

Herpetology in Spain: a current overview through doctoral theses

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This study summarizes the temporal variation, the relative contribution of each university, the research topics addressed, the taxonomic groups studied and the differences in author and its advisors' gender in the 303 PhD theses on herpetology defended in Spain and gathered in Teseo[®] and Dialnet[®] between 1977 and 2020. The number of theses defended per year is around 7 with an upward trend. Complutense and Autonomous University of Madrid universities hosted the highest number of theses, followed by Barcelona and Valencia universities. The most addressed topic was morphology, biometry and anatomy, followed by physiology and histology, genetics and habitat selection. The most studied herpetofauna orders were Squamata and Anura and the families most tackled were Lacertidae, followed by Ranidae and Salamandridae. The most addressed species were native to Spain and without protection status, as opposed to those that were non-native or with protection status. The study of invasive species is very poorly represented. The number of PhD theses defended by men is higher compared to those by women (1.43:1), however, both genders show an upward trend in the number of theses. The results represent an approximation of the development, trends and interests pursued by herpetological research in Spain.

Key words: amphibians; early-career researchers; gender-gap; herpetofauna; PhD dissertation; reptiles; research topic.

Herpetology, the study of amphibians and reptiles, has experimented an increase in the last decades (LOVICH *et al.*, 2012; VITT & CALDWELL, 2013) due to the endangered conservation status of both amphibians (WAKE, 1991; ALFORD & RICHARDS, 1999; COLLINS & STORFER, 2003) and reptiles (GIBBONS *et al.*, 2000; COX *et al.*, 2022). Scientists' concern about the decline of amphibian populations began at the First World Congress of Herpetology in 1989 (STUART *et al.*, 2004), and it is probably one of the most serious examples of a clade-specific biodiversity crisis (ALLENTOFT &

O'BRIEN, 2010; FICETOLA, 2015; ANGELINI *et al.*, 2020). This global interest has been reflected in an increase in scientific publications over the last years (ANGELINI *et al.*, 2020). In any case, there is a growing need for basic information on the biology, ecology and conservation of amphibians and reptiles (McCALLUM & McCALLUM, 2006).

Bibliometric analysis is a suitable tool to evaluate these knowledge gaps (PRITCHARD, 1969) and provide a new approach to that offered by traditional bibliographic reviews (GRANT & BOOTH, 2009). The application of this discipline in the

assessment of herpetological research is scarce, limited to a geographical area (e.g., Brazil: DE PAIVA AFFONSO *et al.*, 2015), addressing the gender-gap (CHULIVER *et al.*, 2021; ROCK *et al.*, 2021) or focused exclusively on a specific taxonomic group (e.g., CAMPOS *et al.*, 2014; ANGELINI *et al.*, 2020; MARÍN-CAPUZ & MENÉNDEZ-BLÁZQUEZ, 2021) or research topic (e.g., habitat conservation: FICETOLA, 2015)

Previous bibliometric analysis show that PhD dissertations offer a good overview of the main lines of research in universities and academic institutions and, therefore, a good representation of the general interest pursued by researchers and scientific disciplines (BARBOSA, 2000; ARDANUY *et al.*, 2009), and it has been already applied to birds (BARBOSA, 2000; MENÉNDEZ-BLÁZQUEZ & BARBOSA, 2021) and mammals (MENÉNDEZ-BLÁZQUEZ & MARÍN-CAPUZ, *unpublished data*). The results of PhD dissertation analysis allow a more careful choice of research areas and focal species to address, and to focus the efforts of future lines of research mainly for the early-career researchers (BAUTISTA & PANTOJA, 2000).

The aim of this study is to assess the historical trend of herpetological research in Spain through PhD dissertations over the last 50 years, to get a broad picture of current trends, the contribution of each university, the research topics addressed, the taxonomic groups studied and its provenance, and the gender differences of the authors and their supervisors.

