

## ZOOSPORIC TRUE FUNGI, HETEROTROPHIC STRAMINIPILES AND PLASMODIOPHORIDS: STATUS OF KNOWLEDGE IN SOUTH AMERICA

Mónica M. Steciow<sup>1</sup>, Aduino I. Milanez<sup>2</sup>, Carmen L. A. Pires-Zottarelli<sup>2</sup>, Agostina V. Marano<sup>1</sup>, Peter M. Letcher<sup>3</sup> & Carlos G. Vélez<sup>4</sup>

<sup>1</sup>Instituto de Botánica Spegazzini, Universidad Nacional de La Plata, calle 53 No. 477, 1900 La Plata, Buenos Aires, Argentina; agosvm@hotmail.com (author for correspondence).

<sup>2</sup>Instituto de Botânica, CP 68041, 04045-972 São Paulo, Brasil.

<sup>3</sup>Department of Biological Sciences, University of Alabama, Tuscaloosa, AL35487, USA.

<sup>4</sup>Departamento de Biodiversidad y Biología Experimental, Universidad de Buenos Aires, Ciudad Universitaria, Pabellón II, 4° piso, C1428EHA Ciudad Autónoma de Buenos Aires, Argentina.

**Abstract.** Steciow, M. M.; A. I. Milanez, C. L. A. Pires-Zottarelli, A. V. Marano, P. M. Letcher & C. G. Vélez. 2012. Zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids: status of knowledge in South America. *Darwiniana* 50(1): 25-32.

Zoosporic true fungi and fungal-like organisms include unrelated groups in the kingdoms Fungi, Straminipila and Protozoa. There is very little information on the diversity of these organisms in many ecosystems of great biodiversity, particularly tropical or neotropical areas. Research assessing their diversity has been mainly conducted in Argentina and Brazil using multiple baiting techniques, resulting in the discovery of many new taxa and new records. To date, 434 species in these groups have been recorded for both countries. Continuing research is necessary to provide a more comprehensive understanding of their diversity in South America. Few specialists are available to study such extensive areas, which are being degraded by deforestation, land/clearing, pollution and other anthropogenic activities that affect the habitat of these organisms, long before surveys can be carried out by mycologists and protistologists. Hence, attempts to gather information about the diversity of zoosporic true fungi, heterotrophic Straminipila and Plasmodiophorids from South America are urgently needed, and should receive high priority.

**Keywords.** Argentina; Brazil; heterotrophic straminipiles; plasmodiophorids; zoosporic true fungi.

**Resumen.** Steciow, M. M.; A. I. Milanez, C. L. A. Pires-Zottarelli, A. V. Marano, P. M. Letcher & C. G. Vélez. 2012. Hongos zoospóricos verdaderos, Straminipilas heterotróficos y Plasmodioforidios: estado del conocimiento en América del Sur. *Darwiniana* 50(1): 25-32.

Los hongos zoospóricos verdaderos, los straminipilas heterotróficos y los plasmodioforidios, son grupos de organismos filogenéticamente no relacionados pertenecientes a los reinos Fungi, Straminipila y Protozoa. Existe escasa información disponible acerca de estos organismos en ecosistemas de gran biodiversidad, particularmente en áreas tropicales y neotropicales. En Sudamérica, las investigaciones sobre su diversidad han sido principalmente realizadas en Argentina y en Brasil utilizando técnicas de cebado múltiple, resultando en el descubrimiento de nuevos taxones y nuevas citas. Hasta el momento, en ambos países se han registrado 434 especies pertenecientes a estos grupos, lo que demuestra que se necesitan más investigaciones para ampliar su conocimiento en Sudamérica. Existen pocos

especialistas disponibles para estudiar áreas tan extensas, las cuales están siendo degradadas por la deforestación, la contaminación, y otras actividades antrópicas que afectan el hábitat de estos organismos, antes de que su diversidad pueda ser estudiada por micólogos y protistólogos. De esta forma, los estudios tendientes a reunir información sobre la diversidad de los hongos zoospóricos verdaderos, los Straminipilas heterotróficos y los Plasmodioforidios deben ser considerados altamente prioritarios en Sudamérica.

**Palabras clave.** Argentina; Brasil; hongos zoospóricos verdaderos; Plasmodioforidios; Straminipilas heterotróficos.

## INTRODUCTION

Zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids belong to the phyla Blastocladiomycota, Chytridiomycota, Neocallimastigomycota, Hyphochytriomycota, Labyrinthulomycota, Oomycota and to the Class Phytomyxea of the kingdoms Fungi, Straminipila and Protozoa. They are found worldwide and to date approximately 1,900 species have been described (Kirk et al., 2008). All these organisms have zoospores, and thallus morphology ranges from microscopic single cells to a filamentous system.

They commonly inhabit the same ecological niches (Sparrow, 1968; Nascimento et al., 2011) and are essential components of the microbial food webs as saprobes decomposing plant and animal substrates, parasites of algae, macrophytes, crustaceans, fishes, amphibians, invertebrates and protists, and as food resources for consumers such as metazoan zooplankton (Niquil et al., 2011).

Despite their cosmopolitan distribution and their importance in ecosystems, the diversity of these groups remains under-explored, especially in tropical and subtropical areas. Milanez et al. (2007) have recently summarized the status of the knowledge of zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids from Brazil, but information from other South American countries have been scattered throughout the literature and have never been extensively reviewed.

