

Costa Rica Publications in the Science Citation Index Expanded: A bibliometric analysis for 1981-2010

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Abstract: Despite of its small size, the Central American country of Costa Rica is internationally recognized as one of the world leaders in conservation and as the Central American leader in science. There have been no recent studies on the country's scientific production. The objective of this study was to analyze the Costa Rican scientific output as represented in the Science Citation Index Expanded. All documents with "Costa Rica" in the address field from 1981 to 2010 were included (total 6 801 publications). Articles (79%) were more frequent than other types of publication and were mostly in English (83%). *Revista de Biología Tropical* published the most articles (17%), followed by *Toxicon* and *Turrialba* (2.5%). The *New England Journal of Medicine* had the highest impact factor (53.484) with nine articles. Of 5 343 articles with known institutional address, 63% were internationally collaborative articles (most with the USA) with *h* index 91 and citation per publication 18. A total of 81% of all articles were inter-institutionally collaborative articles, led by the Universidad de Costa Rica. This reflects research and education agreements among these countries. Universidad de Costa Rica ranked top one in inter-institutionally collaborative articles, the rank of the total inter-institutionally collaborative articles, and the rank of first author articles and corresponding author articles. Studied subjects and journals in our sample are in agreement with dominant science fields and journals in Costa Rica. Articles with the highest citation were published in *New England Journal of Medicine*. The largest citation of medical articles reflects the general interest and wider readership of this subject. All corresponding and first authors of the high impact articles were not from Costa Rica. In conclusion, the scientific output of Costa Rican authors is strong in the areas related to conservation but the impact is higher for biomedical articles, and Costa Rican authors need to improve their position within research teams. *Rev. Biol. Trop.* 60 (4): 1649-1661. Epub 2012 December 01.

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Despite of its small size, the Central American country of Costa Rica is internationally recognized as one of the world leaders in conservation and as the Central American leader in science (Weidner & Jänicke 2002, Monge-Nájera & Nielsen 2005). The large growth of the Costa Rican population after 1950 stressed ecosystems that included rich marine communities such as the Costa Rica dome, Caribbean reefs in Cahuita, tropical rain forests in the Pacific and Caribbean coasts, cloud forests and paramos (Weidner & Jänicke 2002). The same phenomenon affected the

other six Central American countries, including the larger and richer Guatemala and Nicaragua, but only in Costa Rica was the conservation problem attacked with a combination of large scale reserves supported by scientific research (Weidner & Jänicke 2002). Why Costa Rica, with a population of about 4 600 000, produced more scientific articles than the rest of Central America combined, which has a population of about 37 400 000 inhabitants (population data: Centro Centroamericano de Población: <http://ccp.ucr.ac.cr/>), is an interesting question that has not been answered.

Possibly the earliest bibliometric analysis of Costa Rican scientific output was the study done by Monge-Nájera & Díaz (1988), which was limited to one specific journal, the *Revista de Biología Tropical*. It found that zoological articles were more common than botanical articles and that most Costa Rican authors published in Spanish, in contrast with many of their Latin American colleagues. It also found a growing tendency to publish shorter papers written by more than one author (Monge-Nájera & Díaz 1988). Shortly afterwards, a bibliometry of the Costa Rican journal *Turrialba*, published by the Inter-American Institute for Cooperation on Agriculture, concluded that Costa Rican agricultural articles dealt mainly with plant pathology, plant physiology and soils (Barrientos & Monge-Nájera 1990). The studies of snake venoms published in the *Revista de Biología Tropical* and other journals were analyzed by Gutiérrez (2002), who found that Toxinology has become a fruitful and stimulating research field in Latin America, leading to improved antivenoms and management of snake-bitten patients. Cortés & Nielsen (2002) found that the first paper published in the *Revista de Biología Tropical* related to marine science was in 1963 and that, 20 years later, marine biology represented on third of the journal's output. Most publications were full articles on Ecology (135 papers) and among this, chiefly coral reefs (28).

The publications of authors from Costa Rican institutions that were included in the Science Citation Index Expanded (SCI-Expanded) during 1999-2001 were 722, distributed in 328 journals, 90.7% corresponded to original research articles. The contribution of *Revista de Biología Tropical* increased from 10.0% in 1999 to 19.1% in 2001. There was a predominance of biomedical (33.3%) and biological (27.5%) sciences, followed by agronomical (15.5%) sciences, chemistry (13.6%), physics (5.0%), geological sciences (3.6%), and mathematics (1.5%) (Lomonte & Ainsworth 2002). Only 45.2% of the articles had been cited at least once to July 15, 2002. The ten most cited references ranged from 26 to 114 citations.

