NOTE

An online identification tool for the gerrhosaurids of Madagascar and associated islands (genera *Zonosaurus* and *Tracheloptychus*)

Un outil de détermination en ligne des espèces de gerrhosauridés de Madagascar et des îles associées (genres *Zonosaurus* et *Tracheloptychus*)

Ewen CARRIOU[(1)]* & Aurélien MIRALLES[(1)]

[(1)] *Institut de Systématique, Évolution, Biodiversité (ISYEB), Muséum national d'Histoire Naturelle, CNRS, Sorbonne Université, EPHE, Université des Antilles, 57 rue Cuvier, 75231 Paris cedex, France.*

* Corresponding author: ewcarriou@gmail.com

Résumé - Les Zonosaurinae, sous-famille de Gerrhosauridae endémique de Madagascar, sont des lézards terrestres de taille moyenne représentés par 19 espèces des genres *Zonosaurus* et *Tracheloptychus*. Afin d'accompagner chercheurs, naturalistes et gestionnaires dans l'identification de ces organismes, nous avons produit la première clé d'identification interactive pour ce groupe, permettant une identification fiable et justifiable. Les descriptions taxonomiques originales et les redescriptions morphologiques subséquentes des espèces de Zonosaurinae ont été compilées afin de construire une base de données descriptive de ces espèces sous Xper3 (Kerner *et al.* 2025). Celle-ci a été ensuite utilisée pour générer une clé d'identification à accès multiple en ligne, enrichie de diverses illustrations et disponible sur https://app.xper3.fr/xper3GeneratedFiles/publish/identification/-3416196680092925574/mkey.html.

Mots-clés - Base de données descriptive, Description taxonomique, *Tracheloptychus*, *Zonosaurus*.

The Gerrhosauridae Fitzinger, 1843 form a family of scincomorph squamates endemic to sub-Saharan Africa and Madagascar. Only two genera of gerrhosaurids are present in Madagascar: *Tracheloptychus* Peters, 1854 and *Zonosaurus* Boulenger, 1887 (Fig. 1), and they form a monophyletic lineage (subfamily Zonosaurinae Lang, 1991). The two genera are each monophyletic according to Blair *et al.* (2015), although Recknagel *et al.* (2013) found *Tracheloptychus* potentially nested within *Zonosaurus*. They differ from other genera of Gerrhosauridae by the presence of prefrontal scales and the absence of frontoparietals (Brygoo 1985). Zonosaurinae are found in almost all ecoregions of Madagascar, except for high altitudes, and a subspecies of *Zonosaurus madagascariensis* (Gray, 1831), *Z. m. insulanus* Brygoo & Böhme, 1985, is also present away from Madagascar in the Glorioso Islands (France) and at Cosmoledo (République des Seychelles). Of the 19 species of Zonosaurinae, eight are considered vulnerable or threatened according to the IUCN Red List (IUCN 2025). This article presents the first online interactive identification key for Zonosaurinae species. This key was developed with Xper3, and designed for researchers, naturalists, students, and natural area managers to support them in the identification and monitoring of these species. It is intended for users with some knowledge of squamates, but many characters can be identified by neophytes. To be usable by the widest possible audience, it has been written in English, and is available free of charge at the following address: https://app.xper3.fr/xper3GeneratedFiles/publish/identification/-3416196680092925574/mkey.html.

The sources used are the original species descriptions (Gray 1831, Peters 1854, Grandidier 1869, Boettger 1881, Steindachner 1891, Boulenger 1896, Angel 1939, Brygoo & Böhme 1985, Lang & Böhme 1989, Raselimanana *et al.* 2000, Raselimanana *et al.* 2006) as well as the revision of the Gerrhosauridae of Madagascar published by Brygoo (1985).
For practical reasons, we prioritized descriptors (characters) (1) that clearly discriminate between species, (2) whose character states are documented for all species, and (3) that can be observed with the naked eye or a magnifying glass (the aim being to identify species in the field and release them safely,

