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Father Zimmermann (1871–1950): the first Brazilian diatomist

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This paper describes the scientific life of Father Zimmermann, Brazil's first diatomist. Father Zimmermann, a Jesuit priest born in Ehingen, Germany in 1871, studied theology in Britain in the early 20th century. His scientific life began in Portugal where, with other Jesuits, he founded the scientific journal *Brotéria*, for which he wrote several papers on diatoms. After the fall of the Portuguese monarchy in 1910, several conservative priests, including Zimmermann, immigrated to Brazil. In Brazil, he became a teacher at the Padre Antonio Vieira School in Salvador in the state of Bahia, where he taught a myriad of disciplines. In addition to his teaching and religious activities, along with his fellow priests, Zimmermann continued to edit *Brotéria*. By the end of his career in Portugal, Zimmermann had described a total of 69 new but not all valid diatom names. In 1913, Zimmermann began a series of articles entitled 'Contribuição para o estudo das diatomáceas dos Estados Unidos do Brasil' (Contribution to the study of diatoms of the United States of Brazil), in which he described two new genera and 49 new species from rivers, lakes, wetlands, reservoirs and beaches in the states of Bahia, Minas Gerais, Rio de Janeiro, São Paulo and Rio Grande do Sul. In addition to his taxonomic descriptions, Zimmermann who was an accomplished naturalist, also wrote about diatom movements and evolution. His diatom studies were compiled in a book entitled *Diatoméés*, which has never been published. Father Zimmermann's contribution to the study of diatoms deserves proper recognition. This paper aims to serve such purpose. Farther Zimmermann died in Salvador in 1950.

Keywords: *Father Zimmermann, diatomist, marine and freshwaters waters, Brazil*

Introduction

Biographical details

The priest, teacher, naturalist and researcher Karl Zimmermann (28 March 1871–21 October 1950) was born in Ehingen in the Kingdom of Württemberg (currently the state of Baden-Württemberg, Germany) and died in Salvador, Brazil (Fig. 1). He divided his life between his religion, his teaching as a professor of Latin, music, German, physics, chemistry, history, geography, design and geometry at the San Fiel College, Louriçal do Campo and San José do Porto in Portugal, and his work as a diatom researcher. Farther Zimmermann entered the Society of Jesus by way of the Province Ignatian of Lyon on 7 September 1890, obtained his ordination on 2 February 1908 and, soon after, joined the monastery of Barros da Torre where he was responsible for coordinating the music and where he earned a degree in humanities. He began teaching in 1895. While working as a teacher between 1896 and 1899, he studied philosophy. He went on to study theology, dividing his time between England and Ireland, and completing his humanities education in 1905 (Franco 2003).

News of Zimmermann's death was given in three obituaries, published in two journals of the city of Salvador, capital of Bahia state: two in *A Tarde* (23 October 1950 and 25 October 1950) and one in *Diário de Notícias* (7 November 1950), the latter being written by one of his students. By 1920, the priest had asked for his secularization, so that he could cease to be a Jesuit and become a diocesan priest. No obituary was published in *Brotéria*. This work is, therefore, an attempt to shed light on a few of the various aspects of his life, in particular, his scientific work.

Although of German origin, he used the name Carlos Zimmermann (a translation into Portuguese of his Christian name) in articles published in *Brotéria*, probably because he spent most of his life in Portuguese-speaking countries. It is of interest to note that his name appears in several databases, such as the California Academy of Science (CAS) Catalogue of Diatom Names and Algaebase, in different forms: Zimmermann, S.J.C.; Zimmerman, C.; Zimmermann, C.; C. Zimmermann, C. Zimmermann, S.J.; or S.J.C. Zimmermann. The spelling 'Zimmerman' is, certainly a simple orthographic error for Zimmermann.

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Fig. 1. Father Karl Zimmermann (1871–1950). Photo courtesy of Father Geraldo Antonio Almeida S.J., Salvador, Bahia.

The ‘S.J.’ is a reference to the Society of Jesus, as Zimmermann was a Jesuit priest, abbreviated as S.J., SJ, SI or s.i., (the latter two abbreviations reflecting the Latin name of the order). Thus it is correct to refer to Zimmermann as: Karl [Carl, Carlos] Zimmerman (1871–1950) [S.J. (Society of Jesus, Societas Iesu, S.J., SJ, s.i.)]. The International Plant Names Index (IPNI, <http://www.ipni.org/ipni/authorsearchpage.do>) offers the abbreviation ‘C. Zimm.’. It would seem appropriate that, in future, current databases standardize the spelling of the name and use of the accepted abbreviation for his work.

Early work

Zimmermann’s scientific publishing began with a series of four articles entitled ‘Microscopia vegetal’ (Zimmermann 1902, 1903, 1904, 1906b). In this series, which was dedicated to encouraging high school teachers to use microscopes in their classes, Zimmermann commented on the use of the microscope in Portuguese schools, especially public high schools. He also emphasized the importance of using a microscope as a teaching resource, linking theory with practice. Zimmermann’s interest in teaching and research is evident from these papers. He discusses the parts of the microscope, the various accessories available and their use: camera lucida, Abbe drawing apparatus, clipboards, various microtomes, with comments on their advantages and disadvantages. He then relates in great detail all the relevant methods of making slides for microscopic observations, including fixation, dehydration, infiltration, inclusion, gluing and the colouring of plant material. He outlines some rules and good practice for teachers when making microscopic observations: they should be made in a laboratory, which is the best place for the microscope; the kinds of objectives, lighting, etc. He concludes with

drawings obtained from his slides: pollen, a leaf of *Pinus*, *Micrasterias*, *Closterium* and *Zea mays*.

