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Spatial Distribution and Diversity in Diatom Flora of the North Flowing Plateau Rivers (Bundelkahnd, Central India)

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Abstract: Here we report a study of the distribution of diatom flora within the Central Highlands ecoregion in Central India south of the river Ganga. Epilithic diatom samples were obtained from three north flowing plateau rivers situated between 23°30' to 26° N and 78°30' to 82° 30' E in Bundelkhand region (Central India). The samples were collected from four, four, and three equidistantly located stations in the Ken, Paisuni and Tons rivers, respectively. The samples were obtained by scraping 3x3 cm surface area of small stones. Permanent mounts of acid-peroxide treated samples were prepared in Naphrax and examined for flora. The flora comprised 205 taxa from 42 genera in the River Ken, 211 taxa of 39 genera in River Tons and 202 taxa of 42 genera in the River Paisuni. Among 293 taxa (49 genera) recorded from these rivers only eighty six taxa were common. All rivers were highly diverse (H) and even (E), especially the Paisuni. Various parameters of diversity decreased longitudinally in the Ken and Tons only.
Key words: Central Highlands, diatoms, diversity, spatial distribution, plateau rivers

I. INTRODUCTION

The freshwater biodiversity is distributed in a fundamentally different pattern from that in marine or terrestrial systems. Organisms on land or in the sea live in media that are more or less continuous over extensive regions and species adjust their ranges to some degree as climate or ecological conditions change. But freshwater habitats are relatively discontinuous, and many freshwater species do not disperse easily across the land barriers that separate river drainages into discrete units. The loss of biodiversity in an ecosystem has important implications, including diminished resistance and resilience to disturbance, system simplification, and loss of ecological integrity. Critical to preventing losses of biodiversity is an understanding of patterns in taxa richness (a commonly used measure of biodiversity) at a variety of spatial scales (WRI et al. 1992). Agenda 21 emphasizes the role of biodiversity in the sustainable development of the uplands. In the mountain stream and river ecosystems, diatoms are the major primary producers of the grazing food chain, and are known to constitute over 80% of the phytobenthos density (Nautiyal et al 1997, 2004 a, b).

Little progress has been made to document the diatom flora and measures of species diversity in the mountains streams and rivers of India (Rout and Gaur 1994; Nautiyal 2005, Nautiyal and Nautiyal 1999, Nautiyal et al. 2000, 2004 a, b; Jüttner and Cox 2001). The interest is more recent because the uplands, like Himalaya have witnessed a lesser degree of human interference compared to Alps and other mountain chains and can serve as reference sites (Ormerod et al. 1994, Cantonati et al. 2001, Nautiyal et al. 2004 b) and because increased developmental activities, consequent urbanization is affecting these rather pristine waters (Nautiyal et al. 2000). Hence, a study was designed to determine the richness pattern and diversity of the benthic diatom communities in the rivers of Central Highlands Ecoregion in Central India. The rivers in northern part of this ecoregion form the lower part of the Gangetic drainage. The terrain is characteristically plateau with intermittent hills of the Vindhyan ranges. Biodiversity studies in this region are important in view of the river linking programme (Ken-Betwa Link) in the Bundelkhand region (NWDA 2006) and future impacts of climate change.

II. MATERIALS AND METHODS

A. Study area

The rivers in northern part of the Central Highlands Ecoregion form the part of the Gangetic drainage in its middle stretch. The characteristic terrain is plateau with intermittent hills of the Vindhyan ranges. The rivers Ken, Paisuni and Tons selected for the study are located between 23°30' to 26°N, 78°30' to 82°30'E. These rivers find their source in the Kaimur series of the Upper

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Vindhyan range and flow northwards through the Bundelkhand plateau from north of Narmada, around Tropic of Cancer to higher latitude along southern fringe of the Indo-Gangetic Plains. The rivers Ken and Paisuni join the right bank in the lower part of the Yamuna before its confluence with the Ganga at Allahabad and Tons joins the Ganga, after the confluence of the Yamuna and Ganga. The Ken and Tons are ca. 4 times longer compared to 100 km long Paisuni, having an average gradient of 0.91 m km^{-1}, 2.0 m km^{-1} and 1.02 m km^{-1}, respectively. Small patches of dry deciduous forest occur in the middle stretch of the Ken River and the headwaters of the Paisuni. Agriculture is the main landuse along their banks. Considerable human activity (pilgrimage to Chitrakut Dhama) occurs in the headwaters of the Paisuni.

