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COLLECTION AND TAXONOMIC STUDIES OF THE BLUEGREEN ALGAE AND NATURAL POLLUTION

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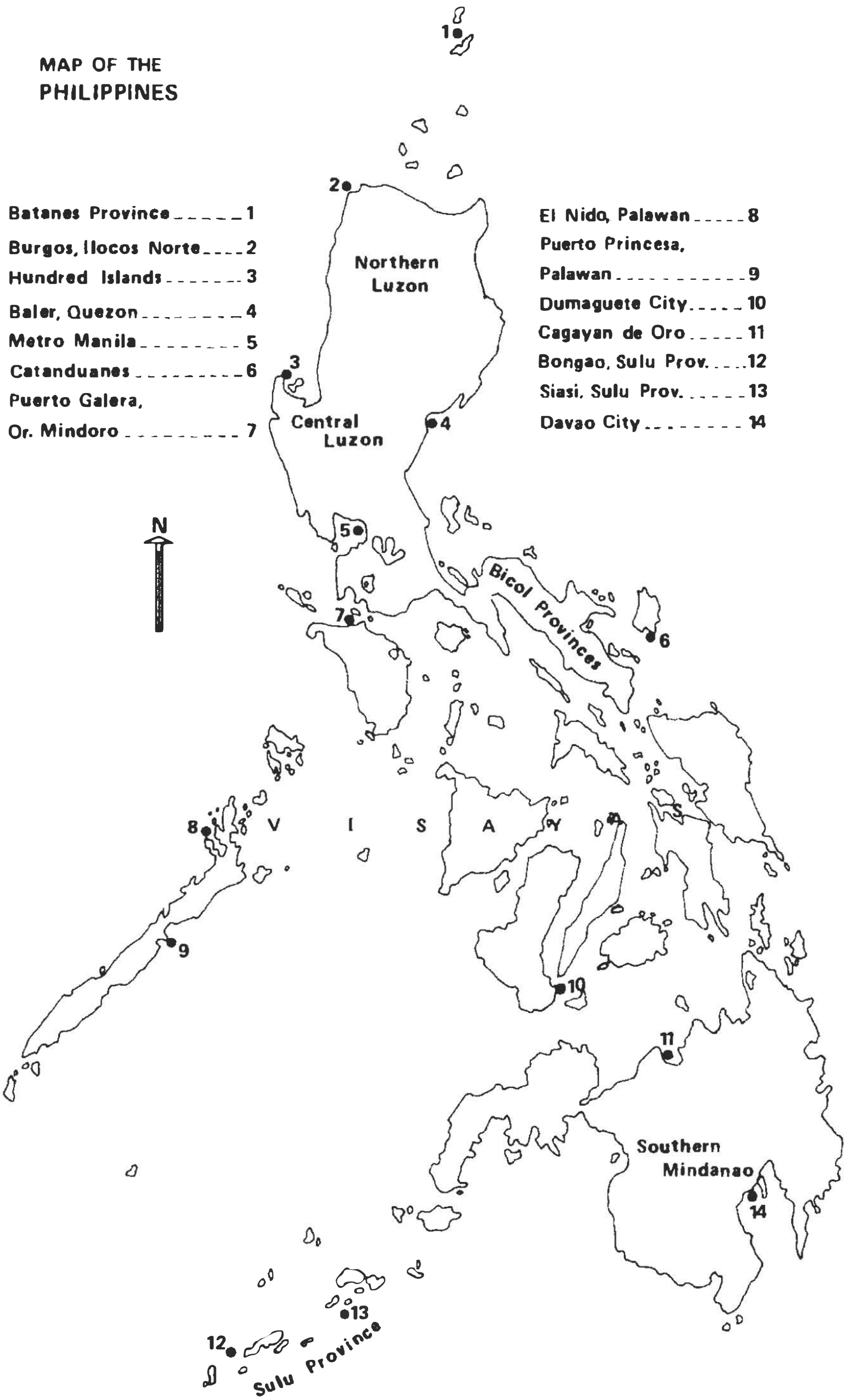
Introduction

I pursued as much as possible in about 30 years the various habitats of the bluegreen algae in the Philippines. In 1962, there was published in the Philippine Journal of Science Vol. 91, No. 3, a monographic treatment of these algae which gives a complete record of 162 species and 3 forms. The ecology of the distribution of the algae was supplemented by a close observation and record of habitats where the materials were collected. See map on page 54.

