



Three decades of Chondrichthyan research in Brazil assessed from conferences' abstracts: patterns, gaps, and expectations

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Of the almost 1,300 currently known Chondrichthyan species, 13.4% occur in Brazilian marine and freshwater environments and more than a half are under extinction threat. There are three main scientific events in Brazil committed to present and discuss research on fishes (including Chondrichthyes): EBI, SBEEL, and ISPCNF. We analyzed 1,584 submitted abstracts to these events over the last 30 years and noticed that, within Chondrichthyes, studies regarding Systematics were less representative (17%). However, the most shocking result concerned the proportion of women in authorship: almost 30% of abstracts were co-authored only by men, and only 25% of those in Chondrichthyan Evolution had women as last authors, demonstrating that a few women are acting as principal investigators in this area of research in Brazil since they might be leaving academia due to lack of support. Besides, the orders Carcharhiniformes and Myliobatiformes represented 66.9% of all studied taxa throughout the years, revealing a research bias on studied taxa which in turn has impacted directly on our knowledge of Chondrichthyan biodiversity and conservation planning. Most importantly, the neglected area of taxonomy needs to be enhanced to allow for appropriate species identification and threatening status evaluation.

Keywords: Chondrichthyes, Conservation, Gender representativity, Scientific events, Systematics.

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De quase 1300 espécies de Chondrichthyes atualmente conhecidas, 13,4% ocorrem no Brasil em ambientes marinhos e de água doce, sendo que mais da metade está ameaçada de extinção. Há três grandes eventos científicos no Brasil dedicados à apresentação de pesquisas sobre peixes (incluindo Chondrichthyes): EBI, SBEEL, ISPCNF. Analisamos 1584 resumos enviados a esses eventos nos últimos 30 anos e percebemos que, dentro de Chondrichthyes, estudos relacionados à Sistemática foram raros (17%). Porém, o resultado mais impactante diz respeito à proporção de mulheres na coautoria: quase 30% dos resumos foram co-autorados exclusivamente por homens e somente 25% daqueles em Evolução de Chondrichthyes tiveram mulheres como últimas autoras, demonstrando que poucas mulheres estão atuando como pesquisadoras principais nessa área de pesquisa no Brasil já que elas podem deixar o ambiente acadêmico devido à falta de suporte. Além disso, as ordens Carcharhiniformes e Myliobatiformes representaram 66,9% de todos os táxons estudados ao longo dos anos, revelando um viés com relação aos táxons estudados, o que por sua vez tem impactado diretamente no nosso conhecimento da biodiversidade de Chondrichthyes e planejamento da conservação. Mais importante, a negligenciada área da taxonomia necessita ser aprimorada para permitir identificação adequada das espécies e a avaliação dos seus estados de ameaça.

Palavras-chave: Chondrichthyes, Conservação, Eventos científicos, Representatividade de gênero, Sistemática.

INTRODUCTION

The chondrichthyan diversity consists of more than 1,294 valid species distributed worldwide in marine and freshwater environments, which are classified in 14 orders and 66 families (Last *et al.*, 2016; Ebert *et al.*, 2021; Fricke *et al.*, 2023). Until now, a total of 199 species including 167 marine elasmobranchs and chimaeras and 32 freshwater stingrays were recorded in Brazilian waters (Rosa, Gadig, 2014; Gomes *et al.*, 2019; Silva, Loboda, 2019; Loboda *et al.*, 2021) of which more than half (53.3%) were considered to be facing a high risk of extinction (IUCN, 2021).

According to the Red Book of Threatened Brazilian Fauna (ICMBio, 2018), 27 species are categorized as Critically Endangered (CR) and among these are the sawfishes *Pristis pectinata* Latham, 1794 and *P. pristis* (Linnaeus, 1758), and the daggernose shark *Isogomphodon oxyrinchus* (Valenciennes, 1839). Two shark species, *Carcharhinus isodon* (Valenciennes, 1839) and *Schroederichthys bivius* (Smith, 1838), are considered to be regionally extinct in Brazil (ICMBio, 2018). Moreover, about 15% of species are categorized as Data Deficient (DD) indicating the need for more studies about these taxa.

Given the alarming situation of chondrichthyan populations around the world, scientists have played an essential role to amplify our knowledge on the diversity and life traits of sharks, rays, and chimaeras, as it has also been observed for species distributed in Brazilian waters (see Rosa, Gadig, 2014 for a brief history). The results of Brazilian research have been published in scientific journals and presented in international,

national, and regional conferences over the years. These meetings have shown to be extremely relevant as spaces for researchers to improve the oral communication of knowledge and to develop themselves, their ideas, and networking (Gomes, 1981). The main national conferences about fishes held in Brazil have been promoted by two scientific societies, the Brazilian Ichthyological Society (Sociedade Brasileira de Ictiologia, SBI, in Portuguese) and the Brazilian Society for Elasmobranch Studies (Sociedade Brasileira para o Estudo de Elasmobrânquios, SBEEL, in Portuguese). Two editions of a third event, the International Symposium on Phylogeny and Classification of Neotropical Fishes (ISPCNF), were organized by SBI members together with US researchers and were the stage for valuable discussions and advances on the systematics of neotropical fishes, including chondrichthyans.

Previous papers have analyzed trends and contents of conference abstracts on Chondrichthyes (Huvneers *et al.*, 2015; McCallen *et al.*, 2019; Shiffman *et al.*, 2020) and two abstracts presented at the 2018 Sharks International (Azevedo *et al.*, 2018; Viana *et al.*, 2018) were specially focused on the Brazilian research scenario. Viana *et al.* (2018) provided a historical overview and future research perspectives of Chondrichthyan systematics in Brazil, highlighting the relevance of this research field to uncover a still unknown biodiversity.

In order to evaluate the state-of-art of the Brazilian chondrichthyan research over the last three decades, we performed a survey on conference abstracts analyzing the following aspects: 1) main research areas; 2) a more detailed analysis focused on chondrichthyan systematics; 3) demographic analysis of conference presenters including gender authorship and home institution (geographic region and public/private); 4) study taxa (species, family, and more inclusive categories); 5) trends throughout time.

MATERIAL AND METHODS

Conference abstract books of scientific events focused on fishes and held in Brazil from 1991 to 2019 were analyzed, comprehending the 15 most recent editions of the Brazilian Meeting of Ichthyology (EBI), all 10 meetings of the Brazilian Society for the Study of Elasmobranchs (SBEEL), including the international joint event Sharks International, in 2018, and the two editions (1997 and 2017) of the International Symposium on Phylogeny and Classification of Neotropical Fishes (ISPCNF). Oral and poster presentations were analyzed together, excluding invited talks and lectures, since those were chosen by the organizing committees and does not necessarily represent the reality of the research scenario in Brazil such as the proportion of researchers working on each area, or number, gender, and proportion of co-authors. In total, 27 scientific events and 11,428 abstracts on fishes presented over the last three decades were analyzed and, of these, 1,584 included or focused on chondrichthyans. Abstracts were read and manually sorted according to their main research area, total number and gender of authors per abstract, gender of first and last authors, first author's affiliation, and studied taxa for each event and edition (Tab. S1).

Research area of each abstract was categorized as 'Ecology' (ECO), which includes reproductive biology, telemetry, age and growth, feeding ecology, and life history; 'Evolution' (EVO): morphology, population genetics, taxonomy, species' lists,

phylogeny, distribution, and biogeography; ‘Physiology’ (PHY): sensory physiology and metabolism, and ‘Others’: environmental education and science outreach. In order to proceed with a more thorough approach on chondrichthyan systematics, abstracts coded as EVO were specified as Systematics (evolutionary morphology, taxonomy, phylogenetics, phylogeography, biogeography, and population genetics) and non-Systematics (descriptive morphology, checklists, occurrence records, descriptive genetics, and DNA Barcoding). Considering that Systematics is the biological research area which investigates the relationships and diversification of living things to understand their evolutionary history (Hennig, 1966), we included the abovementioned categories under “Systematics” to classify abstracts as it was one of our goals to identify the proportion of studies regarding Chondrichthyan Systematics (ChonSyst) that has been developed in Brazil. We investigated the number of abstracts in ChonSyst in general and those within EVO. Besides, there are many subcategories under ECO and PHY that we did not aim to contemplate on this research. Studied species, families, and orders were acknowledged in analyses according to their names’ specification on title or abstract. When dealing with species, only abstracts that specifically mentioned their names were considered; however, in analyses of Chondrichthyan orders, we included abstracts that mentioned not only the order, but also family, and/or species. In some cases, when abstracts did not indicate which taxonomic levels they were analyzing, we recognized only higher ones (*e.g.*, Batoidea, Elasmobranchii). Threatened status of each Brazilian species following IUCN (2021) was also noted.

