



SPECIAL ARTICLE

Bibliometry of Costa Rica biodiversity studies published in the *Revista de Biología Tropical/International Journal of Tropical Biology and Conservation* (2000-2010): the content and importance of a leading tropical biology journal in its 60th Anniversary

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Abstract: Central America is recognized as a mega diverse “hot-spot” and one of its smaller countries, Costa Rica, as one of the world’s leaders in the study and conservation of tropical biodiversity. For this study, inspired by the 60th anniversary of the journal *Revista de Biología Tropical*, we tabulated all the scientific production on Costa Rican biodiversity published in *Revista de Biología Tropical* between 2000 and 2010. Most articles are zoological (62%) and 67% of authors had only one publication in the journal within that period. A 54% of articles were published in English and 46% in Spanish. A 41% of articles were written in collaboration among Costa Rican institutions and 36% in collaboration with foreign institutions. The Collaboration Index was 2.53 signatures per article. Visibility in American sources was 56% in *Google Scholar* and 42.66% in the *Web of Science*, but the real visibility and impact are unknown because these sources exclude the majority of tropical journals. *Revista de Biología Tropical* is the main output channel for Costa Rican biology and despite its small size, Costa Rica occupies the 10th. place in productivity among Latin American countries, with productivity and impact levels that compare favorably with larger countries such as Brazil, Mexico, Argentina and Chile. *Rev. Biol. Trop.* 60 (4): 1405-1413. Epub 2012 December 01.

Key words: research trends, bibliometry, biodiversity, Costa Rica.

All of Central America is recognized as a mega diverse “hot-spot” and one of its smaller countries, Costa Rica, is among the world’s leaders in the study and conservation of Tropical biodiversity, was well as one of the best studied Latin American countries from the point of view of scientometrics (Monge-Nájera & Ho 2012). In number of species per area, Costa Rica is among the 20 most diverse countries in the world: with 0.03% of the global land area, it has 4.7% of the described species; with 0.16% of the world’s oceans, Costa Rica has 3.5% of the known diversity of coastal marine species. But these numbers are a fraction of the total: of an estimated million species found

in Costa Rica, only 19% have been described (SINAC 2009).

The bibliometric study of scientific research in Costa Rica began in 1988 with a study by Monge-Nájera & Díaz about the 35 first years of the journal *Revista de Biología Tropical* a study that pioneered the use inferential statistics to test quantitatively defined hypotheses (Monge-Nájera & Díaz 1988). Two years later Barrientos & Monge-Nájera (1990) analyzed a total of 1 529 articles published between 1950 and 1989 in the journal *Turrialba*. Their study about that once important and now discontinued journal found that the most frequent subjects were physiology and

plant pathology, followed by soil science and agronomic techniques.

Other studies covered the scientific publications from Costa Rica included in the *Science Citation Index* (SCI). Lomonte & Ainsworth (2000) analyzed the years 1980-1998 and collected a total of 1936 references, distributed in 627 journals. They found an average annual increase of 5.8% (i.e. around 150 publications) per year in the last 3 years of that period. A follow-up studied for the period 1999-2001 found that 19 % of the articles in that index had been published in *Biología Tropical* (Lomonte & Ainsworth 2002). A later study about productivity (not impact) used *Biological Abstracts* instead as the source for publication data because the *Biological Abstracts* have a better coverage of journals that publish articles on tropical ecosystems and organisms (Monge-Nájera & Nielsen 2005). Unfortunately, a full index of impact for Latin American journals and for other tropical journals does not exist and even the *Biological Abstracts* study is based on incomplete data because that index does not include all tropical journals. In Latin America, which in the *Biological Abstracts* sample leads the world's production of tropical biology papers, the most productive countries were Argentina, Chile and Costa Rica; a second block included Uruguay, Brazil, Cuba, Mexico, Panama and Puerto Rico (Monge-Nájera & Nielsen 2005).

In contrast with the common practice of trying to extract patterns from large statistical samples of scientists, a more recent study relied on a very different approach by presenting an in-depth analysis of an individual science career: that of Luis Diego Gómez Pignataro. Gómez was one of the outstanding Latin American botanists of the 20th century according to Bohlen (1993), and his productive career that covered 39 years (1968-2009) was studied by Monge-Nájera *et al.* based not only in productivity but also on the personal life events through which Gómez lived (2010). The bibliometric analysis of his publications found that he produced 222 articles, in a total of 37 journals, mainly *Brenesia*, *Revista de Biología*

Tropical, *American Fern Journal* and *Phytologia* and that he did not fit well into the expected patterns of how personal life affects scientific productivity (Monge-Nájera *et al.* 2010).