In addition to publishing his diatom studies, Zimmermann wrote a paper on the observatory at San Fiel College (Zimmermann 1902b); an article about ‘Epidascopio’, the database of the time (Zimmermann 1903b); an article on the anatomy of an insect gall produced by a given plant (Zimmermann 1906a); a contribution to the Cecidi-ans of Kent (Zimmermann 1907); a paper describing the relationship of the Jesuits and astronomy (Zimmermann 1906b); and reviews of scientific books (Zimmermann 1909a, 1912).

The diatoms of Portugal and Madeira

Between 1906 and 1910, Zimmermann began a series of papers on the study of diatoms (Zimmermann 1906c, 1909a, b, 1910b). These were a compilation of diatoms identified in Portugal by other researchers, but included new discoveries made by Zimmermann. In his first diatom article, Zimmermann sought collaboration in the collection of samples from different regions of Portugal:

Como não me é possível percorrer todas as regiões de Portugal, peço obsequiosamente a coadjuvação de todos os que se interessam por este genero de estudos. Pequeno é o incommodo. Basta recolher as algas ou limos que se encontram nos regatos, charcos, poços, rios e praias do mar, ás quaes andam associadas as Diatomaceas; deixam-se seccar para mais facilmente se poderem remetter pelo correio, e pôde assegurar-se que qualquer insignificante colheita conterá grande abundancia d’estes seres admiraveis. De boa vontade enviarei aos colleccionadores uma preparacao de todas as especies encontradas na colheita, se assim se desejar. (Zimmermann 1906c: 245).

As I cannot go to all the regions of Portugal, I humbly request the assistance of all who are interested in such studies. It should be little trouble. Simply collect the algae or slime found in streams, ponds, wells, rivers and beaches of the sea, where diatoms are associated; let them dry out so that they can be easily sent by mail, and it is certain that any minor collection will contain a great abundance of these wonderful beings. (Our translation).

In these papers, Zimmermann presented 27 diatom families, 73 genera and 400 species, 340 of which were first species records in Portugal. Significantly, before Zimmermann's work, only 60 species were known in Portugal. Zimmermann also studied the diatoms of Madeira, where he recorded 211 different species (Zimmermann 1909c, 1911). Zimmermann's final contribution while living in Portugal was an article aimed at a lay audience, which explained where to find, how to prepare and how to mount diatoms permanently onto slides (Zimmermann 1910a). By the end of his studies in Portugal and its territories, Zimmermann had described 19 new diatom species (Appendix).

The diatoms of Brazil

On 5 October 1910, the Republic of Portugal replaced the monarchy, which led to the departure of several conservative priests from Portugal to Brazil. In 1911, Zimmermann, with others priests, founded and became a teacher at Padre Antonio Vieira School, a traditional, private religious high school that still exists today, where he taught history, trigonometry and languages, among other disciplines. In addition to his teaching and religious activities, he continued to edit *Brotéria* with his fellow priests and added a subtitle, the *Portuguese–Brazilian Journal*, which transformed *Brotéria* into one of the first Brazilian scientific journals.

In 1913, Zimmermann started a series of articles entitled 'Contribuição para o estudo das diatomáceas dos Estados Unidos do Brasil' (Contribution to the study of diatoms of the United States of Brazil) (Zimmermann 1913, 1915b, c, d, 1916a, b, 1917b, 1918a, c, d), in which he eventually described 49 new species (some of them described in Zimmermann 1917a, 1918b, 1919b).

As in Portugal, Zimmermann continued his studies by compiling data from diatomists who had worked with samples taken from Brazil. Many descriptions of diatom species did not include a sample location or collector's name, so Zimmermann took care to produce as complete a bibliography as possible (Zimmermann 1913). In his first sentence, Zimmermann wrote:

Não me consta que jamais diatomo­logo algum se occupasse *ex professo* do estudo das diatomáceas do vasto território do Brazil. (Zimmermann 1913: 149).

To the best of my knowledge no other naturalist has taken care of the study of diatoms in the vast territory of Brazil. (Our translation).

Zimmermann proposed bringing together the scattered diatom floristic treatments from the countless publications describing diatoms found in Brazil. At that time, there was documentation for 15 families, 35 genera and 93 species (Zimmermann 1913). While in Brazil, Zimmermann also continued publishing papers about his time in Portugal (Zimmermann 1914a, b).

During seven years of Brazilian diatom studies, Zimmermann analysed samples from the states of Bahia, Minas Gerais, Rio de Janeiro, São Paulo and Rio Grande do Sul. The samples were collected by Zimmermann and nine collaborators from rivers, lakes, wetlands, reservoirs and the sea (Todos os Santos Bay, Santos and Guarujá).

Zimmermann published two further compilations in *Annaes do 5º Congresso Brasileiro de Geographia* (5th Brazilian Congress of Geography) in Salvador. In the first, Zimmermann recorded diatoms from Todos os Santos Bay, where he collected three plankton samples and identified 35 species belonging to 23 genera and 14 families (Zimmermann 1916c). In the second, Zimmermann described diatoms found in Dique do Tororó, a reservoir constructed by the Dutch in 1624 to protect the city against pirates (Zimmermann 1916d). In Dique do Tororó, Zimmermann found 26 diatom species, one of which was planktonic (*Cyclotella meneghiniana* Kützing), with the others found on the water hyacinth, *Eichhornia crassipes* (Martius) Solms-Laubach.

Beyond taxonomy

Almost all of Zimmermann's studies were devoted to taxonomy, presenting identifications (with and without descriptions of species and illustrations) and information on the collecting sites. However, he did introduce the reader to some aspects of the ecology of diatoms (Zimmermann 1916c). In the introduction to 'Florula diatomologica do plankton superficial da bahia da Cidade do Salvador' (Zimmermann 1916c), he discusses the importance of the phytoplankton community for the trophic economy of aquatic systems, and provides data on the cycling of silica, citing calculations by Otto Zacharias (but not the year) on Lake Plön. He also discussed the sedimentation process of diatom valves and the formation of deposits, citing several with the metric variations in their thickness. There are paragraphs discussing variables, in particular, the weight of diatomaceous earth and water, form resistance and viscosity of the medium, which interfere with the sedimentation process, explaining that, because bodies are denser than water they can remain suspended in the liquid medium. Finally, Zimmermann discusses the shifting opinions concerning evolution. This is discussed in more detail below.