MATERIALS AND METHODS

For the bibliometric analysis, we used the PhD theses information across the en-

tire available time range in the databases of doctoral theses Teseo[®] v.4.2 and Dialnet[®]. We selected the herpetological thesis available in these online resources and summarised the information of interest in a database. We extracted the relevant information by reading the abstracts and the cover of the thesis. In case this was not enough to obtain the necessary information, we did a quick search within the text of the thesis, looking for the key words of interest (e.g., species; study site). We analysed the same variables used by BARBOSA (2000) and MENÉNDEZ-BLÁZQUEZ & BARBOSA (2021): number of theses defended per year, number of theses defended in each university; assignment of research topic of each theses within the categories defined by BAUTISTA & PANTOJA (2000) (“Atlas and Checklist”, “Behaviour”, “Biological Conservation and Wildlife Management”, “Evolution”, “Foraging”, “Nutrition and Diet”, “Genetics”, “Habitat Selection”, “Morphology, Biometry and Anatomy”, “Paleontology”, “Parasites and Diseases”, “Physiology and Histology”, “Pollution”, “Population Dynamics”, “Reproduction and Breeding Biology”, “Taxonomy and Systematic” and “Veterinary”); and the taxonomic order and family species in which each theses is focused.

We have carried out a regression analysis between the number of species of each herpetological order in Spain and the number of theses dealing with each of them in order to check whether the taxonomic orders with a greater number of species are dealt with by a greater number of theses. Note that Paleontology was approached as a distinct category, due to the

controversial taxonomic place of dinosaurs (PARSONS, 2004). In addition, and completing the study of the research topics, we have explored the distribution of these by universities in a graphical way to check which universities have the highest number of theses per topic.

In addition, for each doctoral thesis we obtained the number of supervisors (directors, co-directors, advisors, etc.) and their gender, the database in which the thesis was found, whether each study species is under any protection status (at national and international level), are autochthonous or allochthonous species for Spain (defined as species whose distribution is not established in Spain, including the Canary and the Balearic archipelagos), and whether they are considered as invasive alien species. The PhD thesis encompassed in Paleontology category were not assessed for the sections concerning the species.

We also analysed the gender differentiation of the authors and thesis supervisors over the years. We utilised gender-API web server (www.gender-api.com), which uses the first and/or middle name to determine the probable gender (male/female). It is a name-based gender assignment method (e.g., FOX et al. 2018; HOLMAN et al. 2018), which uses a database of name-gender associations (> 6.000.000 names and 189 countries available), giving the probability of gender assignment to each name. In our study, this method was not useful for two names that were excluded from the gender differentiation analysis.

It is necessary to point out that as a same study can cover more than one species and research topic, the sum of the val-

ues of these cited variables is greater than the number of total publications considered in the bibliometric analysis. Theses found in both databases were counted once. Only information about current taxonomic groups (not those that are extinct or can be addressed within palaeontology studies) was registered.

We used the R program version 4.1.1 (R DEVELOPMENT CORE TEAM, 2021) to develop the statistical analysis by using of "stats" R package for all the analysis, except for the Cramer's V correlation ("vcd" R package). The statistical results are showed as mean \pm SD and the significant level was set at $P < 0.05$. Data were first tested for normal distribution (Shapiro-Wilk's test) and nonparametric tests were applied when the data were not normally distributed. We used Pearson (as a parametric analysis) and Spearman (as a non-parametric analysis) correlations to evaluate the temporal trend of the variables (number of theses; gender of author and supervisors), correlating each of them with the range-years. We applied a Chi-square test to evaluate the differences of the authors' gender-gap over the time period and performed a Quade's test as a non-parametric analysis of covariance of both genders over the time. A Cramer's V correlation was carried out to test and explore the association between pairs of research topic addressed together in the same thesis.

RESULTS

The complete list of PhD dissertations in herpetology published in Teseo® and Dialnet® until 2020 can be found at Fig. S1.

