Scale characteristics of *Acanthopagrus bifasciatus* (Forsskål, 1775) from the Southern Red Sea, Egypt

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**Abstract**

*Acanthopagrus bifasciatus* is a member of family Sparidae. It is a tropical coastal fish species distributed throughout the Red Sea and the western Indian Ocean. In the present study, 253 scales from ten specimens of *A. bifasciatus* (*170 - 350 mm Total length*) were examined to elucidate their scale characteristics. A wide spectrum of intraspecific variation between different body regions of *A. bifasciatus* was recorded in terms of scale morphometric indices and primary and tertiary radii counts. The scale characters including rostral field, outer and inner lateral circuli, grooves, denticles, focus region, granulation in caudal field and lateral line canal were studied. Scale morphology and ultrastructure characteristics are important for fish identification, taxonomy and phylogeny.

**Keywords:** Red Sea; *Acanthopagrus bifasciatus*; scale morphometry; scanning electron microscope

1. **Introduction**

Family Sparidae represents one of the most important fish families in the Red Sea and *Acanthopagrus bifasciatus* is member of this family. Its members are carnivorous, marine, brackish, reef-associated and inhabit shallow coastal waters mainly aroreefs at depth ranged from 2-20 m [1, 2]. *Acanthopagrus bifasciatus* is distributed in the Western Indian Ocean from the Red Sea and Arabian Gulf to Natal in South Africa [2]. Scale characteristics have been considered relevant for fish identification, taxonomy and phylogeny especially with great developments of Scanning Electron Microscopy that had facilitated the application of scale microstructures to systematic [3, 6]. The morphological features and ultrastructure of teleost scales were studied by many authors in an attempt to discover new characteristics for scales that may be useful in fish taxonomy [7, 9, 3, 10, 12, 4, 13, 18, 5, 6]. Most of these studies aimed to provide a wide range of valuable scale characters that can reflect a clear taxonomic status. The present study aimed to screening and documenting the diversity of scale characteristics of *Acanthopagrus bifasciatus* from the Southern Red Sea, Egypt in an attempt to determine the valid scale characters for fish identification and to give an interpretation for the surface scale ornamentation in terms of functional approaches.

2. **Materials and methods**

2.1. **Specimen collection**

In the present work, 253 scales from ten specimens of *A. bifasciatus* (*170 - 350 mm Total length* (TL)) were examined to elucidate their scale characteristics. These specimens were collected from the Southern Red Sea, Egypt during the period January 2015 to December 2015.

2.2. **Scale preparation and measurements**

The scales were gently removed from the left side of the body from the following positions on the body (Fig. 1 a):

a- Region A, below the anterior part of the dorsal fin (BDFS).
b- Region B, post-operculum (POS).
c- Region C, below the lateral line, between the pectoral and pelvic fins (BLLS).
d- Region D, caudal peduncle directly above the lateral line (CPS).
e- Region E, anterior lateral line scales (ALLS)
f- Region F, middle lateral line scales (MLLS)
g- Region G, posterior lateral line scales (PLLS) from caudal peduncle region.

The scales of the first four regions (A, B, C and D) were used for morphometric measurements and radii counts. While scales forming the lateral line were examined to show the lateral line pattern, shape and characters of the lateral line canal.

Examined scales were cleaned carefully to remove the adhering tissues debris without damage in the scale surface. Then they were immersed in a solution of 10% ammonia for 24-36 h. to soften adhering tissues and to clean them. Cleaned scales were dried on a filter paper and kept between two glass slides.

Fig. 1b shows the structure of a sectioned scale, types of radii and the morphometric measurements considered. The primary, secondary and tertiary radii were counted to reveal intraspecific variations. The morphometric measurements were treated in terms of indices (L1/L, L2/L, L1/L2 and W/L) where L, L1, L2 and W are scale length, rostral field length, caudal field length and scale width, respectively.

2.3. Microscopic study
Scanning Electron Microscopy (SEM) was used to study the morphology and microstructures of the scales in the rostral, lateral, and caudal regions. The cleaned and dried scales that are used for Scanning Electron Microscope (SEM) examination were mounted and fixed by sticker tape on a specimen holder and coated with a 30-nm layer of gold. The electron micrographs were produced on GAOL G5400LV, SEM in back scattering mode and on a Stereo Scan Cambridge Mark 2A (15 KV ) in Assiut University Electron Microscope Center, Assiut, Egypt.

