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Scale Characteristics of Three *Lutjanus* species (Family: Lutjanidae) from the Red Sea, Egypt

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ABSTRACT

In the present study, the scale characteristics of the three *Lutjanus* species: *L. monostigma, L. ehrenbergi* and *L. bohar* from the Red Sea at Hurghada, Egypt were revealed and taxonomically evaluated in the terms of their morphometry and microstructures using light microscopy and Scanning Electron Microscopy. A wide spectrum of size-free inter-specific scale surface morphological variations were recorded and documented. The scale characters of *Lutjanus* species from different body regions included the overall form of the scales and their morphometrics, radii number, shape of interradial tongues and first circuli delimiting them, form of interradial circuli and form of their denticles, the outer rostrolateral and inner rostrolateral circuli and form of their denticles, granulation of the caudal field and the shape of ctenii. The quantitative and encoded qualitative scale characters of *Lutjanus* species are subjected to cluster analysis. Such analysis revealed two main clusters, the first includes *L. monostigma,* the second one divided into two subculsters, the first includes *L. ehrenbargi* and the second subculster includes *L. bohar*. The results were discussed with those of other freshwater and marine fishes in term of functional morphology and taxonomic validity of scale microstructures. In conclusion, the scale morphology and ultrastrucure reflect patterns of variability valuable in species and generic discriminations with implicit of their functional anatomy and habitat adaptations.

Key words: Lutjanus, scale morphology, ultrastructures, taxonomy

INTRODUCTION

Scale characteristics have been considered relevant for fish taxonomy and morphology by Lippitsch (1990, 1991, 1993), Kuusipalo (1998), Mekkawy *et al.* (1999, 2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005), Harabawy *et al.* (2007) and Reza *et al.* (2009). Moreover, these characteristics are important in using scales in age determination (Elaine *et al.*, 2005; Darafsh *et al.*, 2008; Simon *et al.*, 2008; Granados-Flores *et al.*, 2010). The recent revival of interest in the superficial ornamentation of teleost scales involves also the functional approach in addition to the systematic one (Sire, 1986; Mekkawy *et al.*, 1999, 2003; Mahmoud *et al.*, 2005; Mekkawy and Abdel-Rahman, 2005; Harabawy *et al.*, 2007; Reza *et al.*, 2009).

Scanning Electron Microscopy had facilitated the application of microstructures to systematic as well as the interpretation of their functional interest; although both systematical and functional approaches utilize the surface structure of the scales, the ontogenetic development of these superficial ornamentation has never been studied nor are these studies concerned with their fate in adult fish except for the (Sire, 1986; Mekkawy *et al*., 1999, 2003; Mahmoud *et al*., 2005; Mekkawy and Abdel-Rahman, 2005; Harabawy *et al*., 2007). Theses studies dealt with the status of organization and growth of the surface structure during ontogeny. Sire and Geraudie (1983, 1984) studied in detail scale structure as well as the function of associated cells in scale production of cichlid *Hemichromis bimacultus*. These studies aimed at establishing a wide range of scale character sets for making a well defined taxonomic status and a well founded phylogenic tree of different groups of fishes. Lippitsch (1990-1993) highlighted in some details on the cichlid scale and squamation characteristics.

Studying taxonomic status of different fish species, Mekkawy *et al*. (1999, 2003), Mahmoud *et al*. (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al*. (2007) recorded variable character states on the bases of microstructures and ornamentations of scales of different marine and freshwater species from the Red Sea and the Nile. These authors discussed their result on the bases of functional and systematic points of view. No similar studies were recorded for the most economically important *Lutjanus* species.

The Lutjanidae is a family composed of 17 genera and 103 species of most reef dwelling marine fishes, collectively known as snappers (Allen, 1985). Snappers are mainly confined to tropical and subtropical marine water. The snappers are one of the most important families of fishes in the Red Sea area from the commercial fisheries point of view. 15 species were recorded in the Red Sea (Randall, 1993). In the Egyptian sector of the Red Sea, Lutjanus are abundant and represent the important component of local artisanal catch.

Accordingly, the present work aimed at screening and documenting the diversity of scale characteristics of three *Lutjanus* species: *L. bothar, L. monostigma* and *L. ehrenbergi* from the Red Sea at Hurghada and to answer the following questions in terms of systematic and functional approaches. What are the most useful scale characters for systematic purpose? What are the different states that can be distinguished in these characters? Can these characteristics be treated in morphometric terms? What is the possible functional interpretation of the surface scale ornamentation? The answer of the questions should give the bases for further work on scale characteristics and their exploitation for phylogenitic investigations for Lutjanidae. Amoung the most interesting scale characteristics considered in the present study were the overall form of the scale and their morphometric, the distribution of circuli, radii and granulation form of circulii radii number, shape of interradial denticles and the rostrolateral circuli and delimiting them, form of interradial denticles and rostrolateral circuli and their grooves and denticles and the lateral line canal along the lateral line.

MATERIALS AND METHODS

Specimen collection: In the present study, 511 scales from three *Lutjanus* species namely: *L. monostigma* (110-260 mm in standard Length, SL), *L. ehrenbergi* (110-250 mm SL) and *L. bohar* (150-750 mm SL) were examined to elucidate their scale characteristics. These specimens were collected from the Red Sea at Hurghada, Egypt from January 2002 to December 2002.

Scale measurements and examination: The examined scales were removed from the following position of the body:

- Directly below the anterior part of the dorsal fin (BDFS)
- Behind the Operculum (POS)
- The lateral line regions anterior (ALLS), middle (MLLS) and posterior (PLLS) regions
- Below the lateral line (BLLS) region (between the pectoral and pelvic fins).Scales forming the lateral line canal were also examined on the whole lateral line regions

Figure 1 shows the structure of a sectioned scale and the morphometric measurements considered.

In addition to the general morphology of the scales, their microstructures were studied by Scanning Electron Microscopy (SEM) in the most anterorostral and caudal regions. Scales examined were cleaned by physical careful removing of the adhering tissues debris without damage in the scale surface. Then they were immersed in a solution of 10% ammonia for 24 h to soften adhering tissues and to clean them. After drying for Scanning Electron Microscope (SEM) examination, they were fixed by sticker tape on a specimen holder and coated with a 30 nm layer of gold. The electron micrograph were produced on GAOL, GSMS 400 LV, SEM in back scattering mode and on a stereo scan Cambridge Mark 2A (15 kV).