The number of total theses found is different in each consulted database: 118

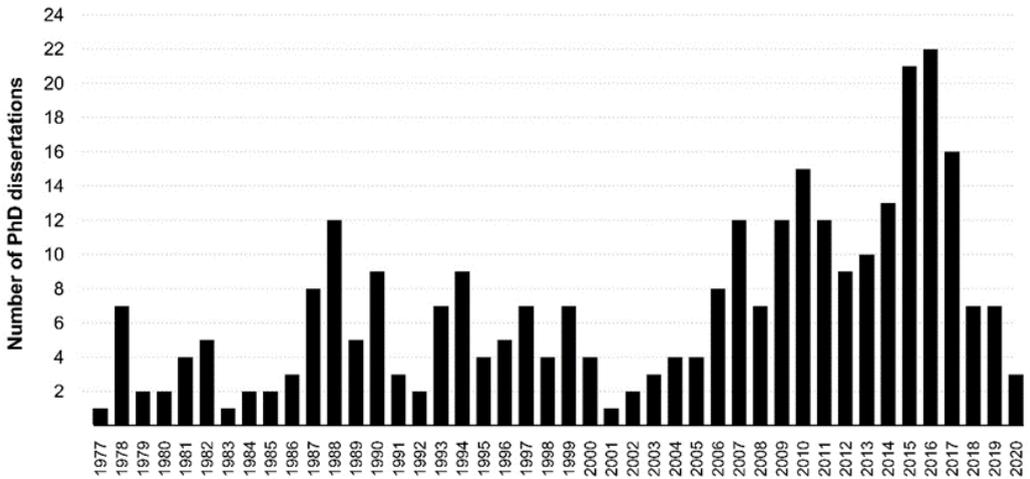


Figure 1: Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 gathered in Teseo® and Dialnet®.

theses were found in both databases, while 168 and 17 were found only in Dialnet® and Teseo® respectively. Thus, there was a significant difference between the databases ($\chi^2 = 54.159$, $df = 1$, $P < 0.001$).

A total of 303 herpetological PhD dissertations were defended between 1977 and 2020 in Spain, an average of 6.89 ± 0.76 theses per year, with a maximum of 22 in 2016 and a minimum of 1 in 1977, 1983 and 2001. There was a growing trend in the number of theses over the years of study (Pearson correlation: $r = 0.569$, $N = 44$, $P < 0.001$; Figure 1). The theses were defended in a total of 32 Spanish universities (Figure 2), being the Complutense University of Madrid the one with the largest number of theses (50 theses which represent a 16.50% of total), followed by Autonomous University of Madrid (31, 10.23%), University of Barcelona (24, 7.92%) and the University of Valencia (22, 7.26%).

Regarding to research topic, Morphology, Biometry and Anatomy (62, 13.60%) and Physiology and Histology (56, 12.28%) followed by Genetics (44, 9.65%), Habitat selection (42, 9.21%) and Paleontology (38, 8.33%) were the most treated topics. In contrast, the topics with the least incidence of study were: Pollution (5, 1.10%), Veterinary (1, 0.22%) and Atlas and Checklist (1, 0.22%) (Figure 3). The potential link between pairs of research topic addressed together among the theses were weak, and there were not significant associations (Cramers's V coefficient: $\varphi_c < 0.3$, $P > 0.05$, for all pairs of associations) (Figure 4). The distribution of the different research topics by university is graphically represented in Figure 5.

According to the authors' gender-gap, we found that the number of theses defended by men (178) was significantly higher than the number defend by women (124) ($\chi^2 = 9.656$, $df = 1$, $P = 0.002$) (ratio of