For *Revista de Biología Tropical*, the journal analyzed in the present article, the first bibliometric study was done about a quarter of a century ago and covered the period 1953-1987, when the most frequent subjects were animal taxonomy, human biology (including medicine), ecology and animal behavior; the articles on botany were less frequent and were mainly related to morphology and taxonomy (Monge-Nájera & Diaz 1988).

There is also a bibliometric study on marine biology (1953-2002) that found 637 articles published in the *Revista de Biología Tropical*. Marine biodiversity represented 27% of the total output for the period, with an important increase in later years. The most frequent subject during this period was ecology, followed by biogeography, parasitism, taxonomy, fisheries and aquaculture. Coral reefs and mangroves dominated the study of marine ecosystems in that period, and the most frequent taxonomic groups were fish, mollusks, crustaceans and annelids (Cortés & Nielsen 2002).

This study, inspired by the 60th anniversary of the journal *Biología Tropical*, updates our bibliometric knowledge for the subject of biodiversity in the decade 2000-2010.

MATERIALS AND METHODS

Study material: We tabulated all the scientific production on Costa Rican biodiversity in *Revista de Biología Tropical* (www.biologiatropical.ucr.ac.cr) between 2000 and 2010 (normal issues and supplements). We included feature articles and brief communications.

Data analyzed: To analyze the visibility of all items in American sources we checked *Google Scholar* and the *Web of Science* during July and August 2010.

Bibliometric indicators: We studied the production of articles by year of publication,

author, affiliation, country, language and topic. We applied the bibliometric indices of collaboration (IC: number of authors per item/total articles, i.e. mean authors per item) and productivity based on Lotka (IP logarithm of the number of original articles that identify the authors in productivity levels, small: with 1 item and a PI equal to zero, medium: 2 to 9 items with IP zero and less than 1, and large producers: 10 or more IP contributions greater than 1).

Data analysis: We created a data base in ProCite 5.0 to record, identify and quantify total production, citation and affiliations. Each author received all the affiliations reported in the total of articles, to consider changes in their working relationships over time. We identified the country by location of affiliation, and included language and author for the IC.

Biodiversity articles are defined here as those reporting about ecosystems or species, and those that analyze the scientific production related to biodiversity of Costa Rica. Genetic articles were excluded except when the genetic analysis was used to measure some aspect of biodiversity. All items were classified by subject (see below for list).

To ensure the quality of the data, we did a normalization process for entries of authors and affiliations as far as sources allowed.

RESULTS

Bibliometry

The total production of the journal during the study period was 1 590 items, of which 23.63% met our definition of biodiversity.

A 62.41% of articles have the descriptor Animals (including invertebrates and vertebrates), 28.93% Plants, Algae 2.73%, Bacteria 2.51%, Fungi 1.14%, Virus 1.37% (6) and Lichens 0.91%. Each article could have several descriptors, for example, of 274 mentioning Animals, only 225 were exclusively zoological, the rest also referred to plants. Of 127 plant articles, only 82 were exclusively botanical. According to subject we found that 133 papers were on Zoology (72 taxonomic), 129 on Ecology, 46 on Botany (12 taxonomic) and the rest had less than 20 articles: Biochemistry 16, Prospecting and Ethology 13 each, Microbiology and Genetic Diversity 6 each. Others (Evolution, Bibliometric studies, Paleontology, Paleocology and Biogeography) had a total of 10 papers. The total of taxonomic studies was 151 (72 Zoology, 12 Botany and 67 other).

Rather than showing a steady increase, the total output of articles in the journal has two “waves” that begin in 2001 and 2008 (Fig. 1). The number of articles on biodiversity follows the same pattern, indicating that each volume

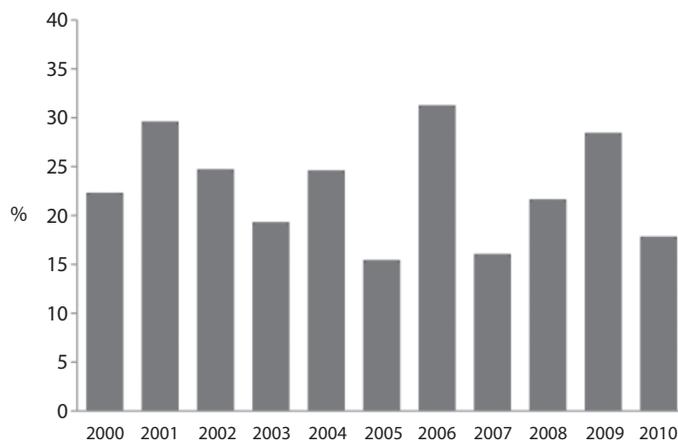


Fig. 1. Proportion of articles on the biodiversity of Costa Rica in *Revista de Biología Tropical* by year of publication.

as a relatively steady proportion of articles that deal with biodiversity (Fig. 1).