Gender definition was established on the author’s first names and followed a binary male/female score system. When the author’s first name was identified, searches on social media (*e.g.*, ResearchGate, LinkedIn) and academic repositories (*e.g.*, Google Scholar, Curriculum Lattes, university websites) were carried out for self-identifying gender pronouns. Furthermore, this determination was based on first names commonly attributed to each gender in Brazil and other Latin countries. In cases where only author’s initials were available or gender determination was not possible, no gender was noted. It was not possible to identify unequivocally the authors’ gender of 47 abstracts, which were excluded from these particular analyses. It is noteworthy that the gender definition performed in this study does not correspond to self-identified gender and that a more detailed investigation on this matter must be conducted to better assess gender diversity in Brazilian ichthyology. Name, State, and country of the primary professional affiliations of first authors were obtained and Brazilian States were divided in Midwestern (Distrito Federal, Goiás, Mato Grosso, and Mato Grosso do Sul), Northeastern (Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Sergipe), Northern (Acre, Amazonas, Pará, Rondônia, Roraima, and Tocantins), Southeastern (Espírito Santo, Minas Gerais, Rio de Janeiro, and São Paulo), and Southern (Paraná, Rio Grande do Sul, and Santa Catarina) regions.

Temporal analyses and combinations among categories were performed. For statistical testing, data were grouped in terms of year, event (meeting’s name), and variables in separate .csv files to be imported to R software (R Development Core Team, 2020). We compared the proportion of systematics abstracts in EBI and SBEEL, the ratio of women as last authors in EVO, and the number of abstracts co-authored only by men *vs.* only by women. To compare the means of these selected variables, we first performed a Shapiro-Wilk test (Shapiro, Wilk, 1965) to inspect for normality on each

dataset; if data were parametric, we conducted a Student's *t* test (Student, 1908), if non-parametric, Mann-Whitney *U* test (Mann, Whitney, 1947), all using the package *stats* (R Development Core Team, 2020). To observe patterns and tendencies, data were grouped and plotted into graphs with *ggplot2* (Wickham, 2016) in R (R Development Core Team, 2020). The complete dataset is available at Tab. S1.

RESULTS

Abstracts. The average number of chondrichthyan abstracts in EBI ranged from 1.3 to 6.6% ($n = 326$, mean 3.5%) of all studies presented along the fifteen events analyzed throughout the last 30 years. Considering the two editions of ISPCNF (1997 and 2017), chondrichthyans were mentioned in 2% and 3.9% of the abstracts, respectively (Tab. 1). All SBEEL abstracts were on Chondrichthyes, since it is an event focused on this group.

TABLE 1 | Dataset with scientific conferences, years, Brazilian states, total of abstracts, absolute numbers, and percentage of chondrichthyan abstracts. EBI = Brazilian Meeting of Ichthyology, ISPCNF = International Symposium on Phylogeny and Classification of Neotropical Fishes, SBEEL = Brazilian Society for the Study of Elasmobranchs.

Conferences	Year	Locality	Total abstracts	Chondrichthyes	%
IX EBI	1991	Paraná	196	12	6.12
X EBI	1993	São Paulo	241	12	4.98
XI EBI	1995	São Paulo	318	16	5.03
XII EBI	1997	São Paulo	399	7	1.75
XIII EBI	1999	São Paulo	610	40	6.55
XIV EBI	2001	Rio Grande do Sul	577	13	2.25
XV EBI	2003	São Paulo	520	7	1.35
XVI EBI	2005	Paraíba	780	35	4.49
XVII EBI	2007	Santa Catarina	1037	34	3.28
XVIII EBI	2009	Mato Grosso	527	15	2.85
XIX EBI	2011	Amazonas	786	27	3.44
XX EBI	2013	Paraná	1033	28	2.71
XXI EBI	2015	Pernambuco	1169	32	2.74
XXII EBI	2017	Bahia	765	24	3.14
XXIII EBI	2019	Pará	1010	29	2.87
I ISPCNF	1997	Rio Grande do Sul	49	1	2.04
II ISPCNF	2017	Paraná	181	10	3.87
I SBEEL	1997	Bahia	74	74	100
II SBEEL	2000	São Paulo	98	98	100
III SBEEL	2002	Paraíba	71	71	100
IV SBEEL	2004	Pernambuco	97	97	100
V SBEEL	2006	Santa Catarina	88	88	100
VI SBEEL	2008	Ceará	96	96	100
VII SBEEL	2011	Rio Grande do Sul	87	87	100
VIII SBEEL	2014	Pernambuco	72	72	100
IX SBEEL	2016	Alagoas	107	107	100
X SBEEL	2018	Paraíba	461	461	100

Research area. The category ECO corresponds to the greatest portion of the abstracts presented in all EBI and SBEEEL events ($n = 1015$, 64.7%), followed by EVO ($n = 473$, 29.9%) and PHY ($n = 71$, 4.5%) (Fig. 1). Studies focused on scientific communication, environmental education, and other themes were included in 'Others' (1.6%).

When considering only abstracts presented in EBI, numbers of studies categorized as ECO ($n = 159$, 48.9%) and EVO ($n = 150$, 46.1%) are quite similar to each other, while PHY corresponds to only 4.6% ($n = 15$). Of the 1,248 abstracts presented in all SBEEEL editions, the majority was focused on ECO ($n = 856$, 68.6%) while EVO ($n = 312$, 25%) and PHY ($n = 56$, 4.5%) were considerably less representative. A similar situation was observed when analyzing only the abstracts presented during the 2018 Sharks International ($n = 461$) in which 72.8% were sorted into ECO, 20% in EVO, and 5.6% in PHY. All abstracts submitted to ISPCNF were within EVO (1 in 1997, and 10 in 2017).

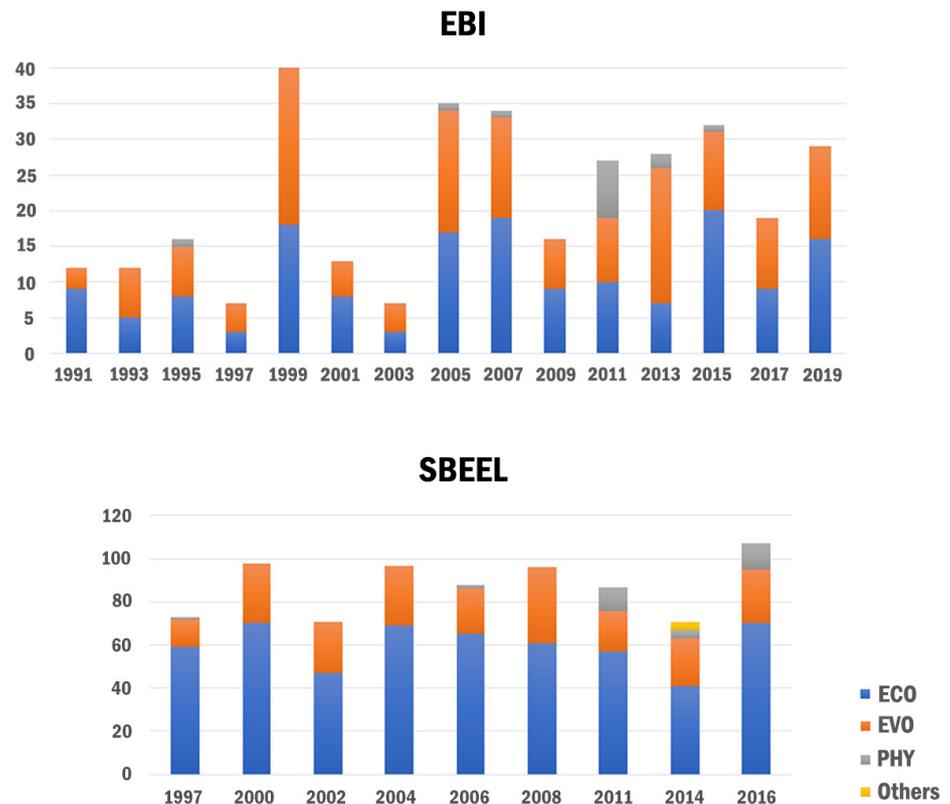


FIGURE 1 | Research area per event over the years. EBI, Encontro Brasileiro de Ictiologia; SBEEEL, Encontro da Sociedade Brasileira para o Estudo de Elasmobrânquios. ECO: Ecology, EVO: Evolution; PHY: Physiology, Others: Other research areas.