The average citation per article was 2.60, and the average number of authors per article was 2.92. In agreement with data from 1980-1998, the University of Costa Rica appeared as the institution with highest productivity of SCI-Expanded publications during 1999-2001, with a contribution of 50.0%. The percentage of publications performed without the participation of foreign co-authors showed a change in its decreasing trend of 1980-1998, stabilizing near the range of 25-30% during the 1999-2001 period (Lomonte & Ainsworth 2002).

A study by Monge-Nájera & Nielsen (2005) mentioned two limitations of studies of scientific productivity based on the Science Citation Index Expanded: that it is an index centered in European and American journals, which seldom cite Tropical Science, and that they rarely correct for population size, ignoring the relative effort that each society places on research. An analysis based on a more representative index, Biological Abstracts, found that while the most productive Latin American countries in total number of articles were Brazil, Mexico and Argentina (large countries with a long tradition of funding scientific research), Costa Rica was very productive when a *per capita* correction was made (Monge-Nájera & Nielsen 2005).

The most recent bibliometric study related with Costa Rican scientific productivity was that of Monge-Nájera *et al.* (2010), which instead of being based on statistical studies of large numbers of scientists, presented an in-depth analysis of a single but important biologist, Luis Gómez, based on their knowledge, as co-workers and friends, of the life frame in which that scientific output was produced. It found that he had the highest productivity before reaching the expected peak productivity age, and that afterwards his productivity fell and never recovered. This reduction in productivity was related with intense teaching and conservation activities (Monge-Nájera *et al.* 2010).

The objective of this study was to analyze the Costa Rican output as represented in the Science Citation Index Expanded, considering subjects, languages, institutions and countries.

MATERIALS AND METHODS

The data were based on the online version of the Science Citation Index Expanded (SCI-Expanded), a multidisciplinary database of Web of Science, Thomson Reuters. According to Journal Citation Reports (JCR), it indexes 8 073 journals with citation references across 174 scientific disciplines in the science edition in 2010. All documents with “Costa Rica” in the address field from 1981 to 2010 were considered. In total, 6 801 publications met the selection criteria. Document information included names of authors, title, year of publication, source journals publishing the articles, contact address, and each year citation times for every publication were downloaded into Microsoft Excel software, and additional coding was manually performed for origin country and institute of the collaborators and impact factors of the publishing journals. Besides, the reported impact factor (IF) of each journal was obtained from the 2010 JCR. Collaboration type was determined by the addresses of the authors, where the term “internationally collaborative article” was assigned to those articles that were coauthored by researchers from outside of Costa Rica. The term “institute independent article” was assigned if the researchers’ addresses were from the same institute in Costa Rica. The term “inter-institutionally collaborative article” was assigned if authors were from different institutes (Li & Ho 2008). All the articles referring to “Costa Rica” were assessed by the following aspects: document type and language of publications, characteristics of article outputs, distribution of output in subject categories and journals, article outputs of institute and collaborative country. The total cited times were collected on 21st May 2011. Total citation times from publication to 2010 were used and recorded as TC2010 (Chen *et al.* 2005). The bibliometric impact of a publication is usually assessed in terms of the number of citations it has received relative to other outputs in the same journal or field. The *h*-index was an indicator of the impact of a scientist or journal and had the advantage of

being objective. It was defined as the number of papers with citation number greater than or equal to *h* (Hirsch 2005). CPP was another indicator which was defined as the total citations since publication to year 2010 (TC2010) per publication. The CPP and *h*-index were applied to evaluate total articles, independent articles, collaborative articles, first author articles, and corresponding articles of institutions and countries respectively.

RESULTS

The total amounts of papers published by Costa Rica since 1900 were counted and displayed in figure 1. Thomas (1900) published the first article in *Public Health Reports* which listed in SCI category of public, environmental & occupational health. Sixteen articles were published in the period of 1900 to 1970. A total of 1 379 and 4 441 articles were published in 1971-1990 and 1991-2010, respectively.