Research Procedure and Observation

The Philippines as a tropical country has generally uniform climate with the annual average temperature of 24° to 31°C except in some isolated places like the Mountain Provinces in Northern Luzon and Mt. Apo in Southern Mindanao. Both are characterized with much higher elevation and consequently exhibiting very much lower temperature. As a whole the country has many inland waters of various sizes in the form of lakes, rivers, ponds, canals and stagnant pools. There are also many low areas oftentimes occupied by squatters while others are waste lands with generally sunken rolling topography. The former are usually moist if not submerged in shallow water almost throughout the year including several premises around many open markets where small private business shops were established permanently. The areas constitute very fertile collecting grounds for the bluegreen algae. It is a perennial sight of natural pollution in very much less developed parts of the Philippines. Undoubtedly this is equally true in other developing countries of the Southeast Asia including the Pacific regions.

On the other hand, in many fishponds generally stocked with milkfish, *Chanos chanos* and tilapia, *Tilapia mosambica* are developed frequently water-blooms of *Microcystis aeruginosa, Oscillatoria tenuis, O. chalybea, O. princeps,* and *Phormidium tenue* during the warm summer months. *Lyngbya aestuarii* oftentimes with some Oscillatoria species grow extensively and develop blanket algae in some fishponds of rice paddies and inland estuaries. Fourteen species generally produce toxicity during the warm summer months (Table page 3). In some rice



Map shows the fourteen stations (solid circles) where collection and study of the benthic marine algae were made. One collection was done in every visit.

paddies are also usually developed abundant growth of *Tolypothrix tenuis* which form algal bloom during some hot weather. Where *Spirogyra* and other green algae such as *Cladophora* and *Rhizoclonium* species grow abundantly, the young rice plants generally become affected with the fast growing green algal filaments. As a result, unusually the rice plants undergo slower growth due to the green algae. Several obiquitous bluegreen algae now start to grow which add to the algal pollution.

In Laguna de Bay, *M. aeruginosa* is an annual waterbloom which usually develop during the late summer months. Oftentimes the bloom is immediately followed with the death of milkfish and other less resistant organisms present in several food chains. The death of the fish sometimes gives a national problem: the bloom which causes adverse effects to the growth of several aquatic organisms add to the sources of natural pollution. This causes inevitably the death of thousands of milkfish due to the complicated nature of pollution accompanied by the slow process of asphyxiation of usually the less resistant organisms. Accordingly, similar phenomenon happens also in other ponds in the country which unfortunately have not been regularly reported.

Records of canals and stagnant pools generally promote growth of *Spirulina subsalsa*, *S. major*, *Oscillatoria tenuis*, *O. chalybea* and *O. princeps*. The majority of collecting grounds visited during the dry season give the prevalence of higher summer temperature from the second half of February to June. Rain is generally least observed during these months. The temperature, however remains almost constant during the rest of the year covered by the rainy season from July to part of September. Repeated observations show that the twenty species reported in this paper are mostly species of natural pollution (See Table). Most of them belong to the family Oscillatoriaceae. There are many other bluegreen algae which are also studied but did not have their habitats classified with those of the polluting species. They may be mentioned as *Aphanothece stagnina*, *Phormidium papyraceum*, *Symploca muscorum* and *Fisherella ambigua*.

