MORPHOMETRIC ANALYSIS OF BENTHIC FORAMINIFERA *AMMONIA* FROM CHILIKA LAKE, ODISHA, INDIA

SUBMITTED BY

DEBASHISH DAS

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UNDER THE GUIDANCE OF

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DEPARTMENT OF GEOLOGICAL SCIENCES

JADAVPUR UNIVERSITY,

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CERTIFICATE FROM THE SUPERVISOR

This is to certify that Mr. Debashish Das has worked under the supervision of Dr. Anupam Ghosh, Assistant Professor in the Department of Geological Sciences, Jadavpur University and completed his thesis entitled "**Morphometric analysis of foraminifera *Ammonia* from Chilika lake, Odisha**" which is being submitted towards the partial fulfilment of his M.Sc. Final Examination in Applied Geology of Jadavpur University in 2019.

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Abstract

This dissertation concerns with the study of *Ammonia* from Chilika Lake, Odisha. Morphologically, three species of *Ammonia* i.e. *Ammonia beccarii, Ammonia tepida* and *Ammonia parkinsoniana* were identified. The morphometric parameters were measured by Image Analysis System. Cluster analysis, performed on the morphological data set (e.g. greatest spiral diameter, umbilical diameter, proloculus diameter, radial sutural furrow length etc.). Based on those observations, three different species of *Ammonia* has been identified.

Contents

1.1 Introduction

There are two most abundant foraminifera genus known worldwide are *Ammonia* and *Elphidium.* They can occur in slightly brackish water and their environments include shallow marine, intertidal area, deltaic and also lagoonal.

The study focuses on the morphological methods in order to investigate taxonomic relationships within the genus *Ammonia.*

1.2 Objectives

- To identify the *Ammonia* genus from Chilika Lake, Odisha
- Morphometric Analysis of *Ammonia* spp. found in the Chilika Lake

1.3 Location and accessibility

Chilika Lake (19°43’ N, 85° 19’ E) is situated on the east coast of Odisha, India (fig1.1). The samples were collected from Satapada area and from the Sea side of the lake. The area can be accessed by train journey to Puri followed by private car from Puri to Chilika.