Systematics. Among all abstracts on Chondrichthyes submitted to the three meetings over the last 30 years, 10.6% were related to Systematics' studies. In EBI, this number of abstracts corresponds to 17.7%, in SBEEL, 8.3%, and in ISPCNF, 63.6%. There is a significant difference (Mann–Whitney U test, with $W = 120$, p -value < 0.05) between Systematics in EBI and SBEEL. However, when examining exclusively the abstracts within the EVO category, those studying Systematics represented 35.7%. Within each event, the proportions were: 38.7% in EBI, 33.3% in SBEEL, and 63.6% in ISPCNF (Fig. 2), showing that within EVO, Systematics represent less than half of the studies (evolutionary morphology, taxonomy, systematics, phylogeography, biogeography, and population genetics). Among the abstracts sorted into EVO, but not included within Systematics, most of them presented checklists of scientific collections or regional ichthyofauna inventories ($n = 97$, 31.9%) and occurrence records of species ($n = 62$, 20.4%).

Number of authors and gender representativity. Average number of authors per study in all events is 3.8. Of the 1,539 abstracts for which authors' gender were identified, 71.2% ($n = 1,131$) presented at least one female author.

Considering all EBI editions, women co-authored 64% of abstracts focused on chondrichthyans *vs.* 73.3% in SBEEL. Of the 11 abstracts on Chondrichthyes presented at the ISPCNF editions, only five have at least one woman in authorship (45.5%). This means that 38.9% of abstracts over the last 30 years had only men as authors (Fig. 3). On the other hand, women-only authors were observed for 6.4% of abstracts in EBI, 6.2% in SBEEL, and 9.1% in ISPCNF (only 1 of the 11 submitted abstracts). An increase in the number of abstracts co-authored by women has been observed over the years, reaching more than 80% in the most recent editions of EBI (2019) and SBEEL (2014, 2016, 2018) (Fig. 3).

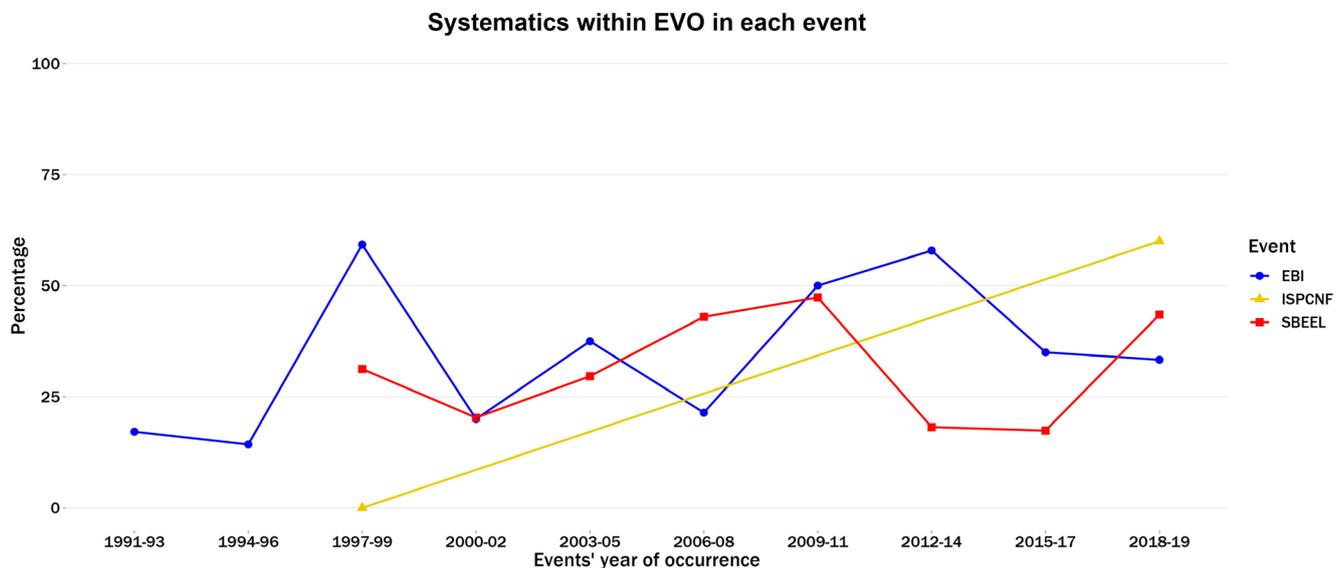


FIGURE 2 | Proportion of abstracts with Chondrichthyan Systematics within Evolution (EVO) per event throughout the years. Blue circle = EBI (Encontro Brasileiro de Ictiologia), red square = SBEEL (Encontro da Sociedade Brasileira para o Estudo de Elasmobrânquios), yellow triangle = ISPCNF (International Symposium on Phylogeny and Classification of Neotropical Fishes). Continuous lines represent the data every two years.

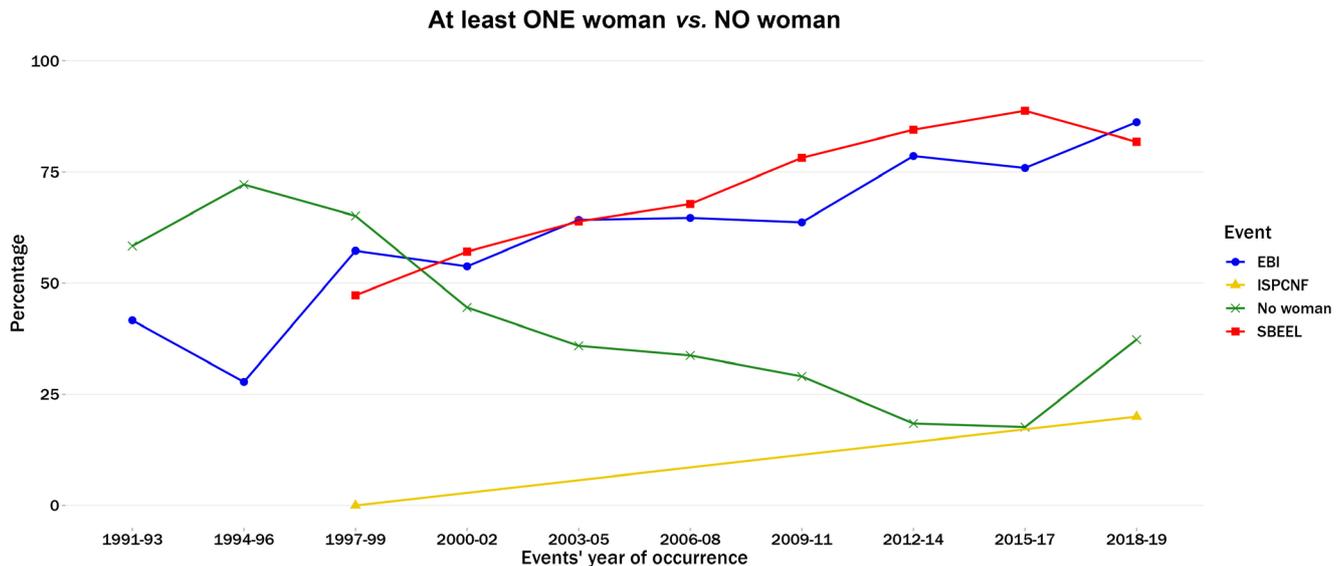


FIGURE 3 | At least one woman vs. no woman in authorship per event throughout the years. Blue circle = EBI (Encontro Brasileiro de Ictiologia), red square = SBEEL (Encontro da Sociedade Brasileira para o Estudo de Elasmobrânquios), yellow triangle = ISPCNF (International Symposium on Phylogeny and Classification of Neotropical Fishes); green cross, no woman. Continuous lines represent the data every two years.