The headwater, middle and lower/mouth zones of selected rivers were sampled to obtain the longitudinal profile of diatom distribution and diversity. Four stations each were selected for sampling the Ken and Tons while three in the Paisuni. Since the Tons and Ken are nearly four times longer two stations were selected in their middle zone. Sampling station in each of these zones was located on the basis of easy accessibility by road. The geographical positions and physico-chemical characteristics of the rivers at these stations are presented in Tables 1 and 2, respectively.

Diatom samples were obtained by scraping 3 x 3 cm area of 3-4 palm sized stones (cobble) surface at each station and transferred to storage vials containing 4% formaldehyde solution. Samples were first cleaned to remove traces of formaldehyde and digested with Hydrochloric acid. The treated samples were repeatedly washed to remove all traces of acid and then cleaned with hydrogen per oxide. The diluted sample was mounted in Naphrax for preparing permanent mounts. Each sample was examined for the flora based on standard literature. The mounts have been adequately stored at the Aquatic Biodiversity Unit.

III. RESULTS & DISCUSSION

A. Flora

The taxon richness barely varied among the plateau rivers; Ken R. 205 taxa from 42 genera, Paisuni R. 202 taxa from 42 genera and Tons R. 211 taxa from 38 genera (Table 3). There is very little intra-river variation. Hence, of 205 taxa observed in the Ken, a large part of the flora (182 taxa) is present at K1 itself and meager additions occur in rest of the river that too at K2. Sixteen taxa were added to the flora of the Ken at K2 some of which persisted at K3 and K4 and few in either of them. Only 4 taxa were added at K3. On the other hand 20 taxa found at K1 did not occur at K2, but some of them were present at K3 and K4 and few in either of them or at K1 alone. Consequently, taxonomic richness with respect to species and genera declined from K1 (182) to K4 (151) in the Ken and T1 (177) to T4 (156) in the Tons. In the Paisuni, richness was similar at P1 (171) and P3 (170) but slightly higher at P2.

The longitudinal decrease in taxonomic richness can be attributed to loss of substrate heterogeneity from source to mouth. The particle size generally decreases from hard substrate (rock, boulder, cobble, pebble, gravel, silt) to only soft substrate (silt, clay) near the mouth, because these rivers flow north from hill-plateau into the Gangetic Plains characterized by alluvial soil. Over half of the flora (>50%) is common from headwaters to mouth in each river; 106 taxa from K1 to K4 in the Ken, 129 taxa from P1 to P3 in the Paisuni and 106 taxa from T1 to T4 in the Tons. Some of the taxa were specific to each river; seventeen each in the Ken and Paisuni and eighteen in the Tons (Table 4). Studies are continuing to understand if these forms are really unique, and if so the possible factors governing their presence, proximate or geographical.

B. Spatial distribution

The present investigation explains the extent of taxonomic richness and diversity in the highland-plateau rivers of Central India. The total flora amounted to 293 taxa of which 86 taxa were common to all three rivers. Any two river accounted for much higher richness; 90% Ken-Tons, 92% Ken- Paisuni and 95% Tons-Paisuni. On same lines each river harbours 70 to 72%, while each station supported 52 to 65% of total taxa. Relatively, lower taxonomic richness in the Ken-Tons suggests higher similarity in their flora attributed to similar stream order though their origins lie in proximity and the channels diverge resulting in considerably distance (ca. 150 Km apart) between them. Comparably, higher richness in the Ken-Paisuni or Tons-Paisuni indicates diversity of flora in these river-pairs. Thus the Paisuni has relatively lower level of similarity with either the Ken or the Tons, irrespective of their distances, possibly due to its low stream order and landuse practices in the basin. Notably, the Paisuni is located between the Ken and Tons, and is closer to the Ken (ca. 50 km apart) while the Tons is nearly 100 km away from the Paisuni in the lower stretches. Thus, the ecoregion appears to support high taxonomic richness attributable to greater diversity of microhabitats and land use practices, rather than the physicochemical factors which were quite similar.