Document type and language of publication: The distribution of the document type identified by Web of Science was analyzed. Sixteen document types were found in the total 6 801 publications from 1981 to 2010. Article (5 343) was the most-frequently used document type comprising 79% of the total publications, followed distantly by meeting abstracts (443, 6.5%), notes (275, 4.0%), proceedings papers (262, 3.9%), reviews (192, 2.8%), letters (120, 1.8%), and editorial materials (106, 1.6%). The others showing less significance were corrections (13), news items (12), biographical-items (eight), reprints (seven), book reviews (six), discussion (six), items about an individual (five), addition corrections (two), and software review (one). Journal articles were used for further analysis because they represented the majority of document types that also included whole research ideas and results (Ho *et al.* 2010). Eighty-three percent of all articles (4 443) were published in English. Several other languages also appeared: Spanish (851), Portuguese (21), French (19), and German (nine).

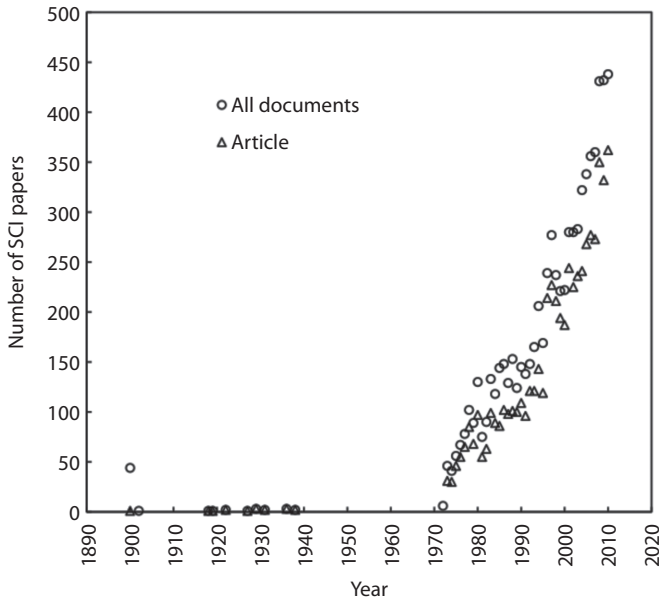


Fig. 1. Trend of the number of SCI publications referring to Costa Rica from 1900.

Subject categories and journals: Based on the classification of subject categories in JCR in 2010, the article output data was distributed in 160 science subject categories. The top twenty productive subject categories are shown in table 1. Biology (943, 18% of all articles) was the most common category included in 85 journals; followed by the categories of plant sciences (391, 7.3%), ecology (375, 7.0%), agronomy (342, 6.4%), pharmacology & pharmacy (256, 4.8%), entomology (244, 4.6%), biochemistry & molecular biology (221, 4.1%), and forestry (203, 3.8%). Moreover, the trends of the top four productive subject categories which included at least 20 articles in 2010 were analyzed in figure 2.

In total, 5343 articles were published in 1 362 SCI-Expanded journals in the period of 1981 to 2010. *Revista de Biología Tropical* published the most articles with 890 articles comprising 17% of all the articles, followed by *Toxicon* and *Turrialba*, which together contribute 2.5% of all the journal articles. The rank of journals changes for the impact factor. *New England Journal of Medicine* won the first

TABLE 1
Top 20 productive subject categories of articles

Subject category	TA	%
Biology	943	18
Plant sciences	391	7.3
Ecology	375	7.0
Agronomy	342	6.4
Pharmacology and pharmacy	256	4.8
Entomology	244	4.6
Biochemistry and molecular biology	221	4.1
Forestry	203	3.8
Environmental sciences	184	3.4
Zoology	184	3.4
Genetics and heredity	177	3.3
Public,environmental and occupational health	170	3.2
Toxicology	166	3.1
Veterinary sciences	138	2.6
Immunology	137	2.6
Infectious diseases	115	2.2
Nutrition and dietetics	115	2.2
Inorganic and nuclear chemistry	113	2.1
Microbiology	113	2.1
Oncology	112	2.1

TA: Number of articles; %: the percentage of articles from different subject categories in total articles.