When looking at the abstracts within EVO, 61.3% presented at least one woman in EBI *vs.* 73.7% in SBEEL, and those with women-only authors were 6.7% both in EBI and SBEEL. If we look only at those Systematics' abstracts, women co-authored 58.6% in EBI, 74% in SBEEL, and 28.6% in ISPCNF, with an average of 11.2% authored only by women and 28.9% only by men.

Taking into account only abstracts first-authored by women in all chondrichthyan research areas, in EBI these represent 41.8%, in SBEEL, 44.3%, and in ISPCNF, 18.2%, with an average of 43.61% within the last 30 years. The proportions of abstracts with a woman as the last author are 17.1% in EBI, 27.3% in SBEEL, and 18.2% in ISPCNF, with an average of 25.1% (Fig. 4), indicating that 74.9% of all abstracts had a man as the last author. Even though the authorship order suggests scientists' contributions, it could be misleading (Sauermann, Haeussler, 2017). However, in Ecology papers it is common for the last author being the advisor and/or principal investigator (PI) (Duffy, 2017), as it is in ichthyological studies.

Within EVO, women are first authors of 38% in EBI, 41% in SBEEL, and 18.2% in ISPCNF, with an average of 39.5%. As last authors, women are 16.7% of abstracts submitted to EBI, 30.8% of SBEEL, and 18.2% of ISPCNF, with an average of 26%, which illustrates that men are advisors and/or PIs of 74% of abstracts in Chondrichthyan Evolution. By comparing the number of abstracts with men or women as last authors in EVO, it is statistically significant (Student's *t* test, with $t = -15.447$, $df = 52$, p -value < 0.05) to suggest there is a difference in leading roles in this research area, with a lack of women occupying these positions as PIs (Fig. 5).

Besides, there is a significantly higher number (Mann-Whitney U test, with $W = 66$, p -value < 0.05) of abstracts presented only by men than only by women. Since 1993, there were only three occasions in which the number of abstracts written only by women were higher than those by men: EBI 1999, SBEEL 2000, and SBEEL 2016. However, this scenario might be changing as the latest event, EBI 2019, had no abstract authored by people of only one gender.

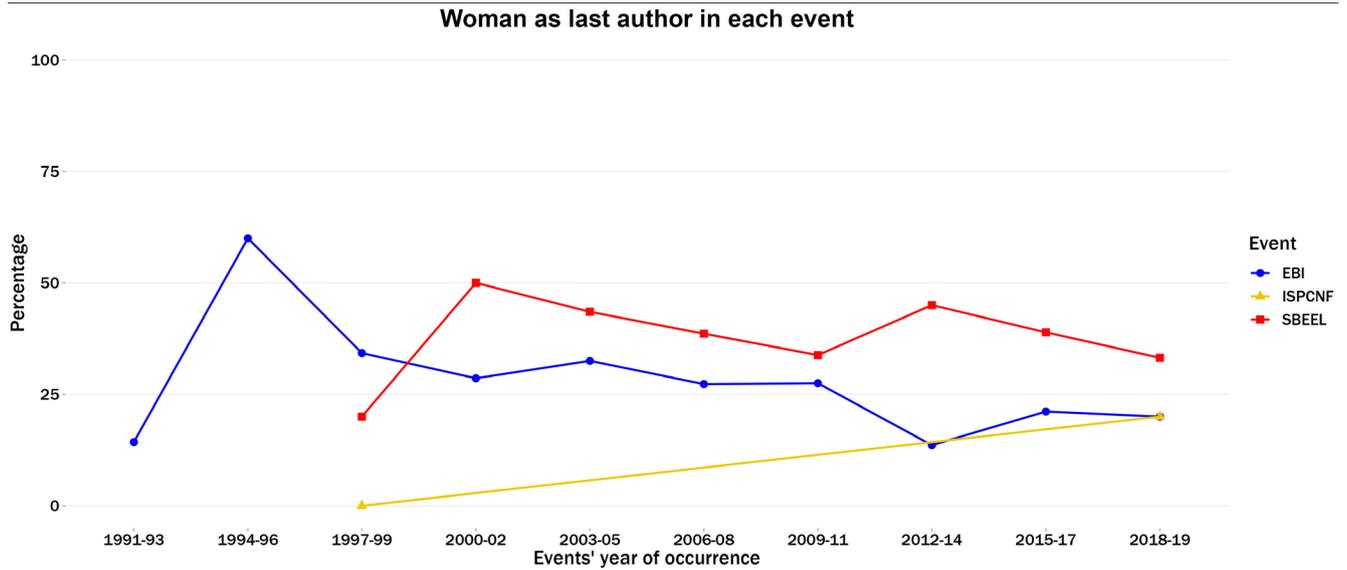


FIGURE 4 | Women as last authors in each event throughout the years. Blue circle = EBI (Encontro Brasileiro de Ictiologia), red square = SBEEL (Encontro da Sociedade Brasileira para o Estudo de Elasmobrânquios), yellow triangle = ISPCNF (International Symposium on Phylogeny and Classification of Neotropical Fishes). Continuous lines represent the data every two years.

Last authorship in Chondrichthyan Evolution

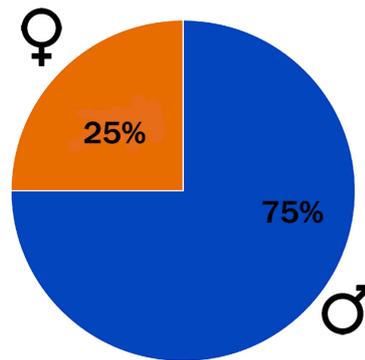


FIGURE 5 | Women versus men as last authors in Chondrichthyan Evolution. Orange, women; blue, men.

Author’s affiliation. In 1,210 (76.4%) of the 1,584 abstracts on chondrichthyans, the first author’s affiliation was identified as a Brazilian institution. Other countries with greater representativity in all scientific events over the years were Argentina (n = 30) and Colombia (n = 22). Of the 325 abstracts presented during EBI editions, only 2.8% (n = 9) were authored by researchers affiliated to foreign institutions whereas in SBEEL conferences (excluding the 2018 edition), a greater percentage was observed (n = 59, 7.5%). When considering only the Sharks International 2018 edition, some of the most representative countries were the United States (n = 89, 19.3%), Australia (n = 39, 8.5%), and Mexico (n = 35, 7.6%).

The Brazilian states with higher numbers of abstracts were São Paulo (n = 300, 24.8%) and Pernambuco (n = 231, 19.1%) whereas the less representative states were Goiás and Rondônia, with just one abstract each. Two Brazilian states, Tocantins and Roraima, were not represented. A major part of abstracts was authored by researchers affiliated to Brazilian public institutions (93.3% in EBI and 89.9% in SBEEL). When considering Brazilian regions, the Northeastern (n = 444, 36.7%) was the region that mostly contributed to the abstracts, followed by Southeastern (n = 413, 34.1%) and Southern (n = 215, 17.8%). The majority of studies presented by authors affiliated to Northeastern institutions were focused on ECO (n = 320, 72.1%) while lower values were observed for EVO (n = 116, 26.1%) and PHY (n = 5, 1.8%); a similar situation was observed in the Southern region (ECO = 68.4% and EVO = 27%). In the Southeastern, approximate numbers for ECO (n = 205, 49.6%) and EVO (n = 183, 44.1%) were found. The highest number and percentage of PHY abstracts was found in the Northern region (n = 25, 19.7%) (Fig. 6).

