UNIVERSIDAD NACIONAL DE COLOMBIA

ACTA BIOLÓGICA COLOMBIANA
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ARTÍCULO DE INVESTIGACIÓN/RESEARCH ARTICLE

META-ANALYSIS OF THE HISTORY OF THE STUDY OF THE FRESHWATER TURTLE AND TORTOISE FAUNA OF COLOMBIA

Meta-análisis de la historia del estudio de las tortugas continentales de Colombia

Brian C. BOCK[1], Vivian P. PÁEZ[1].

[1] Grupo Herpetológico de Antioquia, Instituto de Biología, Facultad de Ciencias Exactas y Naturales, Universidad de Antioquia. Calle 67 n°. 53-108, bloque 7-121. Medellín, Colombia.

For correspondence. brianbock1@gmail.com

Received: 2nd September 2016, **Returned for revision**: 11th October 2016, **Accepted**: 28th November 2016.

Associate Editor: Alan Giraldo.

Citation/Citar este artículo como: Bock BC, Páez VP. Meta-analysis of the history of the study of the freshwater turtle and tortoise fauna of Colombia. Acta biol. Colomb. 2017;22(1):67-76. DOI: http://dx.doi.org/10.15446/abc.v22n1.59876

ABSTRACT

The citations contained in a recent literature review on the freshwater turtle and tortoise species of Colombia were analyzed. Publishing rates on these species have been increasing exponentially since the 1950s, although many of the publications would not be detected using internet-based literature searches. The most common topics of publications were systematics and phylogeography, nesting ecology, and management. In the 1970s and 1980s, the rate of publishing on the ecology and genetics of Colombian populations lagged behind the rate of publishing on these topics for populations of Colombian freshwater turtle and tortoise species located in other countries, but currently the production of the two regions is comparable. Also, in other countries there were trends towards publishing more over time in English and in journals with higher impact factors, but these trends were not significant for publications on Colombian populations. In Colombia, a disproportionate number of studies have been published on large-bodied species that face conservation problems. We argue that future studies of already well-studied Colombian species should focus on evaluating the effectiveness of management programs, and priority also should be given to increasing our knowledge of the many poorly-studied species in the country, especially those currently classified by the IUCN as data deficient (DD).

Keywords: knowledge, literature, meta-analysis, publications, Testudines.

RESUMEN

Analizamos las referencias incluidas en una reciente revisión literaria sobre el estado de conocimiento de las tortugas continentales de Colombia. La tasa de publicaciones sobre estas especies ha incrementado exponencialmente desde los años 1950s, aunque muchas de éstas no podrían haber sido detectadas usando búsquedas de literatura por internet. Los tópicos más comunes de las publicaciones fueron sistemática y filo-geografía, ecología de anidación, y manejo. En los años 1970s y 1980s, la tasa de publicaciones sobre temas de ecología y genética de poblaciones ocupando el territorio colombiano, estuvo por debajo de publicaciones sobre estos dos tópicos con poblaciones de las mismas especies en otras regiones de Suramérica. Sin embargo, actualmente la producción en ambas regiones es comparable. En otros países, detectamos una tendencia temporal significativa de publicar cada vez más en inglés y en revistas de mayor impacto; esta tendencia no fue significativa para las publicaciones sobre poblaciones de tortugas colombianas. En Colombia, un número desproporcionado de las publicaciones son sobre especies de tamaños grandes que enfrentan problemas de conservación. Argumentamos que estudios futuros de las especies de tortugas continentales de Colombia relativamente bien conocidas, se deberían enfocar en evaluar la efectividad de los programas de manejo, y también debemos dar prioridad a investigaciones que aumenten el estado de conocimiento de las especies de tortugas continentales poco estudiadas en el país, especialmente de aquellas que actualmente están categorizadas por la UICN como con datos deficientes (DD).

Palabras clave: conocimiento, literatura, meta-análisis, publicaciones, Testudines.