The aim of this paper is to review the available information through extensive literature review and our own unpublished observations until 2010. We will focus particularly on records of zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids from Argentina and Brazil. The term zoosporic true fungi will be used in this manuscript to refer to members of the Phyla Blastocladiomycota and Chytridiomycota, while het-

erotrophic straminipiles will be used here to refer to the Phyla Oomycota, Hyphochytriomycota and Labyrinthulomycota and plasmodiophorids to the Class Phytomyxea. The information on phytopathogenic *Pythium* and *Phytophthora* from Argentina is summarized by Palmucci et al. (2008) and therefore the species are not mentioned in the list of taxa but considered in the overall richness.

## MATERIALS AND METHODS

The information presented in this review corresponds mostly to Argentinian and Brazilian collections but also information available for other South American countries is included. Unpublished data correspond to collections made by the authors at various collection sites from Argentina and Brazil and employing different types of substrates, according to the multiple baiting technique (Stevens, 1974; Milanez, 1989). In the case of published data, the methodology used to isolate each of the species listed is properly referred in Tables 1, 2 and 3, available as on line supplementary appendix (<http://www.ojs.darwin.edu.ar/index.php/darwiniana/article/view/482/433>).

Each list of zoosporic taxa is arranged alphabetically. Data on biogeography and hosts/ substrates are given in chronological order according to the literature referred.

## RESULTS AND DISCUSSION

To date, 434 taxa have been recorded for both countries, being 174 (14 Blastocladiomycota, 42 Chytridiomycota, two Hyphochytriomycota, three Labyrinthulomycota, 112 Oomycota and one Phytomyxea) for Argentina and 348 (18 Blastocla-

diomycota, 121 Chytridiomycota, five Hypochytridiomycota, four Labyrinthulomycota, 196 Oomycota and four Phytomyxea) for Brazil.

Only 88 taxa were shared by both countries and approximately 10 % of the total numbers were described as new species (Table 1, 2, 3). Most of the species belong to the Blastocladales, Chytridiales and Rhizophydiales among the Fungi, whereas among the Straminipila the Pythiales and Saprolegniales presented the highest number of species in both countries. One order (Lobulomycetales) in the Fungi and three in the Straminipila (Albuginales, Haptoglossales and Peronosporales) have not yet been recorded for Argentina (see Table 4). The total number of species of zoosporic fungi recorded for Brazil, especially in the case of the Chytridiales, is considerably greater as compared with the number of species recorded in Argentina (Table 4). The same difference is observed for the Pythiales.

The number of species already reported in Argentina and Brazil is equal to the 8.7 % and 17.5 % respectively of the worldwide number provided by Kirk et al. (2008). A wealth of information available of South American zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids came from studies made in Brazil. The first record of Chytridiomycota in this country was of *Synchytrium stellariae* Fuckel parasiting the plant *Stellaria media* W. (Hennings, 1896). Some years later, Wolf (1941) identified several species of *Allomyces* E. J. Butler and *Rozella* Cornu, and Karling (1944a,b,c,d,e; 1945a,b,c,d; 1946a,b; 1947a,b) described and noted a great number of species for the first time in Brazil. Posteriorly, Beneke & Rogers (1962, 1970), Rogers et al. (1970) and Milanez (see Milanez et al., 2007 for references) intensified the studies on zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids in this country. Taxonomical studies of the Phylum Oomycota in Brazil are numerous, in particular, those referring to the orders Saprolegniales and Rhipidiales (e.g. Furtado, 1965; Lyra & Milanez, 1974; Milanez & Trufem, 1981, 1984; Schoenlein-Crusius et al., 1992; Pires-Zottarelli et al., 1996; Rocha & Pires-Zottarelli, 2002; Gomes & Pires-Zottarelli, 2006; Miranda et al., 2008). Studies on Peronosporales and Pythiales mainly focused on phytopathological aspects (Viégas & Teixeira, 1943; Joffily, 1947; Carvalho, 1965). In

Argentina, the first studies also involved plant pathogens (Spegazzini, 1887; 1891; 1925), such as phytopathogenic species of *Pythium* Pringsh. and *Phytophthora* de Bary (Frezzi, 1947; 1956). A few number of studies on zoosporic diversity were made in Argentina (Yacubson, 1963; Malacalza, 1968; Beroqui de Martínez, 1969a,b, 1970; López & Mac Carthy, 1985) before Steciow started to study these groups of organisms with major emphasis on freshwater Saprolegniales (e.g., Steciow, 1988; 1993a; 1996; 1997a,b; 2001a,b,c; 2002). Only recently, studies in Argentina started to focus on zoosporic true fungi from the phyla Chytridiomycota and Blastocladiomycota (Marano et al., 2006, 2007, 2008). Thus, as shown in Table 4 there is a scarce number of species of Chytridiomycota documented in Argentina, as compared to the Oomycota.

Overexploitation, water pollution, flow modification, degradation of habitats, invasion by exotic species, and global warming are all affecting fungal diversity in many habitats worldwide. Considering that the estimated percentage of known species of Chytridiomycota and Oomycota is quite small (Mueller & Schmit, 2007), human activities and environmental change may lead to species losses before they have even been discovered. The major fraction of unknown fungal species is predicted to be in tropical areas, where diversity is considered to be higher than in temperate regions because of more favorable environmental conditions and high number of niches (Hyde & Hawksworth, 1997; Hawksworth, 2001). As an example, many new species have been discovered in Argentina and Brazil during the last ten years (Steciow, 2001a,b,c; 2002, 2003a,b; Steciow & Eliades, 2002b,c,d; Steciow et al., 2005; Steciow & Marano, 2006; Steciow & Paul, 2007; Letcher et al., 2008a,b; Steciow & Marano, 2008) and new citations of existing species have been recorded (Steciow & Eliades, 2001; 2002a; Steciow et al., 2001a,b; Rocha & Pires-Zottarelli, 2002; Milanez et al., 2003; Herrera et al., 2005; Rosa et al., 2006; Schoenlein-Crusius et al., 2006; Gomes & Pires-Zottarelli, 2006; Pires-Zottarelli et al., 2007a,b; Pires-Zottarelli & Gomes, 2007; Pires-Zottarelli & Rocha, 2007; Marano et al., 2006, 2007, 2008; Nascimento & Pires-Zottarelli, 2009, 2010; Pires-Zottarelli et al., 2009; Patekoski & Pires-Zottarelli, 2010; Nascimento et al., 2011) demonstrating

**Table 4.** Number of species recorded for each order of zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids in Argentina and Brazil. In grey, the orders which presented a greater number of species in Brazil as compared with Argentina.