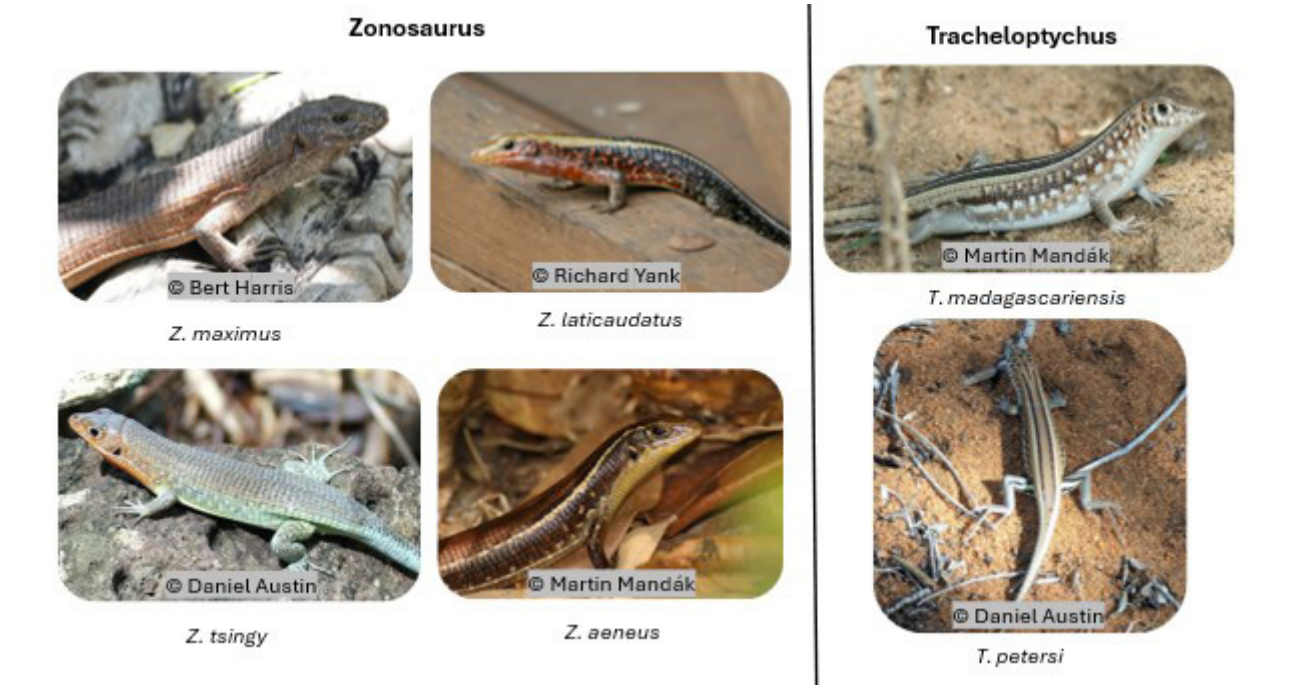

Figure 1 – Photos of several species of Zonosaurinae. On the left four species of the genus *Zonosaurus* (*Z. maximus*, *Z. laticaudatus*, *Z. tsingy* and *Z. aeneus*) and on the right two species of the genus *Tracheloptychus* (*T. madagascariensis* and *T. petersi*).

Figure 1 – Photographies de plusieurs espèces de Zonosaurinae. A gauche quatre espèces du genre *Zonosaurus* (*Z. maximus*, *Z. laticaudatus*, *Z. tsingy* et *Z. aeneus*) et à droite deux espèces du genre *Tracheloptychus* (*T. madagascariensis* et *T. petersi*).

in situ and rapidly). Specimens representing 13 of the 19 Zonosaurinae species were available at the MNHN (Muséum National d'Histoire Naturelle, Paris) and were examined to test the functional effectiveness of the database. Certain details of the specimens were drawn using a camera lucida as a basis for the vector illustrations accompanying the database.