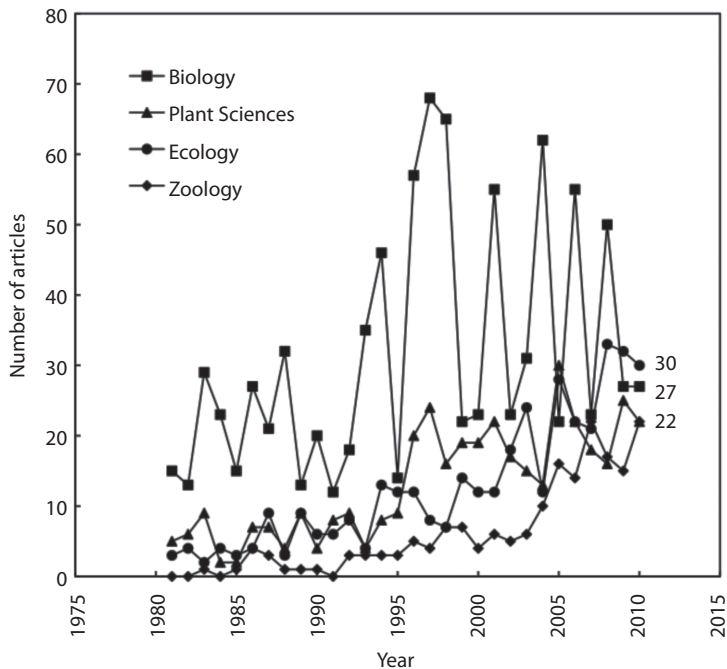


Fig. 2. Trends of the top 4 productive subject categories in 2010.

place with the highest impact factor (53.484) with nine articles, followed by *Nature Genetics* (36.377), *Nature* (36.101), *Lancet* (33.633), *Science* (31.364), *JAMA-Journal of the American Medical Association* (30.011), and *Nature Immunology* (25.668).

International collaboration: When all 5 343 articles with author address are considered, the h index is 94 and CPP is 14. International collaboration articles (3 375, 63%) have an h index of 91 and CPP is 18. When only Costa Rica independent articles (1 968, 37%) are considered, the values are h index 44 and CPP 6.6. The 3 375 internationally collaborative articles were published with 117 countries. The distribution of articles by Costa Rica authors (Fig. 3) has two peaks: 1997 and 2008. The trends of corresponding author articles, first author articles, and total articles were similar while the trend for Costa Rica independent articles was different.

Table 2 presents the top 15 internationally collaborative countries ranked by number of articles with Costa Rica. Number of

internationally collaborative articles, the rank of the total internationally collaborative articles, together with the percentage of total Costa Rica articles and rank of first author articles and corresponding author articles were also exhibited in table 2. Domination in collaborative country was clear: the USA ranked top one in three indicators and was followed distantly by France. Germany had more corresponding author articles with Costa Rica. Collaborative trends of the top six countries which had at least 30 internationally collaborative articles with Costa Rica are shown in figure 4. Costa Rica has had collaborative articles with Spain and Germany since 1988 and 1990, respectively. In 2010, Spain and Germany became the 2nd and the 4th collaborative countries while USA ranked top one and Brazil ranked second position. Mexico was the sixth most important country regarding international collaboration in research.

Inter-institutional collaboration: Of the 5 343 articles, 3 697 (69%) were inter-institutionally collaborative articles, while 1 646

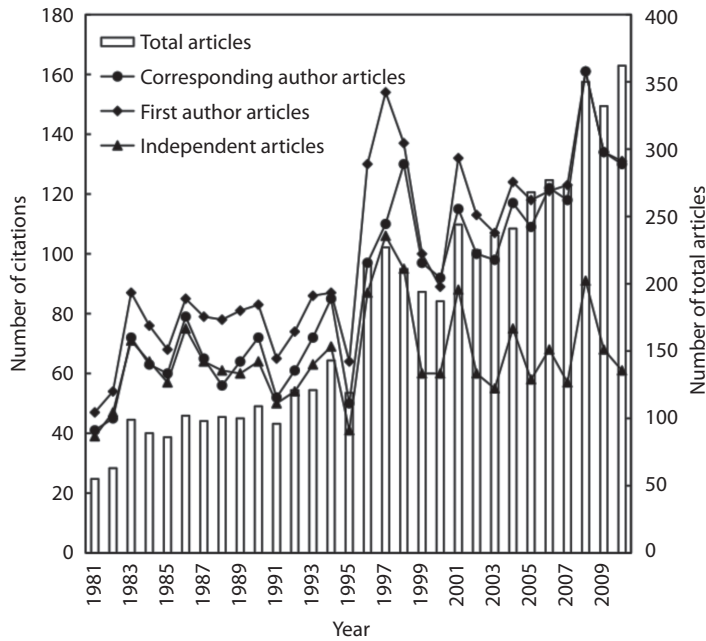


Fig. 3. Distribution of articles by Costa Rican authors.