Statistical analysis: These measurements in terms of raw data (L : scale length; L_1 : caudal field length; L_2 : radial region length; W : scale width) and indices (L1/L, L2/L, L1/L2 and W/L) were analyzed by multivariate analysis to reflect the pattern of size and shape of the scales and their taxonomic importance in species identification. The morphometric scale measurements were analyzed by the discriminant functional analysis and cluster analysis to elucidate intra- and inter-

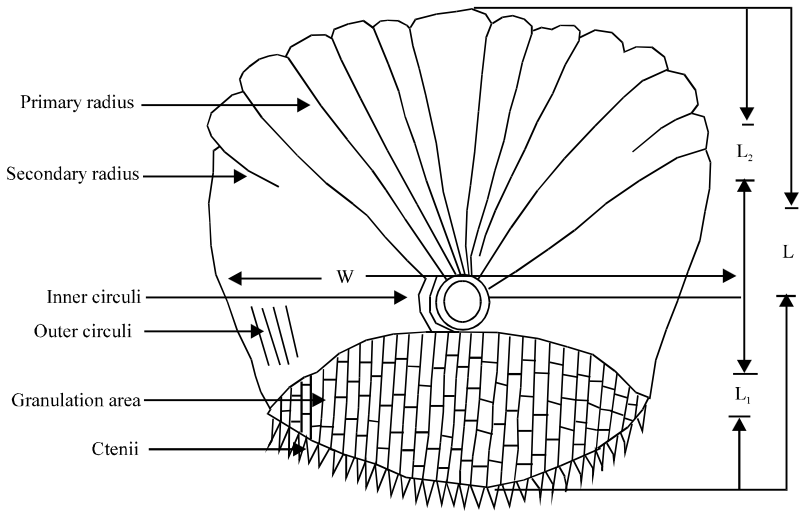

Fig. 1: A diagrammatic structure of *Lutjanus* scale showing the different regions, terms and morphometric measurements used in present work; L : scale length; L_1 : caudal field length; L_2 : rostral field length; W : scale width

specific variations using Statistical package release 5 (Statsoft, 1995). The qualitative characters revealed by SEM were coded and transformed to quantitative ones. Coded characters were analyzed by cluster analysis (Statsoft, 1995).

RESULTS

Scale characteristics: Scales of *Lutjanus* species are mainly of the ctenoid type on all parts of the body of the three species investigated. All scales of *Lutjanus* species considered were of the sectioned type (i.e. with well developed radii), no simple scales were recorded. The scales of such species show a characteristics surface ornamentation which in the simplest case consists of ridges and grooves, forming near circular rings around a center called focus, in addition to some type of granulation or ctenii area. The regenerated scales were also recorded.

The counts of primary radii ranged between 6-18 in *Lutjanus* species whereas the secondary radii ranged between 0-5 in different positions of the body (Table 1-2). Such counts were size free i.e., insignificant correlation with standard length for all species considered. The percentage occurrence and basic statistics of the primary and secondary radii counts of POS, BDFS, ALLS, MLLS PLLS and BLLS of *Lutjanus* species are given in Table 1 and 2. Which referred to variability in the distribution of the primary and secondary radii counts according to body scale position and species postulating intra- and inter-specific variations. Table 3 shows the basic statistics of the scale mrophometric indices (relative to scale length, L) of the three *Lutjanus* species. Only, L_1/L and L_2/L of *L. monostigma* and W/L of *L. ehrenbergi* are correlated with scale radius (L). According to these basic statistics and distributions of different types of radii, the inter-specific variations were evident with some overlapping.

Clustering of the three *Lutjanus* species in term of primary and secondary radii count exhibited two subclusters, one includes *L. ehrenbergi* and *L. bohar* and the other subcluster includes *L. monostigma* (Fig. 2). The inter-specific relationships are also postulated by canonical variates analysis (CVA) of the scale morphometric indices (Fig. 3, Table 4). The pattern of variations reflected by CVA referred to the partial discrimination between the three *Lutjanus* species on CVI only due to the discriminating power of L1/L index that has the higher loading on CVI (Table 4).

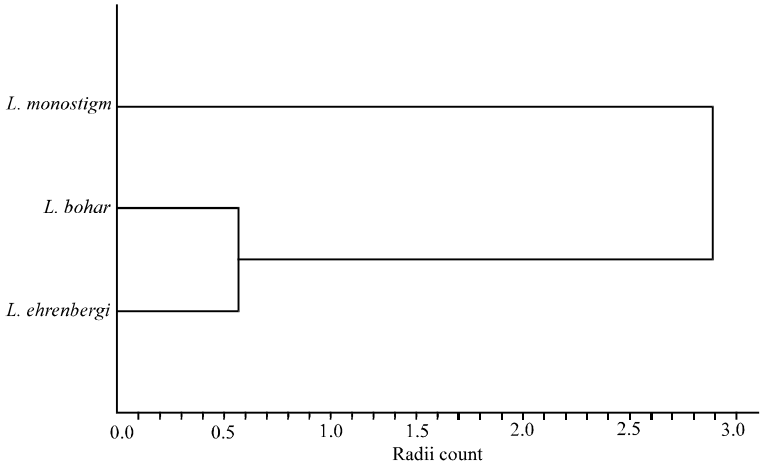

Fig. 2: Clustering (complete linkage, squared Euclidean distances) of the three *Lutjanus* species from Hurghada, Red Sea, Egypt based on scale primary and secondary radii count

Table 1: Percentages of occurrence and basic statistics of primary radii counts of the postopercular (POS), below dorsal-fin (BDFS) and anterior (ALLS), median (MLLS), posterior (PLLS) and below lateral line (BLLS) scales of three lutjanus species from the Red Sea, Hurghada, Egypt

Species	Scales	6	7	8	9	10	11	12	13	14	15	16	17	18	Mean±SD	N
L. monostigma	POS	-	-	12	12	4	28	16	4	8	8	8	-	-	11.56±0.48	50
	BDFS	-	-	19.2	11.5	7.7	23.1	15.4	7.7	11.5	3.8	-	-	-	10.90±0.42	26
	ALLS	8	16	24	28	20	4	-	-	-	-	-	-	-	8.50±0.30	25
	MLLS	-	-	24	16	12	20	16	8	4	-	-	-	-	10.30±0.40	26
	PLLS	-	-	-	-	4	16	12	12	20	20	16	-	-	13.50±0.40	22
	BLLS	-	-	-	-	28	20	36	4	12	-	-	-	-	11.50±0.30	25
L. ehrenbergi	POS	-	-	-	-	8	8	4	-	40	24	12	4	-	13.96±0.40	48
	BDFS	-	-	12	20	8	-	-	-	4	28	8	20	-	13.00±0.70	25
	ALLS	-	4	12	16	16	16	12	8	4	12	-	-	-	10.88±0.50	25
	MLLS	-	-	-	-	28	20	40	4	4	4	-	-	-	11.50±0.30	25
	PLLS	-	-	-	-	12	4	8	16	16	24	16	4	-	13.76±0.40	25
	BLLS	-	-	4	20	16	-	-	4	28	28	-	-	-	12.40±0.50	25
L. bohar	POS	-	-	-	-	-	12	40	36	12	-	-	-	-	12.50±0.20	50
	BDFS	-	-	-	-	12	12	28	28	20	-	-	-	-	12.30±0.30	26
	ALLS	-	4	12	20	12	16	20	12	4	-	-	-	-	10.50±0.40	25
	MLLS	-	-	-	4	4	4	16	20	16	32	-	4	-	13.40±0.40	25
	PLLS	-	-	-	-	-	4	-	16	40	12	20	4	4	14.50±0.30	25
	BLLS	-	-	-	8	36	24	12	4	16	-	-	-	-	11.20±0.30	25