HERPETOLOGY IN SPAIN THROUGH DOCTORAL THESES

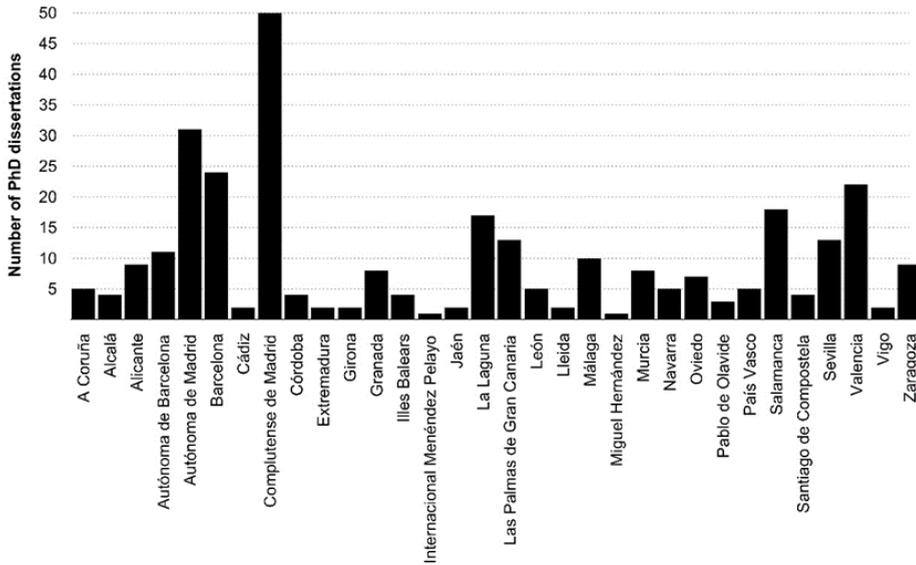


Figure 2: Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 by university gathered in Teseo® and Dialnet®.

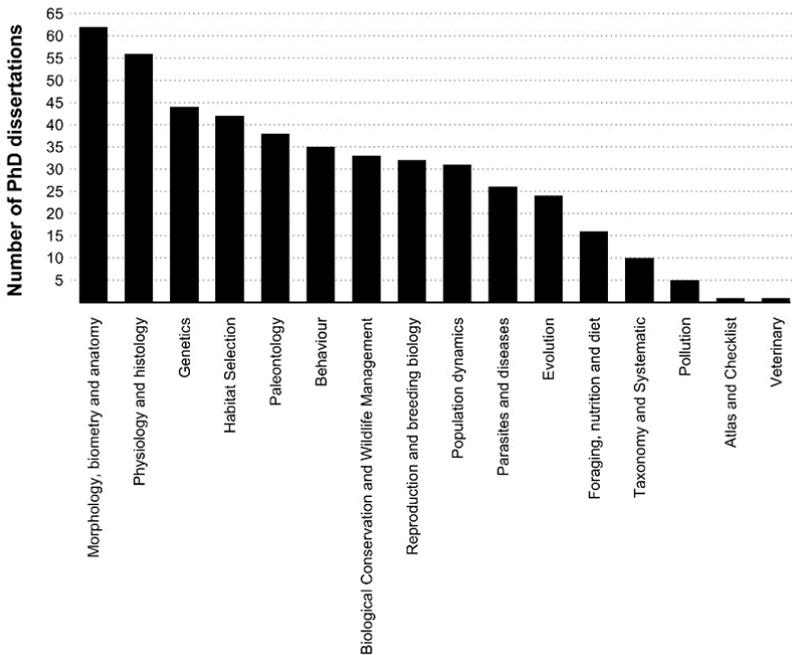


Figure 3: Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 by research topic gathered in Teseo® and Dialnet®.



Figure 4: Correlation matrix based on Cramer's V coefficient as a measure of association between pairs of research topics addressed together in the same thesis on herpetology gathered in Teseo® and Dialnet® between 1977-2020 ($\varphi_c < 0.3$, $P > 0.05$ for all association pairs).

men : women = 1.43:1) however, both genders show a similar slight positive growth in the number of theses defended over the years (women: $r = 0.550$, $N = 44$, $P < 0.001$; linear regression, $Y = -208.2 + 0.105 \cdot \text{year}$; $R^2 = 0.261$; $P = 0.0012$ | men : $r = 0.500$, $N = 44$, $P < 0.001$; linear regression, $Y = -233.1 + 0.118 \cdot \text{year}$; $R^2 = 0.256$; $P = 0.010$ | ANCOVA: $F_{1,1} = 0.003$ $P = 0.955$) (Figure 6A). The theses were overseen by a total of 442 supervisors, 375 of whom were men and only 67 were women, which means there are significant differences between genders

($\chi^2 = 7.297$, $df = 1$, $P < 0.004$). In addition, men supervisors showed a higher upward trend (Spearman correlation: $\rho = 0.707$, $N = 44$, $P < 0.001$; lineal regression, $Y = -828.2 + 0.419 \cdot \text{year}$; $R^2 = 0.43$; $P < 0.001$) in contrast with the women supervisors ($\rho = 0.335$; $N = 44$; $P = 0.09$; lineal regression, $Y = -178.2 + 0.091 \cdot \text{year}$; $R^2 = 0.15$; $P = 0.044$) (Quade's test: $F_{1,43} = 12.476$; $P < 0.001$) over the years (Figure 6B).

