

## GENUS *AMPHISOLENIA* STEIN FROM NORTH-WEST ARABIAN SEA SHELF OF PAKISTAN

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### Abstract

The present paper describes 18 species of the dinoflagellate genus *Amphisolenia* Stein from the northwest Arabian Sea bordering Pakistan, including two new species *Amphisolenia acuta* sp. nov., and *Amphisolenia deltiana* sp. nov., and four new records *Amphisolenia brevicauda*, *Amphisolenia globifera*, *Amphisolenia schauinslandi* and *Amphisolenia* sp., from the area. Most species were rare except *Amphisolenia bidentata* which was most common. The description of the species is supplemented by illustrations and a key to facilitate their identification. Most species were neritic or neritic-oceanic and tropical or sub-tropical in nature which is indicative of the area of study. The species diversity was higher on the Indus Delta shelf area than on Balochistan shelf. Most species occurred in the transition period and less in cold northeast monsoon season. The individuals of a given species varied significantly among each other with respect to their sizes and dimensions.

### Introduction

The genus *Amphisolenia* Stein (1883) is marine and planktonic belonging to the *Amphisoleniaceae* in the order *Dinophysiales*. It is predominantly tropical and subtropical in distribution and has been reported from different parts of the world (Ballantine, 1961; Solum, 1962; Abé, 1967; Wood, 1968; Sournia, 1973; Taylor *et al.*, 1995; Gomez, 2005), but the information from the North Arabian Sea shelf in Pakistan is scanty and sporadic (Noorudin, 1967; Kuzmenko, 1975; Taylor, 1976). Saifullah & Hasssan (1973) studied seven species of the genus from a strictly coastal polluted Karachi harbour. Later, Mansoor & Saifullah (1995) and Saifullah (1999) described a new species and a new variety of *Amphisolenia* from the shelf. Saifullah *et al.*, (2002) then described 9 more species from Pakistan's shelf and deep sea vicinity from samples collected by the Norwegian Fridtjof Nansen cruise during March and April 1977 only. The present study includes the samples collected from the entire area during the period of the cruise from January 19 to June 20, 1977 and, therefore, gives an overall picture of the composition of species of *Amphisolenia* from the area.

### Materials and Methods

Samples were collected during the Norwegian cruise "Dr. Fridtjof Nansen" which was carried out in the North Arabian Sea bordering Pakistan extending from 15m depth contour near shore to 150 nautical miles offshore in the open sea during the period 19 January to 20 June 1977 (Anon., 1978; Saifullah, 1979). In all 75 fixed stations were sampled repeatedly on the shelf and deep sea vicinity. Phytoplankton samples were collected by horizontal net hauls of 5 minutes duration at each station, the mesh size of the net being 40µm. In all 400 samples were collected which were immediately fixed with 4% formalin at the time of sampling. They were later studied and identified in the laboratory employing a light research microscope. The specimens were stained in cotton

blue and mounted on 50% glycerin. The edges of the cover slip were sealed with nail polish to avoid evaporation. Several individuals of a given species were measured to take into account size variations. Temperature was measured by reversible thermometer and salinity by a salinometer.

### Observations and Results

***Amphisolenia* Stein:** The body of this genus has narrow, elongate hypotheca with a slightly swollen midbody, with reduced epitheca and cingulum present at the anterior end, both of which are dislocated dorsally. Along the ventral side of the narrow neck lies the elongated and narrow sulcus. The unique morphological feature of this genus is the presence of shorter left and a slightly longer right ventral hypothecal plate together with the posterior sulcal plate which are arranged transversely along the posterior end of the sulcus. The posterior sulcal plate extends further posteriorly from the flagellar pore on to the general body surface. A tubule opens at the flagellar pore ventro-anteriorly leading deep into the body to a large pusule. The fission suture in the ventro-anterior portion of body enters into the sulcus passing between the two ventral epithecal plates, but posteriorly the suture can be traced to emerge at the posterior end of the body. The antapex is variously modified and is usually a specific criterion. It is also usually provided with number of spinules at the antapex.

#### Key to the identified species of *Amphisolenia* Stein

1. Antapical unbranched ----- 2  
    Antapical branched ----- *A. thrinax*
2. Antapex swollen ----- *A. globifera*  
    Antapex swollen like dumb-bell ----- *A. deltiana* sp. nov.  
    Antapex not swollen ----- 3
3. Antapical much longer (3-7times) than midbody ----- *A. elongata*  
    Antapical shorter ----- 4
4. Antapex foot like ----- 5  
    Antapex not foot like ----- 8
5. One heel projection (spine) ----- 6  
    Two heel projections (spine) ----- *A. biprojecta*
6. Antapex with 2 spinules ----- 7  
    Antapex with 3 spinules ----- *A. palmata*
7. Body "small" (ca. 315µm) ----- *A. sp.*  
    Body "longer" (> 600µm) ----- *A. bidentata*
8. Antapex bilobed ----- *A. taylora*  
    Antapex not bilobed ----- 9
9. Body straight ----- 10  
    Body sigmoid with curvature ----- 15
10. Body small (ca 200µm) antapical equals midbody ----- *A. schauinslandi*  
    Body longer ----- 11
11. Antapex with spinule ----- 12  
    Antapex without spinule ----- 13
12. Antapex with two spinules ----- *A. schroederi*  
    Antapex with three spinules ----- 14  
    Antapex with four spinules ----- *A. rectangulata*

13. Both valves of antapical equal and showing uniform antapex ----- *A. truncata*  
 One valve of antapex not uniform and showing two unequal acute dentation at the antapex ----- *A. acuta* sp. nov.
14. Antapical smaller or equal to midbody ----- *A. schroederi* var. *pakistanensis*  
 Antapical very much longer ----- *A. nizamuddinii*
15. Small species (ca 200µm) ----- *A. brevicauda*  
 Long species (> 500µm) ----- *A. bispinosa*

#### Taxonomic description of the species of *Amphisolenia*

Following is an account of the species of *Amphisolenia* recorded so far from the North West Arabian sea in Pakistan.. Descriptions of only those species are given which are either new species or first reports from the area.