Table 2: Percentages of occurrence and basic statistics of secondary radii counts of the postopercular (POS), below dorsal-fin (BDFS) and anterior (ALLS), median (MLLS), posterior (PLLS) and below lateral line (BLLS) scales of three lutjanus species from the Red Sea, Hurghada, Egypt

Species	Scales	0	1	2	3	4	5	Mean±SD	N
L. monostigma	POS	48	16	20	12	4	-	1.1±0.25	50
	BDFS	34.6	38.5	15.4	7.7	3.8	-	1.1±0.21	26
	ALLS	68	20	4	8	-	-	0.5±0.20	25
	MLLS	16	40	24	20	-	-	1.5±0.20	26
	PLLS	16	36	28	16	4	-	1.6±0.20	22
	BLLS	24	24	36	16	-	-	1.4±0.20	25
L. ehrenbergi	POS	24	48	24	4	-	-	1.1±0.20	48
	BDFS	40	20	32	8	-	-	1.1±0.20	25
	ALLS	32	52	16	-	-	-	0.8±0.10	25
	MLLS	12	40	32	16	-	-	1.5±0.20	25
	PLLS	24	40	16	8	8	4	1.5±0.30	25
	BLLS	16	36	36	12	-	-	1.5±0.20	25
L. bohar	POS	28	28	36	8	-	-	1.2±0.20	50
	BDFS	64	24	12	-	-	-	0.5±0.10	26
	ALLS	60	28	12	-	-	-	0.5±0.10	25
	MLLS	44	48	8	-	-	-	0.6±0.10	25
	PLLS	16	44	20	16	4	-	1.5±0.20	25
	BLLS	64	28	8	-	-	-	0.4±0.10	25

Scanning electron microscopic studies

Rostral field

The inter-radial tongues and 1st circulus: In the inter-radial space, the rostral rim of the scales form tongue-like projections that are free of circuli near the rim (Fig. 4) such tongues and the 1st inter-radial circulus where classified into three forms:

Table 3: Basic statistics (Mean±SD) of the morphometric indices of the postopercular scale of three lutjanus species from the Red Sea, Hurghada, Egypt

Indices	*L. ehrenbergi*	*L. bohar*	*L. monostigma*
L_1/L	0.7±0.03 (0.63-0.76)	0.7±0.03 (0.64-0.77)	0.75±0.04 (0.59-0.87)*
L_2/L	0.3±0.30 (0.24-0.38)	0.29±0.03 (0.23-0.36)	0.25±0.04 (0.13-0.4)*
W/L	1.1±0.09 (0.94-1.36)*	1.09±0.08 (0.92-1.24)	1.16±0.08 (0.91-1.31)
R(index and L)	(-0.33)-(0.27)	(-0.2)-(0.2)	(-0.35)-(1)

* Significant correlation at 0.01 level

Table 4: Standardized coefficients (cv-pos.sta) for canonical variables cvI-cvII derived from forward stepwise discriminant function analysis of the scale morphometrics (relative to scale length) of the three lutjanus species from the Red Sea, Hurghada, Egypt

Indices	CVI	CVII
L_1/L	-1.18	-0.59
L_2/L	-0.17	1.42
W/L	0.34	-0.46
Eigenvalue	0.95	0.31
Cum. Prop.	0.76	1.00

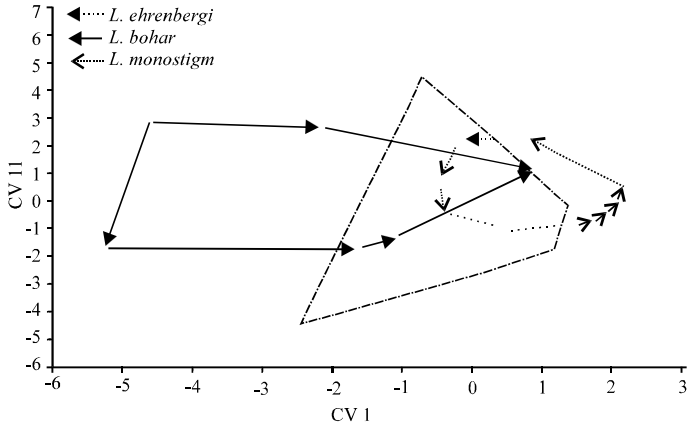

Fig. 3: Plots of scores of canonical variates (CVI and CVII) showing the interspecific scale-morphometric variations of the three *Lutjanus* species from Hurghada Red Sea, Egypt

Scanning electron microscopic studies

Rostral field

The inter-radial tongues and 1st circulus: In the inter-radial space, the rostral rim of the scales form tongue-like projections that are free of circuli near the rim (Fig. 4) such tongues and the 1st inter-radial circulus where classified into three forms:

- **Form 1:** The tongues are convex and the first inter-radial circulus is straight (Fig. 4a), this form was recorded in *L. monostigma* (POS) and *L. bohar* (BLLS)
- **Form 2:** The tongues are convex and 1st circulus is also convex (Fig. 4b), this form was recorded in *L-monostigma* (BDFS), *L. bohar* (POS) and *L-ehrenbergi* (BDFS and DOS)
- **Form 3:** There are no tongues and the rim of the scale in the inter-radial space is convex (Fig. 4c) this form was shown in *L. monostigma* (BLLS), *L. bohar* (BDFS) and *L. ehrenbergi* (BLLS)

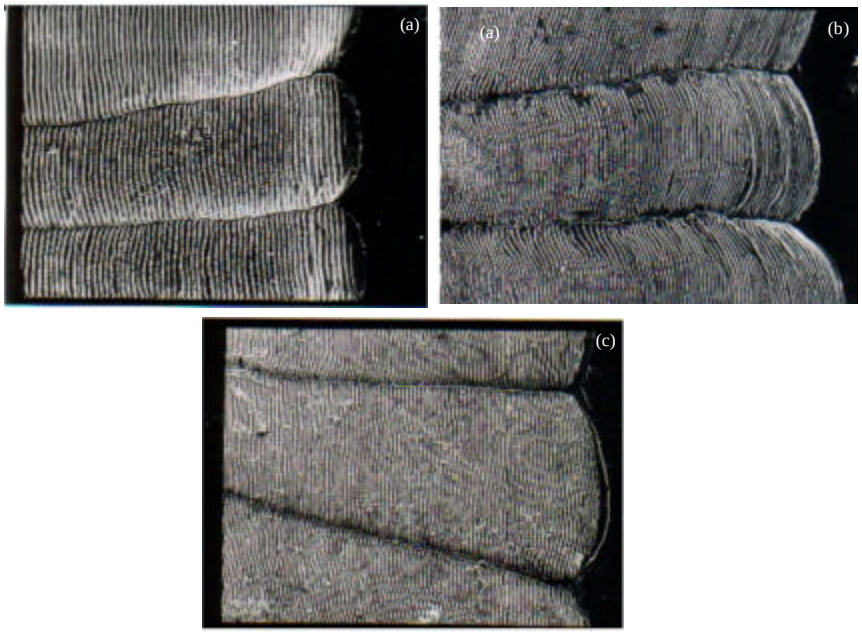

Fig. 4: The inter-radial tongues of the scales of three Lutjanus species from the Red Sea, Hurghada, Egypt, (a) convex tongues and the first circulus is straight, (b) convex tongues and the first circulus is convex and (c) no tongues and the first circulus is convex