INTRODUCTION

Internet-generated bibliographic data bases have facilitated analyses of trends and patterns in the published scientific literature (Arnqvist and Wooster, 1995). There even are guidelines available to help such meta-analyses avoid or minimize certain limitations inherent in them, such as biases that arise because indexing services favor journals published in English or because journals prefer to publish positive results (Csada *et al.*, 1996; Møller and Jennions, 2001; van Leeuwen *et al.*, 2001; Rothstein *et al.*, 2005; Aleixandre-Benavent *et al.*, 2007).

Several meta-analyses have been conducted recently on freshwater turtle and tortoise species (Ashton and Feldman, 2003; Gibbs and Steen, 2005; Fitzsimmons and Hart, 2007; Luiselli, 2008a; Luiselli, 2008b; Perez-Heydrich *et al.*, 2012; Lovich and Ennen, 2013), and most have been based on internet-generated bibliographic compilations. For example, FitzSimmons and Hart (2007) summarized patterns apparent in publications on the genetics of freshwater turtle and tortoise species over a 70-year period, based upon inspection of 262 articles compiled principally from online bibliographic searches, but also supplemented with additional citations provided by experts in this field whom they consulted. However, Lovich and Ennen (2013) used a different strategy in their analysis of patterns in the history of publishing on North American turtle species, by exploiting five previously published literature reviews that spanned 70 years, from the 800 references cited in Pope (1939) to the 5,241 references cited in Ernst and Lovich (2009).

Analyses of publication patterns and trends for neotropical turtle faunas are lacking, in part because much of the relevant literature is in languages other than English in journals not covered by the major indexing services, and also because comprehensive summaries of the literature on neotropical turtle faunas (comparable to Ernst and Lovich, 2009) often are not available. Here we provide an analysis of an extensive literature review compiled recently on the freshwater turtle and tortoise species of Colombia, which contains many citations that would not be detected via internet-based bibliographic searches. The analysis is based on citations contained in an edited volume summarizing the state of knowledge of the rich freshwater turtle and tortoise fauna of this country, which boasts 27 species and seven Families (Páez *et al.*, 2012). The goal of this analysis was to summarize historical trends in publication on Colombian freshwater turtle and tortoise species, to identify biases in publication rates on different topics and study species, and propose priorities for future research efforts.

MATERIALS AND METHODS

"Biología y Conservación de las Tortugas Continentales de Colombia" (Páez *et al.*, 2012) is a 523 paged edited volume containing 20 chapters written by over 40 experts directly involved in research and/or conservation of freshwater turtle and tortoise species in Colombia, or in other countries where these species occur. Most chapters in the volume focus on specific topics in ecology, evolution, or conservation biology, with emphasis placed on the Colombian freshwater turtle and tortoise fauna, while its largest chapter (113 pages) is comprised of summaries of the available literature for all 27 Colombian species.

Data set preparation

Each of the 20 chapters in the book has its own bibliography, so our first step was to consolidate these bibliographies into a data base comprised of 1199 unique citations. Next, we removed 250 citations that were not directly related to turtle biology (for example, articles concerned with different aspects of the country of Colombia, theoretical papers in ecology and evolution, and general books on biology, including herpetology texts).

The remaining 949 citations contained a bias related to the systematic literature. The 27 species accounts in the book each contained a section listing known synonyms for the species, with the number of synonyms reported for a species varying from 0-26 (median = seven alternative names). We suspect this variance was due as much to differences among the different authors in their interests in the nomenclatural history of their subject species, rather than to real differences among the species in terms of their taxonomic stabilities. To correct for this bias, we examined each of the 138 references cited in the synonym and taxonomic history sections of the 27 species accounts and classified them as either being cited principally for nomenclatural reasons vs. being citations that contained additional biological information on the species (as evidenced by their being cited in other contexts in the species account, or in other chapters of the book).

This classification produced two contrasting groups; 87 citations only mentioned in the context of past nomenclatural usage (with a mean publication date of 1908) and 51 citations also mentioned in the book for other reasons (with a mean publication date of 1987). The distinctiveness of this "old taxonomic literature" is even more apparent when compared to the distribution of publication dates for the remaining 811 citations related to turtles contained in the book (mean publication date = 1995). For this reason, the 87 strictly nomenclatural citations were removed from the data base for all subsequent analyses, leaving 862 citations published on different aspects of the biology of turtles for analysis.

