

Trade, Climate and Habitat Shape the Distribution of Pythons in Benin

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Abstract Although Benin is known as one of the most prolific exporting countries of python and where the two native species are highly traded for local consumption and traditional medicine, their conservation remains uncertain in the country. This study used a LEK-based survey with hunters in 224 villages and occurrence data from Global Biodiversity Information Facility database to delineate the spatial density distribution, habitat correlation and climatic influences in *Python regius* and *Python sebae* across Benin. The two species showed wide distributions extending across central Benin, with higher densities in the south. Analysis of the size of the occurrence area revealed that *Python sebae* had relatively the largest range (39,415.67 km²). Density estimates and multiple correspondence analysis in the occurrence areas indicated a relatively high probability of encountering multiple individuals within a single 1 km² grid and a preference of open habitats by the two species. A downward trend in species abundance was observed, highlighting potential conservation concerns. Generalised linear model analysis indicated that rainfall and temperature significantly influenced the presence of *Python regius* and *Python sebae*. These results underline the need for targeted conservation strategies to reverse the declining trends for long-term and effective conservation of these pythons in Benin.

Keywords: Reptiles, Benin, occurrence, climatic influences

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1. Introduction

Reptile rank among the most heavily threatened taxonomic groups globally, largely driven by the expansion of unregulated international trade [1]. They constitute the second most targeted class in global wildlife trade [2] with a substantial proportion of species estimated at 10,316 (21%) currently listed as threatened with extinction on the IUCN Red List. Alarming, nearly half of the threatened and Near Threatened reptile species are directly impacted by international trade [3], underscoring the scale and urgency of this conservation challenge. Among these, pythons represent a particularly vulnerable group. The Ball python (*Python regius*) is most traded reptile species globally [4], while both the Ball and African Rock python (*Python sebae*) dominate domestic wildlife trade markets [5].

These two Pythonidae species face intense harvesting pressure, with specimens obtained from both wild populations and captive-breeding facilities to meet

international demand in the United States, Europe, and Asia [6]. At the regional scale, Benin, Ghana, and Togo constitute the principal reptile export hubs in West Africa [7,8,9].

In parallel with international demand, local exploitation remains substantial. Both *Python regius* and *Python sebae* are extensively harvested for bushmeat consumption and for use in traditional medicine, where they hold high cultural and economic value [5,9], despite their classification as Near Threatened on the IUCN Red List. A nationwide survey of traditional markets in Benin revealed a high diversity of traded reptiles (46 species) across the country's three climatic zones, with squamates accounting for 46% of the trade and the Ball python emerging as the most frequently traded species [10]. Long-term analyses combining IUCN threat status and export indices further highlight the prominence of these species, with *Python sebae* (Ie = 0.90) and *Python regius* (Ie = 0.81) ranking as the two most exploited reptiles over the period 1982–2022. Given their importance for food, medicinal, and spiritual uses locally, as well as their strong appeal in international markets [6], increasing

evidence points to significant population declines in the wild, as reported both by scientific studies [9] and by vendors in traditional medicine markets (BS, pers. obs.).

Despite these mounting pressures, critical gaps persist in our understanding of the ecological adaptability and spatial ecology of these species. The combined effects of overexploitation, habitat fragmentation, ecosystem degradation, and climate change are likely to drive complex spatio-temporal dynamics affecting their distribution, abundance, genetic structure, and ecological requirements [11,12,13]. Such information is essential for informed decision-making and for designing sustainable management strategies that balance local use, international trade, and long-term conservation of python populations in the wild.

In data-limited contexts where conventional large-scale ecological surveys remain challenging, Local Ecological Knowledge (LEK) offers a valuable and cost-effective alternative. Derived from the experiential knowledge of primary resource users such as hunters, LEK provides detailed insights into species distribution, abundance, and ecological characteristics [14]. Rooted in long-term interactions between communities and their environment, this knowledge encompasses perceptions of species composition, population trends, and habitat use [15,16,17]. When integrated with environmental and spatial datasets, LEK represents a powerful tool for modeling species distributions and predicting their persistence [18,19]. Such modeling approaches are widely used to identify key climatic and environmental drivers shaping species distribution patterns and population dynamics across landscapes [18,19,20,21].

