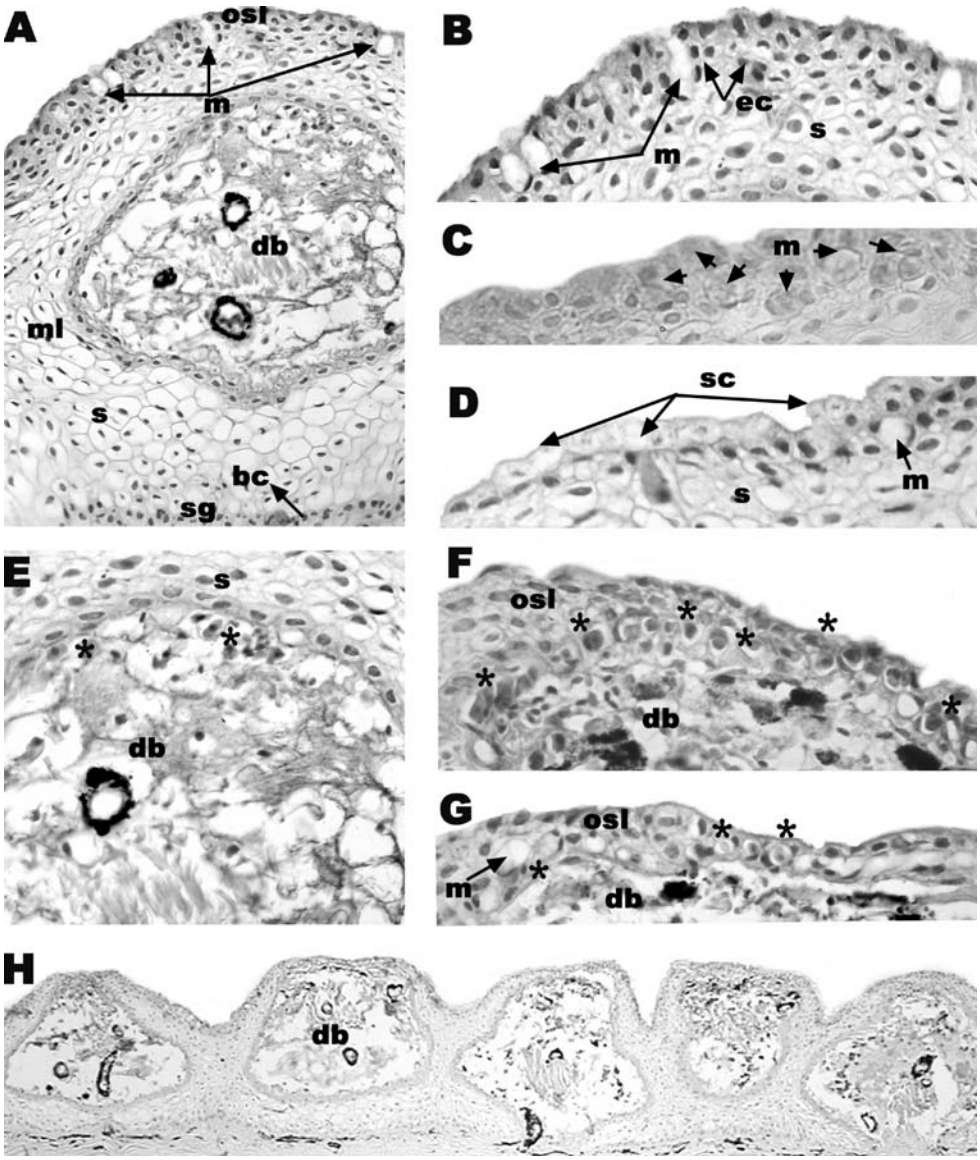

Fig. 1. Transverse sections of the epidermis of *Boleophthalmus pectinirostris*. **A,** The epidermis of the dorsum consists of outermost layer (osl), middle layer (ml) and stratum germinativum. bc, cuboidal basal cell; db, dermal bulge; m, mucous cell; s, swollen cell. Ehrlich haematoxylin and eosin. Bar indicates 25 μm. **B**, A magnification of Fig. 1A. ec, epithelial cell; m, mucous cell; s, swollen cell. Ehrlich haematoxylin and eosin. Bar indicates 25 μm. **C**, The upper jaw. AB (pH 2.5) staining. m, mucous cell. Bar indicates 20 μm. **D**, The upper jaw. m, mucous cell; s, swollen cell; sc, round small cell. Ehrlich haematoxylin and eosin. Bar indicates 15 μm. **E,** The upper jaw. See the dermal capillaries (*) situated near the dermal bulge (db). s, swollen cell. Ehrlich haematoxylin and eosin. Bar indicates 15 μm. **F,** The upper jaw. osl, outermost layer; db, dermal bulge; *, dermal capillaries. Masson Trichrome stain. Bar indicates 25 μm. **G,** The chin. db, dermal bulge; m, mucous cells; osl, outermost layer; *, dermal capillaries. Ehrlich haematoxylin and eosin. Bar indicates 25 μm. **H,** The upper jaw. db, dermal bulges. Ehrlich haematoxylin and eosin. Bar indicates 13 μm.

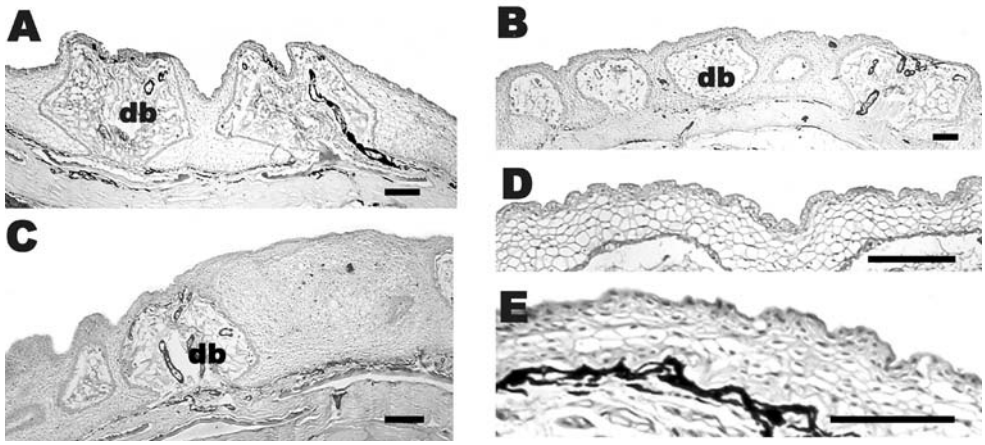

