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Determinants of scientific output: an in-depth view of the productivity of tropical botanist and conservationist, Luis Diego Gómez Pignataro

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Abstract: Bibliometric studies have found that male researchers have their greatest productivity around the age of 40, that female researchers produce less than their male colleagues, that incentives for collaboration are slow to affect productivity and that, just like humans, research institutes become larger, less productive, more expensive to maintain and less able to raise money as they grow old. Almost invariably, these conclusions come from statistical studies of large numbers of European and American scientists, and there are practically no studies about tropical researchers. We present an in-depth analysis of the productivity of an internationally recognized tropical botanist and conservationist, Luis Diego Gómez Pignataro, based on the totality of his published work and on our own knowledge, as co-workers and friends, of the life frame in which that scientific output was produced. His life output departs from the expected pattern in that he had the highest productivity before reaching the expected peak productivity age, and that when he reached it his productivity fell and never recovered. Furthermore, marriage did not produce the expected fall in productivity. A close analysis of his life indicates that in the middle of his career he switched to intense teaching and conservation activities, and this better explains why his output of scientific research articles was low afterwards. This switch may occur in other tropical scientists. *Rev. Biol. Trop.* 58 (4): 1093-1114. Epub 2010 December 01.

Key words: bibliometry, productivity, differences among tropical and temperate scientists, science in “developing countries”, conservation and science.

Scientific productivity generally follows a known curve along the life of researchers. There are famous exceptions such as the French entomologist Jean Henri Fabre, who made most of his vast contribution after the age of 50, but basically, output increases to reach a peak around the time when the researchers are 40 years old and declines with old age, usually after the 60th birthday (Kyvik 1990). Not only productivity, but also the “quality label” that society gives to productivity, is higher for the first years of productivity. This applies to all fields, including music, literature, cinematography, mathematics and biology. For example, Paul McCartney, J.D. Salinger, Orson Welles, John von Neumann and James D. Watson did

not make any significant contributions after their young years (Kanazawa 2003). In the words of Albert Einstein (cited by Brodetsky 1942, p. 699): “A person who has not made his great contribution to science before the age of thirty will never do so”.

The patterns for productivity vary to some extent among scientific fields. In the social sciences, for example, the output remains approximately the same in all age groups, while authors in the humanities tend to have a final peak after the age of 60 years (Kyvik 1990).

More recent studies have asked new questions, such as: Is the pattern the same for women and men?, what is the effect of collaboration on

productivity? Or, do institutions show the same “life pattern” as people?

Female researchers produce less than their male colleagues (Kelchtermans & Veugelers 2008) and follow throughout life a flattened version of the male productivity curve; the same is true for female musicians and fiction writers (Kanazawa 2003). The reasons for the lower productivity of women have traditionally been explained as the result of social limitations, but a biological cause must also be considered (Kanazawa 2003).

How incentives for collaboration affect productivity has been studied in research networks funded by the European Union. During the period of funding, collaboration does not produce an increase in productivity. But productivity after the funding period increases (Defazio *et al.* 2009).

A study of the Italian National Research Council data found that, just like humans, research institutes become larger, less productive, more expensive to maintain and less able to raise money as they grow old (Bonaccorsi & Daraio 2003).

To come to such conclusions, the great majority of studies have done correlation analyses on samples of hundreds of researchers (Kanazawa 2003, Defazio *et al.* 2009), but few have done in-depth observations on individual lives. Besides, almost the totality of studies deal with European or American scientists (Kyvik 1990, Defazio *et al.* 2009) ignoring the rest of the world’s scientific community. In these times of danger for the tropical ecosystems where the majority of biodiversity is found, it is particularly shocking that no such studies exist for tropical researchers.

Our contribution in this article is that we present an in-depth analysis of the productivity of an internationally recognized tropical botanist and conservationist, Luis Diego Gómez Pignataro, based on the totality of his published work and on our own knowledge, as co-workers and friends, of the life frame in which that scientific output was produced.

MATERIALS AND METHODS

The scientific output was obtained from various sources: “Luis Diego Gómez: Personal Bibliography” Organization for Tropical Studies (www.ots.ac.cr), the online-catalogues (OPAC) of Universidad de Costa Rica and Universidad Nacional (www.ucr.ac.cr and www.una.ac.cr), the ISI Web of Science and Google Academic, as well as interviews and other information supplied by close associates and relatives familiar with his work. His book reviews, published for years in the *Revista de Biología Tropical* (www.biologiatropical.ac.cr) were not included. The information was processed with the bibliographies manager ProCite.

