# The study of aquatic macrophytes in Neotropics: a scientometrical view of the main trends and gaps

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(With 9 figures)

## Abstract

Aquatic macrophytes comprises a diverse group of organisms including angiosperms, ferns, mosses, liverworts and some macroalgae that occur in seasonally or permanently wet environments. Among other implications, aquatic macrophytes are highly productive and with an important structuring role on aquatic environments. Ecological studies involving aquatic plants substantially increased in the last years. However, a precise view of researches devoted to aquatic macrophytes in Neotropics is necessary to reach a reliable evaluation of the scientific production. In the current study, we performed a scientometrics analysis of the scientific production devoted to Neotropical macrophytes in an attempt to find the main trends and gaps of researches concerning this group. The publication devoted to macrophytes in Neotropics increased conspicuously in the last two decades. Brazil, Argentina, Mexico and Chile were the most productive among Neotropical countries. Our analyses showed that the studies dealt mostly with the influences of aquatic macrophytes on organisms and abiotic features. Studies with a predictive approach or aiming to test ecological hypothesis are scarce. In addition, researches aiming to describe unknown species are still necessary. This is essential to support conservation efforts and to subsidize further investigations testing ecological hypotheses.

*Keywords:* macrophytes, Neotropics, scientometrics, trends, lacks.

## O estudo de macrófitas aquáticas na região neotropical: uma visão cienciométrica dos principais padrões e lacunas

## Resumo

Macrófitas compreendem um diverso grupo de organismos macrofíticos, incluindo angiospermas, samambaias, musgos, hepáticas e algumas macroalgas que ocorrem em ambientes sazonalmente ou permanentemente inundados. Dentre outras implicações, as macrófitas aquáticas são altamente produtivas e com um importante papel na estruturação nos ambientes aquáticos. Estudos ecológicos envolvendo plantas aquáticas cresceram substancialmente nos últimos anos. Entretanto, uma visão precisa das pesquisas sobre macrófitas na região Neotropical é necessária para uma avaliação confiável da produção científica. No presente estudo, uma análise cienciométrica sobre macrófitas Neotropicais foi realizada com o intuito de identificar os principais padrões e lacunas nas pesquisas sobre esse grupo biológico. As publicações sobre macrófitas na região Neotropical cresceu conspicuamente nas últimas duas décadas. Brasil, Argentina, México e Chile foram os mais produtivos dentre os países Neotropicais. As análises mostraram que os estudos enfocaram principalmente as influências das macrófitas nos organismos e nas características abióticas. Estudos com uma abordagem preditiva ou testando hipóteses ecológicas são escassos. Adicionalmente, pesquisas com o objetivo de descrever espécies desconhecidas ainda são necessárias. Isso é essencial para subsidiar esforços de conservação e investigações futuras testando hipóteses ecológicas.

*Palavras-chave:* macrófitas aquáticas, biodiversidade, ciências da informação.

## 1. Introduction

The Danish book "Lagoa Santa. Et Bidrag til den biologiske Plantegeografi", is one of the first publication concerning Neotropical aquatic macrophytes (Thomaz and Bini, 2003). This classical book was published in 1892 by Eugene Warming who is considered by Arthur Tansley "the father of the modern plant ecology" (Godwin, 1977). The systematic, distribution, phytogeography and ecology of the terrestrial vegetation surrounding Santa Lagoon were the main issues of this book. However, Warming also described the aquatic and amphibian vegetation of this lagoon in details, making the first inferences about aquatic plant zonation and succession.

The aquatic plant community (or macrophytes) comprises a diverse group of macrophytic organisms including angiosperms, ferns, mosses, liverworts and some freshwater macroalgae that occur in seasonally or permanently wet environments (Lacoul and Freedman, 2006; (Chambers et al., 2008). Commonly, four morphotypes (or life forms) are used to classify aquatic macrophytes: submerged, floating-leaved, emergent and free-floating (Sculthorpe, 1985). These plants are capable of colonizing several kinds of aquatic environments (e.g. lakes, lagoons, wetlands, rivers, reservoirs, waterfalls and even bromeliad tanks) with a wide range of limnological features, presenting high plasticity and adaptation ability (Sculthorpe, 1985; Esteves, 1998). In fact, when growing in suitable habitats several species are considered aquatic weeds due to massive colonization and negative effects upon aquatic diversity and ecosystem functioning (Camargo et al., 2003).