Against this backdrop, the combined pressures of overexploitation, habitat heterogeneity and pronounced climatic gradients across Benin are expected to shape the spatial ecology of *Python regius* and *Python sebae*. Benin spans distinct ecological zones ranging from humid southern forests to drier northern savannas, which are known to influence species distribution patterns through variations in temperature, precipitation and habitat structure. In addition, both species share ecological traits but may exhibit differential habitat preferences and adaptive responses to environmental conditions. Furthermore, increasing anthropogenic pressures particularly in southern regions characterised by higher human densities and trade intensity may lead to spatially uneven population distributions. Based on these ecological and socio-environmental considerations, we hypothesise that: (i) both species exhibit higher population densities in southern Benin; (ii) their habitat use is significantly correlated, reflecting both ecological overlap and niche differentiation; and (iii) climatic variables play a key role in determining their occurrence and spatial distribution. To test these hypotheses, this study provides novel insights into the spatial population dynamics of *Python regius* and *Python sebae* at the national scale in Benin. Specifically, it aims to: (i) map the spatial density distribution of both species, (ii) assess their habitat associations, and (iii) analyse the climatic factors influencing their occurrence.

2. Materials and Methods

2.1. Study Area

The study was conducted in Benin (Figure 1) from August to December 2024. Benin is a West African country situated within the Dahomey Gap, an interruption of the Guinean rainforest corridor, and administratively divided into 77 districts from a biogeographical perspective, the country spans three major ecological regions defined by climatic and vegetation gradients. The southern part of the country ($6^{\circ}10'–7^{\circ}15' N$) belongs to the Guineo-Congolian region and characterised by a humid climate with bimodal rainfall whereas the Sudano-Guinean and Sudanian regions characterised by unimodal rainfall. This transitions northward into the Sudano-Guinean zone ($7^{\circ}15'–9^{\circ}45' N$), followed by the Sudanian region ($9^{\circ}45'–12^{\circ}25' N$), both of which experience a unimodal rainfall regime. These latitudinal gradients generate marked variations in temperature, precipitation, and vegetation structure, thereby shaping habitat diversity across the country. Benin covers an area of 114,673 km² and hosts an estimated population of approximately 13 million inhabitants [22]. Natural vegetation accounts for about 26% of the national territory, including a network of protected areas covering 23.3% of the country, which support a rich diversity of wildlife encompassing most major taxonomic groups found in West Africa [23]. According to national forestry legislation, forests are categorised into two main types: (i) state-managed forest reserves under the responsibility of public forestry authorities, and (ii) community forests managed by local populations [23]. In addition to these natural ecosystems, a widespread network of wildlife markets operates across the country, supplying bushmeat and animal-derived products for traditional medicine, and contributing significantly to pressures on wildlife populations [5].

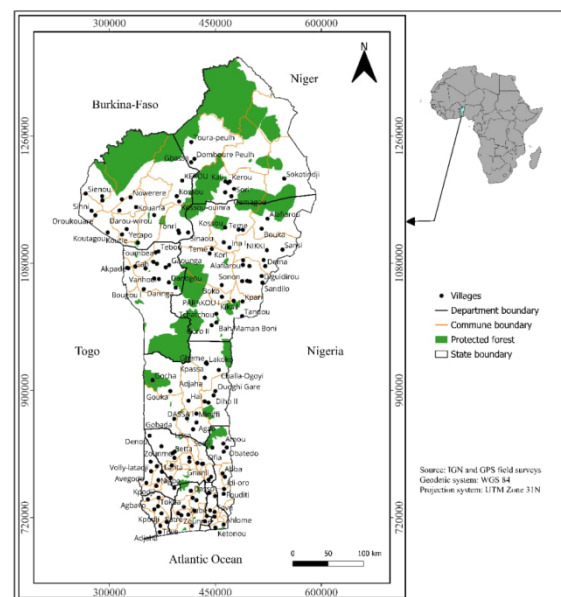


Figure 1. Map of the study area showing the locations of the surveyed villages

2.2. Sampling Plan and Data Collection

2.2.1. Spatial Distribution Data

A spatially explicit sampling framework was developed using a grid-based approach. A total of 228 grid cells (sampling units) of 25×25 km were generated across Benin using ArcMap. This spatial resolution was selected to ensure that each sampling unit encompassed sufficient areas of natural or semi-natural vegetation (i.e., potential hunting zones) alongside human settlements, thereby facilitating the collection of Local Ecological Knowledge (LEK) [18].

From the initial grid, 94 cells were excluded from the sampling scheme. These included 46 cells lacking villages therefore unsuitable for LEK collection—and 48 incomplete cells located along the national boundaries, which were too small and lacked representative habitats. In addition, 12 grid cells located in and around the Pendjari and W National Parks were excluded due to prevailing security concerns in northern Benin. Ultimately, 122 grid cells were retained for the LEK-based survey, with at least one village sampled per grid cell.