The Collaboration Index (CI) was calculated with the formula: $CI = \text{number of authors} / \text{per publication} / \text{number of publications}$.

RESULTS

Luis Diego was one of the most outstanding Latin American botanists of the 20th century (Bohlen 1993) and his mini-autobiography is now available (Bohlen 1993). His productive career covered 39 years (1968-2009), in which he produced 181 articles that were published in a total of 37 journals. The overall mean was 4.6 articles per year but in 1982 he published 15 articles (mostly of the *Plantae Mesoamericanae Novae* series) and 23 articles and other works were published in 1983, many as chapters in Costa Rican Natural History (Janzen 1983).

He also published 41 other works that included books, book chapters, meeting presentations, booklets and maps, and he edited several books by other authors (Table 1).

Half of his articles appeared in international journals published in Costa Rica, one third in the USA and the rest in European, Latin American and Asian journals published in a total of 10 countries (Table 1).

His favorite journals to publish were *Brenesia*, *Biología Tropical*, *American Fern Journal* and *Phytologia* (Appendix 1).

TABLE 1
Country of publication for journals and other printed out put

Country	Number of articles	Number of journals	Other publications*
Costa Rica	95	7	25
USA	56	13	14
Germany	10	5	
Great Britain	7	5	1
Argentina	3	1	
Japan	3	1	
Canada	1	1	
France	1	1	
Italy	1	1	
Honduras	1	1	
No data	3	1	
Total	181	37	40

*Books, maps, among others; see main text.

Nearly 60% of his articles were in English, the rest were mostly in Spanish but he also wrote two in German and one in Italian.

He was the single author in 63% of his articles, with a collaboration index of 1.79. His most frequent co-authors were Jorge Gómez-Laurito, Liuba Kisimova-Horovitz, Rolf Singer and Eckhard Wollenweber. He also published 44 articles with one coauthor, 22 with two, five with three, five with four and five articles with more than four coauthors (Appendix 2).

The productivity curve has many peaks but for articles his greatest output was during the first 20 years of his career. For other publications such as books and maps, he peaked 15 and again 25 years after the beginning. There are three basic time trends in productivity: his output on fungi remained fairly constant throughout his life; the output on ferns had three large peaks in the first 20 years and the output on angiosperms was zero in the first 10 years, it peaked and was kept low afterwards (Fig. 1).

The greatest output was on ferns, fungi and angiosperms (Fig. 2). The complete list of publications appears in Appendix 3.

DISCUSSION

Early life: In the decade of 1990, scientists started to publish internationally at the age of 35, but when Luis Diego Gómez Pignataro began his career in 1968, he was within the standard documented for that period by Bonaccorsi & Daraio (2003), which was around 25 years.

His interest in tropical nature was born in an era in which Costa Rica was experiencing a population boom and the agro-export model was the country's accepted "path to development". The tropical forest was seen as a frontier to conquer, as described by the Costa Rican novelist Fabian Dobles in *El sitio de las abras* (Dobles 1950), a novel that describes the place and time in which Luis Diego grew up. He started publishing the results of his scientific research in the late 1960s but years before, when he was a child growing up amid the dense Caribbean rainforest, he had already begun studying the family garden, reading natural history books and creating his own plant classification system based on morphological

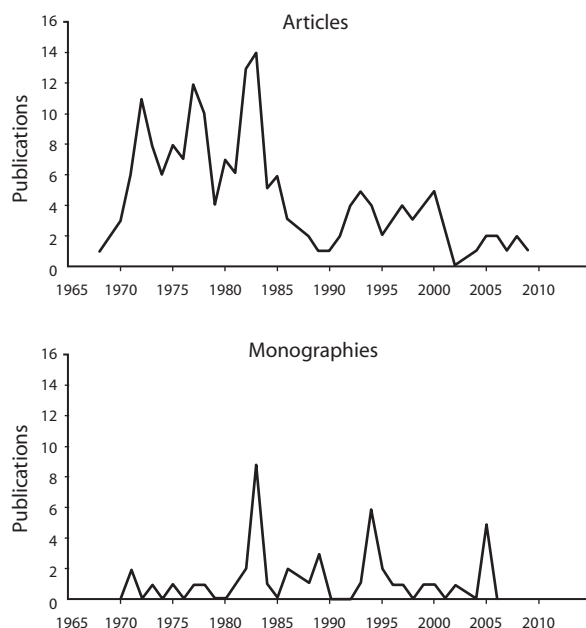


Fig. 1. Luis Diego Gómez Pignataro: total production by year and type of publication, 1968-2010.

characteristics (Bohlen 1993). Thus started a productive career that lasted the typical span of around 40 years (Kyvik 1990).