TABLE 2
Top 15 most collaborative countries of articles during 1981-2010

Country	CA	CA Rank (%)	FA Rank (%)	RA Rank (%)
USA	1 810	1 (34)	1 (21)	1 (22)
France	299	2 (5.6)	2 (2.4)	3 (2.6)
Mexico	268	3 (5.0)	6 (1.9)	5 (2.2)
Germany	261	4 (4.9)	2 (2.4)	2 (2.7)
Spain	260	5 (4.9)	4 (2.0)	4 (2.2)
Brazil	258	6 (4.8)	7 (1.9)	7 (1.8)
UK	235	7 (4.4)	8 (1.6)	8 (1.5)
Canada	212	8 (4.0)	5 (1.9)	6 (1.9)
Netherlands	200	9 (3.7)	10 (1.2)	10 (0.91)
Sweden	161	10 (3.0)	9 (1.3)	9 (1.0)
Colombia	141	11 (2.6)	14 (0.41)	14 (0.36)
Argentina	126	12 (2.4)	12 (0.54)	12 (0.59)
Panama	112	13 (2.1)	13 (0.45)	13 (0.49)
Italy	100	14 (1.9)	11 (0.62)	11 (0.65)
Venezuela	69	15 (1.3)	19 (0.26)	14 (0.36)

CA, internationally collaborative articles with Costa Rica; FA, article with first author;
RA, article with corresponding author; %, share in total Costa Rica articles.

(31%) were single institute articles. Of all the 5 343 articles with author address in the database; 4 323 (81%) articles were inter-institutionally collaborative articles with *h* index

92 and CPP 15 and 1 020 (19%) articles were Costa Rica institute independent articles with *h* index 38 and CPP 7.6. Table 3 listed the top 10 institutes ranked by number of total articles.

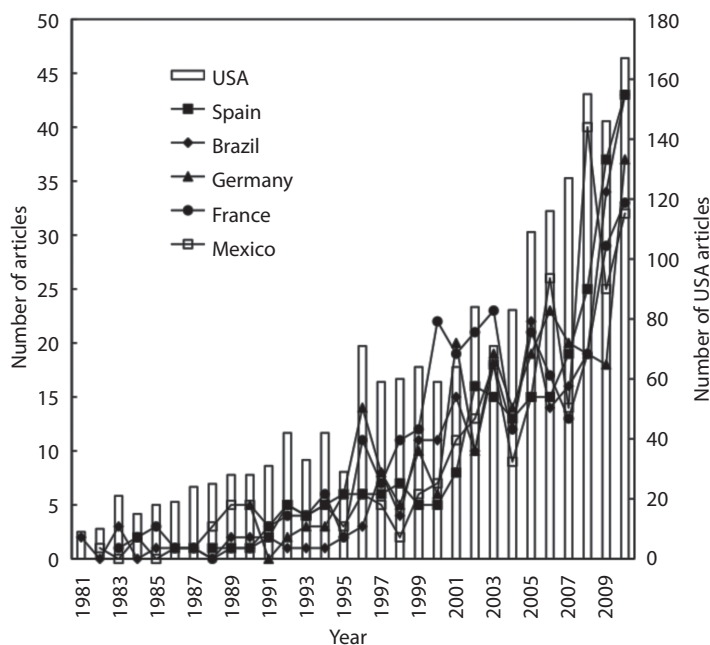


Fig. 4. Top six collaborative countries.

TABLE 3
Top 10 institutes in Costa Rica

Institute	TA	TA R (%)	SA R (%)	CP R (%)	FA R (%)	RA R (%)
Universidad de Costa Rica	2 868	1 (54)	1 (65)	1 (48)	1 (32)	1 (30)
Universidad Nacional	854	12 (16.0)	32 (7.8)	13 (19.6)	14 (6.8)	5 (6.4)
Centro Agronómico Tropical de Investigación y Enseñanza	403	13 (7.6)	7 (6.8)	28 (7.9)	11 (3.8)	9 (3.3)
Caja Costarricense de Seguro Social	261	5 (4.9)	7 (1.3)	4 (6.5)	5 (1.3)	6 (1.0)
Instituto Nacional de Biodiversidad	143	7 (2.7)	8 (1.2)	7 (3.3)	5 (1.3)	11 (0.45)
Instituto Tecnológico de Costa Rica	99	8 (1.9)	6 (1.4)	8 (2.1)	8 (0.94)	7 (0.87)
Organization for Tropical Studies	79	9 (1.5)	10 (0.73)	9 (1.8)	10 (0.62)	9 (0.53)

TA, Total articles; SA, single institute articles; CP, inter-institutionally collaborative articles; FA, article with first author; RA, article with corresponding author; R, rank.