Fig. 2. Transverse sections of the epidermis of *Boleophthalmus pectinirostris*. **A,** The epidermis of the top of the head with dermal bulge (db). Ehrlich haematoxylin and eosin. Bar indicates 100 μm. **B,** The epidermis of the interorbit with many dermal bulges (db). Ehrlich haematoxylin and eosin. Bar indicates 100 μm. **C,** The epidermis of dorsum with dermal bulges (db). The epidermis with the dermal bulges is very thin, but without the dermal bulges is very thick. Ehrlich haematoxylin and eosin. Bar indicates 100 μm. **D,** The epidermis of the sucking disc. The epidermis has no the dermal bulges and is very thin. Ehrlich haematoxylin and eosin. Bar indicates 100 μm. **E**, The epidermis of the 1st dorsal fin without the dermal bulges. Ehrlich haematoxylin and eosin. Bar indicates 100 μm.

a dermal bulge had no blood vessel or dermal capillaries (Figs 2D and 2E). The diffusion distance, the air-blood pathway, between the epidermis and capillary varied, ranging mean 5.5 to 44.3 μm (Table 3). Of them, the top of the head had the lowest value, mean 5.5 μm (2.5 to 7.5 μm), and the operculum and the lateral region were high, mean 14.3 μm (5.0 to 20.0 μm) and 14.0 μm (7.5 to 20.2 μm). The lower jaw and the lateral ventral region had the highest values among nine other different epidermal regions, mean 22.5 μm (17.5 to 27.5 μm) and 44.3 μm (40 to 50 μm), respectively.