Citation classification

All of the remaining citations in the data base were classified according to language (English vs. Other languages) and publication type, as either journal Articles, Chapters in edited volumes, Books, undergraduate and graduate

Theses, Abstracts from meetings, Web pages, or Reports (documents that were printed by government agencies, non-governmental organizations, or university institutions). Books and edited volumes were defined as publications that credited one entity as its publisher (usually a university press, specific branch of a government, or commercial editorial house). In contrast, reports contained the word "report" (or "informe") in the title and/or gave credit as the "publisher" to multiple entities (usually all of the different funding agencies, governmental agencies, non-governmental organizations, or university departments involved in the project).

We also classified each citation into categories related to their pertinence to Colombian turtle species. General publications contained information on the biology of one or more turtle species, but not on species that occur in Colombia. Regional publications contained information on turtle species that occur in Colombia, but that was obtained from non-Colombian specimens or populations, while Colombian publications contained information on Colombian specimens or populations. Most publications were classified into one of these categories based upon our direct inspection of their contents. Of the remaining publications that we could not directly access, many could be unequivocally classified based upon their title, abstract, or from the context in which they were cited in the book. Finally, we classified several of the remaining publications by consulting the authors of the section of the book that cited them. Only six publications in the total data base could not be classified as to the degree of relevance regarding Colombian turtle species by any of these methods.

Each publication also was classified in terms of its principle focus. Categories were: 1) Descriptive studies (sub-classified as a. notes on distribution, b. publications on morphology of living or fossil forms, c. general natural history accounts, and d. records of parasite species); 2) Ecological studies (publications containing more quantitative analyses, sub-classified as a. nesting ecology and temperature-dependent sex determination, b. diet and growth rates, c. demography, predation, and habitat preferences, and d. other behavioral studies); 3) Genetic studies (sub-classified as a. karyotype characterizations, b. population genetics and paternity studies, and c. systematic and phylogeography studies); 4) Management and conservation publications (sub-classified as a. status evaluations, b. management plans and programs, c. documentation of exploitation patterns, and d. scientific evaluations of management techniques); and 5) Bibliographic revisions (sub-classified as a. species accounts and b. meta-analyses of published data). Articles that touched on more than one of these categories or sub-categories was classified as to its apparent principle focus, so that no article was included in more than one category or sub-category.

For the subset of publications on Colombian turtle species (both Regional and Colombian data bases), publications that were articles were classified according to the impact factor score of the journal (2014 scores, Journal Citation Reports, 2015) as either null impact (no impact factor score), low impact (an impact factor score of < 1.0), or high impact (an impact factor score of > 1.0). Journal impact scores change each year, but we assumed most journals remained within these three broad categories over the history of the calculation of impact scores since 1975, and that this classification also reflects the general impact of the journals prior to this time. Finally, for only those citations in the Colombian data base, each was classified in terms of the species of freshwater turtle or tortoise it included. Citations could be classified as containing information on from one to 27 species.

Analyses

Lovich and Ennon (2013) used two metrics to quantify the level of knowledge of turtles in North America; the cumulative number of publications, and the cumulative amount of text contained in those publications (quantified as the number of published pages). In this study, we only consider the number of publications as our metric of knowledge of Colombian freshwater turtle and tortoise species because 1. page number information was lacking for 4 % of the citations in the data base, 2. even for publications with page number information (especially theses and reports), we suspected that many of the pages did not contain new information on the focal species, and 3. the analyses of Lovich and Ennon (2013) showed that both metrics behaved comparably in their study.

To inspect for differences among the citations in the General, Regional, and Colombian data bases in terms of their principal focus, language, and journal impact levels, we employed heterogeneity G-tests (Sokal and Rohlf, 2011). To inspect for temporal shifts in principal focus, language, or journal impact levels in the Regional and Colombian data bases, the publications were divided into five time periods (prior to 1970, 1970s, 1980s, 1990s, and post-1999) and frequencies in each category were compared via heterogeneity G-tests. To compare the rate of publication on Colombian freshwater turtle and tortoise species, the cumulative number of publications in the Regional and Colombian data bases for the period 1812–2012 was calculated. Also, an ANCOVA with year as covariate was conducted on log transformed cumulative publication number values to inspect for differences in both the number of publications in each data set, and their rates of increase, for the period 1950–2012.