However, when the flora of three rivers is compared only 86 taxa were common and few are unique; such as species of Amphipleura, Aneumastsus, Scoliopleura in the Paisuni, Bacillaria in the Tons and Mastogloia in the Ken. The species of these genera are not common in India and hence can be called as specific. Mastogloia smithii and Bacillaria paxillefer are indifferent to current and also found in periodic waters. The peninsular rivers are known to dry up in summer or draught and become discontinuous, and the river exists only as pools.

C. Longitudinal changes

1) *Diversity:* Increase in the values of Index of Dominance at K4 and T4 coincided with decrease in the Shannon and Margalef and Simpson diversity indices Longitudinally, the Ken and the Tons were more diverse in the headwaters with diversity tending to decrease in downstream direction except for the Paisuni which was more diverse in the middle stretch at P2 and thus defied the trend observed in the Ken and the Tons (Table 5). The decrease in diversity corresponded with decline in the altitude of rivers. In the Himalayan rivers the Shannon diversity increased longitudinally and with decrease in the altitude (Nautiyal et al. 1997; Nautiyal et al. 2004 a). The Shannon and other diversity indices along with Evenness were quite high in the Central Highlands Ecoregion. The Shannon diversity > 4.0 have been reported from the River Indus at Ghazi Ghatt, Punjab, Pakistan (2.82-7.95 Ali et al 2003) and various parts of the Himalaya; Shillong stream (1.6-4.1, Rout and Gaur 1994); Himalaya and Alps (2.6 to 4.1, Cantonati et al. 2001). However, the mean diversity estimates [0.79 to 1.19 (0.24)] were much low in the mountain streams of the Nepal Himalaya (Jüttner et al. 1996, Rothfritz et al. 1997) and even other parts of the Himalaya (Nautiyal et al. 2004a). In different tropical rivers, the estimate was low; Bellinger et al. (2006) in different African streams (0.65-1.03).The diversity is influenced by geographical factors (notably latitude, altitude), primary factors (productivity, harshness, climatic variability) and secondary factors (competition, predation, spatial heterogeneity). The primary factors are independent of latitude and hence tend to blur relationship with the geographic factors (Begon et al. 1990). These factors govern the extent of biodiversity in similar ecosystems in different continents. Diversity in local communities can be regulated by local factors (such as competition, disturbance and abiotic conditions) as well as regional factors (such as history of climate evolution and migration). Higher diversity in the Vindhya may be attributed to secondary factors and moderate nutrient levels generated by agriculture. Extensive agriculture is comparable to moderate amount of disturbances, one of the causes for higher diversity (Begon et al. 1990). Jüttner et al. (1996) concluded that taxa richness and diversity index were significantly higher in agricultural streams than in either organically polluted streams or references of Nepal. Bellinger et al. (2006) observed that measures of biodiversity were not useful for distinguishing human land perturbations between deforested and forested watersheds of East Africa as the metrics of biotic diversity (Simpson–Yule, Shannon diversity index) and taxa richness in the undisturbed systems were not significantly different. Besides big dams on these and other rivers of Central Highlands Ecoregion including those on Narmada, ambitious plans are afoot to link the rivers of Bundelkhand region (NWDA 2006). Execution of the Ken-Betwa link has already begun. The present findings will go a long way to assess future changes in the ecology of these rivers due to developmental activities.