Radial groove: According to the radial grooves of the scales of *Lutjanus* species studied there are three different types:

- **Type 1:** The grooves are wide and deep with thin membrane like structure (Fig. 5a), this was recorded in *L. monostigma* (BDFS and BLLS), *L. ehrenbergi* (BLLS and BDFS) and *L. bohar* (BDFS)
- **Type 2:** The grooves are very narrow with thin membrane like structure (Fig. 5b), this form was recorded in *L. monostigma* (POS), *L. bohar* (BLLS) and *L. ehrenbergi* (POS)
- **Type 3:** No grooves due to the overlapping of their sides, this type was recorded in *L. bohar* (POS)

Interradial circuli, grooves and denticles: The grooves between the interradial circuli were wide and flat. In the interradial space, the circuli bear small denticles that can be seen only under high magnification.

Four different characteristics types of denticles on dorsal side of the interradial circuli were identified:

- **Type 1:** The denticles were conical with recurved teeth (hook-like), this was recorded in *L. monostigma* (BLLS), *L. ehrenbergi* (BDFS) (Fig. 6a)
- **Type 2:** The denticles were ampula-like with pointed ends, such types were recorded in *L. monostigma* (POS), *L. bohar* (BDFS) and *L. ehrenbergi* (BLLS) (Fig. 6b)

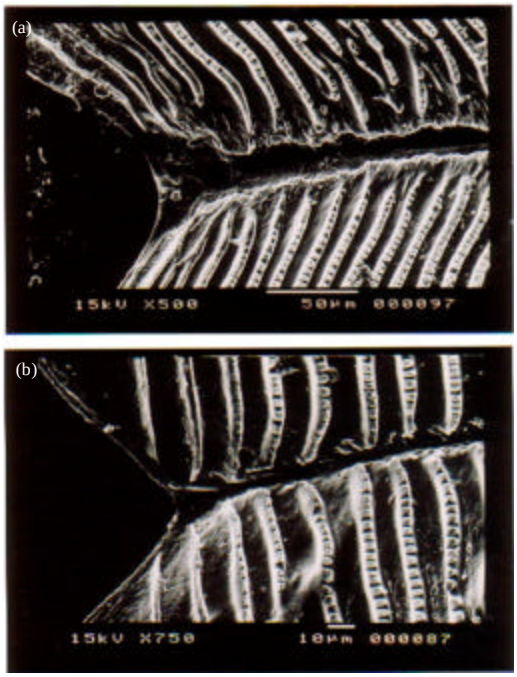

Fig. 5: The radial grooves of the scales of three *Lutjanus* species from the Red Sea, Hurghada, Egypt, (a) wide deep grooves and (b) narrow deep grooves with thin membrane-like structure

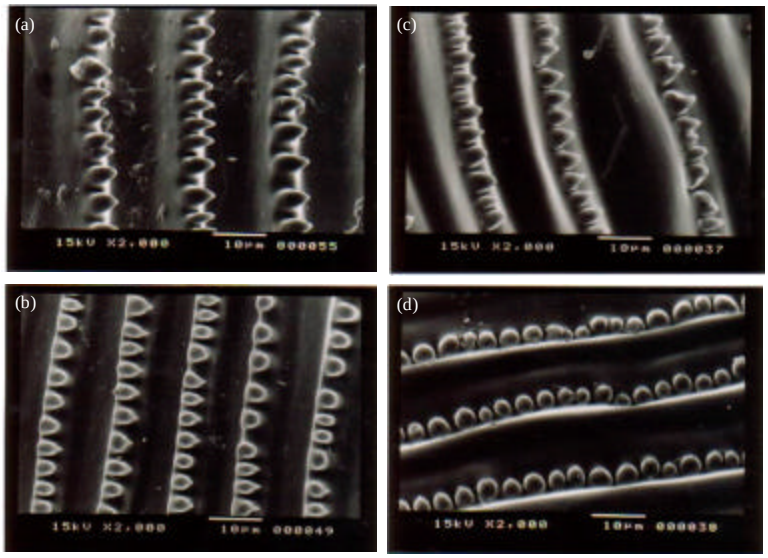

Fig. 6: The inter-radial circuli, denticles and grooves of three *Lutjanus* species from the Red Sea, Hurghada, Egypt, (a) the circuli bear curved conical shaped denticles, (b) the circuli bear ampula-like denticles with pointed ends, (c) the circuli bear irregular, conical mono and bicuspid denticles and (d) the circuli with rounded denticles; the grooves between the inter-radial circuli were flat and wide relative to the circulus thickness

- **Type 3:** The denticles were irregular, conical with mono and bicuspid ends. This type was recorded in *L. bohar* (BLLS) and *L. ehrenbergi* (POS) (Fig. 6c)
- **Type 4:** The denticles were rounded along the crests of circuli, such types were recorded in *L. bohar* (Fig. 6d)

The outer rostrolateral circuli: The most outer rostrolateral circular of *Lutjanus* species studied were free of denticles. The scale of *L. ehrenbergi* (BLLS and BDFS) and *L. bohar* (POS) have only one circulus free of denticles (Fig. 7a) whereas the scales of *L. ehrenbergi* (BLLS), *L. bohar* (BLLS) and *L. monostigma* (BDFS) have two circuli free of denticles (Fig. 7b). However the outer-rostrolateral circuli of *L. bohar* (BLLS) are free of denticles (Fig. 7c). The grooves between the outer circuli may be:

- Wide and flat enclosed by relatively high and thickened circuli (Fig. 7a), such grooves were recorded in *L. monostigma* (BDFS) and *L. bohar* (BLLS and POS).
- Grooves appear as V-shaped enclosed by a wide thickened circuli (Fig. 7b), such grooves were recorded in *L. ehrenbergi* (BDFS, POS and BLLS), *L. monostigma* (POS and BLLS) and *L. bohar* (BDFS).The inner rostrolateral circuli:

The inner rostrolateral circuli are typically irregular and have specific peculiar shapes and their crests are smooth and not denticulate (Fig. 8). The inner rostrolateral circuli are separated by a