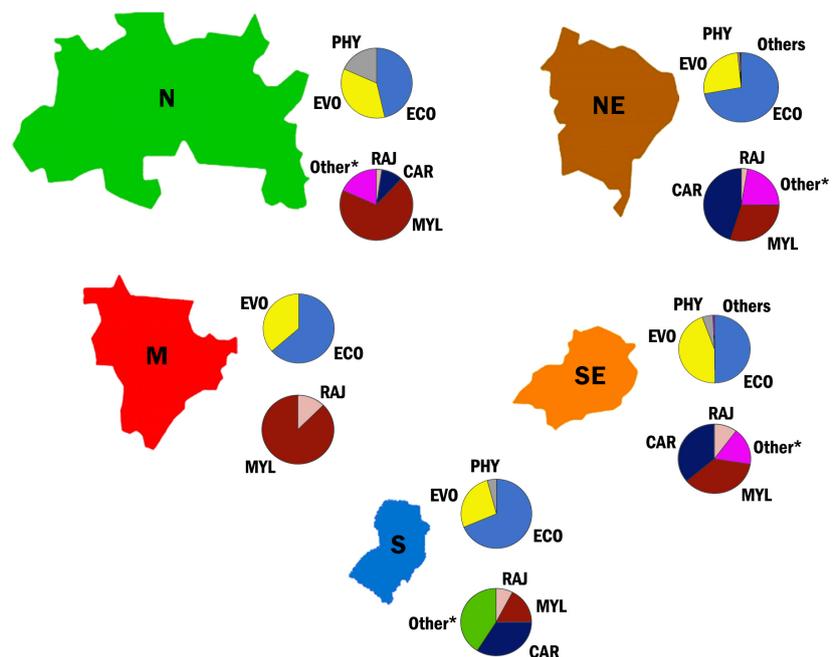


FIGURE 6 | Proportion of each research area and most studied Chondrichthyan orders by Brazilian region. Green, Northern (N); brown, Northeastern (NE); red, Midwestern (M); orange, Southeastern (SE); blue, Southern (S). Upper graph at the right of each region representing research areas: ECO, Ecology; EVO, Evolution; PHY, Physiology. Lower graph at the right of each region representing Chondrichthyan orders: CAR, Carcharhiniformes; MYL, Myliobatiformes; RAJ, Rajiformes; Other*, other orders.

Analyzing the number of abstracts per region and conference, a considerably higher proportion of works presented in SBEEL were authored by researchers affiliated to Northeastern institutions (43.0%), followed by the Southeastern (29.3%) and Southern (17.7%) regions (Fig. 7). In contrast, Southeastern affiliations were more representative in EBI abstracts (n = 150, 47.6%) in comparison to the Northeastern (19.4%), Southern (17.8%) and Northern (14.3%). All Brazilian regions were represented in abstracts presented during the ISPCNF editions, except the Midwestern.

In terms of gender representativity by Brazilian region measured by the percentage of abstracts with at least one woman as coauthor, the Northern (n = 114, 89.7%), Midwestern (n = 9, 81.8%), and Northeastern (n = 331, 74.5%) regions presented a greater gender diversity than the Southern (64.2%) and Southeastern (62.5%). In all regions, only-women authors were observed for less than 10% of abstracts, except for the Northern region (10.2%). Abstracts with women as first authors range from 54.5% considering researchers affiliated to Midwestern institutions to 40.2% in the Southeastern region. Regarding the gender of the last author by region, the Northeastern (32.6%) and Northern (29.9%) presented higher values of women as possible PIs in comparison to the other Brazilian regions (less than 15%).

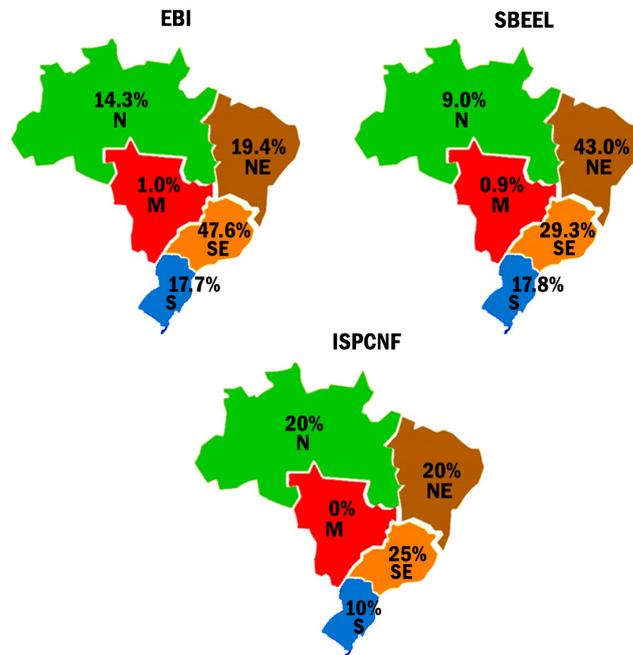


FIGURE 7 | Percentage, per event, of first authors' home institution regarding each of the five Brazilian regions: green, Northern (N); brown, Northeastern (NE); red, Midwestern (M); orange, Southeastern (SE); blue, Southern (S). EBI, Encontro Brasileiro de Ictiologia; SBEEL, Encontro da Sociedade Brasileira para o Estudo de Elasmobrânquios; ISPCNF, International Symposium on Phylogeny and Classification of Neotropical Fishes.

Focal study taxa and their threatened status. Of the 1,584 abstracts analyzed, 1,042 were focused on lower taxonomic levels of chondrichthyans such as families, genera, and species, and 114 (57.3%) of the 199 species recorded for Brazilian waters were recognized on such abstracts. In terms of Order, the most studied one was Carcharhiniformes (36%), followed by Myliobatiformes (30.9%) (Fig. 8). However, when observing each research area separately, this sequence is inverted in PHY (Myliobatiformes, 54.8%, Carcharhiniformes, 17.7%) and EVO (Myliobatiformes, 33.5%, Carcharhiniformes, 31.4%), with the shark Orders Echinorhiniformes and Heterodontiformes having only been studied in terms of ECO (Fig. 9). Abstracts within this last area were twice more numerous than EVO for each chondrichthyan order, except for Chimaeriformes and Rajiformes, in which EVO abstracts corresponded to more than 60%.

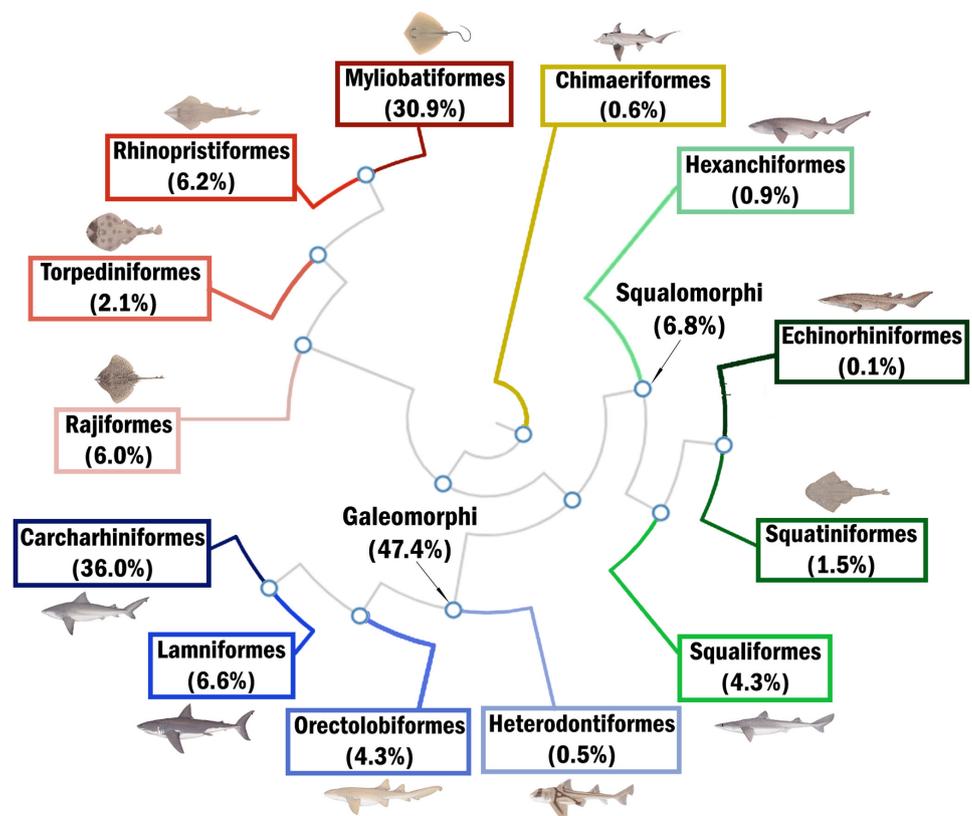


FIGURE 8 | Proportion of abstracts dealing with each Chondrichthyan order (number in parenthesis) on the Chondrichthyan Tree of Life cladogram (www.sharkrays.org, Naylor, 2022).

