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Scientometric analysis of energetic ecology: primary production of aquatic macrophytes

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ABSTRACT. The objective of this work was to perform a temporal quantitative analysis, using the scientometric technique, considering the number of citations that the terms *Primary Production of Aquatic Macrophytes* and *Energetic Ecology* received in a 50-year period (1956 to 2006). The study related 189 papers published in 26 magazines. It was verified that researchers of several nationalities are working on the proposed themes, with a predominance of those from developed countries (USA and Germany). In Brazil, production on these themes, although small, coincides with the results obtained for other themes analyzed using the same research technique. This fact indicates that greater efforts should be made in the search for more intense scientific production in the country, in the different areas of knowledge, especially in the object of this study.

Key words: energy flow, aquatic macrophytes, aquatic ecosystems, primary producers, scientific production.

RESUMO. Análise cienciométrica da ecologia energética: produção primária de macrófitas aquáticas. O objetivo deste trabalho foi o de realizar uma análise quantitativa temporal por meio da técnica de cienciometria, considerando o número de citações que os termos *Primary Production of Aquatic Macrophytes* e *Energetic Ecology* receberam num período de 50 anos (1956 a 2006). Foram relacionados 189 artigos publicados em 26 revistas. Constatou-se que pesquisadores de várias nacionalidades vêm trabalhando os temas propostos, com predomínio daqueles provenientes de países desenvolvidos (EUA e Alemanha). No Brasil, embora seja pequena, a produção dos temas é coincidente com o resultado obtido para outros temas analisados pela mesma técnica de pesquisa. Este fato indica que maior esforço deve ser realizado em busca de uma mais intensa produção científica no país, nas diversas áreas do conhecimento, em especial no objeto deste estudo.

Palavras-chave: fluxo de energia, macrófitas aquáticas, ecossistemas aquáticos, produtores primários, produção científica.

Introduction

The relationships among organisms are limited and controlled by energy flow (ODUM, 1988). Organisms acquire energy from food and use it to perform several activities, such as metabolism, growth and reproduction. Food availability and amount are responsible for the distribution of energy for the various physiological processes of aquatic organisms (DOURADO; BENEDITO-CECILIO, 2005).

Within an aquatic environment, macrophytes represent one of the major sources of organic matter (HENRY-SILVA; CAMARGO, 2005). Due to the concentrations of proteins, lipids and soluble carbohydrates in the cell wall of aquatic macrophytes, this type of vegetation is a diverse food source and favors the development of a microfilm composed of bacteria, protozoa and algae on its surface, which in turn is a primary food source for several phytophilous species. In addition to having a significant role in nutrient recycling, macrophytes provide substrate for consumers and decomposers, water circulation and sediment stabilization, also acting as accumulating filters and contributing to the production of detritus (PEIRÓ; ALVES, 2004).

In spite of the importance surrounding this theme, consistent evaluations have not yet been conducted regarding scientific production on this topic. To Macias-Chapula (1998), the advancement in knowledge produced by researchers must be transformed into information accessible to the scientific community. The objective of science is the production of new knowledge. In reality, science needs to be regarded as an ample social system, in which one of its functions is to disseminate knowledge. Among other tasks would be assuring the preservation of general standards and attributing credit and acknowledgement to works that have contributed to the development of knowledge in various fields. Currently, the most common manner of attributing credit and acknowledgement in science is in the form of citations. The journal article with its list of citations is – and will likely remain – the universally accepted vehicle through which the scientific institution records and publishes the results of its investigations (LIMA-RIBEIRO et al., 2007).

With the use of commercial citations in the last three decades, the importance of citations has gained a new dimension in scientific works. In everything related to science, bibliometric and scientometric indicators have become essential to the scientific community to estimate the state-of-the-art of a given topic (MACIAS-CHAPULA, 1998).

In order to define its ideas and terms, Spinak (1998) considers that bibliometrics comprises the application of statistical analyses to study the characteristics of the use and creation of documents, whereas scientometrics applies bibliometric techniques. Scientometrics may establish comparisons between investigative policies and countries by analyzing their economics and social aspects, and is a segment of the sociology of science, with applications in the development of scientific policies. The same author also affirms that scientometrics involves quantitative studies of scientific activities, including publication – thereby superseding bibliometrics.