IV. Acknowledgement

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Table 1. Geographical co-ordinates of the sampling stations in different rivers of the Central Highland.

River system	Rivers/ Stations with Acronym	Latitude (N)	Longitude (E)	Altitude (m asl)	Distance from source (Km.)
Yamuna	**Ken River**				
(lower	Shahnagar K1	23°59'28.92"	80°18'1.77"	365	ca.10
stretch)	Panna K2	24°44'17.38"	80° 0'41.16"	200	142.5
	Banda K3	25°28'38.25"	80°18'51.62"	95	267.5
	Chilla K4	25°46'15.49"	80°31'36.99"	86	340
	Paisuni River				
	Anusuya P1	25°04’25”	80°52’05”	180	10
	Chitrakut P2	25°10’25”	80°52’12”	135	26
	Purwa P3	25°13’01”	80°54’09”	131	42
Ganga	**Tons River**				
(middle	Amdara T1	24° 6'30.83"	80°36'11.34"	360	20
stretch)	Maihar T2	24°16'14.13"	80°48'18.11"	326	56
	Satna T3	24°33'42.88"	80°54'26.34"	290	98
	Chakghat T4	25° 2'1.06"	81°43'51.75"	94	232.5

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Table 2. Physical and chemical characteristics (minimum and maximum) at different stations of the Central Highlands region (AT, Air temperature; WT Water temperature; C V, Current velocity; C, Conductivity; DO, Dissolved oxygen).

Stream/ River	**A T (^{o}C)**	**WT (^{o}C)**	**C V (cm s^{-1})**	**pH**	**C (µmho cm^{-1})**	**DO (mg l^{-1})**
Ken	11 - 32	15 – 31	0-42	7.0-7.5	165-420	8.6-10.7
Paisuni	10 - 40	16 – 30	2.8-40	7.0-7.7	170-440	8-11.5
Tons	17 - 33	18-33	1.5-35	7.0-7.8	160-420	8.2-10.5

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Table 5. Different indices of diatoms at all stations of Central Highland Rivers.

River Station	**K1**	**K2**	**K3**	**K4**	**P1**	**P2**	**P3**	**T1**	**T2**	**T3**	**T4**
Taxa_S	182	178	159	151	171	183	170	177	186	157	156
Genera	41	39	38	36	39	38	37	35	39	35	35
Dominance_D	0.007	0.007	0.009	0.010	0.007	0.007	0.009	0.007	0.007	0.009	0.010
Shannon_H	5.048	4.982	4.853	4.704	4.984	5.065	4.892	5.01	5.031	4.799	4.715
Evenness_e^H/S	0.832	0.823	0.810	0.794	0.849	0.828	0.752	0.851	0.850	0.825	0.809
Margalef	28.94	27.01	24.61	22.05	27.06	29.38	27.79	26.7	27.83	23.01	22.03
Equitability_J	0.964	0.962	0.958	0.953	0.968	0.964	0.945	0.968	0.968	0.961	0.957

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Table 3. Spatial variations in the number of species occurring in various genera recorded from the Vindhyan Rivers.

GENERA	K	P	T
THALASSIOSIRACEAE			
1. *Aulacoseira*	1	1	
2. *Cyclotella*	1	1	2
FRAGILARIACEAE			
3. *Diatoma*	2	1	4
4. *Fragilaria*	1	1	2
5. *Staurosira*	1	2	1
6. *Synedra*	13	14	15
7. *Tabellaria*	1		1
EUNOTIACEAE			
8. *Eunotia*	3	4	4
ACHNANTHACEAE			
9. *Achnanthes*	1	1	
10. *Achnanthidium*	8	11	10
11. *Planothidium*	3	5	3
12. *Cocconeis*	6	3	3
NAVICULACEAE			
13. *Amphipleura*		1	
14. *Amphora*	10	8	8
15. *Anomoeoneis*		1	1
16. *Brachysira*	1	2	2
17. *Caloneis*	5	3	5
18. *Cymbella*	21	22	20
19. *Cymbopleura*	12	6	10
20. *Encyonema*	4	4	4
21. *Diploneis*	5	5	4
22. *Frustulia*	1		
23. *Gomphocymbelopsis*	1	1	
24. *Gyrosigma*	2	2	3
25. *Gomphonema*	11	10	12
GENERA	**K**	**P**	**T**
26. *Mastogloia*	1		
27. *Navicula*	27	28	29
28. *Navicula* sensu lato	3	4	3
29. *Adlafia*	1	1	2
30. *Aneumastus*		2	
31. *Craticula*	4	3	3
32. *Diadesmis*	1	2	1
33. *Fallacia*	1	1	2
34. *Geissleria*	1	1	1
35. *Hippodonta*	1		2

