Algerian Journal of Biosciences
ISSN: 2716-9375
Journal homepage: http://www.ajbjournal.periodikos.com.br

Original Article

Diversity and distribution patterns of reptiles in the northern Algerian Sahara (Oued Souf, Taibet and Touggourt)

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ARTICLE INFOR

Article history:
Received 15 April 2021
Revised 15 September 2021
Accepted 22 December 2021

Keywords:
Reptiles;
Biodiversity;
Distribution patterns;
northern Algerian Sahara.

ABSTRACT

The present study was based on the observations and captures of reptiles in the Northern Algerian Sahara (2011-2013). The studied habitats were the erg (sand dunes), palm grove, reg, Sebkha, and urban sites. We have identified 30 species (20 Saurians, 9 Ophidians and one Testudines) these species are classified into two orders (Anura and Squamata), 12 families and 22 different genera. Among the identified species, 7 protected species in Algeria and 5 species endemic to the Mediterranean. A total of 93.3% (28 species) are assessed as Least Concern and one species was considered to be Data Deficient (*Scincopus fasciatus*). One species is listed as near threatened (*Uromastix acanthinurus*).

The highest species richness was noticed in the palm groves with 19 species as well as the Shannon diversity index= 3.35. The evenness is at its highest in the sebkha and the urban site with 0.9 and 0.86. The correspondence factorial analysis showed that some species were characteristic of habitats such as *Tarentola neglecta* and *Tarentola deserti* which are a specific species of the urban sites and the palm groves, while Scincus scincus was a specific species of the Erg. The generalized linear model showed that the geographic coordinate, spatiotemporal factors and human activity have significant effect on the distribution of reptiles.

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1. Introduction

The herpetofauna of North Africa is better known in Morocco and Tunisia than in Algeria, among the works we can cite the works of [1,2,3,4,5,6,7,8,9,10,11,12].

Currently, the study of herpetology is few in Algeria, despite the first investigations started toward the first half of the 19th century, with the first notes of [13,14]. Thus, many appeared studies have highlighted the importance of Algerian herpetofauna. The most important are those of [15,16,17,18,19,20,21,22,23,24,25,26]. However, During the last year the most important research carried out on reptiles deals with systematic and morphometric aspects [27,28]. and the inventory of the herpetofauna [29,30,31]. [32,34], studies and analyses of biodiversity patterns at global and regional scales should take into account the effects of spatial continuity. Discontinuous, isolated, and/or fragmented landscapes may have very different spatial biodiversity patterns, both across and within different spatial zones.

The main objective of this study is to investigate the systematic list and the distribution patterns of the reptiles in the northern Algerian Sahara. We have made a comparison between previous works and our data to check for a possible change in the herpetofauna communities. Thus, we highlight the population dynamics, the diversity evaluation and the distribution patterns of the population of reptiles according to the environmental and anthropic conditions.

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Peer review under responsibility of University of El Oued
doi : http://doi.org/10.57056/ajb.v2i2.44

2. Materials and Methods

2.1. Study area

This study was conducted at 30 sites (5 Erg, 7 Palm grove, 4 Reg, 7 Sebkha, 7 Urban site) located in the north of the Algerian Sahara Desert (Fig. 1 and Table 1). With over one million km square, the northern Sahara Algeria is characterized by an arid climate. Rainfall ages between 50 and 100 mm [35]. This ecoregion includes a mosaic of landscapes including the Chott and Sebkha (temporal salt lakes), Daya (Small circular depressions), Hamada (rocky deserts), Wadis (temporal rivers), Regs (sand dune encroachments), and date palm groves [36].