Among other implications, aquatic macrophytes are known as highly productive (Wetzel, 2001) and with an important structuring role on aquatic environments (Jeppensen et al., 1998; Dibble and Harrel, 1997). This is extremely relevant, since aquatic biodiversity has been related to spatial heterogeneity (Grenouillet et al., 2002). Thus, ecological studies carried in aquatic environments must consider the aquatic macrophyte community as an essential component for ecosystem functioning and aquatic biodiversity conservation.

Ecological studies involving aquatic plants substantially increased just after the 60's, following the increase of studies in shallow ecosystems, globally more numerous in comparison to deep aquatic environments (Esteves 1998; Wetzel, 2001; Thomaz and Bini, 2003). However, a precise view of ecological studies using aquatic macrophytes is necessary to reach a reliable evaluation of the scientific production.

According to van Raan (1997), a scientometric (or bibliometric) research of a particular study field is devoted to quantify this subject. Analyzing and measuring the publications of a particular theme provide an output of its trends, scientific productivity, and help to identify gaps in which a greater attention is necessary (Verbeek et al., 2002). Therefore, scientometrics considering publications about aquatic macrophytes in Neotropical ecosystems are essential to the progress of this relevant research field.

In a critical analysis using papers published until 2000, Thomaz and Bini (2003) highlighted that papers about aquatic plants in Brazil were scarce. On the other hand, these authors showed a rapid growth on the number of papers, mainly after the 80's. Accordingly, the scientific production of Latin America also increased steeply in the last twenty years (Hill, 2004). In addition, limnological studies clearly increased in Brazil after 1970 (Melo et al., 2006). In spite of many trends detected by Thomaz and Bini (2003) regarding aquatic macrophytes, the investigation was done just in studies carried out in Brazil. Thus, an evaluation of publications of the whole Neotropics is still necessary.

In a recent review, Chambers et al. (2008) argue that the overall diversity of aquatic plants is highest in Neotropics. However, these authors also affirm that there are unknown species to be described, mainly in tropical areas, impairing estimations of species richness and geographic distribution. Accordingly, the knowledge of biodiversity is inadequate and plagued by Linnean (i.e. that species not yet formally described) and Wallace (i.e. that for most taxa the geographic distribution is still poorly understood) pitfalls (Bini et al., 2006). These authors argue that the best way to circumvent both Wallacean and Linnean pitfalls is to invest in biodiversity inventories, but due to increasing threats, the use of biodiversity surrogates could be a way to select priority areas for conservation when data on species distributions are lacking. This highlights the importance and urgency of an evaluation of ecological studies of aquatic macrophytes in this region. Moreover, this appraisal could subsidize biodiversity conservancy efforts, since macrophytes are key for conservation of several aquatic (e.g., fish and invertebrate) and even terrestrial (e.g., mammals and birds) organisms.

In the current study, we performed a scientometric analysis of the scientific production devoted to Neotropical macrophytes in an attempt to find the main trends and gaps of researches devoted to this group. Specifically, we asked the following questions: i) how fast is increasing the scientific production on macrophytes in the Neotropical region? ii) Where are the studies being conducted and how frequent is scientific cooperation? iii) Where are these results being published? and iv) What are the main characteristics and gaps of the scientific production on Neotropics regarding aquatic habitats, macrophyte life forms, approaches (e.g. experimental, observational or theoretical), and levels of organization?

## 2. Methods

The analysis was based on abstracts of papers published between 1991 and April 2007. We used datasets from the Thomson Institute for Scientific Information

(ISI) (www.isiknowledge.com) and Scopus (www.scopus.com). The papers were selected using the following combination of words on the search field: "aquatic plant* or macrophyte* or aquatic weed*". After this, only the papers authored by researchers from Neotropical countries (Mexico, Mesoamerican countries and South American countries) were selected by using the information on the country of affiliation of the authors. The scientific production per year was also recorded to calculate the percentage of papers concerning macrophytes in Neotropics in relation to total number of papers. The title, abstract, author addresses, publication years and publication journals were recorded for our analyses. Further information to address our questions were taken from abstracts:

i) Ecosystem type: Lakes/lagoons, rivers/streams, reservoirs, wetlands, marine habitats, artificial garden and cenotes (a type of water body found mainly in Venezuela formed in limestone sinkholes).
ii) Aquatic macrophyte ecological groups: submerged, emergent, rooted with floating-leaves, and free-floating;
iii) Level of ecological organization: ecosystem, community, population, individual;
iv) Type of study (that reflects how data were collected): survey, experimental (macro, meso or micro scale), taxonomical, modeling and review; and
v) Main subject: influences of the environment upon aquatic macrophytes (including studies aiming the management of macrophyte populations and communities), influences of other communities upon aquatic macrophytes, influences of aquatic macrophytes upon the environment and other communities, plant features, community description, taxonomy, primary production, evolution, paleoclimate description, diversity estimation, fossil description, commercial use and methods to estimate growth rate. Since some abstracts did not provide all information, the number of papers analyzed concerning each variable varied.