36. *Luticola*	6	3	7
37. *Placoneis*	2	1	2
38. *Sellaphora*	5	5	5
39. *Neidium*	2	4	2
40. *Pinnularia*	3	7	3
41. *Scoliopleura*		1	
42. *Stauroneis*	2		
EPITHEMIACEAE			
43. *Epithemia*			1
44. *Rhopalodia*		1	2
BACILLARIACEAE			
45. *Bacillaria*			1
46. *Denticula*	1	1	1
47. *Hantzschia*	1	1	
48. *Nitzschia*	21	20	25
SURIRELLACEAE			
49. *Surirella*	8	7	5
TOTAL GENERA	**42**	**42**	**38**
TOTAL SPECIES	**205**	**202**	**211**

Table 4. Restricted taxa of the Vindhyan Rivers (Ken, Tons and Paisuni).

TAXA	K	P	T
1. *Diatoma vulgare* v. *producta*			+
2. *Fragilaria* cf. *capucina*			+
3. *Synedra acus* sp.1	+		
4. *S. rumpens* v. *fragilaroides*			+
5. *S. r.* v. *familiaris*	+		
6. *Eunotia lunaris*		+	
7. *Achnanthedium biasoletiana* v. *subatomus (inflata)*		+	
8. *A. exigua* v. *constricta*	+		
9. *A. minutissima* v. *minutissima* or var.?	+		
10. *A. taeniata*			+
11. *Planothidium* lanceolata v. *dubia*		+	
12. *Cocconeis* cf. *scutellum*	+		
13. *Cocconeis* sp.1	+		
14. *Amphipleura pellucida*		+	
15. *Amphora chaurra*	+		
16. *Caloneis* sp.1			+
17. *Cymbella aspera*		+	
18. *Cymbella bengalensis*		+	
19. *C. bengaliformis*		+	
20. *C. sumatrensis*			+
21. *Cymbella* sp.1		+	
22. *C. k.* v. *nonfasciata*			+
23. *C. naviculiformis*	+		
24. *C. rupicola* nov.	+		
25. *Frustulia weinholdii*	+		
26. *Gomphonema angustatum*			+
27. *G. pumilum* v. *rigidum*			+
28. *G. truncatum*		+	
29. *Mastogloia smithii*	+		
30. *Adlafia parabryophila*			+
31. *Aneumastus stroesei*		+	
32. *A. tuscula*		+	
33. *Craticula citrus*	+		
34. *Hippodonta subtilissima*			+
35. *Luticola muticopsis*			+