LEK data were collected through focus group discussions conducted in 224 villages. Each focus group consisted of 8–10 participants, primarily local hunters selected based on the following criteria: age ≥ 30 years, residency of at least 10 years in the area, and voluntary participation [18,24]. Participants were recruited using a snowball sampling approach, and informed consent was obtained prior to each discussion. During each session, presence/absence data of *Python regius* and *Python sebae* were recorded. In addition, the geographic coordinates of surveyed villages and identified potential occurrence habitats were collected using a GPS device in collaboration with participants.

A total of 54 occurrence records for *Python regius* and 48 for *Python sebae* were obtained from field surveys. To strengthen the robustness of the spatial analyses, these data were complemented with occurrence records from the Global Biodiversity Information Facility [25] at the national scale, without temporal filtering to avoid underestimating the species' ecological range. This resulted in an additional 287 records for *P. regius* and 350 records for *P. sebae*.

2.2.2. Species Habitat Data

Information on habitat use and ecological preferences of *Python regius* and *Python sebae* was collected during field surveys through Local Ecological Knowledge (LEK) provided by experienced local hunters. A semi-structured questionnaire was used to guide discussions, allowing both standardised data collection and flexibility for in-depth responses. The questionnaire addressed key aspects including perceived population trends, habitat types associated with species occurrence, major threats, ethnozoological uses, and the commercial value of the species. This approach enabled the integration of detailed, experience-based ecological insights into habitat characterization.

2.2.3. Climatic Factors Data

Climatic variables potentially influencing species

occurrence were obtained from the WorldClim database [26] using the geodata package [27]. The dataset included monthly temperature and precipitation variables covering the entire territory of Benin.

To reduce multicollinearity among predictors, a variable selection procedure was conducted using the nimo package [28], which provides the variance inflation factor (VIF) routine used here for collinearity screening. Variables exhibiting a variance inflation factor (VIF) greater than 10 were excluded, ensuring that only independent climatic predictors were retained for subsequent analyses. To incorporate absence data into the modeling framework, pseudo-absence points were randomly generated outside the estimated home range of each species. Restricting the background to the area lying beyond the kernel-based home range is a deliberate design choice: because our occurrence data combine opportunistic LEK and GBIF records that lack reliable true absences, the home range delineates the portion of Benin where the species is known to occur, and sampling pseudo-absences strictly outside it provides ecologically defensible non-occurrence locations while avoiding the contamination of the absence set with unrecorded presences (false absences) that would arise if background points were drawn across the entire study area, including within occupied range. This approach therefore characterises the environmental conditions that distinguish occupied from unoccupied portions of the country rather than merely tracing a geographic outline, since the climatic gradients of Benin vary continuously and are not aligned with the home-range boundary; the contrast captured by the model is environmental, not purely spatial. The number of absence points was scaled to the spatial extent of each species using a function that increases the relative number of pseudo-absences for species with a small home range and reduces it for species with a large home range, on the rationale that a wide-ranging species is expected to have proportionally fewer genuine absences across Benin. The resulting count was thus proportional to the spatial extent of the species' distribution, allowing for a balanced representation of presence and absence data. These datasets were then combined into a single analytical dataset. Geographic coordinates of both presence and pseudo-absence points were used to extract values from the selected non-collinear climatic raster layers, forming the basis for subsequent spatial modeling.

2.3. Data Analysis and Processing

2.3.1. Spatial Distribution

❖ Estimation of spatial density

Occurrence data derived from field surveys and GBIF were merged into a unified dataset and exported as a shapefile for spatial analyses. All visualizations were produced using the ggplot2 package [29]. Spatial density patterns were analysed using point pattern analysis implemented in the spatstat package [30,31,32]. The study area, defined by the national boundaries of Benin, was projected into the Universal Transverse Mercator (UTM) Zone 31N coordinate reference system using the sf package. The country boundary was then converted into an observation window, defining the spatial domain for

the analysis. For each species, occurrence points were extracted and converted into point pattern objects. Kernel density estimation (KDE) was applied to quantify the spatial intensity of occurrence across the study area. The resulting density surfaces were converted into raster format using the terra package [33] and resampled to a spatial resolution of 1×1 km to enhance spatial detail. Final density maps were produced using ggplot2 and cowplot [34]. All analyses were conducted in R [35].

❖ Estimation of the area of occurrence using Kernel density

Occurrence data were imported using the readxl package [36]. Geographic coordinates were provided in both degrees-minutes-seconds (DMS) and Universal Transverse Mercator (UTM) formats and were processed separately before being harmonised. All coordinates were converted into spatial objects using the sf package [37,38].