#### *Amphisolenia acuta* Gul & Saifullah sp. nov.

##### Fig. 1

Length of body 400-420µm, straight; head slightly inclined anteriorly, twice wider than long, length about 0.17-0.19 the length of neck and 2 times wider than long; cingular lists present with simple ribs; neck 6-8 times longer than wide and its length 0.1 the length of body; sulcal list present.

Midbody fusiform and merges gradually with anterior process and antapical, its greatest width 0.52 the length of neck, ratio between length and greatest width of body 18-20:1; antapical unbranched and straight; its length 0.47 the length of body and 4.62 the length of neck, its width 2 times the width of neck, the right valve in the posterior portion is longer than the left valve, no spines and heel.

#### Latin diagnosis

*Corpus parus rectus valvus longiore quam relictus e antapical. Alesque spinae.*

#### Local distribution

Pakistan shelf, station nos. 85, 102, 233, 252, 301.

#### *Amphisolenia bidentata* Schröder

*A. bidentata* Schröder 1900: 20, 35, pl. 1, f. 16a-e; Kofoid & Skogsberg 1928: 409, f. 56/1; Wood 1954: 205, f. 55; Silva 1955: 124, pl. 2, f.1- 4; Saifullah & Hassan 1973: 150, f. 1A, B; Taylor 1976: 28, pl. 2, f. 21,22.

#### Local distribution

Pakistan shelf, Station nos. 08, 12, 23, 50, 59, 65-67, 78-80, 83, 85, 87, 89, 91, 92, 99, 102, 108- 116, 120-122, 130-136, 141-143, 152, 171, 173, 175, 184, 187, 194, 197, 202-204, 208-216, 224, 225, 226, 228, 230, 231-241, 243, 244, 247, 248, 250, 251, 252, 254, 255-258, 260, 261, 262, 266, 268, 269, 271, 273, 276, 277, 278, 279, 280, 281, 285, 286, 287, 291, 294, 297, 298, 301, 332.

***Amphisolenia biprojecta* Saifullah & Hassan**

Saifullah & Hassan 1973: 153-154, f. 9A-C.

**Local distribution:**

Pakistan shelf, Station nos. 102, 109, 233, 302, 304, 332.

***Amphisolenia bispinosa* Kofoid**

*A. bispinosa* Kofoid 1907: 197, 201, pl. 14, f. 85; Saifullah & Hassan 1973: 152, f. 6A-B.

**Local distribution**

Pakistan shelf, station nos. 7, 120, 223, 233, 234, 235, 241, 251, 286.

***Amphisolenia brevicauda* Kofoid****Fig. 2**

*A. brevicauda* Kofoid 1907: 197, pl. 13, f. 79; Kofoid & Skogsberg 1928: 372, text f. 49, no. 3; text f. 50, no. 6; pl. 6, f. 1-4; Wood 1963: 9, text f. 22.

Length of body 170-189 $\mu$ m, straight and has a moderate sigmoid curvature; the head is inclined anteriorly, about .2 the length of neck and 1.4-1.5 times wider than long; epitheca straight and slightly convex, simple ribs; the neck is long and narrow, 0.24 the length of body and 6-7 times longer than wide.

Mid body elongate, irregularly fusiform and about half as long as the body or somewhat more than twice as long as the neck, ratio between the length and greatest width of the mid body is about 12-14:1, the dorsal margin of the mid body is slightly concave, ratio between its length and width 4.7-5.8:1 and 1.5-1.6 times longer than neck; the antapical unbranched, straight and short, ratio between its length and width 8-10:1, antapex acute without any spinule.

**Local distribution**

Pakistan shelf, station nos. 241, 245, 286.

**General distribution**

Eastern tropical pacific (Kofoid 1907), Vitiaz Strait (Kofoid and Skogsberg 1928), Indian Ocean (Wood 1963).

***Amphisolenia deltiana* Gul & Saifullah sp. nov.****Fig. 3**

Body almost straight, 700-739 $\mu$ m long; head convex, its width 1.6-1.8 times its length; cingular lists present with simple ribs; neck short, narrow, its length about .054-.056 the length of body and 0.073-0.078 the length of antapical; ratio between its length and width 7-9: 1; sulcal list is present.

Midbody fusiform and gradually merges into the anterior process and antapex, its width about 18-22 $\mu$ m and about 0.4-0.5 the length of neck, ratio between length and greatest width of body 33-38: 1; antapical unbranched, straight, lower portion is slightly curved, its length about 0.71-0.73 the length of body, antapex is dumb-bell shaped without any spines and width of foot is 8-10 $\mu$ m.

#### Latin diagnosis

*Corpus longus cum infernus parus e anatapical curvicaudatus et cum dumb-bell forma antapex.*

#### Local distribution

Pakistan shelf, station nos. 141, 285, 304.

#### *Amphisolenia elongata* Kofoid & Skogsberg

*A. elongata* Kofoid & Skogsberg 1928 : 365; Saifullah & Hassan, 1973 : 150, f. 3A-B.

#### Local distribution

Pakistan shelf, station nos. 70, 80, 83, 99, 128, 131, 137, 141, 166, 174, 198, 203, 221, 233, 235, 236, 237, 241, 247, 252, 256, 277, 280, 285, 298, 301.

