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Short note

Enumeration of freshwater algae in Godawari area, Lalitpur district, central Nepal

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Freshwater ecosystems vary in size and composition, and contain large variety of organisms. Freshwater algae are globally ubiquitous and a highly diverse group. Algae are a vast group of photosynthetic organisms and found in many forms, *viz*. individual cells, colonies or extended filaments (Chaterjee & Raziuddin, 2006). They play an important role in the primary producers of ecosystem for various consumers of aquatic fauna. They are one of the most helpful indicators to monitor freshwater ecosystem because of their position at the base of aquatic food webs, and algal indicators provide rapid response to environmental changes compared with commonly used higher organisms (McCormick & John, 1994).

Altogether, 998 algal species are found in Nepal (Rai & Ghimire, 2020). Previously, most of the explorations of the algal flora were carried out in and around the Kathmandu Valley. The contribution of algal explorations especially in the Kathmandu Valley, has been initiated by Hirano (1955, 1963, 1969, 1984) of Kyoto University of Japan and has reported 271 taxa from eastern Nepal and central Nepal (Kathmandu, Rasuwa, Gorkha, Kaski, Manang and Mustang districts). Then, many researchers focused on the explorations of the algal species in Nepal.

Hickel (1973) also studied the phytoplankton in Taudaha (Kathmandu District) and Nagdaha (Lalitpur District). Joshi (1977, 1979) also contributed to the algal explorations from Kathmandu, Lalitpur and Sindhupalchok districts. Similarly, Prasad & Prasad (2001) have also studied the algal diversity of the Bagmati River flowing in Kathmandu, Lalitpur and Bhaktapur districts. In recent period, algological researches have been focused only on the eastern region of Nepal (Rai and Ghimire, 2020). The broad algal exploration all through the country is still to be carried out.

No, any researchers focused on the explorations of the Godawari Area alone, but many of them include some species from that area during algal explorations of the Kathmandu Valley. This is a preliminary work for the exploration of the total algal flora of the Godawari Area. The present work provides only a small stack to pile up the algal flora of Godawari Area in future.

Materials and methods

The study site lies within the Godawari Area situated at the foothills of Phulchoki Mountain of Lalitpur District within Bagmati Province of Nepal (Figure 1). Phulchoki, the highest peak in the Kathmandu Valley, is one of the popular hiking destinations in and around the Valley due to its rich biodiversity and splendid environment. Godawari is also famous because of the National Botanical Garden (NBG) and the Lama Kunda (pond) which is the outlet of "Godawari Kunda", one of the sacred sites in Nepal. The sample collection sites (NBG and Lama Kunda) are

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situated between 28°11′25″–28°12′25″ N latitudes and between 83°55′56″–83°58′50″ E longitudes with the elevation ranging from 1515 m to 1521 m above mean sea level in the south-eastern corner of the Valley. The study sites, moreover, exhibit a subtropical type of climate. The average annual temperature is 15.9°C, with a maximum average of 20.3°C in June and a minimum average of 9.1°C in January in the year 2020 (Climate-data.org, 2020). The average annual precipitation is 2595 mm; November is the driest month, with precipitation as low as 14 mm on average, and July the wettest, with 699 mm precipitation in the year 2020 (Climate-data.org, 2020).

The study area is surrounded by the natural forest of *Alnus nepalensis*, *Schima walllichii*, *Castanopsis indica*, *Prunus cerasoides*, *Pyrus pashia*, *Ziziphus* sp., and so on. The algal species were noticed along some streams, streamlets, and around a man-made coronation pond inside the NBG.

Sample collection and identification

All the samples were collected from the aforementioned two sites during 8–12 Oct, 2020. Ten samples were collected from the National Botanical Garden while 2 samples from the Lama Kunda. The locations of the sample sites were detected using a GPS set (Table 1). The algal samples were collected freely for planktonic forms and by squeezing submerged aquatic macrophytes for epiphytic forms. Each sample was assigned with collection number, and preserved in 4% formaldehyde solution in airtight glass bottles; all the samples so collected were brought to the National Herbarium and Plant Laboratories, Godawari for their identification. The samples were first screened, and their microscopic observation was performed using the HumaScope Premium LED Microscope; the microphotography of the samples was taken with the attached TOUPCAM Camera of 0.5X.

