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70 years of herpetology in India: insights into shifts in focal research areas and gender ratios among authors

Vivek Philip Cyriac[1,2,*], Sneha Dharwardkar[3], Anuja Mital[3], Ashwini Venkatanarayana Mohan[4,*]

1 - Centre for Ecological Sciences, Indian Institute of Science, CV Raman Rd, Bengaluru, Karnataka, 560012, India

2 - The Liana Trust, Sy. No. 1418/1419, Rathnapuri, Hunsur, Karnataka, 1571189, India

3 - Freshwater Turtles and Tortoises Foundation, Thane, 400610, Maharashtra, India

4 - Department of Evolutionary Biology, Zoological Institute, Braunschweig University of Technology, 38106 Braunschweig, Germany

*Corresponding author; e-mail: ashwinivm30@gmail.com; vivek.cyriac@gmail.com

ORCID iDs: Cyriac: 0000-0002-0465-0452; Dharwardkar: 0000-0003-4797-7428;
Mital: 0000-0002-9581-6664; Mohan: 0000-0001-9505-0665

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Abstract. Herpetology in India took off during the British colonial rule with the documentation of herpetofauna. Several studies have outlined the early history of Indian herpetology; however, few have traced the growth of this field since India's independence. We analyse trends in Indian herpetology focusing on taxa, subfields, and authorship over the last 70 years. Of the 1177 published articles we analysed, 64.9% studied reptiles, 26.5% studied amphibians and 8.6% were general herpetofaunal studies. Frogs, lizards, and snakes being the most diverse herpetofauna groups, each accounted for 20-21% of the published articles and significantly outnumber publications on caecilians (2.3%), salamanders (0.4%), chelonians (12.6%), and crocodiles (4.4%). We found a significantly greater number of publications on Diversity & Distribution (34.2%), Taxonomy & Systematics (21.6%) and Ecology (19.4%) compared to other subfields, and detected a decline in Development, Physiology & Cytology and Evolutionary biology studies over the last four decades (1980-2019). The gender ratio among co-authors was dominated by men with only 29.7% of publications containing women authors. The overall proportion of women authors has not changed significantly over decades, but our analyses detected a significant decrease in women first authors and the proportion of women authors when the corresponding authors were men. Women authors were substantially lower in the subfield of Taxonomy & Systematics, and women published significantly more on amphibians compared to reptiles. Overall, we highlight the growth of herpetology in India from two key viewpoints, scientific pursuits, and gender parity among herpetologists.

Keywords: amphibians, gender bias, India, reptiles, trends in herpetology, women in herpetology.

Introduction

Herpetology, the study of amphibians and reptiles, has not only imparted a profound sense of fascination among many biologists but has had a pivotal role in the conceptual development of ecology and evolution providing a glimpse into many fundamental questions in biology (e.g., developmental biology, venomics) (Wake, 2008). Herpetology in India emerged with the incidental collection and documentation of herpetological specimens by naturalists during the pre-colonial period in the 18th century (Smith, 1952; Das, 2003a, b). A more dedicated approach to herpetology started with the works of Patrick Russell who began systematically documenting and identifying snakes in the Indian subcontinent during the late 1700s, giving way to the description of several common snakes by other taxonomists (Hawgood, 1994; Bauer, 2015). The colonial period saw a lot more development in the documentation of amphibians and reptiles, starting with the collections of Edward Blyth in the mid-1800s (Das, 2003a, b). In the late 1800s, Richard Henry Beddome and William Theobald made some of the most prolific herpetological documentations, which was followed by three seminal volumes on the reptiles of British India by Malcolm A. Smith published between 1931-1943 (Das, 2003a). Although most of the early work in Indian herpetology was taxonomical, there was also some developments in the areas of distribution, ecology, anatomy, development, and physiology (e.g., Russell and Home, 1804; Wall, 1919; Mahendra, 1941; Ramaswami, 1935). While a few studies have tracked the development of herpetology in India until colonial rule (e.g., Das, 2003a, b), review publications focussing on trends in Indian herpetology post-independence are scarce and have had limited focus (e.g., Whitaker and Whitaker, 1983; Hebbar et al., 2019).