2.4. Statistical analysis
Basic statistics of scale characteristics were estimated. To clarify intraspecific variation of *A. bifasciatus*, ANOVA was applied on the morphometric indices of scales using SPSS package, release 16.0.0 [19].

3. Results
3.1. General morphology of scales
The scales of *A. bifasciatus* are mainly of the sectioned type (i.e. with well-developed radii) on all parts of the body. The scales of *A. bifasciatus* show distinctive surface ornamentation which in its simplest case consists of circuli and grooves, forming nearly circular rings area center called focus. The scales on the post-operculum region (POS) were the largest ones in comparison with those of the other regions studied. In the rostral part of the scale, the circuli were partitioned by deep and narrow groves (radii) that run radially between the focus and anterior rim. The radii on the scales of *A. bifasciatus* can be categorized into three types depending on their origin and end on the scale including: Primary, secondary, tertiary (Fig. 1b).

3.2. Morphometrics and counts of radii
Table 1 shows the basic statistics of the scale morphometric indices (relative to scale length, L) from four body regions (A, B, C & D). This table reveals intraspecific variations in these scale morphometric characteristics of the four body regions. The indices L1/L and W/L showed significant difference between scales of the four body regions (p<0.05) whereas, L2/L and L1/L2 revealed highly significant difference (p<0.01). Such morphometric indices were size- free (P>0.05) (Table 2).

The percentages of occurrence and basic statistics of the primary, secondary and tertiary radii counts are given in Tables 3-5. Table 3 shows variation in the primary radii counts of the scales from the four regions (A, B, C & D). These counts were ranged between 7 -17. The secondary radii counts ranged between 0 – 1 (Table 4). The tertiary radii counts ranged between 0-5 (Table 5). Such radii counts were size- free (P>0.05) (Table 6).

Table 1: Basic statistics, Mean ± SD and (Range) of the morphometric indices of scales from four body regions of *A. bifasciatus* from the Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Index</th>
<th>Region A (PDFS) Mean±SD (Range)</th>
<th>Region B (POS) Mean±SD (Range)</th>
<th>Region C (BLLS) Mean±SD (Range)</th>
<th>Region D (CPS) Mean±SD (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N= 62</td>
<td>N= 52</td>
<td>N= 81</td>
<td>N= 58</td>
</tr>
<tr>
<td>L1/L*</td>
<td>70.52±3.84 (62.5-77.78)</td>
<td>72.79±4.19 (64.81-81.25)</td>
<td>73.48±4.30 (62.14-81.81)</td>
<td>75.61±5.27 (60.87-85)</td>
</tr>
<tr>
<td>L2/L**</td>
<td>29.46±3.86 (22.22-37.50)</td>
<td>27.06±4.31 (18.75-36)</td>
<td>26.62±4.27 (18.18-37.86)</td>
<td>24.44±5.24 (15-39.13)</td>
</tr>
</tbody>
</table>
Table 2: Correlation coefficient between total length (TL) and the morphometric indices of scales from four body regions of *A. bifasciatus* from the Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Index</th>
<th>TL</th>
<th>L1/L</th>
<th>L2/L</th>
<th>L1/L2</th>
<th>W/L</th>
<th>R1/L2</th>
<th>W/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B (PDFS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C (BLLS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Percentages of occurrence and basic statistics of the primary radii counts of scales from four body regions (A, B, C & D) of *A. bifasciatus* from Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Regions</th>
<th>N</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (BDFS)</td>
<td>62</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.61</td>
<td>4.84</td>
<td>27.42</td>
<td>33.87</td>
<td>24.19</td>
<td>4.84</td>
<td>1.61</td>
<td>1.61</td>
<td>13.5±2.45*</td>
</tr>
<tr>
<td>B (POS)</td>
<td>52</td>
<td>0</td>
<td>5.77</td>
<td>11.54</td>
<td>7.69</td>
<td>13.46</td>
<td>27.42</td>
<td>33.87</td>
<td>15.38</td>
<td>9.61</td>
<td>11.54</td>
<td>5.77</td>
<td>12.5±3.02*</td>
</tr>
<tr>
<td>C (BLLS)</td>
<td>81</td>
<td>2.47</td>
<td>6.17</td>
<td>8.64</td>
<td>13.58</td>
<td>18.52</td>
<td>25.86</td>
<td>20.69</td>
<td>15.52</td>
<td>13.97</td>
<td>6.89</td>
<td>8.62</td>
<td>10.5±2.45*</td>
</tr>
<tr>
<td>D (CPS)</td>
<td>58</td>
<td>1.72</td>
<td>7.89</td>
<td>20.69</td>
<td>25.86</td>
<td>15.52</td>
<td>13.97</td>
<td>6.89</td>
<td>8.62</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10.5±2.45*</td>
</tr>
</tbody>
</table>