Species' areas of occurrence (home range proxies) were estimated using kernel utilization distributions implemented in the adehabitatHR package [39]. The smoothing parameter was determined using the least-squares cross-validation (LSCV) method, ensuring an optimal balance between over- and under-smoothing of the utilization distribution.

The 95% utilization distribution was used to delineate the core area of occurrence for each species. Resulting polygons were clipped to the national boundary of Benin to restrict analyses to the study area. The area of each polygon was then calculated and expressed in square kilometres.

2.3.2. Multiple Correspondence Analysis (MCA) for Habitat Correlation

To investigate the relationships between species occurrence and habitat types, a Multiple Correspondence Analysis (MCA) was conducted using the FactoMineR package [40]. MCA is particularly suited for exploring associations among categorical variables, making it appropriate for analysing species–habitat relationships derived from LEK data.

The results were visualised using the factoextra package [41]. Habitat categories were projected into a two-dimensional ordination space, allowing interpretation of their contribution to the principal dimensions and their association with each species.

2.3.3. Climatic Factors Influencing Species Occurrence

To assess the influence of climatic variables on species occurrence, Generalised Linear Models (GLMs) with a binomial error distribution and a logit link function were fitted for each species. The initial models included all selected non-collinear climatic predictors. A stepwise model selection procedure was applied to remove non-significant variables and identify the most parsimonious model. Final models retained only climatic variables that significantly influenced species presence, allowing the identification of key environmental drivers shaping species distribution.

3. Results

3.1. Spatial Density Distribution of *P. regius* and *P. sebae*

3.1.1. Distribution of Occurrences

The spatial distribution of *Python regius* and *Python sebae* across Benin (Figure 2) was mapped using combined occurrence data from field surveys (*P. regius*: $n = 54$; *P. sebae*: $n = 48$) and the Global Biodiversity Information Facility (*P. regius*: $n = 350$; *P. sebae*: $n = 287$). Both species exhibited broadly similar distribution patterns, suggesting comparable spatial structuring and potential overlap in population distribution. Their ranges extended across much of the country, with a marked concentration in southern Benin and a gradual decline in occurrence toward northern latitudes. Central regions also showed relatively high occurrence densities, indicating their importance as core areas within the species' distribution range. A clear pattern of co-occurrence was observed, with records of *P. regius* and *P. sebae* frequently located in close spatial proximity, suggesting potential habitat overlap or shared environmental preferences. However, *P. sebae* displayed a broader spatial distribution compared to *P. regius*, with occurrences recorded throughout most of the country. Its distribution was particularly pronounced in the southern and central regions, as well as along the eastern corridor, where higher densities were observed.

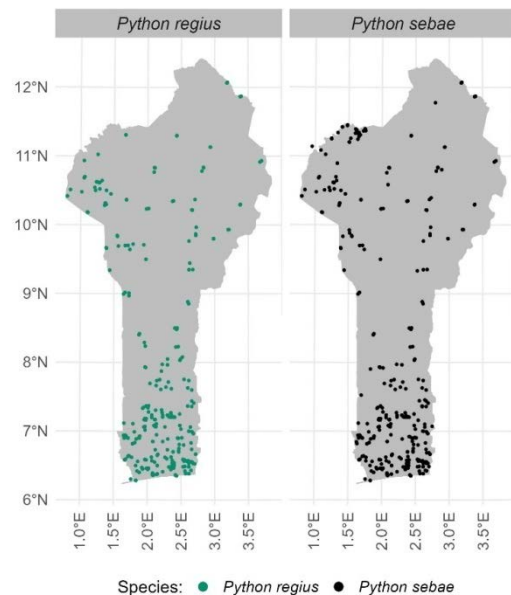


Figure 2. Spatial distribution of *P. regius* and *P. sebae* based on field surveys and GBIF data

3.1.2. Species Density

The spatial density distribution of *Python regius* and *Python sebae* across Benin shows pronounced

heterogeneity at the 1 km² resolution (Figure 3). Both species exhibit peak densities in the southernmost regions, indicating a high likelihood of encountering multiple individuals within a single grid cell. Moving northwards, density values decline progressively across the central regions and become markedly low in northern Benin. In these areas, occurrence is sparse, with grid cells typically supporting few individuals or, in some cases, none at all.