Early explorers and naturalists were almost always men and consequently, just like other branches of STEM, the natural sciences have been dominated by men (Rose, 1983). Herpetology is no different and has generally been considered a male-dominated science (Adler, 1989; Wilson, 1998; Rock et al., 2021). Although the field has seen some prominent women who have made significant contributions (see Myers, 2000; Lenin, 2006; Parenti and Wake, 2016), and women participation has increased over the years, it remains notably low compared to that of the men (Wilson, 1998; Grosso et al., 2021; Rock et al., 2021). The historical existence of gender disparity in STEM fields across the world has been well documented (Holman et al., 2018; De Kleijn et al., 2020; Huang et al., 2020). Although this disparity has been shrinking compared to historical trends, as of 2013, the share of women researchers worldwide stands at just 33.8% (Bello et al., 2021). India, being a culturally diverse country, has its own set of social evils, especially concerning specific socio-cultural roles of women in the society which stems from a gender hierarchical and patriarchal system (Hale, 1989). This reflects in the academic positions and responsibilities held by scientists in India (Swarup and Dey, 2020). India had just about 13.9% of participating women researchers in 2015 (UNESCO Women in Science Fact Sheet, 2019), and ranks 114 in the global gender gap index (WEF Global Gender Gap Report, 2014). Sex-disaggregated data of female researchers as a share of total researchers across scientific disciplines are unavailable for India, which makes it difficult to draw conclusions on overall gender parity trends.

Assessing how and why a field has changed over time can provide insights into the growth of the field. Tracing these developments can help assess the current state of knowledge in the field. Such baseline research aims to pinpoint areas that are unaddressed or understudied, building a roadmap for future developments. Although herpetology has been rapidly growing in India, it lacks an overview of the developments and growth of author participation that could provide insights into the advancements, preferences, and research gaps in the field. Here, we attempt to trace the evolution of the discipline in India by examining temporal patterns of research on different herpetofauna, sub-fields and authorship. In this review, we examine publication trends in Indian herpetology over the last 70 years, starting from the year 1947 when India gained independence from British colonial rule. We also evaluate factors contributing to men and women author participation and highlight gender disparity among herpetologists in India.

Materials and methods

Data collection

The focus of this study was to look at trends in herpetology related publications in India. Therefore, we considered articles on any reptile and amphibian taxa distributed in India. We considered both scientific articles published in journals and newsletters, and restricted our analysis to articles published between 1947, the year India obtained independence, and 2019 to discern trends in post-colonial Indian herpetology. We did not limit our database to include authors of a particular nationality and only focussed on the focal taxa being herpetofauna and their distribution. We obtained metadata for articles indexed by Google Scholar using the following three approaches – taxon search approach, journal search approach and an author search approach. We used the software 'Publish or Perish' (Harzing, 1997) (www.harzing.com/pop.htm) to gather metadata by searching articles between 1947 and 2019 using specific keywords. We used taxa as keywords (e.g., "Amphibians", "Reptiles", "Frogs", "Chelonians", "Crocodiles", "Lizards", "Snakes" etc.) along with "India", "Western Ghats", "North-east India" etc. for the taxon-based approach. We also searched for specific herpetological journals with the keyword "India" for the journal-based approach and used the names of well-known contemporary herpetologists in the author-based approach (supplementary table S1). We used these three search approaches to capture as many studies as possible and to ensure that any articles missed by one of the search approaches will be captured by the others. We also manually included articles that we encountered on Google Scholar during our random searches, which were not included in the original list. We then examined the data to ensure there were no duplicate entries and verified that all the articles were on Indian herpetology. Raw data based on which all classification and analyses carried out in this study is available in supplementary dataset S1.

Data classification

We classified the data according to 10-year chronological categories starting from 1950-59 to 2010-19. Since we found only three articles published between 1947 and 1949, we excluded them from analyses. We classified each article based on the focal group such as amphibians, reptiles or general herpetofaunal studies and further categorised them based on the focal taxa such as caecilians, frogs, salamanders, chelonians, crocodiles, lizards, snakes, and mixed taxa. An example of mixed taxa articles would be herpetofaunal inventories of a focal area or species distribution records that were not restricted to a specific taxon. We then broadly classified articles into eight subfields based on the specific branches of science within biology, such as Taxonomy & Systematics (TX), Diversity & Distribution (DIV), Ecology (ECOL), Behavioural ecology (BH), Evolutionary biology (EVOL), Conservation & Management (CON), Development, Physiology and Cytological studies (DEV) and Others (OT) (supplementary table S2).

Authorship classification

To explore authorship trends and the participation of women authors, we noted the gender of each author as a 'Woman' or a 'Man'. We recognise the fluid nature of gender and consider it a spectrum rather than binary, but we could not gather sufficient information about the authors of all publications analysed for this study to incorporate other gender identities. We do not separately classify foreign authors or Indian origin authors to address the objectives of our study. While there may be power differentials in authorships based on the nationality/ethnicity of authors, we limit our focus on the power differential among genders. The gender of an author was established based on their first name, which we determined through public documents, institutional websites, photographs, scientific and social media platforms. Where the gender was difficult to determine, we examined other articles published by the author to gather information or contacted the specific author by email. For each article, we made a specific note of the gender of the first author, corresponding author, the total number of women authors and the total number of authors. In articles that had two co-first authors and/or more than one corresponding author of different genders, we included the article as two separate entries, one for each gender. However, this was done only to analyse changes in authorship participation and not to analyse changes in the publication trends.