* Differences are highly significant at 0.01 level.

Table 4: Percentages of occurrence and basic statistics of the secondary radii counts of scales from four body regions (A, B, C & D) of *A. bifasciatus* from Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Regions</th>
<th>N</th>
<th>0</th>
<th>1</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (BDFS)</td>
<td>62</td>
<td>70.97</td>
<td>29.03</td>
<td>0.49±0.28</td>
</tr>
<tr>
<td>B (POS)</td>
<td>52</td>
<td>75</td>
<td>25</td>
<td>0.50±0.35</td>
</tr>
<tr>
<td>C (BLLS)</td>
<td>81</td>
<td>76.54</td>
<td>23.46</td>
<td>0.49±0.37</td>
</tr>
<tr>
<td>D (CPS)</td>
<td>58</td>
<td>60.35</td>
<td>39.65</td>
<td>0.49±0.48</td>
</tr>
</tbody>
</table>

* Differences are highly significant at 0.01 level.

Table 5: Percentages of occurrence and basic statistics of the tertiary radii counts of scales from four body regions (A, B, C & D) of *A. bifasciatus* from Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Regions</th>
<th>N</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Mean±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (BDFS)</td>
<td>62</td>
<td>53.23</td>
<td>40.32</td>
<td>6.45</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1±1*</td>
</tr>
<tr>
<td>B (POS)</td>
<td>52</td>
<td>42.31</td>
<td>21.15</td>
<td>34.62</td>
<td>0</td>
<td>0</td>
<td>1.92</td>
<td>2±2.1*</td>
</tr>
<tr>
<td>C (BLLS)</td>
<td>81</td>
<td>34.57</td>
<td>39.51</td>
<td>22.22</td>
<td>3.70</td>
<td>0</td>
<td>0</td>
<td>1.5±1.29*</td>
</tr>
<tr>
<td>D (CPS)</td>
<td>58</td>
<td>55.35</td>
<td>32.14</td>
<td>12.5</td>
<td>1.78</td>
<td>1.78</td>
<td>0</td>
<td>2±1.58*</td>
</tr>
</tbody>
</table>

* Differences are highly significant at 0.01 level.

Table 6: Correlation coefficient between total length (TL) and the radii counts of scales from four body regions of *A. bifasciatus* from the Southern Red Sea, Egypt.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Index</th>
<th>TL</th>
<th>Primary radii</th>
<th>Secondary radii</th>
<th>Tertiary radii</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (PDFS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Primary radii</td>
<td>Secondary radii</td>
<td>Tertiary radii</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.310</td>
<td>0.283</td>
<td>-0.243</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.141</td>
<td>-0.155</td>
<td>-0.141</td>
</tr>
</tbody>
</table>
3.3. Scanning electron microscopic studies

3.3.1. Rostral field
In the inter-radial space, the rostral rims of the scales in seven regions form tongue-like projections that are free of circuli near the rim (Fig. 2a). These projections may be convex or straight. The 1st inter-radial circulus was straight or slightly convex. The radial grooves in the rostral field of the scales in seven regions appeared as a deep irregular groove (Fig. 2b).