## 3. Results and Discussion

A total of 382 papers were analyzed, considering the criteria delineated in our Methods. The total number of papers increased conspicuously in the last two decades (11 in 1990 to 52 in 2006). This tendency is coherent with the clear enhancement in the Latin American scientific production over the last decade (Hill, 2004; Hermes-Lima et al., 2007). Melo et al. (2006) also demonstrated an augmentation of Brazilian publication in international journals between 1970 and 2004.

It is important to note that not only the total number of papers, but also the percentage of papers (in relation to the total scientific production) concerning aquatic macrophytes in Neotropics indexed in Scopus and ISI increased steeply from 1991 to 2006 (Figure 1). The recognition of the importance of aquatic plants on the ecosystem functioning by Neotropical limnologists can be one reason for this faster increase. In fact, Wetzel (2001) argued that the aquatic macrophyte community can be considered one of the most productive communities in the world. Another reason for the ascendant interest in aquatic plants can be related with the recent focus on the structuring role of macrophytes in aquatic habitats. This spatial structure provides refuge against predators and suitable spawning and foraging substrate, hanging more individuals and species of invertebrate and fish (Lansac-Tôha et al., 2003; Takeda et al., 2003; Pelicice et al., 2005), hence, promoting biological diversity. Finally, problems caused by the excessive growth of aquatic vegetation, especially in reservoirs can also be another factor accounting for this trend (Thomaz and Bini, 2003).

Most of the 382 papers have at least one author from Brazil (n = 185; 48% of the papers), Argentina (n = 92; 24%) and Mexico (n = 50; 13%) (Figure 2a). Accordingly, even considering authors from other countries, studies were also frequently conducted in these three countries (Brazil: n = 169; 44%; Argentina: n = 85; 22%; Mexico: n = 40; 10%) (Figure 2b). An explanation is that these countries are the three largest economies among Neotropical countries (World Bank, 2007). In fact, high scientific production is associated with economic development (May, 1997). Additionally, considering the whole scientific production of Latin America, previous investigations demonstrated that Brazil, Mexico, Argentina and Chile were the more productive countries (Hill, 2004; Hermes-Lima et al., 2007). Furthermore, in a study evaluating the scientific impact of nations, Brazil was the only Neotropical country among the 31 most important countries worldwide, occupying the 20$^{th}$ position in number of published papers (King, 2004). Thomaz and Bini (2003) stressed that the variety of environments is also an important factor accounting for the interest on aquatic macrophytes in Brazil.

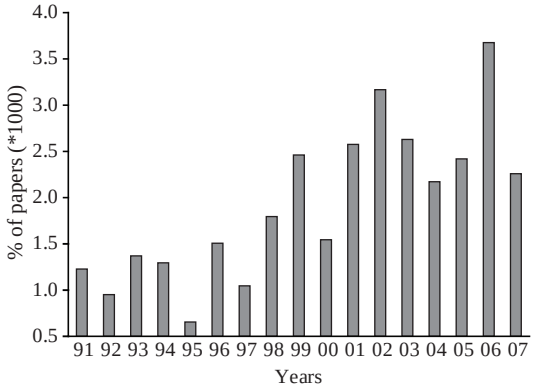


**Figure 1.** Percentage ( in relation to total scientific production) of papers indexed in Scopus and ISI between 1991 and 2007 studying aquatic macrophytes in Neotropical regions (number of papers = 382).