Orders	Argentina	Brazil
Blastocladales	14	18
Chytridiales	17	70
Rhizophydiales	16	23
Lobulomycetales	0	1
Spizellomycetales	3	15
Rhizophlyctidales	1	7
Monoblepharidales	5	4
<b>FUNGI</b>	56	139
Hyphochytriales	2	5
Albuginales	0	9
Haptoglossales	0	1
Lagenismatales	1	0
Leptomitales	6	8
Olipidopsidales	7	6
Peronosporales	0	23
Pythiales	40	75
Rhipidiales	1	5
Rozellopsidales	2	1
Saprolegniales	55	68
Thraustochytriales	3	4
<b>STRAMINIPILA</b>	117	205
<b>PROTOZOA</b>	1	4
Total number	174	348

an increase in biodiversity studies in both countries. Even though, taxonomic surveys need to be carried out globally, covering as many types of habitats as possible.

Zoosporic true fungi and heterotrophic straminipiles are especially adapted to aquatic habitats by the production of zoospores (Sparrow, 1960). For this reason, more intensive sampling has been traditionally carried out in freshwater habitats and most species have been isolated from water or floating organic matter. The chemotactic capacity of the zoospores allows them to different-

ly encyst on the surface of favourable substrates for growing, according to their enzymatic ability (Mitchell & Deacon, 1986). Thus, the type of bait used (i.e. cellulosic, keratinic and chitinic baits) appear to determine and restrict the species composition that are able to grow on a particular type of substrate (Marano et al., 2011). The use of multiple types of baits appeared to be critical for maximizing the recovery of a greater number of species. Many groups such as the Hyphochytridiomycota, the Monoblepharidomycetes and most of the Blastocladiomycota, that are frequently found growing on pustules, are underestimated or even not considered when using a single bait.

Most zoosporic true fungi and heterotrophic straminipiles are ubiquitous and are found throughout the world. They are thought to be cosmopolitan (i.e. they can be found wherever their required habitat is available), although a few examples of limited or restricted distribution can be found in literature. Whether or not some taxa have a limited distribution is debatable. Many areas in both countries are poorly surveyed or have not been surveyed yet. For example, as shown in Table 1, most of the species of zoosporic fungi and heterotrophic straminipiles have been reported from Buenos Aires and only a few records are documented from other provinces in Argentina. This distribution only reflect the distribution of researchers studying these organisms and not their real geographical distribution.

In other countries of South America there are no groups currently in activity and only a few studies documenting their presence in Bolivia, Chile, Colombia, Venezuela and Ecuador are available (Dennis et al., 1970; Orduz et al., 1992; Vivar Muñoz & Bernal, 1998; Zaror et al., 2004; Barriónuevo et al., 2008), most of them published by foreign mycologists (e.g., Nabel, 1939; Emerson, 1941; Dogma, 1973; 1974a, b; Kaosiri et al., 1978; Karling, 1981a,b, 1984). The main question that needs to be addressed is whether global distribution patterns of these organisms are real or merely reflect the regions which have been intensively sampled (i.e., the distribution of specialists). Therefore, any conclusion about the geographical distribution of zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids at this stage is only speculative.

Hopefully this review will provide useful infor-

mation and encourage future research on the diversity of zoosporic true fungi, heterotrophic straminipiles and plasmodiophorids in South America.

## ACKNOWLEDGEMENTS

We are indebted to Frank H. Gleason for valuable comments during the preparation of this manuscript.