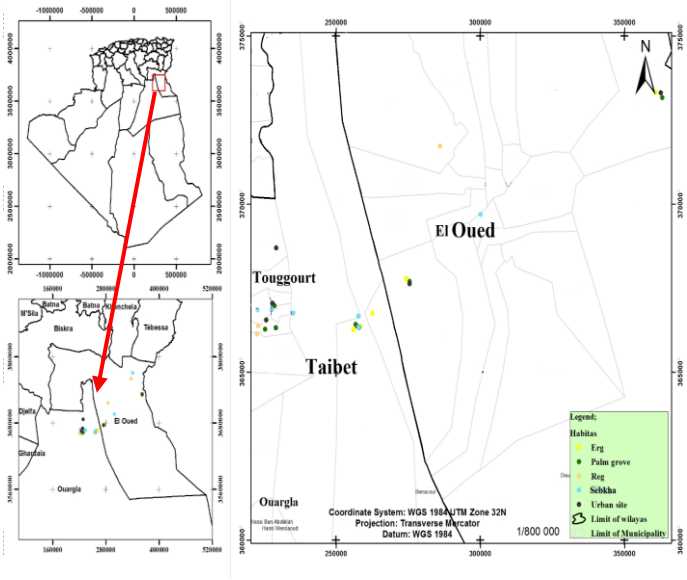


Fig 1. Map representing the study area

2.2. Characterization of the sampled habitats

Among the encountered habitats of the region, we have listed 5 main types, these habitats include both natural (Erg, Reg, Sebkha) and manmade (palm grove, urban) sites (Table 1).

Table 1. Distribution of sampled sites per habitat type

Zone	Habitats	Latitude	Longitude	Altitude (m)
Oued Souf	Erg	33.720533°	7.509145°	35
		33.214256°	6.581443°	98
Taibet		33.114240°	6.467215°	103
		33.082027°	6.415608°	106
Touggourt		33.075665°	6.392124°	107
Oued Souf	Palm grove	33.313861°	6.611812°	38
		33.208761°	6.591097°	98
Taibet		33.081863°	6.406020°	99
		33.089682°	6.394181°	97
Touggourt		33.074910°	6.100188°	84
		33.092124°	6.079815°	62
		33.051686°	6.057968°	72
Oued Souf	Reg	33.978193°	7.246909°	6
		33.550542°	6.667963°	55
Touggourt		32.919356°	5.973676°	90
		33.074281°	6.021903°	78
Oued Souf	Sebkha	33.682528°	7.513711°	4
		33.393982°	6.853879°	71
Taibet		33.082052°	6.405549°	99
		33.110759°	6.402417°	102
Touggourt		33.126305°	6.087383°	64
		33.113328°	6.042083°	67
		33.106095°	6.131150°	79
Oued Souf	Urban site	33.203413°	6.593687°	96
		33.722665°	7.517551°	39
Taibet		33.082148°	6.406590°	99
		33.083414°	6.402333°	100
Touggourt		33.139189°	6.086741°	65
		33.094924°	6.063506°	63
		33.294254°	6.096965°	59

2.3. Reptiles sampling method

The followed sampling procedure consisted in crossing with feet the chosen habitats at a slow rate [29] an average of 1 km perceived in 2 hours and 30 minutes), in order to see or hear the noise of all encountered reptiles. The research of the individuals is also done with the mounting by direct observations of the animals in the open area; and in shelters by raising stones. lizards are usually done by hand. The snakes were captured using traps or pair of pliers, this study spread from June 2011 to June 2013 (twice a month for each zone).

The species identification was mainly conducted by referring to the scaling, staining and the morphometric measurements while using determination keys and references regarding the reptiles [37,21,24,38,25,39,40].

2.3. Data analysis

Conservations status: Determined according to the IUCN Red List of Threatened Species in the Mediterranean [41]; The status of protection of reptiles in Algeria defined based on the list of species protected by Decree No. 35 of Jun 2012 establishing the list of non-domestic animal species protected [42].

The centesimal frequency (Fc) represents relative abundance and corresponds to the percentage of individuals of a species (n) relative to the total number of individuals (N) in a stand. FC = n / N [43]. The frequency of occurrence "Occ" represents the ratio between the number of samples containing related species and the total number of samples achieved. According to the percentage of occurrence, there are four categories: the constant species "CN" is present in 50% or more, the common species "CM" is present in the records of [25-50% [, The occurrence rate of the accidental species "AC" varies between [10-25% [, and the occurrence rate of the very accidental species "VA" is less than 10% [44]. For evaluating the reptile's diversity, we calculate the total specific richness (S), which was estimated by the number of reptile's species contracted at least only once in the total samples. The mean specific richness Sm was processed as the average number of species present in a sample. In

addition, Shannon's index (H' = - Σpi×log2 Pi) and Pielou index or evenness (E = H'/Hmax, with Hmax = log S) were applied for the measurement of the diversity and the organization of the reptile's communities [45,46].