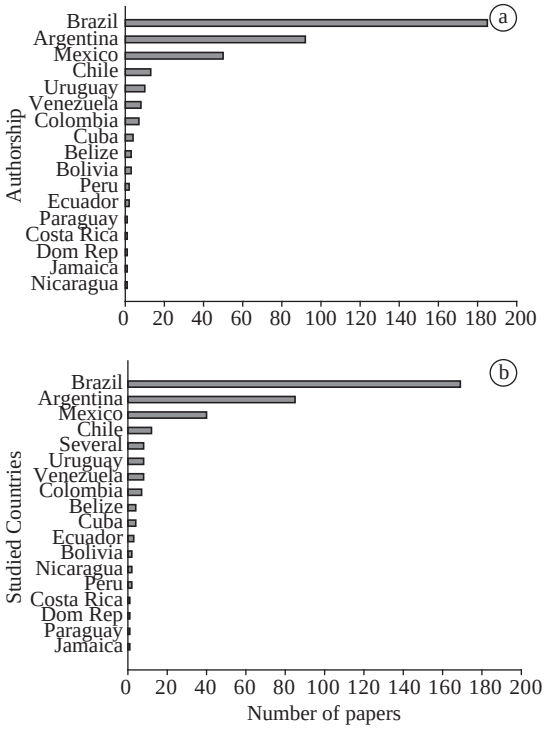


**Figure 2.** Distribution of a) authorship and b) country of study (n = 382) of studies concerning macrophytes in Neotropics. Dom Rep = Dominican Republic. Several = studies realized in more than one country.

Almost one third of the papers (147 out of 382) were done by researchers of at least two different countries (what indicates international cooperation). The country with more cooperation with Neotropical nations was the United States of America (n = 37, 25% of the papers) (Figure 3). This is not a surprise, since this is the country with more scientific expression worldwide (Hermes-Lima et al., 2007). In addition, USA is located in the same continent, what probably facilitates the cooperation with Neotropical countries. Melo et al. (2006) also showed that USA was the country with more cooperation in limnological articles published by Brazilians. Germany had also a large cooperation (n = 16, 11% of the papers) (Figure 3), probably due to the historical importance of this country in modern Limnology (Esteves, 1998). It is also interesting to note that Brazil had some cooperation with other Neotropical countries (n = 13, 9% of the papers) (Figure 3), highlighting the leadership of this country concerning publications about macrophytes in Neotropics. Besides Brazil, other seven Neotropical countries presented cooperation (Mexico, Argentina, Uruguay, Chile, Bolivia, Colombia and Ecuador), but all with relatively lower importance (<5% of the papers each) (Figure 3). This suggests that international cooperation of Neotropical countries among themselves is still not conspicuous and should be stimulated.

A great variety of journals (150) were used to publish studies on aquatic plants and "Hydrobiologia"