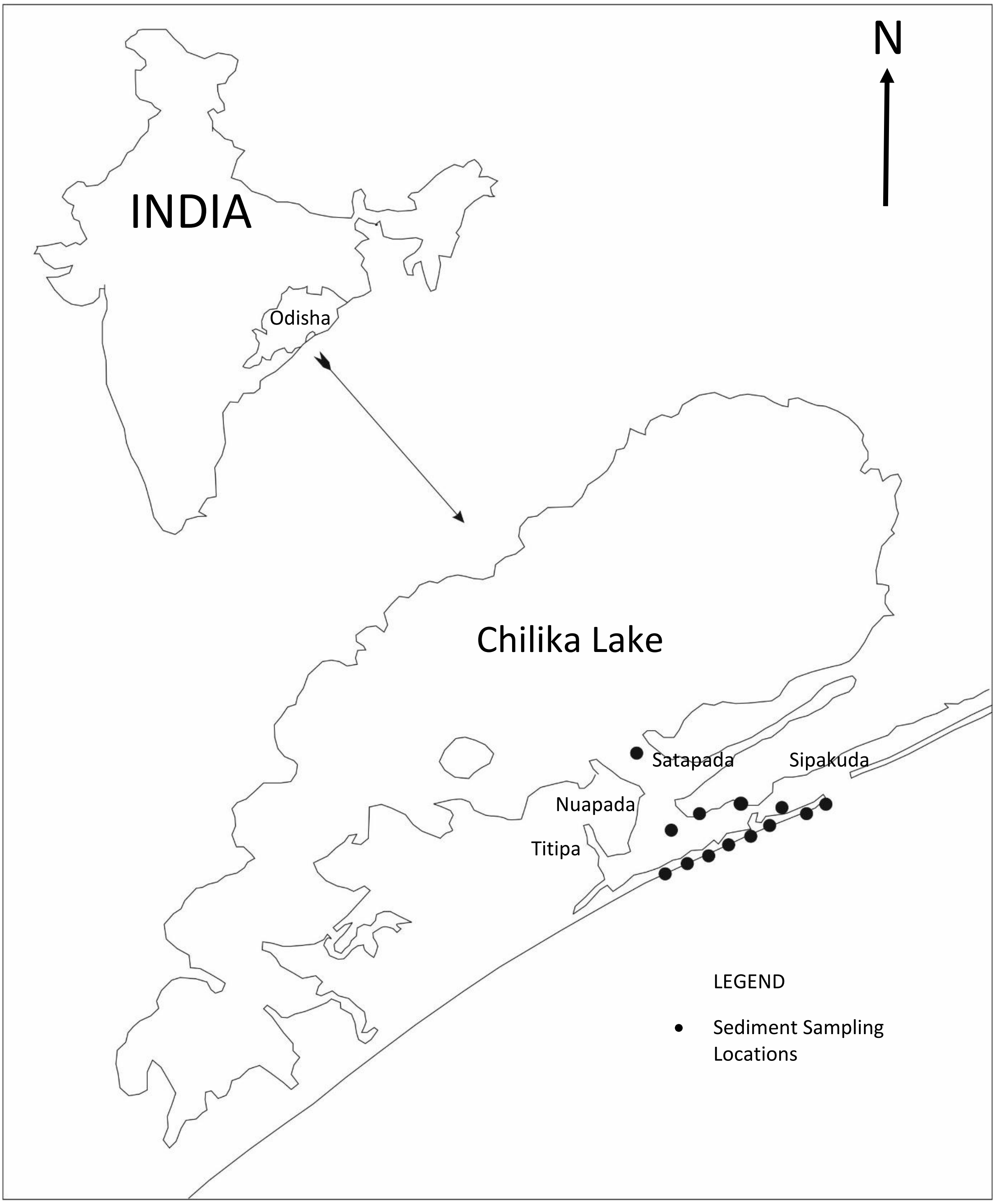


Fig 1.1 Location of Sediment Sample Collection

1.4 Previous Work

Benthic foraminiferal assemblages are widely used as bioproxies for coastal environment monitoring (Areen Sen, Punyasloke Bhadury, 2016). The study investigated seasonal variations in live benthic foraminiferal assemblages from the largest coastal lagoon, Chilika in Asia, which is strongly influenced by tropical monsoons. The investigation revealed an extremely low diversity of benthic foraminiferal assemblages comprising of 12 species of which 8 were agglutinated. The most dominant taxa belong to the genus *Ammonia*. The living assemble was restricted to the topmost 4 cm of the sediment with the majority of assemblages occurring in the top 2 cm. Data analysis revealed the presence of a significant variation in the biotic assemblage, indicating a patchy distribution. As far as the morphometric analysis is concerned, there is no previous work available for *Ammonia* spp. or any other genus from Chilika Lagoon, Odisha.

1.5 Sample Collection

The sampling to collect live specimens of *Ammonia* was done from 13 locations (fig1.1), from which 8 location belongs to the sea side stretch of Chilika and 5 locations were from the interior side of the lagoon in the month of March 2018. The top 10cm x 10cm x 1cm sediments were taken from each location (fig 1.2) and was packed in polythene lock bags (fig 1.3). Each sealed packet was labelled and numbered corresponding to the place of collection. After the collection of sediment samples, they were carefully transferred to the laboratory for further processing and study.

1.6 Methodologies

Top 1cm sediment (10cm x 10cm x 1cm) was collected, washed using 63µm sieve and dried in oven. The dried sediments were splitted using microsplitter. Only the *Ammonia* genus were picked up from 1gm sediments from each location and studied under stereo zoom microscope. Best preserved foraminiferal specimens were chosen for the Scanning Electron Microscope (SEM Facility, Department of Geological Sciences, Jadavpur University) for illustration. Morphometric properties were measured using Image Analysis System.

Fig 1.2 Collecting Sample from the Sea side of Chilika

Fig 1.3 Transferring the sediment sample to polythene lock bag

2.1 Introduction

Ammonia is a genus of marine foraminifers. It is one of the most abundant foraminifera genera worldwide and occurs in sheltered and shallow marine intertidal environments, sometimes in brackish waters. Their occurrence is so varied that they can be found in salt marshes, in fine sediments, in coarse sediments, estuaries as well as in intertidal zones. This indicates their occurrences in variable conditions, i.e. from extremely low temperature (0-5°C) to high temperatures (35°C). Also they have an extreme tolerance to salinity as they can thrive in low salinity (<1‰) to extremely high salinity (>90‰). Larger heavily ornamented specimens are characteristics of hypersaline conditions whereas smaller and thin calcareous specimens are characteristics of normal salinity conditions. Hence salinity and temperature range is the controlling factors of their geographical distribution and morphology. *Ammonia* in present study is referred to three species. The systematic descriptions of these species are given below. The Scanning Election photomicrographs of these species are given in Plates I.

2.2 Systematic

Phylum	: Protista	(Haeckel, 1866)
Subphylum	: Sarcodina	(Schmarda, 1871)
Class	: Rhizopodea	(Von Siebold, 1845)
Order	: Foraminiferida	(Eichwald, 1830)
Suborder	: Rotaliina	(Dellage & Hérouard, 1896)
Superfamily	: Rotaliacea	(Ehrenberg, 1839)
Family	: Rotaliidae	(Ehrenberg, 1839)
Subfamily	: Rotaliinae	(Ehrenberg, 1839)
Genus	: *Ammonia*	(Brünnich, 1972)

Ammonia tepida (Cushman)

Pl. I, Fig 1

Rotalia beccarii (Linne) var. tepida-Cushman, 1926, Carnegie Inst., publ. 344, p. 79, pl. 1, fig 9

The test outline is smooth with no ornamentation and rounded periphery. The umbilical side is characterized by sharp, pointed folium as well as strong deeply notched protoforamen. The spiral side shows the development of raised thickened calcite along the radial sutures as well as over central spiral area. It is smaller (0.3-0.6mm), has 7 to 9 chambers in the final whorl, and has no plug or extraneous calcareous material in the umbilical area. Microstructurally, pore density is high and the pores are regular and are present all throughout the test except at the pointed ends of folia.

Ammonia beccarii (Linne)

Pl. I, Fig. 2

Rotalia beccarii (Linne), Cushman, 1931, pl.8, p. 58, pl. 12, figs. 1-7; pl. 13, figs. 102; -Rasheed, 1969-70c, pp. 157-158, pl. 2, figs. 13-18.

It is recognized by the presence of a small cavity around the umbilical region and interlocular space. The surface is ornamented with granules and beaded sutures. The spiral side shows strong reticulate calcite riblets and raised thickened calcite over central spiral area. It is medium sized (0.5-0.8 mm) and has 8-10 chambers in the last whorls.

Ammonia parkinsoniana (d’Orbigny, 1893)

Pl. I, Fig. 3

Orbigny, A. D. d’. (1839). Foraminiferes, in de la Sagra T., Histoire physique, politique et naturelle de l’ile de Cuba. A. Bertrand. 1-244., page: p. 99 pl. 4, fig. 25-27

It is recognized by the presence of a small umbilicus with medium sized umbilical area. The test outline is relatively smooth with no ornamentation and rounded periphery. The umbilical side is characterized by the development of raised thickened calcite on folia. The spiral side shows the development of raised thickened calcite along the radial sutures and relatively flat proloculus. It has 7 to 8 chambers in the final whorl. Microstructurally, pore density is high and the pores are regular and are present all throughout the test except at the pointed ends of folia.