## BIBLIOGRAPHY

- Arellano, M. L.; A. V. Marano & M. M. Steciow. 2008. Nuevas citas de Saprolegniales (Peronosporomycota, Straminipila) para ambientes acuáticos de la provincia de Buenos Aires (Argentina). *Darwiniana* 46: 36-45.
- Arellano, M. L.; A. V. Marano & M. M. Steciow. 2009. Diversity of zoosporic organisms from terrestrial habitats of the Reserva Natural Selva Marginal Punta Lara (Buenos Aires, Argentina). *Nova Hedwigia* 88: 145-156.
- Baptista, F. R. 2007. *Pythium middletonii* Sparrow e *Pythium dissotocum* Drechsler em alface (*Lactuca sativa* L.): avaliação patogênica e controle biológico. Dissertação de Mestrado, Instituto de Botânica de São Paulo.
- Barrionuevo, J. S.; R. Aguayo & E. O. Lavilla. 2008. First record of chytridiomycosis in Bolivia (*Rhinella quechua*; Anura: Bufonidae). *Diseases of Aquatic Organisms* 82: 161-163.
- Beneke, E. S. & A. L. Rogers. 1962. Aquatic Phycomycetes isolated in the states of Minas Gerais, São Paulo and Paraná, Brazil. *Rickia* 1: 181-193.
- Beneke, E. S. & A. L. Rogers. 1970. Aquatic fungi of Parque Nacional do Itatiaia in the state of Rio de Janeiro. *Rickia* 5: 51-64.
- Beroqui de Martínez, M. E. 1969a. Dos especies nuevas del género *Achlya*. *Darwiniana* 15: 9-13.
- Beroqui de Martínez, M. E. 1969b. Una nueva especie de *Achlya* (Saprolegniales, Phycomycetes). *Kurtziana* 5: 95-99.
- Beroqui de Martínez, M. E. 1970. Contribución al estudio de los Phycomycetes acuáticos de la República Argentina. I. El género *Achlya* en aguas de la ciudad de Buenos Aires y alrededores. *Boletín de la Sociedad Argentina de Botánica* 13: 109-124.
- Carvalho, P. C. T. 1965. Microrganismos do solo associados às podridões dos toletes de cana-de-açúcar. *Revista de Agricultura* 40: 83-94.
- Dennis, R. W. G. 1970. *Fungus flora of Venezuela and adjacent countries*. Additional series III. London: Her Majesty's Stationary Office.
- Dogma, Jr., I. J. 1973. Isolation and pure culture techniques for monocentric Chytridiomycetes. *Nova Hedwigia* 24: 379-392.
- Dogma Jr., I. J. 1974a. Developmental and taxonomic studies on rhizophlyctoid fungi, Chytridiales. IV. *Karlingia granulata*, *Karlingia spinosa* and *Karlingiomyces dubius*. *Nova Hedwigia* 25: 91-99.
- Dogma Jr., I. J. 1974b. Developmental and taxonomic studies on rhizophlyctoid fungi, Chytridiales. III. Chitinophilic Rhizophlyctis with resting spores of sexual origin. *Nova Hedwigia* 25: 51-89.
- Eliades, L.; M. M. Steciow & L. Cano. 2002. Primer registro de *Olpidiopsis varians* y *O. vexans* (Lagenidiales, Oomycota) en limnófitos de la Provincia de Buenos Aires, Argentina. *Darwiniana* 40: 39-43.
- Emerson, R. 1941. An experimental study of the life cycles and taxonomy of *Allomyces*. *Lloydia* 4: 77-144.
- Farr, D. F. & A. Y. Rossman. 2011. Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA ([http://nt.ars-grin.gov/fungal\\_databases/new\\_allView.cfm?whichone=FungusHost&thisName=Phytophthora%20carica&organismtype=Fungus&fromAll-Count=yes](http://nt.ars-grin.gov/fungal_databases/new_allView.cfm?whichone=FungusHost&thisName=Phytophthora%20carica&organismtype=Fungus&fromAll-Count=yes); accessed 13 rd March 2010).
- Figueiredo, M.B.; L. N. Coutinho, C.C. Aparecido & M.M. Passador. 2007. *Abutilon* ornamental (*Abutilon* sp. - Malvaceae) mostrando pústulas de *Synchytrium australe*. *Summa Phytopathologica* 33: 195-198.
- Frezzi, M. J. 1947. *Contribución al estudio del damping-off o enfermedad de los almácigos en la República Argentina*. Dirección general de Laboratorios e Investigaciones Instituto de Sanidad Vegetal, Año III, serie A, N 3. Buenos Aires: Ministerio de Agricultura de la Nación.
- Frezzi, M. J. 1956. Especies de *Pythium* fitopatógenas identificadas en la República Argentina. *Revista de Investigaciones Agrícolas* 10: 1-241.
- Furtado, J. S. 1965. A new aquatic fungus, *Achlya benekei* sp. nov. *Rickia* 2: 121-127.
- Gomes, A. L. & C. L. A. Pires-Zottarelli. 2006. Diversidade de Oomycota da Reserva Biológica de Paranapiacaba, Santo André, SP: primeiras citações para o Brasil. *Revista Brasileira de Botânica* 29: 569-577.
- Gomes, A. L. & C. L. A. Pires-Zottarelli. 2008. Oomycota (Straminipila) da Reserva Biológica de Paranapiacaba, Santo André, SP, Brasil. *Acta Botanica Brasílica* 22: 373-392.
- Hawksworth, D. L. 2001. The magnitude of fungal diversity: the 1.5 million species estimate revisited. *Mycological Research* 105: 1422-1432.
- Hennings, P. 1896. Myxomycetes, Phycomycetes, Ustilagineae and Uredineae. *Nova Hedwigia* 35: 210-211.
- Herrera, R. A.; M. M. Steciow & G. S. Natale. 2005. Chytrid fungus parasitizing the wild amphibian *Leptodactylus ocellatus* (Anura: Leptodactylidae) in Argentina. *Diseases of Aquatic Organisms* 64: 247-252.
- Hyde, K. D. & D. L. Hawksworth. 1997. Measuring and monitoring the biodiversity of microfungi, en K. D. Hyde (ed.), Biodiversity of tropical microfungi, pp 11-28. Hong Kong: Hong Kong University Press.
- Joffily, I. M. 1947. Alguns ficomicetos aquáticos e terrícolas do Brasil. *Boletim da Sociedade Brasileira de Agronomia* 10: 95-113.
- Kaosiri, T.; M. J. Powell & M. C. Viusent. 1978. Stalk length as a taxonomic criterion for *Phytophthora palmivora* isolates from cacao. *Canadian Journal of Botany* 56: 1730-1738.
- Karling, J. S. 1944a. Brazilian chytrids I. Species of *Nowakowskiella*. *Bulletin of the Torrey Botanical Club* 71: 374-389.
- Karling, J. S. 1944b. Brazilian chytrids II. New species of *Rhizidium*. *American Journal of Botany* 31: 254-261.
- Karling, J. S. 1944c. Brazilian anisochytrids. *American Journal of Botany* 31: 391-397.