All herpetofaunal orders were tackled in herpetological doctoral theses in Spain except the order Rhynchocephalia. The

HERPETOLOGY IN SPAIN THROUGH DOCTORAL THESES

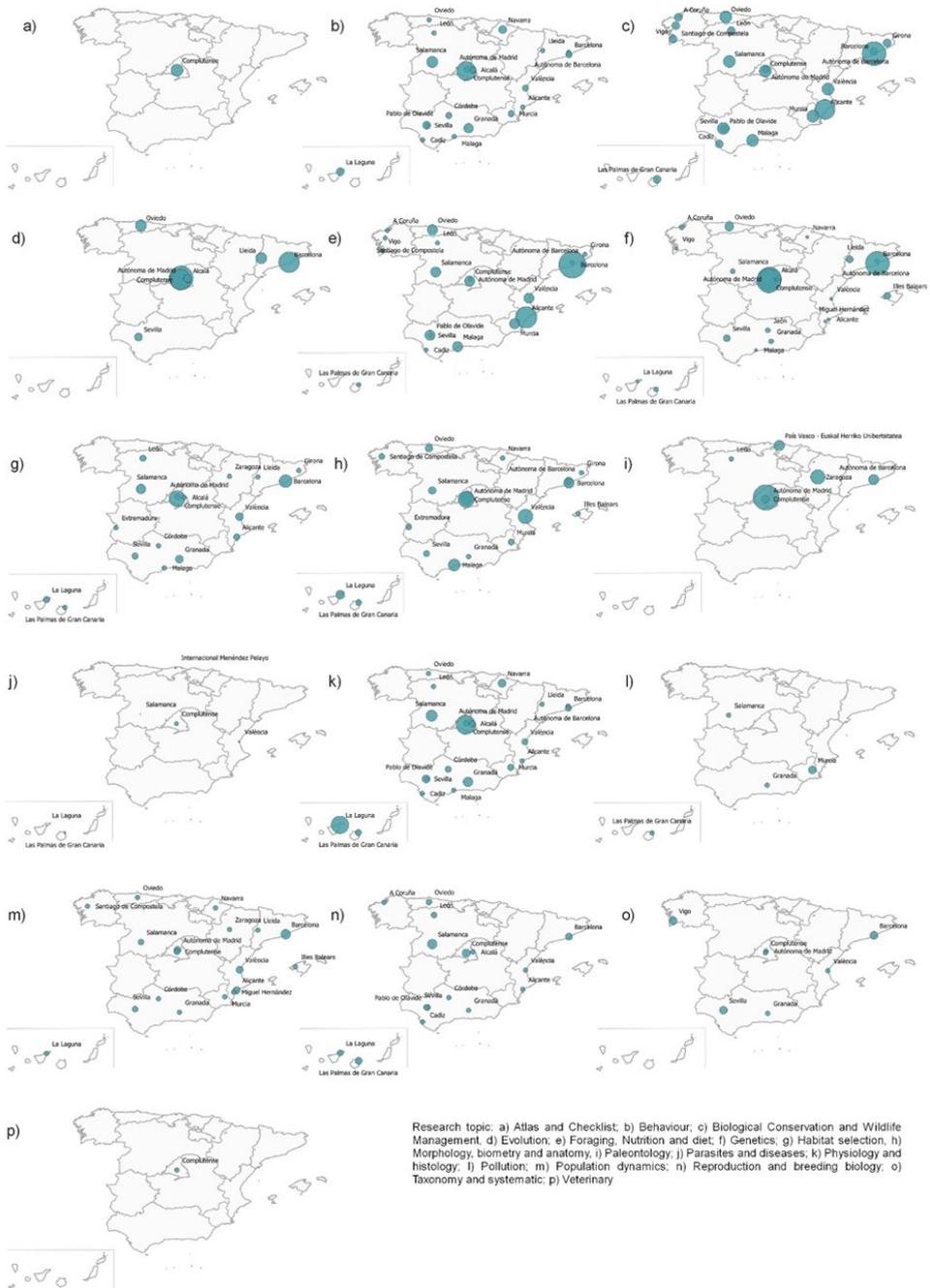


Figure 5: Spatial distribution of thesis topics by university. The size of the circles corresponds to the number of dissertations collected for each university and research topic (a-p). The absence of circle correspond to the lack of theses in this topic.