The final dataset included 1174 journal and newsletter articles published from 1950 to 2019. We acknowledge that our dataset is not exhaustive and may not include all articles published on herpetology from India between 1947 and 2019, but instead only includes articles indexed by Google Scholar. Nevertheless, we believe that our dataset represents a large stratified random sample of articles to determine general trends in the field and evaluate authorship participation.

Statistical analysis

We performed all analyses in R 3.6.0 (R Core Team, 2019). We used a G-test to test for differences in the total number of articles published across taxonomic groupings (TG), specific taxa (ST) and subfields (SF). We first performed a G-test on the total number of articles published against the null expectation, and then carried out pairwise comparisons implemented in the R package *RVAideMemoire v. 0.9-69* (Hervé, 2014). To test for year-wise trends across TG, ST, and SF, we carried out pairwise comparisons on the proportion of articles published in each category during each year class (YC) with that of the previous decade. We tested for differences in the proportions using Fisher's exact test implemented in *RVAideMemoire v. 0.9-69*.

To examine authorship trends and factors influencing the contributions of women, we used Generalized Linear Models (GLMs). Several studies have shown that different factors contribute to the gender of the first and last author in different fields of STEM (West et al., 2013; Salerno et al., 2019). Thus, we performed our analyses to evaluate the predictors of women first authors (FA) and corresponding authors (CA). We also found several articles wherein women were co-authors but were neither first nor corresponding authors. Thus, we also carried out GLMs on the proportion of women authors in herpetological papers. We built multiple sets of GLMs for the presence of women FAs, CAs, and the proportion of women authors as response variables and YC, TG, ST and SF as fixed factors using a binomial distribution implemented in the package *lme4 v. 1.1-12* (Bates et al., 2014). We also tested the influence of CA gender on the presence of women FAs and proportions of women authors. Since we found that ca. 23% (80 of 349) of articles authored by women had the same FA and CA, we fit GLMs on the presence of women

FA after removing articles with the same FA and CA. We also performed GLMs on the proportion of women authors in each article after excluding the CA from the authors' list. We included CA gender as a fixed factor in both the analyses and compared the fit of the resulting models.

For each response variable, we built a set of models by stepwise backward elimination of predictor variables at every step, to evaluate the fit of different models (supplementary table S4). We compared the fit of these models by assessing the Δ Akaike Information Criterion (ΔAIC) value and Akaike weights, which were calculated using *qpcR v. 1.4-1* (Spiess, 2018). We considered ΔAIC values of 2-10 as moderate support and ΔAIC values >10 as strong support for a model (Burnham and Anderson, 2002). We then calculated the estimated marginal means and performed a pairwise Tukey's post hoc test for homogeneity across groups for the best-fit models in the GLM analyses in *emmeans v. 1.4.5* (Lenth et al., 2020).

Results

Publication trends

We first assessed trends in 1174 publications focussed on three taxonomic groupings (TG) within herpetology – amphibians, reptiles and general herpetofaunal studies (table 1, fig. 1). We found that 64.9% of papers were on reptiles, compared to 26.5% on amphibians and 8.6% on herpetofaunal studies. A G-test on the overall number of publications indicated a significant difference between different TG ($G = 581.58$, $df = 2$, $P < 0.05$), with publications on reptiles being significantly higher compared to amphibians ($P < 0.05$) and herpetofaunal studies ($P < 0.05$). Amphibians also had a significantly higher number of publications compared to herpetofaunal studies ($P < 0.05$). The number of amphibians, reptiles or herpetofaunal studies publications increased considerably over successive decades (table 1), but there was no significant change in the proportion of articles on the three TG between most of the successive year classes. However, the proportion of studies on reptiles significantly increased while studies on amphibians significantly decreased in 2010-19 compared to their respective proportions in the year class of 2000-2009 ($P < 0.05$) (fig. 1, supplementary table S3).

When we focussed on specific taxa (ST) within the three taxonomic groupings (TG), we found that the total number of articles also differed significantly across different taxa ($G = 668$, $df = 7$, $P < 0.05$) (fig. 1) (see table 1 for absolute numbers). The total number of articles published on frogs, lizards, snakes, and mixed categories were not significantly different from each other ($P > 0.05$) and accounted for 20-21% each but were significantly greater than those published on caecilians (2.3%), salamanders (0.4%), chelonians (12.6%), and crocodiles (4.4%) ($P < 0.05$). Year-wise trends across taxa showed that proportion of research papers on amphibians (caecilians & frogs) had a marginally significant to significant increase during 2000-09 compared to the previous YC (caecilians: $P = 0.065$; frogs: $P < 0.05$) and subsequently decreased in 2010-19 (caecilians: $P < 0.05$; frogs: $P < 0.05$) (supplementary table S3). In reptiles, there was a significant increase in the proportion of articles on chelonians ($P < 0.05$) and crocodiles ($P < 0.05$) during 1980-89 compared to the preceding YC (supplementary table S3). The proportion of studies on lizards increased significantly during 1960-69 ($P < 0.05$) and 2010-19 ($P < 0.05$) compared to preceding YC while that of snakes decreased significantly during 1980-89 ($P < 0.05$) and subsequently increased during 2010-19 ($P < 0.05$) compared to preceding YC (table 1, supplementary table S3).