The reptile's distribution following to the different prospected habitats was examined with a factorial correspondences analysis (F.C.A), by taking of account the presence/absence of sampling species. furthermore, we examined the correlations between manpower of the populations in the various prospected habitats and during the months of the study period, through the principal components analysis (PCA). The correlations between population abundances and some environmental parameters were tested using a generalized linear model (GLM). The considered parameters were cited like following: altitude (m); longitude and latitude (degrees and minutes), anthropogenic activity (4 levels: 1: Sebkha, 2: Erg and Reg, 3: Palm grove, 4: Urban site), type of habitat (1 for Erg, 2 for Palm grove, 3 for Reg, 4 for Sebkha and 5 for Urban site) and climatic periods, where the cold period is belonging from October to January and the hot period from April to September. Only the variables with $p < 0.05$ have been interpreted as statistically significant. The statistical tests have been achieved thanks to the Software XLSTAT (2010).

3. Results and Discussion

3.1. Results

3.1.1. Systematic list, species protection status and endemism

We have identified 30 species of reptiles belonging on, 22 genera, 12 families and 2 orders. The Scincidae is the most diverse with 6 species followed by the Agamidae with 4 species (Table 2). From the point of view of endemism, 5 species are Mediterranean endemic by IUCN report. In terms of conservation, the identified species were included in the red list with 3 different statutes, namely near threatened NT for Uromastix acanthinurus, data deficient for Scincopus fasciatus and least Concern LC for the rest of species (93.3%). At the national scale 7 identified species are protected in Algeria.

Table 2. Systematic list of reptiles identified in the North Algerian Sahara their ecological status and protection "IUCN Red List", national protection and Mediterranean endemism

Order	S. order	Family	Species	IUCN status	National protection status (SPN)	Mediterranean endemism
Squamata	Ophidia	Colubridae	*Hemorrhois algirus*	LC	No	Yes
			Spalerosophis diadema	LC	No	No
		Lamprophiidae	*Lytorhynchus diadema*	LC	No	No
			Rhagerhis moilensis	LC	No	No
			Psammophis schokari	LC	No	No
		Natricidae	*Natrix maura*	LC	No	Yes
		Viperidae	*Cerastes cerastes*	LC	No	No
			Cerastes vipera	LC	No	No
			Echis leucogaster	LC	No	No
	Sauria	Agamidae	*Trapelus boehmei*	LC	No	No
			*Trapelus tournevillei**	LC	Yes	Yes
			*Trapelus mutabilis**	LC	Yes	No
		Chamaeleonidae	*Uromastix acanthinurus*	NT	No	No
			*Chamaeleo chamaeleon **	LC	Yes	No
		Geckonidae	*Stenodactylus petrii*	LC	No	No
			Cyrtopodion scabrum	LC	No	No
		Lacertidae	*Acanthodactylus scutellatus*	LC	No	No
			*Acanthodactylus dumerili **	LC	Yes	No
			Mesalina guttulata	LC	No	No
		Phyllodactylidae	*Tarentola deserti**	LC	Yes	Yes
			Tarentola neglecta	LC	No	Yes
			Tarentola mauritanica mauritanica.	LC	No	No
		Scincidae	*Chalcides ocellatus*	LC	No	No
			*Scincopus fasciatus**	DD	Yes	No
			*Scincus scincus**	LC	Yes	No
			Scincus albifasciatus	LC	No	No
			Scincus scincus cucullatus	LC	No	No
			Sphenops boulengeri	LC	No	No
		Varanidae	*Varanus griseus*	LC	No	No
Testudines		Testudinidae	*Testudo graeca*	LC	No	No

IUCN Red List: categories of threatened Species of the IUCN Red List (D.D: Data Deficient; LC: Least Concern; NT: Near Threatened) (www.iucnredlist.org), NPS: national protection status [Yes: protected nationally, No: non-protected by the Algerian law]; Mediterranean endemism: endemism status of species in the Mediterranean.