- Karling, J. S. 1944d. Brazilian chytrids III. *Nephrochytrium amazonensis*. *Mycologia* 36: 350-367.
- Karling, J. S. 1944e. Brazilian chytrids IV. Species of *Rozella*. *Mycologia* 36: 638-647.
- Karling, J. S. 1945a. Brazilian chytrids. VI. *Rophalophlyctis* and *Chytriomycetes*, two new operculate genera. *American Journal of Botany* 32: 362-369.
- Karling, J. S. 1945b. *Rhizidiomyces hirsutus* sp. nov., a hairy anisochytrids from Brazil. *Bulletin of the Torrey Botanical Club* 72: 47-51.
- Karling, J. S. 1945c. Brazilian chytrids. VII. Observations relative to sexuality in two new species of *Siphonaria*. *American Journal of Botany* 32: 580-587.
- Karling, J. S. 1945d. Brazilian chytrids. V. *Nowakowskiella macrospora* n. sp. and other polycentric species. *American Journal of Botany* 32: 29-36.
- Karling, J. S. 1946a. Brazilian chytrids. VIII. Additional parasites of rotifers and nematodes. *Lloydia* 9: 1-12.
- Karling, J. S. 1946b. Brazilian chytrids. IX. Species of *Rhizophyidium*. *American Journal of Botany* 33: 328-334.
- Karling, J. S. 1947a. Brazilian chytrids. X. New species with sunken opercula. *Mycologia* 39: 56-70.
- Karling, J. S. 1947b. Keratinophilic chytrids. II. *Phlyctorrhiza variabilis* n. sp. *American Journal of Botany* 34: 27-32.
- Karling, J. S. 1981a. Some zoosporic fungi of Venezuela. *Nova Hedwigia* 34: 645-668.
- Karling, J. S. 1981b. *Rhizidiomyces bullatus* (Sparrow) comb. nov., and other anisochytrids from Venezuela. *Nova Hedwigia* 34: 669-678.
- Karling, J. S. 1984. Zoosporic soil fungi of La Guajira, Colombia. *Nova Hedwigia* 40: 329-340.
- Kirk, P. M.; P. F. Cannon, D.W. Minter & J. A. Stalpers. 2008. *Dictionary of the fungi*. 10th edition. Wallingford: CABI Bioscience Publishing.
- Letcher, P. M.; M. J. Powell, P. F. Churchill, & J. G. Chambers. 2006. Ultrastructural and molecular phylogenetic delineation of a new order, the *Rhizophydiales*. *Mycological Research* 110: 898-915.
- Letcher, P. M.; M. J. Powell & M. C. Viusent. 2008a. Rediscovery of an unusual chytridiaceous fungus new to the order Rhizophydiales. *Mycologia* 100: 325-334.
- Letcher, P. M.; C. G. Vélez, M. E. Barrantes, M. J. Powell, P. F. Churchill & W. S. Wakefield. 2008b. Ultrastructural and molecular analyses of Rhizophydiales (Chytridiomycota) isolates from North America and Argentina. *Mycological Research* 112: 759-782.
- Lyra, N. P. & A. I. Milanez. 1974. Notas para o levantamento dos ficomicetos aquáticos do estado de São Paulo. *Revista do Instituto de Micologia da Universidade Federal de Pernambuco (Recife)* 698: 1-27.
- López, S. E. & S. Mac Carthy. 1985. Presencia de "ficomicetes" parásitos en hongos y algas en la Argentina. *Darwiniana* 26: 61-70.
- López Lastra, C. C. & J. J. García. 1990. Primer registro de simúlidos (Diptera, Simuliidae neotropicales parasitados por *Coelomycidium simuli* Debaisieux (Chytridiomycetes, Chytridiales) en la República Argentina. *Revista de la Sociedad Entomológica Argentina* 89: 91-96.
- López Lastra, C. C. & J. J. García. 1997. Presencia del hongo *Coelomyces iliensis* var. *indus* (Chytridiomycetes, Blastocladiales) como patógeno de larvas de mosquitos (Diptera: Culicidae) en la República Argentina. *Revista Iberoamericana de Micología* 14: 69-71.
- López Lastra, C. C., M. M. Steciow & J. J. García. 1999. Registro más austral del hongo *Leptolegnia chapmanii* (Oomycetes: Saprolegniales) como patógeno de larvas de mosquito (Diptera: Culicidae). *Revista Iberoamericana de Micología* 16: 143-145.
- Malacalza, L. 1968. Hongos parásitos de algas dulceacuicolas. I. *Rhizophyidium globosum* y *R. subangulosus*. *Revista del Museo de La Plata* 56: 79-87.
- Marano, A. V. & M. M. Steciow. 2006. Frequency and abundance of zoosporic fungi in some lotic environments of Buenos Aires province (Argentina). *Journal of Agricultural Technology* 2: 17-28.
- Marano, A. V.; M. M. Steciow & B. A. González. 2006. Primer registro para la Argentina de *Rhizophlyctis rosea* (Spizellomycetales, Chytridiomycota) y notas sobre su frecuencia y abundancia en suelos cultivados. *Boletín de la Sociedad Argentina de Botánica* 41: 183-191.
- Marano, A. V.; M. M. Steciow, M. L. Arellano, A. M. Arambarri & M. V. Sierra. 2007. El género *Nowakowskiella* Schroeter (Cladochytriaceae, Chytridiomycota) en ambientes de la Pcia. de Buenos Aires (Argentina): taxonomía, frecuencia y abundancia de las especies estudiadas. *Boletín de la Sociedad Argentina de Botánica* 42: 13-24.
- Marano, A. V.; M. M. Steciow & M. L. Arellano. 2008. New records of chytridiaceous fungi (Chytridiomycota) from the Reserva Natural Selva Marginal Punta Lara (Argentina) with comments on some previously reported species. *Nordic Journal of Botany* 26: 248-254.
- Milanez, A. I. & S. F. B. Trufem. 1981. Ficomicetos em frutos submersos do Parque Estadual das Fontes do Ipiranga. *Rickia* 9: 7-15.
- Milanez, A. I. 1989. Fungos de águas continentais. In: Fidalgo O. & V. L. Bononi (eds.), *Técnicas de coleta, preservação e herborização de material botânico*, pp. 17-20. São Paulo: Instituto de Botânica.
- Milanez, A. I.; C. L. A. Pires-Zottarelli, I. H. Schoenlein-Crusius & L. G. Lohmann. 2003. Criptógamos do "Parque Estadual das Fontes do Ipiranga, São Paulo, SP. Fungos. 8: Blastocladiales. *Hoehnea* 30: 21-29.
- Milanez, A. I.; C. L. A. Pires-Zottarelli & A. L. Gomes (eds.). 2007. Brazilian zoosporic fungi. São Paulo: WinnerGraph.
- Miranda, M. L. & C. L. A. Pires-Zottarelli. 2008. O gênero *Pythium* no Parque Estadual da Serra da Cantareira, Estado de São Paulo, Brasil. *Hoehnea* 35: 281-288.
- Moreira, C. G. 2006. Avaliação da diversidade e biomassa de fungos associados a folhas em decomposição de *Tibouchina pulchra* Cogn. submersas em reservatórios do Parque Estadual das Fontes do Ipiranga (PEFI), São Paulo, SP. Dissertação de Mestrado, Instituto de Botânica de São Paulo.
- Mueller, G. M. & J. P. Schmit. 2007. Fungal biodiversity: what do we know? What can we predict? *Biodiversity and Conservation* 16: 1-5.
- Nabel, K. 1939. Über die Membran niederer Pilze, besonders von *Rhizidiomyces bivellatus*, nov. spez. *Archiv für Mikrobiologie* 10: 515-541.
- Nascimento, C. A. & C. L. A. Pires-Zottarelli. 2009. Chytridiales (Chytridiomycota) do Parque Estadual da Serra da Cantareira, SP, Brasil. *Acta Botanica Brasílica* 23: 459-473.
- Nascimento, C. A. & C. L. A. Pires-Zottarelli. 2010. Blastocladiales e Spizellomycetales do Parque Estadual da Serra da