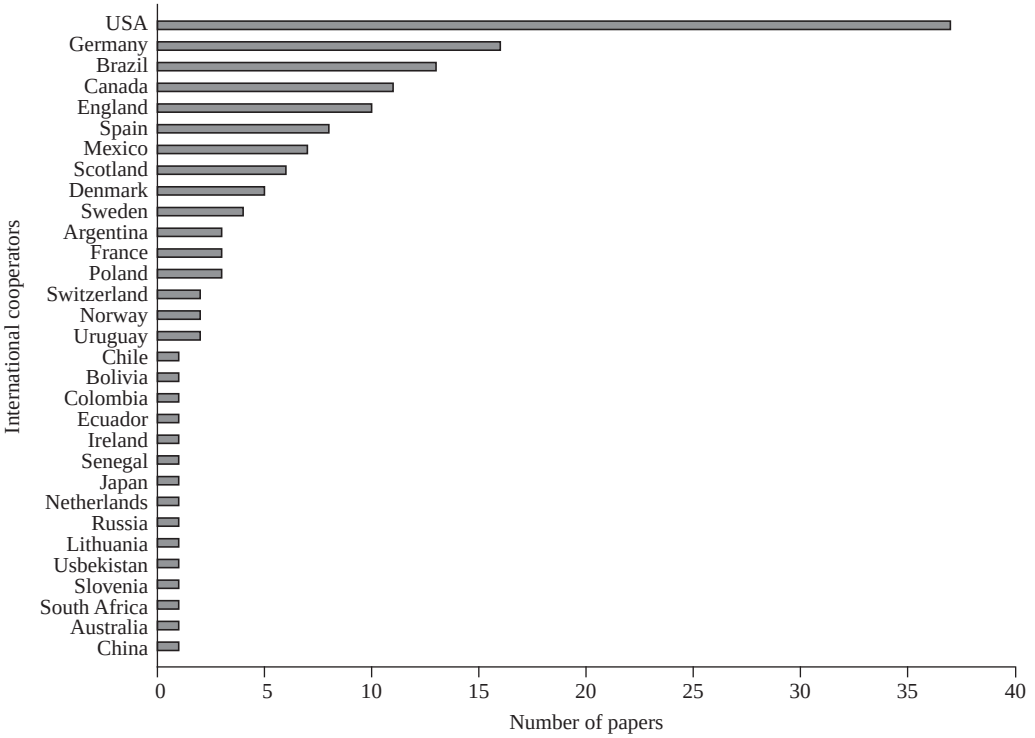


**Figure 3.** Countries that cooperated with studies about aquatic macrophytes realized in Neotropics (n = 147).

was the main one, publishing ca. 16% of the papers (Figure 4). This journal was also the favorite by international Brazilian articles on limnology until 2004 (Melo et al., 2006). Aquatic Botany was the second journal in number of papers concerning aquatic macrophytes in Neotropics (Figure 4). As it is a specific journal in the field, this seems to be the most reasonable choice. In spite of this, "Hydrobiologia", which publishes articles in all sub-fields of Limnology with no bias regarding organisms (Melo et al., 2006), had more papers about macrophytes in Neotropics. The great variety of journals suggests that aquatic plants have been studied for several purposes beyond biology or ecology. For example, there were some articles published in medical journals, since many species have been pointed as shelters for disease vectors, or even have been used in medicine.

Concerning the type of ecosystem investigated, almost a half of the studies were carried in wetlands (n = 119, 44% of the papers) (Figure 5). Wetlands are numerous and occupy large areas in Neotropics (Esteves, 1998) what can explain this tendency. These results indicate that studies with macrophytes are not biased toward more scarce or rare ecosystems, but they are rather carried in the most common type of ecosystem. Lakes and lagoons (n = 70, 26% of the papers) were other ecosystem types highly studied. In addition, although not informed in the abstracts, if we consider the studies carried in lagoons, we would possibly reach the conclusion that these habitats are shallows and located in wetlands. In fact, Esteves (1998) stressed the high abundance of floodplain shallow lagoons in Neotropics, compared to deep lakes, mostly found in temperate regions. Rivers (and streams) (n = 42, 15% of the papers) and reservoirs (n = 27, 10% of the papers) were at an intermediate position (Figure 5). Thomaz and Bini (2003) also recorded few articles studying aquatic macrophytes in Brazilian rivers. According to these authors, the variation in hydrological levels, high turbidity and flow velocity of Brazilian lotic ecosystems limit the development of macrophytes in river main channels, what is a probable cause for the small number of studies in these ecosystems. However, they emphasize that there are some fascinating exceptions, since the aquatic flora is well developed in some rivers (e.g. in the Serra da Bodoquena region;

