



## Advances in studies on testate amoebae (Arcellinida and Euglyphida): a scientometric approach

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**ABSTRACT.** Testate amoebae have a great potential for use in scientific researches due to their ecological characteristics such as abundance, wealth, and generation time. In this way, this study aimed to present a scientometric analysis to describe the evolution of the different advances in researches on testate amoebae and identify a temporal pattern in this evolution. The literature review was based on papers indexed by Thomson Reuters ([www.isiwebknowledge.com](http://www.isiwebknowledge.com)) and SciVerse Scopus ([www.scopus.com](http://www.scopus.com)). In total 562 papers were examined. Results showed a pattern of evolution in scientific studies, most with ecological approach with descriptive and predictive designs. At the global level, researches on testate amoebae progressed in both the number of articles published as well as in the areas studied, especially in Europe and North America. The low number of experimental studies and review articles can characterize the lack of more knowledge to be acquired, both from particular observations (descriptive studies) as well as the observations noted sufficiently predictive of work. In Brazil, studies with testate amoebae are still developing, concentrated in only some regions, but the increased number of studies in recent years allows the prediction of the same overall patterns of advance for Brazilian researches. Thus, we conclude that these organisms are being increasingly used as a tool response in ecological studies.

**Keywords:** protest, geographical distribution, scientometric analysis, time trend.

## Avanços nos estudos sobre amebas testáceas (Arcellinida e Euglyphida): uma abordagem cienciométrica

**RESUMO.** Amebas testáceas possuem grande potencial de utilização em pesquisas de caráter científico pelas suas características ecológicas como abundância, riqueza, e tempo de geração. Nesse sentido, o objetivo do presente estudo foi apresentar uma análise cienciométrica, a fim de descrever a evolução das diferentes abordagens nas pesquisas de tecamebas e identificar um padrão temporal nessa evolução. A revisão dos artigos científicos foi realizada com base nos artigos indexados pela base Thomson Reuters ([www.isiwebknowledge.com](http://www.isiwebknowledge.com)) e pela base SciVerse Scopus ([www.scopus.com](http://www.scopus.com)). Foram analisados 562 artigos científicos. Os resultados demonstraram um padrão de evolução nos trabalhos científicos, sendo a maioria de cunho ecológico com delineamentos descritivos e preditivos. Em âmbito global, as pesquisas com tecamebas apresentaram evolução tanto no número de artigos publicados bem como nas áreas estudadas, principalmente na Europa e América do Norte. O baixo número de trabalhos experimentais e de revisão pode caracterizar a falta de maiores conhecimentos a serem ainda adquiridos, tanto a partir das observações particulares (trabalhos descritivos) bem como das observações suficientemente constatadas dos trabalhos preditivos. No Brasil, as pesquisas com amebas testáceas ainda estão em processo de desenvolvimento, concentradas em apenas algumas regiões. Entretanto, o aumento no número de publicações nos últimos anos possibilita a previsão dos mesmos padrões de evolução globais para as pesquisas brasileiras. Assim, é possível concluir que esses organismos estão sendo cada vez mais utilizados como ferramenta resposta nos estudos ecológicos.

**Palavras-chave:** protista, distribuição geográfica, análise cienciométrica, tendência temporal.

### Introduction

Testate amoebae (Arcellinida and Euglyphida) are protozoa with cytoplasm partially enclosed in a shell or test, with an oral aperture through which pseudopods protrude for locomotion or feeding (SMITH et al., 2008).

These organisms are essentially aquatic and present in a wide array of moist, freshwater habitats, preferentially occupying biotopes associated with marginal vegetation and sediment (ALVES et al., 2012; LANSAC-TÔHA et al., 2007; MATTHEUSSEN et al., 2005). Besides that, several

other studies have registered high densities in plankton (ALVES et al., 2007, 2012; LANSAC-TÔHA et al., 2004, 2008a, 2009; VELHO et al., 1999, 2004).

Abundance, richness and generation time of testate protozoa provide some ecological advantages to these organisms, making them interesting for scientific researches, both in spatial and time scales (FOISSNER, 1999). They respond rapidly to changes in environmental conditions, which give the ability to identify the quality of the water and/or environment, allowing their use as bioindicators (SCHONBORN, 1992). Morphometric and/structural variations in the shell of these organisms can be result of variations in environmental parameters, becoming thus an interesting tool for paleontological studies (NIGAN, 1986).