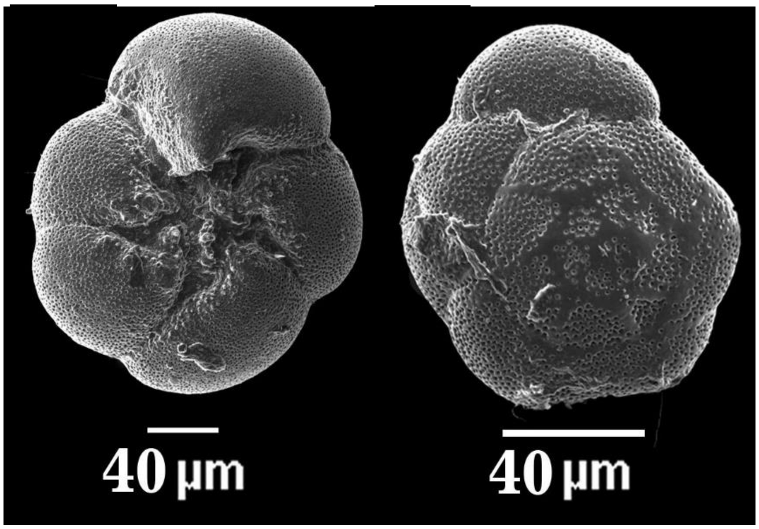


Fig 2.1 *Ammonia tepida*

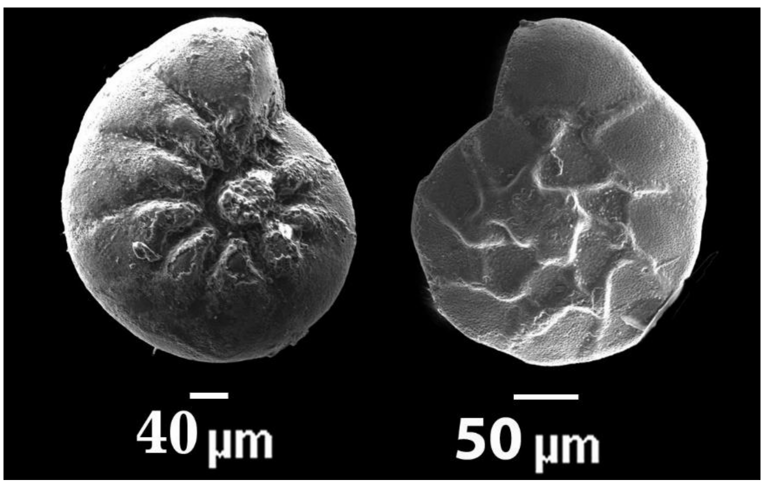


Fig 2.2 *Ammonia beccarii*

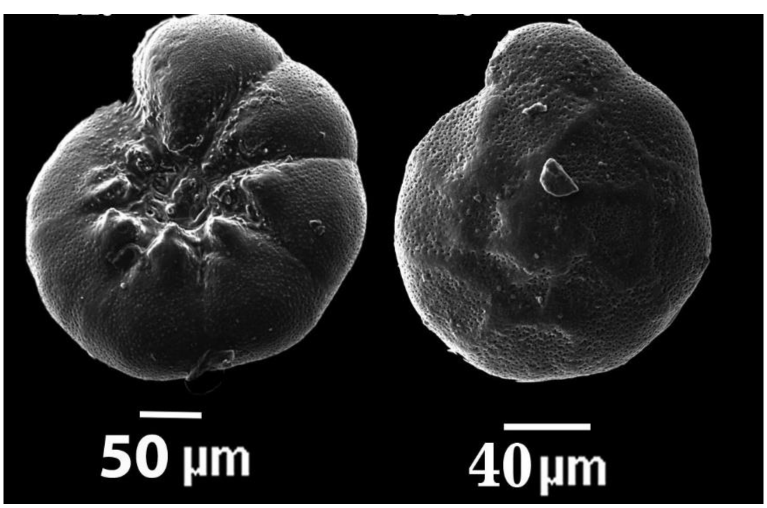


Fig 2.3 *Ammonia parkinsoniana*

3.1 Introduction

Generally, the species in the genus *Ammonia* are quite closely related as far as morphology is concerned. Hence it is difficult to distinguish them with the help of stereo-zoom microscope with naked eyes. By morphometric analysis different physical parameters are compared and the subtle differences were recognized leading to the recognition of different species the genus with more precision.

3.2 Morphometric Measurements

Following parameters were taken into consideration in the morphometric measurements of *Ammonia* spp. (fig 3.1, fig 3.2):

Profile, quantitative measurement:

1. Gsd= greatest spiral diameter

Profile, qualitative 5-point assessment:

1. Umb= umbilical side (concave, flat, low convex, convex, high convex)
2. Spi= Spiral side (concave, flat, low convex, convex, high convex)

Umbilical side, quantitative measurement:

1. Du/d= relative diameter of umbilicus = gsd/largest diameter of umbilicus between end of folia
2. Rfl/w= relative lenth of radial sutural furrows = lenth of radial sutural furrows (n-1:n-2)/ width (perpendicular to periphery) of chamber n-1
3. Maxbos= diameter of largest umbonal boss (if present)
4. Nobos= number of umbonal bosses (if present)
5. Fol^= folium angle (in degrees) of chamber n-1