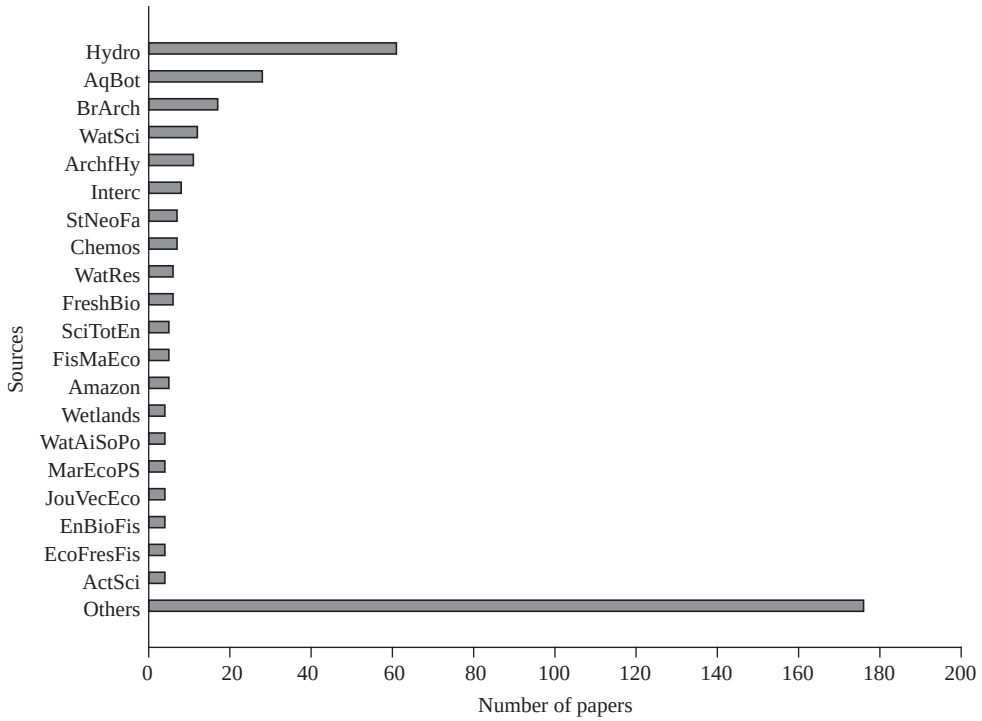


**Figure 4.** Journals indexed in Scopus and ISI used to publish studies concerning aquatic macrophytes in Neotropics between 1991 and 2007 (n = 382). Hydro = Hydrobiologia; AqBot = Aquatic Botany; BrArch = Brazilian Archives of Biology and Technology; WatSci = Water Science and Technology; ArchfHy = Archiv fur Hydrobiologie; Interc = Interciencia; StNeoFa = Studies on Neotropical Fauna and Environment; Chemos = Chemosphere; WatRes = Water Research; FreshBio = Freshwater Biology; SciTotEn = Science of the Total Environment; FisMaEco = Fisheries Management and Ecology; Amazon = Amazoniana-Limnologia et Oecologia Regionalis Systemae Fluminis Amazonas; WatAiSoPo = Water Air and Soil Pollution; MarEcoPS = Marine Ecology-Progress Series; JouVecEco = Journal of Vector Ecology; EnBioFis = Environmental Biology of Fishes; EcoFresFis = Ecology of Freshwater Fish; ActSci = Acta Scientiarum-Biological Sciences.

Scremin-Dias et al., 1999). The studies conducted in reservoirs are probably related to the problems that aquatic macrophytes cause due to excessive growth. Accordingly, excessive growth of aquatic plants in reservoirs has been extensively reported (Thomaz et al., 2003). Finally, few articles also studied aquatic macrophytes in marine environments (n = 13, 5% of the papers), artificial garden (n = 1, 0.4% of the papers) and cenotes (n = 1, 0.4% of the papers) (Figure 5). The low number of papers in marine environments is surprisingly, since Brazil has a wide coastal shoreline (more than 8,000 km wide) with a great variety of habitats (e.g. beaches, swamps, reefs, bays, coastal lagoons) that support high biological diversity (Ab'sáber, 2001).

Submerged, free-floating and emergent macrophytes received almost equal attention and were relatively more investigated than floating-leaved plants (n = 94, 30% of the papers; n = 91, 29% of the papers; n = 85, 27% of the papers; n = 11, 3% of the papers; respectively) (Figure 6). Submerged aquatic plants probably received high attention due to the important structuring role that this group provides in aquatic habitats (Jeppensen et al., 1998). Also, submerged, together with free-floating aquatic plants, are targets of interest in impacted habitats such as reservoirs, since they can cause serious troubles for energetic production and water use (e.g. Thomaz et al., 2003; Aguilar et al., 2003; Marcondes et al., 2003). Furthermore, free-floating aquatic macrophyte species are highly productive in suitable environments (Cook, 1990; Carignan and Neiff, 1994; Talling and Lemoalle, 1999). Emergent aquatic macrophytes are also highly studied, possibly due to the importance of this plants that may have extremely high primary production (Piedade et al., 1991).

The majority of studies using aquatic macrophytes were carried out following an ecosystemic approach (n = 69, 30% of the papers) (Figure 7). This could also be explained by the high importance of aquatic plant communities for the production of organic matter (Piedade et al., 1991). Additionally, the historical roots of limnology in Neotropical regions are strongly correlated to investigations about ecosystem processes and functioning (e.g. Neiff, 1990; Junk, 1997; Esteves, 1998). Studies at individual (n = 65, 25% of the papers) and community (n = 64, 24% of the papers) levels appeared with almost the same importance (Figure 7). Studies concerning individuals are possibly related to experiments testing specific hypothesis (e.g. Menone et al., 2005). On the other hand, studies at community level frequently aim to evaluated patterns in the distribution of the abundance and in the diversity of plant communities, as well as the environmental variables affecting these metrics (e.g. Rolon and Maltchik, 2005). These studies are essential nowadays, since they can support conservation efforts. However, taxonomic studies are still extremely scarce (only nine articles; Figure 7). This is strikingly, since taxonomy is a central issue for ecological and conservational researches (Brandon et al., 2005). Moreover, a reliable assessment of the biological diversity is only reached by improving taxonomical knowledge (Brandon et al., 2005). In fact, as mentioned earlier, Chambers et al. (2008) highlighted the problem of unknown species in tropical areas to species richness estimations.