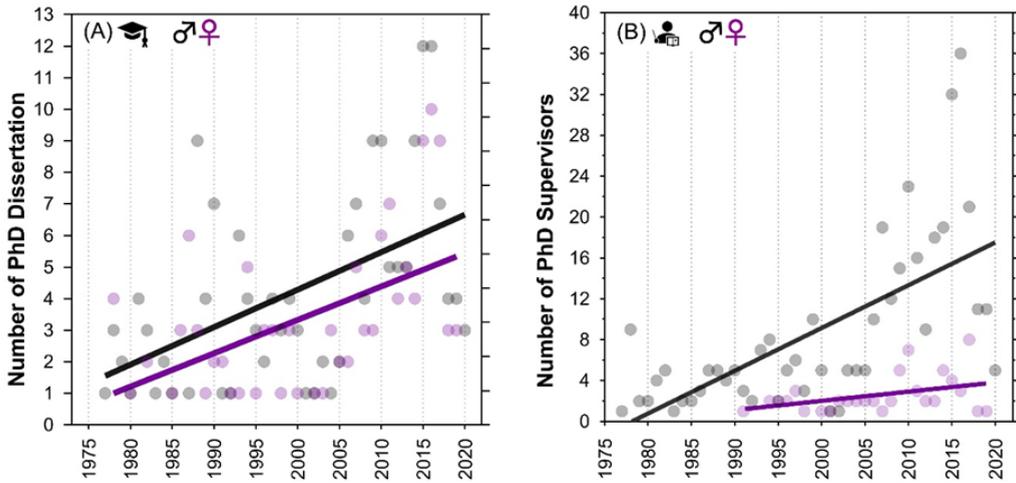


Figure 6: (A) Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 by authors' gender gathered in Teseo[®] and Dialnet[®]. (B) Number of PhD dissertation on herpetology defended in Spain between 1977 and 2020 by directors' gender gathered in Teseo[®] and Dialnet[®]. The black and purple lines represent the number of male and female PhD authors/supervisors per year respectively.

order Squamata is the most herpetological studied group with 41.75% of the total (and, therefore, the most treated group of reptile species), followed by Anura with 26.26% (which is the most amphibian addressed group). The least treated groups were Gymnophiona (1.35%) and Crocodylia (2.36%) (Figure 7). Within the species of the herpetological orders, a total of 47 families have been studied: 27 amphibians (Ranidae, Salamandridae and Hylidae were the amphibian families most addressed) and 20 reptiles (Lacertidae, Chelonidae and Colubridae were the reptilian families most studied) (Figure 8). We found that the most diverse herpetological orders in Spain (those with the largest number of species) are the orders covered in a largest number of PhD theses (linear regression, $Y = 1.350 \cdot \text{species richness} + 27.938$; $R^2 = 0.906$; $P = 0.048$).

In terms of species features, 202 theses (78% of the total) dealt with studies on autochthonous species from Spain (Iberian Peninsula and the archipelagos of the Canary and Balearic archipelagos), 44 (17%) with allochthonous species and only 14 (5%) addressed both autochthonous and allochthonous species at the same time. Of the total number of allochthonous species studied, only 7 theses were focused on invasive species, which represents a 3% of the total amount of doctoral dissertations. Of the total theses in which it was possible to record the species studied, 103 (42%) theses dealt with species under international or national protection categories compared to 144 (58%) which studied species without protection status.