Productivity: In the USA, a study based on 443 academic scientists found that productivity is related to being male, tenured, married and non-native, and that chemists have the highest per capita productivity while scientists in computer science have the lowest (Bozeman & Lee 2003). The number of articles per author increased along the 20th century. In the 1930s, scientists peaked at three articles per year, while that working in the 1960's averaged four articles per year (Hall *et al.* 2003). More recently, the number of yearly international publications per researcher varies from none to 20 but three is typical for Europe (Bonaccorsi & Daraio 2003). The productivity of Luis Diego (4.6 articles per year) can be considered average for good international researchers. Considering that he almost never asked for research funds, his output is extraordinary and shows a known but seldom mentioned finding:

that the most outstanding researchers often get far less financing than their mediocre colleagues (Bonaccorsi & Daraio 2003, Kelchtermans & Veugelers 2008).

The unusually high productivities of 1982 and 1983 probably reflect the fact that the *Plantae Mesoamericanae Novae* series was a field that he knew well and that the chapters in *Costa Rican Natural History* were short: we believe that both required less time than more complex scientific papers and thus his output was higher in these years.

Young researchers tend to produce work of higher quality (Kelchtermans & Veugelers 2008) but we did not study if this applies to the work by Luis Diego.

The 1980s was a period of great transformation in Luis Diego's life. After achieving in 1986 what has been called the National Museum's Second Golden Age, he left to pursue another major rescue project, one that appeared to be a lost cause: what is now the Wilson Botanical Garden.

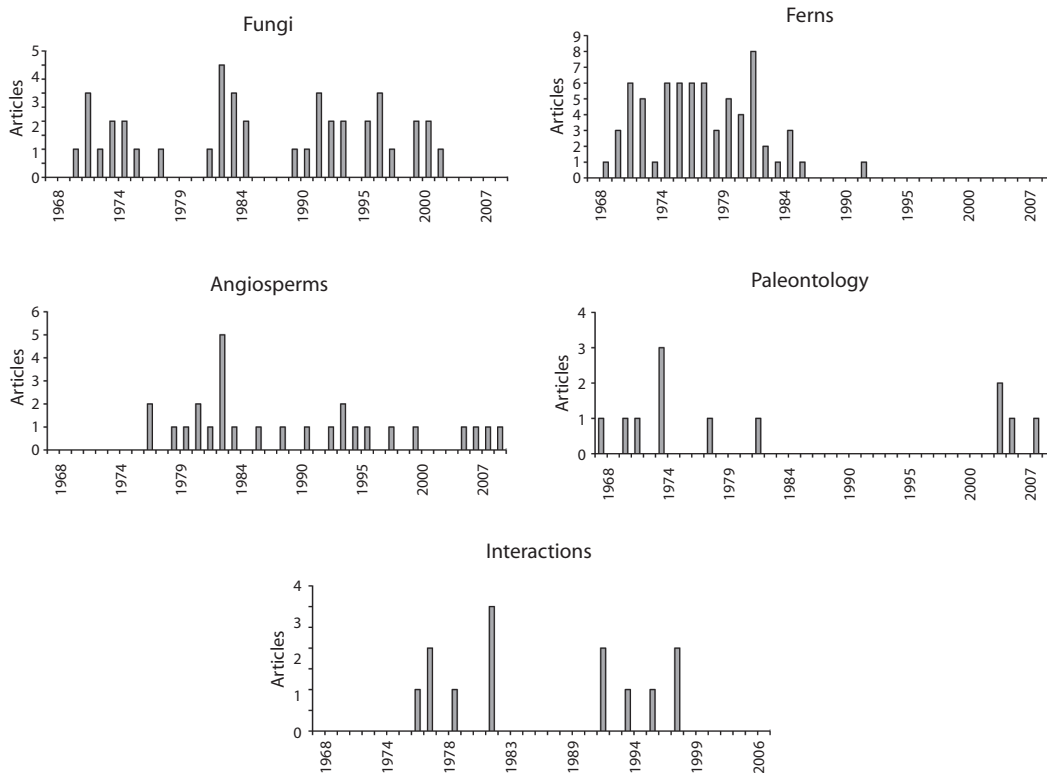


Fig. 2. Luis Diego Gómez Pignataro: total production by subject, 1968-2010.