Umbilical side, qualitative 5 point assessment

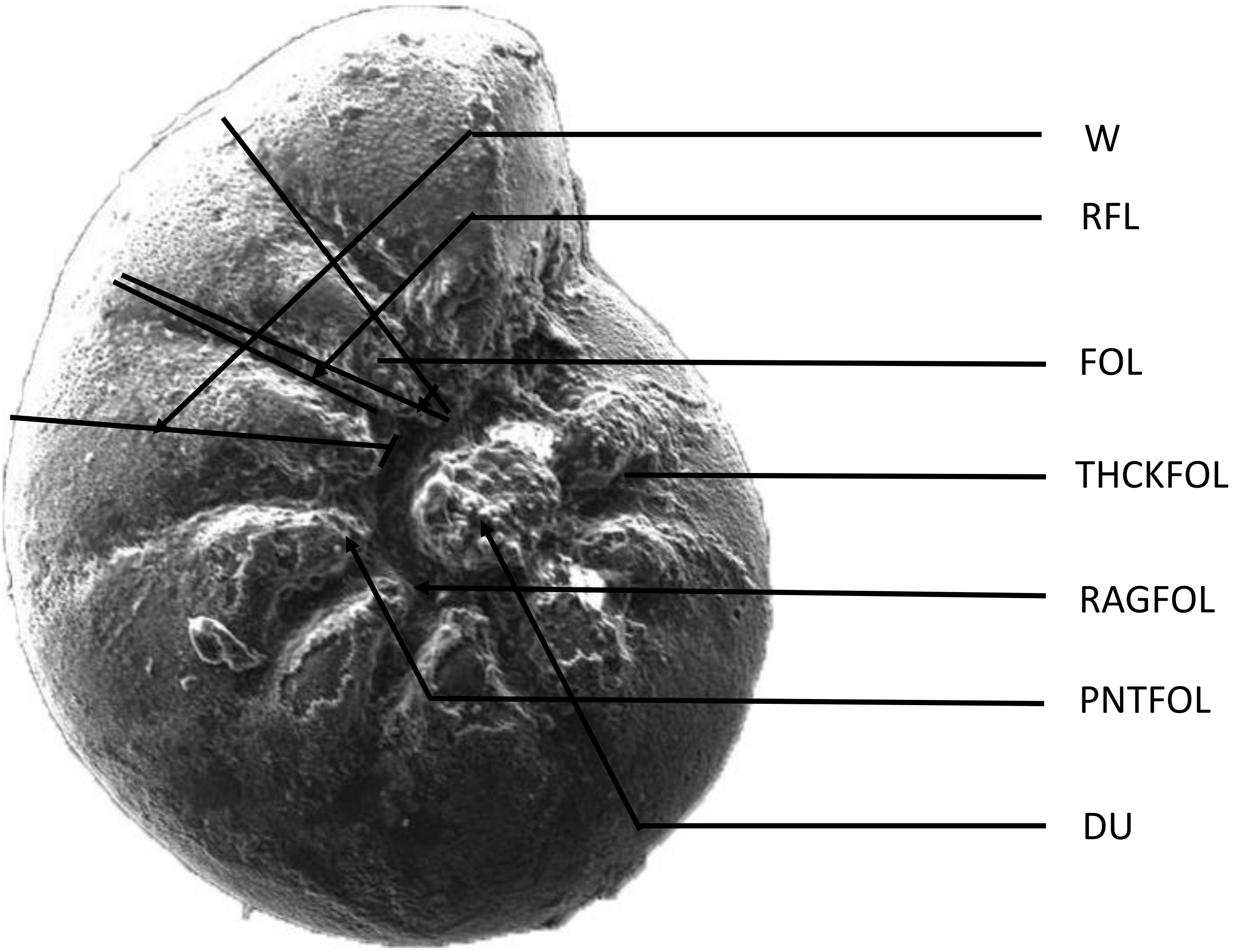
1. Thckfol= development of thickened calcite on folia
2. Protof= deeply notched protoforamen on chambers n… n-3
3. Ragfol= blunt, ragged folium on chambers n… n-3
4. Pntfol= sharp pointed folium on chambers n… n-3

Spiral Side, quatitative measurements:

1. Prol= proloculus largest diameter
2. Chwh1= number of chambers in first whorl
3. Chwh2= number of chambers in second whorl
4. d/wh= mean diameter of each whorl= gsd-prol/2 x no of whorls
5. ch/wh= mean number of chambers per whorl= number of chambers /wh
6. lc/wc= relative chamber (n-1) proportions= max length (parallel to periphery) of chamber/ max width (perpendicular to periphery) of chamber
7. rad^= angle between radial (n-1:n-2) and spiral sutures

Spiral side, qualitative 5 point assessment:

1. radsutcv= radial sutural curvature (suture n-1: n-2)
2. thckrad= development of raised thickened calcite along radial sutures of last whorl
3. spicac= development of raised thickened calcite over central spiral area
4. retcac= development of reticulate pattern of calcite riblets over central spiral area.



Ammonia spp.

Fig 3.1 *Ammonia* sp. with various morphoparameters marked for the umbilical side