One of the pioneering works involving scientometrics was conducted by Lotka (1926), who established the fundamentals of the inverse-square law, by affirming that the number of authors who make n contributions in a given scientific field is approximately 1 n^{-2} of those who make only one contribution, and that the percentage of those who make a single contribution is close to 60%. Since then, several studies have been performed to investigate the productivity of authors in various disciplines (ALVARADO, 2002).

The need to discuss the quality of science based on researcher experience and to establish evaluation criteria for financing gave birth to the formalization of indicators that take these questionings into account. Bibliometric indicators have been progressively adopted in the evaluation of scientific production quality and to establish policies of journal acquisition. Among the indicators, the impact factor (IF), defined by the Institute for Scientific Information (ISI), which is part of Thomson Reuters, has been the most used. Since the 1960s – with the creation of the *Science Citation Index* (*SCI*), the *Social Science Citation Index* (*SSCI*) and the *Arts and Humanities Citation Index* (*AHCI*) –, FI and other indexes have been the objects of generalized controversy and a few mistakes in their use (STREHL; SANTOS, 2002). Currently, the impact factor used to qualify articles and journals is that established by the *Journal Citation Reports* – JCR, which itself is also a product offered by Thomson Reuters.

As such, the studies that make use of scientific production indicators contribute to the knowledge of the researched communities. Such knowledge makes it possible to formulate input, development and research policies that are more adequate to the needs and reality of the various locales and areas of knowledge. In this context, the objective of this work is to perform a temporal quantitative analysis, using the scientometric technique, of the scientific production in the field of Energetic Ecology between 1956 and 2006, focusing on the role of aquatic macrophytes in primary production.

Material and methods

In order to identify the scientific production related to aquatic macrophytes over a period of 50 years (1956 to 2006), the Citation Index of the *General Search* routine was used in the Thomson Isi, Web of Science website, by means of the electronic address www.capes.gov.br. To search for works on aquatic macrophytes, two keywords were used: 1) *Primary Production of Aquatic Macrophytes* and 2) *Energetic Ecology* (as well as synonyms, such as *Bionergetic*) and *Aquatic Macrophytes* (as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*).

Following the search, the articles were grouped and analyzed graphically according to: (i) year of article publication; (ii) author nationality; (iii) author institution; (iv) journal in which the article was published, (v) publication format (article, review or note), (vi) synonyms (EEAP – Energetic Ecology and Aquatic Plant; BAV – Bionergetic and Aquatic Vegetation; BM – Bioenergetic and Macrophytes; EAP – Energetic and Macrophytes; EAV – Energetic of Aquatic Vegetation, and BRSAV – Bioenergetic related with submerged aquatic vegetation), and (vii) number of citations per author.

Results and discussion

According to the assessment, 189 articles related to the primary production of aquatic macrophytes were published in the period between 1956 and 2006 (Figure 1).

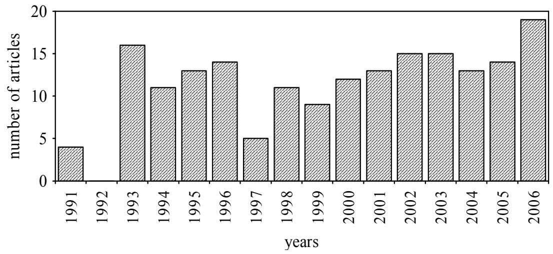

Figure 1. Absolute frequency of the number of articles published between 1991 and 2006 and which included the keyword *Primary Production of Aquatic Macrophytes* (N = 189).

The assessment was conducted for the period from 1956 to 2006, but the publications related to the subject began only in the 1990s. In the period between 1956 and 1989, no articles connected to the topic were published. It can be observed in Figure 1 that the greatest number of articles was published in 1993 and 2006; conversely, in 1991 and 1997 this number was lower, with four and five published works, respectively.

The publications related to the researched topic showed a growing trend in the number of published articles (Figure 1). In 1991, the first articles were published on the subject of primary production of aquatic macrophytes, which was possibly due to the lack of any methodology. In 1992, no articles were published, and in 1993, there was an increase in publications, a likely result of the increase and/or creation of research groups in this field.

The works were published by authors from 30 different nationalities (Figure 2).