The 375 items on the biodiversity of Costa Rica were written by 509 authors who published between 1 and 25 items during this decade (2000-2010).

A 66.79% of authors had only one publication, 31.82% had 2-9 and only 1.37% had more than ten publications. Individually 340 authors have published at least one article on the biodiversity of Costa Rica in the journal, there are 85 authors with two articles, 25 with three and 26 with four, representing 93.51% of total productivity (Table 1). This shows that publications do not usually involving many authors and that knowledge about biodiversity in the country is generated mostly by many authors with low productivity in the journal.

The most prolific authors are Jorge Cortés Nuñez, who published 26 articles and has a 1.40 PI, Alvaro Morales Ramírez, with 13 items and a PI of 1.11, Mayra Montiel Longhi, with 11 articles and a PI of 1.04 and closing this level with ten items each: Ana Mercedes Espinoza Esquivel, Luko Hilje Quirós, Julián Monge-Nájera and María Ethel Sánchez-Chacón with a PI of 1 (Table 2).

Of the seven top prolific authors six are affiliated with the University of Costa Rica (UCR) and of these, four are with the Centro

TABLE 1
Productivity Index (PI) distribution of the 509 authors who published at least one article about biodiversity in the decade 2000-2010 in *Revista de Biología Tropical*

No. articles	No. authors	IP (log10)
1	340	0
2	85	0.3
3	25	0.48
4	26	0.6
5	7	0.7
6	8	0.78
7	4	0.85
8	3	0.9
9	4	0.95
10	4	1
11	1	1.04
13	1	1.11
25	1	1.40

de Investigación en Ciencias del Mar y Limnología (CIMAR).

Affiliations and language

The authors recorded 274 domestic and foreign institutions in their affiliations. These included universities, national and foreign private organizations and the Smithsonian Institution (Table 3).

Of the 509 authors, 56.38% only reported national affiliations, 5.34% list both Costa

TABLE 2
Authors with more articles on the biodiversity of Costa Rica (*Revista de Biología Tropical*)

Nº. of articles	Authors	Affiliations	Country of affiliations
25	Cortés Nuñez, J.	UCR. CIMAR • UCR Escuela de Biología • The Nature Conservancy	CR - US
13	Morales Ramírez, A.	UCR. CIMAR • UCR. Escuela de Biología • UCR. Sede del Pacífico	CR
11	Montiel Longhi, M.	UCR. Escuela de Zootecnia • UCR. Centro de Investigación en Estructuras Microscópicas -CIEMIC	CR
10	Espinoza Esquivel, A.M.	UCR. CIBCM; UCR. Escuela de Biología	CR
	Hilje-Quirós, L.	CATIE. Departamento de Agricultura y Agroforestería. Unidad de Fitoprotección	CR
	Monge-Nájera, J.	UCR. Revista de Biología Tropical • UNED. Centro de Investigación Académica	CR
	Sánchez-Chacón, M.E.	UCR. CIMAR; UCR. Escuela de Biología	CR

TABLE 3
Number of national and international affiliations in articles about the biodiversity of Costa Rica
(*Revista de Biología Tropical*)

Affiliations by author	Affiliations in Costa Rica only	Affiliations in Costa Rica and abroad	Affiliations abroad only	Total authors
1	236	0	172	409
2	40	16	10	65
3	8	9	1	18
4	3	1	1	5
5	0	1	0	1
Without stated affiliation				11
Total	287	27	184	509

Rican and foreign institutions, and 36.14% only foreign institutions. Only eleven authors failed to report their affiliation.

Of a total of 529 affiliations, 312 are from Costa Rica, 111 USA, 24 Mexico, 14 Germany, 11 Spain, 8 Italy, 8 Panama, 6 Great Britain, 4 Cuba and 4 Brazil. Guatemala, Colombia, Sweden and Australia appeared in three cases; Peru, Puerto Rico, Venezuela, Argentina and Norway in two cases, and El Salvador, Uruguay, Dominican Republic, Chile and China had only one case in the affiliations (Table 3).

