Quo vadis biodiversity? Species richness following twenty years of taxonomic revisions on Afrotropical Galerucinae s. str. (Coleoptera, Chrysomelidae)\textsuperscript{1,2}

Thomas Wagner\textsuperscript{1}

\textbf{Abstract}

Galerucinae is one of the most species-rich leaf beetle group with its greatest diversity occurring in tropical forests. There are 1680 nominal species of Afrotropical Galerucinae s. str. (without Alticini) described. Considering global diversity estimations, many unknown species can be presumed. Several taxa traditionally placed in “Monoleptites”, have been revised in the last twenty years. To date 259 species have been re-examined, revealing in 139 valid species and 120 mainly newly recognized synonyms. This large number of synonyms can mainly be ascribed to highly variable colour patterns, a typical character used for the identification of many chrysomelid species. Genitalic structures and molecular work can support a more precise allocation to species. Within around 72,000 specimens of galerucines s. str. from 48 museums and private collections, only 107 species were newly described. After revising approximately 15\% of the Afro-tropical galerucine fauna their species richness decreased from 259 to 246 species, a pattern that appears to be similar to that for other African galerucine groups. Since the estimation of the extent of global diversity based mainly on insect species richness in tropical forests, our current study which is based on hard data suggests a much lower diversity than previously predicted.

\textbf{Keywords}

Africa, Afrotropical, region, biodiversity, Galerucinae s. str., Monoleptites, revision, taxonomy

\textsuperscript{1} 51\textsuperscript{st} contribution to the taxonomy, phylogeny, and biogeography of the Galerucinae.

\textsuperscript{2} Contribution to the 9\textsuperscript{th} International Symposium on the Chrysomelidae, Orlando, FL, USA, September 28, 2016
Introduction

Galerucinae s. str. (without Alticini) is one of most diverse group of leaf beetles in tropical forests, including 1680 nominal species from Africa (Wagner 2006) and 7145 species worldwide (Nie et al. 2017). Among the highly diverse Galerucinae, Monolepta Chevrolat, 1836 is the largest genus of Galerucinae s. str., with nearly 700 described species in the world (Wagner 2007a). When a taxonomic and phylogenetic revision of Afrotropical Monolepta was started, it became clear that this genus as traditionally delimited was a non-monophyletic group (Wagner 1999, 2003, 2004). Monolepta and other taxa with a distinctly elongated first tarsomere of the hind-leg are placed in “Monoleptites” (Wilcox 1973). Subsequently, the relative length of the second to third antennomeres, and the shape of the pronotum were considered to place the “long-legged” African galericines largely in three genera: Monolepta (second and third antennomere of same length, pronotum rectangular); Candezea Chapuis, 1879 (third antennomere much longer than second, pronotum rectangular); and Barombiella Laboissière, 1931 (third antennomere much longer than second, pronotum trapezoidal).

During a period of twenty years, our working group has revised approximately 85% of the “Monoleptites” sensu Wilcox (1973). Besides redefining generic characters in the external morphology, we also studied the genitalic patterns of all the examined taxa for the first time. These were found to be valuable not only to distinguish species, but also to define genera as monophyletic groups within Monolepta (e.g. Wagner 2007a), Candezea (Wagner and Kurtscheid 2005), and Barombiella (Freund and Wagner 2003, Wagner and Freund 2003, Bolz and Wagner 2011). Some species were transferred to Afrocra-nia Hincks, 1949 (Middelhauve and Wagner 2001, Wagner 2007b). We found several phylogenetically isolated taxa that had to be transferred to newly described genera, e.g. Afromaculepta (Hasenkamp and Wagner 2000), Afrocandezea (Wagner and Scherz 2002, Scherz and Wagner 2007), Afronaumannia (Steiner and Wagner 2005), Monoleptoides (Wagner 2011), and Bicolorizea (Heunemann et al. 2015). These supra-specific taxa could be also identified as separate phylogenetic units by molecular data (Wagner in prep.). We included also short-legged Bonesioides Laboissière, 1925 (Freund and Wagner 2003), Galerudolphia Hincks, 1949 (Bolz and Wagner 2005) and the very short-legged Ootheca Chevrolat, 1836 in our revisions (Kortenhaus and Wagner 2010, 2011, 2012, 2013).