As a result of his effort and ability to motivate those around him, from construction workers to scientists and donors, the garden became an international research center and scored the highest rating as a destination for ecotourism. The garden is also an internationally recognized documentation and conservation center, an achievement seen by the local community as their own actions thanks to outreach efforts and environmental education. It is visited annually by biology students from the U.S., Europe and several other regions, and Luis Diego played several simultaneous roles in keeping the garden as a leader in the region.

All this administrative effort did not prevent him from publishing. He designed a fern key that is essential to any current Central American fern ecology and conservation

research. He also studied the extraordinary resistance of ferns to herbivore attack and their biogeographic origin, a subject that he continued to work on until it was extended to all Costa Rica paleo-biogeography. Perhaps his most striking description was his paper on the first American fern preserved in amber, which he called *Grammitis succinea* (Gómez 1982). He found time to continue the series on fungi taxonomy that he had begun in the previous decade and to describe the gastronomic preferences of a squirrel when offered fungi, in the most classic style of natural history.

In the field of history and drawing from his Latin knowledge, he wrote an article on the Roman naturalist Pliny the Elder and how his view influenced the attitude of Spaniards and Latin Americans towards fungi (Gómez 1983).

Supporting talented young people may be the best investment in science (Wallner *et al.* 2003) and Luis Diego was well known for practicing this idea. Gail Hewson, his second wife tells us about his time as head of the Costa Rica National Museum Natural History Department between 1970 and 1985:

“Luis Diego’s botany and taxonomy contribution impress beyond words. He had a formidable career within Costa Rica’s National Museum. It is almost impossible to browse a guide to identification of any Costa Rican flora and fauna group without finding recognition to Luis Diego, for his time, energy and collaboration”.

Rafael Ángel Chacón adds:

“In 1972, when I was only 16 years old, I started to work at the National Museum of Costa Rica. There I met Mr. Luis Diego Gómez. At that time he was the General Director, Natural History Section Chair and the National Herbarium Director. Don Luis, as he was known, called me to be part of the National Herbarium staff, which by that time had 45 000 specimens mounted and cataloged, with much material stored in cardboard boxes. He taught me my first steps in the natural sciences. Under his management, the Natural History Section changed its name to Natural History Department. As the collections were scattered throughout various parts of the museum, with hard work and dedication he built the Natural History Building.

As a person and leader he was outstanding. We shared many things, both personal and work-related. In March 1984, I had the wonderful experience of walking for 22 days by his side, climbing Fabrega Peak in Panama. On the third day we wanted to come back due to the weather. In the tent everything was completely wet and he said “Look, if tomorrow we wake-up with more rain, we’ll turn around and go back”. Fortunately, the next morning the sun shined. The following days, the cold pierced my bones but Luis Diego, always looking ahead, told us: “We will make it!”. To talk about Luis Diego there is only one word in the dictionary: *naturalist*; he

was a true one, an expert on our natural history like there are very few”.

Journals where he published: Like other scientists, he tried to spread his articles among a variety of journals in the hope of reaching a wider audience but concentrated on a few. *Brenesia* was the natural history journal that he had founded in the Museum. To our knowledge, he was not criticized for publishing in his own journal, perhaps this was not an issue because the quality of his work was so widely recognized. He sent many manuscripts to *Biología Tropical* and a possible reason was that the *Revista* is one of the leading journals in tropical research and it has its offices in Costa Rica. The American Fern Journal and *Phytologia* were also good options for him because they are specialized in his field of work.

Perhaps his most seminal contribution in the editorial field was the creation of the journal *Brenesia*, which honors Costa Rica’s first graduate biologist, botanist Alberto Brenes. *Brenesia* quickly became a major scientific journal, with authors of great prestige, thanks to his skillful editorship. *Brenesia*’s foundation was within a broader renewal context, because Luis Diego was Director of Costa Rica National Museum Department of Natural History between 1970 and 1985, bringing the museum not only out of the decline it had suffered after World War II but achieving in that time the recognition of an active international center for botanical and entomological research.

Language: English dominates the scientific productivity of the world (Monge-Nájera & Nielsen 2005). In the case of Luis Diego, his command of the English language was impressive, so is not surprising that he wrote nearly 60% of his articles in the language of science but the fact that he also wrote almost 40% in Spanish is harder to explain. Maybe he wanted to make those articles more accessible to technicians and students. Perhaps he published in German and Italian just “for fun” (Italian was the language of his mother). He also had

knowledge of Aramaic, Latin and Russian. Ana Victoria Lizano says:

“His relationship with Dr. Rafael Lucas Rodríguez was very close. Among their common passion was the love for Latin who he also shared with Jorge Gómez Laurito. It seems that exchanging letters and messages in Latin was among their hobbies”.