Finally, for each of the 27 Colombian freshwater turtle and tortoise species, the total number of citations on Colombian populations or specimens was tabulated. To

inspect for a relationship between the number of citations for a species and the maximum body size known for that species, a Pearson's correlation was calculated, using the body size data reported in Páez *et al.* (2012). Species also were grouped by IUCN National Red Book category (Morales-Betancourt *et al.*, 2015a) and the publication totals were compared using a Kruskall-Wallace test.

RESULTS

There were significant differences among the General data base (n = 253 citations), Regional data base (n = 334 citations), and Colombian data base (n = 269 citations) in terms of the proportion of citations dedicated to different topics (G = 156.42, df = 8, $p < 0.001$), with citations with an ecological focus predominating in the General data base, and the Colombian data base exhibiting a disproportionate number of citations on management and conservation (Table 1). This latter difference also was significant when the General data base was excluded from the analysis (G = 29.81, df = 4, $p < 0.001$).

The rate of publication on Colombian species of freshwater turtle and tortoise species was negligible prior to the 1950s, both in terms of Colombia populations and populations occurring in other countries, but these rates have increased exponentially since that time (Fig. 1). During the period 1950–2012, significantly more publications appeared each year on non-Colombian populations, but the rate of increase (slope) in cumulative number of publications was greater for Colombian populations (ANCOVA, number of publications, $p < 0.001$, rate of increase, $p < 0.001$).

The main focus of studies on Colombian freshwater turtle and tortoise species varied over time, both for Colombian populations (G = 52.54, df = 16, $p = 0.001$) and for populations in other countries (G = 56.81, df = 16, $p < 0.001$). The initial studies were descriptive, with ecological and genetic studies increasing in frequency in the 1970s and 1980s, although the absolute number of such studies in Colombia lagged behind the trend seen in other countries (Fig. 2). Most of the publications cited in Páez *et al.* (2012)

Table 1. Proportion of publications by principle focus and sub-categories for the General, Regional, and Colombian data bases. See the text for fuller descriptions of the sub-categories.

	General	Regional	Colombian
Descriptive studies	32 (13 %)	112 (34 %)	69 (26 %)
Distribution	3	46	16
Morphology	14	13	22
Natural History	11	30	22
Parasites	4	23	9
Ecological studies	174 (69 %)	115 (34 %)	68 (25 %)
Nesting	119	67	39
Growth	9	23	6
Demography	25	14	20
Behavior	21	11	3
Genetic studies	30 (12 %)	45 (13 %)	30 (11 %)
Karyotypes	0	9	2
Pop. Genetics	3	10	10
Systematics	27	26	18
Management and Conservation	14 (5 %)	46 (14 %)	66 (25 %)
Status	1	3	11
Plans	8	12	38
Exploitation	1	23	15
Evaluations	4	8	2
Bibliographic reviews	3(1 %)	16 (5 %)	36 (13 %)
Species accounts	2	6	22
Bibliographic reviews	1	10	14