- Cantareira, São Paulo, Brasil. *Revista Brasileira de Botânica* 33: 693-704.
- Nascimento, C. A.; E. P. C. Gomes, C. L. A. Pires-Zottarelli. 2011. Occurrence and distribution of zoosporic organisms in water bodies from Brazilian Cerrado areas. *Mycologia* 103: 261-272.
- Niquil, N.; M. Kagami, J. Urabe, V. Christaki, E. Viscoghiosi, T. Sime-Ngando. 2011. Potential role of fungi in plankton food web functioning and stability: a simulation analysis based on Lake Biwa inverse model. *Hydrobiologia* 659: 65-79.
- Orduz, S.; J. S. Zuluaga, T. Diaz & W. Rojas. 1992. Five new isolates of the mosquito pathogenic fungus *Lagenidium giganteum* (Oomycetes: Lagenidiales) from Colombia. *Memorias del Instituto Oswaldo Cruz* 87: 597-599.
- Pacheco Marino, S. G.; M. M. Steciow & C. Barbeito. 2009. First report of Saprolegniosis on eggs and a juvenile of "Argentinian silverside" (*Odontheistes bonariensis*). *European Association of Fish Pathologists Bulletin* 29: 10-15.
- Palmucci, H. E.; S. M. Wolcan & P. E. Grijalba. 2008. Status of the genera *Pythium* and *Phytophthora* in Argentina. (<http://www.phytophthoradb.org/pdf/O24Palmucci.pdf>; accessed on 4 th February 2011).
- Patekoski, K. da S. & C. L. A. Pires-Zottarelli. 2009. Patogenicidade in vitro de *Pythium aphanidermatum* e *Pythium dissotocum* em variedades de alface (*Lactuca sativa* L.). *Hoehnea* 36: 161-172.
- Patekoski, K. da S. & C. L. A. Pires-Zottarelli. 2010. Patogenicidade de *Pythium aphanidermatum* a alface cultivada em hidroponia e seu biocontrole com *Trichoderma*. *Pesquisa Agropecuária Brasileira* 45: 805-810.
- Pereira, A. A. & J. R. S. Rocha. 2008. *Pythium* (Pythiaceae): três novos registros para o nordeste do Brasil. *Acta Botânica Malacitana* 33: 347-350.
- Pires-Zottarelli, C. L. A.; A. I. Milanez, I. H. Schoenlein-Crusius & L. G. Lohmann. 1996. Criptógamos do Parque Estadual das Fontes do Ipiranga, São Paulo, SP. Fungos, 6: Chytridiales. *Hoehnea* 23: 77-90.
- Pires-Zottarelli, C. L. A. & A. L. Gomes. 2007. Contribuição para o conhecimento de Chytridiomycota da "Reserva Biológica de Paranapiacaba", Santo André, SP, Brasil. *Biota Neotropica* 7: 309-329.
- Pires-Zottarelli, C. L. A. & M. Rocha. 2007. Novas citações de Chytridiomycota e Oomycota para o Parque Estadual das Fontes do Ipiranga (PEFI), SP, Brasil. *Acta Botanica Brasílica* 21: 125-136.
- Pires-Zottarelli, C. L. A.; A. L. Gomes & C. A. Nascimento. 2007a. *Entophlyctis luteolus* in the Brazilian Atlantic Rainforest. *Mycotaxon* 99: 207-210.
- Pires-Zottarelli, C. L. A.; A. L. Gomes, J. M. Oliveira & A. I. Milanez. 2007b. *Phragmosporangium uniseriatum* in Brazil. *Mycotaxon* 102: 179-182.
- Pires-Zottarelli, C. L. A.; A. S. Santos, A. I. Milanez, M. A. P. Cipriano. 2009. Ocorrência de *Pythiella vernalis* em *Pythium aphanidermatum* de cultura hidropônica de agrião no Brasil. *Summa Phytopathologica* 35: 325-326.
- Rocha, M. & C. L. A. Pires-Zottarelli. 2002. Chytridiomycota e Oomycota da "Represa do Guarapiranga", São Paulo, SP. *Acta Botanica Brasílica* 16: 287-309.