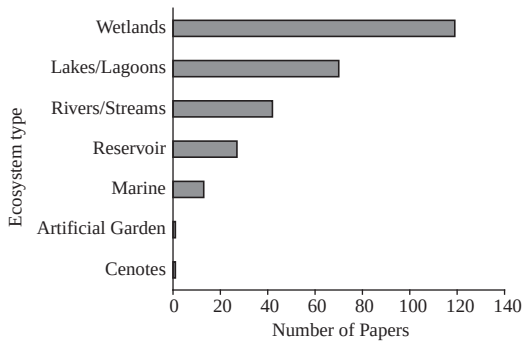


**Figure 5.** Ecosystem type studied in papers concerning aquatic macrophytes in Neotropics and indexed in Scopus and ISI between 1991 and 2007 (n = 273).

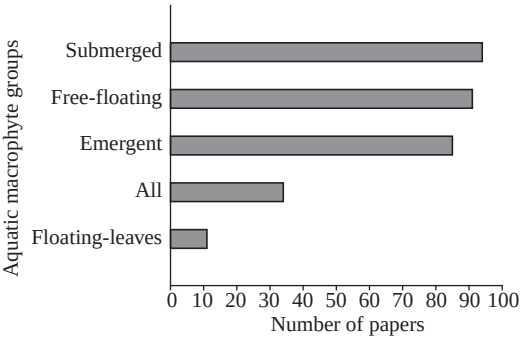


**Figure 6.** Number of studies carried out in Neotropical regions with different groups of aquatic plants (n = 315).

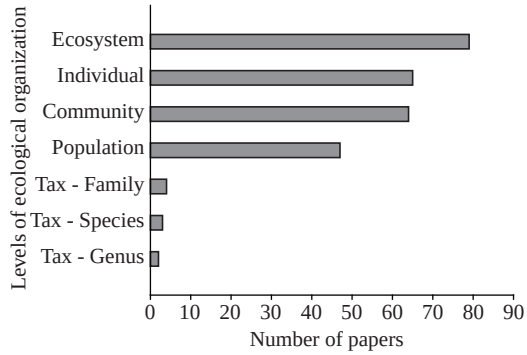


**Figure 7.** Level of ecological organization used in papers studying aquatic macrophytes in Neotropics and indexed in Scopus and ISI between 1991 and 2007 (n = 264). Tax – Family = taxonomic concerning family; Tax – Species = taxonomic concerning species; Tax – Generous = taxonomic concerning generous.

Surveys were the preferable approach in studies about aquatic plants in Neotropical regions (n = 254, 67% of the papers) (Figure 8). According to Peters (1991), theories/hypothesis is firstly generated through observational studies. The test of these hypotheses could be done by experiments could be then reached by experiments. Thus, our results concerning studies of macrophytes in Neotropics indicate that most investigations are still carried in a preliminary way. Accordingly, experiments that complement surveys on the knowledge construction, in any spatial scale, are still rarely carried (Experiment in microscale: n = 64, 17% of the papers; Experiment in mesoscale: n = 19, 5%; Experiment in macroscale: n = 19, 5%) (Figure 8). However, taxonomic studies, the basic step for any ecological study, are also scarce (n = 9, 2%) (Figure 8). In fact, Irgang and Gastal Jr (2003) pointed the lack of taxonomical studies in Brazil. These authors stress that this lead to several doubts about the geographic distribution of species and argue that investigations are essential to describe new species in threatened areas. Thus the study of aquatic macrophytes in Neotropical regions still needs basic researches to provide scientific progress. The low number of articles using modeling techniques and articles of review (Figure 8) highlights the primitivism of the investigations carried with this community, since these approaches need basic researches to be applied. Moreover, these approaches have a predictive power, and therefore, are also essential in conservation efforts (Pace, 2001).