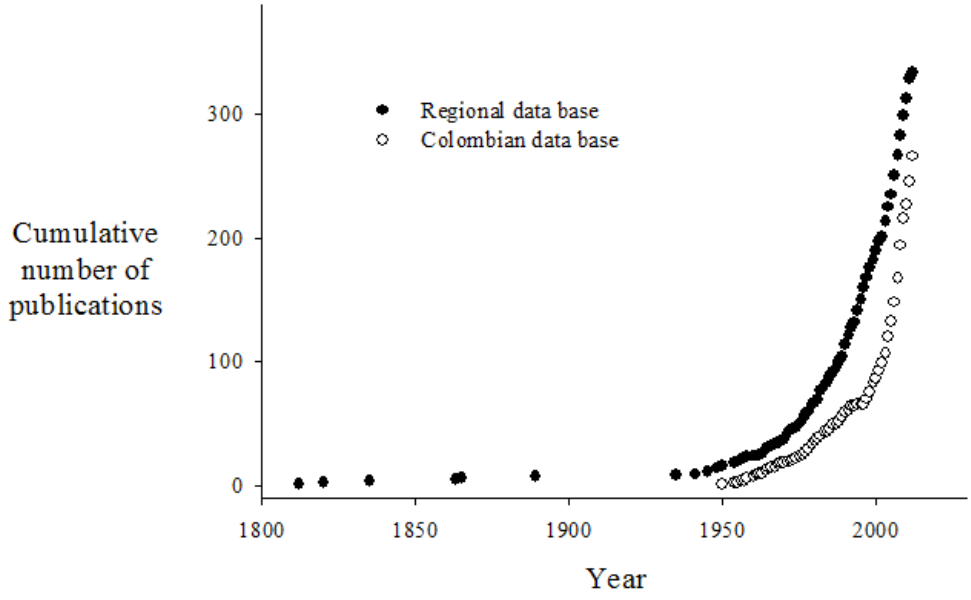

Figure 1. The exponential rate of increase over time in the cumulative number of publications that were conducted on Colombia freshwater turtle and tortoise species, either in other countries (Regional data base) or with Colombian populations or specimens (Colombian data base).

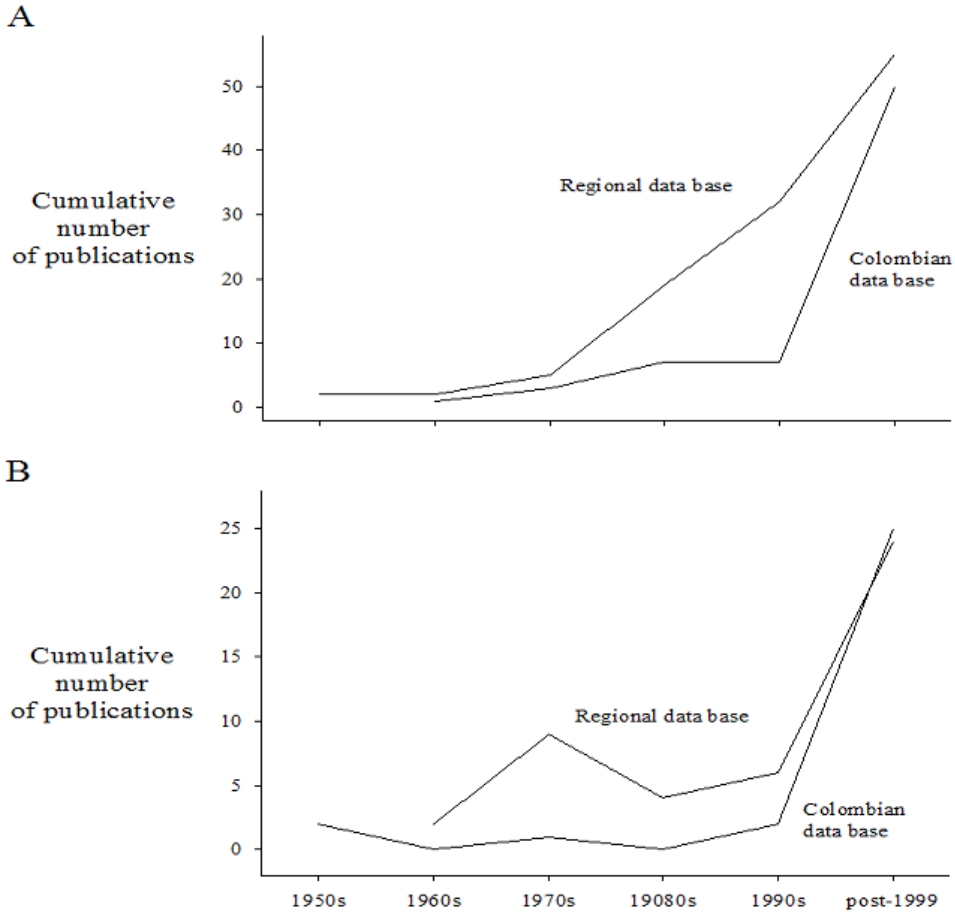

Figure 2. Disparity in the number of publications per decade between the Regional data base and Colombian data base in terms of the number of publications on A. ecology and B. genetics.

with a management and conservation focus were from the post-1999 period.