The testate amoebae have been investigated at the global level and in different habitats. These surveys have been developed since the eighteenth century (ARCHER, 1869; BARKER, 1968; BARNARD, 1879; BLOCHMANN, 1894; EHRENBERG, 1841). The first works were developed basically from taxonomic approaches and some species occurrence, and subsequently considering ecological aspects more complex. The research development contributes to increased knowledge about these organisms, highlighting its ecological importance (LANSAC-TÔHA et al., 2007).

Regarding the great potential of using this group in scientific studies, we aimed at presenting a scientometric analysis on papers focusing testate amoebae, in order to describe the advances of different approaches in researches on these organisms and identify a time trend in this evolution.

## Material and methods

The review of the literature on testate amoebae was primarily based on articles indexed by Thomson Reuters ([www.isiwebknowledge.com](http://www.isiwebknowledge.com)) and then by SciVerse Scopus ([www.scopus.com](http://www.scopus.com)), with the goal to achieve a greater number of papers. The survey was performed in September 2011, using the keyword *testate amoebae*.

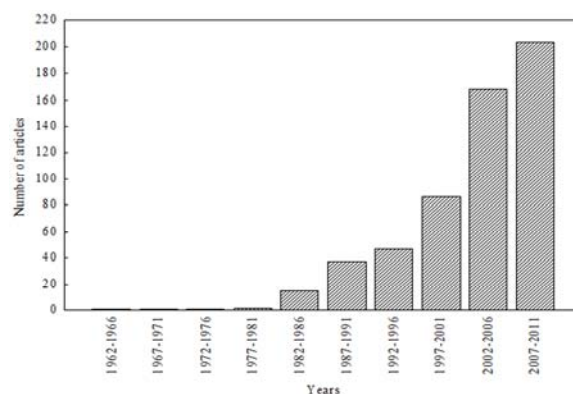
Papers selected were classified according to year of publication, location (Europe, North America, Asia, South America, Africa, Oceania and Poles), approach: ecological, zoological (including taxonomic and biological studies), paleontological and molecular, and design: descriptive (comparative studies), predictive (studies based on prediction model, with or without ecological theories),

experimental (studies performed in laboratory under controlled conditions), and review (literature review). For the studies conducted in Brazil, the same classification was employed, but the geographical locations were divided according to Brazilian regions (North, Northeast, Central West, Southeast and South).

Publication years were pooled into five year-intervals, starting from 1962 (first year of record) and finishing in September 2011. In this way, ten time intervals were obtained: 1962-1966, 1967-1971, 1972-1976, 1977-1981, 1982-1986, 1987-1991, 1992-1996, 1997-2001, 2002-2006, 2007-2011.

## Results

In the total, 907 articles were selected, 422 found in Thomson Reuters and 485 in Scopus. Papers that did not meet the goal of the present study were not considered, ie, work in testate amoebae that were not being used as a tool in response studies, and papers and those occurring in both databases were considered only once, thus for the scientometric analysis 562 scientific papers were used. The number of articles for the last time period (2007-2011) may have been underestimated, since the analysis of the year of 2011 has finished in September (Figure 1).

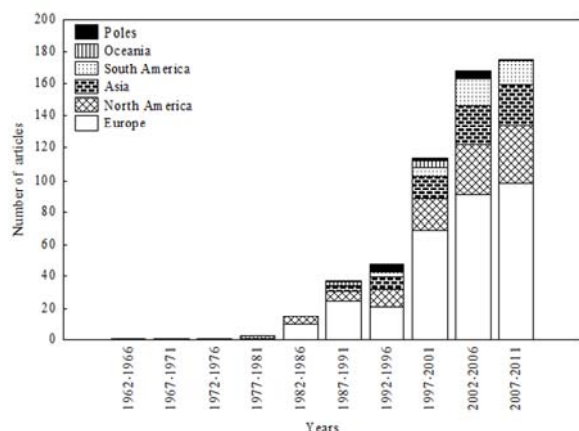


**Figure 1.** Articles indexed by Thomson and Scopus databases which address researches on testate amoebae during the survey period.

The first three time intervals presented lower amounts of published articles ( $n = 1$  each). From 1982, the studies have progressed, with growing number of publications over the years. In this way, the period with the greatest scientific production consisted of the years between 2007 and 2011 ( $n = 204$ ).