We then assessed articles by subfields (SF). The total number of articles published also showed significant differences across SF ($G = 569.48$, $df = 7$, $P < 0.05$) (table 1). There was a significantly greater number of publications on Diversity & Distribution (34.2%), Taxonomy & Systematics (21.6%), and Ecology (19.4%) compared to most other subfields ($P < 0.05$), with Diversity & Distribution outnumbering publications on Taxonomy & Systematics and Ecology ($P < 0.05$). Articles on Development, Physiology & Cytology accounted for ca. 13% and was significantly higher than articles in the field of Behaviour (6.6%), Evolutionary

Table 1. Summary of the publications analysed in this study and categorised by taxonomic group, specific taxa, subfield and women author participation. Note that the same study could be scored twice for sub-fields. Mixed amphibians and mixed reptiles: studies wherein more than one amphibian taxa or more than one reptilian taxa are studied (as per our 'taxa' classification).

	1940-49	1950-59	1960-69	1970-79	1980-89	1990-99	2000-09	2010-19	Total
				Taxonomic group					
Amphibians	1	5	3	11	13	49	99	132	313
Reptiles	2	6	15	64	47	85	160	385	764
Herpetofauna	0	0	0	4	3	18	27	48	100
				Specific Taxa					
Caecilians	1	0	0	2	0	2	15	7	27
Frogs	0	5	3	8	12	25	78	111	242
Salamanders	0	0	0	0	0	3	0	2	5
Mixed amphibians	0	0	0	1	1	19	6	12	39
Crocodiles	0	0	0	6	16	7	5	18	52
Lizards	1	0	8	22	10	18	49	133	241
Snakes	1	4	6	27	5	19	47	144	253
Chelonians	0	0	0	0	14	19	38	77	148
Mixed reptiles	0	2	1	9	2	22	21	13	70
				Subfields					
Taxonomy & Systematics	0	1	1	6	4	21	62	159	254
Ecology	0	2	4	11	13	42	56	100	227
Behaviour	0	0	0	5	4	6	17	46	78
Evolutionary Biology	0	0	0	6	0	4	12	55	77
Diversity & Distribution	2	1	1	14	16	58	115	196	403
Conservation Biology	0	0	0	2	12	10	21	53	98
Development, Physiology & Cytology	1	8	14	43	16	16	25	30	153
Others	0	0	0	1	3	6	9	29	48
Total	3	11	18	79	63	152	286	565	1177
				Women author participation					
Articles with women author present	0	3	4	6	14	20	86	216	349
Women first author	0	3	4	3	9	10	52	93	174
Women corresponding author	0	3	4	5	12	13	53	87	177

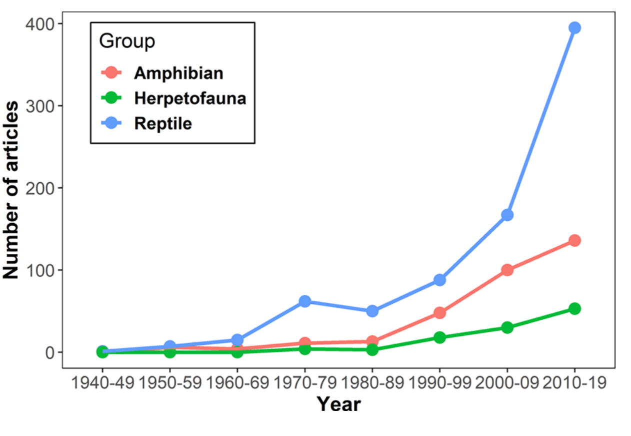

Figure 1. Trends in the total number of herpetological publications over the last 70 years on different taxonomic groupings.

