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Thematic Review

FAPESP and the São Paulo state freshwater algal flora: history and challenges

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Abstract: The BIOTA/FAPESP Program made the "São Paulo State algal flora" possible through a very intensive sampling program that aimed at (1) collecting as equally as possible from lentic, semi-lentic, and lotic environments, (2) performing the most uniform possible coverage of the state's territory, and (3) fostering the collection of periphytic and surface sediments materials that had been extremely neglected till then. The study of all this material made it clear that the biodiversity of the Zygnematophyceae increased by 100%, the Euglenophyceae by 34%, and the Chlorophyceae by 97%, the last being only due to the study of the Chlorococcales. The Bacillariophyceae are in the final phase of their floristic survey, but it is already possible to see an increase in biodiversity of over 700%. Byproducts from the BIOTA/FAPESP algae are a key for the taxonomic identification of freshwater algal genera occurring in Brazil in its third edition, and the production of the most complete algal flora ever carried out in Brazil, that of the Ipiranga River Sources State Park that already totals 919 taxa.
Keywords: *biodiversity; floristic survey; taxonomy.*

A FAPESP e a flórula de algas de águas continentais do Estado de São Paulo: história e desafios

Resumo: O Programa BIOTA/FAPESP possibilitou a organização da "Flora ficológica do Estado de São Paulo" com o desenvolvimento de um programa intensivo de coleta que visou (1) amostrar de forma equivalente os ambientes lêntico, semilêntico e lótico, (2) realizar da forma mais uniforme possível a cobertura do território do Estado e (3) privilegiar a coleta de materiais perifítico e de sedimentos superficiais, que haviam sido extremamente negligenciados até então. O estudo de todo esse material mostrou que as Zygnematophyceae apresentaram aumento de 100% de sua biodiversidade, as Euglenophyceae de 34% e as Chlorophyceae de 97%, porcentual este, entretanto, devido à conclusão apenas do estudo das Chlorococcales. As Bacillariophyceae estão na fase de conclusão de seu levantamento florístico, mostrando que o aumento da biodiversidade deverá suplantar os 700%. Há, finalmente, produtos laterais gerados pelo Programa BIOTA/FAPESP representados pela publicação de uma chave para identificação dos gêneros de algas de águas continentais que ocorrem no Brasil, que se encontra na terceira edição; e a realização da flora ficológica mais completa já produzida em nível brasileiro, a do Parque Estadual das Fontes do Ipiranga que soma, em fase de finalização, 919 táxons.
Palavras-chave: *biodiversidade; levantamento florístico; taxonomia.*

Introduction

The historical roots of algae studies in Brazil are found at the beginning of the XIX century, when a growing interest in the knowledge of the fauna and flora from overseas developed in Europe. Consequently, many voyages were made to the New World, including Brazil, under the auspices of the most diverse financial sources.

It was in this context that, in 1815, King Maximilian Joseph I of Austria, who had arranged the marriage of his daughter, the Archduchess Maria Leopoldina to the Crown Prince of Portugal Pedro IV, and later Emperor Pedro I of Brazil, used this occasion to send along with the royal retinue a scientific commission to study South American natural history. King Dom João VI of Portugal and the royal family were in Brazil as fugitives from Napoleon. The scientists selected to constitute the commission were Carl Friedrich Philip von Martius, a botanist and anthropologist, and Johan Baptist von Spix, a zoologist, both naturalists from Munich, and Giuseppe Raddi, an Italian botanist.

Raddi returned ill to Europe in 1818, but took with him some algae that he had collected on the littoral of the city of Rio de Janeiro, which he published five years later. Raddi (1823) identified two benthic marine macroscopic species (*Fucus natans* Linnaeus and *Fucus bacciferus* Linnaeus) and two others (*Fucus flagelliformis* O.F.Müller var. *tortilis* Raddi and *Ulva undulata* Raddi) that he described as new to science.

In April 1828, Martius published the first results of his 31-month expedition, from December 8, 1817 to June 14, 1820, with Spix through the Brazilian territory (Martius 1828). Eight species of benthic macroscopic marine algae were described there. Those materials he

collected himself are *Ulva mertensii* Martius, *U. schroederi* Mertens, *Zonaria fuliginosa* Martius, *Z. variegata* (Lamouroux) C.Agardh var. *discolor* Martius, *Sphaerococcus chamissoi* C.Agardh, *S. ramulosus* Martius, *S. maximiliani* Martius, and *Sargassum stenophyllum* Martius. Indications of where these materials were collected are quite poor, but it is known that they came from the coast between the states of São Paulo and Bahia.