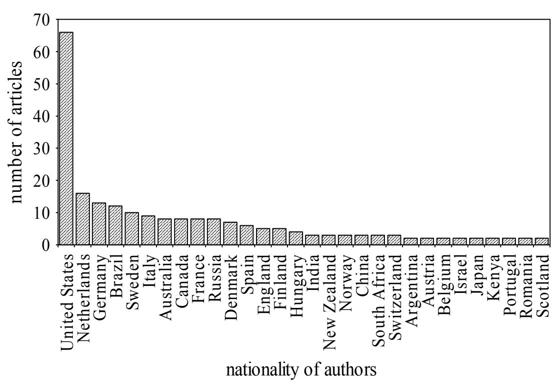

Figure 2. Nationality of authors who published articles containing the keyword *Primary Production of Aquatic Macrophytes*, between 1956 and 2006.

However, 35% were developed by authors from the United States of America. Only 12 studies, corresponding to 6.4%, were published by Brazilians. Nevertheless, this number is higher that those of certain developed nations, such as Italy and Canada. Similar results were observed by King (2004), who highlighted that Brazilian scientific output, in Thomson Isi, is ahead of some countries belonging to the G8 (group of the eight richest nations) and some countries in the European Union. Lima-Ribeiro et al. (2007) justified the small contribution from Brazilians compared to American researchers as a result of the low investment in research. Efforts have intensified only in the last few years, through federal agencies, as very few states in Brazil have foundations that assist and give support to research developed within their states.

Among the 21 institutions, the authors with the highest number of articles (five each – 8.0%) belong to the Institute of Florida University, the Ohio University and the Russian Academy of Sciences (Figure 3). It should be highlighted that, among Brazilian institutions, the Federal University of Rio de Janeiro is placed in the second tier of institutions with the highest number of scientific production, while the Federal University of Minas Gerais is placed in the third tier.

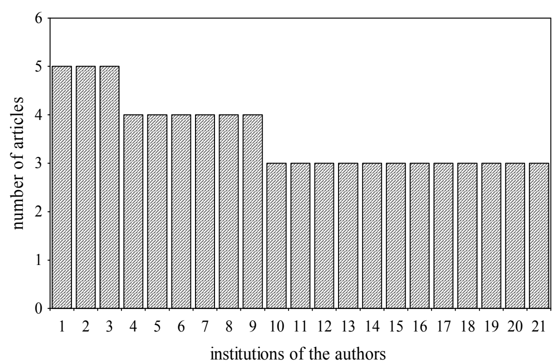

Figure 3. Institutions of the authors of published articles including the keyword *Primary Production of Aquatic Macrophytes*, between 1956 and 2006 (N = 189). 1 = Institute of Florida University; 2 = Ohio Univeristy; 3 = Russian Academy of Sciences; 4 = Hungarian Academy of Sciences; 5 = Netherlands Institute of Ecology ; 6 = Federal University of Rio de Janeiro; 7 = University of Parma; 8 = South Carolina University; 9 = Uppsala University ; 10 = CSIRO Land and Water; 11 = Griffith University; 12 = Institute of Ecosystem Studies; 13 = National Institute for Resources and Environment; 14 = Rutgers University; 15 = Aarhus University; 16 = University of Copenhagen; 17 = Federal University of Minas Gerais; 18 = Florida University; 19 = University of Helsinki; 20 = University of Rostock; 21= University of Wyoming.

The analyzed articles were published in 26 different periodicals. Of these, however, 12 journals had less than four published articles. The majority of articles were published in the journals *Hydrobiologia* (16.9%; 32), *Aquatic Botany* and *Freshwater Biology* (6.9%; 13 each), followed by *Marine Ecology Progress Series* (3.7%; 7) (Figure 4a).