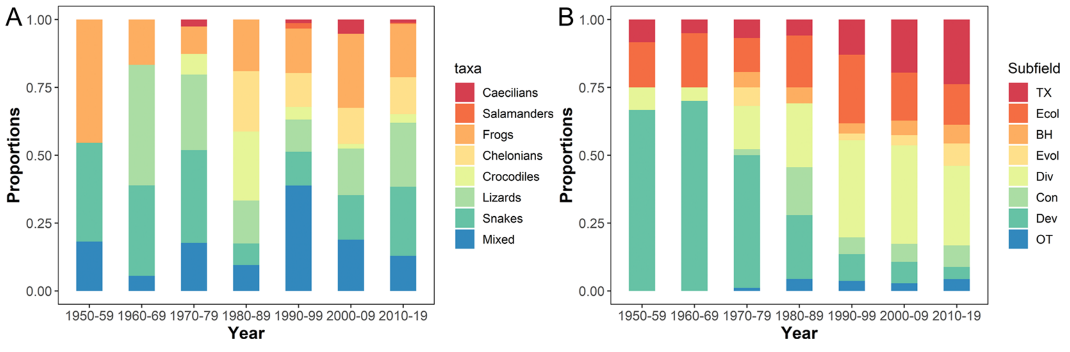

Figure 2. Temporal trends showing the proportion of articles on (a) specific taxa until 2019 and (b) subfields. Subfields: TX: Taxonomy & Systematics, Ecol: Ecology, BH: Behavioural ecology, Evol: Evolutionary biology, Div: Diversity & Distribution, Con: Conservation & Management, Dev: Development, Physiology & Cytology and OT: Others.

biology (6.5%) and Conservation & Management (8.3%) (table 1).

Year-wise trends indicated no significant difference in the proportion of articles published on Taxonomy & Systematics, Ecology and Behaviour (table 1, fig. 2b and supplementary table S3). The proportion of articles on Diversity & Distribution showed a significant decrease in the last decade (2010-19) compared to the preceding YC ($P < 0.05$). The proportion of articles on Conservation & Management increased significantly during 1980-89 ($P < 0.05$) compared to the previous decade but showed a subsequent decline in 1990-99 ($P < 0.05$). The proportion of articles on Development, Physiology & Cytology showed a steep decline from 1980-89 to 2010-19 ($P < 0.05$). Evolutionary biology also showed a significant decrease during 1980-89 compared to the preceding decade ($P < 0.05$).

Authorship trends

Of the 1174 papers assessed, we found that only 29.7 % had at least one woman author present (table 1). We also found that only 14.8 % of papers had women as first authors (FA) and 15% had women as corresponding authors (CA) (table 1). GLMs to identify factors influencing women authorships indicated that year class (YC), taxonomic grouping (TG), specific taxa (ST) and sub-fields (SF) best-predicted women first authorship. This model was strongly supported compared to all other models ($\Delta AIC > 16$). The pairwise tests indicated that the odds of women FAs were significantly greater in 2000-09 and 2010-19 compared to 1970-79 and 1990-99 ($P < 0.05$) (supplementary table S5). The odds of women FA also significantly decreased in articles on snakes compared to lizards ($P < 0.05$) and in Taxonomy & Systematics compared to Development, Ecology and Evolutionary biology ($P < 0.05$) (supplementary table S5). GLMs on women FA after removing single author articles and articles with the same FA and CA indicated that CA gender significantly affected women being FAs ($\Delta AIC > 100$) (supplementary table S4). The analysis indicated that with all else being equal there was a significant decrease in women as FA when the CAs were men (Estimate $= -3.39$, $Z = -12.02$, $P < 0.05$) (supplementary table S5). We found that 59.2% of articles had women FAs when CAs were women, compared to only 3.6% of articles with women FAs when CAs were men.

Tests on the best predictors of women as CA indicated that the model with YC, ST, TG, and SF was the best-fit model and was very strongly supported compared to most other models ($\Delta AIC > 40$). However, this model was only weakly supported against a model containing only YC, ST, and SF as predictors (ΔAIC

= 1.275) (supplementary table S4). Nonetheless, both models are similar since both TG and ST represent levels of the taxonomic organisation. Tukey's post hoc test indicated that women CA were significantly higher in lizards (30.5% of articles with women CA) compared to other reptiles (chelonians, crocodiles, snakes: $P < 0.05$) (supplementary table S5). However, there was no significant difference in women CAs between lizards and frogs, the latter also having 30.5% of articles with women CAs ($P > 0.05$). We also found no discernible effect of YC except that women CAs were significantly lower in 1970-79 compared to succeeding YC (1980-89, 2000-09, 2010-19: $P < 0.05$), and were higher during 1980-89 compared to 1990-99 ($P < 0.05$) (supplementary table S5). We found a clear effect of SF, with the odds of a woman CA decreasing significantly in Taxonomy & Systematics compared to most other SF (only 13 out of 177 studies had a woman CA, see table 1) ($P < 0.05$) (fig. 4, supplementary table S5).