It was, however, in 1833 that the first algal part of Martius' seminal "Flora brasiliensis …" was published. In part 1 of volume 1 of the "Flora ...", Martius described 80 species of algae, seven of which were freshwater (Martius, Eschweiler & Nees 1833). All algal material is kept at the Munich State Herbarium ("Botanische Staatssammlung") in Germany.

This volume of the "Flora ..." is quite problematic, just because it was "octavo" size (21 × 14 cm) and the 40 subsequent ones were "folio" size (21.6 × 33 cm). This is because King Maximilian Joseph I, sponsor of the "Flora ...", did not accept "octavo-sized" publications when the great works of the time were "folio-sized". The king threatened to withhold sponsorship if the size of further publications failed to meet his criteria. Interestingly, all the libraries I have visited in Brazil and abroad keep this part 1 of volume 1 apart from the others. Also, pages 11 and 12 of this volume 1 part 1 inexplicably differ from copies of the same edition. In some copies, *Bryopsis rosae* C.Agardh, *Bryopsis plumosa* (Hudson) C.Agardh, and *Vaucheria dichotoma* (Linnaeus) Martius are on pages 11 and 12, while in others, *Nitella capitata* (Nees) C.Agardh and *Chara domingensis* Turpin *ex* Martius are on the very same pages. And, finally, there was another volume 1 of the same "Flora ..." published later in "folio" size with totally different contents from the small previously mentioned volume 1 part 1.

A characteristic of the XIX century was that most papers were written by European specialists never having been to Brazil, but had received material collected by botanists specializing in higher plants. This explains, at least in part, the relative scarcity of the algal material collected and of the geographical indication of the collecting sites. Most papers published then are lists of the species, varieties, and taxonomical formae from usually restricted localities that rarely included descriptions and illustrations of the material studied. Such material was collected mostly from the state of Rio de Janeiro. References in the herbarium tags to the collecting site of some material are too inaccurate, referring only to Brazil ("Brasilia"), eastern Brazil ("Brasilia orientalis"), etc.

For many years, and predominantly up until 1950, the knowledge of Brazilian marine and freshwater algae was due to the collaboration of foreign specialists who had never been to Brazil, but received material to study in their own countries. Only Francis Drouet, an American expert on Cyanophyceae (now Cyanobacteria), collected material himself with other samples from different algal groups, which he sent to colleagues (Gerald W. Prescott and Ruth Patrick) to study in the United States. Another typical feature of this period is the intermittent collection done, as a rule, in very restricted geographical sites in Brazil. Freshwater algae collection was restricted to Brazil's northern states of Amazonas and Pará; the northeastern states of Ceará, Paraíba, and Pernambuco; the southeastern states of São Paulo, Minas Gerais, and Rio de Janeiro; and the very southern state of Rio Grande do Sul. This phase shall be called the **Phase of Foreign Specialists**.

The first paper published in Brazil based on Brazilian material that includes the contribution of a Brazilian author is dated 1910. Dr. Max Hartmann of the Infectious Diseases Institute ("Institut für Infektionskrankheiten") from Berlin wrote it in collaboration with the Brazilian physician Dr. Carlos Chagas, from Instituto Oswaldo Cruz, in the city of Rio de Janeiro. The paper resulted from the exam of material collected from two swamps in Manguinhos, in the state of Rio de Janeiro. In that paper, the two authors studied the structure of the nucleus and the flagellar apparatus, as well as of the nuclear division of seven flagellates, five of which are presently classified as algae (two Cryptophyceae, two Chrysophyceae, and one Euglenophyceae) (Hartmann & Chagas 1910).

However, it was Dr. Aylthon Brandão Joly, a Professor at the University of São Paulo and a student of William Randolph Taylor, from the University of Michigan, in the United States of America, that effectively started the study of algae in Brazil, and therefore known as the **Father of Brazilian Phycology**. In 1957, Joly started a completely new phase of Phycology in Brazil (**Phase of Brazilian Specialists**) with the publication of his "Contribution to the knowledge of the algal flora of the Santos Bay and surroundings" ("Contribuição ao conhecimento da flora ficológica da Baía de Santos e arredores") (Joly 1957). The paper describes and illustrates 100 species of macroscopic marine benthic algae and represents the first-ever planned floristic survey of algae from a well-circumscribed area. Starting in 1960, Joly initiated the training of well-qualified algal specialists in our country at the Department of Botany of the University of São Paulo. He created a veritable school by acting as the scientific advisor for the capacitation of the first generation of Brazilian phycologists. This school also includes students from Chile and Mexico.