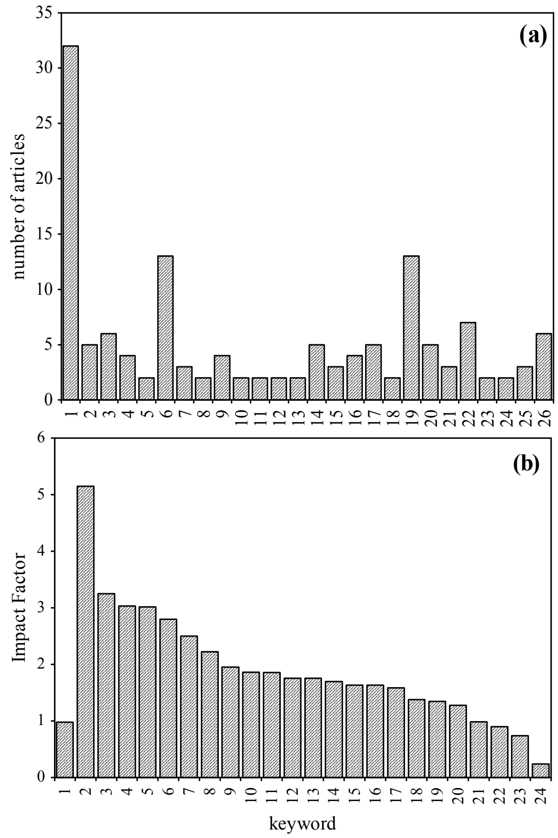

Figure 4. (a) Number of published articles (N = 189) including the keyword *Primary Production of Aquatic Macrophytes*, per journal, for the period 1956-2006. (b) Impact Factor of journals. 1 = *Hydrobiologia*; 2 = *Ecology*; 3 = *Limnology and Oceanography*; 4 = *Oecologia*; 5 = *Water Research*; 6 = *Freshwater Biology*; 7 = *Journal of Phycology*; 8 = *Science of the Total Environment*; 9 = *Canadian Journal of Fisheries and Aquatic Sciences*; 10 = *Bioresource Technology*; 11 = *Biogeochemistry*; 12 = *Marine Biology;* 13 = *Marine and Freshwater Research;* 14 = *Ecological Modelling;* 15 = *Estuarine Coastal and Shelf Science;* 16 = *Estuaries;* 17 = *Journal of the North American Benthological Society;* 18 = *Ambio;* 19 = *Aquatic Botany;* 20 = *Wetlands;* 21 = *Ecological Engineering;* 22 = *Marine Ecology Progress Series;* 23 = *Vegetation;* 24 = *Biologia;* 25 = *Environmental Toxicology and Chemistry;* 26 = *Archiv Fuer Hydrobiologie*

Figure 4b shows the impact factor of journals to which the 189 articles on primary production of aquatic macrophytes belong. It was observed that, although the journal *Hydrobiologia* featured the highest number of published articles, it had a lower impact factor than other periodicals, such as *Ecology* (five published articles), which had the highest impact factor among all 26 researched journals.

Among the observed journals, seven of them have an impact factor greater than two; for 12 others, the impact factor is above one. Therefore, the majority of articles were published in journals with lower impact factor.

The format of most publications is of scientific articles, strongly encouraged among researchers, as only seven publications were found in the form of review and two as scientific notes (Figure 5). This result may be related with a greater ease of publishing, as well as with the clarity in information disclosed on the topic. It was further observed that all publication formats were in the same language, English. This result coincides with those found by King (2004), who verified that English-speaking countries publish most prolifically, thus influencing others nations.

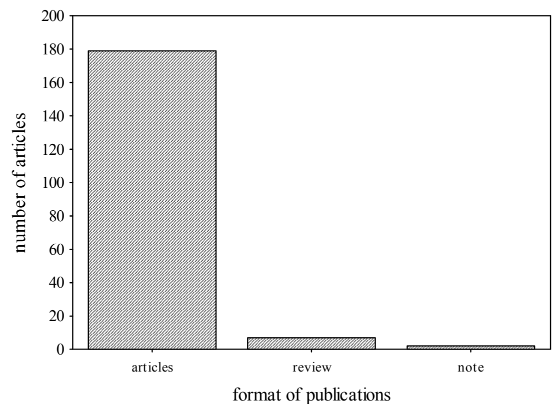

Figure 5. Publication formats (article, review and note) using the keyword *Primary Production of Aquatic Macrophytes* (N = 189), between 1956 and 2006.

In regards to the second keyword – *Energetic Ecology* (as well as synonyms, such as *Bionergetic*) and *Aquatic Macrophytes* (as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*) – a second search was conducted, with the objective of quantifying the production and dissemination of scientific communications on the theme suggested for this study (Figure 6).

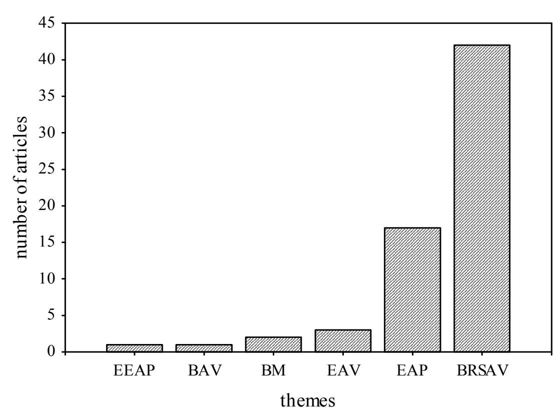

Figura 6. Themes used in the search for articles related to Energetic Ecology of Aquatic Macrophytes: (EEAP) – Energetic Ecology and Aquatic Plant; BAV – Bioenergetic and Aquatic Vegetation; BM – Bioenergetic and Macrophytes; EAP – Energetic and Macrophytes; EAV – Energetic of Aquatic Vegetation e BRSAV – Bioenergetic related with submerged aquatic vegetation.