Collaboration: In recent decades, collaboration leading to coauthorship has been the norm: the mean number of collaborators for one year’s research work is nearly 14, of which 41% are graduate students and 27% are women (Bozeman & Lee 2003). Researchers spend 84% of their time working in collaboration and researchers with more collaborators publish more articles (Bozeman & Lee 2003). Collaborative projects are often done to capitalize on funding opportunities but in the long run they tend to increase researcher productivity (Defazio *et al.* 2009). By modern standards, Luis Diego was a lonely author with only 37% of his articles done in collaboration, possibly because others found it hard to follow his rhythm of work. Even so, he published repeatedly with several colleagues, particularly Jorge Gómez-Laurito, who was both cousin and a tropical botanist; Liuba Kisimova-Horovitz, a German mycologist who visited Costa Rica several times (they shared their love for long walks in the forest); Rolf Singer, the famous German botanist, had been his mentor in earlier years and Eckhard Wollenweber, a leading German researcher in natural products (Luis Diego was always interested in the uses of tropical plants and published a *Botany of the Central Market* column in the Wilson Garden’s *Amigos Newsletter*).

Fields of work: Brilliant researchers tend to work in many fields, in contrast with the rest of their colleagues; classical examples of the first group include Leonardo da Vinci and Benjamin Franklin. Even though the greatest output from Luis Diego came in the areas of ferns, fungi and angiosperms, his published

work covered many other areas and besides excelling in botany and natural history he was also a gifted illustrator and a pianist. Ana Victoria Lizano says:

“Since the times of high school, Luis Diego was a passionate music lover. He played the violin and the piano very well and I think that even gave some public concerts”.

During the 1970s he defined what would be his major working areas. He described palms, bromeliads, algae, fossil figs and horsetail plants, updating the approach by reconstructing not only the organism but also the environmental conditions in which it lived. This was a model for later research on Costa Rica’s paleoclimate and paleo-ecosystems. He started the series *Flora Costaricensis*, which has continued to appear for more than three decades in the prestigious *Fieldiana: Botany*. He also described new fungi and fern species in various journals, always with excellent illustrations from his own hand.

He rescued Costa Rican lichens from oblivion with his research on basidiolichens, which years later would help make possible a dozen other studies from different authors on lichens as bioindicators of air pollution in Costa Rican cities. He published papers on the taxonomy and geographical distribution of fungi and ferns, from places as diverse as Central America, Easter Island and the Venezuelan Guyana. It was also during this period that Luis Diego began publishing about one of his favorite places, Cocos Island, where he studied subjects ranging from plants to flies that were associated with crabs.

He also made some incursions into ecology when he worked with ants associated with *Polypodium* plants (Gómez 1973) and with *Trigona* bees that collect plant gums (Ramírez & Gómez 1978).

He also pioneered historical analyses of Costa Rican science, with biographies of the Swiss botanist Hermann Crist, who described many Central American ferns (Gómez 1977) and the deeply human story of Swiss botanist

Charles Wercklé, who sadly ended his days as an alcoholic in 19th Century Costa Rica (Gómez 1978).

Giving recognition to Costa Rican biologist Clodomiro Picado Twilight, who published the first large ecological study of bromeliad ecology in the early 20th Century, Luis Diego published *The Biology of Bromeliads*, which was to be the first issue of a new serial publication called *Historia Natural de Costa Rica*, which he was unable to continue.

He annoyed some by dedicating his book *Costa Rican Vegetation* “to the bureaucrats, without whose help I would have done more and better” and made some deep comments on the role of egos in Costa Rica science, for example commenting that the Costa Rican National Academy of Science was useless and included some people who should not be there while excluding some who should be in (Gómez 1994). Fortunately for him, apparently few –if any– ever read that book.

Effect of marriage on productivity: The higher productivity that characterizes earlier life in fields as varied as art, science and crime, may be a manifestation of young men’s competitive desire to gain access to women’s reproductive resources (Kanazawa 2003). The idea of a biological origin, explained because higher productivity would have increased male reproductive success in the ancestral environment, is supported by another interesting observation: marriage has a strong “desistance effect” on the productivity of male scientists and artists: men’s evolved psychological mechanism to be highly competitive in early adulthood seems to “turn off” when they get married, have children and experiment a reduced level of testosterone (Kanazawa 2003).