- Rodrigues Junior, A. J. G.; Barros, P. C.; Mendes, M. A. S.; Santos, C. E. N.; Melo, L. A. M. P. de; Hiragi, G. O.; Urban, A. F. 2002. Banco de dados dos 'fungos relatados em plantas no Brasil'. In: EMBRAPA/Recursos genéticos e Biotecnologia, Anais dos resumos dos trabalhos. Ministério da Agricultura, Pecuária e Abastecimento, p. 105 (<http://pragawall.cenargen.embrapa.br>; accessed on 19 th April 2009).
- Rosa, S. M.; M. A. Galvagno & C. G. Vélez. 2006. Primeros aislamiento de Trausthocytriales (Labyrinthulomycetes, Heterokonta) de ambientes estuariales y salinos de Argentina. *Darwiniana* 44: 81-88.
- Santos, A. F. D.; E. D. M. N. Luz & J. T. De Souza. 2006. First report of *Phytophthora boehmeriae* on black wattle in Brazil. *New Disease Reports* 13: 23.
- Schoenlein-Crusius, I. H.; A. I. Milanez, S. F. B. Trufem, C. L. A. Pires-Zottarelli, R. A. P. Grandi, M. L. Santos & K. C. Giustra. 2006. Microscopic fungi in the Atlantic Rainforest in Cubatão, São Paulo, Brazil. *Brazilian Journal of Microbiology* 37: 244-252.
- Simmons, D. R.; T. Y. James, A. F. Meyer & J. E. Longcore. 2009. Lobulomycetales, a new order in the Chytridiomycota. *Mycological Research* 113: 450-460.
- Sparrow Jr., F. K. 1960. *Aquatic Phycomycetes*. Ann Arbor: University of Michigan Press.
- Sparrow Jr., F. K. 1968. Ecology of freshwater fungi, in G. C. Ainsworth & A. S. Sussman (eds.), *The Fungi: an advanced treatise*, pp. 41-93. New York: Academic Press Inc.
- Spegazzini, C. 1887. Fungi patogenici. *Boletín de la Academia de Ciencias de Córdoba* 11: 1-62.
- Spegazzini, C. 1891. Phycomycetae Argentinae. *Revista Argentina de Historia Natural* 1: 28-38.
- Spegazzini, C. 1925. Ficomiceteas Argentinas. Nuevas o criticas. *Revista Argentina de Botánica* 1: 87-93.
- Steciow, M. M. 1988. Algunos Oomycetes de ambientes acuáticos de la provincia de Buenos Aires (Mastigomycotina). *Boletín de la Sociedad Argentina de Botánica* 25: 334-346.
- Steciow, M. M. 1993a. Presencia de Saprolegniales (Mastigomycotina) en Río Santiago y afluentes (Bs. As., Argentina). *Boletín de la Sociedad Argentina de Botánica* 29: 211-217.
- Steciow, M. M. 1993b. Presencia de hongos zoospóricos en Río Santiago y afluentes (Provincia de Buenos Aires, Argentina). *Mastigomycotina. Darwiniana* 32: 265-270.
- Steciow, M. M. 1996. Hongos acuáticos zoospóricos (Oomycetes, Mastigomycotina) en laguna Vitel y tributarios (Buenos Aires, Argentina). *Boletín de la Sociedad Argentina de Botánica* 32: 67-73.
- Steciow, M. M. 1997a. Análisis cuali-cuantitativo de los hongos zoospóricos de Laguna Vitel y tributarios (Chascomús, Argentina). *Boletín Micológico* 12: 49-53.
- Steciow, M. M. 1997b. Abundancia y frecuencia relativa de los Oomycetes en Río Santiago y afluentes (Buenos Aires, Argentina). *Gayana Botánica* 54: 39-52.
- Steciow, M. M. 1997c. The occurrence of *Achlya recurva* (Saprolegniales, Oomycetes) in hydrocarbon-polluted soil from Argentina. *Revista Iberoamericana de Micología* 14: 135-137.
- Steciow, M. M. 1998. Hongos acuáticos (Chytridiomycota, Oomycota) de la Laguna Vitel y tributarios (Buenos Aires, Argentina). *Darwiniana* 36: 101-106.
- Steciow, M. M. 1999. Hallazgo de *Blastocladia globosa* y *B. pringsheimii* (Blastocladales, Chytridiomycota) en el arroyo Vitel Sur (Provincia de Buenos Aires, Argentina). *Darwiniana* 37: 335-339.
- Steciow, M. M. 2001a. A new freshwater species of *Achlya*