#### *Amphisolenia globifera* Stein

##### Fig. 4

*A. globifera* Stein 1883 : 24, pl. 21, f. 9, 10; Kofoid et Skogsberg 1928 : 388, text f. 11, nos. 1, 2, 4, 8; pl. 49, f. 9; pl. 50, f. 1-5; Balech 1962 : 134, pl. 18, f. 272; Wood 1968 : 19, f.25; Taylor 1976 : 29, pl. 2, f. 26, 27; pl. 3, fig. 26b, 27b.

Length of body 170-192 $\mu$ m, straight, slightly sigmoid, ratio between length and width of body 14.7:1; head convex, subspheroidal or subrectangular, its width 1.2-1.5 times greater than its length; cingular lists present with simple ribs; hypotheca swollen anteriorly; the neck is very long and narrow, 0.18-.20 the length of body, neck 6 times longer than wide; sulcal list present.

Mid body fusiform merging gradually with anterior process and antapical, the mid body is of moderate width, its greatest width is .3 the length of neck; the ratio between its length and width 5.3:1; the antapical unbranched, straight, about 1.8-2.2 the length of the neck, slightly shorter than the total length of anterior process and the mid body, slightly wider than the neck, posterior portion of antapex has a globular terminal with two short pointed spinules.

#### General distribution

Pakistan shelf, station nos. 120, 286.

#### General distribution

Aus dem Atlantischen Meer (Stein 1883), Red Sea and Arabian Sea (Cleve 1903), Indian Ocean (Wood 1963, Sournia 1970), Caribbean Sea (Wood 1968), Bay of Bengal and Northern Indian Ocean (Taylor 1976).

***Amphisolenia nizamuddinii* Mansoor & Saifullah**

Mansoor & Saifullah 1995 : 5-7, f. 1.

**Local distribution**

Pakistan shelf, station nos. 67, 131, 233, 236.

***Amphisolenia palmata* Stein**

*A. palmata* Stein 1883 : 24, pl. 21, f. 11-15; Pavillard 1916 : 1; Jörgensen 1923 : 40, 41, f. 57; Saifullah & Hassan 1973 : 152, f. 4-B.

**Local distribution**

Pakistan shelf, station nos. 102, 233, 236, 298, 301.

***Amphisolenia rectangulata* Kofoid**

*A. rectangulata* Kofoid 1907 : 200, pl. 14, f. 83; Saifullah & Hassan 1973: 153, f. 7A-B.

**Local distribution**

Pakistan shelf, station nos. 50, 99, 109, 120, 128, 131, 204, 216, 233, 241, 257, 271, 302.

***Amphisolenia schauinslandii* Lemmermann****Fig. 5**

*A. schauinslandii* Lemmermann 1899 : 317, 373, pl. 1, f. 18, 19; 1901 : 376; Kofoid & Skogsberg 1928 : 374, f. 49/4, pl. 7, f. 1-8; Schiller 1931 : 169, f. 155; Wood 1968 : 21, f. 31; Taylor 1976 : 29, pl. 2, f. 28, 29; pl. 3, f. 28b; pl. 41, f. 495.

Length of body 400.5-420µm, straight, ratio between length and width of body 11:1; head slightly convex and capitate, 1.7-1.8 times wider than long and its length is 0.16-0.17 the length of neck; cingular lists present; epitheca flattened, anteriorly convex; the neck is long and narrow, 0.12 the length of body and 7 times longer than wide; sulcal list present.

Midbody fusiform merging very gradually with the anterior process and antapical, moderate length, 3 times longer than the length of neck, 2 times wider than the width of head, ratio between its length and width 4.3:1; antapical straight and unbranched, about .45-.47 length of body, its posterior part slightly expanded with 4 spinules, width of antapex 10.5-12µm and length of antapical is 190-191µm.

**Local distribution**

Pakistan shelf, station nos. 83, 115, 228, 233, 234, 235, 241, 245, 247, 257, 280, 286, 298, 300, 301, 302.

**General distribution**

Indian Ocean (Wood 1963, Taylor 1976), Caribbean Sea (Wood 1968), Mozambique Channel (Sournia 1967, 1970).

***Amphisolenia schroederi* Kofoid**

*A. schroederi* Kofoid 1907: 201, pl. 13, f. 81; Kofoid & Skogsberg 1928: 400, f. 49/15, pl. 10, f. 2-4; Taylor 1976: 30, pl. 2, f. 32, pl. 3, f. 32b; Saifullah *et al.*, 2002: 77, f. 1C.

**Local distribution**

Pakistan shelf, station nos. 141, 160, 164, 228, 231, 233, 235, 247, 257, 262, 280, 286, 300, 302, 332.

***Amphisolenia schroederi* var. *pakistanensis* Mansoor & Saifullah**

Mansoor & Saifullah 1995: 7, f. 2.

**Local distribution**

Pakistan shelf, station nos. 85, 102, 136, 216, 241, 247, 270, 286.

***Amphisolenia* sp.****Fig. 6**

Length of body 310-315 $\mu$ m, straight, slightly sigmoid, ratio between length and greatest width of body 13-15: 1; head shows slight anterior inclination, twice wider than long, epitheca convex, anterior cingular list shows slight anterior inclination, the posterior cingular list generally less inclined, cingular list possessing simple rib; neck cylindrical, 0.11 the length of body and 6-9 times longer than wide.

Midbody fusiform, merging gradually with the anterior process and the antapical, ratio between its length and width 6:1, its greatest width 0.6 the length of neck; the antapical unbranched, almost straight with gentle ventral concavity, its length about 3.8 times the length of neck and .45-.50 the length of body; the posterior of antapex foot shaped which is longer than wide, foot possesses a heel spinule on the left valve and two pointed spinules on each corner.