Thickness of the epidermis

The thickness of the epidermis in 15 regions depended on the strata and size of the swollen cell in the middle layer as well as size and the existence or absence of the dermal bulge (Table 2). In the area between the dermal bulges, the thickness of the epidermis varied. The epidermis was

Table 3. Features of the regional epidermis in *Boleophthalmus pectinirostris*, 133 mm Standard length.

Body regions	Diffusion distance near dermal bulge (μm)
	Mean (minimum-maximum)
Interorbit	11.3 (5.0-17.5)
Top of the head	5.5 (2.5-7.5)
Upper jaw	8.3 (2.5-10.5)
Lower jaw	22.5 (17.5-27.5)
Chin	6.3 (2.5-12.5)
Operculum	14.3 (5.0-20.0)
Dorsum	9.3 (5.0-15.0)
Lateral region	14.0 (7.5-20.2)
Ventral region	44.3 (40.0-50.0)

greatly thick in the body and was thin in the fin. In the body regions the interorbit was the thickest, mean 270 μm (239 to 317 μm), and the lower jaw was the thinnest, mean 92 μm (59 to 119 μm). The top of the head, upper jaw and chin showed higher values, above mean 200 μm, whereas the operculum, dorsum and lateral region showed lower values, ranging from 112 to 154 μm (Table 2). However, the thickness of the epidermis with dermal bulges became greatly thinned, up to about 30 μm. Without the dermal bulges, the epidermis of all the fins and the sucking disc was very thin, ranging from 59 to 86 μm (Table 2). The first dorsal fin was thin, mean 59 μm (50 to 69 μm), and the caudal fin was thick, mean 86 μm (50 to 158 μm). In contrast the sucking disc had a more or less thick epidermis, mean 91 μm (40 to 149 μm).

Discussion

The epidermal structures in related to aerial cutaneous respiration in mudskipper fishes, *Periophthalmus, Boleophthalmus* and *Scartelaos,* have been described. The epidermis of *Periophthalmus* showed features, such as a thicker epidermis consisting mainly of a large swollen cell, often called swollen cell, intra-epithelial blood capillaries, abundant blood vessels in the superficial dermis and a definite area with acid mucopolysaccharides in the dermis (Suzuki 1992, Yokoya & Tamura 1992, Zhang et al. 2000, Park et al. 2000, Park 2002). *Boleophthalmus* and *Scartelaos* had a thick epidermis with large swollen cells, epidermis thinned greatly as dermal bulges pushed up the epidermis, large number of blood capillaries and vessels near the surface of the epidermis with the dermal bulges (Al-Kadhomity & Hughes 1988, Low et al. 1990, Yokoya & Tamura 1992, Zhang et al. 2000).

On the epidermis of *B. pectinirostris,* Zhang et al. (2000) reported the structure of five regions of epidermis, such as the top of the head, the operculum, the dorso-lateral body, posterior portion of the abdomen, and the lateral side, but there were no comparative data on epidermal thickness. The thickness of the epidermis was described only in the top of the head, ranging from 290 to 344 μm in the middle layer. Moreover, the dermal bulges and stratum of the swollen cell in the fins and the sucking disc were not mentioned at all.

In our study, the thickness of the epidermis of 15 different regions was variable. In the area between the dermal bulges, the average thickness of the epidermis was thick in 9 different body regions, ranging from 92 to 270 μm, and was thin in all fins and the sucking disc, reaching 59 to 91 μm. Such a thick epidermis in the body skin is well known in other cutaneously respiratory fishes: *Misgurnus fossilis* is 338.7 μm (Jakubowski 1958), *Heteropneustes fossilis* 98 μm, *Mastacembelus pancalus* 44 μm, *Amphipnous cuchia* 119 μm (Mittal & Munshi 1971), and *Monopterus albus* 75 μm (Liem 1967).