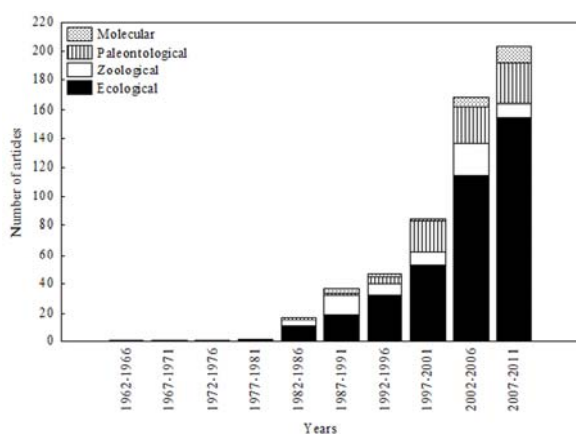
As for geographical location, Europe was the continent with the highest number of published articles, with a total of 317 articles, followed by North America ( $n = 111$ ) and Asia ( $n = 74$ ), South America

(n = 40), Poles (n = 13) and Oceania (n = 7). No record was found for the African continent (Figure 2).



**Figure 2.** Articles published per continent during the survey period.

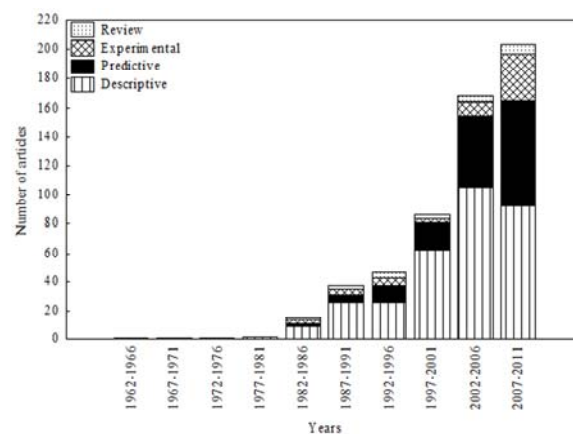
Most of studies presented the keyword *testate amoebae* used with ecological focus (n = 337), followed by paleontological (n = 83), zoological (n = 68) and molecular studies (n = 24). The first studies recorded in the databases (Thomson Reuters and Scopus) presented exclusively ecological focus in the time interval between 1962 and 1966, and zoological focus in the periods 1967-1971 and 1972-1976. After this, the percentage of these two approaches (ecological and zoological) began to share space with paleontological studies. And from the late 80's and early 90's that emerged the first molecular studies with testate amoebae, with an increase over the periods. Even though, ecological and zoological studies were present in all time intervals (Figure 3).



**Figure 3.** Articles classified according to the central focus of the study during the survey period.

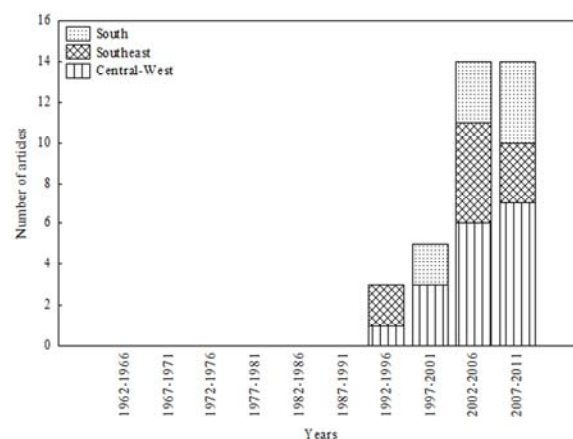
In relation to the design, descriptive studies were the majority, category present in every time intervals (n = 325), with intensification of studies in the early 80's, when also increased the number of published

articles. Predictive works (n = 159) started from 1982 and presented a growing increase over the analyzed periods. Also, experimental (n = 57) and review studies also started from this year. The latter had the lowest number of publications than the other designs employed in the articles (n = 21) (Figure 4).



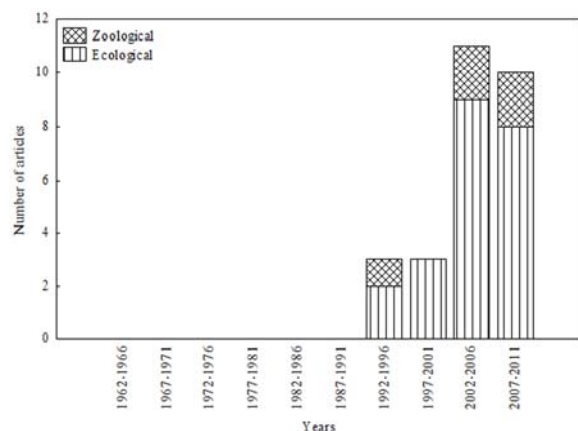
**Figure 4.** Articles classified according to the design used in the study during the survey period.