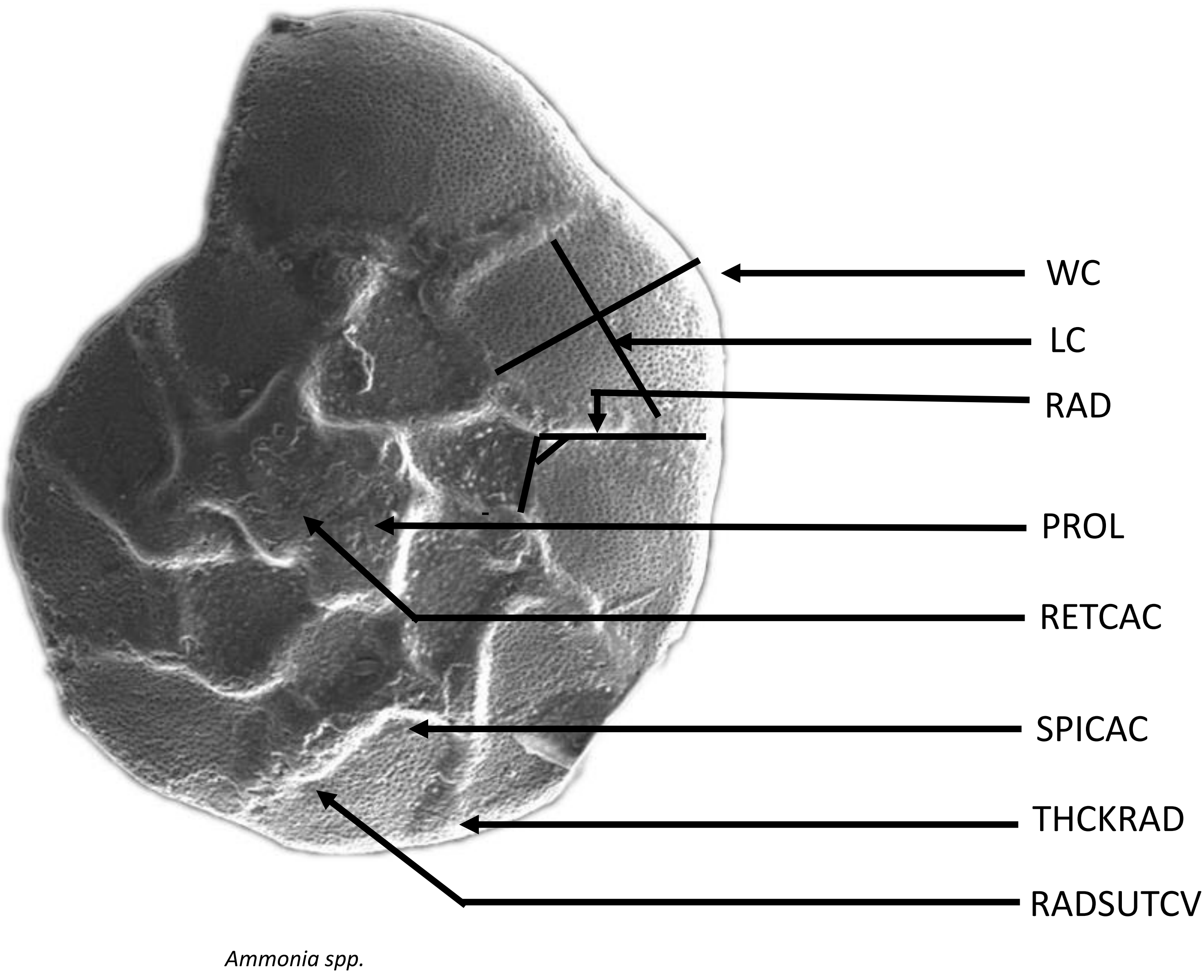


Fig 3.2 *Ammonia* sp. with various morphoparameters marked for the spiral side

Sl No.	Gsd	Prol	Chwh1	Chwh2	lc	wc	rad^	Radsutcv	Thckrad	Spicac	Retcac	Spi	Bos	Nobos
1	236.807	35.983	6	4	82.197	82.455	71.024	1	2	0	0	4	1	1
2	221.622	65.945	6	8	57.733	45.615	72.967	1	3	0	1	2	0	0
3	189.541	55.316	6	5	63.281	46.951	75.982	1	2	1	1	2	0	0
4	307.445	50.477	6	6	84.685	87.167	80.275	2	2	1	0	2	1	1
5	173.781	49.389	8	10	51.302	17.038	71.872	3	1	2	2	2	1	1
6	195.284	44.696	6	7	51.760	53.430	77.872	3	1	2	2	2	1	1
7	199.114	46.984	7	4	62.139	52.289	72.491	1	1	2	1	3	1	1
8	126.4	34.685	5	5	33.308	29.434	75.119	1	1	3	0	2	1	1
9	133.225	28.205	6	9	38.724	42.435	78.738	1	2	2	0	2	1	1
10	129.934	29.627	6	9	35.756	30.186	75.977	1	1	1	1	2	1	1
11	128.327	35.46	6	9	28.234	38.196	72.092	1	1	2	0	3	1	1
12	187.971	57.247	6	6	41.914	47.416	76.435	1	2	1	3	4	1	1
13	109.789	35.083	5	5	28.505	31.740	79.955	1	1	1	0	3	1	1
14	116.847	27.396	6	9	38.204	23.610	70.247	1	1	2	0	3	1	1
15	122.106	27.643	6	5	29.786	30.875	71.968	1	1	1	0	3	1	1
16	212.267	80.297	5	5	99.420	47.878	60.258	3	0	3	0	3	0	0
17	177.444	40.804	8	6	86.048	31.319	50.704	3	0	3	0	3	0	0
18	179.738	43.307	5	5	56.201	46.427	80.494	1	1	3	0	4	0	0
19	175.42	35.167	8	6	83.486	27.652	51.843	3	0	2	1	3	0	0
20	146.507	27.704	8	6	62.764	32.799	47.666	3	0	2	0	4	0	0
21	143.403	36.384	8	6	53.621	28.823	62.556	3	0	2	0	3	0	0
22	172.661	42.024	8	6	78.442	41.006	62.556	3	0	2	0	3	0	0
23	177.711	44.566	7	6	77.505	37.576	60.03	4	0	2	1	3	0	0
24	163.893	41.699	8	7	57.007	39.935	61.225	3	0	3	0	3	1	1
25	178.645	36.042	7	7	64.291	35.272	62.512	2	0	2	0	4	1	1
26	190.753	32.904	8	8	70.879	27.475	50.301	3	0	2	0	3	0	0
27	155.208	40.143	9	5	56.695	30.571	58.1	2	0	1	3	4	0	0
28	154.209	32.603	6	5	87.666	22.100	48.237	4	1	2	1	4	1	1
29	163.277	35.063	7	6	86.201	28.619	64.995	2	0	1	2	4	0	0
30	156.439	32.72	8	6	72.322	27.587	58.588	2	1	1	1	3	1	1
31	233.007	50.754	9	5	59.170	43.943	65.618	1	0	1	1	3	1	1
32	162.611	35.946	9	5	45.701	35.075	63.194	1	1	1	0	3	1	1

33	147.716	34.205	8	3	42.519	39.616	67.218	1	0	2	0	3	1	1
34	140.957	38.875	9	1	34.785	30.444	59.621	1	1	4	0	3	1	1
35	136.013	25.167	8	5	37.994	31.961	63.146	1	1	0	0	3	1	1
36	136.374	36.042	9	5	26.138	26.327	52.219	1	0	1	1	3	1	1
37	135.199	28.024	9	7	26.138	26.327	52.219	1	0	1	1	3	1	1
38	130.365	32.577	9	1	37.454	30.907	63.501	1	1	2	0	2	1	1
39	115.734	23.546	8	3	39.762	35.792	66.905	1	0	1	0	2	1	1
40	133.467	23.329	8	6	49.056	30.056	73.595	1	1	0	0	3	0	0
41	136.371	28.546	8	0	40.278	45.206	71.29	1	1	1	0	2	1	1
42	122.896	25.866	8	0	54.165	33.530	63.958	1	0	2	0	3	0	0
43	126.896	33.286	7	6	45.012	29.066	70.189	1	1	2	0	3	1	1
44	132.737	36.23	9	2	35.195	34.779	62.541	1	1	1	0	2	1	1
45	125.345	24.396	8	4	35.316	27.720	70.462	1	0	2	0	3	1	1