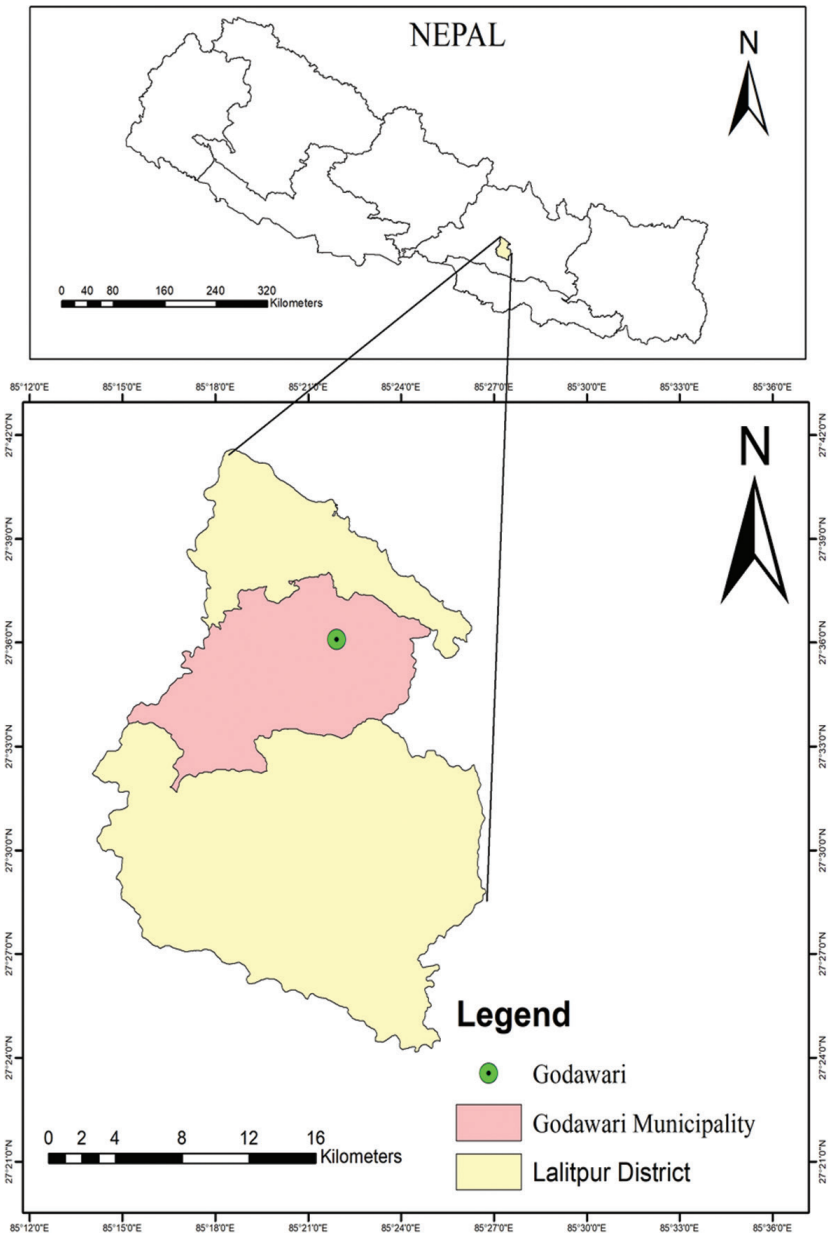

Figure 1: Location map of Godawari area (highlighted in pink color)

Table 1: Description of sampling sites in the study area

Collection No.	Date of collection	Latitude	Longitude	Altitude (m)
NBG1	9th Oct, 2020	27°35'46.227"	85°22'56.547"	1515
NBG2	9th Oct, 2020	27°35'42.681"	85°22'55.646"	1515
NBG3	9th Oct, 2020	27°35'42.687"	85°22'55.646"	1515
NBG4	9th Oct, 2020	27°35'42.687"	85°22'55.646"	1515
NBG5	9th Oct, 2020	27°35'42.687"	85°22'55.646"	1515
NBG6	9th Oct, 2020	27°35'41.733"	85°22'56.547"	1515
NBG7	9th Oct, 2020	27°35'40.023"	85°22'53.009"	1515
NBG8	9th Oct, 2020	27°35'44.336"	85°22'51.073"	1515
NBG9	9th Oct, 2020	27°35'44.336"	85°22'51.073"	1515
NBG10	9th Oct, 2020	27°35'46.567"	85°22'48.381"	1515
LK1	8th Oct, 2020	27°35'53.088"	85°23'11.688"	1521
LK2	8th Oct, 2020	27°35'53.988"	85°23'11.580"	1518

Note: NBG = National Botanical Garden; and LK = Lama Kunda.