In Brazil, 36 papers were found, corresponding to 6.4% of the total number of the papers reviewed this survey. The Central-West was the most productive region (n = 17), followed by Southeast (n = 10) and South (n = 9). Some studies developed in the upper Paraná river floodplain (Paraná-Mato Grosso do Sul State) were considered both in Central-West and South regions, since the samplings were conducted in environments located in the states of Mato Grosso do Sul and Paraná. In the regions North and Northeast no study on testate amoebae could be registered with the used databases (Figure 5).



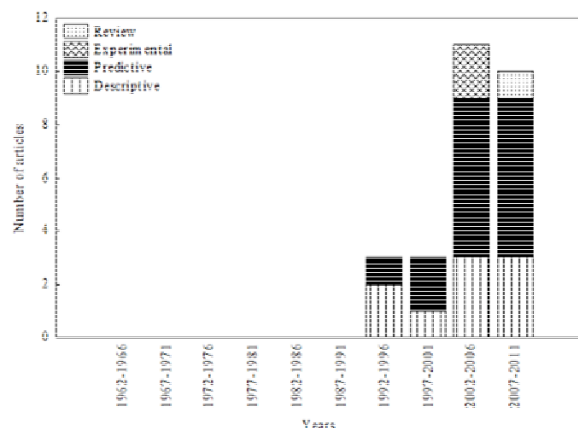
**Figure 5.** Articles indexed by Thomson and Scopus databases per each Brazilian region during the survey period

According to the focus, the Brazilian studies mostly encompassed ecological (n = 22) and zoological studies (n = 5) (Figure 6).



**Figure 6.** Articles classified according to the central focus of the Brazilian studies during the survey period.

Regarding the design, predictive studies were the majority of publications ( $n = 15$ ), differently from observed for studies at global level, being found for all time intervals, with intensification of studies from 1997. Descriptive studies ( $n = 9$ ) were also found in all time intervals, but from 1997 predictive studies were the most representative (Figure 7).



**Figure 7.** Articles classified according to the design used in the Brazilian studies during the survey period.

Experimental studies were verified only between 2002 and 2006 ( $n = 2$ ), period with the highest number of publications. A review study ( $n = 1$ ) was observed in the period of 2007-2011 (Figure 7).

## Discussion

The increase in the number of publications on testate amoebae can indicate the increase of researchers and institutions working in different locations with these organisms, as well as their scientific progress, considering that the number of publications is one of the most used measures to quantify the advance and progress of science

(VERBEEK et al., 2002). However, the low record of studies before the 80's may be caused by the difficulty for scanning and consequent impracticality to make them available in the databases.

According to geographical region, the diversity and abundance of species in Europe are relatively low compared with the great diversity and abundance found in North America and South America. This fact has facilitated the achievement of knowledge on testate amoebae in Europe, which helps justifying the difference in number of articles published between these continents, coupled with the time of study, number of universities and researchers working in each continent (BEYENS; MEISTERFELD, 2001).

The first studies registered in the databases basically addressed taxonomical aspects (identification of new species) and ecological aspects related to the occurrence and distribution of testate amoebae (HEAL, 1962; LAMINGER, 1971; LOUSIER; PARKINSON, 1981; NETZEL, 1975). Afterwards, with the previous knowledge acquired it was possible to identify the main characteristics of these organisms and their respective functions in the environment, such as for example their role as bioindicators, and consequent ecological importance in the environment, justifying thus the emergence of researches with applied focus, like the paleontological (LANGDON et al., 2003; VALIRANTA et al., 2011).

The publication of articles with molecular approach on testate amoebae has started only in 1987. This knowledge area is still recent, once the discovery of the DNA structure occurred in 1953 with the publication of 'Molecular structure of the nucleic acids' (WATSON, CRICK; 1953). And from this study that emerged new possibilities for developing molecular biology for be later applied on testate amoebae.

Moreover, zoological approaches that had begun the records of studies with testate amoebae, different from ecological approaches, have not kept the same upward trend in the number of publications over the periods analyzed. This is probably due to the knowledge accumulated by zoological approaches in the early periods, which have supported new ecological researches, consequently contributing to increase the number of articles in this area.