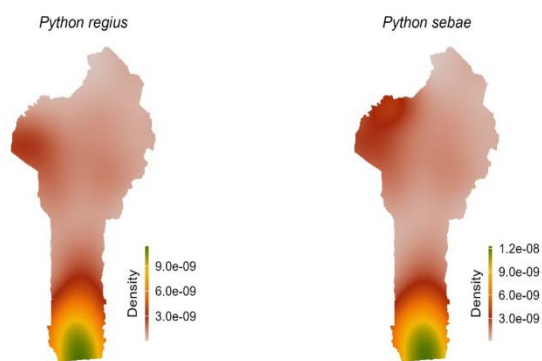


Figure 3. Distribution of the spatial density of *P. regius* and *P. sebae* across Benin on a scale of 1 km²

3.1.3. Area of Occurrence - Home Range

Figure 4 presents the estimated home range distribution of both species. *Python regius* occupies a home range of 33,340.16 km², primarily concentrated in the southern part of Benin. In contrast, *Python sebae* exhibits a larger home range of 39,415.67 km², also centred in the south but extending further northward. This broader spatial extent indicates that *P. sebae* occupies a wider range of habitats compared to *P. regius*, while both species maintain a strong distributional focus in southern Benin.

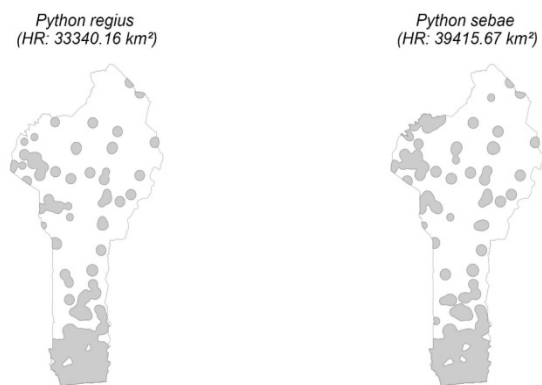
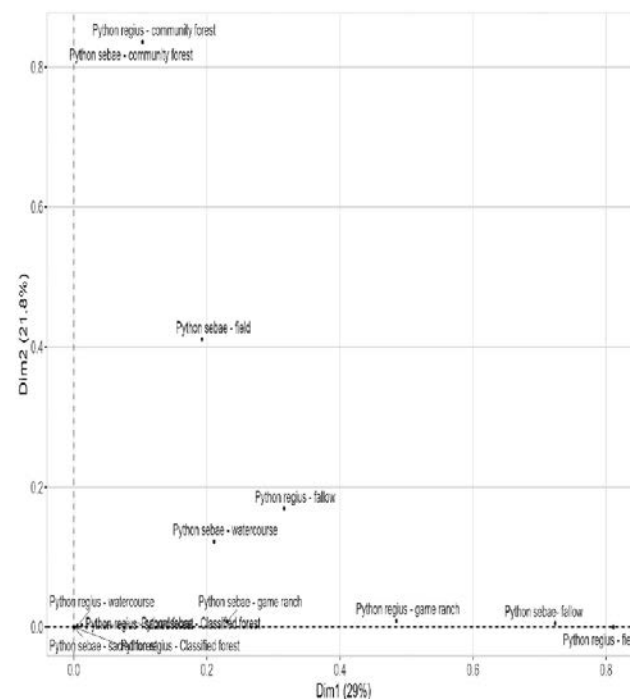


Figure 4. Area of occurrence of *P. regius* and *P. sebae* species in Benin

3.2. Species Habitat Associations

Multiple Correspondence Analysis (MCA) (Figure 5) highlights the relationships between habitat types and the occurrence of *P. regius* and *P. sebae*. The first dimension (Dim1), explaining 29% of the total variance, primarily discriminates between open habitats such as fields, fallows, and game ranches and more structured or protected environments, including sacred forests, classified forests, and community forests. The second dimension (Dim2), accounting for 21% of the variance, further differentiates habitats based on more specific ecological features,

notably watercourses and community forests. Both *P. regius* and *P. sebae* exhibit strong associations with a range of habitat types, including open landscapes as well as forested environments, particularly classified and sacred forests along Dim1, and community forests along Dim2.



Dim1: first dimension; **Dim2:** second dimension

Figure 5. Multiple Correspondence Analysis (MCA) of habitat associations in *P. regius* and *P. sebae* in Benin

Figure 6 shows trends in species abundance. The dominant trend is a decrease in abundance, representing 91.67% and 93.16% for *P. regius* and *P. sebae* respectively.