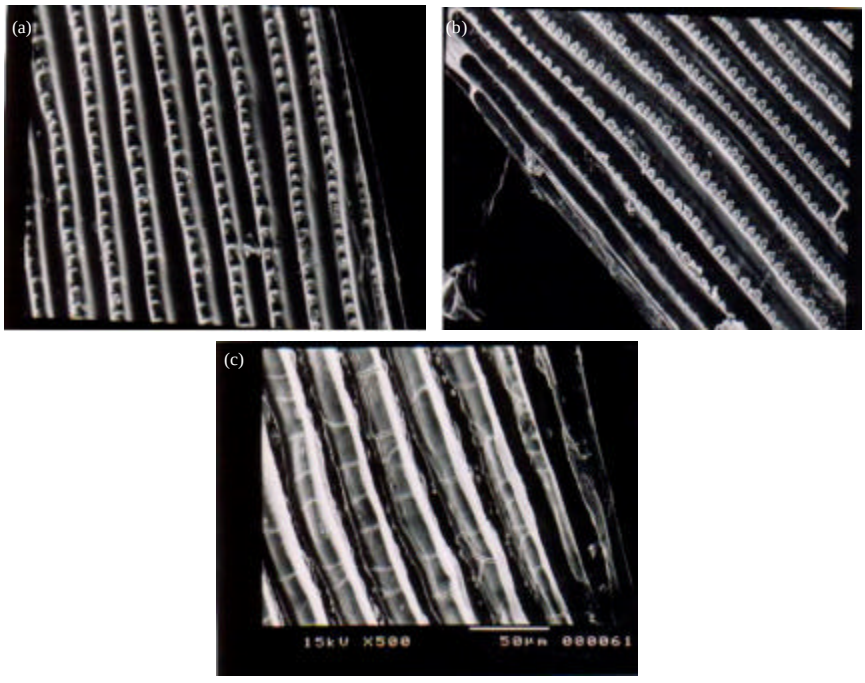

Fig. 7: The outer rostrolateral circuli and grooves of three *Lutjanus* species from the Red Sea, Hurghada, Egypt, (a) the first outer circulus is thin and free of denticles, (b) two outer circuli free of denticles with v-shaped grooves and (c) all of the outer circuli are free of enticles with u-shaped grooves

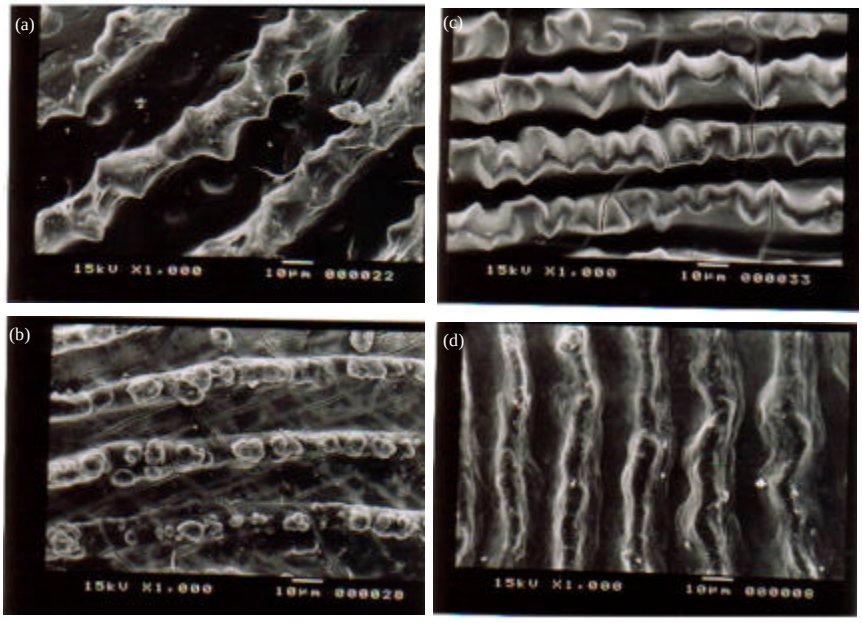

Fig. 8: The inner rostrolateral circuli and grooves of three *Lutjanus* species from the Red Sea, Hurghada, Egypt. The inner circuli have irregular and distinct shapes and are not denticulate (a and b) The inner circuli are separated with a wide flat grooves whereas (c and d) the inner circuli are separated by narrow grooves

wide flat grooves, such grooves were recorded in L-bohar (POS and BDFS) and *L. monostigma* (BLLS) (Fig. 8a,b) and deep narrow grooves recorded in *L. bohar* (BLLS) and *L. ehrenbergi* (POS) (Fig. 8c, d).

Focus region: The circuli of central part of the focus in all scales of *Lutjanus* species studied appear as tubercular ridges. The tubercles in the focus may be scattered in an irregular manner. Such pattern was recorded in the *L. bohar* (BLLS), *L. ehrenbergi* (POS and BLLS) and *L. monostigma* (BLLS and BDFS) (Fig. 9a, b, c). The focus with relative regular circuli was recorded in *L. bohar* (POS) (Fig. 9b). However, the focus may be degenerated (Fig. 9d).

Caudal field

Segmentation of the caudal field and ctenii: The posterior field of the scales appears as rows of segments arranged in parallel lines ends with ctenii at the posterior rim of the scale. The segments of each row occupied alternative position with those of adjacent ones. However, some of these segments are broken and have irregular shapes. Also, it is noted that, the caudal of all scales examined are perforated by a number of pores (Fig. 10a, b).

According to the segmentation of caudal field and shape of ctenii, the following five forms of scales were identified in *Lutjanus* species considered.

- Form 1 with square-like segments extended posteriorly into long pointed conical-shaped ctenii at the rim of the scale, this form was recorded in *L. monostigma* (BDFS) (Fig. 11a)

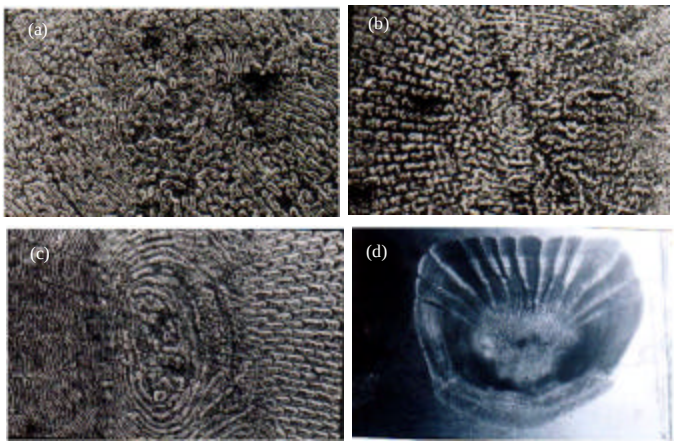

Fig. 9: The focus region in the scales of three *Lutjanus* species from the Red Sea, Hurghada, Egypt, (a) focus with tubercular ridges, (b) focus with wide, near-circular rings, (c) focus with narrow circular rings and (d) focus degenerated

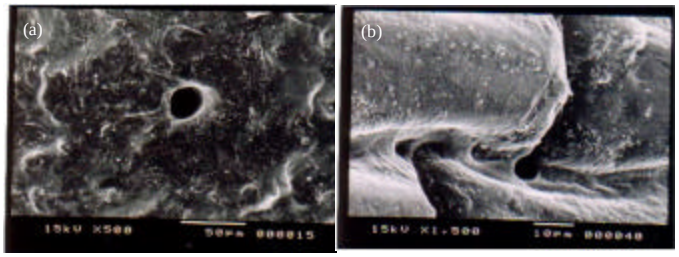

Fig. 10: Pores which are recorded in the caudal field of the scales of three *Lutjanus* species from the Red Sea, Hurghada, Egypt