According to the assessment, 66 articles were published, with one article for themes EEAP and BVA, two articles for BM, three for EAV, 17 for EAP and 42 articles using BRVA. The results showed that, by inputting several keyword-expressions, few works appeared on the topic of Energetic Ecology of Aquatic Macrophytes.

The first articles on the theme were published in 1974, followed by a pause in production for a period of three years, when another article was published in 1977. Only in 1994 did research studies in this field become more consistent, increasing the number of publications. In 2002, there were a greater number of articles published in the aforementioned journals, with a significant decrease in 2005, featuring only two articles (Figure 7). The results of the present work demonstrate this condition of difficult communication which took place in science. However, according to Macias-Chapula (1998), the policies of publications offered by database dealers tend to limit research (in different fields), by giving researcher access to a limited number of periodicals indexed in the databases with higher impact.

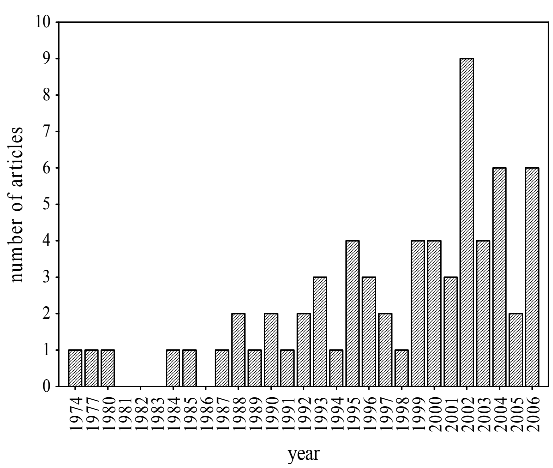

Figure 7. Distribution of the number of published articles (N = 66), between 1956 and 2006, using the keywords *Energetic Ecology* (as well as synonyms, such as *Bionergetic*) and *Aquatic Macrophytes* (as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*).

Articles on the theme Energetic Ecology of Aquatic Macrophytes (and synonyms) were published by researchers from 13 nationalities. The United States of America were the country with the highest number, with 37 articles; followed by Germany, with nine; and Spain, with four articles (Figure 8). In the Thomson Isi source, Brazil contributed with only one article.

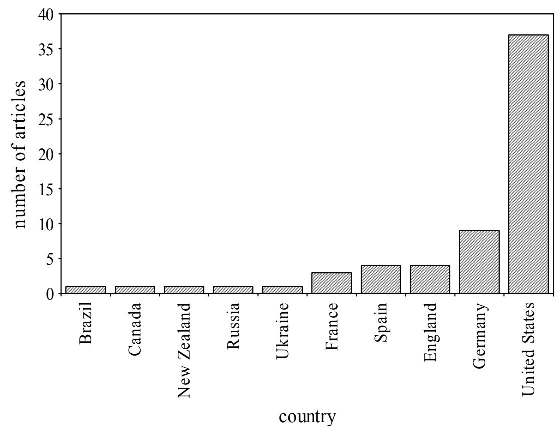

Figure 8. Nationality of authors (N = 66) who published articles between 1956 and 2006, using the keywords *Energetic Ecology* (as well as synonyms, such as *Bionergetic*) and *Aquatic Macrophytes* (as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*).

It is worth mentioning that studies focusing on Energetic Ecology are still scarce in Brazil. Few are the works that seek to establish relationships between energy and the ecology of animal and vegetal organisms in their natural environment. Several studies have focused on experiments that aim to maximize animal production for human consumption (CALDARA et al., 2008; DENADAI et al., 2008; JOMORI et al., 2008). Regarding aquatic macrophytes, several studies have been conducted until now on taxonomy, ecology and management, but very few of them approach (quantitatively) the topic of energy and its role in the transfer of energy in aquatic ecosystems.