Zimmermann also studied the movements of diatoms (Zimmermann 1916d). He observed *Navicula lanceolata* (C. Agardh) Kützing trying to pass under a sand grain. The diatom repeated the movements of advancing and retreating six times, always along the main axis, until it passed

under the grain on its seventh attempt. Zimmermann used this evidence to reject the hypothesis, held at the time, that diatoms moved by the detachment of gas bubbles through the tiny pores of the inner protoplasm. Almost 100 years after Zimmermann's observation, there are two hypotheses about the displacement of diatoms. The first postulates that the release of mucus is responsible for the adhesion and displacement of the cell (Wetherbee *et al.* 1998); the second postulates that microfibrils are responsible for movement (Drum & Hopkins 1966, Edgar & Pickett-Heaps 1983). A third hypothesis, proposed by Bertrand (2008), attempts to reconcile both: propulsion by microfibrils and the release of mucus.

Evolution

Zimmermann used diatoms to discuss and demonstrate his position on the theory of evolution (Zimmermann 1916c). It is clear when reading the introduction to his article published in *Annaes do 5º Congresso Brasileiro de Geographia* that he changed his position on the theory of evolution during his life.

In Zimmermann (1916c), the last 12 paragraphs of the Introduction are dedicated to presenting his position on evolution. In one of the paragraphs he wrote:

Confesso, que em tempos fui um entusiastico defensor da theoria da evoluçao, e ainda lhe não lhe sou adverso. A adaptação quer activa, quer passiva, quer funcional, sem duvida existe e tem exercido um papel preponderante, quer na ontogenese, quer na philogenese dos seres organicos. Que ella porém por si só possa explicar esta multiplicidade de seres que povoam o nosso globo, estou hoje longe de admitir. Fui levado a esta maneira de pensar pelos meus estudos especiaes sobre as diatomáceas. (Zimmermann 1916: 451).

I confess, that in time I was an enthusiastic advocate of the theory of evolution, and still am not adverse to it. Adaptations, active, passive or functional, no doubt exist and have played a major role either in the ontogeny or phylogeny of organic beings. But this alone cannot explain the multiplicity of beings that inhabit our globe. I am far from admitting this today. I was led to this way of thinking by my special studies on diatoms. (Our translation).

Zimmermann continues, presenting his disagreement with current evolutionary theory and stating an erroneous view of homogeneity of the aquatic environment, known today as the 'paradox of plankton' (Hutchinson 1961).

Como, pois, explicar a immensa variedade de formas só por meio da adaptação, considerando sobretudo que o influxo do meio é sempre o mesmo ou incomparavelmente menos multiplo do que em terra firme, e que as diatomaceas offerecem naturalmente maior resistencia em virtude da sua carapaça siliciosa e inerte? (Zimmermann 1916: 452).

How, then, can one explain the huge variety of shapes only through adaptation, especially considering that the influence of the medium (water) is always the same or incomparably less variable than on land, and that diatoms naturally offer

greater resistance to change because of their siliceous and inert valves? (Our translation).

The main argument Zimmermann uses to confront evolutionary theory is the belief that the fossil record of diatoms is continuous:

Bem sei que ás difficuldades contra o evolucionismo tiradas da paleontologia se responde com o missing link. Muito bem; porém este élo não devia faltar nas diatomaceas. (Zimmermann 1916: 452).

I know that difficulties against evolution drawn from palaeontology are countered by the idea of missing links. Very well, but this link should not be lacking in diatoms. (Our translation).

Zimmermann believed in the indestructibility of the valves; he continued:

Não podemos invocar, como já disse, o *missing link*. A carapaça das diatomaceas formada por silica pura é, por assim dizer indestructível. Resiste ao calor mais intenso e á acção de quasi todos os ácidos mesmo os mais energicos. Não podemos, portanto, admitir que uma immensidade de formas intermediarias, desapparecesse pelo influxo de não sei que agentes externos. Estas formas intermediarias, repito, deviam existir, considerando a sua indestructibilidade relativa. (Zimmermann 1916: 452).

We cannot rely, as I have said, on missing links. The valves of diatoms are composed of pure silica, which is indestructible. Resisting the most intense heat and the action of almost all acids, even the most severe. We cannot therefore admit that a multitude of intermediate forms disappeared by the influx of processes unknown. These intermediate forms, I repeat, should be present, considering their relative indestructibility. (Our translation).

The data used by Zimmermann to discuss this comes in part from secondary information, since he worked exclusively with recent species. He continued to discuss the issue of the fossil record, expressing an understanding that is now considered incorrect. The oldest fossil record date for diatoms is ca. 190 million years ago (Julius & Theriot 2010), while the oldest fossil record of life is ca. 4.5 billion years ago.

Conhecemos jazidas de diatomaceas de quasi todas as regiões do mundo desde a epoca em que pela primeira vez se manifestou a vida sobre o nosso globo. E que vemos? (Zimmermann 1916: 452).

We know diatomaceous deposits from almost all regions of the world since the time life first manifested itself on our globe. And what do we see? (Our translation).

Zimmermann argued about the continuity of change expected in the fossil record of diatoms:

Grande numero de especies são em tudo perfeitamente identicas ás especies que hoje povoam os nossos rios, lagos e mares. Até encontramos especies mais perfeitas, e são exactamente estas que no decorrer dos tempos desappareceram. Como explicar este facto incontestável pela evolução lenta e continua sob o influxo da adaptação?