![Fig 2: Scanning electron micrographs show (a) the Inter-radial Tongues (IRT), 1st inter-radial circulus (IRC) and Radii (R) in the rostral field of the scales recorded in *A. bifasciatus*; (b) Deep radial grooves(R) with irregular split.](image)

3.3.2. Inter-radial circuli, grooves and denticles
The intercircular grooves in the rostral field were narrow (Fig. 3a). The interradial circuli bear strong small denticles or tooth-like structures with thick free ends oriented backwardly, some denticles were based on vesicle like base.

3.3.3. Outer lateral circuli, grooves and denticles
The outer lateral circuli were low and bear weak denticles (Fig. 3b). The grooves between circuli were wide and flat.

3.3.4. Inner lateral circuli, grooves and denticles
Inner lateral circuli were thick and separated by V-like grooves (Fig.3c). These circuli bear thick and wide denticles with rounded tops.

![Fig 3: Scanning electron micrographs show (a) The inter-radial circuli; (b): The most outer lateral circuli and (c): The inner lateral circuli recorded in scales of *A. bifasciatus*. Denticles (D), vesicle-like bases (V), groove (G), inter- radial circuli (C) and outer lateral circuli (OLC).](image)

3.3.5. The focus region:
This region was characterized by unique pattern of horny plates-like structures surrounded by rows of tubular ridges in scales and noncircular found (Fig. 4a&b).

![Fig 4 (a & b): Scanning electron micrographs show: The focus region with horny plates-like structures surrounded by rows of tubercular ridges recorded in scales of *A. bifasciatus*. The focus region (F) and tubercular ridges (TR).](image)

3.3.6. Caudal field
The granulation area in caudal field has no circuli but contains bear shape segments and conical shape centii extended posteriorly in the ctenoid scales of seven regions (Fig. 5a).

3.3.7. Lateral line canal
The lateral line canal is divided into a rostral wide tube extend anteriorly to some extent end and do not reach the anterior margin. In caudal field, there were three pores extend from the center of the scale toward the posterior margin having V-like shape (Fig. 5b).

![Fig 5: Scanning electron micrographs show the lateral line canal and its pores in caudal field of *A. bifasciatus*.](image)
The present study revealed also that the shape of the first interradial circuli was convex or straight and all denticles on the interradial circuli were oriented posteriorly towards the scalar focus, while those found the inner lateral circuli are slightly oriented towards the scale center. This means that the denticles have multi directions and hence, may be involved in the mechanical anchoring of the scale into the covering dermis to prevent the movement or detachment of the scale. Jawad [10] stated that small-sized processes located on the circuli cannot anchor the scale in the dermis as securely as can the well-developed denticles but may be anchored in the surrounding tissue by the bundles of the collagen fibers. The pattern of granulation of the caudal field including shape and size of segments and ctenii and overall caudal field of the scales of A. bifasciatus were constant with fish size. Such findings emphasized on the importance of caudal field of scales as a taxonomic characters not only at the level of species or genera but also at family level [31, 23, 24, 9, 11, 12, 4].

The anterior opening of the lateral line canal of A. bifasciatus studied is hidden by an evelike extension cantilevered over it. The anterior opening is wider than the posterior one. The cantilevered anterior extension of the canal may help in direction of water motion speed and direction [32]. A wide range of various structural patterns of lateral line canals was recorded in different teleost species by many authors [29, 10, 12, 4, 5]. Its form was ranged from a simple perforation to a long canal with or without simple to highly complex cantilevered extensions acting as covers for the anterior opening.

Variations in the shape and position of the anterior and posterior openings of the lateral line canal reflect its importance to differentiate between some fish species belonging to the same genus or different genera. Also, it may be important in identification of groups (orders, families, genera and species) especially when combined with other equally impressive characters of scale structure [31, 12, 4].

5. Conclusion
The quantitative scale characters (morphometric indices and radii counts) displayed a lot of intraspecific variations in A. bifasciatus studied. Application of scanning electron microscope to reveal morphology, ultrastructure and surface ornamentation of fish scale had facilitated its utility to distinguish the taxonomic groups over a continuum ranging from higher taxa to species.

6. Acknowledgment
Great appreciation to the group of Electron Microscope Center, Assiut University, Egypt for help and kind cooperation.

7. References
3. Mekkawy IAA, Wassif ET, Basimdi AAM. Scale