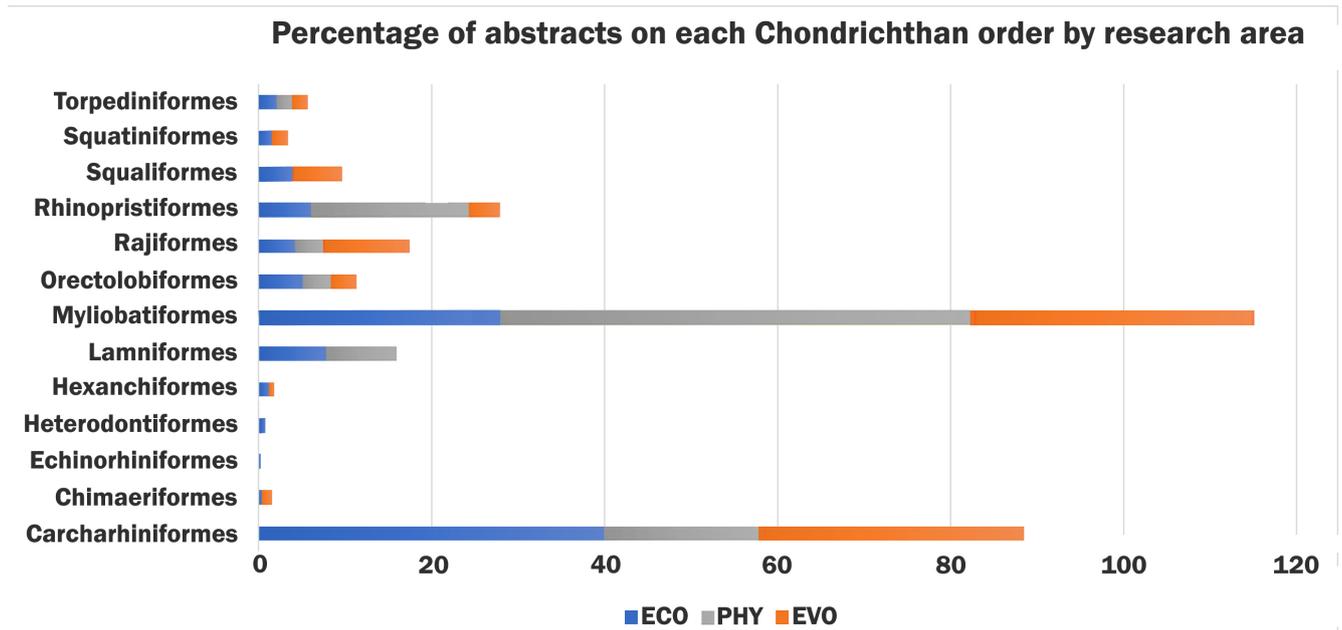


FIGURE 9 | Proportion of abstracts with each Chondrichthyan order and proportion of studies by research area: ECO, Ecology; EVO, Evolution; PHY, Physiology. The percentage might be higher than 100% since some abstracts were counted twice as they dealt with more than one order.

Within Carcharhiniformes, the shark genera *Carcharhinus* Blainville, 1816, *Prionace* Cantor, 1849 (blue shark), and *Rhizoprionodon* Whitley, 1929 were the most representative and the blue shark was the most cited species, with more entries ($n = 56$) than all sleeper and dogsharks (Somniosidae and Squalidae, order Squaliformes) ($n = 46$) and angel sharks (Squatinidae, order Squatiniformes) ($n = 16$). Myliobatiformes was mostly represented by freshwater stingrays (Potamotrygoninae), manta rays (Mobulidae), and the dasyatid genus *Hypanus* Rafinesque, 1818. In the Northern region, Myliobatiformes were the focal taxon of 74.1% of abstracts, depicting the freshwater stingrays' native area of occurrence (Fig. 6). Regardless of the research area, the proportion of threatened species in abstracts that studied taxa at species level was approximately 60% of non-threatened species, 30% threatened, and 10% data deficient ones.

DISCUSSION

In this study, we identified some patterns and trends in Brazilian chondrichthyan science through the analysis of conference abstracts presented over the last three decades. We observed the predominance of ecological studies rather than those focused on evolution or physiology, besides a great proportion of abstracts studying Carcharhiniformes and Myliobatiformes with less emphasis on other groups. In general, we noticed an increasing number of abstracts over the years, meaning that more researchers have been working on chondrichthyans and that the creation of research groups, in addition to SBEEL itself, has boosted the interest for this zoological group (Rosa, 2009; Rosa, Gadig, 2014; Wosnick, Palmeira-Nunes, 2020). Below, we discuss separately each analyzed topic herein.

Research area. A considerably higher percentage of abstracts focusing on ecological aspects of chondrichthyans was observed when analyzing EBI and SBEEL conferences together. A similar situation was also presented by Shiffman *et al.* (2020) for the abstracts submitted to the Meetings of the American Elasmobranch Society as they observed a great number of works that could be included in our ECO category (reproductive biology, movement/telemetry and life history). In Huvneers *et al.* (2015), ‘General biology and ecology’ and ‘Conservation and management’ were recorded as the main topics across the Sharks Down Under and the 2010 and 2014 Sharks International conferences.

It is worth noting that evolutionary studies were proportionately more representative in EBI than in SBEEL events and this could be related to the ‘ecological tradition’ of SBEEL and its members. It seems that systematists attend more EBI events maybe because there is more room for discussion or specialists working on similar issues, even though on other groups, such as bony fishes.

The predominance of ecological studies can be justified by the larger number of specialists working on subjects related to this research field in comparison to the low number of systematists in leading roles in Brazil. Of the 20 Brazilian chondrichthyan researchers listed by Rosa (2009), nine have developed studies on systematics (mainly taxonomy) and, from these, only five are currently affiliated to a scientific institution. Taxonomy can be defined as ‘the foundation of all other biological sciences’ since any study begins with a valid species name (Simpfendorfer *et al.*, 2011; White, Last, 2012). The scarcity of permanent taxonomists and limited research funds directed to this area have negatively impacted the conservation and fishery management of chondrichthyan species, since taxonomic units are not well-known as they should be (Rosa, Gadig, 2014).

Viana *et al.* (2018) argued that we are facing a taxonomic impediment in Brazil, given the large number of undescribed species and species complexes in need of taxonomic investigation. Among the suggestions presented by Rosa, Gadig (2014) and Viana *et al.* (2018) to improve chondrichthyan systematics in Brazil are the creation and modernization of scientific collections, implementation of modern research methodologies (*e.g.*, molecular sequences and techniques), and the strengthening of the collaborative network among national and international specialists. We add to this list the urge for public and private funding directed to taxonomic studies and the training of new taxonomists.

Despite being the less representative field, Physiology has become a more prominent research field since 2011, when a great number of abstracts related to this discipline was observed in EBI and SBEEL events. Huvneers *et al.* (2015) noted that studies focused on physiology nearly tripled when analyzing more recent international shark conferences, which is also true for the last edition of Sharks International (2018).

Few interdisciplinary studies focused on scientific communication and environmental education were observed in our analysis (category ‘Others’) and were restricted to SBEEL conferences. Huvneers *et al.* (2015) noted that the number of abstracts focused on social science and environmental education in Sharks International Conferences has increased over the years as has also been observed in the SBEEL events (Azevedo *et al.*, 2018). However, numbers remain considerably low (less than 3%). As pointed out by Azevedo *et al.* (2018), although we have observed advances in research focused on the human perception of sharks, it is important to highlight the need for more interdisciplinary studies and bring chondrichthyan science closer and closer to the general public.