Mais. Se esta evolução tivesse existido, havíamos de encontrar as diatomáceas fósseis em estado de confusão tal que uma classificação e identificação de espécies se tornasse completamente impossível em virtude da transição quasi insensível de uma forma á outra que a adaptação havia de produzir. Porém, estamos longe disto.

Podemos até afirmar que as diferentes espécies fósseis se diferenciam mais pronunciadamente umas das outras do que hoje sucede com varias espécies. (Zimmermann 1916: 452).

A large numbers of species are all perfectly identical to species now inhabiting our rivers, lakes and seas. We can find more perfect species, and these are exactly like those of the past.

How can this undeniable fact be explained by the slow and continuous evolution under the influence of adaptation?

In addition, if this trend had existed, we would find fossil diatoms in such a state of confusion that classification and identification of species would become completely impossible because of the almost imperceptible transition from one form to another produced via adaptation. But that is far from the truth.

We can even say that the different fossil species differ more sharply from one another than they do from various species today. (Our translation).

It seems, therefore, that Zimmermann did have a conflict between his religious beliefs and the knowledge he derived from science. However, in his closing discussion of evolution he clearly stated that it was not his religious ideas that made him change his position:

Não julgue alguém que me tornei menos favorável á theoria da evolução em virtude do caracter sagrado de sacerdote catholico que reveste a minha individualidade. Sei muito bem, como naturalista e como theologo que a theoria *scientifica* da evolução não está de modo algum em opposição com os ensinamentos certos da Igreja catholica. Razões de caracter puramente scientifico e de modo algum theologico operaram esta mudança. (Zimmermann 1916: 452–453).

Do not judge someone who has become less favourable to the theory of evolution because he is a Catholic priest. I know very well, as a naturalist and as a theologian, that the scientific theory of evolution does not in any way conflict with certain teachings of the Catholic Church. Reasons of a purely scientific and theological view operated to affect this *change*. (Our emphasis and translation).

While it may seem unusual by today's standards to accept that a priest could believe and express confidence in the theory of evolution in public, the truth that species change over geological time has been accepted by most with little doubt. The debate as it stands today is concerned with the mechanisms that attempt to explain the changes. According to Bowler (1985), evolutionary theories fall into five categories: (1) Darwinian natural selection, (2) Lamarckism, (3) orthogenesis, (4) the theory of mutation, and (5) theistic evolution. Some intense religious beliefs held by scientists suggest that change is not random, but could

be directed to a predetermined destination through the will of God (Bowler 1985). Thus, Zimmermann, was part of the current thought of the time.

Discussion

It is not known whether Zimmermann was trained in the identification of diatoms, but we believe that he was self-taught. In his 'Microscopia Vegetal' papers (Zimmermann 1902), he describes the procedure for making observations using a microscope, and it is clear from his writing that there was no authority or mentor involved. Zimmermann was one of seven Jesuit priests that founded the Sociedade Portuguesa de Ciências Naturais (Portuguese Society of Natural Sciences) and he was a member of the Royal Society of Microscopy of London (Romeiras & Leitão 2012).

By 1919, Zimmermann had compiled the papers he had published in *Brotéria* to form a book which he entitled *Diatoméas* (the original cover image is shown in Fig. 2); it was never published. In this work, Zimmermann included all the species of diatom that had been reported in *Brotéria* and he also included additional species. In the prologue, Zimmermann described where an interested reader might find diatoms and how they are collected from plankton and benthic specimens in freshwater or marine environments, as communities or individuals. He also described how diatoms can be cleaned of organic material and how to prepare permanent slides. He wrote about the biology and morphology of diatom frustules, and advised researchers to keep a diary of their observations in the laboratory and in the field; he discussed the instruments needed to study diatoms, microscope manufacturers and the shops where photographic equipment could be bought. The second part of the book was devoted to diatom taxonomy, including keys to the identification of family, genus and species; he included descriptions, photographs and/or drawings of the species.

No references for species identification were provided in Zimmermann's articles; however, we believe that some books – which he indicated were indispensable bibliographies for species identification – should form part of the references: Kützing (1844), Ehrenberg (1854), Smith (1853, 1856), Rabenhorst (1864), Donkin (1870), Brun (1880), Van Heurck (1880), De Toni (1891), Héribaud (1893), Peragallo (1891), Peragallo & Peragallo (1897–1908) and Schmidt et al. (1874–1959), among others.

While still in Portugal, Zimmermann was responsible for the creation of the herbarium at San Fiel College. He was director of the herbarium from 1897 to 1904 and from 1907 to 1910, when the priests were expatriated and the herbarium was transferred to the University of Coimbra (Lado & Pando 1989, Tavares 1924). According to Tavares (1924), at this time, the herbarium held 5000 samples of fungi, lichens, mosses, phanerogams and diatoms (3000 diatoms species are included in the collections bought from Tempère and Peragallo). The pitfalls of curating the diatom collection



Fig. 2. Cover image of the original manuscript for Zimmermann's *Diatomées* (1919).

(and other hazards, such as his persecution by a sniper when he was fleeing Portugal) were recorded by Zimmermann in 1914. The herbarium collection contained several samples from Portugal and its overseas territories. Of the collections, microscopes and library that formed his laboratory, only his collections and some manuscripts were restored to Zimmermann, thanks to a friend unnamed. The new provisional government of the Republic restored only one publication to Zimmermann (1914). Henriques (1922), responsible for the transfer of the collections, does not mention the diatom collection, and therefore, its fate is unknown. Unfortunately, we were not able to locate, in Brazil, any slides used by Zimmermann in his studies. However, Almeida includes an original photograph of a diatom that Zimmermann identified (de Almeida 2002: nv42, p. 181), and we have found 21 original photographs of Zimmermann's diatoms.