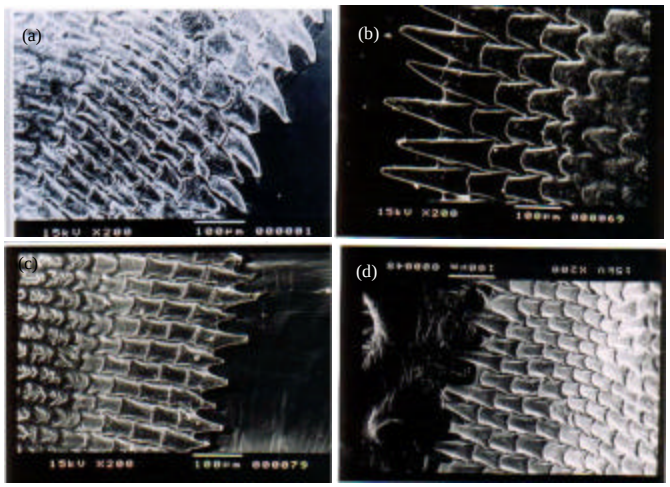

Fig. 11: Granulation patterns of *Lutjanus* species from the Red Sea, Egypt, (a) square-like segments with conical shaped ctenii, (b) rectangular-like segments with long irregular ctenii with blunted end, (c) irregular segments with curved pointed ctenii and (d) slightly rectangular segments with monocuspid, bicuspid and tricuspid conical ctenii

- Form 2 with slightly rectangular segments extending posteriorly into monocuspid, bicuspid and tricaspid conical ctenii, this form was recorded in *L. bohar* (POS and BDFS) (Fig. 11b)
- Form 3 with irregular segments extended posteriorly into curved pointed centii; this form was recorded in *L. ehrenbergi* (BDFS) (Fig. 11c)
- Form 4 with slightly square segments extended posteriorly into ctenii with long neck and irregular curved ends. Such form was recorded in *L. ehrenbergi* (BLLS) (Fig. 11d).
- Form 5 with rectangular segments extended posterirly into conical with cutted ends ctenii; this form was recorded in *L. monostigma* (POS)

The separations line and the shape of granulation area: The border between rostral and caudal field easily recognizable since the grooves between circuli become broad and many circuli have a dead end or merge with neighboring ones, therefore the circuli do not invade the posterior field of the scale.

The area of granulation in the caudal field was found to be sharply separated from the anterior rostral field. According to the separation line and the shape of granulation area, five types of scales in *Lutjanus* species studied were identified (Fig. 12).

- **Type 1:** The separation line is straight and the granulation area is semicircular, this type was specific for *L. bohar* (Fig. 12a)
- **Type 2:** The separation line is convex and granulation area is like convex lens. This type was recorded in *L. monostigma* (POS and BLLS) and *L. ehrenbergi* (POS) (Fig. 12b)
- **Type 3:** The separation line is straight with shallow groove at the central part and granulation area is rounded shaped, this was recorded in *L. ehrenbergi* scales (Fig. 12c)
- **Type 4:** The separation line is convex and the granulation area is V-shaped, this form was specific for *L. monostigma* (Fig. 12d)
- **Type 5:** The separation line is Λ-shaped and granulation area is divided into bundles separated by grooves, this type was recorded in the lateral line scales of all *Lutjanus* species (Fig. 12e)

Lateral line canal: The lateral line canal on the scales of three *Lutjanus* species studied exhibited similar pattern since it occupies the midline of the scale. Such canal extends from the anterior rim of the scale to the anterior side of granulation (granulated) area. Such canal decrease gradually from the anterior to the posterior field. It was noticed that the posterior opening of the canal is gradually deviated posteriorly to become near the posterior rim of the scale (Fig. 13a-f). The anterior canal opening is hidden by a cap-like extension cantilivered over it and posterior canal opening occurs medially in the focus region (Fig. 13b).

The aforementioned qualitative scale characteristics (31 scale characters) including the interradial tongues and shape of 1st circulus, the radial grooves, interradial circuli, grooves and denticles, the outer rostrolateral circuli and grooves, the inner rostrolateral circuli and denticle, the separation line and the shape of granulation area were coded and subjected to cluster analysis to elucidate the pattern of the interrelationships between the three *Lutjanus* species studied. Such pattern of encoded characters and that based on the size-free morphometric indices (insignificant correlation with SL at 0.01 level) of postopercular scales were similar to the pattern given by radii (Fig. 2) since *L. bohar* was grouped with *L. ehrenbergi* in a single sub-cluster whereas *L. monostigma* is represented by another one.

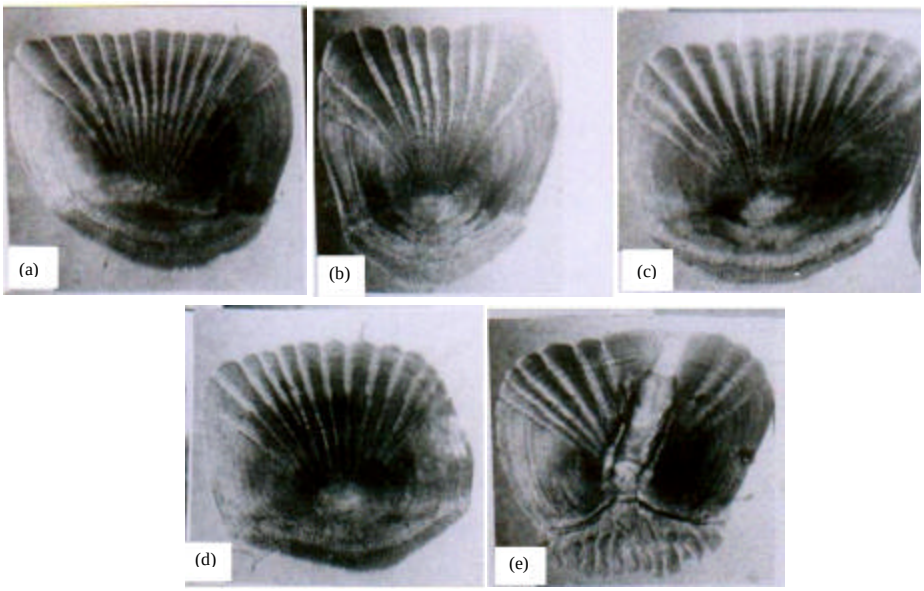

Fig. 12: Types (a-e) of scales identified in three Lutjanus species from the Red Sea, Hurghada, Egypt according to the rostrocaudal separation line and the shape of granulation area in caudal field