Number of inter-institutionally collaborative articles, the rank of the total inter-institutionally collaborative articles, together with the rank of first author articles and corresponding author articles appear in table 3. The Universidad de Costa Rica ranked top one in three indicators and was followed distantly by Universidad Nacional and the Centro Agronómico Tropical de Investigación y Enseñanza, and Universidad Nacional, which also had more corresponding author articles and more single institute articles.

Impact of highly cited articles: A history of citation of the top six most cited articles (TC2010>500) is shown in figure 5. The article titled “Epidemiologic classification of human papilloma virus types associated with cervical cancer” (Muñoz *et al.* 2003) was published in *New England Journal of Medicine* by eight authors from France, Spain, Costa Rica, USA, and Netherlands, had the highest citation of our sample and sharply increased in citation after its publication. All these six articles were

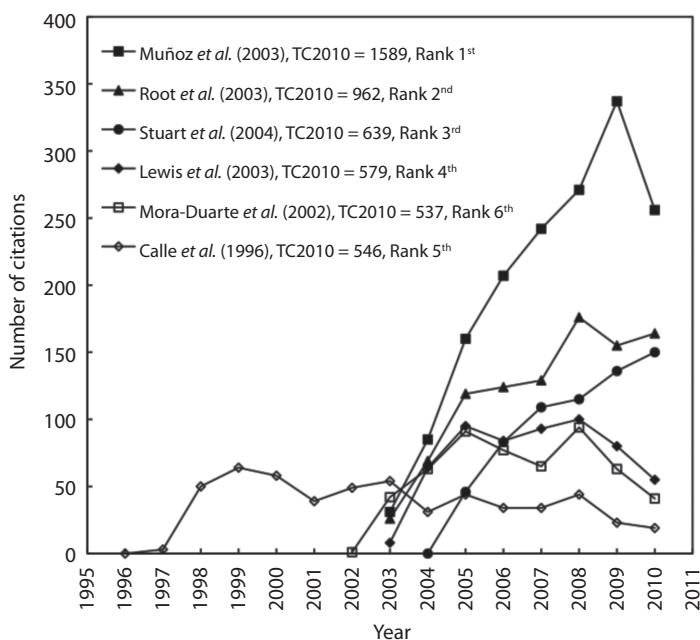


Fig. 5. Top six most cited articles (TC2010>500).

international collaboration. The only one with a Costa Rican first author article was “Comparison of caspo fungin and amphotericin B for invasive candidiasis” (Mora-Duarte *et al.* 2002) also published in *New England Journal of Medicine* by 10 authors from Costa Rica, USA, Canada, Brazil and Chile. Four articles were cited more 100 times in 2010. Figure 6 shows the citation history of these four high impact articles which were published in recent years: 2003, 2004, and 2006. Corresponding and first authors of the high impact articles were not from Costa Rica. Seven high impact Costa Rican independent articles cited more than 10 times in 2010 were also analyzed (Fig. 7). The highest citation in 2010 was the article titled “Life-history diversity of canopy and emergent trees in a neotropical rain-forest” (Clark & Clark 1992) published in *Ecological Monographs*, that was cited 19 times in 2010 and 336 times since its publication.

The most recent article listed in figure 7 is “Differential effect of environment enrichment and social isolation on depressive-like

behavior, spontaneous activity and serotonin and norepinephrine concentration in prefrontal cortex and ventral striatum” (Brenes *et al.* 2008) published in *Pharmacology, Biochemistry and Behavior*, and originating in the Universidad de Costa Rica.

DISCUSSION

The clear domination of full articles over communications, notes, reviews and other types of scientific publication probably results from the general existence, in Costa Rican institutions, of “Professional Career Boards”, whose members score publications instead of using the scores given to the journals where the work is published (similar to the practice in other countries). The scores are used to define increases in the salary of the researchers and usually are given only for full articles, discouraging the publication of other types of work. We have no explanation for the two peaks in number of articles around 1998 and 2008. Nearly all Costa Ricans speak Spanish, but