**Local distribution**

Pakistan shelf, station nos. 241, 247, 252.

***Amphisolenia taylori* Saifullah & Hassan**

Saifullah & Hassan 1973: 152-154, f. 4A- B.

**Local distribution**

Pakistan shelf, station nos. 241, 247.

***Amphisolenia thrinax* Schütt**

*A. thrinax* Schütt 1893: 271, 299, 301, f. 81; Lemmermann 1899: 319, 331, 373; - 1901: 376; Kofoid 1907: 199, 200; Wood 1968: 21, f. 33; Taylor, 1976: 30, pl. 2, f. 20; Saifullah *et al.*, 2002: 78, f. 1B.

**Local distribution**

Pakistan shelf, station nos. 120, 228, 241, 242, 300, 301.

***Amphisolenia truncata* Kofoid & Michener**

*A. truncata* Kofoid & Michener 1911 : 294; Jörgensen 1923 : 40, 43, f. 58; Kofoid & Skogsberg 1928 : 406, pl. 11, f. 1- 12; Saifullah *et al.*, 2002 : 79, f. 1A.

**Local distribution**

Pakistan shelf, station nos. 102, 132, 233, 234, 241, 285, 304.

**Discussion****Species composition**

Eighteen species of *Amphisolenia* are hereby reported which include all the species already described by Saifullah & Hassan (1973), Mansoor & Saifullah (1995) and Saifullah *et al.*, (2002). Saifullah & Hassan (1973) described seven species from a small inshore area of Karachi harbour whereas Mansoor & Saifullah (1995) and Saifullah *et al.*, (2002) reported nine species from the shelf during a short period of the cruise (15<sup>th</sup> March-26<sup>th</sup> April, 1977). The present large number of species may be accounted for the fact that it included numerous samples collected from the shelf during the entire period of the cruise (19.01-20.06. 1977). The additional 6 species that were not encountered earlier by the aforementioned authors include *A. acuta* sp. nov., *A. brevicauda*, *A. deltiana* sp. nov., *A. globifera*, *A. schauinslandii* and *A. sp.* Kuzmenko (1975) described only two species from the part of North Arabian Sea bordering Pakistan which may be due to the fact that the area was sampled for a very short period of time.

When compared with other areas like Bay of Bengal, Eastern Arabian Sea and Central Indian Ocean (Subrahmanyam, 1958; Taylor, 1976) the number of species of *Amphisolenia* is large. Even when compared with the total number of species recorded in the world (Gomez, 2005) the present one is about half of that. The observed richness in species diversity in the area may be accounted for the fact that both the sampling and study were intensive and extensive as well. As many as 400 samples from 75 stations were collected repeatedly using vertical and oblique net hauls during six months cruise of Fridtjof Nansen. Moreover, several research workers studied these samples. Another important thing to note is that being very poor in numbers and also very narrow and needle shaped, individuals of *Amphisolenia* easily escape the fine meshes of the net and also the sight of the observer on the microscope.



The most common species *A. bidentata* resembled closely with *A. palmata*, *A. lemmermanni*, *A. palaeotheroides* and *A. asymmetrica* on the basis of possession of asymmetrical valves and posterior portion of foot shaped antapex with distinct heel spinules on the left valve. Kofoid & Skogsberg (1928) have mentioned that these species form a natural group named as '*Palmata group*'. It exhibited greater variation in size with length of body varying between 710-850µm, and some individuals even measuring up to 550µm. Such small specimens resembled closely the specimens illustrated by Abé (1967) but differed from the aberrant form of *A. bidentata* described by Saifullah & Hassan (1973) in possession of a well defined heel. Kofoid & Skogsberg (1928) have mentioned variability in length of body, width of body, width and relative length of the foot like posterior part of the antapical. They have stated that in daughter cells the width of mid body increases with the age of individual.

Our specimens of *A. palmata* agree well with that described by Kofoid & Skogsberg (1928) in their dimensions, with the exception of length of antapex (575µm). They have also pointed out the variable characters of this species such as shape of the longitudinal axis of the body, length and width of body and amount of torsion in the posterior part of antapical.

*A. bispinosa* and *A. rectangulata* agree well with the previous records (Kofoid & Skogsberg, 1928; Saifullah & Hassan, 1973). *A. rectangulata* resembled *A. schauinslandi* and *A. quadrispina* on basis of symmetrical posterior portion of antapical, with four spinules arranged symmetrically, two on each valve (Kofoid & Skogsberg, 1928). *A. bispinosa* also resembled closely with *A. curvata* (Kofoid & Skogsberg, 1928).

It is notable that *A. elongata* and *A. schroederi* differed from those described by Kofoid & Skogsberg (1928) particularly in their dimensions. Thus the former species is longer and later smaller in size than earlier described. *A. elongata* is also closely related to *A. extensa* in similarity of posterior portion of the antapical (Kofoid & Skogsberg, 1928).

*A. thrinax* resembles closely with *A. projecta*, *A. bifurcata*, *A. quadricuda* and *A. quinquecauda* in having a bifurcated antapical. According to Kofoid & Skogsberg (1928) these species form a natural systematic group, the '*bifurcata group*', which in many respects is the most highly differentiated group in the genus. *A. truncata* is similar in size to that described by Saifullah *et al.*, (2002) and its closest known relative is *A. complanata* (Kofoid & Skogberg, 1928).

*A. schroederi* var. *pakistanensis* and *A. nizamuddinii* described by the Mansoor & Saifullah (1995) and Saifullah *et al.*, (2002) and *A. biprojecta* were also recorded in this study. *A. biprojecta* resembles *A. bidentata* (Wood, 1968) in the possession of two terminal spinules and its sigmoid antapical.