Algal Diversity in the State of São Paulo

1. Information until 1998

Algal knowledge in the state of São Paulo is very scattered among a number of publications divided into taxonomic and ecological. The taxonomic publications are mostly floristic surveys of relatively restricted areas, based on spot collections from a few water bodies in the municipality of São Paulo and the city of Pirassununga and neighboring regions, including Leme, Laranja Azeda, Campinas, Descalvado, and Rio Claro. A significant part of this material was collected by Dr. Johan Albert Constantin Löfgren, also known as Alberto Löfgren, and sent for study to Dr. Carl Fredrik Otto Nordstedt in Lund, Sweden. The material was initially part of Nordstedt's private collection, and later on transferred to the Botanical Museum (LD) in Lund.

The first document on the occurrence of freshwater algae material in the state of São Paulo is in the exsiccatae collection prepared and distributed by V. Wittrock and C.F.O. Nordstedt. It is a collection of algal material gathered from marine and freshwater systems mostly around Europe, which was organized in fascicles of 50 pieces each and distributed between 1877 and 1889 by V. Wittrock and C.F.O. Nordstedt, and later between 1893 and 1903 by V. Wittrock, C.F.O. Nordstedt and G. Lagerheim. *Desmidium laticeps* Nordstedt is part of exsiccata nº 366-fascicle nº 8 of this collection. The material was collected from a running water system in the city of Pirassununga, however, without further specification of its gathering site (Wittrock & Nordstedt 1880). In the index of the plants deposited at the herbarium of the São Paulo Geographic and Geological Commission, the species is listed without,

however, including further details on the sample collection site other than "running water" (Edwall 1896).

Papers published during the 19th century include, as a rule, some very brief descriptions of all specimens identified, measurements of their diagnostic characteristics, and illustrations. Until the mid-twentieth, contributions by foreign specialists to the knowledge of the Brazilian freshwater algae predominated. During this phase, emphasis must be placed on the work of Olof Borge published in 1918, which resulted from the examination of samples sent from Brazil to C.F.O. Nordstedt. Borge (1918) is the outcome of the examination of 239 sample units collected by A. Löfgren in the city of São Paulo where he lived and its surrounding regions, and in the city of Pirassununga and neighboring regions. His paper has the largest number of references ever to desmid occurrence in the state of São Paulo. Two hundred and sixty-four desmid species are there documented. Detailed descriptions and illustrations were included only for the taxonomical novelties represented by nine species and five taxonomic varieties. In a few other cases, there are very brief descriptions, including only the diagnostic morphological characteristics. Finally, there are very few illustrations, unfortunately.

Starting in the second half of the 20th century, when Brazilian specialists took over the task of studying algae, there has been greater detail in the descriptions and the inclusion of keys to identify materials. In addition, during this phase, all material studied started to be included in national herbaria.

Ecological papers on freshwater algae used taxonomy as a tool to produce research on phytoplankton and periphyton populations and community dynamics in some water bodies in the state of São Paulo. Taxonomic identification varied considerably in these papers, including some in which the identification was limited to the genus level and others whose identification went up to species, variety, and/or taxonomic forma. Papers in which algae were identified solely to genus were prevalent until the 1980s. In several ecology papers, the names of algae identified are restricted to simple lists. Descriptions and/or illustrations of the respective materials were rarely included. Finally, the vast majority of samples used for the ecological papers were discarded soon after the publication of the paper, so there are no longer any preserved biological samples from these publications. In rare cases, the samples are deposited in official herbaria or are part of the document collections of ecology laboratories. The publications of Brazilian specialists started in 1962. The papers of Bicudo & Bicudo (1962, 1965) are contributions to the knowledge the Desmidiaceae of the São Paulo State Park (today the Ipiranga River Sources State Park). All material identified is described in detail and illustrated in these papers.