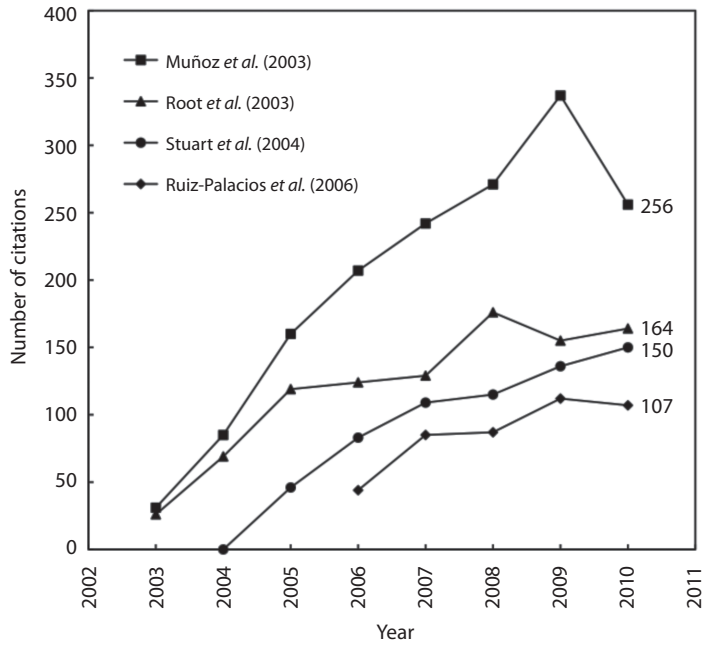


Fig. 6. Articles cited more 100 times in 2010 (Root et al. 2003, Ruiz-Palacios et al. 2006, Stuart et al. 2004).

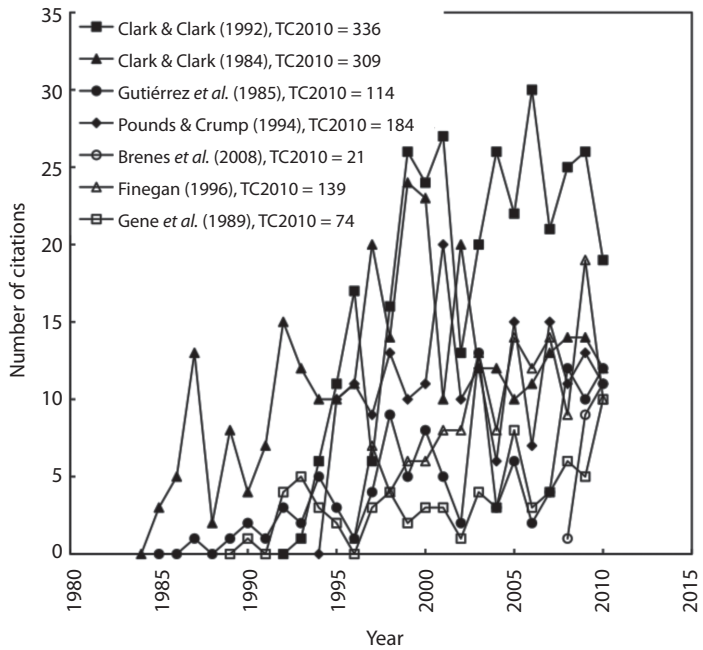


Fig. 7. Most cited Costa Rica independent articles with citation more than 10 times in 2010.

researchers publish mainly in English in order to reach a wider readership. This is a change from earlier results in which Spanish dominated (Monge-Nájera & Díaz 1988). The second largest group publishes in Spanish, maybe because they prefer this language or, in some cases, because they do not have the necessary English skills. Even smaller groups publish in other languages, but the reason is also known: Portuguese is the language of journals from the closest regional power, Brazil, and the production of articles in French and German reflects the number of Costa Rican students who obtain their university degrees thanks to important scholarship programs that those two European nations have in Costa Rica.

The strongest scientific and technical fields in Costa Rica are marine biology, forest ecology, biomedicine and agriculture (Monge-Nájera & Nielsen 2005, Padilla & Martínez 2007). This explains why biology (including botany and zoology), agriculture, pharmacy and other related fields are the main subjects of research. For half a century, Costa Rica had two of the most recognized scientific journals of Latin America, the *Revista de Biología Tropical*, which publishes in all fields of tropical biology and conservation, and *Turrialba*, an agricultural journal published by the CATIE (Barrientos & Monge-Nájera 1990). Unfortunately, *Turrialba* is no longer published. The international importance of both journals explains why they appear predominantly in our results.

The fact that tropical science is published mostly in tropical journals, and that the great majority of these journals are not included in the Science Citation Index Expanded, is basic to the proper understanding of our results, which apply only to journals included in the index and that deal basically with Temperate ecosystem biology. Furthermore, much biological research is done in the biomedical field, where the results are of interest in both Tropical and Temperate countries; as a result, the articles that received more citations in our study were those published in medical journals.