Two new species of *Amphisolenia* are also hereby reported. *A. acuta* Gul *et* Saifullah sp. nov. was recorded during the period of investigation and is characterized by the right valve being longer than the left and the absence of heel spinule is absent (Fig. 1). This species did not resemble with any other species. In *A. taylori*, the antapex is distinctly divided into two symmetrical lobes, each possessing two spinules.

Similarly *A. deltiana* Gul *et* Saifullah sp. nov. exhibited remarkable characters, i.e., curved and dumb-bell shaped antapex not found in any other species (Fig. 3).

*A. brevicauda* (Fig. 2) is characterized with small size of the body and simple unbranched antapical, well set off from the mid body. The peculiar asymmetry of the mid body is unique for this genus. The relative shortness of the antapical and the simple pointed antapex also contribute to the exceptional appearance of this species.

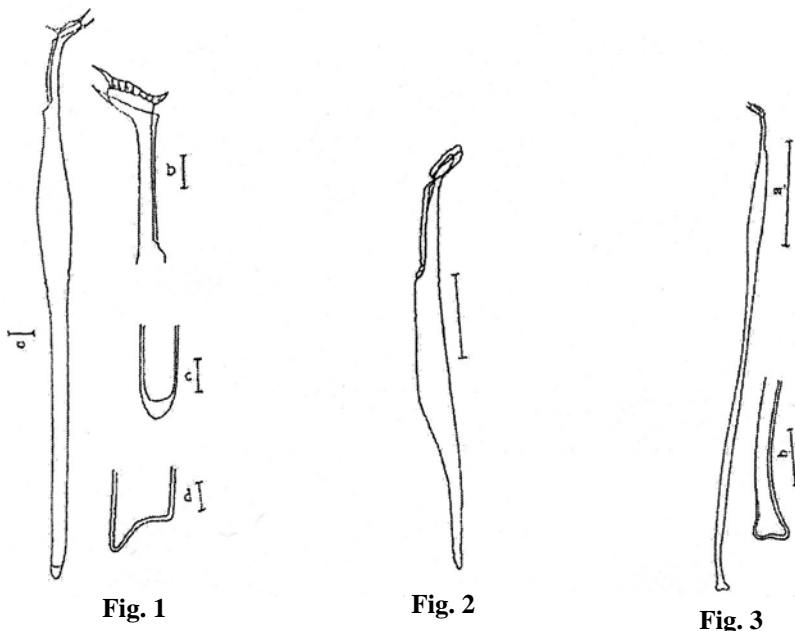


Fig. 1. *Amphisolenia acuta* sp.nov.

a- Lateral view of entire body (scale = 20 $\mu$ m), b- Anterior portion of body (scale = 10 $\mu$ m), c- Anterior portion of antapex (scale = 10 $\mu$ m), d- Posterior portion of antapex (scale = 5 $\mu$ m)

Fig. 2. *Amphisolenia brevicauda*

Lateral view of entire body (scale = 48 $\mu$ m)

Fig. 3. *Amphisolenia deltiana* sp.nov.

a- Lateral view of entire body (scale = 150 $\mu$ m), b- Posterior portion of antapex (scale = 14 $\mu$ m)

*A. globifera* (Fig. 4) is small in size, the straight axis of the body and the unbranched antapical appear to be primitive features of this species. The gradual merging of the mid body into the antapical and the differentiation of the posterior part of the antapical are probably later acquisitions. *A. globifera* is undoubtedly very closely related to *A. quadrispina*. This relationship is indicated especially by the globular shape of the posterior part of the antapical in these species. It is easily distinguished from *A. quadrispina* by its smaller size by having two or no antapical spinules instead of four.

In *A. schauinslandi* (Fig. 5), the mid body is somewhat wider and the posterior end of the antapical is somewhat inflated. *A. schauinslandi* occupies a rather isolated position among the species of *Amphisolenia*, however, the shape and the structure of the posterior end of its antapical is suggestive of *A. rectangulata*.

The unidentified *Amphisolenia* sp., described by Taylor (1976) was also present in the study area. It closely resembles *A. bidentata* Schröder but differs in being shorter (length 310-315 $\mu$ m) and in the gradual fusion of the mid body into the antapical process, the mid body being relatively more slender than in either of above taxa (Fig. 6).

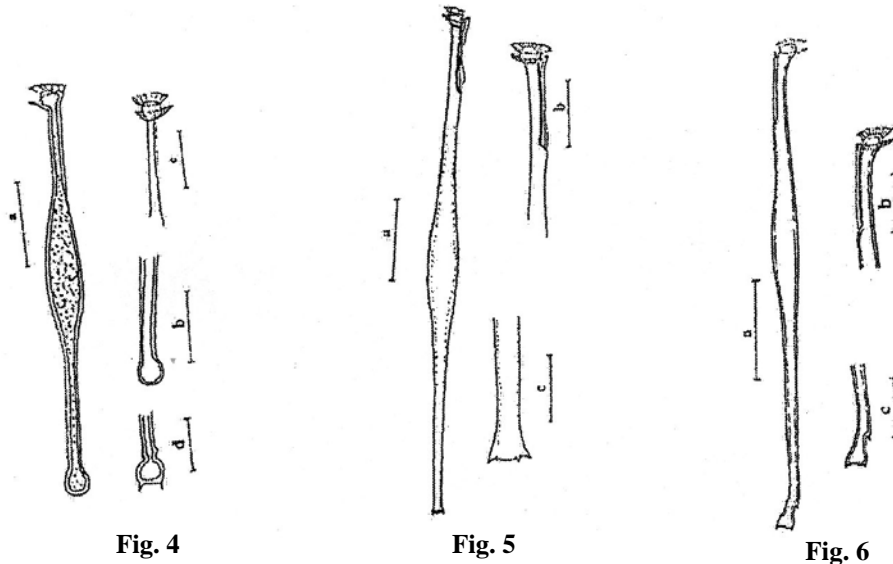


Fig. 4. *Amphisolenia globifera*

a- Lateral view of entire body (scale = 64 $\mu$ m), b- Posterior portion of antapex (scale = 10 $\mu$ m), c- Posterior portion of body (scale = 16 $\mu$ m), d- Anterior portion of antapex (scale = 8 $\mu$ m)