Luis Diego married in 1970 (Bohlen 1993) and had a son, yet his productivity did not decrease (the marriage, however, lasted only 6 years). One change in his life that should have reduced his productivity was the administrative burden that he had as director of the Natural History Department (National Museum) from 1970 through 1985. Yet this reduction did not occur. Besides the articles, he published 41

other works that included whole books, book chapters, meeting presentations, booklets and maps. In the decade of 1980, he made assessments for the National Park Service, which were handed over to the authorities to improve their administrative work. He also published specialized articles on tropical ferns, conservation of natural ecosystems and botanical gardens and about horticulture in Costa Rica.

In 1989 he married for the second time, but again there was no immediate change in his productivity. During this period, he published several studies on the phytochemistry of Neotropical plants and made three major contributions in book form. On one hand, he played a central role as co-author and sponsor of the essays in *Costa Rican Natural History*, published in English by the University of Chicago and in Spanish by University of Costa Rica.

In this regard, Gail Hewson, states:

“Probably his most accessible and widely read work is the first chapter in *Costa Rican Natural History*, entitled “Searchers on That Rich Coast: Costa Rican Field Biology, 1400-1980” (written with Jay Savage). His other contributions to this collection include “Marsh Fern”, “Tree Ferns”, “Parasitic Plants” and “Ferns” (with Warren H. Wagner). Certainly this fascinating and information rich book tops the list of “Required Readings” for students and travelers even though it was first published more than 20 years ago! ”.

On the other hand, he was the author of *Costa Rica’s Aquatic and Amphibious Plants* (Gómez 1984) and the principal author of *Costa Rica’s Flora and Climate* (Herrera & Gómez 1993) both published by the Universidad Estatal a Distancia de Costa Rica. His work on aquatic plants would become a key reference for the study and conservation of wetlands in Costa Rica, and *Costa Rica’s Flora and Climate* still is the principal compendium on the country’s climate, plant ecology and paleoecosystems.

Possible effect of garden’s work on productivity: The marked reduction in his

personal productivity came when he left the National Museum and started work in the Wilson Botanical Garden. The scientific productivity of the Museum also fell noticeably after he left, not only in quantity but also in quality (and has not recovered to this date). In fact, Luis Diego's output was lower after he started working intensively in conservation and in saving the botanical garden. Gail Hewson remembers this period:

"The garden's recovery after the terrible fire of 1994 was the work of many committed individuals and foundations, but none worked harder than Luis to ensure it. The *Amigos Newsletter* went from being a simple letter to OTS friends and staff members, to a very popular quarterly newsletter for visitors, who sought to keep their memories of the garden alive through the colorful, humorous and enlightening prose that characterized Luis. Who can forget his column *Botany in the Central Market* and his reflections on everything from tropical medicine, nature's color, the protocol to transform a meadow in a forest or the wisdom of the local shamans. He had the wonderful gift of being able to awake interest and even occasional controversy among scientists and laypersons alike".

He also found time to work, with much clearer way, in conservation, combining his duties in the botanical garden with publications on Costa Rica's tropical biodiversity, paramo's ecology and conservation and Costa Rica's southern region common trees and birds names. Simultaneously, he became active in the scientific articles publication on fungi systematic, plant physiology and phytochemistry.

During the third decade, even though his output was lower, he made occasional forays into other fields, such as participating in the redescription of the snake *Bothrops supraciliaris* (Solórzano *et al.* 1998) and understanding the bird's role in dispersal of the primitive plant *Zamia*'s (Gómez 1993), a species particularly striking because it survived the Cretaceous-Tertiary extinction (65.5 million years ago) with few changes.

After 2000 he continued his work on the *Flora Costaricensis*, published more on fungal taxonomy and showed that he was still interest in biogeography with the publication of the important *Central America's Ecosystems Map* (Vreugdenhil *et al.* 2002).

The great fire and its effect on his motivation: Shortly after the fire in the garden, he told one of us (JMN): "My collection of San Vito insects burned during the fire. The next day, a nice beetle landed so close that I captured it with my hand. I told myself 'this is the beginning of my new collection', but then I thought of all that I had lost and let it fly away". Then he showed stacks of manuscripts he kept in a drawer and added: "I have all these, but I will never publish them. I no longer feel like it, I think it will make no difference if I publish them or not". This could explain the fall in his productivity, but it does not: the dramatic reduction in productivity had begun years before, just after he left the Museum. What did he lose when he left, that affected his output so much?

Two hypotheses are that he was too busy teaching and that he no longer felt a need to contribute articles to *Brenesia*.