For more than a century Costa Rica has sent its researchers to study in American and European universities, as well as in universities from large Latin American countries. The relationships that they establish there combined with formal cooperation agreements and the recognized quality of Costa Rican research can explain why so many articles are written in collaboration not only with local institutions, but with institutions in the USA, France, Mexico and Germany. On the other hand, the absence of Costa Rican authors as leaders of the high-impact biomedical articles deserves further study.

The institutions with the highest scientific output in our results are also the recognized national leaders in research. The Universidad de Costa Rica is the largest Costa Rican university (35 000 students) and the largest producer of science and technology in Central America (Padilla & Martínez 2007). It is the only Central American University that has a *Ciudad de la Investigación* (Research Complex). The second institution in output is the Universidad Nacional, located in the province of Heredia, which with 15 000 students is the second in the country. This institution focuses on marine biology and social sciences. Third in output is the Caja Costarricense de Seguro Social (CCSS), a large government network of hospitals, clinics and health centers with 35 000 employees that, like the universities, gives financial incentives to those who publish. All the research done by the CCSS is in the health field. The Instituto Nacional de Biodiversidad (INBio) is a private institution whose primary goal is the description of Costa Rican species as a basis for their use (including commercial use) and conservation. This is done mostly for insects, a group in which a procedure developed to describe one species can be readily repeated for other species of the taxon, allowing fast production of many taxonomic articles. In contrast with the other Costa Rican institutions considered in this study, INBio is the only institution whose functions mainly imply the production of taxonomic articles, so its appearance here is not a surprise. The Instituto Tecnológico de Costa

Rica (ITCR) is the only institute of technology in Costa Rica. It has 8 000 students and centers in engineering and informatics, but it also has biotechnology and forestry departments that produced the articles accounted for in our results. Finally, the Organization for Tropical Studies (OTS) is a consortium that includes the Costa Rican universities cited in the previous paragraphs, as well as foreign institutions. Its large output can be explained because it mostly provides facilities for field research leading to publication of scientific articles and because a total of 63 universities participate in the consortium.

Universidad de Costa Rica ranked top one in inter-institutionally collaborative articles, the rank of the total inter-institutionally collaborative articles, and the rank of first author articles and corresponding author articles. Articles with the highest citation were published in *New England Journal of Medicine*. All corresponding and first authors of the high impact articles were not from Costa Rica, a point in which there is room for improvement.

RESUMEN

A pesar de su pequeño tamaño, el país centroamericano de Costa Rica es reconocido internacionalmente como uno de los líderes mundiales en la conservación y como el líder centroamericano en la ciencia. No se han realizado estudios recientes sobre la producción científica del país. El objetivo de este estudio fue analizar la producción científica de Costa Rica, tal como se representa en el *Science Citation Index Expanded*. Todos los documentos con "Costa Rica" en el campo de dirección de 1981 a 2010 fueron incluidos (total de 6 801 publicaciones). Los artículos (79%) fueron más frecuentes que otros tipos de publicación y eran en su mayoría en inglés (83%). *Revista de Biología Tropical* publicó el mayor número de artículos (17%), seguido por *Toxicon* y *Turrialba* (2.5%). El *New England Journal of Medicine* tuvo el mayor factor de impacto (53.484), con nueve artículos. De los 5 343 artículos con dirección institucional conocida, el 63% eran artículos de colaboración a nivel internacional (la mayoría con los EE.UU.) con índice h 91 y las citas por publicación 18. Un total de 81% de todos los artículos eran dirigidos por la Universidad de Costa Rica con la colaboración de otras instituciones. Esto refleja acuerdos de investigación y educación entre países. La Universidad de Costa Rica se situó en el primer puesto en la colaboración en artículos a nivel inter-institucional, y el rango de los artículos del primer autor y artículos con

autores de correspondencia. Los temas estudiados y las revistas de la muestra coinciden con los campos de las ciencias dominantes y revistas en Costa Rica. Los artículos con mayor citación fueron publicados en *New England Journal of Medicine*. La mayor citación de artículos médicos refleja el interés general y un público más amplio para este tema. Todos los autores de correspondencia y el primer autor de los artículos de alto impacto no eran de Costa Rica. En conclusión, la producción científica de autores costarricenses es fuerte en las áreas relacionadas con la conservación, pero el impacto es mayor para los artículos biomédicos, y los autores de Costa Rica necesitan mejorar su posición dentro de estos temas de investigación.

Palabras clave: líneas de investigación, bibliometría, citación, factor de impacto.

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