The three data bases also exhibited differences in the proportion of citations they contained that were published in English (G = 168.36, df = 2, $p < 0.001$), with English predominating (96 %) in the General citations on turtles, but not in the citations on Colombian species. There was a significantly greater proportion of citations in English in the Regional data base than in the Colombian data base (G = 14.26, df = 1, $p < 0.001$). However, this difference was not apparent when only articles were compared (G = 1.46, df = 1, $p > 0.10$). The proportion of citations in English in the Colombian data base did not increase over time (G = 3.82, df = 4, $p > 0.10$), although there was a trend in increasing numbers of citations in English over time in the Regional data base (G = 9.16, df = 4, $p = 0.057$). There also was a trend over time towards publishing articles on Colombian species of freshwater turtle and tortoise species in journals with higher impact factors (significant in the case of the Regional data base; G = 9.83, df = 2, $p < 0.05$), especially during the transition from the pre-1970 to post-1970 periods (Table 2).

Table 2. Proportion of articles with information on Colombian tortoise and freshwater turtle species, classified according to the impact factor ranking of the journal (null = no ranking, low = < 1.0, or high = > 1.0).

Regional literature	Null	Low	High
Prior to 1970	0.70	0.23	0.07
1971-1990	0.43	0.27	0.30
After 1999	0.45	0.27	0.28
Colombian literature			
Prior to 1970	0.56	0.38	0.06
1971-1990	0.47	0.21	0.32
After 1999	0.39	0.28	0.33

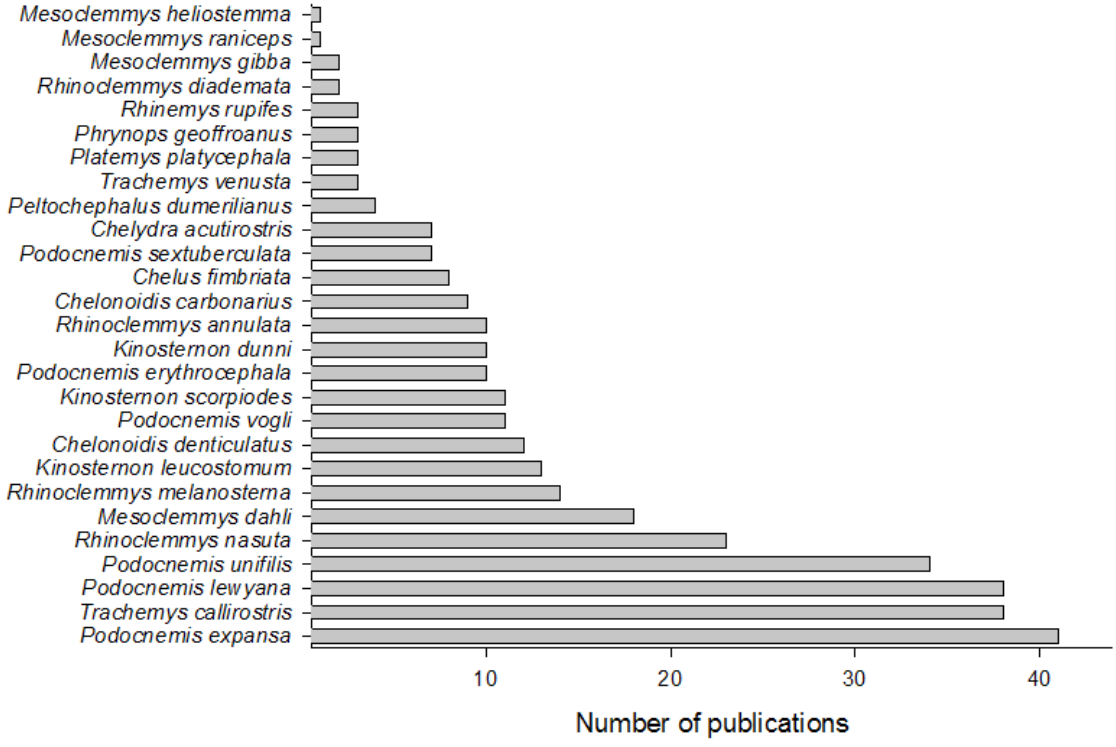

Figure 3. Number of publications on the 27 species of freshwater turtles and tortoises contained in the Colombian data base (Colombian populations or specimens).