The series of studies on diatoms from Brazil was concluded in 1919. It is interesting to note that this date coincides with Zimmermann's trip, together with the Portuguese priest Luiz Vieira, to the city of Barreiras, located 905 km from Salvador, Bahia; Luiz Vieira was appointed vicar of the city of Barreiras (Anonymous 2009). Apparently, these years were dedicated to helping Father Vieira complete the Church Matriz de São João Batista, which began in 1892 and was completed in 1925 (Anonymous 2009), in addition to teaching. Anonymous (2009) reports teaching by a Father Carlos Zimmerman (*sic*, surely a typo) in the school – cited as a private school for the study of languages (journal '*Cidade de Barreiras*' for the year 1924; Anonymous 2009), and there are reports that Father Carlos Zimmerman (Anonymous 2009) took over as director and professor at the federal vocational establishment '*Aprendizado Agrícola*', at the time (1920s) the most important

school in the town of Barreiras. The school was closed after nine years, for political reasons (Anonymous 2009).

In addition to the training of students and his contribution to science, Zimmermann founded a meteorological observatory in the college of San Fiel, which sent bulletins twice daily by telegraph to the central station in Lisbon, Portugal (Zimmermann 1914).

Having evaluated his work, we recognize Zimmermann as a polyglot and polymath and pay tribute to him as one of the first diatomists, and perhaps the first phycologist, from Brazil, who dedicated part of his life to unveiling the microscopic world of algae, especially diatoms. Although his importance in the diatom field is indisputable, some of his writings remain unpublished. A deeper analysis of his many works will provide many new insights into the thoughts of this brilliant naturalist.

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Appendix

Bibliography and taxa described by C. Zimmermann

We have found 37 publications by Zimmermann. All but two appear in the journal *Brotéria*. In 1902, together with Father Cândido Mendes and Father Joaquim da Silva Tavares, Zimmermann founded *Brotéria*, which was devoted to the dissemination of research in the fields of botany and zoology, as well as popularizing science. The journal was named as a tribute to Félix d'Avelar Brotero (1744–1829), an eminent Portuguese botanist (Castel-Branco 2004). The journal began with the title *Broteria*. *Revista de Ciencias Naturaes do Collegio de San Fiel*. In 1907, it was split into three parts: *Broteria*, *Revista de Ciencias Naturaes do Collegio de San Fiel*, *Serie de Vulgarização Científica*,

dedicated to popularising science; and *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel*, *Série Botanica* and *Série Zoologica*, dedicated to the disciplines of botany and zoology, respectively. From 1912, the title became simply *Broteria. Revista Luso-Brazileira*. From 1925, the popular science series was called *Brotéria: Fé-Ciências-Letras*. After 1932, its title was *Brotéria: revista contemporânea de cultura*; from 1965, it was *Brotéria: revista de cultura*; from 1970 *Brotéria: cultura e informação*; from 1999, it reverted to *Brotéria: revista de cultura*; finally, in 2002, becoming *Brotéria: cristianismo e cultura*, which is its title today. The botany and zoology series remained separate from 1907 to 1932, when they united as *Brotéria: ciências naturais*, changing its name to *Brotéria: genética*, now a journal dedicated to studies of genetics.

Zimmermann's articles in *Brotéria* have two pagination systems. Each separate article is given a conventional page number that corresponds to its place in the journal. In addition, each article is given another page number placed in brackets. This second number corresponds to the page number of article sequence such that any series of papers are numbered sequentially by series as well as by journal position. Thus, if reprints are bound together they will gain a continuous page sequence. In the references below, the numbers given in brackets refer to the pagination of individual articles in a set of related papers. For example, there are five parts to the series 'Catalogo das diatomaceas portuguesas'. The second part of the 'Catalogo' has page numbers in *Brotéria* 89–97; its page number in the 'Catalogo' series is 8–16.

All articles published in *Brotéria* are available online via the Digital Library of Real Jardín Botánico de Madrid (<http://bibdigital.rjb.csic.es/ing/Volumenes.php-Libro=1527>).

A portrait of Zimmermann can be found in *Brotéria* [Segundo N° especial], 1927, fig. 1. Two species have been named after him: *Placoneis zimmermannii* Metzeltin & Lange-Bertalot (*Iconographia Diatomologica* 5: 201, pl. 89: figs 10–13, 1998) and *Cymbopleura zimmermannii* Metzeltin & Lange-Bertalot (*Iconographia Diatomologica* 18: p. 68, pl. 199, figs 16, 2007).

Zimmermann's taxon names are given below under the relevant publication. Some of his names appear in his publications without any authorities appended. It is likely that these were not intended as new names or new combinations, but referred to names already published and in use.

Because Zimmermann's specimen collections no longer exist it is not possible to examine the specimens and offer typifications. It would be possible to assign illustrations as types (ICBN Art. 37.4) but we have not done so as some of the illustrations are of ambiguous interpretation. Our list of names below has been corrected for any obvious nomenclatural errors (such as issues of priority) and, where we felt it would least cause problems, we have added new names for taxa described by Zimmermann using a preoccupied name. We have made no other taxonomic changes, but it is of note that some names (taxa) will need to be further examined with respect to both their taxonomy and their nomenclature to avoid problems in the future. For example, Zimmermann's taxon named *Navicula mutica* var. *capitata* has priority over two other taxa with the same name but his taxon is not that which is commonly understood to be *Navicula mutica* var. *capitata*.