Fig. 5. *Amphisolenia schauinslandii*

a- Lateral view of entire body (scale = 105 $\mu$ m), b- Anterior portion of body (scale = 22 $\mu$ m), c- Anterior portion of antapex (scale = 18 $\mu$ m)

Fig. 6. *Amphisolenia* sp.

a- Lateral view of entire body (scale = 61 $\mu$ m), b- Anterior portion of body (scale = 18 $\mu$ m), c- Anterior portion of antapex (scale = 21 $\mu$ m)

### Ecological distribution

*Amphisolenia* Stein is long known as a warm water genus of dinoflagellates (Paulsen, 1908; Lindemann, 1928). It is basically a tropical genus preferring warmer temperature for its occurrence. It is wide spread in the tropical belt of all oceans (Sournia, 1967; Wood, 1968; Taylor, 1976) including the North Arabian Sea (Subrahmanyam & Sarma 1960; Taylor, 1976). It is also apparent that the species occurred more frequently on the Indus Delta shelf (17) than on the Balochistan shelf (14) (Table 1) because the former area is more heterogeneous in physical oceanographic parameters than the latter (Anon., 1978; Saifullah, 1979). *A. bidentata* was the most common and frequent species occupying 54% of all stations. It has also been reported world wide in distribution (Taylor, 1976). Although *A. bidentata* occurred commonly on the shelf it was recorded in great abundance only once on station 236 (13<sup>th</sup> April-15<sup>th</sup> May.1977). Next in order were *A. elongata*, *A. schroederi* and *A. schauinslandii*. The remaining species were rare with a frequency of occurrence of less than 7% (Table 2). *A. taylori* and *A. globifera* were extremely rare with a frequency of occurrence less than 1%.

Table 1. Number of stations occupied by different species in different seasons and different areas.

No.	Name of species	Seasonal occurrence		Different areas	
		N-E monsoon (Jan to Mar)	Transition period (Apr to June)	Sindh	Balochistan
1.	<i>Amphisolenia acuta</i> sp.nov.	2	3	5	0
2.	<i>Amphisolenia bidentata</i>	42	71	63	50
3.	<i>Amphisolenia biprojecta</i>	2	5	7	0
4.	<i>Amphisolenia bispinosa</i>	2	7	5	4
5.	<i>Amphisolenia brevicauda</i>	0	3	2	1
6.	<i>Amphisolenia deltiana</i> sp.nov.	1	2	1	2
7.	<i>Amphisolenia elongata</i>	9	17	14	12
8.	<i>Amphisolenia globifera</i>	1	1	0	2
9.	<i>Amphisolenia nizamuiddinii</i>	2	2	2	2
10.	<i>Amphisolenia palmate</i>	1	4	4	1
11.	<i>Amphisolenia rectangularata</i>	6	7	6	7
12.	<i>Amphisolenia schauinslandi</i>	2	14	12	4
13.	<i>Amphisolenia schroederi</i>	3	13	11	5
14.	<i>Amphisolenia schroederi</i> var. <i>pakistanensis</i>	3	6	5	4
15.	<i>Amphisolenia</i> sp.	0	2	3	0
16.	<i>Amphisolenia taylora</i>	0	2	2	0
17.	<i>Amphisolenia thrinax</i>	1	5	4	2
18.	<i>Amphisolenia truncata</i>	2	5	5	2

Table 2. Temperature and Salinity ranges and frequency of occurrence of different species.

No.	Name of species	Temperature ranges °C	Salinity range ‰	Frequency of occurrence (%)
1.	<i>Amphisolenia acuta</i> sp.nov.	23.80-28.90	36.20-36.71	2.427
2.	<i>Amphisolenia bidentata</i>	22.30-29.90	35.78-36.88	54.854
3.	<i>Amphisolenia biprojecta</i>	22.85-28.90	36.20-36.76	3.398
4.	<i>Amphisolenia bispinosa</i>	23.10-29.50	36.23-36.70	4.369
5.	<i>Amphisolenia brevicauda</i>	26.90-28.40	36.57-36.70	1.456
6.	<i>Amphisolenia deltiana</i> sp. nov.	23.61-28.90	36.53-36.76	1.456
7.	<i>Amphisolenia elongata</i>	21.83-28.90	36.20-36.72	12.621
8.	<i>Amphisolenia globifera</i>	23.39-29.50	36.42-36.70	0.971
9.	<i>Amphisolenia nizamuddinii</i>	23.10-27.34	36.43-36.62	1.942
10.	<i>Amphisolenia palmata</i>	22.85-28.90	36.20-36.71	2.427
11.	<i>Amphisolenia rectangularata</i>	23.10-28.90	36.23-36.65	6.311
12.	<i>Amphisolenia schauinslandi</i>	23.58-29.50	36.23-36.71	7.767
13.	<i>Amphisolenia schroederi</i>	23.61-29.50	36.32-36.76	7.767
14.	<i>Amphisolenia schroederi</i> var. <i>pakistanensis</i>	22.85-29.50	36.20-36.70	4.368
15.	<i>Amphisolenia</i> sp.	27.10-28.10	36.23-36.59	1.456
16.	<i>Amphisolenia taylori</i>	27.20-28.10	36.23-36.59	0.971
17.	<i>Amphisolenia thrinax</i>	23.39-28.90	36.42-36.71	2.913
18.	<i>Amphisolenia truncata</i>	22.85-28.90	36.20-36.76	3.398

Table 3. Measurement of different parts of the species of *Amphisolenia* in  $\mu\text{m}$ .