The database and the identification key were developed using the Xper3 tool. This tool is made for storing and editing descriptive databases and makes it possible to export these data in the form of an identification key with either restricted or open access (Kerner *et al.* 2025, website available at: https://app.xper3.fr). The Xper suite also includes Xper1 Tools, used to calculate the number of descriptors separating each pair of taxa based on the distance between items, and Xper2, used to compute and export database statistics (Fig. 2). Each taxon was represented by at least one photograph of specimens, so that users can access a realistic visual reference of the species in life. These photographs mostly come from the iNaturalist website (2025) and the Reptile Database (Uetz *et al.* 2025). All photographs were used with permission from their respective authors. For the descriptors and their states, vector drawings were created with the Inkscape application, based on Gerrhosauridae specimens housed in the MNHN collections (e.g., Fig. 4B). All illustrations used in the key were deposited on the Zenodo platform and are accessible at the following address: https://zenodo.org/records/16578967.

The taxon descriptions in the Xper3 database were constructed so that each taxon can be distinguished from another by at least one descriptor. In the final database, the average number of descriptors separating a pair of taxa is 6.3 (minimum 1). The key therefore exhibits good redundancy, meaning that it allows identification to be reached by following several different paths (i.e., multiple series of descriptors). The database is composed of 27 descriptors, with an average of three states per descriptor, for a total of 87 states (Fig. 2). The database is 97.4% complete, with 2.6% of states unknown due to missing descriptions in the literature. The descriptors of the database can be divided into four categories (Tab. 1, Fig. 3): (1) colour and pattern descriptors (n = 16), observable with the naked eye; (2) scale-related descriptors (head scalation and lateral fold, n = 5), which require good photographs or handling of the specimen to

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Descriptors :	**Base completion :**
Number : 27	1. Zonosaurus maximus : 92.59%
Illustrated : 27	2. Zonosaurus laticaudatus : 96.3%
Independant : 21	3. Zonosaurus karsteni : 96.3%
Parent descriptors : 3 (including 1 also child)	4. Zonosaurus ornatus : 92.59%
Child descriptors : 4 (including 1 also parent)	5. Zonosaurus haraldmeieri : 96.3%
States :	6. Zonosaurus madagascariensis madagascariensis : 96.3%
Number : 86	7. Zonosaurus madagascariensis insulanus : 96.3%
Illustrated : 65	8. Zonosaurus aeneus : 100%
Min number per descriptor : 2	9. Zonosaurus anelanelany : 100%
Max number per descriptor : 11	10. Zonosaurus bemaraha : 100%
Average number per descriptor : 3.19	11. Zonosaurus brygooi : 100%
Items :	12. Zonosaurus rufipes : 100%
Number : 20	13. Zonosaurus tsingy : 100%
Illustrated : 20	14. Zonosaurus subunicolor : 100%
With descriptions : 20	15. Zonosaurus trilineatus : 92.59%
	16. Zonosaurus quadrilineatus : 92.59%
	17. Zonosaurus maramaintso : 100%
	18. Zonosaurus boettgeri : 100%
	19. Tracheloptychus madagascariensis : 96.3%
	20. Tracheloptychus petersi : 100%
	Total : **97.41%**
	Missing descriptions : 0%
	Unknown descriptions : 2.59%

Figure 2 – Statistics of the database collected with Xper2. Child descriptors are dependant descriptors that only appear if a certain state is chosen on a parent descriptor.

Figure 2 – Statistiques de la base obtenues avec Xper2. Les descripteurs fils ('child descriptors') sont des descripteurs dépendants, n'apparaissant que si un certain état est choisi sur un descripteur père ('parent descriptor').