DISCUSSION

The number of PhD theses on herpetol-

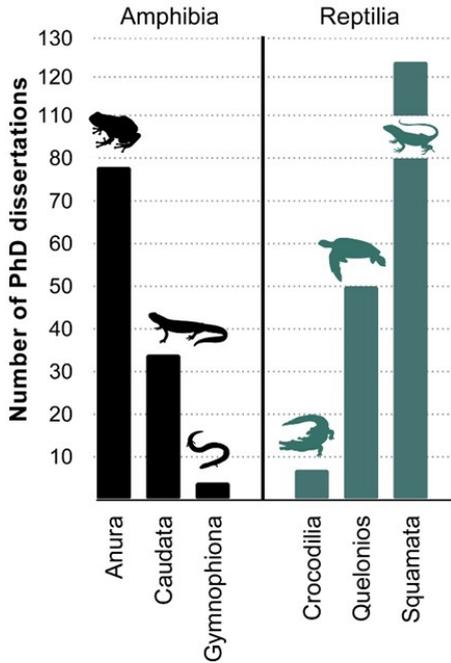


Figure 7: Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 by taxonomic order gathered in Teseo® and Dialnet®.

ogy defended in Spain and gathered in Teseo® and Dialnet® databases, has experienced a positive trend, accumulating a total of 303 dissertations over 44 years. The unequal number of theses between both databases may be due to differences in the age or the managing entity of the two databases. Two distinct periods can be identified in terms of trends in theses publication, before and after the early 2000s (Figure 1). Before the 2000s, the number of theses per year remained constant, reflecting the global trends in these years (McCALLUM & McCALLUM, 2006). From 2006 onwards, an increasing trend in the publication of herpetological doctoral theses began, which can be explained by the general increase of interest in herpetology (ANGELINI *et al.*, 2020). This growth can be attributed to the increase in opportunities and grants offered for the training of pre-doctoral students, as well as an increase in

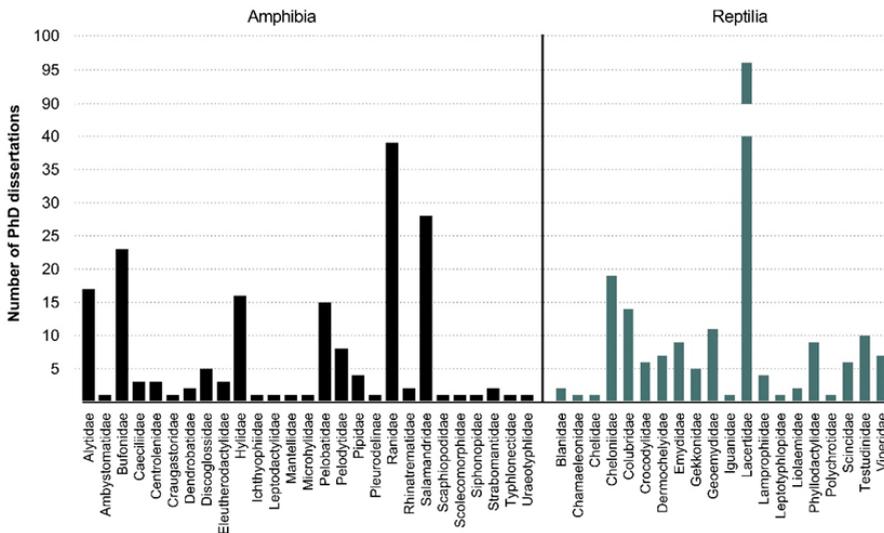


Figure 8: Number of PhD dissertations on herpetology defended in Spain between 1977 and 2020 by taxonomic families gathered in Teseo® and Dialnet®.

the universities linked to private research centres where doctoral studies and training can be carried out (CYRANOSKI *et al.*, 2011).

The distribution in thesis production among universities broadly coincides with the trend observed for ornithological theses (MENÉNDEZ-BLÁZQUEZ & BARBOSA, 2021), being the Complutense, Barcelona and Autonomous University of Madrid those which hosted the higher number of doctoral dissertations in both taxonomic groups. The universities with the highest number of published theses for both taxa are among the best in the field of research in Spain (QS WORLD UNIVERSITY RANKINGS®, 2021). In addition, the differences between universities could be related by intrinsic features of each one (e.g., university size, seniority, the capacity to host students, etc) (MENÉNDEZ-BLÁZQUEZ & BARBOSA, 2021), which can also explain the distribution of the different research topics by university.