Concerning the subjects investigated, the majority of studies evaluated the influences of environment (response to limnological features) on aquatic macrophyte populations and communities (n = 120, 31%) (Figure 9). This indicates the concern of the researches in identifying the main variables affecting aquatic plant growth, decomposition and community structure (e.g. Rolon and Maltchik, 2005; Padial and Thomaz, 2006). Additionally, these papers were also related to studies concerning the management and control of macrophytes. Influences of aquatic macrophyte on other communities was another subject highly investigated (n = 102, 24%) (Figure 9). This highlights especially the recognition of the role of aquatic plants as key components for the biodiversity of aquatic ecosystems (Jeppensen et al., 1998). Another subject highly investigated was the influences of aquatic macrophytes on the environment (n = 82, 21%) (Figure 9). The high attention of this subject reflects the recognition that macrophytes cause strong changes in aquatic ecosystems (e.g., changing water and sediment pH, concentrations of gases and nutrients) and to the common use of aquatic plants on waste water treatments (e.g. Henry-Silva and Camargo, 2006). Plant features (such as chemical composition) had an intermediate interest (n = 36, 8%) (Figure 9). The other subjects were all less studied (< 4%) (Figure 9). Again, it is interesting to note the scarcity of papers dealing with taxonomy (n = 8, 2%), community description (n = 11, 3%) and estimation of diversity (n = 2, 0.5%). This observation is shocking in Neotropical regions, since this region contain seven hotspots (global priority conservation areas) out of the 25 postulated by Myers et al. (2000) and the knowledge (or estimation) of biodiversity is essential to subsidize conservation efforts. Finally, it is also worth to note the lack of investigations directed to "hot" fields of Ecology, such as the impacts of invasive species, the role of plants as foundation species (mechanism of facilitation) and the debates on diversity-stability and diversity-ecosystem functioning, among others.

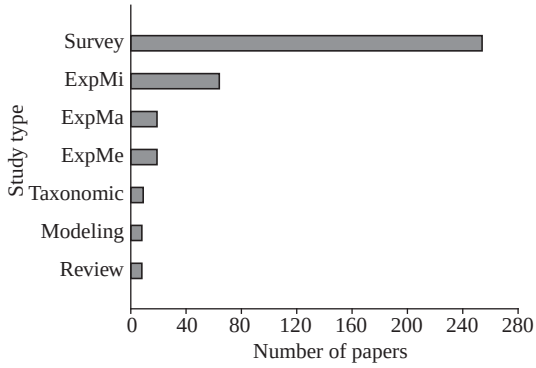


**Figure 8.** The number of papers on aquatic macrophytes published in the period 1991-2007 using different approaches (see classifications in Methods section; n = 381). ExpMi = Experiment in microscale; ExpMa = Experiment in macroscale; ExpMe = Experiment in mesoscale.

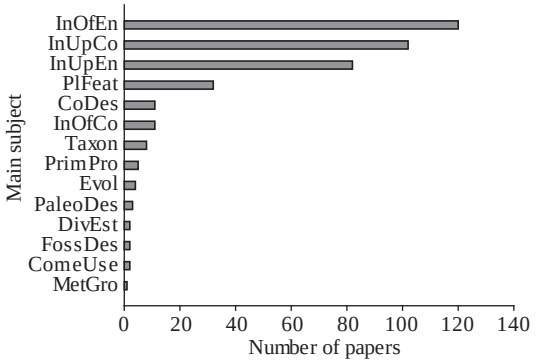


**Figure 9.** Main subjects of the papers concerning aquatic macrophytes in Neotropical regions (n = 382). InOfEn = Influences of the environment upon aquatic macrophytes; InUpCo = Influences of aquatic macrophytes upon other communities; InUpEn = Influences of aquatic macrophytes upon the environment; PlFeat = Plant Features; CoDes = Community Description; InOfCo = Influences of other communities upon aquatic macrophytes; Taxon = Taxonomy; PrimPro = Primary production; Evol = Evolution; PaleoDes = Paleoclimate description; DivEst = Diversity estimation; FossDes = Fossil description; ComeUse = Commercial use; MetGro = Methods to estimate growth rate.

The scientometrics research can be considered the area of research that utilizes information contained in publications to obtain a scientific output of its trends and lacks (Verbeek et al., 2002). Based on scientometrics, our investigation helped us to identify several patterns and gaps in the study of aquatic macrophytes in Neotropical regions. Despite the rapid growth in number of publications about this community, which was even faster than in other areas of limnology, there are relatively few articles and the majority of the studies were carried in a few countries. In addition, the cooperation among Neotropical countries is still scarce. In general, our analyses showed that the studies dealt mostly with the influences of aquatic macrophytes on organisms and abiotic features. Although these approaches are adequate for macrophytes, they usually lack a deeper conceptual framework necessary to be included in "hot" areas of Ecology. Together with these investigations, basic researches aiming to describe unknown species are also necessary. In consequence, studies with a predictive approach or aiming to test ecological hypothesis, essential to direct conservation efforts, are also rare. In fact, biodiversity inventories (a basic research) and the use of biodiversity surrogates (an approach to predict biological diversity) are the best ways to select priority areas for conservation (Bini et al., 2006). Hence, our results showed the paucity of studies on macrophyte biodiversity, essential to support conservation efforts and to subsidize further investigations testing ecological hypotheses.

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