The morphological observation of green algae focused mainly on the presence of chloroplast, shape and size of the cells and filaments; in the case of diatoms, presence of raphe and presence or absence of centriole were observed. Similarly for blue green algae, presence and absence of sheath, heterocyst, shape and size of cells were taken into consideration. The identification of taxa was done by referring to the standard taxonomic manuals (Desikachary, 1959; Prescott, 1961; Philipose, 1967). Nomenclature as well as classification were accomplished as per Guiry & Guiry (2021).

Results

The present study documented a total of 19 algae under 17 genera, 14 families, 12 orders and 4 classes (Table 2). Ten taxa were identified up to the species-level and eight only up to the genus-level. *Microspora* is closely related to *amoena* species. Lack of high magnification lens to view the internal structures of algae, and sometimes non-appearance of valve view in diatoms while observing through the microscope were the major reasons for difficulty in identifying all taxa up to the species level.

Bacillariophyceae was found to be the dominant class with six species belonging to five different genera. It was followed by Chlorophyceae, Zygnematophyceae and Cyanophyceae (four species each). However, Klebsormidiophyceae was represented by single taxa i.e. *Klebsormidium flaccidum* (Figure 2).

Table 2: List of freshwater algae reported from the study area (Classification based on Guiry & Guiry, 2021)

S. N.	Algal taxa	Family	Order	Class	Phylum
1	[1]*Oscillatoria princeps*	Oscillatoriaceae	Oscillatoriales	Cyanophyceae	Cyanobacteria
2	[1,2]*Oscillatoria* sp.				
3	[1,2]*Phormidium* sp.				
4	[2]*Pseudanabaena* sp.	Pseudanabaenaceae	Synechococcales		
5	[2]*Oedogonium* sp.	Oedogoniaceae	Oedogoniales	Chlorophyceae	Chlorophyta
6	[2] *Hydrodictyon reticulatum*	Hydrodictyaceae	Sphaeropleales		
7	[1]*Pediastrum duplex*				
8	[1]*Microspora* cf. *amoena*	Microsporaceae			
9	[2]*Closterium moniliferum*	Closteriaceae			
10	[1]*Pleurotaenium trabecula*	Desmidiaceae	Desmidiales	Zygnematophyceae	Charophyta
11	[1]*Cosmarium granatum*				
12	[2]*Spirogyra* sp.	Zygnemataceae	Zygnematales		
13	[2]*Klebsormidium flaccidum*	Klebsormidiaceae	Klebsormidiales	Klebsormidiophyceae	
14	[1]*Amphora* sp.	Catenulaceae	Thalassiophysales	Bacillariophyceae	Bacillariophyta
15	[1]*Nitzschia* sp.	Bacillariaceae	Bacillariales		
16	[1]*Gomphonema sphaerophorum*	Gomphonemataceae	Cymbellales		
17	[1]*Ulnaria* sp.	Ulnariaceae	Licmophorales		
18	[1]*Ulnaria ulna*				
19	[2]*Pinnularia viridis*	Pinnulariaceae	Naviculales		

Note: [1] species found at NBG; [2] species found at Lama Kunda; and [1, 2] species common at both the sites.