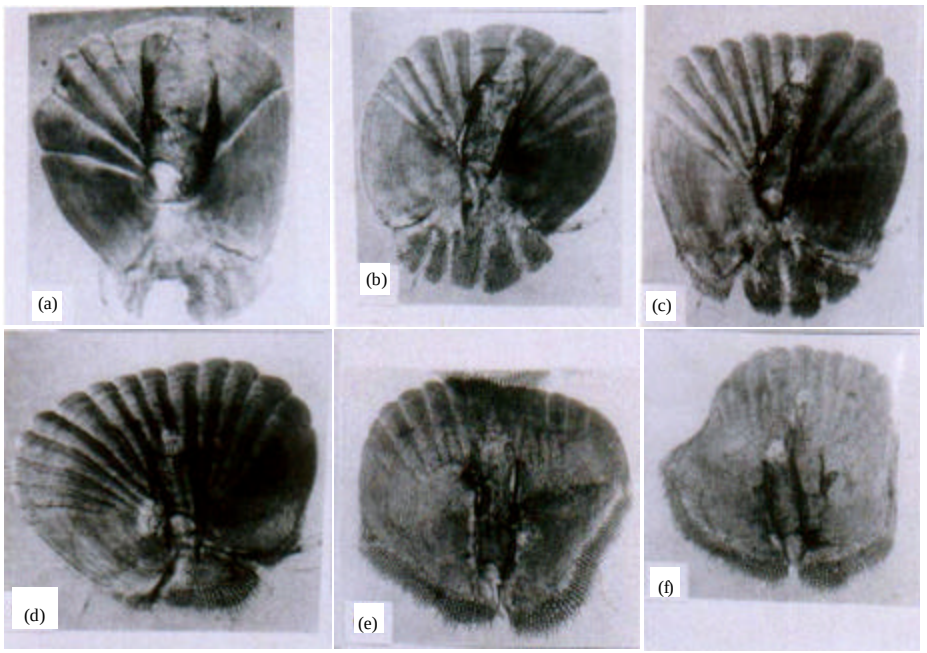

Fig. 13: The lateral line canal of scales of *Lutjanus* species from the Red Sea, Hurghada, Egypt Showing the characteristics and variable position of the lateral lines

DISCUSSION

Lippitsch (1989-1993) investigated the potential of scale and squamation characters for some cichlid systematic elucidating a wide spectrum of unexplained useful characters and suggesting that these characters are strongly determined gentically with little intraspecific variations and with independence from each other. She assessed the character states in the cichlid fishes and their polarity and presented phyletic hypothesis concerning relationships between taxa with assemblage and those out side groups. She postulated that the meristic scale characters which are usually given in species descriptions, seemed to provide no phylogenetic insight. According to the results of the present work and studies of Mekkawy *et al.* (1999, 2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005). Harabawy *et al.* (2007), similar situation was recorded for the three *Lutjanus* species studied in the present investigation. The genetically fixed scale characters would not appear to be subjected to such strong selectional pressures in spite of their functional significance referred to by Sire (1986) as would be for characters associated with tropic apparatus in cichlids (Lippitisch, 1992). So, these characters are therefore less likely to be the result of convergent evolution. These findings may be applied on the *Lutjanus* species studied in the present work concluding that their size-free genetically fixed scale characters are expressions of their divergent evolution.

Sire (1986) suggested that the surface of the overlapped and free regions of the scale of cichlid fishes do not change after they are formed. The stability of the surface structures of rostral and caudal field suggest their taxonomic importance for the identification of the *Lutjanus* species considered, in agreement with the findings reported by Lippitsch (1990-1993), Mekkawy *et al.* (1999, 2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al.* (2007).

Mekkawy *et al.* (1999, 2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al.* (2007) studied the stability of scale characters of some widely distributed marine and freshwater elucidating that they were not controlled by the environmental factors. In agreement with these studies, the current three species of *Lutjanus* were subjected to the same environmental factors of the marine fishes and hence their impacts were omitted. So, the inter-specific variations were considered to be genetically controlled. On the bases of quantitative and qualitative scale characters, these *Lutjanus* species were divided into two main groups, one includes *L. bohar* and *L. ehrenbergi* and other includes *L. monostigma*. These finding emphasized on the fact that the scale characters are genetically controlled and the first two species are closely related.

The circuli of the rostral field and their variable shaped denticles which directed towards the scalar focus suggest that they are involved in the mechanical anchoring of the scale into the covering dermis (i.e. they may act as minute hooks preventing movement or detachment of the scale), as already proposed for other teleosts (Sire, 1986; Mekkawy *et al.*, 1999, 2003; Mahmoud *et al.*, 2005; Mekkawy and Abdel-Rahman, 2005; Harabawy *et al.*, 2007). This explains why the isolated scales always have a well defined strip of skin adhering to it after removal (Lanzing and Bower, 1974; Mekkawy *et al.*, 1999) reported that the shape and distribution of denticles on the interradial and rostrolateral circuli permits two conclusions: (1) as all of the denticles are not oriented to a specific direction they constitute multi directional anchoring and (2) as the denticles are concentrated on the interradial circuli and absent on other rostrolateral ones, the anchoring is more important in the radial part of the rostral field and near the focus and less important in outer part of rostrolateral field (the newly formed circuli). These conclusions were confirmed by the present study and those of Mekkawy *et al.* (1999, 2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al.* (2007).

The patterns of granulation in the scale caudal field of the *Lutjanus* species studied were constant with fish size (Sire, 1986) stated that randomly deposited numerous tubercles are merely the mineralized remains of the bundles of collagen fibers that maintain the covering tissue close to scale surface preventing their sliding probably resisting frictional forces from several directions. The deposited granules recorded in most cases of *Lutjanus* species suggest the pronounced specilization in doing such a function and constant anchor through the caudal region. The epidermal cover of the *Lutjanus* species studied like other swimming fishes undergo friction forces due to water flow in coral reef habitats. These forces are directly transmitted to the free region by the bundle of anchoring collagen as suggested by Sire (1986) and confirmed by Mekkawy *et al.* (2003), Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al.* (2007).

Circuli and denticles of the interradial of the rostral field offer a resistance to these functional forces by mechanical anchoring. As postulated by Mekkawy *et al.* (1999) for *Epinephelus* emphasized by Mahmoud *et al.* (2005), Mekkawy and Abdel-Rahman (2005) and Harabawy *et al.* (2007) for other marine and freshwater fishes.

The granulation area of the scale of *Lutjanus* species studied in the present work was perforated by a number of pores. One can postulate that such pores may act as minute canaliculi through which the mucous can pass to cover the fish body which is significantly decreasing the friction between the fish and water and it promotes the healing of wounds (Holcick, 1989). In addition, these pores may represent apart of the lateral line system. Similar situation was recorded by Mahmoud *et al.* (2005) for *Lethrinus* species and Jawad and Al-Jufaili (2007) for *Saurida tumbil*.