GLMs on the proportion of women authors indicated that the model with YC, TG and SF was the best-fit model and was moderate to strongly supported compared to all other models ($\Delta AIC > 2.7$) (supplementary table S4). Tukey's post hoc test indicated that the odds of women authors being present has significantly increased in the last decade compared to 1970-79 ($P < 0.05$) and 1990-99 ($P < 0.05$) (supplementary table S5). Women authors were also significantly higher in publications studying frogs (38.3% of all amphibian papers) compared to all other reptiles (23.3% of all reptile papers) ($P < 0.05$) (supplementary table S5). The odds of women authors also significantly decreased in Taxonomy and Systematics compared to most other subfields ($P < 0.05$) (supplementary table S5). GLM on the proportion of women authors after excluding the CA indicated that the model with CA gender was strongly supported against other models ($\Delta AIC > 26$) (supplementary table S4). This model indicated that the odds of women authors were significantly lower when the CA was a man (Estimate $= -1.16$, $Z = -5.56$, $P < 0.05$). The average ratio of women-to-men after excluding the CA was higher when the CA was a woman (ratio = 0.30) compared to the ratio when the CA was a man (ratio = 0.10).

Discussion

Publication trends

We used metadata from 1174 research papers published between 1950-2019 to understand changing trends in focal taxa, research questions and parity in the gender of participating authors. Overall, we observed divergent trends between research on reptiles and amphibians, with reptiles having received greater attention in herpetology compared to amphibians (fig. 1) and taxa such as caecilians, salamanders, crocodiles, and chelonians had fewer publications as compared to frogs, lizards, and snakes (fig. 2a, supplementary fig. S1). These differences among taxa may partially be driven by differences in species richness within these groups. For instance, there are two species of salamanders, 39 species of caecilians, three species of crocodilians and 34 species of chelonians (Aengals et al., 2018; Dinesh et al., 2020), all of which accounted for the lowest number of articles we recovered (see table 1). On the other hand, frogs, lizards, and snakes are among the most diverse groups in India (Aengals et al., 2018; Dinesh et al., 2020) with each group accounting for more than 240 published articles (see table 1). However, whether these taxonomic differences in published articles are due to biases in research interests or related to species richness within these taxonomic groups needs further evaluation. We also find that articles on Evolutionary biology, Behavioural ecology, Conservation & Management and Development, Physiology & Cytology have received little attention and have declined in subsequent years. The reduction in studies on Development, Physiology & Cytology could be driven by the retirement of a few academics dedicated to this subfield, which likely led to fewer researchers in the following generations pursuing these fields. At the same time, Diversity & Distribution, Taxonomy & Systematics and Ecology were dominant research questions compared to most other subfields (fig. 2b, supplementary fig. S2). The proportion of articles published on Taxonomy & Systematics was significantly greater than most other subfields (except Diversity & Distribution). The relative ease of generating and analysing genetic data with advancements in molecular tools, and excessive importance towards taxonomy and distribution for conservation efforts may be drawing more attention to these subfields (Wiens, 2008). Further, the low number of labs in India focussed on herpetological research with ecological, behavioural, or evolutionary questions may also contribute to the reduced focus on these subfields.

Authorship trends

Herpetology has been considered a male-dominant field (Adler, 1989), and women's representation has been considerably low (Wilson, 1998; Grosso et al., 2021; Rock et al., 2021). Our review finds that, just like most fields in STEM, herpetology has been historically dominated by men, and has remained so (supplementary fig. S3). Only 29.7% of the analysed publications in this study were authored/co-authored by women. As far as we know, this is the first study highlighting the comprehensive gender gap in Indian herpetology. Unlike other global assessments of women authorships in science (Holman et al., 2018) and in herpetology (Rock et al., 2021) that found increased women participation in recent times, our analyses on authorship trends found no discernible trend in women authorship across year class except for a significant drop in few decades. In addition, we found that the proportions of women authors decreased significantly with men as corresponding authors. Salerno et al. (2019) found that the gender of the last author predicted women co-authors in ecology and zoology in Latin American countries with women participation decreasing considerably when the last author was a man. While women-led labs published more with women co-authors with about 46% of articles having women first authors, men-led labs published with only 17.6% women co-authors and had only about 28% articles with women first authors (Salerno et al., 2019). Similar patterns of male homophily in collaboration networks and a decrease in female co-authorship in men-led labs have also been observed in South American herpetological journals (Grosso et al., 2021). Our study also corroborated these findings wherein men-led groups (proxied by the corresponding authorship) published less with women co-authors (ca. 20.1%), of which only 5.2% of articles had a woman as the first author.

Research has suggested that women leaders can enhance the participation of early-career women (Blickenstaff, 2005; Goulden et al., 2011; Ecklund et al., 2012; Jones et al., 2014; Sardelis and Drew, 2016; Farr et al., 2017; Potvin et al., 2018). Although we do not specifically examine how women leadership influences author participation, we found that women first authors are higher in number, and account for 59.2% of articles, when the corresponding author is a woman. We also found that the proportion of women authors was on average three times higher when the corresponding author was a woman, supporting the view that women role models are important to increase women representations at early-career stages (Drury et al., 2011; Sheltzer and Smith, 2014).