At present, some 250 species of Afrotropical Galerucinae s. str. have been revised and these data are used here as a case study on their general species richness. Global insect diversity caught the attention of entomologists, and a broader audience, in the 1980s, when data of canopy fogging in tropical forests were extrapolated to 30 million species of insects (Erwin 1982). This started a controversial discussion in the community (e.g., Stork 1988, Thomas 1990, Gaston 1991), but more detailed “calculations” led to a much lower number that levelled off at around six million species (Ødegaard 2000, Basset et al. 2012). The author’s empirical data of species revisions in a quite highly diverse tropical leaf-beetle group is used here to address the question, What is the global diversity of Galerucinae s. str.?
**Material and methods**

Our revisions of Afrotropical galerucines are currently published in 40 papers with a taxonomic focus (Wagner and collaborators 1993–2017) based on around 72,000 specimens from 48 collections which includes all the major museum collections that house African insects.

**Results**

Up to now, 259 species have been re-examined, resulting in 139 valid species and 120, mainly newly recognized synonyms (Fig. 1). The high variability of colour pattern, a typical character for many chrysomelid species, caused the high number of synonyms (46%). Genitalic structures and molecular data can make more reliable species identification. The large number of specimens examined revealed only 107 new species described. After revising approximately 15% of the Afrotropical galerucine fauna, the species number decreased from 259 to 246 species.

**Discussion**

The high polychromatism in many galerucine species is the cause of the majority of synonyms, since colour patterns were used by previous authors as very definite species specific characters. When species are widely distributed, the number of synonyms increase even more. *Monolepta vincta* Gerstaecker, 1871, has a pan-Afrotropical distribution and ten synonyms have been found for his species (Wagner 2005), six of these synonyms are provided in two publications of Victor Laboissière (1920a, b). This is not a reproach for Laboissière, who was the most productive taxonomist on the Galerucinae world-wide. The majority of species described by him are still valid, but in his early publications, his work was based on a very “classic”, Linnaean species concept, as it was customary for that time. Later in his career (e.g. Laboissière 1940), he used genitalic patterns for species identification, being one of the first taxonomists in Chrysomelidae to do so. Further examples of widely distributed African galerucines with a large number of synomyns are *Neobarombiella flavilabris* (Weise, 1903) with eleven and *Neobarombiella senegalensis* (Laboissière, 1923) with ten synonyms.

Other diverse Afrotropical Galerucinae s. str. appear to indicate a similar “over-description” rate. *Diacantha* Chevrolat, 1836 (syn. *Hyperacantha* Chapuis, 1879) is the second most diverse group of African galerucines in terms of some 120 described species. A few spot checks revealed there are a large number of synonyms in this genus too, and *Diacantha* might be another taxonomic “nightmare”, revealing a lower number of valid species subsequent to formal revision.
On the other hand, revisions of tropical phytophagous insects can result in a strong increased number of species. Examples are the weevil genera *Euops* Schönherr, 1839 from New Guinea with 24 valid species before revision, and 160 additional new species there after (Riedel 2006), and the litter-dwelling *Trigonopterus* Fauvel, 1862 from the Sundaland area (mainly Malaysia, Indonesia) which was monotypic and comprised 98 species after being revised (Riedel et al. 2014). Alexander Riedel’s studies on East Asian weevils revealed six times more species after the revision of *Euops*, and a much larger increase in *Trigonopterus* with their cryptic life-history, whereas our conclusion brought decreased species richness to light. The results may reflect the two extremes along a continuum, but both data sets imply that more recent “calculations” on global insect diversity, with around six million species, are much more reasonable than the higher numbers “believed” before.

**Acknowledgements**

Many thanks to all my co-workers for the taxonomic work, all students at several stages of their academic careers for the good work they did in sorting material, picking up label data, compiling distribution data, dissecting genitalia and doing the molecular work before writing their theses, Alexander Riedel for information on the south-east Asian weevils, and reviewers Ron Beenen, Jan Bezdek, Caroline Chaboo, Beth Grobbelaar, and one anonymous reviewer for valuable comments on the manuscript.
References

Basset Y et al. (2012) Arthropod diversity in a tropical forest. Science 338: 1481–1484. https://doi.org/10.1126/science.1226727

Bolz H, Wagner T (2005) Revision of Galerudolphia from tropical Africa (Coleoptera, Chrysomelidae, Galerucinae). Insect Systematics and Evolution 35: 361–400. https://doi.org/10.1163/187631204788912436

Bolz H, Wagner T (2012) Neobarombiella, a diverse, newly described genus of Afrotropical Galerucinae (Coleoptera, Chrysomelidae). Zootaxa 3463: 1–112.