- from Tierra del Fuego Province, Argentina. *New Zealand Journal of Botany* 39: 277-283.
- Steciow, M. M. 2001b. *Achlya fuegiana*, a new species from Tierra del Fuego Province (Argentina). *Mycologia* 93: 1195-1199.
- Steciow, M. M. 2001c. *Saprolegnia longicaulis* (Saprolegniales, Straminipila), a new species from an Argentine stream. *New Zealand Journal of Botany* 39: 483-488.
- Steciow, M. M. 2002. *Saprolegnia milnae* (Saprolegniales, Straminipila), a new species from an Argentine river (Tierra del Fuego province, Argentina). *New Zealand Journal of Botany* 40: 473-479.
- Steciow, M. M. 2003a. A new species of *Brevilegnia* (Saprolegniales, Straminipila) from Buenos Aires Province, Argentina. *Mycologia* 95: 934-942.
- Steciow, M. M. 2003b. *Saprolegnia oliviae* sp. nov. isolated from an Argentine river (Tierra del Fuego Province, Argentina). *FEMS Microbiology Letters* 219: 253-259.
- Steciow, M. M. & A. M. Arambarri. 2000. Southernmost occurrence of a tropical fungus: *Monoblepharella mexicana* (Monoblepharidales, Chytridiomycetes). *Nova Hedwigia* 70: 11-116.
- Steciow, M. M. & L. A. Eliades. 2001. Primer registro de *Allomyces neomoniliformis* (Chytridiomycota) y *Dictyuchus missouriensis* (Oomycota) aislados de un suelo agrícola (Buenos Aires, Argentina). *Darwiniana* 39: 15-18.
- Steciow, M. M.; L. A. Eliades, A. M. Arambarri. 2001a. Nuevas citas de Blastocladiales (Chytridiomycota) en ambientes contaminados de Ensenada (Buenos Aires, Argentina). *Darwiniana* 39: 15-21.
- Steciow, M. M.; L. A. Eliades, A. M. Arambarri. 2001b. El género *Gonapodya* (Monoblepharidales, Chytridiomycota) en ambientes contaminados de Ensenada (Buenos Aires, Argentina). *Boletín de la Sociedad Argentina de Botánica* 36: 203-208.
- Steciow, M. M. & L. A. Eliades. 2002a. Mohos acuáticos con metabolismo fermentativo en aguas contaminadas del Partido de Ensenada (Buenos Aires, Argentina). *Boletín de la Sociedad Argentina de Botánica* 37: 5-11.
- Steciow, M. M. & L. A. Eliades. 2002b. *A. robusta* sp. nov., a new species of *Achlya* (Saprolegniales, Straminipila) from a polluted Argentine channel. *Microbiological Research* 157: 177-182.
- Steciow, M. M. & L. A. Eliades. 2002c. A new species of *Saprolegnia* (Saprolegniales, Straminipila), from a polluted Argentine channel. *New Zealand Journal of Botany* 40: 679-685.
- Steciow, M. M. & L. A. Eliades. 2002d. *Thraustotheca terrestris* a new species from Argentine agricultural soil. *Nova Hedwigia* 75: 227-235.
- Steciow, M. M.; C. C. Lopez Lastra & M. Dick. 2005. *Scoliolegnia hypogyna* (Saprolegniales, Oomycetes), a new species from Misiones Province, Argentina. *Mycotaxon* 91: 381-391.
- Steciow, M. M. & A. V. Marano. 2006. *Blastocladia bonaerensis* (Chytridiomycetes, Blastocladiales), a new species from Argentine polluted channel. *Mycotaxon* 97: 359-365.
- Steciow, M. M. & A. V. Marano. 2008. *Achlya anomala* (Saprolegniales, Straminipila), a new species from an Argentine stream. *Botanica Lithuanica* 14: 49-56.
- Steciow, M. M.; A. V. Marano & B. A. González. 2006. Primera cita de *Allomyces macrogynous* (Fungi) en un suelo agrícola del pdo. de Luján, *Actas del XX Congreso Argentino de Ciencias del Suelo*, 19-22 de septiembre de 2006, Salta (Argentina), en CD-ROM.
- Steciow, M. M. & B. Paul. 2007. *Saprolegnia bulbosa*, a new species from an Argentine stream (Buenos Aires Province, Argentina), its taxonomy, ITS region of rDNA, and comparison with related species. *FEMS Microbiology Letters* 268: 225-230.
- Stevens, R. B. 1974. *Mycological guidebook*. Seattle: Univ. of Washington Press.
- Teixeira, L. D.; C. L. A. Pires-Zottarelli & H. Kimati. 2006. Temperature effects on mycelial growth and pathogenicity of *Pythium* spp. occurring in hydroponic lettuce. *Summa phytopathologica* 32: 221-226.
- Viégas, A. P. & A. R. Teixeira. 1943. Alguns fungos do Brasil (Phycomycetes). *Bragantia* 3: 223-269.
- Vivar Muñoz, V. & F. L. Bernal. 1998. Control de saprolégniales por ácido acético, cloruro de sodio y verde malaquita en huevos de trucha arcoiris. *Boletín Micológico* 13: 29-34.
- Wolf, F. T. 1941. A contribution to the history and geographic distribution of the genus *Allomyces*. *Mycologia* 33: 158-173.
- Yacubson, S. 1963. Ficomicetos endobióticos en Desmidiáceas. Comisión del Museo Argentino de Ciencias Naturales de Buenos Aires. *Hidrobiología* 1: 1-5.
- Zaror, L.; L. Collado, H. Bohle, E. Landskron, J. Montaña & F. Avendaño. 2004. *Saprolegnia parasitica* in salmon and trout from southern Chile. *Archivos de Medicina Veterinaria* 36: 71-78.