Gender representativity. Through the analysis of 1,584 abstracts on Chondrichthyes submitted over the last three decades to conferences in Brazil, it is clear the discrepancy of authorship's gender. Even though 71.2% of all abstracts had, at least, one woman as a co-author, it cannot be disregarded that 28.8% had no woman at all. Wosnick, Palmeira-Nunes (2020) showed that women have been working with Elasmobranchs in the Amazon for some time and this number might be growing. However, to understand this historical scenario of fewer women than men, we need to look at the past situation of Chondrichthyan research in Brazil and observe its change throughout the years.

According to Rosa (2009), until 2008 there were seven research groups formally registered in Brazil studying Chondrichthyes, of which only one was led by a woman, Dr. Rosângela P. T. Lessa, who still maintains her group active. Besides, Rosa (2009) also listed 20 PIs until 2008 of which only five were women. The lack of women in leading roles negatively affects the permanence in academia and the development of their own identity as young female researchers (Levinson *et al.*, 1991; Sealy, Singh, 2010), and could also contribute to a process known as “leaking pipeline” (Knobloch-Westerwick *et al.*, 2013; Reuben *et al.*, 2014; Estrada *et al.*, 2018; Hughes, 2018). Other factors that could hinder the long-term retention of women in ichthyology as well as in other STEM fields are the systematic underrecognition of female researchers, sexual harassment (78% of women within marine sciences have reported some negative experience with their mentors; Women in Ocean Science, 2021), home management, family care, and sexist behaviors (Knobloch-Westerwick *et al.*, 2013; Slobodian *et al.*, 2021). As women frequently do not reach positions as a PIs, there will be a lack of female PIs acting as role models for younger scientists.

When looking more specifically into the research area of Chondrichthyan Systematics, there is a clear difference on the gender-proportion of last authorship (position generally, but not always, occupied by a PI): 26.6% of women as last authors *vs.* 73.4% of men as last authors. Currently, there are less than five women in Brazil who act as PIs in Chondrichthyan Systematics (ChonSyst) and advise a small number of students in comparison to men (V. Slobodian and collaborators, work in progress). If assessing the percentage of women PIs in ChonSyst abstracts among all events over the last 30 years, they represent only 2.8% of the abstracts, while men are more than twice this value: 7.8% (Fig. 10). Besides, there is another factor contributing to the leaking pipeline within the study of Systematics: the comparative morphological study of specimens for systematics and taxonomic investigations requires the observation of many individuals as possible, which is usually accomplished by visitations to scientific collections or by requesting loans to international museum collections. However, many chondrichthyan species are represented by large specimens and have wide distributions, which makes it difficult for shipping and compels researchers to travel overseas to do such study. Young researchers with funding could accomplish these travels to perform their taxonomy study; however, those who have already graduated and especially mothers, who need a stability to raise their children, are less prone to spend months travelling abroad than a man who is also a father (Goulden *et al.*, 2011; Hipólito *et al.*, 2020; Staniscuaski *et al.*, 2020). Therefore, this line of research becomes unsustainable as women progress in their careers, reaching a point where they need to leave academia.

Given those data, how is it possible to change this scenario and retain women scientists in chondrichthyan research? This is the question permeating this research and, even though there is data to support the permanence of women in science, there is

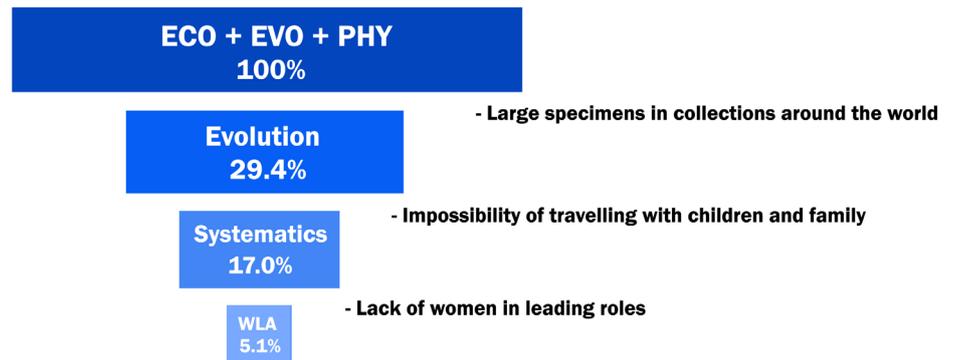


FIGURE 10 | Funnel representing the total number of abstracts with Chondrichthyes, the proportion of studies with Evolution within those, the proportion of Systematics, and the final proportion of women acting as last authors (WLA) in Chondrichthyan Systematics. The “leaking pipeline” is demonstrated by the reasons women might be leaving academia in the right side of the image. ECO, Ecology; EVO, Evolution; PHY, Physiology.

no simple solution. The system in which academics are embedded need to change, providing more support and collaboration to women through international partnerships for the examination of specimens and data sharing. As a consequence, researchers could stay at their home institutions without the need to travel abroad and to spend fundings that most of the time are unavailable for scientists from developing countries. Another desirable change is to cease the biased financing towards male PIs instead of female (Witteman *et al.*, 2019). Besides, funding agencies could contemplate women with families by designing targeted grants for this group of researchers that suffer with stringency of deadlines (Staniscuaski *et al.*, 2020).

To cite some recent transformations in the Brazilian zoological scenario (Slobodian *et al.*, 2021), the two most recent directorship of the SBI were composed only by women and the discussions promoted by the collective “Ictiomulheres” have invited all researchers to pursue and ensure gender equality in Brazilian ichthyology. Likewise, the three editions (2020, 2021, 2022) of the online symposium “ELASMulheres”, an event organized by female Brazilian chondrichthyan scientists, aimed to reach researchers from all Brazilian regions and enabled the submission of abstracts from a variety of research areas within Chondrichthyes (Soares *et al.*, 2021; Petean *et al.*, 2022). To promote the participation and representativity of women in the abstracts presented, those must have been co-authored by at least one woman. Additionally, each participant had to pay a small fee that was entirely used to award female researchers who first-authored the three best Undergraduate and the three best Graduate/Professional oral talks.

The representation of other minorities such as ethnical groups and LGBTQIAP+ people could not be accessed in this study but further information on these demographic aspects should be gathered in future conferences. Scientific societies should inquire their events’ participants to create a profile of researchers and attendants to identify marginalized groups within the Brazilian ichthyology, understanding the reasons of their marginalization. This is the first step to provide adequate environments of equality and inclusion in Chondrichthyan-related events in which people feel safe and free to be who they are. Furthermore, measures to prohibit discrimination, sexual harassment, retaliation, bullying, and unreasonable behavior need to be adopted, including general

procedures for reporting incidents. To address these issues and to develop a conference Code of Conduct, a SBI Equity and Diversity Committee was officially created at the last meeting that was held in September 2022.

Brazilian regions. The greater participation of non-Brazilian chondrichthyan researchers in events promoted by SBEEL could be explained by the fact that such conferences are exclusively focused on Chondrichthyes rather than EBI or ISPCNF.

Of the 10 SBEEL conferences, seven were held in Northeastern States (Tab. 1) which may have contributed to the higher numbers of abstracts first authored by researchers based in this region. Regarding EBI editions, one-third of the meetings took place at São Paulo State, thus reflecting the greater representativity of the Southeastern region in those conferences. Despite the proximity to the local chosen to host EBI and SBEEL conferences, many students and young professionals fail to attend to these events since there are high costs involved, such as registration fees, plane tickets, and accommodation. In this case, the creation of a fund diversity initiative similar to the Young Professional Recruitment Fund program of the American Elasmobranch Society (Shiffman *et al.*, 2022) could contribute to make meetings more accessible and inclusive to early career researchers living in all Brazilian regions.