3.1.2. Spatial variation of centesimal frequency and occurrence frequencies

In order to give an idea of the numerical importance of the different species, we have opted to calculate centesimal frequency (Fc) in percentages for the various specimens recorded according to the habitats (Table 3).

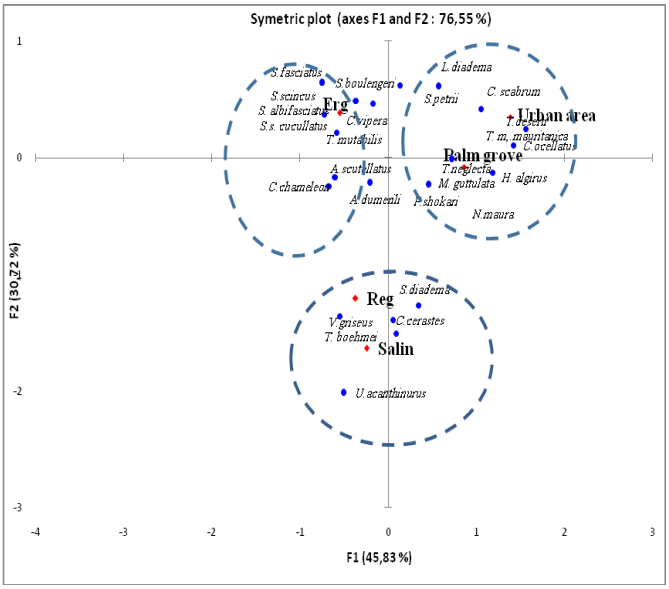
Table 3. Centesimal frequency, constant and scale of constancy of the different herpetological species collected in the types of habitats

Species	Erg			Palm grove			Reg			Sebkha			Urban site		
	Fc	Occ	C	Fc	Occ	C	Fc	Occ	C	Fc	Occ	C	Fc	Occ	C
A. dumerili	7.2	15.1	AC	1.49	14.29	AC	30.2	20	AC	-	-	-	-	-	-
A.scutellatus	30.5	48.48	CM	8.96	28.57	CM	38.5	40	CM	-	-	-	-	-	-
C. cerastes	-	-	-	2.99	14.29	AC	6.25	30	CM	16.7	20	AC	-	-	-
C. vipera	7.44	39.39	CM	8.96	28.57	CM	-	-	-	-	-	-	4.5	12.5	AC
C. ocellatus	-	-	-	5.97	14.29	AC	-	-	-	-	-	-	4.55	12.5	AC
C. chamaeleon	0.99	6,06	VA	-	-	-	-	-	-	-	-	-	-	-	-
C. scabrum	0.25	3.03	VA	1.49	14.29	AC	-	-	-	-	-	-	22.73	25	CM
E. leucogaster	-	-	-	-	-	-	1.04	10	AC	-	-	-	-	-	-
H. algirus	-	-	-	1.49	14.29	AC	-	-	-	-	-	-	-	-	-
L. diadema	0.99	12.12	AC	2.99	14.29	AC	-	-	-	-	-	-	-	-	-
M. guttulata	-	-	-	-	-	-	1.04	10	AC	-	-	-	-	-	-
N. maura	-	-	-	4.48	14.,29	AC	-	-	-	-	-	-	-	-	-
P. schokari	0.25	3.03	VA	1.49	14.29	AC	4.17	30	CM	-	-	-	4.55	12.5	AC
R. moilensis	-	-	-	1.49	14.29	AC	-	-	-	-	-	-	-	-	-
S. fasciatus	0.25	3.03	VA	-	-	-	-	-	-	-	-	-	-	-	-
S. albifasciatus	1.74	21.21	AC	-	-	-	-	-	-	-	-	-	-	-	-
S.scincus	25.56	39.39	CM	-	-	-	-	-	-	-	-	-	-	-	-
S. cucullatus	7.69	21.21	AC	-	-	-	-	-	-	-	-	-	-	-	-
S. diadema	-	-	-	1.49	14.29	AC	3.13	20	AC	16.67	20	AC	4.55	12.5	AC
S. boulengeri	1.24	9.09	VA	1.49	14.29	AC	-	-	-	-	-	-	-	-	-
S. petrii	-	-	-	4.48	14.29	AC	-	-	-	-	-	-	-	-	-
T. deserti	-	-	-	7.46	57.14	CN	-	-	-	-	-	-	31.82	25	CM
T. mauritanica	-	-	-	2.99	14.29	AC	-	-	-	-	-	-	18.18	12.5	AC
T. neglecta	1.74	9.09	VA	38.81	42.86	CM	1.04	10	AC	-	-	-	9.09	25	CM
T. graeca	-	-	-	1.49	14.29	AC	-	-	-	-	-	-	-	-	-
T. boehmei	-	-	-	-	-	-	6.25	20	AC	16.67	20	AC	-	-	-
T. mutabilis	4.96	27.27	CM	-	-	-	-	-	-	-	-	-	-	-	-
T. tournevillei	6.45	33.33	CM	1.49	14.29	AC	-	-	-	-	-	-	-	-	-
U. acanthinurus	-	-	-	-	-	-	1.04	10	AC	-	-	-	-	-	-
V. griseus	2.73	9.09	VA	-	-	-	7.29	40	CM	50	20	AC	-	-	-