Since then, a greater advance was observed in the studies on these testate protozoa. The researches became more specific, correlating the morphology and biometry with species ecology (TODOROV, 2002); and still gave rise to more developed ecological approaches, such as population dynamics (ALVES et al., 2008), analysis on the influence of

spatial connectivity and heterogeneity on these organisms (ALVES et al., 2010; VELHO et al., 2003), besides the studies with molecular approach that solved some taxonomical divergences (GILBERT et al., 2003; HEGER et al., 2010).

With the present survey, most of studies with testate amoebae at global level presented a trend for using descriptive and predictive designs. This is probably because these methods are related to the search for basic knowledge, i.e., from particular observations sufficiently verified (descriptive design) it is possible to draw general inferences that may indicate probable casual routes (predictive design) for further performance of experimental and review studies.

The number of articles published in Brazil may be considered low when compared with the number of publication found in other parts of the world, especially when considered the geographical extent of the country. According to Lansac-Tôha et al. (2007), researches with testate amoebae are still beginning, particularly in Brazil, although in recent years (time interval 2002-2006 and 2007-2011) there is a considerable increase in the number of publications, once the development of these studies is practically restricted to the regions South, Southeast and Central-West of the country. Nevertheless, many studies performed in Brazil have been published in journals not indexed to databases used in the present study, such as the case of important studies already conducted in the North region of the country, which were not estimated in the present survey (LANSAC-TÔHA et al.; 2008b; WALKER, 1978 and 1982, among others).

Furthermore, the first records of studies with testate amoebae in Brazil occurred from the mid-90's on the databases of the present study; which can be considered late, since the first studies at global level were recorded from 1962.

The dominance to date of studies in the South, Southeast and Central-West regions is due to the contribution of studies mainly developed in plankton samples in the upper Paraná river floodplain (Paraná-Mato Grosso do Sul State) (ALVES et al. 2008; 2010; AZEVEDO; BONECKER, 2003; LANSAC-TÔHA et al. 2007; VELHO et al, 1999; 2003; 2004 and 2008a, among others), in the studies performed in the Doce river (Minas Gerais State) (BONECKER et al., 1996), in the Tietê river (São Paulo State) (FULONE et al., 2005; LAHR; LOPES, 2006 and 2007), and researches conducted by Cardoso and Marques (2004); Vieira et al. (2007) and Bini et al. (2007), among others.

In agreement with the approach, the Brazilian studies different from observed at global level to date have not presented the same progress in the focuses of the studies, once it was not recorded paleontological or molecular studies for the databases used in the present study. Nevertheless, there are important researches in the paleontological area developed in Brazil, which were published in journals not indexed in the bases Thomson Reuters and Scopus (CLOSS; MADEIRA, 1962, 1967; EICHLER; BONETTI, 1995, among others).

As for the design employed in the Brazilian studies, the development of studies presented a trend similar to the other publications found in the databases used, regarding the advance in the study process with testate amoebae. However, differently from the global level, the predominance of predictive design was possibly due to the advance of studies on testate amoebae in the South, Southeast and Central-West regions. On the other hand, the reduced number of descriptive studies in recent time intervals can indicate a scarcity of researches developed in the North and Northeast regions of the country.

Besides the low number considered of articles published in Brazil, the trend of approaches and design proves that researches with testate amoebae are still under process of development. However, the considerable increase in the number of articles in recent years may indicate that the Brazilian studies come to acquire the same patterns of advance of the other studies at global level.

## Conclusion

Our results showed that despite the number of papers published in scientific journals indexed by Thomson Reuters and Scopus and the pattern in the advance of studies during the survey (49 years), the studies with testate amoebae at global level are in development process, considering that the majority is concentrated in the European continent. Also, there is a high number of descriptive and predictive studies compared with the low number of experimental and review researches. This can characterize the lack of additional knowledge to be achieved from particular observations (descriptive) and sufficiently verified in the predictive studies, for the development of greater applications in experimental studies, which consequently provide bases for surveys of knowledge review.

In contrast, Brazil owing the low number of published articles, the trend of approaches, design used and scarcity of studies performed in some regions indicate that researches are still under a

development process. Nevertheless, the increased number of Brazilian publications in recent years allows predicting the same patterns of advance observed at global level, primarily in the Central-West region of the country, which dominates the Brazilian studies on testate amoebae so far.

In the meantime, although the scientometric analysis is considered an important tool to evaluate the scientific progress, there are controversial issues relative to the determination of the global impact of a given article or relevance of a scientific journal. This because ancient studies are frequently not available in the databases, as well some journals that are not indexed.

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