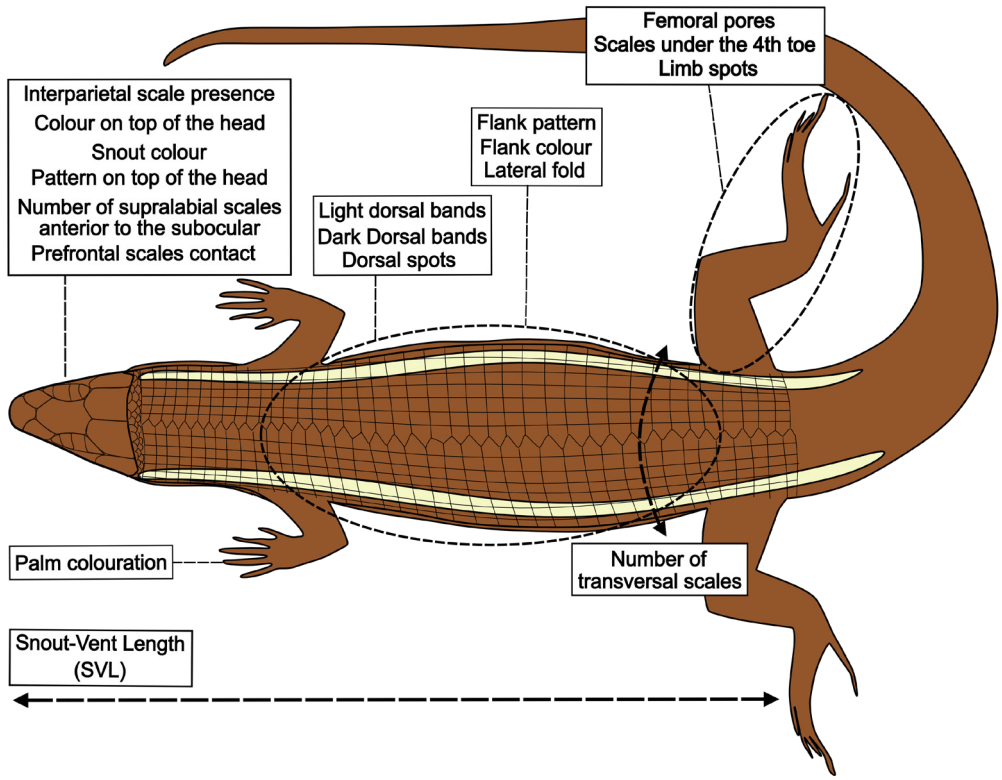

Figure 3 – Diagram indicating the regions of a specimen that must be observed to fill in the descriptors.

Figure 3 – Schéma indiquant les régions d'un spécimen à observer pour remplir les descripteurs.

Table 1 – List of the 27 key descriptors and the number of states associated with each, organised by category.

Tableau 1 – Liste des 27 descripteurs de la clé ainsi que leur nombre d'états, arrangés selon leur catégorie.

Category of descriptor	Descriptors, with the number of associated states
Colour and pattern (16):	Colour on top of the head (3); Dark dorsal bands (3); Dorsal colour (3); Dorsal spots (3); Feet colour (2); Flank colour (4); Flank pattern (3); Light band termination (3); Light band width (2); Light dorsal bands (5); Light dorsal band shape (3); Limb spots (4); Pattern on top of the head (2); Snout colour (2); Throat colour (3); Throat pattern (3)
Scalation (5):	Contact of the prefrontal scales (2); Lateral fold (2); Number of supralabial scales anterior to the subocular (5); Number of supralabial scales posterior to the subocular (2); Interparietal scale (2)
Countable descriptors (5):	Number of femoral pores (3); Number of longitudinal scale series (from chin to cloaca) (2); Number of scales under the 4th toe (2); Number of transversal scale series (on the back and flanks) (4); Snout-vent length (SVL) in cm (3);
Location of observation (1):	Localisation (11)

be observed; (3) countable descriptors (n = 5), which require handling of the specimen to be measured; and finally, (4) the location of the observation within the different ecoregions (Fig. 4A).

The key was tested by four researchers on photographs, and by us on around 30 preserved individuals from the MNHN collections (two to three individual for each of the available taxa). Because of the incomplete nature of the Zonosaurinae collection the MNHN, the following taxa could only be tested on photos: *Zonosaurus anelanelany*, *Z. bemaraha*, *Z. brygooi*, *Z. haraldmeieri*, *Z. maramaintso*, *Z. subunicolor* and *Z. tsingy*.