Related to the research area, prominent specialists have driven research on fisheries and ecological aspects of chondrichthyans in the Northeastern region, such as Rosângela P. T. Lessa (Universidade Federal Rural de Pernambuco) and Fábio Hazin (*in memoriam*, Universidade Federal Rural de Pernambuco). Meanwhile, a significant portion of evolutionary studies on sharks, rays, and chimeras has been conducted by researchers affiliated to Southeastern institutions (Rosa, 2009); numbers of EVO abstracts were considerably higher in EBI editions held in São Paulo State. The predominance of evolutionary studies in Southeastern States can be related to the presence of the two largest Brazilian fish collections in this region (Museu de Zoologia da Universidade de São Paulo and Museu Nacional, Rio de Janeiro). In addition to providing access to various specimens collected over many decades, both museums have postgraduate programs focused on Zoology and evolutionary themes, which have contributed to the formation of new systematists.

Studied taxa and their threatened status. Even though batoids comprise the majority of valid Elasmobranch species (56% *vs.* 41% of sharks) (Fricke *et al.*, 2023), most studies presented in Brazilian meetings regard sharks (Galeomorphi, 47.4%, and Squalomorphi, 6.8%) (Fig. 8), a scenario also observed within the American Elasmobranch Society meetings over the last 30 years (Shiffman *et al.*, 2020), and previous Shark International Conferences (Huvneers *et al.*, 2015). The appearance of the blue shark, *Prionace glauca* (Linnaeus, 1758), as the most studied species (5.5% of all mentioned ones) is an example of the taxonomic bias in which model species are more often studied and cited than others, as observed in studies with fishes, that represent 48% of vertebrate species, but mentioned in only 14% of vertebrate papers (Bonnet *et al.*, 2002). The preference for some taxa might be due to their easy accessibility, such as coastal species (Shiffman *et al.*, 2020), and not considering their evolutionary distinctiveness (Stein *et al.*, 2018). Then, the reason why Rajiformes are poorly represented in abstracts (6.02% of taxa) might relate to their occurrence environment, such as deep sea with difficult access, and the

lack of charisma of skates, as this trait biases research and interest, thus the neglect of this group (Prokop *et al.*, 2022).

There is a need to overcome the taxonomic bias, with researchers working with highly-represented taxa dominating the area of investigation, as well as being in well-ranked positions within evaluating committees and journals. To achieve it, people should become aware of their own prejudices and their influence on others, and important decisions such as conceding a fellowship, a grant, or accepting a manuscript should be accomplished by a myriad of people with a diversified background and knowledge (Bonnet *et al.*, 2002).

Of those abstracts on rays, there are 160 on Potamotrygoninae freshwater stingrays, which is a group known as having taxonomic issues (Fontenelle *et al.*, 2021), with many species still considered as complexes that need to be better identified in independent units, such as *Potamotrygon scobina* Garman, 1913 (Fontenelle, Carvalho, 2017), *P. orbignyi* (Castelnau, 1855) (Silva, Carvalho, 2015), and *Paratrygon aiereba* (Walbaum, 1792) (Loboda *et al.*, 2021). Without understanding the taxonomic unit we are dealing with, other data such as its distribution, feeding, and reproductive behaviors might be misleading, since researchers could be investigating a complex of species instead of only one. Therefore, a collaborative network between taxonomists and specialists in other fields like ecology and physiology would be desirable in order to better identify species and lineages (Simpfendorfer *et al.*, 2011).

Of all studies regarding Potamotrygoninae, only 13.12% are taxonomic and population genetics that contribute to the knowledge on the diversification and identification of species, which leads to the question: of the more than 150 studies with Potamotrygoninae species submitted to conferences for the last 30 years, do they really relate to those mentioned species, or should researchers take new approaches after taxonomic issues are solved within the group (Bortolus, 2008)? Besides, of the 39 currently valid Potamotrygoninae species, 20 have already been evaluated by IUCN specialists; however, only four have a status other than Data Deficient (DD), one Endangered (EN), and three Least Concern (LC). The species *Potamotrygon brachyura* (Günther, 1880), *P. falkneri* Castex & Maciel, 1963, *P. ocellata* (Engelhardt, 1912), *P. schuhmacheri* Castex, 1964, and *P. scobina* are examples of DD ones that are in need of taxonomic studies for an updated evaluation (IUCN, 2021).

When looking at all IUCN evaluations of Chondrichthyan species, of the 1223 taxa, 131 need taxonomic studies; of these, 29% are Data Deficient, 35.9% are Least Concern, and 35.1% are already threatened (IUCN, 2021). Furthermore, the most recent evaluations by specialists of Chico Mendes Institute for Biodiversity Conservation (ICMBio, 2014, 2018) left 20% of the chondrichthyan species as Data Deficient, which suggests these taxa need more studies, including systematic ones. Of those submitted abstracts mentioning species names, 30 used “sp.” or “cf.” when referring to the taxon examined. Of those, only six were focused on taxonomy, meanwhile the other 80% of the studies using “sp.” or “cf.” investigated a taxon that might not be an independent lineage, but a complex or an undescribed species. Once more, the data here presented shows the relevance of systematics as a basic research prior to other studies taking place (Engel *et al.*, 2021).

Regardless the research area, the proportion of threatened species in abstracts that studied taxa at species level remained similar to their current overall status (Dulvy *et al.*, 2021): approximately 60% of abstracts dealt with non-threatened species, while 30% threatened, and 10% Data Deficient ones. Of the 391 threatened chondrichthyan

species, 56.3% regard rays (Dulvy *et al.*, 2021) and due to new taxonomic studies, 6.5% of species had their status changed since the last evaluation in 2014 (Dulvy *et al.*, 2021).

Trends throughout time. Before 1997, works on Chondrichthyes were also presented during the meetings promoted by the Work Group on Fisheries and Research of Sharks and Rays (Grupo de Trabalho sobre Pesca e Pesquisa de Tubarões e Raias, in Portuguese) from which SBEEL was created. In general, we observed an increase in the total number of abstracts on Chondrichthyes presented in EBI conferences after the creation of SBEEL, with some peaks registered in 1999, 2005 and 2007 (Tab. 1). In 1997, the low number of abstracts may be related to the realization of other two events (SBEEL and ISCNPf) in the same year.

The percentage of abstracts in ChonSys authored only by men in EBI went from 100% in 1993 to 100% co-authored by at least one woman in 2019, in a great example of changes being made. Differently, in SBEEL, at least 41.7% of ChonSys abstracts were co-authored by women since its beginning in 1997, in a more equitable academic environment. However, the worst scenario is observed at the ISCNPf, in which the first edition had 100%, and its second had 66.7% of ChonSys abstracts authored only by men, in a clear demonstration that, even though women are gaining space in ChonSys in Brazil, there is still a tortuous way to reach a truly diverse and equitable scenario.

We hope that data presented here may have shown that women are still lacking space in Chondrichthyan Systematics research in Brazil. Even though we have seen changes, they are not enough, and women are leaving academia due to lack of support and the existence of many sexist barriers. To overcome this “leaking pipeline” we suggest more international collaboration allowing researchers to combine and compare data without the need of traveling for long periods to examine specimens deposited in museums all over the world, besides support from funding agencies and researcher colleagues that consider the distinct scenario in which women are inserted.

When talking about scientific conferences, the experience of “ELASMulheres” should be considered since this was the first Brazilian event on Chondrichthyes that openly discussed gender inequality. In the last two editions of EBI (2019 and 2022), roundtables and talks on gender representativity within ichthyology were part of the scientific program but much still needs to be done to expand such discussions and effectively provoke changes. Male attendants of scientific conferences should be remembered and encouraged to invite more women to get involved in their workshops and research groups, since they could also benefit themselves by producing a higher quality science as discussed by Campbell *et al.* (2013). Diversity, equality, and inclusion should not be just issues for women and minoritized groups to discuss but for all members of the academic society as well. A summary of recommendations to improve these issues in scientific societies was provided by Shiffman *et al.* (2022).

We expect the data presented here are useful not only for creating a more diverse academic environment, but also setting research priorities within Chondrichthyes’ research. Our results showed that most studies encompass the same few Chondrichthyan orders (Carcharhiniformes and Myliobatiformes), demonstrating the deficiency in researching the whole group diversity, which leads to serious conservation biases and lack of knowledge to evaluate and manage species. Finally, it is important to emphasize the relevance of doing taxonomic studies within Chondrichthyes since we can only apply effective conservation measures for known species.

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Karla D. A. Soares: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing-original draft, Writing-review and editing.

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