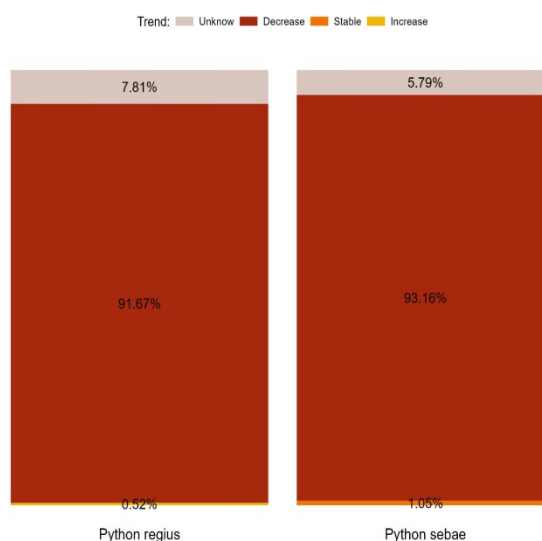


Figure 6. Trends in abundance of *P. regius* and *P. sebae*

3.3. Influence of Climatic Factors

The results of the Generalised Linear Models (GLMs)

highlight the influence of climatic variables, particularly temperature and precipitation, on the occurrence of *Python regius* and *Python sebae* across Benin (Table 1). The final binomial logit models showed an acceptable fit, with an Akaike Information Criterion (AIC) of 518.75 for the *Python regius* model and 546.77 for the *Python sebae* model.

For *Python regius*, precipitation emerged as a key positive driver of occurrence. Rainfall in June (prec_6: estimate = 0.0334, $p = 0.003$) and September (prec_9: estimate = 0.0583, $p < 0.001$) significantly increased the probability of presence. Temperature effects were more variable. Average temperatures in February (tavg_2: estimate = -2.88, $p = 0.002$) and minimum temperatures in June (tmin_6: estimate = -3.70, $p < 0.001$) showed significant negative effects, indicating reduced occurrence under cooler conditions. In contrast, maximum temperatures in April (tmax_4: estimate = 1.22, $p = 0.006$) and August (tmax_8: estimate = 3.18, $p < 0.001$) had significant positive effects, suggesting that warmer conditions during these periods favour species presence.

For *Python sebae*, similar patterns were observed, although with some distinct seasonal responses. Precipitation in June (prec_6: estimate = 0.0453, $p < 0.001$) positively influenced species occurrence. Average temperatures in February (tavg_2: estimate = -3.53, $p < 0.001$) had a significant negative effect, whereas average temperatures in September (tavg_9: estimate = 4.02, $p < 0.001$) and December (tavg_12: estimate = 5.37, $p < 0.001$) showed strong positive effects. In addition, maximum temperature in April (tmax_4: estimate = 2.48, $p < 0.001$) significantly increased the likelihood of occurrence.

Overall, these results indicate that both species are positively associated with increased precipitation during the rainy season and higher temperatures during the warm periods, while cooler conditions tend to limit their occurrence. However, *Python sebae* appears to exhibit a stronger association with warmer conditions later in the year, suggesting subtle differences in climatic sensitivity and ecological responses between the two species.

Table 1. Generalised linear model (GLM) results showing the effects of monthly temperature and rainfall on the presence of *P. regius* and *P. sebae* in Benin

cli_var	Estimate	Standard error	z-value	Pr(> z)	significant	species
prec_6	0.033	0.011	2.930	0.0034	**	<i>Python regius</i>
prec_9	0.058	0.010	5.569	0.0000	***	<i>Python regius</i>
tavg_2	-2.885	0.953	-3.027	0.0025	**	<i>Python regius</i>
tmax_1	-1.059	0.484	-2.187	0.0287	*	<i>Python regius</i>
tmax_4	1.218	0.439	2.774	0.0055	**	<i>Python regius</i>
tmax_8	3.182	0.728	4.373	0.0000	***	<i>Python regius</i>
tmin_6	-3.702	0.677	-5.468	0.0000	***	<i>Python regius</i>
tmin_11	3.470	0.512	6.779	0.0000	***	<i>Python regius</i>
prec_4	0.028	0.016	1.771	0.0765	Ns	<i>Python sebae</i>
prec_6	0.045	0.011	4.212	0.0000	***	<i>Python sebae</i>
prec_9	0.015	0.009	1.778	0.0754	Ns	<i>Python sebae</i>
tavg_2	-3.531	0.952	-3.710	0.0002	***	<i>Python sebae</i>
tavg_9	4.018	0.919	4.373	0.0000	***	<i>Python sebae</i>
tavg_12	5.368	0.643	8.343	0.0000	***	<i>Python sebae</i>
tmax_1	-2.185	0.487	-4.491	0.0000	***	<i>Python sebae</i>
tmax_4	2.480	0.392	6.328	0.0000	***	<i>Python sebae</i>
tmin_6	-5.621	0.883	-6.362	0.0000	***	<i>Python sebae</i>

*** = significant; **cli_var** = climatic variable; **Ns** = not significant; **Pr** = probability; **prec** = precipitation; **tavg** = average temperature; **tmax** = maximum temperature; **tmin** = minimum temperature; **z-value**: represents the number of standard deviations that a data point is from the mean of a data set.