Fc: Centesimal frequency, Occ: frequency of occurrence, C: Categories, —: species absence, CN: constant species (Occ≥50%), CM: common species (25%≤Occ<50%), AC: accidental species (10%≤Occ<25%), VA: very accidental species (Occ<10%).

In the North Sahara we note that *A. scutellatus* is the most frequent species (Fc = 30.5%) in the Erg, the other species have frequencies that fluctuate between Fc = 0.25% and 25.6%. three classes of species are noted in the erg. For the palm grove, *Tarentola neglecta* dominates with Fc = 38.8%, the rest of the species mention a Centesimal frequency which varies between 1.4% and 8.9%. The class most noted in the palm grove is that of accidental species

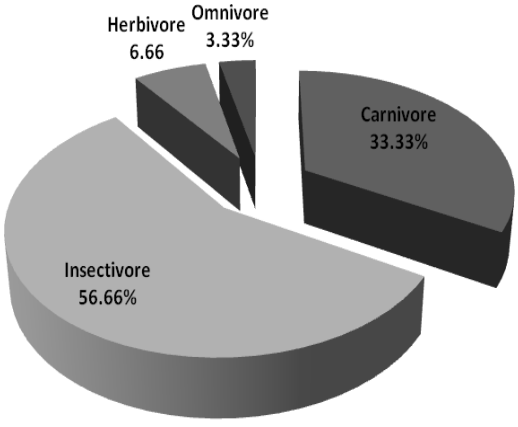
(15 species), it should be noted that the constant class is present by *T. deserti* (Occ= 57.14%). In Reg the most reported species is *A. scutellatus* (Fc = 38.5%), followed by *A. dumerili* (Fc = 30.2%). the most dominant class is that



of accidental species followed by accessory species (4 species). In Sebkha, the dominance of the species *V. griseus* (Fc = 50%) is noteworthy, the most dominant class is that of the accidental species represented by 4 species). *T. deserti* is the most frequent species (Fc= 31.8%) in the urban site, followed by *C. scabrum* (Fc = 22.7%), the other species have frequencies which fluctuate between Fc= 4.5% and Fc= 18.18% (Table 3).

3.1.3. Biogeographic and trophic status

The species listed are grouped into 4 distinct trophic categories: carnivores, herbivores, insectivores and omnivores. The category of insectivores dominates the other categories with 18 species (60%), It is followed by the category of carnivores with 10 species, (33.3%) (Fig.2). From a biogeographical point of view, we note the dominance of Saharan elements and elements Saharo-Sindian with respectively 53.6% and 25%, after come the elements Mediterranean with 15.4%.