The publications on Colombia populations or specimens of freshwater turtle and tortoise species was biased towards larger bodied species ($r^2 = 0.16$, $p < 0.05$) and also was biased towards species with conservation problems, especially the two Critically Endangered species (Podocnemis expansa Schweigger 1812 and Podocnemis lewyana Duméril 1852; Kruskal-Wallis test, $p < 0.05$). The number of publications on Colombian populations or specimens, in rank order by species, is presented in Figure 3.

DISCUSSION

The bibliographic data we obtained from the Páez *et al.* (2012) edited volume contained certain biases. For example, the General data base contained a disproportionate number of ecological studies that were cited in the theoretical chapters of the book, with an under-representation of descriptive studies (Table 1). Considering only the literature that focused directly on Colombian species, there also was an under-representation of theses and reports in the Regional data base, as compared to the Colombian data base (Table 1). However, these biases probably do not invalidate the conclusions presented here. At least the data set we analyzed was preferable to attempting to conduct an analysis on only the results of an internet-based bibliographic search, which would have missed most of the theses and reports (19 % of the total citations in the book), as well as 46 % of the articles cited (because they were published in non-indexed journals).

The exponential rate of increase in the cumulative number of publications on Colombia species of freshwater turtle and tortoise species is similar to that documented by Lovich and Ennen (2013) for North American turtle species, with both patterns probably reflecting the exponential rate of human population growth over the past half century, with concomitant increases in both the number of turtle species facing conservation problems (Cohen, 1995) and the number of researchers earning doctorates and publishing on turtles during their careers (Cyranoski *et al.*, 2011).

More of what we currently know about the Colombian freshwater turtle and tortoise fauna comes from studies conducted in other countries where these species also occur (with the exception of the three endemic species, obviously). This is not surprising, given that many non-endemic Colombian freshwater turtle and tortoise species have wide geographic ranges, occupying as many as 19 additional countries that occur from Mexico to Argentina (median number of additional countries for the non-endemic Colombian species = five; Páez *et al.*, 2012). But the rate of increase in publications on Colombia populations seems to be currently higher than in other countries, suggesting that the cumulative number of publications on Colombia populations will soon exceed those based on populations outside of Colombia (Fig. 1). This could be a genuine trend, or simply the result of the authors of the species accounts being more familiar with recent publications on Colombian populations, but it nevertheless reflects a significant recent increase in knowledge on the Colombian freshwater turtle and tortoise fauna.

Concomitant with the exponential increase in publishing on Colombian freshwater turtle and tortoise species were increases, at least for studies conducted outside of Colombia, in the proportion of publications appearing in English, and in the impact of the journals where articles were published. Even so, only 19.3 % of the information published on Colombian freshwater turtle and tortoise species cited in the Páez *et al.* (2012) book appeared in indexed journals.

The earliest citations on Colombia populations and specimens of freshwater turtle and tortoise species mentioned in the Páez *et al.* (2012) review were the taxonomic study of Williams (1954) and the descriptive natural history and distributional studies of Medem (1956, 1958), with more ecological studies by Medem appearing in the 1960s (for example, Medem, 1964, 1966). It is not clear why the number of ecological studies in Colombia lagged behind the number of ecological studies of Colombian species in other countries during the 1980s and 1990s (Fig. 2A). However, the limited number of genetic studies on Colombian populations during this period (Fig. 2B) may have been related to the governmentally imposed disincentives for genetic research in Colombia at that time (Grajal, 1999; Fernández, 2011). Currently, ecological and genetic studies of Colombian populations are appearing at a rate comparable to that seen in the other countries that share these species, with the preponderance of ecological studies focusing on nesting ecology and the majority of genetic studies focusing on systematics and phylogeography (Table 1).

Only in the past two decades have publications on the management and conservation of Colombian freshwater turtle and tortoise species become common. Unfortunately, most of these publications consist of non-peer reviewed reports ("grey literature") that often merely propose management strategies for particular species/areas, with only limited efforts to evaluate the levels of exploitation or the status of Colombian populations, and almost no rigorous scientific monitoring of the effectiveness of the different management programs being implemented.