Sl No.	Maxbos	du	rfl	w	fol^	umb	thckfol	protof	ragfol	pntfol	du/Gsd	rfl/w	maxbos/gsd	ch/wh	lc/wc
1	42.024	64.272	58.979	65.48	48.796	3	4	4	4	3	0.271411	0.900718	0.17746097	5.00	0.996871
2	0	60.618	46.374	93.537	36.423	0	4	3	3	1	0.27352	0.495782	0	7.00	1.265658
3	0	39.867	45.525	71.706	54.754	0	3	3	3	1	0.210334	0.634884	0	5.50	1.347809
4	35.208	52.465	118.524	127.254	42.581	2	4	4	4	3	0.170648	0.931397	0.114518044	6.00	0.971526
5	19.522	27.375	66.336	70.7	32.777	2	4	4	3	3	0.157526	0.938274	0.112336792	9.00	3.011034
6	21.213	47.281	53.293	75.151	42.68	1	1	2	2	2	0.242114	0.709146	0.108626411	6.50	0.968744
7	19.784	45.905	52.594	68.861	48.414	1	3	3	2	3	0.230546	0.76377	0.099360166	5.50	1.188376
8	18.409	22.44	32.335	43.055	32.89	2	3	2	2	3	0.177532	0.751016	0.145640823	5.00	1.131616
9	25.485	33.54	39.08	43.378	35.6	3	3	2	2	3	0.251755	0.900918	0.191292926	7.50	0.912549
10	15.853	33.388	37.144	47.346	43.892	1	2	2	1	2	0.256961	0.784522	0.122008096	7.50	1.184523
11	17.724	26.785	39.439	49.944	42.873	1	3	2	3	3	0.208725	0.789664	0.138115907	7.50	0.739187
12	38.579	58.798	45.627	57.829	49.172	3	4	2	2	3	0.312804	0.788999	0.205239106	6.00	0.883963
13	25.167	30.183	32.46	38.799	38.833	2	3	3	2	2	0.274918	0.83662	0.229230615	5.00	0.898078
14	10.425	17.604	39.346	46.832	43.233	1	2	2	3	3	0.150659	0.840152	0.089219235	7.50	1.618128
15	11.049	19.59	36.747	41.403	49.002	1	1	2	3	2	0.160434	0.887544	0.090486954	5.50	0.964729
16	0	17.507	69.085	81.261	42.97	0	0	2	1	4	0.082476	0.850162	0	5.00	2.076528
17	0	15.691	59.893	70.47	51.712	0	1	3	1	4	0.088428	0.849908	0	7.00	2.74747
18	0	10.746	76.717	85.614	63.364	0	0	2	1	4	0.059787	0.89608	0	5.00	1.210524
19	0	14.858	71.076	75.048	49.247	0	0	2	1	4	0.0847	0.947074	0	7.00	3.019167
20	0	13.289	60.07	82.193	55.917	0	1	2	1	4	0.090706	0.730841	0	7.00	1.913595
21	0	13.698	60.942	62.568	47.741	0	0	3	1	3	0.095521	0.974012	0	7.00	1.860355
22	0	12.119	73.005	81.86	62.621	0	0	4	2	4	0.07019	0.891828	0	7.00	1.91294
23	0	13.096	70.141	81.52	60.729	0	0	3	1	4	0.073693	0.860415	0	6.50	2.06262
24	11.119	15.036	61.496	69.63	64.142	1	1	3	1	3	0.091743	0.883183	0.067843044	7.50	1.427495
25	11.545	14.079	90.002	101.038	48.042	1	1	4	2	4	0.07881	0.890774	0.064625374	7.00	1.822721
26	0	13.544	69.221	80.893	61.254	0	0	3	1	4	0.071003	0.855711	0	8.00	2.579763
27	0	10.506	55.874	59.094	65.459	0	1	4	1	3	0.06769	0.945511	0	7.00	1.854535
28	13.821	15.367	63.792	75.983	45.635	1	0	3	1	3	0.09965	0.839556	0.089625119	5.50	3.966787
29	0	10.746	78.587	82.069	66.617	0	2	4	2	4	0.065815	0.957572	0	6.50	3.01202

30	10.302	13.267	64.769	66.757	65.613	1	1	2	1	3	0.084806	0.97022	0.065853144	7.00	2.621597
31	34.403	46.071	58.057	72.583	40.076	2	1	4	2	3	0.197724	0.79987	0.147647925	7.00	1.346517
32	19.35	33.484	53.451	67.585	53.685	2	3	3	1	3	0.205915	0.790871	0.11899564	7.00	1.302951
33	21.012	27.489	59.043	63.639	38.698	2	2	3	1	3	0.186094	0.92778	0.142245931	5.50	1.073278
34	14.354	16.789	52.825	54.633	38.938	2	3	3	1	3	0.119107	0.966906	0.101832474	5.00	1.14259
35	13.13	17.52	53.648	56.39	49.294	2	1	3	2	3	0.128811	0.951374	0.09653489	6.50	1.188761
36	24.186	31.826	44.684	49.656	39.329	2	2	2	0	3	0.233373	0.899871	0.177350521	7.00	0.992821
37	14.423	23.957	60.989	61.846	42.539	2	1	3	1	3	0.177198	0.986143	0.106679783	8.00	0.992821
38	12.397	14.296	42.685	46.911	47.023	1	1	0	2	3	0.109661	0.909915	0.095094542	5.00	1.211829
39	14.065	16.329	49.449	51.237	33.304	2	2	2	2	3	0.141091	0.965103	0.121528678	5.50	1.110919
40	0	10.746	55.14	59.893	48.94	0	1	4	1	4	0.080514	0.920642	0	7.00	1.632153
41	11.8	13.796	33.441	50.58	51.644	1	2	3	3	3	0.101165	0.661151	0.086528661	8.00	0.890988
42	0	10.425	53.685	62.208	43.632	0	1	3	1	3	0.084828	0.862992	0	8.00	1.615419
43	20.89	27.396	39.632	46.154	53.722	1	2	1	1	3	0.215893	0.85869	0.164622998	6.50	1.548614
44	10.746	14.611	26.153	43.946	46.547	1	1	1	2	3	0.110075	0.595117	0.080957081	5.50	1.011961
45	17.483	19.719	35.888	44.477	55.141	2	2	1	2	3	0.157318	0.806889	0.139479038	6.00	1.274026