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- ZIMMERMANN C. 1906c. Microscopia vegetal. *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel* 5: 229–242 [88–101].
- ZIMMERMANN C. 1906d. Catalogo das Diatomaceas portuguesas. I. Centuria. *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel* 5: 245–251 [1–7].
1. *Navicula mesolepta* Ehrenberg var. *thermes* (Ehrenberg) [= *Navicula mesolepta* var. *thermes* (thermes) Van Heurck 1885: 80]
- ZIMMERMANN C. 1907. Contribution à la connaissance des Cécidies du Kent. *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel Zoologia* 6: 103–108.
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- ZIMMERMANN C. 1909b. Catalogo das Diatomaceas portuguesas. II. Centuria. *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel* 8: 89–97 [8–16].
- ZIMMERMANN C. 1909c. Catalogo das Diatomaceas portuguesas. III. Centuria. *Broteria. Revista de Ciências Naturaes do Collegio de San Fiel* 8: 97–103 [17–22].
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2. *Achnanthes longipes* f. *major elongata* C. Zimmermann 1909: 118, *nom. invalid*
 3. *Achnanthes longipes* f. *minor decussata* C. Zimmermann 1909: 119, *nom. invalid*
 4. *Grammatophora serpentina* f. *minor* C. Zimmermann 1909: 124, *nom. invalid*
 5. *Aulacodiscus amoenus* var. *madeirensis* C. Zimmermann 1909: 126, pl. 9, fig. 1
- ZIMMERMANN C. 1910a. As diatomaceas: como se colhem e se preparam. *Brotéria: serie de vulgarização científica* 9: 42–51 [1–10].
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6. *Achnanthes longipes* f. *lata* C. Zimmermann 1910: 99, *nom. nud.*

7. *Gomphonema gracile* var. *lanceolatum* [possibly =*Gomphonema gracile* var. *lanceolata* (*lanceolatum*) (Kützing) Cleve 1894: 183]
8. *Cystopleura argus* var. *capitata* C. Zimmermann 1910: 99, *nom. nud.*
9. *Eunotia arcus* var. *curta* [possibly =*Eunotia arcus* f. *curta* Brun 1901: 7]
- ZIMMERMANN C. 1911. Beitrag zur Kenntnis der Diatomaceen-Flora der Inseln Madeira und Porto Santo [II]. *Broteria. Revista de Sciencias Naturaes do Collegio de San Fiel* 9: 103–120 [15–32].
10. *Navicula acrosphaeria* [=*Navicula acrosphaeria* (Brébisson 1838: 19) Kützing 1844: 97, pl. 5, fig. 2]
11. *Navicula forcipata* var. *punctata* [=*Navicula forcipata* var. *punctata* Cleve 1895: 65]
12. *Navicula liber* var. *tenuistriata* [=*Navicula liber* var. *tenuistriata* (Cleve 1894: 54) H. & M. Peragallo 1897–1908: 72, pl. 9, fig. 7]
13. *Gomphonema constrictum* var. *curta* [=*Gomphonema constrictum* var. *curta* (Grunow in Van Heurck 1880: 123, pl. 23, fig. 8) Van Heurck 1896: 270, pl. 7, fig. 298]
14. *Gomphonema intricatum* var. *pumila* [=*Gomphonema intricatum* f. *pumila* Grunow in Van Heurck 1880: 24, fig. 35, 36]
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- ZIMMERMANN C. 1914a. Ia. Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 11: 5–12 [17–23].
- ZIMMERMANN C. 1914b. Catalogo das Diatomáceas portuguesas. Appendice. *Broteria. Revista de Sciencias Naturaes do Collegio de San Fiel: Serie Botanica* 12: 115–124 [31–40].
- ZIMMERMANN C. 1914c. Contribuição para o conhecimento das diatomáceas da Provincia de Moçambique. *Broteria. Revista Luso-Brazileira: Serie Botanica* 12: 155–162 [1–8]
15. *Scolioleura westii* var. *stauroneiformis* C. Zimmermann 1914: 156 [2]
- ZIMMERMANN C. 1915a. Algumas diatomáceas novas ou curiosas. *Broteria. Revista Luso-Brazileira: Serie Botanica* 13: 33–36 [1–4].
16. *Ceratoneis arcus* f. *typica* C. Zimmermann 1915: 36 [4], pl. 4, fig. 9
17. *Ceratoneis arcus* f. *trigibba* C. Zimmermann 1915: 36 [4], pl. 4, fig. 10
18. *Ceratoneis arcus* f. *arcuata* C. Zimmermann 1915: 36 [4], pl. 4, fig. 11
19. *Ceratoneis arcus* f. *semirecta* C. Zimmermann 1915: 36 [4], pl. 4, fig. 12
20. *Glyphodesmis varians* C. Zimmermann 1915: 33 [1]
21. *Glyphodesmis varians* var. *elegantula* C. Zimmermann 1915: 34 [2], pl. 4, fig. 3
22. *Glyphodesmis varians* var. *elongata* C. Zimmermann 1915: 33, pl. 4, fig. 4
23. *Glyphodesmis varians* var. *genuina* C. Zimmermann 1915: 33, pl. 4, fig. 1
24. *Glyphodesmis varians* var. *tumida* C. Zimmermann 1915: 33, pl. 4, fig. 2
25. *Gomphonema bipunctatum* C. Zimmermann 1915: 34 [2], pl. 4: fig. 5 non *Gomphonema bipunctatum* Krasske, *nom. illeg.*, 1943: 87 [= *Gomphonema duplipunctatum* Lange-Bertalot & Reichardt in Lange-Bertalot *et al.* 1996: 88].
26. *Eunotia fidelensis* C. Zimmermann 1915: 35 [3], pl. 4: fig. 6
27. *Eunotia pectinoides* C. Zimmermann 1915: 35 [3], pl. 4: fig. 7 non *Eunotia pectinoides* J.R. Carter 1966: 454, pl. 9, figs 4, 5, 22 [= *E. johncarterii* D.M. Williams in Williams & Reid 2002: 142]
28. *Pleurosigma retusum* C. Zimmermann 1915: 35 [3], pl. 4: fig. 6
- ZIMMERMANN C. 1915b. II Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Broteria. Revista Luso-Brazileira: Serie Botanica* 13: 37–56, est. IV–VII [5–24]
29. *Eunotia didyma* var. *parallela* C. Zimmermann 1915: 54 [22], pl. 6, fig. 14
- ZIMMERMANN C. 1915c. II. Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 13: 6571 [25–31].
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- ZIMMERMANN C. 1916a. IV Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 14: 85–103 [58–75].
- ZIMMERMANN C. 1916b. V Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 14: 130–157 [76–103].
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- ZIMMERMANN C. 1916d. Contribuição para o estudo da Flora Diatomologica do Lago chamado Dique da Bahia. *Annaes do 5º Congresso Brasileiro de Geographia*, 470–484, [figs] I–IV.
30. *Navicula bahiensis* C. Zimmermann 1916: 473, Pl. 1, fig. 2 (see below, taxon number 45)
31. *Navicula placentula* var. *tropica* C. Zimmermann 1916: 475, Pl. 2, fig. 8 (see below, taxon number 44)
32. *Navicula placentula* var. *tropica* f. *multicostata* C. Zimmermann 1916: 475, Pl. 2, fig. 9 (see below, taxon number 44)
- ZIMMERMANN C. 1917a. Algumas diatomáceas novas ou curiosas [II]. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 15: 5–7 [5–7].
33. *Achnanthes solea* C. Zimmermann 1917: 5, pl. 1, fig. 3 non *Achnanthes solea* Hustedt 1952: 389, figs 60–61 [= *Achnanthes wellsiae* Reimer in Patrick & Reimer 1966: 255, pl. 16, figs 1517; = *Astartiella wellsiae* (Reimer in Patrick & Reimer) Witkowski & Lange-Bertalot in Moser, Lange-Bertalot & Metzeltin 1998: 360; the online *Catalogue of Diatom Names* notes that the epithet should have been 'solea', possibly *nom. illegit.*]
34. *Navicula henriquesii* C. Zimmermann 1917: 6, pl. 1, fig. 4
35. *Navicula lusitanica* C. Zimmermann 1917: 5, pl. 1, figs 1, 2
36. *Navicula umbilicata* C. Zimmermann 1917: 7, pl. 1, fig. 6 = *Navicula zimmermannii* Gomes & D.M. Williams, **nom. nov.** [non *Navicula umbilicata* Ehrenberg 1856: 328, 334, fig. 30].