4. Discussion

This study highlighted (i) the spatial distribution of the population densities of *Python regius* and *Python sebae* at a 1 km² resolution across the entire territory of Benin; (ii) the relationships between these species and habitat types in Benin; and (iii) the influence of climatic variables, notably temperature and precipitation, on the probability of occurrence of these species.

4.1. Spatial Population Trends of *P. regius* and *P. sebae*

Our work extends the research of Sinsin and Kampmann (2010) [42], which primarily focused on southern Benin. Knowledge of the spatial distribution of species is a fundamental component for guiding conservation strategies and biodiversity management [20,43]. Our results indicate

that the occurrence zones of *Python regius* and *Python sebae* show substantial similarities, with relatively high densities in certain regions of Benin. This confirms the findings of Luiselli et al. (2001), Luiselli (2006) and Bolnick and Fitzpatrick (2007) [44,45,46], who report a sympatry characterised by an interspecific relationship between snake species, where their distribution overlap. Moreover, this distribution suggests that these species possess a considerable capacity to adapt to varied environmental conditions. Similar observations have been reported in several West and Central African countries, where both species occupy a wide range of natural and human-modified habitats [47,48,49]. The high presence of these species in certain areas may also reflect their ecological plasticity and ability to exploit habitats altered by human activities. Several studies have shown that some reptile species can persist in fragmented or disturbed landscapes provided that ecological conditions remain favorable for their survival [50,51].

In this study, *Python regius* and *Python sebae* were frequently observed in open or semi-open environments. This finding corroborates the results of Segniagbeto et al. (2024) [52], which showed that these species display a high tolerance to degraded environments, particularly in agricultural and fallow areas. Studies conducted in Nigeria and Ghana also indicate that the royal python is often found in savannas, forest–savanna mosaics, and agricultural areas, exploiting the availability of prey such as small mammals [49,53]. However, extensive distribution alone does not necessarily reflect the conservation status of a species. Certain species may maintain relatively abundant populations in degraded habitats while undergoing long-term declines due to anthropogenic pressures [54,55].

In Benin, both species are present across almost the entire national territory. Nevertheless, the highest densities are observed in the southern part of the country, likely linked to more favorable climatic conditions and greater habitat diversity. Parameters related to vegetation structure and land use generally become more significant at finer spatial scales. Therefore, understanding the spatial distribution of *Python regius* and *Python sebae* is essential for informing conservation strategies and habitat management planning at national and regional levels.

4.2. Species Habitats and Threats

Our findings indicate that *Python regius* and *Python sebae* are strongly associated with open habitats, particularly fallows and cultivated areas, demonstrating their ability to persist in human-modified environments. This pattern agrees with previous studies that reported frequent occurrence of both species in degraded savannas, agricultural lands, and fallows [56,57]. The broad habitat ranges of *P. regius* and *P. sebae*, spanning savannas, forest–savanna mosaics, agricultural areas, forests, rocky habitats, and riparian zones, further illustrate their ecological adaptability [48,49,58].

Nevertheless, this adaptability does not protect them from the growing impacts of human activities. Across tropical regions, habitat conversion, ecosystem degradation, climate change, and unsustainable harvesting are recognized as major threats to reptile populations [59,60]. In Benin, additional pressure arises from hunting for consumption, traditional medicine, and cultural purposes [61,62]. International trade, particularly involving *P. regius*, further intensifies exploitation of wild populations, with thousands of individuals collected annually in Benin, Ghana, and Togo to supply the global pet market [1,6,7,63]. The ongoing expansion of commercial agriculture, especially cotton cultivation in northern Benin, is likely to exacerbate these pressures through continued habitat transformation [64].

4.3. Climatic Factors Influencing the Distribution of *P. regius* and *P. sebae*

Species distribution modeling is an essential tool for understanding species–environment relationships and predicting the potential effects of climate change on future distributions [43,65]. Results from the generalised linear model (GLM) indicate that precipitation and temperature

significantly influence the presence of *Python regius* and *Python sebae*. This finding aligns with numerous studies showing that reptiles, as ectothermic organisms, are highly dependent on climatic conditions for thermoregulation, reproduction, and survival [66,67]. Climatic variables, particularly temperature and precipitation, play a major role in determining reptiles' geographic distribution and habitat suitability [68,69,70]. These results corroborate the work of Kpéra et al. (2020) [71], who demonstrated that *P. regius* distribution is influenced by climatic and environmental gradients between northern and southern Benin. Several studies have also shown that climatic variables are critical determinants of reptile distribution at large spatial scales [43,65]. Vegetation structure and land use become more relevant at finer spatial scales.