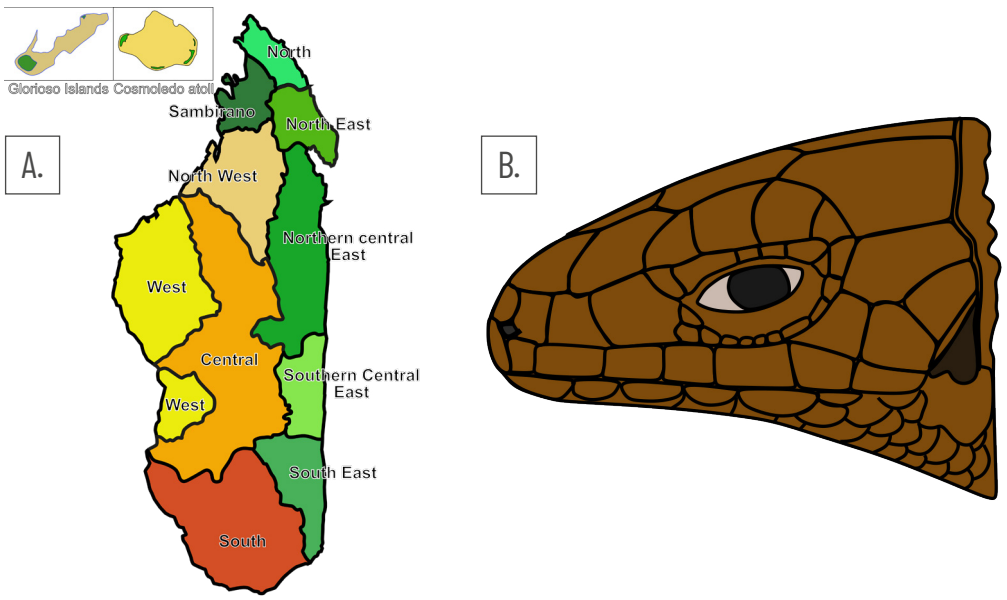

Figure 4 – A: Map of the ecoregions of Madagascar, based on the division of Boumans *et al.* (2007). B: Vectorial drawing representing the cephalic scales of a *Zonosaurus*.

Figure 4 – A : Carte des écorégions de Madagascar, refaite d'après Boumans *et al.* (2007). B : Dessin vectoriel schématisant l'écaillure céphalique d'un *Zonosaurus*.

All tests proved successful, except for certain individuals of *Z. rufipes* (Boettger, 1881) for which the key could not clearly determine whether they belonged to *Z. rufipes* or *Z. subunicolor* (Boettger, 1881). These two species are considered morphologically similar (Brygoo 1985, Glaw & Vences 2007) and can only be distinguished by colouration (red feet and black bands under the throat in *Z. rufipes* versus dark feet and a uniformly coloured throat in *Z. subunicolor*). This exception is most likely due to the loss of colouration in alcohol (rapid fading of red pigments). The present work provides the first online identification tool for Zonosaurinae. It could represent a first step toward the development of a suite of digital tools dedicated to the identification of Madagascar's reptiles, which should ultimately facilitate the fieldwork of biologists and naturalists. However, with 470 species of reptile species recognised in Madagascar so far (Uetz *et al.* 2025), building a comprehensive set of identification keys for all of them would represent a considerable undertaking. We hope that in the coming years, various modules similar to this one, focusing each on particular taxa (ex. at the family level), will help expand this offering. Ultimately, these could be interconnected through a higher-level identification tool, allowing users to be directed toward specialized keys.

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Authors contributions
AM developed the project. EC collected the data, drew the illustrations and designed the key. EC and AM both wrote the manuscript and gave the final approval for publication.

Conflict of interest
The authors do not declare any conflict of interest in this study.

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