From the study of 50 sample units collected from several localities in the state of São Paulo and of a few from Minas Gerais, Bicudo (1969) identified 95 species, 66 varieties that are not typical of their respective species, and also 16 taxonomic formae not typical, but of their respective varieties, totaling 177 desmid taxa. Twenty of such taxa were described for the first time and proposed as new to science. Bicudo (1969) added descriptions and illustrations for all 177 taxa. The later paper also includes artificial keys for the identification of all species, varieties, and taxonomic formae included.

Several Master of Science theses and Doctoral dissertations referred to the occurrence of freshwater algal material in the state of São Paulo. There are 19 publications, 13 of which are based on material from three locally called lakes, but which are in fact reservoirs in the Parque Estadual das Fontes do Ipiranga area, namely: Garças, Ninfeias, and IAG lakes. Most these publications (Ramírez 1996, Nascimento-Moura 1997, Lopes 1999, Vercellino 2001, Crossetti 2002, 2006, Barcelos 2003, Ferragut 2004, Fonseca 2005, Biesemeyer 2005, Fermino 2006) only refer to the algae in their lists of the material identified during the respective studies. There are other publications under the very same circumstances, which were prepared using material from the Guarapiranga Reservoir (Beyruth 1996), Jurumirim Reservoir (Nogueira 1996, Ferreira 2005), Barra Bonita Reservoir (Calijuri 1999), and 30 fish ponds located in the city of São Paulo Metropolitan Region (Gentil 2007). Lopes (1999) was published (Lopes *et al*. 2005) and its contents is the very same as that of Maria Rosélia Marques Lopes' dissertation; and Crossetti (2002) was divided into two publications (Crossetti & Bicudo 2005a, 2005b) that included the full contents of her Master of Science thesis.

There are other thesis and dissertations that included brief descriptions (mainly measurements) and/or illustrations of the identified specimens, thus allowing re-identification of all material included. In this regard, Marinho (1994) included brief descriptions and measurements for *Euastrum bipartitum* Willi Krieger var. *bipartitum*, *E. brasiliense* O.Borge var. *convergens* Willi Krieger, *E. cuspidatum* Wolle var. *goyazense* (Kurt Förster & Eckert) Kurt Förster, *E. denticulatum* (Kirchner) F.Gay var. *denticulatum*, *E. luetkemuelleri* F.Ducellier var. *luetkemuelleri*, *E. sibiricum* Boldt var. *sibiricum* f. *sibiricum*, *E. sublobatum* Brébisson *ex* Ralfs, *E. turneri* W.West var. *turneri* f. *turneri*, *Micrasterias arcuata* Bailey var. *arcuata*, and *M. decemdentata* (Nägeli) W.Archer gathered from the Jacaré Pond. The results of Marcelo Manzi Marinho's thesis were published three years later (Marinho & Sophia 1997). Calijuri (1999: fig. 64) illustrated a not fully mature form of *Micrasterias radiosa* Ralfs (today *Micrasterias sol* (Ehrenberg) Kützing).

In the second half of the 20th century and mainly during the years 1970-1990, knowledge of the Brazilian freshwater algal flora experienced a significant breakthrough due to the dedication of specialists such as Ana Alice Jarreta de Castro, Andréa de Araújo, Dayse Vasques Martins, Ermelinda Maria De Lamonica Freire, Ieti Ungaretti, Ivania Batista de Oliveira, Laine Sormus de Castro Pinto, Luís Nélio Cavalcanti Rodrigues, Maria da Graça Loureiro Sophia, Maria Teresa de Paiva Azevedo, Sílvia Maria Mathes Faustino, and Susana Petersen Schetty, among others. The majority of such professionals are today, however, retired and far from the business of science, whereas some have devoted themselves entirely to teaching (Luís Nélio Cavalcanti Rodrigues).

Information After 1998

There is no comprehensive list of the freshwater algae ever cited for the state of São Paulo, but incomplete ones, *i.e*., lists without synonyms and including erroneous citations. Such lists include a total of 1,551 taxa known up to 1998, which are distributed in their taxonomical classes as follows (Table 1).

A glance at the table above shows that some of the totals are even very distorted due to the absence of specialists in the algal groups. The Charophyceae numbers look, however, very real due to the existence of specialists devoted to the group. The numbers for Cryptophyceae, Cyanophyceae (Cyanobacteria), Euglenophyceae, Rhodophyceae, and

Table 1. Taxonomic classes and numbers of taxa known up to 1998.