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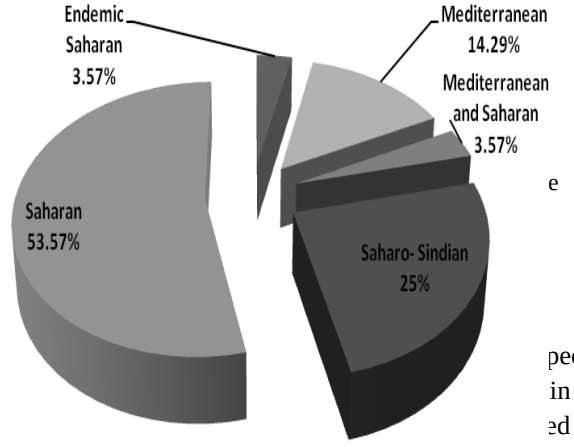

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2.6 and H'= 3.3 b ues of the equity index vary between 0.71 (reg) and 0.9 (sebkha) (Table 4).

B

Table 4. Diversity indices of herpetological communities in five habitat types of Northern Algerian Sahara: S: total species richness; S_m: mean specific richness, SD: Standard deviation, H': Shannon diversity index, E: equitability

	Erg	Palm grove	Reg	Sebkha	Urban site	Total
S	16	19	11	4	8	30
Sm	3	3.9	2.4	0.8	1.4	2.6
SD	2	2.6	1.6	1.8	1,5	2.1
H' (bit)	2.95	3.35	2.45	1.79	2.58	3.6
Hmax (bit)	4	4.25	3.46	2	3	4.9
E	0.74	0.79	0.71	0.9	0.86	0.74

3.1.5. Following distribution methods, FCA and PC A

The illustration of the scatter plots formed by the FCA shows the existence of 3 groups according to the herpetofaunic composition. The first scatter plot represents the habitats characterized by an important anthropic activity (Palm grove and urban site) represented by Phyllodactylidae (*T. deserti* and *T. neglecta*) and Gekkonidae (*C. scabrum*). The second group represents two habitats (reg and saline) with predominance of

of Scincidae (*S. albifasciatus*, *S. cucullatus* and *S. boulengeri*) (Fig. 4).

In function of seasons, the PCA allowed to distinguish the stands of the ambient temperature (spring

and fall), and the stands of the great heat, which begins in April and finishes in August, and which are separated by the x-axis, by against during the cold period (January and December), the results of the PCA, indicated almost a total absence of the reptiles except for some identified individuals during this period (Fig.6).

Fig. 4. Factorial correspondence analysis (FCA) of populations reptiles in 5 habitats

composed

The PCA delimits three reptiles groups in function of the 5 studied habitats, namely the group of Reg and Erg, the group of palm groves and urban site, and the group only by the saline habitat (Fig. 5).

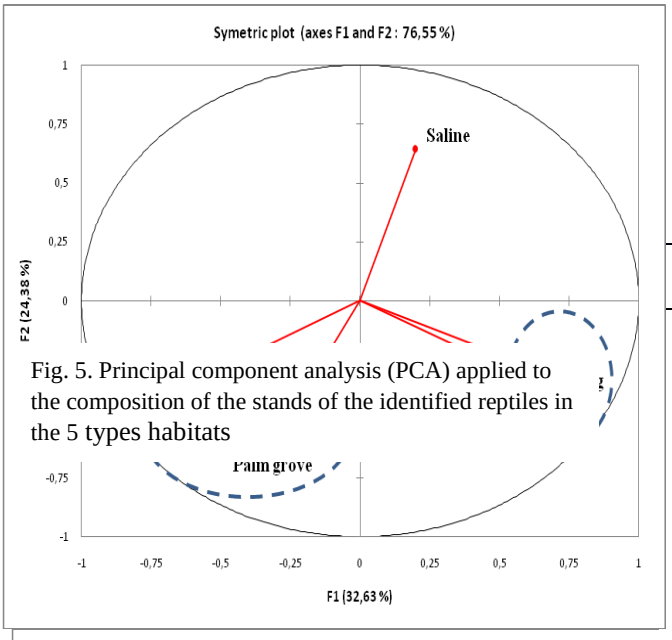

Fig. 5. Principal component analysis (PCA) applied to the composition of the stands of the identified reptiles in the 5 types habitats