3.4 Results and Discussions

The spiral side character has been plotted in fig 3.3 i.e., Prol (diameter of proloculus) versus Gsd (greatest spiral diameter). After plotting the data for all the specimens, three clusters were found (indicated by different colours). Here the three clusters represent three different species.

The umbilical side characters has been plotted in fig 3.4 i.e. du/gsd (diameter of umbilicus/ greatest spiral diameter) versus rfl/w (length of radial sutural furrow/width). After plotting the data for all the specimens, three clusters were found (indicated three different colours). Here the three clusters represent three different species.

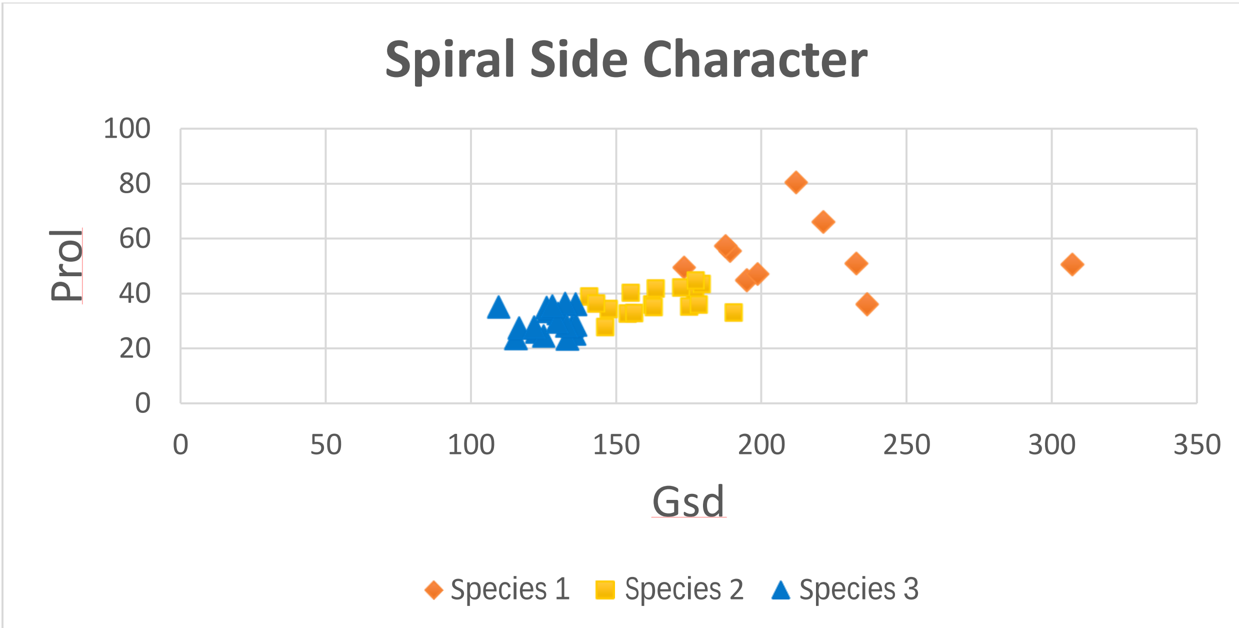

Spiral Side Character
Prol
Gsd
100
80
60
40
20
0
0
50
100
150
200
250
300
350
Species 1
Species 2
Species 3