Among the most interesting scale characteristics are the position of the anterior and posterior openings of the lateral line canal and its branches on the scales (DeLamater and Courtenay, 1974; Khalil *et al.*, 1982). These authors used the variable position of the anterior and posterior openings of the lateral line canal to differentiate between some fish species belonging to the same genus or to different genera. Khalil *et al.* (1982) recorded some pattern of displacement of the lateral line canal and in turn their openings on the scales directed toward the caudal end. They found such pattern of displacement to be valuable in species identification. Lateral line canal position on scales of *Lethrinus* species showed no definite trend (Mahmoud *et al.*, 2005). Mekkawy *et al.* (1999) revealed that no definite scale lateral line canal was record in *Epinephelus* species studied. In the present work, the lateral line canal was represented by unbranched tube extending from the scale of the caudal field to the beginning of the rostral field through the focus; Caudally no displacement of the lateral line canal on scales. No taxonomic value and no inter- or intra-specific variations in the shape of the lateral line of Lutjanus species studied.

In conclusion, freshwater and marine fish species may share in different patterns of scale characteristics, Moreover, the intra-specific, inter-specific and inter-generic differences are restricted to the frequencies of their distribution depending on the genetic factors and the range of environmental factors controlling these genetics. In addition, fishes of the same habitat have common scale ultrastructure with variable distribution among species. However, some scale characteristics may be species specific or even genus specific.

REFERENCES

Allen, G.R., 1985. FAO species catalogue vol. 6. Snappers of the world an annotated and illustrated catalogue of Lutjanid species known to date. FAO Fish. Synopsis, 6: 208-208.

Darafsh, F., A. Mashinchian, M. Fatemi and S. Jamili, 2008. Study of the application of fish scale as bioindicator of heavy metal pollution (Pb, Zn) in the *Cyprinus carpio* of the Caspian Sea. Res. J. Environ. Sci., 2: 438-444.

DeLamater, E.D. and W.R. Jr. Courtenay, 1974. Fish scales as seen by scanning electron microscopy. Florida Sci., 35: 141-149.

Elaine, E.B., C.S. Esther Guadalupe and G. Cabello, 2005. Age determination of *Mugil curema* valenciennes, 1836 (Pisces: Mugilidae) in the cuyutlan lagoon, colima, Mexico. Int. J. Zool. Res., 1: 21-25.

Granados-Flores, K., M. Gallardo-Cabello, E. Espino-Barr and E.G. Cabral-Solis, 2010. Age determination of *Microlepidotus brevipinnis* (Steindachner, 1869) (Pisces: Haemulidae) in the coast of Jalisco, Mexico, by reading otoliths and scales. Int. J. Zool. Res., 6: 1-12.

Harabawy, A.S.A., I.A.A. Mekkawy and U.M. Mahmoud, 2007. A comparative study on scale characteristics and their functional morphology of four Goatfishes (Family Mullidae) from the Red Sea. J. Egypt. Soc. Biotech. Environ. Soc., 9: 123-163.

Holcick, J., 1989. The Fresh Water Fishes of the Europe. Vol. I/II: General Introduction to Fishes. Aula-Verlag, Wiesbaden Press, Germany, pp: 20-127.

Jawad, L.A. and S.M. Al-Jufaili, 2007. Scale morphology of greater lizardfish *Saurida tumbil* (Bloch, 1795) (Pisces: Synodontidae). J. Fish Biol., 70: 1185-1212.

Khalil, A., E.G. Yoakim and I.A.A. Mekkawy, 1982. Identification of two Nile fish species of the genus *Alestes* by scale characteristics. Bull. Fac. Sci. Assiut Univ., 11: 185-207.

Kuusipalo, L., 1998. Scale morphology in Malawian cichlids. J. Fish. Biol, 52: 771-781.

Lanzing, W.J.R. and C.C. Bower, 1974. Development of colour patterns in relation to behavior in *Tilapia mossambica* (Peter). J. Fish. Biol., 6: 29-41.

Lippitsch, E., 1989. Scale surface morphology in African Cichlids (Pisces, Perciformes). Ann. Musee Roy Afr. Centr. Sci. Zool., 157: 105-108.

Lippitsch, E., 1990. Scale morphology and squamation patterns in Cichlids (Teleostei, Perciformes): A comparative study. J. Fish Biol., 37: 265-291.

Lippitsch, E., 1991. Comparative investigation on scale characters in Cichlids. Ann. Musee Roy Afr. Centr. Sci. Zool., 263: 97-102.

Lippitsch, E., 1992. Squamation and scale character stability in Cichlids, examined in *Sarotherodon galilaeus* (Linnaeus,1758) (Perciformes, Cichlidae). J. Fish. Biol., 41: 355-362.

Lippitsch, E., 1993. A phyletic study on *lacustrine haplochromine* fishes (Perciformes, Cichlidae) of East Africa, based on scale and squamation characters. J. Fish. Biol., 42: 903-946.

Mahmoud, U.M., I.A.A. Mekkawy and A.S.A. Harabawy, 2005. Scale characteristics of seven species of genus Lethrinus (Family Lethrinidae) from the Red Sea, Egypt. J. Zool., 44: 545-580.

Mekkawy, I.A.A., S.M.A. Shehata, S.A. Saber and A.G.M. Osman, 1999. Scale characteristics of five species of genus *Epinephelus* (Family: Serranidae) from the Red Sea, Egypt. J. Egypt. Ger. Soc. Zool., 30: 71-102.

Mekkawy, I.A.A., U.M. Mahmoud and A.S.A. Harabawy, 2003. Identification of four *Labeo* species by their scale characteristics from the Nile, Egypt: Morphometrics and scanning electron microscopic study. Bull. Fac. Sci. Assiut. Univ., 31: 21-41.

Mekkawy, I.A.A. and G.H. Abdel-Rahman, 2005. Comparative study of scales of five species of parrotfishes (Family Scaridae) from the Red Sea, Hurghada, Egypt with emphasis on their functional morphology. Egypt. J. Zool., 44: 421-443.

Randall, J.E., 1993. Red Sea Reef Fishes. IMMEL Publishing Ltd., London, pp: 192.

Reza, E.H., B. Somayeh, Z. Halimeh and S. Fatemeh, 2009. Scale morphology of tank goby *Glossogobius giuris* (Hamilton-Buchanan, 1822) (Perciformes: Gobiidae) using scanning electron microscope. J. Biol. Sciences, 9: 899-903.

Simon, K.D., A.G. Mazlan, Z.C. Cob, A. Samat and A. Arshad, 2008. Age determination of archer fishes (*Toxotes jaculatrix* and *Toxotes chatareus*) inhabiting Malaysian Estuaries. J. Boil. Sci., 8: 1096-1099.

Sire, J.Y. and J. Geraudie, 1983. Fine structure of the developing scale in the Cichlid *Hemichromis bimaculatus* (Pisces, Teleostei, Perciformes). Acta Zool. (Stockh.), 64: 1-8.

Sire, J.Y. and J. Géraudie, 1984. Fine structure of regenerating scales and their associated cells in the Cichlid *Hemichromis bimaculatus* (Gill). Cell Tiss. Res., 237: 537-547.

Sire, J.Y., 1986. Ontogenetic development of surface ornamentation in the scale of *Hemichromis bimaculatus* (Cichlidae). J. Fish Biol., 28: 713-724.

Statsoft, 1995. Statistica for Windows. Stasoft, Inc., Tulsa, OH.