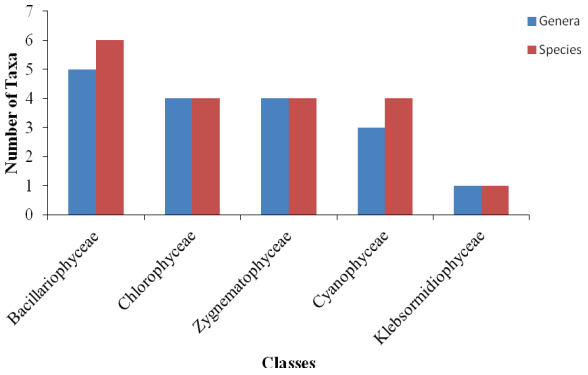

Figure 2: Dominant classes of algal species in the study area

The species occurring in both the localities were *Phormidium* sp. and *Oscillatoria* sp. The species (10 i.e. 52%) recorded only from NBG showed high species richness in the NBG locality than in Lama Kunda. Among the observed taxon, there were also diverse thallus organizations. For example, coccoid forms in *Cosmarium granatum* and *Closterium moniliferum*, filamentous in *Oscillatoria* sp., *Oedogonium* sp., *Microspora* cf. *amoena*, *Spirogyra* sp., *Klebsormidium flaccidum*, etc., non motile coenobia in *Pediastrum duplex* and *Hydrodictyon reticulatum* and unicellular in all Bacillariophyta. Besides, some other interesting findings were also explored during the study. The *Hydrodictyon reticulatum* and *Spirogyra* sp. were blooming in the Lama Kunda affecting the growth of other algal species.

Taxonomic description

Cyanophyceae

1. *Oscillatoria princeps* Vaucher ex Gomont (Figure 3: 1)
   Desikachary (1959): P. 210, Pl. 37, Figs. 1, 10, 11, 13, 14; Rai and Dhakal 2020, P. 129, Figs. 77–78.
   Trichomes-end slightly bend, not constricted at the cross walls, mostly forming a thallus, blue-green, or more or less brownish; end-cells rounded or hemispherical, slightly capitate; Trichomes 20–50 µm broad; cells 2.5–6.5 µm long.

2. *Oscillatoria* sp. (Figure 3: 2)
   Wehr & Sheath (2003): P. 155, Figure 16.
   Trichomes straight or somewhat irregularly undulate, motile by gliding or oscillating; sheaths missing in vegetative state; end cells screw-like coiled.

3. *Phormidium* sp. (Figure 3: 3)
   Wehr & Sheath (2003): P. 141, Figure 12A.
   Filaments arranged in tufts, not in fascicles, forming flat, slimy mats; filaments vary incurvature, without pseudo-branches, usually entangled, slightly too strongly waved or loosely and irregularly screw-like coiled; sheaths facultative.

4. *Pseudanabaena* sp. (Figure 3: 4)
   Yu *et al*. (2015): P. 4, Figure 2.
   Trichomes solitary, usually straight or slightly bend, cylindrical, consisting of few to several cells; seldom long with many cells; generally, with conspicuous constrictions at cross-walls; cells cylindrical with round ends, longer than width, rarely close to isodiametric.

Chlorophyceae

5. *Oedogonium* sp. (Figure 3: 5)
   Shrestha & Rai (2017): P. 47, Pl. 1, Figure 15.
   Filaments solitary, unbranched; vegetative cells cylindrical, capitate, with numerous pyrenoids; basal cell with holdfast; terminal cell obtuse.

6. *Hydrodictyon reticulatum* (Linnaeus) Bory (Figure 3: 6)
   Halder (2015): P.169, Figure 1–2.
   Plant macroscopic, grass green; free floating, colonies reticulate; 6 cells adjoined together end to end walls repeatedly forming hexagonal mesh, and whole structure of the alga appears as cylindrical net; net may vary in size; cells coenocytic, elongate, and cylindrical; cells 51.2–54.8 µm long and 9.1–10.8µm broad.

7. *Pediastrum duplex* Meyen (Figure 3: 7)
   Prescott (1961): P. 223, Pl. 48, Figure 4; Philipose (1967): P. 121, Figure 43b.
   Colonies usually of 16-32 cells, sometimes4,

8, 64 or 128 celled with small lens shaped perforations between cells; inner cells quadrate to angular in shape, inner side of marginal cells concave, outer side produced into two short truncate processes; colonies 38–90µ m in diameter; marginal cells 13 µm long, 9–11.5 µm broad; inner cells 11 µm long, 8–9 µm broad.

8. *Microspora* cf. *amoena* (Kützing) Rabenhorst (Figure 3: 8)
Das & Adhikary (2012): P. 169, Pl. 1, Figure 10.
Thallus filamentous, unbranched, thickened cell wall, cross wall lamellated; cells 46-57 µm long and 31.3–32 µm broad.

Zygnematophyceae

9. *Closterium moniliferum* Ehrenberg ex Ralfs (Figure 3: 9)
Bando *et al*. (1989): P. 7, Figure 2k.
The ventral side of the mid-region is usually inflated; the cell ends are broadly rounded and often slightly recurved. At first glance, the cell wall seems to be smooth but at high magnification, it appears delicately striate; cells 225–300 µm long, 36-39µm broad; apices 7.5–9 µm broad, 247–276 µm distant.