37. *Glyphodesmis sigmodea* C. Zimmermann 1917: 7, pl. 1, fig. 5
- ZIMMERMANN C. 1917b. VI Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Broteria. Revista Luso-Brazileira: Serie Botanica* 15: 30–45, est. I [105–119].
38. *Navicula placentula* var. *tropica* f. *multistriata* C. Zimmermann 1917: 31
- ZIMMERMANN C. 1918a. VII Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Broteria. Revista Luso-Brazileira: Serie Botanica* 16: 8–24, [figs] est. II–IV [120–136].
39. *Navicula bahiensis* C. Zimmermann 1918: 8 [120]
40. *Plagiogramma itaparicanum* C. Zimmermann 1918: 12 [124] (see below, number 71)
41. *Mastogloia delicatula* C. Zimmermann 1918: 13 [125] = *Mastogloia zimmermannii* Gomes & D.M. Williams, **nom. nov.** [non *Mastogloia delicatula* Cleve 1893: 16, pl. 1, fig. 20] (see below, number 62).
- ZIMMERMANN C. 1918b. Algumas diatomáceas novas ou curiosas. [III] *Broteria. Revista Luso-Brazileira: Serie Botanica* 16: 84–93, [figs] est. II–IV [8–17].
42. *Achnanthes ambigua* C. Zimmermann 1918: 93 [17], pl. 3, fig. 17
43. *Amphora brasiliensis* C. Zimmermann 1918: 87 [11], pl. 2, fig. 7
44. *Brasiliella helix* C. Zimmermann 1918: 91 [14], pl. 3, figs 13–16
45. *Campylodiscus guarujanus* C. Zimmermann 1918: 89 [13], pl. 2, fig. 10
46. *Cocconeis britannica* var. *tropica* C. Zimmermann 1918: 90 [14], pl. 3, fig. 8
47. *Coscinodiscus lineatus* var. *multiareolatus* C. Zimmermann 1918: 93 [17], pl. 4, fig. 3
48. *Cymbella capitata* C. Zimmermann 1918: 93 [17], pl. 4, fig. 4 = *Cymbella zimmermannii* Gomes & D.M. Williams, **nom. nov.** [non *Cymbella capitata* Pantocsek 1892, pl. 10, fig. 160, nec *Cymbella capitata* Brun 1895: pl. 14, fig. 27bis, 28, nec *Cymbella capitata* Héribaud 1903: 50, pl. 9, fig. 6].
49. *Eunotia brasiliensis* C. Zimmermann 1918: 86 [10], pl. 2, fig. 4
50. *Eunotia fragilarioides* C. Zimmermann 1918: 87 [11], pl. 4, fig. 5
51. *Eunotia jaburuensis* C. Zimmermann 1918: 86 [10], pl. 2, fig. 5
52. *Frustulia lanceolata* C. Zimmermann 1918: 87 [11], pl. 2, fig. 6 = *Frustulia zimmermannii* Gomes & D.M. Williams, **nom. nov.** [non *Frustulia lanceolata* Agardh 1827: 626, nec *Frustulia lanceolata* Berkeley 1833: 13, pl. 4, fig. 1]
53. *Halurina itaparicana* C. Zimmermann 1918: 90 [14], pl. 3, figs 4–5
54. *Hantzschia amphioxys* var. *capitata* C. Zimmermann 1918: 88 [12], pl. 2, fig. 8 = *Hantzschia amphioxys* var. *zimmermannii* Gomes & D.M. Williams, **nom. nov.** [non *Hantzschia amphioxys* var. *capitata* Pantocsek 1902: 104 (83), pl. 9, fig. 243 (= *Nitzschia amphioxys* var. *capitata* (Pantocsek) F.W. Mills 1934: 1194), nec *Hantzschia amphioxys* var. *capitata* (O. Müller) J. Frenguelli 1945: 196, pl. 12, fig. 8, nec *Hantzschia amphioxys* var. *capitata* (O. Müller) Cleve-Euler 1948: 49 (= *Hantzschia amphioxys* f. *capitata* O. Müller 1909: 34, pl. 2, fig. 26)]
55. *Hydrosera brasiliensis* C. Zimmermann 1918: 94, pl. 4, fig. 6 (there appears to be a page missing from the journal as page 94 refers to the second page of an entirely different article, which lacks a title page, even though the index to the volume gives p. 94 as the source of the protologue for *Hydrosera brasiliensis*).
56. *Mastogloia delicatula* C. Zimmermann 1918: 91 [15], pl. 3, fig. 11