Species	Length of the body	Length of head	Width of head	Length of neck	Width of Neck	Width of midbody	Length of midbody	Length of antapex	Width of antapex
<i>A. acuta</i> sp.nov.	400-420	7-8.5	15-16.25	40-43	5-6.25	20-22.5	162-170	190-199	10-12.5
<i>A. bidentata</i>	710-850	5-6.5	12.5-16	45-48	6-7.5	20-23	163-180	498.7-615	-
<i>A. biprojecta</i>	652.5-700	8-9.5	14-18	38.5-42	5-7.75	21-25	140-165	466-483	8-9.45
<i>A. bispinosa</i>	645-675	7-8.5	13-14.5	45-50	6.5-7.5	18-20	195-212	398-405	6.75-8
<i>A. brevicauda</i>	170-189	8-9.5	12.5-14	42-46	6-7.25	12-15.5	70-73	50-60	5-6.75
<i>A. deltiana</i> sp.nov.	700-739	8-10.5	15-17.5	38-42	4.2-6	18-22	140-155	514-532	8-10
<i>A. elongata</i>	710-790	6.25-7.5	15-17.5	40-46	5-6.5	15-22.5	160-175	468.7-551	6.25-7.5
<i>A. globifera</i>	170-192	7.5-8	9-12.25	31-40	5-6.5	11.5-13	62-69	70-75	3.5-6
<i>A. nizamuiddinii</i>	640-670	6-7.5	15-16.25	34-37.5	5-6.75	18.5-20	140-150	460-475	6.5-9
<i>A. palmata</i>	778-815	6-8	18-20	45-50	6-7.5	26-28	152-163	575-594	10-12
<i>A. rectangularata</i>	536-665	6.25-8	16-17.5	45-47	5-7.25	18.7-21	123-150	362-460	7.5-11
<i>A. schroederi</i>	440-490	4-7	13-16	50-58	3.5-5	26-28	225-245	161-180	5-7
<i>A. schroederi</i> var. <i>pakistanensis</i>	405-425	5-6	9-11.75	50-55	4-5.75	18-20	215-225	135-139	7-10
<i>A. schuinslandi</i>	400.5-420	8-9.5	15-17	50-54	6.5-7	35-38	152-165	190-191	11-12
<i>A. sp.</i>	310-315	6-7.5	18-21	36-37	4-5.5	20-23	128-130	140-141	7-8.5
<i>A. taylora</i>	608-635	9-10	15-18	42-46	6-7.5	21-24	147-155	410-424	15-18
<i>A. thrinax</i>	875-911	6.25-8.5	30-32	50-60	8.75-9.25	40-45	200-215	619-628	-
<i>A. truncata</i>	590-615	6-7	15-16.5	34-38	5-6.25	20-23.5	160-175	390-395	8.5-10

The present study was carried out during two seasons only, namely the N-E monsoon season (January - March) and the transition period (April - June). All the species occurred during the two seasons except *A. taylori*; *A. brevicauda* and *A. sp.* which occurred only in transition period. *Amphisolenia bidentata* (Table.1) occurred overwhelmingly during the entire period and *A. elongata*, *A. schauinslandi* and *A. schroederi* only moderately during the transition period only.

Size variation among different species of *Amphisolenia* was very pronounced and may be as large as more than five fold. The smallest species was *A. globifera* and *A. brevicauda* not reaching a length more than 170µm whereas the longest species was *A. thrinax* with a length of 910µm (Table 3). There was even significant variation in size within a given species. For example length of *A. bidentata* varied between 550-850µm and of *A. elongata* between 710-790µm. The part of the body which showed maximum variation of size was the antapical.

Most species occurred in a wide range of temperature during the period of study in the area. Only three species *A. brevicauda*, *A. sp.*, and *A. taylori* occurred in very narrow range (Table 2). As regards the salinity tolerance it appears that all the species occurred in a narrow range of 35.78-36.89‰ during the period of study.