Taxonomic group (class)	Number of taxa
Cyanophyceae (Cyanobacteria)	388
Chlorophyceae	108
Zygnematophyceae	639
Charophyceae	31
Oedogoniophyceae	49
Euglenophyceae	110
Dinophyceae	8
Bacillariophyceae	61
Chrysophyceae	9
Xanthophyceae	62
Cryptophyceae	43
Prasinophyceae	21
Raphidophyceae	8
Rhodophyceae	14
TOTAL	**1551**

Zygnematophyceae are also much more accurate. On the other hand, due to the absence of specialists in some other groups, the numbers for the Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, and Xanthophyceae are quite underestimated. It is also important to consider that Charophyceae, Cryptophyceae, and freshwater Rhodophyceae are relatively small algal classes in terms of the number of species and infraspecific categories (taxonomical richness) and, certainly, this is one cause for them being more and better studied. Because their siliceous exoskeleton is the base for their taxonomy of genera and infrageneric categories, Bacillariophyceae and Chrysophyceae did not even have their floristic inventories started at the time due to the lack of specialists and laboratories equipped with electron scanning and transmission microscopes. Finally, the lack of a well-established collection program for freshwater algae in the state of São Paulo led to much more collection in semi-lentic systems (reservoirs and weirs) than in lotic systems (rivers and creeks), and also a non-uniform coverage of the state's geographical area. All of this together makes evident the erroneousness of most taxa numbers recorded until 1998. Whereas such numbers are somewhat reasonable for some groups, they are totally erroneous for others.

The creation of the BIOTA/FAPESP Program in 1998 unveiled a new panorama for the floristic survey of freshwater algae of the state of São Paulo with an intensification of the sample-collecting program of these algae. Two years of the very intensive gathering of material attempted to fill in the gaps previously mentioned. First, a collection program was organized to allow the greatest possible coverage of the São Paulo State's physical area. Furthermore, the project also aimed at sampling, in proportions as equivalent as possible, the lentic, semi-lentic, and lotic environments, and paid much more attention to the previously neglected lotic systems. In addition, much more attention was given to the collection of periphytic material and to that living on the surface sediments of water bodies since such environments include species very seldom or never found in the plankton.

The next step was to thoroughly study the material and publish the results. It was determined which volumes would be published,

Table 2. Taxonomic groups (classes) to be studied and possible order of publication.

Taxonomic group (class)
Cyanophyceae (Cyanobacteria) vol. 1
Chlorophyceae '*sensu amplo*' vol. 2
Ulvophyceae vol. 3
Charophyceae vol. 4
Zygnematophyceae vol. 5
Oedogoniophyceae vol. 6
Chrysophyceae vol. 7
Haptophyceae vol. 8
Xanthophyceae vol. 9
Eustigmatophyceae vol. 10
Bacillariophyceae vol. 11
Euglenophyceae vol. 12
Cryptophyceae vol. 13
Raphidophyceae vol. 14
Rhodophyceae vol. 15
Phaeophyceae vol. 16

Table 3. Order in which monographs were published.

Taxonomic group (class)	Year of publication
Charophyceae vol. 5	2004
Cryptophyceae vol. 11	2007
Ulvophyceae vol. 3	2009
Zygnematophyceae vol. 4(1)	2014
Zygnematophyceae vol. 4(2)	2015
Zygnematophyceae vol. 4(5)	2016
Phaeophyceae vol. 14	2016
Zygnematophyceae vol. 4(4)	2018
Euglenophyceae vol. 6	2018
Zygnematophyceae vol. 4(3)	2019
Chlorophyceae vol. 2(1)	2022
Chlorophyceae vol. 2(2)	2022

but the order of publication did not follow this scheme, but that in which the results became available. Table 2 shows the original order established, and Table 3 the order in which they were actually published.

At this point, the inevitable question is: has there been an increase in the knowledge of the algal biodiversity in the State of São Paulo?

The answer is yes and Table 4 shows an increase of nearly 100% in the biodiversity for the Zygnematophyceae, an algal group whose study is already concluded for the state. There was also an approximately 97% increase in Chlorophyceae considering, however, that only one taxonomic order, the Chlorococcales, has been studied up to now. Chlorophyceae 'sensu stricto', freshwater Ulvophyceae, Klebsormidiophyceae, and Ulotrichophyceae, the

Table 4. Number of taxa per taxonomic group before and after 1998.