Erwin TL (1982) Tropical forests: their richness in Coleoptera and other arthropod species. The Coleopterists Bulletin 36: 74–75.

Freund W, Wagner T (2003) Revision of Bonesioides Laboissière, 1925 (Coleoptera; Chrysomelidae; Galerucinae) from continental Africa. Journal of Natural History 37: 1915–1976. https://doi.org/10.1080/00222930110096519

Gaston KJ (1991) The magnitude of global insect species richness. Conservation Biology 5: 283–296. https://doi.org/10.1111/j.1523-1739.1991.tb00140.x

Hasenkamp R, Wagner T (2000) Revision of Aframaculepta gen. n., a monophyletic group of Afrotropical galerucinae leaf beetles (Coleoptera: Chrysomelidae). Insect Systematics and Evolution 31: 3–26. https://doi.org/10.1163/187631200X00282

Heunemann LO, Dalstein V, Schulze M, Wagner T (2015) Bicolorizea gen. nov. from tropical Africa (Coleoptera: Chrysomelidae, Galerucinae). Entomologische Zeitschrift 125(4): 235–246.

Kortenhaus S, Wagner T (2010) Revision of Ootheca Chevrolat, 1837 from tropical Africa – Redescriptions, descriptions of new species and identification key (Coleoptera: Chrysomelidae: Galerucinae). Zootaxa 2659: 1–52.

Kortenhaus S, Wagner T (2011) Oothecoides gen. nov. from tropical Africa, with redescriptions and description of six species (Coleoptera: Chrysomelidae: Galerucinae). Entomologische Zeitschrift 121: 259–269.

Kortenhaus S, Wagner T (2012) Description of Ootibia gen. n. from tropical Africa with revision of two described species and description of three new species (Coleoptera: Chrysomelidae: Galerucinae). African Entomology 20(2): 350–370. https://doi.org/10.4001/003.020.0210

Kortenhaus S, Wagner T (2013) Oosagitta gen. nov. from tropical Africa, with revision of two species and description of four new species (Coleoptera: Chrysomelidae, Galerucinae). European Journal of Taxonomy 58: 1–24. http://dx.doi.org/10.5852/ejt.2013.58

Laboissière V (1920a) Diagnoses de Galerucini nouveaux d’Afrique (Col. Chrysomelidae). Bulletin de la Société entomologique de France 1920: 50–53.

Laboissière V (1920b) Diagnoses de Galerucini nouveaux d’Afrique (Col. Chrysomelidae). Bulletin de la Société entomologique de France 1920: 98–101.

Laboissière V (1940) Galerucinae. Institut des Parcs Nationaux du Congo Belge, Bruxelles. Exploration du Parc National Albert 31: 1–98.

Middelhauve J, Wagner T (2001) Revision of Afrocrania (Coleoptera: Chrysomelidae, Galerucinae). Part I: Species in which the males have head cavities or extended elytral extrusions. European Journal of Entomology 98: 511–531. https://doi.org/10.14411/eje.2001.066
Nie R-E, Bezděk J, Yang X-K (2017) How many genera and species of Galerucinae s. str. do we know? Updated statistics (Coleoptera, Chrysomelidae). In: Schmitt M, Chaboo CS (Eds) Research on Chrysomelidae 7. ZooKeys 720: 91–102. https://doi.org/10.3897/zookeys.720.13517

Ødegaard F (2000) How many species of arthropods? Erwin’s estimate revised. Biological Journal of the Linnean Society 71: 583–597. https://doi.org/10.1111/j.1095-8312.2000.tb01279.x

Riedel A (2006) Revision of the subgenus *Metaeuops* Legalov of *Euops* Schoenherr (Coleoptera, Curculionoidea, Attelabidae) from the Papuan region. Zootaxa 1181: 1–102.