#### References

- Abé, T.H. 1967. The armoured Dinoflagellata. II. Prorocentridae and Dinophysidae (C). *Ornithocercus, Histioneis, Amphisolenia* and others. *Publ Seto mar. Biol. Lab.*, 15(2): 79-116.
- Anonymous. 1978. Survey results of Dr. "Fridtjof Nansen" January-June 1977. Joint Norad/Pakistan project, Fish Assessment Survey of Pakistan Waters, Bergen. p. 1-12.
- Balech, E. 1962. Tintinninoinea y dinoflagellata del Pacifico segun material de las expediciones Norpacy Downwind del Instituto Scripps de Oceanografia. – Rev. Mus. argent. Cienc. Nat. Bernardino Rivadavia Inst. nac. *Invest. Cienc. Nat.*, 7(1): 1-253.
- Ballantine, D. 1961. *Gymnodinium chukwanii* n. sp. and other marine dinoflagellates collected in the vicinity of Zanzibar. *J. Protozool.*, 8(2): 217-228.
- Cleve, P.T. 1903. Report on plankton collected by Mr. Thoruld Wulff during a voyage to and from Bombay. *Ark. Zool.* 1: 329-391.
- Gomez, F. 2005. A list of free –living dinoflagellates species in the world's oceans. *Acta Bot. Croat.*, 64(1):129- 212.
- Jørgensen, E. 1923. Mediterranean Dinophysiaceae. Report on the Danish Oceanographical Expeditions 1908-10 to the Mediterranean and adjacent seas 2 (Biol.), J. 2: 1-48.
- Kofoid, C.A. 1907. New species of Dinoflagellates. *Bull. Mus. Comp. Zool. Harv.*, 50: 161-208.
- Kofoid, C.A. and J.R. Michener. 1911. Reports on the scientific results of the Expedition to the Eastern tropical Pacific in charge of Alexander Agassiz. 22. New genera and species of dinoflagellates. *Bull. Mus. comp. Zool. Harv.*, 54: 265-302.
- Kofoid, C.A. and T. Skogsberg. 1928. The Dinophysoideae. *Mem. Mus. Comp. Zool. Harv.*, 51: 1-766 + 31pl.
- Kuzmenko, L.V. 1975. Systematic composition of Phytoplankton of Arabian Sea. *Oceanology*, 34: 15-38.
- Lemmermann, E. 1899. Planktonalgen; Ergebnisse einer Reise nach dem Pacific. *Abh. Naturw. Ver. Bremen*, 16: 313-398.
- Mansoor, S. and S.M. Saifullah. 1995. A new species and a new variety of *Amphisolenia* Stein from the North Arabian Sea bordering Pakistan. *Pak. J. Bot.*, 4(1): 5-8.
- Nooruddin. 1967. An account of the phytoplankton of Karachi with a note on their seasonal variations and distribution. *Agricul. Pakistan*, 1: 1-18. *Oceans. Acta Bot. Croat.* 64(1): 129-212.
- Ostenfeld, C.H. and J. Schmid. 1901. Plankton far det Røde Hav og Adenbugten. *Vidensk. Medd. Naturh. Foren. Kjöbenhavn.* 1901: 141-182.

- Paulsen, O. 1908. *Peridinales. Nordisches Plankton* (Bot. Teil). 18: 1-124.
- Pavillard, J. 1916. Recherches Sur les peridiniens du Golfe du Lion. - Trav. Inst. Bot. Univ. Montpellier, ser. Mix., Mem. 4: 9-70 + 3pl.
- Saifullah, S.M. 1979. Occurrence of dinoflagellates and distribution of chlorophyll 'a' on Pakistan's shelf. In: (Eds.): D.L. Taylor and H.H. Seliger. Toxic Dinoflagellate Blooms. Elsevier/North Holland, N., 203-208.
- Saifullah, S.M. 1999. Validity of new species and sub-species of *Amphisolenia* Stein. *Pak. J. Bot.*, 31: 219-220.
- Saifullah, S.M. and D. Hassan. 1973. Planktonic dinoflagellates from inshore waters of Karachi: II. *Amphisolenia* Stein. *Pak. J. Zool.*, 5(2): 149-155.
- Saifullah, S.M., H.S. Baig and S. Mansoor. 2002. The dinoflagellate genus *Amphisolenia* Stein from the North Arabian Sea shelf of Pakistan. *Pak. J. Bot.*, 34(1): 73-80.
- Schiller, J. 1931-1933. Dinoflagellateae. Rabenhorst's Kryptogamen Flora Teil 1. Akademische Verlag, Leipzig, 1-617.
- Schröder, B. 1900. Phytoplankton des Golfes von Neapel. -*Mitt. Zool. Stat. Neapel.*, 14: 1-38 + 1 pl.
- Schütt, F. 1893. Das Pflanzenleben der Hochsee. *Ergebn. Plankton Exped. I A*: 243-314.
- Silva, E.de S. 1955. Dinoflagelados do plankton marinho de Angola. *An. Jta Invest. Ultramar*, 10(2): 109-191.
- Solum, I. 1962. The taxonomy of *Dinophysis* populations in Norwegian waters in view of biometric observations. *Nytt Mag. Bot.*, 10: 5-33.
- Sournia, A. 1967. Contribution a la connaissance des peridiniens microplanctoniques du Canal de Mozambique. *Bull. Mus. nat. Hist. Nat. Paris, Ser.*, 2, 39(2): 417-438.
- Sournia, A. 1970. A checklist of planktonic diatoms and dinoflagellates from the Mozambique Channel. *Bull. Mar. Sci. Gulf. Caribb.*, 20: 678-696.
- Sournia, A. 1973. Catalogue des especes et taxons infraspecifics de Dinoflagelles marins actuels. I. Dinoflagelles libres. *Beih. Nova Hedwigia*, 48: 1-92.
- Stein, F. R. 1883. Der Organismus der Flagellaten, 3(2): 1-30.
- Subrahmanyam, R. 1958. Phytoplankton organisms of the Arabian Sea off the west coast of India. *J. Indian Bot. Soc.*, 37(4): 435-441.
- Subrahmanyam, R. and A.H.V. Sarma. 1960. Studies of the phytoplankton of the West coast of India. *Ind. J. of Fisheries* 7(2): 307-336.
- Taylor, F. J. R. 1976. Dinoflagellates from International Indian Ocean Expedition. *Bibliotheca Botanica Heft.*, 132: 1-234 + 46 pls.
- Wood, E. J. F. 1954. Dinoflagellates of Australian region. *Austr. J. Mar. Freshwat. Res.*, 5(2): 171-351.
- Wood, E. J. F. 1963. Check list of the dinoflagellates recorded from the Indian Ocean Rep. Div. Fish. Oceanogr. Commonw. *Sci. ind. Res. Org. Austr.*, 28: 1-55.
- Wood, E. J. F. 1968. *Dinoflagellates of the Caribbean Sea and Adjacent Areas*. University of Miami Press, Coral Gables, Florida. 1- 143.

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