Model projections indicate that central and southern Benin are the most suitable areas for the studied species. These results are consistent with Sinsin and Kampmann (2010) [42], which reported high herpetological diversity in these regions. The climate in these areas is subequatorial, characterised by a bimodal rainfall regime with two wet seasons alternating with two dry seasons [72]. Such climatic conditions favor resource availability and habitats suitable for reptiles. Our results also align with Segniagbeto et al. (2024) [52], who reported that *Python regius* is abundant in multiple West African ecosystems, including humid savannas, swamp forests, and gallery forests. These regions are also key sources for international reptile trade. Benin, Ghana, and Togo are among the main exporters of live reptiles for the global pet trade [6,7,73].

These findings are particularly relevant for conservation, as they identify bioclimatic zones favorable to species persistence. They provide a foundation for developing sustainable management strategies for python populations in Benin. Given the risks of overexploitation and local population declines, it is crucial to strengthen community awareness programs and promote sustainable wildlife management practices. In practical terms, the high-density areas identified in southern and central Benin largely coincide with the existing network of protected areas, state-managed forest reserves, and community forests described in the study area. This spatial overlap highlights the critical role of protected areas as core refuges for biodiversity conservation, particularly for species subjected to anthropogenic pressures such as habitat loss and exploitation. Numerous studies have demonstrated that protected areas contribute significantly to maintaining viable wildlife populations by reducing habitat degradation and limiting unsustainable harvesting [74,75].

The density and home-range maps generated in this study provide valuable spatially explicit information that can support evidence-based conservation planning. Spatial prioritization approaches have been widely recognized as effective tools for identifying areas where conservation interventions can maximize ecological benefits while optimizing limited management resources [76]. In this context, the high-occurrence cells identified for *Python regius* and *Python sebae* should be considered priority zones for strengthening the regulation of harvesting and trade activities, enhancing law enforcement, and implementing long-term monitoring programs.

Furthermore, several of these priority areas encompass

community-managed forests, underscoring the importance of involving local communities in conservation strategies. Community-based natural resource management has been shown to improve conservation outcomes when local stakeholders are actively engaged in decision-making and benefit-sharing mechanisms [77]. Given the socio-economic importance of pythons in Benin, particularly through trade and traditional uses, collaborative governance approaches could contribute to balancing species conservation with local livelihoods. Integrating conservation actions within the existing legal and territorial framework offers a practical and cost-effective pathway for translating the spatial patterns identified in this study into management interventions. Such an approach is consistent with contemporary conservation strategies that advocate the alignment of species management with established protected-area networks and landscape-scale conservation planning to ensure long-term population persistence [78,79]. Overall, the data generated in this study offer a valuable baseline for future research on python distribution and conservation across West Africa, taking into account seasonal trade patterns and potential climate change impacts.

5. Conclusion

In this study, *Python regius* and *Python sebae* showed wide distributions extending across central Benin, with higher densities in the south. These results are useful for targeting the occurrences to be studied on a finer scale. The habitats of these species need to be integrated into development plans, and maps showing their distribution will help to guide surveys as part of inventories or monitoring. The study also revealed that ecological factors, in particular temperature, play a determining role in the presence and spatial distribution of *P. regius* and *P. sebae*. Despite the adaptability of pythons to open habitats, these two species, which are the most widely exported in international trade, could suffer local extinctions. Finally, this study could help redefine the status of these species, so that they are better taken into account in protection and conservation projects. As a consequence, human activities should be considerably regulated in the areas of high concentration of the occurrences collected as part of this study.

Author Contributions

B. Sossa: Conceptualization, data collection, data analysis, and manuscript drafting; R. B. Badou: Data analysis and interpretation, contribution to manuscript writing. S. Zanzo: Methodological support and review of the manuscript; G.N. Kpéra: Data interpretation and critical revision of the manuscript. G. Nobimè: Contribution to data analysis and manuscript revision; A.E. Assogbadjo: Scientific supervision, methodological guidance, and critical review of the manuscript; C.A.M.S. Djagoun: Conceptualization, scientific supervision, validation of results, and final revision of the manuscript. All authors read and approved the final version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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