Costa Rican institutions with the most affiliations were: Escuela de Biología (UCR) with 83, Centro de Investigación en Ciencias del Mar y Limnología (CIMAR, UCR) 37, Centro de Investigación en Biología Celular y Molecular (CIBCM, UCR) 26, Escuela de Ciencias Biológicas (UNA) 25, Facultad de Microbiología (UCR) 19 and Instituto Nacional de Biodiversidad (INBio) 14. The following institutions had ten affiliations each: Centro de Investigación en Enfermedades Tropicales (CIET, UCR), Centro de Investigación en Productos Naturales (CIPRONA, UCR) y Programa de Posgrado en Biología (SEP, UCR). The foreign institutions with most affiliations were: Instituto de Ecología de la Universidad Nacional Autónoma de México 9, Instituto Smithsonian de Investigaciones Tropicales (Panamá) and Associated College of the Midwest (Estados Unidos) 7 each, Università degli Studi di Firenze, Dipartimento di Biologia Vegetale (Italy) and University of Bremen,

Center for Tropical Marine Ecology (ZMT, Germany) six each.

A 54.4% of articles were published in English, 45.6% in Spanish and one item is fully bilingual (Spanish-English).

Collaboration Index and other collaboration

The IC ($IC=f/a$, where $f=N^{\circ}$. of signatures $a=N^{\circ}$. of articles) is 2.53 signatures per article. One fifth (22.66%) of articles are signed by a single author (Table 4).

A 77% of articles with written in collaboration with authors from other institutions, 41% with other Costa Rican institutions and 36% with foreign institutions.

TABLE 4
Collaboration Index (CI) for articles on the biodiversity of Costa Rica (*Revista de Biología Tropical*)

Signatures per article	Number of articles (a)	Number of signatures (f)
1	86	86
2	140	280
3	78	234
4	40	160
5	16	80
6	6	36
7	3	21
8	4	32
9	1	9
10	1	10
Total	375	948

Visibility

A 56% of articles appear with citations in Google Scholar and 42.66% in the Web of Science (Table 5).

The most cited article during the study period in Google Scholar was "Introduction to Physidae (Gastropoda: Hygrophila); biogeography, classification, morphology" published by Dwight W. Taylor in 2003. In the Web of Science, the most cited article was "The function of female resistance behavior: Intromission by male coercion vs. female cooperation in sepsid flies (Diptera: Sepsidae)" by W. Eberhard in 2002 (Table 6). However, these are incomplete data because both Google Scholar and Web of Science do not properly cover tropical journals and because citation was updated only to August 2010. The true impact of all articles published in tropical biology journals remains unknown for lack of an index that covers them.

TABLE 5
Citation in Google Scholar and Web of Science for articles on the biodiversity of Costa Rica (*Revista de Biología Tropical*)

N.º of times cited	N.º articles in Google Scholar	N.º articles in Web of Science
1	63	60
2	34	37
3	38	20
4	17	16
5	17	7
6	5	5
7	10	2
8	4	1
9	7	4
10	3	2
11	0	1
12	2	0
13	1	0
15	2	1
16	1	0
20	2	0
21	0	1
23	2	1
34	1	0
43	0	1
56	1	0
Total	210	159

DISCUSSION

According to *Biosis*, over the past three decades the most studied taxa, by far were species from the animal kingdom (67%), followed distantly by plant species (37%). This value for animals was 11 times higher than for fungi (6%) and 30 times higher than for microorganisms (2%). Among animals, the groups better represented in the biodiversity output were the invertebrates, especially arthropods (Michan & Llorente-Bousquets 2010). These values are very close to our own results for animals (62%), plants (32 %) and microorganisms (3%).

The peaks of productivity in the *Revista* can be explained by the occasional production of marine ecosystem supplements, that are made basically of biodiversity articles. These supplements are of two basic types, monographic collections produced by CIMAR, the University of Costa Rica's Marine and Fresh Water Research Center, and by the Association of Marine Laboratories of the Caribbean (AMLC).

The production of most information by authors of few articles is a common pattern in science, possibly explained by the fact that many articles result from student dissertations. Many students go to different activities after graduation and disappear from the records of scientific publication. Their professors tend to be coauthors when the dissertations are published, and thus appear for many years in the literature and become recognized authorities. Of course, this is not the only cause for their productivity and there are exceptions to this pattern.