Our study found that the proportion of women authors was generally higher in research papers focussed on frogs compared to individual reptile categories and mixed herpetofaunal studies (supplementary table S5, fig. 3a, b). A recent global analysis on herpetological research has also highlighted that fewer

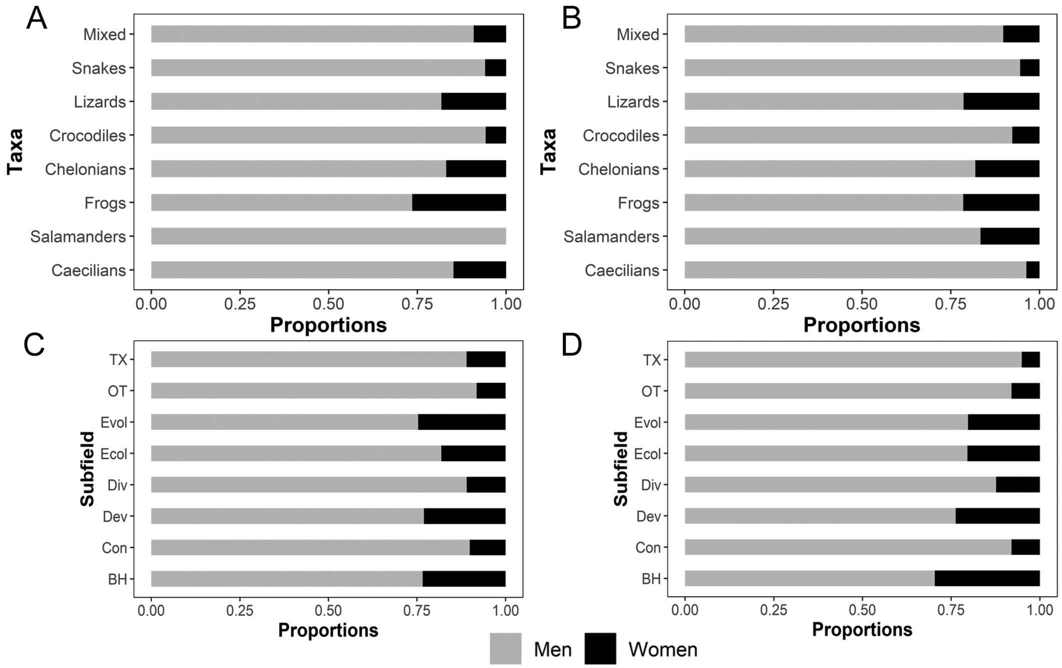

Figure 3. Plot showing the contributions of Women and Men as first (a, c) and corresponding authors (b, d) across specific taxa and subfields. Subfields: TX: Taxonomy & Systematics, Ecol: Ecology, BH: Behavioural ecology, Evol: Evolutionary biology, Div: Diversity & Distribution, Con: Conservation & Management, Dev: Development, Physiology & Cytology, and OT: Others.

women author publications have studied caecilians, crocodiles, lizards, and snakes in the last decade (Rock et al., 2021). Comparing different subfields, we found that the women first authors, women corresponding authors and the proportion of women authors were significantly lower in Taxonomy & Systematics (figs. 3c and 4). This stark underrepresentation of women in Taxonomy & Systematics despite a large number of publications suggests that Taxonomy & Systematics remains a field dominated by men in the context of Indian herpetology (fig. 2b). While the reasons for this underrepresentation of women in taxonomy can be many, it could be driven by the fact that most taxonomic labs and museum curatorial positions in Indian herpetology have historically been occupied or led by men, and inherent biases in collaborating or recruiting women students could add to women being underrepresented in the field.

Studies across the world have highlighted the prevalence of gender gap, and underrepresentation of women and other minorities across all branches of STEM, specifically in leadership positions, including positions in scientific societies (e.g., Hult et al., 2005; Monroe et al., 2010; Potvin et al., 2018; Rushworth et al., 2021). This gender gap is more pronounced in South Asia where women represent only 18.5% of all researchers, with India and Nepal being at the lower end across Asia, Africa, and the Pacific, having less than 14% of women researchers (UNESCO Women in Science Fact Sheet, 2019). India also has only about a 7-10% share of women members in national science academies or councils (Godbole and Ramaswamy, 2008; Bello et al., 2021). Similarly, only 11.2% of the faculty positions in Indian research institutions are currently occupied by women (https://biaswatchindia.