Grey literature has been criticized because it is difficult to access and often suffers from a lack of peer review (Hopewell *et al.*, 2005). Our results also suggest that it is quickly forgotten; 80 % of the grey literature reports on Colombian populations were from the post-1999 period, with only one pre-1970 report being cited in the book (Dahl and Medem, 1964). We suspect that old grey literature reports are not cited because most grey literature

citations are cases of self-citation, perhaps not strictly in the form of the same author citing their previous reports (reports often fail to even provide authors names!), but at least of authors citing reports produced recently by their own government office, non-governmental organization, or university institution.

For the North American turtle fauna (sea turtles excluded), Lovich and Ennen (2013) found citation number was not related to body size or the conservation status of the species. For Colombian species, citation number increased both with increasing body size and increasing levels of conservation threat to the species. This may be because in Colombian the principle threat to turtle species is the over-exploitation of larger species, while in North America, a larger percentage of threatened turtles are small-bodied species at risk due to habitat loss. It also may be because North American herpetologists avoid studying threatened species due to their declining population sizes and problems associated with obtaining permits for studying these species (Lovich and Ennen, 2013). In contrast, in Colombia the limited funding opportunities are preferentially directed towards the economically important, over-exploited, large-bodied turtle species, obliging Colombian herpetologists to confront permitting issues to be able to conduct studies.

Lovich and Ennen (2013) found no evidence that the exponential increase in knowledge of the turtle fauna of North America had helped alleviate the conservation problems faced by many of those species. Similarly, the exponential increase in knowledge of the Colombian freshwater turtle and tortoise fauna over the past half century has not resulted in improvements in the conservation status of Colombia's threatened species. There have been non-genuine changes to the conservation status of some species because new information has accumulated to show their initial IUCN categorization was incorrect (Castaño-Mora, 2002; Morales *et al.*, 2015a). But only effective implementation of existing environmental legislation will likely reverse the declining trends affecting many populations of Colombian freshwater turtle and tortoise species.

Lovich and Ennen (2013) classified turtle species in North America into three groups in terms of the number of citations per species: extremely well-studied, well-studied, and poorly-studied species. For Colombia, *P. expansa, P. lewyana, P. unifilis, T. callirostris, and perhaps R. nasuta* and *M. dahli* could be considered well-studied species, with the remaining species being poorly-studied. We argue that future research on the already well-studied species would best be directed towards monitoring demographic tendencies and evaluating the effectiveness of existing or future management programs (Páez *et al.*, 2015). We also hope the explosion of knowledge on Colombian freshwater turtle and tortoise species continues, including the trend of publishing more in indexed journals in English, but hopefully in a way that also includes more of the poorly-studied species (Morales-Betancourt *et al.*, 2015b; Forero-Medina *et al.*, 2016), especially those that lack IUCN conservation status categorization (being listed currently as Data Deficient).

CONCLUSIONS

The literature cited in the edited volume "Biología y Conservación de las Tortugas Continentales de Colombia" (Páez *et al.*, 2012) provided a data base that allowed a meta-analysis of publication trends on the 27 species of freshwater turtles and tortoises of Colombia. Such an analysis based upon an internet search approach would not be possible because of the high proportion of studies on the Colombian freshwater turtle and tortoise fauna that appear in languages other than English in non-indexed journals or in other types of publications. This meta-analysis showed that the publication rate on Colombian turtle species is increasing exponentially, but is biased towards the study of large species that face conservation problems. Future studies should prioritize the evaluation of the effectiveness of management programs designed to conserve these species, as well as seek to obtain basic biological information on the remaining under-studied portion of the Colombia freshwater turtle and tortoise fauna.

ACKNOWLEDGMENTS

We thank the Instituto de Investigaciones Biológicas Alexander von Humboldt for their publication series on "Recursos Hidrobiológicas y Pesqueros Continentales de Colombia" that made the publication of the Páez *et al.* (2012) book possible, and to the authors of the different chapters in that book for their thoroughness and help in providing information on the citations they used.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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