57. *Navicula cancellata* var. *brasiliensis* C. Zimmermann 1918: 85 [9], pl. 3, fig. 6
58. *Navicula elliptica* var. *tropica* C. Zimmermann 1918: 85 [9], pl. 3, fig. 3 = *Diploneis elliptica* var. *tropica* (C. Zimmermann) Frenguelli 1933: 414, pl. 4, fig. 9
59. *Navicula fatigans* C. Zimmermann 1918: 85 [9], pl. 3, fig. 10
60. *Navicula formosa* var. *jaguaripensis* C. Zimmermann 1918
61. *Navicula guarujana* C. Zimmermann 1918: 84 [8], pl. 2, fig. 2
62. *Navicula sobralensis* C. Zimmermann 1918: 84 [8], pl. 2, fig. 1
63. *Navicula submissa* C. Zimmermann 1918: 85 [9], pl. 3, fig. 12
64. *Navicula torpedo* C. Zimmermann 1918: 86 [10], pl. 4, fig. 2
65. *Plagiogramma itaparicanum* C. Zimmermann 1918: 91 [15], pl. 3, fig. 9
66. *Pleurosigma brasiliense* C. Zimmermann 1918: 90 [14], pl. 3, fig. 2
67. *Pleurosigma itaparicanum* C. Zimmermann 1918: 89 [13], pl. 3, fig. 1 [= *Gyrosigma itaparicanum* (C. Zimmermann) Andrade & Teixeira 1957: 183, pl. 3, fig. 1]
68. *Rhaphoneis (Raphoneis) itaparicana* C. Zimmermann 1918: 90 [14], pl. 3, fig. 7
69. *Schizostauron brasiliense* C. Zimmermann 1918: 86 [10], pl. 2, fig. 3
70. *Stenoneis radiata* C. Zimmermann 1918: 93 [17], pl. 4, fig. 1
- ZIMMERMANN C. 1918c. VIII Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Broteria. Revista Luso-Brazileira: Serie Botanica* 16: 113–122 [138–146].
- ZIMMERMANN C. 1919b. Quelques Diatomées nouvelles ou curieuses. *Broteria. Revista Luso-Brazileira: Serie Botanica* 17: 97–100, [figs] planche 3 (5) [21–24].
71. *Achnanthes lanceolata* var. *brasiliensis* C. Zimmermann 1919: 99 [23], pl. 3 (5), fig. 8
72. *Fragilaria undata* var. *brasiliensis* C. Zimmermann 1919: 100 [24], pl. 3(5), fig. 7
73. *Navicula cardinaliculus* var. *margaritacea* C. Zimmermann 1919: 97 [21], pl. 3(5), fig. 9
74. *Navicula jequitinhonhae* C. Zimmermann 1919: 98 [22], pl. 3(5), fig. 10
75. *Navicula mutica* var. *capitata* C. Zimmermann 1919: legend to pl. 3, fig. 4 non *Navicula mutica* var. *capitata* Østrup in Héribaud 1920: 53, pl. 7, fig. 17, nec *Navicula mutica* var. *capitata* Hustedt in Schmidt 1936: pl. 405, figs 35–36, invalid, nec *Navicula mutica* var. *capitata* Hustedt 1937: 233, pl. 17, fig. 5 (= *N. mutica* var. *distinguenda* Hustedt 1939: 381 = *N. nivalis* Ehrenberg 1853: 528]
76. *Navicula mutica* var. *rhombica* C. Zimmermann 1919: 99 [23], pl. 3(5), fig. 4 [as *Navicula mutica* var. *capitata* on legend to pl. 3, fig. 4] non *Navicula mutica* var. *rhombica* Skvortzov 1938: 270, pl. 2, figs 16, 17

77. *Navicula torrendi* C. Zimmermann 1919: 98 [22], pl. 3(5), figs 12 = *Pinnularia torrendi* (C. Zimmermann) Frenguelli 1933: 399, pl. 3, fig. 16
78. *Navicula torrendi* var. *capitata* C. Zimmermann 1919: 98 [22], pl. 3 (5), fig. 3 = *Pinnularia torrendi* var. *capitata* (C. Zimmermann) Frenguelli 1933: 399, pl. 3, fig. 16
79. *Navicula torrendi* var. *capitata* f. *nana* C. Zimmermann 1919: 99 [23], pl. 3(5), fig. 5
80. *Navicula torrendi* f. *typica* C. Zimmermann 1919: 98, pl. 3(5), figs 1–2
- ZIMMERMANN C. 1919a. IX Contribuição para o estudo das diatomáceas dos Estados Unidos do Brazil. *Brotéria. Revista Luso-Brazileira: Serie Botanica* 17: 5–16 [147–158].