Luis Diego was a passionate man and this included his teaching activities. He personally participated in the graduate and undergraduate courses taught at the Wilson Botanical Gardens, lecturing and acting as a guide in field trips. Unofficial data in the OTS files indicate that from 1986 to 2008 there were 177 graduate courses with 3 566 students. Additionally there were 56 undergraduate courses. Luis Diego was program coordinator in six of the eight *Ethnobiology* courses taught in Costa Rica, attended by a total of 103 students, participated in similar courses in Peru and even got scholarships for some Peruvian students to travel to Costa Rica (Guiselle Castro, OTS, pers. com.). He also spent time hosting many visiting scientists and student group, so it is easy to see that he did not have much free time to write and we accept this hypothesis as a good candidate to explain the reduction in his productivity.

The “Journal Hypothesis”: Future researchers may test the other hypothesis: that during the museum years he felt the need to write for *Brenesia* because the journal did not receive enough manuscripts and that he published far less after he left the journal because he no longer felt responsible for filling it up.

Conclusion: The 222 publications that Luis Diego Gómez Pignataro contributed to world science are an extraordinary output for a lifetime but he might have produced even more if he had stayed in an European or American research center, with access to far superior resources. Nevertheless, like so many other scientists (as found by Bonaccorsi & Daraio 2003), he chose to stay in his native land, to the great benefit of Latin American biology.

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RESUMEN

Los estudios bibliométricos han encontrado que los investigadores de sexo masculino tienen su mayor productividad aproximadamente a los 40 años; que las investigadoras producen menos que sus colegas masculinos, que los incentivos para la colaboración tardan en aumentar la productividad y que, al igual que los seres humanos, los institutos de investigación se hacen más grandes, menos productivos, más costosos y menos capaces de recaudar dinero a medida que envejecen. Casi siempre, estas conclusiones provienen de estudios de un gran número de científicos europeos y estadounidenses, y prácticamente no hay estudios sobre los investigadores tropicales. Aquí presentamos un análisis detallado de la productividad de un botánico y conservacionista tropical reconocido internacionalmente, Luis Diego Gómez Pignataro, basado en la totalidad de su obra publicada y en nuestro propio conocimiento de su vida como compañeros de trabajo y amigos. Su vida se aparta del patrón esperado en que tuvo su mayor productividad en los primeros 20 años de carrera y produjo comparativamente poco en los siguientes 20 años. Además, el matrimonio no produjo el descenso esperado en su productividad. Justo a la mitad de su carrera se dedicó

intensamente a actividades de enseñanza y conservación, lo que explica esa baja en su producción. Este patrón podría darse en otros científicos tropicales.

Palabras clave: bibliometría, productividad, diferencias entre científicos tropicales y de zonas templadas, ciencia en “países en desarrollo”, conservación y ciencia.

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APPENDIX 1

Titles of periodicals and publishers by country

Titles of periodicals	No. of manuscripts	Country	Publishing house
Brenesia	51	Costa Rica	Museo Nacional de Costa Rica. Departamento de Historia Natural
Revista de Biología Tropical	34	Costa Rica	Universidad de Costa Rica
Lankesteriana	4	Costa Rica	Universidad de Costa Rica. Jardín Botánico Lankester
Revista Geológica de América Central.	3	Costa Rica	Universidad de Costa Rica. Escuela Centroamericana de Geología
Biocenosis	1	Costa Rica	Universidad Estatal a Distancia. Centro de Educación Ambiental.
Historia Natural de Costa Rica. Biología de las Bromeliáceas	1	Costa Rica	Museo Nacional de Costa Rica. Departamento de Historia Natural
O'Bios	1	Costa Rica	Universidad de Costa Rica. Boletín de la Escuela de Biología
American Fern Journal	20	USA	The American Fern Society

APPENDIX 1 (Continued)