Taxonomic group (class)	Number of taxa	
	Before 1998	Actual
Cyanophyceae (Cyanobacteria)	388	388
Chlorophyceae	108	213 (*)
Zygnematophyceae	639	1155
Charophyceae	31	31
Oedogoniophyceae	49	49
Euglenophyceae	110	147
Dinophyceae	8	8
Bacillariophyceae	61	445 (*)
Chrysophyceae	9	9
Xanthophyceae	62	62
Cryptophyceae	43	43
Prasinophyceae	21	21
Raphidophyceae	8	8
Rhodophyceae	14	14
TOTAL	**1551**	**2593**

(*) Provisional number since volumes are not yet finalized.

latter three classes derived from the Chlorophyceae 'sensu amplo', are in their final phase of being studied and it is already possible to identify a substantial increase in their biodiversity. A 34% increase in biodiversity was detected for Euglenophyceae. Biodiversity doubled for Zygnematophyceaen due to the intensive and more organized collecting program adopted, including the collection of periphytic material, because the Zygnematophyceae prefer this kind of habitat in nature. The increase in the number of Euglenophyceae taxa was due to the gathering of material from the surface sediments of the water bodies, which allowed the collection of non-pigmented heterotrophic specimens that inhabit this kind of environment, since they do not need light to synthesize their energy and the nutrients they need are much more abundant in this compartment of the systems. The study of the Chlorophyceae 'sensu amplo' has barely started, so their 97% increase in biodiversity is false as it is due to the study of the Chlorococcales, and it is believed that this number shall increase considerably when the inventory of all other orders is complete. As was already mentioned, the number of Cyanophyceae (Cyanobacteria), Charophyceae, and Cryptophyceae taxa remained stable after 1998 because their taxonomic inventories were already complete before the start of the BIOTA/FAPESP Program. The Bacillariophyceae are being studied intensively in the state of São Paulo, and the results of these investigations have been presently presented in Master of Science theses and Doctoral dissertations that were never published or published in just small parts. Preparation for the volume of this algal class will begin in 2023. However, it is already possible to speculate that its increase in biodiversity will exceed 700%. Studies of Dinophyceae, Chrysophyceae, Xanthophyceae, Prasinophyceae, and Raphidophyceae have not yet begun, which explains why the taxa numbers before the start of the BIOTA/FAPESP Program and the current numbers are identical in Table 4.

Algal Collections

Algal material is part of the collections of basically two herbaria in the state: the Herbário Científico do Estado "Maria Eneyda P. Kauffmann Fidalgo" (SP) before of the then Instituto de Botânica (today the Instituto de Pesquisas Ambientais) of the Environment, Infrastructure and Logistics State Department of São Paulo and the Botany Department (SPF) of the Instituto de Biociências of the Universidade de São Paulo.

Concerning freshwater algae, the largest collection is part of the Herbário Científico do Estado "Maria Eneyda P. Kauffmann Fidalgo" (SP), and presently includes about 791 exsiccatae of Charophyceae and a little more than 5,000 vials of material preserved in a 4-5% formalin water solution. There is another collection whose specialty is freshwater macroalgae deposited in the Botany Department (SJRP) of the Instituto de Biociências of the Universidade Estadual Paulista, São José do Rio Preto campus. Finally, the collection of approximately 4,000 sample units in the Ecology and Evolution Biology Department of the Universidade Federal de São Carlos in São Carlos must be mentioned. The samples were collected for ecological studies and have been studied very little from a taxonomic perspective. This same Department keeps the only living collection (near 200 sample units) of freshwater algae in the state of São Paulo in the form of cultivates in liquid media.

The algae collection of the Instituto de Pesquisas Ambientais herbarium is under the care of the Biodiversity Conservation Center and includes about 26,000 exsiccatae mainly of marine forms, but also includes some Charophyceae, all of which are very well taken care of and kept in special cabinets in a suitable environment. The level of computerization, done with Excel, is about 92% of the total number of exsiccatae. While the algae collection of the Department of Botany at the University of São Paulo is marine only and includes about 18,000 exsiccatae, with its level of computerization, using Lotus software, at about 75%. The algae collection at the São José do Rio Preto campus of the Universidade Estadual Paulista is independent of the institutional herbarium, and is well cared for, however, the Department of Ecology and Biology of Evolution of the Federal University of São Carlos has not yet started computerization.