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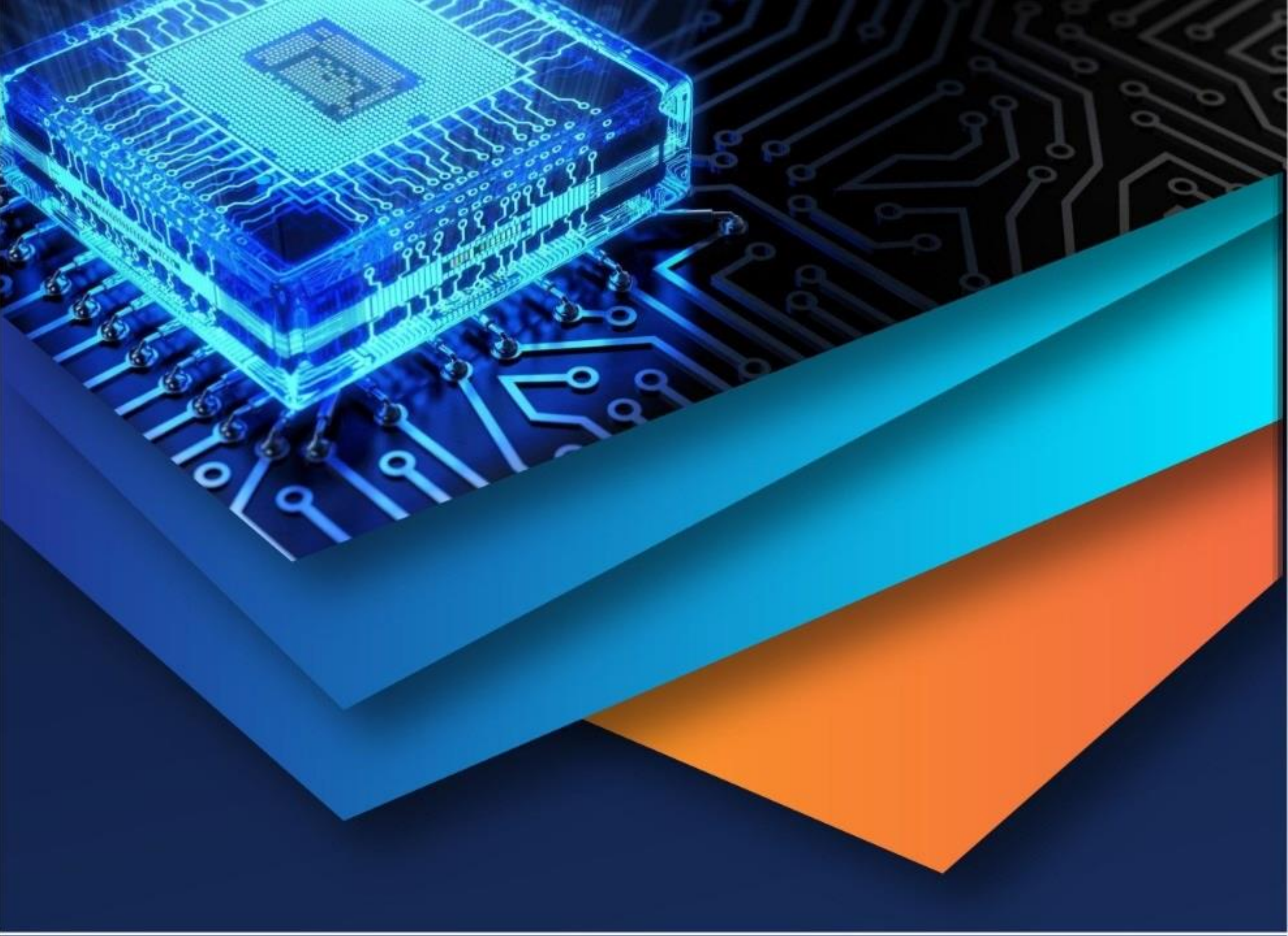
36. *Sellaphora americana* v. *americana*			+
37. *S. hustedtii*	+		
38. *Neidium binodiforme*		+	
39. *N. hercynicum*		+	
40. *Pinnularia acrosphaeria*		+	
41. *P. borealis*		+	
42. *Scoliopleura peisonis*		+	
43. *Stauroneis anceps*	+		
44. *S. nobilis*	+		
45. *Epithemia* sp.			+
46. *Rhopalodia parallela*			+
47. *Bacillaria paxillifer*			+
48. *Nitzschia acuta*	+		
49. *N. compressa* v. *compressa*			+
50. *N. umbonata*	+		
51. *Nitzschia* sp.			+
52. *Surirella* sp.		+	



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