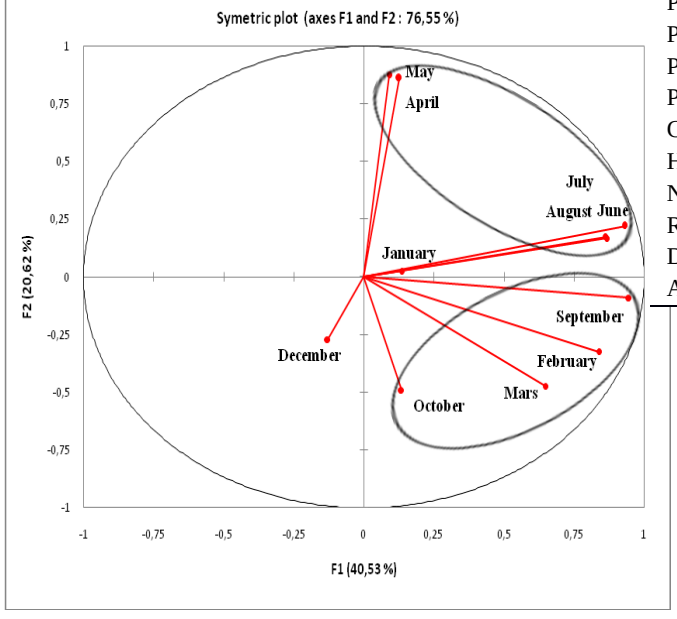

Fig 6. Principal component analysis (PCA) applied to the composition of the stands of identified reptiles during each month of the year

3.1.6. Generalized linear model GLM

The generalized linear model was used to examine the influence of different factors of abiotic nature (Altitude (m); longitude; latitude), anthropic (human pressure), and spatio-temporal (type of habitat, and period) on the abundance of species of identified reptiles. The generalized linear model reveals a significant positive effect of geographic coordinates (altitude, latitude and longitude), habitats (erg, reg, palm grove and urban site) and periods. In addition, the salinity and the human pressure do not have any significant effect on the variation of the abandoning of stands of studied reptiles (Table 5).

Table 5. Generalized linear model GLM analyzing the effect of the spatio-temporal factors and human pressure on the abundance of the reptile's populations identified in the Algerian Sahara.

Variable	**Estimate**	***SE***	***Z*-value**	***P***
Constante	-66.7	21.5	-3.11	0.002
Altitude (m)	0.00828	0.00242	3.42	0.001
Longitude	-1.510	0.390	-3.88	0.000
Latitude	2.295	0.722	3.18	0.001
Erg	0.4716	0.0761	6.19	0.000
Palm grove	-0.3676	0.0765	-4.81	0.000
Reg	0.295	0.136	2.17	0.030
Saline	0.096	0.135	0.71	0.476
Urban site	-0.207	0.102	-2.02	0.043
Pression 1	0.139	0.284	0.49	0.624
Pression 2	0.745	0.101	7.35	0.000
Pression 3	0.281	0.136	2.06	0.039
Pression 4	-0.522	0.137	-3.81	0.000
Pression 5	-0.644	0.180	-3.59	0.000
Cold period	-0.475	0.154	-3.09	0.020
Hot period	0.475	0.154	3.09	0.020
Null deviance	807.11			
Residual deviance	668.01			
Dispersion	4.058			
AIC	1154.64			

3.2. Discussion

A total of 30 species was captured in the study area. They are distributed in 2 orders (Chelonia and Squamata), in 12 families and in 22 different genera. According to [21], having worked on the reptiles of the North Western Sahara (Beni- Abbes) captured 27 species of reptiles during four years, whereas, we inventoried 25 species of reptiles during two years.

We found that the 17 species of Saurian are insectivores. The insects are a very important prey source for lizards from arid environments, and that these reptiles tend to feed on ants more frequently in arid than in wetter environments [47]. Almost all species in carnivore's

category belong to the Ophidian, [48] Ophidians feed mainly on lizards and small mammals, especially rodents. The dominance of Saharan elements in the Sahara would be explained by the conditions of the environment favorable to the adaptation of these elements (high temperature, low humidity).