All scientific production elaborated by an institution or a single researcher circulates through scientific literature, or through informal or formal communication channels. The theme in study was published in 39 scientific journals. The periodicals *Hydrobiologia*, *Transactions of the American Fisheries Society* and *Biochemie und Physiologie der Pflanzen* contributed the most to disseminate the results of the studied theme (*Energetic Ecology* as well as synonyms, such as *Bionergetic*; and *Aquatic Macrophytes* as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*) (Figure 9). These results did not differ from those found in the first theme, in which the journal *Hydrobiologia* also obtained a significant index – although with low impact, as previously mentioned. Perhaps, the demand for publication in that journal is related to the scope of the journal, which offers a broad spectrum of themes to be published, when compared to the other periodicals.

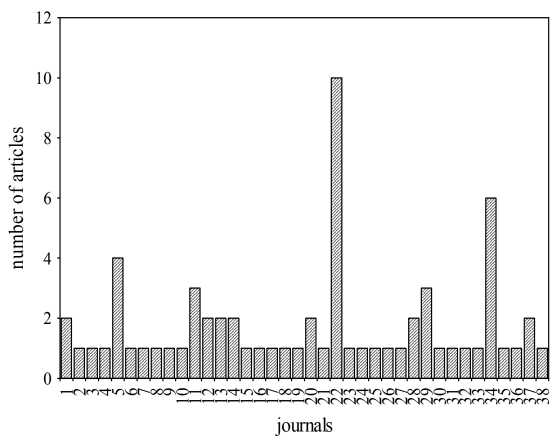

Figure 9. Journals in which articles were published, between 1956 and 2006, using the keywords *Energetic Ecology* (as well as synonyms, such as *Bionergetic*) and *Aquatic Macropytes* (as well as synonyms, such as *Aquatic Plant* and *Aquatic Vegetation*) (N = 66). 1 = *Annual Review of Entomology*; 2 = *Applied Soil Ecology*; 3 = *Ardeola*; 4 = *The AUK*; 5 = *Biochemic and Physiologie der Pflanzen*; 6 = *Canadian Journal of Fisheries and Aquatic Sciences*; 7 = *Drum. Umd. Edu.*; 8 = *Ecología, Manejo y Conservación de los Humedales*; 9 = *Ecological Applications*; 10 = *Ecology*; 11= *Ecology of Freshwater Fish*; 12 = *Ecotoxicology and Environmental Safety*; 13 = *Environmental Biology of Fishes*; 14 = *Environmental Toxicology and Chemistry*; 15 = *Estuaries*; 16 = *Evolutionary Ecology*; 17 = *Fish and Fisheries*; 18 = *Fisheries*; 19= *Fisheries Research*; 20 = *Freshwater Biology*; 21 = *FS Phase Ecological*; 22 = *Hydrobiologia*; 23 = *Environmental Biology of Fishes*; 24 = *Journal of Freshwater Ecology*; 25 = *Journal of Crustacean Biology*; 26 = *Journal the North American Benthological Society*; 27 = *Limnology and Oceanography*; 28 = *Marine Ecology Progress Series*; 29 = *North American Journal of Fisheries Management*; 30 = *Oceanology*; 31 = *Plant Biology*; 32 = *Physiology Biochemical Zoology*; 33 = *The Journal of Animal Ecology*; 34 = *Transactions of the American Fisheries Society*; 35 = *Water Science and Technology*; 36= *Weed Science*; 37 = *Wetlands Ecology and Management*; 38 = *Zhurnal Obshchei Biologii*

Within the scientific field, Macias-Chapula (1998) affirms that the most common form of giving credit and acknowledgment to science is through the number of citations an article receives. Thus, commercial citation indexes have appeared in the last few decades, creating a new dimension in the scientific field. A bibliographic citation is the expression of a relationship between two documents – citing and cited. It is therefore fundamentally important to have fair policies that allow greater access to information by whoever makes the citation, and higher visibility for quality periodicals so they can be cited by the scientific community. In that aspect, developing and non-English speaking countries must make efforts to fully encourage researchers to publish and have their periodicals valued by the international community.

It is concluded that based on the scientometric approach, science can be portrayed by the results achieved in each field. The advancement of knowledge produced by researchers must be transformed into information that is accessible to the scientific community. Thus, science is a social process, and research is developed within a context of exchange. In regards to the aforementioned themes, there is much yet to be done, and the field of research is fertile. However, the working locale must be prioritized and science needs to be regarded as an ample social system.

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