In air-breathing fishes, the middle layer of the epidermis contained several kinds of epidermal gland cells, which function for partial oxygen uptake and cause an increase of the thickness in the epidermis (Jakubowski 1958, Liem 1967, Mittal & Munshi 1971, Johansen 1970, Mittal & Banerjee 1974, Whitear 1986, Park & Kim 1999, 2000, Park 2002). In *B. pectinirostris,* however, the middle layer of the epidermis had a simple structure containing a swollen cell. The simple structure of the epidermis was characteristic of *Periophthalmus* and *Boleophthalmus*, which undergo cutaneous respiration using air (Whitear 1986, Al-Kadhomity & Hughes 1988, Yokoya & Tamura 1992, Zhang et al. 2000, Park et al. 2000, Park 2002). In our observation, the swollen cell did not show any reactions against histochemical tests. These properties were not reported in *Boleophthalmus*, but only in *P. modestus*

(Suzuki 1992). Also, it is known that the swollen cell has desmosome in some *Periophthalmus* (Whitear 1986, Suzuki 1992, Park 2002). It was concluded that the swollen cell is a modification of an epidermal cell for cutaneous air respiration.

The blood vessels and capillaries in *B. pectinirostris* were found just beneath the stratum germinativum, which is the apex of the dermal bulges as those known in other *Boleophthalmus* (Al-Kadhomity & Hughes 1988, Zhang et al. 2000). In *B. boddarti*, *B. sussumieri*, and *B. pectinirostris*, the diffusion distance between the closest capillary endothelial cells to the epidermis, was between 2 and 6 μm, but these data were only in the dorsal body (Zhang et al. 2000). From our results on 15 epidermal regions of *B. pectinirostris*, it was clear that the diffusion distance is variable and is closely related to their life modes. As in Table 3, the value of the diffusion distance showed a trend, becoming lower in order of the top of head, the chin, the upper jaw, the dorsum, the interorbit, lateral region, and the operculum, ranging average 5.5 to 14.3 μm. In contrast, the lower jaw and the ventral region had high value, average 22.5 and 44.3 μm, respectively. *B. pectinirostris* stay in their burrows during high tide, at which time the burrows are submerged. They emerge from their burrows when the mudflat is exposed to the air by the ebb tide, and move about on the mudflat, exposing all or a part of their bodies to the air. While in the water, they expose the head and a part of the dorsum above the water (Murdy 1989, Kim & Park 2002). On the basis of the value by regions, it can surmised that regions toward the upper regions of the body exposed to the air showed low values. In contrast, the lower regions of the body, such as the ventral region or the lower jaw, which are frequently immersed in the water or soft mud, had high values. Therefore, these differences of the diffusion distance by regions seem to be clearly related to their amphibious mode.

The dermal bulge of the epidermis was known as a general structure in *Boleophthalmus*, but in all the fins and the sucking disc they were not described (Al-Kadhomity & Hughes 1988, Zhang et al. 2000). In *B. pectinirostris*, none of the fins and the sucking disc had the dermal bulge, and consequently blood capillaries did not exist, thus differing from other regions. Due to the absence of the dermal bulge, the epidermis of all the fins and the sucking disc became greatly thin. These dermal bulges were closely related to the embedded small scales in the dermis. In many regional epidermises, the dermal bulge was situated in the dermis with scale, and there was not the dermal bulge in all the fins and the sucking disc without scale. Exceptionally, however, the interorbit, the head and the chin without scale had dermal bulges. These differences may be related to their behavioral mode. Also, some inner portions of the dermal bulges had amorphous and acelluar dermal tissues, which are positive with PAS and AB, AB (pH 2.5)-PAS reaction. We do not know why a small portion of dermal substances showed acid polysaccharides. Such structures in the epidermis of *Boleophthalmus* were not described in the previous reports.

The mucous cells were situated mainly in the concave epidermis between dermal bulges and separated from blood capillaries as was reported by Zhang et al. (2000). They were predominantly acid mucopolysaccharide in nature, although there were a few neutral mucopolysaccharides. In other species of the genus *Boleophthalmus,* such nature on the mucous cell had not been described in the previous reports. The presence of acidic mucopolysaccharides in the mucous cell has also been reported in the following other cutaneously respiring fishes as *Monopterus, Mastacembelus*, *Amphipnous*, and *Misgurnus* (Mittal & Munshi 1971, Mittal & Banerjee 1974, Mittal et al. 1980, Park & Kim 1999, 2000). In addition, the mucous cell of epidermis acts as a barrier to infection and desiccation and to prevent abrasion (Mittal & Munshi 1971).

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