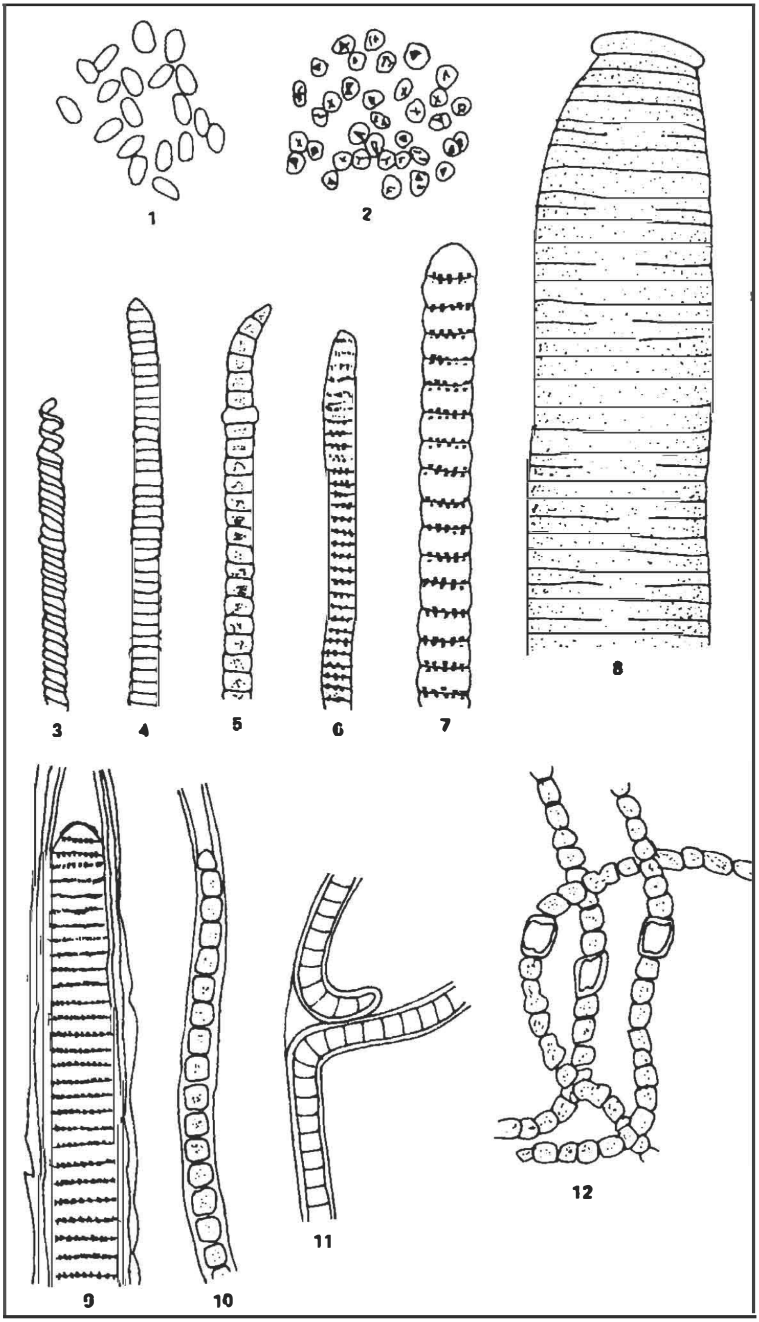
The species of the genera *Oscillatoria* and *Spirulina* have apparently very thin sheaths which could obstruct or slow down infrequently the flow of the cell nourishments and wastes of metabolism. The easy passage of raw materials needed in food synthesis and the release of wastes due to cell activities are in the maximum. As a result, the cells in the filaments in immensely increased proportion multiply faster than those of the other organisms in the same habitat.