The Instituto de Pesquisas Ambientais has the only permanent slide collection of diatoms (Bacillariophyceae) prepared with material from the state of São Paulo. The study of these algae requires very special preparation of slides, that may be permanent if stored under proper temperature and humidity conditions, and the collection of the Herbário Científico do Estado "Maria Eneyda P. Kauffmann Fidalgo" already totals approximately 11,000 permanent slides, including several nomenclatural types.

Byproducts

The BIOTA/FAPESP Program produced two main byproducts during the development of the project "Algal flora of the State of São Paulo" (Process FAPESP nº 1998/04955-3). The first one was derived directly from the survey of specialized literature carried out to start the BIOTA/FAPESP project, and from the intensive material gathering after 1998. Publication of the book "Gêneros de algas de águas continentais do Brasil: chave para identificação e descrições" (Bicudo & Menezes 2005, 2006, 2017) replaced the "Algas de águas continentais brasileiras: chave ilustrada para identificação de gêneros" (Bicudo & Bicudo 1970). The replacement was needed because Bicudo & Bicudo (1970) did not

Table 5. Number of taxa published by groups (classes) of PEFI freshwater algae.

Taxonomic group (class)	Number of taxa
Cyanophyceae (Cyanobacteria)	86
Chlorophyceae "sensu amplo" (*)	173
Zygnemaphyceae	167
Oedogoniophyceae	15
Charophyceae	5
Euglenophyceae	99
Dinophyceae	32
Bacillariophyceae (*)	165
Chrysophyceae	51
Prasinophyceae	21
Craspedomonadophyceae	23
Xanthophyceae	47
Eustigmatophyceae	5
Cryptophyceae	21
Raphidophyceae	8
Rhodophyceae	2
TOTAL	**919**

(*) Group whose study is not yet complete.

include complete descriptions of the genera, and was quite outdated due to the 35-year lapse between the first and the second identification keys. After three revised and updated editions, the present key includes 591 genera, is the only one of its kind available in Brazil, and is also used in several South American countries. In Brazil, it is a veritable '*vade mecum*' for every laboratory working on biological control of water quality, as well as for all universities with freshwater algae taxonomy in their undergraduate and, especially, graduate courses.

The other BIOTA/FAPESP byproduct is the "Flora Ficológica do Parque Estadual das Fontes do Ipiranga" in São Paulo. The material was collected for a little over 40 years in the PEFI, "Parque Estadual das Fontes do Ipiranga" area including the monthly collections over the last 20 years at one of its systems, the Garças Lake, and resulted in the most complete flora ever published in our country. It includes plankton, periphyton, and surface sediments of the park's water bodies, and presently puts together 919 taxa (Table 5). Never in the world had such an algal flora been published. The publications started in 1991 in sporadic "Hoehnea" fascicles, the journal of the former Instituto de Botânica, now the Instituto de Pesquisas Ambientais of the Environment, Infrastructure and Logistics State Department. About 98% of the flora has already been published, and it is hoped to be concluded towards the end of next year when the idea is to publish everything together in a book.

Finally, it is important to mention the most extensive continuous series of physical, chemical, and biological information obtained on a Brazilian freshwater environment, the Garças Lake in the PEFI. There were 20 years of uninterrupted monthly sampling that constitute the lake data bank. Such a series of samplings allowed us to know the lake's physical and chemical behavior, and the plankton community's biological behavior, with all this information, together being used for the proposal of a recovery plan for the lake (today very polluted) and, more than that, being of great assistance to temperate climate systems that are presently gaining tropical features due to the global warming.

Future Perspectives

The completion of the study of the freshwater algal flora for the state of São Paulo is necessary. Knowledge of this flora is fundamental to conducting research in various biological science projects that use taxonomy as a cornerstone (morphology, physiology, ecology, omega taxonomy, cytology, genetics, evolution, etc., to mention a few). None of these scientific branches of biology can even begin their studies if there is no proper taxonomy. The freshwater algal flora will also be fundamental to all laboratories dealing with the ecological control of drinking water and water pollution. Knowledge of the algal flora of pristine and polluted environments will help conservation people decide the degree of recovery needed for different systems to be preserved. Finally, the BIOTA/FAPESP freshwater algae project will be able to inform specialists in applied science about which species may have some potential use as biofuel, food, and in pharmaceuticals.

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Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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