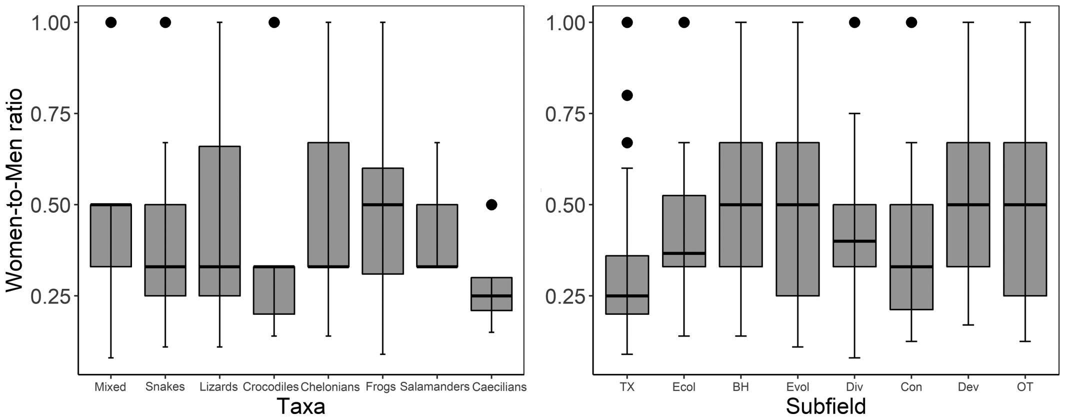

Figure 4. Boxplot showing the women-to-men ratio in articles with women authorships across different specific taxa (a) and different subfields (b) (see table 1 for raw values). Subfields: TX: Taxonomy & Systematics, Ecol: Ecology, BH: Behavioural ecology, Evol: Evolutionary biology, Div: Diversity & Distribution, Con: Conservation & Management, Dev: Developmental Biology, Physiology & Cytology, and OT: Others.

com/base-rates-of-indian-women-faculty/), indicating a stark disparity in women representation at higher academic levels (Indian National Science Academy Report, 2004). Despite India reporting to have about 51.4% of female tertiary graduates in the natural sciences in 2018, the proportion of women tends to reduce as they climb higher up their academic careers owing to the 'leaky pipeline', with significant drops after the doctoral degree (Wickware, 1997; Luckenbill-Edds, 2002; Godbole and Ramaswamy, 2008). Social stigmas associated with the physical, risky, and the outdoor nature of herpetological research affects women much more than men, as women endure additional challenges such as gender conformity that is associated with outdoor or adventure related careers.

Diversity across research groups brings different perspectives and approaches to addressing new research questions (Adams, 2013; Swartz et al., 2019). For instance, women have made more significant contributions to the understanding of female vocalisation in birds, a phenomenon that was rarely known (Haines et al., 2020). Equal gender participation can speed up the scientific growth of a field because diverse groups outperform homogenous groups in terms of problem-solving and innovations (Freeman and Huang, 2014; AlShebli et al., 2018; Swartz et al., 2019).

Past, present, and future of Indian herpetology

Indian herpetology has evolved considerably over the years, from species documentations and inventories to addressing more complex questions in biology using scientifically advanced and rigorous methods. Current advances in molecular techniques and molecular species delimitation methods have resulted in a burst of new species discoveries and more taxonomic clarity on under-studied cryptic groups of reptiles and amphibians. These studies also highlight that a large portion of the diversity remains unnoticed and undocumented, calling for continued taxonomic investigations. We detected a significantly large percentage of articles on diversity and distribution in the form of natural history notes, mostly compiling species inventories and distribution, indicating that herpetological explorations are still underway. While such natural history notes are key to forming novel hypotheses (Futuyma, 1998; Grant, 2000; Greene, 2005), they often lack community or population-level data. This lack of quantitative data on herpetofauna limits our abilities to formulate questions to understand patterns and processes (Bartholomew, 1986), and therefore quantitative studies must come to the forefront (Cyriac and Umesh, 2021), more so considering the relative ease of access to certain kinds of data through citizen science initiatives (Cohn, 2008; O'Donnell and Durso, 2014).

Our study provides valuable insights into the growth of herpetology in India and the potential to inform a balanced development of this field in the future. The growth of herpetology in India depends on efforts towards inclusivity, the openness of herpetologists to new questions and ideas from diverse communities, available funding, and infrastructural support from academic institutes. While this paper outlines the broad aspects of changing trends and gender gaps in Indian herpetology, further explorations into the patterns of research and gender representation across different regions and disciplines of STEM will be key to formulate strategies for inclusivity focussed policy changes and scientific progress.

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Authors contributions

Conceptualization, Methodology, Formal Analysis, Writing – Original Draft: VPC; Investigation, Resources, Data Curation, Writing – Review & Editing: AM, AVM, SD, VPC; and Visualization: VPC & AVM.

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