Our results are in agreement with the 2012 *CIMAR* data, which identified coral reef ecologist Jorge Cortés Núñez as the most productive researcher of this center with 68 scientific papers (*CIMAR* 2012 unpublished analysis of internal database).

English clearly dominates the scientific literature. Other languages do not reach 2% of the biological papers included in *Biological Abstracts*, July-December 2002 edition

TABLE 6

Most cited papers in Google Scholar and Web of Science, biodiversity of Costa Rica (*Revista de Biología Tropical*)

No. of times cited in Google Scholar	No. of times cited in Web of Science	Article in <i>Revista de Biología Tropical</i>
56	22	Taylor, Dwight W. 2003. Introduction to Physidae (Gastropoda: Hygrophila); biogeography, classification, morphology. Vol 51 (Supl 1): 1-287.
33	43	Eberhard, William G. 2002. The function of female resistance behavior: Intromission by male coercion vs. female cooperation in sepsid flies (Diptera: Sepsidae). Vol 50 (2): 485-505.
23	23	Saravia-Otten, Patricia; Rojas-Umaña, Ermila; Arce-Estrada, Viviana; Guevara, Corina; López, Juan Carlos; Chaves-Olarte, Esteban; Velásquez, Rubén; Rojas-Céspedes, Gustavo; Gutiérrez-Gutiérrez, José María. 2002. Geographic and ontogenetic variability in the venom of the neotropical rattlesnake <i>Crotalus durissus</i> : Pathophysiological and therapeutic implications. Vol 50 (1): 337-346.
23	15	Stern, Margaret; Quesada-Avenidaño, Mauricio; Stoner, Kathryn E. 2002. Changes in composition and structure of a tropical dry forest following intermittent cattle grazing. Vol 50 (3-4): 1021-1034.
20	21	McGlynn, Terrence P.; Kirksey, S. Eben. 2000. The effects of food presentation and microhabitat upon resource monopoly in a ground-foraging ant (Hymenoptera: Formicidae) community. Vol 48 (2-3): 629-641.
20	9	Altrichter-Cateula, Mariana; Carrillo-Jiménez, Eduardo; Sáenz-Méndez, Joel C.; Fuller, Todd K. 2001. White-lipped peccary (<i>Tayassu pecari</i> , Artiodactyla: Tayassuidae) diet and fruit availability in a Costa Rican rain forest. Vol 49 (3/4): 1183-1192.

(Monge & Nielsen 2005). More recent data indicate that in the *SCI* English represents 89 % of all articles, while in *Biosis* it is 72% and in the *CAB* 58% (Michan & Llorente-Bousquets 2010). Our results are closer to the *CAB* value with 54%. On the other hand, Spanish is important in the *Revista* with 46% of articles, a value that is higher than in *SCI*, *Biosis* and *CAB*. This importance of Spanish probably reflects two facts: that Spanish is also an official language in the *Revista* and that the audience for Neotropical studies mostly speaks Spanish, followed by Portuguese, but Portuguese speaking scientists can read scientific Spanish easily thanks to the similarities among both peninsular languages. The general trend, however, is toward an increasing proportion of articles being published in English.

Scientific research with the most citations in Costa Rica is found on the biomedical publications (Lomonte & Ainsworth 2002,

Monge-Nájera & Ho 2012) but this subject was outside the scope of the present article, which is about biodiversity, despite the fact that often medical products are the result of surveys on applied biodiversity.

Costa Rican researchers have collaborated with international scientists for more than a hundred years (Méndez-Estrada & Monge-Nájera 2003). On the other hand, Lomonte & Ainsworth (2002) found that the most cited papers in the *SCI* were published in collaboration with researchers from foreign institutions. This reflects the access that foreign authors have to non-tropical journals, which are the nearly the only ones included in that particular index (*SCI*). It does not reflect the quality of local work or the impact of articles published in non *SCI* journals, which are the vast majority of tropical journals. It is clear to us that a citation index for Latin American journals does not exist and thus current impact factors so often

give for tropical journals are not scientifically valid: they can only be presented as “impact in American indices”.