10. *Pleurotaenium trabecula* Nageli (Figure 3: 10)
Prescott (1961): P. 18, Pl. 3, Figure 4.
Cells medium-sized, straight, cylindrical, basal inflation of semi-cells slight but definite, with 1–3 swellings beyond it; semi-cells usually a little swollen in the mid-region and slightly tapered to apex; apex truncate with rounded angles without any tubercle; wall punctate or smooth; cell length 316–516 µm long and 39–40 µm broad; isthmus 32–35 µm wide; apices 20–22 µm broad.

11. *Cosmarium granatum* Brebisson ex Ralfs (Figure 3: 11)
Prescott *et al*. (1981): P. 146, Pl. 185, Figs. 1–3.
Cells small, constriction deep, sinus closed; semi cell trapezoid with rounded basal angles and apex; cell wall punctuated; cells 30–37 µm long and 20–26 µm broad, isthmus 4–7 µm.

12. *Spirogyra* sp. (Figure 3: 12-13)
Srivastava *et al*. (2018): P. 5, Figure 2 (O).
Filaments long and unbranched; cells cylindrical, short, to very long in some species, with plane; replicate, chloroplast a parietal band or ribbon which may be spirally twisted.

Photoplates

Figure 3: 1. *Oscillatoria princeps*, 2. *Oscillatoria* sp., 3. *Phormidium* sp., 4. *Pseudanabaena* sp., 5. *Oedogonium* sp., 6. *Hydrodictyon reticulatum*, 7. *Pediastrum duplex*, 8. *Microspora* cf. *amoena*, 9. *Closterium moniliferum*,10. *Pleurotaenium trabecula*, 11. *Cosmarium granatum*, and 12 & 13. *Spirogyra* sp.

Photoplates continued….

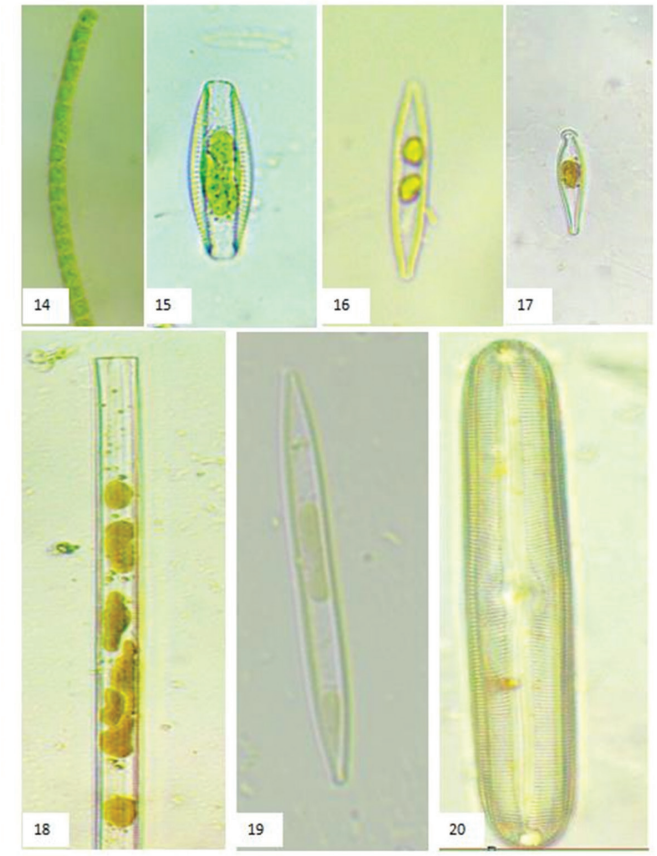

Figure 4: 14. *Klebsormidium flaccidum*, 15. *Amphora* sp., 16. *Nitzschia* sp., 17. *Gomphonema sphaerophorum*, 18. *Ulnaria* sp., 19. *Ulnaria ulna*, and 20. *Pinnularia viridis*

15. *Nitzschia* sp. (Figure 4: 16)
Foged (1980): P. 656, Pl. 13, Figs. 5–6.
Valves long, narrowly linear with almost parallel margins and oblique; cuneata constricted, sub-capitates poles.

