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

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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

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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 heterotrophic 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 Hyphochytriomycota, 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 Blastocladiales, 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 & Hawkswort, 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 & Elíades, 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 & Elíades, 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**
Blastocladiales	14	18
Chytridiales	17	70
Rhizophydiales	16	23
Lobulomycetales	0	1
Spizellomycetales	3	15
Rhizophlyctidales	1	7
Monoblepharidales	5	4
FUNGI	56	139
Hyphochytriales	2	5
Albuginales	0	9
Haptoglosales	0	1
Lagenismatales	1	0
Leptomitales	6	8
Olpidopsidales	7	6
Peronosporales	0	23
Pythiales	40	75
Rhipidiales	1	5
Rozellopsidales	2	1
Saprolegniales	55	68
Thraustochytriales	3	4
STRAMINIPILA	117	205
PROTOZOA	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 differently 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 studing 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; Barrionuevo 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.

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