Fig 3.3

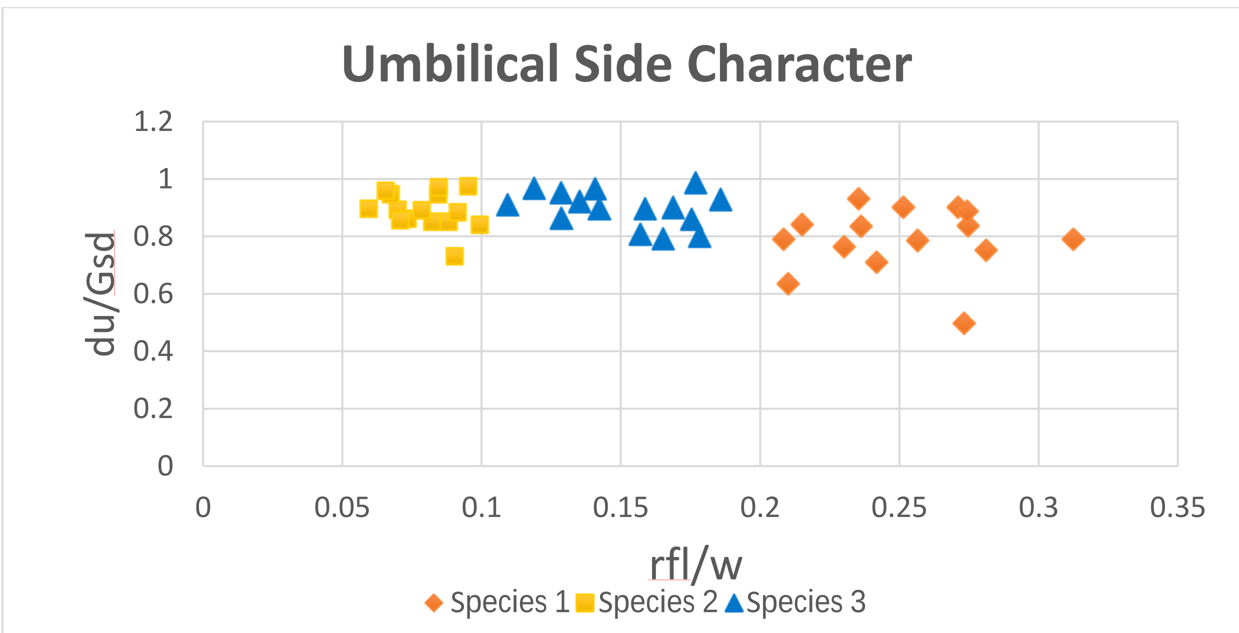
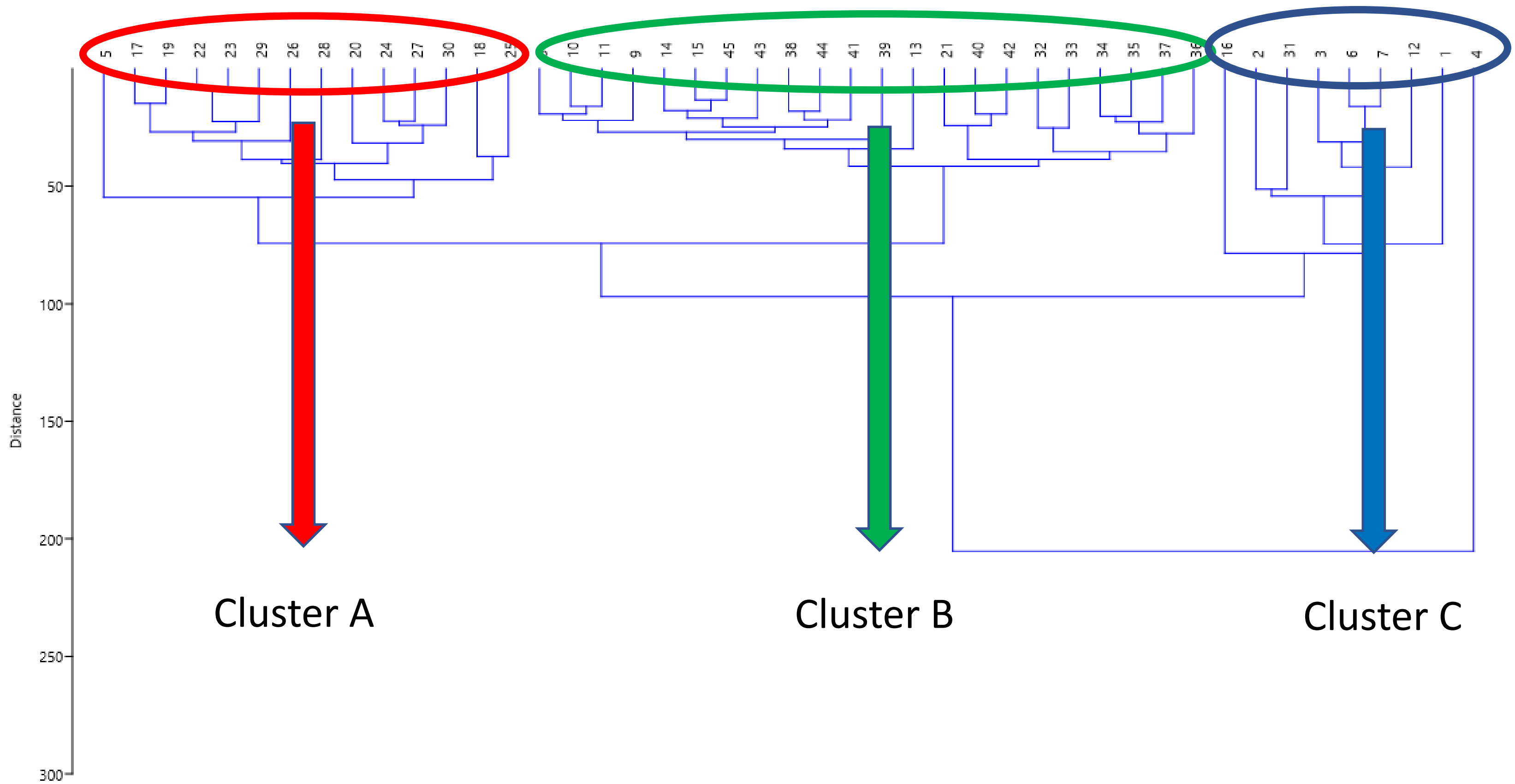

Umbilical Side Character
du/Gsd
rfl/w
1.2
1
0.8
0.6
0.4
0.2
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Species 1
Species 2
Species 3

Fig 3.4

Cluster analysis was carried out with the help of Past 3.14 software using all the morphometric parameters and plotted in figure 3.5. Here also three clusters were found indicated by three ellipses (each in different colour) and named as Cluster A, Cluster B and Cluster C.

After correlating with morphometric data, Cluster A was recognized as *Ammonia tepida* as they had smooth rounded periphery, pointed folium in the umbilical side, thickened calcite along the radial sutures as well as over central spiral area, 7 to 9 chambers in the final whorl. Cluster B was recognized as *Ammonia parkinsoniana* as they had small umbilicus, relatively flat proloculus, 7 to 8 chambers in the final whorl, test outline is relatively smooth. Cluster C was recognized as *Ammonia beccarii* as they had 8 to 10 chambers in the final whorl, presence of small cavity around the umbilical region, large boss etc.

CLUSTER ANALYSIS



Past 3.14

So far three different species of *Ammonia* have been identified from Chilika Lake, Odisha from morphometric analysis:

1. *Ammonia tepida*
2. *Ammonia parkinsoniana*
3. *Ammonia beccarii*

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