Morphology, Biometry and Anatomy followed by Physiology and Histology are the most addressed topics. Genetics is also a well-covered topic, probably due to the emergence of this discipline as a conservation tool in recent decades (JEHLE, 2010), and the increasing accessibility of novel technologies. Further, Habitat Selection is also fundamental to wildlife research (ARROYO *et al.*, 2016). As concluded by FICETOLA (2015), amphibian studies focused on habitat conservation has been undergone methodological and thematic shifts but have been focused on one potential threat only.

Likewise, Behaviour, Biological Conservation, Reproduction and Popula-

tion Dynamics arouse relative interest to develop herpetological theses, coinciding with the trend of ornithological thesis in Spain (MENÉNDEZ-BLÁZQUEZ & BARBOSA, 2021). However, Palaeontology attracted greater interest in developing theses in the area of herpetology mainly on reptilian species. Due to the broad scope of this discipline, it would be advisable to be treated as a single topic of study in a future bibliometric analysis.

A gender-gap inequality is found in herpetological science in Spain. There is a significant difference in the number of theses defended by women and men, and also, regarding to gender of the supervisors, with a clear bias towards men in both cases. This fact shows the underrepresentation of women in science (e.g., MONROE *et al.*, 2008; SHEN, 2013), both at early (JÄHNIG *et al.*, 2019), and senior stages of their scientific career in disciplines such a Zoology and Ecology (SALERNO *et al.*, 2019; LERMAN *et al.*, 2021) or in Herpetology (e.g., ROCK *et al.*, 2021). However, finding no growth-trend differences between the authors' gender could be supporting the gender balancing in some STEM fields at early stages (CHERYAN *et al.*, 2017).

In reference to taxonomic groups, the most studied orders are directly related with the number of species gathered in each one, with Squamata and Anura being the most addressed and also the most diverse in Spain. This trend is also extrapolated at family's level, with Lacertidae gathering the vast majority of herpetological dissertations. Ranidae and Salamandridae also concentrate the amphibian research focus. This fact could be explained by the need to know the key factors of the

amphibians decline crises (ANGELINI *et al.*, 2020), and the current risk of extinction of reptile species (COX *et al.*, 2022). Some other points could be probably related to its ease regarding sampling designs (BROWNE *et al.*, 2007) or their suitability to be considered as model animals in experimental research (BRATTSTROM, 1979). Another factor is the presence of conservation problems or the implementation of protection categories as in the case of the family Cheloniidae (IUCN, 2021), which can lead the research efforts. Finally, in order to achieve a correct interpretation of the results, it is necessary to highlight the presence of works focusing on a considerable diversity of amphibians among the theses analysed. This explains the higher numbers of amphibian families present in the final analysis, but with a low level of representation.

The greater interest of young researchers for autochthonous herpetofauna could be explained by logistical reasons and proximity, as well as the continuation of already established lines of research. However, this statement should be interpreted with caution given the lack of previous information on doctoral theses in herpetology in Spain. Furthermore, most of the few theses covering invasive alien species are focused on the ecological effects of them on native fauna, because dealing with aliens is complicated once they have been introduced (HUSSAIN & ASHOK, 2012). Thus, the few allochthonous studied species have been addressed to find new areas and/or species that have not been the subject of prior research outside Spain.

Finally, the values of species under a national red list and the IUCN Red listing protection status show that they are of considerable interest and more likely to attract

funding for their study by researchers (RODRIGUES *et al.*, 2006). However, the values between protected and non-protected species are similar, a positive signal considering that each species needs to be studied, since its conservation status could undergo constant changes. In addition, the background of information constituted by the study of abundant species are applicable for the conservation of those more scarce or difficult to research (ANGELINI *et al.*, 2020).

In this study, we have tried to obtain an overview of the research trends and current state in herpetological science in Spain based on PhD dissertations. Future research should be focused on filling the data-gaps on certain groups (YOUNG *et al.*, 2004), and this can be achieved with the use of bibliometric analysis. This study tries to offer these points to be addressed in future research, as well as the sociological factors involved (*e.g.*, gender-gap) for a better knowledge about Spanish herpetology.

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