The structure and diversity parameters of reptile communities varied among habitat types. The Palm grove conceals a higher diversity by inputs to other sites but urban site is also fairly well diversified. According to [53], the Palm grove represents a veritable forest offering a meso-climate which is very favorable to the organism's life. Also, the Palm grove and the urban site are distinguished by the presence of the physical entities, which provide important varieties of ecological conditions necessary for the reptiles reproduction, availability of food, avoidance of predators and rest [54,55,56]. The herpetofauna diversity are in fact proportionally related to the structural complexity of the habitat [57,58]. Those could be the reason for which diversities is less complex habitats, as it is the case of the Erg and the reg. The modification of habitats by the man causes a considerable loss of the biodiversity of endemic species, but on the other side, its effect is reduced for certain species which herpetological tolerate these disturbances [59].

The factorial analysis of the correspondences of the spatial distribution of reptiles in the Algerian Sahara has shown that there are species characteristic of the different habitats surveyed. In palm groves and urban sites, we observed the dominance of Phyllodactylidae and Gekkonidae, according to [39], most tarentes prefer relatively dry open areas, including artificial habitats such as houses and dry stone walls. [60] noted that urban site, rural area and vegetation, especially under the bark of dead plants, are considered as potential biotopes for the *Tarentola* genus in Tunisia. The humidity which characterizes the saline habitat during certain period of the year and the presence of the stones occupied by very sparse Chamaephytes in the Regs, are considered as favorable conditions for Colubridae [61]. For the Erg habitat, our results agreed with those of [31], who reported that the majority of Lacertidae and Scincidae in Great Oriental Erg (Oued Souf).

The principal components analysis (PCA) delineates three type groups of habitat: natural habitats (erg and reg), anthropic habitats (palm groves and urban sites); and the wetland habitat (sebkha). These three groups correspond to the usual phenology of the reptile's viewpoint micro-habitat, ecological niche and spatial proximity and connectivity between the different habitats [62]. The type of habitat can have a positive or negative impact on the abundance of reptiles, but it will not have any impact on the latter. These results are presented by several authors [49,50,51,52]. As a function of the seasons, the PCA indicates that the abundance of identified reptiles in the North Sahara is proportionally linked to a thermal gradient. In fact, the hot period is favorable for the life of the majority of reptiles during which the necessary ecological conditions for their activities are met. On the other hand, the falls in temperatures during the cold period induces the reduction in the reptile's activity and the specimens encountered during this period are generally in state of winter diapause. According to [39], the reptile's activity, depends of external heat and they generally spend the winter period in a state of torpor at the bottom of hole in the ground or a crack of rock where they will generally be protected from frost and cold [63], similarly reported that the temperature is one of the responsible patterns for the variation of the reptile's richness.

The GLM analysis shows that geographic coordinates, have a significant effect on the variation in the abundance of the studied reptiles. Our results are similar to those of [64] The GLM with a model of linear multiple regressions showed that human population, habitat diversity, and altitude range positively affected the total richness of terrestrial vertebrate species. Moreover, the abundance of the reptiles decreases with the degree of human pressure. Our results were corroborated with those of [57] who has shown that the highest abundance of herpetofauna in South India is registered in the zones of low degree of development, consequently low human pressure.

4. Conclusion

We conclude that human activities directly affect the abundance and diversity of reptiles in our study area and that these deserve to be considered in the socio-economic development programs of the Saharan (agriculture, industry, ...)

Acknowledgments

We thank all the engineers and technicians of the commune of Taleb El Arbi MM. Monsef, Bouras, Messaoud Guendoul. thanks to all people of Taibet, Belghith and Touggourt for their cordial accommodates and their assistance in the field work.

Conflict of Interest

The authors declare that they have no conflict of interest

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Recommended Citation
Mouane A., Harrouchi A., Ghennoum I., Sekour M. Diversity and distribution patterns of reptiles in the northern Algerian Sahara (Oued Souf, Taibet and Touggourt). *Alger. j. biosciences*. 2021, 02;02:078-087.