Titles of periodicals and publishers by country

Titles of periodicals	No. of manuscripts	Country	Publishing house
Phytologia	13	USA	Texensis Publishing
Fieldiana. Botany	5	USA	Chicago Natural History Museum
American Journal of Botany	3	USA	Botanical Society of America
Annals of the Missouri Botanical Garden	3	USA	Missouri Botanical Garden
Biotropica	2	USA	Association of Tropical Biology and Conservation
Bulletin of the Torrey Botanical Club	2	USA	Torrey Botanical Society
Journal of the Lepidopterists' Society	2	USA	The Lepidopterists' Society
Mycotaxon	2	USA	Mycotaxon
BioScience	1	USA	American Institute of Biological Sciences
Botanical Gardens Newsletter	1	USA	University of California Botanical Garden, Berkeley
Heliconia Society International Bulletin	1	USA	Heliconia Society International
The Coleopterists Bulletin	1	USA	The Coleopterists Society
Nova Hedwigia	3	Germany	Schweizerbart and Borntraeger Science Publishers
Zeitschrift für Naturforschung. Section C, Biosciences	3	Germany	Verlag
Biochemical Systematics and Ecology	2	Germany	Elsevier
Beiträge zur Biologie der Pflanzen	1	Germany	Duncker & Humblot
Veröffentlichungen aus dem Übersee-Museum Bremen	1	Germany	Museum Bremen
Fern Gazette	2	England	British Pteridological Society
Proceedings of the Royal Society of Edinburgh	2	Great Britain	The Royal Society of Edinburgh.
Studies on Neotropical Fauna and Environment	1	Great Britain	Taylor & Francis
The Mycologist	1	Great Britain	The British Mycological Society
Transactions of the British Mycological Society	1	Great Britain	The British Mycological Society
Chemical & Pharmaceutical Bulletin	3	Japan	Pharmaceutical Society of Japan,
Darwiniana	3	Argentina	Instituto de Botánica "Darwinion"-
Canadian Journal of Botany	1	Canada	National Research Council
Atti dell'Istituto Botanico e Laboratorio Crittogamico dell'Università di Pavia. Serie 6	1	Italy	Istituto Botanico e del Laboratorio Crittogamico dell'Università di Pavia.

APPENDIX 1 (Continued)

Titles of periodicals and publishers by country

Titles of periodicals	No. of manuscripts	Country	Publishing house
Museum Internacional	1	France	UNESCO
Ceiba	1	Honduras	Escuela Agrícola Panamericana Zamorano
Herb	3	Unknown	Unknown
Total	181		

APPENDIX 2

Number of authors per article

Number of articles	Coauthors to L.D. Gómez
14	J. Gómez-Laurito
7	L. Kisimova-Horovitz
6	R. Singer, E. Wollenweber
5	F. Oberwinkler
4	W.H., Jr. Wagner
3	C. Chiu-Ming, J. García-Jiménez, C.A. Laurito-Mora, T. Murakami, Y. Saiki, A.L. Valerio-Zamora, F.S. Wagner, J.W. Wallace
2	S.C. Hsiao, K.E. Malterud, J.D. Mauseth, J.I. Mead, N. Tanaka, C.E. Valerio-Gutiérrez
1	R.M. Alfaro, G.E. Alvarado-Induni, R.S. Anderson, A. Atmella-Cruz, J. Bergelson, Braker, H.E., J. Bruce, G. Cooper-Driver, B.I. Crother, R. Cubero-Murillo, C.M. D'Antonio, C.C. Daehler, V.H. Dietz, M. Dörr, J. Favre-Bonvin, P.H. Gamboa, D.E. Giannasi, J.C. Godoy, D.R. Gordon, D.J. Graham, G.S. Hartshorn, L. Hartshorn, D.A. Henk, L.R. Hernández-S., O. Herrera-MacBryde, W. Herrera, R.J. Hobbs, A. Holt, K.R. Hopper, C.E. Hughes, S. Imhof, P.H. Jolivet, M. Kappelle, T. Kruckow, M. LaHart, R.R.B. Leakey, W.G. Lee, P.E. León-Azofeifa, R.W. Lichtwardt, L.L.M. Loope, D.H. Lorence, S.M. Louda, S.G. Lucas, A.E. Lugo, K.R. Markham, E. Martínez, A. Mata-Jiménez, L. Mata-Jiménez, P.B. McEvoy, J. Meerman, A. Mendoza, A. Meyrat, J.T. Mickel, J. Monge-Nájera, J.M. Mora-Benavides, R. Morales, V.V. Méndez-Alvarez, J. Ness, D.J. O'Dowd, R.A. Ocampo-Sánchez, D.N. Pegler, D.H. Pfister, J.D. Pittillo, D.J. Pool, R.S. Pozner, E.A. Pérez-Gamboa, B. Pérez-García, L.G. Pérez-Rivera, C.A. Quesada-Mateo, W. Ramírez-Benavides, R. Riba, D.M. Richardson, C.H.F. Rowell, M. Rowell-Rahier, L. Ryvarden, T. Satake, M. Savage, E. Schmid, A. Sivanesan, R. Soeder, C. Solera-Mora, A. Solórzano-López, R. Solórzano-Soto, F.G. Stiles, S.L. Swift, J.A. Jr. Tosi-Olin, A. Ugalde-Viquez, A. Umaña-Quesada, J.L. Villa-Lobos, C. Villalobos, P.M. Vitousek, D. Vreugdenhil, K.S. Walter, H.C. Weber, R. Weels, D.M. Windsor, D.L. Yopp.

APPENDIX 3

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