Despite its small size, according to information accessed in Essential Science Indicators (Web of Knowledge, Thomson Reuters, 2011-2011) by Sanz-Casado (2011), Costa Rica occupies the 10h place in productivity among Latin American countries, with a productivity/impact in American indices of 84/70, a value that is high when compared with Brazil (15/20), Mexico (29/33), Argentina (35/36) and Chile (43/40) for 2001-2011. The *SCI* citation (probably a fraction of the real citation) for Costa Rica was, on the average, 12.11 per document, against 6.41 for Brazil, 16.60 for Mexico, 8.24 for Argentina and 8.87 for Chile (Downloaded: November 28, 2011, http://lat-index.ucr.ac.cr/docs/Presentacion_costa%20ricavlatinoamerica.pdf). According to Michan & Llorente-Bousquets (2010) the countries that dominate the study of Latin American systematic biology are the largest countries in the region, i.e. Brazil, México, Argentina and the USA, followed by Venezuela, Perú, Colombia and Costa Rica.

Most of the author affiliations of this study were: Costa Rica, USA, Mexico and Germany. This can reflect several facts: that the journal is published in Costa Rica, and the existence of historical research ties between Costa Rican and German universities, but the importance of the USA as a scientific producer even in the tropics is clear from our data.

The Centro de Investigación en Biología Celular y Molecular (CIBCM), the Escuela de Biología and CIMAR are the University of Costa Rica's centers with more projects supported by the institution (Arellano & Jensen 2006) and this list is the same we found for centers that produce the most articles in the *Revista*, suggesting that productivity reflects the support received to do research. Similarly, our results are consistent with previous studies, which found that the University of Costa Rica (the largest in the country) is also the university with the higher scientific output (Lomonte & Ainsworth 2002).

Other studies also found that the average number of authors per article increased in the later decades of the 20th Century. For example, from 2.10 in 1980-1998 to 2.92 in 1999-2001 (Monge-Nájera & Díaz 1988, Lomonte & Ainsworth 2002). Nevertheless, to our knowledge the Collaboration Index had not been formally calculated previous to this article. In any case, our value of IC=2.53 can be a baseline for future comparisons.

In *Google Scholar* the most cited paper was signed by Dwight W. Taylor (1932-2006), a well known paleontologist and biogeographer of mollusks. His “Introduction to Physidae (Gastropoda: Hygrophila). Biogeography, classification, morphology” in the *Revista* is considered a flagship publication of profound influence (Scarabino 2007). In the *Web of Science* the article with most citations dealt with cryptic female choice and was written by William Eberhard, a renowned and prolific biologist who works in the University of Costa Rica and the Smithsonian Tropical Research Institute (STRI).

Our main conclusions are that Costa Rica biodiversity publications have become an important part of the study of Neotropical nature, that despite the mid-level visibility in American Databases the real impact of these publications is unknown because those sources exclude the majority of tropical journals. Furthermore, *Revista de Biología Tropical* is the main output channel for Costa Rican biology and despite its small size, Costa Rica occupies the 10th place in productivity among Latin American countries, with a productivity and impact that compare favorably with larger countries such as Brazil, Mexico, Argentina and Chile.

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RESUMEN

América Central es reconocida como región megadiversa y uno de sus países más pequeños, Costa Rica,

se encuentra entre los líderes mundiales en el estudio y conservación de la biodiversidad tropical. Este estudio, inspirado por el 60 aniversario de la *Revista de Biología Tropical*, actualiza nuestro conocimiento bibliométrico sobre la materia. Hicimos un listado de toda la producción científica sobre la biodiversidad de Costa Rica en la *Revista* entre 2000 y 2010. La mayoría de los artículos son zoológicos (62%) y el 67% de los autores sólo tuvo una publicación en la revista durante ese periodo. Un 54% de los artículos fueron publicados en inglés y un 46% en español. Un 41% de los artículos fueron escritos por autores de instituciones de Costa Rica y el 36% en colaboración con instituciones extranjeras. El Índice de Colaboración fue de 2.53 firmas por artículo. La visibilidad en fuentes estadounidenses fue de 56% en *Google Scholar* y 42.66% en *Web of Science*, pero el impacto real se desconoce porque estas dos fuentes de datos excluyen a la mayoría de las revistas tropicales. *Revista de Biología Tropical* es el principal canal de salida de la biología costarricense y, a pesar de su pequeño tamaño, Costa Rica ocupa el décimo lugar en productividad entre los países de América Latina, con una productividad e impacto que se comparan favorablemente con países más grandes como Brasil, México, Argentina y Chile.

Palabras clave: tendencias de investigación, bibliometría, *Revista de Biología Tropical*, biodiversidad, Costa Rica.

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