16. *Gomphonema sphaerophorum* Ehrenberg (Figure 4: 17)
Rai (1970): P.11, Figure 9.
Valves broad; capitate head pole and slightly capitate foot pole; axial area linear, narrow, and widening into a small circular central area with an isolated pore on the primary side of the central nodule; raphe straight with distinct central nodules; striae punctate and slightly radiate, wider at the centre of the valve; valves 44 µm long and 9 µm broad.

17. *Ulnaria* sp. (Figure 4: 18)
Tiffany & Britton (1952): P. 236, Pl. 63, Figure 722.
Valves solitary, conspicuously linear with nearly parallel edges and cuneate ends; broadly linear in girdle view; pseudo-raphe narrowly linear; central area usually not evident.

18. *Ulnaria ulna* (Nitzsch) Compere (Figure 4: 19)
Rai *et al*. (2012): P. 6, Figure 11.
Valves solitary, linear to linear lanceolate, gradually attenuated towards the rostrate or broadly rounded ends; central area quadrangular having small lineate striae on both margins; striae coarse, lineate, transverse and parallel; valves 55–235 µm long and 5–9 µm broad.

Klebsormidiophyceae

13. *Klebsormidium flaccidum* (Kützing)
Silva *et al*. (1972): Figure 4: 14; Mikhailyuk *et al*. (2015): P. 757, Figure 2 (a–c).
Filaments long, cells cylindrical; Hpieces present rarely; chloroplast covers 1/2–2/3 of the cell inner surface; with smooth margins; pyrenoid large, surrounded by several layers of starch grains; cells 8-12 µm long and 6-10 µm broad.

Bacillariophyceae

14. *Amphora* sp. (Figure 4: 15)
Park & Koh (2012): P. 105, Figure 2.

Frustules elongate-elliptic with truncated apices; valves lunane with acute apices, ventral margin slightly inflated in the middle; Raphe moderately curved, somewhat distant from the ventral margin; central raphe endings slightly inflated; axial area distinct on the dorsal side, semi-lanceolate; valves 32–49 µm long, 15 µm broad.

19. *Pinnularia viridis* (Nitzsch) Ehrenberg (Figure 4: 20)
Rai *et al*. (2012): P. 8, Figure 16; Rai & Khadka (2017): P.12, Figs. 60–62.
Valves, solitary, linear to elliptic-linear, almost parallel or slightly convex sides and broadly rounded ends; Axial area less than ¼ of cell diameter, narrow near the poles, widened centrally; Central area round or elliptical; Raphe thick, undulate with a one-sided central pore; Transverse striae coarse, lineate, 6–9 in 10 µm, slightly radial medianly and convergent polarly, crossed by a wide longitudinal band; valves 44–125 µm long and 8–25 µm broad.

Discussion

Analysis of these data revealed that a total of 19 freshwater algae, 6 species belonging to Bacillariophyta were recorded from the Godawari Area. Most of the Chlorophyta species were found in the Lama Kunda including highly blooming species of *Hydrodictyon reticulatum*, *Spirogyra* sp. indicating the eutrophic status of the water body (Bhakta *et al*., 2011). Blooming of *Hydrodictyon reticulatum*, *Spirogyra* sp. in the Lama Kunda might be due to sewage runoff or might be due to the internal origin of nutrients coming from the sediments leading to the increase in the nutrient pool.

Comparative occurrence of algal forms in the water bodies of Godawari Area (Hickel 1973; Joshi 1977, 1979; Prasad & Prasad, 2001) showed that no species were common to the present findings. The physical destabilization of the sample collection sites may have been the reason for the change in the species composition over time (Ozer *et al*., 2019). Habitat specificity of the occurrence of algae was also observed, for example, there were *Hydrodictyon reticulatum* and *Spirogyra* sp. blooming at the Lama Kunda, but not in the NBG.

Conclusion

The algal diversity of Godawari consists of five major classes with 19 species, viz, i) Bacillariophyceae (6 species), ii) Chlorophyceae (4 species), iii) Zygnematophyceae (4 species), iv) Cyanophyceae (4 species), and v) Klebsormidiophyceae (1 species). The occurrence of the species in terms of trophic status indicated that the water bodies in the Lama Kunda were more eutrophic than those in the NBG. Thus to use the water bodies in the Lama Kunda, the pond needs to be changed from eutrophic to oligotrophic.

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