In the phenomenon especially of excess population of many bluegreen algae, there is inevitably the accompaniment of excess toxicity. The reserved food of the algae being proteinaceous, when they die produce a toxicity which generally inhibits the growth if not kill other organisms in the immediate vicinity. This is one source of excessive pollution commonly happening in many canals including the indefinitely stagnant waters and other places mentioned elsewhere. The atmosphere gives an obnoxious odor which is a nuisance to the immediate vicinities. On the other hand, the great majority of species with generally prominent sheaths fail to

Table. Representative species of the collection to show the nature of the habitat from where many bluegreen specimens are generally available

Species	*Permanent Water*		*Usually Wet*		*Usually Dry*	*Remark*
	Much Pollution	*Less Pollution*	*Mostly Wet*	*Moist or Dry* –		
1. *Microcystis aeruginosa*	xx					*Spirulina subsalsa*,
2. *Spirulina subsalsa*	xx					*S. major*, *Oscillatoria*
3. *Spirulina major*	xx		x			*prolifica*, *O. tenuis*, *O prin-*
4. *Oscillatoria prolifica*	xx					*ceps* and *O. chalybea* were
5. *Oscillatoria tenuis* ,	xx	x	x			collected dominant in perma-
6. *Oscillatoria princeps*	xx	x	x			nent canals with much pollu-
7. *Oscillatoria chalybea*	xx	x				tion. They do not have
8. *Phormidium inundatum*		x	xx			conspicuous sheaths. *Lyngbya*
9. *Phormidium retzii*		x	x			*martensiana* is an exception.
10. *Symploca muscorum*			xx			Usually dry habitat did
11. *Lyngbya major*		xx	xx			not yield much specimens
12. *Lyngbya martensiana*	xx					except some Scytonema species.
13. *Porphyrosiphon fuscus*				x		
14. *Microcoleus vaginatus*		x	xx			
15. *Nostoc communutun*		x	x			
16. *Desmonema wrangelii*			x			
17. *Tolypothrix tenuis*		xx				
18. *Scytonema hoffmannii*				xx	x	
19. *Scytonema guyanense*				xx	x	
20. *Calothrix braunii*				x		

Note: Species 1 to 14 are major sources of pollution, the rest of the species up to 20 do not contribute much.



One plate: 1. *Coccochloris stagnina*, 2. *Microcystis aeruginosa*, 3. *Spirulina subsalsa*, 4. *Phormidium autumnale*, 5. *Oscillatoria brevis*, 6. *O.*, *granulata*, 7. *O. tenuis*, 8. *O. princeps*, 9. *Lyngbya aestuarii*, 10. *Symploca muscorum*, 11. *Scytonema guyanense*, and 12. *Nostoc muscorum*. All x 810 except *S. guyanense* x 355.

grow as fast and therefore the increase in pollution is very much less during the year.

There are additional characteristics in the bluegreen algae which may be differrently developed aside the presence of very thin sheaths, which should influence easily the permeability of some structure of the cell wall together with the membrane. Others are subsequently inherent in the growth and development of the species. Unfortunately, they are not within the scope of investigation and therefore should need another study and discussion.

Additional bluegreen algae of wide distribution and where they grow in abundance should be studied further. A biochemist must be available to study the relative potency of toxicity which these algae produce in many habitats. He should be able to suggest controlled measures after consultation with the researcher. When the necessary data is completed, one very practical way to eradicate, if not control the growth of the bluegreen algae, is to introduce currents which accelerate the aeriation of the locality concerned. What presently appear to be clear like several standing waters can be colonized later by the fast growth of ubiquitous bluegreen algae (see plate again with first 12 figures).

KEY TO FAMILIES

1. Unicellular to colonial forms . . . . Chroococcaceae
1. Always filamentous forms 2
    2. Cells of trichomes uniform, heterocysts absent . Oscillatoriaceae
    2. Cells of trichomes not uniform, heterocysts present 3
3. Trichomes generally narrower within the sheath . . . . Nostocaceae
3. Trichomes generally much wider within the thicker gelatinous sheath . . . . Scytonemataceae

Family CHROOCOCCACEAE

1. Cells less in diameter, contents finely granular . . . . . *Aphanothece stagnina*
1. Cells larger in diameter, contents coarser with psuedovacuoles . . . . *Microcystis aeruginosa*