Riedel A, Tänzler R, Balke M, Rahmadi C, Suhardjono YR (2014) Ninety-eight new species of *Trigonopterus* weevils from Sundaland and the Lesser Sunda Islands. ZooKeys 467: 1–162. https://doi.org/10.3897/zookeys.467.8206

Scherz X, Wagner T (2007) Revision of *Afrocandezea* Wagner & Scherz, 2002 from tropical Africa (Coleoptera: Chrysomelidae, Galerucinae). Entomologische Zeitschrift 117: 161–183.

Steiner I, Wagner T (2005) *Afronaumannia* gen. nov., a new monophyletic group of leaf beetles from Africa (Coleoptera: Chrysomelidae, Galerucinae). Entomologische Zeitschrift 115: 15–24.

Stork NE (1988) Insect diversity: facts, fiction and speculation. Biological Journal of the Linnean Society 35: 321–337. https://doi.org/10.1111/j.1095-8312.1988.tb00474.x

Thomas CD (1990) Fewer species. Nature 347: 237. https://doi.org/10.1038/347237a0

Wagner T (1999) An introduction to the revision of afrotropical *Monolepta* and related taxa (Chrysomelidae, Coleoptera). In: Walloßek D (Ed.) Systematik im Aufbruch. Tagungsband zur ersten Jahrestagung der Gesellschaft für Biologische Systematik in Bonn vom 17.–19. September 1998, Courier Forschungsinstitut Senckenberg 215, Frankfurt, 215–220.

Wagner T (2003) Present status of a taxonomic revision of afrotropical *Monolepta* and related groups (Galerucinae). In: Furth DG (Ed.) Special Topics in Leaf Beetle Biology. Proceedings V International Symposium on the Chrysomelidae, Foz do Iguacu 2000. Pensoft, Sofia, 133–146.

Wagner T (2004) Phylogeny of Afrotropical *Monolepta* and related taxa (Galerucinae). In: Jolivet P, Santiago-Blay JA Schmit M (Eds) New Developments in the Biology of Chrysomelidae, Academic Publishing, The Hague, 75–84.

Wagner T (2005) Revision of the vincita Species-group of *Monolepta* Chevrolat, 1837 from Africa, Arabia and the near East (Coleoptera, Chrysomelidae, Galerucinae). Bonner zoologische Beiträge 53: 255–282.

Wagner T (2006) AfriGa – An illustrated electronic catalogue of Afrotropical Galerucinae (Chrysomelidae, Coleoptera). Chrysomela 47: 7–8.

Wagner T (2007a) *Monolepta* Chevrolat, 1837, the most speciose galericine taxon: redescription of the type species *Monolepta bioculata* (Fabricius, 1781) and key to related genera from (Chrysomelidae, Coleoptera). Journal of Natural History 41: 81–100. https://doi.org/10.1080/00222930601127384

Wagner T (2007b) Revision of *Afrocranina* (Coleoptera: Chrysomelidae: Galerucinae) Part II: Species in which the males lack head cavities or extended elytral extrusions. European Journal of Entomology 104: 801–814. https://doi.org/10.14411/eje.2007.101
Wagner T (2011) Description of *Monoleptoides* gen. nov. from the Afrotropical Region, including the revision of nine species (Coleoptera: Chrysomelidae, Galerucinae). Bonn Zoological Bulletin 66(2): 169–199.

Wagner T, Freund W (2003) Revision of *Barombiella violacea* (Jacoby, 1984) (Coleoptera: Chrysomelidae, Galerucinae). Entomologische Zeitschrift 113: 258–262.

Wagner T, Kurtscheid A (2005) Revision of *Candezea* from continental Africa (Coleoptera, Chrysomelidae, Galerucinae). Journal of Natural History 39: 2591–2641. https://doi.org/10.1080/00222930500102611

Wagner T, Scherz X (2002) *Afrocandezea* gen. nov. from tropical Africa (Coleoptera: Chrysomelidae, Galerucinae). Entomologische Zeitschrift 112: 357–362.

Wilcox JA (1973) Chrysomelidae: Galerucinae: Luperini: Luperina. In: Junk W (Ed.) Coleopterorum Catalogus Suppl. 78: 433–664.