Family OSCILLATORIACEAE

1. Trichomes filamentous and spiral 2
1. Trichomes also filamentous but not spiral 3
    2. Spirals of trichomes apparently attached to each other . . . . *Spirulina subsalsa*
    2. Spirals of trichomes far apart . . . . *S. major*
3. Trichomes aggregated in a common gelatinous sheath 4

3. Trichomes free from the gelatinous sheath 5
   4. Apical cell of individual trichome capitate . . . . *Microcoleus vaginatus*
   4. Apical cell of individual trichome rotund not capitate . . . . *M. paludosus*
5. Sheaths of trichomes hardly visible 6
5. Sheaths of trichomes conspicuous, thick and striated . . . . *Lyngbya aestuarii*
   6. Trichomes up to 10u in width 7
   6. Trichomes more than 10u in width 8
7. End of trichomes rounded . . . . *Oscillatoria amphibia*
7. End of trichomes sharply tapering . . . . *O. animalis*
   8. Width of trichomes much wider up to 60u . . . . *O. priceps*
   8. Width of trichomes much narrower 9
9. Cells of trichomes not constricted at joints towards apex 10
9. Cells of trichomes constricted at joints and bent towards apex . . . . *O. chalybea*
   10. End cell shaped like proboscis . . . . *O. proboscidea*
   10. End cell rotund . . . . *O. limosa*

Family NOSTOCACEAE

1. Thallus irregularly expanded, filaments free, regularly or spirally coiled . . . . *Anabaena spiroides*
1. Thallus irregularly expanded, filamen'ts entangled, not regularly and spirally coiled 2
   2. Trichomes narrow, 3-5u wide . . . . *Nostoc muscorum*
   2. Trichomes narrow, 4.5-6u wide . . . . *N. communi*

Family SCYTONEMATACEAE

1. Filaments floating usually colonial, cushion-shaped, sheaths very conspicuous . . . . *Tolypotrix tenuis*
1. Filaments growing mostly in moist rocks and soil, sheaths conspicuous and not striated, false branching present . . . . *Scytonema guyanense*

Remarks: The manuscript attempts to enumerate as much as possible the blue-green algae which were observed to be the sources of major pollution so far studied in the Philippines. Collections were made in Luzon and partly in the Visayas and Mindanao areas.

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Joventino D. Soriano, Discussant

The lifelong and painstaking work of Dr. Gregorio T. Velasquez on the blue-greens will stand out as an example of a basic research with great significance for a long time. As his former masteral thesis student some thirty years back, I have always admired his undying enthusiasm and interest in his studies. I do not know of any word in any language that would best describe his love for his work and, except his wife, Dr. Carmen C. Velasquez, who is likewise a fiercely research-oriented professor, I have yet to see another Filipino scientist who has been gifted with the strong determination and persistence to work, with or without honorarium, on his research project everyday be it on weekdays, week-ends or holidays. Dr. Velasquez has indeed shown us how to do research well and may his life serve as an example to our young and promising scientists that indeed the proverbial pot of gold literally awaits at the end of the rainbow for those who will take the so-called rocky and rugged path of dedicated research. The government is supporting financially the national scientists of our country through an adequate monthly pension when they are already too old to earn a living. This is our nation's way of showing its appreciation and gratitude to these scientists for work well done far beyond the call of duty. It is not too late for anybody in the academic or technical professions to begin *today* a new life – a quite fruitful life fully dedicated to productive research the Velasquezés way.

To evoke further interest in the blue-green algae and to enable us understand some of the biological processes in the cell, it has been known for a long time that the cells of Myxophyceae are structurally different from those of green algae and other higher plants. A review of recent electron microscopic studies appear to support this view.

With regard to the cell wall and cell sheath, the cells are attached to each other by a wall often forming a bead-like trichome. Each cell is surrounded by a mucilaginous sheath with many short fibrils. These fibrils extend from the outer wall outward through the mucilaginous sheath. The sheath surrounding an akinete or heterocyst appears to be a compact fibrous material. This may explain the resistance of these reproductive bodies to conditions of dessication and pollution commonly observed in population centers.

Concerning cytoplasmic particles, the lamellae which probably correspond to the photosynthetic apparatus of higher plant cells divide the cytoplasm into several layers of varying widths. The lamellae appear to be concentrated at the peripheral region of the cell probably for maximum light reception.

Dense granular bodies measuring about 300-350 Å in diameter are distributed all over the cytoplasm. Small ribosome-like particles are densely distributed toward the central region of the cell. Another kind of particles which measures about .4-.8 micro in diameter show a dense matrix made up of particles as "dense structured granule" and are thought to be mitochondria-like bodies in the blue-green algal cell.

One or more vacuoles of varying sizes have been observed throughout the cell. They lack of definite membrane.

Regarding the nucleoplasm, a network of fine fibrils has been commonly observed more or less toward the center of the cell. The nucleoplasm lacks of membrane and assumes an irregular form. It gives a positive reaction to the Fuelgen test and is thought by many workers to be an "incipient nucleus."

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Macrina T. Zafaralla, Discussant

It is indeed very timely that no less than Dr. Velasquez, father of Philippine phycology, chose to focus the subject of his paper on the most important group of freshwater algae in the Philippines today.

The Cyanophyta is the most important because presently, the biggest bulk of research money ever put into a particular algal group is being funneled into blue-green algal studies. These studies include nitrogen fixation by free-living bluegreens, N_2-fixation by the Anabaena-Azolla symbiosis and lately, single-cell protein production from *Spirulina*. Count among these the funds that are now being siphoned to ecological studies involving the aquatic environment where the blue-greens, cosmopolitan and perennial as they are, always capture the attention of those who search for biological indicators of water quality.

Dr. Velasquez, the grand old man of Philippine phycology, is the incontestable Filipino botanist of world-wide renown in as far as blue-green algal taxonomy is concerned. He pioneered the field of science which he represents in this country, therefore, to hear him stress the importance of systematic studies is a salute to the few of us phycologists who devote the most productive part of their lives to this painstaking scientific endeavor.

The importance of taxonomy cannot be overemphasized. The strides achieved in phycology are founded on the strength of floristic investigations.

Dr. Velasquez made references on the population down to the cellular level of organization. Algal associations with certain environmental conditions and situations were cited by him like the algal blooms or water blooms particularly those of *Microcystis* in Laguna de Bay which are frequently followed by the now-famous fish kill phenomenon. Population studies involving phytoplankton like *Microcystis* are vital in the determination of the carrying capacity of a body of water. At the cellular level, the professor made mention of the cellular characteristics of species which necessitate the formation of control measures so that these organisms would not pose aesthetic problems in the environment. Another facet of research identified was that on algal toxins.

In addition to what the professor has underscored in his paper, and to backup his foresight, I would like to add that today, there stands the challenge for researchers of algae and of other organisms as well, to identify where they should begin and participate in the task of environmental protection/conservation and food production.

The professor made mention of algal species of natural pollution. Algal indicators of environmental change need further refinement for these to be of greater reliability and applicability. We look forward to the day when the structural and functional features of algal communities can be used to predict occurences of dreaded environmental phenomena such as that of a fish kill. Algal assays to reflect the extent of environmental contamination by heavy metals, agricultural pollutants, enriching nutrients and the like are basically at the infancy of experimentation under local conditions. We need to develop algal assays that are adapted to local conditions.

There is a need for us to be able to relate with resource managers and decision makers so that what appears to be purely academic stuff does not only go beyond the shelves of our offices but also land on the decision maker's table. This end can be achieved by participation in the design and implementation of environmental impact assessment and evaluation systems for development projects.

Dr. Velasquez's paper strikes me as a valuable endorsement of the long-held view that there is more to the science of phycology than what we algologists are presently doing. The professor has stressed some of the research gaps. Every researcher on algae should perhaps join the professor in his commitment to timely directions for algal research in the Philippines today.